U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

# Recommendations for EHRP 5 - Year Plan of USGS

## *(Earthquake Engineering Perspective)*

**compiled by**

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**from**

**Recommendations Developed by Contributors to**
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## *(Earthquake Engineering Perspective)*

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### EXECUTIVE SUMMARY

This document represents a compilation of recommendations for the USGS component of the Earthquake Hazard Reduction Program (EHRP) to be conducted during the next five years. These recommendations represent the proceedings of a workshop entitled "Earthquake Engineering and Risk" organized to review the 5 Year EHRP Plan of the USGS. The workshop focused on products and issues important for Earthquake Engineering, which as a profession requires information from all major components of the EHRP. Workshop discussion also emphasized the importance of these products for earthquake insurance, emergency management, and disaster recovery. Recommendations of the working groups focused on the overall USGS EHRP, the National Seismic Hazard Mapping Project, and the National Strong-Motion Program. Written recommendations of the working groups, participants and invitees are provided in detail. A brief, but limited summary is presented here.

Two types of products were identified by the workshop participants, basic or foundation products and high-level integrative products.

**Basic or foundation products identified to be of highest priority are:**

- National earthquake catalog (incl. historic events) with consistent moment magnitudes for Mw $\geq$ 3.
- Digital active fault data base (fault traces, recurrence times, slip rates, magnitudes ...)
- Strong motion recordings of all major damaging US earthquakes in densely urbanized areas
- Rapid dissemination of strong motion recordings via Internet, ftp, ... for disaster response, engineering, and research.
- Regionally-specific attenuation relationships
- Surficial geology and shallow Vs data bases and maps for urban areas

- Detailed 3D databases of Vs, Vp, Qs, Qp for sedimentary basins in urban areas with significant seismic risk for models of 3D basin response were important, but of somewhat lower priority,

**Integrative products identified to be of highest priority are:**

- National probabilistic seismic hazard maps and associated products ("Design maps re BSSC", hazard curves, uniform hazard spectra, uncertainties, de-aggregation, etc.), such as those used as a basis for design maps in building code provisions,
- Site amplification factors that are frequency and amplitude dependent (as well as regionally-specific) to adjust rock values of ground motions to soil conditions,
- Maps of expected ground motions for scenario earthquakes, including site amplification and 3D basin effects were determined to be of medium-high priority.
- Workshops, Public forums, Code contributions, ...

**Bullet recommendations indicating workshop consensus** are briefly summarized below. Complete text and additional recommendations are provided in the body of the report.

- **EHRP goals in 5 Year Plan should be stated more clearly**. The plan should identify time-specific objectives, activities and tasks that will be implemented to achieve stated goals.
- **A critical role recommended for the USGS in the EHRP** is the provision of basic *(earth-science)* hazard information for use by federal, state, and local governments and private sector organizations responsible for implementing earthquake safety measures.
- **Partnering relationships need to be pursued proactively** by the USGS to efficiently use resources and facilitate the acquisition and dissemination of critical information needed to mitigate the potentially disastrous effects of future earthquakes.
- **The USGS role in loss estimation and risk assessment** should involve partnering arrangements between the USGS and other organizations, especially FEMA with the USGS providing critical earth science hazard information.
- **The National Seismic Hazard Mapping Project** success in completing the 1996 seismic hazard maps should be extended based on workshops of geoscientists and users,
- **Improvements in the National Seismic Hazard Maps in the short term** (3 years) should include 1) consensus fault parameters outside of California, 2) uncertainty quantification for seismic sources, seismicity, and attenuation and their effects on the hazard, 3) more consistent national earthquake catalog, and 4) additional professional and public workshops.
- **Improvements in the National Seismic Hazard Maps in the long term require** digital data bases for active seismic sources and surficial geology in urban areas. USGS needs coordinated effort with state and local governments to compile these data bases.

- **On-scale measurement of earthquake-induced strong shaking is essential** for reduction of losses from subsequent earthquakes in densely urbanized areas of the US.
- **The USGS should establish an Advisory Board to assist the USGS in the planning and implementation of the National Strong Motion Program (NSMP).**
- **The NSMP of the USGS should enhance the national capability for the collection, processing and dissemination of strong-motion accelerogram data** from significant earthquakes. Instrumentation should be increased in regions of moderate to high seismicity outside California so that strong motions from all magnitude 6 or greater earthquakes will be recorded adequately.
- **The NSMP of the USGS should establish an aggressive schedule for replacing analog strong-motion instruments** with digital accelerographs and installing remote (telemetry) access capability.
- **A coordinated USGS effort to develop simplified soils maps** from compilations of surficial geologic information is recommended for improved national seismic hazard maps, national loss estimates (HAZUS), and a variety of other earthquake hazard mitigation efforts.
- **More extensive USGS workshop, public forum, and committee participation** is recommended to; communicate with users, identify user needs, improve practical uses of USGS products, and facilitate the development of improved earth science contributions to new building codes and other hazard mitigation efforts.

