STATEMENT OF
DR. CHARLES MANDEVILLE
VOLCANO HAZARDS PROGRAM COORDINATOR
U.S. GEOLOGICAL SURVEY
U.S. DEPARTMENT OF THE INTERIOR
BEFORE THE
HOUSE COMMITTEE ON NATURAL RESOURCES
SUBCOMMITTEE ON ENERGY AND MINERAL RESOURCES
REGARDING
VOLCANO HAZARDS: EXPLORING THE NATIONAL PREPARATION AND RESPONSE STRATEGY

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Chairman Lamborn, Congressman Holt, Members of the Subcommittee, thank you for holding this hearing and for the opportunity to appear before you to discuss U.S. Geological Survey (USGS) research and monitoring of volcano hazards. My name is Charles Mandeville, and I am the coordinator of the USGS Volcano Hazards Program. In my statement today, I will first describe the ongoing eruption at Kilauea in Hawaii and then provide a broad overview of the volcano threats facing the Nation and USGS efforts to understand and mitigate volcano hazards.

Hawaii Kilauea Puʻu ʻŌʻō Eruption and June 27th Lava Flow Response

Kilauea's East Rift Zone has been in continuous eruption for more than 31 years. This ongoing eruption ranks as Kilauea's most destructive since an explosive eruption in 1790 that killed more than 80 people. Most of the lava flows from East Rift Zone eruptions since 1986 have flowed south, and in 1990 most of the town of Kalapana was destroyed by flows erupted from the Kupaianaha vent. A Federal disaster was declared for coastal communities impacted by the Kupaianaha eruption.

A new vent developed high on Puʻu ʻŌʻō ʻs east flank in 2011. This vent has erupted lava flows moving to the northeast and is the source of the June 27th flow, named for the date it started. The June 27th flow is the first to threaten a residential area since 2010-2011. The USGS Hawaiian Volcano Observatory is continuously monitoring this eruption and is precisely mapping the flow front, tracking lava breakouts upslope, measuring flow advance rates, and measuring tilt, inflation, and deflation of the volcano. USGS scientists are measuring gas emissions, recording and analyzing earthquakes, and analyzing thermal infrared and visible webcam images of the eruption. Frequent helicopter overflights track the active flow and formation of lava tubes and facilitate field investigations by USGS staff on the ground. Scientists are modeling lava flow advancement for forecasts of flow paths and estimated time of arrival to the threatened community of Pāhoa and to critical infrastructure such as Pāhoa Village Road, HI130. On November 3rd, the President approved a Major Disaster Declaration (FEMA-4201-DR) for the State of Hawaii as a result of the Puʻu ʻŌʻō volcanic eruption and lava flow.

The USGS is working closely with the County of Hawaiʻi Mayor's Office, County Civil Defense, and other local government agencies to continuously provide updated information on lava flow activity and Kīlauea Volcano. USGS staff have regularly participated in Town Hall Meetings sponsored by the Mayor's Office and County Civil Defense since Sept. 2nd. Decades of public outreach by USGS staff at the Hawaiian Volcano Observatory have built trust in the USGS as the authoritative voice for information on volcanic activity. Daily updates on activity and maps are available at http://volcanoes.usgs.gov/hvo/activity/kilaueastatus.php

USGS Mission

The United States is one of the most volcanically active nations in the world. The largest eruption in the 20th century was Katmai, AK, in 1912. The largest volcano in the world, Mauna Loa, and one of the world's most active volcanoes, Kilauea, are in Hawaii. There have been three major eruptions in the conterminous United States in the past 100 years: Lassen Peak, CA, in 1914-17, and Mount St. Helens, WA in 1980-86 and again in 2004-08. An average of two eruptions per year in the Aleutians disrupts the hundreds of passenger and cargo flights traveling the North Pacific Air Routes between North America and Asia daily. Extending back into geologic time, several of the largest eruptions the planet has experienced occurred at Yellowstone, WY, and Long Valley Caldera, CA.

