USGS
science for a changing world

RESPONDING TO GLOBAL EARTHQUAKE HAZARDS

PAGER—Rapid Assessment of an Earthquake's Impact

PAGER (**P**rompt **A**ssessment of **G**lobal **E**arthquakes for **R**esponse) is an automated system to rapidly assess the number of people and regions exposed to severe shaking by an earthquake, and inform emergency responders, government agencies, and the media to the scope of the potential disaster. PAGER monitors the U.S. Geological Survey's near real-time U.S. and global earthquake detections and automatically identifies events that are of societal importance, well in advance of ground-truth or news accounts.

The U.S. Geological Survey's National Earthquake Information Center (NEIC), located in Golden, Colorado, reports over 30,000 earthquakes a year. Tragically about 25 of these cause significant damage, injuries, or fatalities. The U.S. Geological Survey (USGS) often detects earthquakes well before eyewitness reports are available. It must then decide rapidly whether Federal and international agencies should be alerted to a potentially damaging event. In the past, the USGS primarily relied on the experience and intuition of its on-duty seismologists to estimate the impact of an event. To improve the accuracy of the assessment, the USGS has developed PAGER, an automated system to rapidly estimate the number of people and settlements exposed to severe shaking during earthquakes occurring anywhere in the world.

PAGER provides important information to help emergency relief organizations, government agencies, and the media plan their responses to earthquake disasters. Content includes instrumentally-determined earthquake parameters of location, magnitude, and depth and an estimate of the number of people exposed to different severities of shaking—a useful indicator of potential impact. For most events, the system generates a comment describing infrastructure vulnerability in the region, and damage and fatality reports from previous nearby earthquakes. A table summarizes the predicted shaking intensity at nearby population centers, and maps provide quick visual overviews of shaking levels and population densities.

This information is available on the USGS earthquake website http://earthquake.usgs.gov/ and as a printable, one-page report with accompanying description such as that shown in the following pages. Fundamental to such a system, the USGS operates a robust computational and communication infrastructure necessary for earthquake response.

PAGER results are generally available within 30 minutes of a significant earthquake, shortly after the determination of its location and magnitude. However, information on the extent of shaking will be uncertain in the minutes and hours following an earthquake and typically improves as additional sensor data and reported intensities are acquired and incorporated into models of the earthquake's source. Users of PAGER exposure estimates should account for uncertainty and always seek the most current PAGER release for any earthquake.

Collapsed adobe church in Pisco, Peru, following the August 15, 2007, magnitude 8.0 earthquake. For events such as this, PAGER provides emergency relief organizations with information that helps them determine which areas likely require the most attention. Photograph by Emily So, EEFIT, United Kingdom.

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USGS science for a changing world

