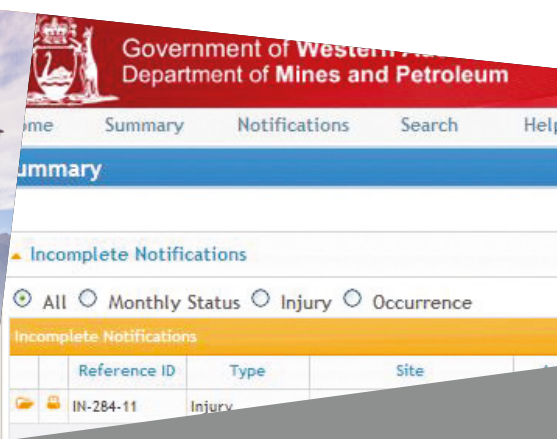


REPORT

Analysis of serious injury data in the Western Australian mining industry, July-December 2013

What lessons can we learn?



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Reference

Department of Mines and Petroleum, 2015, Analysis of serious injury data for the Western Australian mining industry, July-December 2013: what lessons can we learn? – report: Investigation Services and Resources Safety Division, Department of Mines and Petroleum, Western Australia, 29 pp.

ISBN 978 1 922149 43 5

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Resources Safety

Department of Mines and Petroleum
100 Plain Street
EAST PERTH WA 6004

Telephone: + 61 8 9358 8002 (general queries)
+ 61 8 9358 8154 (publication orders)

NRS: 13 36 77

Facsimile: + 61 8 9358 8000

Email: ResourcesSafety@dmp.wa.gov.au
(general queries)

RSDComms@dmp.wa.gov.au
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1 Introduction

1.1 Aims

The *Fatal accidents in the Western Australian mining industry 2000-2012: What lessons can we learn? – report* was published by the Department of Mines and Petroleum in 2014. It considered underlying causation factors and active failures that have contributed to fatal accidents. While some safety performance indicators are showing slight downward trends, the fatality incidence rate appears to have plateaued, apart from the fatality-free year in 2012. Industry and the government are committed to improving safety outcomes and this report provides a state-wide view of the current injury profile.

The fatalities review is a powerful tool in understanding the causes of accidents and fatalities in Western Australian mines. However, there are clear benefits in not waiting several years to analyse the circumstances around a group of fatal accidents with a view to preventing similar incidents. For this reason, serious injury data was chosen for analysis to see if, being the “next level down” from a fatality, it could be used as an indicator to assist in understanding the causation factors behind fatal accidents.

1.2 Analytical approach

A six-month sample of data for injuries reported for the period 1 July to 31 December 2013 was selected for detailed analysis from the Department’s Safety Regulation System (SRS). The suitability of using the six-month data set was established by interrogating injury data recorded in SRS for 2002 to 2013 to determine whether the sample size was representative.

Trends and clusters in data relating to causation factors and critical activities were identified and compared to those of the fatalities review to assist in verification and the development

of an industry risk profile. Occurrence notifications were also used to help understand the mechanism of injury and develop a more comprehensive industry risk profile.

Subgroups of serious injury types were investigated further to see if meaningful and potentially leading performance indicators could be identified.

Note: The general safety theory and practice that inform this report are discussed in detail in the fatality report.

1.3 Structure of report

This analysis draws heavily on a comparison with the findings of the fatalities review, which is summarised in Chapter 2.

There are legislative requirements that determine the incident information notified to the Department of Mines and Petroleum. The Department’s online Safety Regulation System (SRS) is used to manage the notifications and store the data. Chapter 3 outlines the reporting requirements and how the data is processed.

Chapters 4 to 7 describe how the data was analysed and present the results and interpretations.

The significance of the data analysis and potential use of the findings are discussed in Chapter 8.

Chapter 9 presents strategies for industry to reduce the incidence of serious and fatal injuries.

Note: The SRS codes used for groupings, and graphs and supporting data are available in digital format. Contact RSDComms@dmp.wa.gov.au for further information.

2 Findings from the fatalities review

2.1 Overview

The fatalities review considered 52 detailed investigation reports prepared by mines inspectors for work-related mining fatalities for the period 2000 to 2012. The review findings are based on the causation factors identified through an analysis of evidence contained in the inspectors' reports.

There was an average of 4 fatal accidents each year for the 13 years covered by the fatalities report. This was a period of major expansion in the Western Australian mining industry, with the mining workforce increasing from about 40,000 to 100,000 workers.

The review findings were considered from the aspect of active failures and latent conditions.

- Active failures relate to the factors that contributed to the final events triggering the accident (e.g. vehicle collisions, falls from height, crushed between components and rock falls).
- Latent conditions are those factors that might be prevalent at a mine, in the industry or in society as a whole (e.g. hours of work, rosters, fatigue, quality of training and supervision).

2.2 Active failures

About 75 to 80 per cent of the fatal accidents involved repeat scenarios with common causation factors.

Ten critical activity areas were identified:

- falls from height involving inappropriate application of preventative measures
- departures from original equipment manufacturer (OEM) procedures, mainly involving fitters in workshops
- run-away vehicles where park brakes were not applied, or downward vehicle momentum exceeded braking capability
- vehicles driven over edges such as waste dumps, stock piles or underground stopes
- vehicle collisions, with contact between various types of mobile plant
- electrical contacts in open panels with live conductors exposed
- rock falls just beyond the limit of supported ground
- pit wall failures onto or under workers and vehicles
- inrush situations in underground mines
- tyre handling where pressure was involved, or gravity caused the tyre to fall or roll.

2.3 Latent conditions

Factors identified as latent conditions include:

- occupation of the deceased worker – fitters and machine operators were most at risk
- duration of the deceased worker in their role
- duration of the deceased worker at the mine site
- duration of the supervisor in the role
- for workers and supervisors, the first six to twelve months of employment appears to be the most significant time period
- a lack of or inadequate training in hazard awareness such that hazards were often unrecognised
- a lack of or inadequate training in critical tasks associated with known hazards and known precautions
- the time of day, which appears to affect the propensity of workers to make errors
- quality of supervision to ensure work conducted according to standards
- the working environment, particularly in the early 2000s, with underground being four to five times more hazardous than the surface.

Note: The fatalities review found no particular correlation to different commute schedules, and the age of the worker did not appear to be significant.

2.4 Recommendations

The analysis suggested potential areas of improvement for industry are:

- improved hazard identification and risk assessment
- the development of principal hazard management plans (PHMPs)
- the use of written work procedures for all critical tasks
- supervision and observations to ensure compliance with procedures
- the pro-active involvement of workers in safe work system development
- improved training of workers and supervisors in procedures and processes
- improved site induction and familiarisation in the early months of employment
- adequate breaks during the shift to reduce the potential for human error.

3 Injury and occurrence reporting requirements

3.1 Legislative framework

Under the *Mines Safety and Inspection Act 1994* and Mines Safety and Inspection Regulations 1995, a mining operation (including exploration operations) must report the following to the Department:

- accidents involving injury to persons
- occurrences (commonly referred to as notifiable incidents for reporting purposes).

For injuries, section 76 of the *Mines Safety and Inspection Act 1994* specifies the type of injury that must be reported and by when.

3.2 What is injury data and how is it reported?

A serious injury is defined in legislation as an injury that results in the injured person being disabled from following his or her ordinary occupation for a period of two weeks or more. This definition is inclusive of lost time and restricted work injuries.

If a **fatality** has resulted from an injury, it is classed as a serious injury.

A **minor injury** is a reportable injury that is not classified as serious where the person is away for less than two weeks.

Serious injury information is submitted using the Department's Safety Regulation System (SRS) as a notifiable incident report, and at the end of each month in a mining injury report. Minor injuries are also reported at the end of the month in the mining injury report.

Although not defined by legislation, the following types of injury are used in safety performance measures published by the Department. They are notified by mining operators when submitting injury and monthly status reports.

A **lost time injury** (LTI) is a work injury that results in an absence from work for at least one full day or shift any time after the day or shift on which the injury happened.

A **restricted work injury** (RWI) is a work injury that is not a LTI but results in the injured person being unable to fully perform his or her ordinary occupation (regular job) any time after the day or shift on which the injury happened. This is regardless of whether or not the person is rostered to work, and where alternative or light duties may be performed or hours restricted

3.3 Quality assurance of injury data held in SRS

When mining operators submit injury reports via SRS, a quality assurance (QA) process is undertaken during which coding standards are applied to each injury report against a set of defined categories. Codes are available for about 70 injury types, 90 occupations, and more than a hundred machines, mines and a range of activities. In total, several hundred coding splits are applied at the QA stage.

Since 2002, the same quality assurance standards have been applied to data in accordance with departmentally derived standards, and to address the range of commute rosters.

The QA process can take several months to complete as medical and injury outcomes are resolved.

3.4 What is occurrence data and how is it reported?

Occurrences or notifiable incidents are unplanned incidents that do not necessarily result in injury to a person or damage to property. Under the *Mines Safety and Inspection Act 1994*, the following occurrences are required to be reported:

- extensive subsidence, settlement or fall of ground or any major collapse of any part of the operations of a mine, or any earth movement caused by a seismic event [s. 78(3)(a)]
- outbreak of fire above or below ground in any mine [s. 78(3)(b)]
- breakage of a rope, cable, chain or other gear by which persons are raised or lowered [s. 78(3)(c)]
- inrush of water from old underground operations or other source [s. 78(3)(d)]
- accidental ignition of dust below ground or the discovery of the presence of potentially harmful or asphyxiant gas or an outburst of such gas in any part of a mine [s. 78(3)(e)]
- accidental ignition or detonation of explosives, or any delayed or fast ignition of explosives [s. 78(3)(f)]
- explosion or bursting of compressed air receivers, boilers, or pressure vessels [s. 78(3)(g)]
- every electric shock or burn to a person and every dangerous occurrence involving electricity [s. 78(3)(h)]
- incidence of a person being affected by poisoning or exposure to toxic gas or fumes [s. 78(3)(i)]
- loss of control of heavy earth-moving equipment, including failure of braking or steering [s. 78(3)(j)].

In addition to the occurrences listed above, other reportable incidents and accidents under the mines safety legislation include:

- an injury that is serious or appears to be serious, including a fatality [s. 76 (2)(a)]
- a potentially serious occurrence or incident [s. 79]
- incidents affecting registered plant [r. 6.36].

Occurrences or notifiable incidents are submitted as a notifiable incident report via SRS. The Department must be notified whether or not anyone was injured, and whether or not there was any damage to property.

4 Methodology for serious injury analysis

4.1 Establishing a representative sampling interval

One of the aims of the serious injuries analysis is to determine a reporting time period that can be routinely used to provide meaningful and timely information on safety performance trends.

The sampling interval chosen needs to provide a data set of sufficient size and duration that it would be representative of longer term trends but also capture more recent activity. Since late 2002, reporting and quality assurance standards have been sufficiently consistent to provide a reliable base for comparison purposes. Hence, to select the appropriate sampling interval, serious injury data was collated and summarised for 2002 to 2013.

Figure 1 shows the total number of serious injuries (classified as lost time or restricted work injuries) increasing over the 12-year period, mainly due to an increase in the number of serious RWIs. During this period, the number of workers employed in the industry increased from around 40,000 to 100,000. The normalised data (Figure 2) show that the incidence rate (number of serious injuries reported per 1,000 workers) decreased slightly over that period and has levelled out since 2011, suggesting that, at least recently, there have not been significant changes in safety processes and mining techniques and therefore injury performance.

Since 2011, the numbers of serious injuries reported annually represent significant data sets. Six-monthly data sets were then extracted (see Table 2 in Chapter 8) to see if the shorter

duration would provide sufficient samples and if there was any seasonal variation.

There is no obvious bias for either total injuries or serious injuries, with similar numbers of injuries for both six-month periods in any one year. The serious injury data follow a similar trend to the total injury data. It was therefore considered that the most recent six-month data set would be suitable for the analysis.

