RESUMED **[2.59 pm]**

COMMISSIONER: Reconvene at 15.00 and I certainly welcome Dr Andy Barnicoat and Martin Wehner, is it?

MR WEHNER: Wehner.

COMMISSIONER: Mr Jacobi.

MR JACOBI: Dr Andy Barnicoat is the chief of Geoscience Australia's Community Safety and Earth Monitoring Division. Dr Barnicoat has carried out research for a variety of areas in the geoscience mineral systems, mineral geology, structural geology and has examined those aspects both within Australia and overseas.

Mr Martin Wehner has been a structural engineer with Geoscience Australia since 2009 and since joined Geoscience Australia, whose research work has been centred on the vulnerability of structures to flood, wind and earthquake, and he participated in post-disaster damage surveys to: Padang, earthquakes; Brisbane for flood; Kalgoorlie for earthquakes and Christchurch. In each case, he's led the post-survey data analysis to develop vulnerability relationships and calibrate existing relationships. We call both of them to the commission.

COMMISSIONER: Welcome. I might start the ball rolling with just if you could give us an overview of the seismic monitoring activity here in South Australia.

DR BARNICOAT: Certainly. So Geoscience Australia operates a national seismic network of just over 80 seismic monitoring stations within Australia and in Australian offshore territories. Those stations are operative 24 hours a day, seven days a week, 365 days a year, and the signals are sent back to Geoscience Australia in Canberra where they are analysed and interpreted in essentially or very close to real time. If we could perhaps have the first slide on there. So in South Australia, there are a range of seismic stations and Geoscience Australia operates 11 seismic monitoring stations, which we had read on the map here, within South Australia, with another four in the neighbouring portions of Western Australia and Victoria.

If we just flip to the next slide a minute, this is a typical seismic monitoring station, and this one is Mulgathing in South Australia, there's a hut in the background which contains the solar power system and the data acquisition equipment. Then that round thing is a cover over what we called a seismic vault as typically a borehole is somewhere between two and three metres deep to get a seismometer and the other monitoring equipment itself well over the level of surface disturbance. Then in this case here, we've got what's called a VSAT communications connection there, which is a satellite connection. VSAT stands for "very small aperture terminal", I think. But anyway, so that's what at typical seismic station looks like. There will be perhaps a local custodian and then maintenance conducted by Geoscience Australia staff on an appropriate basis, both a preventative basis and fixing of issues and so on.

So if we go back to the previous slide now, there are also in South Australia - I should say that the Geoscience Australia network around the country is designed to monitor earthquakes of magnitude 3.5 and above anywhere within Australia. Magnitude 3.5 is something you would certainly feel, but it wouldn't cause any damage at that level. So we can measure all earthquakes in Australia at a level below those causing damage upwards. In fact, our network will typically monitor less than magnitude 3.5, but 3.5 is the design minimum.

The South Australian Government network, which is in the purple diamonds on this figure is an additional network focused more strongly around Adelaide with Adelaide obviously representing the area of greatest exposure to seismic hazard within South Australia given the population density and the built environment density there. There are a series of privately operated seismometers. I can't tell you any more about those, I'll be honest.

Then we've also got a small number of seismometers that have been installed under the Australian seismometers in school program, which is something that came out of a government educational infrastructure research fund. This part of it is managed out of the Australian National University in Canberra. So there are a series of schools in South Australia, as indicated there. I think there's five of them in the State that have seismometers in them that are also certainly dated back in real time.

MR JACOBI: I think you indicated that you can detect within other regions earthquakes to asperity of frequent 5.

DR BARNICOAT: Yes.

MR JACOBI: Are we in a different position with respect to other regions of the State given the density of some of the seismometers?

DR BARNICOAT: In the Adelaide area between our network and the local government network here, we can detect earthquakes down to about a magnitude 1, which really is very, very small. That really is, in the words of a colleague recently, not enough to wobble a jelly on a plate, so that really is a very small amount. I mean, it might feel like someone jumping up and down in the room next door, or a book falling of a shelf or something like that, but it really will be very, very small. So we can monitor very, very small things in the Adelaide region because of that denser network.

