Earthquake preparedness:
Movement of persons to a safe area

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World population has grown from 1.5 billion to over 7 billion in the last century and migration to urban areas is at its highest. As a result, human and economic loss associated with earthquakes has increased substantially. Past catastrophic events in Japan, Chile, and Mexico have prompted government officials, citizen groups and non-governmental organizations to work together to establish a systemic culture of preparedness, resilience and education which have become international models.

One aspect of hazard mitigation has been the implementation of a public earthquake early-warning systems. This system requires both the capability to alert all citizens as well as to solidify competent population response. In order for these systems to succeed, it is required that the technology of early notification is sound and accurate and that is combined with a well-established and well-practiced response (movement plan). Preparedness of citizens to respond appropriately is paramount. Therefore, drills and education of residents are necessary components for a successful process. The timing of the warnings is directly related to the proximity of the epicenter and, thus, the public is directed to evacuate to appropriate safe areas (Espinosa-Aranda, Lee, 2003).

Structural collapse is the primary cause of casualties in an earthquake, accounting for 75% of all deaths – with 25% of casualties due to non-structural causes (refer to pie chart below). Additionally, the time of day that an earthquake occurs has long been known to affect the number of people killed (Coburn, AW, et al. 1992, Coburn, AW 1994). For example, during the Great Tokyo earthquake of 1923, 447,000 people died because it occurred during lunch time when people were using their stoves. Moving to a safe area prior to building damage prevents human loss and reduces injury. Although fear is a natural emotion at this time, emotional reaction does not result in panic behavior (Bourque, et al. 1992, Prati et al. 2012). Furthermore, selfish behaviors are practically non-existent, while helpful behavior and cooperation are frequent (Bourque, et al. 1993, Drury and Cocking 2007, Ohta and Ohashi 1985, Prati et al. 2012). Mawson (2005), in his Social Attachment Model of human behavior in disasters, concludes that affiliation and cooperation are typical responses in the event of a disaster.

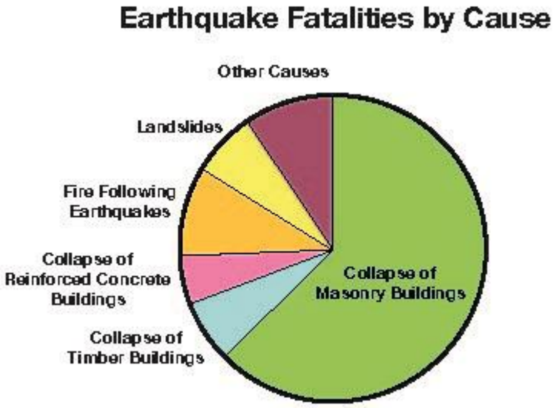

Figure 1
Causes of Death in Earthquakes 1900-1992

(*Note that fatalities due to earthquakes from 1993-2011 totals 1,154,630 - USGS. But, according to a publication by USGS Geological Survey engineering geologist, Thomas L. Hozer (March 2013), it is estimated that, 'A total of between 2.6 and 3.1 million people are estimated to die in quakes in the (21st) century…The number of quakes with a death toll over 50,000 may climb to 25 from a total of only seven in the 20th century. Those numbers assume the global population will climb to 10.1 billion by the year 2100.')

Coburn, et al. (1992) further explains occupant survival and building collapse by stating,

> "…it is clear that not all the occupants that are inside a building when an earthquake occurs are trapped if it collapses. People escape before collapse, or the collapse of the structure is not total, or they are able to free themselves relatively easily by their own efforts….A large magnitude earthquake can have a minute or more of strong ground motion but the strongest amplitude shaking often occurs during the early part of the earthquake. A ductile building may collapse over a period of several tens of seconds. A brittle building may collapse more quickly. In the epicentral areas of large earthquakes there are reports of weak buildings collapsing almost instantaneously. Tests of evacuation times show that people cannot get out of a building from anywhere above the first floor in less than thirty seconds, even if they are capable of walking during the violent shaking (Georgescu 1988). "

Mexico is a leader in terms of earthquake preparedness and resilience. The most extensive research found in publication on these two subjects have been written about Mexico's approach to preparedness and resilience. The program for rapid response for public and private schools for children in Mexico City started after the September 1985 earthquakes which killed more than 10,000 people and injured 30,000. The Mexican Secretariat of Public Education proposed the practice of preventive actions and, since 1992, response plans in the schools have been drawn up as part of the earthquake hazard reduction program**.** Evacuation drills at schools are held monthly and at times with even greater frequency. Officially, the education program for rapid response has become a part of the Mexico City public school program. Children in secondary schools leave the classroom and the ensuing evacuations are orderly and well-coordinated. Children unable to evacuate, due to location, move to pre-designated safe places (Espinosa-Aranda, Lee, 2003).

