TRANSCRIPT OF PROCEEDINGS

ACM MARK BINSKIN AC (Retd), Chair

THE HON DR ANNABELLE BENNETT AC SC, Commissioner

PROF ANDREW MACINTOSH, Commissioner

IN THE MATTER OF THE ROYAL COMMISSION INTO

NATIONAL NATURAL DISASTER ARRANGEMENTS

HEARING BLOCK 1, DAY 1 TRANSCRIPT

CANBERRA

10:00 AM, MONDAY, 25 MAY 2020

MS D HOGAN-DORAN SC and MS J AMBIKAPATHY appear as Counsel Assisting

<RESUMING 10:02 AM>

COMMISSIONER BINSKIN: Good morning. This is the beginning of the first substantive hearing of the Royal Commission into National Natural Disaster Arrangements. I begin by acknowledging the traditional owners of the land on which we meet today, the Ngunnawal people, and pay my respects to their elders, past, presents and emerging. I also acknowledge and pay my respects to the traditional custodians of country throughout Australia, their connections to land, sea and community and to all elders past, present and emerging. I extend that respect to all Aboriginal and Torres Strait Islander people watching today.

I also acknowledge and welcome my fellow Commissioners, the Honourable Dr Annabelle Bennett and Professor Andrew Macintosh, who join me here today. At the outset, we reaffirm our recognition of the profound impact of natural disasters, in particular the 2019-2020 bushfire season have had on our nation. While it is necessary to address the current worldwide COVID-19 pandemic, we have not forgotten the devastation of the bushfires or the ongoing effects experienced by those in disaster-affected communities across the country. We have visited many of these communities and appreciate the challenges they are still facing.

We know many of those communities across Australia are also still grieving. The tragic loss of life, the destruction of homes, the significant loss of livestock and millions of hectares of forest has been devastating, and continues to deeply affect people and their recovery. In many cases the ongoing effects of the bushfire season are being further compounded by the measures necessary to address the COVID-19 pandemic. On behalf of the Commission, I extend my deepest sympathy to those who have lost loved ones, or have suffered injuries or loss. We also acknowledge those who continue to suffer.

We encourage anyone listening today who needs support through this time to contact Lifeline, Australia's dedicated support service, and further details and support available can be found on our website. Commissioners and I are acutely aware of the inevitability of the next bushfire season and those to come. To that end, we have moved swiftly to conduct our inquiry as expeditiously as possible. During our community forums in fire-affected communities earlier this year, many people recounted their experiences of the recent bushfires. Those stories are part of our history and deserve a place amongst the stories of our time. This is why we recently launched our 2019/2020 Bushfire History Project, inviting people to share their videos or photographs taken during the bushfires or of the ongoing recovery. People can also submit a short video account of what they experienced during the bushfires. This collection of videos and photographs will be catalogued for our future generations to understand the impact that the 2019-2020 bushfires had on our nation and our people.

Further information on this important historical project can be found on our website. As I mentioned earlier, today marks the beginning of our substantive hearings. To comply with the national COVID-19 health measures, our public hearings will be

conducted electronically with proceedings live streamed via our website. Members of the public would normally be welcome, and indeed invited, to attend Royal Commission hearings in person; however, that is not possible. Our hearings will only have essential personnel in the hearing room with all witnesses appearing by video link or giving their evidence by pre-prepared videos.

Likewise, the public health measures have had an impact on those who we have been engaging with the Commission. We acknowledge the pressures that the current health crisis has placed on a number of entities engaging with us, and we have been pleased to be flexible to enable engagement with this inquiry alongside that critical response. We thank the many individuals and we thank the organisations who have assisted the communication - sorry, the Commission in its work to date.

The Commissioners and I recognise that each of us brings with us a diverse professional background and experiences that assist us in conducting our inquiry. This includes knowledge of different government entities and involvement with different experts and organisations in both a professional and a personal capacity, or both. Commissioners have agreed that in any situation which may give rise to an actual or perceived conflict of interest, Commissioners will openly identify the particulars of that possible conflict to one another, to our official secretary, and counsel assisting the Commission, where appropriate, will take further mitigatory action.

There have been a number of parties who have been granted leave to appear and the terms on which that leave has been granted have been communicated to them. The parties granted leave will be published on our website. Due to the technical complexities involved in the use of video conferencing facilities, I will not ask each party's representatives to formally announce their appearance. And, with that, thank you, Ms Hogan-Doran.

MS HOGAN-DORAN SC: Commissioners, time is short and so I will make only brief remarks before calling the first of today's witnesses on the changing global climate and natural disaster risk.

Much has happened in the five weeks that have passed since our ceremonial hearing on 16 April. The ongoing impact of the global coronavirus pandemic has been profound. As the evidence will show, the recovery from the devastating impacts of the 2019-2020 bushfire season has been slowed and fragmented. Planning for future seasons appears to have been interrupted.

As to the logistical challenges for the Commission in preparing substantive hearings during a global pandemic, the constraints have been daunting. I acknowledge and give my personal thanks to the many people who have assisted this Royal Commission during this difficult time. Commission staff, solicitors and counsel have worked tirelessly, often times in isolation at home, or in Canberra far away from young families and elderly relatives, to ready the matters for hearing.

When I addressed you in April, the Royal Commission had received about 400 submissions. That number quickly grew to some 1700 submissions. In addition to preparing this fortnight's public hearings, several background papers and the first of several issues papers have been prepared and published. Video consultations have commenced with various stakeholders and many more are planned for coming weeks.

In these hearings over the next two weeks, up to 50 witnesses will assist the Royal Commission. Each has been issued either a compulsory notice to give a statement of information to themselves or to their organisation, and each will attend under summons.

While this hearing block will largely involve evidence from Commonwealth Government agencies and industry representatives, the Commission will also hear evidence from members of the communities affected by the devastating 2019/2020 bushfires. This evidence should serve to reinforce the importance of the Commission's work.

Our approach to the evidence will be layered rather than sequential. As we look to set the scene for the Royal Commission's work, we will continue to search for evidence and insights as material continues to come to hand.

As at 22 May, last Friday, 73 notices to produce have been answered. Responses to 159 notices to give information had been received, with some 16,589 documents being produced, totalling some 242,530 pages. In light of the coronavirus pandemic and the public health restrictions, most State and Territory Governments requested, and were granted, substantial extensions to produce documents and provide information to the Royal Commission. Some notices have only been answered in recent days and others remain due to be responded to. The delay in the production schedule has influenced our choice and sequencing of topics for public hearings. We expect that, with the ongoing cooperation, this will ensure that the important work of this Royal Commission can be accomplished.

And to today, the Letters Patent and the Terms of Reference acknowledge the changing global climate and the challenge this poses to Australia's ability to prevent, mitigate and respond to bushfires and other natural disasters. This morning, you will hear evidence, Commissioners, from three national science agencies of the Commonwealth of Australia: the Bureau of Meteorology, the CSIRO and Geoscience Australia. Their evidence today will explore the changing climate in Australia and natural hazards. Further witnesses from the Bureau of Meteorology, the CSIRO and Geoscience Australia will return to give evidence during the course of the Commission's inquiry.

And to the first two witnesses: Commissioners, the Bureau of Meteorology and the CSIRO play an important role in monitoring, analysing and communicating observed and future changes in Australia's climate. Collaboratively, these two agencies contribute to research that underpins the health, security and prosperity of

Australians in areas such as weather and ocean prediction, hazard prediction and warnings, climate variability and climate change, water supply and management, and adaptation to climate impacts. Every two years the Bureau of Meteorology and CSIRO publish a report on the state of the climate. The last report was published in 2018. A new report is currently being prepared.

Geoscience Australia is the national public sector geoscience organisation. It is the pre-eminent source of information on Australia's geology and geography for government, industry and community decision-making. This work covers the Australia land mass, marine jurisdiction and territories in Antarctica. Geoscience Australia's work aligns with the Commonwealth Government's science and research priorities and supports global and domestic initiatives. One key area of work is supporting Australia's community safety to strengthen Australia's resilience to the impact of hazards.

Commissioners, there is a large bundle of material that has been prepared for each of these witnesses. Each of the witnesses this morning will address you and provide their evidence by way of a presentation, which will be accompanied by a PowerPoint presentation, which will include animations. If it is convenient, I will now call Dr Karl Braganza of the Bureau of Meteorology.

COMMISSIONER BINSKIN: Dr Braganza, good morning.

DR BRAGANZA: Good morning to you.

<KARL BRAGANZA, AFFIRMED>>

MS HOGAN-DORAN SC: Dr Braganza, have you prepared a curriculum vitae for the Commission and provided it for our purposes?

DR BRAGANZA: I have.

MS HOGAN-DORAN SC: And a PowerPoint presentation, *The Influence of Climate Variability and Change on the 2019-2020 Australian Bushfire Season*?

DR BRAGANZA: That's correct.

MS HOGAN-DORAN SC: And have you also provided four additional documents which are publications of The Earth Systems and Climate Change Hub?

DR BRAGANZA: I have.

MS HOGAN-DORAN SC: And those are *Bushfires and Climate Change in Australia, East Coast Lows and Climate Change in Australia*, *Thunderstorms and Climate Change in Australia*, and *Tropical Cyclones and Climate Change in Australia*?

DR BRAGANZA: That's correct.

MS HOGAN-DORAN SC: If it's convenient, Commissioners, I propose that those documents be identified and tendered. I will read onto the transcript the document codes and the proposed exhibit numbers for those documents.

COMMISSIONER BINSKIN: So those documents will be received as an exhibit as marked and as you read.

MS HOGAN-DORAN SC: Thank you. The first is Dr Braganza's curriculum vitae which is BOM.502.001.0078 which is proposed exhibit 1.1.7.

EXHIBIT 1.1.7 DR BRAGANZA'S CURRICULUM VITAE, BOM.502.001.0078

MS HOGAN-DORAN SC: The next is exhibit 1.1.1, which is the PowerPoint presentation which is exhibit ID BOM.502.001.0001.

EXHIBIT 1.1.1 POWERPOINT PRESENTATION, BOM.502.001.0001

MS HOGAN-DORAN SC: The next, exhibit 1.1.2 Earth Systems and Climate Change publication, *Bushfires and Climate Change in Australia* is BOM.503.001.0001,

EXHIBIT 1.1.2 EARTH SYSTEMS AND CLIMATE CHANGE, PUBLICATION, BUSHFIRES AND CLIMATE CHANGE IN AUSTRALIA, BOM.503.001.0001

MS HOGAN-DORAN SC: The next, exhibit 1.1.3, Earth Systems and Climate Change Hub publication, *East Coast Lows and Climate Change in Australia* is exhibit number BOM.503.001.0005.

EXHIBIT 1.1.4 EARTH SYSTEMS AND CLIMATE CHANGE HUB PUBLICATION, THUNDERSTORMS AND CLIMATE CHANGE IN AUSTRALIA, BOM.503.001.0005

MS HOGAN-DORAN SC: The next exhibit 1.1.4, Earth Systems and Climate Change Hub publication, *Thunderstorms and Climate Change in Australia*, document ID, BOM.503.001.0009.

EXHIBIT 1.1.4 EARTH SYSTEMS AND CLIMATE CHANGE HUB PUBLICATION, THUNDERSTORMS AND CLIMATE CHANGE IN AUSTRALIA, BOM.503.001.0009

MS HOGAN-DORAN SC: And finally - no, I withdraw that. Penultimately, exhibit 1.1.5 Earth Systems and Climate Change Hub publication, *Tropical Cyclones and Climate Change in Australia*, BOM.503.001.0013.

EXHIBIT 1.1.5 EARTH SYSTEMS AND CLIMATE CHANGE HUB PUBLICATION, TROPICAL CYCLONES AND CLIMATE CHANGE IN AUSTRALIA, BOM.503.001.0013

MS HOGAN-DORAN SC: And finally the joint Bureau of Meteorology and CSIRO report, *State of the Climate 2018*, BOM.503.001.0017.

EXHIBIT JOINT BUREAU OF METEOROLOGY AND CSIRO REPORT, STATE OF THE CLIMATE 2018, BOM.503.001.0017.

MS HOGAN-DORAN SC: That's the material concerning Dr Braganza. Dr Braganza, the PowerPoint presentation - just excuse me for one moment, Dr Braganza, while I am further amplified. Perhaps while that is being done if the PowerPoint presentation can be readied, if it's convenient. As I understand it, Dr Braganza, you will be indicating when - to the operator when to move forward through the presentation?

DR BRAGANZA: That's correct.

MS HOGAN-DORAN SC: The Commissioners may have questions during the course of your presentation but otherwise I will be inviting the Commissioners to ask any questions at the end.

DR BRAGANZA: Understood.

MS HOGAN-DORAN SC: When you're ready, Dr Braganza.

DR BRAGANZA: Sure. So today we're going to talk about the influence of climate variability and change on the 2019-2020 Australian bushfire season. We're looking at the influence of long-term trends, its interplay with natural variability, and what that means for extreme events. So that's the types of natural hazards that influence natural disasters. So that's the over-arching theme of the talk.

Can we go to the next slide, please. So this is a high resolution satellite loop of the fires that occurred on the south coast of New South Wales and East Gippsland towards the end of 2019. To examine those long-term trends and natural variability, we're going to look at the events leading into these events, so what we call antecedent conditions which is really the preceding two years of climate variability and change influencing these events.

Can we go to the next slide, please. So we will start with talking about Australia's natural climate drivers. So what were they doing in the lead-up to the summer of 2019-2020. We can go to the next slide, please. So this is a graph of Australian rainfall variability. The blue lines here are where the Australian continent has experienced rainfall above the average that it received during 1961 to 1990, and the red line is where we received rainfall below that average. As you can see there's a great deal of continental variability. So Australia is quite unique for a continent, in

that large swathes of the country move from very wet to very dry conditions periodically.

Not many continents experience that kind of cohesive variability, or coherent variability across large spatial scales. Normally, you would have one area wet and one area dry, for example. But Australia is an island in the middle of these two tropical pacific oceans, in the Indian and Pacific and that's what drives this rainfall variability. So drought, including severe and protracted drought, is a natural part of the Australian climate system and wet conditions, including very wet conditions are also a natural part of our climate. These changes also influence extreme events. So the frequency and severity of heatwaves and droughts, tropical cyclones and heavy rainfall are influenced by these decadal shifts in the Australian climate.

If we can go to the next slide, please. So why does Australia experience such large year-to-year and decade-to-decade variability? It's largely to do with the movement of warm and cold water in the Indian and Pacific Oceans. So, over time scales of months to years, we have movements, very large movements, of warm water, in this instance in the tropical Pacific Ocean. What we're looking at here is the development of something called an El Niño event. That's where the warm waters in the tropical Pacific move to the east of the basin, and you can see this classic warm tongue that defines an El Niño event. The same thing happens in the Indian Ocean and this massive movement of warm water is significant enough to affect global climate and to exert the largest influence on Australian climate variability from one year to the next and from one decade to the next.

We can go to the next slide, please. So I'm just going to quickly explain how these oscillatory modes, so these oscillations in the global climate system work. It's important to understand how these work to understand the influences on the 2019-2020 fire season. It's important also to understand that there's some predictability in these events. So, operationally, when we're looking at the horizon leading into summer, we often get months notice of the types of conditions that we're going to see. So there's three states that the Pacific Ocean likes to sit in and this is called the El Niño southern oscillation or ENSO. The neutral phase, which is the state that it sits in most often, describes a pattern where the trade winds blow from east to west across the Pacific. They pool warm water to the north of Australia, and we generally get atmospheric moisture following that warm water.

So it rains typically climatologically on average to the north of Australia in this neutral phase. El Niño basically describes an intensification of these pattern. So the trade winds blow more strongly. We warmer water to the north of Australia and an intensification have that rainfall pattern, often dragging rainfall down across the entire Australian continent. During an El Niño event, it's the opposite of that. So we have a reversal of the trade winds. We actually shift the warm water to the eastern Pacific. The atmospheric moisture tends to follow that warm water and we get wet conditions in South America and Southern and North America, and dry conditions

over Australia. In 2019, we had a neutral phase event. So we didn't get much help for either dry or wet conditions from El Niño or La Niña.

If we go to the next slide, please. There is a cohort event, so in the Indian Ocean, and it's called the Indian Ocean Dipole. So, similarly during a neutral phase the predominant pattern is for rainfall over the Indonesian region, and during what is called a negative phase of the Indian Ocean Dipole, that pattern intensifies and we have warmer water to the north-west of Australia, which typically results in more rainfall over parts of the country, particularly the south-east.

A positive Indian Ocean Dipole is where that pattern reverses and the warm water tends to shift to the coast of East Africa and it takes the rainfall with it. And we often experience drier conditions in Australia associated with what's known as a positive IOD. From May to December in 2019 we were under the influence of a positive IOD. So this was favouring drier than average conditions over much of Australia and certainly the south-east.

If we can go to the next slide, please. A third climate influence that's very important is what's called the Southern Annular Mode. So this describes the belt of westerlies that circumnavigate the Antarctic continent. These can either push up further north or they can contract further south to around Antarctica. A positive phase of the southern annular mode typically sees the storm tracks, so those cold fronts that bring rainfall to the south of Australia shift further south, and we can get drier conditions over southern Australia.

We can also get slightly wetter conditions into eastern Australia. During a negative southern annular mode, those westerlies push further north and that's what we saw over October to December. That pattern was associated with a typical summer response at the negative SAM in Australia, and what that means is drier conditions over eastern Australia, and stronger westerly winds or more predominant westerly winds, which can assist fire weather into southern Queensland and New South Wales.

We also have something in weathering climate circles known as a southern stratospheric warming event. The important thing to understand about that is the Southern Annular Mode is generally a shorter-lived event than the IOD and ENSO, but it was sustained by this southern stratospheric warming event. So it acted on the Australian climate for some months in spring and early summer. So we had two influences in a positive IOD and a negative SAM that were favouring drier and warmer conditions over south-eastern Australia ..... So we're now going to switch to look at long-term trends and they're the climate drivers. Obviously, climate is changing, so the global - the globe is warming and Australia's climate is responding to that.

We go to the next slide. So there's trends in a range of climate indicators, most solidly in temperature. So Australia has warmed by 1.4 degrees, mostly since the middle of last century. That trend is going on in the background. What we've got

here is a list of things that are now impacted by that trend. So these are changes that are impactful, they're phenomena and they're ones that are emerging from that background of natural climate variability. So natural climate variability is large in Australia. For us to notice the trends, they have to rise above that background noise. And we can see that now in the increased frequency of large-scale heatwaves and record high temperatures in a longer fire season with more extreme fire danger days and in prolonged higher temperatures. So we also have marine heatwaves that impact on our ecosystems like the Great Barrier Reef.

We have reduced average rainfall in the cool season, which we'll also focus on talking about here. Events that are starting to be apparent, so we have trends globally in heavy rainfall and obviously trends for increased sea level. These trends are starting to emerge from that background of natural climate variability, and in Australia heavy rainfall has a very large natural variability. So we would expect that trend to continue into the future and to become apparent as time goes by.

Next slide, please. So if we can summarise the various influences leading into that 2019-2020 fire season in the next slide. So we had a positive Indian Ocean dipole which made itself felt from May to December but most acutely over that spring period and December, affecting south-east Queensland, South Australia, New South Wales, Victoria and Tasmania. Next. We had a negative southern annular mode, so increased likelihood of above average temperatures and below average rainfall in spring and summer across large parts of New South Wales southern Queensland, and an increased spring and early summer fire risk in New South Wales and southern Queensland as well.

Next. We had not much help from ENSO, so we had neutral conditions in the Pacific, and on the next slide, and we also have trends going on in the background. So material to the events of the summer, we had an increased likelihood of warmer than average temperatures because of the background trend, an increased likelihood of reduced cool season rainfall, and an increased likelihood of a longer fire season and higher fire danger. So, when we talk about these events, how they reinforce each other, we have trends going on that were reinforced by two drivers in positive IOD and the Southern Annular Mode. As we will see over the course of this presentation, that means that we're not just favouring warmer and drier conditions, we're actually pushing up into events that start to become more often unprecedented or beyond the historical record.

Next slide. So we're going to go variable by variable here. I'm going to talk about temperature first, then rainfall, and then I'll talk about fire weather, which collects quite a few meteorological variables together. Next slide. So I'll start these variables breakdowns with the trend first. Australia has warmed by about 1.4, 1.5 degrees over the last 100 years. This is a graph looking at extreme national heat days. So in Australia we can calculate the temperature of the entire continent daily as the average of all of our weather stations across the continent. Then we can place that into percentile. So what we're looking at here is the number of times the national daily

temperature reached the 99th percentile, so the top one per cent of warmest days historically.

If you look at the early half of this record, you can see the natural variability that I have talked about. So some years we have spikes. Each decade we would have a spike in the number of national daily temperatures reaching the 99th percentile. Some years we didn't have any such days, and that natural variability is largely driven by the modes of variability that I discussed earlier. We can also see a very significant trend now. So the number of such days is greatly increased. The number of years without any such days has now gone and we have the spike days that are much more extreme than in the past. So in 2013, which was Australia's warmest year on record at the time, we had 27 such days, and in 2019 we had 43 such days. It took several decades to accumulate just what we saw in 2013, for example. So that makes a big difference to Australia's environment and ecology, and to the operational and built systems to manage these events. If they occur once every decade or once every few years, it's quite different to them occurring every year or several times per year.

We can go to the next slide, please. So just some examples of record-breaking heatwaves, and I have chosen these two examples and we will come back to them when we talk about projections. So one is, iconically, the Black Saturday heatwave and day of severe fire weather across south-eastern Australia. This was a notable event for the duration of heat with individual site records. So what does that mean? Individual sites broke their all-time records. We had temperatures pushing up into the high 40s in South Australia and Victoria. We had a very long heatwave. So Melbourne, for example, had three days above 43 in the week before Black Saturday. That heatwave was associated with about 500 excess deaths across South Australia and Victoria. And, of course, Black Saturday itself, the bushfires claimed 173 lives. It challenged our health systems. It also challenges things like our energy system in making sure we can keep lights on into all jurisdictions.

