

Lessons from the Canterbury events: preliminary improvements to the online felt reports

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ABSTRACT: In 2004, the GeoNet project operated by GNS Science implemented an internet-based questionnaire. Its aim was to provide an automatic intensity assignment in New Zealand's Modified Mercalli (MM) intensity scale based on answers to a set of standardized questions. The devastating Darfield (4 September 2010, $M_w=7.1$) earthquake and its two main aftershocks (22 February 2011, $M_w=6.2$ and 13 June 2011, $M_w=6.0$) have shown how well-known these reports have been to the public, with nearly 15,000 reports completed. For these shocks, nearly 600 reports have been assigned with MM intensity values of 8 or above, indicating major earthquake damage and the need for a detailed analysis of the damage, building by building. This huge amount of invaluable information has served as a way of testing the methodology and provided a check for any further required information. The usability of the web interface is also being reviewed to remedy common mistakes and to adopt concepts common in other online questionnaires. New improvements are proposed for the algorithm, including new questions to take account of all types of damage and other relevant issues. These changes could provide an improved algorithm to assign intensities in a more reliable way in future New Zealand events.

1 INTRODUCTION

In 2004, GeoNet implemented an algorithm to automatically assign intensity values in New Zealand's MM (Modified Mercalli) intensity scale (Dowrick 1996), based on felt information captured from a web interface questionnaire. The algorithm used to assign intensity values looks for multiple indicators of an intensity level through the answers given in the felt reports. It uses an upside-down pyramid technique, where more positive indicators are required to move to the next intensity level, and assigning an intensity when there are not enough indicators for the next level (Coppola *et al.*, 2010). The felt report questionnaire is divided into seven stages: *Your details* (stage 1), *Your experience of the earthquake* (stage 2), *Earthquake effects within your building* (stage 3), *Earthquake effects to your building* (stage 4), *Neighbourhood effects* (stage 5), *Your comments* (stage 6), and *Summary* (stage 7).

The success of the online questionnaire project was seen following earthquakes such as the magnitude 6.8 Gisborne event in December 2007, when more than 3,400 felt reports were received. The high public response to the initiative resulted in the increase in the number of felt reports by up to two orders of magnitude since its implementation in 2004 until 2010 (Coppola *et al.*, 2010). The Canterbury earthquakes of 2010-2012 have challenged the facility, when it needed to deal with more than 7,500 felt reports for the September 2010 Darfield event, over 4,200 for the Christchurch main aftershock in February 2011 (figure 1) and over 3,000 for the June 2011 shock. The number of felt reports received is still increasing with the most recent events of 23 December 2011 and 2 January 2012, with more than 2,100 reports received up to the present. The online questionnaire is providing invaluable information for our better understanding of the site effects occurring in the region as well as the damage caused to residential and commercial buildings, besides providing very useful information for emergency management agencies.

GeoNet's felt reporting questionnaire has been thoroughly reviewed, following the main Canterbury earthquakes. The large number of felt reports received have given us a great opportunity to check how the questionnaire was working among end-users (or reporters) and look for improvements to the process. Importantly, the large number of felt reports assigned automatically with intensity 8 (nearly 600 for the December 2010, February 2011 and June 2011 events), needed to be manually reanalysed individually in order to assign an appropriate intensity value, as the existing algorithm is limited to assign intensities up to not more than 8 (Coppola *et al.*, 2010). Above MM 8, buildings start to suffer considerable damage and the assignment of intensity values turns into a more complicated task which involves an engineering study of the building's damage level and building class (Coppola *et al.*, 2010).

Apart from assigning intensity values, the review of the first 300 felt reports with MMI=8 from the 22 February 2011 event identified advantages and disadvantages with the 2004 version of the questionnaire.