In the Mexico City community of H. Rosario, towers broadcast a clearly audible signal when the SAS is activated. This system functions without difficulty, affording residents of the community sufficient time to evacuate their apartments. A community organization had been created after the 1985 earthquake disaster that has conducted consistent training in appropriate response actions, including those which should be taken in a warning situation. Residents indicated that they and others around them were frightened when the signal sounded but responded by turning off gas and lights and evacuating their buildings according to established procedures. The group of residents and bystanders were able to direct people to the pre-designated evacuation routes and outdoor assembly locations. No one reported witnessing behavior such as running, shoving, or other actions associated with extreme fear and flight reactions (Flores, P.J., Goltz, D. 1997).

In March of 2012, a 7.4M earthquake rumbled in Mexico City and, in one Montessori school, students aged 6 months to 6 years were already evacuated, gathered in the front lobby of the school, a location city engineers had earlier indicated as a safe spot (Miller, L. 2012).

In Japan, most people travel by train and there is an average daily commute of three hours. In the event of an earthquake, passengers are trained to exit stations immediately. Commuters evacuate because, in past history, many have died from either smoke inhalation or drowning after a tsunami has flooded the subway.

The implication is clear. With an early warning system, evacuation plans in place and regular drill education for the public, people can and do move to safe areas or even exit buildings prior to and/or during earthquakes.

With no warning system in place and no system of evacuation to a safe area, people react instinctually. Although fear in these situations are inherent, behavior remains cooperative and movement is orderly. Following is a video depicting a typical scenario of unpreparedness in regard to drill education - even the teacher reacts by running. Note that this is in California where students are taught to duck, cover and hold on. Other videos depict Japanese students who are alarmed but instinctually run out of the room. Students in Mexico and China (April 2013) and the adults in a legislative session in Mexico City calmly follow systemic training. When evaluating each scenario, one can observe consistent order and cooperation. None of the persons moving during the earthquakes listed above were injured or killed.

Human behavior before or during an earthquake is more consistent when there are early-warning systems, organized education in emergency protocol and collective trust in a system invested in the protection of its citizens. This is especially critical for our children who are mandated to attend unsafe schools in known earthquake zones. This risk is unacceptable and the urgency in the U.S. Pacific Northwest is critical.

One of several seismic hotspots in the world is located just 50 miles off of the Pacific Northwest coast. Subduction zones, like the ones in the Pacific Northwest, Japan, Chile, and the Indian

Ocean, produce the largest earthquakes in the world. Called mega or super-earthquakes, geologists estimate the next one to hit Oregon to be about 9.0 in magnitude (Baker 2010, Baker 2011, Chang 2010, Wang 2009) and will occur as Wang contends, "It's not if, but when" (Baker 2010, 2011).

A seismic risk assessment conducted by Oregon's Department of Geology and Mineral Industries (DOGAMI) in 2007, shows that 1,018 of Oregon's 2,185 school buildings are at "high or very high risk" of collapse during a major earthquake (Open-File Report O-07-02). Yumei Wang, DOGAMI engineer and geohazards leader, affirms that, "other states and countries are far ahead of Oregon on seismic school safety." She adds that after an earthquake, "Oregon politicians are going to slam their fists and say we need to do this now," (Baker, 2009, 2010). Furthermore, Brian Tucker of Palo Alto, California provides insight into why it is important to act now rather than later and why people have not acted as of yet. He professes that people do not pay attention to signs, thinking such a disaster will only happen somewhere else. Tucker says, "The story is getting boring (to the public)…" when referring to repeated tragedies that could have been largely averted by being proactive (Showstack 2010).

