COMMISSION RESUMES ON WEDNESDAY 19 OCTOBER 2011

MR MILLS ADDRESSES THE COMMISSION

JUSTICE COOPER ADDRESSES (VIA VIDEO LINK) NORMAN ABRAHAMSON, ADJUNCT PROFESSOR OF CIVIL ENGINEERING, UNIVERSITY OF CALIFORNIA, BERKLEY

MR MILLS ADDRESSES PROFESSOR ABRAHAMSON:

Now I hope that this will be the same as what you and I discussed at least in writing before this so what's proposed is that you will begin this session with whatever time you feel you need to give an overview of the points that you have made in your peer review paper and particularly raising any issues where there might still be some difference of view between aspects of what you've been saying and what the GNS witnesses or Professor Pettinga may be saying and then at the end of that the proposal is that there then be, effectively, a panel discussion which will be you obviously and the GNS people and Professor Pettinga where you'll be able to talk to each other and discuss any outstanding issues and that will particularly give an opportunity to the Commission members to ask questions of the various experts. Is that what you were expecting?

PROFESSOR ABRAHAMSON:

Yes.

NORMAN ABRAHAMSON (AFFIRMED)

JUSTICE COOPER:

Q. Well now would you then proceed as Mr Mills has foreshadowed to give us in a summary way the conclusions that you have arrived at so far in your review of the GNS paper?
A. And may I ask just, is there and the amount of time you were expecting, is this a five minute, 10 minute, 30 minute (inaudible 09:34:15)
Q. No you can, I would like you to decide what you're comfortable with as a, as a summary which makes and explains the main points that you wish to make.
A. Okay. Well good morning I will begin with, in my review I had, had divided it into three main categories. One issue was, was the occurrence of the Canterbury earthquake sequence and the ground motions consistent with the models that have been used in the national seismic hazard map, the other topic, should there be a change in the methods that are used. If you open the national seismic hazard map and I've included some comparisons with, with US practice and then also should there be, the third major topic, should there be changes for the Christchurch area in particular given that there's this ongoing earthquake sequence occurring there. So with the first topic in, in general when we try to deal with earthquakes they are, and rare events, we cannot predict where they will occur. All that we can do is give broad probabilities of, of where they are more likely to occur. I think in the end while we are always surprised or not expecting a large earthquake in a particular location the fact that you had the, the model included magnitudes up to 7.2 in this region in the current versions indicate that in general you say this earthquake is, it is consistent with our models and would not cause you to, to make a major change. The one issue that I think happens on the looking at the February aftershock is that you're looking at a very shallow earthquake and that that

earthquake on the order of a kilometre to the top of the rupture indicates that the model used for the depths of the earthquakes should be adopted to accommodate shallower events. Currently the shallowest earthquakes are allowed to be 10 kilometres and the proposed modification was to make those five kilometres. In my view the earthquakes occur over a broad range of depths and in that range it is important to capture the variability of what future earthquakes should be but that's one area in the, in the part of the source model that I think, that didn't capture the occurrence of the Canterbury earthquake sequences. Talking about the, the ground motions from these earthquakes the report identified several, compared the ground motions recorded during the four largest earthquakes in the sequence with the ground motion prediction equations by McVerry et al. These are the ways that we numerically estimate what the ground shaking will be for a given magnitude and distance and as well they were looking at measures teleseismically, that is, at larger distances trying to measure aspects of the energy released in the, in the earthquake. In reading the report I felt that it emphasised quite a bit that there were higher stress drops for these earthquakes. In general a stress drop is, I would say, if I summarised, magnitude gives you a total amount of energy to release in an earthquake and the stress drop tells us how, that is really how compact that energy is when it's released in space or time. So the more compact it is the higher stress drop occurs and you get larger ground shaking, the more spread out it is in space or time you get lower stress drops and lower ground shaking. In, in my looking at the ground motion data I think these appear to have similar, just variability that we see from earthquake to earthquake as compared to the McVerry model. So looking at the, the, the ground shaking it is not convincing to me that there is a systematically higher stress drop in earthquakes in this area.

0939

The analysis, (inaudible 9:39:00) looking at the teleseismic data that is around the world and so forth indicated that these had higher apparent stresses which were summarised in the report as higher energy magnitudes. Because of that finding they suggested increasing the ground motion model in the Canterbury area to account for potentially for a systematic increase in stress drops in future earthquakes in that area so I think that's still one of the topics that we're in disagreement on. As far as I can see these earthquakes appear, as I said, similar to typical earthquakes with the variability that we normally get which is large. So there's variability from one earthquake to another and there's large variability in ground motions from one location to another during a given earthquake. The other aspects that were discussed, three things that could be attributed to some of the large ground shaking in the Central Business District were effects for directivity. This is a rupture coming towards you and it creates somewhat of a shock wave condition where the waves being generated in different parts of the fault, the shaking all piles up onto one another and amplifies the ground shaking. Other aspects described were basin effects and site effects so basin effects are capturing the effect of the waves propagating through a complicated 3D velocity structure of the earth there and they could cause constructive interference of waves and they can generate surface waves and other aspects that can amplify the lower frequency ground motions, a long period of ground motions and site effects are usually related to the soil conditions right underneath the site that may amplify or de-amplify the ground shaking. So the report talked about, the issue of forward directivity I think you can say in looking at these past earthquakes there is clear evidence that a forward directivity was one of the causes of the strong shaking yet this is a difficult thing to handle for future earthquakes because there will be variability. Sometimes the next earthquake will come towards you, sometimes it will go away from you. So in my judgement this is not a systematic effect. It's really an effect that leads to part of the variability in our ground motion models. One of the aspects of our ground motion models I should have started out with is that there's two parts of them. There's a median, that is the average ground motion given a magnitude in distance and then there's the standard deviation or describing the variability about that average and so directivity primarily, in my view, is contributing to this variability about the average. It's difficult I think, therefore, to account for this specifically for future earthquakes and I think the appropriate place to put that effect is in the standard deviation of the ground motion model. The other aspects being the basin response and site effects were discussed but not enough information was available at the time to actually sort of quantify these in specific locations. Again in my judgement this is a part of the ground motion model that is actually should be expected to be repeatable and is more systematic and I think it would be good to take advantage of what these recordings are and to actually try to accommodate the specific values that you found in the Central Business District area or other parts if there are systematic areas where there's a systematic increase in the ground motion compared to the average and you'd like to see this systematic factor occurring over multiple earthquakes so you need to have several earthquakes to try to get at that. That was one part of the report I would have liked to have seen a stronger push towards trying to use this type of information. This is really where the future of our ground motions models are going as we collect data. We want to be able to actually start to fine-tune our ground motion models in terms of how well they work in particular locations. The other topic was the large vertical ground motions during this earthquake. That's a very common feature that we've seen close in to large earthquakes. Again in my judgement this is probably not the main cause of damage and I think it's mentioned in the GNS report that the areas of large damage were also associated with large horizontal shaking so my advice on that is simply not to get distracted by the verticals. They can be important in certain circumstances but in general we attribute damage really to the strong horizontal shaking. I did note that, and I think we'll talk later about changes that the way the verticals are modelled currently in the New Zealand Building Code is very simple, using a scale factor of the horizontal and we know that's not very accurate. There are better models available so this might be a good time to change that piece of the model going forward are part of the Building Code. So that's I guess the big summary for dealing with the view of what happened. Then the next main topic being should there be changes to either the ground motion models, the source characterisation models, that is, locations, rates and sizes of earthquakes or the methods used to develop national seismic hazard maps, in all of New Zealand not just related to the Christchurch area. I'll break that down into the source characterisation first and then the ground motion. So for characterising the earthquake sources as I mentioned earlier, I think the key change that I would see for going outside of New Zealand or outside of the Christchurch area is to allow for earthquakes that occur at a shallower depth than just the 10 kilometre depth limit that was used. Part of the issue here becomes, do you have the resolution to determine really what are the depth ranges of earthquakes and we don't know them that accurately but in doing the forward modelling of the earthquakes I believe we have evidence from other areas of the world that there is a range and that they do come up shallow, not always, but they can and so by accommodating the chance of shallow earthquakes occurring you also add to the sort of probabilistic nature of the model and adds to the variability of the total set of ground motions that come out. The maximum magnitude was discussed in the report and whether that should be revised. In my past experience the maximum magnitude of 7.2 that's in the zones right now is a pretty high magnitude and I would not expect very much change in your computed hazard values from background earthquakes if you increase that. I think it is worth looking at in terms of sensitivity but I think that magnitude to me makes perfect sense. There is a trend in the earthquake science field to start allowing larger and larger earthquakes to occur. Here in California there's a push to allow magnitude 8 earthquakes for example to happen anywhere. My view is that they are much more likely to be occurring on faults that you identify when they get up to that size of earthquake but whether this was 7.2 or 7.5 I would be very surprised if that would significantly change your hazard maps but I would suggest that being looked at at least in terms of sensitivity. Also the report indicated that the faults identified in the Canterbury earthquake sequence could now be added into the national hazard map. I think that's the natural thing to do. Clearly you want to add all your new information given their low occurrence intervals I agree with the conclusion in the report that this is unlikely to have an impact on your hazards with 500 year return periods for example. For the need to change the ground motion models I will say this as a broad case issue that currently the national seismic hazard map in New Zealand is based on a single ground motion model and I would strongly recommend that you broaden that out to more than one model. We know that earthquake ground motion models lead to some of our largest uncertainties that we have in dealing with the limitations of our science to compute hazard and so really this ought to be a topic where you look at bringing in either a couple of additional models developed for New Zealand or from other parts of the world or using the current models and adjusting them up and down to create a suite of alternative models but you'll find that this really then starts to give you a set of models that we will identify where the actual solution is, where the real ground motion models will be in the future and then as you start to collect more and more data you can refine that but that's an area that I think that the National Hazard Map is not following but what is more standard practice of using multiple suites of ground motions or models.

0949

I understand the issues of trying to find models that fit with the New Zealand needs, the way you've designed site conditions and so forth. The models need to be applicable to New Zealand but I think you can do that, as I said, either by deriving some new models and I understood in some discussions with the GNS people that there are new models sort of on their way as well as or, as I said, just broadening, taking your reference model now, and broadening it out to capture the possible ranges of value. So there is some guidance that I put in here on my report on how that could be done. The basic concept that we use is areas with less data should have a larger uncertainty or larger ranges in their ground motion models in areas with lots of data or, excuse me, with fewer data. So if we go to comparing California versus New Zealand for example our ground motion models are better constrained in California yet we still have a pretty broad range of what those models are so, in my judgement, the New Zealand, the uncertainty with the New Zealand ground motion models are, should be at least as large as what we have in California where we have much larger data sets to work with and that's the US Geological Survey in the US uses that kind of an approach to broaden out the uncertainty in the ground motion models. As I noted before on the vertical component, I think it makes a lot of sense for you to switch to models that are geared towards building codes that do incorporate the verticals in a much more accurate way than the single scale factors that have been used in the past in the US and I think in the New Zealand Code it's simply a scale factor of .7 so there's plenty of models out there that could be used to improve that part. It's just bringing that, deciding to do that in your Building Code. I did talk in my review about the lower limit of the Z factor. I had that explained in a discussion with the GNS folks. They explained to me how they're capturing that lower limit from a magnitude six and a half earthquake at 20 kilometres using 84 percentile ground motion but then scaling that by a factor of two-thirds back down so I think overall the lower limit that you're using is a reasonable value. The .13 is consistent with the kinds of lower limits that are used elsewhere. I do think that's fundamentally one way that you decide you want to capture future unknown earthquakes. This is sort of our safety net for if we miss something we do put a lower limit on. If you want to improve safety that's one way that you can think about doing it is increasing that lower limit but there's always a cost and that's a trade-off in terms of what is acceptable risk and whether or not you want to spend more money to try to improve these levels of safety. As I said, I think what you're using now is already consistent with international practice so the question just being whether you want to go even above that for added safety to try to cover more of these earthquakes on unidentified faults in the future.

Okay, the bigger issue is, and I had discussed this with GNS last week, is the use of magnitude weighting factors in the National Seismic Hazard Map. This is not standard practice around the world. I understand the need for this or why they were developed and I do want to put in a warning in my discussion here that anything you do in building codes you have to be very careful how everything fits together. Building codes are notorious at putting different pieces together. Sometimes we know one is highest high, another is highest low but we put them together to try to get the right answer out so you have to be careful about adjusting one part of a building code without thinking through all the other pieces so while I'll talk a bit about the science side of this I would not tell anyone to run and make a change without thinking it through completely in terms of the impacts on how it fits with the other parts of the code so I'll just be talking on the loading side but there's always the capacity side that you have to think through and these need to match up. So the magnitude weighting factors that are used are really I think primarily being used to account for the very large high frequency or short period ground motions that are coming out from large magnitudes in the McVerry model and so shown in one of the pictures that I had at figure 2 in my review shows that the magnitude 5s from the McVerry model produced very large ground motions at .1 seconds compared to the larger magnitudes. The part of the reason you can bring magnitude weighting factors is to correct for that deficiency or what I would see is a bit of a weakness in the ground motion model we don't see that kind of a large shape in California for example. Our magnitudes 7s and our magnitudes 5s are shifted a little bit but not nearly as much as what's happening here. I have looked at the technical basis given for the magnitude weighting factors and, in my view, it's fairly tenuous. It's based on a study of the valuations of small magnitude earthquakes versus large magnitude earthquakes for large, rigid structures. Basically it was intended for nuclear power plants. This is the Kennedy et al study and that study was trying to look at issues of magnitudes really in the four and a half to five range that were a problem in the eastern United States and can they find a way to say that these large nuclear facilities would not be damaged by that kind of a ground shaking. I have not seen anyone else take this kind of information and apply it to regular structures and I think that is, on a technical basis, a difficult thing to simply show. Most of the technical arguments are given around duration. That is, smaller earthquakes will have shorter shaking or time of shaking than larger earthquakes but all the evidence I've seen in the last 20 years has really focused on a frequency content being the primary descriptor of damage to structures and duration is a secondary piece of it so I think that is not the fundamental issue that's going on in terms of damage ability between large magnitudes and small magnitude earthquakes. Having said all that, given the strong peak in the McVerry model of the short periods from small magnitudes I understand why these magnitude weighting factors were put together with this model to move forward into your Building Code. My concern is if you derive new models going forward that don't have this feature then you should not be using the magnitude weighting factors there so my view is fundamentally they don't belong there but I think they do fit when put with the McVerry model because of the strong short period ground motions that you're getting from that particular model. So it's back to my warning to you on any changes really need to be thought through as to what goes on. So if you change the ground motion models moving forward to bring in some new models for example then this whole issue of applying these magnitude weighting factors would need to be reviewed. Finally I think in the end when we're looking at what's appropriate this all comes down to, you know, should the Building Code be changed and how, it comes down to risk and what is acceptable risk so in the earthquake business we don't do anything where we say we design for the worst case and give people zero risk, there's always going to be a risk and then our question is, What is the acceptable values? I think the guidance document, the discussion in the report is brief on this and I did get additional information from Graeme McVerry about where the risk numbers come from. In my view these risk numbers come from.

0959

In my view these risk numbers are actually not, are likely to be unachievable as written in the report. I don't think we make anything like these kinds of risk numbers in California. The values, I think, are shifted, your goal is a bit too low and I think almost very difficult to obtain. So in trying to think what's appropriate we have to start to get to realistic risk numbers as well and in deciding what to do. I think our numbers are probably at least two to maybe, you know, 10 times higher than the kinds of numbers that you're looking at as a goal here. That's not for me to decide. That's really a broad social issue in New Zealand. Do you want to have more safety at higher cost or do you accept the kind of risk numbers that were used that are acceptable around the world. So my only comment here is I just think we talk about numbers here in the range of 10 to minus four to minus six as an example of risk of collapse I know that we are nowhere near those kinds of numbers in California. A new building these days we're shooting for a risk of collapse of two times 10 to minus four so double the high end of that range. Finally the last large topic, should there be changes in the model, in particular in the Canterbury area, to account for this ongoing earthquake sequence. This is really, to me, a very interesting topic. No-one that I know of has done something like this to try to capture the short-term changes but I think it is a really good idea to take this on. Earthquake sequences and aftershock sequences go on for years so it's not as if after a few months everything is finished and we're done with the aftershocks so there will be an elevated level of hazard. I think that the report in terms of modelling the earthquakes comes up with several different approaches to use. I think that it's a reasonable model going forward that captures the decay of earthquakes occurring but noting that decay is going to be over periods of, you know, five or 10 years or more while there is still a significant elevation in the hazard. I think the approach to include those into your hazard analysis is a good one. An issue though that I have with that is even so I think the numbers started to get very high so there was a revision to the lowest magnitude included in the hazard analysis, that is instead of using earthquakes down to magnitude five they were included down only to magnitude five and a half. The justification for that, just the short note in the report, was that based on the judgement of the New Zealand engineers the magnitude five earthquakes would not be damaging to structures. I am not confident with that conclusion. The reason being you may many magnitude five earthquakes, that's what an aftershock sequence is going to do, and really here you're trying to think about the unusually energetic magnitude five so we're back to the concept of a very high stress drop occurring, a large, or an earthquake in a particular area where the wave propagation leads to large basin effects or whatever could be occurring and so, in my view, those ought to still be in there and I think you are, again, starting to deviate from standard practice by increasing that limit. I fully understand, though, the issues of trade-off of cost and the impacts if the numbers get too big it becomes economically unviable to try to meet these higher values but my own view is that they ought to still have been left in there and integrated or included in the magnitude fives and above and if you need to simply accept more risk in the short term that would be the way to do it but my view is that by taking those out you are potentially under-estimating the risk and it doesn't do a lot of benefit to set a high risk goal and then not meet it by changing, apparently meeting it but not really meeting it by changing the kinds of earthquakes that you're including. The issue of changing the stress drops, changing the ground motion model in the Canterbury area was primarily focused on stress drop, being the only sort of easy way to change the model. As I indicated before I am not at all convinced that you have systematically higher stress drops in this sequence. Looking at the, you do have higher ground motions in the first say five kilometres to six kilometres from these earthquakes but by 20 to 30 kilometres the ground motions, again, that were shown in the report are back to average or below average and stress drop really ought to affect all of those ground motions and be raising them, not just the closest in ones, so I think it's not a stress drop effect it is something else that is going on. You could argue that you don't have any other way to do it so you want to increase the ground motions to pick up those larger motions in the five kilometre range. I would prefer that you say it that way and not try to say its due to stress drop. If it's a proxy for that just say we see higher ground motions in the first five kilometres, we're going to scale the model up by factor one and half or something to capture those, acknowledging that you'll now be larger, much higher than the observed ground motions at larger distances. I think that's an appropriate or a reasonable thing to do but I found the scientific basis of moving it onto stress drop to be unconvincing and a little bit misleading as to what is really going on there. It looks like a different rate of attenuation as opposed to stress drop differences in that area. Finally, as I said, side effects, I would think that, I would suggest that you try to take advantage of this data that you're collecting to see if you can do in a sense of micro-zonation or looking at areas to see is the side amplification in certain areas there much different than your standard site factors that you've got in the building code. If they are you should make those adjustments because those are likely to repeat themselves from time to time or in future earthquakes and I think that ought to be a part of your building code even going forward, thinking about how do you start to incorporate recordings from earthquakes into an area so that you can micro-zone the area as opposed to just using standard ground motion models with standard side amplification always in your hazard map. That's a change that not a lot of people are doing but it's clearly where the earthquake science is on this site. I think you have a great opportunity to try to do something with that in the Canterbury region and I think that's the end of my review.

JUSTICE COOPER:

Now Mr Mills were you planning to ask any questions of Professor Abrahamson at this stage.

MR MILLS:

No I had not proposed that, sir. I thought the most helpful thing, at least initially, would be either for the Commissioners to now ask questions or…

JUSTICE COOPER:

Yes, I'll check with my colleagues about that and then we would go on to the panel discussion. Yes, well, Richard do you have any questions.

PROFESSOR FENWICK:

I've got questions but I think it would be better if we directed the ones from Mr Abrahamson first rather than mine where are more general.

JUSTICE COOPER:

I see, you'd like your questions addressed by the panel as a whole.

PROFESSOR FENWICK:

Yes.

JUSTICE COOPER:

Sir Ron.

SIR RON CARTER:

Thank you gentlemen. I have had the opportunity to go through your report, noted the points you raised in that and have repeated this morning so I think the issues that you've raised are clear enough for me enough to be interested to hear the response from those other New Zealand engineers and geo-scientists that are with us. I'd like to proceed with the panel.

JUSTICE COOPER TO DR ABRAHAMSON:

Q. All right. Can I just check that I'm understanding one of the things that you've said this morning as I understood it you think that in terms of risk you said the goal that we've established in New Zealand is too low, you're saying that we're aiming to eliminate more risk than is the case in California is that – have I understood that?

A. Yeah. Yes and I think that's not just in New Zealand I think everywhere we have been underestimating what the risk values are so that when we're now trying to go back and see what we're getting with new building design it is really not – we were not as safe as we had sort of originally had our, had our goals set at, so I, I think it's good to try to get a realistic number put there so that you can start to really do the science and engineering to see that you need those goals because my expectation is if you were able to calculate some of the risks it – or some of your even newer structures that you would probably not meet these current risk goals.

Q. All right. Well there's another thing I'd like your help with bearing in mind that by training I'm a lawyer so you'll have to forgive me, if you will, I understand that there's a significant controversy between you and those form GNS who have reported to us about this issue of high stress drop. If you're right and they are wrong what are the consequences of that?

A. If, if I'm correct in future earthquakes in that area will also be similar to the current ground motion model that's been used so that if the difference would be if they were, if I was right you would have lower design values for your new, for your structures than if, if the GNS model is correct. In the Canterbury region. That would be the bottom line.

Q. So that if you're right again the current New Zealand thinking may be over-estimating the consequences of future earthquakes in Christchurch?

A. Correct but I would qualify that by saying there's other recommendations that I gave you which would push it the other way right so there's, it's not just one set of calculations that's going on.