MR JACOBI: What's the historical depth of the data sets that are available from these?

DR BARNICOAT: Across Australia as a whole, we have a record of earthquakes going back to the mid 19th century. The earliest events recorded there are from observations rather than monitoring networks. The monitoring networks were successively deployed at a whole range of places around the country, probably from about 1900 or thereabouts onwards, perhaps a bit before. Since the middle of the 20th century, we've had a reasonable seismic network around the country and the current network was reinforced just over a decade ago.

That's not true, actually. Probably earlier than that. It was really identified after the Newcastle earthquake in the mid 1980s, so since 1990 or thereabouts we've had a network something like the current (indistinct) so there's a decent observational record for the 50 or 60 years across Australia as a whole.

MR JACOBI: Aside from measurements that we can draw from instruments, I'm interested in hearing the evidence that's been used for making predictions about the likelihood or probability of earthquakes in the future. Are there other data sources that are available other than sources taken from instruments?

DR BARNICOAT: Yes, in terms of creating a view about earthquakes we can also look at faults on the surface, and if we move two slides forward, I think, at this point - sorry, just go back. This is just a picture of the 24/7 monitoring system in Canberra, which is, if you like, the earthquake portion of the join Australian tsunami warning centre. The tsunami portion of that is manned by the Bureau of Meteorology in Melbourne, but this monitors earthquakes for tsunamis but also earthquakes around the world anyway, so we draw upon not just our own domestic network but also international networks to which we have access to data so we can identify earthquakes around the world and notify of those that have potential impact on Australian interests.

If we go forward another two slides. One more. This is a map showing both Australian earthquakes that we know about from 1841 to the present date. It's a magnitude 4 and above earthquakes, and the size of the circles is dependent on the size of the earthquake. The black lines which are principally but not solely in the southern portion of the country represent faults that are obvious at the earth's surface, so this is a break in the landscape that is clearly interpreted as a fault. Now, if this got a surface expression of that nature that means that the earthquake is, or the activity on that fault has been, in geological terms, quite recent, because the fault hasn’t been eroded down.

It probably hasn’t been eroded down to smoothness. For example, if any of you know the Canberra area, on the road from Canberra to Sydney around Lake George there's a large hillside there on the side of Lake George. That is a fault scar, and that's one of the ones that's marked, in fact it's the one that's marked just to the east of Canberra on the map there. That can be used as further indication of where in recent geological times there have been earthquakes, so that's a very good time period where we can get some indication of a repeat frequency from looking at the geological deposits around those faults to understand what the return sort of earthquakes on those structures are and the typical size of those earthquakes.

MR JACOBI: I think on that chart you've picked earthquakes above the magnitude of 4. Is there a particular reason for selecting 4, in general?

DR BARNICOAT: We have broader data that certainly shows all the known earthquakes across Australia of the same time period, but because of the lack of physical networks, people and so on in the early parts of the period, we don't have a reliable distribution of those earthquakes. There's not a complete distribution, so for the larger earthquakes we get a much better view about where they are. Seismic network will certainly now be picking up all earthquakes of that magnitude above and across the country, for example.

MR JACOBI: I understand an earthquake of magnitude 4 has attached with it a narrative description in terms of its damage to buildings. How is that characterised?

DR BARNICOAT: It's very good to generalise that because it depends how close you are to the earthquake and what the nature of the ground on which you are, so if the ground is soft you get an amplification effect associated with the earthquake and the ground shaking gets more severe, that's why I thought it was a comparatively modest sized earthquake in Newcastle. Because Newcastle was built really above a soft ground, soft soils, the shaking was amplified and a lot more damage was caused than would typically be caused by an earthquake of that size.

MR JACOBI: Coming back to the picture we have in front of us, you've identified, as I understand it, that this data set drawn from instrumentation – are all the red dots drawn from instrumentation? Is that right?

