The Third Wave

Australian Mesothelioma Analysis & Projection

March 2016

31 March 2016

Mr Peter Tighe
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Dear Peter

The Third Wave – Australian Mesothelioma Analysis & Projection

This report documents our analysis and projection of Australian mesotheliomas, including those cases relating to on-going non-occupational exposure sources. Although high risk exposure segments (e.g. asbestos miners and tradesmen) are often the focus of attention for asbestos-related projections, an increasing number of current mesotheliomas are attributed to lower dose non-occupational exposures.

Our base scenario is based on current available information and scientific evidence. It is intended to reflect a 'central estimate', in the sense that there is no intentional bias to understate or overstate the projection. However the known delay between asbestos exposure and mesothelioma emergence, as well as incomplete information, necessitates many assumptions to project future cases. For this reason, the eventual outcome will almost certainly vary from the projections and a wide range of plausible scenarios could be constructed.

The reliances and limitations in this report are an important part of our work. These should be read by any person receiving this report.

We look forward to discussing our results with you further.

Yours sincerely

Brett Riley

David McNab

Fellows of the Institute of Actuaries of Australia

The Third Wave

Part I Executive Summary

1 Introduction

The Asbestos Safety and Eradication Agency (ASEA) has retained Finity Consulting Pty Limited (Finity) to project the number of mesothelioma cases diagnosed in future years in Australia. ASEA is a Commonwealth statutory authority, providing a national focus on asbestos issues via the National Strategic Plan on Asbestos Management and Awareness. It considers workplace health and safety, environmental and public health matters in this context.

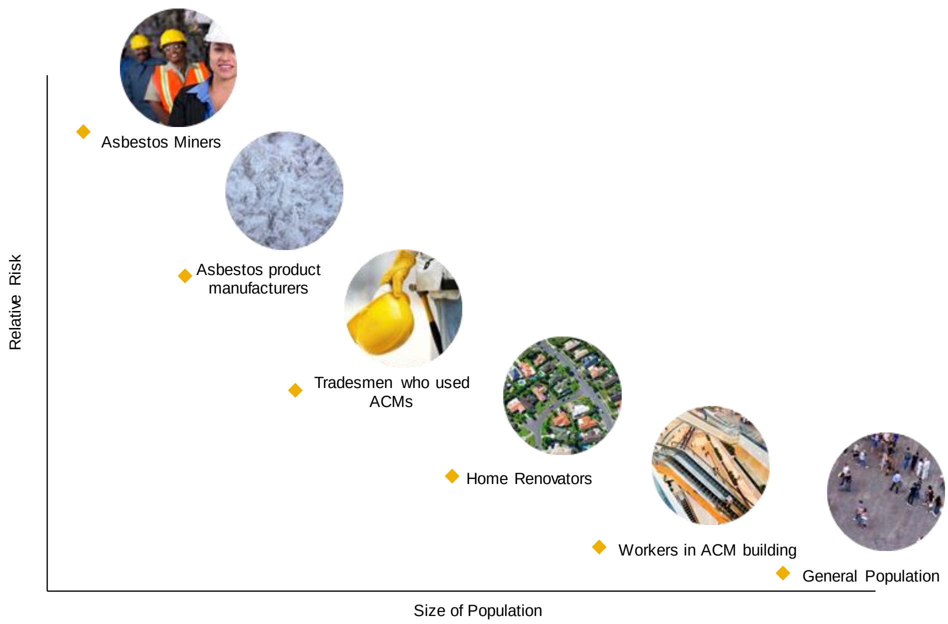
The purpose of our advice is to support discussions around asbestos exposure and to inform policy options for future asbestos management in Australia.

An increasing proportion of cases are arising from exposure other than during asbestos mining, manufacture and heavy industrial use (the 'first wave') and mainstream product use (the 'second wave'). This so-called 'third wave' arises from other sources of exposure, including disturbance while living in, or renovating, a home containing asbestos containing materials (ACMs). The third wave also includes 'background' cases, where the source of exposure may not be known. Third wave cases are generally caused by low-dose asbestos exposure and typically occur later than the first and second waves.

Less is known about the Australia-wide impact of the third wave compared to the earlier waves. ASEA has asked Finity to give special consideration to third wave exposures and the associated mesotheliomas in our projection of all Australian mesotheliomas.

Figure 1 shows some key groups of people who have been or will be exposed to asbestos. We have ranked them based on the size of the exposed population and the relative lifetime risk of contracting mesothelioma (per exposed person) in each group.

Figure 1 – Relative Size and Lifetime Risk of Contracting Mesothelioma



Note: this chart is not drawn to scale and is for illustration purposes. Not all groups exposed in Australia are shown.

Asbestos miners are a small group but probably had the highest lifetime risk of contracting mesothelioma due to high fibre concentrations from their work. By contrast, the entire Australian population is exposed to background levels of asbestos with significantly lower fibre concentrations on average.

The purpose of Figure 1 is to illustrate that the high risk groups are not the only sources of mesothelioma in Australia.

The remainder of this summary provides an overview of the main points from our full report. The reader requiring more detail should read the full report and accompanying appendices for a better understanding of the work done, its limitations and its implications. The full report also contains references to the publicly available data, papers and other research which we have used.

2 Scope

We estimated the number of past and future cases of Australian mesothelioma as at 31 December 2014. Our estimates include several scenarios to indicate a range of plausible outcomes and emphasise the uncertainty around the projection. More extreme outcomes are possible. Our projections focus on cases arising from identifiable asbestos exposure, both occupational and non-occupational. However, we also consider situations where mesothelioma arose from 'background' or unidentified exposure.

Our 'base scenario' may be viewed as the most likely of the specific scenarios documented in this report. It is a 'central estimate', with no intentional bias to over or understate the projection. The alternative scenarios show other plausible outcomes. Unless stated to the contrary, any discussion of our projection or model in this summary refers to the base scenario.

The number of 'cases' refers to individuals diagnosed with mesothelioma. This differs from the number of 'claims' where an injured person makes a legal claim for compensation for their injuries, either for statutory benefits or at common law. We do not consider the compensation status of any of the mesothelioma cases that we have projected.

The following are also ***not*** covered within this report:

- Other asbestos-related malignant diseases, such as lung cancer. While it is widely accepted that asbestos exposure does increase the risk of contracting lung cancer, other factors may cause lung cancer (e.g. cigarette smoking). To best understand the effect of non-occupational asbestos exposures we restricted our study to mesothelioma.
- Non-malignant asbestos-related diseases such as asbestosis.
- Splits within our projections of mesotheliomas by Australian state, industry, occupation or type of mesothelioma (e.g. pleural vs peritoneal).
- Property remediation costs.
- Estimates of economic cost or the value of mesothelioma cases.

3 Approach

Our projections are based on a population exposure and incidence model. This allows for many factors which influence the number of mesotheliomas over time, including:

- The volume of asbestos fibres affecting the exposed population.
- The intensity and duration of the exposure.
- The age distribution of the population when exposed, as well as the gender mix.
- The relative risk of different asbestos products and types of asbestos fibres.
- The impact of changes in asbestos handling practices and exposure regulations over time.
- The incidence of mesothelioma by duration since exposure. Mesothelioma is known to have a long latency period and incidence rates increase exponentially based on time since exposure.
- Mortality rates from other causes affecting the exposed population.

The model is based on historical mesothelioma data from the following sources:

- Public data from the Australian Institute of Health and Welfare (AIHW) covering all Australian cases for the period 1982-2011, including statistics by age and gender.
- Australian Mesothelioma Registry (AMR) data for the period 1 July 2010 to 9 July 2015. The AMR collates mesothelioma data from the state cancer registries, also split by age and gender. This dataset had no personal details for individuals with mesothelioma (e.g. name or address). This file covered all Australian states but excluded cases from the Australian Capital Territory and Northern Territory. We estimated an allowance for these missing cases.
  - A subset of cases included the results of the AMR's exposure questionnaire and interview process.
- We also used a wide range of published information on asbestos and mesothelioma. The papers and sources are cited throughout our full report and listed in Appendix A.

For this project we were able to incorporate information on the consumption, removal and the remaining asbestos stock over time. This information, provided to us by ASEA, came from a 'stocks and flows' model developed by Blue Environment Pty Ltd. The stocks and flows model gives estimates of the quantity of asbestos first used, remaining in situ and removed in each past and future year, including splits by broad product types (e.g. asbestos sheeting, pipes, friction products and roofing). The consumption data in this model matches the widely used public estimates of national asbestos consumption.

We consider the Blue Environment model to be fit for purpose for our project. We acknowledge the enhancements to our model from using this information, although the projections provided in this report remain the responsibility of Finity.

A key part of the process is to calibrate the model to past observed cases and known characteristics of those cases such as age, gender, exposure periods and known sources of exposure. We calibrated and projected different waves of exposure to form our aggregate view. Our ability to calibrate the different waves was assisted by the provision of exposure information from the AMR. This detail, not publicly available for individual cases, provided us with an improved understanding of the characteristics of cases from different exposure sources. We acknowledge its importance to the projection. The different segments which we have projected and shown are:

- Wave 1&2: this includes the occupational exposures from waves 1 and 2. It also includes the non-occupational exposures linked to these waves, including family members exposed to asbestos brought into the home by a worker ('dusty families'), those living near an asbestos factory or asbestos mine. This group covers asbestos exposures occurring from 1921 to 2002 (the last year of published consumption, before asbestos was banned in Australia on 31 December 2003).

- Wave 3 Total. This includes the following sub-groups:
  - Occupational post-2003: this covers lighter occupational exposure resulting from in situ asbestos in workplaces or asbestos removal, covering exposure from 2003 to 2055.
  - Wave 3 Domestic: this concerns non-occupational exposures in Australian homes linked to construction, asbestos in situ and its removal. It includes exposure to home renovators, those living in a house during a renovation, those living in a home with asbestos or working on a car at home which contains asbestos in the brakes or clutch. This group covers exposure in the years 1960 to 2055. This approach is broadly consistent with detailed exposure data available from the Western Australian Mesothelioma Register.
  - Background exposures: mesotheliomas in this category have no identifiable exposure to asbestos. We discuss the nature of these exposures later in this summary.

To make our approach manageable we did not model asbestos exposure from removals after 2055. Exposure after 2055 is expected to produce a small number of additional cases (perhaps an additional 1% above the cases we have already projected in our base scenario). Omitting this period does not materially impact the conclusions in our report.

4 Principles and Underlying Assumptions

There are many assumptions, explicit and implicit, that support our projections. Some of the important assumptions for interpreting this report are:

1. Most cases of mesothelioma are caused by asbestos exposure.
2. There is no safe threshold for asbestos exposure. All asbestos is carcinogenic.
3. For a proportion of mesothelioma cases it will not be possible to identify a possible or probable source of exposure.
4. Exposure to white asbestos (chrysotile) can cause mesothelioma, although it is less toxic than blue asbestos (crocidolite) and brown asbestos (amosite).
5. There is a rough offset between diagnoses in Australia of people who were exposed to asbestos overseas, and people exposed in Australia who live overseas by the time they are diagnosed.
6. Risk for a person or group:
   (a) Is proportional to the dose, or average fibre-load i.e. the fibres per millilitre of air when they were exposed. So risk is reduced by any precautions taken, such as wetting asbestos-containing materials (ACMs) before cutting them, or wearing protective equipment.
   (b) Is proportional to their duration of exposure.
   (c) Varies based on their age at exposure. Mesothelioma is a latent disease which rarely emerges within the first 10 years after exposure and typically around 40-50 years later. All other factors being equal, our approach assumes that those exposed at younger ages face more risk of contracting mesothelioma across their lifetime than those exposed at advanced ages, due to more expected years of life after being exposed and the rising incidence by duration since exposure.

7. The information provided by patients or their families in the AMR exposure survey is reasonably accurate, unbiased and broadly representative of the overall profile of cases, including those who did not provide details of their exposure.

8. We assume that there are no medical improvements or potential discoveries (such as a new vaccine) which reduce the occurrence of mesotheliomas in future.

9. We assume no changes over time to the criteria for diagnosing mesothelioma. Similarly, we assume no change in the completeness of diagnoses.

10. Under our base scenario, we assume that there is no significant change in future in the risk associated with handling in situ asbestos.

11. The majority of mesotheliomas diagnosed within Australia have been reported to the AMR (and predecessor organisations).

5 Data

Figure 2 shows the latest data on historical mesotheliomas, split by gender and year of diagnosis.

Figure 2 – Historical Mesothelioma Cases by Gender and Year of Diagnosis

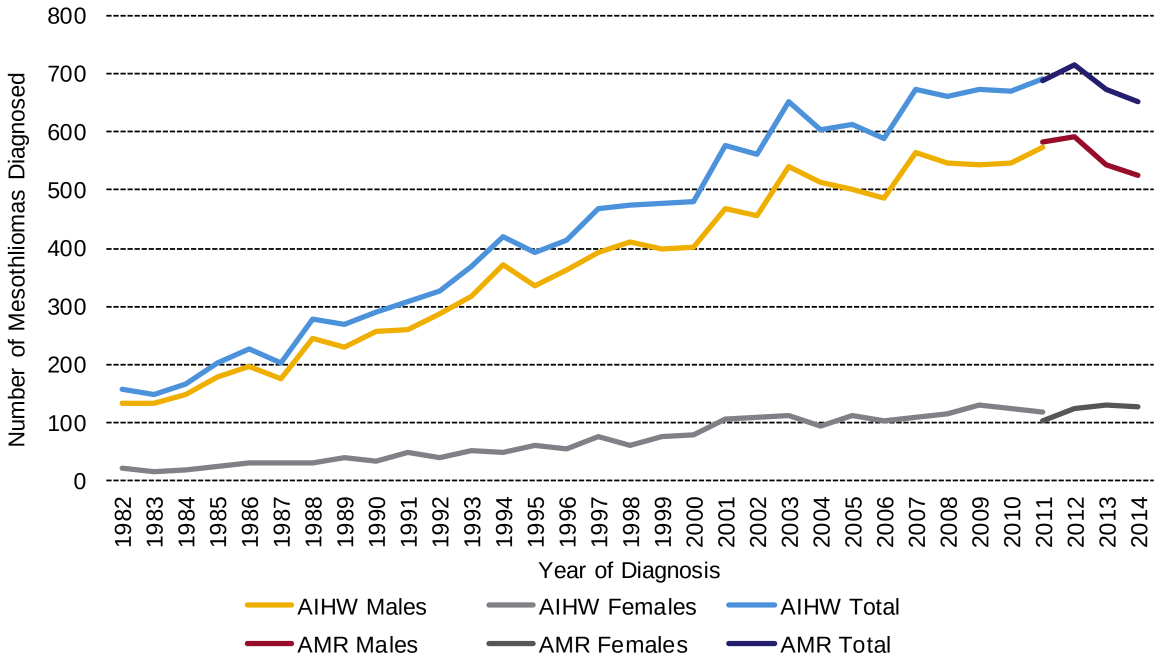


Figure 2 shows a rising trend in mesotheliomas since 1982, for men, women and in total. The female proportion of cases has also increased, from about 12% in the early 1980s to 18% in recent years.

The lower number of cases in 2013 and 2014 may reflect delays between diagnosis and reporting to the AMR. Analysis of the data in AMR annual reports shows that cases can be reported for up to three years after the year of diagnosis, and possibly longer. We have analysed these delays and allowed for further unreported cases from the later diagnosis years shown above. Unreported cases are also known as 'Incurred But Not Reported', or 'IBNR' cases. Once we include these late reports (not shown in Figure 2), we expect the level of mesotheliomas has been relatively flat over 2011-2014, at just over 700 mesotheliomas per annum on average.

We also considered the potential for past cases of mesothelioma to have been misdiagnosed by physicians or incorrectly classified by the state cancer registries. We consider this to be a small risk, for the reasons given in Section 3.1 of the full report.

The AMR data file provided to us excluded cases from the Australian Capital Territory and Northern Territory, collectively representing around 1-2% of all cases. We grossed up the data received to allow for these missing cases when setting overall case numbers for Australia.

Age Profile

The average age at diagnosis has also increased, from about 63 years in the early 1980s to 74 years in 2014. Females have been, on average, around two years younger than males at diagnosis.

Few people are diagnosed below age 50, due to the long latency of mesothelioma (often more than 40 years). The proportion diagnosed at advanced ages (85 or older) is rising.

Exposure Data

Our projection comprises several waves, based on their different exposure profiles. This requires us to allocate the latest data for total cases by exposure wave.

The AMR offers an exposure survey to collect information on possible sources of asbestos exposure for the participant. The AMR is supported in this process by the Monash Centre for Occupational and Environmental Health and Hunter Research Foundation.

From this assessment the AMR assigns scores of ‘unlikely’, ‘possible’ or ‘probable’ to each of the person’s identified jobs and potential sources of non-occupational exposure (e.g. ‘ever lived near an asbestos mine or asbestos products factory’ or ‘ever did major home renovations which involved asbestos products’).

In the data provided to us, out of a total of 3,264 mesothelioma patients, 539 people (17%) provided exposure information which we could use. Some cases had multiple sources of exposure; for these we allocated each case to the various sources of exposure on a risk-weighted basis. More detail on the allocation of cases to exposure sources is available in Section 3.5 of the body of the full report.

Table 1 summarises the resulting profile of the 539 cases which provided exposure information from AMR assessments made from 1 July 2010 to 30 April 2015.

Table 1 – AMR Exposure Profile

Source	Females	Males	Total	% of Total
Occpuational	**20**	**310**	**330**	**61%**
Non-Occupational	**82**	**95**	**177**	**33%**
Asbestos in the home (incl. renovations)	49	59	108	20%
Worker brought dust home ('dusty families')	22	5	27	5%
Serviced brakes and clutch	0	19	19	4%
Other exposure	11	13	23	4%
Unconfirmed Exposure Source	**8**	**24**	**32**	**6%**
Total	**110**	**429**	**539**	100%
% of Total	20%	80%		

The data shows that 61% of recent cases are attributed to confirmed occupational exposure. Another 6% of cases do not have a confirmed 'possible' or 'probable' source of exposure; these may be due to occupational or non-occupational exposures, including secondary background exposures.

Of the remaining third, 20% relate to exposures in the home (renovations or living in a house with ACMs). A further 4% relates to domestic exposures from working on car brakes and clutches at home.

The 5% of cases from workers bringing dust home and 4% of cases from other exposure (e.g. living near asbestos mines or factories) are non-occupational in nature. However, they are strongly associated with wave 1&2 exposures. We grouped these exposures with occupational wave 1&2 exposures in our projection.

Men comprise 94% of the confirmed occupational cases, reflecting historical employment patterns and the high risk of exposure among blue collar workers. The non-occupational cases are more evenly split between males and females.

Overall, 20% of cases submitting exposure information are female. This compares with the aggregate AMR data provided to us for this review (i.e. all cases including those who did not submit exposure information), where women represent 18% of cases.

Extrapolating to All Cases

With the exception of some modest adjustments to the gender mix and the split between occupational and non-occupational cases, we assumed the 17% of all patients who provided exposure information were broadly representative of all cases. In the base year for calibrating our model (2013) this implies:

- 452 occupational Wave 1&2 cases per annum.
- 63 environmental Wave 1&2 cases each year (e.g. 'dusty families' and living near asbestos mines and factories).
- 193 Wave 3 cases, including background cases.
- 708 cases in total.

More detail on this profile is contained in Table 5.6 in the body of the full report.

There is uncertainty surrounding the extrapolation of the exposure subset to all cases. On the one hand, some will contend that Wave 1&2 occupational cases might be underrepresented in the group that provided exposure information to the AMR. This is because older patients may be less likely to provide exposure information, due to a greater risk of dying soon after being diagnosed or from an inability to recall the circumstances of their exposure. Wave 1&2 cases are older on average at present compared to Wave 3, due to their earlier exposure profile.

We have also heard anecdotal evidence that some Wave 1&2 plaintiffs have deliberately not provided exposure information to the AMR for fear of jeopardising their common law claims for compensation against previous employers or other defendants.

Conversely, Wave 3 cases could be underrepresented in the AMR exposure subset. This is because they typically have lower levels of cumulative asbestos exposure (compared to Wave 1&2 cases) and may not know their exposure source. Due to this limited understanding it might be inferred that those with Wave 3 exposure are less likely to complete the exposure survey, if they think they have little or no information to offer.

We analysed data from the Dust Diseases Board (DDB) when extrapolating the AMR exposure data to the full set of mesotheliomas. The DDB pays no-fault statutory benefits to any person exposed to asbestos while employed as a worker in New South Wales. Based on DDB data we estimate that there are currently around 160 occupational mesotheliomas each year on average in NSW. We extrapolated this to 445 Australian occupational mesotheliomas each year, based on NSW having 36% of the Australian population in 1975. Using this analysis, and other considerations, we assumed 452 occupational cases in 2013 in our base scenario. This represents 64% of total mesotheliomas, slightly higher than the 61% share of cases in the AMR data completing the exposure questionnaire.

We compared our approach to other data (e.g. Western Australia Mesothelioma Register). These other sources supported our approach. More detail is included in our full report.

6 Assumptions

As noted previously, our projections are based on a population exposure and incidence model. This allows for many factors which influence the number of mesotheliomas over time, including:

- The incidence of mesothelioma by duration since exposure. Mesothelioma is known to have a long latency period and incidence rates increase exponentially based on time since exposure.
- The volume of asbestos fibres affecting the exposed population.
- The relative risk of different asbestos products and types of asbestos fibres.
- The impact of changes in asbestos handling practices and exposure regulations over time.
- The age distribution of the population when exposed, as well as the gender mix.
- Mortality rates from other causes affecting the exposed population.
- The intensity and duration of the exposure.

Our assumptions in relation to each of these factors are discussed in the following subsections.

Mesothelioma Incidence

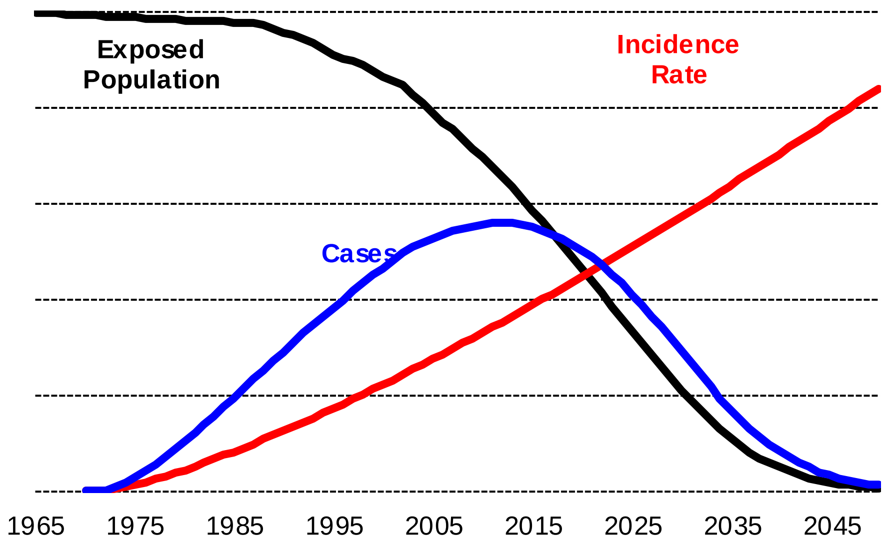
We use a standard epidemiological incidence model derived from mesotheliomas from Johns Manville exposure in the United States (Stallard et al, 2005). This has been used by Finity to model asbestos-related claims and liabilities for over 10 years.

There are a number of other models available, including exposure models developed by Professor Geoffrey Berry (Berry, 1991 and Berry, 1999), age-cohort model forms developed by Professor Julian Peto and others (as described in Lowe et al, 2004) and variations of each type developed by Dr Mark Clements and others (Clements et al, 2007a). We discuss some of these alternative models briefly in Appendix C of our full report.

The model provides useful exposure-based outputs to test model fit (e.g. average age at diagnosis, average duration of exposure, average year of first exposure and case counts in each year split into different years or periods of exposure). Our model has been tested against a number of Australian portfolios and has usually required little recalibration once the model is established. Based on this performance we considered it to be appropriate for this assignment.

Consistent with many other epidemiological models, our incidence rates increase with time since exposure. Figure 3 illustrates conceptually how we use an incidence model to project future cases. In this hypothetical example we project the incidence rate and the number of cases for a single year of exposure (1965). The exposed population declines over time as the people in the exposed group age and die from other causes. However, the likelihood of mesothelioma being diagnosed increases with time since exposure. The combination of these two effects creates a ‘wave’ of cases emerging from 1965 exposure.

Figure 3 – Hypothetical Incidence Model: Number of Cases

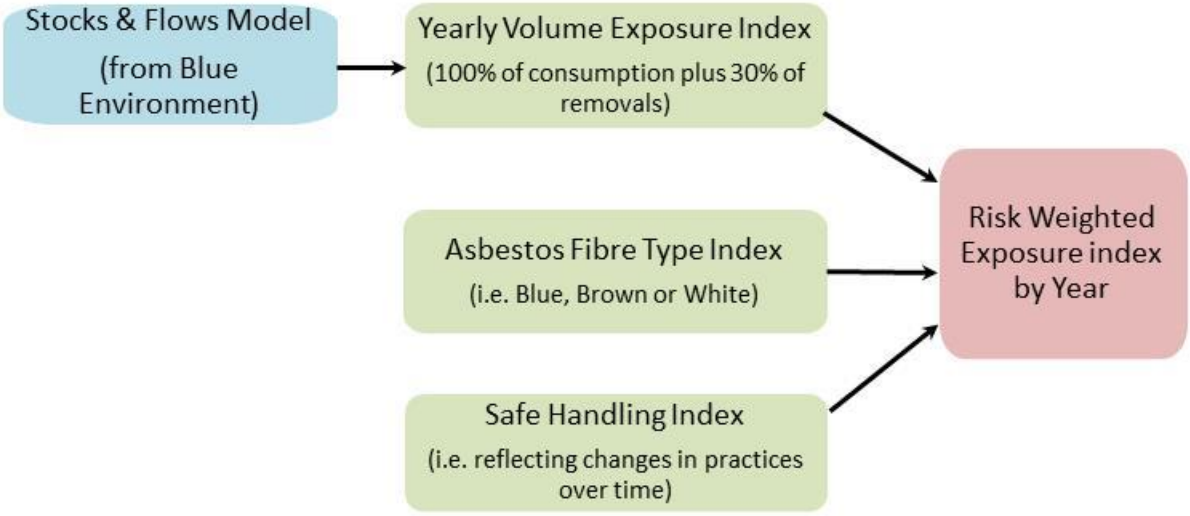


In this hypothetical example the number of cases is projected to peak around 2010 i.e. 45 years after first exposure.

Exposure

Figure 4 shows the components of our risk weighted exposure index. The shape of this index influences the peak in mesotheliomas diagnosed in our model, as well as the pattern of cases increasing up to that peak and then reducing in later years.

Figure 4 – Asbestos Risk Weighted Exposure Index



We briefly discuss each component below.

Stocks & Flows Model and Volume Exposure Index

Table 2 shows the Blue Environment assumptions for asbestos removal rates, which vary by product. We show the average number of years until removal and the number of years until 90% of the asbestos is removed. The assumptions shown relate to one year of asbestos consumption.

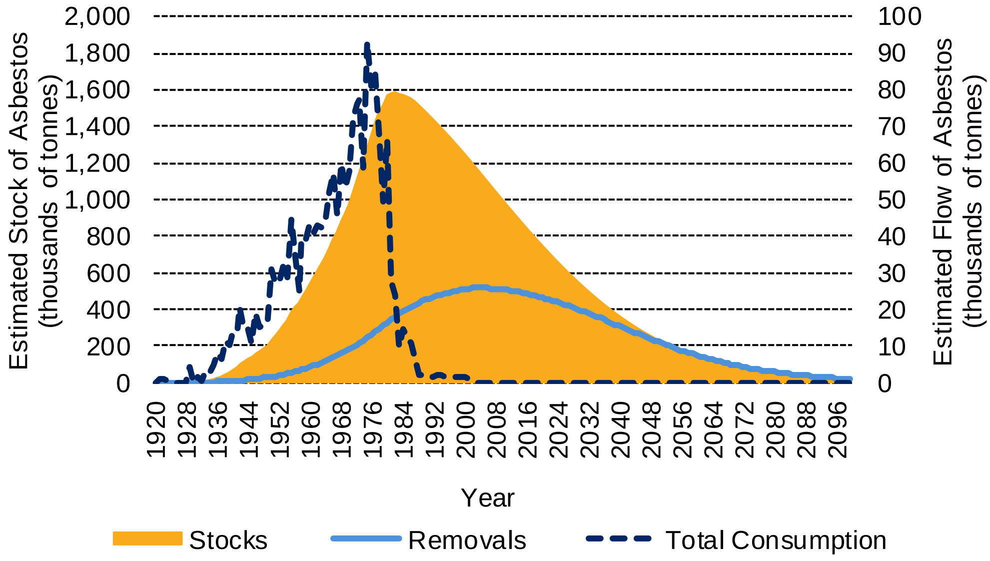
Table 2 – Summary of Blue Environment Removal Assumptions

	Product Lifespan	
Product Group	Average	Until 10% left
Cement sheeting - domestic	60	100
Cement pipes	50	80
Cement sheeting - commercial	40	75
Flooring products	15	50
Friction products	10	20
Roofing	40	75
Other	10	20

The Blue Environment assumptions suggest that friction, flooring and ‘other’ products have relatively short lifespans, with assumed average lives of 10-15 years after consumption. By contrast domestic cement sheeting has the longest run-off, with an assumed average lifespan of 60 years.

Figure 5 shows the resulting stocks and flows model output.

Figure 5 – Asbestos Consumption, Removal & Stocks – Total



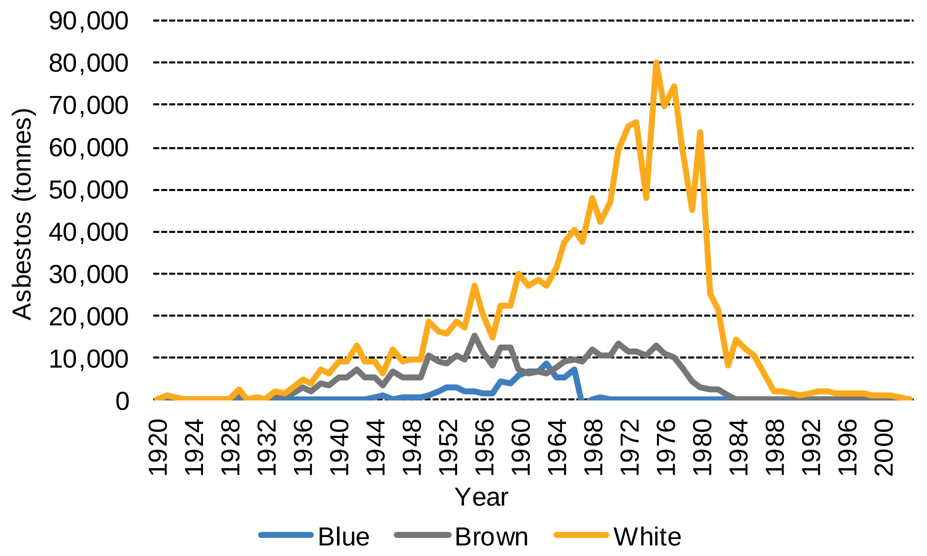
The level of consumption increased strongly from 1945 to the 1970s, before falling sharply in the early 1980s. We used separate versions of this model for domestic and commercial uses of asbestos.

A key assumption in our model is that asbestos removals represent 30% of the risk of consuming the same volume of fibres. This is because some of the high risk activities during consumption (e.g. sanding and cutting ACMs) do not occur during removal.

Mix by Type of Asbestos

Figure 6 shows net asbestos consumption in Australia split by asbestos type.

Figure 6 – Australian Net Asbestos Consumption by Asbestos Type and Year



Blue asbestos was used until the mid-1960s. Around 10,000 tonnes of brown asbestos was consumed each year from the late 1940s until the late 1970s. Its use ended in 1983. By volume, white asbestos comprised the largest share of consumption and was used until it was banned at the end of 2003.

Blue asbestos is regarded as the most toxic form of asbestos. In Australia this was consumed mainly in the 1950s and 1960s, although blue asbestos was always less than 10% of the total consumption. It was withdrawn from use much earlier than brown and white asbestos. Brown asbestos was a significant contributor to net consumption up until the 1950s but was not consumed much after 1983. White asbestos was the dominant form used in Australia.

Although blue and brown asbestos were withdrawn from consumption before white asbestos, our projection of removals allows for the historical mix of types of asbestos in previous consumption years. In other words, our model allows for the fact that during the in situ and removal phases some people will be exposed to blue and brown asbestos after the1980s.

The consumption weightings in Figure 6 are combined with risk weightings for each type of asbestos to derive a risk index reflecting the use of differing types of asbestos over time. The assumptions we used for the risk weighting were obtained from the Asbestos Working Party (AWP) of the Institute and Faculty of Actuaries in the UK. The relative risk weights summarised below, when combined with the other assumptions, produced a good back fit to the actual experience. We summarise this back fit later in this summary.

- Blue asbestos: 20
- Brown asbestos: 16
- White asbestos: 1

These relative risk weights suggest that a given volume of blue asbestos is assumed to have 20 times the toxicity of the same volume of white asbestos. Similarly, brown asbestos has 16 times the riskiness of white asbestos. Based on these relativities, the risk-adjusted levels of blue and brown asbestos reached higher peak levels than white asbestos. This is in contrast to the absolute levels of each type of asbestos consumed, as shown in Figure 6.

There is some debate about whether white asbestos causes mesothelioma. The World Health Organisation asserts that white asbestos can cause mesothelioma (WHO, 2006). In our review of the literature cited for this report the balance of opinion seems to support this view.

An alternative set of risk weights was developed by Hodgson and Darnton, based on risk relativities in cohort studies. Those relativities are as follows:

- Blue asbestos: 500
- Brown asbestos: 100
- White asbestos: 1

These risk weightings significantly reduce the effective weight for white asbestos compared to the two other types. The weight for brown asbestos is also lower relative to blue asbestos.

We tested the impact from using the Hodgson and Darnton weights. In this alternative scenario there are 12% fewer cases projected in 2015-2100. This indicates the sensitivity of our model to a significant change in the relativities. Further testing showed that the change in the blue to brown relativity is the main reason for the reduction in projected mesotheliomas. We set out all alternative scenarios tested in Section 6.

Risk Index – Asbestos Handling

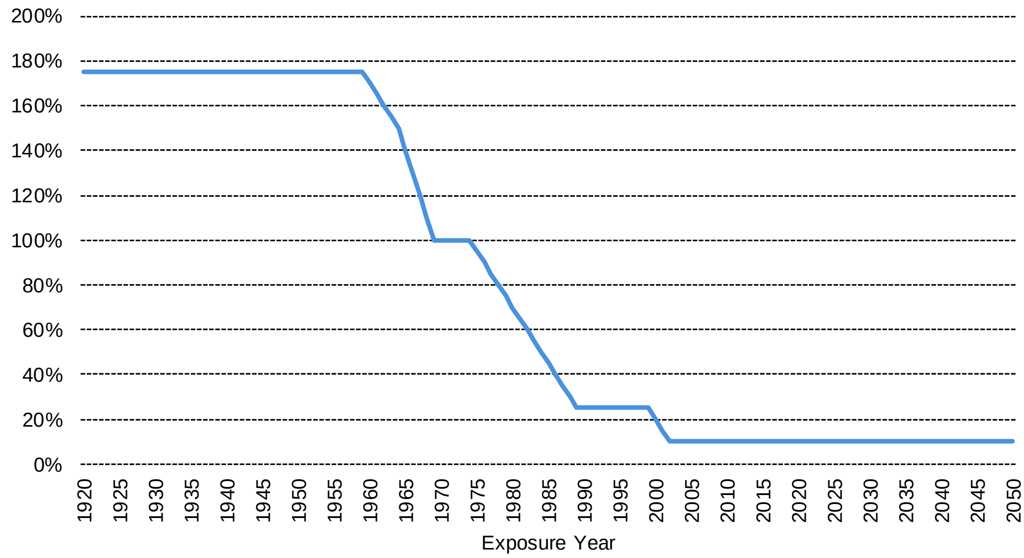
In addition to the mix by asbestos type, we also allowed for changes in risk levels over time arising from changed procedures and any precautions taken at differing points in time to minimise asbestos exposure. We refer to this as the 'asbestos handling' or 'safe handling' factor. In a work-related setting these actions and processes are part of an occupational health and safety framework. Our selected factors are judgemental and based on changes in regulation and the fibre load estimates of various activities under different conditions over time.

Our factors are shown in Figure 7 and are assumed to be the same for domestic and occupational exposures. In preparing this index we assumed that the level of compliance with applicable laws and regulations was broadly unchanged over time, and that the guidelines and regulations are the main drivers of changes in the asbestos handling factors.

We calibrated the factors relative to a score of 100% in 1970. The factors in other years were set to broadly reflect the changes over time shown in Table 5.5 of our full report.

We tested the shape shown above by changing the selected factors and reviewing the impact on how the model fits the historical experience (in particular, the number of cases in each year for 1988-2014). This testing was done in conjunction with reviews of the other model assumptions. The asbestos handling factors for the years 1921-1975 were most relevant for this back fitting. We found that the selected factors gave a strong back fit (combined with our other assumptions).

Figure 7 – Asbestos Handling Factors



Age at First Exposure

We assumed the following average ages at first exposure:

- Wave1&2: 38 years of age in 1921 decreasing to 33 years in 1950 and to 18 years in 1961 and later years.
- Occupational post-2003: 29 years for all periods.
- Wave 3 Domestic: 30 years of age for all periods.

The age of the exposed population at first exposure is assumed to be different for each wave, based on the profile of each group. This leads to different average life expectancies after exposure. This affects lifetime rates of mesothelioma incidence.

People in the Wave1&2 group first exposed in the 1920s are assumed to have an average age at first exposure reflecting the average age of the entire working population at the time. This is because asbestos was not widely used and was being introduced to incumbent workers.

The average age of those first exposed during the 1950s and 1960s is likely to be lower. We assume that younger people entering the workforce are the main group who were first exposed to asbestos during this time. Asbestos use became widespread after the Second World War, so most workers using asbestos at any point in this period would have been first exposed when they left school or higher education and started working.

For non-occupational Wave 1&2 exposures we assume a broadly similar age profile for wives and partners. Our distribution of ages allows for some exposure for children (e.g. dusty families) and the elderly (e.g. residents living in asbestos towns and near industry).

Wave 3 Domestic and Occupational post-2003 exposures are assumed to be similar. People employed in asbestos removal or completing home renovations are assumed to be mostly of working age.

Mortality Rates

We used standard male mortality rates, with the following adjustments:

- The key risk segments in Wave 1&2 are blue collar workers. To accommodate this we added a mortality loading of 30% on standard mortality rates at younger ages, decreasing to a nil loading at older ages.
- We assumed 0.5% per annum mortality improvements in the past and future.
- We made reductions to the male mortality rates, to approximately allow for the proportion of women in these groups. Female mortality rates are consistently lower than male rates. The reductions were:
  - Wave 1&2 and Wave 3 Occupational: 2%.
  - Wave 3 Domestic: 5%.