In all, there are 169 potentially active volcanoes in the United States. It is the mission of the USGS Volcano Hazards Program to deliver effective forecasts, warnings, and information related to volcano hazards based on the scientific understanding of volcanic processes. These warnings and forecasts are grounded by monitoring and field-based and laboratory research. Creation of the Volcano Hazards Program in the early 1980's provided for a comprehensive long-term approach to reduce volcanic risk in the United States based on four organizing activities:

- volcano monitoring,
- fundamental research,
- volcanic hazards assessments, and
- emergency-response planning and public education.

We cannot prevent volcanoes from erupting. However, if a volcano has a proper real-time monitoring network installed, feeding data to one of the USGS volcano observatories, the USGS can provide the public with forecasts and warnings of eruptive activity, enabling the public to move themselves and their property out of harm's way before the eruption occurs. Emergency managers, critical infrastructure operators, the military, and the general public can plan actions to mitigate the effects of volcanic ash or lahars (volcanic mudflows) once an eruption begins. The USGS can also quickly refute false reports of eruptions or impending activity, thus preventing unnecessary social and economic disruption.

The USGS strives to improve the accuracy and timeliness of its forecasts, warnings, and notifications of volcanic activity by improving the Nation's volcano monitoring infrastructure to detect unrest at the earliest possible stage, providing time for community response actions, and to track activity whether it leads to an eruption or not. An underappreciated – and difficult - part of monitoring volcanic activity is identifying when an eruption is truly over and the public can resume normal activities as a volcano returns to sleep for perhaps decades or centuries.

The USGS seeks to increase understanding of the physical processes that result in the accumulation of magma (underground molten rock) below ground and magma ascent and eruption at the surface that generates hazards and impacts. The USGS maintains a breadth of scientific expertise and experience in its observatory staff and its collaborative partners to provide expert advice needed by the Nation during volcanic crises. The USGS continues to sustain and improve capabilities of USGS laboratory and field experimental facilities needed to measure and quantify key physical, temporal, and chemical features of volcanic systems and processes. Creating a state-of-the-art volcano monitoring infrastructure for the Nation is a long-term project; the USGS fosters innovation and application of advanced technologies in monitoring instrumentation, alarm schemes, data analysis, remote sensing, modeling, and experimental techniques to better quantify and interpret unrest and potential for eruption.

Threat

Volcano threat is the combination of hazards (the complete range of dangerous or destructive natural phenomena that volcanoes produce) and exposure (people, property, and critical infrastructure at risk from volcanic phenomena). Of the 169 potentially active volcanoes in the United States and its Territories, 58 have erupted during the last 200 years.

A national assessment of volcano threat level conducted by USGS in 2005 assigned each of the 169 volcanoes to one of five Threat Groups: Very High Threat, High Threat, Moderate Threat, Low Threat, Very Low Threat. Results of this assessment were 5 Very High Threat volcanoes in Alaska, 3 in California, 2 in Hawaii, 4 in Oregon, and 4 in Washington. The number of High Threat and Moderate Threat volcanoes by state is 58 in Alaska, 8 in California, 3 in Hawaii, 8 in the Commonwealth of the Northern Mariana Islands, 2 in Oregon, and 1 each in Washington, Wyoming, Arizona, Colorado, Nevada, New Mexico, and Utah. Volcanoes in the United States can produce several hazards, including

- eruption columns and ash fall,
- large volcanic rocks falling within 2 miles of the vent,
- lava flows that move downslope in response to gravity and lava domes that can collapse due to oversteepening,
- pyroclastic flows (hot, fast-moving avalanches of rock, ash, and gases that can travel at more than 100 miles per hour),
- toxic gases,
- volcano landslides or debris avalanches, and
- lahars (volcanic mudflows) that tend to follow river valleys down from the summits of volcanoes.

