

**ECONOMICS AND INDUSTRY  
STANDING COMMITTEE**

**INQUIRY INTO SAFETY-RELATED MATTERS  
RELATING TO FLNG PROJECTS IN AUSTRALIAN WATERS  
OFF THE WESTERN AUSTRALIAN COAST**

**TRANSCRIPT OF EVIDENCE  
TAKEN AT PERTH  
WEDNESDAY, 26 NOVEMBER 2014**

**SESSION TWO**

**Members**

**Mr I.C. Blayney(Chair)  
Mr F.M. Logan (Deputy Chair)  
Mr P.C. Tinley  
Mr J. Norberger  
Mr R.S. Love**

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**Hearing commenced at 10.38 am**

**Mr RUSSELL STRINGER**

**Acting Regional Director for Western Australia, Bureau of Meteorology, examined:**

**Mr ANDREW DAVID BURTON**

**Meteorologist, Bureau of Meteorology, examined:**

**Mr BRADLEY SANTOS**

**Acting Regional Manager, Severe Weather Services, Bureau of Meteorology, examined:**

**Mrs CAROLINE CROW**

**Client Relations Manager, Commercial Weather Services, Bureau of Meteorology, examined:**

**The CHAIR:** On behalf of the Economics and Industry Standing Committee, I would like to thank you for your appearance before us here today. The purpose of this hearing is to assist the committee in gathering evidence for its inquiry into safety-related matters concerning floating liquefied natural gas projects in Australian waters off the Western Australian coast. You have been provided with a copy of the committee's specific terms of reference. At this stage, I would like to introduce myself and the other members of the committee present today. I am the Chair, Ian Blayney. With me is the Deputy Chair, Hon Fran Logan; and joining us is our other member, Mr Shane Love. The Economics and Industry Standing Committee is a committee of the Legislative Assembly of the Parliament of Western Australia. This hearing is a formal procedure of the Parliament and therefore commands the same respect as given to proceedings in the house itself. Even though the committee is not asking witnesses to provide evidence on oath or affirmation, it is important that you understand that any deliberate misleading of the committee may be regarded as a contempt of Parliament. This is a public hearing and Hansard is making a transcript of the proceedings for the public record. If you refer to any documents during your evidence, it would assist Hansard if you would provide the full title for the record.

Before we proceed to the inquiry's specific questions that we have for you today, I need to ask you the following: have you completed the "Details of Witness" form?

**The Witnesses:** Yes.

**The CHAIR:** Do you understand the notes at the bottom of the form about giving evidence to a parliamentary committee?

**The Witnesses:** Yes.

**The CHAIR:** Did you receive and read the information for witnesses briefing sheet provided with the "Details of Witness" form?

**The Witnesses:** Yes.

**The CHAIR:** Do you have any questions in relation to being a witness at today's hearing?

**The Witnesses:** No.

**The CHAIR:** Would you please state your full name and the capacity in which you appear before the committee?

**Mr Santos:** Bradley Santos, acting severe weather manager, Western Australia.

**Mrs Crow:** Caroline Crow, client relations manager, commercial weather services.

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**Mr Burton:** Andrew Burton, regional forecasting centre, operations manager.

**Mr Stringer:** Russell Stringer, acting regional director for Western Australia at the Bureau of Meteorology.

**The CHAIR:** Do you have an opening statement?

**Mr Stringer:** Yes, thank you Mr Chairman. I would like to make an opening statement to provide some information about the Bureau of Meteorology, about tropical cyclones and the hazards they pose off the Western Australia coast, and about services provided by the bureau. The intention is to keep this brief and to respond to specific questions of interest to the committee. We will also provide written material to the committee as a follow-up to this hearing, if helpful.

Firstly, some information about the bureau. The Bureau of Meteorology is a commonwealth agency within the Environment portfolio. We operate under the authority of the Meteorology Act 1955 and the Water Act 2007. Our vision is to provide Australians with environmental intelligence for safety, sustainability, wellbeing and prosperity. The outcome we aim to deliver is summarised as “informed safety, security and economic decisions by governments, industry and the community through the provision of information, forecasts, services and research relating to weather, climate and water”. The bureau receives most of its funding from the Australian government and delivers public good services to the community. We also provide commercial services which involve tailored value-added services to clients in a marketplace where there are or could be other service providers.