DR BARNICOAT: I think on this map – I don't think so. I can't be absolutely confident because I haven't put this map together but I suspect that the earlier earthquakes, which will be terrestrial rather than offshore in this case here, are going to be – some of them derived by estimation from felt reports, so where we have a number of reports of people, what they felt when they felt it. We can actually work out approximately where the epicentre is and what the size of the earthquake was.

MR JACOBI: Moving to magnitude, I think you've got larger dots there, 5.0 to 5.9. In terms of the experience of damage I'm just wondering about whether there can be any general characterisation made with respect to the relationship between the severity of the earthquake and damage in terms of above a particular level you experience a particular outcome.

DR BARNICOAT: Yes, we can make some general statements about that. So above an earthquake magnitude of 5.5 more damage is expected in buildings which are of what we might describe as poor to average construction standards. That's not necessarily a majority of reflection. Older masonry buildings, for example, unless they have been reinforced, are not of a high standard with respect to earthquake resistance. We would expect damage to buildings of that nature over several tens of square kilometres with a magnitude 5.5 earthquake, depending, though, on the nature of the soils, the ground on which the building was built. So if they're built on bedrock that's very much what we expect. If they were built on rather soft soils then we would get rather more damage, potentially, under those circumstances.

When we get to magnitude 6.5, so one unit higher – because the earthquake magnitude scale is a logarithmic scale, that means a lot more energy involved in there, 10 times more energy – we're going to start getting severe damage of buildings of poor to average construction over a couple of hundred square kilometres and well constructed buildings will only suffer minor damage over tens of square kilometres. So magnitude 5.5 really is the sort of size earthquake we're starting to get concerned about damage to built infrastructure. On a magnitude 6.5 it's getting really quite significant then.

To put those into context what I can say, perhaps, is that we typically expect in Australia of the order of one magnitude 6.5 earthquake every decade or so. There's normally one earthquake – well, there's normally more than one earthquake of magnitude 5 across Australia in a year. So recently we had a cluster of three earthquakes off the coast of Queensland, off the Sunshine Coast. We had three earthquakes within about three days of a magnitude greater than 5. That's quite unusual to get that sort of concentration of earthquake activity at one time.

MR JACOBI: I'm just wondering about whether – I know we had a map earlier – whether we can put the seismicity of South Australia into an overall global context.

DR BARNICOAT: Certainly. This map shows what are deemed to be significant earthquake over about a period of 4000 years. So clearly for the bulk of that period they are observations rather than measurements that have been used to derive these earthquakes. But this is out of the US, the National Geophysical Data Center there, a compilation. You can see that there are a few areas across the world where significant earthquakes occur or have occurred through that period. Around the Pacific Ring of Fire, so up the western coast of South America, through the Caribbean but also up through Central America and up the western side of the US, the Aleutians across to Kamchatka down to the coast just east of Japan and the Philippines and then down towards Indonesia, across to Solomon Islands and then down through New Zealand – the Pacific Ring of Fire there where the Pacific Plate is being subducted, as we say in geological terms, is diving down beneath the overlying crust. So those subduction are the site of the world's great earthquakes.

There are similar earthquake zones that carry on through the continents, parts of Asia, through the Himalayas, through Iran, Turkey and the Mediterranean and the Alps, which are associated with the remnants of such subduction zones where continents have actually collided in geological history but there's still geological activity in those areas. Those areas are marked by a lot of earthquakes very regularly and that's where, as I say, the world's great earthquakes occur – the big earthquake off the coast of Chile in 1960, the Tokyo earthquake of Japan a few years ago, the Sumatran earthquake and so on, earthquakes of up to magnitude 9 of even up to perhaps 9.5.

Those are the largest earthquakes we know about and those areas regularly have earthquakes because there is continued movement of the geological plates, and that movement is accommodated by plates sticking and then slipping. The slip is an earthquake and then they stick for another 100 or 200, 500, 100 years and then they slip, but that movement is continuing.

We can see in contrast that within most continents – and in particular within Australia we are well away from those plate boundaries and earthquake activity is known and much, much more sparse. So in global terms all of Australia is of low to moderate activity and South Australia, likewise, has low to moderate seismic hazard compared to the rest of the world.

