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Department of Earth,
Environmental and Planetary
Sciences

September 30, 2014

Dr. Suzette Kimball, Acting Director
U. S. Geological Survey, MS 905
12201 Sunrise Valley Drive
Reston, VA 20192

Dear Suzette:

This letter is to advise you of recent activity by the National Earthquake Prediction Evaluation Council (NEPEC) on three subjects: (1) review of a USGS strategic plan for improved forecasting of time-varying earthquake probabilities, (2) ongoing work by the NEPEC to foster improved risk communication in the Pacific Northwest, and (3) engagement of prediction researchers outside of the seismological community in the rigorous testing of their methods. These subjects have been discussed by the NEPEC over some time, most recently at our meeting in Menlo Park, California on November 4-5, 2013.

Improved forecasting of time-varying earthquake hazard

We were briefed on USGS plans for developing improved methods for estimating time-varying earthquake probabilities, and for designing and deploying products to communicate time-varying risk. These activities define a rapidly expanding field of work known as "Operational Earthquake Forecasting" or OEF.

In their 2011 report to the Italian government following the L'Aquila earthquake, the International Commission for Earthquake Forecasting defined OEF as "the continual updating of authoritative information about the future occurrence of potentially damaging earthquakes, and the officially sanctioned dissemination of this information to enhance earthquake preparedness in threatened communities." As such, OEF is already done on a limited basis by the USGS, in the form of automatic aftershock probability statements issued by the California Integrated Seismic Network using a protocol vetted by our California sister committee, the CEPEC, and on an *ad hoc* basis outside of California following some especially newsworthy earthquakes including the 2010 Haiti and 2011 Virginia earthquakes. At our meeting in Golden, Dr. Lucy Jones summarized a draft document, "USGS Strategy for Operational Earthquake Forecasting (OEF)," which is a five-year vision calling for an integrated program of research, development and evaluation of forecast models, design and testing of information products, and integration of forecast methods into the operations and product stream of USGS seismic networks. The plan

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other parts of the country and abroad, and for developing a broader suite of forecast information products.

We found the plan to be well thought out. It outlines a sensible strategy for evaluating additional methods for estimating time-dependent probabilities for operational use, including methods based on seismicity patterns, observations of changes in deformation, and Coulomb stress calculations. The plan appropriately focuses most attention on changes in hazard and risk arising from earthquake clustering, and sensibly avoids emphasis on forecasting based on other observations currently beyond our capability. The plan proposes specific tasks and milestones for work to be carried out by USGS staff in collaboration with many outside partners.

The strategic plan includes development of OEF information products that respond to user needs, collaboration on product design with communication experts, and rigorous evaluation of products both before and after they're operationally deployed. The Council was very interested in work—already under way by the USGS's Science Applications for Risk Reduction (SAFRR) program—to foster collaboration between seismologists and social scientists with expertise in risk communication, to gain insights on how to most effectively communicate earthquake forecasts and other risk-related information to various target audiences, such that appropriate actions are taken. The Earthquake Hazards Program and the SAFRR project have also taken steps to collaborate with key users such as emergency managers to identify user actions that can be informed by OEF information from the USGS.

The NEPEC endorsed the draft strategic plan, and I presented the plan and our endorsement to the SESAC at their meeting on October 30, 2012. The SESAC concurred with our endorsement, an updated version of which is attached to this letter. The SESAC also received an update on OEF strategic planning at their May, 2014 meeting.

In our discussions with USGS staff, we recommended that work begin early in the course of the project to extend the aftershock forecasting methods being used in California to the rest of the USA. Such extension will not be trivial, but is important, as substantial hazards exist in many regions of the country. At our recent meeting we heard that such work is underway by members of the Earthquake Science Center in Menlo Park and Pasadena, and that staff of the Pacific Northwest Seismic Network have expressed interest in such work. Work is also underway to lay the groundwork for estimating aftershock probabilities in other parts of the world.