I will move on now to talk about tropical cyclones and their occurrence off the Western Australia coast. Tropical cyclones are low pressure systems that form over warm tropical waters and have gale force winds near the centre—that is, sustained winds of 63 kilometres an hour or greater, and gusts in excess of 90 kilometres an hour. The intensity of a cyclone is defined by its maximum wind strength in categories increasing from 1 to 5, with 5 being the most intense. When a tropical cyclone reaches category 3 intensity it is called a severe tropical cyclone; which is equivalent to a hurricane or typhoon in some other parts of the world. As the wind speed increases, the power of the wind to do damage increases almost exponentially. Hence a category 5 severe tropical cyclone has the potential to do around 100 times the damage of a category 3 severe tropical cyclone. The two cyclone hazards of greatest significance to offshore operations are winds and waves. While the category system gives an indication of the maximum winds, it does not directly indicate the expected wave heights because these are driven by other factors, such as the overall size and speed of movement of the cyclone. The Australian cyclone season officially runs from November to April, although very few occur in November. On average, about five tropical cyclones occur each season over the warm ocean waters off the north west coast—that is, between longitudes 105 degrees east and 130 degrees east. On average, about two of these cyclones cross the coast, one of which is severe.

In other tropical parts of the world where there are extensive offshore oil and gas installations, such as the Gulf of Mexico or the South China Sea, cyclones typically form at a distance and then move into the area of interest. In contrast, the Timor Sea and Browse Basins are areas where cyclones often form in situ. This makes it more difficult to provide accurate forecasts at long lead times. However, since they are areas of formation, the cyclones have typically not had as much time to intensify. Cyclones tend to intensify as they head further south toward the Pilbara, so cyclones off the Pilbara coast are likely to be stronger than cyclones in the Timor Sea. We can illustrate this by considering how many severe tropical cyclones passed through the Timor Sea, the Browse Basin and the North West Shelf over a forty year period from 1971–72 through to 2010–11. In each case, a circle of radius 220 kilometres was considered—that is, 120 nautical miles, or two degrees of latitude. The number of severe tropical cyclones experienced in each region was one, nine and 30 respectively—that is, one in the north west part of the Timor Sea, nine in the Browse Basin and

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thirty off the North West Shelf. I need to caution that that is just a quick and indicative inspection of cyclone occurrence, but it helps to illustrate the point.

Large cyclones have gale force and stronger winds over broad areas, and hence can generate larger waves. On the other hand, small cyclones pose their own challenges. Although they are smaller, they can be just as intense, and they tend to intensify and weaken very quickly, which makes it harder to forecast their intensity. Small cyclones generally occur early or late in the season, and this is a period when cyclones are likely to form further north—that is, in the Timor Sea.

Finally, I turn to the services provided by the bureau. The Bureau of Meteorology operates tropical cyclone warning centres in Perth, Darwin and Brisbane, which provide an array of tropical cyclone products. The bureau works closely with emergency services organisations, other government authorities, the media, industry, and commerce in cyclone-prone areas to ensure that warnings are distributed to adequately meet community needs. There is a very high level of international cooperation in tropical cyclone research and forecasting. Through this collaborative approach, the forecast processes the bureau uses are similar to those in other centres such as the US National Hurricane Centre and the La Reunion Regional Specialised Meteorological Centre operated by MeteoFrance. The bureau's commercial weather services section provides tailored tropical cyclone services to industry at commercial rates. These services include seasonal outlooks, which provide an estimate of the level of tropical cyclone activity in the coming season; intra-seasonal outlooks, which provide a four-week trend; seven and three-day outlooks; and three or six-hourly forecasts, once a cyclone has formed or when formation is imminent.

That was just a brief statement about the bureau, about tropical cyclones and about our services. We will now endeavour to answer your specific questions and follow up with written material if that helps.

**The CHAIR:** Thank you very much.

**Mr F.M. LOGAN:** Thank you very much indeed for that overview. You answered a couple of questions that we have here. I am sure that all of you are aware of the reasons why the committee is undertaking this inquiry. We have already done an investigation into the economic impacts of floating liquefied natural gas on Western Australia, and now we are looking at the safety issues surrounding the installation of FLNGs in Western Australian and commonwealth waters off the north coast. I am sure you are aware of the Shell *Prelude* proposal, which is the world's largest vessel, located 475 kilometres north of Broome in the Browse Basin. You touched on how the Browse Basin is impacted by cyclones a little bit. Could you detail a bit more for us the history of cyclonic activity in that particular area of where that installation will be?

[10.50 am]

**Mr Stringer:** In the Browse Basin—I might pass that across to Andrew or Brad.

**Mr Burton:** You might have noted the strong gradient, when you referred to the north west area of the Timor Sea, where in that particular period of record, only around one severe tropical cyclone had passed within the location, yet there were nine just going that little bit further south to the Browse Basin location. That shows as you move away from the equator, there is a certain distance where, if you are very close to the equator, you only very rarely get tropical cyclones. We referred in the opening statement to the fact that in that particular zone you are also slightly more likely to see the smaller tropical cyclones. The very typical path for a tropical cyclone, the almost classical path for a tropical cyclone affecting the Pilbara for example, is for it to form in the Timor or Arafura Sea areas, to have a low that possibly even comes all the way from the Coral Sea, it tracks across, depending on the time of the year, either through the ocean areas just at the north of the Top End or actually across the Top End and then back into the Timor Sea–Joseph Bonaparte Gulf area. From there, it is more likely to have a path that is not as affected by land. It will begin to intensify. It will then follow that classic recurvature path. A cyclone that is just travelling in a general

westwards direction will tend to also track slightly towards the south as it goes. There is a physical effect that leads to this.