Duration of Exposure

Exposure continuation rates within each exposed population are used to project the years of asbestos exposure after first exposure. These rates do not project mortality, but rather how long a person remains in an exposed situation (e.g. in an exposed workforce). Our assumptions are based on testing the back fit of our models, as well as benchmarking to a number of other asbestos portfolios we have reviewed. A pattern of year-on-year exposure continuation rates is applied to each entry-year cohort. Specifically:

- Wave1&2 has 18 years of exposure on average.
- Occupational post-2003 exposures occur for an average of 15 years, reflecting the greater tendency in recent years for workers to change jobs, compared to earlier periods.
- Wave 3 Domestic exposures are for 2 years on average.

The occupational exposures represent prolonged exposure over a person's working life. The Wave 3 exposure reflects the shorter timeframes over which this group was typically exposed, such as home renovators.

Background Cases

For a proportion of mesotheliomas it will not be possible to identify a likely source of exposure. The number of these background cases, both now and in the future, is highly uncertain. This is because the exposure sources of background and low dose mesotheliomas are often poorly understood.

Potential sources of exposure for background cases could include:

1. Unknown primary exposure to asbestos due to unknown or forgotten past exposures. By primary exposure we mean that the person was directly exposed to asbestos fibres within their workplace or in their home. Unknown sources will typically involve small doses of exposure.
2. Unknown secondary exposures e.g. due to renovations or construction on a neighbouring property.
3. Asbestos remaining in the air due to historical consumption within Australia.

   Many have argued that there is an underlying level of mesotheliomas due to small fibre loads in the air in industrialised countries, particularly in cities. These small fibre loads might arise from historical asbestos consumption, and thus have no correlation to the future stock of ACMs or their removal.
4. Asbestos in the air due to the current in situ stock of asbestos. The small fibre loads described above could also be due to fibres released from recent disturbances to the current stock of ACMs, including their removal. This source of exposure is thus likely to end when all ACMs have been removed from the built environment.
5. Exposures to carcinogens other than asbestos, such as from radiation, plombage or erionite exposure in Turkey. Exposure to some viruses (e.g. SV40) may increase the risk of contracting mesothelioma as well, though this is inconclusive.
6. Cases developing due to spontaneous abnormal cell development, with no known exposure to carcinogens. This is a known explanation for some forms of cancer. However, it is generally accepted that some carcinogenic exposure (typically asbestos) is required to cause mesothelioma and spontaneous cell development cannot cause this specific cancer.

From this list we have excluded Category 1 from our definition of background cases. We have treated primary exposure cases as part of the main occupational and non-occupational wave projections.

Category 5 above is unlikely to be a significant factor for background cases of mesothelioma, particularly in the future. For the reasons given above we also rule out Category 6 as a source.

Our analysis and projection assumes that asbestos exposure is the primary driver of mesothelioma, noting that on a per capita basis Australia had the highest per capita usage of asbestos, and also has the highest per capita incidence of mesothelioma. The overwhelming cause of 'background' mesothelioma is also assumed to be asbestos exposure. This approach is consistent with the view adopted by most others.

Our projection of background cases includes Categories 2, 3 and 4 above. Noting the uncertainty over exposure sources, the ability to estimate the level of 'background' cases in future is imprecise. There are two possible approaches for projecting these cases:

1. Background cases are assumed to increase over time as the population grows. Background exposures due to Category 3 (as listed above) might be expected to be correlated to the size of the population.
2. The number of cases is assumed to be related to the actual ‘stock’ of asbestos. In this situation the level of background cases reduces over time broadly following, on a lagged basis, the pattern of asbestos removals. This approach would be appropriate for background exposures from Categories 2 and 4 (as listed above).

Noting this uncertainty, and our intention to project a ‘central estimate’, our base scenario has adopted the following approach for projecting background cases:

- Background cases from 1988 to 2014 increase in line with population growth.
- Future background cases after 2014 are an average of the projections based on population growth (method 1. above) and the asbestos ‘stock’ (method 2. above). This means there is a 50% weight on both projection methods.

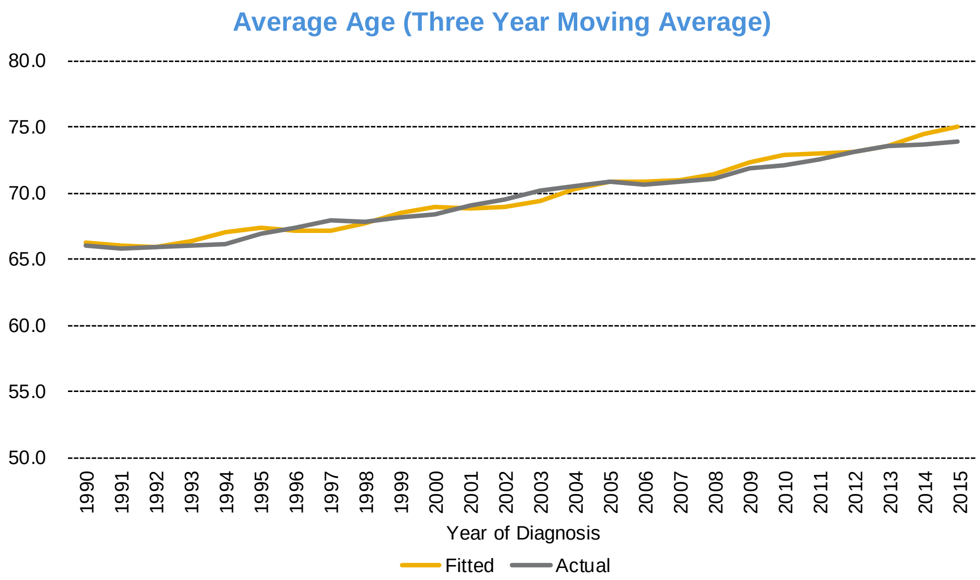
While our approach to project background cases has minimal impact on the current and historical number of cases, the approach has a very material effect on the projection after 2050. The sensitivity of the projection to this feature is highlighted in Section 6 of our full report.

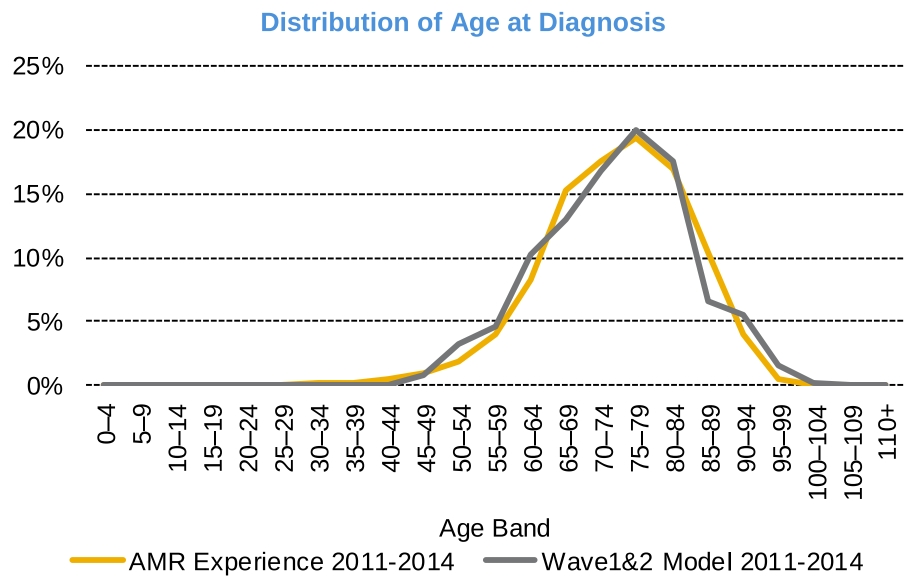
7 Back Testing Results

Section 6 of the full report shows a comparison of various metrics observed historically with those produced by our model. A few of these back-tests are summarised below.

Figure 8 demonstrates that our model closely reproduces both the average age and age distribution of past mesotheliomas for wave 1&2.

Figure 8 – Actual vs Modelled – Age Profile





We also achieved a good fit for average age in our Wave 3 model. For cases diagnosed in 2011-2014, the AMR dataset has an average age of 69. For the same period our model projects an average age of 70 years.

Table 3 summarises the actual and projected average year of exposure i.e. the year of midpoint exposure, for mesothelioma cases from the AMR data. It also shows average latency (from the same midpoint exposure). The actual experience is based on cases completing the AMR exposure questionnaire.

Table 3 – Actual vs Modelled – Exposure & Latency

	Wave 1 & 2		
	Actual	Model	Difference
Average year of exposure	1971	1973	1
Average latency (from midpoint of exposure)	42	41	-1

Note: values may not add due to rounding

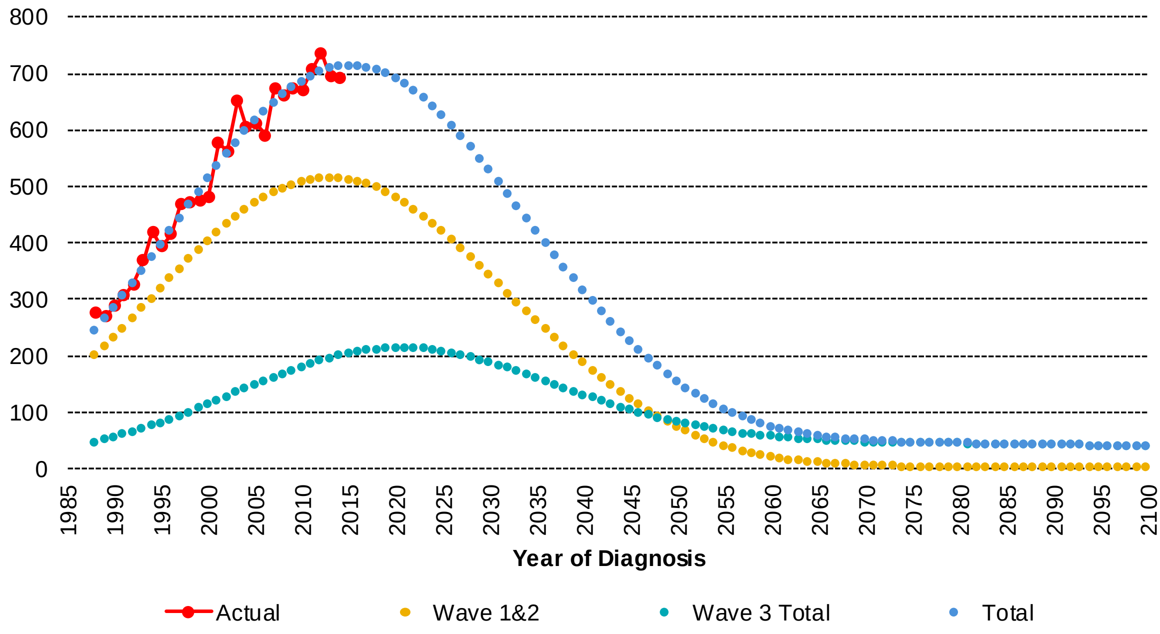
Overall we are satisfied with the model fit, although this is not sufficient in itself to demonstrate that the projections are appropriate. We also consider our projections to be suitable, due to the exposure based approach we have taken, comparisons to other projections available to us and our confidence from using the epidemiological model for the past 10 years.

8 Results

Base Scenario

Figure 9 shows our base scenario projection, along with the observed cases from 1988 to 2014.

Figure 9 – Historical and Projected Mesothelioma Cases (Base Scenario)



Under our base scenario we project 19,427 cases of mesothelioma diagnosed in Australia between 2015 and 2100. Fifty eight per cent of these (11,264 cases) are attributed to the run-off of 'industrial' exposures from the first and second waves, with the remaining 42% (8,163 cases) coming from the third wave (including background mesotheliomas).

Our base scenario projection indicates that we have reached the peak number of cases in 2015 (712), and that the number should decrease noticeably after 2020. The long term trajectory shows the number of cases halving to 350 per annum in about 2040 and reaching 100 per year in the 2050's. The total future cases are 27 times the 712 cases in 2015.

The Wave 1&2 cases will decline relatively quickly from now, from 510 in 2015 to about 100 a year by 2050 and practically no cases by the late 2060s. This segment is estimated to have peaked in 2013 (513 cases). The total future Wave 1&2 cases are 22 times the number in 2015.

Wave 3, on the other hand, will remain significant for much longer. We estimate 202 cases in 2015, after which the expected number will remain close to that level for at least another 20 years. From the middle of the century the majority of new mesothelioma cases will arise from third wave exposure. Our projection assumes a further 50 or so cases per annum from this source in each year from about 2060 onwards.

Due to its later exposure profile, Wave 3 Total cases are projected to peak in 2021 (212 cases). Also, the total cases for this group in the period 2015-2100 are 41 times the number in 2015.

Uncertainty

The projections in this report are based on the information currently available to us. There are many uncertain factors and assumptions, both implicit and explicit, underlying the projection. Some of this uncertainty reflects difficulties caused by inputs which cannot be measured directly or where information is incomplete.

The eventual outcome will almost certainly vary from our projections due to uncertainties associated with:

- The historical and future volumes of asbestos fibres inhaled by exposed individuals, including the pattern of asbestos consumption and removals.
- The riskiness of removal compared to consumption.
- Uncertainty about the functional form of the relation between the mesothelioma incidence rate and time.
- The relative toxicity of different types of asbestos.
- The impact of precautionary measures to minimise inhalation of asbestos fibres, both in the past and in the future.
- The on-going rate of future improvements in non-asbestos related mortality.
- The cause of mesothelioma for background cases.
- The profile (age, gender, latency and exposure source) of historical mesothelioma cases.
- The assumed split of cases between the exposure waves.

A further source of uncertainty arises because outcomes are dependent on future events extending many years into the future. Some outcomes are dependent on future actions e.g. practices for handling ACMs in 2015 and later years.

While we characterise our base scenario as a ‘central estimate’, it clearly sits within a wide range of plausible outcomes.

Section 6 of the full report considers individual sources of uncertainty in more detail, and shows scenarios whereby the projections could readily vary by a few thousand cases. More extreme outcomes are possible. We describe a range of plausible outcomes below.

Alternative Scenarios

As noted above, there is considerable uncertainty surrounding our projection. Our base scenario is one plausible outcome. Alternatives of up to +/-10% in total future cases are possible from changing single assumptions. Wider variation is possible from changing several assumptions simultaneously.

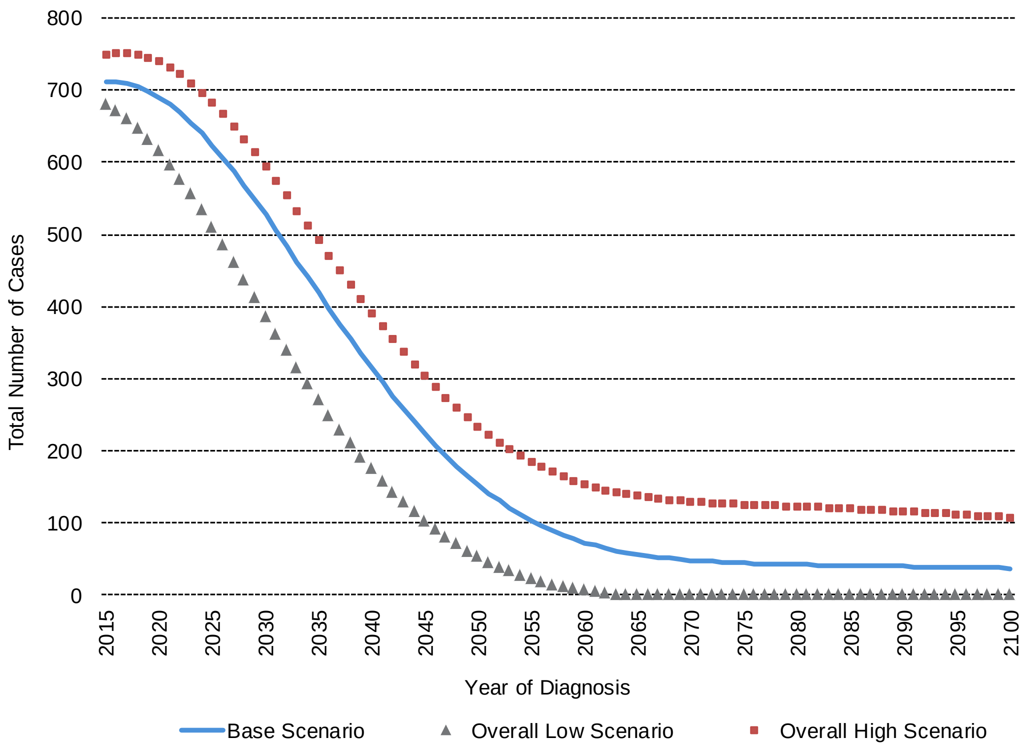
Figure 10 combines the alternative scenarios tested in Section 6 of our full report, in order to produce an indicative range of plausible variation around our base scenario. Those scenarios tested the following:

- The relative riskiness of blue, brown and white asbestos, as described previously.
- Higher and lower risk levels associated with asbestos removal compared to consumption (10% and 50% compared to 30% in the base scenario).
- Higher and lower asbestos handling factors.
- Alternative splits for 2013 cases between Wave 1&2 and Wave 3 Domestic exposures.
- Different patterns for background cases, which either track Wave 3 Domestic cases (so run-off earlier in the 21st century, compared to our base scenario) or follow the Australian population (so are higher than the base projection).
- Alternative assumptions for unreported (i.e. IBNR) cases in 2013. For the low estimate we assumed no further unreported cases for the period analysed i.e. 15 fewer cases per annum

compared to the base. For the high scenario we assumed an additional 32 unreported cases in 2013, taking the total to 740.

We measured the variation in the projection output from those scenarios (versus the base). We aggregated the variations that increased the projection, to estimate a plausible high end scenario. We did the same for those scenarios which led to fewer cases, for the low end. The resulting range around the base scenario is shown in Figure 10.

Figure 10 – Indicative Range of Outcomes Considered by Alternative Scenarios



Compared to the base scenario of 19,427 mesotheliomas, Figure 10 shows a range of approximately +/- 33% around the base case. Specifically:

- The low scenario projects 12,748 future cases (6,680 fewer than the base scenario).
- The high scenario projects 25,764 future mesotheliomas (6,336 more than the base).

This range around the base scenario is indicative and should not be interpreted as the minimum or maximum possible outcome. More extreme outcomes are possible. The indicative range is also simplified in that:

- It adds the impact of the individual scenarios described previously. It takes no account of possible multiplicative effects, offsets or partial impacts arising from these factors. It assumes that they all occur in full, as described.
- Some factors have not been tested. For instance, we did not test variations to the stocks and flows model of consumption and removal. An earlier or later pattern of exposure would probably lead to variation around our base scenario. We did not test this particular component of our model because we achieved a strong fit to the actual number of cases in 1988-2014, so focused on other uncertain factors.

Some of the drivers of the range of outcomes shown in Figure 10 are specific features of our model (e.g. the allowance for unreported cases in 2013). However, the range also incorporates the potential impact of current and future asbestos management practices. These mainly affect future cases after 2050.

9 Conclusion

We project about 19,000 cases of mesothelioma diagnosed in Australia between 2015 and the end of the century.

An increasing proportion of these cases relate to non-occupational exposures spread across the broader Australian community. This has been identified as an emerging public health problem. These 'third wave' cases are generally associated with relatively low doses of asbestos exposure and include some individuals who will be unaware that they have even been exposed to asbestos. Based on our estimates, the third wave currently represents around one in every three mesotheliomas diagnosed.

This proportion is projected to increase in future, due to the later exposure profile for this wave, compared to earlier occupational exposures. Significant volumes of ACMs remain in situ today. Allowing for this current stock of asbestos, we project over 8,000 future cases of third wave mesotheliomas.

The high and increasing incidence of mesothelioma in Australia is due to many factors. One reason that is often overlooked is the reluctance to recognise the causal significance of low dose occupational and non-occupational exposures.

The magnitude of third wave mesotheliomas highlights the importance of asbestos removalists, tradesmen, other workers, home renovators, businesses and all levels of government taking appropriate action. This includes raising awareness of ongoing asbestos exposures, and following risk minimisation strategies to deal with these exposures. This is particularly important because home renovation is so popular in Australia at present. By doing so, it is possible that there could be significantly fewer deaths from mesothelioma in Australia in the 21st century.

10 Acknowledgements

We would like to acknowledge the following people for their support or review of this assignment:

- The AMR, and by extension the state cancer registries, for providing the mesothelioma case data and reviewing this report.
- Blue Environment, whose 'stocks and flows model' of asbestos consumption, removal and remaining asbestos stocks was used with ASEA's permission.
- Professor Lin Fritschi of the Epidemiology and Biostatistics Department of Curtin University, for providing an independent peer review of our report.
- ASEA staff and the ASEA Research Advisory Committee for providing further review and feedback on this report.

Appendix A of the full report lists the body of research and publicly available information used in this project.

11 Reliances and Limitations

This report has been prepared by Finity in accordance with the Code of Conduct of the Actuaries Institute.

Any distribution of the report must be in its entirety. Any publication of extracts from the report must be approved in advance by Finity in order to meet our professional obligations relating to the potential to mislead third parties by using our report for purposes that were not intended.

We have relied on the accuracy and completeness of the data and other information (qualitative, quantitative, written and verbal) provided to us for the purpose of this advice. We have not independently verified or audited the data, but we have reviewed the information for general reasonableness and consistency. The reader of this report is relying on ASEA and the Australian Mesothelioma Registry and not Finity for the accuracy and reliability of the data. If any of the data or other information provided is inaccurate or incomplete, our advice may need to be revised and the report amended accordingly.

It is not possible to estimate future mesothelioma cases with certainty. As well as difficulties caused by inputs which cannot be measured directly, such as historical levels of asbestos exposure, or incomplete data, outcomes are also dependent on future events, including legislative, social, and medical changes. In particular, we can only estimate future levels of exposure; these will be affected by future removal rates and precautions which may or may not be followed by a large number of people. Deviations from our estimate, perhaps material, are normal and are to be expected. In the case of mesothelioma projections the uncertainty is heightened due to the need to make assumptions many years into the future.

Our report is based on a continuation of the current environment with allowance for known or projected changes in exposure profiles. It is quite possible that one or more changes to the environment could produce an outcome materially different from our estimates.

This report is being provided for the sole use of ASEA for the purpose stated in Section 1 of this summary. It is not intended, nor necessarily suitable, for any other purpose. This report should only be relied on by ASEA for the purpose for which it is intended. We understand that this report will be made available to third parties, to support the purpose stated in Section 1. Such distribution is acceptable on the condition that this entire summary, rather than any excerpt, is distributed.

Third parties, whether authorised or not to receive this report, should recognise that the furnishing of this report is not a substitute for their own due diligence and should place no reliance on this report or the data contained herein which would result in the creation of any duty or liability by Finity to the third party.

Our report should be considered as a whole, including all appendices. Members of Finity staff are available to answer any queries, and the reader should seek that advice before drawing conclusions on any issue in doubt.

Part II Detailed Findings

1 Introduction

1.1 Purpose

Finity Consulting Pty Limited (Finity) has been engaged by the Asbestos Safety and Eradication Agency (ASEA) to provide projections of Australian mesothelioma cases, including those arising from 'third wave' asbestos exposure. ASEA is a Commonwealth statutory authority, providing a national focus to asbestos issues via the National Strategic Plan for Asbestos Management and Awareness (ASEA, 2014). It considers workplace health and safety, environmental and public health matters in this context.

The purpose of this advice is to support discussions around asbestos exposure and to inform policy options for future asbestos management in Australia.

1.2 Scope

Finity has estimated the number of current and future Australian mesothelioma cases. Our estimates include scenarios intended to indicate a range of plausible outcomes and emphasise the uncertainty around the projection. Our projections focus on cases arising from identified asbestos exposure, both occupational and non-occupational. However, we also consider situations where mesothelioma arose from 'background' or unidentified exposure.

The number of 'cases' refers to individuals diagnosed with mesothelioma. This differs from the number of 'claims' where an injured person makes a legal claim for compensation for their injuries, either for statutory benefits or at common law. We do not consider the compensation status of any of the mesothelioma cases that we have projected.

The following are also not covered within this report:

- Other asbestos-related malignant diseases such as lung cancer. While it is widely accepted that asbestos exposure does increase the risk of contracting lung cancer, other factors may cause lung cancer (e.g. cigarette smoking). For this reason we restricted our study to mesothelioma.
- Non-malignant asbestos-related diseases such as asbestosis.
- Splits within our projections of mesothelioma cases by Australian state, industry or occupation.
- Projections for different types of mesothelioma (e.g. pleural versus peritoneal or other types).
- Property remediation costs.
- Estimates of economic cost or the value of mesothelioma cases.

1.3 Basis of Projections

Our projection basis:

- Is based on an epidemiological Population Exposure and Incidence Model (PEIM). After modelling exposure to asbestos, we apply an incidence curve showing the rate of contracting mesothelioma. This generally increases with the delay after exposure to asbestos.
- Uses our analysis and interpretation of historical mesothelioma case data from several sources (discussed below). The main data file provided by the Australian Mesothelioma Registry (AMR)

contained cases reported to the AMR up to 9 July 2015. As we worked with calendar years in our analysis and projection, we effectively prepared our projection of future cases as at 31 December 2014 (i.e. for cases reported in 2015 and later).

- Uses historical Australian asbestos consumption data from 1921 to 2003, after which asbestos use was banned in Australia (with limited exceptions).
- Is based on an asbestos consumption and removal model prepared by Blue Environment Pty Ltd ('Blue Environment'). This model was commissioned by ASEA in 2015 and provided to us by ASEA for the purposes of our projection (Blue Environment, 2015).
- Aims to make use of all pertinent information available to us, including statistics on cases and their demographic and exposure profile, as well as other high-level exposure information.
- Estimates the number of people diagnosed with mesothelioma. We have not considered deaths arising from mesothelioma, although we note that for those diagnosed with this disease, death usually occurs within two years of diagnosis.

Our projections are subdivided by wave of exposure. We elaborate on these groups in Section 4.4. These are important for both our interpretation of data (Section 3) and our projections (Sections 4 and 5).

Our base projection should not be interpreted as a precise guide to the number of expected mesothelioma cases in each future year. Rather, we have provided an indication based on our interpretation of all available information. In our view the base scenario may be viewed as the most likely of the specific scenarios documented in this report. It is a 'central estimate', with no intentional bias to over or under state the projection.

The alternative scenarios presented show plausible outcomes and indicate the likely variation in outcomes that could occur. However, more extreme outcomes are possible.

References to years in this report are for calendar years, unless otherwise stated.

1.4 Acknowledgements

We would like to thank and acknowledge the following people who provided expert advice or review for this assignment:

- The AMR, and by extension the state cancer registries, for providing the mesothelioma case data and reviewing this report.
- Blue Environment, whose 'stocks and flows model' of asbestos consumption, removal and remaining asbestos stocks was used with ASEA's permission.
- Professor Lin Fritschi of the Epidemiology and Biostatistics Department of Curtin University, for providing an independent peer review of our report.
- ASEA staff and the ASEA Research Advisory Committee, for providing further review and feedback on this report.

1.5 Data

We used the following key data sources during the course of this project:

- The AMR provided a list of all mesothelioma cases reported to state cancer registries in the period 1 July 2010 to 9 July 2015. To maintain privacy the case data excluded personal information (e.g. name, address, date of birth and state). Cases were received from all states. The cancer registries of the Australian Capital Territory (ACT) and Northern Territory (NT) did not provide their case data, because they required further assurances and sign-offs by Finity before releasing their data to us. This would have delayed our project, so we decided to work without ACT and NT data and gross up the remaining cases to produce a complete Australian estimate. The ACT and NT comprise around 1-2% of all Australian mesotheliomas, so this approximation is reasonable.
- The Australian Institute of Health and Welfare (AIHW) compiled statistics on total Australian mesotheliomas from 1982 to 2011, including splits by age band and gender (AIHW, 2015). We used this to prepare a more comprehensive dataset for the years before the AMR commenced.
- The Blue Environment 'stocks and flows' model. We understand that this has been calibrated to data for Australian asbestos consumption, as well as volumes of in situ asbestos-containing material (ACM) removed over time. While we did not complete a detailed peer review of this model, its outcomes seemed reasonable, based on our high level review. The stocks and flows model is a useful advance on methods and information available until now and appropriate to incorporate within our projection.

We also relied on our experience, knowledge and understanding of Australian mesothelioma cases when using the data listed above and projecting future cases. Appendix E contains more detail on Finity and our experience in projecting asbestos cases, claims and liabilities.

In addition we have used a number of publicly available academic papers, reports and other data on mesothelioma, asbestos exposure and other areas (e.g. population figures) relevant to this project. These are cited throughout our report and listed in Appendix A.

1.6 Principles

We acknowledge that there are some contentious points when it comes to mesothelioma and its causes, although many of these points have been tested through significant medical and epidemiological research over time. Throughout this project we have adopted the following underlying principles:

1. Most cases of mesothelioma are caused by asbestos exposure (Park et al, 2013).
2. There is no safe threshold for asbestos exposure. All asbestos is carcinogenic (WHO, 2006).
3. For a proportion of mesothelioma cases it will not be possible to identify or infer a possible or probable source of exposure (AMR, 2015). In our projection we have grouped all of these sources together under the heading of 'background' cases.
4. Exposure to white asbestos (chrysotile) can cause mesothelioma (Park et al, 2013 and WHO, 2006), although it is less toxic than blue asbestos (crocidolite) and brown asbestos (amosite) (Berry, 1999).
5. There is a rough offset between diagnoses in Australia of people who were exposed to asbestos overseas, and people exposed in Australia who live overseas by the time they are diagnosed. The changes in rates of mesothelioma due to the effects of immigration and emigration are difficult to estimate. They are affected by:

(a) Patterns of asbestos use and exposure profiles in different source countries.

(b) The number of immigrants from different countries and when they arrived in Australia.

(c) The number of emigrants and when they left Australia.

(d) Exposure to asbestos after arriving in the destination country.

(e) Historical changes in the factors above as well as future changes.

6. Risk for a person or group:

(a) Is proportional to the asbestos dose, or average fibre-load i.e. the fibres per millilitre of air when they were exposed. So risk is reduced by any precautions taken, such as wetting ACMs before cutting them, or wearing protective equipment (Breslin, 2015).

(b) Is also proportional to their duration of exposure (Berry, 1999).

(c) Varies based on their age at exposure. Mesothelioma is a latent disease which rarely emerges within the first 10 years after exposure (Ferguson et al, 1987 and Berry, 1991). In our experience mesotheliomas are typically diagnosed around 40-50 years after first exposure. All other factors being equal, our approach assumes that those exposed at younger ages face more risk of contracting mesothelioma across their lifetime than those exposed at advanced ages, due to their higher average remaining years of life after being exposed and the rising risk of incidence after exposure.

(d) Varies based on the type of asbestos they were exposed to (see point 4. above).

7. The information provided by patients or their families in the AMR exposure questionnaire is reasonably accurate, unbiased and broadly representative of the overall profile of cases, including those who did not provide details of their exposure. There are several arguments why the true level of third wave cases may be over or underrepresented in the subset that provided exposure information. We discuss this further in Section 3.5.

8. We assume that there are no medical improvements or potential discoveries (such as a new vaccine) which reduce the occurrence of mesotheliomas in future.

9. We assume no changes over time to the criteria for diagnosing mesothelioma. Similarly, we assume no change in the completeness of diagnoses.

10. Under our base scenario, we assume that there is no significant change in future in the risk associated with handling and removing in situ asbestos.

11. Our modelling implicitly assumes that the majority of Australian mesothelioma cases diagnosed since 1982 have been reported to state cancer registries, and then to the AMR (and predecessor organisations) and the AIHW.

While some of these points may be debated, alternative views will have limited bearing on the broad conclusions drawn in this report. We have tested some of these points in our alternative scenarios where possible.

1.7 Compliance with Standards

This report and advice is prepared in accordance with the Actuaries Institute Code of Conduct (Actuaries Institute, 2009). This code outlines the standards required of actuaries in a professional capacity. There are no other Actuaries Institute professional standards which apply to this advice.

1.8 Control Processes and Review

Our projection and this report have been subject to technical review and peer review as part of Finity's standard internal control process. These include the following:

- Technical review focuses on the data and numerical work involved in the project. The technical reviewer tests the data, models, calculations and results, and also reviews our written advice from a technical perspective.
- Peer review is the professional review of a piece of work. The peer reviewer reviews the approach, assumptions and judgements, results and advice.

1.9 Structure of Report

The remainder of this report is as follows:

Section 2:	provides a list of key terms and their definitions
Section 3:	summarises data on historical mesothelioma cases in Australia
Section 4:	summarises our projection approach
Section 5:	describes the key assumptions used in our base scenario projection, but also considers assumptions under alternative scenarios
Section 6:	summaries the results of our base scenario projection and model fit. This section also includes a number of alternative scenarios exploring key sources of uncertainty within this projection
Section 7:	contains the reliances and limitations associated with our advice.

The appendices set out further details of our work.

2 Key Definitions

Acronym or Key Term	Definition
1st wave (or 'wave 1')	Heavy industrial use of asbestos, including asbestos mining, milling, manufacturing asbestos products, installation and transportation. Peak exposures often occurred prior to the 1970's in these industries.
2nd wave (or 'wave 2')	Downstream asbestos product use within occupations, particularly in the building industry. This involved high exposures in some jobs (e.g. carpenters). Peak exposures were mainly in the 1970's.
3rd wave (or 'wave 3')	Later occupational and non-occupational exposures, usually with lower intensity and lower cumulative exposures. Jobs exposed in this group include white collar occupations. This cohort also covers domestic non-occupational exposures (e.g. home renovators). Peak exposures are potentially later than the 1970's. These exposures are also spread more broadly across the Australian population.
ABS	Australian Bureau of Statistics
ACD	Australian Cancer Database
ACM	Asbestos Containing Material
AIHW	Australian Institute of Health and Welfare
AMR	Australian Mesothelioma Registry
ASCC	Asbestos Safety and Compensation Council
ASEA	Asbestos Safety and Eradication Agency
AWP	Asbestos Working Party of the Institute and Faculty of Actuaries, United Kingdom
Background cases	Mesothelioma cases which cannot be attributed to a source of asbestos exposure.
DDB	Dust Diseases Board, a public body in New South Wales (NSW) providing compensation, treatment and support for workers and their families where the worker had work-related exposure to harmful dust in NSW.
DIY	Do It Yourself renovator
'Dusty Families'	Exposure to asbestos in the home for non-workers. This arises from a worker bringing dust into the home, typically on their clothes and person. Common means of exposure are from spouses washing clothes and family members (including children) otherwise coming into contact with the worker.
HRF	Hunter Research Foundation
ICD	International Classification of Disease
Incidence	The rate at which mesothelioma is contracted in a population exposed to asbestos, calculated per person per year. We measure incidence rates relative to the survivors from the original exposed population, but at a future point in time.
MonCOEH	Monash Centre for Occupational and Environmental Health
Mortality	In this report mortality this refers to deaths in an exposed population from any cause, not just from mesothelioma. Because the mesothelioma mortality rate is low in most populations, 'mortality' effectively relates to deaths from all other causes.

Acronym or Key Term	Definition
NHMRC	National Health and Medical Research Council
Occupational post-2003	In our projection, mesotheliomas arising from exposure in the workplace after the ban on asbestos consumption on 31 December 2003
Survival	In this report the term ‘survival’ refers to the time from a person being exposed to asbestos until they are either diagnosed with mesothelioma or die from other causes.
Wave 1&2	In this report, this refers to mesotheliomas arising from exposure in the workplace (including related environmental exposures such as dust brought into the home by workers), for the exposure years 1921 to 2003.
Wave 3 Domestic	In this report, this refers to mesotheliomas arising from non-occupational exposures in and around homes, for the exposure years 1960 to 2055. This category excludes ‘dusty family’ exposures and environmental exposures for people living near asbestos mines or plants. These exclusions are captured under the Wave 1&2 group.
Wave 3 Total	In this report, this refers to the sum of Wave 3 Domestic, Occupational post-2003 and Background cases.

3 Mesothelioma Profile in Australia

This section provides a summary of the profile of historical mesothelioma cases in Australia, including our interpretation of the data received. Additional background information is included in Appendix B.

3.1 Data Sources

3.1.1 The Australian Mesothelioma Registry

The latest incarnation of the Australian Mesothelioma Registry (AMR) commenced in June 2011 and has collected information on mesotheliomas diagnosed in Australia since 1 July 2010. This database collates information from the state cancer registries.

The AMR provided Finity with a listing of all mesothelioma cases reported to state cancer registries in the period 1 July 2010 to 9 July 2015. The AMR data did not include information from ACT or NT cancer registries or any personal identifying information, as noted in Section 1. In all other respects the data cover all Australian mesotheliomas.

In addition to high level statistics, the AMR collects asbestos exposure information by surveying those who respond to an invitation to provide details on the nature of any episodes of exposure. After a case is notified to the AMR the collection of exposure information happens after a lag, due to the time taken to contact the individual and then collate and report their responses. These exposure data make the AMR one of the most comprehensive up to date information sources on mesothelioma incidence in Australia. For this reason we have used the AMR database as the main exposure information source in our review.

3.1.2 The Australian Institute of Health and Welfare

The Australian Institute of Health and Welfare (AIHW) has recorded high level data on all Australian mesotheliomas from 1982 until 2011. This dataset is also a collation of information from the state cancer registries and includes information on age at diagnosis and gender.

3.1.3 Data Accuracy

The AMR and AIHW rely on the state cancer registries to capture and record cases of mesothelioma. The accuracy of state-based cancer records in turn depends on correct diagnoses by treating physicians and accurate classification of individual cases when these are aggregated in the state cancer registries.

It is our understanding that techniques for diagnosing mesothelioma are well established in Australia. Few, if any, cases should have been misdiagnosed in the last 20 years.

The accuracy of historical mesothelioma reporting is sometimes questioned. This is because there was no specific code for mesothelioma in the International Classification of Diseases (ICD) coding system until the Tenth Revision (ICD-10), which has been used since 1997 (Watson, 2004). Under ICD-9 and earlier versions, mesotheliomas could be classified as lung cancers, pleural cancers, peritoneal cancers or cancers with no site specified (Wojcik et al, 2014). The coding under ICD-9 (used from 1979 to 1996 in Australia) was more reliable than earlier revisions to the classification (Ferguson et al, 1987).

Cases Since 1982

Australian national cancer registry coverage began in 1982. In the state and territory databases, cancers are coded under the ICD-Oncology system (ACD, 2015). Professor Fritschi confirmed that ICD-Oncology includes both the topography (based on the site of the primary tumour and is almost identical to ICD-10) and the morphology (i.e. the type of cells in the tumour). The morphology codes 9050 to 9055 are specific to mesothelioma and have existed in ICD-Oncology since 1975, so Australian cancer registries have been able to accurately identify mesotheliomas since that date.

Apart from the cancer registries, strong oversight of mesotheliomas (and their exposure profile, where possible) has come via other channels. The Australian Mesothelioma Surveillance Program operated from 1 January 1980 to 31 December 1985. The Australian Mesothelioma Register then replaced the surveillance program on 1 January 1986, but was discontinued in 2007 (Soeberg et al, 2016). This register was separate from the latest incarnation (the Australian Mesothelioma Registry), which commenced on 1 July 2010. There has also been robust supervision of mesotheliomas in Western Australia (WA), and the nature of their exposure, via the WA Mesothelioma Register (Olsen et al, 2011).