The USGS national assessment of volcano threat level used an estimate of the number of people living within 30 km [roughly 19 miles] of an active volcano as one of several exposure factors to determine overall threat score. Similar data for U.S. volcanoes have been computed more recently from the LandScan population dataset produced by the Oak Ridge National Laboratory and indicate that for several U.S. volcanoes there are more than 1,000 people living within 30 km of the summit. At Mt. Shasta in California, more than 10,000 people live within 30 km of the summit. For several Very High Threat volcanoes (Baker, Glacier Peak, Rainier, Mount St. Helens in WA, Mt. Hood in OR) more than 1 million people live within 100 km [62 miles] of the summit, and more than 100,000 people live within 100 km of the Very High Threat to High Threat volcanoes Lassen, Clear Lake, and Medicine Lake in California; Mauna Loa, Kilauea, and Hualalai in Hawaii; Crater Lake, Newberry, and South Sister in Oregon; and Adams in Washington.

The most widespread hazard from explosive eruptions is volcanic ash (small fragments of volcanic glass, rock, and minerals) and ash clouds that can impact communities on the ground and commercial and military aviation hundreds to thousands of miles away from the source. Explosive eruptions generate eruption columns that inject ash to commercial flight levels (30,000 feet), and ash ingestion can lead to catastrophic jet engine failure, as well as severe damage to critical flight control instrumentation and the sand-blasting of cockpit windows and leading edges of wings, rudder, and rear stabilizers. On December 15, 1989, KLM Flight 867 bound for Anchorage and carrying 231 passengers inadvertently flew into the ash cloud from Redoubt volcano, 150 miles away, which had started to erupt 10 hours earlier. All four engines flamed out, and the crippled jet dropped from an altitude of 27,900 feet to 13,300 feet in five minutes. Fortunately, the crew was able to restart all engines and land the jet safely at Anchorage. The plane sustained severe damage requiring $80 million in repair costs. Closure of Icelandic and European air space during the April 2010 eruption of Eyjafjallajokull in Iceland led to an economic loss for Europe of approximately 4 billion EUR ($5 billion US), as a result of a relatively small eruption.

The USGS is actively engaged in efforts to address issues associated with volcanic ash. USGS scientists led the International Airways Volcano Watch Operations Working Group organized under the International Civil Aviation Organization (ICAO) to provide the scientific foundation for decisions and international policies related to volcanic ash detection and forecasting in order to minimize future closures of airspace.

Therefore, proximity to air traffic routes and major airports is another of the important exposure factors used to calculate volcano threat level in the USGS national assessment. According to the CAPA Centre for Aviation, on average 350,000 passengers fly across the North Pacific region each week. Cargo traffic in the region is also significant: 71% of all Asia-bound cargo from the United States and 82% of all U.S.-bound cargo from Asia transit through Anchorage International Airport. Because of the threat posed to aviation from volcanic ash, even the most remote volcano needs to be monitored at some level. There are 63 active volcanoes in the Alaska Peninsula –Aleutian region, which experiences an average of 2 eruptions per year.

Volcanic ash fall can have significant impacts on other critical infrastructure such as the power grid. As little as 0.6 inch of ash accumulation can cause flashover on insulators on power lines, resulting in power loss to communities and businesses. This problem is exacerbated if the ash is wet as a result of rain accompanying an eruption. Ash accumulation on roofs can create the secondary hazard of roof collapse if the ash gets saturated with water thereby exceeding the strength of the roof structures. Ash fall can reduce visibility along highways and roads; as little as 0.5 inch of ash can render roads slippery and clog air filters on car and bus engines, forcing the temporary closure of roads, airports, and rail stations.

Ash fall can have short-term impacts on drinking water quality resulting in turbid water, and possibly chemical changes to the water if sulfur and chlorine are released from the ash. Agriculture and horticulture may be impacted if there is soluble fluorine in the ash that falls on vegetation grazed on by livestock. This can lead to fluorine poisoning in animals (http://volcanoes.usgs.gov/ash).