In general, a cyclone is blown around by the other winds in the atmosphere, is one way to think of it, although big cyclones do affect the environment and alter their own path. This classic path would take it through the Timor Sea, then heading in a slightly more south westerly direction through the Browse Basin, intensifying as it does so, before it gets down to—depending upon the time of year—a latitude between Broome and Port Hedland. It is likely, in this classic stereotypical scenario, to slow down, possibly reach its peak intensity at that time, or certainly to be intensifying at around that time, and then to recurve. From your perspective, if we are heading down towards the south west, they intensify, slow down and then begin to recurve and come in towards the Pilbara coast, possibly weakening just as we are coming into the Pilbara coast but unfortunately not always. One of the strongest factors that affects tropical cyclone intensity in our region is how the winds are varying with height around the cyclone. If the winds vary strongly with height, we call this windshear; that disrupts the cyclone and can do that quite quickly. In that classic path, you can get quite a few intense tropical cyclones in the Browse Basin but you get, as you saw, even more once you get around to waters offshore from Port Hedland, Dampier, that sort of area.

**Mr F.M. LOGAN:** Just on the height issue, you were talking about the height of the cyclone itself: what are the different sorts of factors involved in the heights of cyclones? For example, in terms of intensities, is a cyclone more intense the lower it is or the higher it is, or does it not matter?

**Mr Burton:** Sorry, do you mean latitude here by being closer to the equator or further away from the equator?

**Mr F.M. LOGAN:** The internal structure.

**Mr Burton:** The atmosphere, we can divide up into the weather part of the atmosphere called the troposphere, and then we go into the stratosphere. Cyclones will always have a vertical extent, if they have any intensity at all, until they become quite weak. They have a full depth through the troposphere.

**The CHAIR:** That is a huge amount of energy.

**Mr Burton:** It is an enormous amount of energy that is released in tropical cyclones.

**Mr Stringer:** The key factor is the thunderstorms in the tropical cyclone, they are kind of a heat engine, and large thunderstorms which extend through the full depth of the troposphere may be 40 000 feet or higher in different parts of the world. The thunderstorms really help to trigger the dynamics of the tropical cyclone. Even to get to a category 1 tropical cyclone you need some good thunderstorm activity around the system so it is getting to the full depth of the troposphere. As it gets more intense, there may be more and more thunderstorms, sometimes out to a bigger radius. It is the intensity and the energy, and the number of thunderstorms and converging winds into the area.

**Mr R.S. LOVE:** You were talking about the different intensities, I suppose, of cyclones, indicating that they might be more intense further south. With the nine or so cyclones that you spoke about, what wind speeds would you be looking at a maximum wind speed in that Browse area?

**Mr Stringer:** There is probably a range over time. The definition of a category 3 is getting wind gusts above that 165-kilometre-per-hour threshold —

**Mr Burton:** Sorry; category 3 would be the hurricane-force winds.

**Mr Stringer:** Sorry; the hurricane-force winds. Categories 4 and 5 there is a whole spread of wind speeds there. Would you have a feeling for what some of the strongest wind strengths would be observed in that area?

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**Mr Burton:** Certainly you can get a category 5 cyclone in the Browse Basin. In fact tropical cyclone Laurence, passing close to the coast, reached category 5.

**Mr R.S. LOVE:** In the Browse Basin?

**Mr Burton:** In the Browse Basin, yes.

**Mr R.S. LOVE:** And that's what, 250 kilometres an hour or more wind?

**Mr Burton:** The gusts will be getting up above 280 kilometres per hour. I do not know whether you are familiar with the American scale? It is best not to go there then!

**The CHAIR:** Maybe it will be, because one of the things that interested us was making a direct comparison between our area here off the north west coast and the Gulf of Mexico. Obviously, there is a lot of oil activity in the Gulf of Mexico.

**Mr Burton:** We find it useful to use those comparisons because there are a lot of people in the industry who come from there. We also find it useful to make comparisons to the public because sometimes they are very aware of the Katrinas and other storms like that. We can make general statements that the Pilbara coastline between Broome and Exmouth, sometimes referred to colloquially as cyclone alley, has the same level of risk for severe tropical cyclones as the Gulf of Mexico. You see the same number of severe crossings. It is just that we have huge gaps between our populated centres, unlike the US. It is a relative hotspot around the world, off the north west coast. In terms of the category system, the American category system, when they refer to a category 1 in the Saffir–Simpson scale, it is already a hurricane, so it is equivalent to a category 3. They then go up to a category 5, but their category 5 is the same as our category 5 essentially. They dice up that part of the spectrum, if you like, a little bit more than us.