MR JACOBI: In contrast to Australia as a whole can the seismicity of South Australia be characterised in relation to other Australian jurisdictions? We might perhaps best go back to the - - -

DR BARNICOAT: I'll go back to the next map, yes. So all jurisdictions in Australia have and continue to record earthquakes. There are a number of zones which are more prone to earthquakes than others. South-east Australia, a band from Melbourne up through Canberra, Sydney and Newcastle and some are more diffusely up through south-east Queensland as well as off-shore earthquakes in the Bass Strait and obviously just east of Tasmania. In Western Australia there are a cluster of earthquakes in the wheat belt. I think Australia's largest earthquake in Meckering in 1968 occurred. That was a magnitude of 6.7, something of that order. Don't quote me on actually what that was but it was in the high 6's occurred there in the late 1960s. As well as other earthquakes offshore in Western Australia and in northern Western Australia.

In contrast, in South Australia the prominent zone of earthquakes is in the Mount Lofty, Flinders Ranges areas. That's quite a well constrained belt of earthquakes and, indeed, the elevation topography in that area is an expression of that earthquake activity, that recent geological activity with those mountain ranges being, in geological terms, a recent occurrence. Their continued existence there is because of the continued seismic activity in that area. So those mountain ranges are uplifting relative to the rest of South Australia.

MR JACOBI: Then I think perhaps to continue on, as I said, away from those particular regions how would the seismicity be characterised, that is away from Mount Lofty and Flinders Ranges?

DR BARNICOAT: In general much, much lower with obviously a limited quantity of earthquakes than we're seeing in other parts of the state, in particular in the northern part of the state up to and across the border with the Northern Territory.

MR JACOBI: Is the cause of the seismicity in the Mount Lofty and Flinders Ranges region understood?

DR BARNICOAT: Not particularly well. What we're seeing here is a description of what has been seen. We know that that area is a deep-seated geological feature, going right the way through the earth's crust. We see this on seismic traverses, the sorts of things that Dr Hill was referring to earlier and I expect your witnesses this morning also spent some time discussing. We see this in the geological record itself as well. The noted geology of that area there shows continuing geological activity, for want of a better phrase, reflected in the nature of the rocks there and the very thick packages of sediment that are developed in parts of the geological cover there, for example, a reflection of continuing vertical movements which would have been associated certainly with earthquakes throughout geological time but certainly associated with very deep-seated major geological features.

MR JACOBI: I want to move on to deal with the predictive models that - - -

DR BARNICOAT: Yes.

MR JACOBI: - - - Geoscience has prepared and I just think in fact probably deal first with the underlying data sets that are used to build or construct those models and I was hoping you might be able to explain those?

DR BARNICOAT: So when we look at seismic hazard which is the prediction of earthquakes, we could produce a map like this, which is a map showing the seismic hazard across Australia and that is of no great relevance to us other than to really reinforce the point that I made earlier that the hot colours here are areas where there is a greater hazard associated with earthquakes and in Australia we are in a comparatively low level compared to many parts of the world. The west of Americas, that band through Europe and Asia and then around the Pacific – the rest of the Pacific Ring of Fire as well. We construct these seismic hazard maps and perhaps we can move on to the next slide which shows the national seismic hazard map that was produced I think in 2012 by Geoscience Australia. This is created using what we call a probabilistic technique. So what we do to construct a map of this nature is we take the evidence of the earthquakes that have occurred and the sorts of earthquakes that have occurred, the sizes they are, where they occur.

We run a whole series of – when we run a model that simulates the occurrence of thousands of those earthquakes we use a particular formulation which allows us from those earthquakes and the distribution of earthquakes, to work out what the ground shaking associated with those – each of those earthquakes is. Then we look at each cell or unit of the model or the map of Australia to see what the peak acceleration that is predicted in those areas will be, from all those thousands and thousands and thousands of earthquakes that we have simulated there. Because the acceleration – the ground acceleration is the thing that causes the damage to the buildings. So this map here is a map of predictive peak acceleration as a fraction of gravitational acceleration, that's relation to gravity, so up to about 0.3 times gravitational acceleration. So there will be three and a half, somewhere between three and a half and four metres per second acceleration. That is in the bright red areas of that map. That is with earthquakes that have a likelihood of occurring of one in 2,500 every year. We can approximate that by saying that will be a statistical average return period of 2,500 years for those earthquakes.