In many cases these programs and registers use data collected from the same underlying sources as the AMR and AIHW. They provide another level of review around the data collection process. In this report we have cited studies of these other databases as a check on our analysis of AMR and AIHW data.

For the reasons given above we are confident that the AIHW and AMR data recorded since 1982 are accurate and appropriate for this project.

Pre-1982 Cases

We could have used data from other sources for mesotheliomas diagnosed prior to 1982. For instance, retrospective searches have identified at least 658 Australian mesotheliomas occurring from 1945 to 1979 (Musk et al, 1989). We did not use these earlier data, because the period 1982-2015 provided a credible recent period for calibrating our model. Furthermore, there may be a possible diagnostic effect that led to more underreported cases at older ages prior to 1982 (Clements et al, 2007a and Leigh et al, 2002). For these reasons it is appropriate to exclude these earlier cases from the calibration.

3.2 Historical Incidence

Figure 3.1 summarises the latest available data on historical mesothelioma cases as reported by the AIHW and AMR, split by diagnosis year.

Figure 3.1 – Historical Mesothelioma Cases By Gender And Year Of Diagnosis

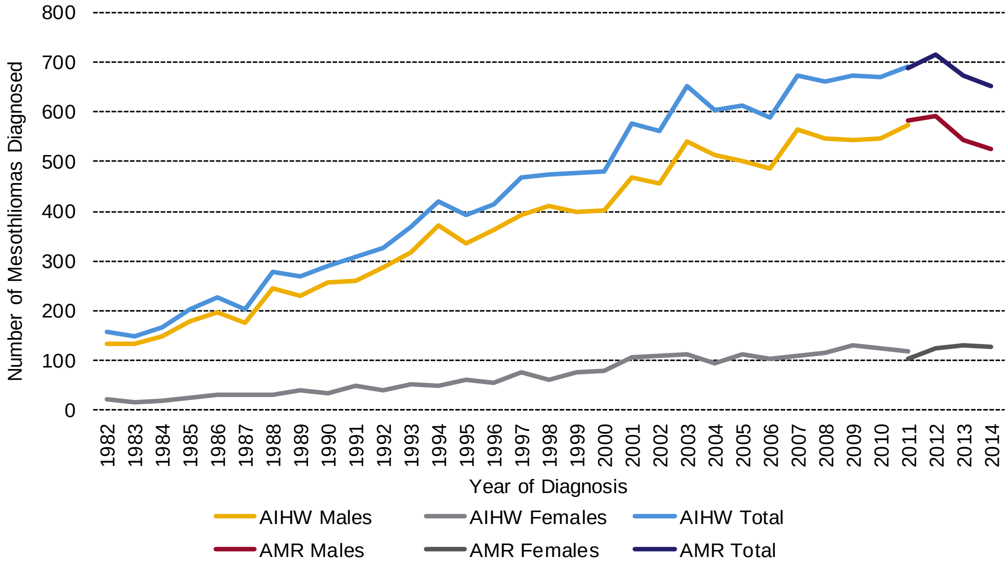
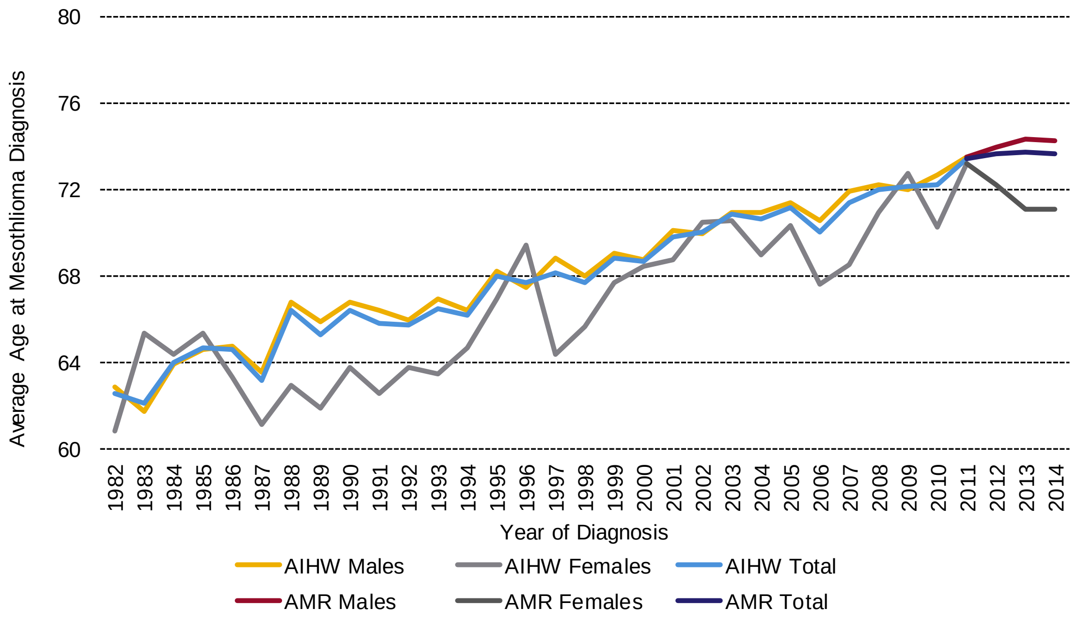


Figure 3.1 shows a rising trend in mesotheliomas since 1982. Cases among both males and females have increased over this period. The lower number of cases in 2013 and 2014 may reflect delays between diagnosis and reporting to the AMR. We analysed data in the AMR annual reports (AMR, 2012 to AMR, 2015); these show that cases can be reported for up to three years after the year of diagnosis, and possibly longer. We have analysed these delays and allowed for further unreported cases from the later diagnosis years shown above. Unreported cases are also known as 'Incurred But Not Reported', or 'IBNR' cases. Once we allow for these late reports, we expect the level of mesotheliomas has been relatively flat over the period 2011-2014, at just over 700 mesotheliomas per annum.

In Appendix C.5 we describe our allowance for unreported cases in more detail. This is important when selecting the current level of mesotheliomas for our projections.

Figure 3.2 shows the average age at diagnosis for mesotheliomas reported by the AIHW and AMR.

Figure 3.2 – Historical Average Age At Year Of Diagnosis By Gender



This chart shows that the average age for all persons has increased steadily from around 63 years in the early 1980s to 74 years in 2014. Females have been, on average, around two years younger than males at diagnosis. The increasing age at diagnosis and differences by gender can be attributed to the long latency of mesothelioma (i.e. the time delay between exposure and diagnosis), increasing life expectancy and changes in exposure over time (in particular, the significant exposure reductions after 1980). The variation in average age over time is discussed in more detail in subsequent sections of the report.

3.3 AMR Mesothelioma Cases: Gender Split

In this report we analyse the gender profile of cases because this provides some insight into the relative contribution of different exposure sources to Australian mesotheliomas. This profiling is also useful because the sex is recorded for all but a small minority of cases.

There are 3,264 cases of mesothelioma in the AMR dataset with a year of diagnosis provided; 581 females and 2,683 males. The proportion of female cases each year has ranged from 15% to 19%, and averaged 18%. This is shown in Table 3.1.

Table 3.1 – AMR Data Split By Gender

Calendar Year of Diagnosis	Females	Males	Total	% Females
2010[1]	65	284	349	19%
2011	104	584	688	15%
2012	123	593	716	17%
2013	129	545	674	19%
2014	126	527	653	19%
2015[2]	34	150	184	18%
Total	581	2,683	3,264	18%

[1] Covers period 1 July 2010 to 31 Dec 2010

[2] Covers period 1 Jan 2015 to 9 July 2015

The data summarised above broadly reconcile to the latest AMR report published for cases diagnosed up to 31 December 2014 (AMR, 2015). Any differences arise because:

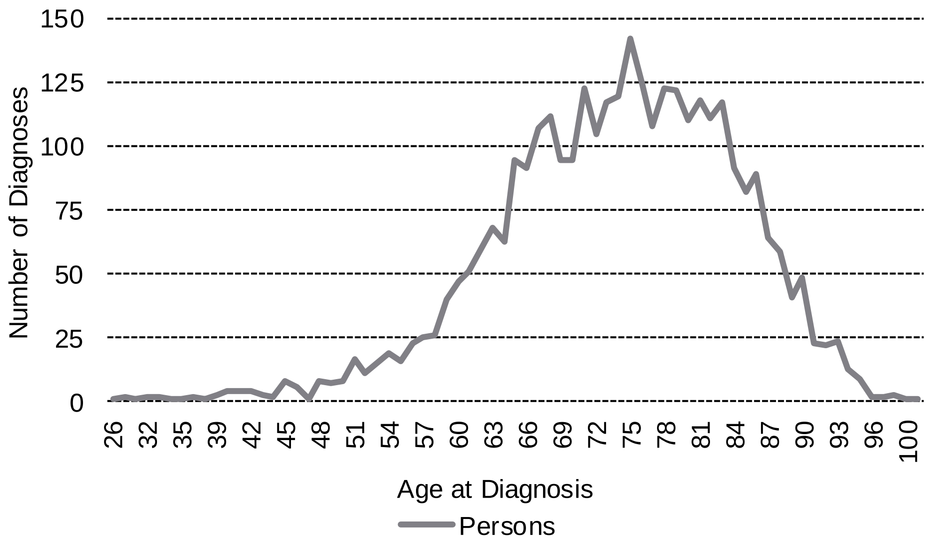
(a) The data file supplied to Finity excludes ACT and NT data. The publicly available AMR report includes all Australian cases.

(b) The dataset supplied to Finity was extracted as at 9 July 2015. The latest AMR report includes cases notified to the AMR by 31 May 2015.

3.4 AMR Mesothelioma Cases: Age Split

We also analyse the age of mesotheliomas at diagnosis to better understand exposure and possible future incidence trends. Of the nearly 3,300 cases reported to the AMR since 1 July 2010, the average age at diagnosis was 72 years for females and 74 years for males. Figure 3.3 shows the distribution of age at diagnosis for these cases.

Figure 3.3 – AMR Data Split By Age At Diagnosis



As expected there are relatively few cases below age 50, due to the long latency of mesothelioma and higher likelihood of exposure occurring as an adult.

3.5 AMR Survey Data: Mesothelioma and Asbestos Exposure

In addition to collating the number of mesothelioma cases and summary data (split by gender, age at diagnosis and diagnosis year), the AMR also oversees an assessment to collect information on the possible sources of asbestos exposure that caused mesothelioma. These 'sources' are jobs or environmental situations (e.g. a home renovation) where the person was exposed to asbestos.

The collection of this information is completed in two parts:

- An initial postal questionnaire. The Monash Centre for Occupational and Environmental Health (MonCOEH) uses information from the postal questionnaire to set appropriate telephone interview questions for each person.
- A follow up telephone interview based on these tailored questions to collect more detail. The interview is conducted by the Hunter Research Foundation (HRF).

Table 3.2 summarises the total AMR database (3,264 cases), split into the following:

1. 'Full interview': patients who completed both the questionnaire and telephone interview.
2. 'Partial interview': patients completed the questionnaire and some telephone interview questions.
3. 'No interview': patients completed the questionnaire only.
4. 'No exposure information': the diagnosis is reported to AMR, but the person with mesothelioma (or their family) has not completed the questionnaire or telephone interview.

Table 3.2 – Summary Of AMR Exposure Data

	Questionnaire Completed with				
Year of Diagnosis	Full Interview	Partial Interview	No Interview	No exposure info	Total
2010	11	0	1	337	349
2011	100	1	13	574	688
2012	135	0	11	570	716
2013	110	0	14	550	674
2014	107	1	14	531	653
2015	26	0	1	157	184
Total	489	2	54	2,719	3,264

The number of cases completing the questionnaire broadly reconciles to the data summarised in the 2014 AMR Annual Report (AMR, 2015). The differences arise because the table above includes cases diagnosed in 2015, and the data extract provided to Finity included more up to date information from completed telephone interviews.

Table 3.2 shows that 545 people have participated in the AMR exposure survey with 90% of participants completing all survey elements. Of the 56 participants who only partially completed the survey, sufficient information was obtained to infer likely asbestos exposure sources in 50 cases. This means that the AMR database includes significant detail on likely sources of exposure for 539 mesothelioma cases.

As noted in Section 1.6, in our base case analysis and projection we have treated this exposure information as accurate and broadly representative of the exposure profile for all cases. This is a key assumption which we cannot confirm, resulting in uncertainty around our projections. If the profile of exposure sources for those who completed the interview is materially different to those with no exposure information, then our projection will likely be impacted. We discuss this issue further at the end of this section. The sensitivity of the projections to alternative exposure profiles is considered in Section 6.

The survey allows participants to nominate multiple sources of occupational and non-occupational exposure, from which MonCOEH assign ratings of 'probable', 'possible' and 'likely' to each exposure source (AMR, 2015). We used this information as follows:

- As an interim step, each identified exposure source was allocated a probability weight, as shown in Table 3.3. These weights were selected by Finity but based on descriptions in the AMR annual reports (AMR, 2015). It is impossible to set these on a published evidence basis, considering how the AMR exposure information is collected and recorded. The weighting reflects the relative likelihood that a particular exposure contributed to the disease. The AMR likelihood grade assigned is based on the patient's recollection of the activity or nature of exposure and the interviewer's judgement about the likelihood and severity of asbestos exposure. Our assumed probabilities are crude, in the sense that the allocated probabilities at this step might sum to less than or more than 100%. They are used simply as a ranking mechanism. We assigned 0% to unlikely sources, so they do not contribute to the assumed exposure sources.

Table 3.3 – Assumed Probabilities

AMR Likelihood Grade	Occupational	Non-Occ
Unlikely	0%	0%
Possible	30%	3%
Probable	70%	7%

- We assigned higher probabilities for occupational exposures, compared to non-occupational exposures, on the basis that work-related risks were greater prior to 1980 (the main period of exposure contributing to mesotheliomas in the AMR data we used). This assumption impacts 224 of the cases where the person with mesothelioma cited both occupational and non-occupational exposure. This group comprises 42% of the 539 cases with exposure information. The gender profile of these cases (98% male) also suggests a strong correlation with pre-1980's occupational exposures. Similar approaches to weighting exposure sources have been taken in other contexts. For instance, under the Australian Mesothelioma Surveillance Program (1980-1985), the asbestos exposures possibly causing the mesothelioma were investigated. Occupational exposures were considered first in this program; only a lack of occupational exposure led the investigators considering non-occupational factors (Ferguson et al, 1987).
- After we assigned probabilities to each source identified from a patient's exposure assessment, we found that in many cases these sum to a total that is above or below 100%. We have used the probabilities in Table 3.3 as a relative ranking mechanism, so that fractions of each mesothelioma can be allocated to each source to reflect their contribution to risk. For this reason we scaled the probabilities assigned to a patient so that they added to 100% for each person. The new scaled probabilities then estimate the relative contribution of each exposure source to the individual's risk of contracting mesothelioma.
- We summed these fractions across the 539 cases that had credible exposure data. This gave the number of individuals estimated to have contracted mesothelioma from each source of exposure. Our approach implies that fractions of cases may be allocated to the different exposure sources.

This process is demonstrated via the following example. In this simplified situation, with only four cases in total, the overall exposure source is attributed as 29% non-occupational (1.16 cases) and 71% occupational (2.84 cases, being the sum of 2.19 and 0.65).

Table 3.4 – Sample Exposure Profile and Scaling

	Job 1				Job 2				Non-Occupational Exposure			
Gender	Exposure Type	Exposure Probability	Assigned Probability	Scaled Probability	Exposure Type	Exposure Probability	Assigned Probability	Scaled Probability	Exposure Type	Exposure Probability	Assigned Probability	Scaled Probability
Male	Carpenter	Probable	0.7	1.00	N/A	N/A	0	0.00	N/A	N/A	0	0.00
Male	Carpenter	Possible	0.3	0.28	Power Station	Probable	0.7	0.65	Lived in asbestos house	Probable	0.07	0.07
Female	Belt Feeder	Unlikely	0	0.00	Shop Assistant	Unlikely	0	0.00	Worker brought dust home	Probable	0.07	1.00
Male	Fitter & Turner	Probable	0.7	0.91	School Teacher	Unlikely	0	0.00	Serviced brakes and clutch	Probable	0.07	0.09
Total				**2.19**				**0.65**				**1.16**

Table 3.5 summarises the allocation of the 539 mesothelioma cases by occupational or non-occupational exposure, using the process described above. We have separated the 32 cases with an unconfirmed exposure source (i.e. where no occupational or non-occupation exposure source was identified as being 'probable' or 'possible'). These 32 cases could not be analysed using the process described above.

Table 3.5 – Exposure Profile – All Persons

Source	Females	Males	Total	% of Total
Occpuational	**20**	**310**	**330**	**61%**
Non-Occupational	**82**	**95**	**177**	**33%**
Asbestos in the home (incl. renovations)	49	59	108	20%
Worker brought dust home ('dusty families')	22	5	27	5%
Serviced brakes and clutch	0	19	19	4%
Other exposure	11	13	23	4%
Unconfirmed Exposure Source	**8**	**24**	**32**	**6%**
Total	**110**	**429**	**539**	100%
% of Total	20%	80%		

Table 3.5 shows that, based on the data and process described above, 61% of cases providing exposure information developed from occupational exposure. This includes those individuals who identified occupational exposures as their only exposure source, as well as a majority share of cases who identified both occupational and non-occupational sources. The gender split of the occupational subgroup is heavily skewed towards males (94%), reflecting the fact that only a small number of women were employed in mining, milling, trades or transportation of asbestos up until the 1980s – areas where occupational asbestos exposure levels were very high.

Thirty three per cent of people contracted mesothelioma from non-occupational exposures, with the vast majority of these cases citing non-occupational exposures as their only source of exposure. The overall gender mix within the non-occupational subset is more balanced, but includes some subsets of exposure which are predominantly female (e.g. 'dusty families' i.e. people residing with a worker who were exposed to fibres brought home on the clothes or person of that worker). Some of the subsets are predominantly male (e.g. servicing the family car at home).

The largest subset of non-occupational exposure, accounting for 20% of current mesothelioma cases in total, is due to ACM found within the home. This subset includes home renovators, those living in a house during renovation and those living in a house containing asbestos.

There were 32 cases (6%) with unconfirmed exposure above background levels. Three quarters of these cases were male. In section 5.2 we describe how we interpreted these data when building an assumed profile for all claims for our projection.

Further detail on the exposure profile of the AMR data is contained in Appendix C.5.

3.5.1 Occupational versus Non-Occupational Sources

In Table 3.3 we selected probabilities so that occupational sources were 10 times more likely to contribute to a person's mesothelioma than non-occupational sources (e.g. 70% for probable occupational exposure versus 7% for probable non-occupational exposure). This is an important assumption and is based on our judgement. We tested the impact if the same relativity was 100 i.e. non-occupational exposures were much less likely to contribute to the mesothelioma risk for those patients who had occupational and non-occupational exposures.

Under this scenario, for the 539 cases shown in Table 3.5, approximately 15 additional cases would be allocated to the occupational group instead of the non-occupational subset. This would increase the occupational group's share of all cases from 61% to 64%. The additional 3% mostly comes from the categories 'servicing brakes and clutch' and 'asbestos in the home (including renovations)'. Such a change is within with the range tested in scenario 5 in Section 6.3 of this report and would not materially alter the projection outcomes.

3.6 Does AMR data with exposure information represent all cases?

This is important when we come to split the total assumed cases in our base year (2013) between the different waves. This is because the waves have different peaks and shapes and the allocation affects the overall projection. The split is also important for asbestos management, policy and awareness campaigns to be managed by ASEA and others.

We have two options when splitting the total cases in the base year. We can assume that:

- The mix implied by the subset of AMR cases with exposure data (17% of all cases) reflects the total dataset.
- Or, the mix is significantly different between the subset with exposure data and all cases, and we can make adjustments.

The key factors which we can vary to make the adjustments under the second option above are gender, the mix by occupation, the mix of non-occupational exposure sources and the broader split between occupational, non-occupational and background cases.

We decided to make modest adjustments to the gender split for each source of exposure when setting our 2013 assumptions, so that the overall assumed split of cases by gender matched the aggregate AMR data. Women comprised 20% of the subset with exposure information but 18% of all cases.

We did not make any adjustments to the allocation within the occupational group. This did not have a significant impact on the projection. We did not project different occupations within this group. When we calibrated our wave 3 commercial model, we considered the jobs which might reasonably incur some exposure after 2003 during asbestos removals or in situ (e.g. office workers). However this wave is small in the context of the total projection, so the allocation of jobs would not materially affect our results.

Similarly, we projected non-occupational cases in aggregate, so the allocation to different exposure sources within this segment should not have a material impact on our output. Further research could analyse this mix further, though this was not a priority for this review.

For cases with both occupational and non-occupational exposure, we described our testing of the risk-based allocation of these cases across the exposure sources in the previous section. This showed a modest impact on results.

We did make modest adjustments to the mix between occupational, non-occupational and background cases. The overall split in the AMR exposure data and in our base year assumption is shown in Table 3.6.

Table 3.6 – Split of Cases by Main Exposure Sources

Source	AMR Data	Finity Assumption
Occupational	61%	64%
Non-Occupational	33%	31%
Background	6%	5%
Total	100%	100%

Our reasons for making these adjustments are described below and in Section 5.2. The adjustments are modest. The mix is broadly unchanged, with around twice as many occupational mesotheliomas as non-occupational cases in both the data and assumed by Finity.

3.6.1 Reasons why the mix might be different

The following reasons explain why occupational Wave 1&2 cases might be underrepresented in the subset of AMR cases with exposure information:

- Patients who die soon after being diagnosed with mesothelioma may be less likely to provide reliable exposure information. This risk is likely to be greater for those diagnosed at older ages, because they will probably have a shorter life expectancy post-diagnosis compared to younger patients. Younger patients would be stronger and expected to live longer on average.
- Patients who are diagnosed at an older age may be less likely to recall the circumstances of their exposure, due to a greater prevalence of dementia or simply from more time having elapsed.
- Our analysis of the AMR data shows that most of the older patients tend to come from Wave 1&2 occupational exposures. So, we may conclude that any age-related effect on the propensity to report exposure information may lead to occupational claims being underrepresented in the subset providing exposure information.
- We also expect that a greater proportion of Wave 1&2 cases are pursuing common law claims against former employers, product suppliers or others, compared to Wave 3 cases. This is because compensation for these claims is well established and it is more straightforward to demonstrate negligence. We have heard anecdotal evidence that some Wave 1&2 plaintiffs have deliberately not provided exposure information to the AMR for fear of jeopardising their claims. This means that occupational claims might be underrepresented in the subset providing exposure information, compared to the full body of Australian mesotheliomas.

Conversely, Wave 3 cases might be underrepresented in the subset of AMR cases with exposure information. This is because Wave 3 cases typically have lower levels of cumulative asbestos exposure compared to Wave 1&2 mesotheliomas (Park et al, 2013). For many Wave 3 cases the person may not know their exposure source. Due to this limited understanding it might be inferred that those with Wave 3 exposure are less likely to complete the exposure questionnaire, if they think they have little or no information to offer.

3.6.2 Testing Our Approach – DDB Benchmarking

As a check on our approach, we analysed data from the 2014/15 Dust Diseases Board (DDB) annual report (DDB, 2015). The DDB pays no-fault statutory benefits to any person exposed to asbestos (as well as a number of other types of dust) while employed as a worker in New South Wales. Around 150-160 new mesotheliomas have been certified (i.e. approved) by the DDB on average each year in the last seven years. Allowing for the fact that a small number of cases may not claim these benefits, it is reasonable to assume that there were 160 mesotheliomas per annum on average over this period in NSW.

We extrapolated to an Australian figure, based on the NSW population in 1975 being 36% of the Australian population (ABS, 2014). We used this as it is approximately the average year of exposure giving rise to mesotheliomas diagnosed in our base year of 2013. Using the assumed 160 NSW cases, this implies around 445 Australian occupational mesotheliomas each year.

We assumed 452 occupational cases in 2013 in our base scenario (64% of the total 708 mesotheliomas assumed, as shown in Table 5.6). This assumption was set after considering this DDB benchmarking analysis, and after analysing the gender profile of claims. The latter point is described further below.

3.6.3 Testing Our Approach – Gender Profile

In setting our overall profile we tested the gender mix for various segments e.g. wave 1 and wave 2 cases combined (including domestic cases from ‘dusty clothes’ brought home by a worker). We compared the mix from our assumed profile against portfolios of common law mesothelioma claims for other Finity clients. The splits were close for groups with similar exposure profiles, giving us further confidence in our approach.

More information on this profiling is set out in Table 5.6.

3.6.4 Testing Our Approach – Other

Asbestos exposure through home renovation has been significant in recent decades (Olsen et al, 2011). The following points are worth noting:

- A survey of Adelaide homeowners showed that significant renovations were performed in about one third of homes in the period 1986-91. These renovations tended to be made to older homes (particularly those over 50 years old).
- In the 10 years to 1999, two thirds of Australian homes built between 1920 and 1949 had been renovated. Since that date we can infer that more renovations have been done for homes built after the Second World War, when ACM’s were more widely used.
- In a national survey of home renovators prepared for a 2009 conference, only around one third of respondents reported that they had taken precautions to reduce exposure to asbestos fibres in or around their home.

A recent survey of NSW households demonstrated that 61% of do-it-yourself (DIY) renovators reported being exposed to asbestos during the renovation (Park et al, 2013). Among all DIY renovators 39%

advised that their partner was exposed, and a further 23% reported exposure to their children. However, only 12% of these respondents reported using respiratory protection regularly (and 28% used protection occasionally). Furthermore, 25% of DIY renovators planned another renovation in the next five years.

This survey also demonstrates significant potential exposure to asbestos during home renovations.

While these examples do not directly corroborate our assumed split by using exposure information in mesothelioma data, they add weight to the argument that home renovator exposure was material for a large proportion of the Australian population.

However, we observe that the proportion of mesotheliomas in Western Australia attributed to home renovations has increased markedly in both men and women since 2003 (Park et al, 2013).

3.6.5 Conclusion

The testing described above supports the assumptions in our base scenario.

For the reasons set out above, we think it is appropriate to assume in our base scenario that the subset of AMR cases providing exposure details are broadly representative of all mesotheliomas. We made some small adjustments to ensure that our assumed split by gender matched the AMR data and the split reconciled to other benchmarks.

Nevertheless, we acknowledge the uncertainty involved in extrapolating the AMR exposure data to all Australian mesotheliomas. In our alternative scenarios we tested variations of 7-8% in the split of baseline (2013) cases by wave. These led to variations in total future mesotheliomas that were around 4% higher or lower than our base scenario. This variation is material but not excessive. More detail is included in Section 6.3.1.

4 Approach

This section describes our analysis and projection approach. A summary of the modelling assumptions is contained in Section 5. More detail is included at Appendix C.

4.1 Introduction

We use a Population Exposure and Incidence Model (PEIM) to project future cases. This applies a risk weighted mesothelioma incidence formula to the surviving exposed population in each projection year.

The key components of this model are:

- Asbestos consumption and removal form the exposure base. We allow for the volume and types of asbestos consumed and removed, as well as the relative reduction in risk over time (if any) from changes in asbestos handling procedures and guidelines. We do not model the number of people exposed directly. Instead we infer that the risk-weighted number of people exposed broadly follows the shape of the volume of asbestos fibres consumed (and then removed). We also link this historical exposure (tonnes of asbestos) to observed counts of actual cases in prior years. This allows the future number of cases to be projected in line with changes in exposure over time.
- The profile of the estimated exposed population. We consider the circumstances of exposure (e.g. occupational or non-occupational), gender, age at exposure and any other environmental factors, to the extent that these may affect our projections.
- The incidence of mesothelioma after the initial asbestos exposure. This is an epidemiological model which estimates the likelihood of developing mesothelioma each year after exposure.

We derive a base scenario of projected mesothelioma cases. In addition, we provide alternative scenarios to understand the variability in the possible outcomes. The results for these scenarios are set out in Section 6.

The rest of this section provides more detail on the key components of our model.

4.2 Overview of Projection Model

We segmented the projection into a number of 'waves', as described in Section 4.4. The projection of cases described above is performed separately for each of these waves.

An estimate of the number of cases is prepared for each year from 1988 to 2100 by assessing:

- The type and volume of asbestos consumed and removed in Australia in each year from 1921 to 2055 (Section 4.3).
- The profile of the exposed population and their probability of surviving to each future year, based on their age at exposure and gender mix (Section 4.4).
- The likelihood of developing mesothelioma in each year after being exposed to asbestos (i.e. our epidemiological claim incidence model). We apply the incidence rate to those surviving to each future year (Section 4.5).

In Section 4.6 we describe the model calibration. This fits the model to the number of known mesothelioma cases to date, as well as the following variables or features of experience (where these are available from the data for each wave):

- Any patterns or trends in these cases.
- The age profile of people with mesothelioma, including the average age and distribution of ages at diagnosis.
- Duration of exposure.
- Year of exposure.

4.3 Asbestos Exposure

4.3.1 Net Australian Asbestos Consumption and Removal

Australian asbestos consumption is modelled as production (locally mined asbestos) plus imports minus exports. We also assume that there is some exposure when asbestos is removed from the built environment.

In our exposure model we used a rolling three year average of net Australian asbestos consumption from 1921 to 2003. We did this to allow for the delay from mining or importing asbestos to its deployment in products containing asbestos. Gravelsons and colleagues state that "…there is no clear cut scientific opinion as to how long the usage period should be. However, we have assumed that it is reasonable for a few years delay between the imports of raw asbestos and their transformation into manufactured products." (Gravelsons et al, 2009, section 4.2.3). Our averaging process also served to smooth the volatile underlying consumption series. This supported the calibration of our model.

Asbestos was used in Australia prior to 1921, but the volumes were very small (World Mineral Statistics Dataset, 2015). For this reason we ignored asbestos consumed up to 1920. Furthermore, these exposures do not materially impact the back fit of our model or our projection of future mesothelioma cases.

We used a model built for ASEA by Blue Environment in order to project the stock of ACMs and asbestos removals. We refer to this as the 'stocks and flows' model. It projects the cumulative stock of asbestos from past consumption, as well as the rate of asbestos removal from this in situ stock in the built environment.

The Blue Environment stocks and flows model also contains the following features:

- It uses the same national asbestos consumption data described above.
- It projects the use of these asbestos fibres in seven Asbestos Containing Material (ACM) product types (cement sheeting – domestic & commercial, cement pipes, flooring products, friction products, roofing and other).
- It estimates the proportion of these products (by volume) that are comprised of asbestos fibres. These proportions were necessary assumptions to assist in the initial calibration of the stocks and flows model, but are unnecessary for the purposes of our projection. As such they have not been incorporated in our application of the model.
- Some differentiation, by product, between domestic and commercial ACMs.
- Assumptions, by product type, for the rate of removal after asbestos has been consumed in a year.

We reviewed this model for reasonableness and goodness of fit. We consider it to be fit for purpose for our review. The stocks and flows model projects that the stock of asbestos will be mostly removed from the built environment by 2100.

To make our overall approach more manageable we did not model asbestos exposure from removals after 2055. Exposure after 2055 is expected to produce a small number of additional cases (perhaps an additional 1% above the cases already projected in our base scenario). Omitting this exposure period does not materially impact the conclusions in our report.

4.3.2 Types of Asbestos

There were three main types of asbestos used in Australia in the twentieth century, namely blue, brown and white asbestos (Driscoll & Leigh, 2008). Blue and brown asbestos are each types of amphibole fibres. More detail on the types of asbestos is given in Appendix B.1.

Each type presents a different risk of contracting mesothelioma (Gravelsons et al, 2009). ACMs in Australia often mixed the different types; for example, asbestos cement sheeting (commonly known as ‘fibro’) contained amphibole as well as chrysotile asbestos until the 1980s (Park et al, 2013).

These ACMs with a mixture of asbestos types were used throughout Australia, with no national register of where the different types were used. By necessity we assume that all three types are present in the remaining stock of asbestos and in the volume of asbestos fibres removed each year.

We used data on the volume of net asbestos consumption by type in each year to create a risk index. This asbestos risk index represents the relative likelihood of mesothelioma incidence arising from exposure in each year due to the different types consumed each year. This risk index assumes a constant volume of asbestos consumed each year. The assumed risk relativities are shown in Section 5.

4.3.3 Asbestos Handling Factor

As research and knowledge around the dangers of asbestos improved over time, workplace and environmental standards for exposure to asbestos were introduced and refined (Watson et al, 2004). In addition to the factors described above, we allowed for these changes by applying another risk index.

Prior to the 1950’s there were few regulations limiting exposure to asbestos (Watson et al, 2004). A number of restrictions and guidelines were introduced between the 1950s and 1980s including safe handling guidelines, exposure limits and warning labels on products. Blue and brown asbestos mining and importation was banned in the early 1980s, with further limits on fibre concentrations in the air (Watson et al, 2004). The 1990s saw the introduction of protective clothing guidelines and training for workers exposed to asbestos. All types of asbestos in Australia were banned from further importation and consumption on 31 December 2003, with limited exceptions in some rare circumstances (ASCC, 2008).

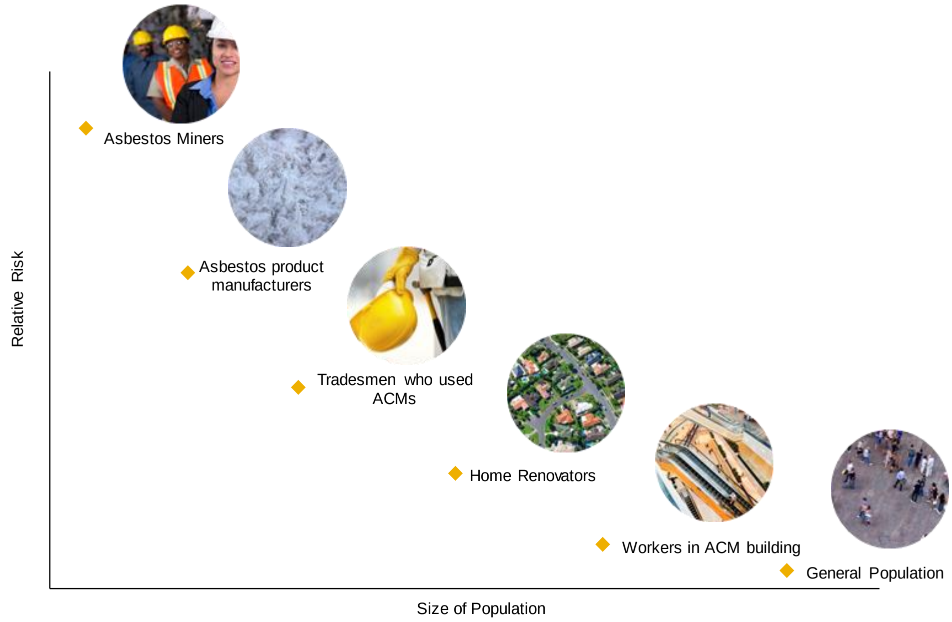
In addition to having regulations in place, the level of compliance with these rules also affects the asbestos handling factor. We are not aware of any published evidence of compliance with asbestos regulations. Compliance may have been relatively poor among renovators and some tradesmen in the past, due to their inability to identify asbestos, lack of awareness of the health risks of asbestos exposure or unwillingness to comply with regulations (ASCC, 2008). These issues may still be relevant today. Our asbestos handling index is constructed to show relativities over time. To the extent that there has been a consistent level of non-compliance with regulations, this is captured in our model via these relativities.

The assumptions underlying our asbestos handling risk index are outlined in Section 5.

4.4 Profile of Exposed Population

Figure 4.1 shows some key groups who have been or will be exposed to asbestos. We have ranked them based on the size of the exposed population and the relative lifetime risk of contracting mesothelioma (per exposed person) in each group.

Figure 4.1 – Asbestos Exposure and Waves



Note: this chart is not drawn to scale and is for illustration purposes. Not all groups exposed in Australia are shown.

In the next few sections we discuss different exposed groups (including some shown in the chart above).

Asbestos Miners

Figure 4.1 indicates that asbestos miners were a small group but had a high relative risk. For instance, there were approximately 7,000 people who worked at Wittenoom, mostly as miners and millers (Berry, 2004). However, due to their exposure to blue asbestos and the nature of their work, this group has faced a high risk of contracting mesothelioma (Leigh et al, 2002). This led to a peak of 56 mesotheliomas diagnosed in the period 1996-2000 (Berry et al, 2012) and an estimated lifetime risk of mesothelioma of 16.6%, higher than all other groups in Australia (Leigh et al, 2002). This estimate of lifetime risk is towards the upper end of likely ultimate outcomes for Wittenoom workers, based on more recent analysis (Berry et al, 2012). Large volumes of white asbestos were also mined at Baryulgil and Woodsreef in New South Wales (Leigh et al, 1997 and Watson et al, 2004).

Background Cases – The General Population

At the other extreme, the entire Australian population is exposed to 'background' levels of asbestos. The fibre concentration for this group is on average significantly lower. However, due to the much larger size of this group, we estimate that this exposure translates to around 35 cases per annum at present.

The lung tissue of people who died from mesothelioma but reported no history of asbestos exposure was analysed using transmission electron microscopy (TEM). This showed that in 81% of cases the asbestos fibre count in their lungs was higher than normal (Leigh et al, 2002). We can conclude that asbestos exposure is the most likely cause of these background cases. An absence of fibres in the lungs could still be consistent with past asbestos exposure, as fibres may have initiated mesothelioma and then been cleared from the lungs before death (Leigh et al, 2002).

The exact risk level at low levels of exposure has not been accurately quantified previously (Park et al, 2013). Berry and colleagues compared analyses of lung tissue samples from Australia, the United Kingdom and United States. The samples were taken for mesotheliomas due to occupational exposure, environmental exposure and no known exposure, and for controls (Berry et al, 1989). The key findings were:

- The occupationally exposed mesotheliomas showed the highest amphibole fibre counts
- For people who died from mesothelioma due to environmental exposure, the analysis demonstrated a higher than usual number of asbestos fibres in the lungs.
- For mesotheliomas due to no known exposure source, the lung tissue analysis showed similar fibre counts to the controls (i.e. the deaths sampled from the general population). This suggests that there is a low (or non-existent) threshold for asbestos fibre exposure to cause mesothelioma. It is unclear what level of exposure causes mesothelioma (ASCC, 2008).

It is difficult to draw strong conclusions about the relationship between the relative risk of mesothelioma and relative levels of asbestos in lung tissue. This is because fibre counts in lungs are affected by exposure periods, lung clearance rates and elapsed time since exposure (Berry et al, 1989).

We discuss calibration of our background cases further in section 5.2.

Other Occupational Groups

As another example of the general pattern shown in Figure 4.1, analysis has shown that in the 1980s larger occupational groups with intermittent asbestos exposure contributed more mesotheliomas, compared to smaller occupational groups with constant and heavy exposure (Ferguson et al, 1987). In Finity's experience these larger groups (e.g. non-construction tradesmen) are still prominent among all occupational mesotheliomas, compared to asbestos mine workers and similar high risk groups.

There are other work-related groups that we have not plotted on the chart above. For instance, we expect asbestos removalists to be a relatively small group. To the extent that they comply with current safe handling, removal and disposal regulations then they are likely to be low risk – perhaps no higher than the risk level shown for 'workers in ACM building'. If these removalists do not take care in their work then their risks could be much higher. It is difficult to say with confidence where historical removalist exposure sits on this scale, though we expect there were some instances where regulations were not followed and exposure levels were raised (ASCC, 2008).