Scientists, particularly those in the fields of geology, seismology and paleoseismology unanimously agree about the inevitability of the Cascadia Subduction Zone (CSZ) megaquake. Wang asserts that "like death and taxes" it's "gonna happen," and that "all of Portland will be shaken hard." She further conveys that there will be landslides and extensive liquefaction that will severely affect industry, development, levies, transportation and, emergency management response. Included in the buildings that will be damaged will be public schools with "a lot of children," a vulnerable population that is important to protect. There are about 300,000 children in the 1000+ at-risk schools and "if the earthquake hits today, we're in trouble." Because children are mandated to go to school and they are sent to schools that are not safe, there is a huge responsibility to mitigate this issue (Baker 2010).

Previously deemed to be a 'dormant fault line' due to lack of written records, it is now known that Pacific Northwest faults have a volatile past and an earthquake in this region is inevitable. Chris Goldfinger, an earthquake and tsunami expert and one of the world's leading experts on subduction zones at Oregon State University, utilized data to create the earthquake timeline for the Pacific Northwest coast (Cascadia Winter 2010, p.8, BBC Documentary 2012). These data note that over the past 12,000 years, Cascadia megaquakes (8.0-9.0) occur on average every 240 years. The last quake of this magnitude in the CSZ occurred in January of 1700 and is the second largest earthquake in U.S history (USGS 2013). Because the last megaquake was over 312 years ago, the Cascadia region is described to be 'nine months pregnant and overdue.'

Oregon's seismic code standards implemented in "1994 did not take into account the extended duration associated with subduction zone quakes, about 4-5 minutes of continuous shaking". Furthermore, the median age of Oregon school buildings is "46 years with almost 1,200 high occupancy school buildings being over 50 years old," (Tesfamariam & Wang 2010, Wang & Burns, 2006).

Few individuals will contest the importance of protecting society's most valuable and vulnerable members, children; and few will contest the importance of providing compulsory education for all children. Even fewer people will argue with the fact that earthquakes kill people and damage property. But these three essential principles are not valid in modern society. In many earthquake-prone countries, a surprisingly high number of school buildings are not constructed to withstand even moderate-sized earthquakes. The fundamental question that we must ask ourselves is: "Why is it so simple to acknowledge the importance of the education and safety of our children, yet so difficult to ensure" (OECD 2004, pp. 19-29).

Those at the greatest risk, should the quake occur during school hours are our children. With 300,000 students mandated to attend schools at high-to-very high risk of collapse (DOGAMI Open file report O-07-02), seismic safety is imperative. Money is scarce however and the cost of retrofitting is currently beyond our reach. Although 'duck, cover and hold on' is still the safest protocol when unable to leave a building, Yumei Wang, GeoHazards team leader at the Oregon Department of Geology and Mineral Industries and school safety advocate, also states in Baker's 2009 article, "The 'duck, cover and hold' drill assumes the building is still standing. That kind of says it all." Wang further contends that,

> "The engineering profession needs to break 'out of the box' and start empowering school administrators. For example, (1) develop very inexpensive mitigation solutions that can be applied to lots of schools in immediate future, (2) communicate risk in a persuasive, non- technical and understandable manner, etc…. Let's hope that the recent tragedy in China will help spur much needed school safety." (Revkin 2008).

CoreFirst personnel recommends a two-pronged approach be considered for earthquake drills. In schools where a full seismic upgrade has been completed, "duck, cover and hold on' makes sense. In unreinforced masonry buildings that have not been upgraded, we recommend evacuation or movement to the areas in the building deemed safest by engineers. The risk to life is too great to consider "duck, cover and hold on" to be a wise protocol.

References

(Articles not hyperlinked are available by request)

Area M. P. *Oregon Department of Geology and Mineral Industries*. *City*, *541*, 523-3133.
http://library.state.or.us/repository/2010/201011091115212/Apr2009.pdf

Baker L. (2009). Portland Monthly. *In the Zone.*
http://www.portlandmonthlymag.com/issues/current-issue/articles/0309-quakes/2/

Baker L. (2010). Oregon Business Journal. *Portland is unprepared for a big earthquake.*
http://www.oregonbusiness.com/articles/92-november-2010/4301-portland-is-unprepared-for-a-big-earthquake

Baker L. (2011). Portland Urbanista. *School items of note*.
http://www.portlandurbanista.com/

BBC Documentary (2012). *Cascadia earthquake 9M is imminent.*
http://www.youtube.com/watch?v=vEgLjgnv_3c

Bourque L. B., et al. (1993). *Human behavior during and after the earthquake disaster*. US Geological Survey Professional Paper 1553 (1993): 3.