We had help from natural variability for this event, in that we're at the end of a very prolonged drought and that tends to assist high temperatures across the Australian continent. In January 2013 we saw a heatwave that was unprecedented. So we broke every sequential national record from one day through to one month in early January. This heatwave was notable for the duration. So we didn't set as many site records but the national daily temperature set many site records. Incidentally, this event was broken both in December, in terms of national daily temperatures and in terms of January temperatures themselves in January 2019. This is a multi--jurisdictional event. So when we talk about the change in the frequency of events, it's these events that are really challenging. We have to allocate resources over a number of States; there was fires in New South Wales and Tasmania associated with this event, for example, and we will come back to these two events later.

If we go to the next slide, please. So the maps I'm going to show you are the historical records for rainfall and temperature and fire weather placed into percentiles. So what does that mean? If we look at a particular event we can tell you where in the historical distribution it sits. So for to this talk I'm going to be focusing

mostly on for temperature, events that occurred in the top 10 per cent of warm periods or highest on record, and for rainfall we will concentrate on those that occur in the lowest 10 per cent of records or lowest on record. So heat and drought is what we will be focusing on.

If we can go to the next slide. So using that decile map, another way to look at the trend over Australia is to look at temperatures this century. So the 20-year period starting in 2000 has been the highest on record compared to all other 20-year periods. So it's the duration of heat that I'm drawing attention to here. You can see over most of the country we have temperatures that are highest on record, very much above average or above average, but for where all the population centres sit, certainly we've seen a very long period, protracted period, of temperatures that are the warmest on record.

We can go to the next slide. So the left graph there is showing the rise in Australian temperature anomalies, so departures from average. And you can see the trend that I've referred to: Australia warming by about 1.4, 1.5 degrees. On the right I've got December maximum temperatures; that's the daytime temperature. You can see there's a trend in December temperatures. You can see what happened in 2019; we have this outlier that is well above the trend. So this is where we start to look at the influence of both the trend and natural variability. So you can see outliers for December temperatures in the past. You can see the spikes that rise well above that trend. As we push that trend further, it increases the chances that we will see events, extreme events, that are beyond our historical experience. So rather than just being warmer than average due to an El Niño or a positive IOD, the trend means we are increasingly likely to see temperatures that are highest on record.

We can go to the next slide, please. And if we look at December map, so if we map that outlier, you can see just over that month we had temperatures over most of the country that was either in the 90th percentile or highest on record, and that's the background setting for the fires that we saw around the country in that month but I will also talk about the fires that occurred earlier in spring as well.

And if we go to the next slide. So I'm now going to switch from temperature to rainfall - next slide - and I'm going to start with those long-term changes. So we're focusing on the cool season here, which is where the most significant changes in Australian rainfall has occurred statistically. So what we've had over those cooler months of the year, April to September, is a higher pressure in the Australian region. So there's a trend towards higher atmospheric pressure. That typically means a reduced chance of rainfall from the sort of cold fronts and cut-off lows that bring rainfall to the southern parts of the continent, most importantly south-west of WA and the south-east of the continent. So, in reducing the chance of that rainfall, you would expect to see rainfall during those months that is less than in the past. And if you look over the 20th century - so, again, analogously to the map I showed for temperature - over the period 2000 to 2019, we see lowest on record rainfall over large parts of Australia that correlate with that trend in pressure.

So this means that we have reduced chances of getting rainfall during that time of the year. In parts of New South Wales we have offset that with some increases in summer rainfall. Importantly here, though, we're looking at the influence of what happens when you remove that cool season rainfall, and then what happens if the summer rainfall doesn't arrive. Summer rainfall is quite variable: it wouldn't arrive typically during a drought period, for example. So this is essentially, as with the temperature, loading the dice in favour of drier conditions.

We can go to the next slide. So we're now going to look over the drought period. So we've looked at the trend in the background. We're now going to look at the natural event, which is drought and severe drought in Australia. It's instructive to look at how the rainfall anomalies progressed since January 2018. So the yellows and reds here are where we've got rainfall deficiencies and that's rainfall that's below average. And if we progress to the next slide, we should see how these rainfall anomalies unfold. So starting in January you can see over several months, the oranges and reds starting to spread. You can see along the east coast we're now getting rainfall deficiencies that are in excess of 600 millimetres less than what you would normally expect.

If you look closely at those regions, you will see that they are corresponding to areas that saw significant bushfire activity; so southern Queensland, northern New South Wales, the east coast of New South Wales, into Victoria and parts of South Australia and Tasmania. Going to the next slide. So the influence of both background trends, warming trends and periodic drought can be seen on this map. So this is a drought map for the past 21 months. What is notable here are the regions of lowest on record rainfall. So it's not just a severe drought. There's large regions and many observing stations that saw rainfall that was very much below their previous historical records and, again, that's that interplay of background trends and natural variability.

We can go to the next slide, please. So I'm now going to try and gather together rainfall and temperature to look at these things in a coincident way when extremes line up in multiple variables. That's when you can actually amplify the kind of extremes that lead to natural disasters and natural hazards as well. So going to the next slide. Fire weather is a phenomena that collects together multiple climate variables. So there's no clearer definition for a compound event, but in meteorology and climatology we're really talking about events where we have coincident extremes in multiple variables at the same time. And these can be for different time scales, for a drought intersecting with a heatwave or it can be within a meteorological event itself such as a fire weather day. So fire weather is a good example of that, and it's a good example of a phenomenon that's influenced by antecedent conditions, so those leading into the event, as well as the day itself.

If we can progress to the next slide. I'm going to be talking about the McArthur Forest Fire Danger Index a lot, or FFDI. So this is a measure for assessing the severity of fire weather. It's a tool that is very commonly used in Australia. It collects temperature, wind speed, relative humidity, and a drought factor. The influences that are very important to fire ignition and the ability of fires to spread in a way that's

difficult to control in Australia. There are other fire danger indices but for climatological purposes this is the one for which we have very good observations going back to 1950, so we can construct this index, and it also is shown to well-describe fire weather, particularly over forested areas in Australia, for scientific purposes. The drought factor within the FFDI changes around the country, but a common one that is used is the Keetch-Byram Drought Index or KBDI. It's essentially a measure of soil and moisture deficit. So if you had a saturated soil, how much less moisture do you have.

Go to the next slide. So, as discussed, it's useful in many parts of the word to integrate the meteorological variables and the fuel information into a single measure, and it's useful for monitoring changes over a long period of time which is what we're doing here. Next slide, please. So droughts in Australia are getting hotter. I have focused here on New South Wales. So the current drought really was centred very firmly on New South Wales and then surrounding States. Droughts are very different in their characteristics. So having a drought index for the whole country is problematic because droughts in their spatial footprint. So, for this talk, we're just looking at New South Wales. The yellow dots there - so what we've got on the bottom axis here is the Keetch-Byram Drought Index, KBDI.

So those yellow dots, if they're closer to the vertical axis, it was less dry, and if they're going to the right then it's drier conditions. On the vertical axis I have maximum temperature. So if you're down near the X axis here then you've got cooler temperatures, and as you go up that scale you've got hotter temperatures. So what you can see here is a clear relationship between rainfall and temperature in Australia. When it's wet, it tends to be cooler, and when it's dry it tends to be warmer. And that's largely because the soils act a bit like an evaporative cooler. As you evaporate moisture from the soils, it tends to cool the surface temperature, so you get this very neat relationship between rainfall and temperature in Australia.

What this graph - what this plot shows is that we are increasing temperatures independent of rainfall. So the orange - the yellow dots there are the scatter of rainfall and temperature or drought factor and temperature from 1911 to 1999, so last century. The yellow - the orange dots are what has occurred from 1999 to 2009. So you can see that those arrange dots are all generally above where the yellow dots sit, and that means that temperatures have increased but they have increased independent of temperature.

If you look at the red dots as well, they're sitting higher again. So in the last 10 years, 2009 to 2019, we've had the hottest temperatures we've seen. And what that means is that we've given a little bit of an extra push to the extreme event. So 2018 and 2019, you can see are both outliers for dryness and heat. So it was, Australia-wide, 2019 was our hottest and driest year on record, and certainly for New South Wales it was. For New South Wales, 2018 was not far behind. So we had 24 months of very exceptional conditions driven by, in part, these background trends and natural variability. I should say there's also a trend in relative humidity, not just in Australia but in all similar environments around the world, and that increase - sorry, that

decrease in relative humidity is due to the rainfall changes we have discussed, the temperature changes, and a range of other factors.

We can go to the next slide, please. So I'm going to start looking back, not at the fire season that just was, but given the fact we had two or three years of very dry conditions over Australia it's instructive to look at what happened in 2018. So this is fire activity along a 600 kilometre stretch of the Queensland coast. And, in terms of our operational experience, this is another event that was unprecedented. So you can see on this satellite image coincident fires over a very, very large stretch of the coast.

Going to the next slide. As we got into summer across Victoria and Tasmania, we had extensive fire activity again. So you can see the smoke plumes here across Tasmania from the 29th of Jan. It was a long campaign season, so that means we had fires burning from spring right through to March in these two southern States. And, again, prior to the year that just was, we were talking about these events as being quite unprecedented and something that we were going to have to look at in terms of changing our operational response now and into the future.

If we can go to the next slide, and this is, of course, the fires that occurred on the south coast and eastern Victoria at the end of December and the start of January. And this is about a 300, 400 kilometre stretch and, of course, there was fires burning to the north of here in New South Wales up to the Queensland border and over, during spring. So that just sets the context here that this isn't a one-off event that we're looking at here. Really, since the Canberra 2003 fires, every jurisdiction in Australia has seen this really - have seen some really significant fire events that have challenged what we do to respond to them, and have really challenged what we thought fire weather looked like preceding this period. So the frequency of these events, if we look at the historical record, seems to be increasing. These large fire events, when you look back over the 20th and 19th century, were not as frequent as they were this century.

We go to the next slide, please. So I'm now going to look at fire weather itself through that index, the FFDI, or the Forest Fire Danger Index. So this is a map showing a trend in accumulated FFDI. So that's where we just add the FFDI every day over a year. So what this map is essentially showing is that almost over all of Australia we're seeing a longer fire season with more fire danger days during that season, and the severity of the worst fire danger days is becoming more severe. You can see that the largest changes are in some parts of the country where we don't have much fuel. That's no surprise. Those parts of the country, the ecology is adapted to having more frequent hot and drier conditions.

If you go to the next map, this is the fire weather trend expressed as a percentage of the average. So what we're looking at now is the change relative to the typical amount of fire weather that every location experiences. And what you can see now, and this is for the season spring, is that you're getting large relative changes in some parts, in lots of parts of the country where there is a great deal more forest fire, forest fuel. Spring has been chosen particularly for significance here. So the fire season is

extending, but that is probably most significant in spring. We're getting early season heatwaves, we're getting the longest extension of fire season into that spring, and it also means that we're having a longer curing season before the summer weather arrives. So, thinking back over this talk the heatwaves are influencing spring. The cool season rainfall leading into this period where we're weighting the odds in favour of less rainfall, and then we're having fire weather start in spring itself.

If we can go to the next slide. So this is an attempt to look at the change in the arrival of the first significant fire danger day. So we've chosen FFDI above 25 to mark the first day of the season. And if you want to read this graph it's for the south coast of New South Wales, so the rainfall districts. It's for anywhere in that location, if we get an FFDI above 25. And you can see in the 1950s, the first day of arrival for significant fire weather was at the end of spring, start of summer, so November to December. If you follow that line down, at present we're getting that first significant fire danger day arriving at the start of spring or end of winter. So that's about three months earlier. That's obviously significant for all of the reasons I've just talked about, and it's similar for eastern Victoria.

If we go to the next slide, and that's just an example of the Bega Valley fire that occurred in August 2018. So this obviously has implications for overlapping fire seasons. So, throughout Australia the fire seasons aren't unified, so Queensland goes a little bit earlier, for example, and ends earlier. Compared to our historical experience then, we have more overlapping fire seasons within Australia and globally as well. So fire seasons in all similar climates around the globe are also extending.

If we can go to the next slide. So now we're just going to look at a map, essentially, of fire conditions from the start of spring, so from the start of September 2019. And just to reiterate we have long-term climate trends and then over this period we also have prolonged multi-year drought. Then we have a positive IOD event which is favouring warmer and drier conditions and the negative SAM event, which is favouring warmer and drier conditions. If we progress to the next slide through, we can see these orange areas starting to grow. So you can see the fire danger accumulated across September and October. Now the northern New South Wales and southern Queensland starting to be highest on record.

Next slide. And then you can see again by November those conditions are starting to worsen and you're starting to see highest on record along the south coast and into Tasmania, South Australia and Victoria. And the next slide. And then, by December, we had record fire danger for the three, four month period over most of the country and, if not, in the 90th percentile. Going to the next slide: so December was a very extreme example of that. So, again, the background trend, this extreme event, a significant outlier, record high fire danger across most of the country and leading into the end of that month and the start of January.

The next slide: so just showing on a graph similar as we did for temperature where 2019 December actually sat. So I've just chosen, for example, here to look at

southern Queensland. On the left you can see a count of the days above - we had an FFDI above 25 in Queensland. So you can see a trend in spring on the left there. You can see extreme events, so 2002, 2013, but that trend again is basically increasing the odds that we will see periods that are unprecedented, and on the right you can see just where December actually sat. So it's a significant outlier, probably driven by the influence of natural variability, but also the trends that have occurred in the months leading up to December. So December itself might not have a strong trend but when all the things come together, then that's when you expect to see the realisation of all those factors in an extreme event such as we saw.

Going to the next slide. And now we're looking at the highest fire danger day within December. So individual days within that month reached highest on record at the daily time scale, and you can see here again it occurred in a lot of areas where we had significant fire activity; so south-east South Australia, eastern Victoria, north-east New South Wales, parts of Tasmania as well. This also shows that there's a lot of regions where we didn't get ignition and we could have. So the Otways, for example, in Victoria. Could conditions have been worse over summer? Certainly they could have if we had more ignitions in these orange zones, and remembering we didn't get much help from El Niño. So if we had El Niño occurring at the same time, which does happen, when we have a positive IOD, then we might have seen worse conditions again.

Next slide. So this is where my discussion of the antecedent or precursor conditions ends, in the days leading up to that fire. But before we do that, just to re-emphasise what we've been talking about. So the top two maps there for the south coast of New South Wales and East Gippsland show the impact of long-term drought. So, as we saw at the end of the millennium drought with the Black Saturday bushfires, this is an extremely significant precondition for the sorts of fires that we have seen. So we had rainfall deficiencies for the three years that were lowest on record, more particularly for eastern Victoria but also significantly for New South Wales as we've discussed. And then just that period, July to December, we saw an intense period of no rainfall as well.

If you look down at the temperatures in the bottom left there, these are forecast maximum temperatures for the 28th of December. So this is, kind of, before the fires got going. We don't need the extreme temperatures on the day. We got them on Black Saturday but the week before where we had temperatures in the mid 40s for consecutive days really adds with low, low relative humidity, it really adds to the curing of fuel, and that's what we saw here as well. December was notable for the intense heatwave that occurred in the middle of the month and continued on up to the fires themselves. We also had fires burning in the landscape already, and that's a really significant factor.

So the FFDIs on the days where we had fire activity in these regions were highest on record, driven largely by wind and humidity, not by temperature. But as well as worrying about ignitions that could start on that day, we had significant fires already burning in the landscape from November. In fact, I think only the Cobargo fire

probably required ignition during this event. There was fires already in the landscape for the other fires. So, from a management perspective, operationally, that makes things harder and it's, you know, tagging back to the things I've talked about, about trends, the rainfall in the cool season, and the early start to the fire season. This is the sort of practical outcome of those changes.

Going to the next slide, please. I will just spend briefly on fire-generated thunderstorms. So the events that we saw since spring really, but most notably over December and January, we saw a lot of what's called pyrocumulonimbus or Pyro-Cbs or fire-generated thunderstorms. So this is where you have fires burning in heavily forested areas. They generate their own weather. So they generate their own thunderstorms. These are a significant risk to fighting fires as well as fire spread. So they change winds at the fire front and aloft, above the fires. They increase transport of burning embers. They have additional sources of lightning to start new fires, and at more spatial scales we get tornados and extreme winds. So southern Australia has, in the evidence we have, seen an increased number of high-risk days for fire-generated thunderstorms and the projections are for that trend to continue.

Examples this century, is Canberra 2003, Black Saturday and many instances over the last fire season. We can go to the next slide. So just summarising those changes to fire weather: a longer fire season arriving earlier in spring most notably, accompanied by more extreme heatwaves including in spring. That influences things I haven't talked about yet so overnight temperature and humidity, for example, where you might get some moisture back into the fuel is affected by the incidence of extreme heatwaves, lower rainfall during the cooler months in some fire-prone regions at the south-west and the south-east. Hotter drought periods, so giving a little extra push to drawing moisture out of the environment when, particularly during the drying phases, and evidence of more favourable environments for fire-generated thunderstorms.

I can go to the next slide. I'm going to finish here with a brief discussion of climate projections and just noting that our colleagues from CSIRO will treat this topic in more detail, so if we can go to the next slide. Just to complete the narrative, I'm going to focus on fire weather itself for the projections but, before I do that, just looking at the way we do climate projections globally. So the dark black line here is Australian average temperature with that 1.4 degree warming trend. The orange and green lines are projected changes to Australian average temperature. The orange is what's called a future, let's call it, a business-as-usual emission scenario where global emissions of greenhouse gases continue at a similar rate to what they have historically, and the green line there is a stabilisation and very, very low future projected greenhouse gas emissions pathway.

For a lot of the work that the bureau does we're looking over the next 20 to 30 years where the emission scenario matters less. Why is that? Over that period, the global climate system is going to continue to warm in response to greenhouse gases that are already in the atmosphere. So the oceans take a while to respond to that additional radiative forcing, so the extra energy from extra greenhouse gases, and that's what

we will see over the next 10 to 20 to 30 years or so. But the projections I'm going to show follow a high emissions scenario. We can go to the next slide.

Now, there's a couple of ways we can look at projections for fire weather. This is a projection for a future climatology in fire weather. What does that mean? We look at a future 20-year period, and average fire weather over that 20-year period from our models. And I've chosen three models here to show we also look at where the models provide certainty where they all agree and where the models provide some information on uncertainty, where they agree less. But the take home from this particular projection, which is for future climatologies, 20-year climatologies in days above 25 FFDI and days in the 95th percentile, is that we're getting increases over most of the country during that period.

Can I go to the next slide, please. Here is another way to look at projections. So in the previous slide we looked at 20-year averages. This is looking at just heatwaves themselves. So now we need to look at weather over multiple days. If you remember, at the start I talked about the events of Black Saturday, so the heatwave leading into that in 2009, and I talked about the heatwave in January 2013. This is what the bureau's weather model sees when it looks at those events. So we take real world data, observed data, and put that through the weather model and you can see the extreme temperatures there. The darks are above 48s and the two historical events. What we have on the right there is the future global climate model, a high emission scenario, and then we take that data and give it to the weather model. And it shows us what the weather would be for that event.

We've chosen a meteorological event that is similar to Black Saturday here, and nominally it occurs in January 2050. But the way we run these models is we run lots of simulations and then we would look for an event in the future that looks like Black Saturday with the additional warming factored in and look at what that looks like. This is the sort of work that is now being done increasingly to look at forward planning for extreme hazards and events. So now we're looking at the heatwave itself, rather than the climatology. If we can go to the next slide. We can drill down from the heatwaves, so multiple days of heat, to days of fire danger. So now we're looking at single days where we're not just looking at heat, we're actually looking at rainfall, temperature, humidity, wind and all the factors that we know influence fire weather. The top panel shows the FFDI, extreme FFDI, that we observed over 2 January, 3 January, 4 January this year, compared with that same period that I showed earlier for January 2015 in the Australian climate model. And, again, what we're looking at here is an intensification of the fire weather into the future. That's where my talk ends. Thanks for listening.

COMMISSIONER BINSKIN: Dr Braganza, thanks for that. Just a question from me, and then I'll open it to the Commissioners, just for a couple of questions. That was an excellent overview and really sets the baseline for the Commission to consider what we need to, as we move forward. Just a question for you: obviously, you would have made tighter predictions as we moved through 2019 leading up to the season. About mid 2019 when you were starting to provide advice to those

committees and that look at what's coming up in the fire season, how did it play out in real time - real life vice what you had predicted leading up to it, please?

DR BRAGANZA: Yes. I think if we look before the 2018-2019 and 2019/2020 fire seasons, we were probably providing similar advice, just due to the drought. And then when we look in 2019 preceding the season just gone, we were also getting strong indications from our forecasts of the seasonal drivers, particularly the IOD and the Southern Annular Mode that we were going to favour drier and hotter conditions. Thankfully for our forecasts at least, that's how it turned out but, unfortunately, the conditions turned out to be very severe. Things really played out the way our forecast models, both in climate and weather, suggested they would.

COMMISSIONER BINSKIN: Thank you very much. I appreciate that. Dr Bennett?

COMMISSIONER BENNETT: Thanks, Dr Braganza. I've just got one question. I saw that you were modelling forward to 2050. Can I bring it back to a shorter time frame? Are you able to give us some analysis of the modelling you've done over, let's say, the next five years?

DR BRAGANZA: It's very difficult to predict climate more than about nine months to a year in advance. So the predictability that we get over that period in Australia largely comes from what the El Niño southern oscillation is doing in the Pacific, and that's why it's important to understand those modes. So, for example, going into the next fire season we have conditions favouring wetter conditions over Australia this year than we had in the preceding two years and that's largely - our knowledge of that is largely to do with what the Pacific Ocean is doing.

Once you go beyond that time scale it becomes very difficult. There's enough chaos in the climate system that such predictions become difficult. So now we look at those time scales probabilistically. So over the next five years you will be looking at the background trends. The thing to really understand about that 2050 projection is it's not a projection specifically for - it's not a prediction of what is going to happen in 2050. We could look over the models, if we ran the models enough, so you ran the models thousands of times, you would probably find an extreme fire event in one of those simulations over the next five, 10 or 20 years, and that really comes down to the luck you have with the drivers that occur at that time.