Volcano Observatories and NVEWS

The USGS operates five volcano observatories, each tasked to monitor volcanoes, issue public warnings and forecasts, and coordinate research activities in its area of responsibility. The *Hawaiian Volcano Observatory*, which recently celebrated its 100th anniversary, is responsible for activity in Hawaii and has been responding since 1983 to the ongoing eruption of Kilauea. The *Cascades Volcano Observatory* was established in the aftermath of the 1980 eruption of Mount St. Helens and is responsible for volcanoes in Oregon, Washington, and Idaho. The *Alaska Volcano Observatory* (AVO), a partnership with the State of Alaska and the University of Alaska, covers volcanoes in Alaska and also those in the Commonwealth of the Northern Mariana Islands. AVO responds on average to 2-3 eruptions annually. The *California Volcano Observatory* is responsible for volcanoes in California and several in Nevada along the Nevada-California border. The last eruption in California was at Lassen Peak 1914-17. Finally the *Yellowstone Volcano Observatory*, a consortium with several State and University partners, covers not only Yellowstone but also numerous volcanic centers in Wyoming, Montana, Utah, Colorado, Arizona, and New Mexico. An important role for all observatories, but especially those that do not have frequent eruptions, is to dispel false rumors that a volcano is erupting or about to erupt, or to inform the public that earthquake swarms felt in volcanic areas are not evidence of an impending eruption. Without the authoritative voice of the observatories, false rumors can lead to unnecessary social and economic costs.

Within its area of responsibility, each observatory not only monitors activity and issues forecasts and warnings but also conducts geologic investigations to determine the hazards posed by each volcano and maintains an extensive communication program to inform the public of the threats posed by the volcanoes in their backyard. Through the observatories, the USGS works with emergency managers and other Federal agencies to develop response plans and conduct exercises to prepare for the next eruption.

The volcano-monitoring and notification systems and expertise of the five U.S. volcano observatories constitute the National Volcano Early Warning System (NVEWS). NVEWS is a national-scale effort by the USGS and its partners to ensure that U.S. volcanoes are monitored commensurate with the threats they pose and that forecasts and warnings of volcanic activity to the public are effective. A USGS priority since 2005, NVEWS guides strategic, long-term improvements to U.S. volcano-monitoring infrastructure and integrated volcano-hazard information products and services for a range of users, including emergency managers, land managers, communities, businesses, other Federal and State agencies, and the public. NVEWS also supports national earth science research efforts by producing long-term monitoring data sets that are the raw material for creating new insights and models of volcanic systems and hazards, leading to better eruption forecasts and warnings.

The USGS is about 30 percent of the way to completing its NVEWS goal of monitoring all hazardous volcanoes commensurate with the threats that they pose; several very-high-threat volcanoes, mainly in the Cascades (Oregon, Washington, and California), have only rudimentary monitoring networks at this time.

Integrating Volcano Monitoring and Fundamental Research

USGS real-time and near real-time ground-based monitoring networks include seismometers, Continuous Global Positioning System (CGPS) instruments, tilt-meters, visible and infrared web cameras, gas measurement spectrometers, and infrasound detectors. Data from ground-based instruments are fully integrated with satellite-based remote sensing data and data derived from field and laboratory studies. The USGS relies on multiple real-time and near real-time data streams in its monitoring efforts. The power of multiple data streams is that changes in seismicity, deformation, or gas emission can be compared and analyzed simultaneously with other observations of the volcano occurring over similar time scales.

Much of the research effort focuses on analyzing the real-time data streams recorded by monitoring networks in order to extract information about what processes are occurring beneath a volcano. It is also very important to "fingerprint" what are normal background signals at a volcano when it is in a non-eruptive state. Doing so requires ground-based instrumentation and long-term recording and analysis of the data. Multiple data streams help us delineate the full suite of precursor signals that herald unrest and escalation towards eruption, as well as to determine when an eruption is waning or over. Integration of multiple types of data allows the USGS to build realistic predictive models that will improve the accuracy of eruption forecasts and warnings.

In addition, instrumentation initially developed for volcano monitoring has been useful in responding to other kinds of natural hazards. For example, the CGPS- and seismometer-equipped instrument "spiders" developed during the 2004-2008 eruption of Mount St. Helens proved quite valuable to the search and rescue operations during the response to the Oso, WA, SR530 landslide in March 2014. Three of the spiders were deployed for monitoring the slide mass and ensuring the safety of search crews.