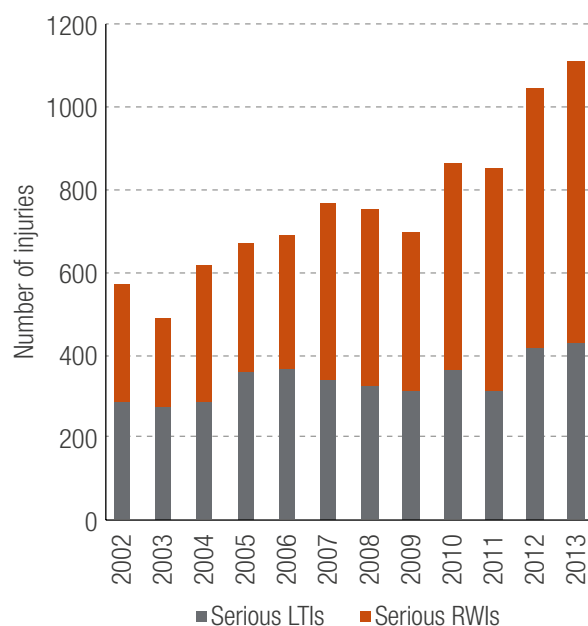


Figure 1 Number of serious injuries reported as LTIs and RWIs for 2002 to 2013

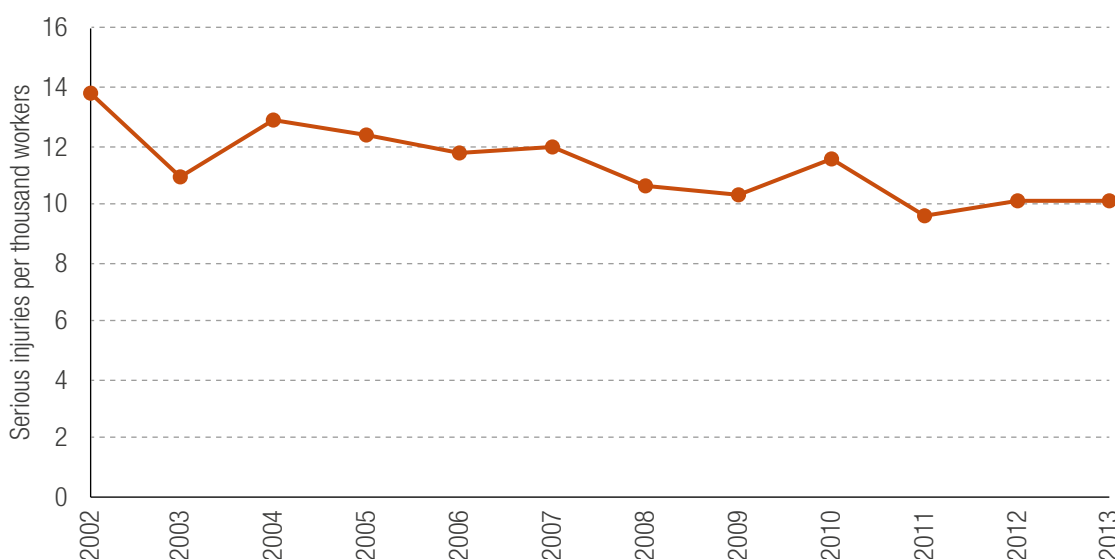


Figure 2 Serious injury incidence rate for 2002 to 2013

4.2 Data sets used in analysis

The six-month period of injury data chosen for analysis covers the period from 1 July to 31 December 2013. This represents the most recent data that had been quality assured at the commencement of the review.

A total of **837** injuries were reported for the review period. This included information on **658** serious injuries, of which **3** were fatalities. There were **179** injuries classified as being minor.

To complement the more detailed analysis of the serious injury data, occurrence reports for this time period were also used to help clarify the details of some serious injuries. The occurrence data set was subsequently used in the development of the industry risk profile (**1,036** occurrences with no injury reported).

4.3 Grouping data

Initially, attempts were made to analyse the injury data using the individual codes assigned at the QA stage. However, the graphs produced were essentially flat with the data appearing as a cloud of unrelated items. Subsequently, the coded serious injury data was grouped by similar occupation groups, activities and injury outcomes. This provided a much clearer pattern of hazard exposures and causation factors in the sample of serious injuries.

At the QA stage, information (e.g. occupation, injury type) is coded, which allows injury data to be grouped in multiple ways for further analysis, including determining injury severity.

A variety of charts was then developed to illustrate causation factors for serious injuries in a manner consistent with the fatalities review. This allowed analysis of possible correlations with the causation factors identified in the fatalities review.

Three-dimensional plots proved useful for assessing trends and clusters of data when two variables were analysed. The plots are presented in this report as screen grabs together with the data plotted conventionally on bar graphs.

Note: The order of items may differ between the three-dimensional plots, which represent the original output, and the bar graphs, where items have been arranged to reflect the review discussion.

4.4 Limitations resulting from reporting requirements under legislation

The definition of serious injury in the *Mines Safety and Inspection Act 1994* does not differentiate injury severity. Rather, it captures injuries that result in a person being away from normal work for two or more weeks. In some circumstances, the mechanism of the serious injury is considered unlikely to result in a fatal or severe physical injury, but it is those circumstances where it may that are the subject of this analysis.

Note: The definition of serious injury in the Model Work Occupational Health and Safety Act differs from that in the Mines Safety and Inspection Act 1994 as it relates to injury type rather than time off work.

Another limitation is that the detail of information reported for injuries is not as in-depth as that provided or gathered for fatality investigations. The key latent conditions for fatal accidents discussed in Section 2.3 could be identified because these incidents were investigated in detail by mines inspectors to a consistent standard over the 13-year period. Unfortunately, similar latent conditions cannot be identified using the injury and occurrence data, which is submitted by mines in accordance with the requirements of the Mines Safety and Inspection Act 1994 — detailed reports are not required for all incidents. However, the notification format approved by the State Mining Engineer does cover active failures associated with incidents. Consequently, comparisons with the fatalities review could be made using active failures identified in the reports.

Also, although medically treated injuries may be an outcome of a potentially serious (or near miss) incident, they are not required to be reported and therefore the lessons learnt are not captured in this analysis.

The occupation, injury type, work activity and nature of injury could not be determined for one injury report. This injury report was not included in the data set where such information was required for the analysis.

Incidence rate (per thousand workers) is used in this report rather than frequency rate (per million hours worked) because the values are higher, allowing comparison of rates at a reasonable scale.

Note: The workforce numbers used to determine incidence rates are based on 2,000 hours worked per year being equivalent to one full-time worker.

5 Analysis of injury data for 1 July to 31 December 2013

5.1 All injury data

Figure 3 shows all injuries in the six-month period in terms of operational activity. Operations activities were responsible for the majority of injuries (55%) followed by maintenance activities (28%).

About 78 per cent of the 837 injuries reported for the six-month period were serious (includes fatalities). When considering the severity of the injury compared to operational activity (Figure 4), it is apparent that the vast majority of serious injuries happen in the operational phase of a mining operation. This includes direct mining in open pits and underground mines as well as work activity in mineral processing plants. Maintenance activities in workshops and fixed plant areas are the second problematic area identified for serious injuries.

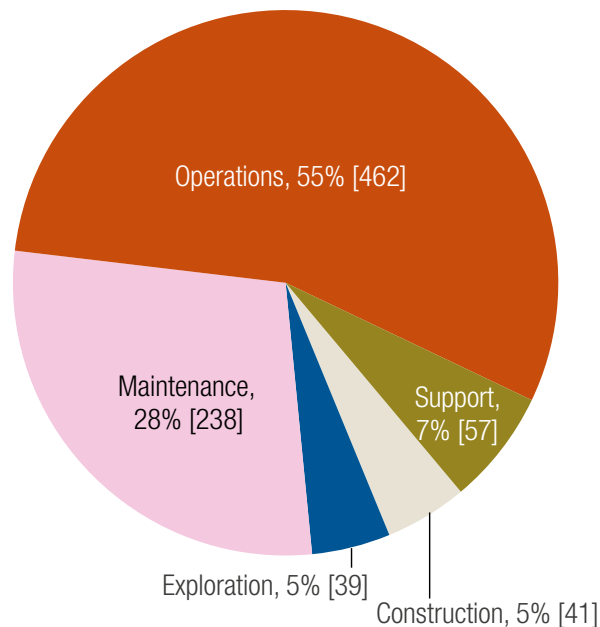


Figure 3 All injuries by operational activity, July-December 2013

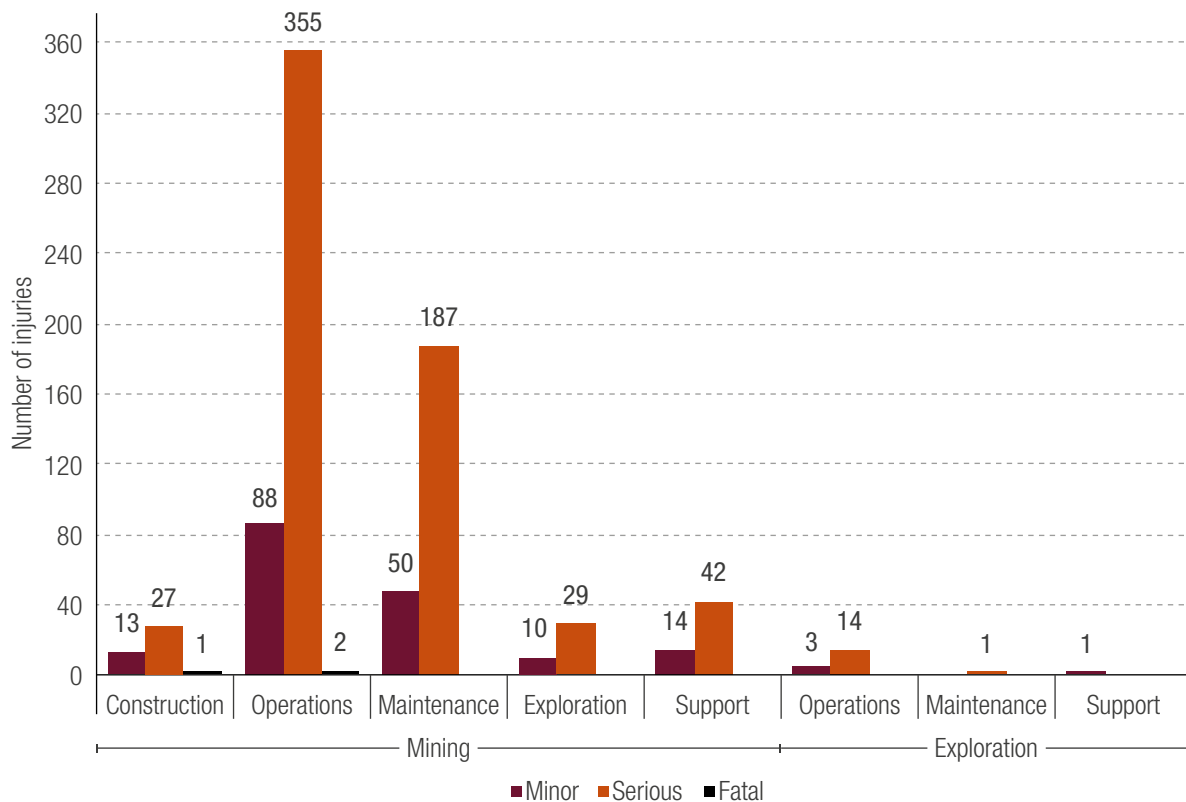


Figure 4 Severity of injury by operational activity, July-December 2013

5.2 Serious injury data

To compare serious injuries with the outcomes of the fatalities review, the information from the serious injury reports was analysed in the same manner.

Serious injuries by employment arrangements

Of the 658 serious injuries (including fatalities) reported in the six-month review period, 444 were for workers employed by principal employers and 214 for workers employed by a contractor. Workers employed through a principal employer had more than double the number of serious injuries compared with contractors.