Non-Occupational Exposures

Although high risk exposure segments (e.g. asbestos miners, product manufacturers and tradesmen working with ACMs) are often the focus for asbestos-related projections, an increasing number of current mesotheliomas (around 33% of cases based on the AMR exposure data) are attributed to non-occupational exposures. The relative risk for this group is lower than the higher risk occupations. This is because the average cumulative exposure to asbestos in non-occupational settings is most likely lower than occupational exposures (Park et al, 2013). These non-occupational exposures have been a focus of our review.

Summary

The purpose of this discussion is to illustrate that there are several groups in Australia that have been exposed to asbestos, varying in size and in the relative risk that members of each group will contract mesothelioma during their lifetime. Some of these groups are overlooked at times in discussions about mesothelioma in Australia.

4.4.1 Wave Splits

The future number of mesotheliomas is determined for groups with similar exposure sources. These sources are referred to as 'exposure waves', to describe the historical differences in type, volume and the dates when asbestos was used.

There are three commonly described waves of asbestos exposure, with each wave generally starting later than the preceding wave(s) (Olsen et al, 2011):

- Wave 1: Heavy industrial use, including asbestos mining, milling, product manufacturing, installation and transportation. This wave includes high levels of exposure to blue and brown asbestos. Peak exposures often occurred prior to the 1970's.
- Wave 2: Downstream asbestos product use, particularly in the building industry. This involved high exposures in some jobs (e.g. carpenters). Peak exposures were mainly in the 1970's.
- Wave 3: Later occupational and non-occupational exposures. These are usually lower intensity and have lower cumulative exposures. Jobs exposed in this group include white collar workers exposed to asbestos at work, as well as domestic non-occupational exposures (e.g. home renovators). While the relative risk levels associated with Wave 3 are considerably lower than earlier waves, the exposed population is likely to be much larger and spread more broadly across the Australian population. Peak exposures are potentially later than the 1970's.

The key differences between the exposure waves are the number of people exposed, the timing and intensity of asbestos exposure, the cumulative level of exposure and the resulting incidence of mesothelioma cases.

We have modelled Wave 3 separately from Waves 1 and 2. Some people may have exposure from multiple sources within these waves (e.g. from work as a tradesman and from doing a home renovation). In these cases our model allows for the cumulative exposure faced by these individuals via the contributions of the different sources of exposure in the wave models.

Occupational Exposures

Wave 1 and wave 2 exposures include some industries and jobs that were historically significant in Australia but have since closed e.g. asbestos mining and milling. There are also many other occupations which were at risk in the past and continue to be, if asbestos is present and proper precautions are not taken (e.g. many trades). Asbestos was used widely prior to the reduction in consumption in the 1980s and the total ban that occurred on 31 December 2003 (Leigh et al, 1997 and Watson et al, 2004). This means that many construction workers in these years may have come in contact with asbestos. Any occupational exposure after 2003 is more likely to be a result of in situ asbestos in the built environment e.g. asbestos removalists, or from exposure to asbestos in the workplace (e.g. asbestos lagging or asbestos cement sheeting).

Non-Occupational Exposures

There are two main groups of non-occupational exposures:

1. Those linked to periods of high intensity occupational exposure: this group includes families exposed to asbestos brought home on a worker's clothes or person ('dusty families'), or those living near an asbestos factory or in a town such as Wittenoom in Western Australia (where blue asbestos was mined from 1937 to 1966 (Berry et al, 2012)) or Baryulgil or Woodsreef in New South Wales. These exposures would have coincided with wave 1 and wave 2 occupational exposures and may have involved relatively high exposure levels, compared to other non-occupational groups. This type of exposure is not likely to be repeated following the reduction in asbestos consumption and improvements in asbestos handling since the 1980s.
2. Exposure linked to asbestos in situ in the built environment: this includes home renovators or families living in homes made from asbestos, or people changing the asbestos-containing brake linings or clutch on their car at home. This exposure could have occurred at any time after asbestos was used in construction or motor products, and continues today due to the remaining stock of ACMs.

Background Exposures

For a minority of mesothelioma cases it will not be possible to identify a likely source of exposure. The future number of these background cases is highly uncertain. This is because the exposure sources are poorly understood for these low dose mesotheliomas.

Potential sources of exposure for background cases could include:

1. Unknown primary exposure to asbestos due to unknown or forgotten past exposures. By primary exposure we mean that the person was directly exposed to asbestos fibres within their workplace or in their home. Unknown sources will typically involve small doses of exposure.
2. Unknown secondary exposures e.g. due to renovations or construction on a neighbouring property.
3. Asbestos remaining in the air due to historical consumption within Australia.

   Many have argued that there is an underlying level of mesotheliomas due to small fibre loads in the air in industrialised countries, particularly in cities. (Breslin, 2015, Gravelsons et al, 2009 and Berry et al, 1989). These small fibre loads are most likely due to historical asbestos consumption, and thus have no correlation to the future stock of ACMs or their removal.
4. Asbestos in the ambient air due to the current inforce stock of asbestos and recent removal activity. The small fibre loads described above could also be due to fibres released from recent disturbances to the inforce stock of ACMs, including their removal. This source of exposure is thus likely to end when all ACMs have been removed from the built environment.
5. Exposures to carcinogens other than asbestos, such as plombage, erionite exposure (especially in Turkey) and radiation (e.g. treating the mediastinum for lymphoma, exposure to thorium dioxide, or atomic energy workers chronically exposed to low levels of radiation) (Breslin, 2015 and Jasani & Gibbs, 2012). There is also some evidence to suggest a possible carcinogenic or cocarcinogenic role of viruses such as simian virus 40 (SV40), which may have contaminated early batches of polio vaccines in the 1950s and 1960s (Jasani & Gibbs, 2012). While the vast majority of mesotheliomas are attributed to asbestos exposure, not all cases are due to asbestos (Clements et al, 2007a).

6. Cases developing due to spontaneous abnormal cell development, with no known exposure to carcinogens. This is a known explanation for some forms of cancer. However, it is generally accepted that some carcinogenic exposure (typically asbestos) is required to cause mesothelioma and spontaneous cell development cannot cause this specific cancer (Breslin, 2015).

From this list we have excluded Category 1 from our definition of background cases. We have allowed for forgotten or unknown primary exposure cases when setting our 2013 base year splits by exposure source.

Category 5 above is unlikely to be a significant factor for background cases of Australian mesothelioma. For the reasons given above we also rule out Category 6 as a source. This leaves Categories 2 to 4 as the main contributors to background cases.

Our analysis and projection assumes that asbestos exposure is the primary driver of mesothelioma, noting that on a per capita basis Australia had the highest per capita usage of asbestos, and also has the highest per capita incidence of mesothelioma (see Watson et al, 2004). The overwhelming cause of ‘background’ mesothelioma is also assumed to be asbestos exposure. This approach is consistent with the view adopted by most others (e.g. Breslin, 2015).

Noting the uncertainty over exposure sources, the ability to estimate the level of ‘background’ cases in future is imprecise. This is one of the key uncertainties in our projection. We have considered two possible approaches for projecting these cases:

1. Background cases are assumed to increase over time as the population grows. Background exposures due to Category 3 (as listed above) are the main driver, and are expected to be correlated to the size of the population in future.
2. The number of cases is assumed to be related to the actual ‘stock’ of asbestos. In this situation the level of background cases reduces over time, broadly following on a lagged basis the pattern of asbestos consumption and then removal. A study tested the amount of crocidolite in the lungs of control cases in the UK (i.e. people who died from causes other than mesothelioma, and who would have mostly had low asbestos exposures). This found significant reductions in fibres in the lungs from the mid-1970s to the mid-1990s. This is most likely due to a reduction in crocidolite in the general environment (Berry, 2002). This finding supports a projection approach linked to the current stock of asbestos.

   This approach would be appropriate if background cases mostly arise from Categories 2 and 4 (as listed above).

Noting this uncertainty, and our intention to project a ‘central estimate’, our base scenario has adopted the following approach for projecting background cases:

- Background cases from 1988 to 2014 increase in line with population growth.
- Future background cases after 2014 are calculated as an average of the projections based on population growth (method 1. above) and the asbestos ‘stock’ (method 2. above). There is a 50% weight on both projection methods.

While our approach to project ‘background’ cases has minimal impact on the current and historical number of cases, the approach has a material effect on the projection after 2050. The sensitivity of the projection to this feature is highlighted in Section 6.

4.4.2 Modelled Wave Splits

Our modelled segments involve slight variations on the standard ‘wave’ classifications described previously. For our projection we used the following groups:

- Wave 1&2: this includes the occupational exposures described above from waves 1 and 2. It also includes the non-occupational exposures linked to these waves, including ‘dusty families’, those living near an asbestos factory or in an asbestos mining town. This group covers asbestos exposures occurring from 1921 to 2002.
- Occupational post-2003: this covers lighter occupational exposure from the year of the asbestos ban in Australia and later years. Exposure is a result of in situ asbestos in workplaces or asbestos removal, covering the period from 2003 to 2055.
- Wave 3 Domestic: this concerns non-occupational exposures in Australian homes linked to construction, asbestos in situ in the built environment and its removal. It includes exposure to home renovators, those living in a house during a renovation, those living in a home with ACMs or working on a car at home which contains asbestos within the brakes or clutch. This group includes exposure in the years 1960 to 2055.
- Background exposures: mesotheliomas in this category have no identifiable exposure to asbestos, as described previously.

4.4.3 Age and Gender Profile

As discussed in Section 3, each exposure wave has a different demographic profile (i.e. gender and age distribution). Wave 1&2 exposures mostly affected males of working age, although some families were also exposed to dust brought into the home, thus affecting some women and children. Our other wave groupings are likely to be closer to the demographic profile for the Australian population. For instance, home renovations potentially affected people of all ages, though in most cases there would have been higher exposure to those working on the renovation, excluding young children or the elderly.

The age and gender profiles in our models determine the age at which first exposure is projected to have occurred and thus the future life expectancy, post-exposure. Women have a higher average life expectancy than men (Australian Government Actuary, 2014), explaining why we consider the mix by sex. These factors affect the future years over which mesothelioma incidence may occur.

Information on the assumed age and mortality profiles of each group is provided in Section 5.

4.5 Mesothelioma Incidence – Epidemiological Model

The incidence of mesothelioma in each year for a particular group is a function of three factors:

- The intensity (level) of asbestos exposure.
- The types of asbestos.
- The duration since first exposure.

We use an application of a standard exposure-based epidemiological incidence model calibrated to mesotheliomas from Johns Manville exposure in the United States (Stallard et al, 2005). This has been used by Finity to model asbestos-related claims and liabilities for over 10 years.

There are a number of other models available, including exposure models developed by Professor Geoffrey Berry (Berry, 1991 and Berry, 1999), age-cohort model forms developed by Professor Julian Peto and others (as described in Lowe et al, 2004) and variations of both type of model developed by Dr Mark Clements and colleagues (Clements et al, 2007a). Another paper by Clements and colleagues provides a good overview of a range of models (Clements et al, 2007b). While the features of these other models have been considered, they have not been used in our projection.

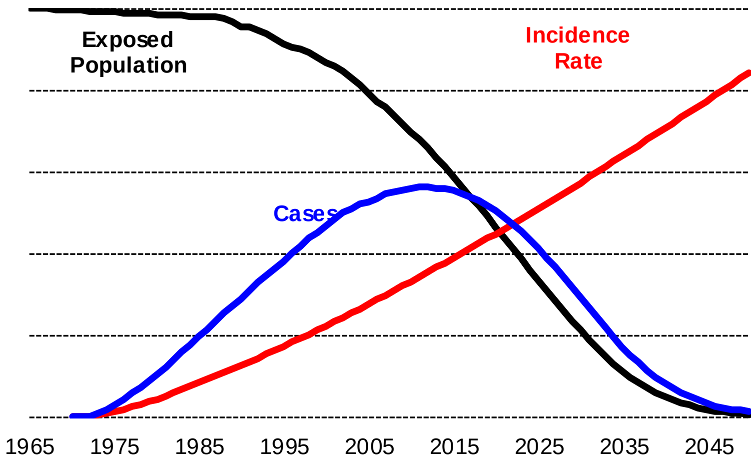
Even though the Stallard et al model was originally developed for US exposures, we expect that the dose-exposure and disease incidence relationships are similar for different exposed groups around the world, if we control for other variables (e.g. different population mortality rates). We have found when testing different exposure based models in the past that they produce broadly similar results, if calibrated appropriately.

A useful feature of the Finity model (based on the Stallard et al version) is that it provides useful exposure-based outputs to test model fit (e.g. average age at diagnosis, average duration of exposure, average year of first exposure and splits of case counts in each diagnosis year into the different years or periods of exposure). Our model has been tested against a number of Australian portfolios and has usually required little recalibration once the model is established. Based on this performance we considered it to be appropriate for this assignment.

Consistent with many other exposure models, our incidence rates increase with cumulative exposure and with time since exposure (Berry, 1991). We note that the relationship between exposure to asbestos and mesothelioma rates 'is best described by a linear non-threshold model' (Ferguson et al, 1987). Among all mesotheliomas reported to 2000, the shortest identified duration of exposure that led to a mesothelioma was a waterside worker exposed for 16 hours while loading crocidolite fibre (Leigh et al, 2002). This adds weight to the view of Ferguson and colleagues.

Figure 4.2 illustrates conceptually how we use our incidence model to project future cases. In this hypothetical example we project the incidence rate and the number of cases for a single year of exposure (1965). The exposed population declines over time as the people in the exposed group age and die from other causes. However, the likelihood of mesothelioma being diagnosed increases with time since exposure. The combination of these two effects creates a 'wave' of cases emerging from 1965 exposure.

Figure 4.2 – Incidence Model: Number of Cases



In this example the number of cases is projected to peak around 2010 i.e. 45 years after first exposure. The illustration implies that improvements in mortality rates (i.e. more survivors from the exposed population at each point in time) will lead to more cases of mesothelioma for that group.

Our projection model uses the estimated profile of the exposed population, making an implicit estimate of the number of individuals who enter this group (e.g. new workers, for occupational exposure) and turnover rates once they join the exposed population (e.g. how many workers leave the exposed workforce each year). From this we have a profile of how many entered and exited the exposed group each year (and thus the duration of exposure for each exposed cohort).

More information on this model, including its parametrisation, can be found in Appendix C.

4.6 Model Calibration

Our model includes a back-fit projection of cases to 1988. As noted previously, the detailed exposure profile produced by our model allows us to compare the profile of these back-fit projected cases with data for actual cases in the same period. Where the information is recorded accurately on historical cases, we reviewed the fit for such measures as average age at diagnosis, average year of first exposure, average duration of exposure and the average delay from exposure to diagnosis ('latency'). We recalibrated our model assumptions to the extent necessary to get a close fit to actual experience, drawing on our understanding of exposure profiles for similar portfolios to expedite this process.

In particular, we calibrated our model in order to fit:

- The shape and the number of reported cases from the AIHW and AMR data for the period 1988-2014.
- The exposure profile of cases diagnosed in 2011-2014, as per the AMR exposure questionnaire and interviews.
- The gender profile of AMR cases diagnosed in 2011-2014.
- The age demographic of reported cases from the AIHW and AMR data for the period 1988-2014.

The projection was also tested for reasonableness, relying on our experience and knowledge of benchmark portfolios.

Further detail comparing the actual and modelled exposure metrics can be found in Section 6.

4.6.1 Allocation of Historical Cases

The AIHW mesothelioma dataset splits cases by age and gender. In addition, we applied judgement to further allocate these historical cases between the Wave1&2, Wave 3 and 'Background' segments in our projection. This allocation is used to consider the historical pattern of cases implied by our wave projection models. The allocation is a useful input to our calibration, but without being a critical component.

The assumptions underlying this split include:

- Background cases are assumed to have increased up to 2014, in line with population growth.
- Wave 3 Domestic cases are assumed to have first emerged around 1980, based on the earliest known reporting of such matters. Western Australia reported a first known case from this source in 1981, with underlying exposures estimated to have commenced around 1960 (Olsen et al, 2011).

We estimated equivalent numbers for Australia and interpolated the intermediate years between 1982 and 2014. Mesotheliomas due to non-occupational exposure have increased in WA in the last 10 years (Olsen et al, 2011). We assume that the same trend applies to Australian cases.

- The Wave 1&2 cases are the balancing item in the allocation.

Table 4.1 shows the resulting allocation of historical mesothelioma cases.

Table 4.1 – Actual Cases – Historical Split by Wave

	All Persons			
Year	Background	Wave 3	Wave1&2	Total
1982	23	3	130	**156**
1983	23	3	121	**147**
1984	24	5	138	**166**
1985	24	8	170	**202**
1986	24	11	190	**225**
1987	25	11	167	**203**
1988	25	18	234	**277**
1989	25	19	226	**270**
1990	26	23	242	**290**
1991	26	25	256	**307**
1992	26	30	269	**326**
1993	27	36	306	**369**
1994	27	46	347	**420**
1995	27	44	323	**394**
1996	27	51	337	**415**
1997	28	58	382	**468**
1998	28	65	381	**473**
1999	28	66	382	**476**
2000	29	70	382	**480**
2001	29	86	462	**577**
2002	29	87	448	**564**
2003	30	108	516	**654**
2004	30	106	469	**606**
2005	30	108	475	**614**
2006	31	109	451	**591**
2007	32	132	512	**676**
2008	32	132	498	**662**
2009	33	136	507	**676**
2010	33	141	499	**672**
2011	34	160	516	**710**
2012	34	168	536	**738**
2013	35	158	502	**695**
2014	35	160	498	**694**

W1&2 includes dust brought home by worker

Testing our Allocation of Historical Cases

The Australian Mesothelioma Surveillance Program identified that 4% of cases in the period 1980-1985 were due to environmental exposure (Ferguson et al, 1987). This study defined environmental exposure as including 'dusty family' cases; we adjusted the results and excluded these, as we group dusty family cases with Wave 1&2. The comparable percentage from our allocation of the data underlying Table 4.1 is 3%, covering the period 1982-1985. The results are sufficiently close.

The same surveillance program showed that a total of 31% of cases in 1980-1985 had either unknown exposure (5%) or no identified source of exposure (26%). Our allocation of cases in 1982-1985 implies that14% of cases can be attributed to background exposure. The difference is most likely due to unidentified occupational exposure in the early years covered by the surveillance program, rather than an understatement of background cases in our analysis.

In a separate study Leigh and colleagues found that, for the period 1980 to 2000, 15% of cases were due to environmental exposure (Leigh et al, 2002). This group includes 'dusty families' but excludes background cases. Analysis of our allocation of cases underlying Table 4.1 shows that for the period 1982-2000, we have attributed 14% to the same non-occupational sources, implying a close fit to the study by Leigh et al. However, their review identified 19% of all mesotheliomas in 1980 to 2000 as having no known exposure history – considerably higher than our allowance of 8% for background cases in the period 1982-2000. In our opinion most of the difference is likely to be due to occupational cases with unidentified exposure.

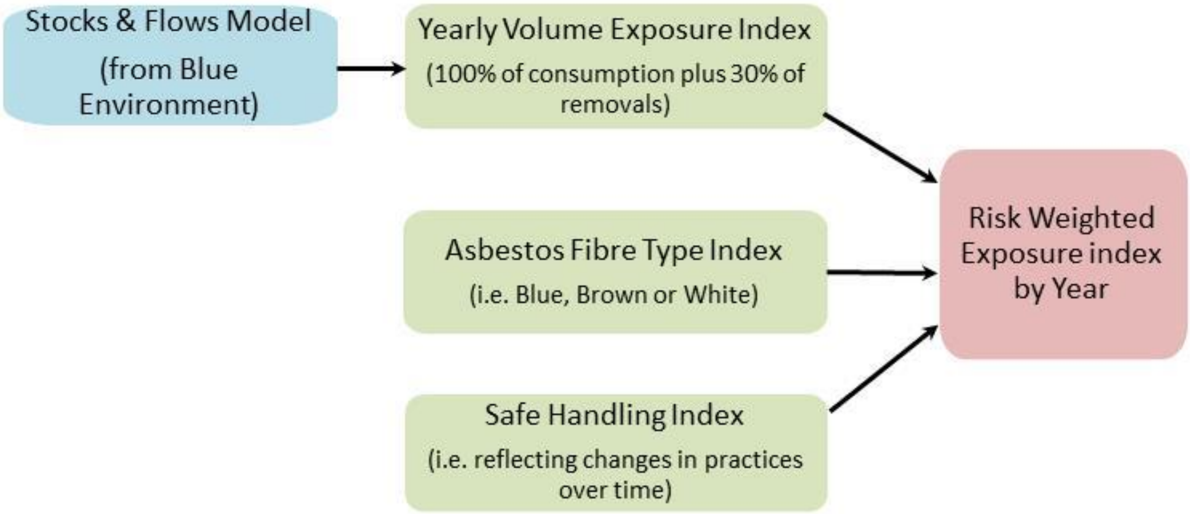
5 Base Scenario Assumptions

In this section we set out the base scenario assumptions. These are applied to our model, as described in the previous section. Details of the assumptions underlying the alternative scenarios are documented in Section 6.

5.1 Exposure

Figure 5.1 shows how we combined data and assumptions to prepare a risk weighted asbestos exposure pattern by year. In the following tables and charts we set out these components in more detail and describe the key assumptions made.

Figure 5.1 – Asbestos Exposure Index



5.1.1 Asbestos Volume Index

The volume index (the amount of asbestos to which people are potentially exposed) is derived from the Blue Environment stocks and flows model. It is set equal to 100% of the asbestos consumed each year (based on a three year moving average for the projection) plus 30% of the asbestos removed in that year. The lower weighting allocated to asbestos removal reflects our assumption that 'all things being equal', the risk at the time of asbestos removal is lower than that associated with the initial asbestos consumption. This is because some of the high risk activities during consumption (e.g. sanding and cutting ACMs) do not occur during removal. We discuss the relative risks of different activities in more detail in Appendix B.2.

Models of exposed populations need to take indirect account of asbestos exposure over time (Clements et al, 2007a). We do this by projecting the total risk-weighted volume of asbestos fibres to which people were exposed, rather than numbers of people.

Our aggregate exposure index is split into the seven products in the stocks and flows model (as per Table 5.1 below) and then further separated for domestic and commercial uses.

The resulting index is used as a measure of average fibre burden in each year. While the number of persons in each population segment is not known, linking each exposure index to observed counts of cases in prior years allows the future number of cases to be projected in line with changes in exposure.

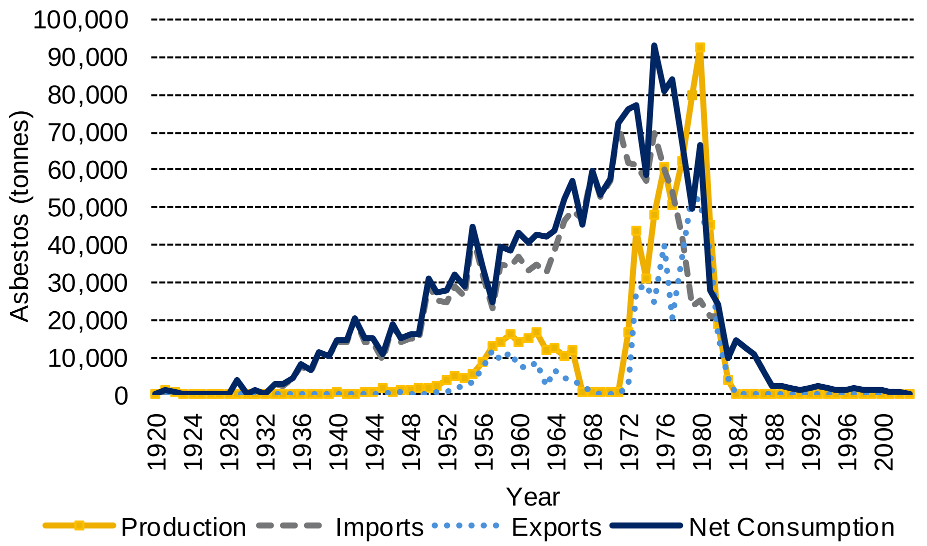
Consumption

The volume of asbestos consumed in Australia forms the basis of our model's exposure profile.

The volume of asbestos consumed in the twentieth century in Australia was 1.9 million tonnes (World Minerals Statistics Dataset, 2015) and is constructed by adding the tonnage of asbestos produced in and imported into Australia each year, and subtracting the volume exported. This consumption pattern is widely accepted and used in the projection of other asbestos exposures (e.g. the Blue Environment stocks and flows model and the KPMG valuation of the asbestos-related disease liabilities of the former James Hardie entities (Donlevy and Gibbs, 2015)).

The profile of the raw tonnage of asbestos produced, imported, exported and consumed is shown in Figure 5.2.

Figure 5.2 – Australian Net Asbestos Consumption by Year



Net consumption peaked in the mid-1970s and then declined sharply until the complete ban on asbestos 31 December 2003. Volumes of asbestos produced in Australia until the 1970s were modest and a large proportion of these were exported. Most asbestos consumed in Australia was imported.

As noted above, the overall volume of asbestos consumed is allocated to seven product types based on assumptions sourced from the Blue Environment model (without modification). Table 5.1 summarises this allocation by decade.

Table 5.1 – Asbestos Fibre Consumption by Product Group and Decade

	Decade								
Product Group	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s
Cement sheeting - domestic	51%	31%	31%	31%	31%	31%	51%	0%	0%
Cement pipes	0%	40%	40%	40%	40%	40%	0%	0%	0%
Cement sheeting - commercial	34%	21%	21%	21%	21%	21%	34%	0%	0%
Flooring products	5%	3%	3%	3%	3%	3%	5%	0%	0%
Friction products	2%	1%	1%	1%	1%	1%	2%	40%	40%
Roofing	3%	2%	2%	2%	2%	2%	3%	0%	0%
Other	6%	3%	3%	3%	3%	3%	6%	60%	60%

In Australia over 90% of all asbestos consumed was used by the asbestos cement manufacturing industry (Leigh et al, 1997). The split in Table 5.1 in the high consumption years (1940s to 1970s) is consistent with this observation.

The consumption within each product group is then allocated between domestic and commercial use. Table 5.2 shows Finity's assumed split of domestic and commercial consumption for each product group. These assumptions are based in part on information contained within the Blue Environment model, but also reflect judgements made by Finity about the historical use of each type of product.

Table 5.2 – Asbestos Fibre Consumption by Domestic and Commercial Use

Product Group	Domestic	Commercial
Cement sheeting - domestic	100%	0%
Cement pipes	0%	100%
Cement sheeting - commercial	0%	100%
Flooring products	60%	40%
Friction products	20%	80%
Roofing	60%	40%
Other	0%	100%

Removals

Having allocated the volume of asbestos consumed by product group, use and year of consumption, we modelled removals. These were based on the Blue Environment assumptions for the lifespan of each product type (also used without modification). For this purpose Blue Environment assumed that the stock of ACMs runs off after consumption according to a Weibull distribution. An example of this distribution's shape is shown in Figure 5.3. In our opinion this approach seems reasonable.

Figure 5.3 – Weibull Distribution Runoff for 100,000 Starting Units

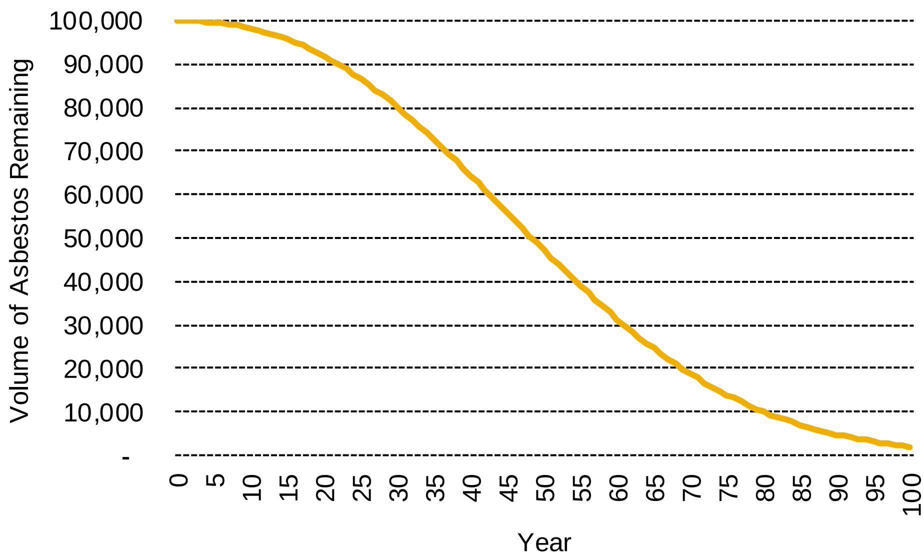


Table 5.3 summarises the Blue Environment assumptions for asbestos removal. The removal rates vary by product. They are expressed in terms of both the average number of years until removal and the number of years until 90% of the asbestos is removed. The assumptions shown relate to one year of asbestos consumption.

Table 5.3 – Summary of Blue Environment Removal Assumptions

	Product Lifespan (years)	
Product Group	Average	Until 10% left
Cement sheeting - domestic	60	100
Cement pipes	50	80
Cement sheeting - commercial	40	75
Flooring products	15	50
Friction products	10	20
Roofing	40	75
Other	10	80

The Blue Environment assumptions suggest that friction, flooring and 'other' products have relatively short lifespans, with assumed average lives of 10-15 years after consumption. Alternatively, domestic cement sheeting has the longest run-off, with an assumed average lifespan of 60 years. This seems reasonable to us, noting both:

- The different lifespans of the underlying structures in which asbestos was used (e.g. the lifespan of a house versus a car).
- The likelihood of deterioration for different products due to their use. For instance, internal asbestos sheeting would typically last longer than flooring products, due to the wear and tear on flooring.

Stocks

The stock of asbestos in situ at any time is calculated as the sum of estimated volumes consumed to date minus the estimates of all asbestos removed to date. The resulting projection of consumption, removals and the asbestos stock is shown below for all domestic products (Figure 5.4), all commercial products (Figure 5.5) and all products combined (Figure 5.6). All charts are shown on the same scale.

Figure 5.4 – Asbestos Consumption, Removal & Stocks – Domestic

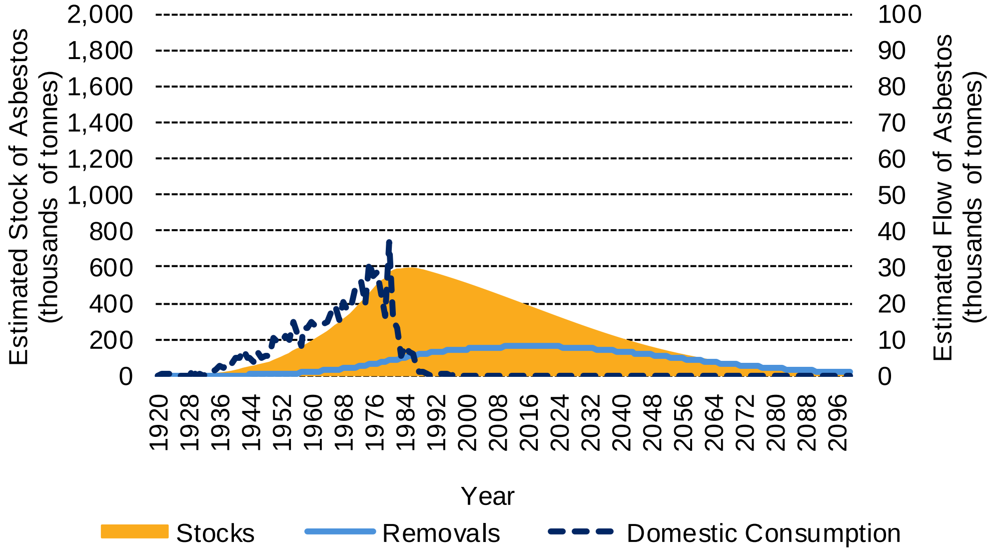


Figure 5.5 – Asbestos Consumption, Removal & Stocks – Commercial

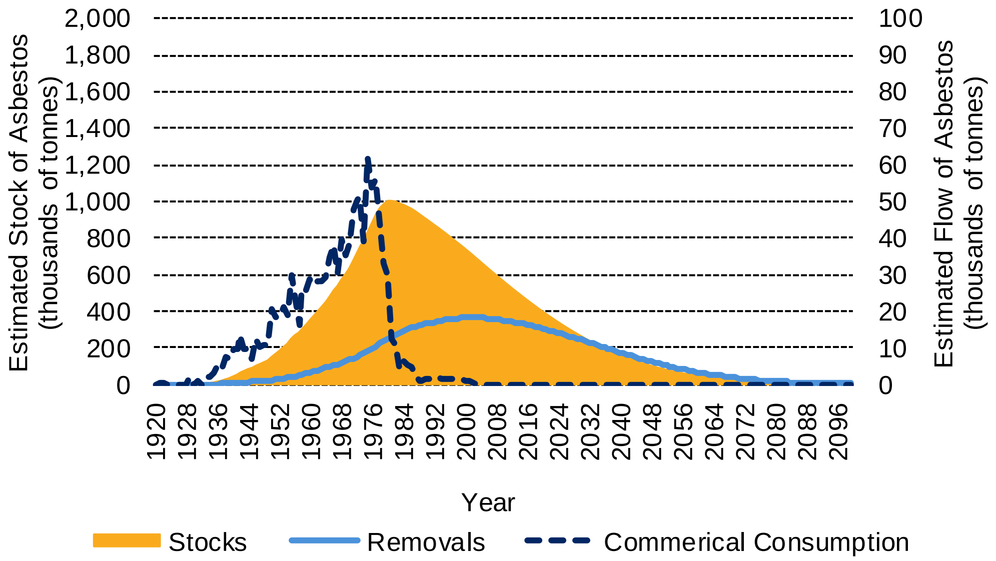
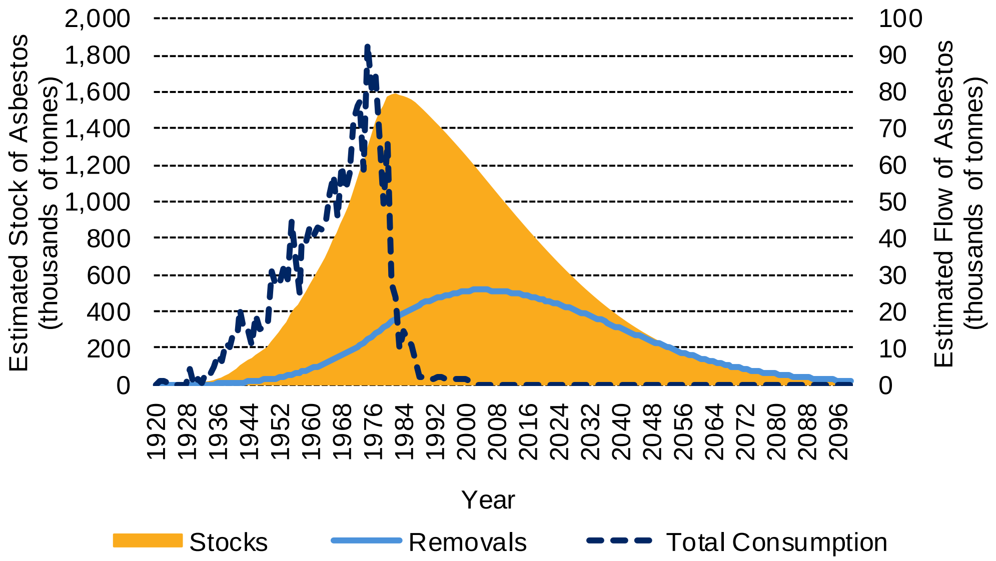


Figure 5.6 – Asbestos Consumption, Removal & Stocks – Total



The three charts above show that a greater volume of asbestos is estimated to have been consumed in commercial products compared to domestic uses. In each case the level of consumption increased strongly from 1945 to a peak in 1975 (commercial) and 1980 (domestic), before falling sharply over the 1980s.

Domestic ACM products are projected to have a slower run-off, before all stocks are expected to be removed by around 2100. This reflects both the longer average lifespan of domestic products versus commercial products and the later peak in consumption.

Exposure Index

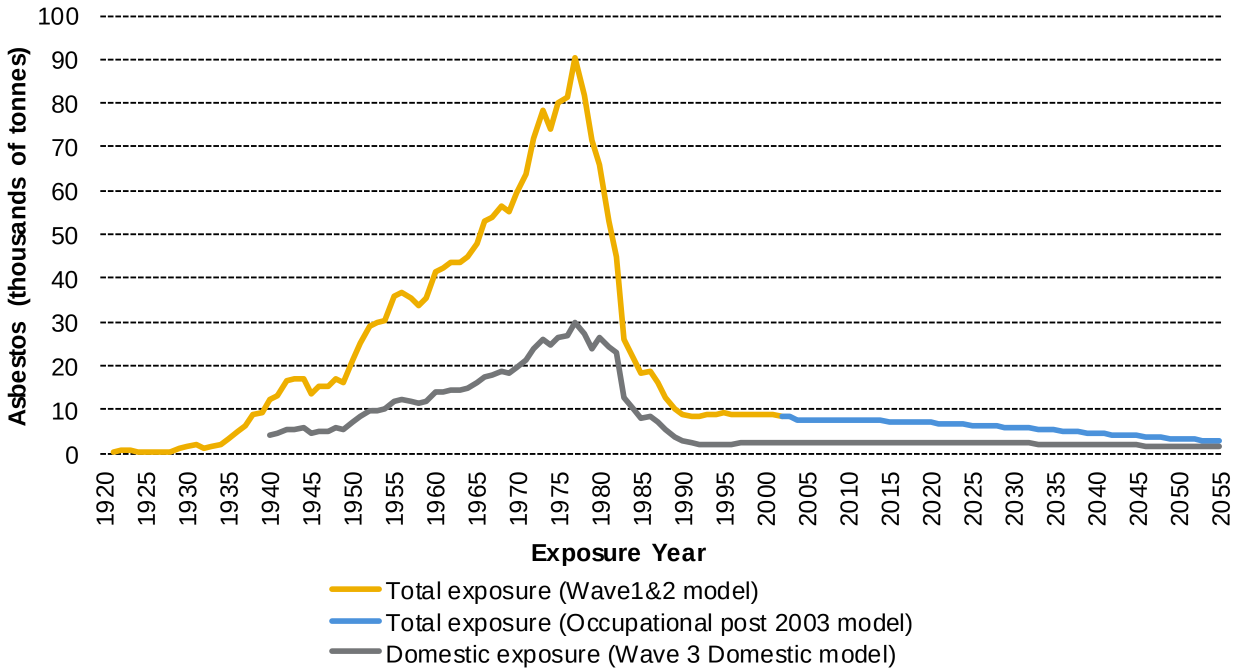
In Figure **5**.7 we show the exposure indices assumed for the waves that we have modelled (but excluding background cases). As previously mentioned, these are:

- Based on a 100% weight for the amount of asbestos consumed, plus a 30% weight for asbestos removed.

- Constructed before we allow for different risk weightings to reflect the changing mix of asbestos types over time (i.e. blue, brown and white asbestos) and changes in 'safe handling' procedures over time. We discuss these factors later in this section.