**The CHAIR:** What they call a category 5 is basically the equivalent of a category 5 here?

**Mr Burton:** Roughly. The boundaries are slightly different but there is not much difference by the time they are talking about a category 5.

**The CHAIR:** How about incidents there? Is it roughly the same to get more or less of them?

**Mr Burton:** There is a similar level of incidents in the Gulf of Mexico to what we would see just off the Pilbara coast.

**Mr F.M. LOGAN:** This is about *Prelude* FLNG: we have heard from Shell that a lot of testing has been done for a one-in-10 000-year event. Are you able to provide any insight into what a one-in-10 000-year event looks like or could you really calculate a one-in-10 000-year event? What would BOM's approach be to the statement of a one-in-10 000-year event?

**Mr Stringer:** I think, to kind of briefly state it, we have not assessed cyclones in those terms—in terms of repeat periods and what one-in-500-year or one-in-1 000-year or one-in-10 000-year intensity would be. Our services are more focused on identifying systems and categorising them as we analyse system by system. We have not done that analysis in those terms, so I guess we could not really characterise what a one-in-10 000-year cyclone would look like.

**Mr F.M. LOGAN:** Would there be any benefit in doing that? I am not suggesting you do it, but evidence coming out of, I suppose, one-in-10 000-year assessment—is there truly any benefit out of that? Are you getting really accurate information?

[11.00 am]

**Mr Stringer:** We talk to different users of meteorological information and quite often engineering design requirements are for these kinds of studies. In the area of rainfall intensity, for example, it is more common for us to look at our rainfall numbers and to come up with these kinds of the statistics to help engineering design work to proceed. But I guess in the area of tropical cyclones, it may just be that we have not been called on by engineering interests for that specific analysis work to be done.

**The CHAIR:** So you do not do it, but would someone else do it?

**Mr Stringer:** There would certainly be expertise around the world that could tackle those kinds of analyses.

**The CHAIR:** Is it pretty much just mathematical or like an average one is this and one-in-100-years is 50 per cent more and one-in-10 000-years might be double or something like that? Is it as basic as that or is there more?

**Mr Stringer:** I will look to my colleagues in a second to see whether they have any further knowledge of that, but I guess a preliminary statement would be that a tropical cyclone has multiple dimensions to it. It is not just one factor from weak to strong. There is the strength of the wind speed, there is also the size of the cyclone and the shape of the cyclone, so it would need some careful thinking about how you weigh those factors up to characterise a one-in-10 000-year system. It is something that we have not addressed as a task in the bureau. I will look to my colleagues now and see whether they have any further thoughts on that question.

**Mr Burton:** Perhaps to give you a bit more of a contrast between the usual way that the bureau and other weather services around the world look at cyclones, both in the short term and the longer scale, is to use full physics models running on supercomputers and to try to investigate the nature of the hazard through that. When we get to looking at the one-in-10 000 or one-in-1 000-year risk, it really is a risk-assessment strategy that has been taken here, so it is very much the companies doing their own proper risk assessment. I am not an expert in that methodology. As Russell was indicating, we are about taking some of those different dimensions of a cyclone, as we have in the database, as has been recorded—there are issues with using the database: there are differences in the database over time, you need to restrict yourself to the satellite era and there are other caveats attached to that database. They take the distribution that we know of in track, intensity, structure, for example, and then use a statistical technique to then generate a much larger database by sampling from that distribution many times to create synthetic cyclones. It is statistical in its nature, but it is certainly a valid way that has been used in many areas to try to overcome limitations of having a very small data set. That is about all the comment we can make on it, I think, because it is not an area that we generally get into.

**Mr F.M. LOGAN:** Could you tell the committee, have Shell or the Maritime Research Institute Netherlands ever contacted the Bureau of Meteorology for advice?

**Mr Stringer:** I am not sure that the group here have the complete knowledge to answer that question. We have a research centre head office in Melbourne that could well have had interactions at that kind of research level. We could take that question on notice if you want follow it up. We have certainly had interactions with Shell on topics in general and in fact, through the ITF there is a project that has only recently been initiated to improve tropical cyclone forecasting off the north west of Australia. So, we certainly have interaction with Shell and other operators on cyclone-related topics in general.

**Mr F.M. LOGAN:** I am advised by the oil and gas industry that operates the facilities offshore that they look at three different sources of advice on incoming cyclones, one of which is BOM's advice. What would be the other two? Do you have any idea who else they would go to? I am sure they would use their own information, the data set or information they have possibly collected.

**Mr Burton:** Do you refer to historical assessment of risk or warnings in real time?

**Mr F.M. LOGAN:** Warnings, yes, so with a facility that is in the path of an oncoming cyclone, I am advised that the platform manager or rig boss would not simply look at BOM advice, they would get two other sources of advice as well. Do you know who else?