Earthquake risk communication in the Pacific Northwest

The NEPEC has had a longstanding interest in the Cascadia margin of the Pacific Northwest, which poses a number of scientific and risk-communication challenges that are distinct from those in California and elsewhere. The complex tectonics superimposes hazards from earthquakes on the subduction interface, within the down-going slab, and in the upper plate directly beneath the region's urban centers. Although very large earthquakes are recognized to have happened in the past, and are expected in the future, the current rate of seismicity is relatively low and understanding of earthquake clustering statistics and other such matters are less well developed than they are to the south. The region also features a rich variety of earthquake-related phenomena including episodic "slow earthquakes" and non-volcanic tremor

that are thought to be important in the earthquake-generating system; however, their relationship to the occurrence of large earthquakes has yet to be worked out.

We can envision a number of situations that would raise concern about a possibly elevated seismic risk, and that would require there to be rapid and effective communication between scientists, and the conveying of prompt, authoritative, consistent, and useful information to decision-makers. Communication is challenging because the region includes three states, two countries, several universities, and a variety of decision-making groups and agencies. It is also challenged by the fact that large earthquakes are rare and because only rarely do earth observations raise concern about the potential occurrence of a major earthquake. Because events can unfold rapidly in the midst of an earthquake crisis, it is worthwhile to discuss in advance the types of information that could prove useful in supporting the work of emergency managers and other decision-makers prior to and during a crisis, and what information the scientific community may be able to provide.

The NEPEC has been considering ways to help move this topic forward. (Recall that the region has no council analogous to the NEPEC or CEPEC, which means either that NEPEC needs to play this role or that a regional body be created.) We have encouraged the USGS to engage in dialog with key officials and groups in the region, to learn what various information customers want and need to hear from scientists at times of elevated concern (for example, following a widely felt earthquake), and to consider how the dispersed scientific community can efficiently and effectively convey that information.

The NEPEC worked with USGS staff in Seattle, Pasadena and Reston to craft the next steps of this effort. We commissioned a white paper on situations that might trigger the need for rapid communication, which might serve to stimulate conversation between scientists and decision-makers in the region. Joan Gomberg of the USGS office in Seattle led the job of collecting views from a variety of earthquake scientists, and delivered a brief report entitled *Earthquake Forewarning in the Cascadia Region*, which summarizes several geologic observations that might raise concern about the potential for a damaging earthquake. These include changes in shallow seismicity patterns, and increased rate of earthquakes or changes in the pattern of slow slip on the subduction interface. We reviewed that draft report and recommended that it be published as a USGS open-file report.

In May of last year, the USGS arranged to make presentations at a FEMA-sponsored meeting of the National Earthquake Program Managers (NEPM) in Seattle. Presentations were given by Lucy Jones, Mike Blanpied, California State Geologist John Parrish, and John Vidale of the University of Washington, who serves as Washington State Seismologist and sits on the NEPEC. These speakers summarized what is known and unknown to scientists during an earthquake sequence or rapid strain event at depth, the roles of the National and California Earthquake Prediction Evaluation Councils (NEPEC and CEPEC), and actions taken by CEPEC and CalOES following large earthquakes.

Directly following the NEPM meeting, and before a meeting of the Western States Seismic Policy Council (WSSPC), the USGS convened a meeting on Communication of Time-changing Seismic Risk. Invitations were sent to participants of the NEMP and WSSPC meetings, as well as to certain university and USGS research staff. The meeting attracted 32 participants, including

the State Geologists of Oregon and California, the heads of emergency management for Oregon and Washington, representatives from FEMA headquarters and FEMA Regions IX and X, and representatives from government agencies and private groups in Alaska, Arizona, California, Oregon, Washington and British Columbia.