So this shows what we predict the maximum acceleration and maximum seismic hazard associated with earthquakes that occur every 2,500 years across the whole of Australia.

MR JACOBI: Could I just get you to pick one point on that map and just walk the commission through what it might show? So if we – perhaps I can pick a section in South Australia, perhaps the orange bar above Port Lincoln.

DR BARNICOAT: Yes.

MR JACOBI: On the Eyre Peninsula and I think there is a contour there that is a circle - - -

DR BARNICOAT: Yes.

MR JACOBI: - - - and I am just wondering whether you could just interpret that, so that we can just make sure that we're absolutely clear about what that means?

DR BARNICOAT: So within that circle that is going to say something of the order of 0.2 G is the maximum predicted acceleration, ground acceleration for hard rock areas. So solid ground. That is point two times G, G is about 9.8 so we are talking about something in the order of two metres per second.
Per second is the maximum predicted ground acceleration in that area.

MR JACOBI: For an earthquake - - -

DR BARNICOAT: For earth – not an earthquake - - -

MR JACOBI: No.

DR BARNICOAT: Any earthquake that affects that area. So it could be an earthquake that occurs some distance away, a big earthquake some distance away would shake the ground there.

MR JACOBI: Yes.

DR BARNICOAT: Or it could be a smaller earthquake within that cell itself. So that is the maximum ground acceleration that we are estimating is – will occur within that site.

MR JACOBI: Now just taking a step back, as I understood you have explained that that is built using probabilistic models - - -

DR BARNICOAT: Yes.

MR JACOBI: - - - and there is a close correlation between what is showing there and indeed the observations that are made - - -

DR BARNICOAT: Yes.

MR JACOBI: - - - on that for – I am just interested in understanding how the data that appeared on the map that appears before us, is built in to that model?

DR BARNICOAT: So there are two critical inputs into this model: one of them is the catalogue of earthquakes that have occurred across Australia, which is, if you like, the extended version of the previous map that we looked at showing the earthquakes; and the second one is something called a ground motion equation. So that's how those earthquakes transmit into ground shaking in Australian conditions, so an earthquake of a given size at a given depth, what that's going to give in the way of ground motion. So those are two of the critical inputs, the core inputs, into the analysis that goes into creating this holistic seismic hazard model.

MR JACOBI: Now, I think going to the next map we have a close-up of South Australia that's drawn from that, and I'm just wondering, bearing that particular chart in mind, accepting that it's a close-up, whether we can say anything from that in terms of predictions of the severity of the earthquakes themselves, and that is, whether we can make observations about the likelihood of earthquakes above a particular severity level.

DR BARNICOAT: We need to be careful here. There are two issues in that question, I think, Chad, if I may say. So this map is shown as not about individual earthquakes, but about the maximum ground acceleration. Okay? So that is not about an individual event, although it will be one particular event that is given as that acceleration, and that is showing something not too different from the earthquake distribution map. It's shown as the Mount Lofty, Flinders Ranges areas, and the northern part of the State as being the areas with elevated hazard relative to the rest of South Australia.

But we can also make some broader commentary. So, as I said earlier, we expect large earthquakes, potentially destructive ones, say, magnitude six and a half or above, to occur somewhere in Australia every few decades. In low seismicity areas like the western portion of South Australia, the likelihood of a magnitude 6.5 occurring within 20 kilometres of any particular site is about one in 150,000. So that's 100,000 to 500,000 year repeated, or something of that nature.

An earthquake that size will typically occur on significant faults, pre-existing faults which will normally, for an earthquake that size, be at least 20 kilometres long, 10 kilometres wide and have at least two metres of displacement on them. That can be detectable. If they're not always at the surface, they can be detectable. So big earthquakes of that nature we expect to occur on pre-existing faults, and those pre-existing faults will either be obvious in the topography or detectable by an appropriate seismic geological geophysical investigation of a site.