Chang, Alicia (March 03, 2010). U.S. News. *Northwest at risk of megaquake like one in Chile.*
http://www.usnews.com/science/articles/2010/03/03/northwest-at-risk-of-megaquake-like-one-in-chile

Coburn A.W et al. (1992). *Factors determining human casualty levels in earthquakes: Mortality prediction in building collapse. Earthquake Engineering Conference 1992, Balkema, Rotterdam.*
http://www.iitk.ac.in/nicee/wcee/article/10_vol10_5989.pdf

Coburn, A. (1994, April). *Death tolls in earthquakes*. In Workshop: Medicine in the International Decade for Natural Disaster Reduction (IDNDR): Research, Preparedness and Response for Sudden Impact Disasters in the 1990s (pp. 21-6). < The> Royal Academy of Engineering.
http://65.182.2.242/docum/crid/Enero2005/CD2/pdf/eng/doc5608/doc5608-contenido.pdf

Drury J., & Cocking C. (2007). *The mass psychology of disasters and emergency evacuations: A research report and implications for practice*. Falmer, Brighton: University of Sussex.
http://www.impact-kenniscentrum.nl/doc/kennisbank/1000011441-1.pdf

Espinosa-Aranda J.M. & Lee W. H.K. (2003). *Earthquake early warning systems: Current status and perspectives. In Early Warning Systems for Natural Disaster Reduction*. Edited by J. Zschau and A. N. Kuppers, p. 409-423, Springer, Berlin.
http://usgsprojects.org/lee/Lee_Espinosa_2003_EWSbook.pdf

Flores P. J. and Goltz, J. D. (1997). *Real-time earthquake early warning and public policy: A report on Mexico City's Sistema de Alerta Sismica.* Seismological Research Letters, 68(5), 727-733. http://srl.geoscienceworld.org/content/68/5/727.short

Georgescu, E. (1988). *Assessment of evacuation possibilities of apartment multistoried buildings during earthquakes or subsequent fires in view of earthquake preparedness*. Paper submitted for 9th World Conference on Earthquake Engineering. ASSESSMENT, 13, 3 2. http://www.iitk.ac.in/nicee/wcee/article/9_vol7_687.pdf

Holzer T. L., & Savage, J. C. (2013). *Global earthquake fatalities and population*. Earthquake Spectra, 29(1), 155-175. https://profile.usgs.gov/myscience/upload_folder/ci2013Feb2015013642954Holzer%20Savage%20Fatalities%20EQ%20Spectra%202013.pdf

Mawson A. R. (2005). *Understanding mass panic and other collective responses to threat and disaster*. Psychiatry: Interpersonal and biological processes, *68*(2), 95-113. http://www.medicine.virginia.edu/clinical/departments/psychiatry/sections/cspp/ciag/conference/articles/s2006/mawson_understanding_mass_panic.pdf

Miller L. S. (March 21, 2012) *Better prepared: Mexico's 7.4 quake causes damage, but no deaths*. http://www.csmonitor.com/World/Americas/2012/0321/Better-prepared-Mexico-s-7.4-quake-causes-damage-but-no-deaths
Mexico's worst earthquake in nearly 30 years was met by stricter building codes and a city prepared by evacuation drills and early warning systems.

Ohta, Y. & Ohashi, H. (1980, September). *A field survey on human response during and after an earthquake.* In Proc. 7th World Conference on Earthquake Engineering (Vol. 9, pp. 345 352).

Ohta, Y. & Ohashi, H. (1985). *Field survey on occupant behavior in an earthquake*. International Journal of Mass Emergencies and Disasters, 3(1), 147-160.

Oregon Department of Geology and Mineral Industries. *Cascadia Publication.* Winter 2010. http://www.oregongeology.org/sub/quarpub/CascadiaWinter2010.pdf

Prati G., et al. (2013). *The 2012 Northern Italy Earthquakes: modelling human behavior*. Natural Hazards (2013): 1-15.