Q. Yes.
A. For example the inclusion of the magnitude 5 to 5½ earthquakes if they did that the numbers would go up.
Q. Yes.
A. Okay, so that tends to push it up.
Q. Yes.
A. The issue of the magnitude weighting factors also if you follow my recommendation moving, in the long term moving forward that may move things back up again as well so there's a lot of counteracting pieces going on here but particularly for stress drop what you said is correct.
Q. Is it too superficial an approach for me to ask bearing in mind the countervailing factors that you've identified where do you end up in terms of the implications for the integrity of structures that are built, is that a question that you can grapple with?
A. I don't know –
Q. What's the next position I suppose?
A. You're right and that I don't have an answer for you because it would require a set of calculations to be done comparing the, the approaches if you took all of what I was recommending compared to all of what GNS was recommending and I haven't done all of those calculations to be able to give you an answer as to if I'm saying the numbers are too low or too high or they are just about right.
Q. But those calculations I infer from what you've just said that they are calculations that could be done?
A. Yes.
Q. And they wouldn't take terribly long to do?
A. That's correct. I think the GNS folks maybe more in the better spot to do them quickly but, well these aren't, these are not difficult calculations to do.
Q. Yes.

A. It just requires having information on the models that are being used particularly the models that they use for the locations of future earthquakes.

KELVIN BERRYMAN (AFFIRMED)

INTRODUCTIONS

JUSTICE COOPER TO DR WEBB:

Q. Dr Webb, in terms of the issues that have been discussed and maybe it leads on logically from my questioning I wonder whether the first issue that we could perhaps address is this debate about the high stress drop, would that be a logical place to start, or is there some other more logical place to start from your point of view?

A. I think the, well the first issue Norm raised was the depth range we're using in modelling and I think we'd completely agreed that it's a good idea to use a range rather than a fixed step, then it needs to come shallower.

Q. Yes.

A. It's just a matter of looking at how we distribute across that range in terms of data we have and knowledge we have of that range with New Zealand earthquakes so we don't see any issue with that point.

Q. Good, so is that, that's an area of agreement is that correct?

A. Yes, that's right. That would then lead us to the stress drop versus –

Q. Yes.

A. – directivity and trying to match these high data values at the distance of say six to eight kilometres from two seriously damaging earthquakes not just one so I guess in previous discussions Norm we mentioned this because they are different sites involved it's not apparent that it's a simple site specific effect although there'd be an outside chance that the same side effect applied to both areas. In the report at the time we were thinking of energy magnitude, I guess there's other evidence and I think you sort of alluded to it as to why we think stress drops are higher but we take on board your point that we're not, certainly not seeing a raising of shaking levels across all distances which is problematic but as you say for us it was a quick fix if you like to try and match those high values of shaking in the six to eight kilometre range that we felt fell outside reasonable variability but of course could be accounted for with directivity and I guess the evidence for, that sort of builds around the directivity would be firstly the fault orientation particularly in February is suited to directivity because the CBD region is sort of off end from that dipping fault.

1019

A. We know from GPS inversion of the slip that the slip direction is aligned in that direction as well which you need to get sort of that off end variability and also I guess in information we haven't really shown because it's still in preparation Bill Fry at GNS Science has been doing what he calls "source tracking", in other words, tracking the energy release as the rupture progresses so that we know that the rupture direction is consistent with that as well so if you add those three things up you would expect high directivity and I guess we had a bit of a discussion with Ralph Archuleta as well. When you look at the records it's not immediately obvious that you can see a fault normal motion clearly but this is where this could well be being obscured by basin effects so I guess our current view is that directivity is important. I take your point though that it could well be more important in the variability in the model than in the change in the mean values although I guess, and Graeme could comment on this, in the existing Code we do make some allowance for directivity in 11 major faults and we could extend that approach. So I will hand over to Kelvin.

DR BERRYMAN:

Just while we're on that same topic I guess Norm from another point of view, and you'll be familiar with this line of argument, that when we do look at the displacement for area coming from both the Darfield earthquake and from the February 22nd earthquake they were very compact sources with very large amounts of displacement for the average for those sorts of magnitudes so I guess that's the thinking also whether we term that "stress drop" we would certainly think of those as very energetic and compact sources as we're seeing elsewhere in New Zealand to some extent compared with other worldwide or, say, compared with California or the plate boundary faults, probably here in Canterbury this looks to be even more enhanced than what we were seeing in some other parts of New Zealand where you've also been familiar with so it was just even a little bit further advanced into that compactness, large slip for area relationship.

PROFESSOR ABRAHAMSON:

Right, so the key issue that I have and we discussed this a bit last week is in the end if we're gonna talk about this being stress drop in terms of the way it goes into a ground motion model is that it scales up the ground motion in all of the distances. It just moves it on and the data that you have in the reports, figures 314 I think and 315 that show the February 22nd and the June 13th event show those high ground motions in that five to I guess it is eight kilometre range but really the deviation is that this slope is steeper, right, so as you go to 20 kilometres it's fallen back down so what it looks to me to be instead of just saying it is a high stress drop event it is also you're getting a slope that is on average a little steeper than or the slope that you use with distance for most models. Now how do we accommodate that? Okay, that becomes a problem whether we actually go in and try say in Christchurch I'm gonna have a different ground motion model with a separate slope. That's a pretty involved process to make that kind of a correction so typically what we start to do is, you know, broaden the variability if that's what's needed to do here or I understand the pragmatic approach of just saying we're gonna scale the ground motions up, we will then capture these higher ground motions at five to eight kilometres which maybe most of the area that you're concerned about. That covers the main built area for example. That's a way to go but acknowledging that that is not truly just, we don't see the evidence in the ground motions that these are high stress drops, the way the corrections for stress drops gets put into the simple models and I think part of the issue here is you need a pragmatic approach to be able to do something quickly, okay, to accommodate it and it's either I think shifting the median up or you could increase the standard deviation. There's two ways to pick that piece up. I just think putting too much emphasis of a physical explanation that it's stress drop is too confident in terms of what the cause is right now of that higher ground motion in the short distances.

JUSTICE COOPER:
Thank you. That's had a full airing that subject. Is there merit in discussing it further this morning or are these issues that need to be thought about some more.

DR MCVERRY:
Perhaps I could just add one comment. Most of what Norm proposes in the way we do the calculations we can in fact implement those pretty quickly. Many of the options already exist in our Code so within the order of a week or certainly within a month I'm sure we could run all the changes that Norm was talking about except the individual site effects would take longer to take longer to determine those but as far as taking up the magnitude weighting, taking up the stress drop and putting in earthquakes for shallower depths, all those sort of things are things that we can do very quickly and come back with the new numbers and seek guidance with Norm on what range of depth we use, all that sort of thing so we can basically implement what he wishes to see and then come to conclusions what answers we believe are the most appropriate.

COMMISSIONER FENWICK:
Can I just take up the issue of the magnitude weighting, just some aspects of it and perhaps come back to others later on but the magnitude weighting as I understand it was done for liquefaction studies and then checked out for ductile structures by a process, as someone has mentioned, 11 earthquakes in connection with nuclear power. That magnitude weighting then assumes that you have ductile structures so what do we do when we have limited or very limited ductile structures or retrofitting URMs which have very little duct

ability, If we have magnitude weightings should we then have a second respecter for those type of structures or is there something which should be built into the engineering side in which case perhaps, you know, it implies the magnitude weightings should perhaps not be in the seismicity side but something which perhaps is applied in the engineering side if it in fact can be justified.

DR MCVERRY:

Yes, Richard, you are correct that the magnitude weighting was originally developed for liquefaction studies. In fact in liquefaction studies these days they actually do a lot more magnitude weighting than they used to but that's another issue. The study which we use for the justification for it was done in the nuclear industry in the US which I'd say in general tends to be ahead of what we do for expanded structures. It was restricted to short periods as Norm mentioned so in the New Zealand Code we were only applying it over the same short period range. In our recent work in Canterbury we've been persuaded to apply it across the board and I'll mention that in passing later in my presentation but that is unusual that we were extending it right across the board. Its justification is to look at duration effects and certainly ductile structures there's a requirement on the engineering side that they be able to withstand multiple cycles. I think most of it is based around four cycles. You'll know better than me and again I agree if you had a brittle structure that one cycle is enough to make it fail. Scaling down the motions wouldn't be appropriate but my understanding, and again you'd need to talk to engineers 'cos that sort of structure wouldn't be allowed in our New Zealand current Code, certainly those sort of structures will exist in Canterbury in our older building style or they would have up till February the 22nd. Whether there's any left now I don't know so, yes, on all those issues you're correct.

COMMISSIONER FENWICK:

I think that's reinforcing some of the points you made actually in terms of the weighting factor but…

1029

PROFESSOR ABRAHAMSON:

Yeah, so, as I said before this is really you are out there on your own in terms of applying these into a building and that's a precarious place to be. Everyone that I've talked to in the US on this topic were a little surprised that these factors would have been pushed all the way into a building code. They're used in liquefaction and well accepted but on structural response I wouldn't say this is a widely accepted issue. I will repeat though what I said earlier on. I believe part of the issue needs to be dealing with what I think in the McVerry model where it is over-estimating the short period contributions from the magnitude five earthquakes and now you have to find a way to correct them so if one part is too high in the model and now you put something else that brings it back down you might be getting the appropriate answer by taking those magnitude weighting factors with McVerry's ground motion model but that would not be appropriate in my view when if you are grabbing a different ground motion model that didn't have that large difference between magnitude fives and sevens after short periods. So its really this fine balance of what goes into a building code.

JUSTICE COOPER:

Yes, now, Dr Webb, what subject shall we address next from your point of view?

DR WEBB:

Oh I'll just comment on where we were at before. I think we understand each other fairly well and particularly the need to match the ground motions is the important thing and the issue is exactly how we go about doing that which we can't resolve this morning but we have a good basis for going forward. In terms of moving through other comments, others may have comments here, I mean an important one is the minimum magnitude which is for the current short term model has been moved up to five and a half.

JUSTICE COOPER:

Yes. How do you react to what Professor Abrahamson has said about that?

DR WEBB:

Well he's best to comment, do you want to comment on that?

DR McVERRY:

Ah, yes, in fact initially we were running our models with the standard five magnitude weighting in and we were coming up with some very high estimates. I don't recall exactly what we were. All of these calculations, the NS was doing the calculations and accepts the ultimate responsibility but they were being discussed on a regular basis, sometimes every, couple of times a week at some stages with the engineering advisory group and they just, I know the values we were getting when we went to magnitude five they were just not prepared to set those as being appropriate design levels because they were considerably increased above the sort of values we have ended up in our various reports. I think some of the values we're talking about are current Z factor for up to February, up to May for Canterbury, for Christchurch, was point 22. In our various reports we are talking about point three, possibly point three four to four one in our current estimates, I think we were getting values up as high as point five five to six when we went down to those lower magnitudes so you can see it as a considerable increase. Point six is the highest hazard factor we have anywhere in New Zealand for the Otira region, very close to the alpine fault and a lot of these faults that sway off the alpine fault in that region. So that gives you some idea of the sort of difference it will make but we would have to run the model again with all the parameters just to check what the difference is but its quite substantial.

JUSTICE COOPER:

So that would have meant a Z factor that was higher in Christchurch than anywhere else in the country.

DR McVERRY:
Oh definitely, well up to the highest, yeah it would be about equivalent to Otira which is about the highest at the moment.

JUSTICE COOPER:
That's not six though is it.

DR McVERRY:
Yes.

JUSTICE COOPER:
It is is it?

COMMISSIONER FENWICK:
Can I just seek a little bit of clarification. Was that in the short period range that these are high?

DR McVERRY:
Well it affects the short period range most. In the current Christchurch situation it tends to affect right across the periods though because the increase in the seismicity, particularly at those lower magnitudes is just so great. I think one of Dr Webb's presentations yesterday showed that at a times 60 factor, something of that order, over what we've had previously so the larger magnitude earthquakes off our big fault systems, which were previously reasonably significant in the long period range for Canterbury, just don't show up at all with the current seismicity model. Everything's been dominated by the moderate magnitudes or low magnitudes which we wouldn't usually expect in this region.

PROFESSOR ABRAHAMSON:
But could I add to that, Graeme, that right now what is your most hazardous spot in New Zealand and isn't it the Christchurch area given this ongoing aftershock sequence.

DR McVERRY:

Oh currently with what we're experiencing. I was talking in terms of averaging over the seismicity we're estimating for the next 50 years when I was talking about those. If we looked at what we're getting right now on any of the models Christchurch would be very high. It's dropping rapidly, even over the course of a few months and our calculations you get quite different values but if we did it starting from June, Christchurch definitely comes out top anywhere in the country.

DR WEBB:

I think Kelvin had another comment relating to this.

DR BERRYMAN:

Yeah, um, Norm just in general I absolutely agree with you about variability versus median values, etc, etc. Just to pick up on one point about the truncation at 5.5, it certainly wasn't driven by a cost consideration or particularly even a risk consideration. Another component part of that is that we've had 28 I think, 28 magnitude 5 to 6 earthquakes so there's a lot of actually observational data in these 28 earthquakes as to whether they've caused any damage so it's not just a statistical driver, we've actually got a lot of observational data and the magnitude fives, except for some of the already damaged URM, they haven't caused particularly significant damage, so we do have that, if you like, calibration point on one side as well.

PROFESSOR ABRAHAMSON:

Okay, I think that's very useful information to know if you have such a large sweep and they are a bunch of them close in as well and you're finding no damage then I think you could come up with a justification for declaring none of those being damaging so I would include more information on that because that's really going to be the key.

DR BERRYMAN:

Yes, of course, a lot of that's quite anecdotal at the moment coming forward, there's such a vast amount of data that's not coming forward in a very coordinated or consistent way as yet. So it's largely anecdotal but that plays into it, although taking the point also that we haven't necessarily sampled the whole range of potential damage from these modest magnitude or moderate magnitude earthquakes. So appreciating that point as well so it's not a black and white, it's just one of the considerations I guess.

PROFESSOR ABRAHAMSON:

I think you want to make sure that if you'd use the model and put those smaller magnitudes into it and let's say you created all those 28 magnitude fives, if you would have been predicting large amounts of damage then something is wrong, okay, that is that you are more justified in either, either it's the magnitude weighting or a complete threshold of eliminating them from the hazard calculation. But I think some check on that, my main, the concern that I have is what about that magnitude 5 that's now at the two sigma level, okay, so it's real, because you're getting so many of them you have a chance of getting a really energetic one and is that also going to be non-damaging or do you also want to try to capture that in your hazard calculation.
1039

DR BERRYMAN:

No, I agree with you that point, yeah, absolutely.

DR MCVERRY:

And I add to that I don't have a, what you'd understand as an epsilon, the aggradation, but I think most of those magnitude 5s are going in at 1, 1½, 2, 2 sigma levels so they are being, being counted as though they were a lot more energetic or stronger ground motions than average in the hazard calculations because the rates of those earthquakes are just so high at present.

PROFESSOR ABRAHAMSON:

If you were going to do any of the tests of the alternatives that I've suggested to you I, I do have to keep coming back to a struggle of, part of this is identifying in topic type, by topic science issues but it all has to fit together and so I would expect that again with, with the given ground motion model and putting all of the, let's say scientific suggestions that I had for you, you would get some really large numbers that may be completely inappropriate. So in doing so I would really encourage you to take a, another model if you can get that in there in a simple way that doesn't have such a, such a piece. It may be the Boore Atkinson model is pretty easy to use and will not have such a huge shift in the high frequencies. If you could demonstrate that without using the, let's say changes that I had recommended but with that kind of a model you got out similar results to using your calculations, your approach with your ground motion model I'd be much more confident in the end that we're coming to the right answer. I do have to keep saying there's a lot of counter-acting things going on that balance out over-predictions and under-estimations at different points and we're trying to get out simple, reasonable numbers in the end for the building code.

DR MCVERRY:

We can certainly implement that. We have the Boore Atkinson code available to us, we'd need to implement it in our national model. I started doing that a few weeks ago but it's been diverted, more urgent things have come up and the whole range of the current Californian models, their basic code is available to us. It's a matter of bringing it into our own software.

JUSTICE COOPER:

How long is that likely to take?

DR MCVERRY:

Well if it was all I was doing it would be a matter of days, yes.

JUSTICE COOPER:

We have to, well I won't make that speech at this point. Richard you have another question?

COMMISSIONER FENWICK:

I was just going to add one further point about the, the model and the good performance of the Christchurch buildings and I, I think there's a potential problem here between the sort of structural aspects, geotechnical aspects and the seismic hazard model. It could well be that the relatively good performance we've seen is down to higher damping effects in the, the type of soils we have here and that's probably something which we really covered in the engineering side of the earthquake action standard perhaps rather than the seismicity model because that will vary round the country and we wouldn't want to draw conclusions perhaps from what's happened in Christchurch and put them on the rest of the country where they might differ because of different aspects there. So it's just a thought to keep in mind.

DR MCVERRY:

Yes, I guess that's sort of something similar to Norm's suggestion of putting site specific factors in, in for Christchurch. Damping would be another issue that could be looked at.

JUSTICE COOPER:

Dr Webb is there another subject that can usefully be discussed at this point from your point of view?

DR WEBB:

Yes, the, the issue around likelihood, annual likelihood of building collapse versus life safety. There may be a little bit of confusion there and I think Kelvin could perhaps lead off on that one.

DR BERRYMAN:

I was actually going to suggest I could ask Graeme a question.

JUSTICE COOPER:

Well that's, that's possible as well.

DR BERRYMAN:

That's possible. This is not, I just picked up on a couple of points there and it was just ringing bells for me that there was a little bit of disconnect or confusion and I think our numbers about either the collapse or the acceptable risk criteria within the New Zealand code is actually an appendix to 1170 where there are some numbers from the, from the structural side but also an adjustment to that in terms of likely exposures of people occupying those buildings and at that point that was where I was going to ask Graeme can he recall, I believe that 10 to the -6 in itself is not the, is not considered to be the tolerable risk level because there's some ameliorating circumstances in terms of exposures within buildings.

DR MCVERRY:

Yes the building collapse, that is, I think where the 10 to the -4 to 10 to the -5 but then there was a risk of, of death factor which I think those ranges were the order of .1 to .01 so that's sort of how we get sort of get down to as low as 10 to the -6. I'd just like to comment that the values that are given in the GNS report have come directly out of a commentary in 1170. I'm not sure who was responsible for that commentary but they, they cite US sources back probably around about late 1990s, 2000s. It may well be that those were the values that were believed to be the target values in the US at that time where more recent work has shown that in fact the actual values are rather higher than that. In terms of –

JUSTICE COOPER:

Just, just clarify. Are you talking about the commentary to NZS1170.5?

DR MCVERRY:

Yes and I, I haven't got it in front of me at the moment but if necessary I could give, give you the, the exact clause. It's somewhere in my notes but I don't have it right, right in front of me at the moment. It's possibly in my comments to, to Professor Abrahamson.

JUSTICE COOPER:

I don't think I've got any notes from you. Mr Mills may have.

DR MCVERRY:

Yes it's in –

DR MCVERRY REFERRED TO C3.1.1

DR MCVERRY:

That sounds about where I would expect to find it, yes. No I don't think, it's earlier than that, it's in the, it's in C2.1 objective 2 on page 7 of the commentary section of 1170.5. But the point I was –

JUSTICE COOPER:

Well perhaps for Professor Abrahamson's benefit you could, you could read out the passage that you're referring to?

DR MCVERRY:

Okay there's a paragraph there, "*Internationally an accepted basis for building code requirements is a target annual earthquake fatality risk in the order of 10 to the -6 referencing ISO2394 1998. In design terms it is generally accepted that fatality risk will only be present if a building fails, ie, collapses. The maximum allowable probability of collapse of the structure is then dependent on the probability of a person being killed given that the building has collapsed. This conditional probability will be dependent on structural type and other factors and is likely to be in the range of 10 to the -2 (indicative probabilities have been proposed as part of the theme of the 2001 project and are reported in reference 5 which was a McGuire reference*." which I think I mentioned in my comments on your review. "*The acceptable annual probabilities of collapse might therefore be in the range 10 to -4 to 10 to -6. These values are inclusive of any collapses that might arise from design and* *construction errors, ie, a lack of compliance with the provisions of the standard in NZBC from which experience will be the major contributors to collapses that do occur*." That, that is the quotation. If, if I may could I just add one further comment that in fact the, the actual probabilities we use for design, even though our target objective is somewhat different than the risk values that have been evaluated in recent California studies.

1049

Target objective is somewhat different than the risk values that have been evaluated in recent California studies. Our actual value, values that are used for design of one over 500 for the standard structure one over 2500 for, for the critical structures and the sort of, the engineering things on what needs to be taken into account in meeting those targets are in fact very similar to what is used in Californian design so even though there's perhaps a little bit difference in the stated target risk levels the actual design levels are in fact very consistent in my view and Professor Abrahamson may like to comment on that.

PROFESSOR ABRAHAMSON:

I agree with that, that I think they're consistent. My main comment is, was related to trying to get some reality in our risk numbers because in the end that's what you have to make some decisions on you know what is going to be an acceptable risk? And we've a hard time I think of getting accurate risk numbers in this whole business and I, I – in my own judgments we are not achieving these very low risk goals that have been put forward and I, I don't think you're out on your own in this I think everyone has, has the same problem that when we discuss this that we say it's really 10 to minus six per year, let's say of fatalities well the numbers really are just bigger than that and so I think it's, it's, it's hard to, for a group to make a decision on acceptable risk if we're not trying to really get accurate numbers on what those risks are but I fully agree your design levels and probabilities are completely consistent with what's being done for example in the US.

DR BERRYMAN:

Could I just make – continue a short response it’s slightly a little bit out of context I guess but another natural hazard risk studies that we are completing in New Zealand are very consistent with the health and safety work that's going on in the UK and it’s more like the, the tolerable risk individual fatality tolerable risk levels are indeed in some other topic areas much more in the frame of what you mentioned Norm more in the, in the two, in the 10 to the minus four range as the, as much more consistent with other international practice, it is what we’re using and suggesting to authorities in New Zealand as targets and indeed as, as currently under discussion in relation to rock fall issues here in Christchurch also in terms of tolerability of future risk.

JUSTICE COOPER:

What are the UK risk levels addressing?

DR BERRYMAN:

They have been in the nuclear industry there's major study being completed for the British Rail and there is a reasonable in my reading of the literature now a reasonable global standard if you like maybe somewhat default standard at times of that range of about 10 to the minus four being the tolerability of individual fatality per annum.

DR WEBB:

Can I just –

JUSTICE COOPER:

Well can I ask another question in case it’s relevant what do they aim for in terms of fatality risk from earthquake in, typically in Europe I imagine there's a European standard as well?

DR BERRYMAN:

It’s something in earthquake space I’m not as familiar with perhaps surprisingly than some other aspects particularly the nuclear industry has pushed this along both in Europe and in the US for many years very advanced.

JUSTICE COOPER TO PROFESSOR ABRAHAMSON:

Q. Do you know the answer to that question Professor Abrahamson?
A. No could you ask that again? I wasn't quite –
Q. It was about the level risk that is aimed for in Europe in their codes?
A. No I don't have that information.