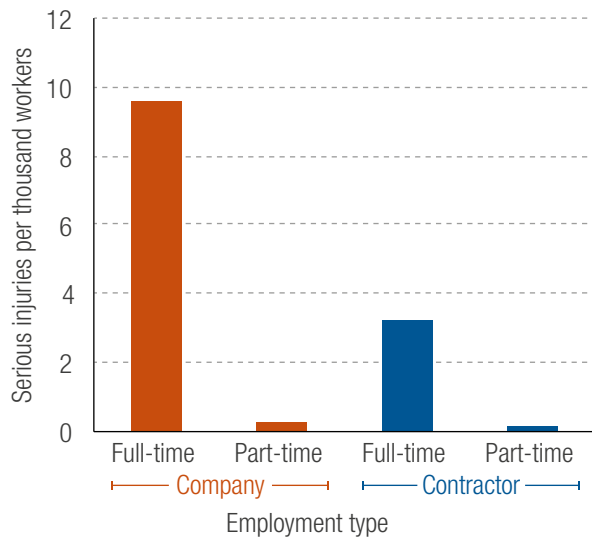


Figure 5 Serious injuries incidence rate by employment type, July-December 2013

Over the six-month period, about 45,000 workers were employed by principal employers and 63,000 by contractors. Normalising the data (Figure 5) shows company workers were three times more likely to be seriously injured.

However, this trend is reversed for fatal accidents, with contractors over-represented in the fatality data. It could be that contractors are often involved with higher risk tasks and activities, such as during the construction phase, or perhaps they are less familiar with the site and its procedures.

These observations suggest that hazard exposure is more important in determining the risk of injury than the employment relationship. For example, if a fitter is working on a machine in a workshop, the hazards associated with the machine components are more important than the employment arrangement. The effectiveness and understanding of the site's safety processes could, however, have a significant influence on the exposure of workers to hazards and adequacy of control measures.

Serious injuries by age group

Age does not appear to be a significant factor in serious injury outcomes, with similar figures between the ages of 23 and 57 (Figure 6), in line with the findings of the fatalities review. The lower numbers of injuries in the younger and older age categories are attributed to lower numbers of workers in those age groups.

Serious injuries by operational activity and environment

Figure 7 shows the distribution of serious injuries between surface and underground environments by operational activity. Overall, 88 per cent of serious injuries happen on the surface,

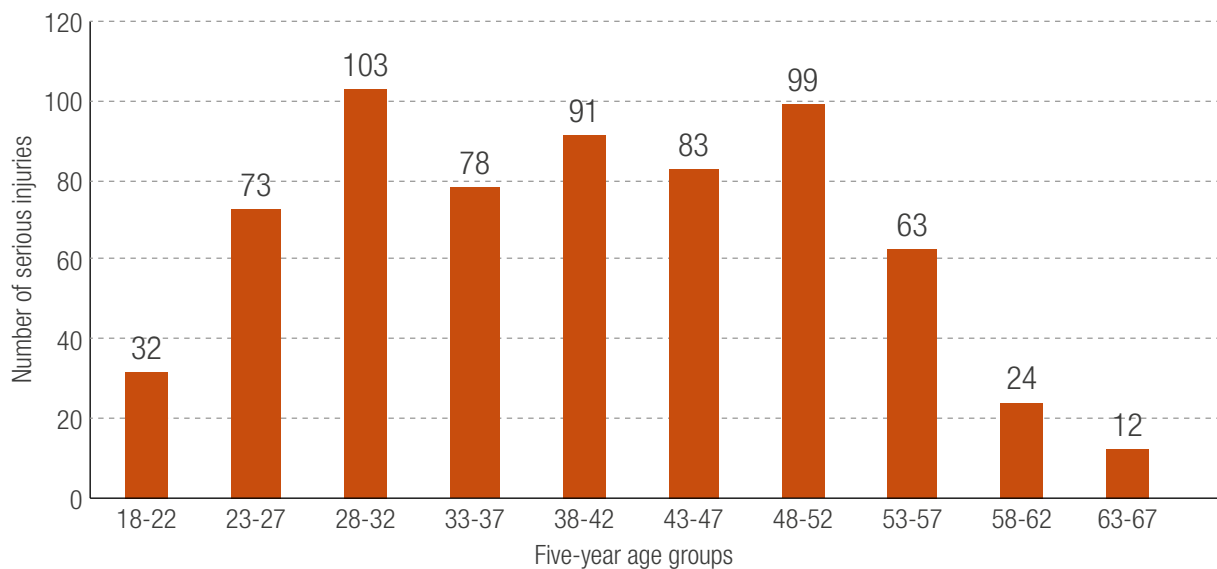


Figure 6 Serious injuries in five-year age groups, July-December 2013

mainly associated with surface mining operations and surface maintenance activities. The third largest group of serious injuries is associated with underground mining operations.

In the fatalities review, 67 per cent of fatalities were associated with surface operations and 33 per cent with underground operations. There was also a fairly even distribution between direct production, maintenance and other activities. Although the parameters examined in the fatalities review were slightly different, both studies show the concentration of injuries associated with direct production and maintenance activities. The people most at risk of injury are those directly associated with the physical work environment and machinery at the mine.

Serious injuries by occupation (grouped)

Fitters constitute the largest single group of workers being seriously injured (Figure 8). When vehicle drivers and mobile plant operators (i.e. surface drivers, surface operators and underground operators) are considered as a whole, they have the highest serious injury exposure.

This reflects the findings from the fatalities review, where fitters and operators of mobile plant were identified as the two occupation groups most at risk.

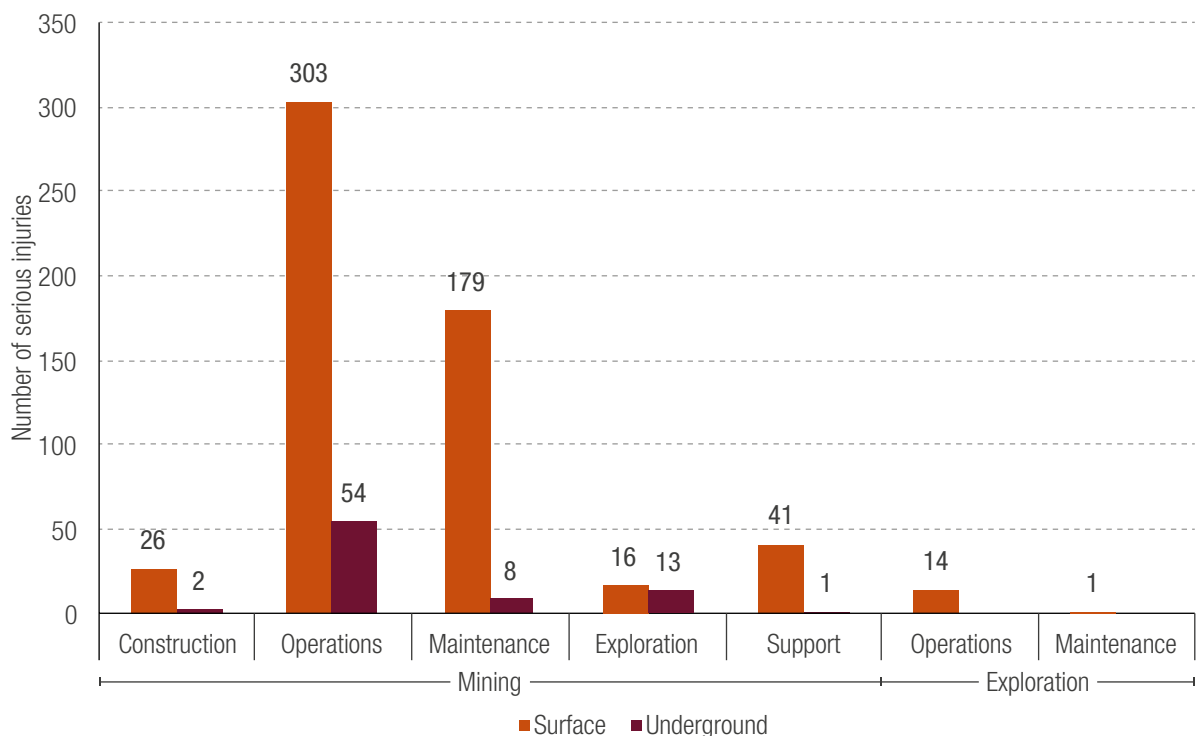


Figure 7 Serious injuries in surface and underground environments by operational activity, July-December 2013

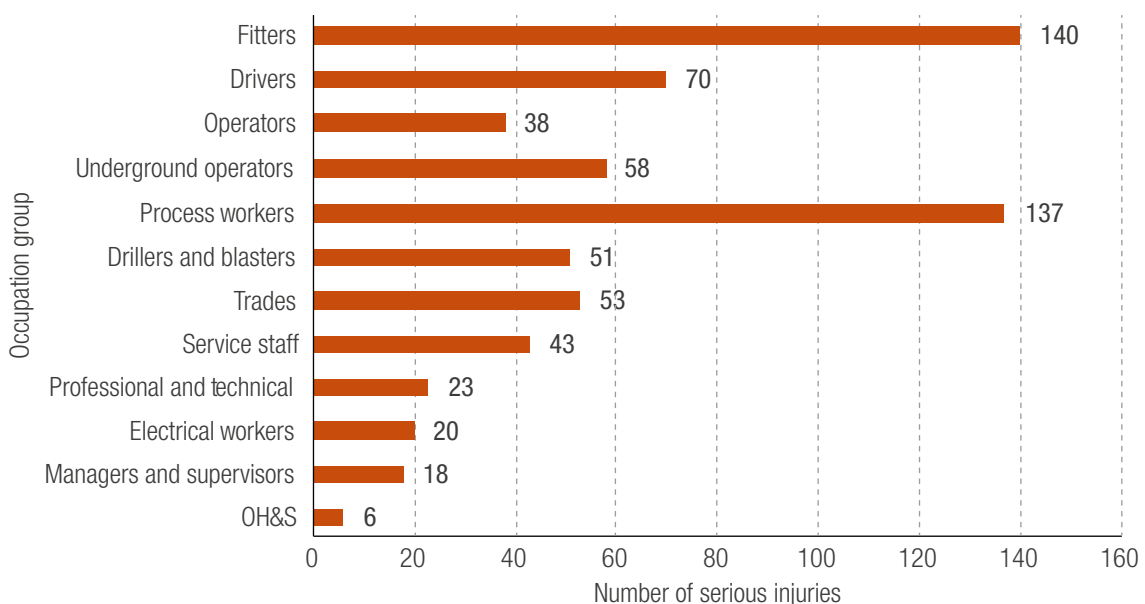


Figure 8 Serious injuries by occupation (grouped), July-December 2013

Process workers comprise a large group identified in the serious injury review that did not appear in the fatalities review. Significant numbers of serious injuries in processing operations are associated with workers moving around the work area, often carrying tools and equipment, and sustaining sprain and strain injuries. Although some of these injuries may be debilitating (e.g. chronic back pain), the potential for such incidents to escalate into a fatality is low.

Two other significant groups identified in the serious injuries analysis are drillers and blasters, and trades. In the fatalities review, one fatal accident was caused by explosives, and rock falls resulted in three fatalities, with two being jumbo operators and one an air-leg miner. The results are broadly consistent and provide direction for further analysis.

Relationship of occupation (grouped) and injury type to number of serious injuries

When looking for potential relationships between occupations and injury type (Figure 9), it is clear that over-exertion dominates and process workers, fitters, and drivers are susceptible to this type of injury. Over-exertion is usually associated with lifting, carrying, pulling, pushing and moving objects, and also includes strenuous and repetitive movements, and awkward or sustained postures. In most serious injuries of this type, there was no contact from an external energy source and therefore little or no potential for a fatality.

Falls from height, and trip and fall injuries mostly involve process workers, fitters and drill and blast workers. Falls from vehicles mostly involve drivers and underground operators. The severity of the injury relates primarily to the height of the fall, and this type of incident has the potential to result in a very serious or fatal accident.

Process workers and fitters, and to a lesser extent trades and underground operators, have a significant number of injuries caused by being struck by or caught between objects.

For drivers and operators associated with vehicles, injuries mainly relate to jarring or jolting events. A smaller number of vehicle-related injuries relate to collision or contact.

Serious injuries by work activity (grouped)

Large numbers of serious injuries are associated with people lifting or moving items or equipment, or moving or walking (mobilisation) around the mine (Figure 10). A significant subgroup of mobilisation relates to stepping down from ladders or stairs on mobile or fixed plant.

Work associated with surface and process tasks, and working with hand tools and equipment also appear to be significant problem areas.

Serious injuries by nature of injury (grouped)

An analysis of the nature of serious injuries clearly shows that joint and muscle sprain and strain injuries dominate the serious injury reports (Figure 11).