The Wave 1&2 and Occupational post 2003 index reflects the total exposure i.e. the sum of domestic and commercial uses of asbestos. The Wave 3 Domestic model has a separate exposure index which only allows for domestic uses of ACMs.

Figure 5.7 – Exposure (Before Risk Weighting)



Some may argue that removal should be a low risk activity compared to consumption. However, the removal of ACMs can potentially expose workers and others to higher levels of airborne asbestos fibres than leaving the materials in situ. This assumes that the in situ ACM is in good condition. Also, a haphazard and poorly controlled removal program can lead to significant fibre release, as happened in parts of the US in the 1980s (ASCC, 2008).

Risk Index – Asbestos Types

The next step in our risk weighted exposure modelling process was to allow for changes in the use of different types of asbestos over time. As discussed below, it is generally accepted that the three asbestos types present different levels of risk for causing mesothelioma; as such, the type of asbestos in the environment is a factor in assessing the future number of mesotheliomas.

Figure 5.8 shows the total net consumption split by the three types of asbestos. The total net consumption from Figure 5.2 was split by applying the known mix by decade, as summarised in Table 5.4 below (Driscoll & Leigh, 2008).

Figure 5.8 – Australian Net Asbestos Consumption by Asbestos Type and Year

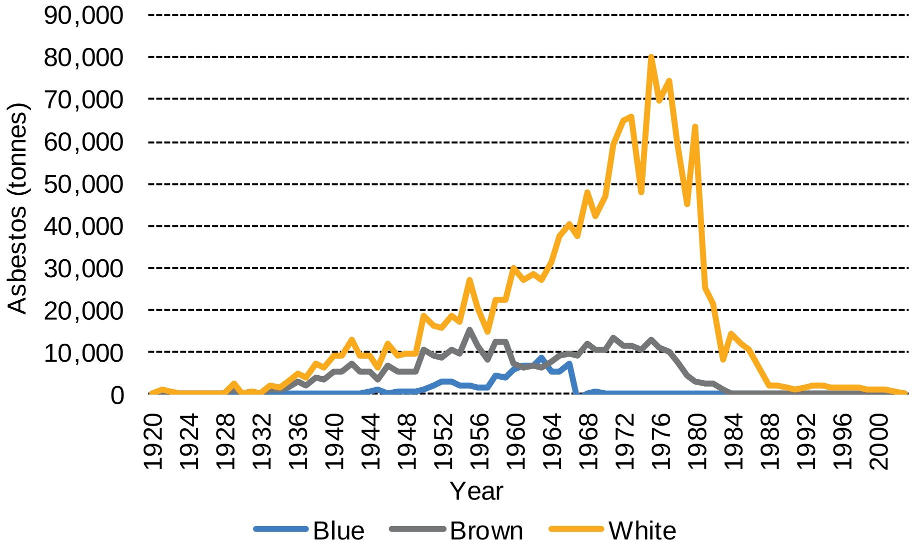


Table 5.4 – Split of Asbestos Consumed by Type of Asbestos

	Asbestos Type		
Decade	Blue	Brown	White
1920s	0%	22%	78%
1930s	1%	35%	64%
1940s	3%	35%	62%
1950s	8%	33%	59%
1960s	9%	18%	73%
1970s	0%	14%	86%
1980s	0%	5%	95%
1990s	0%	0%	100%
2000s	0%	0%	100%

Figure 5.8 shows that blue asbestos was used mostly used from the early 1950s until the late-1960s, although blue asbestos was always less than 10% of the total consumption during this period. Blue asbestos is widely regarded as the most toxic form of asbestos (Berry, 1999, Hodgson & Darnton, 2000, and Gravelsons et al, 2009). Most blue asbestos consumed came from the Wittenoom mine, though a small amount may have been imported in the 1950s (Leigh & Driscoll, 2003). It was withdrawn from use much earlier than brown and white asbestos.

Around 10,000 tonnes of brown asbestos were consumed each year from the late 1940s until the late 1970s. It was a significant contributor to total volumes consumed up until the 1950s but was not consumed much after 1983, when imports of brown asbestos were banned (Watson et al, 2004).

By volume, white asbestos comprised the largest share of consumption and was used until it was banned at the end of 2003 (Watson et al, 2004). From the 1940s to the late1960s all three types of asbestos were used in the asbestos cement industry, with blue asbestos being phased out after this (Ferguson et al, 1987 and Leigh et al, 1997).

Further information on the types of asbestos is provided in Appendix B.

Although blue and brown asbestos were withdrawn from consumption before white asbestos, our projection of removals allows for the historical mix of types of asbestos in previous consumption years.

In other words, our model allows for the fact that during the in situ and removal phases some people will be exposed to blue and brown asbestos after the1980s.

The consumption weightings in Table 5.4 are combined with risk weightings for each type of asbestos to derive a risk index reflecting the use of different types of asbestos over time. The assumptions we used for the relative riskiness of each type of asbestos were obtained from a 2009 paper prepared by the Asbestos Working Party (AWP) of the Institute and Faculty of Actuaries in the UK (Gravelsons et al, 2009). These relative risk weights are:

- Blue asbestos: 20
- Brown asbestos: 16
- White asbestos: 1

In other words, a given volume of blue asbestos is assumed to have 20 times the toxicity of the same volume of white asbestos. Similarly, brown asbestos has 16 times the riskiness of white asbestos. It has been observed that the mesothelioma rate following occupational exposure to uncontaminated white asbestos is much lower than exposure to amphiboles (Berry, 1999).

An alternative set of risk weights was developed by Hodgson and Darnton, based on risk relativities derived from cohort studies (Hodgson and Darnton, 2000). Those relativities are as follows:

- Blue asbestos: 500
- Brown asbestos: 100
- White asbestos: 1

We used the AWP relativities in our base scenario for the reasons set out below.

Firstly, the full set of assumptions used in our base model (including the AWP factors listed above) provides a strong fit to past experience. This provides us with confidence that these assumptions are appropriate for use in our model. The AWP reached a similar conclusion. In section 4.2 of the AWP report cited above, Gravelsons et al acknowledge the Hodgson and Darnton factors, but state that using those factors in their model gives a 'fairly bad fit. We suspect that the 1:100:500 ratios, even if they were fully reliable at an individual level are not really suitable for epidemiological projection purposes, and hence alternative risk relativities may be appropriate.'

We tested the Hodgson and Darnton factors (as shown above) in one of our alternative scenarios described in Section 6.3.1. Under this alternative we are implicitly assuming that the toxicity of brown asbestos decreases relative to blue asbestos (compared to our base scenario assumption). Similarly, the risk associated with white asbestos decreases relative to both blue and brown asbestos. As noted earlier in this section, both brown and white asbestos were used in later years than blue asbestos. These later periods have a stronger bearing on our projection of future mesotheliomas.

In our alternative scenario there are 12% fewer cases projected in 2015-2100. This indicates the sensitivity of our model to a significant change in the relativities. Further testing showed that the change in the blue to brown relativity is the main reason for the reduction in projected mesotheliomas.

There is some debate about whether white asbestos causes mesothelioma (Park et al, 2013). The World Health Organisation (WHO, 2006) asserts that white asbestos causes mesothelioma and the balance of opinion seems to support this view (Park et al, 2013). In all mesotheliomas reported to 2000, 4% were attributed to white asbestos exposure only (Leigh et al, 2002). This information is based on a survey of people who contracted mesothelioma, meaning their recollection may be imperfect. Also, the white asbestos might have been contaminated with amphibole fibres. However, it does suggest that white asbestos alone can cause mesothelioma.

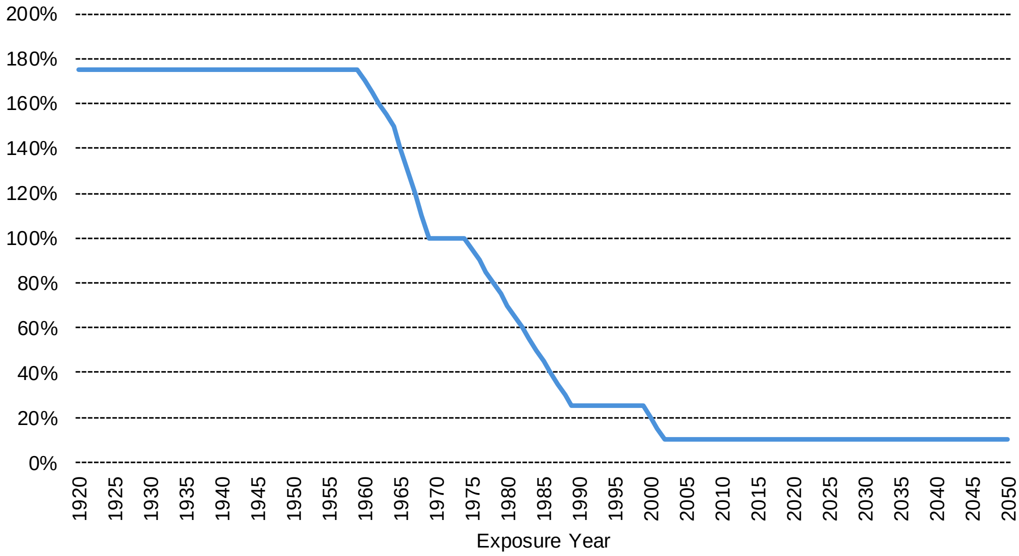
For these reasons we used the risk factors shown above. These are consistent with the view that white asbestos poses a lower, but non-zero, risk of causing mesothelioma.

Risk Index – Asbestos Handling

In addition to the mix by asbestos type, we also allowed for changes in risk levels over time arising from changed procedures and any precautions taken at differing points in time to minimise asbestos exposure. We refer to this as the ‘asbestos handling’ or ‘safe handling’ factor. In a work-related setting these actions and processes are part of an occupational health and safety framework. Our selected factors are judgemental and based on changes in regulation and the fibre load estimates of various activities under different conditions over time. For instance, the end of blue asbestos mining at Wittenoom in the late 1960s reduced overall risk levels for the Wave 1&2 group, as mining is a high risk activity.

Our factors are shown in Figure 5.9 and are assumed to be the same for domestic and occupational exposures. In preparing this index we assumed that the level of compliance with applicable laws and regulations was broadly unchanged over time, and that the guidelines and regulations are the main drivers of change in the asbestos handling factors.

Figure 5.9 – Asbestos Handling Factors



We calibrated the factors relative to a score of 100% in 1970. The factors in other years were set to broadly reflect the changes over time shown in Table **5**.5. Detailed references for Table **5**.5 can be found in Appendix B.2.1. The main source of information for this part was Watson et al (2004), section 2.3.

Table 5.5 – Key Periods for Safe Handling of Asbestos in Australia

Period	Commentary
1930-1940s	Exposure levels (as per those recommended for safe asbestos use) around 300 times higher than recommended level in 1980s
1950s	Cement factories: Progressive introduction of control measures
1960s-1970s	Safe handling guidelines introduced; various sectors replaced asbestos products
1980s	Exposure standards introduced that significantly reduce recommended safe exposure levels
1990s	Protective clothing guildines and training for workers potentially exposed to asbestos

We tested the shape shown in Figure 5.9 by changing the selected factors and reviewing the impact on how the model fits the historical experience (in particular, the number of cases in each year for 1988-2014). This testing was done in conjunction with reviews of the other model assumptions. The asbestos handling factors for the years 1921-1975 were most relevant for this back fitting. We found that the selected factors gave a strong back fit (when combined with our other assumptions), while also reflecting the points listed in Table 5.5.

We understand that warning labels were applied in the late 1970s and 1980s on some ACMs (Watson et al, 2004). However, these may not have been applied uniformly and some unlabelled ACMs may have been used after the 1980s. This issue is similar to the compliance issue noted above and is allowed for implicitly in our model.

Assessing historical levels of non-occupational exposure is difficult. For occupational settings, exposure can be derived from job histories, job exposure matrices, expert assessments and exposure databases. Even then, occupational assessments can be imprecise and different methods can show different results. However, few of these types of studies have been completed for non-occupational exposures (Park et al, 2013).

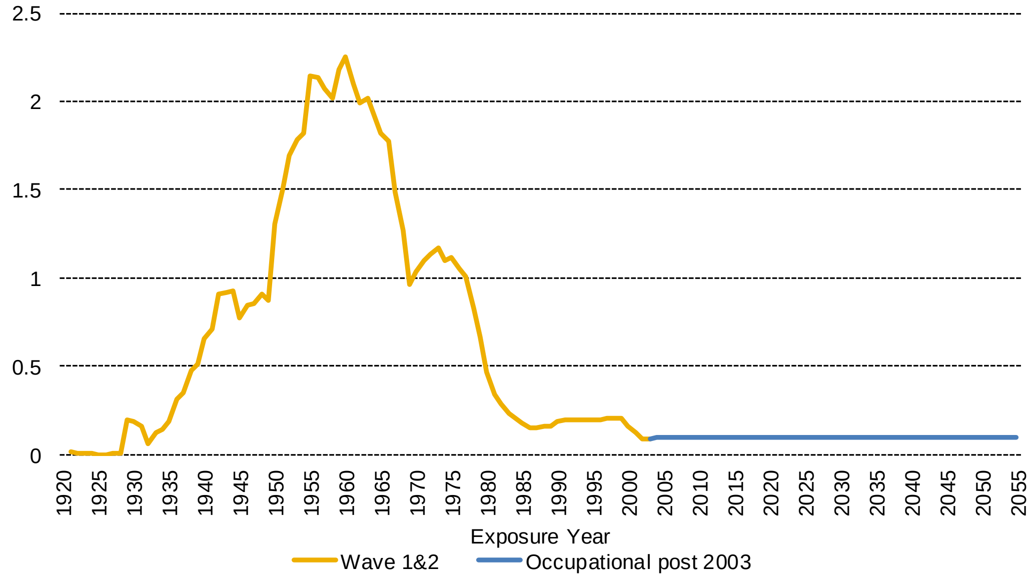
There is considerable uncertainty regarding the relative risk for later exposure periods (1980 and later), most notably because most mesothelioma cases from these exposures are yet to be diagnosed and the assumptions cannot therefore be calibrated to actual outcomes. A review of five studies of occupational exposure in Australia, the UK and Europe since 1999 suggests that, despite regulations and guidance being in place, exposure to asbestos continues to occur in some situations (ASCC, 2008). This supports our assumption of a moderate level of relative risk from 2003 onwards, as shown in Figure 5.9. The sensitivity of the projection to this assumption is considered in Section 6.

5.1.2 Risk Weighted Exposure

Figure 5.10 and Figure 5.11 show the overall risk weighted exposures obtained by combining the exposure volume, fibre type and asbestos handling indices described earlier in this section. Both charts show this risk weighted exposure on a relative scale (compared to 100% for exposure in 1970).

The shape of each of the two risk profile indices shown below is a key driver of the resulting shape of the projected mesothelioma cases (i.e. the peak number of mesotheliomas, and the speed of increase up to and run-off after that peak).

Figure 5.10 – Risk Weighting Assumptions: Wave1&2 and Occupational post 2003



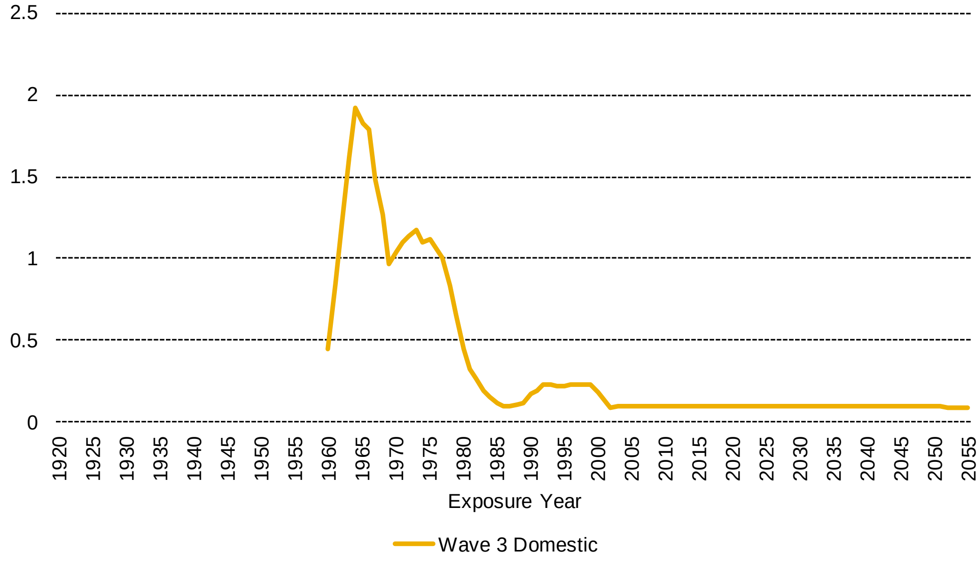
For Wave 1&2 the overall risk weighted exposure increased strongly from 1931 to 1961, mainly because of the increasing volume of asbestos fibres consumed. The change in the mix of types of asbestos contributed to some of this increase (more blue asbestos was consumed towards the end of this period). Our selected safe handling factors were stable over this period.

For the period 1961-1981, the reduction in volumes consumed towards the end of this period made a small contribution to the lower exposure levels. However, there were two more significant drivers of the decrease in risk weighted exposure in these two decades, namely:

- A change in the mix of the type of asbestos consumed. The consumption of blue asbestos ceased in the late 1960s. The proportion of blue asbestos in total asbestos consumed after this date was mostly replaced by white asbestos, a much less toxic form of asbestos.
- Lower asbestos handling risk factors applied throughout this period, reflecting broadly improved handling and better precautions that were taken when using asbestos. It also reflects changes in activity and any associated risks e.g. the end of higher risk mining.

In the next stage (1981-2003), the reduction in risk weighted exposure is modest compared to previous changes. The fall in the volume of asbestos consumed and the ban on using asbestos from 31 December 2003 suggests there should be no risk after 2003. However, there is ongoing exposure from removals. Also, it is impossible to completely eliminate asbestos exposure after 2003 via safe handling practices, meaning risk has not been completely abolished.

Figure 5.11 - Risk Weighting Assumptions: Wave3 Domestic



The Wave 3 Domestic risk curve has a broadly similar pattern to the total exposure curve (Wave 1&2) from the mid-1960s onwards. Prior to 1960 we assumed that there was no Wave 3 Domestic exposure. This is consistent with the time when home renovations involving ACMs are understood to have commenced (Olsen et al, 2011). This approach also provided a good fit to our data.

5.2 Mesothelioma Cases

Having discussed the assumptions regarding the underlying asbestos exposure, we now consider the assumptions relating to mesothelioma cases that result from these exposures. We focus on mesotheliomas in the base projection year (2013).

5.2.1 Number of Cases in Base Year

We used 2013 as the base projection year to calibrate the overall number of cases and split by wave. In this period we assumed 708 cases in total, being the average of our projected ultimate cases for the years 2011-2014 (the period covered by the AMR data). Our projection allowed for our estimate of all unreported (i.e. IBNR) cases for those diagnosis years. The projected cases over this four year period show no clear trend, suggesting reported cases may have plateaued. Our base year (2013) is close to the mid-point of the period.

Further detail on this analysis can be found in Appendix C.5.

5.2.2 Split of Cases by Wave

In Sections 3.5 and 3.6 we described the exposure profile in the AMR data, and the high level changes made and checks we applied when setting our 2013 base scenario profile. We elaborate on our selected profile below.

Table 5.6 summarises the split of cases assumed. This assumed profile for 2013 cases broadly reflects the breakdown in the data for actual AMR cases with exposure information, apart from some adjustments to the split by sex and the overall allocation to the occupational, non-occupational and background groups (as discussed in Section 3.5 of this report). In our base scenario we have assumed that the group of AMR cases with exposure information is approximately representative of all cases.

Table 5.6 – Assumed Split of Cases in 2013

		Numbers			Percentage Split	
Wave	Source	Male	Female	Total	Male	Female
1+2	**Occupational**					
	Asbestos mining / milling	1	0	1	100%	0%
	Abestos removalist	0	0	0	100%	0%
	Cement factory worker	5	0	5	100%	0%
	Furnace industry	4	0	4	100%	0%
	Insulator	4	0	4	100%	0%
	Land transport	25	0	25	100%	0%
	Textile worker	1	2	2	30%	70%
	Trades	305	3	308	99%	1%
	Water transport	39	0	39	100%	0%
	Other occupation	45	19	64	70%	30%
	Total	**428**	**24**	**452**	**95%**	**5%**
	Environmental					
	Dusty family	11	22	34	33%	67%
	Lived near industry	1	2	3	42%	58%
	Asbestos town	3	4	7	47%	53%
	Other exposure	15	4	19	79%	21%
	Total	**31**	**32**	**63**	**49%**	**51%**
3 Dom	**Non-Occupational**					
	Serviced brakes and clutch	23	0	24	99%	1%
	Lived in asbestos house	9	9	18	50%	50%
	Home renovation	44	18	62	71%	29%
	Lived in house during renovation	26	29	55	48%	52%
	Total	**103**	**56**	**158**	**65%**	**35%**
Wave 1&2 exposures		**459**	**56**	**515**	**89%**	**11%**
Total with reported exposure		**562**	**112**	**673**	**83%**	**17%**
Background Cases		**18**	**18**	**35**	**50%**	**50%**
Grand Total		**579**	**129**	**708**	**82%**	**18%**

The 452 occupational claims assumed represent 64% of all 2013 cases. However, when we model Wave 1&2 we include the environmental cases shown above. The 515 Wave 1&2 cases represent 73% of all mesotheliomas.

The overall allocation by gender for Wave 1&2 is close to what we have observed for the asbestos liability portfolios of some other Finity clients, where the exposure sources are similar.

As expected the Wave 1&2 occupational patients are mostly men (95%), reflecting historical employment profiles in the highest risk industries. The split by gender for Wave 1&2 environmental cases is fairly even. This reflects the greater exposure faced by women in ‘dusty families’ (i.e. wives and partners washing dusty clothes) and living near asbestos towns or plants, but offset by greater male exposure in other contexts.

The majority of non-occupational cases in 2013 are attributed to either a home renovation or living in a house during a renovation. Home renovations are now the main activity associated with third wave mesotheliomas (Olsen et al, 2011).

As a check on our allocation, we considered the WA Mesothelioma Register (Olsen et al, 2011). We reviewed mesotheliomas diagnosed from 1960 to 2008 and attributed to home renovation (or living in a house during renovation). Males represented 63% of the cases in this group. The corresponding proportion from Table 5.6 is 60%. Assuming that the gender mix of these non-occupational cases has not changed significantly over time, our profile is similar to the WA experience.

In the WA Mesothelioma Register the same sub-set of non-occupational cases were compared to total mesotheliomas, and split by gender. For the period 2005-08, mesotheliomas among home renovators (or those living in a renovated house) comprised 8% of all male cases and 36% of female cases (Olsen et al, 2011). The corresponding proportions in the 1990s were about 3% and 5%.

We extrapolated the split shown in Table 5.6 over the same period, using the breakdown shown in Table 4.1 of this report. This produced corresponding proportions of 10% for males and 32% for females in the years 2005-08. This result is close to the Western Australian experience. The difference may be explained by the larger relative contribution of Wittenoom claims to WA data, and the heavy use of asbestos cement sheeting in building in some other states. For instance, NSW was a heavy user of asbestos, with 52% of all houses built using asbestos cement from the Second World War until 1954. Over a similar period (to the 1960s) the corresponding proportion for all Australian homes was 25% (Leigh et al, 1997).

Consistent with the WA experience in recent years, we estimate that home renovator cases are the main source of mesotheliomas in women at present (Olsen et al, 2011).

As noted in Section 3.5, we increased the allocation to occupational claims slightly (compared to the AMR exposure data) to reflect our DDB benchmarking results. As a consequence, the proportion of cases assigned to non-occupational and environmental sources decreased.

Background Cases

We assumed 35 background cases of mesothelioma in 2013, with an even split among men and women. This is equivalent to 5% of total cases and 1.5 cases per million of population in 2013. Our assumption for the level of background cases is consistent with a number of sources that refer to the rate of background mesothelioma:

- The UK Health and Safety Laboratory (HSL) prepared an updated model for the Health and Safety Executive (HSE) in 2009. This assumes the background rate of mesothelioma is between 1 and 2 per million people per year (Gravelsons et al, 2009, Section 4.4).
- Professor Breslin estimates a rate of 1 case per million of population per annum (Breslin, 2015).
- For the period 1960-2008, the Western Australian Mesothelioma Register recorded 4.6% of cases as having no known exposure to asbestos after an intensive review of all potential sources (Olsen et al, 2011). This is lower than we might expect for this period for Australian cases; this is most likely because of the greater relative contribution of Wittenoom mesotheliomas in the WA register. The exposed population and mesotheliomas from Wittenoom (work-related and non-occupational) is well-tracked and understood by a number of researchers (e.g. Berry, 2012). We expect that Wittenoom-related mesotheliomas contribute to the greater proportion of WA cases having known exposures.
- North American analyses show that the annual mesothelioma rate in adults with no history of asbestos exposure is about 1.5 per million. Low dose environmental exposure to asbestos has been postulated as a factor in these cases (Berry et al, 1989).

The latest AMR annual report shows that 5% of people interviewed could not recall any asbestos exposure (AMR, 2015). In our AMR exposure data this proportion was 6%; the difference is because our data extract was prepared at a different point in time. In the AMR exposure data provided to us, males comprise 75% of cases with unidentified exposure.

We have assumed 5% of all 2013 mesotheliomas are background cases, with an equal split by gender. We made this adjustment to the AMR exposure data because:

- Some of the AMR cases with unidentified exposure most likely had primary exposure to asbestos (i.e. in the person's workplace or own home). This is the most likely explanation why males are overrepresented in this group in the AMR data. As explained in Section 4.4, we did not include primary exposures in our definition of background cases.
  - The detail on previous jobs worked for the unidentified cases in the AMR exposure data suggests that some of these jobs might still be the most likely source of asbestos exposure. This is despite the AMR exposure assessment rating these as 'unlikely' sources of exposure. For instance, many of the exposures occurred in trades. We have no other information to indicate a more likely cause of how these people contracted mesothelioma.
  - This analysis, plus our consideration of the DDB benchmarking described earlier in this report, led us to increase the allocation of occupational cases in our assumed 2013 profile from 61% (in the AMR exposure data) to 64%.
- Based on the benchmarks listed above, we expect our definition of background cases (i.e. excluding primary exposures) to comprise around 5% of cases. To allow for these in our base year profile of cases of mesothelioma, we decreased the allocation to non-occupational claims from 33% to 31%.
- Given the nature of our definition of background exposure (as described in Section 4.4), we assumed an equal split between males and females for this group.

5.3 Other Assumptions

5.3.1 Age of Workforce

The age of the exposed population at first exposure is assumed to be different for each wave. We did this to allow for different average life expectancies after exposure. This affects lifetime rates of mesothelioma incidence.

People in the Wave1&2 group first exposed in the 1920s are assumed to have an average age at first exposure that reflects the average age of the entire working population at the time. This is because asbestos was not widely used and was being introduced to incumbent workers.

By the 1950s and 1960s the average age of those first exposed during this period is likely to be lower. We assume that younger people entering the workforce are the main group who were first exposed to asbestos during this time. Asbestos use was established and widespread after the Second World War (ASCC, 2008), so most workers using asbestos at any point in this period would have been first exposed when they left school or higher education and started working. A small proportion would have been first exposed later in their working lives.

For non-occupational Wave 1&2 exposures we assume a broadly similar age profile for wives and partners. Our distribution of ages allows for some exposure for children (e.g. dusty families) and the elderly (e.g. residents living in asbestos towns and near industry).

Wave 3 Domestic and Occupational post-2003 exposures are assumed to be similar. This is because people employed in asbestos removal or completing home renovations will generally be spread over the range of working ages.

The assumptions for the average age at first exposure are as follows:

- Wave1&2: 38 years of age in 1921, decreasing to 33 years in 1950 and to 18 years in 1961 and later years.
- Occupational post-2003: 29 years old for all periods.
- Wave 3 Domestic: 30 years of age for all periods.

More information on the assumed age distributions and mortality rates (discussed below) is provided in Appendix C.4.

5.3.2 Mortality

Mortality tables were used to project the surviving exposed population in future years. The projection is based on the age profiles described above. Different mortality tables were used to reflect measured improvements in mortality over time and the periods of asbestos exposure to which they apply.

The tables adopted were as follows:

- Wave1&2 and Occupational post-2003:
  - Australian Life Tables (ALT) 1953-55 males, for the period prior to 1988 (Commonwealth Actuary, 1954).
  - ALT 1990-92 males, for the period 1989 to 2100 (Office of the Australian Government Actuary, 1995).
  - All mortality rates have been adjusted to allow for:
    - Past and future mortality improvements, assumed to be 0.5% per annum.
    - The largely blue collar exposed population. To accommodate this we added a mortality loading of 30% at younger ages, decreasing to a nil loading at older ages.
    - The mix of males and females within these waves. The male mortality rates in each year were reduced by 2% to reflect the proportion of women in these exposed groups. Female mortality rates are consistently lower than male rates.
- Wave 3 Domestic:
  - ALT 1960-62 males, for the period to 1988 (Commonwealth Actuary, 1961).
  - ALT 1990-92 males, for the period 1989 to 2100.
  - As for the other waves, the mortality rates were adjusted to account for:
    - Past and future mortality improvements of 0.5% per annum.
    - The mix by gender in this group. The reduction in mortality rates of 5% reflects the higher proportion of females exposed in this wave.

5.3.3 Duration of Exposure

Exposure continuation rates within the exposed population are used to project the years of asbestos exposure after the first exposure occurs. These rates do not project mortality, but rather how long a person remains in an exposed situation (e.g. in an exposed workforce, for occupational exposures). Our assumptions are based on analysing and studying different exposure profiles for a number of asbestos portfolios. A pattern of year-on-year exposure continuation rates is applied to each entry-year cohort.

This leads to the following exposure profiles:

- Wave1&2 exposures are for 18 years on average.
- Occupational post-2003 exposures occur for an average of 15 years, reflecting the greater tendency in recent years for workers to change jobs compared to earlier periods.
- Wave 3 Domestic exposures are for 2 years on average.

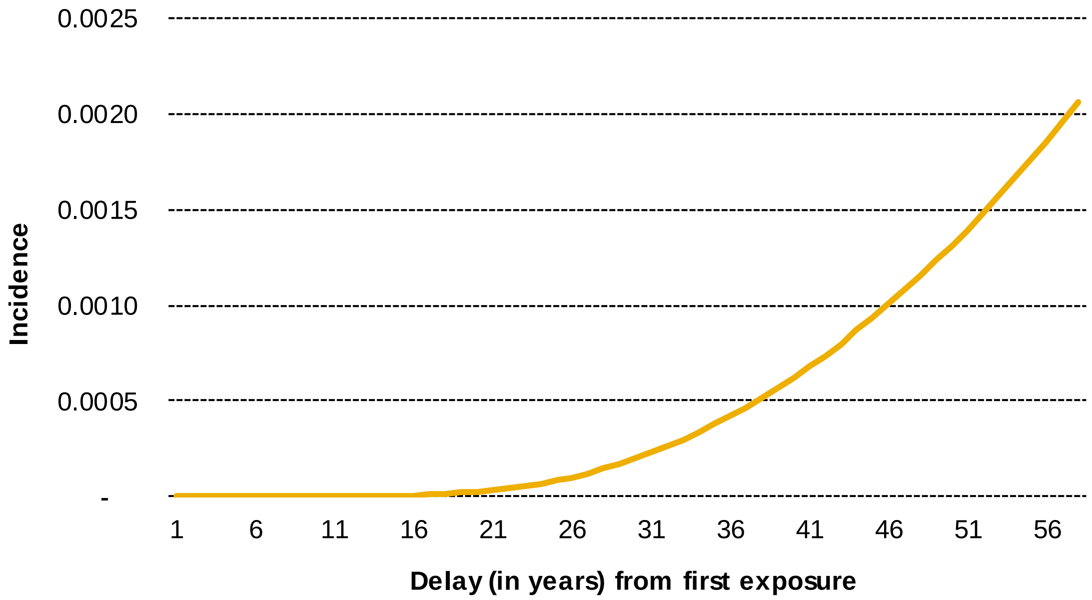
The longer occupational exposures represent prolonged exposure over a person's working life. The shorter Wave 3 exposure reflects the shorter timeframes over which this group was typically exposed, such as during home renovation. For home renovator cases in WA, exposure was often reported as being limited to a single task, which may have lasted for only a few days (Olsen et al, 2011). The reported length of exposure may have also been underreported. Some renovators will have repeated these tasks on other properties or in subsequent renovations at the same house. Our assumption allows for all of these factors.

The full set of assumptions is included in Appendix C.4.

5.3.4 Mesothelioma Incidence Formula

As discussed in Section 4.5, our incidence model was derived from a standard epidemiological incidence model (Stallard et al, 2005). This model and its parameterisation is summarised in Appendix C.3. The relative shape of the incidence rate, relative to the delay from first exposure, is summarised in Figure 5.12. The incidence rates shown below are based on the parameterisation of our Wave 1&2 model. The rates shown have been calibrated to apply to an average high-risk person in this group (typically a blue collar worker) with 18 years of exposure.

Figure 5.12 – Relative Incidence by Delay from First Exposure



The rates shown are the per person incremental risks of contracting mesothelioma each year. For the average person in this model the lifetime risk of being diagnosed with mesothelioma is approximately 2%. This is broadly consistent with the same risk for the average blue collar worker described in Table 2 in Leigh et al (2002).

The chart above shows the large increase in risk with elapsed time after first exposure. Increasing life expectancy raises the risk that more people exposed to asbestos will contract mesothelioma at advanced ages (85 or older). A recent study (Reid et al, 2014) suggests that pleural mesothelioma incidence rates continue to increase after 45 years from first exposure, but at a slower rate than before this point. We have not tested this assertion, though we note that the incidence model described in this report has performed well in projecting mesothelioma cases for portfolios where all cases are now more than 45 years past first exposure.

In our projection we set our exposure index based on the volume of asbestos consumed rather than persons exposed. The chart shown above is an indication only and shows the same risk profile after first exposure for the average person's exposure level (18 years of exposure). By contrast our projection allows for a range of lengths of exposure, covering those with short periods of exposure (i.e. less than one year) up to those with very long exposures (i.e. 20 or more years). Our projection also reflects all the other factors discussed previously in this section which vary over time (e.g. the changing mix of asbestos types and asbestos handling factors). The illustrative graphic in Figure 5.12 does not allow for these other factors, for the sake of simplicity.

The shape of incidence rates for other waves is similar, though the level of risk involved is typically lower than for Wave 1&2.

A worked example of the incidence calculation for one projection year in our model is given in Table C.10 in Appendix C.

6 Results

In this section we set out our results and explore the uncertainty around our estimates. We also summarise the fit of the base scenario model to key metrics.

6.1 Base Scenario

6.1.1 Future Cases

Our assessment of future cases is defined as mesothelioma cases diagnosed in the calendar years 2015 to 2100. These cases are linked to asbestos exposures from 1921 to 2055. Our results are described by:

- The total estimated number of mesothelioma cases from 2015 to 2100.
- The 'multiplier' i.e. total future cases expressed as a multiple of those in 2015.
- The peak year (the year with the most mesothelioma cases diagnosed, by wave and in total).
- The number of mesothelioma cases expected in the peak year for each exposure source.

In this section we have grouped the Wave 3 Domestic, Occupational post-2003 and Background projections and presented these as the 'Wave 3 Total'.

Table 6.1 shows the estimated number of mesotheliomas from 2015 to 2100 as well as the multiplier, for the key two segments of our projection and for total cases.

Table 6.1 – Results: Mesotheliomas from 2015 to 2100

Exposure Source	Mesothlioma Cases 2015 - 2100	2015 Year Cases	Multiplier
Wave 1&2	11,264	510	22
Wave 3 Total	8,163	202	41
Total	19,427	712	27

Table 6.2 shows the estimated peak year and number of cases in the peak year for each wave.

Table 6.2 – Results: Peak Year for Mesotheliomas by Wave

Exposure Source	Peak Year Cases	Peak Year
Wave 1&2	513	2013
Wave 3 Total	212	2021
Total	712	2015

The key observations and comments from Table 6.1 and Table 6.2 are:

- Wave 1&2 cases comprise 58% (11,264) of future mesotheliomas. These come from asbestos exposure up to 2002, the last year with consumption data (World Mineral Statistics Dataset, 2015) and the year before the asbestos ban (Watson et al, 2004).
- Wave 3 Total cases cover 42% (8,163) of projected mesotheliomas over 2015-2100. Within this group, Wave 3 Domestic cases comprise 61% of Wave 3 Total cases with the balance due to background cases and Occupational Wave 3 cases (i.e. those exposed beyond 2003).
- The base scenario implies that the total number of future cases in the 86 years projected (2015-2100) is 27 times the current number of annual cases. The multiplier is much greater for Wave 3

Total (41) compared to Wave 1&2 (22), as the exposure for Wave 3 mostly occurs after Waves 1&2.

- The composition of 2015 cases by wave is broadly similar to the base year we used in calibrating the number of cases (2013).
- Across all exposure sources, the number of future mesotheliomas in the base scenario is expected to peak in 2015. However, actual cases in individual years may vary around this expected level in our projection, due to year to year random variation. Our projected peak year is close to the highest year projected by Clements el al in their age-calendar year projection of males in NSW (2014). However, we do acknowledge that these projections were applied to different populations.

  In our base scenario we estimate that the Wave 1&2 cases peaked in 2013, but the Wave 3 Total cases will peak in 2021. In Table 6.2 we compare the number of cases in the peak year for each segment. As the peak years are different for Wave 1&2 and Wave 3, the sum for these segments (513 plus 212, i.e. 725) does not match the overall peak count (712).

There are significant uncertainties surrounding this projection. Discussion of this uncertainty and some alternative scenarios follows in Section 6.3. For example, it is possible that there may be more occupational and non-occupational mesotheliomas in future if exposure levels for these groups are higher than what we have assumed in our base scenario. Poor management of in situ asbestos and poor handling and disposal during removal would contribute to these increased exposures.

6.1.2 Historical Comparison

Our projection includes a back-fit of historical cases of mesothelioma and their characteristics. The comparison covers the period 1988-2014 where we were able to use AIHW and AMR data, or 2011-2014 where we used AMR data only. In Figure 6.1 we compare our aggregate projection with the actual number of mesotheliomas from 1988 to 2014. We also show the projections for the segments shown in Table 6.1. The projections shown in Figure 6.1 are consistent with the results summarised in Table 6.1.