So while the change in average climate is going to proceed decade-by-decade, changes in extremes can occur within that period because they're influenced by natural climate variability. So really what we're looking at is what's possible over the next 10, 20, 30 year time frame for both average climate and extremes. So we're looking at those extremes that we have in our models as case studies for what is possible over the next period, and then how you use that information really comes down to what you want to do. So if you need to look at what worst case scenarios are, you might just say: look, show me what a worst case scenario is from the modelling. Or if you are wanting to do some staged adaptation, then you might look at how the averages are changing. Does that help answer your question?

COMMISSIONER BENNETT: It does, and if I can just follow on with one more on that. Bringing it back now to the next, let's say, 12 to 24 months and bearing in mind that historically these extreme events have not been every year, although things have been changing, to what extent can you talk about the likelihood of an extreme fire event, for example, occurring in the next year or two, bearing in mind that these trends are still happening? Do you understand my question?

DR BRAGANZA: Sure. Yes, I totally do. So the natural drivers won't reinforce the trends in every year and that's why we will get, you know, year-to-year variability. Looking at the year to date, we've had a lot more rainfall than we have had in 2018 or 2019 already, and the drivers that we look at look like they're favouring, over the next nine months or so, neutral or slightly wetter conditions for Australia. Now, that may or may not happen but at this point what we would be saying is, your chances of getting the sort of season that you saw in 2018-2019 and 2019/2020 are reduced. So what we're going to do now is really look at the amount of rainfall that falls between now and the start of spring to keep updating and reinforcing that outlook.

Beyond that, it's difficult to say except that the trends probably load the dice towards worse fire seasons in general. So unless it rains a lot in 2021, you would expect, on average, to have a significant fire season without any other influences. I will put that in context. When you look over the 20th century, there's only two significant wet periods for Australia. That is around 2010, '11 and '12 where we hit a record-breaking El Niño event, and then in 2016 where we had a really significant negative IOD event. Apart from that, it has been hot and dry. So that is, if you're a water manager and you're looking at your baseline, they really don't look beyond the millennium drought looking backwards for how to set their baseline. And I think that's the kind of framing that is increasingly being used for hazards as well.

COMMISSIONER BENNETT: Thank you very much.

COMMISSIONER BINSKIN: Commissioner Macintosh.

COMMISSIONER MACINTOSH: Thank you. Thank you, Dr Braganza, for the presentation. It was very informative. In your presentation, you put a slide about the south coast showing that the earliest date where we're seeing a plus 25 FFDI is now around July or maybe August. Can you tell us when the latest date in, say, summer or autumn is when we're getting the - basically, when that season is ending?

DR BRAGANZA: Yes, I can. So that location I think is about a month later. So we are extending the fire season at both ends. And for eastern Victoria and south - south coast New South Wales, I think it's around 21 days or a month into autumn as well. Some of that, I should say, might be natural variability because, you know, we would have influence of El Niño events and other things during that period, but we think a significant fraction of it is the trend.

COMMISSIONER MACINTOSH: Just to follow that up, so when you say a month later, what does that mean? What date are we talking in autumn?

DR BRAGANZA: I would have to check but I would say that's pushing things further into April.

COMMISSIONER MACINTOSH: Thanks, Dr Braganza.

DR BRAGANZA: But, sorry, the fire season in eastern New South Wales tends to end earlier and in south-east Queensland earlier again. So once you get easterlies pushing in across the Pacific it tends to increase the humidity and you get less frequent fire weather. When you get westerlies pushing off the continent is when you get significant fire weather for those locations. So protracted drought which means those westerlies are pretty much flowing over very dry, parched landscapes is significant in that regard. So the end to the fire season and start varies in different parts of the country.

COMMISSIONER BINSKIN: Commissioner Bennett.

COMMISSIONER BENNETT: Yes, I've just got one more question, and maybe forgive me if I am wrong, but I remember that during the course of the last fire season there was a lot of talk of wind unpredictability. Is there anything in any of the work that you've done here that you have described that can tell us a little bit about the predictability of the winds during the course of the fire season, where they're coming from and the changes?

DR BRAGANZA: So wind is generally well forecasted at particular scales. In terms of the forecasts for things like phenomena such as fire-generated thunderstorms, that becomes more difficult. I believe there's a number of factors that make the prediction of wind difficult at those time scales. So topography is one of them, for example. So doing forecasts in regions where there's lots of mountains and you have to have regard for fires on up slopes and down slopes can become tricky. The forecasts are generally pretty good but you would have to ask a meteorologist, so a forecast specialist, those questions rather than me, unfortunately.

COMMISSIONER BENNETT: Thank you very much.

COMMISSIONER BINSKIN: Thank you, Dr Braganza, Ms Hogan-Doran.

MS HOGAN-DORAN SC: Dr Braganza, I apologise, I did not take the Commissioners to your curriculum vitae in any detail, which might have assisted. You're the head of Climate Monitoring at Australian Bureau of Meteorology?

DR BRAGANZA: That's correct.

MS HOGAN-DORAN SC: And you have a Bachelor of Science with an honours first class in meteorology and physics?

DR BRAGANZA: Correct.

MS HOGAN-DORAN SC: From the University of Melbourne, sorry. And a PhD in climatology from the School of Mathematics at the Monash University.

DR BRAGANZA: Correct.

MS HOGAN-DORAN SC: And in your role as head of climate monitoring, you're responsible for the preparation and analysis of Australia's instrumental climate record and the official reporting of climate change in Australia?

DR BRAGANZA: Correct.

MS HOGAN-DORAN SC: And you're responsible for the bureau's Climate Risk Services to government?

DR BRAGANZA: Yes, I'm a significant liaison point for getting that information across.

MS HOGAN-DORAN SC: Commissioners, that's all I propose to take Dr Braganza to today. There will be an institutional response from the bureau provided in due course, and other representatives of the bureau to assist you during the course of this inquiry. Might Dr Braganza be excused?

COMMISSIONER BINSKIN: Dr Braganza can be excused. I'd like to thank him very much. It was, as I said before, a very good overview for the Commission.

MS HOGAN-DORAN SC: Is that a convenient time to adjourn?

COMMISSIONER BINSKIN: The commission will take a short break and we will look to come back at 11.30, local time. Thank you.

MS HOGAN-DORAN SC: If the Commission please.

<ADJOURNED 11:14 AM>

<RESUMING 11:30 AM>

MS HOGAN-DORAN SC: Commissioners, junior counsel assisting, Ms Ambikapathy, will take the next witness.

COMMISSIONER BINSKIN: Ms Ambikapathy.

MS AMBIKAPATHY: Commissioners, first I will tender a PDF presentation of a PowerPoint presentation prepared by Dr Helen Cleugh and Dr Michael Grose from the CSIRO. That is at tab 8 of your bundle and it has a document identification

number CSI.505.001.0001. I also tender a copy of Dr Helen Cleugh's, curriculum vitae, which is at tab 9 of your bundle. That is document CSI.502.001.0001. And I tender a copy of Dr Grose's curriculum vitae which is at tab 10 of your bundle, document number CSI.502.001.0003. I tender those documents as a bundle 1.2, each with the identification 1.2.1 down to 1.2.3.

COMMISSIONER BINSKIN: So those documents will be received, as marked. Thank you.

EXHIBIT 1.2.1 PDF POWERPOINT PRESENTATION PREPARED BY DR HELEN CLEUGH AND DR MICHAEL GROSE FROM CSIRO, CSI.505.001.0001.

EXHIBIT 1.2.2 CURRICULUM VITAE OF DR HELEN CLEUGH, CSI.502.001.0001.

EXHIBIT 1.2.3 CURRICULUM VITAE OF DR MICHAEL GROSE, CSI.502.001.0003

MS AMBIKAPATHY: I call Dr Helen Cleugh and Dr Michael Grose.

COMMISSIONER BINSKIN: Dr Cleugh, Dr Grose, thank you very much for joining us this morning.

MS AMBIKAPATHY: Dr Cleugh will you take an oath or an affirmation?

DR CLEUGH: Affirmation.

<HELEN CLEUGH, AFFIRMED>

<MICHAEL GROSE, AFFIRMED>

MS AMBIKAPATHY: Dr Cleugh, you have prepared a presentation with Dr Grose for the Commission?

DR CLEUGH: Yes, I have.

MS AMBIKAPATHY: And Dr Grose, you have prepared a presentation with Dr Cleugh for the Commission?

DR GROSE: Yes.

MS AMBIKAPATHY: Commissioners, that's at tab 9 of your bundle.

COMMISSIONER BINSKIN: Thank you.

MS AMBIKAPATHY: Commissioners, the version that will be played during hearing is an animated version, and the version that is in the court book and the tender bundle is a PDF version of that presentation.

COMMISSIONER BINSKIN: We have it at tab 8.

MS AMBIKAPATHY: Thank you. Dr Cleugh, you have also prepared a curriculum vitae for the Commission?

DR CLEUGH: Yes, I have.

MS AMBIKAPATHY: Commissioners, that's at tab 9 of your bundle.

COMMISSIONER BINSKIN: Thank you.

MS AMBIKAPATHY: Dr Cleugh, you are the Senior Principal Research Scientist with the CSIRO Climate Science Centre?

DR CLEUGH: Yes, I am.

MS AMBIKAPATHY: And you have previously been the director of the CSIRO Climate Science Centre?

DR CLEUGH: Yes, I was.

MS AMBIKAPATHY: And you have a Bachelor in Science with first honours - first class honours in physical geography from the University of Otago in New Zealand.

DR CLEUGH: Yes.

MS AMBIKAPATHY: And you have a PhD in atmospheric science from the University of British Columbia.

DR CLEUGH: Yes.

MS AMBIKAPATHY: And you are currently the Vice-Chair of the World Research Program Joint Scientific Committee.

DR CLEUGH: Yes, I am.

MS AMBIKAPATHY: And a member of the Antarctic Science Platform Steering Group in New Zealand.

DR CLEUGH: Yes, I am.

MS AMBIKAPATHY: And a member of the UK Met Office Partnership Board?

DR CLEUGH: I no longer am on that partnership board. That was a role that was associated with my former position as Director of the Climate Science Centre. I'm no longer a member of that board.

MS AMBIKAPATHY: I see. So was that from 2017 until 2019?

DR CLEUGH: Early 2020, January 28, yes.

MS AMBIKAPATHY: And are you a member of the National Climate Science Advisory Committee?

DR CLEUGH: I was. That committee has paused at the moment, but I was, yes.

MS AMBIKAPATHY: And, Dr Grose, you have also prepared a curriculum vitae for the Commission.

DR GROSE: I have, yes.

MS AMBIKAPATHY: That is at tab 10.

COMMISSIONER BINSKIN: Thank you.

MS AMBIKAPATHY: Dr Grose, you're currently a Senior Research Scientist at the CSIRO Climate Science Centre in Hobart?

DR GROSE: Yes, I am.

MS AMBIKAPATHY: And you are the lead author of the IPCC Sixth Assessment Report?

DR GROSE: I'm a lead author, yes, I am.

MS AMBIKAPATHY: And you have a PhD from the University of Tasmania in Oceans and Atmospheric Science.

DR GROSE: Yes, I have.

MS AMBIKAPATHY: Evidence operator, could you please pull up the presentation. When you are ready, Dr Cleugh and Dr Grose, you may start your presentation.

DR CLEUGH: Thank you, Ms Ambikapathy. This presentation provides, firstly, a brief explanation of weather and climate prediction and the climate drivers that affect Australia's weather and climate. And secondly, it describes CSIRO's climate modelling and national climate projections that inform our understanding of future weather and climate related risks and hazards. Operator, could we go to the next slide, please.

As you are now aware from their presentation this morning, the Bureau of Meteorology provide weather forecasts for the days out to a week ahead and seasonal climate outlooks for one to three months ahead. CSIRO focuses on climate and climate change over multi-decadal to centennial time scales. Our modelling of future climate provides the knowledge, information and foresighting for impact and risk assessments and adaptation planning across many, many sectors. CSIRO have been doing global and regional climate modelling and developing projections of future climates for over three decades. It's important to note here that while climate models do simulate the variability that exists in the climate system, long-term climate projections are not the same as a forecast of what the weather will be like on a particular day or even year into the future.

Operator, could we have the next slide, please. Bridging this gap between shorter-term weather forecasts and longer-term climate projections to predict what the climate might be like in, say, one to two years time, is recognised as a substantial scientific challenge but one that is of great societal relevance and benefit. Recognising this, in 2017 CSIRO embarked upon a long-term decadal forecasting project whose mission is to develop a multi-year, two decadal climate forecasting capability for the benefit of Australia.

Operator, could we go to the next slide, please. This slide shows a schematic of the processes and phenomena which we call the climate drivers that influence Australia's weather and climate. The main climate drivers are the trio of ENSO which affects rainfall especially in east Australia, the Indian Ocean dipole which affects drought and bushfire risk, and the southern annular mode or SAM, which also played a role in the windy conditions that led up to the 2019 bushfire season. There are also features of our meridianal or north/south circulation which affects the location of the subtropical reach that affects the location in turn of our anticyclones, and also the passage and location of rain bearing fronts.

The Bureau of Meteorology will have already explained the influence that these drivers have on our weather and climate on seasonal and multi-year time scales. My key point here is that these drivers are also affected by climate change, and this means that Australia's future climate will be influenced both by the direct effects of global warming associated with climate change and changes in these drivers that are also affected by climate change.

If we could go to the next slide, please, operator. This table is a summary of how these drivers modulate Australia's climate risk. For example, the El Niño phenomenon or climate driver is linked to increased risk of drought, heat and temperature extremes, and reduced risks of floods, while La Niña events are linked to reduce fire danger but increased flood risks. And I would like to note that in the entry under the SAM driver, SAM positive and SAM negative, the increased and decreased unfortunately got reversed in the transpositions. So I want to make the point very clear that a negative southern annular mode does come with increased risk of fire danger, not decreased as you can see on the slide. So there's an error there.

Research to date indicates that in a warming climate the frequency of extreme El Niño, La Niña and Indian Ocean dipole events will increase leading to more extreme weather events in the future. This means that understanding the interaction between climate variability and these drivers and climate change is very important for building preparedness for the changing nature of climate risks into the future. Perhaps put more simply, climate change means that the past is no longer a guide to future climate related impacts and risks.

Can we go to the next slide, please. So climate modelling and climate projections for decades or centuries into the future need to account for the fact that there are multiple future trajectories that are all possible. We don't know which of these will eventuate, and the climate that we will experience in the future depends on three factors that are listed there: firstly, the internal or a natural climate variability that arises as a result of these drivers that we spoke to in the earlier slide. It also very much depends on the emissions of the atmospheric constituents that interact with the climate and cause climate change. This is especially greenhouse gases but also aerosols and other atmospheric constituents, and I will describe these more on the next slide.

The third element is the response of the climate system which will lead to a range of plausible future climates, depending on the scenario of emissions. As you can see in the plot, which is of global temperatures, the long-term trend, which is superimposed by the year-to-year and longer variability which is illustrating this natural climate variability. If we could go to the next slide, please, operator, this is to explain in a little bit more detail this concept of future climate emissions. Because we don't know what they're going to be, we need to represent the range of possible future emissions which affect the climate response.

So climate models need to represent this range and they do that using the representative concentration pathways or RCPs for short. And the plot on the left-hand side shows the RCPs that have been agreed to by the climate modelling community to use, so that we've got a consistent approach. The number that's associated indicates, essentially, the extra energy that is introduced into the climate system as a result of the emission of greenhouse gases and other radiatively active constituents. So the RCP8.5 is a high emissions RCP and a 2.6 would be a low emissions RCP, and the 2.6 refers to extra energy. Using these RCPs means we can explore a future where we had strong mitigation with lower greenhouse gas emissions or and a future with very high ongoing net greenhouse gas emissions or a future that's in between.

So if we could go to the next slide, please, and if you can hit enter to bring up the animation, thank you, which will just be on a continuous loop. So, as I said, the future climate that we experience is a combination of all three factors. The graph is a time series of Australia's observed temperatures and BIAC, both the annual and a longer-term running mean, from 1910 through to the present; and then a sequence in the animation of future climate simulations or three RCPs. You will see this coming

through, the red one being the higher RCP8.5, the blue being an intermediate RCP4.5 and green the low RCP of 2.6.

You can see, as these - this animation of future climate realisations are played, you can see that the response varies between models because the very squiggly lines that you're seeing are actually the realisations of two different models, and you can see that their response to the forcing greenhouse gas emissions, and so on, is actually slightly different. It also shows us that superimposed on this long-term trend is the interannual variability where we have warm years and cold years superimposed on the long-term trend.

If we go to the next slide, please. Thank you. So it's also important to quantify our confidence in climate projections. This practice is to base these confidence assessments on evidence and agreement. This is using the IPCC method - recommended method which ensures consistency across all the modelling efforts that are made by modelling groups around the world. This concept of evidence and agreement contributing to our confidence is shown in the matrix on the top right-hand corner. So you can see that where we have high agreement between different models, with robust evidence that means that we have strong confidence in that result.

And the table that sits underneath that matrix gives us the quantitative measure of that confidence. So if a statement like "Australia will warm substantially through the 21st century and that is a very high confidence statement" means that at least nine out of 10 chance of that statement being correct. The - Australia's national climate projections, which I will describe soon, actually use five lines of evidence to ascribe confidence and they're shown in the graphic on the left-hand side. That includes, as a comparison, across a number of different models. That includes our process understanding, the evaluation of those models and, importantly, where we have heli-terrain or coastal regions we use down scaling to provide finer scale of future climate.

If I could go to the next slide, please, operator. Thank you. So CSIRO have been undertaking long-term climate projections for over 30 years, providing the credible and relevant climate information that's needed to inform planning and decision-making. Our preferred approach is to align the production of our national projections along - align that to the IPCC assessment report cycle, which is currently about seven years. This is because the IPCC's climate assessments are supported by a coordinated climate model and comparison project called CMIP and that provides the latest results from the latest global climate models that are being produced by all the modelling centres around the world. That delivers a multi-model database that can be drawn upon to develop our climate projections.

It also allows us to ensure that we're bringing in the latest science and the latest understanding to embark upon a cycle of continuous, or enabling a cycle of continuous improvement in our projections. As you can see that in the time line in the top right-hand corner, which shows the sequence from the early days in the late

80s, early 90s where our information on future climate was more based on expert judgment and science through to the present of the to 2015 where we delivered the climate change in Australia climate projections, that I will come to in a moment. And it's really fair to say that the science of developing climate projections over those three decades has been transformed to delivering the state of the science that we have done in 2015.

So if I go to the next slide, please. Because we've been doing this for nearly three decades, or more than three decades, it means we can look back and answer the question: well, how well did our promises capture what has been experienced? And this chart does this for one, climate variable, this is temperature. So you can see the observations of temperature in the black line and the red wedge, or plume, shows the projections that were made in the early '90s of temperature in Australia for the decades ahead; and you can see that the temperature observations have been within the projected range.

Now, this is for temperature. Of course, there are other climate variables that are important too. So it's important to know that the observed climate over the last decade, and more, is very consistent with many of the changes that were being described in those earlier projections, both in terms of the sign or direction of change and often in the magnitude. And this is in climate information such as rates of signal, and amounts of sea level rise, increased heat extremes, and increasing extreme fire weather.

Go to the next slide, please. So, as I've indicated, the most comprehensive set of nationally consistent climate projections for regional Australia, including our coasts was delivered in 2015 through the Climate Change in Australia project. The primary goal of that was to provide climate projections for impact assessment and adaptation planning especially in the natural resources management sector. Some of the key features of these projections are illustrated in the graphic on the right-hand side. The key point I want to make here is that these climate projections are credible and salient and, most importantly, they are still current in 2020. This is because the science methods and approach were and remain best practice and they use the latest full set of climate models.

I want to also note that CSIRO worked with many of the States and Territories around Australia to produce nationally consistent and high resolution climate projections to meet the needs of the jurisdictions, especially information about extreme weather and climate events and related risks.

Could I go to the next slide, please. Thank you. The biannual State of the Climate is an important report on Australia's climate variability and long-term climate trends which we produce jointly with the Bureau of Meteorology. The 2018 State of the Climate also included global and national climate projections, including the summary, and if you could just bring up the next table by hitting enter. Thank you. So, many of the long-term climate trends that are already being experienced in Australia now will continue into the future. For example, ongoing global warming

and warming in our region, rising sea levels, a decline in cool season rainfall in south-east and south-western Australia and harsher fire weather conditions in southern and eastern Australia, all are points that you can see in the summary from the State of the Climate.

If we could go to the next slide, please. This means that climate change is adding to Australia's natural climate variability, driving changes and extreme weather, and increasing climate impacts on our water resources, ecosystems, health, infrastructure and economy, both now and continuing into the future. This slide is a summary of some of these climate-related impacts, risks and hazards. In the next sequence of slides I will go through those six climate projections that you can see there, to do with temperatures, fire weather, rainfall, rainfall extremes, tropical cyclones and sea levels. This summary is to give an indication of some of the impacts that are associated. For example, hotter temperatures both over land leading to more heatwaves and in the oceans, leading to marine heatwaves will have impacts on human health, on our ecosystems and on productivity. It also, in the colder parts of Australia, will mean reduced winter mortality for people and livestock, and where crop production is limited by cold then we might see improved productivity.

So if we can go to the next slide, please, to go through the projections mostly from climate change in Australia. So this is a time series graph. The brown line shows our observations and showing that Australia has warmed over the last century, reaching 1.4 degrees by the end of 2019, since reliable records began in 1910. Sorry, I have to wait to get the right file. I will keep talking. It also shows that Australia will continue to warm substantially during the 21st century. There is very high confidence that mean daily minimum and maximum temperatures will continue to increase throughout the century for all regions in Australia, with more frequent and hotter hot days, and if you will excuse me just to stand up so that I can get the lights on it will be better for us all. So my apologies for this.