The USGS meeting resulted in strong endorsement of the plan to discuss, identify, and strengthen (where necessary) communication pathways, regional coordination, and risk messaging that will come into play during earthquake sequences and other times of elevated concern. Although several agencies, committees and groups already recognize and discuss earthquake issues, it was noted that the northwest states lack a formal earthquake response plan akin to that of California, and lack a plan for inter-state and inter-nation communication and coordination during an earthquake crisis. It was noted that there is an existing volcano multi-agency coordination plan as a model for what might be developed for earthquake response coordination, and that FEMA is developing a related annex to its Cascadia earthquake response plan, a process and product that may be helpful. Washington State Emergency Manager John Schelling proposed that the plan be developed under leadership of the Cascadia Regional Earthquake Workgroup (CREW), a public-private coordination body that he chairs. The USGS has received a proposal from CREW to undertake that work, and discussions are underway about potential sources for the approximately $85,000 cost.

The NEPEC is encouraged by this initial exchange of ideas, and looks forward to working with the USGS to foster further discussions and planning, and to participating as needed. It is worth noting that both the development of OEF products and the creation of pre-scripted messages that might be released very rapidly following some event in California or the Pacific Northwest, are likely to alter the ways in which the NEPEC provides advice in support of your Stafford Act responsibility to issue timely warnings of potential earthquake disasters. We can follow a traditional, deliberative sequence of events when time permits, but the rapid pace of electronic communication suggests that the Director and NEPEC should review and preauthorize a more streamlined or automatic process. Whether this will require any changes in interpretation of P.L. 93-288, may need to be considered in the future.

Rigorous testing of precursor-based prediction methods

The USGS Earthquake Hazard Program was born in the late 1970's at a time of excitement in the earthquake research community over prospects for the prediction of large earthquakes. The NEPEC was formed shortly thereafter, with an expectation that we would routinely be asked to comment on predictions and prediction methods being considered for endorsement by the Director. Since that time, it has become clear that short-term, deterministic earthquake prediction is difficult if not impossible. Despite concerted efforts to identify natural signals that might be monitored as earthquake precursors, no such "silver bullet" precursors have been found. As a result, the emphasis of USGS and academic research has appropriately shifted toward other approaches to earthquake risk reduction.

Nonetheless, there are a number of research groups that are continuing the search for earthquake precursors. This includes a small but tenacious community of researchers, some supported by Federal agencies, who believe that precursory signals may be found within ground-based or satellite-based observations of electric and magnetic fields or thermal radiation. There

has been a longstanding lack of understanding and trust between those groups and the more mainstream seismological research community. There have been a number of instances in which members of the latter community (including USGS staff) are put in the position of countering claims of success made to the news media, and there has been a growing frustration within both camps over what has amounted to a stalemate.

In an attempt to bridge this gap in communication and mutual understanding, I suggested to Tom Jordan that the Southern California Earthquake Center bring together researchers from both sides of the debate for constructive dialog aimed at increasing the levels of understanding of each other's data, methods, and assumptions. This led to two workshops held in 2012 and 2013 that were hosted by SCEC with support from NASA, the USGS, and the Department of Homeland Security's science and technology directorate.

These workshops were successful in at least a few regards. First, they attracted leading researchers who presented their data and perspectives concerned with earthquake prediction. Second, they permitted constructive conversation about the benefits of (and need for) rigorous testing of precursor-based methods, and about how such tests might be performed and evaluated. Third, they initiated a useful dialog between program managers at NASA, NSF, USGS and DHS, that yielded support from DHS to the Collaboratory for the Study of Earthquake Predictability (CSEP) in order to develop the software and methods required to test precursor-based predictions. We are pleased to learn that QuakeFinder, a project that aims to predict earthquakes via a network of magnetometers, is in conversation with CSEP in preparation to register their predictions for independent, prospective testing. NEPEC hopes that leadership encourages additional prediction researchers to follow suit, and we will be following these developments with interest.

If you have any comments or questions on these topics or others that fall under the purview of the NEPEC, please feel free to contact me directly or through the Earthquake Hazards Program office.

Sincerely,

Terry E. Tullis

Terry E. Tullis, Chair NEPEC
Professor, Emeritus and Research