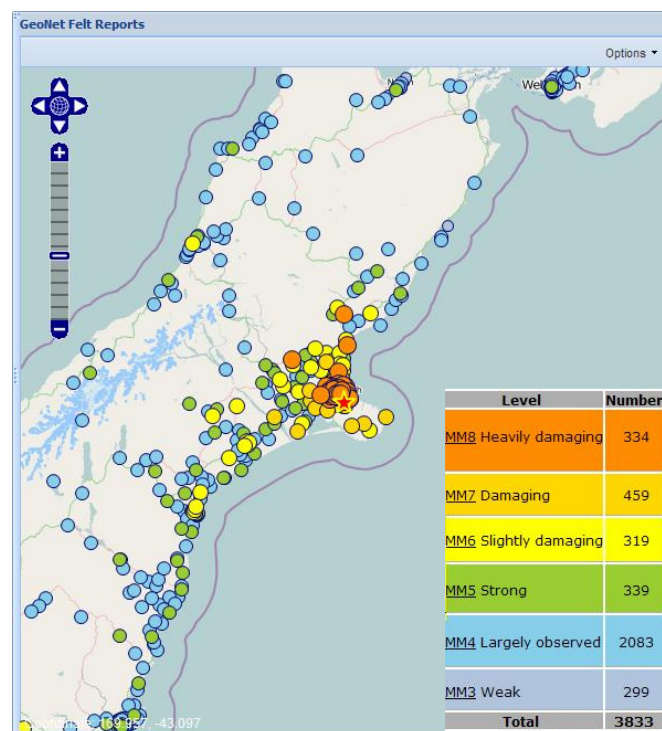


Figure 1. Modified Mercalli intensity values for the Canterbury region from the 22 February 2011 Christchurch earthquake, obtained from GeoNet's online felt reports (<http://www.geonet.org.nz/earthquake/quakes/3468575g-shaking.html>).

The experience from the Canterbury earthquakes have also driven improvements in the usability of the web interface. Background information, accessed by a mouse click, will be provided in future versions of the online felt report. This information will clarify issues such as why certain questions are being asked, what each possible answer means and why the answers to each question will help to assign an intensity value. These improvements will lead to a more comprehensible tool where end-users will find it easier to answer the questionnaire in a more reliable way. It will also help them to understand the importance of each of the questions to provide realistic intensity and damage results, and, in a more global way, the great value of their contribution to understanding New Zealand earthquakes.

2 PROPOSED IMPROVEMENTS TO GEONET'S QUESTIONNAIRE AND ALGORITHM

The proposed improvements for GeoNet's online questionnaire can be classified into different types: mandatory questions, changes in the questions, changes in the answers, changes in the order of the answers and new questions. All these changes in the questions and answers will derive in changes in the algorithm to assign the intensity values.

2.1 Mandatory questions

These are questions that should always be answered by the reporter in order to obtain a valid felt report. These are marked with an asterisk and a blank response to any of them prevents the reporter from going any further in the report. Mandatory questions can be classified in two groups: a) personal data (to contact the person if necessary, such as the name and address), and b) basic data (essential data to assign an intensity value, from the address, date and time of the event to the main questions used in GeoNet's algorithm to assign an MMI value, mainly from stages 2, 3 and 4 (Coppola *et al.*, 2010)). In the present questionnaire, some mandatory questions from class a) are not marked with an asterisk. This causes some users to be unable to continue with the report if they have not answered all of these questions, without knowing why they cannot go any further. Class b) mandatory questions are answered by default as "Don't know/Not applicable" in the current version of the questionnaire. This solution was considered to prevent having any of these questions unanswered before going further on, but this could imply that if any of these questions are skipped by mistake by the reporter, some reports could have non-realistic answers to essential questions. Instead, class b) mandatory questions will be treated as class a) ones: questions will not be answered by default and an asterisk will be shown beside the question. The algorithm will be changed to prevent reporters who have not answered all of these questions from going further on in the report.

2.2 Changes in the questions

Some questions need to be changed in order to be better understood and to avoid confusion. This change affects three questions of the current questionnaire:

1. Question FR4-3: *Choose the most severe damage that occurred to brick/concrete chimneys:* this question is looking for the damage to the chimney of the building where the reporter felt the earthquake, and not for damage to chimneys in general, as it seems to be referring to. In order to avoid wrong answers, the question will be changed to: *Choose the most severe damage that occurred to the brick/concrete chimney in the building where you were.*
2. Question FR5-4: *Did any of the following ground-related damage occur? Check all that apply, if any:* This question from stage 5 (neighbourhood effects) can give us a great amount of information about the effects on the environment, such as landslides or cracks. It can be answered with several answers by ticking different boxes. But the question could be misunderstood by making reporters think they can only give one answer. This has been the case in some of the reports analysed. In order to avoid confusion, the question will be changed to: *Did any of the following ground-related damage occur? Check all that apply, if any (more than one answer is possible):*
3. Question FR5-5: *Did any of the following effects occur? Check all that apply, if any:* This question is looking for effects on the water, searching for tsunami or liquefaction effects. Similarly to question FR5-4, several answers are possible but this is not clear in the way the question is written. To avoid confusion, the question will be changed to: *Did any of the following effects occur? Check all that apply, if any (more than one answer is possible):*