If we go to a region with higher than average earthquake potential in South Australia, say, the Mount Lofty Ranges, if we take an area of 1,000 square kilometres, a magnitude 5.5, which is where we're starting to get damage to those poorly constructed buildings, might occur once every seven and a half thousand years. In a low seismicity area, Tarcoola out in the central west of the State, it might be as infrequent as one in 30,000 years in an area like that. So I think that answers the question that you were asking.

MR JACOBI: And this might be a laboured point as well, but I'm just interested to understand whether the information, either what you just described or in terms of the map that we can see, can be used to predict the area in which earthquakes are more likely to occur.

DR BARNICOAT: The map here is the composite which is based upon that initial distribution that (indistinct) that does show the areas where earthquakes are more likely to occur. So the areas with higher ground acceleration and higher predicted maximum ground acceleration are also areas where earthquakes are more likely to occur, yes.

MR JACOBI: So if we superimpose on that the known fault lines, that would give us a better indication of one of those rare events, where they might occur?

DR BARNICOAT: Yes, but we're still not that good at identifying geological faults in areas of cover. The cover across much of South Australia, as we heard from Dr Hill, is particularly a wicked problem and that means that we know where there are some faults across part of the Nullarbor, for example. We see some there, but in other areas we really don’t have much idea. So a specific area, if one was planning on building something there or doing something significant there of whatever nature, a site investigation would reveal, we would anticipate, any structures of a nature that were going to host major earthquakes.

MR JACOBI: I was just hoping, bearing in mind what we just covered, whether we can step back to the comparative again and compare the position as has been described - I think we've got a slide that demonstrates this - between the position in South Australia and the position as it exists in other more earthquake or more seismically prone areas.

DR BARNICOAT: Certainly, and I apologise for the density of information on these, but you'll appreciate this is a technical matter and unfortunately it means that significant volumes of information occur. So if we take a low seismicity area of South Australia - Tarcoola was the example I quoted earlier - on a 500-year return period we expect the maximum acceleration to be .03, not much. The shaking there will be moderate, will be felt by most everyone. Some windows might be broken, unstable objects might be overturned. A maximum magnitude of earthquake, which is not one that will be a 500-year one, it would be a much bigger one than that, will be up to a magnitude of about 7.3 in area like that, we anticipate.

In a high seismicity area of South Australia - back to the Mount Lofty Ranges - we might expect on a 500-year return period about twice that acceleration, up to .06 in this case here. So remember this is a different repeat period to that on the seismic hazard plan. I'm sorry about that. That's a little bit confusing, I understand. A maximum magnitude of earthquake there might be up to 7.5. Everyone would feel that. Sorry, I'm confusing the two things there. The high seismic area there, the maximum shaking you find in that 500-year period will be heavy furniture moved, a bit of falling plaster, but damage will be slight. A maximum magnitude earthquake in an area like that, which again will be much less frequently than the 500-year repeat period, will be 7.5.

If we then go to north-eastern Hokkaido in Japan where the maximum magnitude earthquake is going to be up to (indistinct) 8.1, we'd expect to see on a 500-year repeat period acceleration is about an order of magnitude greater than those in low seismic areas of South Australia, about .3. Shaking will be severe. Damage will be slight in specially designed structures. In ordinary buildings it will be up to the level of potentially partial collapse, and even greater in poorly built structures. Southeast Hokkaido would experience somewhat larger ground accelerations and that would lead to even more damage there.

In Los Angeles, San Francisco, we are seeing broadly similar levels of ground acceleration, in other words, an order of magnitude greater than those in low seismic areas of South Australia, and six or eight times greater than those in the higher seismic areas of South Australia, and again, we're going to see those severe to violent shakings and those damages which could be, in the case of

San Francisco, like southeast Hokkaido, significant even in well designed and specially designed structures. So even Australia's highest seismic hazard areas most seismological areas of Australia, they are very low hazard compared to those high hazard areas around the Pacific Ring of Fire, say, Japan or California.