COMMISSIONER BINSKIN: Feel free.

DR CLEUGH: It's an energy saving measure but I've been sitting too still.

COMMISSIONER BINSKIN: It's working.

DR CLEUGH: It's taking a while. I know. It's taking a while to wake up.

MS AMBIKAPATHY: Thank you, Dr Cleugh. Please take your time.

DR CLEUGH: My apologies for that interruption. Continuing with the information that's on the slide, so under a high emission scenario, this warming will be large compared to natural variability, both in the near future, say around 2030, with high confidence, and by 2090, late in the century with very high confidence. So I just want to reiterate the point seeing as we had the interruption there with the lighting. The key message here that Australia will continue to warm substantially and that is a very high confidence statement.

By way of illustration, by mid century, what this means is that the temperature that was recorded in Australia in 2013, which was Australia's warmest year on record at that time, that warmest year on record by mid century, under a high emissions RCP8.5 scenario, would be a cool year, or under our low emissions scenario of 2.6 would be an average temperature year. And I would further note that since this chart or graph has been published, 2019, so last year, surpassed 2013 to be Australia's warmest year on record.

So if we could go to the next slide, please. This map shows the additional number of hot days. For the 20 years centred on 2090, so towards the end of this century, for an intermediate emissions scenario or RCP of 4.5 for many of our major cities in Australia. This projected 50 per cent increase in very hot days in many of our cities will likely have substantial impacts; for example, on the health of people living in our cities, especially the elderly and vulnerable, on the productivity of our workforce, on energy demand, and on infrastructure.

Would you go to the next slide, please. Along with temperature, rainfall is very important for Australia. And the climate change in Australia projections or projects are concluded with regard to rainfall that is captured in the picture there, that winter and spring rainfall is projected to decline in southern Australia. Increases or decreases are possible elsewhere and in other regions. The graph on the right-hand side shows an example for rainfall variability and change in southern Australia for two RCPs, RCP4.5 and 8.5.

While the cool season rainfall is highly variable, which you can see in the observations which are the brown line, as we've already indicated that is an observed long-term drying trend in southern Australia, especially in the south-west and in the south-east. The projections of declining winter and spring rainfall into the future, which is a high confidence projection statement, means that this drying trend will continue although there will be continuing large natural variability.

This variability will exceed the trend, especially in the shorter term, so the next decade or so, and especially for the intermediate emissions scenario, RCP4.5. If we could go to the next slide, please. The combination of extreme heat and lower rainfall both contribute to the risk of extreme fire weather, especially in southern Australia. Now, this result you've already heard from this morning, I'm sure, from the Bureau of Meteorology, because it's research that was done by the bureau in collaboration with CSIRO. So the maps that you can see are a map showing the change in the number of dangerous fire weather days. That's where the Forest Fire Danger Index exceeds 25 between the current climate and in the future, 2060 to 2080, so later in the century.

And you can see in the map the key message that the research has shown and that's captured in the gold box on the right-hand side. That fire danger is very likely to increase in the future. That's exacerbated by the increased occurrence of extreme heat events. These dangerous weather conditions for bushfires are likely to occur, at least

in part, due to increasing greenhouse gas emissions. And the other key point that I'm sure the bureau also explained is that the effect that this fire weather has in terms of extreme pyroconvection, which can contribute to dry lightning and therefore provide an ignition source but also affects the spread of fires. So the risk of fire danger is both due to the long-term drying and warming which is conditioning the landscape but also the extreme fire weather that is observed partly due to climate change.

And the other point I just make is that the three maps - you might be wondering why there's three. There's three different modelling approaches used there: a global climate model and two regional model, and the modelling agreement is quite consistent between the three.

Can we go to the next slide, please. So extreme heat and lower rainfall not only have an influence on bushfire weather but also on droughts, and droughts are important for many reasons. Droughts actually precondition the landscape for fires. We have just talked about that. But they also have large impact on our rural communities, on our agricultural production, our water resources, and our ecosystems. So the Climate Change in Australia project, the projections from that project stated that the time in drought would increase; that's a high confidence statement, with a greater frequency of severe drought; that's a medium confidence statement.

That's partly due to the lower rainfall in the cool seasons which we've talked about before, the long-term drying trend, and also increased evaporation which increases the soil moisture deficit. The maps that you can see on the right-hand side are actually from some new research that's still under review, as you can see there in the text, so it's not published yet. That confirms the earlier conclusion from the Climate Change in Australia results. This research again draws across a multi-model ensemble from the CMIP fire database. The plots are for the projected percentage change in meteorological drought, that is rainfall deficit for Australia, and it does this for four attributes or features of drought: the per cent time IN drought, the mean duration, the frequency, and the intensity of the events.

The columns just show the range of the models. There are 37 global climate models contributing to this result. The finding of that new research is that the median projections for per cent, time and drought, mean drought duration, and intensity per drought event, are all mostly increased in the 21st century compared to last century. The median projections result do show, for drought, a small decrease in drought frequency. The authors conclude that while projections do show a large range across the different models, nonetheless there is strong agreement in the projections of increasing drought and extreme drought especially in south-west WA and south-eastern Australia. Projections also showed intensification of drought and extreme drought for all regions of Australia in the future.

Please go to the next slide, please. This next slide actually now goes back to rainfall because, in terms of climate hazard, heavy rainfall is important. The Climate Change in Australia projections found that extreme rainfall events are projected to increase intensity with high confidence. That's both in terms of the wettest day of the year and

the wettest day in 20 years. Although what this means is that although mean rainfall is declining in southern Australia, the rainfall events that we experience will be more intense. The figure that you can see now shows the percentage change by the end of the century. So it's not a time series. It's showing the change by the end of the century for both mean rainfall on the left-hand side and the wettest day and the wettest day in 20 years.

The purple and pink bars show the range and projections across the different models for the two RCPs that you can see there. The grey bar is the contribution from natural variability. The graphic simply reinforces the key message that extreme rainfalls are projected to increase in intensity.

State of the Climate in 2018 notes that these increases in short duration rains extremes, which are already being observed, are often associated with flash flooding. So this means that there is an increased risk of flash flooding into the future, especially in small catchments where the response to rainfall is very rapid, and also urbanised catchments where the impervious cover is as large. So there are flow-on impacts that will result from this including erosion and sediments that have influences on water quality in lakes and rivers and other storages.

If we could go to the next slide, please. Tropical cyclones, of course, are an important feature of Australia's climate, obviously typically up in the north, and another contributor to extreme rainfall events. Climate Change in Australia project did provide projections of tropical cyclone frequency and intensity. This research has been updated in more recent years with new research by CSIRO as part of a national research program. So that research concluded, again using the ..... multi model ensemble, or database, that climate models project a future decrease in the total number of tropical cyclones but an increase in the proportion of high-intensity storms. That is stronger winds and greater rainfall.

The graphic on the right-hand side simply is the information that's sits underneath that statement. For western - western regions, the west of Australia including Western Australia and the eastern region and for Australian region as a whole, again this is a change in frequency by the end of the century. The coloured bars now are not for two different RCPs. This is only for a high emission scenario, RCP8.5 but the two methods of extracting tropical cyclone information out of the global climate model simulations.

Again, the solid bar is the median and the length of the rectangle indicates the range, and you can see there a reduced frequency in tropical cyclones consistent for each of the regions. The important point here for impacts and hazards is that we will see increased impact, especially in our coasts, not only from the increased intensity of tropical cyclones, but that often coincides with the impact of rising sea levels. And so this - I would like to now go to the next slide where we talk about sea level rise. Thank you.

So climate change in Australia concluded that by 2090 global sea levels are projected to rise by between 26 and 55 centimetres for an RCP of 2.6 to 45 to 82 centimetres for an RCP of 8.5. This is a median confidence statement. This is because it depends on factors such as ice sheet melting, but there is also regional variability and differences as well. The time series on the right-hand side is actually from the IPCC assessment showing observations of global mean sea level changes from 1700 through to the present, from a different - quite a large array of observational types, and then projections into the future for two RCPs.

Now, if I could ask the operator to just enter to bring up another graphic, and some more text. Thank you. So sea level rise for Australia will be similar, possibly slightly larger than these global projections. The example in the graph that you can see is actually for Sydney, to provide a local example. This is again observed sea level rise for Sydney from 1950 through to the present, from both the tide gate record and the altimeter's record and then projections, actually for all the RCPs out to 2100.

The dashed lines that you can see there are an estimate of the interannual variability. The other solid lines are, as you've seen earlier, are slides showing the median and the range of the projections for the different RCPs. The key message here is that rising sea levels will pose, or are already and will continue to pose a threat to coastal community and coastal infrastructure by amplifying the risks of coastal inundation and storm surge.

I will conclude here by noting that for the next few decades the rates of sea level rise, both globally and here in Australia are partially locked in by our past emissions but as we look further into the later this century and to centuries beyond that, beyond 2100, those sea levels projections critically depend on the greenhouse gas emissions from now onwards, with both ocean thermal expansion, which contribute to sea level rise and the effect of ice sheets potentially contributing very large amounts of sea level rise over many, many centuries ahead under higher greenhouse gas emissions.

Thank you. That is the end of my presentation.

COMMISSIONER BINSKIN: Thank you, Dr Cleugh. Just a couple of questions and then we can go to Dr Grose. If I take that last part you just said, that summary, even with RCPs and emissions reduced to as low as what would be envisaged, we're still going to see a worsening of natural disasters, at least over the next century. Is that the way I take that?

DR CLEUGH: Yes, you are correct. And that some of the - depending on the extreme events, there's an element of locked in, that some of these are locked in because of emissions that we've already had, yes. Nonetheless, we can have a significant amelioration of some of those impacts by addressing emissions into the future. Commissioner, if it's okay with you, Dr Grose is our technical expert on many of these aspects and if it's okay with you, Commissioner, I would like to ask him if he would like to add some more detailed comments to that question.

COMMISSIONER BINSKIN: Yes, please, Dr Grose?

DR GROSE: Thank you, Dr Cleugh, thank you Commissioner. Nothing much to add in the interests of time, other than I support the statements you've made. It's a little bit different for different types of extremes and disasters, but that general case is very much true. There is also perhaps the other wild card that people talk about of climate engineering to counter some of the effects of climate change. But that's very speculative and not at all, something we account for in the current climate projections.

COMMISSIONER BINSKIN: Thanks for that. And would that affect us in the next 10 to 20 years if that was to happen?

DR GROSE: It's very speculative at the moment. And there's a lot of reasons to be very cautious about employing climate engineering, it needs a lot more research into it. So it's very unknown, even more unknown than the emissions scenario will follow, whether the world will follow any climate engineering to tackle climate change.

COMMISSIONER BINSKIN: Okay. Thank you. I appreciate that comment. Commissioner Bennett?

COMMISSIONER BENNETT: Thank you. I'm just intrigued by one comment that you made almost at the beginning and then another reference later and that was, I want to understand a little bit about SAM and the impact of that on the wind and you said in southern Australia. So I've got a couple of questions. One is: how far into southern Australia does that impact - is that impact felt; secondly, how predictable is it all or how do we know whether it's going to happen or not over the next, let's say, few years; and the third question is, in that same thing, does that have any interconnection with the increase in the day - in the dangerous pyroconvection conditions for southern Australia? So it's dealing with, to the extent to which it has an impact - it may not have one, and you can tell me that's the answer to that - but how far in does it go and what do we do with the predictability of it?

DR CLEUGH: Thank you, Commissioner, for that question. SAM plays an important role in Australia's climate, particularly where the westerlies ..... and again, it it's okay with you, Commissioner, I'd like to bring Dr Grose in here, again because he has great technical expertise on these climate drivers and the influence they have on Australia's climate. So I will pass to Dr Grose.

COMMISSIONER BENNETT: Thank you.

DR GROSE: Thank you, Dr Cleugh, and thank you, Commissioner. Yes, as Dr Cleugh mentioned, SAM affects the latitude and strength of the westerly wind belt that affects the climate of southern Australia. It also then has a flow-on effect to the climate - seasonal climate of parts of eastern Australia as well, because that westerly wind build has a flow-on affects. So the effect varies by season and by

region. However, it is generally associated with high fire danger when it's in certain phases of SAM, and this was the case last year in the lead-up to the 2019/2020 bushfire season.

There was a strong Indian Ocean Dipole event but also SAM conditions were favourable for encouraging bushfire, and this was also linked in part to a periodic event called a southern stratospheric warming south of Australia as well. So all of those three drivers were important and those were documented in the Bureau of Meteorology seasonal outlooks and seasonal reports from last year.

COMMISSIONER BENNETT: Okay. Well, two questions follow on from that, if I may. One is: how far up into Australia are these effects felt in terms of latitude and is SAM affected by changes in climate, sort of in terms of the other modelling?

DR GROSE: Sure. So the effects varies a bit by season and by region. But the effect can be quite far north, obviously not into tropical Australia. It's at the southern tropical and southern temperate zone kind of effect. SAM has been showing a long-term trend towards a more positive phase affected by both greenhouse gas emissions and also the ozone depletion over the stratosphere around Antarctica. Both of those have had an influence on the kind of average or mean condition of ..... mode and that is predicted to continue into the future, affecting the average climate and also climate variability of southern Australia especially.

COMMISSIONER BENNETT: Thank you very much.

DR CLEUGH: Counsel, you asked about the pyroconvection as well.

COMMISSIONER BENNETT: Yes, I did and I was just wondering how that interconnects with SAM?

DR CLEUGH: Yes. It's probably mostly for the bureau to answer because they are the experts there. But what I would say is that I think that pyroconvection is more local, associated with the local event, whereas the SAM is having an influence on conditioning and landscape in the longer term, as Dr Grose explained.

COMMISSIONER BENNETT: So the impact of SAM on wind doesn't directly link into the pyroconvection events?

DR CLEUGH: I - I will check with Dr Grose, my expert, and as I said, I think the bureau would be the ones to really provide that expert information.

COMMISSIONER BENNETT: They were here this morning and I didn't ask that one, because they didn't raise it, so I'm afraid I'm stuck with you.

DR CLEUGH: My assessment, but if you would like, I'm happy to actually follow that up as a - on notice, if you would like. And here to answer your question, my assessment that that would be less of an effect compared to other things that drive

those pyroconvection processes. I think there would be other factors that are perhaps more important. That would be my assessment but, as I said, we would be very happy to follow that up .....

COMMISSIONER BENNETT: Well, Dr Grose is nodding so I'm taking it that that's a fair summary, in general?

DR GROSE: Yes. Again, yes, the same as Dr Cleugh, I'm not an expert in the area but that is my sense of the case. I agree with Dr Cleugh.

COMMISSIONER BENNETT: Okay. Thank you very much indeed.

COMMISSIONER BINSKIN: Thank you. Commissioner MacIntosh?

COMMISSIONER MACINTOSH: Thanks, Chair. I have no questions. I will just say thank you to you both for your presentation today and to CSIRO for your responses both today and in relation to our notices to give.

DR CLEUGH: Thank you, Commissioner.

DR GROSE: Thank you.

COMMISSIONER BINSKIN: Ms Ambikapathy?

MS AMBIKAPATHY: Commissioners, there will be an institutional response tendered in due course that CSIRO has provided. But at this stage, may I ask for Dr Cleugh and Dr Grose to be excused.

COMMISSIONER BINSKIN: Dr Cleugh, Dr Grose, thank you very much for joining us this morning. We appreciate it very much. You're now excused.

DR CLEUGH: Thank you.

DR GROSE: Thank you very much.

COMMISSIONER BINSKIN: Ms Hogan-Doran?

MS HOGAN-DORAN SC: The next witness is Leesa Carson from Geoscience Australia who has a short presentation. In your bundle you find it behind tab D11. That's a PDF version of a PowerPoint presentation that's been prepared by Ms Carson, and then she will be presenting an animated version of that at the hearing. For the purposes of the tender and for the record, the document is GEO.501.001.0001.

I also tender a copy of Ms Carson's curriculum vitae which I will take her to in a moment. It's behind tab 12. That's GEO.501.001.0048. There will also be an

institutional response tendered in due course from Geoscience Australia. Those two exhibits, it is proposed, will be exhibits 1.3.1 and 1.3.2 respectively.

COMMISSIONER BINSKIN: We will take those exhibits and tender - received as exhibits as you've marked them and described.

EXHIBIT 1.3.1 PDF VERSION OF A POWERPOINT PRESENTATION PREPARED BY MS CARSON, GEO.501.001.0001.

EXHIBIT 1.3.2 CURRICULUM VITAE OF MS CARSON, GEO.501.001.0048.

And just confirm, the ones you talked about will be additional exhibits? You added a couple there right at the end, or did I get that confused?

MS HOGAN-DORAN SC: I gave you two - - -

COMMISSIONER BINSKIN: You gave us two, 1.3.1, 1.3.2.

MS HOGAN-DORAN SC: That's it.

COMMISSIONER BINSKIN: And then you said that - that's it?

MS HOGAN-DORAN SC: I was referring to an institutional response which has not yet been received from Geoscience Australia but when it is, we will provide that for the Commission.

COMMISSIONER BINSKIN: Okay. Thanks.

MS HOGAN-DORAN SC: I call Leesa Carson.

<LEESA CARSON, AFFIRMED>.

MS HOGAN-DORAN SC: Ms Carson, you're the branch head of community safety at Geoscience Australia?

MS CARSON: Correct.

MS HOGAN-DORAN SC: And you represent the Australian Government as a technical adviser on the United Nations Expert Working Group on Disaster Risk Reduction?

MS CARSON: Yes.

MS HOGAN-DORAN SC: And that group is to develop indicators to measure global progress in the implementation of the *Sendai Framework for Disaster Risk Reductions*?

MS CARSON: That working group did do that.

MS HOGAN-DORAN SC: You have a Bachelor of Science honours from the University of Melbourne?

MS CARSON: Correct.

MS HOGAN-DORAN SC: And a Master of Science from the Australian National University?

MS CARSON: Correct.

MS HOGAN-DORAN SC: You've been with Geoscience Australia for sometime but you have a background also as a geologist and photogeologist?

MS CARSON: As a geologist.

MS HOGAN-DORAN SC: And you prepared a presentation which we will give in evidence today to the Commissioners?

MS CARSON: Correct.

MS HOGAN-DORAN SC: Right. And you will indicate to the operator when you want to proceed to the next slide.

MS CARSON: Yes.

MS HOGAN-DORAN SC: And at the end of your presentation the Commissioners may have a few questions.

MS CARSON: Okay.

MS HOGAN-DORAN SC: Thank you, Ms Carson. Operator, if the PowerPoint presentation of Geoscience Australia could be brought up? Thank you, Ms Carson.

MS CARSON: Thank you. So I'm going to talk today about the observations and hazard modelling in respect to earthquakes and tsunamis in Australia. So my program has an important contribution to disaster risks, reduction activities conducted for multiple hazards. We have delivered this trusted information, action information, to support informed decision-making for natural hazards across that disaster risk management cycle from preparedness, mitigation, response and recovery. And we have developed an integrated capability to assess risk which is a combination of hazard, exposure and vulnerability. And we have strong sustained relationships with all levels of government, so we can take our national focus and bring it to bear at that local and regional disaster risk activities.

Next slide, please. Next slide, please. Thank you. So large earthquakes can happen anywhere in the Australian continent and Australia experiences about 1000 - sorry, 100, that's a lot of earthquakes, 1000 - 100 earthquakes of magnitudes three-plus per year. The first documented earthquake in Australia occurred shortly after the First Fleet arrived in Australia. However, there is Aboriginal dream stories that suggest a longer history of earthquake observations in Australia, and one of the most interesting ones is that they record a dreaming story near Newcastle. Now, Newcastle is one of the most significant, I guess, earthquakes in Australia's history. But you can see clearly on this map some of the large earthquakes occurrences. So along the south-east side of Australia there, from the Southern highlands down to Gippsland; also in South Australia, the Mount Lofty and Flinders Ranges area; the wheat belt of WA and that north - north-west area of WA.

The earthquake record is more complete in the southern, south-eastern part of Australia due to the early development of European settlement, and this is where the most complete location of our seismic monitoring network is. So the Australian National Seismograph Network has densified over time, which has allowed our catalogue to be more complete, and monitoring of the earthquakes has significantly improved since 1960s which actually, I guess, shows an apparent increase of earthquakes, which is more about our recording of earthquakes.

Next slide, please. Next slide, please. Thank you. This is a table of significant Australian earthquakes, information from our earthquake catalogue, from newspaper reports as well as the costs from the insurance sector. One of the most recent earthquakes, it's not listed here, is the 2019 magnitude 6.6 off Broome. Also listed there is the Newcastle earthquake which in those couple of slides I will give some more details but you will note there it's one of the most costly natural disasters to occur in Australia and it was only a moderate sized earthquake. Thank you. Next slide, please.

MS HOGAN-DORAN SC: Ms Carson, just so you know, there is a short delay for the slides to come up.

MS CARSON: Thank you.

MS HOGAN-DORAN SC: But the operator can hear you. Thank you.

MS CARSON: Thank you. This is an example of the Meckering earthquake, it was a magnitude 6.5 in 1968. There were 20 people injured and luckily no one killed. You can see in the photographs there, there was significant to damage to infrastructure as well as - you see houses damaged. The most impressive image for me is the picture there of the railway line. There's also the surface feature of the earthquake rupture that's about 37 kilometres, and in areas is two to three metres high. This area is in the WA wheat belt. It is known as the south-west seismic zone, and this one, this rupture, this surface rupture, is one of the largest of three that occurred in this region within a 11 year period.

Next slide, please. The Newcastle earthquake: last year was the 30th anniversary of this earthquake and it's one of Australia's most significant natural disasters. In 1989, December, Newcastle was devastated by a magnitude 5.6. So a local magnitude of 5.6 and moment magnitude of 5.4. The epicentre was 15 kilometres south-west of Newcastle. The earthquake claimed 13 lives. 160 people were hospitalised. 50,000 buildings were damaged, and approximately 40,000 of these were homes. 300 buildings were demolished. 30,000 people were affected and 1000 of these were made homeless. It left a bill of approximately $4 billion and that's normalised dollars to 2017. And just to think, the population at the time was - for Newcastle, was 155,000. Currently the population for Newcastle is 450,000.