Figure 6.1 – Base Scenario: Overall Projection

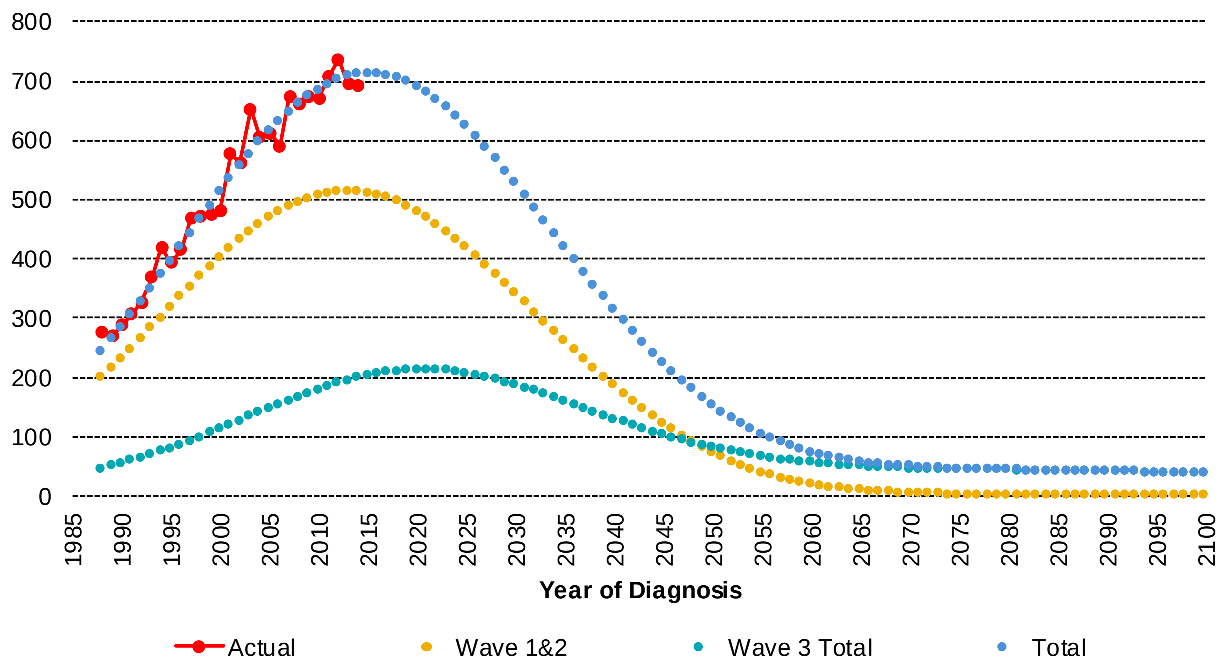


Figure 6.1 shows that, in aggregate, our projection aligns closely to actual experience back to 1988. While there is volatility in actual cases diagnosed from year to year, the general trend and level of reports matches the projection.

Our base scenario estimates that we have reached the peak for the number of cases in 2015 and that the number should drop below 700 per annum after about 2020. These results are broadly consistent with other analyses and projections (Soeberg et al, 2016 and Clements et al, 2007a). The long term trajectory shows the number of cases halving to 350 per annum in about 2040 and reaching 100 per year by the 2050's.

Figure 6.2 and Figure 6.3 show the projection for each wave grouping, comparing this to the assumed historical experience. The process for allocating actual historical cases between the various waves was described in section 4.6.1 and 5.2.2.

Figure 6.2 – Base Scenario: Wave 1&2 Projection

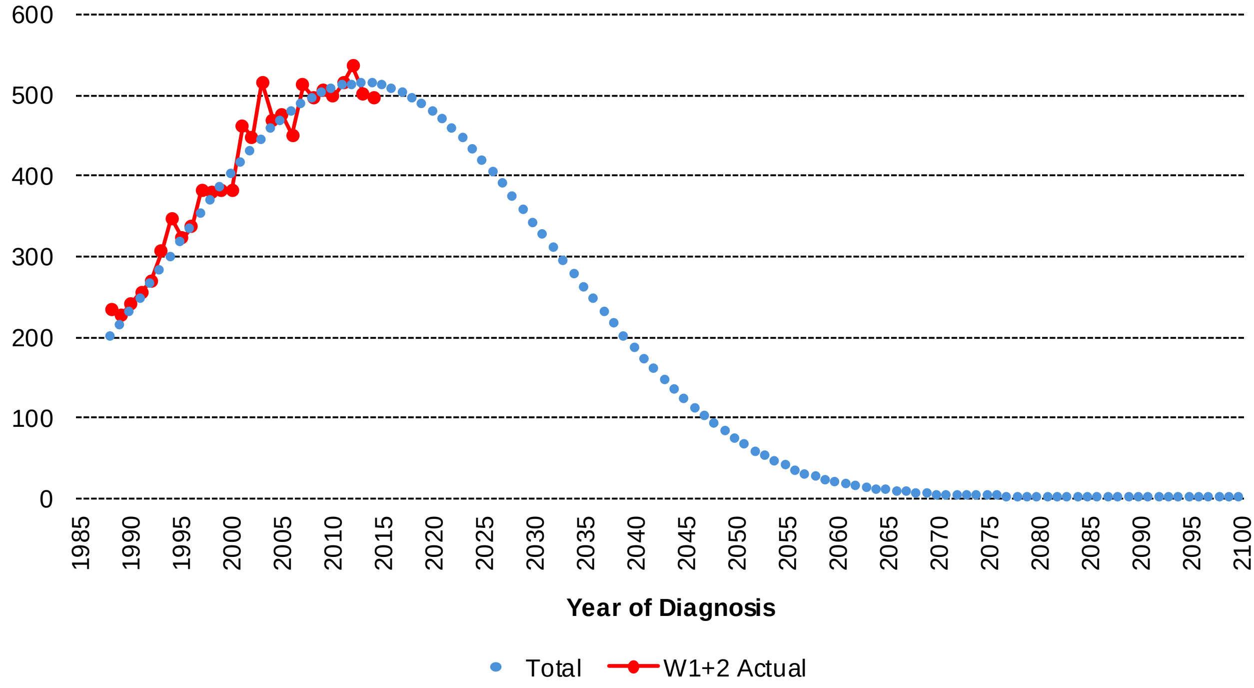


Figure 6.2 shows a good fit to our construction of the actual historical experience, noting that we have estimated the split of actual cases between the different segments based on the AMR data and other information sources. For this segment we project that claims peaked in 2013. Wave 1&2 is projected to decline relatively quickly from now, from over 500 a year currently to about 100 a year by 2050 and few, if any cases from 2070 onwards.

A study of mesotheliomas I the US found that a reduction in exposure, particularly to amphibole asbestos, is expected to result in diminishing mesothelioma risk to a population about three decades after reduced exposure (Weill et al, 2004). Australia banned the importation and mining of blue asbestos in 1981. A similar ban was applied to brown asbestos in 1983 (Watson et al, 2004). Our projected peak in Wave 1&2 cases is in 2013 i.e. 30 years after the ban. This result is consistent with the rule of thumb.

Wave 3, on the other hand, will remain significant for much longer. This is shown in the chart below.

Figure 6.3 – Base Scenario: Wave 3 Total

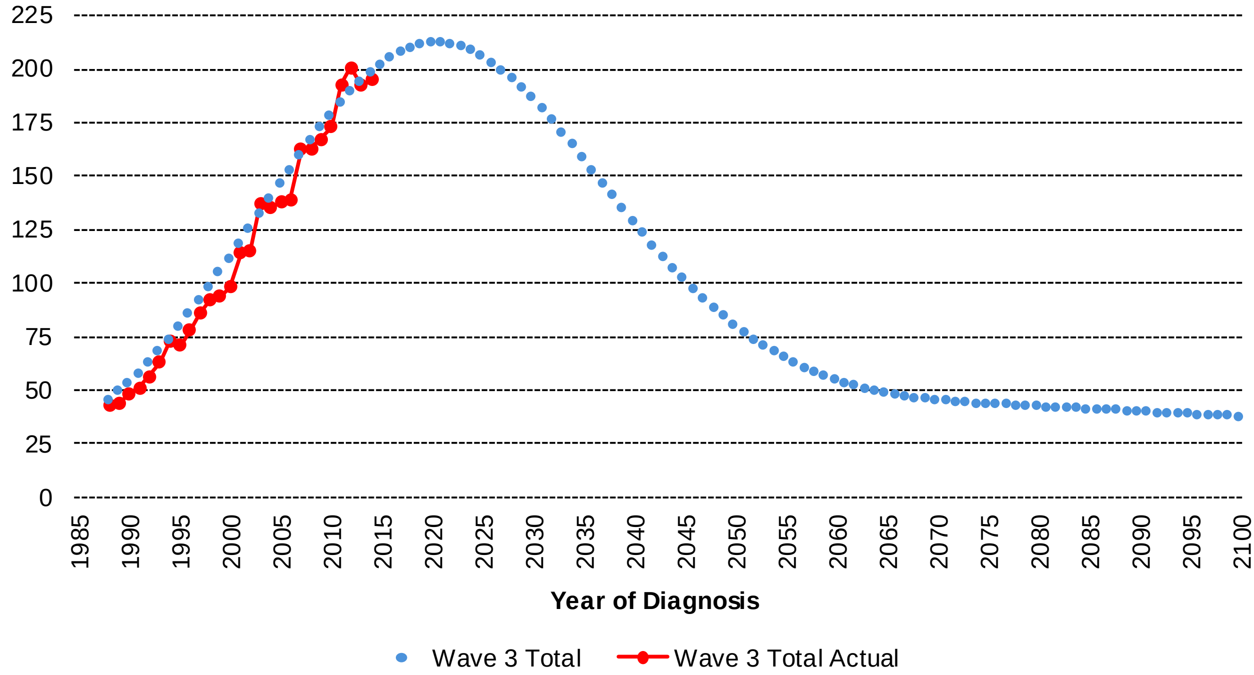


Figure 6.3 also demonstrates a good fit to the actual experience based on the assumed historical case split (as described in section 4.6.1 and 5.2.2). Over the period 1988-2014 our projection overestimates the actual experience by 3% in aggregate. We note that the projection of this segment uses parameters which are either consistent with the Wave 1 & 2 segment, or are based on external information. As a result we are comfortable with this 3% difference in the context of the uncertainty in splitting the historical cases between waves. More importantly, the trend in our model is consistent with the assumed historical trend.

There are currently about 200 Wave 3 mesotheliomas each year. We have projected Wave 3 Total cases to peak at 212 per annum in 2021, before declining to around 45 per annum in 2070. We expect this level of cases to persist while the remainder of the outstanding asbestos stock is removed from Australian houses, commercial and industrial properties. This is expected to occur around 2100, based on the work by Blue Environment (described in Section 4.3). Therefore cases from this source may not cease until 2150, or possibly later. We limited our projection to the year 2100, noting the uncertainty beyond this point.

In their 2011 paper, Olsen et al note that it is likely that wave 3 cases in Western Australia (particularly those from home renovator exposure) will increase in future. In our opinion this conclusion can be extrapolated to Australian cases, and is consistent with our findings.

Our projection shows that from the middle of this century the majority of new mesothelioma cases will arise from third wave exposure.

6.2 Base Scenario: Other Metrics

In the previous section we showed that the actual and modelled historical cases were close over the period 1988-2014. In this section we consider other output from our models and the fit of this output to actual data, where available. The actual and projected results for these other measures are also close, providing us with confidence that the base scenario from our model is appropriate.

6.2.1 Average Age

Figure 6.4 shows the actual and projected average age for each year of diagnosis (1988 to 2015) for Wave 1&2 cases. We used the AMR data received as at 9 July 2015 to measure 2015 experience to date. To remove some volatility in the observed average ages we have shown the three year moving average. This chart includes all mesotheliomas reported to the AIHW and AMR. The majority of these relate to the Wave 1&2 segment, so we have used these without adjustment in calibrating our model.

Figure 6.4 – Base Scenario: Average Age – Wave 1&2 (Three Year Moving Averages)

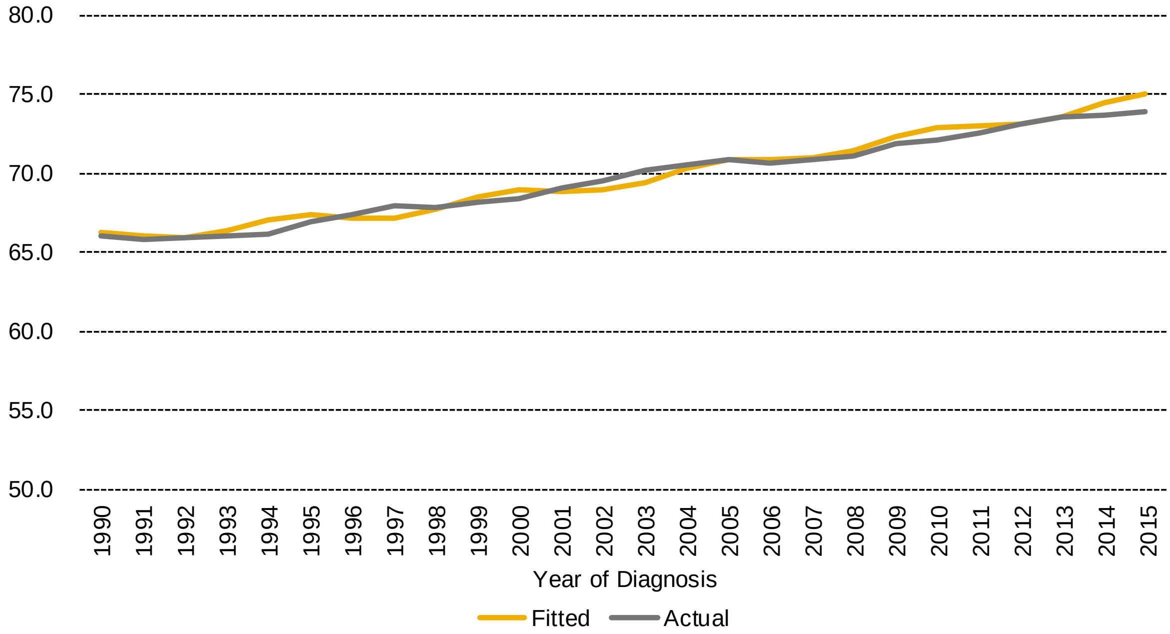


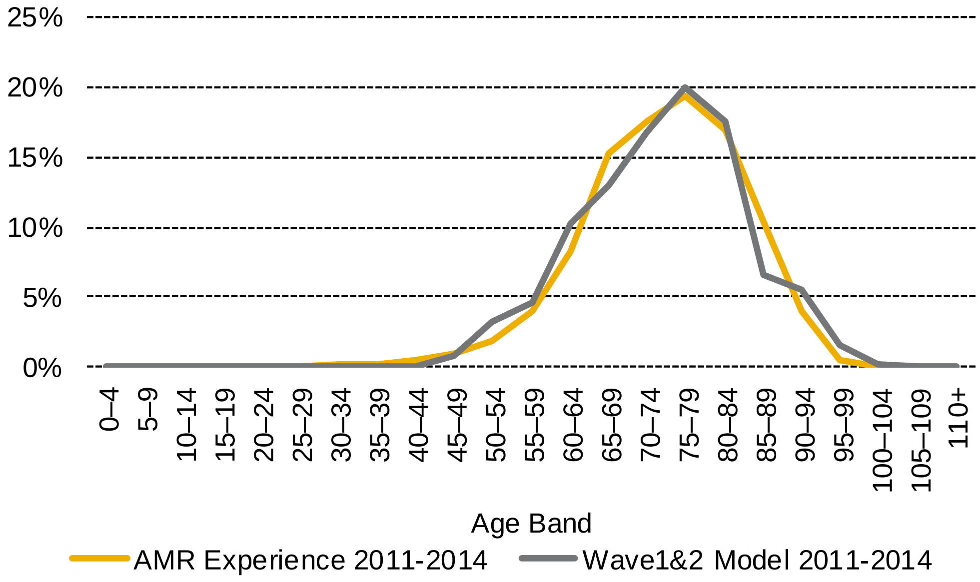
Figure 6.4 shows that our model reproduces the average age quite closely. The average age at diagnosis has increased from about 66 years in 1990 to 74 years by 2015. This trend has been observed in other studies (Soeberg et al, 2016). This reflects two factors:

- The exposed population is effectively closed to new members, so the survivors are ageing. As the ages of those in the group increase over time, so too should the average age for those contracting mesothelioma. This is the main explanation for the increasing average age observed.
- Improvements in mortality rates have led to more people living longer, facing an increased risk of contracting mesothelioma. This also lifts the average age at diagnosis, as the projection moves to later years.

6.2.2 Age Distribution

Figure 6.5 shows that our model also achieves a similar spread of ages to the actual experience in the AMR data for Wave 1&2 cases.

Figure 6.5 – Base Scenario: Age Distribution at Diagnosis: 2011-2014, Wave 1&2



6.2.3 Average Age by Wave

Table 6.3 summarises the average actual and projected age at diagnosis for the two main segments of our projection. The averages span the period 2011-2014, which are the complete years contained in the AMR exposure data.

Table 6.3 - Actual and Projected Age Profile of Cases by Wave

	Average age at diagnosis		
2011- 2014	Actual	Model	Difference
Wave 1 & 2	73	74	-1
Wave 3 Total	69	70	0

Table 6.3 shows that the model provides a good fit to the data. The Wave 3 Total average ages are around four years lower than the Wave 1&2 averages, reflecting their younger age profile. The figures in the table above may not appear to reconcile due to rounding.

The relativities shown above are consistent with the WA Mesothelioma Register. This shows that, for the period 1960 to 2008, WA non-occupational cases (excluding Wittenoom residents) had an average age at diagnosis of 65. The average for the same period for all occupational mesotheliomas was 70 years (Olsen et al, 2011). The difference between these groups (five years) is comparable to the gap of four years shown in Table **6**.3. The WA average ages are lower because they span a longer and earlier period of time compared to the national AMR data used in Table **6**.3.

6.2.4 Exposure Profile of Reported Cases

Wave 1&2

Table 6.4 summarises the actual and projected average year of first and midpoint exposure and latency (from midpoint exposure). As with Table 6.3, the averages span the period 2011-2014.

Table 6.4 – Actual and Projected Exposure Profile of Wave 1&2 Cases: 2011-2014

	Wave 1 & 2		
2011- 2014	Actual	Model	Difference
Average first exposure	1961	1965	4
Average midpoint of exposure	1971	1972	1
Average latency (midpoint of exposure)	42	42	0

This fit to exposure profile, while not perfect, is close enough for the purposes of this projection. The difference in the actual and modelled average year of first exposure is due to a simplification in our model. The AMR data show that in practice many of those in the Wave 1&2 group had broken periods of exposure, working in one job with possible or probable asbestos exposure, then employment with no likely exposure, then another job with exposure. By contrast, our model makes a simplifying assumption that each person's exposure is continuous (in order to keep the model manageable). In our judgement this difference should have little bearing on our results. We calibrated our assumptions so that the average midpoint of exposure provided a close match, as this is the key effective date of exposure.

We expect the observed latency for mesotheliomas from this group to increase over time. This is reflected in different measurements of latency over time. For instance, for mesotheliomas reported to the Australian Mesothelioma Surveillance Program and Australian Mesothelioma Register up to 1995, the mean latency from first exposure to diagnosis was 37.4 years (Ferguson et al, 1987). Wave 1&2 cases will comprise the majority of mesotheliomas reported up to 1995. While we do not have access to the underlying data, we estimate the corresponding average latency from mid-exposure to be around 30-35 years.

This is lower than the average latency observed from the AMR data for 2011-2014 cases (42 years, as shown in Table 6.4).

Wave 3

The AMR exposure dataset does not include periods of exposure for non-occupational exposure, so the same comparison cannot be made. However, we can summarise our model output for this wave. For the same projection period (2011-14), the average year of first exposure was 1969 and average midpoint of exposure was 1970. This reflects the later exposure profile and shorter average length of exposure for this group, compared to those cases in Wave1&2.

The WA Mesothelioma Register covers home renovator mesotheliomas from WA reported in 1960-2008. These mostly arose from exposure in the 1960s and 1970s (Olsen et al, 2011). This is broadly consistent with our model output.

The WA Mesothelioma Register reports a shorter average latency from first exposure to diagnosis for home renovator cases (33 years) compared to occupational cases for the period 1960-2008 (ranging from 37 to 44 years) (Olsen et al, 2011). This relativity is consistent with the output from our model, for the same reasons given above.

6.3 Uncertainty

So far in Section 6 we have presented results and the model fit for our base scenario. We characterise the base scenario as a 'central estimate', in the sense that there is no intentional bias to under or overstate the projection. It is a plausible and likely scenario.

However, there are many uncertain factors and assumptions, both implicit and explicit, underlying the projection. Some of this uncertainty reflects difficulties caused by inputs which cannot be measured directly or where information is incomplete, such as:

- Historical levels of asbestos exposure.
- The split of AIHW case data by wave.
- The uncertainty from our extrapolation from the AMR cases with exposure data to set the profile for all cases in 2013.

There is also uncertainty because outcomes are dependent on future events extending many years into the future. Some outcomes are dependent on future actions e.g. practices handling ACMs in 2015 and later years.

In our opinion, the key sources of uncertainty within our projection are:

- The pattern of asbestos consumption and removals (particularly the latter). This also includes the relative riskiness of removing asbestos compared to original consumption.
- The relative exposure in different years arising from the processes and precautions taken at different stages (if any) to minimise asbestos exposure. In this report we have described this as an ‘asbestos handling’ or ‘safe handling’ factor. When thinking about workplaces it might alternatively be described as an ‘occupational health and safety factor’.
- Uncertainty around the functional form of the relation between the mesothelioma incidence rate and time (as described in Berry, 1991).
- The relative toxicity of different types of asbestos.
- Our lack of understanding of the underlying source of exposure for ‘background’ cases, and hence how many of these cases may be diagnosed in future years. These could include a number of sources of low dose exposure (e.g. neighbours doing home renovations).
- Future improvements (if any) in non-mesothelioma mortality rates above the level assumed in our model. If life expectancy increases due to a general lowering of mortality from other sources, then there are more survivors available from the exposed population at future dates to contract mesothelioma.
- The age profile for those first exposed to asbestos for each wave.
- The impact of asbestos exposures occurring outside Australia for immigrants who were diagnosed in Australia. Similarly, there is the offsetting effect for those cases diagnosed overseas among Australian emigrants who were exposed to asbestos in Australia. In Section 1.6 we listed the factors that may invalidate this assumption. We note that, to the extent that these issues are reflected in the AMR case data in recent years, our model is self-calibrating to allow for these factors. We assume no further net impact from these factors in future.
- Changes in the pattern of reporting mesothelioma cases to the AMR over time by the state cancer registries.
- The assumed split of cases between the waves for 2013 cases. The split in the base scenario involves judgement in extrapolating from the subset that completed the exposure questionnaire. There is also judgement in allocating cases where people were exposed in both occupational and non-occupational settings.

6.3.1 Alternative Scenarios

To highlight the uncertainty surrounding the base projection and reveal the assumptions with the potential to cause the greatest variation in our projections, we prepared scenarios to test the impact on future cases from each wave arising from a number of the features listed above. We applied each of the scenarios in isolation to the base model. We did not include multivariate sensitivities in our projection (i.e. where several assumptions change at once), but we have summarised the range of outcomes implied by each of our scenarios in Figure 6.11. The scenarios shown are not intended to reflect the full range of potential outcomes.

In this context the base scenario should be viewed as one potential state of the world. Other plausible scenarios are possible and must be considered.

For each alternative scenario we changed the assumption value(s) and then rescaled the projected number of cases in 2013 to match the 708 mesotheliomas projected in the base scenario. We did this because in practice, if we were adopting different assumptions, we would scale the resulting projection to match the actual number of cases. We did not test the quality of the back fit for each alternative to the same level of detail as we did for the base scenario, in terms of the trend and number of cases in the years 1988-2014, or age or exposure related metrics.

Table 6.5 shows the assumptions we have tested and summarises the values used in our base scenario and the alternative values tested in the higher and lower cases (as appropriate).

Table 6.5 – Key Assumptions: Base and Alternative Scenarios

Scenario	Assumption	Base Scenario Value		Low Alternative Value		High Alternative Value	
1	Base Scenario						
2	Asbestos consumption risk relativity (type of asbestos)	Blue Brown White	20 16 1	Blue Brown White	500 100 1		
3	Asbestos Removal volume riskweight	30%		10%		50%	
4	Asbestos Handling Index shape	2003+	10%	1992 – 2002 2002 – 2015 2015+	10% 5% 0%	1984+	50%
5	2013 Cases split among waves	Wave1&2 Occup post-2003 Wave3 Dom Background	73% 0% 22% 5%	Wave1&2 Occup post-2003 Wave3 Dom Background	80% 0% 15% 5%	Wave1&2 Occup post-2003 Wave3 Dom Background	65% 0% 30% 5%
6	Background Cases	Background cases projected with 50% weight to each of population growth and Wave 3 Dom shape		Background cases projected as Wave 3 Dom shape		Background cases projected with population growth	

The impact on the projected number of mesothelioma cases is shown in Table 6.6.

Table 6.6 – Alternative Scenarios: Results

Assumption	Base Scenario Cases 2015 - 2100	Low Scenario Cases 2015 - 2100	High Scenario Cases 2015 - 2100
Base	19,427		
Asbestos risk relativity		17,024 2403 fewer -12%	
Asbestos Removal volume risk weight		18,646 781 fewer -4%	20,162 735 more 4%
Asbestos Handling Index shape		18,842 585 fewer -3%	21,476 2049 more 11%
2013 Cases split among waves		18,659 768 fewer -4%	19,927 500 more 3%
Background Cases		17,556 1871 fewer -10%	21,657 2230 more 11%

In broad terms the total number of future mesotheliomas varies by around +/-4% for plausible changes to some assumptions, though the deviation could be up to +/-12% (i.e. around 2,400 more or fewer mesotheliomas). Changes to combinations of assumptions would likely lead to a wider range of variation, perhaps +/- 35% or more.

The following charts show the impact of the alternative scenarios on mesothelioma cases in each future year.

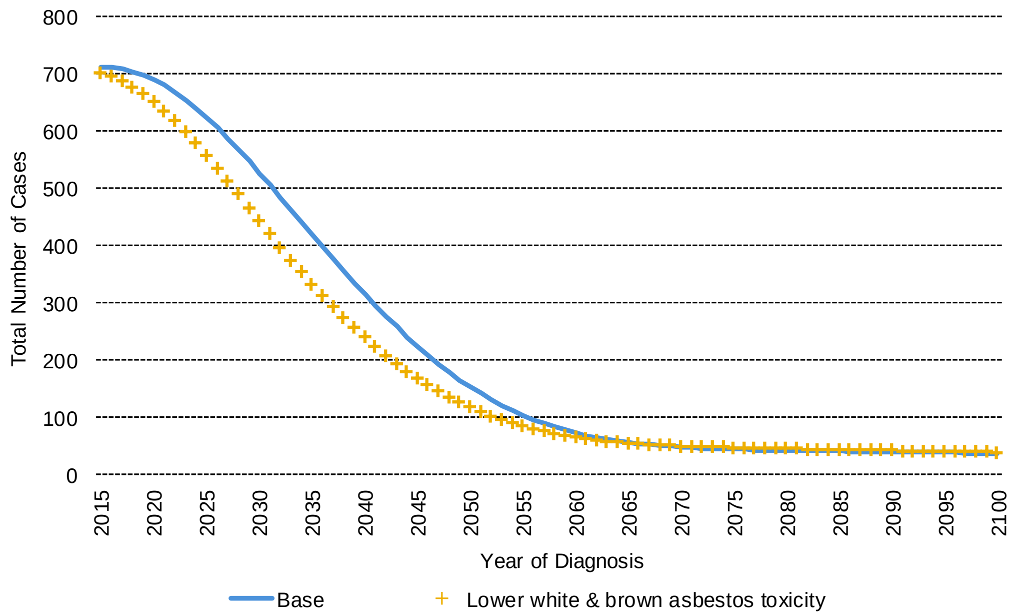
Risk of Different Types of Asbestos

The World Health Organisation (WHO) has stated that exposure to white asbestos can cause mesothelioma (WHO, 2006). In our experience this position is supported by a majority of people familiar with different types of asbestos, though a minority do maintain that white asbestos does not cause mesothelioma. The majority view is reflected in our base scenario.

We tested the impact on case numbers assuming white asbestos carries a much smaller risk of causing mesothelioma. As shown in Table 6.5 we used the Hodgson and Darnton relativities described in Section 5.1.

This alternative scenario leads to 2,403 (12%) fewer cases, mainly due to the end of blue asbestos consumption in the late 1960s. Future mesotheliomas are mainly due to exposure from 1970 onwards. In our alternative scenario we assume that blue asbestos is riskier (compared to the other types of asbestos); it thus assumes a greater 'responsibility' for all mesotheliomas diagnosed so far. This implies a lower level of responsibility for brown and white asbestos, in terms of the cases already diagnosed. This lower contribution from brown and white asbestos leads to the lower level of future cases under this alternative scenario. It also leads to an earlier peak year for total mesotheliomas (2013, compared to 2015 for our base scenario).

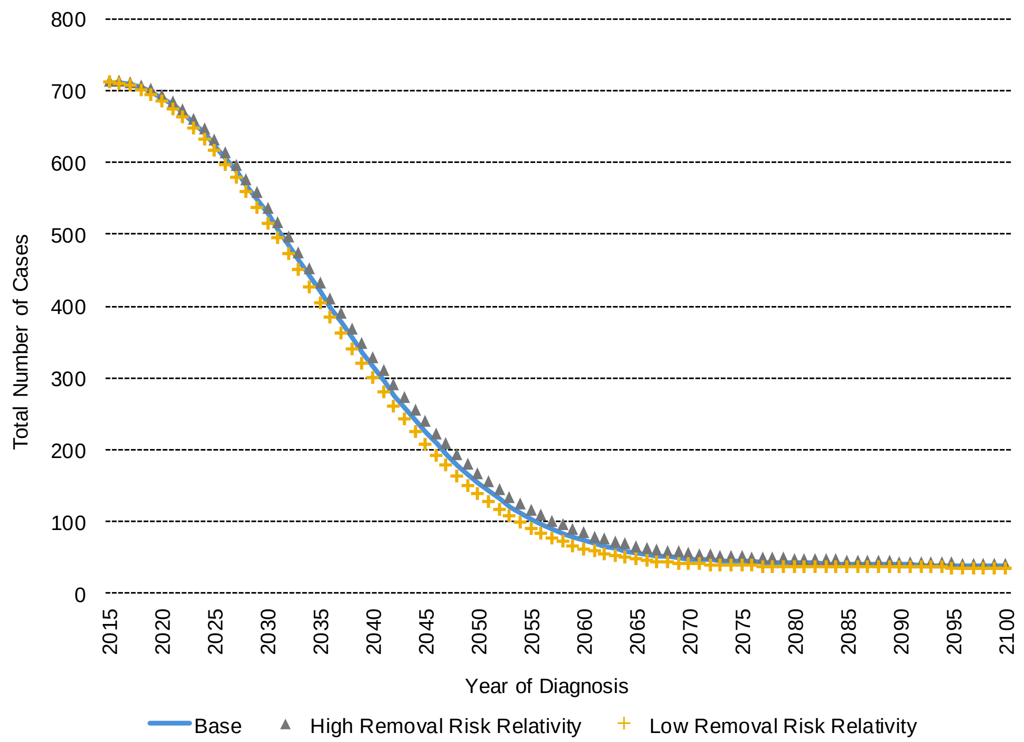
Figure 6.6 – Alternative Scenario 2: Lower White Asbestos Toxicity



Risk of Removal vs Consumption

The chart below shows the impact of varying the relative risk of removals (compared to consumption).

Figure 6.7 – Alternative Scenario 3: Riskiness of Removal vs Consumption



In the base scenario we assumed that the risk of mesothelioma due to asbestos removals is lower than the risks associated with original consumption, for a given volume of ACMs. In our base scenario we assume that removals represent 30% of the risk of consumption.

These alternative scenarios test the sensitivity of the projection if we assume a higher level of removal risk (50%) or a lower level (10%). Each of the high and low scenarios leads to increases or decreases of around 730 to 780 future cases (i.e. +/- 4%).

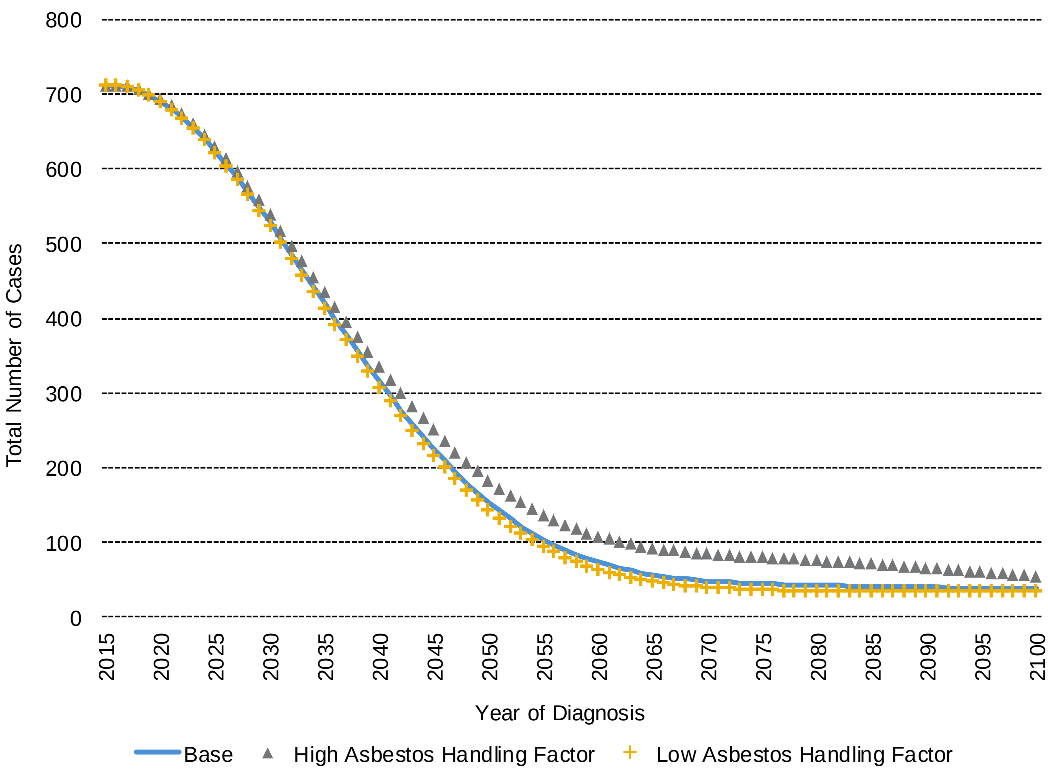
This indicates that the removal risk weight is not a particularly sensitive assumption.

Asbestos Handling Risk

The asbestos handling index is set after considering historical changes to awareness, regulation and changes in activities and processes. By its nature it is subjective. The process we followed in setting the base assumptions is described in Section 5.1.

The level of risk post-2003 (10% of 1970 risk levels) is based on changes in the level of permissible exposure over time, and estimates of overall reductions in fibre concentrations in the air for those exposed. Our alternative scenarios test the impact of higher or lower safe handling relativities.

Figure 6.8 – Alternative Scenario 4: Asbestos Safe Handling Levels



The high scenario assumes a 50% safe handling factor in 1984 and all later years. The low alternative assumes 5% from 2002 and then 0% from 2015 onwards.

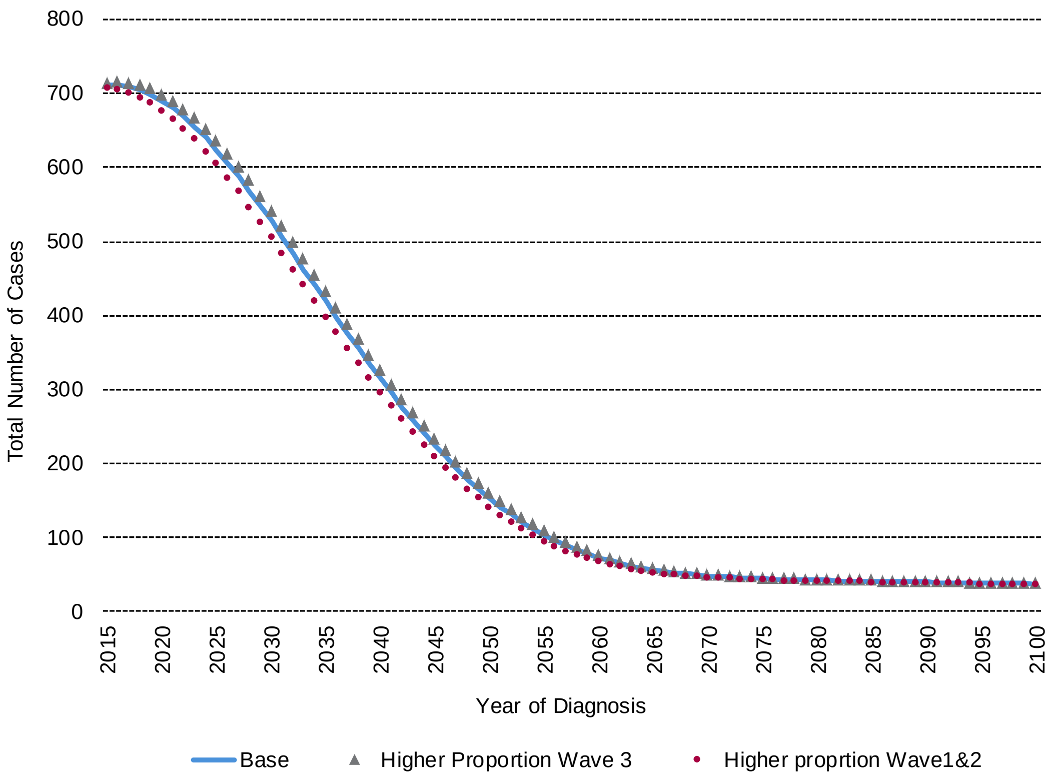
The high scenario (i.e. assuming safe handling is unchanged from 1980s levels) adds around 2,000 more cases relative to the base scenario. Alternatively, further improvements to risk levels (and in particular eliminating all risk after 2015) would reduce future mesotheliomas by around 600 cases. These scenarios indicate the importance of safe handling and removal of in situ asbestos. This includes the risk to workers inadvertently exposed to ACMs (e.g. poorly managed asbestos within buildings).

Allocation of Historical Cases to Waves

The base scenario was calibrated to 708 cases diagnosed in 2013, split into Wave1&2 cases (73%), Wave 3 Domestic (22%) and Background (5%). This allocation is based on the AMR exposure survey being broadly representative of the whole set of mesothelioma cases, as described in Section 3.5. We made some minor changes to the allocation implied by the AMR data.

We tested alternative allocations of 2013 mesotheliomas between these sources. We left the background allocation unchanged at 5%, but tested a high Wave 1&2 allocation of 80% and a low allocation of 65% of cases. The results are shown in Figure 6.9.

Figure 6.9 – Alternative Scenario 5: Change in Mix of Cases in 2013



The results show:

- The higher allocation to Wave 1&2 (a period with earlier exposure to asbestos on average) results in 768 (4%) fewer cases.
- The higher allocation to Wave 3 Domestic (a period with later exposure to asbestos on average) results in 500 (3%) additional cases.

In Section 3.5 we provided justification for the assumptions in our base scenario. However, other allocations of 2013 cases between the waves are plausible. In particular, the range tested above is reasonable, but has a modest overall impact on our projection.