2.3 Changes in the answers

Slight changes have been proposed for the answers to two of the questions that could improve the understanding of the questions as well as the assignment of the intensity level:

1. Question FR2-3: *What were you doing when the earthquake occurred?* This question is looking for the kind of activity the reporter was doing when the event occurred. The answers to the present question are: *Sitting/Lying; Standing; Walking/Running; Sleeping; Travelling in a vehicle.* While these answers cover the main activities referred to in the intensity scale, the answer related to sleeping should be separated into two possible answers in order to know if the reporter was woken up by the event or not, an essential data in macroseismic scales. The former would lead the algorithm to the next question and assign a non-zero intensity value,

while the latter will be considered “not felt”, and thus the report will have a null intensity value. The proposed new answers to this question will be: *Sitting/Lying; Standing; Walking/Running; Sleeping and slept through it; Sleeping and was woken up; Travelling in a vehicle.*

2. Question FR2-4: *How would you best describe the shaking?* The way people feel the shaking is a mandatory question used to assign an intensity value, and thus needs to be well understood by the end-user. The descriptions of the possible “shaking intensity” felt by the reporter need to be very clear. An information panel to be opened with a click or mouse-over in case the reporter needs extra explanation for each of the answers is being implemented in the questionnaire (see the usability section below). In addition, two of the answers to this question will be changed by adding an example of the passing of different vehicle traffic similar to that shaking levels: answers *Gentle, hardly recognised as an earthquake* and *A jolt or mild, but unmistakably an earthquake* will be changed to *Gentle, hardly recognised as an earthquake (vibration similar to the passing of light trucks)* and *A jolt or mild, but unmistakably an earthquake (vibration similar to the passing of heavy traffic)*, respectively.

2.4 Changes in the order of the answers

Most questions in the present felt reports have been organized to have answers of the type: No damage-Low damage-High damage-Don’t know. This order is considered the best one and is widely used in other online questionnaires (Euro-Mediterranean Seismological Centre, EMSC; European Seismological Commission, ESC; USA “Did you feel it” questionnaire, Wald *et al.*, 1999; British Geological Survey, BGS). Answers to all questions should have the same structure to avoid reporters making mistakes in their answers. It is highly recommended to maintain this structure throughout the felt reports. Some of the questions in the present questionnaire do not have this order in their answers and will be changed accordingly. This applies to the following questions:

1. Stage 3 questions: FR3-5 (*Were cupboard or appliance doors thrown open?*, which will have the answers in the order *No; Yes; Yes, and contents were ejected; Don't know/Not applicable*), FR3-6 (*Did any small items of furniture, appliances (such as TV, computer, microwave) or light machinery slide (not just sway) or topple over?* , new answers *No; Yes, slid a little (less than 5 cm); Yes, slid a lot (more than 5 cm) or toppled over; Don't know/Not applicable*), and FR3-7 (*Did any large fixtures, appliances (such as fridge, stove or filing cabinet) or heavy machinery slide (not just sway) or topple over?*, new answers *No; Yes, slid a little (less than 5 cm); Yes, slid a lot (more than 5 cm); Yes, toppled over; Don't know/Not applicable*).
2. Stage 4 questions: FR4-1 (*Was the hot water cylinder (not header tank) damaged?*, new answers *No; Leaked; Fell over; Don't know/Not applicable*), FR4-2 (*The hot water cylinder is...*, new answers *Not restrained; Restrained; Don't know/Not applicable*), and FR4-4 (*The brick/concrete chimney is...*, new answers *An old chimney (that is, not reinforced); A modern chimney; Don't know/Not applicable*). This last question involves higher intensity values for a modern chimney having the same damage than an old chimney.
3. Stage 5 questions: FR5-1 (*How many chimneys were damaged or fell?*, new answers *None; A few; Many; Most; Don't know/Not applicable*) and FR5-3 (*Did any underground pipes develop leaks or cracks?*, new answers *No; Yes; None; A few; Many; Don't know/Not applicable*).

Other questions where the order is being changed are questions FR4-11 (*The ground is mainly...*) and FR4-12 (*When was the building constructed?*), where the *Don't know/Not applicable* answer is being changed to the end, to be consistent with the rest of the questions and avoid possible mistakes.