Next slide, please. Geoscience Australia has the full earthquake ..... We monitor, alert and analyse and alert earthquakes of magnitude 5-plus. We conduct post-disaster surveys for significant events. We feed that data into our earthquake damage models so that we can update risk assessments, and our national scale hazards assessment is used for preparedness.

The photos here, the one in the bottom - bottom right-hand corner, is one of our seismic sites. And then the larger photo is our National Earthquake Alert Centre which also forms part of our joint Australian tsunami warning system with the Bureau of Meteorology. The map shows our network of seismic stations. So you can we there's the red triangles there are sites that Geoscience Australia maintain and monitor for - actually for nuclear monitoring on behalf of the Australian Government and for the Comprehensive Nuclear Test Ban Treaty Organisation. But that data also feeds into our seismic network.

The green is our national seismograph network of seismic monitoring stations. We have approximately 100. The purple is the joint urban monitoring program which is a State and Federal program of seismic monitoring in larger population centres. And the yellow represents seismometers in schools, which is a partnership with ANU where instruments are run and monitored by schools; the research on seismo-effects as well as educational awareness. For this network, DA can assure a networking monitoring down to a threshold of a magnitude of 3.5. While on magnitude, earthquakes are commonly detected and recorded through our website Geoscience Australia at Earthquakes@GA.

Australia is the most seismically active stable continental region in the world, having experienced nine of the 15 documented surface rupturing earthquakes from all global stable continental regions. In spite of this activity, the Australian land mass remains one of the most vastly instrumented continents. For example, the whole Swiss Seismological Service Network of over 100 stations could easily fit in the spatial gaps for our network.

In addition to this system we also deploy what we call a rapid deployment kits at short notice to areas affected. These kits allow detailed monitoring of the location and the number of aftershocks to catch a rare strong brown motion, the large aftershocks, that improve our understanding of hazard modelling capability.

The next slide, please. This slide shows the National Earthquake Alert Centre's products. So in addition to the basic earthquake location and magnitude, GA, Geoscience Australia, provides new real-time situation awareness tools to provide actual information for earthquake shaking intensity for emergency managers and first responders. So what you can see here is up on the left-hand side is what we refer to as a shake map, and the main image in the middle is the community internet intensity maps. This is for the 2019 magnitude 6.6 offshore from Broome. So the community internet intensity maps are felt reports, submitted online via a questionnaire at the Earthquakes@GA web page. Based on the responses to these questionnaires, a shaking intensity can be calculated, and aggregated to give a grid extent.

These maps provides critical ground truth-in-information on the extent and degree of shaking in the region. The shake maps combine observational data with theoretical models, generate near real-time maps of ground motion and shaking intensity through significant earthquakes. Through this earthquake, GA received felt reports from over 1700 individual responses, which I think is pretty impressive in a region that is vastly populated to this event. They were felt as far away as Darwin and down to Esperance in the south.

Next slide, please. Just some background on magnitude versus intensity. An earthquake's magnitude is related to the energy released at its epicentre. Magnitude is measured on a logarithmic scale. The intensity of an earthquake refers to the level of ground shaking at any location. The earth shaking intensity decreases with the increased distance from an earthquake, and the modified McKelly intensity scale, what we refer to as the MMI, a simplified version is on the right there. It's commonly used to describe the effects of an earthquake at a given place. It is a qualitative assessment of the earthquake effects on people and structures; where the earthquake magnitude is a quantitative measure based on physical recordings made at seismometers.

This example here is a shake map for the Newcastle event and it shows the shaking intensity. The dots are observations. So there was, at the time people recorded by hand or on paper their experiences of that earthquake and submitted them. So we have now collated all that information and then we have modelled that 1989 Newcastle earthquake to provide a shake map. And as you can see for Newcastle, it was strong to very strong, on the edges severe.

Next slide, please. Thank you. So our earthquake catalogue in geological time is very short. So we need to look for other information to understand earthquake hazard. Australia has low rates of erosion, relative to the fault relief building, combined with relatively sparse vegetation in much of the country. This allows geologists to identify potential active features that could post large earthquakes from the geological recent past.

Geoscience Australia has developed a database of approximately 360 features nation-wide that are suspected of being active in the current ..... stress fields which

developed in the last 10 to five million years. These features could reasonably host large earthquakes, magnitudes of 7 and larger, again in the future. The recurrence time of large earthquakes on any one fault can be determined by trenching. So the photo on the bottom right-hand side is an example of trenching, and a trenching investigation of the WA fault scar. The investigation found the last large earthquake on this fault was about 8000 years ago and the fault could generate an earthquake of a magnitude 6.8 to 7.

Only a handful of Australian fault scars have been trenched. The map up in the right top shows neotectonic features in south-eastern Australia. These neotectonic features are colour coded by fault estimated by the long-term slip rate in metres per millions of years. And the image you see there is Lake George fault, one of Australia's most active faults. It is likely that there are many small potentially active faults that have not yet been identified. And of all this historic surface structures that have occurred in Australia have occurred in unanticipated locations, meaning they could not have been identified prior to the event.

Next slide, please. The National Seismic Hazard Assessment 2018: this is our hazard assessment and indicating the peak ground acceleration at 10 per cent probability of being exceeded in 50 years. The map on the left shows the neotectonic features which I was just talking about in the previous slide, and these features have been incorporated into this hazard assessment. The National Hazard Assessment requires a probabilistic seismic hazard analysis, and this defines the levels of earthquake ground shaking at a given location has a likelihood of being exceeded in a given period.

The method considers all possible earthquakes that have a given likelihood of affecting a given site within the investigation period, and typically this is the life of a building. One of the fundamental uses of a National Scale Seismic Hazard Assessment is the national building codes and standards. The input and derived products of these assessments are used in a range of infrastructure and community safety applications informing seismic design and construction of infrastructure and in critical post-disaster facilities, the risks, mitigation strategies and also the insurance sector for their insurance and reinsurance premiums for asset portfolios.

The integration of modern seismic hazard models into the National Building Code provides the most effective way to reduce human casualties and economic loss from future earthquakes. Next slide, please. Thank you. Not just a map, often we visualise assessments as a single map. Shown here on the top right hand corner is Geoscience Australia's tropical cyclone hazard assessment and it's more than just a single map. You can think of a hazard assessment as a stack of maps where each layer in that map relates to a particular average recurrence interval. You may want to understand the maximum wind speed for an average recurrence interval for 100 years hazard for the whole country, or you might be interested in understanding how that wind speed changes with the average recurrence interval at a particular location. And naturally as the average recurrence interval increases, that means the event becomes less frequent and the wind speed increases.

But this example here is Exmouth in WA. You can see, if you take an average recurrence interval of 1000, that this potentially has a category 4 to 5 cyclone; where, if you are looking at an average recurrence interval of 50, it is a much lower category. There's much more behind these hazard assessments. They're a treasure trove of scenarios. But a tropical cyclone has an assessment. There are over 1650,000 scenarios nationally and for the earthquake and tsunami there are millions. These scenarios are what we call synthetic. They represent plausible future scenarios for planning. The scenarios have been generated by sophisticated models using high performance computing and they are available openly.

Next slide, please. Returning to earthquakes, another aspect is site response and based on amplification. So ground shaking is known as amplification at sites on soft soils and in sedimentary basins. The diagrams here show the seismic plates travelling fast through bedrock into the overlying sedimentary basins and the wave speed slows considerably because the energy is conserved. The amplitude of the waves increases to compensate for the slower velocity. So often coastal areas, reclaimed land, along, kind of, river channels are particularly vulnerable to this ground deformation, and you would have probably seen images of liquefaction where the ground becomes liquid. This map on the right is a section of our 2017 Australian seismic site condition map for Victoria. The green colours represent harder or firmer rock, where the yellows and orange represents the softer soils.

Next slide, please. So earthquake risk assessments. So risk assessment, we combine the hazard, exposure, vulnerability, to understand the risk of our community to events. This example is from a current project in Perth. The stakeholders include the State Government and major infrastructure owners. It shows the earthquake risk across Perth, combining the damage related to risk and the community resilience. This is highly constructive to decision-makers to determine the cost benefit of taking certain approaches to reducing risk.

An important point to keep in mind, the risk assessment is done for multiple hazards and the decision-maker is in the position to understand what hazard is driving the risk and, more importantly, what exposed elements is driving the risk. So thinking about the hazard assessment as a stack of maps for the whole spectrum of average recurrent intervals, we are able to be positioned to assess our risk. A single scenario is not enough to understand risk. We need that full spectrum of average recurrence intervals.

Next slide, please. Let's turn to tsunamis. Tsunamis are waves generated when the ocean is disturbed over a broad area in a short period of time. And the graphic there on the left-hand side shows a tsunami being caused by an earthquake, where you have that sudden uplift over - and it could be over tens of hundreds of kilometres, and this generates a series of waves that propagate along distances. Tsunamis are not only caused by earthquakes but also landslides and volcanic activity. They can disturb the ocean and produce those tsunamis. This map shows tsunami sources and it's from the National Oceanic Atmospheric Administration database, which is the

most widely used international database. The lines are the plate tectonic boundaries, and most tsunamis are generated by earthquakes near that convergence conduction zone. And Australia, as you can see, is in the mid plate location, meaning that most of the tsunamis that are generated are far from us.

Next slide, please. So I'm just going to go through some observations of some tsunamis. So last week was actually the 60th anniversary of the Chilean event. The tsunami was, you know, typically dangerous close to the source, but the waves are highly directional. This means they can be dangerous far from the source. And we can see this when we show the animation of Hawaii and Japan are impacted. So we will see as the earthquake has generated the tsunami and you can see those waves propagating across the surface and impacting Australia, the US and as far away as Japan, and you can see the wave heights and the depths there. So far away sites are affected and it depends on the fault location, flip and size. For the 1960 Chilean earthquake, it was not well positioned, or well positioned for Australia; we did not receive very large waves. However, there was certainly widespread marine damage, boats were damaged, erosion and inundation in Bateman's Bay.

But moving on to the Sumatran 2004 tsunami, a 9.2 earthquake, this is the Indian Ocean tsunami. 250,000 people were killed. Most of the fatalities were around the western Indonesian, Sri Lankan, Thailand and India. There were also 300 deaths in Somalia, 5000 kilometres from the source. And again, you can see that directionality of the waves. In Australia we had widespread waves up to about one metre in WA. Again, we were lucky, the tsunami was not well located to direct large waves to Australia, but we still reported some marine hazards. There were 35 ocean rescues, damaged boats, and some mild or minor land inundation.

Next slide, please. This is the 2006 Java tsunami, a magnitude 7.7, so this was a much smaller earthquake than the previous cases. However, it was well located to affect Australia. You can see the directionality of the waves, and the event led to historically high run-ups in Australia. 7.9 metres at Deep Point near Shark Bay in WA. This is a remote area, and some people were camping in this region and their beach campsites, as you can see in the photos, were damaged. There is reports of people in knee-high or chest-high water. They are reporting the sound of a roar like a freight train for the first wave that came in. The tsunami heights can vary quite a bit over short distances. So these people were not hit with a 7.9 metre wave, but it highlights the importance of the tsunami directionality.

Next slide, please. The tsunami has a modelling, we first look at, is a two-step process: understanding what the source is, what kind of tsunamis that might be generated and how often. And the second set is to model that inundation. The first step can be conducted over large spatial scales in the case of earthquakes, and Geoscience Australia's probabilistic tsunami hazard assessment offers a nationally consistent approach. This figure shows the earthquake sources using the probabilistic tsunami assessment with a global coverage of major earthquake source zones. For other tsunami sources, such as landslide and volcanos, the science is relatively less well developed, and there's no characterisation at these scales. And then the second

step is taking that tsunami hazard modelling and undertaking inundation modelling. So this slide just shows where the source zones for Australia's Probabilistic Tsunami Hazard Assessment.

Next slide, please. Now, for each of those source zones that you saw on the previous slide, the Probabilistic Tsunami Hazard Assessment creates a large number of earthquake scenarios and we model their tsunamis, and we also estimate the magnitude and frequency of earthquakes at all those sources. There is a lot of research and testing underlies what is being done. We use data from historical tsunami events to check our models. We use earthquake catalogues and plate tectonic information to model the earthquake frequency. There is normally much uncertainty in the frequency of large earthquakes and tsunamis, mainly because they're rare and they're relatively ..... with historical events is very sure. Because it is modelled at such a global scale, the models are fairly coarse and do not include inundation. This slide shows the simulation of a tsunami for one possible scenario. The Probabilistic Tsunami Hazard Assessment provides one million such scenarios which then can be forced into inundation models anywhere in Australia.

Next slide, please. This figure shows the offshore slides of a tsunami with a 500 year average return interval, according to the Probabilistic Tsunami Hazard Assessment. As you can see here on that north-west coast - stands out as having high waves and this is because of that east arc and you recall some of those tsunamis, the 2006 earthquake tsunami event. Also on the east coast is prominent - not as much as I guess you could say the north-west - but this area in the east is exposed to a large range of Pacific Rim earthquakes, and we saw the Chilean example in South America, but also closer to home is the Kermadec-Tonga region, French, which is north of New Zealand.

Next slide, please. So the Probabilistic Tsunami Hazard Assessment is an offshore model and we need to bring that onshore to understand the hazard. We want to know where the areas of potential exposure to that tsunami inundation are, and also understand some of that marine hazard, the unusual currents that will occur in estuaries. This kind of information will guide emergency response as well as design some of those evacuation routes. It's essential input to understand the risk, having knowledge of where people and infrastructure are located, and how risky is our currently situation. For this purpose, we need to simulate the tsunami near shore and on shore. So these examples here are from Tasmania and south-east Queensland.

This kind of modelling requires high resolution elevation data. Coverage of this - of that type of data is advancing rapidly in recent years with the collection of what's referred to as lidar information, so it's this remote sensing method to measure and map topography and bathymetry. Old data requires still quite a lot of manual processing to clean up, and be suitable for doing the modelling. This type of modelling is also very computationally intense and, depending on the size and the resolution, requires quite fast computers to help the modelling.

Apparently Australia is - has limited coverage of tsunami inundation modelling and a lot of the work is on very old poor quality elevation data and does not take into account the most recent Probabilistic Tsunami Hazard Assessment.

Next slide, please. So, in summary, although we've focused on earthquake and tsunami, GA has a broad capability that underpins and supports the Australian disaster risk reduction activities from multiple hazards in alignment with the national disaster risk reduction framework. Our focus is targeted at priority one, understanding disaster risk, as in exposure and vulnerability. While earthquakes and tsunamis occur less frequently than other hazards experienced in Australia, their consequences are potentially catastrophic. These hazards suffer, due to the short recorded history, a lack of complete and events catalogues. Comprehensive, open, accessible, databases for all hazards make it easier to test and parameterise these models, underpin our understanding of hazards, and also provide a ready source of stories to communicate hazards to the public. Thank you.

COMMISSIONER BINSKIN: Thank you, Ms Carson, appreciate that brief. Commissioners' question? Commissioner Bennett? Commissioner Macintosh? Thank you, Ms Hogan-Doran.

MS HOGAN-DORAN SC: Thank you, Ms Carson. Commissioner, might Ms Carson be excused from her summons?

COMMISSIONER BINSKIN: Yes. She can be excused. Thank you very much, and thank you for taking the time to prepare that and be able to present it to us today. I appreciate it very much.

MS CARSON: Thank you.

MS HOGAN-DORAN SC: Chair, I note the time. If it's convenient to you, the next three witnesses are constituting as a panel. If that could proceed at 2 pm?

COMMISSIONER BINSKIN: We can do that at 2 pm. We will have Professor Townsend in the meantime?

MS HOGAN-DORAN SC: No, Professor Townsend, her evidence - she's one of our community witnesses - has been prerecorded. Rather than it play over the lunchbreak, we propose that it would complete the evidence today and go after the three panelists.

COMMISSIONER BINSKIN: After the three panelists?

MS HOGAN-DORAN SC: Yes. We don't expect the three panelists to take the whole of the afternoon.

COMMISSIONER BINSKIN: Okay. In that case, we will adjourn until - what time did you say?

MS HOGAN-DORAN SC: 2 pm.

COMMISSIONER BINSKIN: We will adjourn until 2 pm. Thank you.

<ADJOURNED 12.56 PM

<RESUMING 2.00 PM

COMMISSIONER BINSKIN: Ms Hogan-Doran?

MS HOGAN-DORAN SC: Commissioners, this morning you heard evidence from the Bureau of Meteorology, the CSIRO and Geoscience Australia about natural hazards and the influence of climate change. This afternoon you will hear three witnesses who will further explore natural disaster risk in Australia and some of its impacts and consequences. The evidence of these three witnesses will be taken concurrently; that is, in a panel. I propose to call each of them, the witnesses sworn and then tender their material, and then engage with each of them in turn.

So I call Mark Leplastrier, Ryan Crompton and Sharanjit Paddam.

COMMISSIONER BINSKIN: Mr Leplastrier, Mr Paddam, Dr Crompton, welcome. Thank you for joining us this afternoon.

MS HOGAN-DORAN SC: If you take them in turn, Mr Leplastrier, will you take an oath or an affirmation?

MR LEPLASTRIER: An affirmation, thank you.

<WITNESS MARK LEPLASTRIER, AFFIRMED>

MS HOGAN-DORAN SC: Mr Paddam, will you take an oath or affirmation?

MR PADDAM: Affirmation, please.

<WITNESS SHARANJIT PADDAM, AFFIRMED>

MS HOGAN-DORAN SC: And Dr Crompton, will you take an oath or affirmation?

DR CROMPTON: Affirmation, please.

<WITNESS RYAN CROMPTON, AFFIRMED>

MS HOGAN-DORAN SC: Mr Leplastrier, you've provided a witness statement dated 22 May 2020 under a notice issued by the Commission?

MR LEPLASTRIER: Yes.

MS HOGAN-DORAN SC: Do you have that witness statement with you?

MR LEPLASTRIER: I do.

MS HOGAN-DORAN SC: And do you adopt its contents as true and correct?

MR LEPLASTRIER: I do.

MS HOGAN-DORAN SC: Commissioners, I propose that that be - that statement which is doc ID, LEP.500.001.0001 be marked as exhibit 1.1.1.

MS HOGAN-DORAN SC: There are also two reports that have been exhibited to that statement, Mr Leplastrier. The first one is a report of SCG Economics and Planning: *At What Cost Mapping Where Natural Perils Impact on Economic Growth and Communities* from November 2016; is that correct?

MR LEPLASTRIER: That's correct.

MS HOGAN-DORAN SC: I propose, Commissioners that that be exhibit 1.5.2, and that is ID: IAG.001.001.0011.

MS HOGAN-DORAN SC: And the third document, Mr Leplastrier, is a report called *Severe Weather in a Changing Climate* published in November 2019. It's proposed that that be exhibit 1.5.3 and document ID IAG.001.001.0046.

COMMISSIONER BINSKIN: Those three documents will be received as exhibits as marked.

EXHIBIT 1.1.1 WITNESS STATEMENT OF MR LEPLASTRIER, LEP.500.001.0001

EXHIBIT 1.5.2 REPORT OF SCG ECONOMICS AND PLANNING: AT WHAT COST MAPPING WHERE NATURAL PERILS IMPACT ON ECONOMIC GROWTH AND COMMUNITIES, NOVEMBER 2016 IAG.001.001.0011.

EXHIBIT 1.5.3 REPORT SEVERE WEATHER IN A CHANGING CLIMATE PUBLISHED IN NOVEMBER 2019, IAG.001.001.0046

MS HOGAN-DORAN SC: Mr Paddam, you've provided a witness statement to the Commission dated 21 May 2020. Do you have that with you?

MR PADDAM: I do.

MS HOGAN-DORAN SC: And do you adopt its contents as true and correct?

MR PADDAM: I do.

MS HOGAN-DORAN SC: You have also provided three additional documents from the Actuaries Institute. Those will be identified, it is proposed, Commissioner, as - sorry, I am sorry, I apologise, I've missed exhibit 1.6.1 will be that witness statement.

MS HOGAN-DORAN SC: Exhibit 1.6.2, 1.6.3 and 1.6.4 will be as follows. The Australian Actuaries Institute Climate Index, November 2018, doc ID SHP.501.001.0001. The next being the *Actuaries Climate Index, Some Comments on Extremes* published December 2018, doc ID SHP.501.001.0019. And the third, I will just ask Mr Paddam some questions about that.

Mr Paddam, you provided yesterday a number of documents. Can I have that document shown on the screen. It is SHP.502.001.0001. And are these three pages that you have provided which are recent - perhaps if you could describe them in short? They are taken from that website link contained on that page and are the most current, composite and individual component indexes - indices from the Australian Actuaries Climate Index; is that correct, Mr Paddam?

MR PADDAM: That's right and they also contain the North American Actuaries Climate Risk Index.

MS HOGAN-DORAN SC: Thank you, Mr Paddam. And that will constitute exhibit 1.6.4, Commissioner.

COMMISSIONER BINSKIN: Thank you. So we will take those four documents as exhibits as marked.

EXHIBIT 1.6.1 WITNESS STATEMENT OF SHARANJIT PADDAM DATED 21 MAY 2020.

EXHIBIT 1.6.2 AUSTRALIAN ACTUARIES INSTITUTE CLIMATE INDEX, NOVEMBER 2018, SHP.501.001.0001.

EXHIBIT 1.6.3 ACTUARIES CLIMATE INDEX: SOME COMMENTS ON EXTREMES PUBLISHED DECEMBER 2018, SHP.501.001.0019.

EXHIBIT 1.6.4 CURRENT, COMPOSITE AND INDIVIDUAL COMPONENT INDEXES - INDICES FROM THE AUSTRALIAN ACTUARIES CLIMATE INDEX, SHP.502.001.0001.

MS HOGAN-DORAN SC: And the final matter of housekeeping: Dr Crompton, you provided a report dated 22 May 2020 under notice issued by the Commission?