Relationship of nature of injury and work activity (grouped) to number of serious injuries

When the nature of injury and work activity (grouped) are plotted (Figure 12), the serious sprain and strain injuries are mainly attributable to workers walking around, lifting and moving items in the workplace, or engaged in general surface activities.

Such injuries do not involve a significant transfer of stored energy from the working environment to the worker and have little potential for a fatal or major injury outcome. Consequently, if sprains, strains, and the two unspecified injuries are filtered from the serious injury data (Figure 13), it is easier to see injuries that have the potential for fatal outcomes.

Figure 13 shows the next most common serious injuries are those involving fractures. The highest numbers of incidents relate to mobilisation, with people walking around or stepping off objects. Some fractures were caused by people tripping over their own feet or items left lying around, while others involved stepping down from the lower steps of ladders or steps on mobile equipment.

If mobilisation and lifting are excluded from the work activities, then there are significant groupings relating to working with equipment, use of hand tools, process tasks, surface tasks, underground tasks and vehicle interactions. These activities align more closely with the factors identified by the fatalities review.

The energy transferred to the worker determines the injury severity. If a worker is struck by a falling object then it is factors such as the weight, fall height and trajectory that determine the injury severity. Similarly, if a worker is caught between or struck by a machine component, it is primarily the force of contact and the body part affected that determine the severity.

When fractures, crushing and amputation injuries are considered as a whole, the main activities implicated are working with equipment, lifting or moving items or using hand tools. This correlates with fatal accidents where workers such as fitters are caught between or struck by moving plant and equipment. Similarly, workers engaged in maintenance work on plant in workshops and process plants can be struck by tools. Power tools are dangerous because of the rotational forces and potential energies involved.

Note: Figure 9 is on pages 12 and 13 for ease of viewing.

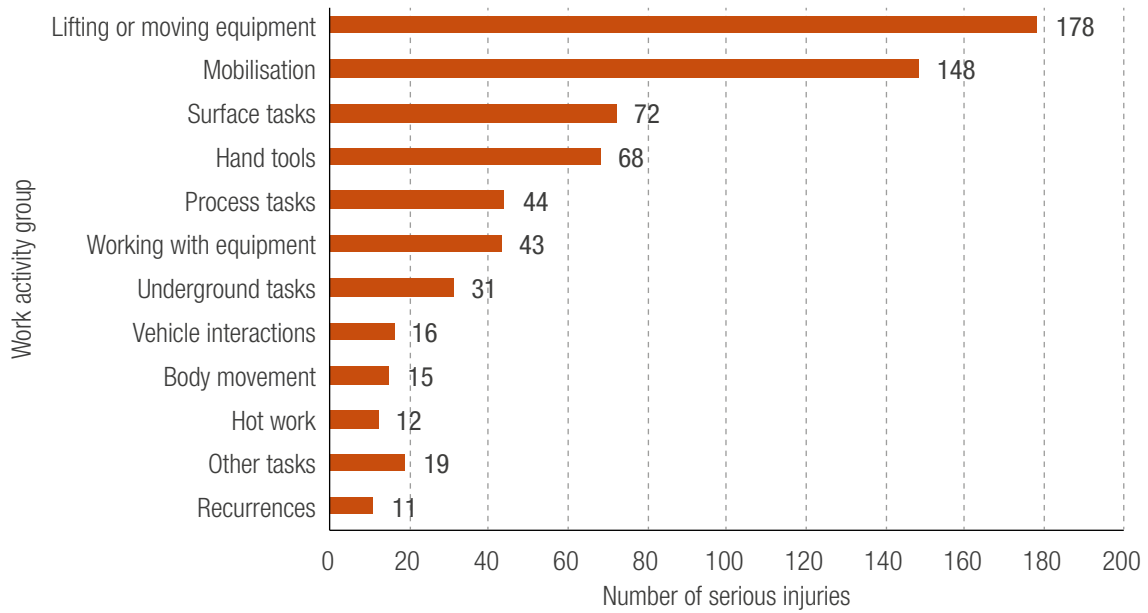


Figure 10 Serious injuries by work activity (grouped), July-December 2013

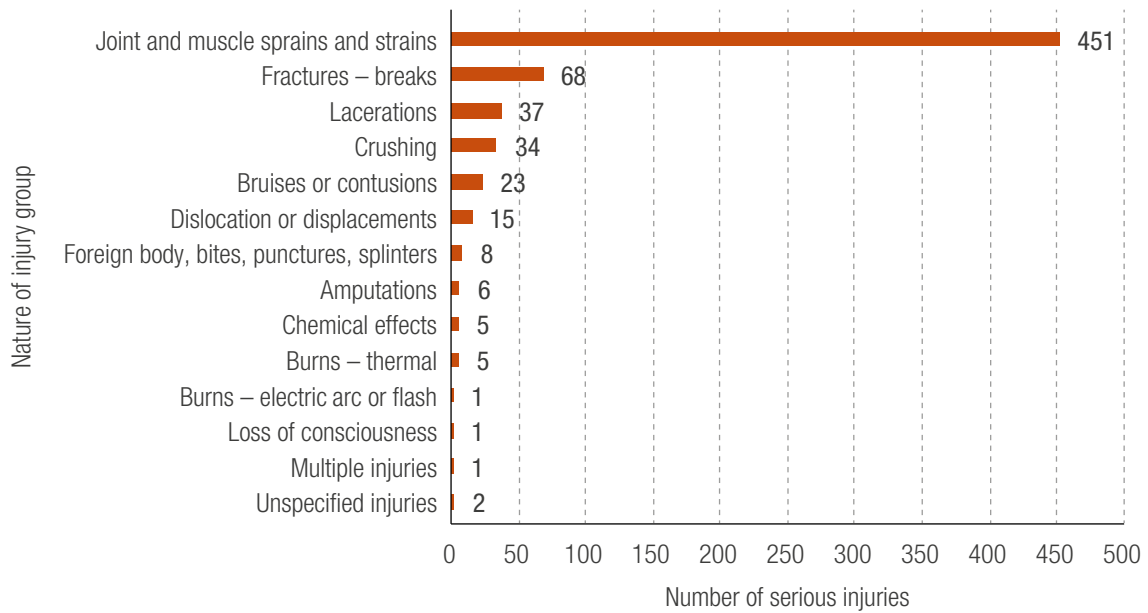
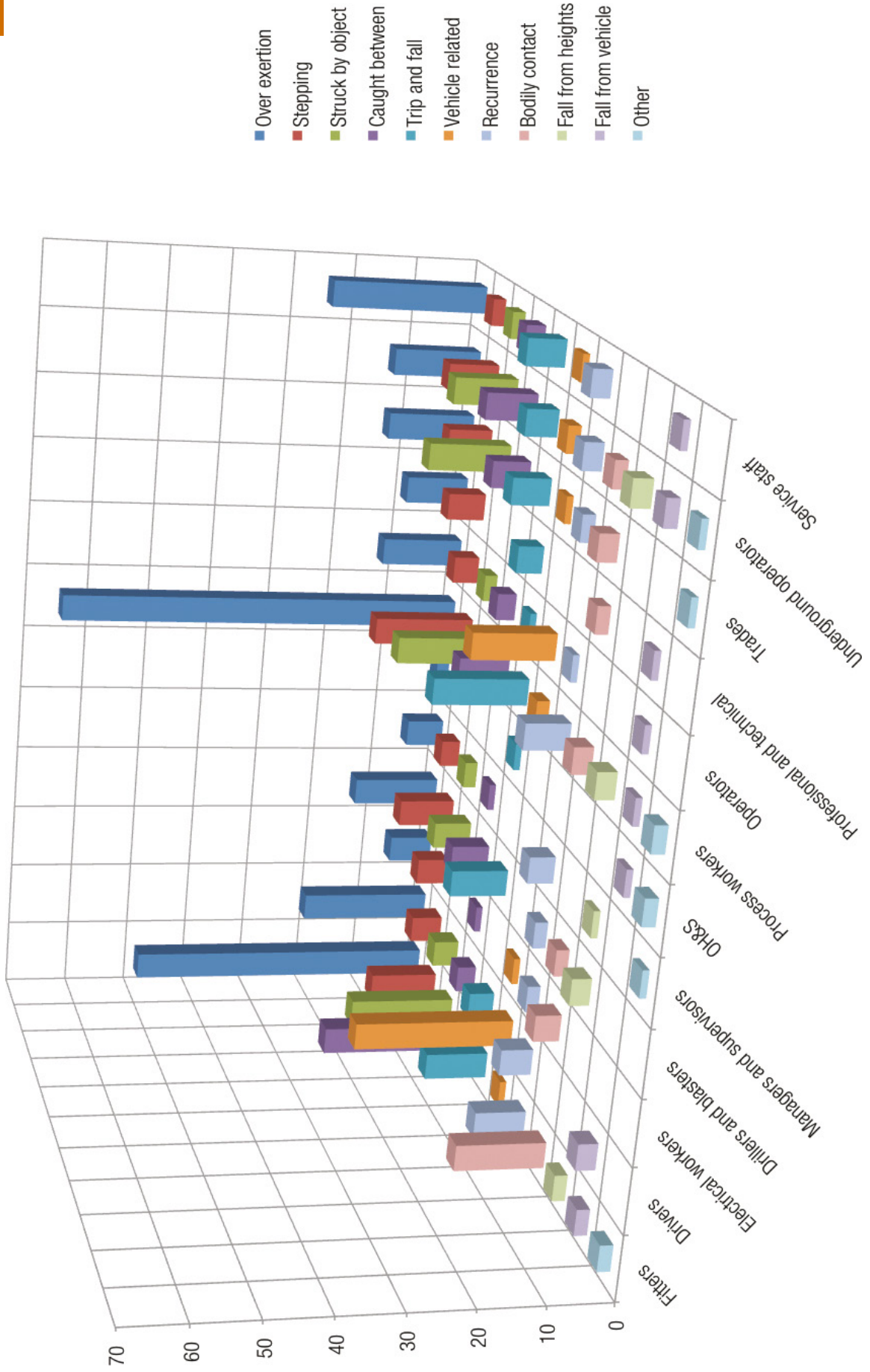


Figure 11 Number of serious injuries by nature of injury (grouped), July-December 2013