GSN

USAID FROM THE AMERICAN PEOPLE

M 8.0, NEAR THE COAST OF CENTRAL PERU

Origin Time: Wed 2007-08-15 23:40:56 UTC
Location: 13.36˚S 76.52˚W Depth: 30 km

PAGER
Version 2
Created: 2 hrs 14 minutes after the earthquake

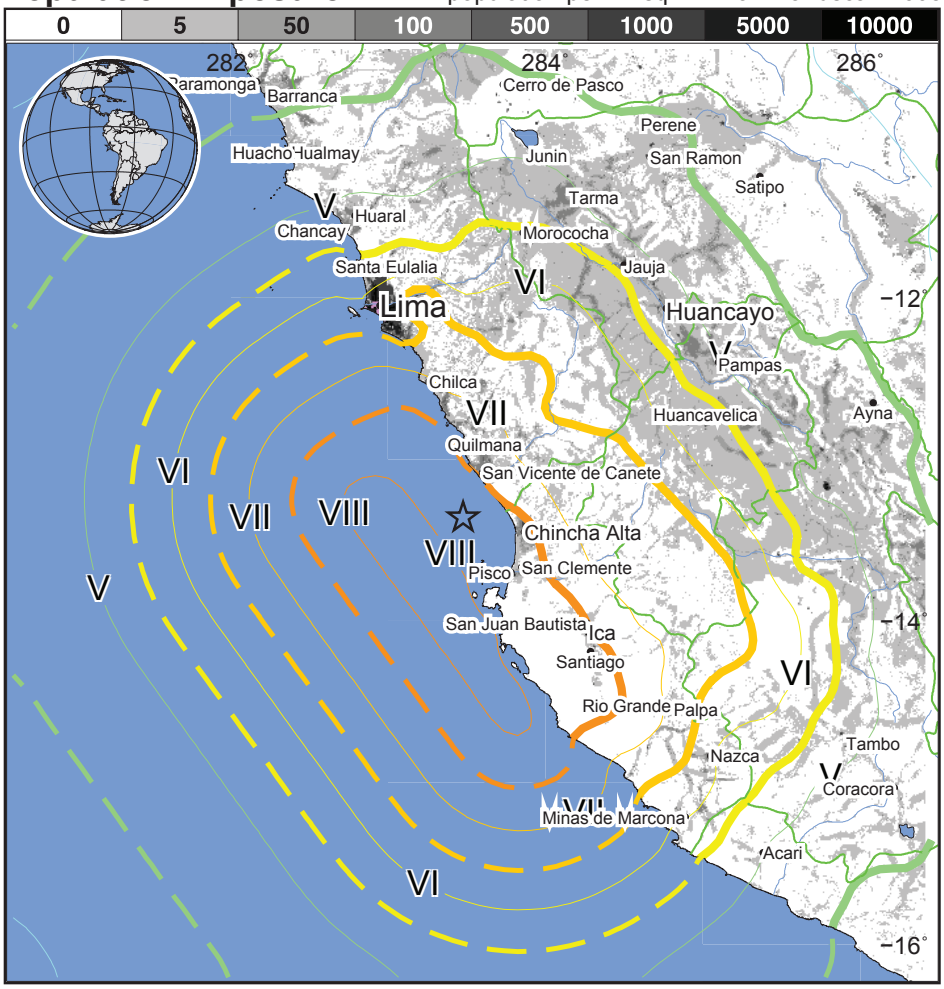
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	527k*	2,285k*	7,875k	1,297k	449k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landscan 2005



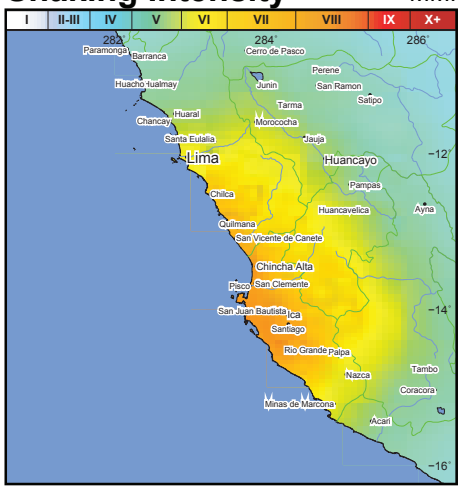
Selected City Exposure

MMI	City	Population
VIII	**Chincha Alta**	**153k**
VIII	Villa Tupac Amaru	11k
VIII	**Pisco**	**61k**
VIII	**San Clemente**	**15k**
VIII	**Santiago**	**10k**
VIII	Subtanjalla	9k
VII	**Ica**	**246k**
VI	Chosica	88k
VI	**Lima**	**7,737k**
V	**Huancayo**	**376k**
V	Ayacucho	140k

bold cities appear on map (k = x1000)

Shaking Intensity

MMI



Users should consider the preliminary nature of this information and check for updates as additional data becomes available. Population exposure estimates are NOT a direct estimate of earthquake damage; comparable shaking will result in significantly lower losses in regions with well built structures than in regions with vulnerable structures. Overall, structures in this region are vulnerable to earthquake shaking, though some resistant structures exist. A magnitude 8.4 earthquake struck the Arequipa, Peru region on June 23, 2001 (UTC), with estimated population exposures of 180,000 at intensity VIII and 1 million at intensity VII, resulting in 139 deaths. Recent earthquakes in this area have also triggered landslide hazards that have contributed to losses.

This information was automatically generated and has not been reviewed by a seismologist.

http://earthquake.usgs.gov/pager/ Event ID: us2007gbcv

PAGER report on damaging earthquake in Peru.