DR CROMPTON: That's correct.

MS HOGAN-DORAN SC: Do you have that with you?

DR CROMPTON: Yes, I do.

MS HOGAN-DORAN SC: You have a number of corrections you wanted to make to that report. If we could just have those marked to the record, and please tell me if this is correct. On page 9, line 24, you refer to 110 year record, and your correction, as I understand it, is that it should say 121 year record; is that correct?

DR CROMPTON: That's correct.

MS HOGAN-DORAN SC: The second correction is a correction to figure 4. Figure 4 specifies death rates per 100,000 population from bushfires in Australia for the financial years 1899-1900 to 2019-2020. I understand there's a correction you wish to make to insert into that. Would you be able to identify that correction for the benefit of the transcript?

DR CROMPTON: It's just for clarity that 1899/1900 refers to the year 1900 which is not consistent with the previous figures, so it's for clarity.

MS HOGAN-DORAN SC: Am I to understand it that it's not the financial year but the calendar year 1900 is that what you're referring to?

DR CROMPTON: No, no. It's just the year beginning 1 July 1899 in that figure refers to 1900 on the figure itself.

MS HOGAN-DORAN SC: And then you also have a correction to page 7, table 1, The Breakdown of Normalised Australian Insurance Losses by Peril Based, 1966 to 2017. And I understand the word "based" should be deleted from that heading; is that correct?

DR CROMPTON: That's right. That's correct.

MS HOGAN-DORAN SC: Subject to those amendments and corrections, is the content of your report true and correct?

DR CROMPTON: Yes, that's correct, yes.

COMMISSIONER BINSKIN: So with those amendments that document will be received as an exhibit as marked 1.7.1.

EXHIBIT 1.7.1 REPORT OF DR CROMPTON DATED 22 MAY 2020

MS HOGAN-DORAN SC: That's right. Thank you, Commissioner.

Just excuse me one moment, gentlemen. Mr Leplastrier, if I may commence with you. You're the Executive Manager of the Natural Perils Team at IAG Limited; is that correct?

MR LEPLASTRIER: That's correct.

MS HOGAN-DORAN SC: And you have a Bachelor's degree with first class honours in Atmospheric Science from Macquarie University.

DR CROMPTON: Correct.

MS HOGAN-DORAN SC: And you've been a leader of IAG, if I may call, Insurance Australia Group by its acronym, IAG's Natural Perils Team since around 2005.

DR CROMPTON: Yes, that's right.

MS HOGAN-DORAN SC: I understand you know each of Mr Paddam and Mr Crompton. I note you're a member of the Advisory Board of Risk Frontiers which is Dr Crompton's organisation, and you've been a member of that Advisory Board since 2008?

MR LEPLASTRIER: Yes.

MS HOGAN-DORAN SC: And you also know Dr Paddam in relation to work with the Insurance Council of Australia; is that correct?

MR LEPLASTRIER: The Time and Measurements Standard Initiative.

MS HOGAN-DORAN SC: Thank you. Now, we've heard this morning in evidence of natural hazards. What's the difference, if anything, between natural hazards and natural perils, noting that IAG has a natural perils team. Can you explain that difference to the Commissioners, just before we get underway?

MR LEPLASTRIER: It was one and the same. Natural hazards is the term typically used outside of the insurance industry, but natural perils is often used within the insurance industry but we principally mean the same thing.

MS HOGAN-DORAN SC: IAG Natural Perils Team, what constitutes it, or who works within that team and works with you, Mr Leplastrier?

MR LEPLASTRIER: Yes, so I have a team more grounded in natural hazards than you would typically see in a normal insurance analytical team. So we have meteorologists, engineers, statisticians in the team.

MS HOGAN-DORAN SC: Do you have also have atmospheric scientists, and hydrologists, and mathematicians?

MR LEPLASTRIER: That's correct.

MS HOGAN-DORAN SC: And what's the role or purpose of that team?

MR LEPLASTRIER: The team looks at the natural peril risk for an insurance company and what's the cost, both for reinsurance requirements, so when large single events might impact a large population. It's understanding there's very large losses and what sort of reinsurance provisions we may need. The other part of it is understanding the pricing perspective, so how much of the natural peril risk needs to be factored into insurance policies. Another aspect of it - of what our team does is provides some of those alerts and forecasts for our claims areas, for upcoming impacts, so they can better respond. And we also get involved in estimating losses in the early days after a large natural catastrophe.

MS HOGAN-DORAN SC: In the period leading up to November 2019, IAG partnered with the National Centre for Atmospheric Research, which is based in the United States, for the preparation of a report which you've exhibited to your statement, Severe Weather in a Changing Climate. What's the purpose of that report and if we might have it called up now, it is doc ID IAG.001.001.0046.

MR LEPLASTRIER: Okay. The report is part of an ongoing program of work looking at the impact of climate change on severe weather types, things like tropical cyclones, bushfires, east coast lows, floods and hail events. They're the sort of events that cause damage to property. And IAG is a large property insurer, so we need to understand how those types of severe weather changing under a changing climate, what has happened to date and what's happening in the future. The actual report to be released in 2019 was based on a particular piece of work which occurred mostly through around 2017 where we were trying to provide a more formal, I suppose, framework of how we look at future climate change scenarios by using kind of more standard kind of reference bound carbon emission trajectories.

So what we realised through that report - so the first part of it was to try and understand how the risk - the property risk that we insure, how that may change with severe weather under these future climate scenarios, and we used, you know, +2, +3 degree global mean temperature scenarios as the main basis; and to try and estimate how - what does that mean to a property risk perspective, what do these future scenarios look like, and to give us an idea of where we're heading into and what may be the things we need to consider today. What we realised through that piece of work was that there's an enormous amount of activity right now in disclosing climate-related financial risk for the finance industry in particular, and we realised that first step of trying to understand the global thinking on climate change science is going to be repeated by many, many stakeholders. So we thought this is an opportunity to release our work to act as a base for others to build on, and hopefully we can collectively move forward, establishing more centralised and accurate sources of information.

MS HOGAN-DORAN SC: So, Mr Leplastrier, IAG partnered with NCAR, if I may refer to it as that. How long has that collaboration been going on and why you did you approach NCAR, the National Centre for Atmospheric Research, it being based in the US, not in Australia?

MR LEPLASTRIER: Yes, our the collaboration started around 2012/2013, although we've known the authors of the report, who are part of NCAR, and have been in the risk assessment, high risk assessment world for quite some time. That particular - we partnered with NCAR mainly because they're one of the leading institutions worldwide into looking at how severe weather may change with climate change. The US has a population, you know, more than 10 times Australia, and that population is exposed to the same kind of hazards that we have here in Australia. So it's not surprising some of the better - the best institutions in the world are housed there.

MS HOGAN-DORAN SC: Now, if we could go to - I take you to the key assessments made that are set out in the executive summary report. If we could go, operator, to page 49, or .0049, and if I could have you just focus on key assessments are, and down from there, the page. Just in summary, Mr Leplastrier, could you speak to what the key insights or key findings were of this work in collaboration with NCAR and as published in this report in respect of tropical cyclones in particular in the Australian region?

MR LEPLASTRIER: Okay. Did you want me to focus on the other severe weather as well?

MS HOGAN-DORAN SC: I'm going to come to each of those in turn.

MR LEPLASTRIER: Okay. So tropical cyclones, you know, our focus is on the more severe end of tropical cyclones, so the more severe category 4s and 5s in particular because they cause the most risk. And our assessment is that while tropical cyclones may decline in numbers overall for our region, we believe the more intense cyclones will become more frequent. There's also a - we believe a broadening of the areas affected by cyclone, a bit of a southward and poled expansion, meaning that places that are on the fringe of cyclone activity, like the south-east Queensland or north-east New South Wales area, are going to increasingly be exposed to cyclones going forward. While they're not a high risk area at the moment, we believe that - one of the faster changing areas; similarly for south-west Western Australia.

MS HOGAN-DORAN SC: Just to speak to that, if we could go to figure 9 on page 66, operator, and just zoom in on figure 9. Figure 9 summarises the expected regional changes to the frequency of all tropical cyclones, low intensity cyclones (Australian categories 1 and 2) and intense tropical cyclones (Australian categories 3, 4 and 5). Does that summarise what you were just identifying to the Commissioners?

MR LEPLASTRIER: Yes, but there's a couple of other points that I probably need to point out from that slide. So typically, from the scientific literature, you will have information for the Australian region. So typically you will have information in the south-west Pacific, and if I highlight that box out to the east off the Queensland coast where it's showing a slight decline in cyclones overall, mostly coming from the weaker cyclones, possibly not a lot of change with the stronger ones, that's the kind of statistic that you will get from the typical scientific literature of how cyclones are

likely to affect - likely to change with further climate change in the Australian region.

What we've done with this particular slide, though, is to interpret from that basin-wide information, how do we think the changes in cyclones, what are the characteristics for change when you actually get to the different coastlines. So what we're trying to demonstrate here is, we believe there's going to be quite different impacts around the coastlines of Australia. We believe that there might be a slight reduction, perhaps, in the frequency of the cyclones in the far north; more frequent intense ones through the middle of, say, Queensland, but a faster changing rip as you move southwards. So it's really pointing out that you could have quite disproportionate impacts around the country, and the plan for that is important.

MS HOGAN-DORAN SC: And could we also then go to page 69, operator, and I will have you look at figure 10. Zoom in on figure 10. Figure 10 tracks the 10 most significant tropical cyclones to have affected the south-east Queensland and north-east New South Wales regions since 1954. The horizontal dashed line shows the mean latitude of maximum intensity of tropical cyclones at 21.5 degrees south and the latitude of Brisbane at 27.0 degrees south. Mr Leplastrier, I might just have you again assist the Commissioners by the distinction I understand you to be drawing between tropical cyclones taking place - or having activity over deep water but then come into the coast and where they interact with the coast by reference to Australia's population centres, particularly in south-east Queensland and north New South Wales.

MR LEPLASTRIER: Yes, can I clarify the question? Did you want me to describe what we're trying to demonstrate by that figure?

MS HOGAN-DORAN SC: Indeed.

MR LEPLASTRIER: Yes. We're trying to help the reader understand how we've taken the basin-wide statistic of the south-west Pacific and make it relevant for changes on the coastline in, say, the south-east Queensland, north-east New South Wales area. So those tracks basically - what happens in that area is the cyclones typically form well to the north, and they reach a maximum intensity well to the north of that area and, as they travel in that south-west direction towards the coast, they typically decay or decline in intensity. What we expect in a warmer world, in some of these future climate change scenarios, is that the intensity is likely to occur slightly further south, and those cyclones will most likely decay less because the heat content of the ocean will allow them to maintain their intensity further south. So you can end up with a very different change in statistics of cyclones in that, you know, those southern areas of cyclone activity now compared to what the basin-wide statistic might look like.

MS HOGAN-DORAN SC: You spoke then about the southern movement or the poleward movement in the scenario for future tropical cyclone activity. If I could have you look now at figure 17 on page 82 which is now looking at the question of

severe thunderstorms and, in particular, the hail component. So just to recap for the benefit of the Commissioners, the report captures - or the report addresses a number of severe weather events, one we have just touched upon, tropical cyclones, also increasing in flooding, and now hailstorm events. This schematic graph on page 82, figure 17, shows the relative change in large and giant hailstorm frequency between the 1950s and then a climate change scenario at the extreme of plus 3 degrees. What is thought to be portrayed or explained by this figure, Mr Leplastrier?

MR LEPLASTRIER: Okay. So this is another area where you won't find this detail in published literature, typically. So again, we're focused on severe hail that causes damage. We're looking at the large and giant hail spectra, not any hail. So we've concentrated on the stuff that damages property, damages car panels, damages roofing. So what we again show, that will - there's quite regional variation in how we expect the hail climate change; we believe typically there's a shift southwards and there's a shift towards the more extreme end of hailstorm. So we think there's going to be a higher frequency of the more severe, the giant hail that's represented here.

Now, what I should emphasise in this slide as well as the previous slide on cyclones is this is our best interpretation of how we think the risk will change, and we've - we're encouraging feedback from the scientific community to challenge us on this and also to help - I suppose it's to emphasise where we believe more research needs to be done to firm up this evidence. But this is where we think, using the information that's available in the literature and our best scientific interpretation, our understanding of the physical environment of how we think things will play out.

MS HOGAN-DORAN SC: And I understand that there is ongoing work and a proposed further issue of this report some time perhaps this year or early next year; is that right, Mr Leplastrier?

MR LEPLASTRIER: That's right. We're working on about a July time frame to update the report, but typically because a lot of the work was done previously in 2017 and there's been some very worthwhile scientific studies that have happened since that point.

MS HOGAN-DORAN SC: And I might take you then to - in the executive summary, you also addressed the phenomenon of the, and the impacts of the east coast lows. But if we might pass over that and consider bushfire risk assessment. Can the witness be shown page 50 of the report, operator, and paragraph 5.

One of the key assessments you set out in this report, that was set out by you and the co-authors in the report, is that:

"Bushfire risk, as measured by the trends in fire danger indices, is likely to increase in almost all locations nationally, leading to more frequent and extreme events, and longer fire seasons. The rate of increase varies by location and will depend on where the system changes and site specific factors at regional levels."

And what I wanted to do is to take you to then, to page 91 of your report and to the passages under the heading "Regional Interpretations for Risk Assessment for Australia". Now, as I understand it, is this correct, Mr Leplastrier: this report was, as you said, most of the work was done in about 2017 and the references that are here in these passages are primarily from 2016. And, as I understand it, the work that is being done will be further updating in particular your bushfire risk assessment for Australia. One of the propositions that you adopt in this passage is that bushfire is one of the fastest growing climate risks facing Australia but that there's limited information in the literature about trends in the extreme and catastrophic bushfires that typically drive most of the property bushfire risk. What problems have you seen in terms of information, in terms of being able to make assessments of risk in relation to bushfires in Australia?

MR LEPLASTRIER: Okay. So bushfire, the indices that we were relying on in this report are quite simplistic. So this is typically the McArthur Forest fire danger indices and there are better indices or indices that supplement this, such as the Haines or C-Haines index, which were part of the updated report, and that actually helps provide a bit more information of where atmospheric instability actually increases, or might be a better measure of the fire risk behaviour from an atmospheric perspective, that might be better than FFDI in some circumstances. So that's one aspect of it, but there's a whole lot of other things. This is just the fire weather. You've still got the ignition sources, the vegetation response, and things like that. So there's - it's quite a complex area to understand all of the different things at play.

MS HOGAN-DORAN SC: Thank you, Mr Leplastrier. I might just pause with you for a moment now and go to Dr Crompton. Dr Crompton, in your report - and if the operator will bring up RYC.500.001.0001. Dr Crompton, this report that you have prepared for the Royal Commission which was based on a submission that you provided through the public submission process, has more recent - incorporates more recent surveys - damage surveys that have been undertaken by Risk Frontiers; is that correct?

DR CROMPTON: I'm not sure it incorporates any more recent damage surveys than what was in the original submission.

MS HOGAN-DORAN SC: I apologise. I mean from the period of the IAG *Severe Weather Report* compared to your report.

DR CROMPTON: Yes, so there's a couple of damage surveys undertaken from Black Summer, that's correct.

MS HOGAN-DORAN SC: All right, then. If we could go to page 4 of that. The first thing I want to ask you some questions about, Dr Crompton, is the burnt area surveys that you have done of the areas that were burnt during the most recent bushfires, particularly New South Wales and Victoria. If we could just focus in on the first paragraph and then we will go to the graphs. Thank you, operator. In this paragraph -

I'll just state it for the benefit of the record and then I want to ask you a couple of questions about it - you note that:

"In terms of the total bushfires area burnt in New South Wales and Victoria, the 2019-2020 year to date is already the largest since data based on satellite imagery first became available to measure this in November 2000."

What is the satellite? Just as a preliminary question, what is the satellite imagery that you're referring to in your report there?

DR CROMPTON: So the satellite imagery is a publicly available dataset, though it's a dataset which is called the Modus Burnt Area Product which is from NASA. So the data itself is available since November 2000. It contains burnt pixels globally on a daily basis at 500 metres per resolution. So it's a satellite derived dataset.

MS HOGAN-DORAN SC: All right. And could the witness now be shown figure 1, both (a) and (b), and the notation at the bottom. And, Dr Crompton, could you explain what these figures show to the Commissioners?

DR CROMPTON: Sure. So the figure shows the total bushland area burnt in New South Wales which is in the top section, and Victoria in the bottom section, which is based on that satellite derived data, the Modus Burn Area Product. So we take that data and we aggregate it for 12 month periods beginning July 1. We also select only those pixels that intersect into bushland areas, and we use a land covered Australia to do that. But due to the lag in data availability, the current 2019 season is based on data up to February 2020. So the total bush - the total bushland area burn in New South Wales and Victoria for that 2019-2020 Black Summer period year to date is the largest over the last 19 seasons, and this is particularly so in New South Wales, as you can see in the top figure, where the area that was burnt was more than three times larger than any other season.

MS HOGAN-DORAN SC: And what is the position for Victoria compared to previous seasons, Dr Crompton?

DR CROMPTON: Yes, so Victoria is also the largest but it's comparable to some of the earlier seasons. And I will just note that I - there are other longer-term datasets that are available but this publicly available satellite dataset only goes back to November 2000.

MS HOGAN-DORAN SC: All right. I will take you next to the next portion of your report which addresses Black Summer's building damage and insured loss. Now, that's only insured losses, not economic impact more broadly or uninsured losses. If we go to page 5 of your report and the second and third paragraphs and have those blown up, and then I'm going to take the Commissioners to the normalised figure on the next page. What's the effect of your understanding from your analysis, Dr Crompton, in relation to the comparable damage - bushfire building damage from the Black Summer compared to previous seasons?

DR CROMPTON: So in normalised terms and looking at it from an Australian perspective, the loss from Black Saturday is comparable to - to other seasons. It may become the most damaging since 1925. The Black Summer estimate to date, the damage to date, is a lower bound as it only includes destroyed houses and not other types of buildings. So I think it's also mentioning the underlying dataset Risk Frontiers maintains - called PerilAu, so it's a database of natural hazard building damage and fatalities in Australia, and it's derived from newspaper archives and other official documents as well. So it has been used in a lot of publications. It has been used in a lot of studies for emergency services across Australia. So the records that are available are since 1900 inside of that database. There are some earlier records, but in terms of bushfire it's the most reliable since 1925. So, counsel, were you going to show the figure? Shall I stop there or - - -

MS HOGAN-DORAN SC: Yes, I am.

DR CROMPTON: Okay.

MS HOGAN-DORAN SC: Before we do that, your figures for - may we take it from what you've said, that although you've had all this additional archival material - - -

DR CROMPTON: Yes.

MS HOGAN-DORAN SC: - - - for years prior to the 2019-20 season, the 2019-2020 season analysis is not based on as complete a record as the earlier seasons; is that correct?

DR CROMPTON: That's right. So everything up until the current Black Summer, 2019-20 season there has been effort to capture building damage from different building types, not only houses. Whereas in that 2019-20 year that is using the number of destroyed houses only. And that data is taken directly from AFAC, and the estimate is 3094 houses.

MS HOGAN-DORAN SC: When you refer to AFAC, that acronym stands for?

DR CROMPTON: The Australasian Fire and Emergency Services Authorities Council, if I am - I am pretty sure.

MS HOGAN-DORAN SC: Thank you. The Commissioners will be hearing from them next week. So, Dr Crompton, just before I pass to the next figure, in the second paragraph on the page, you make the point that there's a differential in the damage that has been experienced between New South Wales and Victoria when compared with earlier seasons.

DR CROMPTON: Yes, that's right. So if we were to, without showing the actual figure itself, if we were to plot the same figure as what I think you're about to show for New South Wales, then New South Wales, the damage in terms of the 2019-20

season would be by far the most damaging season, with current estimates about 2.5 times as large as any other season.

MS HOGAN-DORAN SC: All right. If you just go to figure 2, which I think is the one you're speaking of, but I think this is for all of Australia?

DR CROMPTON: Yes, that's right.

MS HOGAN-DORAN SC: That's on page 6. So this is a figure for normalised bushfire building damage in Australia since 1925. If I just pause before I ask you to say too much about it, just explain for the Commissioners and confirm for the record what you mean by "normalised"?

DR CROMPTON: So when we normalise a loss, that means that what we're seeking to do is to estimate the impacts of past events on present society. Depending on what type of data you are normalising, the normalisation process can be slightly different. So, in this case, the metric that we - the building damage is recorded inside a PerilAu, it's called a house equivalent. So that is essentially taking damage to the built environment - it might include commercial and industrial buildings as well as houses - and converting that using floor areas and relative building costs to an equivalent number of houses destroyed. So when we normalise house equivalents, we adjust for the change in the number of dwellings over time.

MS HOGAN-DORAN SC: And so how would you correlate the loss in terms of destroyed buildings with the area of burnt bushland? So you've recorded the bushfire building damage in this figure, and the earlier figure that I took you to was the bushland burnt area in New South Wales and Victoria. What kind of correlation is there between those two variables?

DR CROMPTON: Yes, the correlation is not very strong at all. So in New South Wales, in Black Summer, it's a very good example where you have a season where you have a very large burnt area that corresponds to a very large number of damage to the built environment. Whereas there are plenty of other examples through time where that correlation doesn't exist. So Black Saturday is a good example where you had extreme impacts. But not a - you know, an otherwise reasonably unremarkable burnt area. And the same with Victoria for Black Summer, in that the burnt area is the largest over the last 19 years but the damage in Victoria over Black Summer was not large compared to other loss years.

MS HOGAN-DORAN SC: And is that because the exposure of populations depends on - to the extent of - the exposure to fire and bushfire depends on the vulnerability of that population; that is, its proximity to the ongoing fire front. Is that an aspect of consideration?

DR CROMPTON: Yes. Again, I just confirm you can hear me now? I just had a bit of trouble with sound then. Can you hear me still, counsel?

MS HOGAN-DORAN SC: Yes, I can. Did you hear the question, Dr Crompton, or do you require me to repeat it?