2.5 New questions

The analysis of the Canterbury sequence online felt reports has also been useful to look for possible new questions that could help assign intensity values in a more reliable way. These have been considered necessary to take into account new information not used before. The new questions

proposed for the new version of GeoNet felt reports are:

1. Question FR2-5: *What was your reaction?* The observer's reaction to the earthquake is a very useful type of information usually included in online reports but not included in the present felt report. It will be added as a mandatory question and could be used to assign an MMI value. The preliminary proposed answers for this question are: *No reaction/Not felt; Very little reaction; Excited but not alarmed; A bit frightened; Very frightened; Extremely frightened/Panic; Don't know/Not applicable.*
2. Question FR2-6: *How was the earthquake felt by other people?* How other people felt the earthquake is essential data that should be added as a question in stage 2 of the felt report. Although not a direct personal experience from the reporter, this question could enormously help to distinguish MMI values up to 7. The recommended new question may be used to assign an intensity value and added to the list of mandatory questions. The proposed possible answers are: *Only felt by people on upper floors; Generally noticed by people indoors, but not outside; Generally noticed by people both indoors and outside; Don't know/Not applicable.* Note: this question is already in the felt report as a non-mandatory question in stage 5 with different possible answers. We think this question should be mandatory and included in stage 2, in order to calibrate the minimum intensity value before carrying on with damage descriptions to the houses and buildings (stages 3 and 4). The proportion of people who felt the earthquake is a very valuable type of information. Also, the wording of the answers are now more adapted to MMI scale descriptions. In any new version of the questionnaire, the question in stage 5 will be replaced by this one in stage 2.
3. Question FR2-7: *Where you were at the time of the earthquake, did anyone run outdoors in fright?* Other people's reaction to the earthquake may also be included and used to assign a MMI value (so added as a mandatory question). Possible answers are: *No one; One or two; Few; Many; Most; Everyone; Don't know/Not applicable.*
4. Question FR3-3: *Did doors and/or windows rattle?* A question related to the doors and/or windows rattling could be added and used to assign a MMI value. It is a classic test for an intensity value of 4 or above and should be a mandatory question that could be treated in the algorithm in the same way as question FR3-4 (related to effects on glasses, dishes and ornaments). The proposed answers to this question are: *No; Rattled slightly; Rattled loudly; Don't know/Not applicable.*
5. Question FR3-8: *What other effects were caused to objects? Check all that apply, if any:* In order to assign MMI values with a higher level of confidence (especially for values between 5 and 7), some questions related to effects on fittings may be added in stage 3, especially in objects not considered at the present in the felt reports such as open doors, pictures, bells and pendulum clocks. These questions could be treated as extra information which could help to distinguish between consecutive MMI values, but should be used to assign a MMI value, and they are added to take advantage of the richness of the macroseismic scale. A basic tick box option is suggested for these questions, and the possible answers are described as follows: *Filing cabinets or "easy glide" drawers opened (or shut); Open doors swung; Glassware and/or crockery were broken; Windows cracked; Earthenware toilet fixtures cracked; Pendulum clocks stopped, started or changed rate; Hanging pictures knocked against the wall; Hanging pictures fell from the wall.*

Table 1 shows a summary of the improvements proposed for the new GeoNet online questionnaire. These are currently being carefully analysed and considered for future versions of the algorithm.

3 ADDITIONAL IMPROVEMENTS AND USABILITY OF THE WEB INTERFACE

The many tens of thousands of reports received during the Canterbury sequence have also served to identify areas that can improve the quality of macroseismic information. The GeoNet system development team is currently refining the questionnaire to address these issues.

Table 1. Summary of the proposed improvements in GeoNet's online questionnaire.

Ref.	Question	Changes			
		Mandatory	New	Quest ¹	Ans ²
FR1-1*	Name	√			
FR1-2*	Email address	√			
FR1-3*	Road address	√			
FR1-4*	Suburb or town, homestead name or nearest locality	√			
FR1-5*	City or region	√			
FR1-6*	Date of earthquake	√			
FR1-7*	Time of earthquake	√			
FR2-1*	Where were you at the time of the earthquake?				
FR2-2	What was the built environment?				
FR2-3*	What were you doing when the earthquake occurred?				√
FR2-4*	How would you best describe the shaking?				√
FR2-5**	What was your reaction?		√		
FR2-6**	How was the earthquake felt by other people?		√		
FR2-7**	Did anyone run outdoors in fright?		√		
FR3-1	Please select the type of building or structure:				
FR3-2*	Did hanging objects sway?				
FR3-3**	Did doors and/or windows rattle?	√	√		
FR3-4*	Did objects such as glasses rattle, topple over or fall off shelves?	√			
FR3-5*	Were cupboard or appliance doors thrown open?	√			√
FR3-6*	Did any small items of furniture slide or topple over?	√			√
FR3-7*	Did any large fixtures slide (not just sway) or topple over?	√			√
FR3-8**	What other effects were caused to objects?		√		
FR3-9	Check which services failed, if any:	√			
FR3-10*	Was there any damage to the building itself?				
FR4-1	Was the hot water cylinder (not header tank) damaged?				√
FR4-2	The hot water cylinder is...				√
FR4-3	Choose the most severe damage that occurred to chimneys:			√	
FR4-4	The brick/concrete chimney is...				√
FR4-5	Choose the most severe damage that occurred to water tanks:				
FR4-6	Choose the most severe damage that occurred to exterior walls:				
FR4-7	Choose the main building material for the exterior walls:				
FR4-8	What damage occurred to the entire building?				
FR4-9	What other damage occurred? Check all that apply, if any:				
FR4-10	Choose the structural style of the building foundations:				
FR4-11	What is the main type of ground under the building?				√
FR4-12	The ground is mainly...				√