Revkin A.C (2008). *From Sichuan to Oregon: Schools at Risk.* New York Times. http://dotearth.blogs.nytimes.com/2008/05/21/from-sichuan-to-oregon-schools-at-risk/

Showstack R. (2010). *Haiti Earthquake Underscores Need for Better Use of Seismic Information*. Eos, Transactions American Geophysical Union, 91(4), 30. http://onlinelibrary.wiley.com/doi/10.1029/2010EO040002/abstract

United States Geological Survey (USGS), (2013). *Largest earthquakes in the United States.* http://earthquake.usgs.gov/earthquakes/states/10_largest_us.php

Five largest Earthquakes in U.S. History – By Magnitude (USGS)
*Note that increase in population and infrastructure greatly increases loss from disaster

	Regional Maps	Date	M	Information
1	Prince William Sound Alaska	03/27/1964	9.2	The Great Alaska EQ of 1964
2	Cascadia Subduction Zone	01/26/1700	9.0	Additional information and links
3	Rat Islands, Alaska	02/04/1965	8.7	
4	Andreanof Islands, Alaska	03/09/1957	8.6	300 aftershocks EQ and tsunami effects/links
5	Shumagin Islands, Alaska	10/11/1938	8.2	The earthquake generated a tsunami, which was recorded at Dutch harbor, Seward, and Sitka, Alaska and at Hilo and Honolulu, Hawaii.

United States Geological Survey. *Largest and deadliest* earthquakes *by year: 1990-2011*. http://earthquake.usgs.gov/earthquakes/eqarchives/year/byyear.php

Wang Y. & Burns, W. J. (2006). *Case History on The Oregon Go Bond Task Force: Promoting Earthquake Safety In Public Schools and Emergency Facilities.* In Proceedings of the 100th Anniversary Earthquake Conference, Commemorating the. http://www.oregongeology.com/sub/projects/rvs/EERI-GO-Bond-text.pdf

Wang Y. (2009). *Lifeline Resiliency: A Look at Earthquake Risk in Portland, Oregon*. ASCE American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering Conference, Jun 28- Jul 1, 2009, Oakland, CA. http://cedb.asce.org/cgi/WWWdisplay.cgi?172939

Additional Resources

(Articles not hyperlinked are available by request)

Allen R.M., et al. (2009). *The status of earthquake early warning around the world: An introductory overview.* Seismological Research Letters Volume 80, Number 5 September/October 2009.
http://www.eew.caltech.edu/docs/Allen_Gaspirini_SRL.pdf

Atwater, et al. (2005). *The orphan tsunami of 1700.* University of Washington Press, Seattle, WA 98145. U.S. Department of the Interior.
http://pubs.usgs.gov/pp/pp1707/chapters/01_FrontMatter_Intro.pdf

Baily J, Wolf, E. (2011). *Cascadia's seismic certainty: Putting earthquake safety on the green schools agenda.*
http://www.sustainableschools.org/documents/Earthquake-Article-Fall-2011.pdf

Berlinski, C. (2011). *The politics of earthquakes*. Los Angeles Times 2011.
http://articles.latimes.com/2011/jul/24/opinion/la-oe-berlinski-earthquakes-20110724

BBC Documentary (2012). *Cascadia earthquake 9M is imminent.*
http://www.youtube.com/watch?v=vEgLjgnv_3c

Carrillo, C. (2011). . Terra: The power of research. *Cascadia roulette*. Interview with Bob Yeats. Oregon State University, 2011.
http://oregonstate.edu/terra/2011/01/cascadia-roulette/

Fraser S. et al. (2012). *Tsunami evacuation: Lessons learned from the Great East Japan earthquake and tsunami of March 11, 2011.* GNS Science Report 2012.
http://crew.org/sites/default/files/SR 2012-017.pdf

Government of Chile National Emergency Bureau Ministry of the Interior (ONEMI): *Basic integral security guide for visitors and foreign residents.*
http://www.santiago.diplo.de/contentblob/422340/Daten/14470/

If you feel a quake:

- Be calm. If you have completed the previous steps, you have prepared
- Stay apart from windows. Open the doors. The best shelters, are: solid buildings, good and solid furniture
- Avoid lighting matches or any FIRE before checking gas escapes
- Do not evacuate if your house or building is a solid one
- An evacuation must be always performed towards safety zones previously defined as secure.
- Do not use elevators
- If you drive on a highway, get far from bridges and high roads
- On an open street be always far of cornices, electric cables and hanging signs

Guest Columnist (March 29, 2011). The Oregonian. *Seismic safety is an unfinished job at Portland schools.* http://www.oregonlive.com/opinion/index.ssf/2011/03/seismic_safety_is_an_unfinishe.html

Mexico Seismic Registry *Centro de Instrumentación y Registro Sísmico, a.c.* http://www.cires.org.mx/index.php
Steps (in order, please note they have warning systems): Stay Calm, Eliminate fire sources, Move away from windows and unsecured objects, Do not use elevators, Locate self in security zone, Find evacuation route.