Q. Is the Californian approach matched in other states in the United States?
A. Yes it's supposed to, the goal is that it's across the country that we're having similar risks.
Q. Yes.
A. Our goal is to try and get consistency in risk from different natural hazards so if you're in a part of the country where your risk is from hurricanes that would get the, the risk of being killed by an earthquake versus flooding or hurricanes or fires to all be on the same order, that's, that's kind of our goal or how we try to figure out how safe to be to try to balance those out so you're not spending a whole lot more on one particular natural hazard compared to others.
Q. Yes I can see the logic of that.
A. It's logical but difficult to do –
Q. Yes.
A. – is the problem.
Q. Dr Webb.

DR WEBB:

Just while we're on this subject though I think we need to be very careful about what risk measure or risk metric we're using so we've been talking this morning really about individual annualised risk of death. Often what becomes very important in large buildings or earthquakes affecting cities is the mass fatality risk for which we tend to use different metrics and it then takes on either rather than an individual concern it becomes a community, city or national concern and the Christchurch earthquake's a very, very good example of that so the metrics for that are a little different from the, what you get in terms of this discussion about individual annualised risk.

JUSTICE COOPER TO DR WEBB:

Q. So for my benefit that is then reflected in more stringent provisions that relate to buildings where large numbers of members of the public might gather?
A. Yes, and also then of course you get into a different debate about what acceptable occurrence of mass fatality is.
Q. Yes.
A. Which again is not for, is for science, the science can inform that but in the end it ends up being community, I mean it has to be.
Q. The community never has that discussion do they?
A. No.
Q. They haven't in my life time. I'm only 56.
A. Yes. Well it's, um, one way of looking at it if you look at natural hazard impacts in New Zealand you've got maybe a handful of examples of fatality levels like we saw on February the 22nd and one approach is to look at what was the national reaction to that, did we have a Royal Commission? Did we put steps in place to change things which is an indication that at the time for those events we thought the fatalities were unacceptable? That is one approach to get a feeling for the levels. The other area is large dam safety Norm where I guess it's often looked, people use these F-N curves I guess which drives you to fairly conservative dam design, you might want to comment on that perhaps for us?

PROFESSOR ABRAHAMSON:

So we look at for large dams when we do risk calculations somewhere on the order of you know one fatality per 10 to the minus four probabilities and the 100 you would use 10 to the minus six and a thousand we would be using 10 to the minus seven and so forth. I can tell you in California those goals are completely unachievable. We have used them in areas where we have very, very low seismic activity but our, our, we do not have a risk of, based or risk informed approach to seismic design and dams in California so we are actually we might be taking some risks that are much over what those, those F-N curves are. It would be accepted let's say in other parts of the country where the seismicity is not so high. We simply can't afford to fix them all to those kinds of levels.

DR BERRYMAN:
Whereas in New Zealand in fact there is that risk based approach to the downstream consequences of dam break failure and they are following that 10 to the minus four individual fatality risk in relation to the classification of hydro dams in New Zealand so it is quite well advanced. I might also think that it's, that it's a target in New Zealand I don't know whether the reality would quite match it but certainly it's considered very strongly within dam safety evaluations in New Zealand so…

PROFESSOR ABRAHAMSON:
Yeah I think there you are well ahead of what we're doing in California and I have been trying to get them to move things along and improve what we do.

DR McVERRY:
Yes, there's just one other issue I'd like Professor Abrahamson's view on. It is likely that we are going to end up with very peaked spectra when we do these calculations, or I'm sure you recognise.
1059
One method that is used often is not to, is to truncate those spectra at some short period so we don't actually go back to the peak for example in eastern US I believe that if you just, your hazard calculations you may well find the spectra peak at .1 second but I think the level that you use for your plateau is maybe .3 seconds. Could you comment on whether that would be an

acceptable manner to avoid the very peaky nature in any results we may come up when it comes to implementing them for engineering design?

PROFESSOR ABRAHAMSON:

I think that part of the calculation that you're doing focused on the half of a second spectral acceleration, which is your base map you're using for your Z values, that an alternative instead of moving to the uniform hazard spectra which, I assume, that's what's driving you to your very peak values, is to apply a more standard spectral shape to that half second value right away rather than pushing yourself through uniform hazard spectra which are not appropriate. Right, that's kind of what you're getting back to. They're two peaked, they're not appropriate for design but that's a fundamental shortcoming of the uniform hazard spectrum as well as, as I said before, my concern that the McVerry ground motion model is over-estimating the short periods from the small magnitudes and we've had a problem with a lot of other ground motion models also staying up too high at these smaller magnitudes. But I think you could go about this by not pushing yourself all the way through that UHS step but to get to your question about truncating the peaks I know that that is very common practice in structural engineering or in coming up with design motions. You're spectra already were very high amplifications over the peak acceleration. I think you had factors of three or something like that, right two to three, those are already very big values so I'm not sure that all of your spectral shapes are wrong and I would consider going straight to a spectral shape that is making sense as opposed to the magnitude weighting approach. So maybe my approach to you would be to stay away from a uniform hazard spectrum driving your shape of your spectrum because that really can get things off too far.

DR McVERRY:

Thank you, that's useful guidance and, no doubt, that will have more interaction on this when we come to doing our calculations.

DR WEBB:

I just have one more or I think across the panel I've just got one more minor point to ask Norm really. Norm, you mentioned earlier you seemed quite comfortable with our approach to determine a lower limit for the Z factor which might be applicable in a few parts of the country and you mentioned that its consistent with what is used elsewhere. I can see this potentially being a bit of an issue for some areas such as Auckland. So can you provide or perhaps point us to some other international examples so that we can see a bit of the detail, maybe not now but a comment would perhaps –

PROFESSOR ABRAHAMSON:

Sure, I will give you some examples of how we came up with, some numbers that are used elsewhere so you can see what they're like. They are on the order of this, you know, in a point one two to point one five G range which is effectively what you have with your Z factor, right. So they're, they get at them in a very different way and so I think part of my confusion was starting with a six and a half 84th percentile sounded like an extremely robust lower limit but then when you multiply by the two-thirds and other factors then it comes down to be about the same as what's used elsewhere but I can send you some references for what's used in different areas.

DR WEBB:

Right, that's very good, thanks.

JUSTICE COOPER:

Yes, nothing further? Professor Abrahamson we're very grateful to you for lending your expertise to this project which is a matter of great concern and gravity for this country. I infer from things that have been said this morning that you are willing to stay with us in the weeks and months ahead. We have a target reporting date of the 11th of April next year and I think issues have been raised in this discussion which we will want to see progressed with a view to having an update, both from your point of view and from GNS's point of view as to any further progress that has been able to be made towards agreement or whether disagreements simply end up being maintained. We would like to know, to hear from you again later in the process if that will be all right.

PROFESSOR ABRAHAMSON:
I would be glad to help however I can. I know these people, this group very well at GNS and so we talk outside of this project as well so I'm happy to continue to help.

JUSTICE COOPER:
Thank you and we're obliged to you for your time today, thank you.

PROFESSOR ABRAHAMSON:
Okay, thanks.

COMMISSION ADJOURNS: 11.05 AM

COMMISSION RESUMES: 11.25 AM

GRAEME MCVERRY (ON FORMER AFFIRMATION)

EXAMINATION CONTINUES: MR MILLS

A. If we could resume with the PSHA slide please. Is that coming through, everything okay, fine. When I finished yesterday I was just running through the PSHA calculation process and just to summarise that, it involves calculating the rate of exceedance of various acceleration values, spectral acceleration values and the components were that we work through each of our earthquake sources in terms, in our model, we have the rate of the earthquake itself and then we multiply that by the probability of exceeding a particular ground motion level at the site. So that gives the contribution from a particular earthquake and then we sum those over all of the sources of our model which are all the fault sources, all the gridded sources for the whole range of magnitudes that are covered on those gridded sources. So that is how the calculations, the basic calculations are done. If we could now move onto, it'll be 10C.7, GNS 10C.7. That's the one. So this is just putting up a slide that Dr Webb showed you yesterday. It's comparing how different the make-up of the hazard is currently in Canterbury on the right-hand side where there are previous modelling and the point I'll make is, is you can see how in the current earthquake sequence everything is dominated by the low magnitudes, the short distances while previously the larger faults in the area from about sort of 30/40 kilometres away right through the Alpine fault were also making quite noticeable contributions and that has quite an effect on some of the things that will follow, some of those issues have obviously just been discussed in the session preceding this but just to refresh you of the different make-up in terms of the magnitude and distance of the earthquakes. Now if you could resume on my presentation, 10D4. Thank you. So yesterday you saw how the motions in central Christchurch on February the 22nd compared with our design levels and in the main they greatly exceeded them. One point of view might be that we've had that earthquake and yes we got very strong ground motions but we can go back to where we've always been in moving forward but, in fact, again, as you've seen from earlier presentations we have a very rich ongoing earthquake sequence in Canterbury which is likely to produce stronger motions than, than have been taken account of in the pre-existing loading standard so, so we perhaps need to address that and that's where the rest of my presentation will be addressing. There are certainly greater increased seismicity rates currently and running through over years rather than months from where we were prior to September and also for whatever reasons the motions in the CBD were higher than our models predicted and there's several possible causes. There was quite a bit of discussion this morning on which of those are the actual causes but there's certainly within that first 10 kilometres or so of the February 22nd earthquake the motions were enhanced on what our models would predict so we need to account for the increased seismicity and the under-prediction, at least in the very, the first 10 kilometres from the source of our current models. Next please. We have developed some new hazard models for Christchurch which from the discussions this morning you'd see are still very much, elements of it are being debated but this is where we're at the moment. We have a model which accounts for the ongoing earthquake sequence. It's using those various models that Dr Webb showed yesterday for the very short-term aftershock type model, the longer term which is really for counting for triggering and then the long-term enhanced rate and then they are also being combined with, I was going to say our standard fault model but that's not quite true because we have looked at the closer faults to Christchurch across to the Alpine fault and we have re-evaluated the probability of them rupturing over the next 50 years and taken account of the time since their most recent rupture and have modified the probabilities of that occurring slightly but they in fact having very little influence on the new hazard calculations but there has been that modification to the fault model. Grid source. Previously we had layers at 10 kilometres, 30 kilometres going all the way down to 90 kilometres. Because of the shallow depth we have placed all the earthquakes that are being estimated based on the current sequence at five kilometres depth rather than 10 kilometres. There was some discussion this morning whether we should have some of them brought even closer to the surface but this is where we're at, at the moment. Our ground motion model, we've put in a factor which increases the motions from standard estimates. We've used something which accounts for stress drop which is possibly a surrogate for other effects such as directivity for which we don't have suitable models so readily available and the stress drop increases the motions at all distances rather than just close to the source and it's possible that that is not the right physical effect but it is giving some enhancement over what our standard model would do.

JUSTICE COOPER:

Q. Just can I ask, when you say suitable models are not readily available for directivity am I right in thinking it would be unlikely that such models ever would be available?

A. I, I think that, there's some in what we call the grey literature, so there's people who are using them but, are showing results but not sort of making the actual models available and whether through our contacts with people we can get access to those, it's possible. We do have a model for directivity which we apply to our major faults after we've done our initial hazard calculations but it's an outdated model which, it was developed 10 - 15 years ago and there are more modern models which I say are not things you can just pick up easily from the literature but are out there which account better for the physical things that are happening in –

1135

COMMISSIONER CARTER TO DR McVERRY:

Q. These are unpublished.

A. They’re in the, yeah I think they’re unpublished there, there are elements of them unpublished and I think some of those we may be able to use but we certainly don’t have them implemented and we’d need to talk to the developers to obtain them and make use of them.
Q. You wouldn't generally rely on unpublished model would you?
A. No exactly because the point is that they're still a work in progress. I think the main reason they’re unpublished is the developers regard them as work in progress and they’re not ready for the final situation. They do, the model we use currently would actually have little effect for an event of the magnitude in February. Some of the newer models would actually give quite strong directivity effects for that sort of event so I know, just using the 15 year old models they don’t do the right things in terms of the period bands they effect and the effect they’d have for that magnitude. But they’re potentially available, whether we’re talking about a month or two or a year or two we’d need to talk to the people working this field and we still have the problem that yeah they haven’t been thoroughly reviewed like the other elements of the model.
Q. Dr McVerry the return period that you’re using in the model for the recent Canterbury sequence that will be based on the aftershock predictions that you’ve been showing, is that correct.
A. Sorry I missed the first part there.
Q. Well the recent earthquakes that we've experienced over the last few years, the last year have got a long period of, the primary earthquake has got a very long period of return period but the aftershocks which you’re using for the next 50 years those are the elements that you’re putting into your model.
A. Yes, the seismicity model is based on all the aftershock data, it was those seismicity models that Terry Webb was showing yesterday so they’re very much data driven by what has happened over the last 12 months or so in the Christchurch region and they have those very enhanced seismicity rates as a result.
Q. So you’d need to rerun your model in a another few years to show what the effect of the reducing aftershock sequence would be.

A. Ah, yes, from what's happening now we're estimating what might be happening in 10 or 15 years time so we do have, the current seismicity rate is falling off all the time in our models but we'll certainly be re-evaluating it down the track to make sure that the model is tracking the same as the actual events but we aren't putting in the current rates for the next 50 years we've got a decay in those current rates according to models that have been in the international literature, mainly in the earthquake forecasting area, certainly not in structural design use but they are very thoroughly reviewed.

Q. Thank you, thank you, that answers my question thank you.

A. Also I showed you that last slide which shows the dominance from the magnitude five to six events which does cause issues from an engineering design point of view which I may touch on a little bit later so we have made adjustments to account for that, particularly the advice that we're having from engineers that those less than 5.5 have been of little significance in terms of damage to well engineered structures or modern type structures but certainly caused more damage to structures that had already been damaged in the main shock but as far as fresh damage goes the advice we've been receiving is that they've had little effect.

Q. But that could be peculiar to the Canterbury earthquakes.

A. That advice has been coming through some members of the engineering advisory group who have been in consultation with us as we've been developing our new models. It's not the whole of that group and I'm not even sure that they're actually taking that, discussing that advice with other members. It's just that the people who have been assisting us have been involved with that group and the amount that they're interacting with the full membership of that group I really don't know. And the final thing I showed yesterday that there are strong peaks out around about two and a half three seconds which we believe part of that is due to site effects, probably a combination of site effects and source effects. We're not in a position just yet to model those in our calculations over the course of the next months to a year or so we're hoping to be able to incorporate those so what we're showing so far is limited to a maximum of 1.5 seconds because we know we aren't accounting for those effects. Sorry next please. The next slide please. Yes it's in the 10D series I think 10D.5 is probably the one we're looking for.

JUSTICE COOPER:

We've just had 10D.5.

DR McVERRY:

Okay sorry 10, this is the next in that sequence.

JUSTICE COOPER:

10D6.

DR McVERRY:

Yeah, so there has been discussion of the maximum magnitudes that we've been using for our source of gridded seismicity. As I mentioned yesterday our overall earthquake model consists of fault sources plus (inaudible 11.42.31) seismicity which is based on historical earthquake catalogue. Previously up until the middle of last year we were using a maximum magnitude of 7 in the Christchurch area for those gridded sources which has now been updated to 7.2 and all the larger magnitudes were associated with specific known faults, two examples there are the Porters Grave fault and I think these were perhaps the magnitudes from the previous model rather than where we've got to now. But 7.5 and 8.1 and there's a whole myriad, our current model's got about over 500 faults throughout New Zealand like that. In the modelling that we've been using post-February, which is the one that's accounting for the current sequence, in fact the gridded seismicity goes up to 7.9 but with very low probability of exceeding those. That is mainly coming from the triggering type model. It does have a very low probability of triggering very high magnitudes so that's just put in there because normally we'd have a maximum of 7.2 for these point sources but, in that specific model, it does go higher.

EXAMINATION CONTINUES: MR MILLS

A. Thank you next please. Yeah there has been some confusion with the maximum magnitude we've been using for our standard hazard calculations for the distributed sources, this value that's gone from 7.0 to 7.2. At that maximum magnitude there is very low probability but when we finish our hazard calculations we actually compare that with a lower, have a lower design level motions which are associated with a specific event which we take, and this comes into play mainly in the Auckland region in the north, about Bombay Hills and north as it happens, a little bit in south-eastern Otago as well - Dunedin is just on the boundary, as you move south from Dunedin this comes into play – and this is based on a scenario earthquake, we've chosen a magnitude 6.5 earthquake at 20 kilometres distance.

1145

The 6.5 comes about because in these very low activity regions it's possible that there have been earthquakes in the past which, mainly 'cos they don't rupture to the surface and because they're fairly infrequent that things that have happened since they occurred there may have been deposits which hide the surface features of them if they did rupture to the surface. Geologists tell me it's possible that there are 6.5 earthquakes in those regions that they can't identify from the surface geology so it's much the same reason for going to 7.2 but the 6.5 is perhaps a more likely magnitude for these hidden earthquakes. The 7.2 is an extreme one. The 20 kilometres that is a subjective choice. If we had a direct hit it would lead to very extreme motions and we might be looking at a Z factor of maybe .3 rather than .13 so it would come into play over a lot of the country.

COMMISSIONER FENWICK:

Q. What return period do you use for that 6.5 at 20 kilometres?

A. The 6.5 doesn't have a return period associated with it. We compare the one over 500 or the 500 year return period motions with the motions we get from the scenario event. If the scenario event exceeds it we take the value from the scenario event so it's really just cutting off how low our contours go from our hazard mapping design. We have a minimum level.

Q. Graeme, the two-thirds factor in there does that come from the sort of approach used in California?

A. Yes they have a similar factor.

Q. That's a sort of a ratio between the ultimate limit state and the collapse limit state?

A. Yes that's what's intended. Using the design provisions we believe the 50% margin at least between the actual levels we designed for and the motions that can be withstood. For example in Christchurch the modern design levels were .22 and the motions were probably .4 or above so, you know, there certainly seems to be that limit there for the newest construction.

Q. When you look at all the other motions in the other areas you do base those on the 84 percentile don't you?

A. No for the other regions we go through this probability calculation. You've got the rate of the earthquake multiplied by the probability of getting to a specific acceleration level and when you add up all the contributions you get a rate then you find out what the 500 year value is from all those contributions so some of the earthquakes may have gone in at below average levels, others will have gone in at greatly enhanced, maybe 95 percentile level even in some cases but those ones will be probably small contributors because the probability is so low. So there's a whole range of different uncertainty levels have gone into the actual hazard calculations but for the scenario we choose 84 percentile which is a standard value which is used in engineering when you're doing a scenario analysis for the sort of structures that 1170 covers. You'll see higher values for nuclear facilities and the like. They might go to 95 percentile values there it's a standard value and, as I say, it applies only in the lowest hazard areas. Christchurch was well above that level so it wasn't having any influence in Christchurch. There was some confusion. I think this arose because our report said the Z factors are largely probabilistically derived but not totally. I thought well we need to mention that we do have this limit and I just said it. It's based on a magnitude 6.5 at 20ks at 84 percentile level and a couple of our reviewers came back and I said, "No, no, those values are higher." I haven't mentioned the two-thirds 'cos I was only mentioning it in passing so, as you heard today, Professor Abrahamson said at the .13 value we've got is quite an appropriate value. The initial reports were saying well you've done your calculations wrong. The values you should be getting are higher than that but that has all been resolved now.

JUSTICE COOPER:

Q. The Z value of 0.13 does it have its origins in some international standard?
A. No, in fact...
Q. You say it's a minimum allowable value?
A. That was really something that came in the judgement of our Code Committee. I think partly was when we brought in this new hazard model we found that in the lower seismicity parts of New Zealand we were getting quite a lot reduced values that we had in the previous Code and we were a bit uncomfortable, Auckland I think previously would have been somewhere round about .2 in terms of this Z factor. The Z factors in previous codes were off the peak of the spectrum so you can't compare them directly and I think our direct hazard calculations comes in with a value of about sort of .1 and we were a little uneasy 'cos there's so little seismicity in the lower seismicity areas that we don't think we've got a good handle on what the true rates are because our seismicity model is really based on the last 40 years in essence for the low magnitudes that occur there so there was a lot of uncertainty and we wanting to be somewhat cautious so we chose this value which is about two-thirds of what the previous design level would have been for Auckland rather than a half and the difference between .1 and .13 mightn't sound much but in terms of the frequency or the return period it's about a factor of two in return period so a .13 for Auckland in the

model at the time at least was about a 1000 year return period rather than the usual 500 that's applied where this minimum value doesn't come in.

Q. Well I'm just interested in the phrase "minimum allowable", now allowable by some method or allowable by some person or by some law. What are you talking about?

A. Allowable according to the structural 1170.5 New Zealand standard that has a minimum Z value of .13 can be used.

Q. Yes well I know it's in there but I suppose I'm wondering why it's in there?

A. Well the reason, I've been trying to explain the reason why, it was a caution I guess on the part of the Code Committee mainly because we were uncertain how low the value really is in Auckland and (inaudible 11:53:07) a huge reduction which if an earthquake happened if we were designing to the very low values there would have been damage which I think would have been unacceptable so we have chosen if you get a medium size earthquake in the general region, not a direct hit, but if you design for these levels you should come through okay. If we just went with the probalistic *[sic]* ones we would get caught out.

Q. So it reflects a judgement that has been made –

A. Certainly.

Q. – about what is a conservative level at which to pitch the hazard factor?

A. Yes, certainly.

Q. So who made that judgement?

A. The co-committee collectively.

Q. They are named individuals are they?

A. I think they are named in the preface to 1170, whether they're in the preface to 1170.5 or the overall one.

Q. Well is this the technical committee – BE-006 –

A. Yes

Q. – 04?

A. That will be right, yes.

Q. Mr Andrew King and others?

A. Yes.
Q. Is that so. That is as you understand it. There's a list of persons – Professor Bull, Charles Clifton, David Durroch, Rob Jury, Graeme McVerry?
A. That's right, yes.
Q. Is that you?
A. Yes. I mean I will have had –
Q. And Professor Peter Moss and Dr Arthur O'Leary?
A. That is correct.
Q. So that group met together and formed that judgement?
A. Yes, they met together. It was a very protracted process because we were trying to do a common code with Australia that fell over so I think it lasted about five or six years. I think the final stage when we went to New Zealand only was about two years' worth of meetings that probably, two to three monthly intervals with a lot of correspondence in between. So various members contribute various parts of the code but they all get discussed by the, the code committee.