*Mandatory questions; **New questions; ¹Changes in the question; ²Changes in the answers

Table 1. Summary of the improvements in GeoNet’s online questionnaire. (cont.)

Ref.	Question	Changes		
		Mandatory	New	Quest ¹ Ans ²
FR4-13	When was the building constructed?			
FR4-14	What do you believe caused the building damage?			
FR5-1	How many chimneys were damaged or fell?			√
FR5-2	How much damage was suffered by stone/brick/concrete walls?			
FR5-3	Did any underground pipes develop leaks or cracks?			√
FR5-4	Did any of the following ground-related damage occur?		√	
FR5-5	Did any of the following effects occur?		√	
FR6-1	Your comments			

*Mandatory questions; **New questions; ¹Changes in the question; ²Changes in the answers

Note: some questions have been shortened with respect to the felt reports

1. Address matching

The matching of reports to New Zealand place names is best achieved when a suburb or locality is combined with a region name. Lists prompting the reporter with common locations will help them fill in the form and prevent misspelt place names.

Separate boxes will be used to isolate postcodes and rural delivery numbers so that they do not interfere with address matching logic, which has been a significant problem

2. Earthquake matching

In choosing earthquakes to report, the end-user will be told how long ago the shake occurred. It is erroneous to assume that a person feeling an earthquake can judge accurately when it occurred and what its magnitude was. When felt earthquakes are isolated in time, this works satisfactorily, but during periods of high seismicity, letting the user choose their event by “time since the shaking” is the best method of getting them to choose the correct event.

3. Form usability

It is intended to retain the current layout of questions and answers, and to also provide supplementary information as to why the questions are being asked and how the answers help the derivation of the intensity (figure 2). Descriptions of some of the answers to help end-users choose correctly will also be provided. This will include descriptions on the “shaking intensity” levels (gentle, jolt, moderate, strong, violent) and clarifying concepts (like the way to distinguish between a hairline crack and a wide crack). This extra information will be available as mouse-over spots next to the questions.

4 CONCLUSIONS

The Canterbury earthquakes have provided a rich resource of information to geologists, seismologists and engineers, who are now updating their models and improving their understanding of the seismicity and seismic hazard in the region. GeoNet’s online felt reports contain much about macroseismic intensity, site effects and building damage effects that can be extracted from the nearly 15,000 felt reports received from the general public. The Canterbury earthquakes have been the biggest test of the present algorithm and have helped identify areas for improvement, including the usability of the web interface.

All of the proposed improvements are being considered for implementation in the next version of GeoNet’s online questionnaire, as a result of lessons learned from the Canterbury earthquake sequence and the public reporting of the felt effects.

GeoNet Felt Report

The location where the earthquake was felt.

Street Address: 12 High Street
e.g. 2740 Winding Road or 11b High Street or Flat 4, 42 Victoria Road

Rural Delivery (RD) number: (Optional)

Postcode: (Optional)

Suburb, Town or City: A
Halswell Richmond
Homby
Hoon Hay
Havelock North
Hastings
Harewood
Heathcote Valley
Hokowhitu

Region or Province:

Date of earthquake:

Time of earthquake:

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Figure 2. A mock-up of the proposed address collection screen for the new online questionnaire, showing the question marks to allow the viewing of supplementary information, and prompt boxes for the more common locations in New Zealand.

5 ACKNOWLEDGEMENTS

The authors wish to thank the GeoNet team for the implementation and monitoring of the online earthquake questionnaire. This work would not have been possible without the efforts of so many people in the Canterbury region who have generously filled in felt reports after each of the earthquakes, providing us with a great amount of information to understand the extent of the damage caused and look for improvements for future implementations.

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