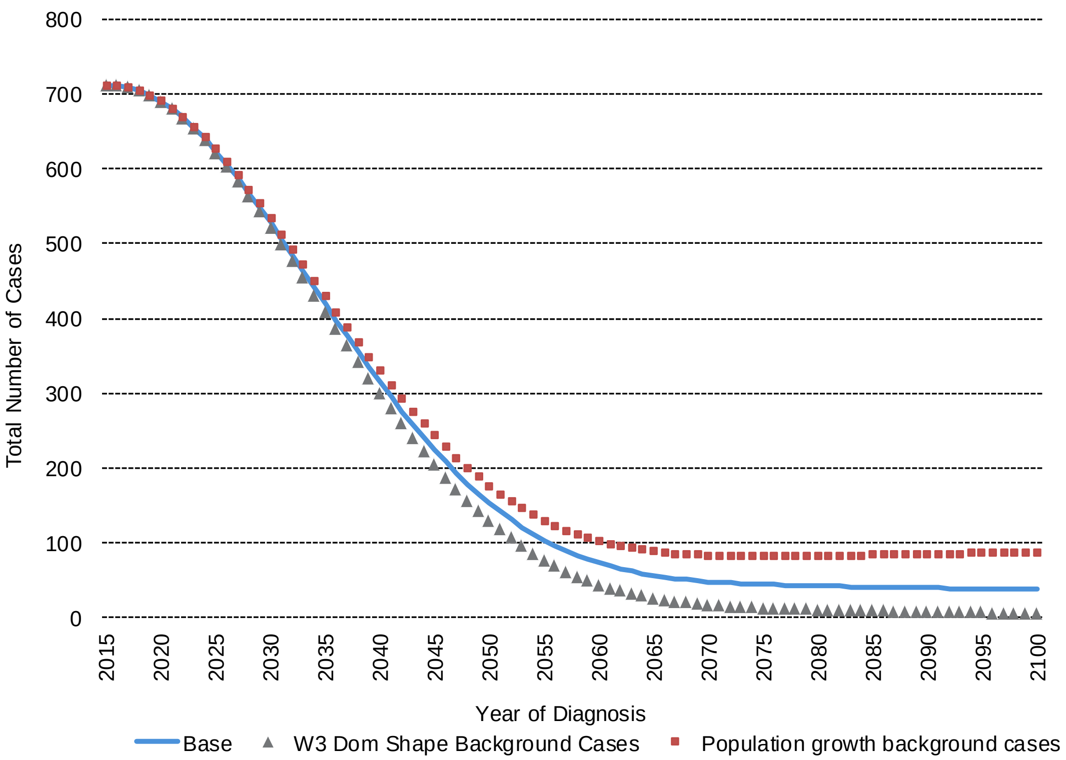
Background Cases

There is significant uncertainty around the source of exposure for background mesotheliomas and therefore the future number of background cases. In this scenario we show a projection of future cases considering two alternatives:

- Background cases vary in line with the Australian population and relative risk levels do not change over time. This scenario results in 2,230 (11%) more cases.
- Background cases are correlated with the volume of asbestos in situ and relative risk levels will reduce to zero as asbestos is removed from Australia's built environment. This scenario results in 1,871 (10%) fewer cases.

The size of this range demonstrates the significant uncertainty surrounding background cases. The results are shown in Figure 6.10.

Figure 6.10 - Alternative Scenario 6: Background Cases



This chart shows that the alternatives lead to either no mesotheliomas by around the year 2080, or a plateau of around 100 per annum from 2070 onwards. Our base scenario sits between these two extremes. This factor is the main source of uncertainty around our projection after 2060.

6.3.2 Implied Range from Alternative Scenarios

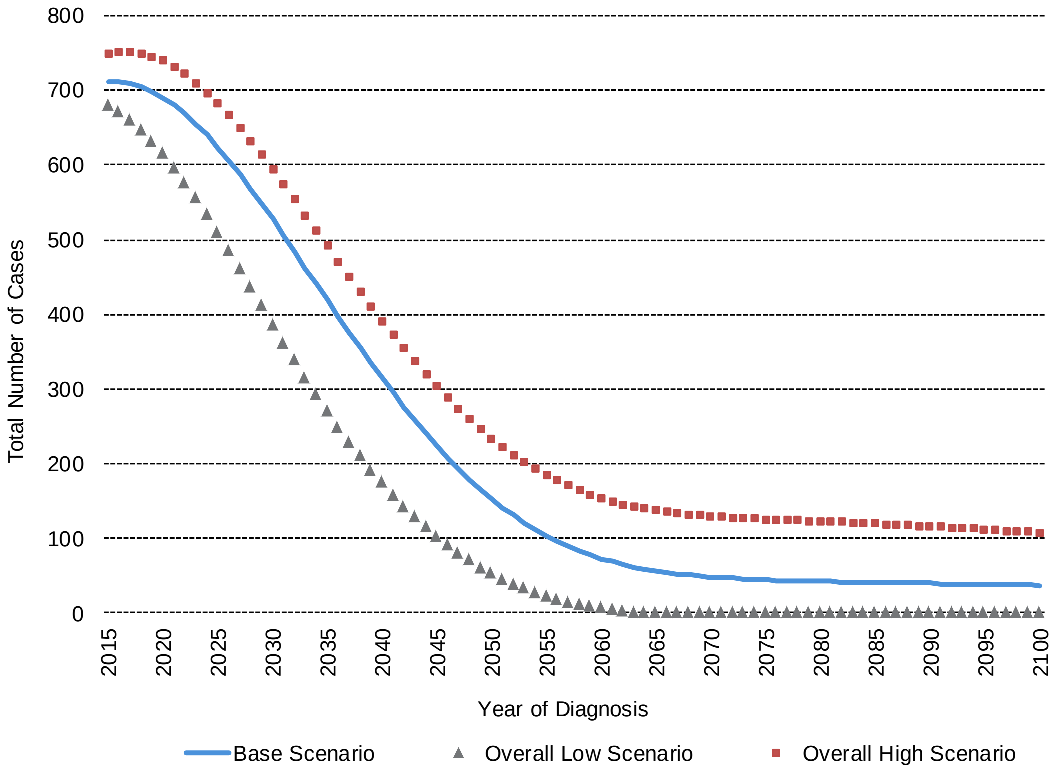
As noted previously, there is considerable uncertainty surrounding our projection. Our base scenario is one plausible outcome. Alternatives of up to +/-12% in total future cases are possible from changing single assumptions. Wider variation is possible from changing several assumptions simultaneously.

Figure 6.11 combines the alternative scenarios tested previously in this section, to produce an indicative range of plausible variation around our base scenario. We have not recalibrated the model inputs to simultaneously vary multiple assumptions. Instead we measured the variation in the projection output i.e. the number of cases shown in Figure 6.6 to Figure 6.10. We aggregated the variations for those scenarios that increased the projection (above the base case). We did the same for those scenarios which led to fewer cases.

In addition, we included one other scenario to test different assumptions for unreported (i.e. IBNR) cases in 2013. For the low scenario we assumed 15 fewer cases per annum i.e. no further unreported cases for the period analysed. For the high scenario we assumed an additional 32 unreported cases in 2013, taking the total to 740.

The resulting range around the base scenario, from adding the variations in Table 6.6 and the preceding paragraph, is shown in Figure 6.11.

Figure 6.11 – Indicative Range of Outcomes Considered by Alternative Scenarios



Compared to the base scenario of 19,427 mesotheliomas, Figure 6.11 shows a range of approximately +/- 33% around the base case. Specifically:

- The low scenario projects 12,748 future cases (6,680 fewer than the base scenario).
- The high scenario projects 25,764 future mesotheliomas (6,336 more than the base).

The range shown is simple, for the following reasons:

- It adds the impact of the individual scenarios described previously. It takes no account of possible offsets or partial impacts arising from these factors. It assumes they all occur in full as per Table 6.5.
- The range does not test more extreme outcomes, which are possible.

- Some factors have not been tested. For instance, we did not test variations to the stocks and flows model of consumption and removal. An earlier or later pattern of exposure would probably lead to variation around our base scenario. We did not test this particular component of our model because we achieved a strong fit to the actual number of cases in 1988-2014, so focused on other uncertain factors.

Some of the drivers of the range of outcomes shown in Figure 6.11 are specific features of our model (e.g. the allowance for unreported cases in 2013). However, the range also incorporates the potential impact of current and future asbestos management practices. These mainly affect future cases after 2050.

6.4 Conclusion

We project about 19,000 cases of mesothelioma diagnosed in Australia between 2015 and the end of the century.

An increasing proportion of these cases relate to non-occupational exposures spread across the broader Australian community. This has been identified as an emerging public health problem (Park et al, 2013). These 'third wave' cases are generally associated with relatively low doses of asbestos exposure and include some individuals who will be unaware that they have even been exposed to asbestos. Based on our estimates, the third wave currently represents around one in every three mesotheliomas diagnosed.

This proportion is projected to increase in future, due to the later exposure profile for this wave, compared to earlier occupational exposures. Significant volumes of ACMs remain in situ today. Allowing for this current stock of asbestos, we project over 8,000 future cases of third wave mesotheliomas.

The high and increasing incidence of mesothelioma in Australia is due to many factors. One reason that is often overlooked is the reluctance to recognise the causal significance of low dose occupational and non-occupational exposures (Leigh et al, 2002).

The magnitude of third wave mesotheliomas highlights the importance of asbestos removalists, tradesmen, other workers, home renovators, businesses and all levels of government taking appropriate action. This includes raising awareness of ongoing asbestos exposures, and following risk minimisation strategies to deal with these exposures. This is particularly important because home renovation is so popular in Australia at present (Olsen et al, 2011). By doing so, it is possible that there could be significantly fewer deaths from mesothelioma in Australia in the 21st century.

7 Reliances and Limitations

This report has been prepared by Finity in accordance with the Code of Conduct of the Actuaries Institute.

Any distribution of the report must be in its entirety. Any publication of extracts from the report must be approved in advance by Finity in order to meet our professional obligations relating to the potential to mislead third parties by using our report for purposes that were not intended.

We have relied on the accuracy and completeness of the data and other information (qualitative, quantitative, written and verbal) provided to us for the purpose of this advice. We have not independently verified or audited the data, but we have reviewed the information for general reasonableness and consistency. The reader of this report is relying on ASEA and the Australian Mesothelioma Registry and not Finity for the accuracy and reliability of the data. If any of the data or other information provided is inaccurate or incomplete, our advice may need to be revised and the report amended accordingly.

It is not possible to estimate future mesothelioma cases with certainty. As well as difficulties caused by inputs which cannot be measured directly, such as historical levels of asbestos exposure, or incomplete data, outcomes are also dependent on future events, including legislative, social, and medical changes. In particular, we can only estimate future levels of exposure; these will be affected by future removal rates and precautions which may or may not be followed by a large number of people. Deviations from our estimate, perhaps material, are normal and are to be expected. In the case of mesothelioma projections the uncertainty is heightened due to the need to make assumptions many years into the future.

Our report is based on a continuation of the current environment with allowance for known or projected changes in exposure profiles. It is quite possible that one or more changes to the environment could produce an outcome materially different from our estimates.

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Our report should be considered as a whole, including all appendices. Members of Finity staff are available to answer any queries, and the reader should seek that advice before drawing conclusions on any issue in doubt.

Part III Appendices

A References

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B Asbestos – Background Information

In this section we provide a brief overview of asbestos use in Australia and the medical conditions caused by asbestos exposure. More information is available in the references cited throughout this report.

B.1 What is Asbestos?

Asbestos is a naturally occurring mineral fibre with two main types:

- Serpentine – chrysotile (‘white’ asbestos).
- Amphibole – anthophyllite, amosite ('brown' or 'grey'), crocidolite ('blue'), tremolite and actinolite.

The three types of asbestos used in Australia in significant quantities were white, brown and blue asbestos (in order of increasing toxicity).

Asbestos is an affordable, sound absorbent, strong, fire and heat resistant material. Asbestos is naturally occurring in Australia and many other parts of the world, and was viewed as an attractive fibre for use in insulation, construction and friction products prior to the awareness of its dangers (Virta, 2002).

B.2 Asbestos Usage in Australia

Records of asbestos use in Australia show significant asbestos mining, importation of raw asbestos fibres, processing asbestos fibres into products and construction using asbestos products since the 1930s. Chrysotile was the main type of asbestos mined in Australia until 1939 and then after 1966; during the intervening period crocidolite was extracted from the Wittenoom mine in Western Australia and comprised the majority of volumes mined in those years (Leigh et al, 1997). Asbestos was mined in Australia until 1984, when the practice was banned.

The main sources of raw asbestos imports were Canada (chrysotile) and South Africa (crocidolite and amosite). Many manufactured asbestos products were also imported, including asbestos yarn, cord and fabric, asbestos joint and millboard, asbestos friction materials and gaskets, as well as some asbestos cement (Leigh et al, 1997).

Asbestos was widely used in construction between the 1950s and 1980s (Park et al, 2013). From the late 1970s onwards the use of asbestos in Australia was widely regulated, starting with occupational exposure limits (Soeberg et al, 2016). Its use had virtually ceased by the early 1990s. The importation of products containing asbestos was banned in 2003.

Asbestos still exists ‘in situ’ in our built environment, mainly in construction material. It is most commonly found as ‘fibro’ sheeting in domestic homes but also exists as insulation, cement and linoleum floor coverings among other things.

Australia consumed a significant amount of asbestos. By 1954 Australia was the fourth largest consumer among Western nations for gross consumption of asbestos cement products (after the USA, UK and France) and had the highest per capita consumption (Leigh et al, 1997).

B.2.1 Safe Handling Guidelines

This section provides more detail relating to the timeline provided in Table 5.5. It relates to changes in the assumed safe handling relativities over time.

Some key milestones are as follows:

- A time weighted average exposure level was recommended in 1938. This was around 300 times higher than the limit imposed under Occupational Health and Safety legislation introduced in 1983 (Watson et al, 2004).
- Progressive introduction of control measures from late 1950s helped reduce exposure in asbestos cement factories.
- The exposure conditions at Wittenoom improved after 1957 (Berry, 1991).
- The Australian Navy introduced safe handling guidelines in 1968 (Watson et al, 2004).
- The NSW building union banned the use of asbestos in 1970 (ADFA, accessed 2015).
- NSW spray insulation ceased in 1976 (ADFA, accessed 2015).
- Victorian labour laws changed for asbestos handling; James Hardie products contain warning labels e.g. to wet product before cutting it – all in 1978 (ADFA, accessed 2015).
- Awareness of asbestos risks in the Victorian power industry improved such that workers entering the industry after the 1980s should have been able to avoid exposure (Watson et al, 2004).
- In 1981 the National Health and Medical Research Council (NHMRC) adopted exposure standards for asbestos (Watson et al, 2004).
- In 1983 the NHMRC updated these exposure standards to lower exposure to Brown asbestos. In addition, Occupational Health and Safety legislation placing a limit on acceptable exposure levels in the workplace (Watson et al, 2004).
- In 1988 code of practice for safe removal of asbestos was introduced in Australia in 1988 and updated in 2002 (Watson et al, 2004).
- In 1991 Australian Standards 1715 and 1716 prescribed the appropriate protective clothing to be worn in areas where asbestos existed (Watson et al, 2004).
- In 1994 national model regulations were introduced for the control of hazardous workplace substances including training for workers potentially exposed to asbestos (Watson et al, 2004).
- The current fibre concentration limit is 0.1 fibres/ml (weighted exposure over any 8 hour period) (enHealth, 2013). This is 10% of the exposure limit introduced in 1981 (1 fibre/ml).

B.2.2 Fibre Load

It is also useful to consider the measured (or estimated) concentration of fibres in the air, as an indication of the relative riskiness of different activities involving asbestos. These relativities can be used to inform the relative levels of risk in different time periods, including present and future exposure levels.

Table B.1 shows various estimates and measurements of the concentration of asbestos fibres in the air over time for a range of activities. These fibre load estimates have come from several sources.

Table B.1 – Fibre Load Measurements/Estimates – Various Sources

Exposure Type	Period	Fibres / mL	Source
High exposure to asbestos miners/millers	1940s-1970s	200.00000	enHealth - Asbestos: a guide for householders and the general public, Feb 2013, page 17
Asbestos pulverisors/disintegrators in AC industry	1950s	150.00000	Roberts and Whaite, 1952 quoted in Leigh et al, 2002
Baggers at Wittenoom	1960s	600.00000	Major, 1968 in Leigh et al, 2002
Wittenoom - mining blue asbestos - low	1960s	650.00000	Dust Dieseases Update UNSW Facilty of Law, Understanding Asbestos Induced Diseases (presentation), Professor Breslin 24 Feb 2015
Wittenoom - mining blue asbestos - high	1960s	1500.00000	"
Shipyards and shipbuiding/repairs - low	1960s	200.00000	"
Shipyards and shipbuiding/repairs - high	1960s	400.00000	"
Background air - rural	1970s	0.00001	"
Background air - city	1970s	0.00010	"
Asbestos cement products - handling	1970s	0.70000	"
Asbestos cement products - sanding	1970s	5.70000	"
Lagging - removal - low	1970s	1.50000	"
Lagging - removal - high	1970s	100.00000	"
Lagging - spraying	1970s	28.00000	"
Renovations of AC-clad buildings - low, no precaution	1980s	0.10000	Brown, SK, reference 20 in Park et al, 2013, Asbestos exposure during home renovation in NSW. US figures. Limited Aust. data available.
Renovations of AC-clad buildings - high, no precaution	1980s	0.20000	"
Background air - low	2013	0.00001	enHealth - Asbestos: a guide for householders and the general public, Feb 2013, page 17
Background air - high	2013	0.00020	"
Current workplace limit - over 8 hrs	2013	0.10000	"

Some of these fibre loads represent maxima or extreme concentrations, rather than averages experienced over a week or year. Some activities (e.g. the use of power tools) can produce high concentrations of asbestos fibres in the air in the short term. Home renovation work may increase background fibre concentrations over the medium term, leading to increased cumulative exposures for those close to the affected site (Olsen et al, 2011).

Nevertheless, the fibre loads tabulated above provide an indication of the extremely wide range of concentrations experienced by different groups, with the historical risk levels in high risk occupations many times higher than those experienced by home renovators. Similarly, home renovators face risk levels significantly higher than background exposure levels.

B.3 Diseases associated with Asbestos Exposure

Inhaled asbestos fibres may cause a number of diseases, including (in increasing severity for most cases):

- Asbestos Related Pleural Disease (ARPD) – a non-malignant disease that may restrict a person's breathing capacity.
- Asbestosis – a non-malignant disease that also restricts a person's breathing capacity.
- Lung cancer – a malignant cancer with a number of causes, including smoking and exposure to asbestos.
- Other cancers have been associated with asbestos exposure, such as ovarian and laryngeal cancer. However, the evidence of a link is not as robust as it is for lung cancer and mesothelioma, and some debate whether asbestos does cause these other cancers (IIAC, 2015).
- Mesothelioma – a malignant cancer that is mostly caused by exposure to asbestos, the focus of this report (Virta, 2002).

A person exposed to asbestos may contract any of these diseases, even if the exposure is brief. However, exposure does not guarantee the onset of any of these conditions. People working with asbestos have historically demonstrated a higher risk of contracting a disease due to their more frequent and heavier exposure.

The absolute levels of exposure shown in Table B.1 are approximate. However, as noted in earlier studies they serve as a means of ranking the riskiness of different sources of exposure and periods of time (Rogers, 1990).

B.4 Asbestos: A Legal Context

The link between asbestos exposure and the increased risk of developing mesothelioma has been a non-contested fact in the Australian litigation environment since the first Asbestos Related Disease (ARD) patients were awarded damages in the 1980s. These early cases involved plaintiffs suing for negligence because they had been exposed to asbestos after defendants knew (or should have known) that asbestos exposure could lead to negative health consequences.

In the current legal environment ARD sufferers who can prove exposure in the workplace either claim statutory workers' compensation benefits (if applicable) or start legal proceedings against their former employer (or other relevant defendants) if they can demonstrate negligence at common law.

Not everyone who acquires an ARD will be able to obtain damages. Some may have been exposed without knowledge of where or when this occurred. As such, they cannot attribute their exposure to any particular asbestos manufacturer, supplier or employer, and therefore are unable to prove negligence by any specific defendant. Alternatively, their disease may have been caused by background levels of asbestos exposure, particularly in cities and larger towns.

C Projection Model

In this appendix we provide further details of our model for projecting claim numbers and the results of these projections.

C.1 Nature of Our Projection Model

Our projection model is both statistical and exposure based. This is in contrast to some models where the focus is on the statistical fit to the mesothelioma data and the simultaneous estimation of several parameters. These models give little or no consideration to other information not reflected in the mesothelioma data. They may give limited consideration to the findings from other similar studies. For instance, it has been observed that statistically based age-cohort models do not always provide reliable predictions, particularly among later cohorts which have faced lower exposure but are at an immature stage of their development. Statistical models can overestimate the exposure faced by these groups (Clements et al, 2007a).

Our aim is to construct a model that fits the observed data on mesothelioma cases but which also builds on knowledge of historical asbestos use and exposure patterns and the features of other similar models. One criticism of this approach is that it may involve estimation of many parameters.

Including additional information is desirable in an asbestos projection model (Clements et al, 2007a). It is now accepted that cumulative exposure to asbestos fibres is a key driver of mesothelioma incidence (Berry, 1991). In our opinion an approach that blends external exposure information within a statistical framework is appropriate, as it makes use of all information available to the researcher.

A good description of the different forms of projection model is given by Clements et al, 2007b.

C.2 Stocks and Flows Asbestos Removal Assumptions

Table C.1 summarises the assumed product lifespan parameters (in years) and the resulting Weibull distribution parameters from the Blue Environment stocks and flows model.

Table C.1 – Asbestos Product Profile (from Blue Environment)

	Product Lifespan		Weibull Parameters	
Product Group	Average	Until 10% left	Shape	Scale
Cement sheeting - domestic	60	100	2.1	68
Cement pipes	50	80	2.4	56
Cement sheeting - commercial	40	75	1.6	45
Flooring products	15	50	2.0	17
Friction products	10	20	1.4	11
Roofing	40	75	1.6	45
Other	10	20	1.4	11

Other key inputs sourced from this model were documented in the main body of this report.

C.3 Epidemiological Incidence Model

Our incidence formula is an adaptation of the Stallard et al (2005) model. This formula is a modification of the Occupational Safety & Health Administration's (OSHA) 1983 model of mesothelioma mortality. In the OSHA formula, the minimum lag (or latency period) 'w' is 10 years and the exponent 'k' is set equal to 3.0.

Stallard et al modified the OSHA formula to apply it to populations where the asbestos exposure level was unknown. Different relative risks were modelled by fitting the model separately to different occupational groups.

Stallard et al fitted their model to data presented by Selikoff & Seidman on 458 mesothelioma deaths among 17,800 North American insulation workers in 1967-86. They concluded that the 10-year minimum latency model gave a better fit than the no latency model. With w=10 the best fit for the exponent k was k=2.83.

In our application we dropped the assumption made by Stallard et al that the duration of employment has constant intensity of exposure and instead use exposure factors as discussed previously. Consequently, we separate 'b' into two components, one reflecting the relative risk (= risk-weighted exposure duration), while the other is the scale parameter B.

We define the following symbols:

- R_t is the asbestos risk-weighting factor for year t
- E_{ij}^{N} represents the number of people whose asbestos exposure commenced in year i, ended in year j and are still alive in year N
- C_{ij}^{N} represents the number of cases arising in year N from the exposed population whose exposure commenced in year i and ended in year j.

For the cohort whose exposure started in year i and ceased in year j, the number of risk-weighted years of exposure for each person is $\sum_{t=i}^{j} R_t$.

The projected number of cases in year N is a function of the number of survivors (E_{ij}^{N}), their average risk-weighted years of exposure, the duration of exposure (= j – i + 1) and the years since first exposure (N – i).

Specifically, for the cohort where exposure began in year i and ceased in year j, the projected number of cases in year N is equal to the case incidence function times the projected surviving population:

$$C_{ij}^{N} = I_{ij}^{N} \, . \, E_{ij}^{N}$$

where the incidence function I_{ij}^{N} for malignant cases is:

I_{ij}^{N}	=	0	if N - i < w
	=	$b\,(N - i - w)^k$	if $w < N - i \leq w + j - i$
	=	$b\,(N - i - w)^k - b\,(N - j - w)^k$	if $w + j < N$

in which:

w	=	the 'lag' of 10. This is the minimum latency period from first exposure
k	=	exponent of 3

b = $B\left[\sum_{t=i}^{j} R_t\right]$

B = scale parameter which varies for each of our projection models and adjusts the number of cases to equal the actual number in the base 2013 year.

The values for B which we calibrated to our different wave models were as follows:

Wave	**B**
Wave 1&2	1.39×10^{-8}
Wave 3 Domestic	1.83×10^{-7}
Wave 3 Commercial	1.06×10^{-8}

These factors are projected simultaneously to produce future case numbers in a format identical to the population survival projection. This format allows us to directly identify the modelled number of cases in each future year by year of first or last exposure, by any given year of exposure or by distribution of exposure.

C.3.1 Other Considerations For Incidence Models

For a given lag, there is a range of plausible exponent values. For instance, in his mesothelioma model with a lag of zero, Professor Berry estimated a 95% confidence interval for k of 2.66 to 4.42, with a maximum likelihood estimate of 3.52 (Berry, 1991). This demonstrates the uncertainty in selecting the exponent.

Different estimates of the lag (w) and the exponent (k) have been suggested in a range of mesothelioma studies. Comparable fits to data can be achieved by reducing the lag and increasing the exponent (Berry, 1991). However, the consensus among medical experts is that very few mesotheliomas can occur within 10 years of first exposure (Berry, 1991), but that a lag period longer than 10 years would be inappropriate.

Berry also developed models allowing for the elimination of asbestos fibres from the lungs at rates of 6.8% and 15% per annum. Clements et al estimated a rate of elimination of 10% to 15% per annum for crocidolite, but said elimination is faster for chrysotile (Clements et al, 2007a). Including elimination rates in the model leads to higher values of k (Berry, 1991) and some moderation in incidence rates 40-50 years after first exposure, compared to models with no elimination (Berry et al, 2012). Different studies show conflicting evidence about whether mesothelioma incidence rates should increase at a slower rate from 40 years after first exposure (Berry, 1991).

Elimination of fibres from the lungs is the most likely explanation why mesothelioma rate relativities in exposed groups are higher than what the lung fibre contents of these groups would suggest (Berry et al, 1989). Previous transmission electron microscope analysis of UK mesotheliomas and controls indicates that elimination of fibre from the lungs occurs in both groups, and is consistent with the different patterns of use of crocidolite, amosite and chrysotile. Also, chrysotile is much less biopersistent than amphibole fibres, so that the amount of white asbestos in the lungs at death is mainly a reflection of recent exposure (Berry, 2002).

Also the parameters for w, k and λ (the elimination rate) are often correlated.

The original Berry model formulation applied primarily to crocidolite exposure from Wittenoom. Other relationships may be suitable for populations exposed to amosite, chrysotile or a mixture of fibres.

We have not explicitly modelled elimination of fibre from the lungs. While it is viewed by some as a desirable model feature (Clements et al, 2007a), we have implicitly allowed for this effect through our choice of a lower exponent. Berry suggests that an appropriate value for the exponent sits between 3 and 4 (Berry, 1999). An alternative view is that an exponent of 3.5 is reasonable, if moderated by a function for the elimination of fibre (Clements et al, 2007a). Our lower exponent (3.0) achieves a similar net effect.

C.4 Risk Weighted Population Model

Table C.2 contains the estimated exposure in each year for each of our modelled waves. The exposure in each year is the asbestos consumed (based on a three year average) plus 30% of the volume projected to be removed each year. More detail on our approach and assumptions is set out in Sections 4 and 5 of this report.

Table C.2 - Estimated Exposure by Year (tonnes)

	Wave				Wave				Wave		
Year	1+2	3-Dom	3-Comm	Year	1+2	3-Dom	3-Comm	Year	1+2	3-Dom	3-Comm
1921	394			**1966**	53,134	17,652		**2011**		2,371	7,563
1922	643			**1967**	53,737	17,840		**2012**		2,380	7,515
1923	717			**1968**	56,377	18,715		**2013**		2,388	7,462
1924	351			**1969**	55,270	18,329		**2014**		2,394	7,404
1925	300			**1970**	59,532	19,747		**2015**		2,398	7,342
1926	300			**1971**	63,935	21,212		**2016**		2,401	7,275
1927	300			**1972**	71,748	23,821		**2017**		2,402	7,203
1928	300			**1973**	78,443	26,052		**2018**		2,402	7,128
1929	1,327			**1974**	74,114	24,578		**2019**		2,400	7,048
1930	1,356			**1975**	79,999	26,538		**2020**		2,396	6,963
1931	1,799			**1976**	81,532	27,032		**2021**		2,390	6,874
1932	1,000			**1977**	90,322	29,965		**2022**		2,383	6,781
1933	1,494			**1978**	81,962	27,135		**2023**		2,374	6,684
1934	1,935			**1979**	71,689	23,664		**2024**		2,363	6,583
1935	3,427			**1980**	65,969	26,540		**2025**		2,351	6,479
1936	5,133			**1981**	53,092	24,207		**2026**		2,337	6,370
1937	6,429			**1982**	44,836	23,143		**2027**		2,321	6,259
1938	8,693			**1983**	26,099	12,718		**2028**		2,304	6,144
1939	9,410			**1984**	21,816	10,301		**2029**		2,285	6,027
1940	12,125	4,061		**1985**	18,116	8,214		**2030**		2,264	5,906
1941	13,188	4,415		**1986**	18,635	8,467		**2031**		2,242	5,784
1942	16,665	5,579		**1987**	16,090	7,029		**2032**		2,219	5,659
1943	16,806	5,622		**1988**	12,859	5,219		**2033**		2,194	5,532
1944	16,969	5,672		**1989**	10,161	3,709		**2034**		2,168	5,404
1945	13,747	4,585		**1990**	8,742	2,643		**2035**		2,141	5,274
1946	15,087	5,032		**1991**	8,613	2,343		**2036**		2,112	5,143
1947	15,166	5,055		**1992**	8,523	2,036		**2037**		2,083	5,012
1948	16,934	5,645		**1993**	8,791	2,090		**2038**		2,052	4,880
1949	16,060	5,347		**1994**	9,062	2,143		**2039**		2,020	4,747
1950	21,371	7,128		**1995**	9,145	2,179		**2040**		1,988	4,614
1951	25,211	8,412		**1996**	8,955	2,191		**2041**		1,954	4,482
1952	29,211	9,749		**1997**	8,936	2,215		**2042**		1,920	4,350
1953	29,729	9,916		**1998**	9,000	2,245		**2043**		1,885	4,218
1954	30,324	10,108		**1999**	9,045	2,272		**2044**		1,850	4,088
1955	36,023	12,015		**2000**	8,995	2,291		**2045**		1,814	3,958
1956	36,749	12,249		**2001**	8,863	2,302		**2046**		1,777	3,830
1957	35,466	11,808		**2002**	8,630	2,304		**2047**		1,740	3,703
1958	33,745	11,222		**2003**		2,292	8,234	**2048**		1,702	3,578
1959	35,366	11,757		**2004**		2,273	7,751	**2049**		1,665	3,454
1960	41,622	13,850		**2005**		2,291	7,745	**2050**		1,627	3,333
1961	42,200	14,033		**2006**		2,308	7,730	**2051**		1,588	3,213
1962	43,673	14,517		**2007**		2,323	7,708	**2052**		1,550	3,096
1963	43,515	14,454		**2008**		2,337	7,680	**2053**		1,512	2,980
1964	44,737	14,854		**2009**		2,350	7,646	**2054**		1,473	2,868
1965	48,051	15,956		**2010**		2,361	7,607	**2055**		1,435	2,757

No Wave 3 Commerical exposure until 2003

Table C.3 shows the assumed risk weightings, combining the exposure summarised in Table C.2, the impact of a changing mix of types of asbestos over time (see Table 5.4) and the safe handling risk factors (summarised in Figure 5.9). These risk weightings represent relativities between years rather than absolute values.

Table C.3 - Risk Weightings

	Wave				Wave				Wave		
Year	1+2	3 Dom	3 Comm	Year	1+2	3 Dom	3 Comm	Year	1+2	3 Dom	3 Comm
1921	1%	0%		**1966**	178%	178%		**2011**		10%	10%
1922	1%	0%		**1967**	149%	149%		**2012**		10%	10%
1923	1%	0%		**1968**	127%	127%		**2013**		10%	10%
1924	1%	0%		**1969**	97%	96%		**2014**		10%	10%
1925	0%	0%		**1970**	104%	104%		**2015**		10%	10%
1926	0%	0%		**1971**	110%	110%		**2016**		10%	10%
1927	0%	0%		**1972**	114%	114%		**2017**		10%	10%
1928	0%	0%		**1973**	117%	117%		**2018**		10%	10%
1929	19%	0%		**1974**	110%	110%		**2019**		10%	10%
1930	19%	0%		**1975**	111%	112%		**2020**		10%	10%
1931	16%	0%		**1976**	106%	106%		**2021**		10%	10%
1932	6%	0%		**1977**	101%	101%		**2022**		10%	10%
1933	12%	0%		**1978**	83%	83%		**2023**		10%	10%
1934	14%	0%		**1979**	66%	66%		**2024**		10%	10%
1935	19%	0%		**1980**	47%	44%		**2025**		10%	10%
1936	32%	0%		**1981**	34%	32%		**2026**		10%	10%
1937	35%	0%		**1982**	29%	27%		**2027**		10%	10%
1938	48%	0%		**1983**	23%	19%		**2028**		10%	10%
1939	51%	0%		**1984**	20%	15%		**2029**		10%	10%
1940	65%	0%		**1985**	17%	11%		**2030**		10%	10%
1941	72%	0%		**1986**	15%	9%		**2031**		10%	10%
1942	91%	0%		**1987**	15%	10%		**2032**		10%	10%
1943	91%	0%		**1988**	16%	11%		**2033**		10%	10%
1944	93%	0%		**1989**	16%	12%		**2034**		10%	10%
1945	77%	0%		**1990**	19%	17%		**2035**		10%	10%
1946	85%	0%		**1991**	20%	20%		**2036**		10%	10%
1947	85%	0%		**1992**	20%	23%		**2037**		10%	10%
1948	91%	0%		**1993**	20%	23%		**2038**		9%	10%
1949	88%	0%		**1994**	19%	22%		**2039**		9%	10%
1950	131%	0%		**1995**	19%	22%		**2040**		9%	10%
1951	151%	0%		**1996**	20%	23%		**2041**		9%	10%
1952	170%	0%		**1997**	20%	23%		**2042**		9%	10%
1953	179%	0%		**1998**	20%	23%		**2043**		9%	10%
1954	182%	0%		**1999**	20%	23%		**2044**		9%	10%
1955	214%	0%		**2000**	16%	18%		**2045**		9%	10%
1956	213%	0%		**2001**	13%	14%		**2046**		9%	10%
1957	208%	0%		**2002**	9%	9%		**2047**		9%	10%
1958	202%	0%		**2003**		9%	9%	**2048**		9%	10%
1959	219%	0%		**2004**		10%	10%	**2049**		9%	10%
1960	225%	45%		**2005**		10%	10%	**2050**		9%	10%
1961	210%	84%		**2006**		10%	10%	**2051**		9%	10%
1962	199%	120%		**2007**		10%	10%	**2052**		9%	10%
1963	202%	162%		**2008**		10%	10%	**2053**		9%	10%
1964	192%	192%		**2009**		10%	10%	**2054**		9%	10%
1965	182%	183%		**2010**		10%	10%	**2055**		9%	10%

No Wave 3 Commerical exposure until 2003

Table C.4 shows the assumed yearly exposure continuation rates (excluding mortality) in the exposed populations, by duration since entry. The low rates for the Wave 3 Domestic population reflect the fact that these exposures are short lived for most people in this group. The decrement rate each year (i.e. the proportion of the population leaving each year) is one minus the continuation rate shown in Table C.4.

Table C.4 – Yearly Exposure Continuation Rates by Duration since Entry

	Wave				Wave		
Year	1+2	3 Dom	3 Comm	Year	1+2	3 Dom	3 Comm
1	95%	40%	95%	**26**	98%	25%	95%
2	98%	40%	95%	**27**	98%	25%	95%
3	98%	40%	95%	**28**	98%	10%	95%
4	98%	40%	95%	**29**	98%	10%	95%
5	98%	40%	95%	**30**	95%	10%	95%
6	98%	40%	95%	**31**	95%	10%	95%
7	98%	40%	95%	**32**	95%	10%	95%
8	98%	40%	95%	**33**	95%	10%	95%
9	98%	40%	95%	**34**	95%	10%	95%
10	98%	40%	95%	**35**	95%	10%	95%
11	98%	40%	95%	**36**	95%	10%	95%
12	98%	40%	95%	**37**	95%	10%	95%
13	98%	40%	95%	**38**	95%	10%	95%
14	98%	40%	95%	**39**	90%	10%	90%
15	98%	40%	95%	**40**	90%	10%	90%
16	98%	40%	95%	**41**	85%	10%	85%
17	98%	40%	95%	**42**	75%	10%	75%
18	98%	25%	95%	**43**	65%	10%	65%
19	98%	25%	95%	**44**	55%	10%	55%
20	98%	25%	95%	**45**	45%	10%	45%
21	98%	25%	95%	**46**	35%	10%	35%
22	98%	25%	95%	**47**	25%	10%	25%
23	98%	25%	95%	**48**	15%	10%	15%
24	98%	25%	95%	**49**	5%	5%	5%
25	98%	25%	95%	**50**	0%	0%	0%

In addition to the decrements implied from these standard exposure continuation rates, we also applied calendar year specific decrements. In many years no additional decrement was applied.

The additional decrements were required for our cross tabulation of the exposed population by year of entry to and exit from the exposed group. These were needed so that the standard continuation rates shown in Table C.4 produced the correct census of exposure in each year (estimated by total fibre exposure), as per Table C.2).

The additional decrements were mostly required for our Wave 1&2 model. This is because the aggregate exposure (from the stocks and flows model) is variable from year to year, due to historical variations in asbestos fibres consumed in Australia. Even though we smoothed this pattern by using three year averages, enough variation remained to require these adjustments.

The additional calendar year decrements are set out in Table C.5. They represent the proportion of survivors at that point in time (from all prior years of entry) that leave the exposed population at that point in time as additional decrements.