1155

Q. I understand.
A. So it's a consensus at the end of the code committee which then gets adopted by Standards New Zealand and then I'm sure others here will know more about the legal process that goes on beyond that.
Q. Thank you.
A. The next slide please. These are the results we got initially in our new modelling. We were asked to come up with just the new Z factor not changing our spectral shapes from what existed in 1170 and the usual normalisation is in terms of a shallow soil spectrum but we were aware, and we were considering mainly the Christchurch CBD when we started this, it then sort of got extended to, to the Christchurch region but the, the most common site class in there is deep soil rather than shallow soil so we, we worked on adjusting the shallow soil spectrum and, and getting a Z factor which matched our hazard calculations for that site class rather than going through, through the shallow soil one. We used

the, we took the earthquakes that, that we estimate will occur over the next 50 years with this time-varying model. The reason we chose 50 years is that is the default structural lifetime that is used in 1170 and I believe it is the lifetime that is used for almost all structures in, in application – 1170 does tell you what you have to do if you have a structure that's expected to, to last say only 25 years and there are provisions that you can't design for 25 years and then use it for 50 and also you go to higher design values if you've got an intended life of 100 years. The bridge standard which uses all the same hazard input is 1170. For bridges, for the major highway bridges at least, their default design life is 100 years so they're sort of basically working off the 1000 year spectra where a normal structure would be using the 500 years, same factor of 2 in (inaudible 11:57:36) sort of reflects in the return period.

Q. Am I right in thinking that those years are stipulated in, in the Building Act. The 50 year rule in the, in the building, data in the Building Code?
A. I'm not sure. It is something that is in the standard but whether that relates right back to the Building Act I'm really not sure.

MR MILLS ADDRESSES JUSTICE COOPER - IN THE BUILDING CODE

JUSTICE COOPER:
Q. Do you know how that was fixed on?
A. I have no idea. It's something that I think has been around for many, many years but I've been involved in the last two standards and sort of knew the one before that and I think the 50 years has been there, so that's going back about 1976 and I believe for 50 years has been through all of those standards, certainly in the 1984, the 1992 one it certainly was, 1976 I'm reasonably certain it was there too.
Q. But I mean it's just a convenient …
A. Certainly.
Q. Or what's judged to be a sensible –
A. Yes.

Q. – point to use for design purposes. There's no suggestion that buildings –
A. No we're well aware –
Q. - properly designed buildings won't last –
A. Yes certainly there are many buildings that are older than 50 years.
Q. – for more than 50 years.

COMMISSIONER CARTER:

Q. Dr McVerry do you do a sensitivity analysis in which you vary some of the numbers which you use. I mean a thought just on that particular point of 50 years, if you used earthquakes over 75 years do you get a much different answer or?
A. We haven't actually done those particular calculations. We've certainly compared the 500 year with the 1000 year or, or other shorter ones which in usual circumstances doubling the design life would be equivalent to doubling the return period. In this particular situation where the seismicity is reducing of course that's not quite, that's not true because the extra 50 years of seismicity would be a lot lower than the first 50 years of seismicity in our new models. Previously it would have been just the same rate, sort of just going on for twice as long so you just …
Q. Well if we go into a period in which there's a regular occurrence of more, of more seismic events then there will be a change in the whole basis on which your, your model produces?
A. Yes certainly. With these time varying models it very important that you do your calculations for a stated duration, that you're doing it for the next 50 years not any 50 years and if you're really interested in 10 years you look at 10 years, if you're really interested in 100 years you look at 100 years. I mean obviously we've got a lot more uncertainty in what's going to be happening 100 years out than perhaps what's going to be happening 10 years out in terms of the seismicity models but that is, on a theoretic basis, is how the calculations would need to take into account the duration that's intended to be applied for. And just to give

you an indication, we came up initially with a value of .3 compared with the 1170 value for Christchurch, a .22 and we had approximately point, equivalent to .z equals .4 or a little bit greater motions in the CBD in February. Next please. And this indicates the basis of how we came up with that z equals .3. The dashed curve here is what we did get directly from our hazard calculations. The solid curve is using the NZS1170 spectral shape factor for deep soil which I mentioned yesterday, multiplied by the z factor of .3. You can see that that gives a reasonable sort of match over part of the spectrum. Because the, those spectral shape factors are truncated it, a little bit beyond .5 seconds it certainly cuts off the peak of the hazard spectrum at short periods and there was a little bit of discussion this morning about that but for the period range it was mainly intended to be used from about .5 seconds out to 1½ seconds. That is a reasonable approximation or maybe even somewhat conservative approximation to the actual hazard results. We started this work really looking at the redesign or evaluation of structures in the CBD, as I mentioned later on it got intended to being used through the Canterbury region for wherever our new z factor was higher than the, the pre-existing one. As I mentioned it excludes the effects of that long period peak which we think is related to site effects so it was limited in the period range for which it could be used which – if someone's trying to build a new 20-storey structure in Christchurch they have nothing available at present that they can use. So we need to obviously address that if that sort of structure is to proceed in Christchurch. Next please. Because this is an ongoing thing there are two things that occurred, initially the software we were using was US software which is really used for earthquake forecasting. The reason we had to use that was our current New Zealand seismic hazard model software which is intended for really seismicity models that were constant in time couldn't accommodate the new seismicity models we had, we were coming up with and unfortunately hidden in that US software were, were some defaults where various parameters which aren't what we normally apply in New Zealand and also then the June 13th event came along.

1205

That pushed up the seismicity levels again so we re-did our calculations to account for most of those, for both of those issues, and I think the most important issue was the US they use the geometric mean which is sort of an average of the two horizontal components for designing their structures. In New Zealand we've always used the larger horizontal component and there is a difference of typically 15 percent but it can be a lot more between those so when we put in the increased seismicity, changed some of these parameters that we were initially unaware of to the New Zealand default values, we came up with increased Z factors which I'll show you in a slide in a minute. We actually got a range of .34 to .41 which I'll show you shortly where that came from and again just comparing them with Wellington values and the motions in the CBD in February which are both around the .4 level. Next slide please. Previously, again the solid black curve is the new calculations directly out of the hazard model. Previously over an extended period range 1170 spectral shapes will match that when scaled appropriately but now we've got a, the hazard spectra are somewhat steeper so we can't match it at all periods. We can match it at some specific periods so what I've done there is for the half second to one and a half second range the two bound, so Z equals .3 is that lower bound red curve; Z equals .41 is the higher bound blue curve. So they're the sort of values that are being discussed at present. The higher bound is matching at one second the lower bound at one and a half seconds and you can see that they had a spectral shape is certainly different from the standard code one. There was a little bit of discussion at the end with Norm Abrahamson about whether we should use the sharply peaked shapes that are coming directly out of the hazard calculations or whether we should go with more standard ones and he suggested that probably we should be using more standard ones but scaling them in some way to match the current seismicity and this is what we've done here, we've taken the actual hazard results, used them to scale our current code spectra at particular periods and, again, the longer period side effects were not included because we haven't developed our models for that yet. Next please. We've been talking, these seismicity models are very strongly in time so what you've seen so far is if we took the Z factor with a one over 500 annual probability of accidence, on average over the next 50 years. We've also done calculations year by year and looked at how that would change, what would be the one over 500 rate of accidence in any year through that 50 year period. We haven't done it for each of the years but we've done enough to show very clearly the trend. The Z equals .3 value, the lower bound, that would be the average for that over the 50 years. Later in the piece it would fall below it, early on it's way above it. Next slide please. We've got three curves here. The dotted black one is the 50 year average, that's the Z equals .3 which I'll call 'Z min', it was that lower bound and all of these are in terms of the lower bound value rather than the upper bound value. Pre-using the 2010 model that we've been developed just prior to September we'd have actually come up with .2 rather than the code value of .22 that came from the 2000 model. The important curve here is showing how the Z factor, if we look at year by year, how that changes with time. So a year out from the 1st of October it would have been sitting at .48. It falls off very rapidly from that. By June 2013, the year starting then, it would be down to .4, which is the Wellington level. The 50 year average value is reached after about eight years and then it's basically comes out to a virtually constant value well from 20 years out it gets very close to it after 15 years which is just coincidentally the .3 value which was our initial Z estimate, but that's purely coincidence that that is the same as what we were getting in our earlier model. Next please. Actually sorry I've had one to add in. Yes if I could have 07/30 please, the slide out of Terry Webb's. Sorry, this one is a little hard to see, just trying to, oh yes one possibility that has been discussed is rather than aiming at this one over 500 annual probability of accidence what happens if we choose a somewhat lower value, say that .3 value that we either came up with initially or which is where we're trending to from about 20 years out. If we chose that initially what would be the enhanced accidence rate. So instead of one over 500, I'm sorry this is not very clear, but the first year or so it would be maybe a six or something like that enhancement – thank you that is better – yeah these yellow triangles are the ones that are relating to the Z factor, the others are to various other parameters but you can see that after about 10 years that enhancements, this is on a log scale so that sort of maybe a 30 percent enhancement and then trending to one over 500 probability for the later years. But if we chose, and this was actually done for the Z equals .3 case, early on if we chose that value instead of a one over 500 annual probability of accidence it would be one over 500 multiplied in this case by three and they're some of the issues that sort of are being grappled with in setting the new design values and also this information is sort of great interest to insurers as well knowing that when a design level is chosen, which will perhaps be a 50 year average or where we're trending in 50 years, how enhanced is the risk in the short term so that's just showing that there is consideration of these sorts of issues.

COMMISSIONER FENWICK:

Q. Can you just explain to me, initially the value is .22 and I had always imagined that in 50 or 60 years time we would return to that level now you're sort of indicating on this graph it returns to about .3. Now is this due to a new calculation or the fact that there are new faults that have been discovered or what's the cause for that increase in the very long term value.

A. The basic cause of that, as I think Terry Webb touched on yesterday, it depends on how long a period we average this enhanced seismicity rate. At the moment they've been doing a calculation starting from 1950 up to June or July whenever the calculations were done. You could say this enhanced rate could be averaged out over the last 100 years or whatever. So it's to do with the time period that is used to average out what we're getting presently over what has happened in the past. Our model has got this enhanced activity that we've had since September going into it, so that increases the previous long term average.

1215

Q. That's a 60 year period though?
A. Sorry, 60 year sorry.
Q. So that would lead to some quite absurd results wouldn't it because there would come a time when suddenly the effects of this current increased seismicity ceased to exist and presumably you'd go back to the .22 overnight?
A. I agree with you that, yes, hopefully we would return to what we've had sort of over the last 150 years and that is one aspect of the model that I think does need attention.

JUSTICE COOPER ADDRESSES MR MILLS:

Mr Mills, I don't think we've got this interesting diagram in our materials, in our folders have we.

DR MCVERRY:

It's in one of the reports but not in the presentation as such. It's 7.30 under tab 10. That's in one of the Z factor reports, the most recent of those two Z factor reports.

MR MILLS:

Yes, it's the September GNS report that came after the main report that was received by the Commission and if you go to page 24 of that report.

JUSTICE COOPER:

This is a report that hasn't been brought to our attention at any stage. We had the Z factor report from May, the one with the errata is that right, but we haven't had the report at tab 10 drawn to our attention at any stage. I have found that diagram anyway. Can I ask, this throws further light on the ongoing work that's being done on the Z factor?

MR MILLS:

It does. It certainly had some issues in that September report that warrant a review at some point.

JUSTICE COOPER:

Q. Can I ask, is there going to be yet another report at the conclusion of what I understand is an ongoing consideration of what the Z factor should be?
A. That may well depend on directions from the Commission I suspect in light of some of the things that have been discussed over the last few days. For example, if we pursued some of Professor Abrahamson's issues there would certainly be some modification coming out.
Q. Yes, well putting that on one side though, you have described an ongoing process that relates to the Z factor because as I understand it the Earthquake Recovery Act and the Order In Council process under that was used to lift the Z factor in Christchurch from .22 to .3. Correct me if I'm wrong, but there hasn't been any formal legal alteration since that was done has there?
A. That's correct. This is a report that has been provided to, I think it's DBH has certainly been issued it in draft form and CERA and it is really on their table to decide what they do with it.
Q. I see. So apart from these issues that have latterly arisen in our processes, GNS had done what it was intending to do with relation to the further amendment to the Z factor?
A. Yes.
Q. I understand.

MR MILLS:

If you look at the abstract which begins, our numbering is page 5, a roman numeral 3 and if I understand this correctly, if you look at that last paragraph there I think that captures some of the points that Dr McVerry's talking about about altering the 500 year return period in order to maintain Z factor as it was versus raising the Z factor but staying with the conventional 500 year period.

JUSTICE COOPER:

Q. I'm pleased we've had this discussion?
A. It's certainly not GNS' call on which approach we should take. We're just providing the –
Q. Yes, I understand that.

EXAMINATION CONTINUES: MR MILLS

A. If we could go to 10D.15 please in my original presentation. We're getting towards the end here now, but there has been quite a lot of discussion from members of the public, all sorts of people about if we get the great alpine fault event what does that do for Christchurch. The presentation yesterday showed you some of the acceleration histories that we've estimated for that from some synthetic modelling. This is showing the same results in terms of response spectra. That red curve there is what we've estimated for the Botanical Gardens site in Hagley Park which is one of the GeoNet strong motion sites, one of those four records that we've been discussing. It is comparing it with the spectra of two actual recorded motions in quite large earthquakes, one in Taiwan which is the magnitude 7.6 Chi-Chi earthquake which is the blue dotted line and the very damaging Wenchuan earthquake in China in 2008, magnitude 7.9. There are not very many really large earthquakes which we have recorded motions from so these are a little bit lower magnitude than the alpine fault but they're approximately the same distance so it's to indicate that at least in the up to one second, our models are certainly in line with recorded motions and may be falling away a little bit longer period and there are some reasons in our modelling that that is why it's interim. We need to combine our current form of model with another form of model to address some of the long period part of the spectra. But the important thing to note is we've been talking about accelerations from about five times above the spectra to well over 10 times above. Both the estimates that we've done for the alpine fault motions and actual recorded motions for similar magnitude events that those sort of distances elsewhere in the world indicate that the motions are likely to be a lot weaker than has already occurred in Christchurch or in any of the values that are being suggested as appropriate design level motions for Christchurch. Next please.

1225

COMMISSIONER FENWICK:

Q. Can I just –

A. Oh sorry.

Q. Question you on that, that's showing if I'm reading this correctly you peak ground the acceleration of the order of .13, .12 g?

A. Yeah.

Q. The sort of peak ground accelerations we got in February in the CBD I think were about .8 g so there's –

A. That would be correct yes.

Q. Round about a magnitude of six difference. Now the .8 g induced liquefaction, .12 g if I'm again interpreting the weighting, the liquefaction weighting factor of the higher one the power of 2.5 that would sort of indicate we, we might not get liquefaction under the Alpine fault earthquake?

A. Ah, certainly any calculations based on the peak ground acceleration would indicate no liquefaction in the Alpine fault. There are, are issues about appropriate hazard measures perhaps for liquefaction which I think –

Q. Some doubt here?

A. (inaudible 12:26:04) hearing next week or the week after I believe on all those sort of issues but, but certainly on the, the techniques or the methods being used to evaluate liquefaction this would indicate that liquefaction wouldn't occur I believe.

Q. Would not occur?

A. Would not, not occur whether that, how close that is to reality that's for other people to judge. My understanding was the minimum trigger levels were about .1 g but I, I haven't seen all the recent work, perhaps I've got trigger levels a little lower than that now I don't know.

EXAMINATION CONTINUES: MR MILLS

A. Next please. There's also been a lot of discussion about the vertical motions in Christchurch. There is no doubt that they were very strong, the 11.70 code has a very simple provision for vertical motions that they've just been taken is .7 times the horizontal, while in Christchurch the vertical at least at short periods peak ground acceleration and the peak of the spectra were a lot stronger than, than the horizontal and this is common for near source motions in general but it is also occurs only over a very short period range that, either high frequency or short period in the, the spectrum. Though 11.70 the actual requirements are very simplistic there is a commentary in, in 11.70 in the hazard section I think it's probably the, the last commentary clause in it which does give appropriate guidance on vertical spectra, these area some of the things that have been raised in Professor Abrahamson's review and we at GNS Science we routinely use these modified procedures when we were asked to estimate vertical spectra for specific sites which reflect the sort of character that, that is mentioned in Professor Abrahamson's report and it would be relatively straight forward to recommend that procedure or some similar procedure for 11.70 whether the vertical motions contributed much to the damage or otherwise that is over, I'm sure, to some of your later hearings will discuss that I'm not in a position to comment on that other than say yes the motions are very high and we can model those sort of motions and come up with a code type procedure for accommodating those.

Next slide please. And this is just giving a comparison of the horizontal and vertical motions. We've got two, two, these are the response spectra plots that you've seen previously. On the left-hand side the various sites around the CBD and I think this particular plot is showing both horizontal components for those four sites. On the right-hand side it's showing the vertical spectrum. The vertical scale is actually half, the horizontal one so where the peak value on the, on the vertical which looks very similar to the peak value on the horizontal is actually twice the horizontal motion so, but the main thing to note is that while the horizontal motions are affecting a wide range of structural periods the vertical motions are over a very limited period range. So, so this is one of the features why you can't just scale up a horizontal, even if you had a lot larger scaling factor you'd still end up with a totally inappropriate spectrum because the character, the spectral shapes for vertical and horizontal are very different in the near source range.

Next please. Okay, just to summarise my presentation, I've shown that we're, our current estimates are coming up with a Z value of at least .34 for the Christchurch region which is based on matching our current estimates of the one over 500 annual excedence probability, deep soil spectrum at point, at .5 seconds and it is increased from the earlier recommendation that has been promulgated by DBH of .3 as increased design values for the Christchurch region. The Z factor certainly varies with time. The first year it's .48 but dropping to .3 over the longer term compared with the pre-September values of .22 for Christchurch or .4 for Wellington. The actual motions in 22nd of February were about .4 or higher and we're still addressing that long period peak which we believe's related to site period and source effects. And if we could perhaps move through I think there's a blank slide and then one further slide. This is just some of the issues that Norm Abrahamson was bringing out this morning about different ways of doing our calculations. This is just the summary of what we're doing currently for Christchurch versus what 11.70 has in it and so it gives you an indication of the sort of parameters that we can change very easily in our calculations and many of them are pertinent to some of the suggestions we had this morning. We had – 11.70 is for the distributed seismicity has a shallowest layer of 10 kilometres. Our fault models come right, right to the surface where they are modelling surface faults while we've gone from 10 k we've brought it to 5 k which, and I've put pluses and minuses on things which are increasing or decreasing the motion so we do have a shallow depth we usually use. Professor Abrahamson is suggesting that we have some sort of distribution from maybe as shallow as 1 k through to I presume something deeper than five kilometres so that could affect the calculations. Our usual calculations have a magnitude of five which we're using, 5/5 now. Our usual calculations have no stress drop factors. We're now using a stress drop factor for a stress drop ratio that's 1.5 times what we believe the standard is for New Zealand. Magnitude weighting is something which I hadn't sort of discussed in any great detail but is covered in the various reports you've received. Previously that was applied to .5 second period, it's now been applied to all periods and previously we used this parameter to get the Z factor. We're now using another parameter which would give quite a bit lower value than if we used this one and the previous spectral shape is close to an upper bound for anywhere in New Zealand apart from some truncation at short period that's for each site class not if you took in the specific site effects at any individual location which we concede can be quite different from the average steep source spectrum for example while the .34 value is a lower bound one, so that's just a sort of summary of the various parameters that have gone into our modelling thank you.

COMMISSIONER CARTER:

Q. Just one matter that interests me and that is the decision to move from magnitude 5 to magnitude 5.5 in your summary of earthquakes based on consideration of damage that's occurred in Christchurch as advised by the engineering colleagues. Is that something that you'd want to pursue over a wider audience because there are geotechnical characteristics in Christchurch that conceivably could alter the way buildings have performed and whether or not you would get a different answer for the rest of New Zealand if you included the 5.0 magnitude as recommended by Professor Abrahamson?

1235

A. Okay. On the first issue yes the reason for increasing the 5.5 is on the advice of our engineering colleagues that there has been little damage in those smaller earthquakes is, Kelvin Berryman mentioned this morning in our discussion, that is somewhat anecdotal at present. We have actually at GNS been trying to encourage the engineers who are providing the advice, could you please put the evidence together in some sort, sort of report so it has firmer grounding and that is still, still to happen. Yes if we increase the 5 to 5.5 over the rest of New Zealand it would decrease the hazard estimates. In places like Wellington it would have very little effect because there it's the large faults that are driving the motion. As we go to, away from large faults though, yes, it would have some effect, nowhere as much as it's having in these Christchurch calculations but yes it does have some effect and if we went universally to 5.5 we might be making changes of the order of say .03/.05 to the Z factors in the lower hazard areas of New Zealand. That, that's just a sort of a guess. We've done a lot of these sensitivity analyses in the past and that's my sort of recollection of the sort of changes it makes.

COMMISSIONER FENWICK:

Q. We've discussed the magnitude weighting factor and certain aspects of it but not others. So the magnitude weighting factor it reduces, it's been used in 1170 to reduce the effect of lower magnitude earthquakes, the response spectra from them for the short period and now extended, did you say, over the whole long period. Is it possible to find the picture you had on the screen this morning when I came in, when we came in first thing?

A. The trial, trial one that we-

Q. Yes.

A. – had up which …

Q. No it wasn't that. Perhaps we should leave this then for the panel later on.

BRIEF DISCUSSION – LOCATION OF SLIDE

COMMISSIONER FENWICK:

Q. I think we'll leave it for the panel when – that's it, right. Now the, the magnitude, February earthquake was magnitude 6.2 and if you work back to the magnitude weighting factor on that it would be .78. So if you take the response spectrum from the 6.2 earthquake and I've just taken the average of the one which is plotted above, the response factor and it's compared against the New Zealand response spectrum and you can see that the average one which is the thick red line – no, on the top diagram which you won't be able to reach – but the thick red line there is the average one. That you can see is predominantly above the 2500 year return earthquake which is the solid black line. Now I have re-plotted that now applying the magnitude weighting factor to that value and you can see in the lower figure, you can see now that that is in, that's the dotted line, yes, against the other and against the spectra and you can see now it's predominantly below the 2500 year line. Now I agree that between the 0. period and .5 there's a little bit of double counting but above that range, .5 up to the five seconds, I don't think there's any double counting. Is that a correct (inaudible 12:40:02)?