Prompt Assessment of Global Earthquakes for Response

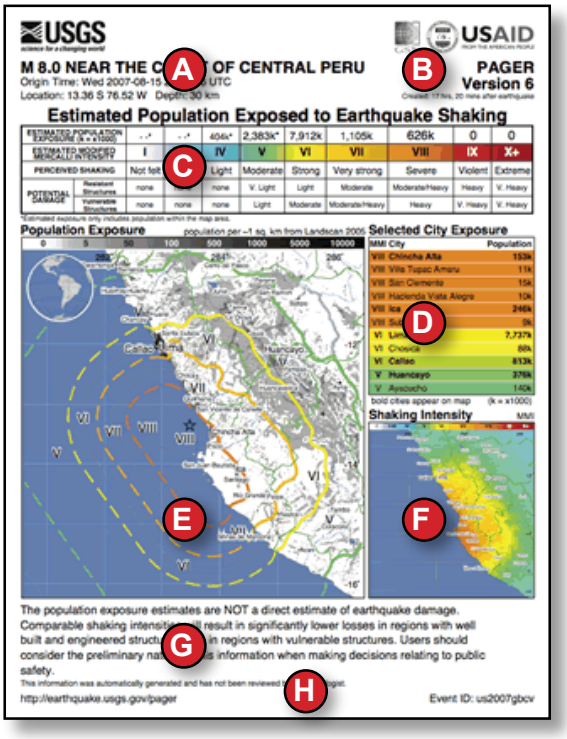
Background

PAGER provides estimates of the number of people and names of cities exposed to severe shaking following significant earthquakes anywhere in the world. These estimates are generally available within 30 minutes of an earthquake's occurrence and are updated as more information becomes available. The content provided by PAGER is used to assess the possible shaking impact of an earthquake and to prioritize regions for further reconnaissance. However, PAGER currently does not provide casualty estimates and does not consider secondary effects such as landslides and tsunami. For tsunami warnings see: http://tsunami.gov/.

PAGER alerts are available in a one-page summary and web pages with extended content at http://earthquake.usgs.gov/pager/.

A Summary of the basic earthquake parameters, including origin time, magnitude, hypocenter, and the name of the region where the earthquake took place.

B The version of the PAGER alert and the time the alert was created. New versions of the alert are generated when the earthquake information is improved or supplemental ground shaking constraints become available.



C Table showing population exposed to different estimated Modified Mercalli Intensity (MMI) levels and the possible damage at different intensity levels for resistant and vulnerable structures. MMI describes the severity of an earthquake in terms of its effect on humans and structures and is a rough measure of the amount of shaking at a given location. Unlike earthquake magnitude, intensity varies with distance from the fault. Population outside the map bounds are not included in the totals.

D Table of MMI estimates for selected settlements. A maximum of eleven settlements that fall within the map boundary are included in the table. The table contains country capitals and the six settlements with the highest estimated intensity. The remaining settlements listed are selected by population. The settlement name, location, and population are obtained from the freely-available GeoNames geographical database.

E Map of MMI contours plotted over population. The regions of integer MMI values are separated by the thick contour lines and labeled with Roman numerals. The total population exposure to a given MMI value is obtained by summing the population between the thick contour lines. This total is shown in the population exposure table.

F Map of shaking intensity. This map shows the estimated MMI as a continuous color scale. The ground shaking estimates can be obtained from http://earthquake.usgs.gov/shakemap/.

G Region or earthquake-specific commentary. The comment may contain a general description of the vulnerability of the buildings in the region and an account of damage and population exposure for previous nearby earthquakes. In some cases, the potential for fires, landslides, liquefaction, or other hazards will be noted.

H Footer information, including a link to the latest version of the PAGER alert, the internal event-identification number, and a warning statement if the alert content was not reviewed by a seismologist.

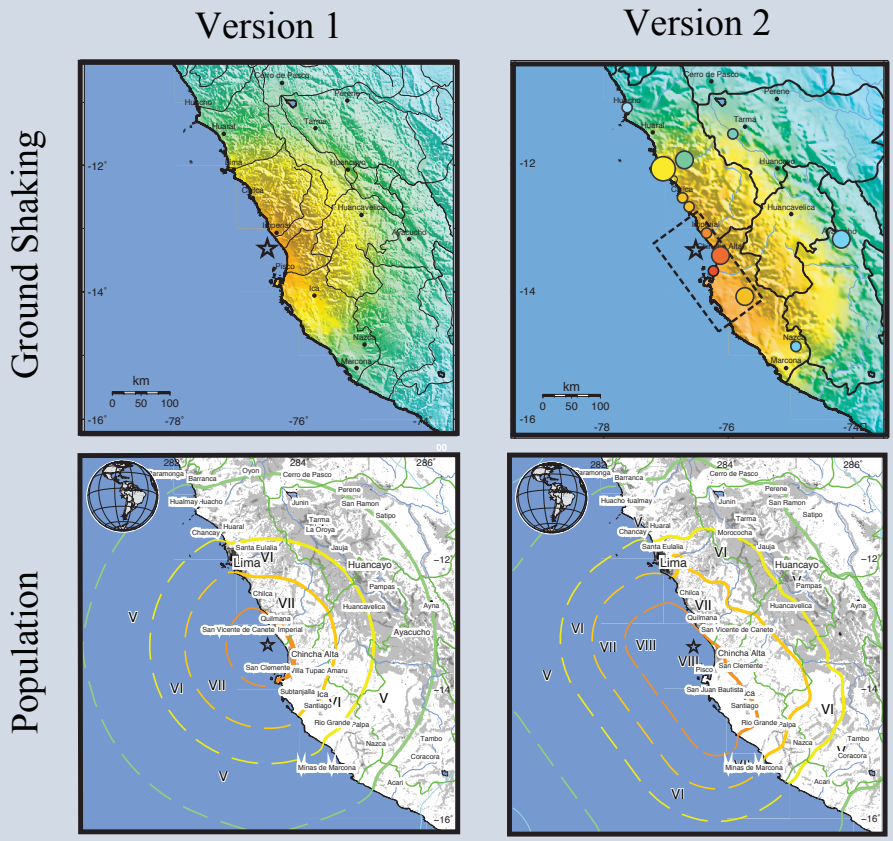
Explanation of PAGER report.