MR JACOBI: I think (indistinct) we pick you up somewhere, and that is that it's implicit in what's just been shown on the table that the design of buildings dramatically affects the damage with a given event.

MR WEHNER: Absolutely.

MR JACOBI: And I'm just interested to understand how earthquake resistance is built into what's described as a specially designed structure.

MR WEHNER: So that is a structure which is more frequently undertaken these days where the building is specifically designed to resist the effects of ground shaking. It contrasts to perhaps older buildings where there was no consideration of ground shaking considered in the design. So if you're designing your building to resist ground shaking you normally provide a ductile structure which is a structure that can absorb the energy imposed on the building by ground shaking through deformation of the structure as opposed to an older construction style which might be more brittle and, hence, cannot sustain much movement without fracture and subsequent failure.

MR JACOBI: I understand you have some involvement in the development of engineering standards for the Building Code of Australia. I'm seeking an understanding of how the question of earthquake resistance is built into planning regimes and other regimes in Australia.

MR WEHNER: What happens is that the state legislation and regulations reference that the construction has to comply with the National Construction Code and particularly parts 1 and 2 which is the Building Code of Australia, and within the Building Code of Australia it stipulates the hazard magnitude or, return period if you like, that a particular type of structure has to be designed to resist, depending on the function of that structure. When I say function, that's called – in the BCA it's called the importance level which relates to the hazard that that particular structure presents to life and property in the event of its failure. So a structure that is more hazardous, so something that might be storing hazardous chemicals or is acquired in a post-disaster function as a hospital or a police station, would be required by the BCA to be designed for a greater level of ground shaking or more intense ground shaking than, say, a domestic house or an isolated shed structure.

DR BARNICOAT: I'll perhaps add there that the building code stipulates the minimum standards that a structure must be created to. There is no restriction on them being built to withstand more hazardous events, and that is potentially a requirement that could be put in place through planning approvals or other approval processes, of course.

MR JACOBI: I'm also interested to understand – to the extent to which the commission is required to consider potential structures that would include those that maybe used in the enrichment of uranium, the potential for nuclear generation or those for the storage of radioactive or nuclear waste, am I right in understanding that at least, I think, the latter two would represent the higher hazard end of that spectrum that you've described?

MR WEHNER: In fact, they would be beyond that. They would be of greater danger, perhaps, to the surrounding populous than an importance level 4 structure in the Building Code of Australia. They would require a structure-specific hazard assessment and you would probably be looking at a design requirement to resist earthquakes of much longer return periods than is set out in the Building Code of Australia. This process is done today on structures that do present greater hazards. So, for example, a very large dam would require its own assessment of the hazards for which it should be designed because it presents a greater risk to the populous than the level of structures that are set out in the BCA.

MR JACOBI: So taking the example of something that exists today, in terms of a dam and in terms of its assessment is the life of that dam relevant to the - - -

MR WEHNER: Of course. So the idea is to select a design magnitude of hazard, whether it's an earthquake or some other hazard, that will ensure that there is an acceptably low probability of failure during the life of that structure. So obviously as the life of the structure gets longer and longer, the probability that a given level of event occurring in that life becomes greater. To keep the risk of failure at an acceptably low level you'd have to select a higher or greater hazard magnitude to design to.

MR JACOBI: Now, for the purpose of the analysis that we've just done on – I think the greatest of the return periods we picked was one in every two and a half thousand.

MR WEHNER: Yes.

MR JACOBI: If one was designing a dam, for example, what sort of return periods would one be needing to contemplate?

MR WEHNER: Could be going out as far as 1 in 10,000 years return period.

MR JACOBI: Now, in terms of siting considerations, again, I think perhaps to work from a dam which is an extreme risk given its potential for failure, what are the sort of siting considerations that need to be taken into account to address the particular earthquake risk?