A. Yes that'd be what would happen if we applied magnitude weighting to that, that actual spectrum I agree so that perhaps is a more appropriate comparison with the, with what we're currently are doing in the code process. Yes so it would only apply to the short period, part of it -

Q. Yes.

A. – previously. So previously it would apply out to here well now as shown it would apply to the whole spectrum.

Q. The next point is, of course, I understand that came about because of the apparent good performance of the buildings in Christchurch, you know, that none of the modern buildings collapsed, they satisfied non-collapse criteria for a 2500 year event. But if we're changing the factor to allow for that then this presumably should be changed right throughout New Zealand because it is unlikely the Christchurch buildings are better is it than they are elsewhere in the country?

A. Okay I think that's going beyond what we're recommending. The, the reason we're extending it to the longer period for Christchurch is because the hazard is being dominated by these low-magnitude earthquakes at all period bands. That is probably true in some of the lower seismicity areas. In our standard model up in Northland for example but we've already got the Z equals .13 there. Somewhere like Wellington it would have very little effect because we're just getting very few contributions from, from low magnitude events but yes in places that were dominated by basically estimates that are coming of our seismicity grid it would have a similar sort, sort of effect, yep but we're not recommending that currently. It's a Christchurch specific thing.

Q. Would you agree that this area of magnitude weighting is something which we really do need a bit of research into it to see how applicable it is and whether one can apply to a less ductile and more ductile structures and so on?

A. Yes certainly. It was something that was intended for the short period range. It was to overcome some short comings of the New Zealand model that tended to, to give very high accelerations which we, we did do a little bit of comparison with, with a few real spectra for a magnitude 5 to 5.5 earthquakes in New Zealand. I know we did that investigation for the Huntly Power Station which is, the hazard there is governed by these small magnitude events so we looked at how realistic and we found that without the magnitude weighting we were certainly over-estimating even the normal spectra before we started doing any modifications to them. So it was sort of justified so some extent there. Professor Abrahamson mentioned if we take it out for New Zealand as a whole there are issues that arise for engineering design and that all our spectra start becoming rather peaked to the extent that most engineering design I think is based, a lot of assumption are based around first mode dominance and if you have a very peaked spectrum the higher modes have a lot more effect and I suspect you'll know a lot more than me on, on what, what implications that has for a whole lot of design assumptions. So we have to be careful in sort of changing one thing on its own because it could lead to a lot of unintended consequences so. Yeah, it was put in initially to overcome an issue we were aware of in our New Zealand model which seemed to give the desired sort of result and it was something that was in the literature. It was in the literature for nuclear power station design which, as you can imagine, is usually at the forefront. It's usually way ahead of what's being done for standard structure. So that was why we were, we were prepared to accept that even though it's not done in standard design codes anywhere in the world the fact it was used for something that's usually done way beyond standard design codes, but limited to the short period structural range not the longer period ones, was, was why it was thought justifiable to overcome some other deficiencies.

Q. Can I have one more quick point. You say the, the spectra are based, you measure the spectra in two directions in the field.

A. Yep.

1245

Q. Now so one direction will have a higher motion than the other or do you do this period by period. When you're taking the maximum are you taking the maximum from each access for that period range or do you just choose, select what appears to be the maximum in general?

A. Okay there are two things. To start with there are recorded motions, we have the vertical motion then we have two horizontal components at right angles to each other and you can actually sort of rotate, you can take those and rotate them to any direction then you'd get the true maximum in any horizontal direction on a period by period component. We don't go that far. We take basically the A is recorded motions but we do look period by period and take the stronger at each period so it's really an envelope of the two otherwise we would have problems or if they cross over which is the stronger we'd have to do some average across periods or something like that so that is correct. It is truly an envelope.

Q. And it's very conservative as a result of that.

A. Yes, yep, yeah.

Q. All right thank you very much.

MR MILLS TO THE COMMISSIONERS RE WHEN MR ELLIOTT WILL BE ASKING QUESTIONS

WITNESS EXCUSED

DR WEBB:

Right so a lot of the discussion to date has been implications for Christchurch and short-term changes to things such as the Z factor but also coming out of this morning's discussion with Professor Norm Abrahamson we sort of were touching on some national implications. So the aim of this presentation is really to explore a little bit some of those national implications and then really conclude our evidence. So the next slide please. So just re-capping. We've talked quite a bit about in terms of the very unfortunate scenario that happened in February that caused such devastation and deaths, proximity was the causative factor and so we need to think nationally well what other cities are near faults or other earthquake sources due to buried faults we don't know about. So we'll talk a little bit about that, touch again, just to refresh the importance of shallow earthquakes versus where we get deep earthquakes in the country which are naturally more benign because no-one's close to them and then we get into this area that we discussed quite a lot this morning and I don't really want to repeat all that but I think Norm's comments were very useful here. In terms of the detail here about stress drop, directivity, basin effects, these affect the way in which you treat the ground models differently. In some cases average or mean or median shaking levels may be changed by these effects and, in other cases, the likely variability from earthquake to earthquake or even from place to place will be what's changed rather than this average level so we have to think carefully about that and that effects, when we look nationally, how we might treat things I think. So, yes, the question we're really addressing is, given what's happened here, what are the national lessons? So I don't think there's a particularly natural break point in this so but we are taking sort of issue at a time so it will be okay if we carry on a bit more. Next slide please. Um I have to apologise for this slide which is, you can see through these transparent colours the New Zealand fault map and so you've got to try and ignore the colours on this map and look at the faults and the first bullet point on the right there, of course, if you look at the map and think about where our cities are many cities are close to known faults. For a lot of those faults there is some reasonable information but more information really does help the model and when you've got really good fault information you can bring in conditional probability which, in simpler terms, means that given that for a well developed fault that may behave from earthquake to earthquake in a sort of predictable way – Wairarapa fault near Wellington's an example of that – if you've got good information on when the last event was and the average time between events you can do better than just a random guess or the likelihood for the next event, so that's a conditional probability approach and we've been implementing that through what we call the It's Our Fault project in the Wellington region for a number of years and for the Wellington fault, rather than the Wairarapa fault, so the Wellington fault that goes right through the city we're currently in a situation where the likelihood of a rupture is below the long-term average and over the next few hundred years that likelihood will climb. So that's an example where good fault information just change the current assessment of risk and we are also able now to start introducing that kind of assessment for the alpine fault as well because there's some recent information that really helps with the past behaviour of that fault in a project led, in fact, by Kelvin Berryman. If we move onto the next bullet point, not the next line thanks, sorry. We've talked a bit and particularly with Jarg's presentation about the possibilities of more investigations about some of these faults that don't have a clear surface expression there's a lot of places one can look so it's an expensive process and will take time so it's, we shouldn't have the expectation that you can do it every year everywhere and GPS is possibly a way to help target detailed investigations but the other way is also to think about say in a city that's already got a known active fault presumably design will take into account the issues for that city.

1255

It might be something we want to explore a little more in a panel session when we could call on, perhaps, Graeme to comment on the specific issues. But if there's a dearth of known active faults in the city that's in a reasonably active area seismically you could see that finding blind faults could in fact change the way in which you want to increase design levels. Finally, if we look globally there are examples and I guess around 1994, 1995, the term "urban earthquake" was coined due to earthquakes that created quite a number of casualties in North Ridge and Coe Bay and so they are magnitude 6 earthquakes in the magnitude 6-6.9 range, very devastating because right inside a city so that sort of really is there to emphasise the importance of proximity and the real dangers of magnitude 6 earthquakes close to cities and what makes this worse I guess is that of course magnitude 6 earthquakes are a lot more frequent than magnitude 7 earthquakes which in turn are more frequent than 8 so there's a very quick factor of 10 for each increase in magnitude, a factor of 10 drop in the rate so in fact 6 is something we are likely to experience ahead of 7s or 8s so in terms of what hits us next we have to worry about these and then very unfortunately, and we shouldn't dwell on it, the Bam earthquake was catastrophic in its impact so if we just quickly flick to the next slide and of course not helped by very very poor construction standards but basically half the population killed and almost instantly so that's what a close hit can do if you don't have good building standards. So we should move on from that and yes I think I can deal with this slide before lunch. Jarg showed a good slide, same pattern of seismicity but all the spots were red and they were all shallow, crustal earthquakes. I've got a more complex slide here in that we've got, using different colours to show the depths of the earthquakes and the deepest are down at 600 kilometres deep. It's very very deep although those earthquakes just occur under Taranaki and are quite unusual. If we forget then seismicities going down under the North Island to 2-300 kilometres depth in a dipping structure that goes under the North Island called a "seduction zone" so it's really this incoming colliding plate and it's sinking down under the North Island. It's doing the opposite in Fiordland so the Australian plate there is coming in and sinking down underneath so in those two areas you get zones of deep earthquakes so often when earthquakes are felt or recorded on the Geo Net website depth is mentioned and in the medium you'll often hear the comment, "Ah, but earthquake wasn't damaging even though it was magnitude 5 or 6" and they are reasonably frequent. There's a few every year, not damaging because of the depth so I'm just talking about this now to try and provide a bit more clarity about that. Here we're talking about earthquakes that maybe say from 50-300 kilometres deep. If you think on earlier presentations how shaking drops away with distance from the fault line, not distance across the surface of the earth, distance from that fault plain where the energy was radiated from if you were say 50 kilometres away even from a reasonably large earthquake the shaking will be a lot less and all these other earthquakes in the plot that Jarg showed that can happen in many parts of the country that are in the brittle surface crust in the top 10 kilometres, say, they are the ones that are really going to do the damage. I think that's a good place to stop.

COMMISSION ADDRESSES COUNSEL

COMMISSION ADJOURNS: 1:02 PM

COMMISSION RESUMES: 2.14 PM

DR WEBB:

All right so prior to lunch I'd just finished talking about the concept of depth, when it matters, when it doesn't matter, the key thing being if you've got shallow crustal earthquakes of say even magnitude 5 and above they can produce high levels of ground shaking. I now move on to talk about some of these other factors that were discussed as part of our review meeting this morning as well and wanted to start with this concept of stress drop that we talked a bit about yesterday so just to refresh a little bit on that the determination of the amount of slip on parts of faults in both September and February showed, for example, in September up to five metres of slip of the fault surface, one side compared to the other, in places but quite concentrated, particularly so in February where there was up to two metres of slip in places, concentrated on a small area, and, as Professor Abrahamson mentioned this morning, had that slip been less but over a bigger area then the intensity of the seismic waves would have been less. So enhanced stress drop is an issue for shaking. There's still some debate, and you would have picked up on that this morning, of the extent to which that stress drop factor is important in these Canterbury earthquakes. There is certainly some indications that it is but it's not unequivocal and, in fact, when you look at the shaking that occurred beyond that distances from the fault of more than 10 kilometres the shaking is probably below expected levels rather than higher. So there are some matters that the science has still got to address in terms of that. If we did show that stress drop was important in some earthquakes and were wanting to enhance the ground shaking or the predicted hazard levels to take account of that there are a couple of key areas in which we might look. If you have areas where slip rates, the rate at which strain is accumulating on faults and in the long-term average how quickly those faults slip or how often they have large earthquakes, if those rates are very low there's generally a long time between earthquakes and the fault becomes stronger if you like. It may be what would be analogous to a healing effect so when the fault finally does break the amount of slip will be greater and the shaking will be greater. So you could look in areas of New Zealand where the strain accumulation was slow and we know those areas from both studies of active faults, lack of earthquakes or from modern techniques such as using global positioning systems, GPS, to look at sort of centimetre levels of earth movement annually and candidate areas, there'd be a number of them in New Zealand so in terms of this coloured slide here we could look at Canterbury down through Southland as areas of reasonably low slip rate. We could look at north-west Nelson in particular, so Buller region up through north-west Nelson, again reasonably low slip rates, and then following north-east from there through perhaps Taranaki, Auckland, Northland, so a number of areas of the country where slip rates are low so the possibility in those areas that you may get enhanced stress drops although other factors that would need to be considered in that would be to think about the rock types present. So if rocks are weaker high stress drops probably can't be supported. We do intend, as a part of future research, to look at earthquakes that have occurred over the past decade or so for which we've got reasonably good quality data from the GeoNet project that's funded by the Earthquake Commission, so looking at GeoNet data and perhaps other data sources to look at what stress drops have been in some of our historic or more recent earthquakes to see if we can get a better picture of what stress drop levels are important. That would also be quite useful for informing this ratio that we have to take between the stress drops, for example, in recent Canterbury earthquakes compared to average stress drops. So we would have better information with that kind of study about what the average should be. Another way of thinking about these very highly energetic earthquakes is that they may, in fact, be related to the earth's crust in those areas being particularly strong and a measure of strength is perhaps what we would call the seismogenic thickness of crust, in other words over what depth range in the crust will it support earthquakes before it becomes too hot and too ductile and no longer sufficiently brittle to support earthquake failure. Probably, in terms of a national picture, the type of crust under Canterbury could well be the strongest in the country but there are other candidate areas that might be in the sort of middle level range and then there will be other areas where we would have more average or below average crustal strength. So if we were to come at stress drop from that view point Canterbury and maybe a little south of there would be one of the prime areas where you'd expect that to happen. So if you're building a national hazard model we have to think about that regionalisation so you obviously don't want to put in a stress drop factor for the whole country because that would do what we call overcook the model in other regions. And then the final bullet there, so if you can get a handle on these things there are ways for matching the expected or likely ground shaking and building (inaudible 14.21.21) into your hazard model. Next slide please. So as part of the unresolved issues that we talked about this morning, the extent to which directivity is important. If it was important there are ways to handle this and we mentioned again this morning that it's already handled a bit in our existing code, would need to be added for smaller earthquakes. So in terms of national issues one can make some allowance for directivity providing you've got the information on the faults. So, currently, as I've said, it's in the model for about 11 major faults. One could well add it to the model for smaller faults. There's a bit of a debate, which you would have picked up on this morning, is directivity something that when you adjust it or allow for it in the model you allow average values to increase a bit or given that there's already quite a lot of variability in the model that's being allowed for do you consider it as part of that variability and maybe in certain places where you know there are candidate faults that could have high directivity you then make some additional allowance for variability. Bearing in mind though that these models are data driven and some of the variability you see in models could already be because of directivity effects in which case you don't want to double count. Always dangerous to double count in models because, again, you'll come up with estimates that are too high. So that's, yes, so directivity, of course, can happen wherever we've got faults but if you link it to stress drop, as what I talked about a day or two ago, if high stress drop is driving high speed of rupture failure in the earthquake that will naturally also drive more directivity. So the things are linked when you come to look at the national perspective of where this can happen. And I think to sort of finish off talking a little bit more and thinking about basin effects, again these can be modelled, if you've got a good basin model you can use numerical techniques to model the shaking you'll get from given earthquakes and this has been done over the past decade there are some models produced for the Wellington and Hutt Valley region by GNS Science and other modelling of this kind also done in the past at University of Canterbury.

1424

So certainly we can model some, some of these basin effects. The best models of course are fully three dimensional because basins are not simple 1- or 2-D, 2 dimensional structures, best models are fully 3-dimensional but I guess a key point and a good observation by Professor Abrahamson this morning, need to think in terms of, say for the Christchurch CBD, if there's some site specific or even basin specific effect there that you'd expect to happen for a range of earthquakes that would be something that you'd want to allow for specifically in your model and not part of variability and you could well come up with similar arguments for, for other areas. And this is, if we get, got, we shouldn't get too much into the detail here but if you looked at different kinds of basin effects, simply due to thickness of gravels, basin edge effects, whole of basin reverberations, you can think that, well some of them maybe you would treat as variability and the others you might treat as a change in the mean level of the hazard. The key thing though if you are to model, and one further point on that. If the way the basin responds is dependent on the position of the earthquake in terms of how the wave front arrives at the basin, if that effects the basin response you don't know where future earthquakes will come from so you can get a high variability. But if there are certain characteristics to the basin response that are reasonably consistent no matter what the wave arrival direction and you can determine that by numerical modelling then you are going to get a more consistent effect that should be built more explicitly into your model. So those are the kind of issues if you, if you want to take this learning nationally that we'll be facing in terms of the challenge for the modelling. And, again, all these models will be dependent on good knowledge of the geotechnical characteristics and particularly the shape of the basin floor and that is going where reflection seismic profiling can add some good information. Next slide please. Right. So this is really concluding that, this part of the presentation and it really comes back, so I'll be quite brief. We've talked about this before. If we're to make some decisions on priority of work we'd often be guided by the estimated risk and although there are particular issues facing Christchurch that Jarg talked about that need to be set aside and dealt with separately if you're looking at where you'd take this work nationally I believe that level of risk is a good guide as to how you should proceed and come back to the point that the most likely thing that is next beyond what could hit us here in Christchurch, because of the high aftershock rate, would be something in the moderate to large range in the seismically – large range earthquake in a seismically active part of the country and if it's close to a city you're going to have things that we saw in Gisborne, Christchurch two or three years ago and, of course, what we saw in Christchurch with four earthquakes in the past year. That concludes that. There is one issue that we haven't come back to discuss yesterday and that's to do with stress changes in the Christchurch area. I do have a power point slide of that if you wish. The (inaudible 14:28:32) presentation, thanks – and the next slide. Right. So there's been some published work by overseas researchers and also some work by GNS science and these are all models of stress changes. This is the GNS science model. The models are qualitatively similar but if you want to look at precise details of the models you see differences and, in fact, we can, at GNS we can produce a number of models that all differ slightly. There are a lot of assumptions involved but I've got three slides here that have been done consistently and they do give you a reasonable feel I think for the stress changes that might have occurred. But just by way of introducing a little more complexity, when you measure the – so if we just step back for a minute. Strain accumulates over the earth. There's a, there's a fault trace running through it. It becomes, the strain's too much, the fault ruptures, releases seismic waves and slip on the fault and it de-stresses an area around it. And so in this slide the blue areas are areas that were de-stressed by the Darfield earthquake on September 4th but the kind of de-stressing of course depends on depth because if you remember the fault slip happened at over a certain depth range and in quite a complex pattern. This takes all this into account but we're, we're saying for six kilometres depth. So, yes, the blue areas were de-stressed, the red areas were areas where stress was enhanced and you can see a small lobe on this diagram that would affect, a small red to orange lobe that would affect Christchurch. In terms of getting a feel for how big the stressors are, the stressors, we've got on the bottom a legion here which shows the stressors in mega pascals. I being a bit old-fashioned and long in the tooth tend to think more in terms of Bar which is a factor of 10 difference. So if we think of our stress drop, a measure of the stress change and a unit called Bar, Bars, in an earthquake typically the stress drop might be 30 to 100 Bars and some of the Canterbury earthquakes where we argue that the stress drop is higher it might be, say, 150 or 200 Bars. This bottom scale at the very right-hand end where it's, the darkest red, the strongest red colour there the change is just 4 Bars. And this actually, actually I think confused seismologists about a decade ago where we saw clustering in catalogues, we thought it was coincidental but it happened too often for it to be coincidental. We couldn't understand that really small changes in stress do trigger other earthquake activity. So maybe as low as 2 Bars could trigger other, other activity or maybe slightly smaller than that but that becomes a bit debatable and it's not just stress change that triggers earthquakes. There are other things that we don't understand so well and I mentioned I think on the first day the effect, for example, on crustal fluids changing pore pressure and changing the strength of faults could well be quite an important factor but very hard to get a handle on these things. So if we go back to our stress changes, we've released a lot of stress but we've also, we've increased some stresses in some places but compared to this drop here of, of near the fault of 150 Bars these stress increases are only around 4 Bars. So there you might think there's no net gain in terms of getting rid of stress but there is actually. It's happening in close to the fault. So if we move on and put in another earthquake. So here we've put in the February event, again quite a big blue area where stressors have been decreased but you can see that – and if we change the scale here and made the extreme, the scale at the bottom of, of this figure and instead of having it plus or minus

4 Bars had it plus or minus 2 Bars in terms of red you can see how in some plots you might look at Christchurch would appear as red on those plots if you just scaled things up and, again, as we said the 2 Bar level is sufficient. But you see February did relieve stressors and this relates back I guess to what Jarg was saying yesterday in terms of the Boxing Day sequence, I'm not sure where it plots on this diagram, but close to that there will have been stress release that affected that area from the February event. If we add in the third event by going to the next slide please. That's sort of enhanced the blue area I guess and created a red area that's south of the fault but I have to say this third event might not have the latest fault data in it so it might be a little inaccurate. It doesn't really alter the picture though for the rest of Christchurch. So you can see an area of slight enhancement of stress over part of the Christchurch area still, quite a big area where stressors are decreased and the bigger increase actually well away. So in work going forward we want to use this kind of information to inform the expert elicitation process when we try and re-distribute what the statistics are telling us about future large earthquakes. So if we were working just off this picture, which we won't, we'll be looking off a range of this kinds of pictures at different depths, for example, but if you were just working off this one you'd want to re-distribute quite a lot of future seismicity out in these other areas in terms of what we talked about, the EEPAS model. So that's the end of my presentation.

1434

JUSTICE COOPER ADDRESSES MR MILLS:

Mr Mills, the slides and diagrams that we've just seen, we'll need sets of those for our materials. We have been given additional slides used by Dr Pettinga, that can go into tab 2.

WITNESS PANEL:

DR WEBB, DR BERRYMAN, PROFESSOR PETTINGA AND DR MCVERRY

JUSTICE COOPER CONFIRMS ALL PANEL MEMBERS ARE ON FORMER AFFIRMATIONS

MR MILLS:

I just have a very limited number of questions and they're mostly designed simply to clarify for me at any rate, the points that have already been made by one or other of you. The first question I wanted to ask is a general one which will relate to the structure of NZS 1170, so I wonder if it might help to put that up. On my number it's numbered SEI STA0001 and in the folder it was tab 14. I thought this might make it less of a discussion just between us and might lend itself to some wider understanding if anybody is watching this or listening to it who doesn't understand any of this. Now, the question I would like to get some further explanation for is really about the way in which NZS 1170 works and again, just for any wider audience, NZS 1170 is described as structural design actions, earthquake actions New Zealand. Tell me if I'm correct, and it may well be you Kelvin, that NZS 1170 is divided up into several sections and the sections that GNS Science particularly has input into is section 3 which is, if we could just turn over a couple of pages to section 3, at page 2 of those documents. So that's the section headed "site hazard spectra" as you very well know because you'll be very familiar with all of this, but there are then later sections in NZS 1170 and they're not all up there but the next one is the structural characteristics and the next one is the design earthquake actions and so on. Principally what I'd just like your clarification on is whether section 3 is the section that is the principal section into which GNS has its input, with the later sections being those that relate more to input from structural engineers?