The PAGER Process

At the heart of PAGER are the timely and accurate earthquake location and magnitude determinations that the USGS has been producing for decades. PAGER uses these earthquake parameters to calculate estimates of ground shaking by using the methodology and software developed for ShakeMap (http://earthquake.usgs.gov/shakemap/). The ShakeMap system produces maps of regional ground shaking using a site-specific ground-motion amplification map, seismic wave attenuation equations, and reported or recorded intensities. The number of people exposed to various levels of shaking is then calculated by combining the maps of predicted ground shaking with Oak Ridge National Laboratory's Landscan population database. Finally, PAGER generates a regionally specific description of the vulnerability of the exposed population and infrastructure, potential for earthquake-induced landslides, and, if available, damage and fatality reports from previous nearby historic earthquakes for comparison purposes and damage projection.

Using the estimates of population exposure, PAGER determines the scope of the catastrophe and issues alarms to emergency responders, government agencies, and the media. PAGER is an iterative and interactive system. As subsequent information becomes available, more accurate maps of ground shaking are produced, refined estimates of population exposures are made, and updated alarms are issued, if necessary.

Multiple PAGER alerts are produced in the hours following a significant earthquake. These alerts increase in accuracy and detail as more information becomes available. The initial PAGER alert (left column) is completely automatic and is generally available within 15 to 30 minutes of a significant earthquake. At this point, little is known about the extent or geometry of the ruptured fault, and there are often no instrumental recordings or first-hand reports of shaking available from near the epicenter.



MMI	Population Exposure	Perceived Shaking
IX	0	Violent
VIII	330,000	Severe
VII	854,000	Very Strong
VI	8,232,000	Strong

MMI	Population Exposure	Perceived Shaking
IX	0	Violent
VIII	449,000	Severe
VII	1,297,000	Very Strong
VI	7,875,000	Strong

Subsequent alert versions include any intensities reported by people in the epicentral region via the online USGS "Did You Feel It?" system (http://earthquake.usgs.gov/dyfi/). The colored circles in the top right map show the reported intensity at a city, and the circle's size is proportional to population. For large earthquakes, information about the fault geometry and size (black dotted rectangle) is added when it becomes available. Using these constraints on faulting, new estimates of ground shaking and population exposure are calculated, and new alerts are issued if exposure estimates change significantly.

Ongoing PAGER Developments

At present, PAGER notifications and Web pages provide estimates of the population exposed to each seismic intensity level, a useful indicator of potential impact. USGS is improving the system to include a more comprehensive alert that will include casualty estimates, motivated by the idea that an estimated range of possible number of deaths will aid in decisions about humanitarian response.

The ability to model casualties and economic loss is being developed through several models that use approaches ranging from largely empirical to largely analytical. Selection of the most appropriate model for a particular earthquake will depend on how much is known about local building inventory and their vulnerability.

To calibrate the loss models, the USGS has generated an atlas of 3,900 ShakeMaps of significant global earthquakes that have occurred during the last 36 years. The calibration of loss methodologies relies on this atlas and on fatality and damage data collected by the NEIC. Related USGS developments under the auspices of the PAGER Project include rapid determination of fault geometry, size and rupture characteristics, global estimates of seismic soil-amplification patterns, ShakeMap enhancements, ground-motion and loss-uncertainty analyses, and intuitive ways to portray casualty and loss information and their uncertainties.

Acknowledgments

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