In addition to instruments supported by USGS funds, USGS observatories rely on approximately 200 CGPS geodetic instruments and several borehole seismometers and strain meters operated by UNAVCO Inc. and funded by the National Science Foundation under the EARTHSCOPE Plate Boundary Observatory program. The EARTHSCOPE program will end in 2018, and it is uncertain at present what level of support for these geodetic instruments will be available after 2018. These instruments provide highly valuable data, and the loss of this information would seriously impact USGS monitoring capability at a number of volcanoes.

Satellite-based remote sensing technology has become a primary tool for volcano monitoring and is routinely used by USGS volcano observatories and others to detect and track unrest and eruption. Synthetic Aperture Radar, an all-weather tool, is critical for situational awareness of processes taking place at volcano summits exhibiting unrest, but hidden by clouds. Interferometric synthetic aperture radar (InSAR) provides images of the volcano deformation with high precision even before other eruption precursor signals are recorded. For U.S. volcanoes that lack ground-based instrumentation, the USGS depends on satellite-based monitoring, infrasound arrays, and the World Wide Lightning Location Network, an informal consortium, for detection of remote eruptions. The network is especially useful for detecting eruptions at high latitudes such as in Alaska, where thunderstorms are rare and intense lightning generally signals an eruption.

The USGS performs field-based research including volcano mapping and characterization of deposit types including lava flows, ash fall deposits, lahars, and deposits generated by pyroclastic flows and surges. This research establishes the footprint of volcanic hazards on the landscape and informs the development of hazard assessments and credible eruption scenarios. This "boots on the ground" research establishes the maximum range of hazards that a volcano may exhibit in future events and advances our understanding of eruptive processes. This place- and process-based knowledge facilitates the design and optimization of monitoring networks and instrument suites and overall monitoring efforts.

Laboratory-based research on natural volcanic rock, ash, and other rock samples helps to determine eruption history and frequency and elucidates how the samples originated.

Communications and Products

Under the National Volcano Early Warning System, the USGS standardized the volcanic activity alert notification system used at all U.S. observatories. Goals of this alert-notification system are to communicate a volcano's status clearly to non-specialists, help emergency response organizations determine proper mitigation actions, and prompt people and businesses at risk to seek additional information and take appropriate actions. The USGS uses a tiered alert-level system to rank changing conditions at volcanoes. The system uses four *terms* (Normal, Advisory, Watch, Warning) to notify people of ground hazards such as lahars and lava flows and four *colors* (Green, Yellow, Orange, Red) to notify the aviation sector of ash-cloud hazards. USGS Volcanic Activity Notices and Volcano Observatory Notices for Aviation announce alert-level changes at a volcano or significant activity within an alert level. Situational awareness is conveyed to the public through Daily/Weekly/Monthly Updates and a Daily U.S. Summary of Elevated Volcanic Activity. All notices are transmitted via email through a Volcano Notification Service and posted to the web.

USGS volcano hazard assessments are another critical information product. These result from geologic investigations of a volcano's eruptive history and thus provide a guide to what it is capable of doing in the future. These hazard assessments provide the scientific foundation for educating communities about volcano hazards and developing emergency response plans with local communities, emergency responders, and state agencies long before episodes of volcanic unrest begin. These plans define the responsibilities and coordinated actions of various government agencies in dealing with a restless or active volcano. They range in scope from national ("National Volcanic Ash Operations Plan for Aviation"), to regional ("Alaska Interagency Operating Plan for Volcanic Ash Episodes"), to volcano-specific ("Mount Rainier Hazards Response Plan"). The assessments also provide the basis for realistic eruption scenarios used by local emergency response agencies to conduct table-top volcano response exercises.

In response to the need to provide quantitative forecasts of ash fall to the public, the USGS embarked on a multi-year project to develop and implement an ash fall model (Ash3d). Ash fall can extend hundreds of miles downwind from a volcano. Knowing when the fall will start and stop and how much ash is likely to fall is critical to limiting its effect on communities. Ash fall forecasting and reporting is a joint USGS-National Weather Service activity, and the two agencies worked together to devise a severity index for ash fall. In tandem with the ash fall model, the USGS and the Alaska Division of Geological and Geophysical Surveys developed a web-based system to collect ash fall reports from the public, using this information to correct ash fall forecasts and improve the model.