DR MCVERRY:

I'll answer that because I was involved in the committee that put together this standard and that is correct, section 3 defines the hazard and the ground motions and then the later sections were mainly structural engineering input to change those into design loadings and displacements and the like. There was interaction in some minor parts but that division is in general how it worked.

MR MILLS TO DR MCVERRY:

Q. Yes, that's principally the way in which this particular New Zealand standard is intended to work isn't it, GNS inputs theirs, other professions, particularly structural engineers, input elsewhere into the standards, is that right?

A. That's correct.

1444

Q. And in the work that GNS is doing, the so-called Z factor is one of the principal results that comes out of section 3 and then gets married with work that's being done on the structural issues in the other parts of the standard?

A. That's correct both the Z factor, really those four factors are spelled out in that first equation they're all really GNS input, the spectral shake factor, the Z factor, the return curve factor and linear fault factor are all derived initially from GNS.

Q. Yes, thank you. I want to ask you then about the process by which the increase in the Z factor was arrived at in Christchurch or for Christchurch following the Canterbury earthquake sequence, or the Christchurch earthquake sequence. Am I correct in my understanding that here that usual process that we've just agreed on is not quite the way it worked in arriving at the .3 factor for Christchurch.

A. Ah yes what we did for Christchurch is we took our revised seismicity models and the modification to the ground motion models and developed the spectra for the site conditions most appropriate to the Christchurch CBD. We then went into this standard and chose the scaling of spectral shape factor choosing the Z factor that matched the hazard spectra at various spectral periods. Usually the Z factor we'd calculate off a shallow soil spectral value. Here we sort of targeted our results with the, for the site class that at least we were working with in the main, which is the deep soil conditions for Christchurch.

Q. Am I also, is it also correct that there was more input from some structural engineers at any rate in arriving at the Z factor on this occasion than would normally be the case when GNS was defining the Z factor for a particular area.

A. I think that would be correct but even in developing the code though there was a lot of iterations on various parameters that were used in our hazard calculations but I'd say in this case there were certainly probably more direct discussion and particularly the effect of the small magnitudes there was a lot more input from engineers on those.

Q. And this is the issue that we've heard some discussion about today already, particularly in the interchange between yourselves and Dr Abrahamson, about the extent to which GNS was prepared to accept this .3 as a Z factor on the basis of some assurances that were being given by some members of the engineer advisory group about the performance of the Christchurch buildings.

A. That would be the case, certainly the more recent ones, I'm just trying to recall when the magnitude weighting was applied across the board, I think that was only in the more, no that was applied accidentally early on so yes so that would be the case yes.

Q. I know we've been over this before but I just wanted to clarify how this had worked. Now I want to ask you then about the extent to which issues of policy choice are embedded really or are behind some of the what, to a layperson at any rate, looks like very precise scientific language that one finds, particularly in s 3 of the New Zealand standards and again I was hearing some of this in the exchange with Dr Abrahamson this morning about the extent to which really behind some of these judgements it's a policy judgement rather than a purely scientific judgement. I just want to ask you one or two things about that. Now I think the areas that have already been particularly identified in relation to this, but correct me if I'm wrong, are the first of all the decision about the maximum magnitude that could be expected anywhere in New Zealand of 7.2.

A. That was a science decision made by some of our geologists. Dr Berryman may be able to, I don't know whether he was directly involved, I certainly wasn’t, I was (inaudible 14.49.13) that this was an outcome of some discussions among our geologists.
Q. So that you say was pretty heavily straight science.
A. That was straight science yeah yeah.

DR BERRYMAN:

That was a, every few years, um it’s not on a regular basis, when we need to improve we feel that it’s time to look again at the national seismic hazard model as a separate piece of science work the time had come for when a significant amount of new information had come forward so in science research base, the national seismic hazard model is developed as a piece of science and it’s within that context that the maximum magnitude or some of these other parameters that go into the national hazard model, including updates on information about active faults and also some techniques about the gridding of the background seismicity comes into play. So that was an assessment looking backwards over the previous model, taking information that had been gleaned since the last update in 2002 and bringing that forward in what is now the current model. It brought about that change from a background maximum magnitude of 7.0 to 7.2. Now that had been through the science discussion phase prior to September.

MR MILLS TO DR MCVERRY:

Q. Okay thank you. The decisions that were made around the 6.5 magnitude, again there was discussion of this this morning and the distance from the site that has been chosen as the point from which that 20 kilometres is measured and the depth below the surface level. To what extent are the decisions that have been made around that, working backwards from some what I would call policy decisions about the costs and benefits of requiring certain standards of structural building work.
A. Okay I was certainly involved in the committee that made those decisions. The magnitude 6.5 would have been a number that I would

have put up to the committee but that was from discussion with our geologist at the time what sort of magnitudes do you think we're possibly not able to see up in those northern areas of New Zealand where it mainly applies. The 20k distance was initially sort of probably a little trial and area, what numbers do we get at 10k or 30k, and that would have been a sort of consensus with the engineers. Once we'd come up with the values which we thought were about appropriate the whole code went through an economic evaluation process which I wasn't involved in. Some of the committee members were and the outcomes of that I don't really know except eventually the standard was adopted so I assume it must have past the required tests on that but I could not tell you what effect that particular aspect had on the costs for Auckland in particular.

DR BERRYMAN:
I guess, Graeme, it might be useful, the process, this is a code committee of standards New Zealand and that's where I guess some of our research contributes to a formally constituted committee of the standards New Zealand. The science underpins that sometimes and is recognised as an input and on other occasions, in such as this discussion of the minimum magnitude, it's a very much a code committee decision informed by the science but it's not part of the hazard model per se.

DR McVERRY:
Certainly the economic consequence, that was not done by the code committee as such, there were some members of the code committee involved but basically the committee put up a draft standard which then I'm not sure if it was standards New Zealand or some other organisation then ran all these economic tests. These days it might be someone like DBH but I'm not even, I suspect they weren't there at the time this happened but it may have been some predecessor of them perhaps. I can't answer who it was done for but I know this process did occur.
1454

MR MILLS TO DR MCVERRY:

Q. But would you agree with me that imbedded in the figures and equations and graphs and so on that one finds in here there are decisions being made within the standards process that involve assumptions about acceptable levels of risk and the costs that can be justified by somebody's assumptions about what are acceptable levels of risk?

A. Certainly to some extent and one of the issues is rather than being purely a technical committee that is perhaps being asked to provide something that meets certain levels of risk we were perhaps in a bit of a void or vacuum situation. The committee itself was often having to make those judgements because I don't think any the legislation had guidance which we could directly use.

Q. Yes, well that's what I was curious about particularly about the way this is working because I think this is going to come up in some later papers in discussion about how these decisions are being made and who's making them and whether that's appropriate for them.

DR BERRYMAN:

A. If I can please interrupt. I would say also in that space it's really taking, very strongly taking best international practice that was available at the time and I would say that the people sitting on the Code Committee do not sit in isolation of the international scene in that sense particularly with respect to performance expectations around, shall we say, the collapsed criteria, something like that so it's very much an international field and I think New Zealand has taken guidance and is being very consistent with that risk-based approach.

DR MCVERRY:

A. Certainly the return periods that are used for various things are consistent with particularly US practice and European practice. There may be some very slight variations. The Americans talk about 10% in 50 years, probability of exceedence we talk about a 500 year or one in 500 which are very slightly different. Ten percent in 50 years would translate to 1:475 or 472. New Zealand decided they'd use a round figure of 500 but the difference is inconsequential so we're doing our best to follow international practice. There are some issues. We have to formulate things in a slightly different way just because we're following ISO standards which have got one or two requirements which I don't think the Americans confirm to but again they are not issues of any great importance. They're a Z factor, this funny factor of a half that comes into the Z factor. That was because the ISO standards require that that scaling factor should be equal to the code value for the rock peak ground acceleration and there are technical reasons why we don't want to use rock ground acceleration as such for scaling our spectra so we sort of worked out our scaling factor and then put in the appropriate factor so it equated so there are issues like that but the end result is consistent with US practice in particular.

MR MILLS TO DR MCVERRY:

Q. I'm not suggesting for a minute that this is out on a limb. As I say, I'm more interested in just exploring this question about the extent to which these apparently very objective numbers and calculations really have embedded in them. Some pretty significant social policy choices which have been made and I think we are in agreement that they do. Now if it was thought desirable to make the principal big choices that are embedded in here more transparent, would there be a way of fairly readily doing that, say with s 3, within s 3?

A. Usually that could be covered in the commentary clauses and I guess there are a number of higher level documents that it's under. I think the Building Act and the Building Code and various other things and some of these policy decisions could perhaps be set in those higher level documents so the decisions weren't having to be made to the technical standard level.

Q. Yes thank you. That's of interest. Now the next question I just wanted to ask you a little bit more about, and again it's had quite a lot of discussion so I don't want to spend too much time on this, but this is this issue about the current high level of seismicity in Christchurch and the fact that it declines over time and again just so that it's easier for anyone else to follow this who isn't as familiar with it, could we have the GNS graph which is the one that you first showed us of the meeting we had about a week ago, GNS 0009A, which I think are the various graphs we had and shows it most clearly. Now we've already had a discussion about what this means and the much heightened level of seismicity risk at the present time and for some time to come. What I'm interested in is whether you have any further comment on how to respond to that in the practical world of having to begin the rebuild of Christchurch and I notice that I think it was Professor Abrahamson for one said, "Well you could have different building standards that apply at different times." I'm just interested whether there's anything more that any of you want to contribute to the issue that pretty clearly jumps out for me at any rate, and most of us I think, looking at that graph there?

DR WEBB:

A. I'd just like to reinforce what has been said earlier about this being work in progress. Its two planned activities would maybe change the picture of how this EEPAS model contributed through breathing seismicity out and formed by the coloured clover leaves I showed you just before and then this point in terms of this descending coincidentally to a .3 level and flatten everything out there, that being influenced by decisions you make about how you treat the level of activity from background seismicity where what you're really interested in is what will happen over the next 50 years or so. So is the past 50 or 60 years the best judge of that or 140 years. It's really what's the best measure of the next and that could pull that long-term level down and that will pull down the 50 year average and if we're deciding to use this 50 year window for proxy for life-time of a building be it economic or useful life, that 50 year level will come down as a result so people do need to be aware that the science is progressing and these numbers will change and there will be a range of time-frames for different contributions from the science.

Q. Let's just assume for the moment that it doesn't change, and recognising it well might, but if that is roughly where we end up after you do your further work do you have any thoughts that you feel comfortable adding now as to what the response might then be to that in terms of the construction response to it?

DR BERRYMAN:

A. In socialising this graph around the community quite a lot in the last few months I think it comes back to this discussion of one of the challenges with formally setting the Z value at a very high level is that there's a lot of observation still being, analysis still taking place on actual building performance in Christchurch and yet we know that there has been some very unfortunate behaviours but by and large there has been some very good behaviours of many of the modern buildings. If the Z value were to be too high then some of the buildings that have been through a greater than design level event and done quite well would under the classification of Z values and earthquake risk buildings as it relates to Z values earthquake that have demonstrably worked very well would be classified as earthquake risk. They have just survived.

150400

Q. Yes.
A. Yes they have just survived.
Q. Buildings, yes.
A. Buildings.
Q. Buildings that have demonstrably performed very well, yes.
A. Would be reclassified as being earthquake risk buildings yet demonstrably they have performed above the level of the code level let alone two thirds of the code, so there are some dist- what shall we say, there is, appears to be quite a lot of structural resilience in much of the built environment and that's where Z factor alone can only be one component of a wider, the wider equation in terms of code or levels or actual performance.

Q. So am I correct that I'm hearing from you at least in part that the ultimate response to that should it stay the way it is depends pretty heavily on a very good understanding of how buildings really did perform?
A. Yes.
Q. Yes.
A. This is just one part. Now in terms of the construction industry at present in, especially in the residential sector there is again with modern buildings taking away a liquefaction issue there's been a lot of rather good performance, yes there's been damage, there's been damage that has been you know most, many, many of the residences in Christchurch even on quite good ground conditions have suffered some damage but it is not above what the Earthquake Commission cap is and I think that if we examine those buildings we also find that they readily accommodate this higher Z factor without being compromised within the first few years so there's certainly further discussion to take place in that realm but we should be rather careful about this little corner in here of Z factor or any of the hazard factors being higher than code meaning that you cannot, you cannot move until we come down to the code level because a lot of actual observation suggests that there's quite a lot of residual capacity.
Q. Yes.

JUSTICE COOPER:
Q. I've just got a difficulty following something you've said there Dr Berryman, you were talking about residential buildings?
A. Mhm.
Q. I think you said happily accommodating this higher Z factor. Did I hear that correctly and if so what does it mean?
A. Yes. The code has got a Z factor in it.
Q. Yes.
A. It would appear based on the actual performance of buildings.
Q. Yes.

A. That they still have quite a lot of re- reserve capacity shall we say even at code level and that's been demonstrated very widely across the region –
Q. I understand that.
A. Right so that even now if the effected zone, you know, Z factor is point .45 we could build to the existing code level and still have very satisfactory performance.
Q. Well I think I follow that too but that's not, I think, the idea that you were conveying earlier perhaps I didn't understand it but you're not saying are you, I mean if you change the Z factor you have to alter the design of the building don't you? You have to do something differently or more robustly or…?
A. There's two, there's two – there's, this is where other colleagues outside this –

DR WEBB CONFERS WITH DR BERRYMAN

A. Yes there's two standards there's a residential standard.
Q. Yes.
A. And there's a commercial building standard.
Q. Yes.
A. The commercial building standard I think the Z factor applies to rather directly.
Q. Yes.
A. In the building, the residential building standard has been zoned in the country so that there's a step change at certain Z factor levels.
Q. Oh I see. Well that explains it thank you. I'm buried in the CBD?
A. Yeah quite so. Yeah, it was just a question about the beginnings of the rebuild. The rebuild is liable to be starting in the residential space before it starts into the commercial space.
Q. Yes.
A. Just wanting to cover that.

DR WEBB:

It's probably worth noting that with Z at around these kinds of values .3, .34 you're actually pushing very near a step change to a higher level requiring a higher level of domestic construction.

EXAMINATION CONTINUES: MR MILLS

Q. I have only one other question.

COMMISSIONER FENWICK TO DR McVERRY:

Q. If I could just butt in while that picture's there, just looking at it I wondered how that average was calculated because to me the average would mean that the area between the dotted 50 year return period the area above that line between the blue line and the dotted line and the area between the blue line and the bottom line should be equal and looking at that it looks as though that line is too high. I just wonder how that average was obtained it doesn't look as though it's the normal sort of rules that apply?
A. It's really a 50 year average of the seismicity. We worked out the seismicity rates year, year by year added them up to the total number of earthquakes we'd expect in 50 years which - they can be fractional number of earthquakes for – the rates are calculated and then worked out the number of times the various hazard levels would be exceeded in 50 years so it's really it's based off the 50 year average seismicity rather than perhaps a straight average of that curve as you –
Q. Of the hazard.
A. – as we see and I think the full report does sort of mention that that but it discussed –
Q. A little unfortunate shorthand from there.

JUSTICE COOPER ADDRESSES MR MILLS – AVAILABILITY OF DOCUMENT – TAB 11

EXAMINATION CONTINUES: MR MILLS

Q. I've only got one other question and it's actually –

DR WEBB:

We had one other point relating to the areas under this bracket because at the, the vertical axis starts at June 2011 whereas that first point there is October 2011. If you plotted the point on the axis I think it's just off the top, it's a very high value and so already by now it's descended a lot and so there would be a little bit of additional area there that you can't really see. The bigger effect if probably due to what Graeme –

DR McVERRY:

Yes I, yes I think the starting time is something like June the 30th it was a week or two after the June 13th event.

MR MILLS TO DR WEBB:

Q. I've only got one other question it's for you Dr Webb and it's actually an unrelated question to what this hearing has been about but because you're here I wanted to deal with it now so you don't have to come back again for the hearing that will be related, to which this really relates. And it relates to the advice that GNS gave during this earthquake sequence period on seismicity predictions and specifically what I'm interested to know is whether post the September earthquake and prior to the February earthquake the Christchurch City Council asked GNS officially for any advice on the potential magnitude of future earthquakes or aftershocks following the September earthquake?
A. No there was no official advice or certainly no client or letter report which is how we convey official advice.
Q. Yes.
A. Produced for Christchurch City Council.
Q. All right, what I want to do next is to have you look at a document.

1514

WITNESS REFERRED TO DOCUMENT

Q. And it's GNS 4, document 4.1, it's at tab 12 for the Commissioners, have you got that in front of you? Once you've had a chance to just look at that I just want to ask if you're able to identify that document?

A. Yes that's an early estimate of likelihood of aftershocks of different size ranges and also the aftershock decaying plot and I guess that was requested of us by Roger Sutton of Orion and was sent to him. There's an associated email that you'll have, I forget the date I think it's 30th of September.

Q. I'm not sure that I have that.

A. I've got a note of that (inaudible 15.14.45)

Q. If there is another document that goes with it that we ought to have do we need to, do you think we need to formally produce that or are we just gonna get a copy of that and…

A. Well if we, no there is a date in the document which is September 20th 2010, the date at which the calculations are effective from.

Q. Do you mean the document that I asked you about?

A. Yes.

Q. Yes.

A. In that second paragraph.

Q. Yes, yes.

A. And it was sent the same day as that.

Q. Yes all right so that was requested by Orion Energy advice on, as it says, probabilities of aftershocks and larger events after the Darfield earthquake. Now just before I ask you perhaps to explain that a little more fully as to the content of it. is that the sort of advice you would have given to the Christchurch City Council if they had asked, similarly, for advice on that issue?

A. Um, well it would depend, I think, on the nature of the request. Orion asks specifically for likelihood of aftershocks.

Q. Yes.

A. So had Christchurch City asked for that we would have provided exactly the same information for them. But as you've seen in terms of what we're able to provide another example is, essentially, the revised hazard model but that took, we were talking about that earlier, probably took at least two months to calculate the first iteration of that model and so, I mean, had we started those calculations on the 4th of September it would probably be November before we developed something in terms of likelihood of ground shaking, future ground shaking as opposed to likelihood of aftershocks. Now, of course, you can take the likelihood of aftershocks and then do some scenario analysis of given those aftershocks occurring in specific locations what would the ground shaking due to them be and this falls back on components of the national hazard model that we've already talked about over the past few days. You can come up with mean and statistical estimates of the ground shaking.

Q. Yes but I take it you're telling me that had this same question been asked that is framed here at this time by the Council this is the advice you would have given.

A. Yes, that's correct.

Q. Can I ask you then, just finally, to just explain in your own words a bit what it is that that document is saying.

A. Well I guess we start by saying very very briefly actually how we've calculated these numbers, the time periods for which these forecasts are valid and then for magnitude ranges of 5 to 5.9, 6 to 6.9 and above 7 the likelihoods in periods of week, month, year of aftershocks fitting those criteria occurring.

Q. And just because there are, not everyone's got this document in front of them, can you summarise what that advice was as recorded here?

A. Sure. I mean the number people are probably most familiar with is the likelihood of an aftershock over the next year, although at that time they may have been interested in a week but if we look at the one year numbers, there was say an 89 to 100 percent, so very high likelihood of something in the magnitude five range, 37 to 57 percent of something in the six range and even at that very early stage, sort of the six to nine percent probability of something even bigger than seven and that sort of probably in terms of the model we're now using more in the realm of the

EEPAS model than the step model in terms of prediction. Another thing to note in this document is we were trying to draw some comparison back to likely levels of shaking in Christchurch had there been no earthquakes as a comparison. That's a little bit difficult to do because in the table we're predicting likelihood of aftershocks that will have consequent shaking but we're not talking about the shaking we're talking about the aftershocks so in this other comparison where we come up with say a number of 26 percent chance of some level of ground shaking had there been no activity due to a magnitude 6 to 6.9 earthquake. That number's not directly comparable but was the best number we could come up within a short time to help inform the thinking around the change in the level of risk. In fact as you've seen and what we've presented over the past few days the elevation of the risk is actually quite a lot higher than what you would determine by directly comparing those percentages. So it's not a perfect comparison but its what we did at the time thinking we need to calibrate people a bit to normal risk and here's the enhanced risk. And then, finally, on that diagram we show the aftershock decay and that, of course, shows this familiar pattern of very rapid decay at the beginning and then quite a long tail after that.

Q. Yes thank you Dr Webb, I have no other questions.

JUSTICE COOPER:

Q. Those percentages, or the year, the period of a year runs from the 20th of September 2010, is that right?

A. Yes that's right, yep.

Q. So in that year there's a 37 to 57 percent chance of a magnitude 6 to 6.9 earthquake, is that what this document is telling us.

A. Yes that's right yeah.

Q. Can you just break that down a bit. The percentage chance, can you just explain that concept, 37-57 percent chance. What does that mean?

A. Oh if you weren't particularly lucky or unlucky you're right on the boundary between you'd get half an earthquake in the year. So if you,

well you can't, if you could take two years and the rate wasn't dropping off, so it was a constant rate, then you'd get one earthquake (inaudible 15.22.28)
Q. You would get, you are saying there will be an earthquake sometime within the next two years of that magnitude.
A. Or another way of saying well there's just a 50/50 chance of getting even the one year.
Q. Yes I see all right. Did any other organisation in Canterbury ask for advice other than Orion?
A. Kelvin can you comment on, there was quite a lot of advice.

DR BERRYMAN:

There was quite a lot of what shall we say less formal advice provided, not through official requests for written feedback but because the scientists we were embedded in the emergency operations centre post Darfield continuously for the first three weeks meant that on a daily basis the emergency operations centre, which was managed as a regional declaration and therefore managed through Environment Canterbury, received updates essentially on a daily basis of what was happening.

JUSTICE COOPER TO DR BERRYMAN:

Q. Well at what stage were these figures arrived at? This advice is given on the 20th of September.
A. Yes.

1524

Q. Are you saying that you were aware of this information earlier than that?
A. Not in such a quantified form but in a more general form that it was, it's well known that an earthquake, an aftershock of 1 magnitude less than the main shock is a typical aftershock magnitude so the advice from very early to, to, in briefings, particularly slightly more formally through the Emergency Operations Centre where there's a response structure was that the expectation could be, typically a magnitude 6 could follow, could be in the aftershock suite of a magnitude 7 or 7.1 so. That advice

was quite widely, and indeed informally I did brief not the officials of Christchurch City but the Mayor and the councillors in that period of three weeks in general terms in terms of the likelihood of a significant aftershock.