DR CROMPTON: No, I think I did. So the random nature that exists in the episodic nature of the extremes that are prevailing, figure 2, is due to the distribution of exposure. So throughout Australia, in particular, the population is inhomogenously distributed. So the time series of damage that exists in that figure 2 is very much a function of whether a fire has impacted a populated area, and how big that populated area is that has been impacted.

MS HOGAN-DORAN SC: Could you explain this next to us. Figure 3 on the next page, page 8, which is the cumulative distribution of buildings destroyed, this time in relation to the distance from nearby bushland for recent major events?

DR CROMPTON: Sure.

MS HOGAN-DORAN SC: What does this tell us about the proximity to bushland as a risk factor in these different locations, and in particular when one looks at this graph, we understand that the purple line, which is near the centre, is the New South Wales south coast, which are from the most recent bushfire season, these figures taken we've just had the pointer by the operator - is taken from December 2019 damage surveys by Risk Frontiers?

DR CROMPTON: Yes. So we undertake damage surveys after all major natural disasters in Australia, and bushfires are no different. So the two curves that have been added through the experience of Black Saturday - sorry, of Black Summer are the New South Wales South Coast curve in purple, as you mentioned, and the yellow curve which is for Rappville. So what our research has shown over a number of fires, and this is the number of fires since the year 2000, is that distance to bushland is demonstrably the most variable that determines building vulnerability to bushfire. So if you take the New South Wales South Coast curve in purple, on the X axis of this curve we have the percentile of all destroyed buildings, and on the Y we have the distance from the adjacent bushland.

So where that purple curve intersects the X axis, the horizontal axis, that's at a level of 38 per cent. So if we read across then to the left-hand side to the Y axis of the curve, we see that that distance from adjacent bushland is one metre. So what that is telling us is 30 per cent - 38 per cent of the homes destroyed and that we surveyed in that New South Wales south coast fire, were within one metre of bushland. So there was almost no separation whatsoever. If we follow that New South Wales South Coast curve in purple back to the 80th percentile, we can see that 80 per cent of the destroyed structures were within 100 metres of bushland.

And where all of the curves across the different fires are starting to converge in the top right-hand corner is at roughly 1000 metres, which is the largest distance, generally, that we've observed damage, noting that in the New South Wales south coast fires we also observed some buildings being destroyed at around 1.3

kilometres. The other feature of this figure that is evident in the Duffy curve and that is for the Canberra 2003 bushfires and the Rappville curve in yellow, is the effect of embers. So if you look at where the Duffy curve is hitting the Y axis, the vertical axis of the curve, that is at around the 40 metre mark. So there were actually no buildings that were destroyed in Duffy until you hit that 40 metre mark.

So that really illustrates the ability of embers to penetrate the built environment, and a similar situation was observed with the Rappville, fire and both of these fires occurred under very strong winds. So the other point finally, just to make on the curve, is that our evidence also too that we collected after Black Saturday was focused on Kinglake and Marysville, and you can see that where those two curves, the one in black and red hit the X axis, is at 25 per cent. So in those fires, you had 25 per cent of the - of the destroyed structures within one metre of bushland. So when you have a combination of buildings that are built very close to bushland, you have extreme fire weather conditions and then you have a fire in those buildings, then they don't stand generally .....

MS HOGAN-DORAN SC: Dr Crompton, I'll just - - -

DR CROMPTON: So definitely the research highlights the importance.

MS HOGAN-DORAN SC: Dr Crompton, I will just have you just pause for a moment because we're getting some breaking in your transmission. I will just get an update on whether or not that's from our end or your end. It's his end. All right. Dr Crompton, I'm informed it's coming from your end, or at least the transmission into our systems. Had you completed what you wished to say in relation to figure 3?

DR CROMPTON: I was just going to add that the research does highlight the importance of land use planning in bushfire prone locations.

MS HOGAN-DORAN SC: All right. Thanks very much. Now, just one last matter I want to take you to on the next page. You also maintain in your database a record of fatalities, and you've made a preliminary assessment in relation to comparable fatalities in the period since - in the last decade. You note that you record 65 deaths due to bushfires since 2009 to most recently, and you've made some observations that in a summary way - and I will have the operator bring that up for the Commissioners, from about line 15, with comparing - with the paragraph commencing:

"While a lot more detail is available from the database on causes of death and activities at the time of death."

You have noted the disproportionately high rates of deaths amongst a number of people. If you could just identify those, as those coming from your analysis - your fatality database; is that correct?

DR CROMPTON: Yes, that's correct. Yes, that's correct. Yes. So again just noting the disproportionally high rates amongst professional volunteer firefighters, males aged 60 and over, trying to save their own property with pre-existing health conditions, males aged 55 attempting their own evacuation, and males and females aged 55 in their house. Yes, that's right.

MS HOGAN-DORAN SC: Thank you. One of the other things that is done in your report is to see not just the - not to only look at the experience of bushfires, and in particular the bushfires in the 2019-20 season but to also compare those fatalities as against other natural disasters in Australia. And if I could have the Commissioners taken to the next page, page 10, to, in a sense, explain the ranking, if I could use that term, for comparable numbers of fatalities between 1900 and 2015, broken down by peril category. Just highlighting on that table 2, what is the most deadly natural hazard in Australia, based on that historic data?

DR CROMPTON: Yes. Yes, sure. Sure. So from our analysis of the fatalities over that period, 1900 to 2015, which is taken from the peril loss database - and now pointing out that this is the recorded number of fatalities and has not been normalised in any way - is that the heatwaves are clearly Australia's natural - deadliest natural hazard. They account for almost half of the total number and almost five times the number of fatalities than do bushfires. So a relevant statistic to this, for the 2009 Black Saturday bushfires that reflects the importance of heatwaves, and this comes from the Victorian Department of Health, was that there were 374 excess deaths in Victoria due to the heatwave that preceded Black Saturday, and that compares to the 173 fatalities that were due to the bushfires themselves. And Dr Braganza, earlier this morning, alluded to a similar figure but including in Victoria but also outside.

MS HOGAN-DORAN SC: And one of the other matters that you have done is to identify locations based on the experience historically of national - sorry, I withdraw that - natural hazards becoming natural disasters because of the coincidence of exposure and vulnerable populations. You have undertaken analysis of ranking of annual loss including damages from different natural hazards and identified them by postcode, that is where people live. If we could go to table 3 which is on page 12, and it's the last matter I want to take you to, Dr Crompton.

DR CROMPTON: Sure.

MS HOGAN-DORAN SC: And what do we see here?

DR CROMPTON: Yes, so the purpose of this table is to demonstrate that it's possible to identify what areas of Australia pose the greatest risk for financial loss of insurable assets such as residential, commercial and industrial property. So we've done this using our suite of probabilistic catastrophe loss models which are for flood, bushfire, hail, tropical cyclone and earthquake. So we calculated the average annual loss for each Australian postcode based on exposure information, which is derived from Geoscience Australia's National Exposure Information System, or NEXIS for short, their NEXIS database. So this shows the top 20 postcodes nation-wide, and the

results are also illustrated in a figure in my statement as well. So Bundaberg is ranked with the highest AAL relative to all other postcodes. All the highest rated postcodes, as you can see from this table, are in Western Australia, Queensland or New South Wales, with either flood or tropical cyclone being the most significant perils within each.

So this information about relative natural disaster risks is useful in determining national mitigation investment priorities. So the rankings can vary according to the loss metric that is used, or geographic boundaries if we use something else other than a postcode. And the final point is that the postcodes, using those as - or using a postcode ignores the potential losses attributable to wider scenarios. So, for an example, as an example, the potential losses due to flooding are greater than just the postcode of Windsor and the catastrophe loss models are able to analyse those types of scenarios as well.

MS HOGAN-DORAN SC: All right. Thank you very much, Dr Crompton. We may return to you. If I might now turn to Mr Paddam - no. Yes, sorry. I'm reminded. Mr Leplastrier, one connection to what Dr Crompton has just said in terms of the financial impact of natural disasters, annexed to your statement was an earlier report in which IAG had a role in its preparation. That is IAG.001.001.0011. While that is being brought up, what was this? This, for the benefit of the transcript, is, as I understand it, Mr Leplastrier, a joint report by IAG and SGS Economics and Planning, published in November 2016:

"At what cost? Mapping where natural perils impact on economic growth and communities."

What was the genesis of this report and the purpose of this report?

MR LEPLASTRIER: Yes, so this - this report applies that, I suppose, an extra perspective of what you needed to consider when you're planning for natural disasters. So we - this report focuses on economic activity, where it actually resides, and where it intersects natural hazard exposure. So it's an extension to say how an insurer would look at risk and just look at the annual loss perspective at a particular street address for that business or for that home, and this is really looking at the economic activity of an area, and that should be considered as part of your land planning and disaster planning.

MS HOGAN-DORAN SC: Can I get the operator to go to page 16 and to the second column just near the top. You have, if you could zoom into the sentence, "LGA" - that, I take it, is local government areas:

"Local government areas with high and extreme risk of bushfire generated $175 billion or 10.8 per cent of GDP and are home to 2.2 million people, that is 9.2 per cent of the population."

What were you seeking to convey by that part of the executive summary, Mr Leplastrier?

MR LEPLASTRIER: Okay. So I am - I was only part - my team was only part of some of the input to this report.

MS HOGAN-DORAN SC: Yes.

MR LEPLASTRIER: But I can - I can help - - -

MS HOGAN-DORAN SC: Interpret.

MR LEPLASTRIER: - - - what I believe that that paragraph will say. So a local government area is quite large and so what they're saying is that the local government areas that intersect with bushfire risk generates, you know, about 10.8 per cent of GDP, you know, you've got about two point million people living there. It's not to say that every risk addressed in that LGA is exposed there but it does focus on there's a lot of local government areas with high bushfire risk and significant productivity, from an economic perspective.

MS HOGAN-DORAN SC: And may we take it that whereas, what the earlier observations of Dr Crompton was which focus on the normalised losses from property damage and then identifying the economic impact is not just the economic impact, or the risk of economic impact is not limited to property damage but to the activity and the economic activity in the area; is that correct?

MR LEPLASTRIER: That's correct.

MS HOGAN-DORAN SC: Right. Now, I just pause from that and now go to Mr Paddam. Mr Paddam - no - the Actuaries Institute which you're a fellow of and have been for some time, some may ask, and perhaps you can assist, what is the role of an actuary?

MR PADDAM: So generally speaking actuaries are involved in the assessment of risk, in the quantitative assessment of risk. We are practitioners and work with industry, governments and a range of stakeholders in the analysis of risk broadly. For insurance companies, we are involved in a range of functions, some of which are mandated by the - by legislation and by the regulator.

Primarily, we're looking at the financial sustainability of the insurance company so that this insurance company is able to pay claims in the future. We look at a range of issues. So one example is we may work with teams like - actuaries may work with teams like Mark's teams and provide advice - be advised by Ryan - sorry, Mr Leplastrier's team and Dr Crompton's team that provides advice on what the impacts of these natural disasters are.

We would then incorporate that within pricing of insurance contracts, looking at the adequacy of pricing of contracts. We would also look at the valuation of insurance liabilities, what money the insurance company has to put aside to pay claims on events that have happened. We would look at the capital requirements for the insurance company as well as the financial reporting of all of this information.

MS HOGAN-DORAN SC: Now, you've been a fellow - you've been an actuary since the - since 1994 and a fellow since 2000. You're a Fellow of the Institute of Actuaries Australia. The Institute has undertaken - undertook a project in 2018 to create what's known as the Australian Actuaries Climate Index. What is that index and how is it going to assist or is it intended to assist actuaries, the public and policy makers in addition to the companies that you ordinarily would have an actuary advise?

MR PADDAM: Yes. So we created the index to look at trends in extreme weather across Australia to help policy makers, actuaries, companies, the general public about the impact of such events in Australia. We specifically wanted to look at extreme events, so we looked at extreme data within extreme events or within the data, and created an index to show how that might - is changing over time.

MS HOGAN-DORAN SC: So you focus on extreme events, but why focus on extreme and the extreme of extreme events? What's the relevance of that analysis?

MR PADDAM: So what we find is that it is the extreme events that provide - damage a range of things, that actually negatively impact. So insurance claims, for one example, are driven by extreme events. They're not driven by average weather from day to day. They're driven by the occurrence and frequency and severity of extreme events. We've also seen, as Dr Crompton has shown, human lives and loss of life are also driven by extreme events and there are a number of economic factors that are driven by the extreme events.

So generally in Australia we build buildings and we have systems that are designed - that have thresholds so that they're designed to survive under most types - most ranges of events. But at the extreme events, they have failed. So buildings fall down, fires start, and so it's the extreme events that drive the losses that we may experiences on a financial level, on an economic level, on a social level and an environmental level.

MS HOGAN-DORAN SC: I see. Mr Leplastrier, would you wish to comment on that and then focus on the extreme of extremes?

MR LEPLASTRIER: No, I agree with Sharanjit. It's the extreme end that's really the part that's unusual, the part that's often beyond our design codes and land planning that's driving the bulk of the risk.

MS HOGAN-DORAN SC: Commissioners, that might be a point for me to stop and invite any questions from you.

COMMISSIONER BINSKIN: Thank you. We do have a few questions. I will start with Commissioner Bennett first.

COMMISSIONER BENNETT: Thank you. Thank you, Chair. I've just got a few questions, maybe some of you that I simply didn't quite understand or I want to clarify a couple of things that you said during the course of your evidence and the description of your report. Perhaps I will start with Mr Leplastrier because I've got my note on that one first. You did the combined study with the United States people and you were saying that there were a lot of common elements between Australia and the United States. So I guess I've got a couple of questions about that. The first one is: is there any impact then on the American analysis on insurance premiums that are then calculated for Australia?

MR LEPLASTRIER: Perhaps I need to clarify my previous comment. So we partnered with NCAR with an ongoing piece of research and this particular report that we released in November last year was compiled between NCAR and IAG. But what it did was it went out and looked at all of the global literature on how severe weather events that we care about here in Australia - tropical cyclones, east coast lows, flood, hailstorms - looked at all of their global literature to amend where a fair portion of that literature actually came from Australian research institutions. I'm not sure of the statistics but I imagine at least half of the research we quote is from Australian research. And we've just basically condensed all that research into how we think extreme weather will change within the Australian context. We did not go and estimate insurance premiums and there weren't any influence, I suppose, on how America looks at, I suppose, the risk to insurance premiums. It was completely isolated from that.

COMMISSIONER BENNETT: Okay. So if I can put it another way, despite the fact that you're looking at extreme weather pictures around the world, if you saw - and I'm thinking of cyclones, for example, in the United States, we get to hear about those a lot - you know, if there were lots of these extreme events outside Australia but none in Australia, then there would be no impact at all on insurance premiums paid by Australian households?

MR LEPLASTRIER: I think I understand the question. You're saying that if we didn't really see - - -

COMMISSIONER BENNETT: I'm looking at the - I'm trying to get an idea of the impact of overseas information. I guess if I can put it in a global way. Overseas events, overseas information, and let's say a demonstrated use of technology to avoid an extreme event arising in another jurisdiction and what the impact would be on the - perhaps Mr Paddam could also come in on this if it's relevant - but does that have any impact on the assessment of risk in Australia and then the assessment of insurance premiums?

MR LEPLASTRIER: Yes. I'm struggling to quite understand the question. Can I - I've made these two connections and let me know if I've got this right. So there's the insurance industry buys insurance, called reinsurance.

COMMISSIONER BENNETT: Yes.

MR LEPLASTRIER: And those reinsurers are global in nature and the cost of that capital to offset some of our exposure as an insurance company is impacted by global events. So you can have a very active hurricane season in the US, for instance, may impact on the cost of borrowing that capital. Does that answer the - one of the questions?

COMMISSIONER BENNETT: Yes, it does answer one of them. It doesn't answer it completely because I guess you initially said - talked about the similarity between the Australian experience and the American experience, for example, in a lot of events and bushfires, one could see, could be, you know, we hear about the wild fires in California. So I was just wondering, when you were trying to assess risk and look at the extent of devastation perhaps in the different parts of the world, to what extent do you bring that together to work out what your risk calculation is for Australia and that then flows on, I assume, to insurance premiums?

MR LEPLASTRIER: Yes, so there's - the way we analyse or try to understand severe weather risk within climate modelling, for instance, the severe weather phenomena, the severe thunderstorms, the tropical cyclones or hurricanes, as they're called in the US, have very similar characteristics. So there's a lot of mutual research into the subject matter of tropical cyclones which is quite transferable from one region to the next. But there are particularly nuances that you must understand within, say, the Australian domain that are quite different.

So you can't just pluck something off the shelf that we've done in the US to say that applies to the east coast of Queensland, for instance, because there's very important features of our climate system around Australia that actually won't allow that to happen. But some of the sensitivity studies understanding general effects on increasing ocean temperature, for instance, that provides a lot of insight into how cyclones in general will respond and that kind of thing is quite transferable.

COMMISSIONER BENNETT: Are bushfires as transferable?

MR LEPLASTRIER: Yes.

COMMISSIONER BENNETT: Bearing in mind some of the evidence we heard this morning about particular weather events and climate drivers in Australia?

MR LEPLASTRIER: Yes, the principles are the same but the unique conditions or weather systems that set up fire conditions might .....

COMMISSIONER BENNETT: Okay.

MR LEPLASTRIER: So you've got the same kind of temperature but how they come about and become I suppose exacerbated by extreme fire, you might have a few different mechanisms to think about there.

COMMISSIONER BENNETT: Okay. That just takes me through I guess to my question to Dr Crompton, and again you may have explained it thoroughly and I may have missed it. You probably did explain it thoroughly and I probably did miss it, but I would like to ask you some questions about the distance of buildings from the bushland. Now, I understand the one metre point and I think you made a very telling comment actually in your written report about how in some ways they could be seen as part of the fuel load when they're that close.

But I'm trying to understand the differences that you've observed over time in the ember transfer, if I can call it that, with the bigger distances and how has that - was that particularly different in the 2019/2020 Black Summer fires? I mean, did that - I didn't quite follow it from the diagram. Is that something that's always happened, has happened a lot before or was this a particular occasion where that ember movement was unusually or for the first time as great as it was?

DR CROMPTON: Certainly in Duffy, so the thing that was in common between the 2003 fire in Duffy in Canberra and the Rappville fire in northern New South Wales is that both of them had very - occurred under very strong winds. So that enabled the embers to travel a long distance. So we have seen that before in the Canberra fires. So it also had to do with the way the building environment is also set up as well, in terms of how close it is to the bushfire or not. There was separation in the case of Duffy. So I mean, if there had not been strong winds then perhaps, and I'm speculating, the damage in Duffy may not have been as bad because there was some separation of 40 metres but certainly we have had strong winds in the past occurring - - -

COMMISSIONER BENNETT: Okay. Thank you, I'll leave to the .....

DR CROMPTON: - - - and coinciding in fire.

COMMISSIONER BINSKIN: And from memory there are very tall trees just to the west of Duffy as well. Commissioner MacIntosh?

COMMISSIONER MACINTOSH: Thank you, Chair. I will go to Mr Leplastrier first, if I could. Can I take you to the *Severe Weather in Climate Change* report which for our purposes is - it is page 46.

MS HOGAN-DORAN SC: If I may assist, Commissioner, IAG.001.001.0046. Good. Too quick.

COMMISSIONER MACINTOSH: On - for your purposes, page 46, there's a statement here that:

"There is significant scope for next generation models like NARCliM to provide a more comprehensive and granular base for establishing fire weather risk indices and understanding the risk of climate change."

I just wondered whether you could - and you noted this before as well - give us a bit more flavour about that. So are there manifest efficiencies with our existing indices and are there known abilities for us to improve what we're currently using?

MR LEPLASTRIER: Yes. I think we've met with DPIE and the principal meteorologist in my team in particular on the next generation and what opportunity there would be available to really, I suppose, establish fire weather indices that are as informative of the actual fire itself as possible. So I mentioned before about the forest fire danger indices, McArthur Forest Fire Danger Indices is an aspect of how to look at fire weather risk but there are other indices such as Haines and C-Haines that will provide extra information.

I'm not across the detail of the next generation models. It's something that I would normally refer to the principal meteorologist in my team, but I believe there's going to be finer resolution of those models which will allow to provide more granular output, more specific to locations.

COMMISSIONER MACINTOSH: Thanks very much. If I could, I will direct a similar style question to Mr Paddam. And this comes from your statement. You have there comments about - firstly, about:

"The capacity to have improved meteorological and other data capturing, including a program of investment improved weather stations across Australia."

Could you just talk to that a bit more? Again, is there known weaknesses with our existing weather stations?

MR PADDAM: Yes. So there's a range of areas that we can improve the observational data that we use within our - within the current modelling that we do. And what this recommendation that we outlined in our - in my written statement talks to is capturing better observational data. Yes, improved weather stations would be very helpful for that, including a better coverage across Australia as well as ensuring we - things like anemometers are all upgraded across all of them.

I would say that this would be a scenario that the Bureau of Meteorology can help with, rather than ourselves, but we understand that we would want more information. An example as well about - so the other data capture, if we compare with say what happens in the United States around capturing data on tropical cyclones, was they have facilities and they regularly fly aeroplanes into tropical cyclones to gather data about those tropical cyclones and how they're behaving and trying to understand what's going on within their cyclones, or the hurricanes as they would be there.

We don't have that facility in Australia and I think as the risk increases over time, understanding the behaviour of land falling Australian tropical cyclones, we do need more observational data. I think Mark has made the point earlier about some of the information that we need is particularly around the ones that are hitting land fall and the process is at a local level of what happens to tropical cyclones. And we - we're not capturing that data.

Indeed, in many - in many cases, what we see in tropical cyclones is that wind speed measures, things like anemometers get blown away or will break during the tropical cyclone. So we actually don't get that reliable data sometimes for actual events that happened in the past.

COMMISSIONER MACINTOSH: Thanks very much. One last one, if I may, Chair. In the paragraph, or dot point 2, two down from that one, and it reads:

"Public availability of flood hazard maps across Australia. Currently these are driven by individual councils, including a consistent specification for such studies."