**Mr Stringer:** I do not think we would be in a position to identify exactly which other sources of information they would give strong weight to. There could be quite a large number of possible sources of information. Just in the provision of commercial weather services there would be a lot of

capable providers of information, and then in the public domain there are many sources of cyclone-related information. Just to quote an anecdote, my brother lives in North Queensland and last year a cyclone was approaching and he sent me an email saying that the US website he was looking at said this about the cyclone and it was different from what the bureau was saying. So, there are many other sources of information in the public domain, some of them quite technically sophisticated. But I do not think that we have the knowledge of what Shell would give greatest weight to in addition to our own information, which hopefully they do give some weight to!

**Mr R.S. LOVE:** Is there any suggestion whether patterns might be becoming more dangerous in the north west or changing in any way with talk of global warming and all that sort of thing? What is the expectation there for the future over the next 50 years on the horizon?

**Mr Stringer:** That is an interesting question, and, I guess, again, we do not have the expertise here today to do justice to the question, but we did bring with us just one reference on that question, which we believe is kind of authoritative. With regard to past trends, this article, “Tropical cyclones and climate change” that was published in *Nature Geoscience*, in 2010, and is authored by a panel of 10 experts, who were brought together by the World Meteorological Organization. I guess that their conclusions are fairly cautious, as you would expect. With regard to past trends it remains uncertain whether past changes in any tropical cyclone activity, including their frequency, intensity, rainfall and so on, and it remains uncertain whether past changes exceed the variability expected through natural causes. In other words, not identifying a clear trend up till now in what has been observed. Using theory and understanding of cyclones and modelling and projecting forwards, with regard to frequency, it is likely that the global frequency of tropical cyclones will either decrease or remained essentially unchanged—which is kind of a fairly heavily qualified kind of statement. With respect to intensity, some increase in the mean maximum wind speed of tropical cyclones is likely with projected twenty-first century warming. Increases may not occur in all tropical regions. The frequency of the most intense storms will more likely than not increase by substantially larger percentage in some basins. With respect to rainfall, rainfall rates are likely to increase. The projected magnitude is in the order of plus 20 per cent within 100 kilometres of a tropical cyclone’s centre. With respect to the location of genesis, the tracks and duration of cyclones, we have low confidence in projected changes in tropical cyclone genesis locations, tracks, duration and areas of impact. Existing models projections do not show dramatic large-scale changes in these features. I guess, in summary, it is a fairly heavily qualified and cautious outlook on the trends. Again, this is probably an area where further work is ongoing and we might get a clearer indication of trends with further work.

[11.10 am]

**Mr F.M. LOGAN:** I have seen though, Russell, in media articles—I am not too sure whether they are from BOM, I think it was work done both here and in the United States—that there was a view that the definition of category 5 cyclones was not going to be enough, that there would possibly have to be introduced a category 6 cyclone, because of changes in weather patterns and increased intensity of cyclones. I am sure that you have heard that as well. What is the bureau’s view on that?

**Mr Stringer:** It is certainly an interesting concept. Our category 5 stands as an open-ended system, so any cyclone above the threshold intensity is a category 5 system by definition.

**Mr F.M. LOGAN:** So it could go up to any speed?

**Mr Stringer:** It could go to infinity.

**Mr F.M. LOGAN:** Yes, I see.

**Mr Burton:** Were that physically possible.

**Mr Stringer:** In those cases, when we look at our operations, we take it cyclone by cyclone, and try to identify and rate the intensity as the system evolves and hopefully as our modelling allows us to predict the systems. It would be described as a category 5 system once it is above that threshold.

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**Mr F.M. LOGAN:** In terms of the way in which cyclones work themselves, applying it to Prelude—this is all theoretical, we are not asking for an absolute definition. As you are aware, the Prelude FLNG facility is effectively like a floating city. It is 500 metres long, 78 metres wide, it is 45 metres from the handrail to the waterline not including everything that is stacked up on top of it, so it is like a big piece of a city sitting out there, 460 kilometres off the coast. If it was directly hit with the edge of a cyclone—you talked earlier about the shapes of cyclones and that they have different shapes—what would be the normal length of time of the cyclone passing over this vessel, and what could be the length of time, because, obviously, cyclones come in different shapes? How long would that vessel be subject to cyclonic activity if it was directly hit? I am only asking you to talk theoretically, because obviously cyclones are all different.

**Mr Stringer:** I guess we can start by considering that question related to a point and then extend it to the size of the facility we are talking about. Andrew, Brad would you?