DR MCVERRY:

And I guess I should mention a specific hazard study that took place in this time. It was actually requested I think on the Thursday before the September earthquake. It was, certainly the ultimate client were Fonterra for the new plant at Darfield. I may have been working with one of their consulting engineers and we delivered a hazard report to them a month or two after the September earthquake. We weren't in a position to do the ground motion estimates associated with the aftershock sequence but we did incorporate an early model of the Greendale fault in, in that. It's not to do with aftershocks but just it was a hazard estimate for Canterbury that occurred in that time period and after the February earthquake we've actually done an update of that which did use the sort of seismicity models we've been talking about here. So that was, I'll just mention that for completeness.

JUSTICE COOPER TO DR MCVERRY:

Q. So in, in November was it, you provided that advice to Fonterra?
A. Sometime around then. I would have to go and check the exact date.
Q. But that wouldn't have received any wider circulation?
A. That was a purely consultancy report which, at the time I think it was quite sensitive, the fact that they were wanting to proceed there. I believe it's under construction now.

JUSTICE COOPER:

Gentlemen I must say that I think my fellow commissioners are very pleased and impressed with the quality of work you've produced and the energy that you've put into working hard to respond to our requests. I can't help but note though that in that, around that question of the matter of whether you would use 5 or 5.5 as the magnitude of earthquake that you'd build into your model and the accumulating the, the geophysical information that you work with, it raises the question of the interface between engineering consequences of the work that you produce and therefore the, the way in which the interface works between GNS Science and the engineering community. I can't help but notice there's a tightly integrated organisation called GNS Science working with your professional colleague from the university addressing this question. The engineering community is dealing with matters that have very high degrees of variability in them. Buildings can be designed with differing factors of safety, with materials that have got different properties, some that are more resilient than others, designs of deflection of buildings and all those sort of things come into it and I'm just wondering if given an ideal world and about to recreate the way the way in which geosciences, geophysical information is incorporated into design techniques and design choices do you think New Zealand's got the model right and, you know, if you felt there were the ways in which the two communities of science and engineering could, could integrate their thinking that are any different to what you're using today, you know, I would encourage you to say so because those are the sort of matters that are in my mind at the moment.

DR MCVERRY:

Perhaps I'll answer specifically on what happened in terms of the z factor report, or reports. That work was all done where we were having very regular consultation with members of the engineering advisory group that I think was under DBH or Cera, DBH and, and certainly early calculations would have been done for magnitude 5 and the arrival at the final ones with magnitude 5.5 was in consultation with, with that, that group because that was feeding back some of the engineering versus the straight-out hazards. Perhaps Terry or Kelvin may like to answer on sort of the more general issue.

DR WEBB:

I'd certainly like to cite one thing, it actually was a comment and I forget, have forgotten who made it but a comment out of the US soon after the September earthquake, I'm sorry it may have in fact been the February earthquake, basically saying there's an enormous opportunity here and we've missed a profession answer on. The comment was about getting earth scientists, engineers and architects together in terms of redesign because it's often architectural features that make life, as I understand it, difficult for engineers. Ideally you have the three professions working well together to get the best result.

DR MCVERRY:
And we've also been working very closely with engineers on some of the liquefaction issues, specifically the EQC and their advisors and there's been a similar interaction between the engineering and the hazard estimates for, and the (inaudible 15:30:52) for various estimates for various purposes.

COMMISSIONER CARTER:
I tried to make it clear at the beginning, my question certainly wasn't in any way intended as critical of, of the work that you're producing, just have we got the right process in going about that exercise because that's what we, or I perceive and my colleagues perceive is that if there are things that we can do to improve the process then we, it might be a good time to say that. Thank you.

DR BERRYMAN:
Sir Ron if I might be, if I could add a couple of comments. Perhaps in a slightly wider perspective I think that there has been through the Earthquake Engineering Society in New Zealand a longstanding dialogue, tends to be somewhat at a, a scientific level if I can include science into the, scientific, the engineering into the scientific level –

JUSTICE COOPER:
Sorry, which society are you talking about?

DR BERRYMAN:
The New Zealand Earthquake Engineering Society has been a forum for very widespread dialogue between the sciences and engineering for a very long time, since the 19 – and I'm sure Richard I think could give me a better date –

COMMISSIONER FENWICK:

It's '68, 1968.

DR BERRYMAN:

'68, since 1968, it had, it had geologists on it on the steering committee of that and has done so ever since 1968. So that's at one, one level. I would, the only other comment I would, or two comments maybe, one would be that, that sometimes hasn't translated as effectively into some of the policy areas although I would note that Graeme here as a, as an earthquake engineer of GNS Science and has been part of Code Committee work in the past through Standards New Zealand, I was a member of one of those committees in the past as a geologist also. So there has been that, I think that it can be improved and should be improved and we should learn the lessons from this exercise. We've, in the response phase I think many of the professions have come together very, very well and very effectively. The challenge is to maintain that going forward as we go back into a more business as usual activity. The only other comment would be in our research space, beginning in October 2009 the, the then Foundation for Research Science and Technology took a lot of the competition out of the Natural Hazards Research Sector and placed it into a consortium which I manage as the New Zealand Natural Hazards Research platform which integrates, which specifically sets out to integrate across the geological, engineering and social sciences. Now we've been sorely tested in that space all in the last, in the last year. We're coming from a very competitive environment to a collegial environment so we haven't changed the cultures entirely around the country as yet but there are some very good, I see that, I'm biased in this but I do see that as a very great opportunity now to bridge the gaps between some of the disciplines and if we can build on the experiences here in Christchurch that will go in a well for the future across those discipline boundaries.

1534

COMMISSIONER CARTER TO DR BERRYMAN:

Q. Thank you our intent will be to improve things and we're conscious that there are very serious efforts being performed by both private and state sector organisations, the Ministry etc, but it does seem to be something well worth examining. Just a question again there about the organisation you've been interacting with. New Zealand Society of Earthquake Engineers or the Society of the Engineering, New Zealand Society of Engineering?

A. Both, in fact, although I would say over the longer period of time it's the Earthquake Engineering Society that's had the broader, the broader discipline participation. Graeme, I'm sure, is a member of IPENZ or the structure groups.

DR McVERRY:

No, no, I'm only a member of the New Zealand Society of Earthquake Engineering. I have from time to time attended IPENZ conferences, certainly not in recent years because the speciality, the earthquake speciality, which is my main interaction with engineers, the earthquake society runs those conferences, the IPENZ ones are a lot broader so there would only be a few items of direct interest to me and similarly my opportunity to address people on current issues would be a lot less to the whole range of engineers as opposed to those who are in the earthquake engineering fraternity.

COMMISSIONER CARTER:

Well thank you for those comments. I should add that there is a session later during the New Year in which we'll be looking at organisational matters. I just thought it was timely seeing the question of interaction between yourselves and engineers in determining an approach you made to developing the Z factor for Christchurch might be as well just to place the interest on the table at this stage. If you'd like to give more thought to the topic I'm sure we'd be very considerate of GNS's views and experience, thank you.

COMMISSION ADJOURNS: 3.36 PM

COMMISSION RESUMES: 3.55 PM

DR WEBB:

EXAMINATION: MR ELLIOTT

Q. (Inaudible 15:55:38 – audio volume low) ... struggling to understand some of what has been said, so I'm just going ask you some questions around the topics, so firstly the earthquakes, secondly some questions around the assessment of seismic risk including information that is and might be available to the public and then the role played by GNS. So just starting with GNS, it's correct isn't it that GNS is a company, Dr Webb?
A. Yes, a Crown owned company.
Q. So 100% owned by the New Zealand government.
A. Yes, that's right but registered under the Companies Act, yes, and so probably worth understanding the structure then since we're a company. We have a board appointed by government and so they are responsible to the shareholders and the two shareholding Ministers are the Minister of Science, or perhaps more accurately the Minister of CRIs and the Minister of Finance.
Q. And you operate like a private company in the sense that you generate financial reports which are available to the public and which nominate profit and loss over certain reporting periods?
A. Yes, that's right.
Q. The revenue if you like that you generate comes from public research contracts, consultancy work, monitoring geological hazards for EQC, advice to central and local government and government grants, is that right?
A. Yes, that's right but to sort of put that in a better context, a lot of research in public good, so that's creating new knowledge and basically for GNS in terms of the areas we cover, broadly speaking it's science research and it's for public benefit. So that's what a lot of the publicly

funded work is about and in addition to that we have this other consultancy activity but that is often value added in terms of taking the research and to a more applied end to meet the needs of a range of end users, be they owned by government or privately owned businesses.

Q. So according to your website one of the things you do is hazard modelling, in particular with earthquakes you model strong quakes to determine and design for the severity and characteristics of strong ground shaking. Is that something that you are constantly doing or doing on a case by case basis as contracted?

A. I guess we would certainly do it on a case by case basis but also I guess it's closely integrated with our ongoing research programmes in terms of producing national level models rather than site specific models.

Q. And by models what you're doing is, predicting may not be the best word, but predicting as best you can horizontal and vertical accelerations at various sites around New Zealand?

A. That's right, likelihood of ground shaking is what is boils down to, yes.

Q. And there has been much evidence about graphs around horizontal and vertical accelerations. They are the descriptions you're using effectively for ground shaking at a given site in the horizontal and the vertical directions, is that right?

A. I'll let Graeme respond to that because it's a bit more complex.

DR MCVERRY:

That's basically correct. Often our reports are in terms of the spectra that we've been mainly talking about here. In some circumstances for engineering purposes they also require the acceleration histories which they can then input into their computer models to do time-step by time-step analyses so we're often recommending them but that's all based on matching in certain ways to our initial hazard estimates. They'd be the two main products.

MR ELLIOTT TO DR WEBB:

Q. Dr Webb, is GNS the only private provider of this range of services in New Zealand?
A. For a lot of what we do, I guess we are the predominant provider especially in Graeme's engineering seismology expertise. When you step back a little to the government research funding, that's where what Kelvin Berryman said earlier about the natural hazards research platform is important because there you have a group of five or six providers working together in the more basic and targeted basic research to inform and improve our knowledge of natural hazards nationally.
Q. And so they are providers such as University of Canterbury, NIWA?
A. NIWA, University of Canterbury, University of Auckland, Massey University and a social science team at Opus in Wellington.
Q. Opus the company?
A. Yes.
Q. And I assume that your resources are finite. If there is a competition between your resources say, just to give an example, you were deciding between carrying out blind fault mapping in a city and some sort of offshore fault analysis such as was discussed yesterday, who decides where those resources are put and how do you make that decision?
A. Right. That's a very good question. So prior to the 1st of July just past, 2011, the government research funding was allocated through a mix of long term funding and contestable process but there were different pots of money if you like in what were called output expenses so roughly I think there was energy and minerals output expense and so the foundation for research, science and technology would have these various processes for allocating these monies, some of which was contestable as I mentioned, a lot of which was, and really I think needed almost Cabinet level approval to change the sums in output expenses so that really determined what research providers ended up doing because it had to be related to the funding available and the output expense. What's happened since 1 July is that a lot of that money has

been devolved, so it still comes to us from the new, the organisation that has been formed out of Ministry of Science and the Foundation, that's Ministry of Science and Innovation, MSI, but a lot of that money now comes to GNS as what we are calling core funding for carrying out research under our statement of core purpose which if you read that for GNS is a lot about earth science. So it has things like hydrocarbons has been an example and of course a lot of hazards research, so now the process for making decisions about how that money is spent in terms of the balance factors across GNS is more up to GNS although there will be close scrutiny of that I think by the Ministry of Science but it's very early days so as a starting point we've said for this first year we're not making radical changes. We need time to let the system bed in and the decision making process and how it works to be got in place, so in the first year there are very few changes to the levels of funding across the different topic areas in earth science and another thing we're very aware of in our current thinking, if you make large changes, internally you immediately have a problem with preserving your national research capability so a lot of our staff are PhD level, highly specialised, it's hard for them to change fields and work effectively in different fields. So if you start changing emphasis quickly you come up with quite big capability issues and you may lose national capability that actually in five or 10 years time suddenly becomes important but is actually quite hard to recreate in a hurry. So our current feeling is, and as I said, so far we're making little change although in future years there will be change I'm sure, but change may have to be reasonably gradual because of these capability issues.

1605

A. The other thing around the process it's really the responsibility of the GNS board to monitor this process and decisions will be informed by a high level advisory group and so GNS is looking for external national and external advice from scientists and end users who will all have an input through this advisory group as to the decisions that are made.

Q. So where the Ministry of Science allocates some money is that tagged for a certain purpose now?
A. Well I guess the direct Crown funding, if you like, is now coming through to GNS and to other CRIs in a similar way and that can be used in areas that are related to the statement of corporate intent and the statement of core purpose agreed with the Ministry of Science, so you have to work in those areas. Then MSI will also be running contestable processes in more specific areas such as one labelled Hazards and Infrastructure, they'll be running a contestable process there I expect in the next year to 18 months.
Q. So the current position is that if MSI allocates the money it's over to GNS to decide whether it's put towards earthquake research or one of its other strains of –
A. Just be careful because if they're allocating money to GNS through our success in a contestable process they will have put out an RFP in an area after which the consultation they've done they see high priority research needs, people will bid for that money and those that are successful in getting and get funded will have to carry out the work according to what they proposed and what was assessed by MSI for work in a specific priority area. However, if it comes to the direct core funding or direct Crown funding that comes to CRIs there's more onus on the CRI and the CRI board and the advisory group to make decisions around that that would be more flexible in the long term.
Q. There was discussion yesterday about the state of the art system from the University of Calgary, is that something which you've used before this recent period, that sort of technology?
A. Well Jarg mentioned yesterday both I guess a number of universities have small systems for acquisition of land seismic data and NIWA and other oil industry ships also visit New Zealand so GNS does some off-shore seismic work often looking at quite large scale problems like the shape under the ocean floor of the subduction zone to inform likelihood of large subduction zone earthquakes and associated tsunamis, so that kind of study. Currently we don't do very much work in terms of land

seismics, that's more, I guess, both Victoria and Canterbury University have that capability for the small scale detailed land seismic work and we've worked in collaboration with both, I think, to do some of that work. Currently GNS itself does not own land seismic equipment.

Q. Dr McVerry referred earlier on to a private body, Fonterra, in this case contracting to receive some advice. Does GNS face a difficulty where providing advice privately about being constrained to provide advice publicly?

A. Oh we must be aware that as a CRI a couple of things, we must work for New Zealand benefit, that's the first thing that we have to do under the CRI Act. The second thing is we have to be financially viable, which is different from say a privately owned company where the motivation is shareholder, generation of wealth for the shareholder. For a CRI the first thing is this research for New Zealand benefit. So if we did get to a stage where there was potentially a conflict between say providing advice to central government or local government versus a private client it would be a strong onus on us, because we're government owned, to look to the interests of the government, local government or central government body first. But, in fact, when you look at past track record in seismic hazard its been quite an interesting process and I'll get Kelvin to perhaps talk to this a little. An area where, I mean I don't think designing a structure for a large dairy company creates any conflict at all, we're just feeding them the design inputs they need for meeting requirements under various regulations but if you think about large dam safety issues and the work we've done with Dam Watch and others, URS based in Christchurch for example, in the past, looking at large dam safety issues, whether dams need to be rebuilt because they're near active faults, this kind of issue, you can see that a private interest would want the least money spent on large dam safety whereas the public regulator, be it regional, local council or whoever is responsible, would want a high level of safety and there's been quite an interesting process of providers such as GNS or URS doing the work but it having enormous scrutiny by international reviewers and that's how the conflict has been managed, if you like. The client is paying people to do the work but also there's very good international review of what's then done and so conflict's avoided. Kelvin -

Q. Can I just ask this question, this might deal with the issue. Are you saying that if in the context of a private contract you discovered a hazard to the people of New Zealand or part of New Zealand that you would then disclose that hazard notwithstanding that it was a private contract in which it originated?

A. Oh well I think we'd have to if it became, yes, a matter of public safety. Well I think, I'd like to think anyway you'd be able to persuade your client to do that, yeah.

DR McVERRY:

Often in our hazard projects where we're investigating faults and the like we have written in that that information then becomes GNS for other purposes. We wouldn't disclose the specific advice that we'd given to our client but we'd be able to make use of the new data for national good purposes.

JUSTICE COOPER:

Q. That happens quite often but is that your standard stance?

A. Yes, yes.

Q. So who's saying yes, Dr Webb's saying yes.

DR WEBB:

I'll say yes.

MR ELLIOTT TO MR WEBB:

Q. Just turning to the role played by GNS in relation to the Canterbury earthquakes, you've already been asked some questions about this by Mrs Ford and by Mr Mills. I can produce this up on the screen if you want to see it but you're aware of it, I'll just quote it to you. So according to the most recent annual report from GNS the chairman and Chief Executive's review under the heading "Canterbury Earthquakes, a

Statement, throughout", and that's I think the Canterbury Earthquakes sequence, "throughout we provided advice to central and local government in close collaboration with the geotechnical engineering and construction industries based in Christchurch. While this is our prime duty to advise government on questions of science we also provided answers to a huge number of questions from the news media and the public. In this context we wish to thank the scientists from the University of Canterbury and Victoria who had the capacity to help us with the task of public communication". So just in summary is that an accurate statement of the role played by GNS through the Canterbury earthquake sequence.

A. Oh yes definitely .

Q. In addition to the evidence you gave just before the break about information provided to Orion you've also produced a document, 14.1 at Tab 19 Your Honour, GNS 14.1. Is that an email from GNS offices or employees to Richard Smith?

A. Um, yes.

Q. And that was sent on 9th of September 2010.

A. Right.

1615

Q. Is that right?

A. Yes.

Q. It's from Matt and Annemarie. Who are they?

A. Matt Gerstenberger and Annemarie Christopherson both work for GNS in part of our time varying hazard team.

Q. And who is Richard Smith?

A. He works for Ministry of Civil Defence and Emergency Management in Wellington.

Q. Could you just explain what, in brief, in summary form what you were saying or what was being said to Richard Smith in that email?

A. I think it's running by Richard some aftershock probabilities, similar, along similar lines to what was provided to Orion but at this stage not in tabular form and I think somewhere in there is mentioned the, the likelihood or – well I'm not sure, I'd have to read it, the, of a magnitude 6.

JUSTICE COOPER:

Q. Yes there's a reference about half way down of the probability of magnitude greater than 6 will be, I suppose it means, 7% by tomorrow.
A. Right.

EXAMINATION CONTINUES: MR ELLIOTT

Q. The sentence there that reads, "The social science recommendation is that we should be providing what we know in terms of some basis numbers. Although we as scientists are well aware that more m5s are likely to come we do not want the occurrence of two more in the next week to be a surprise to the public." Can you just explain to us, does that reflect a philosophy within GNS about what the public might be told?
A. Yes this was quite interesting because GNS has had for about 15 years now a social science team that works very closely with the physical scientists and so on occasions like this they're very good at guiding us as in what are the most effective messages for the public at different times and so GNS was in the media and I, I think you probably have various information, certainly talking about this issue that there's likely to be an aftershock of roughly a magnitude unit less. So a magnitude 6 aftershock of the, of the September earthquake somewhere in the aftershock zone.
Q. And that's what you're saying to Civil Defence in that email?
A. Well the, the relationship, we have an MOU actually with Civil Defence and work with them very, very closely. So what happens –

JUSTICE COOPER:

Q. An MOU, a memorandum of understanding?
A. Yes.

EXAMINATION CONTINUES: MR ELLIOTT

A. And what happens under that MOU is the minute there's a serious earthquake that's likely to have caused damage we send a liaison officer who's a highly trained seismologist usually straight to the Beehive Bunker when it's activated and so they sit in there as a liaison officer. So they would have been providing verbal advice of this kind within, probably within an hour or so of the earthquake having occurred and I think, as we've already mentioned, subsequent to that Kelvin Berryman here was, spent a lot of time in the emergency at ECan, emergency operations centre here providing similar advice to ECan.
Q. And that email attached to some documents didn't it, the first one being document 14A.1 [tab 20 Your Honour].
A. Okay, yep.
Q. That was the attachment?
A. Yes, yeah.
Q. And again you note just at the very end, "The maximum expected magnitude is about 6 and with each day that the event does not occur the probability that it will occur decreases."
A. Right.
Q. So again that's what you're saying to Civil Defence?
A. Yeah.
Q. And you also attached document 14B.1, tab 21. Is that right?
A. Yes.
Q. And again there's a comment down the bottom, "The probability of a magnitude 6 or larger to occur within the next week is 8%."
A. Right.
Q. And then 14C1, tab 22, was also attached.
A. Yes.
Q. And that's just a graphical version of the -
A. The aftershocks decay rate, yes, mmm, mmm.
Q. You mentioned also that you sent information to Orion, that's been referred to already. You also posted information on your website, is that right, and you've produced tab 13, document 8.1. So Dr Webb can you

confirm that that's a document you've produced as being a copy of the post on the GNS internet website?
A. Yes that's right. The content management system as it's called for the website enables us to retrieve what was posted at any particular time and, so that's the, that's the posting from that date, yeah.
Q. The 23rd of September 2010?
A. Mmm.
Q. And if I go to the next page and that's document 8.2, down the bottom you're informing people there that GNS has modelled the aftershock sequence with forecasts in the table below, "Frequency of aftershocks will continue to diminish but they will occur for many weeks after a large earthquake such as this," and then at page 8.3, down the bottom and then over to page 8.4 you're setting out that aftershock forecast. Is that right?
A. Yes so it mentions they'll continue for some months to come, yes and then, that's right the table sets out the expected number at different time periods, the number observed and a four-week forecast. That's right.
Q. You at GNS also produce press releases I understand?
A. Yes, that's right.
Q. Starting off on 4 September and that first one is at tab 16, document 12.1.
A. That's right, yeah.
Q. We should have 12.1 on the screen, that's 12A.1 and in that one Dr Ristau is being quoted as saying, "A rule of thumb for a large earthquake at a shallow depth such as this is that the largest aftershock will be about 1 unit of magnitude lower than the main shock," and it also states, "There are several known active faults under the Canterbury Plains and the Canterbury foothills but at this stage it appears the earthquake has not occurred on a known fault."
1625

JUSTICE COOPER TO DR WEBB:

Q. As I said in two separate paragraphs there. You see those paragraphs there?
A. Ah, yes, yes.

MR ELLIOTT TO DR WEBB:

Q. Document 12A.1, Tab 17, was another press release from GNS on the 10th of September, is that right?
A. Yes that's right, yep.
Q. And in that there's a quote that there's still a possibility of an aftershock larger than those experienced so far but the chances of this happening are decreasing by the day.
A. That's right yep.
Q. And there's also a quote from one of the social scientists you mention down the bottom that people should remember that if they're inside when the shaking starts move no more than a few steps to a safe place and drop, cover and hold.
A. Yes.
Q. And I think, just for the sake of completeness, GNS also released some press releases about placing miniature quake recorders in people's homes.
A. Right, yeah.
Q. In the period following September.
A. Mhm, yeah.
Q. And that was done.
A. Yes, mmm.
Q. And there was another press release issued about there being a good uptake of people who were willing to do that and then at Tab 18, document 12B.1, there was a media release from GNS after the February earthquake, 25th of February, in which it stated that "Aftershocks had been spreading both east and west since the magnitude 7 quake, this has resulted in increased stresses in the earth's crust in the Canterbury region. An expanding cloud of aftershocks,

particularly at both ends of the main fault rupture, was a familiar pattern with large earthquakes worldwide. Dr Berryman saying that seismic energy travelled in waves and could be reflected off hard surfaces much like sound waves with the epicentre of Tuesday's earthquake in the Port Hills a large amount of energy could have been reflected off hard volcanic rock at depth. This would have compounded the impact of the earthquake at the surface. Geologists had suspected for some time that there were buried and unrecognised faults in Canterbury. Some might not have moved for many thousands of years but had been reactivated as stresses in the earth's crust, as the earth's crust had been redistributed since September 2010". So that seems to be the extent of what GNS was saying to the public via media releases, is that right, about up to that date about September and February?