A



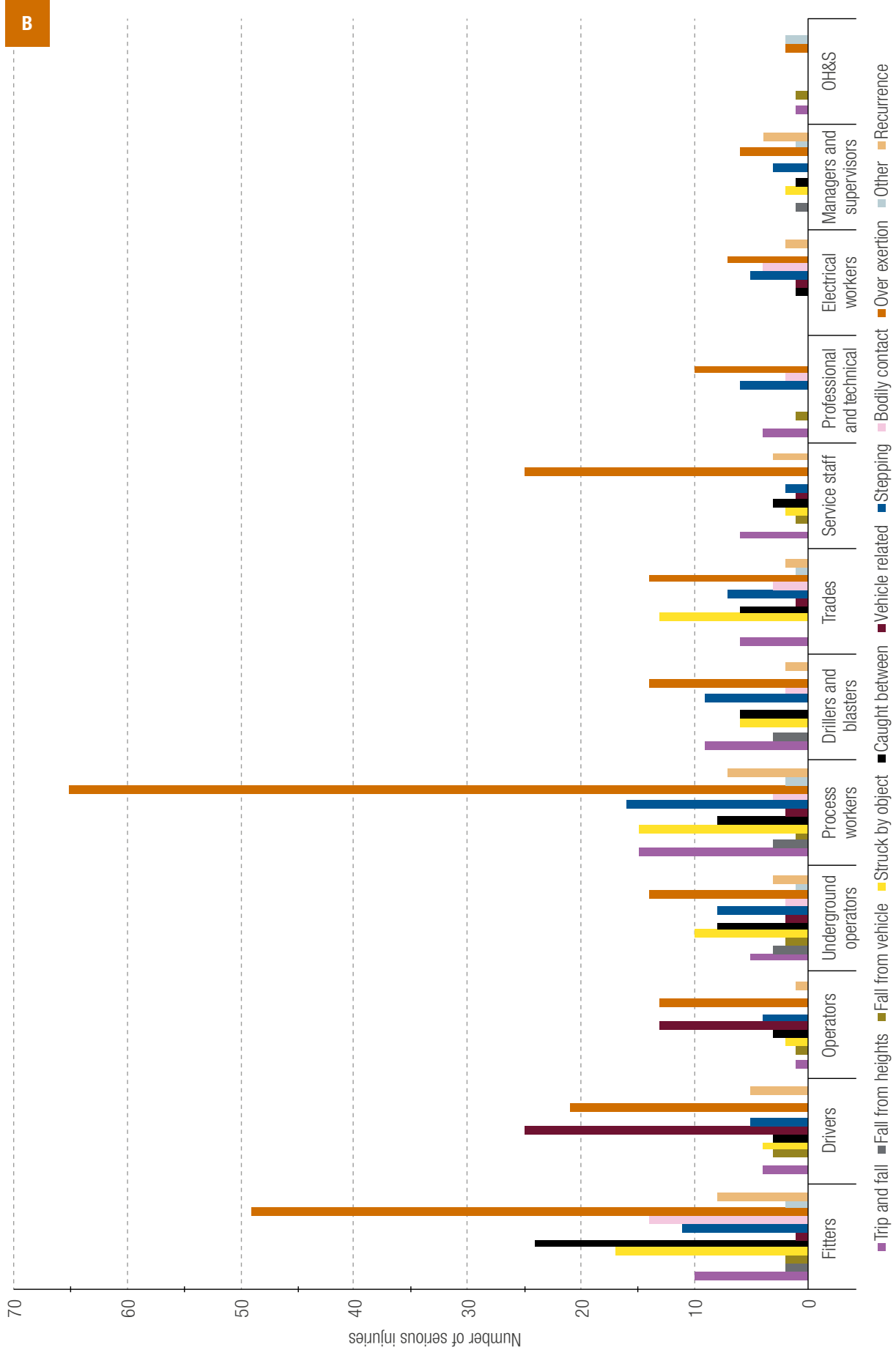
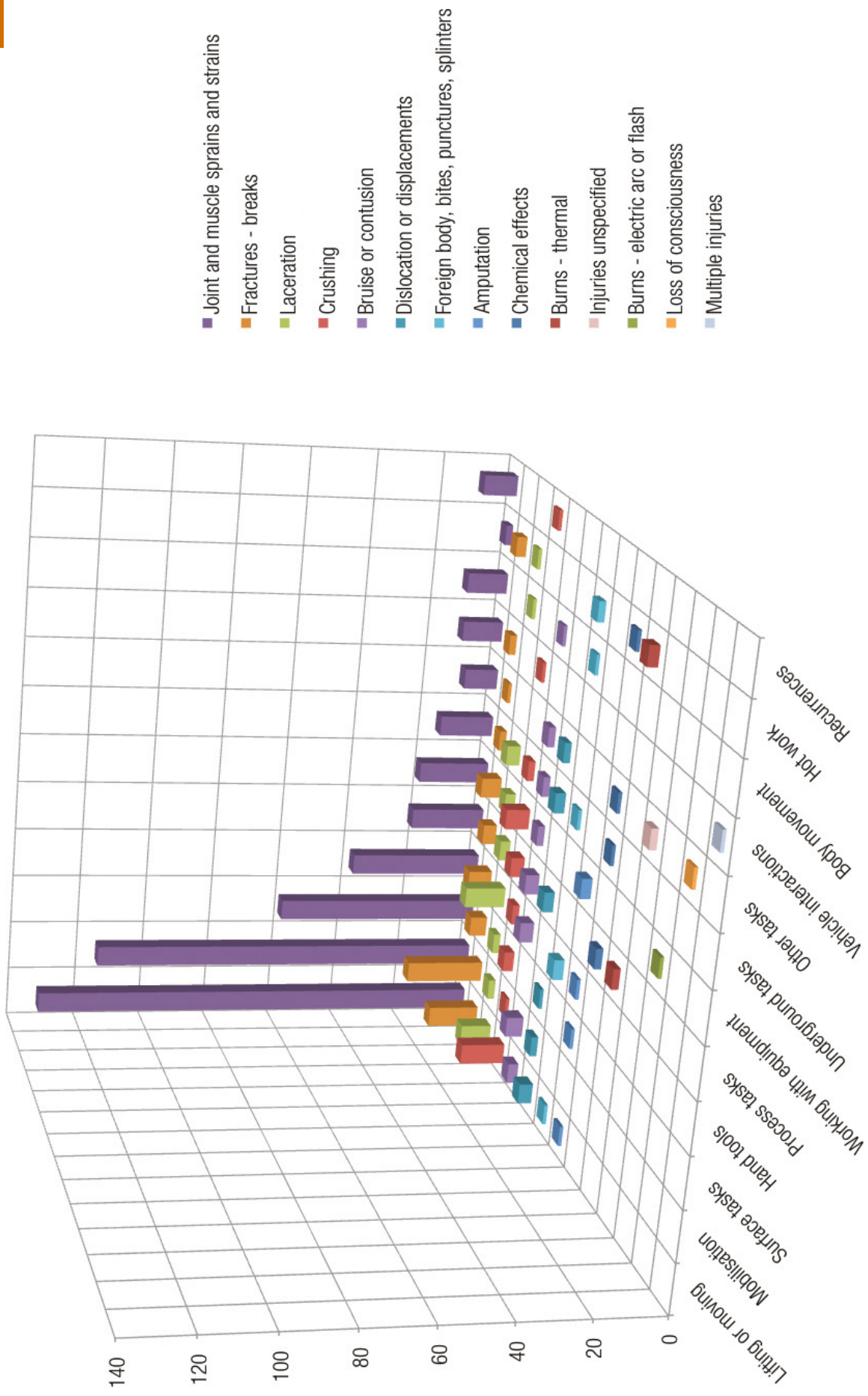


Figure 9 Serious injuries by occupation (grouped) and injury type, July-December 2013. Data presented as **A** three-dimensional plot (screen grab) and **B** bar graph

A



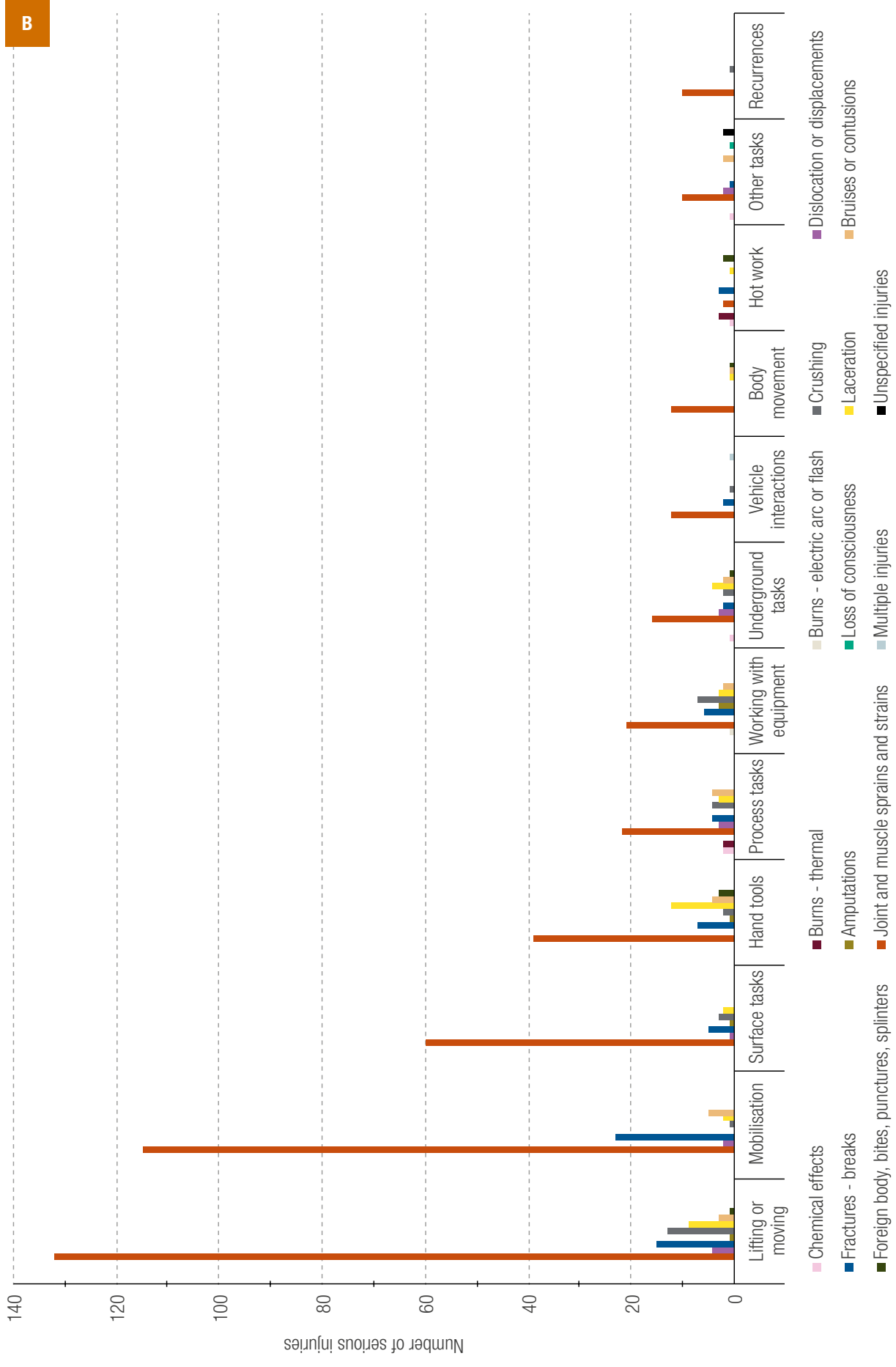
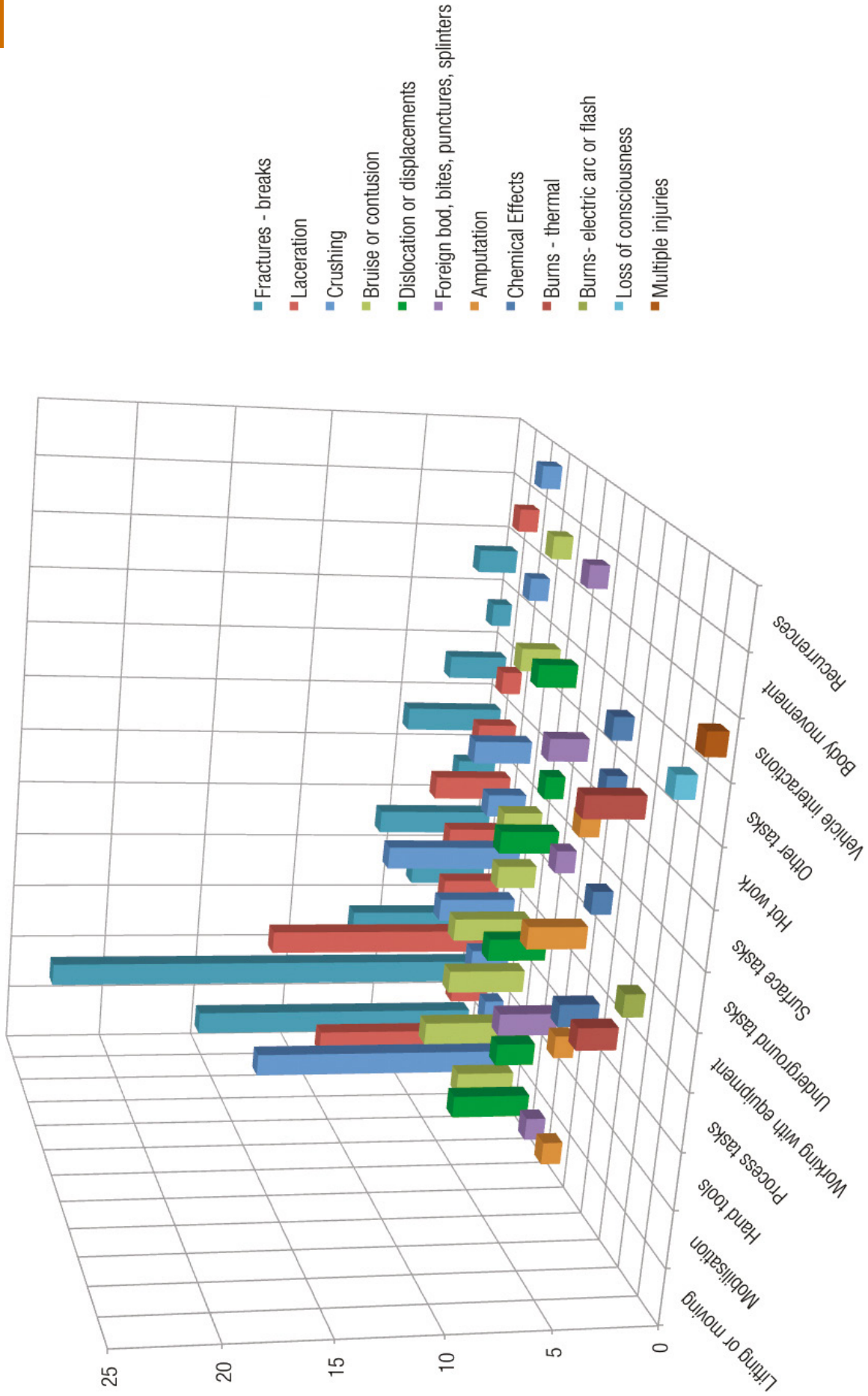