MR WEHNER: So what you want to do with siting is to reduce the hazard magnitude, or level of ground shaking as far as possible, through siting. That means keeping the structure away from known potential sources for earthquake, keeping it away from soft soils that will deleteriously magnify ground shaking, and potentially even liquefy if there's soils that have the potential to liquefy, and keeping it away from slopes that might fail in the earthquake. Earthquakes do cause landslides from time to time, if the slopes have the right characteristics. By doing that, you are immediately, even though you might still need to select a longer term period earthquake as the design event, you're reducing the magnitude of that earthquake to design to.

MR JACOBI: Now, I think you've given three examples of particular risks that one must address, in terms of design considerations. Are there other ancillary related design considerations that one needs to take into account?

MR WEHNER: Yes. In designing an important facility, it's not just the structure which needs to be resistant to ground shaking. Everything about the structure needs to be resistant, because the facility needs to be, essentially, fully functional following an earthquake, and you can't afford to have damage to either the structure, or to some other ancillary component on which the facility depends, to run.

For example, things like emergency generators or maybe even water supply. Access: if there's a single point of access to the facility that goes over a bridge, and it's essential that you have access to the facility, there's no point having a facility that survives an earthquake quite happily, but that bridge is destroyed, because it will obviously not permit personnel or equipment to get to the facility.

It's important that not only the facility's structure, but anything within it that is essential to the functioning of the facility, or other infrastructure external to the facility that supports its functionality, all needs to be designed to the same level.

MR JACOBI: Let's tune to the question of structural form. Are there any adaptations made to structural form to manage earthquake risk?

MR WEHNER: In ordinary buildings, as I mentioned earlier, such as the one we're sitting in now, advantage is taken to reduce the magnitude of the forces that the building has to resist. In certain other structures, when the structure goes ductile if you like, and deforms, there is consequential damage but the idea is that that’s limited to a level whereby the building does not collapse. So you have safety preserved.

If you have a different kind of facility whereby it has to remain completely functional following an event, you can’t have that damage occurring. Damage has to be absolutely minimal, and so the ductility that is inherent in the structure cannot be taken account of. The structure has to be designed to resist an earthquake without damage, and that will attract, and that will essentially mean that it has to resist much larger forces. That has to be taken into account, right from design.

DR BARNICOAT: I think, in simple terms, you can engineer against just about any event (indistinct) the more it’s going to cost you. So there’s a cost benefit analysis. I’m putting it in very simple terms, engineers like to be incredibly precise, but I think I could be reasonably confident we would be making a statement about nature, just to put it into context, really.

MR JACOBI: I’m hoping you might address, are there special considerations for sub-surface facilities?

MR WEHNER: Yes. I guess essentially there are two main challenges with sub-surface facilities. The first one is water ingress, obviously. The ground will have water in it, either permanently or transiently, and groundwater ingress can obviously lead to deterioration of the contents of the underground facility or even the structure of the surrounding walls. The other one is if the groundwater is chemically corrosive. Over a long period of time that can lead to corrosion of the retaining structure and obviously have deleterious effects. Underground structures can have advantages too. They're inherently away from potential impacts from aircraft or surface vehicles.

MR JACOBI: Can I just deal with the implication – is there a question of interaction when one is designing, given the potential for earthquakes and the potential for surface and groundwater? I'm just wondering about whether there's an interaction there that needs to be taken into account in terms of engineering buildings.

MR WEHNER: Not so much in the interaction. Obviously structures that are underground will behave and respond differently to ground shaking than structures that are above the ground. There's no real interaction, as it were. It's just another criteria that the designer of the structure has to cope with

DR BARNICOAT: Perhaps to pick up on where you heading there with that question, Chad, obviously if liquefaction is a problem, if you've got some form of interaction there between groundwaters or waters and the ground shaking there but, frankly, if you're dealing with a piece of infrastructure that represents some sort of high hazard you really do need to site that in an area where liquefaction is not going to be a problem. So you seek to have it built on firm foundations on solid ground, essentially.

COMMISSIONER: Gentlemen, thank you for coming across and thank you for your evidence. We'll now adjourn till 0900 tomorrow morning – correction, 10 am.

MATTER ADJOURNED AT 3.47 PM UNTIL WEDNESDAY, 23 SEPTEMBER 2015