Table C.5 – Additional Calendar Year Decrements Applied to Exposure Continuation Rates

	Wave				Wave				Wave		
Year	1+2	3-Dom	3-Comm	Year	1+2	3-Dom	3-Comm	Year	1+2	3-Dom	3-Comm
1921	0.0%			**1966**	0.0%	0.0%		**2011**		0.0%	0.0%
1922	2.4%			**1967**	0.0%	0.0%		**2012**		0.0%	0.0%
1923	2.4%			**1968**	0.0%	0.0%		**2013**		0.0%	0.0%
1924	50.0%			**1969**	0.0%	0.0%		**2014**		0.0%	0.0%
1925	28.6%			**1970**	0.0%	0.0%		**2015**		0.0%	0.0%
1926	23.1%			**1971**	0.0%	0.0%		**2016**		0.0%	0.0%
1927	2.4%			**1972**	0.0%	0.0%		**2017**		0.0%	0.0%
1928	2.4%			**1973**	0.0%	0.0%		**2018**		0.0%	0.0%
1929	2.4%			**1974**	4.8%	0.0%		**2019**		0.0%	0.0%
1930	2.4%			**1975**	0.0%	0.0%		**2020**		0.0%	0.0%
1931	2.4%			**1976**	0.0%	0.0%		**2021**		0.0%	0.0%
1932	50.0%			**1977**	0.0%	0.0%		**2022**		0.0%	0.0%
1933	2.4%			**1978**	9.1%	0.0%		**2023**		0.0%	0.0%
1934	9.1%			**1979**	0.0%	0.0%		**2024**		0.0%	0.0%
1935	2.4%			**1980**	9.1%	0.0%		**2025**		0.0%	0.0%
1936	2.4%			**1981**	20.0%	0.0%		**2026**		0.0%	0.0%
1937	2.4%			**1982**	16.7%	0.0%		**2027**		0.0%	0.0%
1938	2.4%			**1983**	45.9%	18.0%		**2028**		0.0%	0.0%
1939	2.4%			**1984**	20.0%	0.0%		**2029**		0.0%	0.0%
1940	2.4%	0.0%		**1985**	28.6%	0.0%		**2030**		0.0%	0.0%
1941	2.4%	0.0%		**1986**	9.1%	0.0%		**2031**		0.0%	4.8%
1942	2.4%	0.0%		**1987**	20.0%	0.0%		**2032**		0.0%	0.0%
1943	2.4%	0.0%		**1988**	33.3%	0.0%		**2033**		0.0%	0.0%
1944	2.4%	0.0%		**1989**	42.9%	0.0%		**2034**		0.0%	0.0%
1945	20.0%	0.0%		**1990**	41.2%	0.0%		**2035**		0.0%	0.0%
1946	2.4%	0.0%		**1991**	13.0%	0.0%		**2036**		0.0%	0.0%
1947	2.4%	0.0%		**1992**	9.1%	0.0%		**2037**		0.0%	0.0%
1948	2.4%	0.0%		**1993**	0.0%	0.0%		**2038**		0.0%	0.0%
1949	4.8%	0.0%		**1994**	0.0%	0.0%		**2039**		0.0%	0.0%
1950	2.4%	0.0%		**1995**	0.0%	0.0%		**2040**		0.0%	0.0%
1951	2.4%	0.0%		**1996**	13.0%	0.0%		**2041**		0.0%	0.0%
1952	2.4%	0.0%		**1997**	4.8%	0.0%		**2042**		0.0%	0.0%
1953	2.4%	0.0%		**1998**	0.0%	0.0%		**2043**		0.0%	0.0%
1954	2.4%	0.0%		**1999**	0.0%	0.0%		**2044**		0.0%	0.0%
1955	2.4%	0.0%		**2000**	4.8%	0.0%		**2045**		0.0%	0.0%
1956	2.4%	0.0%		**2001**	9.1%	0.0%		**2046**		0.0%	0.0%
1957	4.8%	0.0%		**2002**	20.0%	0.0%	0.0%	**2047**		0.0%	0.0%
1958	9.1%	0.0%		**2003**		0.0%	0.0%	**2048**		0.0%	0.0%
1959	2.4%	0.0%		**2004**		0.0%	4.8%	**2049**		0.0%	0.0%
1960	2.4%	0.0%		**2005**		0.0%	0.0%	**2050**		0.0%	0.0%
1961	0.0%	0.0%		**2006**		0.0%	0.0%	**2051**		0.0%	4.8%
1962	0.0%	0.0%		**2007**		0.0%	0.0%	**2052**		0.0%	4.8%
1963	0.0%	0.0%		**2008**		0.0%	0.0%	**2053**		0.0%	4.8%
1964	0.0%	0.0%		**2009**		0.0%	0.0%	**2054**		0.0%	4.8%
1965	0.0%	0.0%		**2010**		0.0%	0.0%	**2055**		0.0%	4.8%

The starting age distribution for each model is shown in Table C.6.

Table C.7 shows the average starting age adjustment factor by year of first exposure i.e. in 1921 the average starting age for Wave1&2 is 18.2 plus 20 years = 38.2 years. These factors reflect the fact that asbestos was introduced to an existing workforce in those early years (pre-1945), where the average age of the workforce at first exposure is older than the starting workforce. These factors reduce over time as the average age at first exposure to asbestos decreases, until a point when asbestos use was widespread and first exposure mostly occurred when workers left school and first started work.

Table C.6 – Age Profile at First Exposure

	Wave 1+2		Wave 3 Dom		Wave 3 Comm	
Age Band	Proportion	Average Age	Proportion	Average Age	Proportion	Average Age
0-20	86%	17.0	10%	9.0	20%	17.0
21-25	10%	22.5	15%	22.5	20%	22.5
26-30	2%	27.5	25%	27.5	20%	27.5
31-35	1%	32.5	20%	32.5	20%	32.5
36-40	1%	37.5	15%	37.5	10%	37.5
41+	1%	45.0	15%	45.0	10%	50.0
Average age		**18.2**		**30.0**		**28.7**

Table C.7 – Age Profile Adjustment by Year of First Exposure

YOFE	Wave 1+2	YOFE	Wave 1+2
1921	20	**1962**	0
1922	20	**1963**	0
1923	20	**1964**	0
1924	20	**1965**	0
1925	20	**1966**	0
1926	20	**1967**	0
1927	20	**1968**	0
1928	20	**1969**	0
1929	20	**1970**	0
1930	20	**1971**	0
1931	19	**1972**	0
1932	19	**1973**	0
1933	19	**1974**	0
1934	19	**1975**	0
1935	19	**1976**	0
1936	19	**1977**	0
1937	18	**1978**	0
1938	18	**1979**	0
1939	18	**1980**	0
1940	18	**1981**	0
1941	18	**1982**	0
1942	17	**1983**	0
1943	17	**1984**	0
1944	17	**1985**	0
1945	17	**1986**	0
1946	16	**1987**	0
1947	16	**1988**	0
1948	16	**1989**	0
1949	15	**1990**	0
1950	15	**1991**	0
1951	12	**1992**	0
1952	12	**1993**	0
1953	8	**1994**	0
1954	8	**1995**	0
1955	6	**1996**	0
1956	6	**1997**	0
1957	5	**1998**	0
1958	4	**1999**	0
1959	4	**2000**	0
1960	4	**2001**	0
1961	0	**2002**	0

It has been observed that most occupational asbestos exposure in the United Kingdom occurred between the ages of 20 and 50 (Hodgson et al, 2005). In our view it is reasonable to assume a similar distribution in Australia. Our age assumptions set out above are consistent with this range.

Table C.8 and Table C.9 summarise the mortality rates and surviving population by age. We made adjustments to the standard male mortality rates (from the ALT 1953-55, ALT 1960-62 and ALT 1990-92 life tables) to derive mortality rates for the exposed population, allowing for the gender mix and blue collar loadings. These adjustments were described in Section 5.3.2. We have not shown the ALT 1960-62 mortality rates in the following two tables, as these are similar to the ALT 1953-55 rates.

In our modelled workforces we have ignored any potential 'healthy worker effect', referring to the approach described by Professor Berry (Berry, 1991). This is where people must by definition not be chronically ill at the time they join a workforce. This effect declines over time as members of the group develop illnesses. The effect is expected to have a small impact on the projection.

Table C.8 – Mortality Rates by Age

	1953-1955	Proj to 1988		ALT1990-1992	Proj from 1989		Blue Collar Loading	
Age	Males	W1+2 and Occup post-03	W3 Dom	Males	W1+2 and Occup post-03	W3 Dom	W1+2 and Occup post-03	W3 Dom
20	0.19%	0.18%	0.16%	0.13%	0.12%	0.12%	30%	0%
21	0.19%	0.18%	0.16%	0.13%	0.13%	0.12%	30%	0%
22	0.19%	0.18%	0.16%	0.13%	0.13%	0.12%	30%	0%
23	0.18%	0.18%	0.15%	0.13%	0.13%	0.12%	30%	0%
24	0.18%	0.17%	0.14%	0.13%	0.13%	0.12%	30%	0%
25	0.17%	0.17%	0.14%	0.13%	0.13%	0.12%	30%	0%
26	0.17%	0.16%	0.14%	0.13%	0.13%	0.12%	30%	0%
27	0.17%	0.16%	0.14%	0.13%	0.13%	0.12%	30%	0%
28	0.17%	0.16%	0.14%	0.13%	0.13%	0.12%	30%	0%
29	0.17%	0.16%	0.15%	0.13%	0.13%	0.12%	30%	0%
30	0.17%	0.17%	0.15%	0.13%	0.13%	0.12%	30%	0%
31	0.17%	0.17%	0.15%	0.13%	0.13%	0.13%	30%	0%
32	0.18%	0.18%	0.16%	0.13%	0.13%	0.13%	30%	0%
33	0.19%	0.18%	0.17%	0.14%	0.13%	0.13%	30%	0%
34	0.20%	0.19%	0.17%	0.14%	0.14%	0.13%	30%	0%
35	0.21%	0.20%	0.18%	0.14%	0.14%	0.13%	30%	0%
36	0.22%	0.21%	0.20%	0.15%	0.14%	0.14%	30%	0%
37	0.23%	0.23%	0.21%	0.15%	0.15%	0.14%	30%	0%
38	0.25%	0.25%	0.23%	0.16%	0.16%	0.15%	30%	0%
39	0.27%	0.27%	0.26%	0.17%	0.16%	0.16%	30%	0%
40	0.30%	0.29%	0.29%	0.18%	0.17%	0.17%	30%	0%
41	0.32%	0.32%	0.31%	0.19%	0.18%	0.18%	30%	0%
42	0.36%	0.35%	0.35%	0.20%	0.20%	0.19%	30%	0%
43	0.39%	0.38%	0.38%	0.22%	0.21%	0.21%	30%	0%
44	0.43%	0.42%	0.42%	0.24%	0.23%	0.22%	30%	0%
45	0.48%	0.47%	0.46%	0.26%	0.25%	0.24%	30%	0%
46	0.53%	0.52%	0.51%	0.28%	0.28%	0.27%	30%	0%
47	0.59%	0.58%	0.56%	0.31%	0.30%	0.29%	30%	0%
48	0.66%	0.65%	0.62%	0.34%	0.33%	0.32%	30%	0%
49	0.73%	0.72%	0.69%	0.38%	0.37%	0.36%	29%	0%
50	0.82%	0.80%	0.76%	0.42%	0.41%	0.40%	27%	0%
51	0.91%	0.90%	0.85%	0.46%	0.45%	0.44%	26%	0%
52	1.02%	1.00%	0.94%	0.52%	0.51%	0.49%	24%	0%
53	1.14%	1.11%	1.04%	0.58%	0.57%	0.55%	23%	0%
54	1.26%	1.24%	1.15%	0.64%	0.63%	0.61%	21%	0%
55	1.40%	1.37%	1.27%	0.72%	0.71%	0.68%	19%	0%
56	1.55%	1.52%	1.40%	0.80%	0.79%	0.76%	17%	0%
57	1.70%	1.67%	1.55%	0.90%	0.88%	0.85%	16%	0%
58	1.87%	1.83%	1.70%	1.00%	0.98%	0.95%	14%	0%
59	2.04%	2.00%	1.88%	1.12%	1.09%	1.06%	14%	0%
60	2.22%	2.18%	2.07%	1.24%	1.22%	1.18%	13%	0%
61	2.42%	2.37%	2.28%	1.38%	1.35%	1.31%	13%	0%
62	2.64%	2.58%	2.51%	1.53%	1.50%	1.45%	13%	0%
63	2.87%	2.81%	2.75%	1.69%	1.66%	1.61%	13%	0%
64	3.13%	3.07%	3.01%	1.87%	1.83%	1.78%	13%	0%
65	3.41%	3.34%	3.28%	2.06%	2.02%	1.96%	13%	0%
66	3.72%	3.65%	3.56%	2.27%	2.22%	2.15%	12%	0%
67	4.07%	3.98%	3.86%	2.49%	2.44%	2.36%	12%	0%
68	4.45%	4.36%	4.18%	2.73%	2.68%	2.59%	11%	0%
69	4.86%	4.76%	4.53%	3.00%	2.94%	2.85%	10%	0%
70	5.32%	5.21%	4.92%	3.29%	3.22%	3.13%	9%	0%
71	5.80%	5.69%	5.35%	3.62%	3.54%	3.43%	8%	0%
72	6.32%	6.20%	5.81%	3.98%	3.90%	3.78%	7%	0%
73	6.87%	6.73%	6.31%	4.38%	4.29%	4.16%	5%	0%
74	7.45%	7.30%	6.85%	4.82%	4.72%	4.58%	4%	0%
75	8.06%	7.89%	7.42%	5.31%	5.20%	5.04%	3%	0%
76	8.70%	8.53%	8.03%	5.85%	5.73%	5.55%	2%	0%
77	9.41%	9.22%	8.68%	6.43%	6.30%	6.11%	2%	0%
78	10.18%	9.97%	9.39%	7.07%	6.93%	6.72%	1%	0%
79	11.03%	10.80%	10.18%	7.76%	7.61%	7.37%	0%	0%
80	11.96%	11.72%	11.04%	8.50%	8.33%	8.08%	0%	0%
81	12.97%	12.71%	11.98%	9.30%	9.11%	8.83%	0%	0%
82	14.06%	13.78%	13.00%	10.14%	9.94%	9.63%	0%	0%
83	15.21%	14.91%	14.09%	11.04%	10.81%	10.48%	0%	0%
84	16.43%	16.10%	15.26%	11.98%	11.74%	11.38%	0%	0%
85	17.69%	17.34%	16.49%	12.98%	12.72%	12.33%	0%	0%
86	19.01%	18.63%	17.79%	14.02%	13.74%	13.32%	0%	0%
87	20.40%	19.99%	19.14%	15.11%	14.81%	14.36%	0%	0%
88	21.85%	21.41%	20.54%	16.26%	15.93%	15.45%	0%	0%
89	23.38%	22.91%	21.98%	17.44%	17.09%	16.57%	0%	0%
90	25.01%	24.51%	23.44%	18.62%	18.25%	17.69%	0%	0%
91	26.74%	26.21%	24.93%	19.94%	19.54%	18.94%	0%	0%
92	28.58%	28.01%	26.43%	21.39%	20.96%	20.32%	0%	0%
93	30.51%	29.90%	27.94%	22.75%	22.30%	21.62%	0%	0%
94	32.54%	31.89%	29.47%	24.09%	23.61%	22.89%	0%	0%
95	34.66%	33.97%	31.02%	25.52%	25.00%	24.24%	0%	0%
96	36.88%	36.14%	32.58%	26.91%	26.37%	25.57%	0%	0%
97	39.19%	38.40%	34.16%	28.12%	27.55%	26.71%	0%	0%
98	41.58%	40.75%	35.77%	29.07%	28.49%	27.62%	0%	0%
99	44.05%	43.16%	37.40%	29.83%	29.23%	28.34%	0%	0%
100	46.58%	45.65%	39.03%	30.45%	29.84%	28.93%	0%	0%

Table C.9 – Surviving Population by Age (relative to 100,000 at age 20)

	1953-1955 Males			ALT1990-1992 Males		
Age	Unadjusted	W1+2 and Occup post-03	W3 Dom	Unadjusted	W1+2	W3 Dom
20	100,000	100,000	100,000	100,000	100,000	100,000
21	99,814	99,763	99,836	99,874	99,839	99,880
22	99,626	99,524	99,674	99,744	99,674	99,757
23	99,441	99,288	99,518	99,613	99,508	99,633
24	99,261	99,059	99,369	99,484	99,343	99,510
25	99,087	98,838	99,225	99,355	99,178	99,387
26	98,919	98,624	99,087	99,226	99,014	99,264
27	98,754	98,415	98,950	99,097	98,850	99,142
28	98,591	98,208	98,812	98,968	98,686	99,019
29	98,428	98,001	98,671	98,839	98,523	98,897
30	98,264	97,793	98,528	98,711	98,360	98,775
31	98,097	97,581	98,381	98,581	98,196	98,652
32	97,926	97,365	98,230	98,451	98,031	98,528
33	97,750	97,141	98,075	98,320	97,864	98,404
34	97,567	96,910	97,912	98,187	97,696	98,277
35	97,377	96,669	97,742	98,052	97,524	98,148
36	97,177	96,417	97,562	97,913	97,348	98,016
37	96,965	96,149	97,369	97,769	97,166	97,879
38	96,738	95,862	97,160	97,620	96,977	97,738
39	96,495	95,555	96,932	97,465	96,781	97,590
40	96,231	95,222	96,682	97,302	96,575	97,435
41	95,945	94,862	96,406	97,130	96,357	97,272
42	95,634	94,470	96,104	96,947	96,127	97,098
43	95,295	94,043	95,772	96,752	95,880	96,912
44	94,923	93,576	95,407	96,543	95,615	96,713
45	94,514	93,062	95,007	96,316	95,329	96,497
46	94,062	92,495	94,569	96,069	95,018	96,262
47	93,563	91,870	94,089	95,799	94,678	96,005
48	93,010	91,178	93,560	95,503	94,305	95,723
49	92,397	90,412	92,979	95,178	93,897	95,414
50	91,719	89,575	92,340	94,820	93,450	95,072
51	90,968	88,661	91,634	94,423	92,963	94,695
52	90,136	87,663	90,858	93,985	92,432	94,277
53	89,217	86,576	90,004	93,499	91,851	93,814
54	88,202	85,394	89,067	92,960	91,215	93,300
55	87,088	84,117	88,041	92,361	90,520	92,729
56	85,867	82,743	86,921	91,696	89,761	92,095
57	84,536	81,271	85,702	90,959	88,932	91,392
58	83,096	79,701	84,377	90,143	88,027	90,613
59	81,545	78,034	82,941	89,241	87,040	89,751
60	79,884	76,266	81,385	88,246	85,960	88,800
61	78,110	74,393	79,702	87,150	84,781	87,754
62	76,220	72,406	77,887	85,949	83,491	86,604
63	74,211	70,302	75,933	84,634	82,083	85,346
64	72,079	68,074	73,842	83,202	80,551	83,974
65	69,823	65,723	71,618	81,647	78,889	82,483
66	67,441	63,248	69,268	79,965	77,095	80,868
67	64,929	60,656	66,801	78,152	75,172	79,127
68	62,289	57,957	64,222	76,207	73,124	77,256
69	59,520	55,154	61,536	74,125	70,951	75,251
70	56,626	52,260	58,747	71,904	68,657	73,109
71	53,616	49,290	55,858	69,538	66,242	70,824
72	50,505	46,266	52,872	67,024	63,710	68,391
73	47,311	43,206	49,799	64,360	61,062	65,809
74	44,061	40,137	46,654	61,544	58,300	63,074
75	40,780	37,080	43,458	58,580	55,426	60,187
76	37,495	34,053	40,232	55,472	52,446	57,153
77	34,232	31,076	37,002	52,229	49,367	53,980
78	31,011	28,159	33,789	48,869	46,199	50,681
79	27,855	25,320	30,615	45,413	42,962	47,276
80	24,784	22,570	27,499	41,888	39,677	43,789
81	21,820	19,925	24,464	38,326	36,370	40,252
82	18,990	17,393	21,534	34,763	33,057	36,697
83	16,320	14,996	18,736	31,237	29,771	33,161
84	13,838	12,761	16,095	27,790	26,552	29,685
85	11,564	10,706	13,639	24,461	23,435	26,307
86	9,518	8,850	11,390	21,287	20,455	23,064
87	7,709	7,201	9,363	18,303	17,644	19,992
88	6,136	5,762	7,571	15,537	15,031	17,122
89	4,796	4,528	6,016	13,011	12,636	14,477
90	3,674	3,491	4,694	10,742	10,477	12,079
91	2,756	2,635	3,594	8,742	8,565	9,942
92	2,019	1,944	2,698	6,999	6,892	8,059
93	1,442	1,400	1,985	5,502	5,447	6,422
94	1,002	981	1,430	4,250	4,233	5,034
95	676	668	1,009	3,226	3,233	3,882
96	442	441	696	2,403	2,425	2,941
97	279	282	469	1,756	1,785	2,189
98	170	174	309	1,263	1,293	1,604
99	99	103	198	896	925	1,161
100	55	58	124	628	655	832

Table C.10 illustrates the application of our incidence model. It projects Wave 1&2 cases diagnosed in 2015. Detail is shown for exposure in the 1960s (with other periods summarised).

Table C.10 – Incidence Projection for Wave 1&2 2015 Cases

	Year of First Exposure (YOFE)												
	Earlier	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Later	Total
Year of Last Exposure	**Index of Survivors in 2015[1]**												
Pre-1960	1,778												1,778
1960	117	211											328
1961	115	80	55										251
1962	113	79	21	82									295
1963	111	77	21	31	28								268
1964	108	75	20	31	11	78							324
1965	106	74	20	30	11	30	163						433
1966	104	72	19	29	10	29	62	241					567
1967	102	71	19	29	10	29	61	91	75				487
1968	100	70	19	28	10	28	59	90	29	155			587
1969	98	68	18	28	10	28	58	88	28	59	8		491
Later	4,798	3,340	895	1,356	479	1,348	2,849	4,304	1,371	2,888	158	145,240	169,027
Total	7,650	4,217	1,107	1,645	570	1,570	3,252	4,814	1,503	3,102	166	145,240	174,835
	Years of Cumulative Exposure												
Pre-1960	various												
1960	various	0.5											
1961	various	1.0	0.5										
1962	various	2.0	1.0	0.5									
1963	various	3.0	2.0	1.0	0.5								
1964	various	4.0	3.0	2.0	1.0	0.5							
1965	various	5.0	4.0	3.0	2.0	1.0	0.5						
1966	various	6.0	5.0	4.0	3.0	2.0	1.0	0.5					
1967	various	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.5				
1968	various	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.5			
1969	various	9.0	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.5		
Later	various	various	various	various	various	various	various	various	various	various	various	various	

Risk Weight by Calendar Year of Exposure										
Calendar Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Risk Weight	225%	210%	199%	202%	192%	182%	178%	149%	127%	97%

	Year of First Exposure (YOFE)												
	Earlier	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Later	Total
	Incidence Rate												
Pre-1960	various												
1960	various	0.005%											
1961	various	0.018%	0.004%										
1962	various	0.068%	0.016%	0.004%									
1963	various	0.148%	0.063%	0.015%	0.004%								
1964	various	0.254%	0.136%	0.059%	0.014%	0.003%							
1965	various	0.380%	0.233%	0.126%	0.054%	0.013%	0.003%						
1966	various	0.526%	0.349%	0.215%	0.116%	0.049%	0.012%	0.003%					
1967	various	0.682%	0.478%	0.319%	0.195%	0.104%	0.044%	0.010%	0.002%				
1968	various	0.839%	0.611%	0.429%	0.283%	0.170%	0.089%	0.036%	0.008%	0.002%			
1969	various	0.991%	0.742%	0.539%	0.373%	0.242%	0.143%	0.073%	0.029%	0.006%	0.001%		
Later	various	various	various	various	various	various	various	various	various	various	various	various	
Year of Last Exposure	**Projected Cases in 2015**												
Pre-1960	2.56												2.56
1960	0.46	0.01											0.47
1961	0.64	0.01	0.00										0.65
1962	0.83	0.05	0.00	0.00									0.89
1963	1.05	0.11	0.01	0.00	0.00								1.18
1964	1.28	0.19	0.03	0.02	0.00	0.00							1.52
1965	1.51	0.28	0.05	0.04	0.01	0.00	0.00						1.89
1966	1.75	0.38	0.07	0.06	0.01	0.01	0.01	0.01					2.31
1967	1.99	0.48	0.09	0.09	0.02	0.03	0.03	0.01	0.00				2.74
1968	2.20	0.58	0.11	0.12	0.03	0.05	0.05	0.03	0.00	0.00			3.18
1969	2.38	0.68	0.14	0.15	0.04	0.07	0.08	0.06	0.01	0.00	0.00		3.61
Later	210.75	79.43	17.74	22.29	6.45	14.61	24.58	29.04	7.15	11.60	0.49	65.12	489.25
Total	227.39	82.22	18.25	22.78	6.55	14.77	24.75	29.16	7.16	11.61	0.49	65.12	510.24

1 We measure changes in exposure to asbestos each year based on the model of consumption plus removals, as described in our full report. This volume of asbestos fibre consumed is a proxy for the number of people exposed. After exposure we project the percentage of people in this group who survive to later years i.e. do not die from other causes. As such the index of survivors shown in this table does not represent the actual number of people exposed. Changes in other risk factors over time (e.g. changing mix of types of asbestos or improvements in the handling of ACMs) are captured in the risk weights.

Table C.10 shows variation in the number of cases diagnosed in 2015, by year of first exposure in the 1960s. The number of assumed entrants to the exposed population varies by year. We also assume additional decrements after the first year of exposure in some cases (see Table C.5), so that our standard exposure continuation rates (see Table C.4) produce the required total level of exposure in each calendar year from all prior entry cohorts.

C.5 Number and Allocation of Cases

C.5.1 Number of Cases – Late Reporting Allowance

Table C.11 shows the historical pattern for reporting cases to the AMR for the complete years available (2011-2014). It also shows our allowance for unreported cases as at the date of this report (also referred to as 'IBNR', or Incurrred But Not Reported). We add the IBNR cases to those reported to date to estimate the ultimate number of cases for each year of diagnosis.

Table C.11 – Development of AMR Cases

	Development Year					
Year of Diagnosis	0	1	2	3	IBNR	Ultimate
2011	612	27	24	25	5	693
2012	619	33	64		15	731
2013	575	99			30	704
2014	653				50	703

The majority of cases diagnosed in a year are reported in the same year (development year 0), but some cases are reported to the AMR in later development years. Our IBNR allowances are slightly lower than historically observed levels. This reflects an apparent catch up in reporting cases by the state cancer registries to the AMR in calendar year 2014. In the context of this catch up our late reporting allowances do not seem unreasonable.

There was no apparent trend in the ultimate number of mesotheliomas over the period shown above. The average number of ultimate cases per annum from Table C.11 is 708. We calibrated our aggregate projection to this level in 2013, as this is close to the mid-point for the period 2011-2014.

C.5.2 Detailed Allocation of AMR Cases

Table C.12 summarises the detailed allocation of the 539 mesothelioma cases in the AMR data with exposure information, by occupational, non-occupational or unconfirmed exposures. The allocation follows the process described in Section 3.5. By their nature unconfirmed exposures cannot be allocated to the occupational and non-occupational groups.

Table C.12 – Allocation of AMR Cases

Source	Occupational Exposure	Non-Occ Exposure	Both	Total
Occpuational	**122.0**	**-**	**207.9**	**329.9**
Asbestos mining / milling	-	-	1.0	1.0
Abestos removalist	-	-	0.3	0.3
Cement factory worker	2.4	-	1.5	3.9
Furnace industry	1.0	-	1.8	2.8
Insulator	-	-	2.3	2.3
Land transport	5.2	-	12.8	18.0
Textile worker	1.0	-	0.8	1.8
Trades	74.8	-	161.5	236.3
Water transport	8.3	-	22.5	30.9
Other occupation	29.3	-	3.3	32.6
Non-Occupational	**-**	**161.0**	**16.1**	**177.1**
Serviced brakes and clutch	-	13.7	5.3	19.0
Worker brought dust home ('dusty families')	-	25.9	1.0	26.9
Lived in asbestos house	-	13.2	1.1	14.3
Lived near industry	-	2.3	0.4	2.7
Home renovation	-	45.4	4.3	49.6
Lived in house during renovation	-	41.7	2.4	44.0
Wittenoom	-	4.4	0.6	5.0
Other asbestos towns	-	-	0.4	0.4
Other exposure	-	14.5	0.8	15.2
Unconfirmed Exposure Source	**-**	**-**	**32.0**	**32.0**
Total	**122.0**	**161.0**	**256.0**	**539.0**

Table C.12 shows that 122 cases (23%) had confirmed occupational exposures only, based on their exposure assessment. A further 161 (30%) identified non-occupational exposures as their only source, and the remaining 256 patients (47%) identified both as areas where they were exposed to asbestos. This last group included 32 cases (6%) where the exposure source was unconfirmed.

A majority (330, or 61%) of cases identified some occupational exposure, while a further 21% (111) of patients identified asbestos exposures in their home (e.g. during a home renovation or residing near asbestos industry). As noted above, 6% had unconfirmed exposure. The remaining 12% (66) identified other environmental (non-occupational) exposures.

There are different groups with occupational and non-occupational exposure. It is important to note that one individual with occupational exposure can also be in the non-occupational group. This is demonstrated in the table above by the cases allocated to the 'Both' exposure category.

As seen in Figure 3.1 the number and proportion of female mesothelioma cases is rising. Rising female incidence rates have also been observed by others (Soeberg et al, 2016a). This is likely due to the changing sources of exposure for those recently diagnosed with mesothelioma. Specifically:

- Only a small number of women were employed in mining, milling or transportation up until the 1970s – areas where asbestos exposure levels were very high. This Wave1&2 exposure is the cause of the highest proportion of cases to date, due to its earlier profile and heavy exposure. The low female employment rates in these industries explain the high proportion of male cases. This source of cases has peaked and should comprise a declining percentage of all future cases.

- 'Dusty families' covers those family members exposed to fibres brought home on the clothes of a worker. In these cases, women and children were exposed to reasonably high levels of asbestos. A significant number of female cases have been observed from this source. These are generally attributed to the worker's wife or partner washing the dusty clothes on a regular basis.
- The most significant causes of mesothelioma in women to date are 'other occupations' (not identified, and different to the other jobs listed) and third wave non-occupational exposures (e.g. home renovators, those living in a house during renovation and those living in a house containing asbestos). These findings are based on the AMR data. For these sources of exposure the cases are more evenly spread among men and women.
- Women comprise only 25% of the unidentified exposure cases to date.

Table C.13 and Table C.14 show the number of female cases and the female proportion, by type of asbestos exposure. The format is the same as that used in Table C.12. We analysed this information to test if the split by gender for each source was consistent with our general understanding of where men and women mostly received asbestos exposures. This served as a high level check on the data. It also assisted us in setting the 2013 base year split by wave, as all AMR cases identified the person's gender.

Table C.13 – Exposure Profile - Females

Source	Occupational Exposure	Non-Occ Exposure	Both	Total
Occpuational	**16.0**	**-**	**4.3**	**20.3**
Asbestos mining / milling	-	-	-	-
Abestos removalist	-	-	-	-
Cement factory worker	-	-	-	-
Furnace industry	-	-	-	-
Insulator	-	-	-	-
Land transport	-	-	-	-
Textile worker	1.0	-	0.8	1.8
Trades	2.0	-	1.4	3.4
Water transport	-	-	-	-
Other occupation	13.0	-	2.0	15.0
Non-Occupational	**-**	**81.0**	**0.7**	**81.7**
Serviced brakes and clutch	-	0.4	-	0.4
Worker brought dust home ('dusty families')	-	21.3	0.3	21.6
Lived in asbestos house	-	9.0	-	9.0
Lived near industry	-	2.3	0.1	2.3
Home renovation	-	14.9	0.2	15.1
Lived in house during renovation	-	24.9	0.1	25.0
Wittenoom	-	3.7	-	3.7
Other asbestos towns	-	-	-	-
Other exposure	-	4.7	0.1	4.8
Unconfirmed Exposure Source	**-**	**-**	**8.0**	**8.0**
Total	**16.0**	**81.0**	**13.0**	**110.0**

Table C.14 – Exposure Profile – Females (Percentages)

Source	Occupational Exposure	Non-Occ Exposure	Both	% Total
Occpuational	**13%**	**0%**	**2%**	**6%**
Asbestos mining / milling	0%	0%	0%	0%
Abestos removalist	0%	0%	0%	0%
Cement factory worker	0%	0%	0%	0%
Furnace industry	0%	0%	0%	0%
Insulator	0%	0%	0%	0%
Land transport	0%	0%	0%	0%
Textile worker	100%	0%	100%	100%
Trades	3%	0%	1%	1%
Water transport	0%	0%	0%	0%
Other occupation	44%	0%	61%	46%
Non-Occupational	**0%**	**50%**	**5%**	**46%**
Serviced brakes and clutch	0%	3%	0%	2%
Worker brought dust home ('dusty families')	0%	82%	31%	80%
Lived in asbestos house	0%	68%	0%	63%
Lived near industry	0%	100%	18%	87%
Home renovation	0%	33%	5%	30%
Lived in house during renovation	0%	60%	4%	57%
Wittenoom	0%	83%	0%	73%
Other asbestos towns	0%	0%	0%	0%
Other exposure	0%	33%	10%	32%
Unconfirmed Exposure Source	**0%**	**0%**	**25%**	**25%**
Total	**13%**	**50%**	**5%**	**20%**

Females comprise half of all non-occupational cases in this dataset but only 13% of occupational-only exposures (among the confirmed exposures). The overall proportion (20%) among the cases surveyed is higher than, but broadly comparable to, the broader AMR database (18%; refer Table 3.1). This suggests that the female exposure survey response rate was slightly higher than for men.

D Summary of Results

The following table summarises the total projected cases as shown in Figure 6.1 and Table 6.1.

Table D.1 – Total Projected Cases: 2015 to 2100

	Wave					Wave					Wave			
Year	1+2	3 Dom	3 Comm	Backg.	Year	1+2	3 Dom	3 Comm	Backg.	Year	1+2	3 Dom	3 Comm	Backg.
1988	198	20	0	25	**2026**	404	163	0	39	**2064**	9	12	4	33
1989	214	23	0	25	**2027**	388	160	0	39	**2065**	8	11	4	33
1990	230	27	0	26	**2028**	373	156	0	39	**2066**	7	10	4	33
1991	247	31	0	26	**2029**	357	152	0	39	**2067**	6	9	4	33
1992	264	36	0	26	**2030**	341	147	0	39	**2068**	5	9	4	33
1993	281	41	0	27	**2031**	325	142	0	38	**2069**	4	8	5	33
1994	299	46	0	27	**2032**	309	137	0	38	**2070**	3	7	5	33
1995	316	52	0	27	**2033**	292	132	0	38	**2071**	3	7	5	33
1996	334	57	0	27	**2034**	276	126	0	38	**2072**	2	6	5	33
1997	351	63	0	28	**2035**	261	121	0	37	**2073**	2	6	5	33
1998	368	70	0	28	**2036**	245	115	0	37	**2074**	1	6	5	33
1999	385	76	0	28	**2037**	230	109	0	37	**2075**	1	6	5	33
2000	400	82	0	29	**2038**	215	104	0	36	**2076**	1	5	5	33
2001	416	89	0	29	**2039**	200	98	1	36	**2077**	1	5	5	33
2002	430	96	0	29	**2040**	186	92	1	36	**2078**	1	5	5	33
2003	444	102	0	30	**2041**	172	87	1	35	**2079**	0	5	4	33
2004	456	109	0	30	**2042**	159	82	1	35	**2080**	0	5	4	33
2005	468	115	0	30	**2043**	146	76	1	35	**2081**	0	4	4	33
2006	478	122	0	31	**2044**	134	71	1	34	**2082**	0	4	4	33
2007	487	128	0	32	**2045**	122	66	1	34	**2083**	0	4	4	33
2008	495	134	0	32	**2046**	111	62	1	34	**2084**	0	4	4	33
2009	501	139	0	33	**2047**	100	57	1	34	**2085**	0	4	4	33
2010	506	145	0	33	**2048**	90	53	2	34	**2086**	0	4	4	33
2011	510	150	0	34	**2049**	81	49	2	33	**2087**	0	4	3	33
2012	512	154	0	34	**2050**	72	45	2	33	**2088**	0	4	3	33
2013	513	159	0	35	**2051**	64	42	2	33	**2089**	0	4	3	33
2014	512	162	0	35	**2052**	57	38	2	33	**2090**	0	3	3	33
2015	510	165	0	36	**2053**	50	35	2	33	**2091**	0	3	3	33
2016	507	168	0	37	**2054**	44	32	2	33	**2092**	0	3	3	33
2017	502	170	0	37	**2055**	39	29	3	33	**2093**	0	3	3	33
2018	495	172	0	38	**2056**	33	26	3	33	**2094**	0	3	2	33
2019	488	173	0	38	**2057**	29	24	3	33	**2095**	0	3	2	33
2020	479	173	0	38	**2058**	25	22	3	33	**2096**	0	3	2	33
2021	468	173	0	39	**2059**	21	20	3	33	**2097**	0	3	2	33
2022	457	172	0	39	**2060**	18	18	3	33	**2098**	0	3	2	33
2023	445	171	0	39	**2061**	16	16	4	33	**2099**	0	3	2	33
2024	432	169	0	39	**2062**	13	15	4	33	**2100**	0	3	2	33
2025	418	166	0	39	**2063**	11	13	4	33					

The ability to accurately classify cases from some of these sources will be difficult in future. This is because an increasing proportion of cases will be due to low doses of exposure. We expect that identifying the likely source of exposure in these cases will often be difficult.

E About Finity

Finity Consulting Pty Limited (Finity) is an actuarial and insurance consulting company, focused on the general and health insurance industries. Finity is Australia's largest independent general insurance consulting practice, providing analysis to advise and assist organisations with their strategy and financial management.

We currently have 101 staff in Sydney, Melbourne and New Zealand, including 44 Fellows of the Institute of Actuaries of Australia (fully qualified actuaries) as well as 18 Associates of the Institute and actuarial students.

Finity is an Australian privately owned company. We are wholly owned and managed by our staff (mainly the firm's Principals).

E.1 Our Asbestos Credentials

Finity is recognised in the industry as a leading actuarial advisor on modelling Australian ARD liabilities. Landmark papers to actuarial seminars in 1991 and 1993 by Geoff Atkins and Tim Andrews (both of whom are Finity Principals) established the basis for Australian actuarial work in this field.

Our staff wrote a paper in 2000 which alerted the industry to claims deterioration during the 1990s and emerging asbestos-driven bankruptcies in the United States. In 2009 we published research on the uncertainty around ARD liabilities and how defendants, insurers and reinsurers might set risk margins above central estimates of their liabilities (e.g. for balance sheet provisioning or prudential regulation).

Our continuing research efforts over more than 20 years allow us to maintain up-to-date best practice ARD projection models, and also enhance our understanding of the drivers of the number of asbestos cases and asbestos liabilities. Key papers resulting from this research are:

- *Asbestos-Related Diseases – The insurance cost (1991)* – Atkins and Andrews
- *Asbestos-Related Diseases – The insurance cost Part 2 (1993)* – Atkins and Andrews
- *Recent Trends in Asbestos-Related Diseases (1996)* – Atkins, Watson and Smith
- *Asbestos Liabilities (2000)* – Watson and Hurst
- *IAAust Asbestos Working Group Discussion Paper (2004)* – Prepared by the Institute of Actuaries of Australia Asbestos Working Group, chaired by Bruce Watson
- *Asbestos Liabilities & the New Risk Margins Framework (2009)* – Riley and Watson.

We have advised most of the companies and authorities which have significant exposure to ARD claims in Australia. At present we value the liabilities for around 15 defendants, insurers and reinsurers with ARD liabilities, so have a broad view of the issues facing defendants and their insurers. While specific details of this work cannot usually be made available, the body of knowledge which we have developed through this work and through our continuing research provides us with detailed and up-to-date knowledge of the ARD medical and claim environment in Australia and overseas.

Finity has an asbestos practice of 15 actuarial staff. The team meets regularly throughout the year and focuses on monitoring new medical, epidemiological, legal and political developments, both in Australia and overseas, so that we can alert our clients to significant events and maintain up-to-date projection models.