The inference there being that we currently have a weakness or a deficiency in our flood mapping. I just wondered whether the other participants, Ryan - sorry, Dr Crompton or Mr Leplastrier, whether you two would agree with that statement made by Mr Paddam?

MR LEPLASTRIER: You go first, Dr Crompton.

DR CROMPTON: Sorry. Mr Leplastrier, are you going? I just missed you then. Are you going to lead?

MR LEPLASTRIER: No, you can go first if you've got something to say.

DR CROMPTON: So Commissioner Macintosh, just to make sure that I heard the question correctly: that is, whether there are deficiencies in council flood studies; is that the question?

COMMISSIONER MACINTOSH: Yes, there seems to be weakness with our availability of flood hazard maps. Mr Paddam, please explain if I've misinterpreted that.

MR PADDAM: So I guess some background to this may be in order. So we do have something called the National Flood Insurance Database which is maintained by the Insurance Council of Australia and I believe Risk Frontiers has a role in that as well. So this is - that process provides insurers with access to much better information today than we had, say, 10 years ago in terms of that. But there's a - what that - what that process relies on is a large part of that relies on getting information from local councils who undertake individual blind studies.

The problem is, is that there's a substantial amount of work that the NFID team have to do to then collate them together because different councils will use different measures. They will, say, use a one in 100 mapping. Some will use different versions of that. And we don't necessarily have coverage across the whole country. There are also issues regarding the - I guess the use of that data. Councils don't always allow us to make that information public.

So that's one part of it, the quality of the data and the difficulties in obtaining it, even though we have the NFID. But the second part to this comment here is about making that available to the public in a much more consistent way. Some of the restrictions that councils place on the use of their data means that insurers aren't necessarily able to give that information out to the public and that's, I think, a - from a public perspective, which is where I'm coming from from the Actuaries Institute, we think that would be a much - would be a very useful information for the public to know.

COMMISSIONER MACINTOSH: Thank you, Mr Paddam. Can I then direct to Mr Leplastrier and Dr Crompton, do you agree with those statements that that's something that you've encountered? Problems with both quality and accessibility?

MR LEPLASTRIER: You go first, Dr Crompton.

DR CROMPTON: Sure. So in terms of accessibility, so Risk Frontiers has been a part of the development of the national flood information data since the end of 2008 for the Insurance Council. So prior to that we had embarked upon collecting flood studies from local councils previously and were developing using that to develop a flood modelling capability. By the experience, reflecting on that experience is that it was not always easy to be able to access flood studies from some local councils. And since NFID, the inception of NFID, the ICA, the Insurance Council of Australia have been the ones responsible for collecting flood studies.

COMMISSIONER MACINTOSH: Thank you. Mr Leplastrier, do you have anything to add?

MR LEPLASTRIER: Yes, I would like to - yes, so in answer to your first question, I do agree with Sharanjit's statement. That's a fairly correct statement from my perspective. But I would like to add, there's been a lot of progress in recent times with state government coordinating flood mapping on behalf of local government. I'm not across the detail. It's actually a conversation I had with my principal hydrologist earlier today.

So there's a lot of good progress in trying to coordinate at the State level, but the reality of today's flood mapping that's underpinning most of the areas around Australia is part of legacy data, that has a lot of problems with consistency in its format and availability of the accurate full depth information across a range of floods which you need. But it is a good news story on one front as far as the significant progress over the last decade or so.

COMMISSIONER MACINTOSH: Thanks very much. Thank you, Chair.

COMMISSIONER BINSKIN: So Mr Paddam, I just want, and just need you to clarify for me, why wouldn't the information that's there be made available? Is it an accuracy issue or are there other reasons?

MR PADDAM: Commissioner, I've not personally been involved in the obtaining that information, so this is - this is more what I'm observing in terms of the teams I work with, and the issues and challenges they face. I believe it's - it's a combination of technical problems, but also I do understand that councils are concerned as well about any liability issues that may arise from wider availability of some of this data. And that's not an area that I have any expertise in, but I believe it has been an issue that has affected the collation and sharing of this information.

COMMISSIONER BINSKIN: Okay. Thank you very much for that. Mr Leplastrier, any comment on that part of it? Then I have a question for you - another question for you.

MR LEPLASTRIER: I do, yes. Again, I'm not in the actual detail but my understanding from the specialists in my team, that some of the restrictive - some of the licence terms of which the flood study was done may not allow a council to share the information. We must also emphasise that some of these studies are very large in volume as far as data concerns, and so there are costs involved in making it available. And so that's one of the - in the recommendations in my statement is around how we can actually have funding on a regular basis to help, I suppose, compile a database to facilitate that access, as well as making sure the studies that are done, are done under the right sort of licensing conditions that enable broader sharing.

COMMISSIONER BINSKIN: Okay. I appreciate that. In that case, I will take you to Dr Crompton's report. So RYC.500.001, page 0008, and so that's the figure 3 that we had before. Quite a good diagram, this one. So similar question to the flood information. So first of all, Mr Leplastrier, I assumed you would take this information that's here, and that would form a part of your risk analysis when you're looking at insuring properties or properties in communities around Australia? Would that be right?

MR LEPLASTRIER: Yes, that's correct. And I think, if I could add a piece to it as well, is we have to understand the probability of different intensity levels of fire to make sense of this kind of graph because not every fire will follow a particular, I suppose, trajectory here, as far as the percentage of houses burnt within a certain distance to vegetation. It will depend on the fire conditions of the day, whether it was a very rare catastrophic fire or whether it was, I suppose, not quite as severe conditions. But that is - that kind of information is the basis to help us understand risk.

COMMISSIONER BINSKIN: That's right. The conditions of the day would be one variable that you - it would be difficult to control, but the data here has the level of

control that could be put into place. So we've been talking about, from an IAG perspective, being quite reactive in how you take all this data and you look to look at your risk. Does IAG take this sort of data and then try and inform governments and at local government level and up in planning and the like to try and look to reduce the risk on those variables that they can?

MR LEPLASTRIER: Yes, and we haven't done so much on bushfire. We've done a lot more on things like flood. It's a much more mature risk modelling framework that's fairly consistent in how we look at it from a land planning, flood plain management perspective as well as how an insurer would look at the risk from a - to understand pricing and its exposure from large flood events.

But for bushfire, it's not quite as mature in how we would look at the risk - the risk modelling framework and that's one of the things I would like to suggest that we try and move towards as a community. There are bushfire risk models out there, and Dr Crompton can talk about the ones that they've developed, but we're not talking - well, the ones that are out there are not necessarily both used for underpinning, say, land planning requirements as well as, say, insurance risk assessment and I think we've got to somehow work towards a common base there so we're talking the same language.

COMMISSIONER BINSKIN: Okay. I appreciate that and thank you very much for the answer. We will be coming back, I think, at some stage on this particular area. I've got one more question but before that I will go to Commissioner Bennett.

COMMISSIONER BENNETT: .....

COMMISSIONER BINSKIN: I've got more. Can I just - a final one, it's more just trying to understand again the data of it. If I go to IAG.001.001.0029 which is figure 6 which is bushfire risk - we will put it up. So there's that diagram which we will visit quite quickly. So as I understand it, that's the risk score by LGA across Australia of bushfire risk.

Can we go to the next one which is figure 7, please, which goes in on Victoria and New South Wales. And I'm just interested - and the top one there - just interested in how this is determined. If I look just east of Albury there on the border, in Victoria I guess we're very high, but in New South Wales we're medium. Now, I've seen the Murray River, it's not that big. So why would it be on one side very high and on the other side medium, please?

MR LEPLASTRIER: Okay. So I'm not sure I can answer your question there. This is - this data came from the ICA I believe, the NFID dataset. I'm not - I wasn't part of the actual analysis of how they rolled up. But I suspect this is an artefact of the way we look at bushfire risk management and things stop at State borders. So we don't necessarily have continuous information across a State boundary. The natural hazards, well, floods, bushfires, coastal erosion don't care about State borders and that's one of the, I suppose, aspects the Federal Government could help facilitate.

COMMISSIONER BINSKIN: Okay. So you think this is probably more a consistency of datasets and the way they're measured?

MR LEPLASTRIER: Yes, I believe that's probably the case.

COMMISSIONER BINSKIN: Okay. Thank you very much for that. Commissioner Bennett?

COMMISSIONER BENNETT: Well, that takes me straight into actually one area that I've got a couple of questions I wanted to ask. There's been some discussion about information and information sharing, and I notice that in particular Mr Paddam pointed out that, you know, there were some key limitations of the AACI and it doesn't incorporate certain information about exposure and vulnerability, and so there is missing information that you probably like to bring to bear. And you spoke about the difficulties of getting certain information.

If each of you were king for a day, as it were, and was able to set up a plan for the sorts of information to which you would want access, if you could get it, in order to do your jobs better, and we could take fire as the example, bushfire, where would you be looking for that information if you could get it freely with all the, you know, appropriate confidentiality regimes or whatever in place, or copyright or whatever it is you want to deal with? Where would you be - what would you want to set up? I mean, I don't know who - I don't mind who goes first. Mr Leplastrier is laughing. Mr Paddam, why don't you go?

MR PADDAM: I'm happy to go first. But I will say I wouldn't have all the answers here. I think it's interesting that you've taken, Commissioner - and quite rightly given recent events - bushfire as an example. I think one comment I will make is that, especially if we go back to some of the evidence Dr Crompton has provided in terms of the financial - the insured impact of bushfires, generally speaking - and this is - this is a statement probably about the past and not necessarily about the future - bushfires have not generated substantial insurance losses with a few exceptions, such as the Black Saturday number.

And what tends to happen is, when we think about the risk from the actual hazards, it's the intersection both of the hazard, of fire itself but also the exposure, where it's happening, and the vulnerability in terms of what are the protections in place. Now, with bushfires the insurance exposure is in the things we actually provide insurance coverage for tend to be in cities, tend to be in big cities in the middle of the cities. So where bushfires start to have an impact on insurance is when they are on the edge of suburbs or, you know, generally on the edge of cities.

And what we find - so, for example, one of the figures quoted by Dr Crompton in his testimony has been there was about 3000 homes that were destroyed over the - over the Black Summer. Now, that's a very large number and there's - there are - that's caused a lot of problems for a lot of people and I'm not trying to underplay that, but

in an insurance portfolio more broadly, for example, if we look at the hailstorms that hit Canberra a few months ago, in 15 minutes those hailstorms damaged a whole suburb. They were hitting - they were hitting things in the middle of a city and caused substantial financial loss and if we were to do it per second of natural disaster, that would way, far more than six months of bushfires did from an insurance - - -

COMMISSIONER BENNETT: Thank you.

MR PADDAM: I think - let me know - and I think it would be wrong - as an actuary I would say it would be wrong to focus on natural disasters purely in terms of insured losses. They have far broader impact and insurance is almost the piece at the end that tries to financially compensate people because - and it's a suboptimal outcome because people's lives, even if they're insured to the full extent of the damage, are very adversely affected by these natural disasters.

COMMISSIONER BENNETT: Thank you.

MR PADDAM: So there's some things you can't compensate for.

COMMISSIONER BENNETT: Thank you. I'm not sure, I'm looking for missing information.

MR PADDAM: Sure. I'm going off track here. So my point being from an insurance perspective I don't think bushfire would be the one that I would say we would want to focus resources on. My - in terms of financial risk, floods and tropical cyclones are far bigger financial risks for us to - - -

COMMISSIONER BENNETT: And you have all the information you need? Are you satisfied you've got all the information available to enable you to do your job on that?

MR PADDAM: No.

COMMISSIONER BENNETT: That was one of the questions I'm asking. Where would you be looking for that information that you're not getting at the moment that you would want to have, sources?

MR PADDAM: So there's different levels of information. First of all, there is underlying raw observational data which I talked about previously in terms of weather stations and ability to examine some of these events. I think, secondly, is the - is then coding that into hazard maps to understand what - - -

COMMISSIONER BENNETT: I will interrupt you just for a second. I'm not looking at - only looking at raw data. I'm looking at where you believe there is information that has already been collated perhaps for other purposes to which you don't have access that you would like to have access like government departments,

other entities. If you were a supremo of information, the supremo of information gathering, and you could get it from where you knew it was, I'm just trying to work out, you know, there's been some talk about not having sufficient information. So I just want to know where would you be looking? I don't know, perhaps I can see Mr Leplastrier and Dr Crompton are nodding too. So perhaps, you know, you could - while you think about it, Mr Paddam, why don't we go and see if Mr Leplastrier can help me on this one.

MR PADDAM: Sure.

MR LEPLASTRIER: Okay. So I think I understand the question. You're saying of what we know exists, what would be our wish list in access to it?

COMMISSIONER BENNETT: Yes, where you know there might be information that can actually help you make these predictions and work out exactly what you need to do, and you can't get access at the moment but you believe that access would be helpful?

MR LEPLASTRIER: Yes, so if we start with flood, there are still pockets of flood studies that exists that aren't made available to insurers or perhaps more widely to the general public. And I think the ICA could help provide a list of some of those areas where we struggle to actually get the data even though we know it exists within council.

COMMISSIONER BENNETT: Do you make all of your data freely available to everybody else? I don't mean everything you do in your life. I mean in terms of, you know, assessment of natural disasters and the information that you need to come to a conclusion on predictions?

MR LEPLASTRIER: No. No, we don't disclose everything we do. We're unable to in some circumstances because perhaps we don't own the data. We are trying to release information where we can in a very carefully considered way that also protects the privacy issues of our customers' data. So the release of our Severe Weather Report is one of those examples where we said this is better that we release this so we can get other input and also to help others in trying to establish some of those central sources of information.

We are also driving some projects through either jointly in the past, say with IAG Suncorp Water Ingress Study that we did with James Cook University, where we're trying to drive some of the insights we have within our claims data to help inform the building industry and building codes on how we can tighten up risk, and there's a couple of projects in the ICA at the moment. I'm the chair of the Data and Knowledge Group of the Climate Action Committee. So there's two projects there where we're using insurance data to help inform the damage that arises to modern construction in the floodplain or tropical cyclones.

COMMISSIONER BENNETT: Thank you.

MR LEPLASTRIER: So we are releasing - carefully releasing our stuff. But back to your first question, there's a couple of datasets, particularly say on coastal erosion, I know a very good study was done by the Victorian government looking at coastal erosion under different ..... scenarios, and I don't believe that dataset is necessarily available publicly, but it's something that's absolutely needed from a national perspective to role out right across the nation under one kind of common format. So I know that exists and that would be very informative for not just insurers but the community at large.

COMMISSIONER BENNETT: Thank you, Mr Leplastrier. Dr Crompton? Dr Crompton, do you have anything to add to that?

DR CROMPTON: Yes. Only just a couple of, you know, examples. So sticking with bushfire, so there will be information that is held around what the different types of ignition sources are. So that sort of information is certainly helpful. There's a whole range of ignition sources from arson through to natural ignition sources.

Going to the damage, the information that was used to produce, that data has been collected from Risk Frontiers either commissioning their own services to collect some of that data through aerial imagery. In the case of the south coast fire that was - the information was collected on, you know, literally on the ground. I mean, that - we had some support from the bushfire natural hazards CRC on that front. But collecting that data using other various forms of remotely sensed techniques as well.

Again, sticking with New South Wales South Coast about half or just over half ..... we surveyed just over half the number of buildings and that's, you know, some of these studies, as I said, are us literally going out into the field and driving around on a house-by-house basis. So collecting this information that is really so important. Things like, you know, turning to tropical cyclones that was mentioned earlier, you know, the amount of anemometer data, you know, in terms of the network that is available is - could be a lot more comprehensive to inform the development of a tropical cyclone wind field.

We provided some seed funding to the cyclone testing station at upper James Cook University many years ago for them to develop some mobile ..... to erect when a tropical cyclone was approaching land. And I mean, one on the hail side is, you know, the release of hail radar data. So there's been some work recently around radar and at the moment that's being decided whether there will be - that will be released under a commercial licence.

And then finally, I think from a national perspective, one of the very big gaps is maintaining an economic loss database. The Insurance Council of Australia database have insured losses, underpins so many studies from Productivity Commission inquiries into natural disaster funding in 2014 through to other economic loss studies from the Bureau of Meteorology It is often used and the way it is extrapolated to an economic loss is fairly basic and there's a lot of information which would be held in

various government departments that could be pulled together to create an economic loss database.

COMMISSIONER BENNETT: Thank you very much. Mr Leplastrier, you put your hand up and so does Mr Paddam. Can we just - very shortly though. Go on. Can I? Mr Leplastrier, go ahead, please.

MR LEPLASTRIER: Yes, so very quickly. In my statement I talked about a couple of other places where we're sharing data externally, and there was one with the Bureau of Meteorology so we're sharing de-identified claims data to help the Bureau of Meteorology calibrate or validate their new generation weather radar. So that will help I suppose understand - better understand damage on the ground so they can actually fine-tune their community warnings and alerts.

We've got two other projects, one with the University of Technology Sydney and another one with DPIE. The DPIE one is looking at how we can use that claims data to help understand hailstorm environments in the Mark Lim model. So it's a better, so the Mark Lim model won't model hailstorms per se, but you can at least understand some of the hailstorm environments that lead to that. So there's a few activities where we're trying to work with these partners using the claims data with some of these climate modelling tools.

COMMISSIONER BENNETT: But it seems to me to be a fairly - I mean, these arrangements seem to be opportunistic or ad hoc - I don't mean that in a bad sense - rather than having a systematic wide standardised method of interaction of information?

MR LEPLASTRIER: That's correct. I think the nature of the way we fund research projects - - -

COMMISSIONER BENNETT: That's not a criticism.

MR LEPLASTRIER: - - - generally. No, no, no, but I think there's an opportunity to think about if we were to set up a research program to research bushfires or tropical cyclones or hailstorms we could become much more coordinated in how we would go about that. So you're actually building stepping stones to a better state rather than research governed by short-term funding arrangement. So we do find a lot of research being quite sort of scattergun in a sense.

COMMISSIONER BENNETT: Thank you.

COMMISSIONER BINSKIN: Okay. Thank you very much.

COMMISSIONER BENNETT: Mr Paddam wants to say - - -

COMMISSIONER BINSKIN: Mr Paddam, putting your hand up at a Royal Commission. That's a good job.

MR PADDAM: Sorry, I just wanted to say, just broadly, I was trying to answer your question, Commissioner, before in terms of new sources of data. If we were to focus on existing sources of data that we don't have access to, I would underline Mr Leplastrier's point about coastal inundation and coastal flood mapping as well as tidal information and those studies that have been undertaken by local councils. It's very - there is no centralised source or collation project for that across Australia. And I think, given the evidence we've heard regarding sea level rise, that is an important dataset to make available.

I also would underline Mr Leplastrier's points regarding a coordinated approach because we do have - and particularly an example is the downscaling climate modelling that's done. Currently it's not necessarily, so we talked about NaCLIN being New South Wales centred but there are other down scaling data sources but they're not necessarily done in a consistent way, and I think there is a lot of value that can be extracted from existing data by coordinated better approaches.

COMMISSIONER BENNETT: Thank you very much indeed. I appreciate that. Back to the chair.

COMMISSIONER BINSKIN: Thank you, gentlemen. That was a very good discussion. We appreciate that very much. Ms Hogan-Doran?

MS HOGAN-DORAN SC: I have no further questions for these witnesses at this time. We do anticipate that with Dr Crompton and Dr Leplastrier's organisations both having foreshadowed updated reports or further reports which we do expect will be delivered during the course of this Commission's work, that we will check back in with them and bring those updated reports to you. And if there are questions that arise from them, we will be hoping to address them through them. In those circumstances though, might they be excused?

COMMISSIONER BINSKIN: The three gentlemen may be excused pending further summons based on the further submissions. But gentlemen, thank you very much this afternoon. It was a good discussion. We got a lot out of it. We appreciate it. Thank you.

MR LEPLASTRIER: Thank you.

MR PADDAM: Thank you.

MS HOGAN-DORAN SC: Commissioners, I note the time. What it is proposed now is to complete today's evidence with the evidence of the community witness. Professor Sue Townsend, who was Professor of Indigenous Australian Studies and Course Director at the Wiradjuri Language Culture and Heritage course at the Charles Sturt University, she lost her home near Tumbarumba in the Snowy Mountains in the Dunns Road fire on 31 December 2019.

Her evidence was taken by video in Holbrook in New South Wales on 11 May by counsel assisting Kess Dovey. I propose now to tender the video and the transcript of her evidence. The video is RCN.704.000.0002 and the transcript is POW.500.001.0001 and they will respectively be, it is proposed, exhibits 1.4.1 and 1.4.2 respectively.

MS HOGAN-DORAN SC: As I foreshadowed, the Commission will be invited to receive a number of different prerecorded video extracts of the evidence given by community witnesses. The Commission's counsel have respected - sought to respect the restrictions that have been imposed on us all in the last two months in relation to COVID-19 and social distancing requirements, and we are thankful to the, and appreciative of the assistance that has been given to us by members of the community to enable us to bring these accounts - these direct accounts to you.

What is proposed is that this video will commence and at the conclusion, that the hearings would adjourn until tomorrow morning. The video from Professor Townsend's examination is about 59 minutes long. And the transcript will be available in due course.

COMMISSIONER BINSKIN: Thank you for that. We will take the video and the transcript as exhibits as marked.

EXHIBIT 1.4.1 VIDEO OF PROFESSOR TOWNSEND'S INTERVIEW, RCN.704.000.0002

EXHIBIT 1.4.2 TRANSCRIPT OF PROFESSOR TOWNSEND'S INTERVIEW, POW.500.001.0001

COMMISSIONER BINSKIN: We will watch the video and at the end of the video we will take an adjournment until 10 am tomorrow morning. Thank you, Ms Hogan-Doran.

MS HOGAN-DORAN SC: If the Commission pleases.

<VIDEO OF PROFESSOR TOWNSEND PLAYED TO COMMISSION>

<ADJOURNED TO TUESDAY, 26 MAY 2020 AT 10 AM>