International work

Significant foreign natural disasters in the past decades have been tragic reminders that geological hazards not only impact individual countries but can also have a dramatic effect globally. Volcano eruptions anywhere can have a detrimental impact on U.S. diplomatic and military interests and also on U.S. socio-economic interests such as disrupting the global supply chain.

The USGS has participated internationally in volcano-related projects since the 1940s. Early efforts were ad hoc and typically involved just one or two USGS scientists in a short-term project. A transition from piecemeal projects to coordinated foreign initiatives occurred in 1986, when the Volcano Disaster Assistance Program (VDAP) was created in partnership with the U.S. Agency for International Development's Office of Foreign Disaster Assistance, in the aftermath of the 1985 eruption of Nevado del Ruiz in Colombia that killed 20,000-25,000 people. VDAP collaborates with foreign counterparts to reduce volcanic risk globally by responding to emergencies at restless volcanoes at the request of the affected countries. VDAP is widely recognized for its outstanding performance in saving lives and enhancing the capabilities and stature of national volcano-monitoring organizations, as well as for its cost effectiveness. Since 1986, VDAP has responded with scientific expertise, equipment, and training to 28 major volcanic crises in more than a dozen countries. Recently, VDAP's long-term involvement with Indonesian volcano scientists and effective consultation during the 2010 eruption of Merapi aided the Indonesians in their decision to expand the evacuation zone, saving more than 10,000 lives. During these emergencies, VDAP also briefs U.S. embassy and military officials about the situation and the impact on local U.S. interests.

USGS volcano scientists working overseas not only further U.S. interests through science diplomacy but also bring important hazard mitigation lessons home for use in the United States. Knowledge and experience gained overseas feed directly back to our domestic responses to and preparation for volcanic eruptions. This is especially important in the conterminous United States, where eruptions are infrequent but the associated risks, including the possibility of evacuations, are extremely high.

Global reporting

Stakeholders within the U.S. Government and the private sector require up-to-date information about emerging and existing volcanic hazard activity worldwide. In 2000 the USGS and the Smithsonian Institution's Global Volcanism Program launched the online Weekly Volcanic Activity Report (http://volcano.si.edu/reports_weekly.cfm), a preliminary global overview of recent volcanic activity, to provide national and global situational awareness of new and ongoing events. As part of its rollout of the online version of the Volcanoes of the World 4th Edition, the Global Volcanism Program conducted a survey of users' needs and found that more frequent information was at the top of the list of unmet needs. The USGS and the Smithsonian are now experimenting with producing a daily report. Interested agencies include the U.S. Air Force Weather Agency, U.S. military commands, USAID, the White House National Security staff, the United Nations and European Global Disaster Alert and Coordination System, the International Atomic Energy Agency, and the International Civil Aviation Organization.

Thank you, Mister Chairman, for the opportunity to provide the Subcommittee with the Department's views on volcano hazards and the capabilities of the USGS to prepare for and respond to volcanic eruptions. Although eruptions cannot be prevented, research and monitoring can make communities across the Nation safer and stronger. I will be happy to answer any questions you may have.

For more information

USGS Volcano Hazards Program website http://volcanoes.usgs.gov/

USGS Hawaiian Volcano Observatory website http://hvo.wr.usgs.gov/; includes links to current information on Kilauea eruption

The National Volcano Early Warning System (NVEWS), By John Ewert, Marianne Guffanti, Peter Cervelli, and James Quick, U.S. Geological Survey Fact Sheet FS-2006-3142, 2006. http://pubs.usgs.gov/fs/2006/3142/

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http://pubs.usgs.gov/gip/135/, 2011.

The Novarupta-Katmai eruption of 1912—largest eruption of the twentieth century; centennial perspectives, by Wes Hildreth and Judy Fierstein: U.S. Geological Survey Professional Paper 1791, 259 p. 2012.