Figure 12 Serious injuries by nature of injury (grouped) and work activity (grouped), July-December 2013. Data presented as **A** three-dimensional plot (screen grab) and **B** bar graph



B

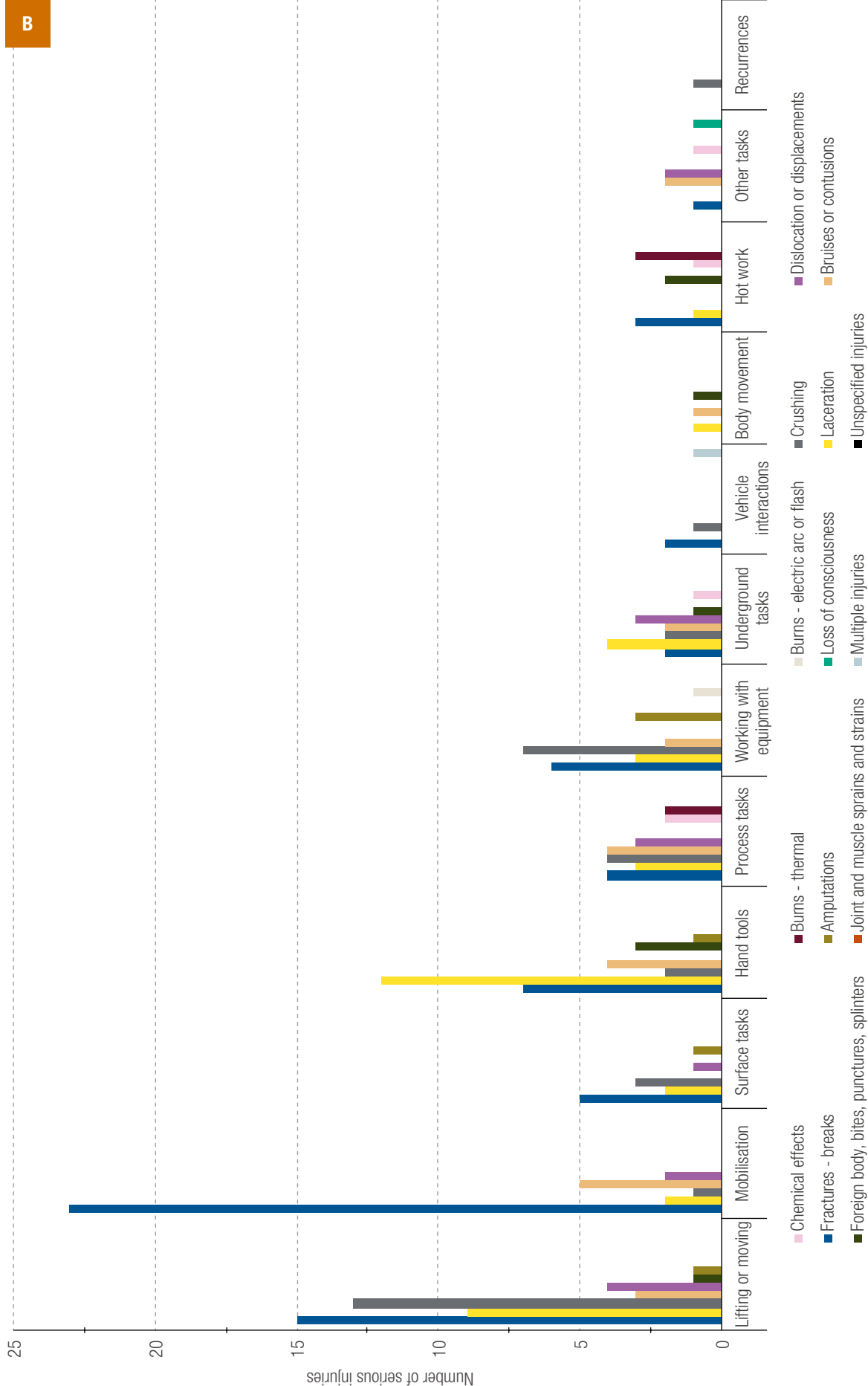


Figure 13 Serious injuries (excluding strains and sprains, and unspecified injuries) by nature of injury and work activity (grouped), July-December 2013. Data presented as **A** three-dimensional plot (screen grab) and **B** bar graph

6 Identifying potentially significant factors for serious injuries

6.1 Energy transferred

The analysis presented in Chapter 5 shows that the level of energy transferred to the worker has a strong influence on the injury outcome. It has identified factors that can lead to fatal and serious injuries as a result of physical contact between the working environment and a worker.

Two groupings of serious injuries are recognised in this analysis, categorised as follows:

- low-consequence serious injuries
- high-consequence serious injuries.

Low-consequence serious injuries

There is a large number of sprain and strain injuries, which often result in people being off work for more than two weeks. The majority of these injuries relate to activities that are unlikely to result in a fatal or a more severe serious injury, and therefore they are not analysed further.

Note: These injuries are termed low-consequence with respect to their potential to be fatal, not their potential to result in chronic or longer term health impacts.

High-consequence serious injuries

Fewer serious injuries involve a transfer of energy from the working environment to the worker, resulting in severe injuries. Significantly, the associated work activities have potential to result in fatal accidents or major physical injuries. Essentially these are the injuries that are a level of severity down from the fatal category.

The analysis identified three groups within the high-consequence serious injuries data set. One group is associated with repetitive tasks, and therefore represents a larger data set, which was assessed to determine its suitability as an indicator for fatalities. The remaining groups are associated with low-frequency incidents or rare events with high-potential outcomes.

Repetitive high-consequence serious injuries

Two combinations of injury type were identified for the common high-consequence serious injuries:

- amputations (i.e. severed body parts), fractures and crush injuries
- lacerations, dislocations or displacements, and bruises or contusions

When the associated work activities are considered, these types of injuries have causation factors in common with those identified in the fatalities review:

- falls from height
- suspended or dropped loads
- crush hazards with machines and equipment.

It should be possible to use a detailed knowledge of the risks associated with these high-consequence serious injuries to develop strategies to reduce the risk of injury and highlight fatality potentials. This proposal is explored further in Section 6.2.

Low-frequency high-consequence serious injuries

There is no direct correlation between the numbers of high-consequence serious injuries for vehicle accidents, rock falls, and electrical incidents, identified as critical activities in the fatalities review, and fatalities. For example, vehicle incidents represent three of the top ten categories for fatalities but their representation in the high-level serious injuries is not as pronounced.

This is probably due to the nature and frequency of the incident coupled with the stored energy associated with the work activity. If a large rock falls and hits someone, a fatal or high-consequence serious injury would result. If the rock misses the person, there is no physical injury. Similarly, for a vehicle collision or electrical contact, the outcome is likely to be either:

- a fatal or high-consequence serious injury, or
- a minor or no injury.

Rare high-consequence serious injuries

An aspect of hazard identification that is unlikely to be highlighted in a single six-month sample is that related to high-potential events. High-potential events are defined to be any incident or near miss that could, in other circumstances, have realistically resulted in one or more fatalities. Fortunately, such events are infrequent but potential scenarios must always be treated as a high priority. Examples include:

- inrushes of water, mud or fluids
- major fires
- explosions
- major pit wall failures
- major collapse of underground workings
- failures of tailings dams and waste dumps
- release of toxic or inflammable gases underground
- exposure to toxic or inflammable substances or gases on surface.

6.2 Analysis of repetitive high-consequence serious injuries

The repetitive high-consequence serious injuries are divided into two combinations, representing escalating injury severity:

- **106** incidents involving amputations, fractures and crush (AFC) injuries
- **75** incidents involving lacerations, dislocations and bruises.

Note: Serious injuries resulting in a fatality or multiple injuries were excluded from this analysis.

The detailed descriptions in the injury reports were then used to assign work scenarios (Table 1), analogous to the critical activities identified in the fatalities review. The proportion of injuries attributed to each work scenario is similar for both injury combinations.

Lacerations, dislocations and contusions could be considered the “next level down” to AFC injuries, so it was thought there would be more injuries in this group than the AFC injuries group, but this is not the case. A possible explanation is that some of these injuries might not meet the criteria for reporting under the legislation and therefore are not in the data set.

Note: Irrespective of their regulatory status as serious injuries, information on lacerations, dislocations and contusions could be collected by a site and used as part of its risk profiling (see Chapter 7).

The crushed or caught between or against scenario is responsible for the greatest number (43) of high-consequence serious injuries.

Combining the two falls and slips scenarios gives a total of 51 high-consequence serious injuries. This is consistent with falls from height being the most common cause of fatal accidents identified in the fatalities review.

Common hazards identified in the injury reports are:

- falls and slips
 - tripping over loose rocks
 - tripping over items of equipment
 - slipping on uneven surface or change in elevation
- falls and slips from height
 - falling off trailers or platforms
 - descending ladders and steps
 - exiting mobile plant on access ladders
- suspended or dropped loads
 - large fixed plant components
 - maintenance of mobile plant
 - loading drill rods
 - pipes and fans
- use of tools
 - drills and grinders
 - hammers, mallets and sledge hammers
 - pipe and flogging spanners, torque and pipe wrenches
- machinery and equipment
 - drills and lathes
 - contact with loaders
 - rotating blades, bars and fans

Table 1 High-consequence serious injuries by nature of injury and work scenario, July-December 2013

Activity (Grouped)	Amputation, fracture, crush injury	Dislocation, laceration, contusion	Total
Crushed or caught between or against	26	17	43
Falls and slips – level surface	17	13	30
Falls and slips – elevated workplace	12	9	21
Suspended or dropped item	16	8	24
Hand tools – manual and power	12	11	23
Machinery and equipment	9	5	14
Lifting by hand or exertion	8	9	17
Hoses or vessels under pressure	2	2	4
Vehicle collisions	2	0	2
Electrical	1	0	1
Tyres	1	1	2
	106	75	181

- lifting by hand
 - boxes and cabinets
 - heavy machine parts
 - guards and plates.

6.3 Analysis of low-frequency and rare high-consequence serious injuries

The low-frequency and rare high-consequence serious injuries are problematic when trying to establish whether there are trends and clusters in the data. Fortunately, there are few such injuries over a six-month sampling period. Rather than extend the sampling period, which defeats the aim of trying to find a data set that can provide a more immediate indication of safety performance, a more detailed analysis of the (more numerous) occurrence reports is being undertaken as part of the ongoing study of the industry risk profile.

7 Risk profile for Western Australian mines

7.1 Establishing a risk profile for Western Australian mines

The concept of the accident triangle was applied to the serious (including fatal) and minor injuries and occurrences reported for the six-month review period (Figure 14). The boundaries are based on the severity of the physical injury. High-consequence serious injuries comprise amputations, fractures, crush injuries, dislocations, lacerations and contusions. The remaining serious injuries and minor injuries are classified as “other” injuries. Occurrences are those incidents for which no injury was reported.

Note: The serious injury definition in the Mines Safety and Inspection Act 1994 was not used as it is based on time off work rather than injury severity. In addition, 78 percent of injuries were classified as serious under this definition and therefore are not suitable for the accident triangle approach.