A. Sure. There would have been a lot happening in radio and TV.

Q. I see.

A. That's probably not captured here. Kelvin did you have (inaudible 16.28.45)

DR BERRYMAN:

(Inaudible 16.28.52) a very very constant attention from the radio, print media, television to some extent as well. Um, that may be all of the formal press releases. I honestly don't remember now.

DR WEBB:

Just as an aside, if I may, the, your reference to people volunteering to house miniature earthquake recorders is well worth noting and that the data from those recorders will help to resolve a lot of the issues we talked about this morning so we've got a much higher density of strong ground motion recordings in the Christchurch area thanks to people being prepared to house them and those data will feed through to future research that will help determine whether these things are side effects, directivity, stress drop, whatever. So it's a very important contribution by the community that we would like to note, thanks.

MR ELLIOTT TO DR BERRYMAN:

Q. I'll ask one or two questions about that sequence shortly when I'm talking about the February earthquake. I'm just gonna move on to the September quake in a moment but just one other piece of information which has been referred to as the database of active faults in New Zealand. If a New Zealander out there wanted to know where those active faults were that is something they could access is it via your website or via request.

A. Yes, its accessible on the website to a certain level of resolution through GNS website, go into active faults and it's there, it's available. There's a bit of contextual information. The mapping is not of very large scale or very detailed scale should I say, it would be more simpler. We hold more detailed information than that but it's released as a public, publicly available at a scale, I think its one in 100,000, where you can't zoom to any more than that largely because the information is all not complete at the same scale and with GIS and the like people are notoriously wanting to zoom up to see where their house sits in relation to a fault but the fault is not known to that level of precision. So that's the only, there's a little bit of a filter on it I would say for general public access.

MR ELLIOTT TO DR WEBB:

Q. So you've referred in your report to the earthquake of 7 September – I'm sorry 4 September, thank you Your Honour. Those reading the report will come across the comment that you describe it as a rare and unexpected event. I can refer you to that comment if you like or do you recall that?

A. That's right yes.

Q. Can you just explain to people who might have read that report, we see in the report that there is a diagram in which there seems to have been recorded over 50 earthquakes of more than 6.5 since 1840 in New Zealand. There have been at least two earthquakes local to Christchurch, one under Addington and Spreydon in 1869. There was a, we know of a steady build up of ground deformation to the east of the alpine fault. You've shown us again here and also in your report what looks like quite a patchwork of active faults in the Canterbury and surrounding regions and there's the earlier reference to suspicions of faults for some time. Can you explain to the lay person how they reconcile those things with your statement that it was a rare and unexpected event in September.

A. Right, it would probably be helpful if I could refer to my ancillary information, powerpoint. Sorry I'll try and find it under –

JUSTICE COOPER TO DR WEBB:

Q. Is that Tab 6?

A. Ah, no 10G and slide 10 would be good.

Q. Oh 10G yes it is in our file its Tab 6 I think.

A. Oh it is Tab 6, yes thank you.

Q. Do you want to refer to all of these?

A. I think it's probably the last three but if we started with 10 that would be good.

Q. Well its, that's the one headed Regional (inaudible 16.34.28)

A. Yes.

Q. All right thank you.

A. So in terms of thinking about hazard levels for Christchurch and when we build the hazard model that we've talked about over the past few days there are three independent databases we can use to build that model and we use them in slightly different ways. The thing to note though, all these databases are incomplete and so that's why we call on all three but if we talk through quickly the three, what these three separate sources of data are saying about, say, level of hazard in Christchurch versus that inland or in other parts of the country.

1635

They're all telling the same story so if we look first at the way tectonic strain is accumulating across the country, it's measured by precise, repeat, precise global positioning system measurements to an accuracy each time we do a measurement of less than a centimetre. Go back in a few years and if things have moved, say, 100 centimetres you've got quite an accurate reading. You can produce a map like is shown in this slide where the intensity or redness of the colours relates to the deformation rate so you can see there Christchurch's (inaudible 16:35:50) strain that's accumulating. Christchurch is sitting with a low rate of accumulation compared to say Wellington or Central South Island Alpine Regions. So that's our first line of evidence so when I say all data sets are incomplete these data have been collected over 10 or 20 years. They are truly reflective of the very long-term strain accumulation rates you need to build up strain on a fault that will result in an earthquake. Probably they are but of course we can't be sure but this is what the current strain accumulation is.

Next, I think we want to go up two slides. This might suffice. This slide shows both the other data sets actually or forms of them so firstly the known active faults and we've added in the Darfield fault and the slip rates, the long-term slip rates of those faults so we've got at the far top left of that diagram the Alpine fault with a slip rate, average slip rate, of 27mm per year compared to Porters Pass which actually showed up on our hazard de-aggregation plot the other day, accumulating, strained or average slip rate if you like of 3mm per year. So about a factor of 10 down on Alpine fault. Come to the Darfield fault we're down to .2mm per year. That's probably not terribly accurate but it can't be enormously higher than that, another factor of 10 down and we mentioned a rough calculation because of the offset Jarg had seen with the seismic reflection, the offset of volcanics for the February the 22nd fault where we're down at .01mm per year average slip rate so another factor of 10 down. So the previous slide that I showed had the changes that GPS sees in strain accumulation over the past two decades. These faults are telling us about the rate at which strain is released and of course due to the fact that you can measure offsets of faults that date back to movements thousands of years ago where in the case of the February the 22nd fault, the date is actually covering a time period of up to

8,000,000 years. Here is the same pattern, exactly the same pattern, but it measured, essentially because of the geological data, over a time-frame of up to millions, certainly thousands to millions of years. Our third and complete data set, of course, is historical seismicity as measured by instruments or from other inference in terms of damage to buildings which is gleaned from newspaper reports for earthquakes say in the 1800s and here we've got a reasonably short-term plot of background seismicity in terms of the green and yellow circles, the green being earthquakes in the magnitude 3 up to magnitude 4 I guess and the little yellow dots the twos through to magnitude 3 and that's in the year preceding the September the 4th 2010 earthquake and again you can see that background seismicity rate dropping off as you move away from these high strain rates in the Alps, out towards Christchurch. We should probably also look at historical earthquakes so if we go back two slides. This slide, map of New Zealand, and firstly looking at the colours on the map they are an earlier version I think of our National Seismic Hazard model and also shown on the plot the magnitude six and a half and greater earthquakes that occurred between 1950 and 2006. So the first thing to note which is not that obvious but it is to a seismologist I guess is that there aren't very many earthquakes in that time period. It was very quiet. We were certainly concerned about complacency through a period of low seismic activity particularly when you think about the time period before that but in general those earthquakes occurring in the brighter colours on that plot which are the areas of higher seismic hazard and you'll note again from that version of the hazard model Christchurch sitting in the low to moderate hazard in terms of the green colour on that map compared to the deep reds further inland near Otira and hopefully if we go forward one slide we'll see some more earthquakes added to that plot so this is the preceding roughly 100 years of earthquakes, much more activity over that time period and again generally the earthquakes falling in the areas that the National Seismic Hazard model. So now I've talked about the three sets – so GPS data, fault slip rate data and historical seismicity – that all tell the same story of where the rates of seismic activity have been or are expected to be high in the country. Christchurch sits in a low to moderate category rather than a moderate to high or very high category. Of course as we've mentioned over the past couple of days that's changed now that activity has started here because you've got aftershocks and potentially some other consequent knock-on effects so the hazard will be elevated up towards some of those higher levels for some time.

Q. Just on that last of the three is the reasoning just because it hasn't happened here we don't expect it to happen here?

A. Ah, no because that reasoning would be correct if you went back about 20 years in terms of how we built seismic hazard models and we didn't have good active fault data to inform the models and we didn't have geodetic data. All we had was historical seismicity and you can see from this plot that where the Alpine fault is on this plot there have been no earthquakes but of course we know now that the Alpine fault poses quite a high level of hazard to the Central South Island and that's through bringing in these other data sets so what you say would have been true I don't know maybe 20 or more years ago we would predict the future activity based on where earthquakes occurred in the past and so you'd make some mistakes with that kind of model but modern seismic hazard models, be they New Zealand, US or Japan especially in terms of well developed seismic hazard models taking into account these other factors to give you a more accurate picture of likely future activity.

DR BERRYMAN:

A. You mentioned those early historical earthquakes – 1869, 1870 – those are included in the hazard model for the Canterbury region. They are not excluded or lost sight of. They are part of this expected magnitude 7 earthquake that could occur somewhere on faults that we don't yet know about so those are part of the suite of earthquakes that provides us with the likelihood of earthquakes that are not on known active faults and when we look at the estimates of those from the historical seismicity that magnitude 7 would occur somewhere within the Canterbury Plains once every several maybe five, 8,000 years. So all of the data we've got coming forward is saying that the Darfield earthquake and followed by a very large aftershock these occur, they must occur because of the strain rates, but they will occur on average only once every several thousand years so very unfortunately Christchurch has been exposed to a one in several thousand years event so it makes it rare and very difficult to forecast. On average it's a very, very rare event.

1645

MR ELLIOTT TO DR WEBB:

Q. Can I have document 10C.3 please. I'm just going to ask you to give a little explanation about this diagram for those who may be trying to understand what it means. Am I right in saying that each of those coloured spots on the diagram is, effectively, the epicentre of an earthquake.

A. Yes that's right.

Q. And the epicentre of an earthquake is the surface point above which the energy of that earthquake emanates.

A. Ah, not quite, so for a small earthquake that's true because it's small, spatially the area of fault that ruptured is small so the dot above the epicentre is a good representation of where energy was released from at depth within the earth below that point. For a large earthquake that's not true because faults, as you can see from this diagram with the big yellow dashed and red line, are quite long and so for the Darfield earthquake the epicentre is the green star with the black outline, that's where below that point on that map, that's where the earthquake started, its where the earthquake initiated and, of course energy was then released from that point in a southwest direction on that yellow dashed fault and then a lot of energy as the rupture moved along the red line moving towards Christchurch. So you can see energies released over a big area but started at the green start.

Q. Earthquakes, am I right, can only occur on a fault?
A. That’s essentially true yes, earthquakes occur on faults and if it’s a big earthquake it has to be on a big fault. Often a small earthquake might occur on a very small fracture or fault but equally well could occur as just as a rupture on a part of a large fault.
Q. A fault being, maybe its crude, putting it crudely, but its an area of stress under the ground.
A. Well its, no its more really a fracture in the rock, um, yes, often a plainer fracture in the simplest case but can be more complex than that, yeah.
Q. So below each of those coloured dots on that diagram there is a fault.
A. Yes, yes that's right, but could be very very small.
Q. And so one of your roles since September and so on has been to identify what those faults look like.
A. Um, I guess the concern, as I said large earthquakes occur on large faults so if we’re worried about what’s going to do bad things to us in terms of damage we worry about where the bigger faults are because the crust is just permeated with these smaller fractures, some of which might be inactive and others which might be more active. The thing we worry about are the bigger faults that will support large earthquakes.
Q. So looking at the yellow line running from south west to north-east there are a series of red and blue dots below that line –

JUSTICE COOPER:

There's a number of lines that could be described in that way Mr Elliott. Are you talking about the one, the more easterly –

MR ELLIOTT:

The eastern lines Your Honour.

MR ELLIOTT TO DR WEBB:

Q. Those red and blue dots might be part of that fault that you’ve delineated with the dotted yellow line because the fault runs at an angle under the ground, is that right?

A. Yes, that's a pretty good description so yes with it dipping to the south-east – thanks Kelvin – yes a lot of those earthquakes will be very close to the fault-line or probably on it and then others are a bit further away in terms of stress changes have affected a bigger area and they're part of that stress redistribution process. For the post-June event, which are the blue circles, I'm not sure how apt that, that's an earlier interpretation the orthogonal or right angles yellow dotted line clearly, as Jarg has mentioned, there's activity happening on an extension of that line further to the south or the south-east.

Q. And I'm sorry the work you were doing with the machine from Canada involves working out how big the faults might be does it so that you can know what forces to expect.

PROFESSOR PETTINGA:

It initially is used to investigate whether there are actually faults present that are, that have evidence of displacement of the strata extending up towards the ground surface. In combination with the aftershock seismicity information that we see on this map we're able to put some possible constraints on the lengths of those faults as well, so that's the combination of those two that provide us with some idea of the length and location and the proximity to the ground surface of some of those faults that we were describing yesterday.

MR ELLIOTT TO DR WEBB:

Q. Just a few questions now about the earthquake of 22 February. We've learned that there were statements made, in one form or another, about the possibility of an aftershock of one magnitude less. Just really asking you to address a perception that some may have had within Christchurch that our city or out building or our house got through the seven so we'll get through the six. It's emerged that the magnitude of an earthquake is different to what might be felt at a particular site, is that correct, they are two different things?

A. Yes, so, that's right, so just to refresh people the magnitude is a measure of the size of the earthquake in the earth and can be related to the size of fault that ruptured and how much slip was on it. Whereas, of course, everyone knows how the intensity of shaking varies between different earthquakes and, of course, that's dependent on the size but also how far you are from that fault that ruptured because the shaking dies off very quickly with distance.

Q. So in terms of what we might learn, I suppose, from this is that magnitude may not give a good indication of ground accelerations if, for example, it's a lower magnitude earthquake but it's closer to a city.
A. Yes that's right.
Q. Or shallower or if there are effects such as stress drop or a basin effect.
A. Yes.
Q. They are things which might mean that a lower magnitude earthquake could result in higher ground accelerations at a particular site.'
A. That's right yep.
Q. You mentioned in your report that there's a scale called the Modified Mercalli Scale.
A. That's right.
Q. As one measure of earthquake force for want of a better word. Could that document be…

DISCUSSION BETWEEN JUSTICE COOPER AND MR ELLIOTT

Q. You've, there's a Modified Mercalli Scale for New Zealand isn't there?
A. Yes, there's a version that's customised to New Zealand in terms of the descriptors, that's right.
Q. But you've, in fairness I've only raised this question yesterday, you've not been able to produce that document today but will you produce that document please to the Royal Commission.
A. Oh sure, yeah.
Q. And I've shown you and the Commissioners have a document which apparently emanates from California. You've read that document.
A. Yes.

1655

Q. And does it generally accord with the modified Mercalli intensity scale in New Zealand subject to some alterations which you'll (inaudible 16:55:12) point out?
A. That's right, yes, mmm. The, I think the New Zealand system's called Modified Mercalli. I'm not sure if overseas ones, but certainly we've, in the past that original document's been taken and customised, the words customised to suit New Zealand context in terms of how you assess levels of shaking that you're experiencing.
Q. So that scale provides 12 different categories of, I suppose, subjectively, what type of experience a person might have of a different, different types of earthquake. Is that right?
A. Yes, that's right.
Q. Ranging from instrumental then to weak and slight up to intense, extreme and cataclysmic?
A. Right.
Q. And to give an example an intense earthquake is described as, "Some well-built, wooden structures destroyed, most masonry and frame structures destroyed with foundation rails bent." Can we go to slide 10A.8. So that was, was that the situation in terms of aftershock activity up until 22 February 2011?
A. Yes that's right.
Q. So as at that time we knew that there could be an aftershock of up to 1 magnitude less anywhere within the aftershock zone?
A. Yes that's right, yep.
Q. And the aftershock zone includes those areas in which the green dots appear?
A. Yes you have to be a little bit pragmatic about how you define the zone because you can see green dots up in the top left-hand corner which may be part, you'd have to check the rates but may be part of –

INTERJECTION, UNKNOWN SPEAKER:
They're triggered.

EXAMINATION CONTINUES: MR ELLIOTT

A. They are triggered, right but you, remember you have some background, a low level of background activity going on. So when you look at aftershocks for such a long period there's some background events. So when you draw a circle around what you're going to call the aftershock zone you just have to use a little bit of judgment and allow some points to lie outside that zone but even so, I mean if the point you're making, there were early aftershocks near Lyttelton is it and obviously the Boxing Day activity. You'd incorporate all them. If you're to draw a line around the aftershock zone they would fall within it.

Q. So the Box - Central Christchurch, does that indicate where the Boxing Day aftershocks were?

A. Yes, mmm, yeah.

Q. So if someone had come to GNS say after Boxing Day and said, we just want to give the people of Christchurch an understanding of what to expect if this one less occurred under the city could GNS have calculated the likelihood ground forces and given a figure say based on the Mercalli scale that would have given people an understanding of what they might expect.

A. Yes it's quite straightforward to, to calculate a diagram showing the Mercalli intensity and so when an earthquake occurs at any time in New Zealand the GeoNet website puts up the calculated Mercalli intensity because by then the magnitude and depth of the earthquake are known. So it calculates and produces the map, essentially automatically. So that can certainly be done and it can be done for any scenario in terms of depth, magnitude and location.

DR BERRYMAN:

Could I just add a small point, point to that. I think your line of questions is really valuable and certainly in that period of December and January we're very aware of where would this magnitude 6 occur if it were to occur and I guess we were guided by at that stage with that plot there that where most of the aftershocks were occurring that's where most of the stress was being felt of this redistribution of the stress field and so if we were to think that there's going to be a magnitude 6 somewhere we did communicate the thought that the worst possible case was directly under the city in the Boxing Day area. Another possibility is out to the south-west there where, around Wigram or Lincoln, another area is at Rolleston and another area is a way out at Hororata. So for the city those different scenarios, my guess, you would have an mm intensity in the city that could range from 2 to 10, given those different distances and scenarios. There's about five or six obvious scenarios where that future earthquake might occur within that aftershock region.

MR ELLIOTT TO DR BERRYMAN:

Q. Sorry do you mean 2 to 10 on the Mercalli -
A. Yes.
Q. - scale.
A. So that's not particularly helpful in terms of advice going forward. You can be particularly optimistic or particularly pessimistic and so it wasn't really a reasonable approach to try and do that at that time because of the range of places, judging by where the stress was being redistributed the ranges of places where that magnitude 6 might occur.
Q. Is there a social science dimension to GNS's decision about what to communicate. By that I mean, for example, we don't want to alarm people?
A. No, not to not communicate but not to alarm unnecessarily but earlier on a piece of work, one of the pieces of evidence brought forward it, it did say that we will be open with all of the information we have and that was in writing and that's very much the policy.

DR WEBB:

Perhaps also, and we almost touched on this earlier in terms of the social science advice, in the very early post-September period. So we're only talking about the first couple of weeks, basically the social science advice, as I can express it as a physical scientist, was basically that you've got a traumatised population and what can you do to help them cope best and that really is to get them coping with aftershocks. So it was fine to talk about aftershocks and the, they have a need and a right to know so that's why this, we regularly talked about the possibility of a 6, so that certainly wasn't, wasn't being hidden but was thought unhelpful at that time and this is just the first couple of weeks is talking about the possibility of an event bigger than Darfield itself – in terms of its magnitude and so that doesn't really occur very publicly in what we're telling people for some weeks later when we're talking about 5 and above or 6 and above. So that was the social science advice. So basically all information but in terms of information that wasn't going to be helpful in terms of their coping in that first couple of weeks. There was, there was not a lot of emphasis on this, the things we've talked about over the past few days of the likelihood of, of triggered, larger events, somewhere in the greater region and these are issues now that are being talked about very openly and people have to plan for and the likelihoods are reasonably low so that, in those first couple of weeks the advice was that, let's get people focussed on coping with their response and recovery and the ongoing aftershocks.

DR BERRYMAN:

And preparedness being the principal way that the general public can cope with further earthquakes is the same consistent message about being prepared, coupled with the probability of these really large earthquakes being quite small, especially a triggered, larger event than the Darfield earthquake. The probability was even at the beginning quite small, that's rather alarmist to say there could be even bigger, I'm talking magnitude now, not intensity, that that would be an even larger event. So only the fact that a larger than magnitude 7 earthquake with a probability down in the 1 or 2%, that was thought to be unhelpful.

JUSTICE COOPER TO DR BERRYMAN:

Q. On this slide that's displayed, the fault that ruptured on the 22nd of February is also shown isn't it?
A. Yes that's like a forecast. It's shown in advance of the –
Q. It's a bit confusing isn't it –
A. Yes.

Q. – when it's purporting to show the position up until February the 21st but that's, that's just to remind us of where it was when it eventually did rupture.

DR WEBB:

And also perhaps to bring attention to the fact that those two larger earthquakes near Lyttelton probably did lie very close to the fault plane that did finally rupture, in fact could well have been on it. Kelvin can you comment on the exact relocations, what they show?

DR BERRYMAN:

I, I don't, I'm not aware of the exact relocation but it must have lain very close to the eventual rupture in 22nd February but that, that was the 8th of September aftershock which did upset the city quite a lot. I know I was there at the Latimer Hotel.

JUSTICE COOPER TO MR BERRYMAN:

Q. Where's that shown on this?
A. That's the one near Lyttelton between the city centre, across the line of the future fault, to lie just north of the Lyttelton harbour, that one there. That was a 5.1, 8th of August, only three days after the Darfield earthquake and even up until that time –
Q. What date – 8th of September.
A. Sorry 8th of September.
Q. Your forecasting again.
A. Yes I'm not very reliable. Um, so that was thought to, even up until that, just before February the 22nd rather an outlier in that whole pattern but with hindsight we recognise that's where the February 22nd earthquake came back to.

COMMISSION ADJOURNS: 5.07 PM