NOVA PBS (March 2011). *Japan's killer quake.* Includes discussion with Chris Goldfinger and Yumei Wang and the similarities between the subduction zones in Japan and the Pacific Northwest.
http://www.pbs.org/wgbh/nova/earth/japan-killer-quake.html

PBS News hour (2012). *Would a major earthquake sink Portland or Seattle in liquefied soil?* http://www.pbs.org/newshour/bb/science/jan-june12/liquefaction_04-12.html
This will affect emergency management response.

PBS News hour (2008). *Oregon mulls shoring up schools against earthquakes.* http://www.pbs.org/newshour/bb/science/july-dec08/quakespending_07-25.html

Smith, M, Upton, J. (March 22, 2012). *Why California lacks an earthquake warning system Like Mexico's.* https://www.baycitizen.org/news/earthquakes/why-california-mexico-earthquake-warning/

Spence, R., & So, E. (2009). *Estimating shaking-induced casualties and building damage for global earthquake events*. NEHRP Technical Report 08HQGR0102. http://earthquake.usgs.gov/research/external/reports/08HQGR0102.pdf

Tesfamariam S. et al. (2010). *Risk-based Seismic Retrofit Prioritization of Reinforced Concrete Civic Infrastructure: Case Study for State of Oregon Schools and Emergency Facilities.* 9th US National and 10th Canadian conference on earthquake engineering: reaching beyond borders, July 2010, Toronto, CN.

University of Liverpool Faculty of Science and Engineering. http://www.liv.ac.uk/science-and-engineering/

Wang Y., (2009). *Lifeline Resiliency: A Look at Earthquake Risk in Portland, Oregon*. ASCE American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering Conference, Jun 28- Jul 1, 2009, Oakland, CA.

Wang Y. (2012). *Oregon Schools: Accelerating seismic school safety*. Oregon Department of Geology and Mineral Industries, 2012. http://2012am.eeri.org/wp-content/uploads/2012/05/2-Wang-2012-NEC-memphis-Oregon-schools-YW.pdf

Wang Y., Raskin, J., Wolf, E. (January 09, 2011). The Oregonian. *Oregon should make itself resilient for a big quake.* http://www.oregonlive.com/opinion/index.ssf/2011/01/oregon_should_make_itself_resi.html

Wang Z. (2009). Kentucky Geological Survey, University of Kentucky. *Seismic hazard v. seismic risk.* Seismological Research Letters Volume 80, Number 5 September/October 2009. http://www.seismosoc.org/publications/SRL/SRL_80/srl_80-5_op.html

Yeats R.S. (2003). Oregon State University. *Seismology and society: A college course in why it all matters*. Seismological Research Letters September/October2003 Volume74, Number 5, September/October 2003.

Yeats R.S. (2004). *Living with Earthquakes in the Pacific Northwest: A Survivor's Guide: Second Edition, Revised and Expanded*. Oregon State University Press 2004. http://osupress.oregonstate.edu/book/living-with-earthquakes-in-pacific-northwest

Zschomler, Ruth (July 22, 2010). The Oregonian. *Cascadia subduction zone: Are Portland and Seattle prepared for an earthquake and tsunami?* http://www.oregonlive.com/earthquakes/index.ssf/2010/07/earthquakes-west-coast-portland-seattle.html

Videos

Building collapse in Philippines (2007).

Chile Earthquake: People running out of hotel, scared (2010)

Discussion of school evacuation protocol after Tibetan 6.9M earthquake – safe movement during an earthquake

Dubai residents discuss evacuation during an earthquake (April 2013) – no injuries or casualties

Earthquake Montage National Geographic

Japan earthquake: Narrow escape for office workers (March 2011). BBC – Asia Pacific

More than 1,000 Oregon schools would crumble in major quake (May 2013)

Schools not ready for megaquake (August 2012).

Tangled blame in quake deaths Washington Post (June 2008)