A check sample was then prepared for the last six months of 2010 to test the consistency of the ratios. There were 3 fatalities, 146 high-consequence serious injuries, 589 other injuries and 983 occurrences with no injuries. The proportions are similar, confirming the validity of using this tool to represent the injury risk profile for the Western Australian mining industry.

Based on data for the past few years and normalising for a workforce of 100,000, Figure 15 shows the generalised accident triangle that can be referenced as the six-month injury risk profile for the past five years. This may be used state-wide as a reference point for tracking industry safety performance, or by sites or companies for comparative purposes with their own data.

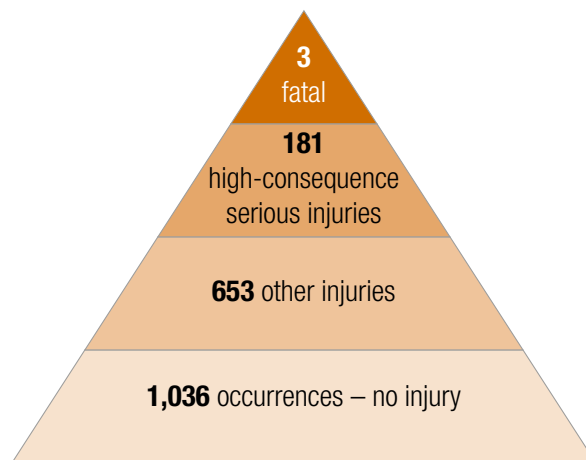


Figure 14 Accident triangle compiled using injury reports and occurrence data, July-December 2013

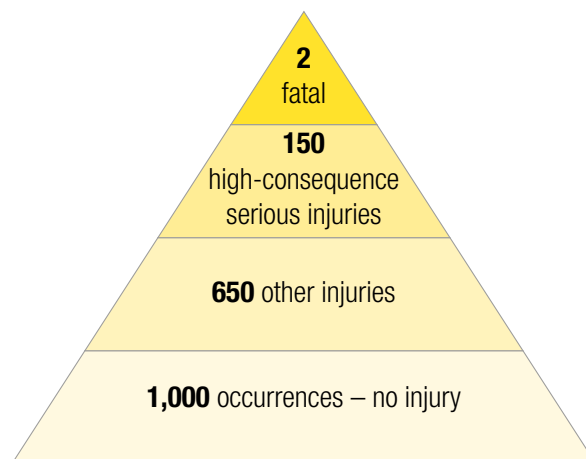
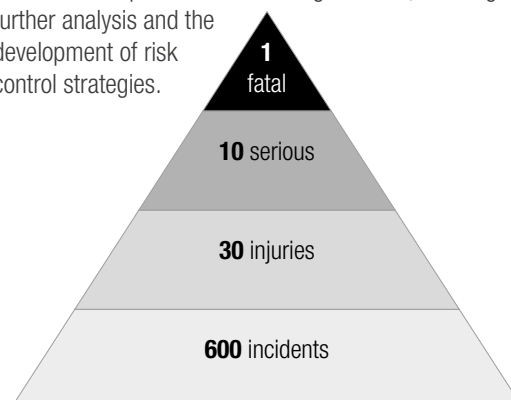


Figure 15 Accident triangle representing the six-month injury risk profile for a Western Australian mining workforce of 100,000

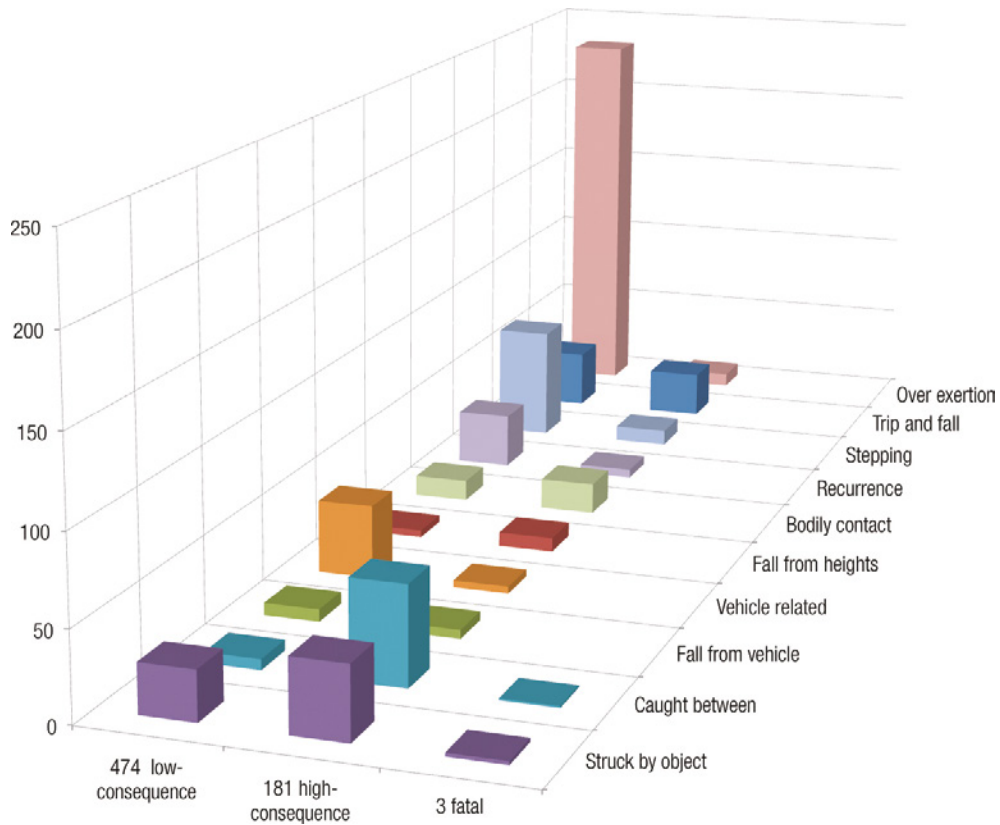
In 1969, Frank E Bird Junior, Director of Engineering Services for the Insurance Company of North America, undertook a study of 1,752,498 incidents and accidents reported by 297 cooperating companies. His aim was to investigate the relationship between the number of fatal accidents, injuries and incidents with no personal injury. Findings were presented using an **accident triangle**.

The accident triangle illustrates the ratio between fatal accidents, serious injuries, injuries and incidents. It provides a way of analysing injuries and incidents in any organisation or industrial system. The ratios within the triangle will be industry or enterprise dependent. For Bird's study, the ratio was 1 fatal accident to 10 serious injuries, 30 injuries and 600 incidents. The boundaries depend on the definitions used for types of injury and incident reporting standards.

Using the accident triangle approach, it may be possible to identify factors that cause incidents and injuries. The risk profile of a particular industry, enterprise or activity can then be represented in a triangle format, allowing further analysis and the development of risk control strategies.



A



B

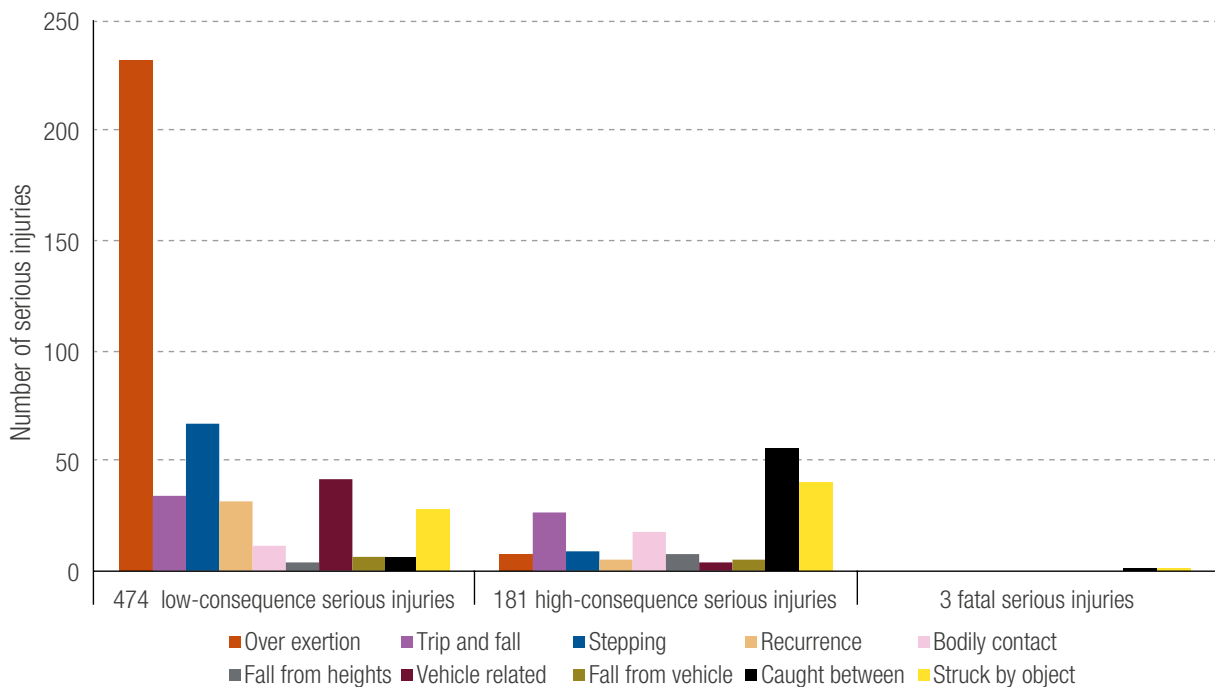


Figure 16 Incident type and energy transferred (i.e. consequence) that resulted in serious injury, July-December 2013. Data presented as **A** three-dimensional plot (screen grab) and **B** bar graph

7.2 Detailed Western Australian mining industry risk profile

A more detailed industry risk profile can be developed by analysing groups of activities using sub-sets of incident types and injuries to develop an injuries-only accident triangle.

When incident types are displayed within the injury groups shown in Figure 14, the peaks in the graph (Figure 16) can be used to identify potential problem areas and activities. A detailed analysis of the situations and circumstances can then be undertaken from the description of the incident.

For example, the low-consequence over-exertion group dominates Figure 16. However, from a risk management perspective, this type of incident is unlikely to result in fatal accidents.

For high-consequence serious injuries, being struck by an object or caught between objects corresponds to a higher potential for a serious or fatal outcome.

Low-consequence vehicle-related injuries are associated with activities that result in jolting or jarring injuries. Although there are fewer, the high-consequence vehicle-related injuries are more serious, and can be caused by collisions or contacts

between vehicles and workers. A similar relationship can be determined for the fall-related groupings.

When the same information is presented in the accident triangle format (Figure 17), it is obvious that fatal accidents relate to being struck by an object and caught between objects. These incident types dominate in the high-consequence level of the triangle, and are represented in the low-consequence level.

In contrast, over-exertion, stepping and vehicle-related jarring incidents dominate the bottom of the triangle but this dominance does not carry through to the upper levels.

Trips and falls, and fall from height incidents are represented in both the high-consequence and low-consequence levels. Fall from height incidents are a major cause of fatalities throughout Australia and in the mining industry.

Note: This approach does not assist with analysing low-frequency and rare high-consequence serious injuries for a six-month data set, because those injuries are numerically insignificant and therefore difficult to display, let alone identify any patterns. However, industry could use this modified accident triangle as a tool for looking at data collected over a longer time period, or combined with data from other jurisdictions.