**Mr Santos:** I will offer a couple of comments. It depends firstly on the size of the individual tropical cyclone, each cyclone is unique. When we talk about size, we generally talk about the radius to gale force winds. That is just the wind hazard, we also have rain bands which spiral around the tropical cyclone's centre, and we also have wind and wave impacts. The first point is the size, and the second point its actual movement and how fast it is moving. For a very large and very slow moving tropical cyclone, cyclonic impacts could be experienced over a number of hours, but if it is a smaller compact system and moving very fast, the cyclonic weather may only last for a small number of hours. There is a full range of possibilities depending on those factors.

**Mr Burton:** I could add to that say that if you look at the duration of gale force winds that we have recorded at places like Port Hedland with the passage of cyclones there and other locations, it is possible to have the gale force duration extend for more than a day in the extreme, but it is more likely to be in the order of hours—the duration of the extreme winds. I am not sure if you are familiar with the typical wind profile as you travel closer to the centre of a cyclone. At first, as you come to the gale force winds, the winds will be going up and down a bit and may drop out of gale force winds and back into them, but they are only slowly increasing as we go in closer to the centre. Then we get to where the storm force winds are; this is equivalent to a category 2 sort of rating. Then the wind speed will start to rise more rapidly as we get very close to the actual area where the most destructive winds are and that can be a relatively small area very close to the eye of the intense cyclone. The time that they will experience hurricane force winds is not likely to exceed more than a few hours—you are not going to get up into over a day. Most cyclones in our part of the world do tend to maintain a steady track. There are other parts of the world where cyclones tend to do a Mr Squiggle, if I may be parochial about it, and in those cases you have islands that have had cyclones in their vicinity for several days, but that is not typical in our basin. To sum it up, I would say that gale force winds can extend for longer than a day, but it is more typical to see them in the six-to-12 hour range. The hurricane force, what we call very destructive wind gusts, is more likely to be in the range of several hours.

**Mr F.M. LOGAN:** And the wind gusts, what is damaging parts of the cyclone? Is it the constant wind pressure as it comes across whatever it is—town, facility or whatever—or is it wind gusts? Because we have information that wind gusts were recorded at 408 kilometres an hour at Barrow Island, which I think there were the highest in the world or something. That sounds like it is going to cause a lot of damage, or it could.

**Mr Burton:** Yes—science is never black and white, absolutely sure. On the balance of probabilities that 408 kilometres an hour gust was a genuine recording of a gust. We would not categorise it, and this is getting into the technical description of it. You may be familiar with the fact that a cyclone in its outer bands, in particular, can have tornadoes. Cyclone Carlos, that passed several years ago, while it was still north of Port Hedland, a tornado went through the Karratha CBD area and caused greater damage than the centre of the cyclone, when the centre of the cyclone came close to

Karratha. There are also tornado-like vortices that can occur in the eye wall of a cyclone, in that dense area. That is what we believe would have caused that 408 kilometre an hour gust. There are these transient features. We try to categorise the intensity of a cyclone by the maximum wind speed that is likely to be a bit more long-lived than those sort of transient gust. We do not pin the intensity of a cyclone on to something like that. Wind is a very tricky parameter to characterise when you start to think about these issues.

In relation to the damage, again, all that I can say, because it is not my area of expertise, there are wind engineering experts who could make more comment, but what I know from my interactions with them, is that the duration of the wind that will have the greatest effect will depend upon the nature of the structure that you are looking at and how that has been engineered. The reason that we focus in public messaging on the gusts—technically a three-second gust is what we look at—is because many of the structures that we are talking about in communities, we are advised by the wind engineers, have been in the past, will respond to that level of wind, that duration of wind. But that may be very different when we start to talk about other structures, so I cannot comment in relation to what affects offshore infrastructure.

The only other point that I would like to make is that the waves and the seas tend to respond mostly to winds of around a 10 minute duration, which is why that is the World Met Organizations standard for reporting sustained winds is to take the average over 10 minutes.

[11.20 am]

**Mr F.M. LOGAN:** What was the category of cyclone that hit and did the damage in Exmouth?

**Mr Burton:** Vance?

**Mr F.M. LOGAN:** It was Vance, yes.

**Mr Burton:** That was a category 5 system.

**The CHAIR:** What is the interplay between the waves and cyclones? For any given category of cyclone, can you assume straight from that the size of the waves you will be getting, or does that vary?

**Mr Burton:** It does vary, as Russell indicated in his opening address. The wind speed obviously does have an effect on the wave field that is generated, but other important factors are what is referred to as fetch, the distance over which those winds have been blowing effectively in a straight line and forcing that wave to grow and grow and grow. With a small tropical cyclone, where the winds are curving around quite tightly, the fetch, the distance of those winds building that ocean up will be much shorter. If we take two tropical cyclones that differ only in their size, and otherwise have the same intensity of wind, then we would expect the larger one to create larger waves and larger swells. The next factor that is most commonly talked about in building the wave field is actually the speed of the movement of the cyclone. In a typical cyclone, the winds are forcing the waves and the bigger waves, the swells, are actually propagating out ahead of the cyclone. We see swells arrive with very long distances well ahead of the cyclone. As the cyclone starts to move faster than is typical, it can get to a speed where it is almost effectively keeping up with that wave field, so it continues to force it. They have a technical term they call enhanced fetch, so this then has the effect of building that wave field even higher. So a large fast moving cyclone would be the worst possible scenario for building waves.