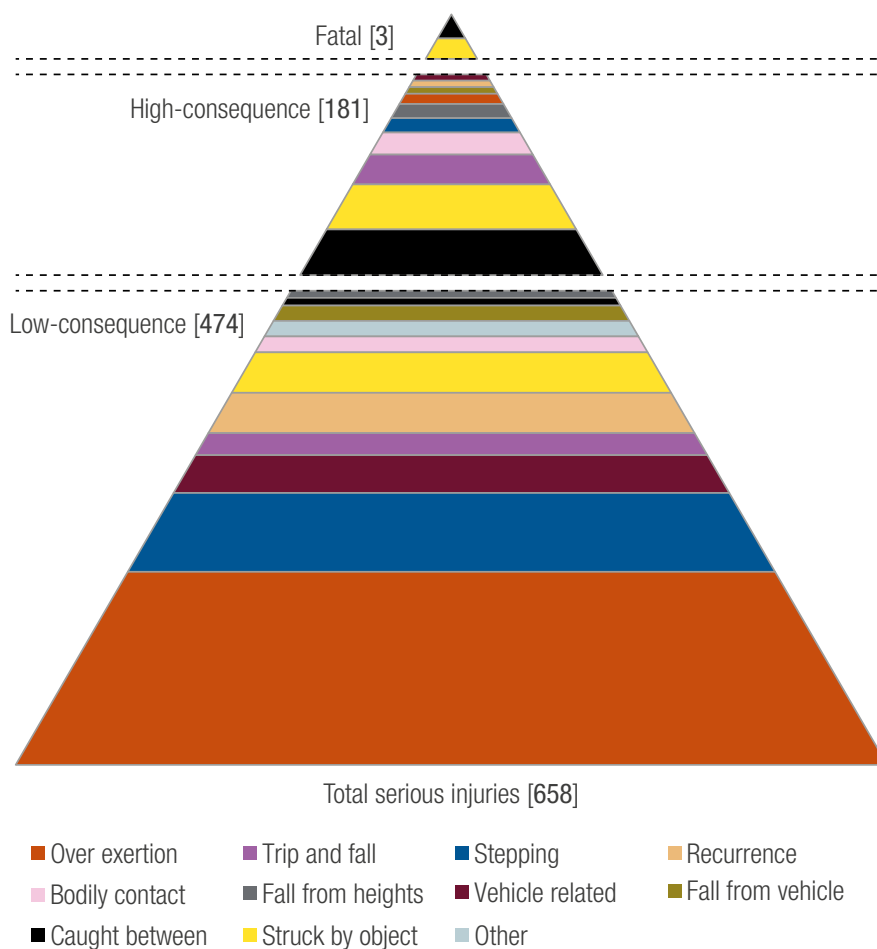


Figure 17 Serious injuries-only accident triangle displaying the same six-month data set as Figure 16. For each level of the triangle, the area of each colour band is representative of the number of serious injuries in that level

8 Tracking improvements in fatality accident performance

Over the past decade or so, there has been a downward trend in the incidence rates for total injuries and serious injuries (Figure 18). However, during this period there has not been a corresponding decrease in the fatality incidence rate, which has averaged about 0.05 over the same period. Over the past decade, there have been two to three fatalities each year, with a peak of six in 2009 and none in 2012.

The last step-change in fatal accident performance in Western Australian mines was between 1998 and 2002. This change was mainly evident for the underground environment and is attributed to improved mine design and geotechnical advances in ground support standards.

Lag indicators (including LTI, RWI and serious injury frequency rates) cannot be accurately applied to help evaluate the effectiveness of safety measures to reduce fatalities. In particular, these indicators do not adequately reflect the severity of injury to people.

The fatality data set, fortunately, is too small and irregular (i.e. 52 accidents over 13 years) for statistical analysis to evaluate the ongoing success of safety strategies.

One reason for analysing the serious injury data was to see if there were alternate measures that could more accurately track fatal accident performance (other than fatalities).

Section 6.1 analyses high-consequence serious injuries, and separates the injury types into two groups. This larger data set, compared to fatalities, is statistically more robust, can be collected over a shorter time period, and should reflect the issues of that site and time period, allowing the identification of trends and clusters in the data.

Amputations, fractures and crush injuries were identified as the most severe injuries that weren't fatal. Table 2 shows that the most recent six-month data set provides sufficient high-consequence serious AFC injuries for further analysis and there is no obvious bias, with similar numbers for both six-month periods in any one year.

The incidence rate for this group of injuries is plotted in Figure 18. The trend is flat, as for fatalities, suggesting that it might be useful as a near-term indicator to monitor whether safety initiatives and changes to work practices are succeeding.

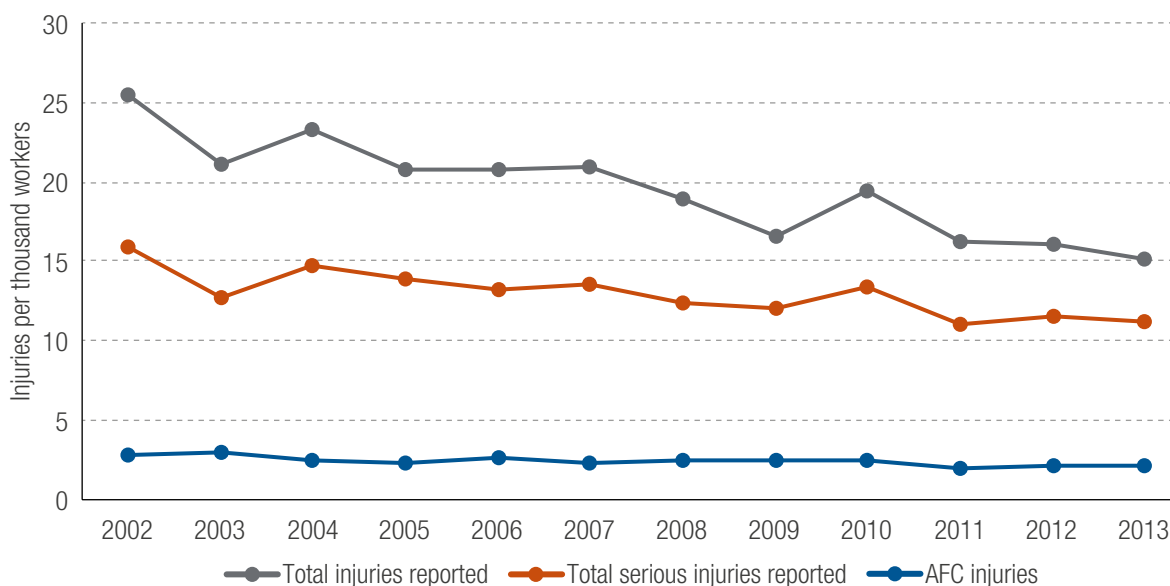


Figure 18 Annual incidence rates for all injuries reported, serious injuries reported and high-consequence serious injuries comprising amputations, fractures and crush injuries (AFC injuries), 2002-2013

Table 2 Total injuries and serious injuries (excluding fatalities) reported in six-month increments from 2002 to 2013

Year	Six-month data set	Total injuries reported (including fatalities)	Serious injuries reported (excluding fatalities)	Amputation, fractures and crush (AFC) injuries
2002	1 January to 30 June	505	319	54
	1 July to 31 December	550	338	61
2003	1 January to 30 June	467	288	68
	1 July to 31 December	466	277	63
2004	1 January to 30 June	570	365	52
	1 July to 31 December	544	338	64
2005	1 January to 30 June	605	395	68
	1 July to 31 December	527	358	61
2006	1 January to 30 June	568	372	85
	1 July to 31 December	637	399	73
2007	1 January to 30 June	669	429	66
	1 July to 31 December	672	434	79
2008	1 January to 30 June	677	436	87
	1 July to 31 December	660	430	93
2009	1 January to 30 June	526	385	90
	1 July to 31 December	598	429	76
2010	1 January to 30 June	717	503	86
	1 July to 31 December	735	504	97
2011	1 January to 30 June	721	499	88
	1 July to 31 December	714	477	86
2012	1 January to 30 June	846	597	118
	1 July to 31 December	812	588	99
2013	1 January to 30 June	827	585	123
	1 July to 31 December	837	655	106
	Total	15,450	10,400	1,943

9 Strategies to address fatal and serious injury causation factors

9.1 Applying findings of serious injuries analysis

Risk profiles

There is a clear advantage in analysing recent injury data rather than waiting several years for more fatal accidents before attempting to assess the latest industry risk profile.

Considering the fatal accident and serious injury data together has allowed a more comprehensive understanding of the risk profile of the Western Australian mining industry. The risk profile, presented as a six-month accident triangle (Figures 14 and 15) and a serious injuries-only six-month accident triangle (Figure 17), can be used to focus attention on the critical activities, occupations and hazards identified from this serious injuries analysis and the fatalities review.

Many companies and sites have well developed safety systems. Information from the serious injuries and fatalities reviews can be incorporated into their current systems to improve systems of work, hazard identification, training programs and supervision standards. It is recommended that mining operators modify the industry risk profile to their specific conditions. They can then use the modified risk profile to improve current systems of work, including hazard identification, control implementation, training programs and supervision standards.

The risk profiles generated by a more detailed analysis of particular industry sectors and types of mining operations may allow an even more targeted approach for safety strategies.

AFC incidence rate

Present key performance indicators (KPIs), such as incidence or frequency rates for LTIs, RWIs, total injuries reported and serious injuries reported, provide a measure of overall performance but do not reflect fatality trends. Further analysis of the serious injury data has identified a performance indicator, based on a subgroup of serious injury types, which appears to reflect fatality trends. A KPI based on the incidence rate for amputations, fractures and crush injuries (AFC) has potential as a lead indicator to measure the effectiveness of fatality prevention strategies.

Regulatory response

The Department will use these findings to identify priority targets for the minerals sector and help drive the next step change in safety performance by:

- improving hazard awareness and control selection
- promoting the adoption of appropriate risk management strategies
- supporting effective leadership and positive cultural change.

In particular, data relating to the industry risk profile and AFC injuries will be monitored and industry updated regularly.

Sites are reminded of the importance of concentrating on the identification of critical tasks and activities that can cause fatal and high-consequence serious injuries when undertaking hazard identification and developing their risk profile.

9.2 Hazard and precaution-based safety

The fatalities review showed that the majority of fatal accidents were caused by commonly occurring events and processes. The hazards associated with these accident types are well known and in most cases there are known precautions.

The repetitive high-consequence serious injury data shows similar features to those found for the fatalities review, with common incidents such as falls from height, suspended load, and machinery contacts recurring in the data.

The serious injury and fatalities reviews have independently identified that the three main hazards for all workers are:

- working at height (and subsequently falling)
- working under a suspended load or object with components that can move
- contact with machines and heavy components (with the potential to be struck or crushed).

In many work situations, simply being aware of common hazards can prevent workers from being exposed to the risk of injury. The repetitive nature of many of the incidents causing injury indicates that complex risk assessment processes are not required for most routine tasks. Significant improvements can be achieved in fatal and serious injury performance simply by consistently applying known standards and procedures.

The concept of “golden safety rules” can be used to reinforce awareness of critical activities and appropriate controls. For example:

NEVER start work if there is a risk of falling from height.

NEVER stand under anything that can fall on you.

NEVER place any part of your body where it can be crushed.

9.3 Other strategies

The recommendations of the fatalities review should be followed to address other causation factors implicated for incidents resulting in serious injuries. These are summarised in Section 2.3.

Appendix 1 Useful resources

Department of Mines and Petroleum

www.dmp.wa.gov.au/ResourcesSafety

Department of Mines and Petroleum, 2014, *Fatal accidents in the Western Australian mining industry 2000-12: What lessons can we learn? – report*. Investigation Services and Resources Safety Division, Department of Mines and Petroleum, Western Australia, 17 pp.

Department of Mines and Petroleum, 2013, *Accident and incident reporting — guideline (3rd edition)*. Resources Safety, Department of Mines and Petroleum, Western Australia, 19 pp.

The Department also produces annual safety performance reports, significant incident reports, safety bulletins and incident summaries for industry awareness, which can be used by mining operations to develop their risk profiles.

International Council on Mining and Metals (ICMM)

www.icmm.com

Health and safety critical control management: good practice guide

Australian and International Standards

www.standards.org.au

AS/NZS ISO 31000 Risk management – Principles and guidelines

IEC/ISO 31010 Risk management – Risk assessment techniques

AS/NZS 4801 Occupational health and safety management systems – Specification with guidance for use



Government of **Western Australia**
Department of **Mines and Petroleum**
Investigation Services and Resources Safety

Department of Mines and Petroleum
100 Plain Street
EAST PERTH WA 6004

Investigation Services

Telephone: + 61 8 9222 3333
NRS: 13 36 77
Facsimile: + 61 8 9222 3862
Email: dmp@dmp.wa.gov.au
Website: www.dmp.wa.gov.au

Resources Safety Division

Telephone: + 61 8 9358 8002
NRS: 13 36 77
Facsimile: + 61 8 9358 8000
Email: ResourcesSafety@dmp.wa.gov.au
Website: www.dmp.wa.gov.au/ResourcesSafety