**Mr R.S. LOVE:** Does the depth of the ocean make any difference to that wave height?

**Mr Burton:** If you are in very shallow water it will, but once you are in water that is three times as deep as the height of the waves, then it is not really going to have much of an effect.

**Mr F.M. LOGAN:** From your historical data, we talked about the intensity of cyclones, what about the number of cyclones? Have you seen any changes in the northern Australian weather patterns to

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see if there would be either an increase or a decrease in the number of cyclones from your own historical records?

**Mr Stringer:** I guess as an opening statement, just a cautionary statement, the databases are a very tricky thing to manage reliably with the changes in the observing systems available to us over the decades. The huge step function in history was when the satellite era took off and we could see from space where cyclones were really occurring and the number of cyclones detected took a large leap up. The last three or four decades there have been enhancements in radars on the coastline. I guess that is a preliminary caution that our databases, we have tried to capture the numbers and occurrences, but we do need to be very cautious in how we interpret those numbers. With so few cyclones each year, the statistics are very up and down. In terms of the north west, Brad and Andrew, what do the numbers look like over the decades?

**Mr Burton:** There is no discernable trend, and that is true for every database in the world. Because of these problems with the observing systems in particular, you mentioned that change of bringing satellites in was a huge function, but then we have had an increasing number of satellites, different types of satellites, more information and different techniques for actually analysing cyclones and a different level of detail that was recorded in the database. Some of these things make it very difficult, and when you analyse it very carefully, you find that you cannot reliably detect a trend in the databases. The short answer is: we do not know.

**The CHAIR:** What collaboration is there between the bureau and the offshore petroleum industry in collecting weather data? Do you think there is room for greater collaboration, especially when you consider how important it is to the offshore industry?

**Mr Stringer:** I think in general terms there are some very basic factors in our skill at monitoring and predicting cyclones and the observing network that is really up there as one of the key elements. We try very hard to maintain a good observing network operated at public expense and in the public interest. Where we are pushed for specialised attention off the north west, which is a little bit outside the public area of interest, it really does help if we can get additional observations and the operators are certainly aware of the value and importance of observations. I will pass over to my colleagues in a minute to talk about specific considerations and achievements that there have been, but the kinds of technologies that we can look at are: automatic observing stations measuring temperatures and winds locally; we can look weather watch radar to see tens of kilometres up to a couple of hundred kilometres from their location at the rain fields and hence you can infer where the cyclone is from those facilities; and probably at the far more elaborate end of the spectrum and getting out to where you would weigh up costs versus benefits, in the US they have aircraft reconnaissance missions and even automated drone small aircraft automatically collecting observations for a region. It is an important element of the operations for successfully monitoring and predicting cyclones. There are a range of options available, and I might hand over to my colleagues to talk about what has been or is contemplated specifically in the north west. Or is that a little bit beyond what we have actually put in place with the operators?

**Mr Burton:** If you are interested in collaboration with industry in terms of viewing them as partners as much as clients, then certainly there has been history of that from the Bureau of Meteorology and specifically the Western Australian region starting back in the 1980s with more of a land-based industry warning the Tropical Cyclone Industrial Liaison Committee. Through that, that gave rise in fact to the installation of the Dampier radar, which served the public good but also served industries' needs in improving the cyclone warning service that they were getting. We have seen that kind of an attitude carry through to today where both in terms of the general way in which industry tends to have a need for longer lead time warnings than communities, because they are response times, so in a general sense they tend to drive us to develop products as the science allows out towards those longer time frames. We referred in the opening address to seven-day outputs for cyclogenesis. Two decades ago we would not have entertained that idea because the science would

not have supported it, but industry continues to press us and as we feel we are able to meet that need, then we tend to develop those products. What tends to happen is then as the science progresses and we are continually pushed to develop further products, some of those products we are able to transition into the public arena, and so the public gains a benefit from that collaboration. That is just generally in terms of helping us to drive the science and the services that we deliver. There are other examples where industry has helped to sponsor or has funded very specific small-scale research, either looking at the historical risk of a particular area or trying to understand the risk in a general sense. There is also currently, I think, as was referred to, a project through ITF which you may be familiar with, the Industry Technology Facilitator, that is seeking to improve our ability to forecast cyclones off the north west coast and to improve the way that we are able to forecast the resultant wave fields from those cyclones—two important aspects of that project without going into too much detail.

**The CHAIR:** Every installation off the coast, has every one of them got one of your weather stations on it so it becomes an observation post?

[11.30 am]

**Mr Burton:** No. But we do have access to—one of the operators in particular operates Waverider buoys at some of their installations, and they make those observations available to us to benefit both the warnings that they receive, but also everybody in the industry and importantly the Australian community gain the benefit of those observations.

**The CHAIR:** What sort of data comes out of that?

**Mr Burton:** From some of them we get wind direction and speed—these are the elements that are important to us—they measure currents and other things, but the wave height, significant wave height, is the ever-important parameter that we get from those; and air pressure. So, for us those are the most important things and that does help us greatly to have those observations off the coast. Satellites are wonderful but a bit of ground truthing, as it is called, from surface observations helps enormously.

**The CHAIR:** Do you approach companies to see if they will do that for you, or is it they come to you to see if you are improving and if they can do stuff for you or how does that work?

**Mr Burton:** Through forums such as the TCILC or through regular meetings with industry there seems to be just an ongoing dialogue where they are looking for ways that we can improve the service and we will try to give an outline to them of all the ways in which the service can be provided, and if they can see the cost–benefit then they will say to us, “Okay, can we put a project up? Can we help in some way to improve the observations?”, as with the Dampier radar example or with those Waverider buoys.

**Mr F.M. LOGAN:** Would you like to see more companies involved in observation data? Would it be helpful?

**Mr Burton:** We are meteorologists; we are data hungry.

**Mr F.M. LOGAN:** Okay; fair enough; good.

**Mr Stringer:** It is a tricky question. There is also a balance between other initiatives which help the whole cyclone warning and prediction process that the computer power we have and the science understanding that we have is also important in achieving good long-term predictions, so we are certainly engaging with the operators on those topics as well.

**Mr R.S. LOVE:** Just in terms of radar facilities and the like—one in Broome and one in Darwin—is that at the base? Is there a gap there in the middle where you do have a bit of difficulty seeing what is actually happening?

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**Mr Burton:** There is also Wyndham and Halls Creek. So, Wyndham does give us some useful range. There is a part there where it is the zone where between any radar is going to be around about 300 kilometres and so certainly it is not particularly useful; it is too high up and not giving you the correct information that you really want. So, the radars are well positioned to manage the community risk, to maximise the benefit to the Australian community, and that is the Bureau of Meteorology's responsibility really, to split the funds in the wisest possible way. Again, as I say, if people are coming up with some more data, we will always say yes. And would it be nice to have a radar in the Browse Basin? Yes, of course, but again we have to weigh that up against where the money can be best spent.

**Mr R.S. LOVE:** That could be something that the government may change its view on as well as expending a very large amount of revenue from the Browse Basin. I have another little question just to add to it very quickly. We have spoken a lot about cyclones but are there any other tropical or weather circumstances in the Browse which would be of interest to someone in terms of worker safety or safety of the facilities and such?

**Mr Stringer:** Another meteorological feature often experienced in that part of the world is tropical squall lines. Organised systems of thunderstorms which line up and move for a long period of time can bring fairly strong and gusty winds and obviously need to be managed by any operations offshore there. I guess can we elaborate on squall lines in some way?

**Mr Santos:** Tropical squall lines generally originate over land and they can push offshore and maintain themselves for a number of hours—in extreme cases, have lasted 24 hours—and they contain very strong and gusty winds and rainfall, but it is the wind which is the most important feature and we can typically see severe wind gusts, so they are wind gusts in excess of 90 kilometres per hour with these systems. The other point to raise is the monsoon. During our tropical cyclone season we see a monsoon trough, which is an area of very strong wind, very heavy rainfall and some heavy swells, which typically generate over just north of the WA coastline. And during an active monsoon, that trough can drift further to the south and then when the season retreats that trough will retreat as well. So, in an active monsoon we can see strong to gale force winds, so we can see very heavy rainfall and also heavy swells associated with that monsoon trough, and they can last for a period of a couple of days up to a week or so in general.

**Mr R.S. LOVE:** Lightning events in that area, are something that I had a little bit of a question with the builders of FLNG about what happens about lightning and I did not really get much of an answer. Is that a regular occurrence in that area?

**Mr Burton:** All thunderstorms involve lightning, but continental thunderstorms would tend to have more lightning than maritime thunderstorms. But, as I say, all thunderstorms involve lightning by definition.

**Mr R.S. LOVE:** Okay; thanks.

**The CHAIR:** That is fascinating. I would like to thank you for your evidence before the committee today. A transcript of this hearing will be forward to you for correction of minor errors. Any such corrections must be made and the transcript returned within 10 days from the date of the letter attached to the transcript. If the transcript is not returned within this period, it will be deemed to be correct. New material cannot be added via these corrections and the sense of your evidence cannot be altered. Should you wish to provide additional information or elaborate on particular points, please include a supplementary submission for the committee's consideration when you return your corrected transcript of evidence. Thank you very much.

**Hearing concluded at 11.37 am**

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