## EARTHQUAKE ENGINEERING AND RISK WORKSHOP TO REVIEW USGS 5 YEAR EHRP PLAN

### Preamble --- Earthquakes, A Severe National Threat

Staggering losses in and near Northridge, California ($15 to $25 billion) and Kobe, Japan (> $100 billion) demonstrate the potential impact of moderate to large earthquakes on modern urbanized societies. Estimates near $200 billion for future possible worst-case scenarios in the United States further emphasize the possible impact of earthquakes on our society and the urgency for improvements. "To address the need to make NEHRP and our nation's earthquake research effort more effective ... OSTP directed ... a review of the research and implementation issues related to earthquake hazards."[1] This review produced a plan for a National Earthquake loss reduction Program (NEP) with established goals in nine major areas with specific targets, products, and timelines. The plan states that "Existing federal programs will be stream lined and tailored to attain these goals; no new funding is expected".

### Purpose

The purpose of the Earthquake Engineering portion of the Workshop is to review the research and data acquisition programs of the U. S. Geological Survey as documented in the *5*

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Author Affiliation

*Year Plan* in the context of the NEP plan. Emphasis will be placed on review of the program from an Earthquake Engineering Perspective. The workshop will focus on review of the overall USGS EHRP program, review of the National Seismic Hazard Mapping Project, and review of the National Strong-Motion Program.

Seismic hazard maps are vital links between earthquake research and the mitigation of earthquake risk. This workshop will define critical needs of the user community and identify how best the USGS can fulfill those needs. In addition to engineering applications, the seismic hazard maps have broad use in insurance applications, loss estimation studies, and emergency management planning. The workshop will encompass discussion of seismic hazard maps on national, regional, and local scales. The workshop will address broad policy issues concerning seismic hazard maps and identify specific technical issues that should be the focus of efforts to improve seismic hazard mapping.

Strong-motion recordings of major earthquakes in densely urbanized areas provide the basis to design and build earthquake resistant structures and to resolve critical research issues pertaining to crustal failure and seismic radiation. The USGS conducts the National Strong-Motion Program to acquire measurements of strong ground shaking and structural response needed for Earthquake Hazard Reduction. The program is operated in cooperation with federal, state, and local agencies and regional advisory committees, including Army Corps of Engineers, California Division of Mines and Geology, Department of Energy, General Services Administration, Hawaii Civil Defense, Metropolitan Water District of Los Angeles, Municipality of Anchorage, Utah Geological Survey, Univ. Puerto Rico, Veterans Administration, California, Oregon, and Washington Departments of Transportation, and a Consortium of Major California Universities. The National program is responsible for instrumentation at 550 sites in 33 states and the Caribbean with multiple-channel systems in 50 buildings, 10 bridges, and 90 dams. The workshop will identify critical products of the program and provide recommendations regarding critical issues relevant to its successful operation during the next 5 years.

The NEP plan points out that "the principal threat of earthquakes is shaking damage and the collapse of buildings and other structures that have been inadequately designed to resist seismic forces. " Consequently, reduction of potentially catastrophic losses of life and property during future earthquakes requires a well balanced program to improve retrofit, construction, and design practice of man-made structures based on a thorough assessment of potential shaking levels and the potential for secondary failures associated with liquefaction, landsliding, and water inundation.

As one of the principal participants of NEHRP, the United States Geological Survey has a major responsibility for providing the fundamental data sets and methodologies critical for geographic assessments of potential earth-science hazards. The USGS is the primary federal agency responsible for the acquisition, and dissemination of information on strong shaking in and near structures. It is also the primary federal agency responsible for mapping and characterizing earthquake sources for purposes of evaluating earthquake potential and associated shaking potential.

This Review of the USGS Program is intended to evaluate the balance of the program, identify priorities, and develop recommendations for changes to accommodate possible

reduced funding levels. Evaluations in the workshop are to be based on the 5 Year Plan, general salary and OE level funding summaries for the major elements of the program, participant evaluation of program performance and societal needs.

## "EHRP WORKING GROUP" RECOMMENDATIONS FOR THE OVERALL USGS EARTHQUAKE HAZARD REDUCTION PROGRAM

**Members -- H. Shah, *Chair,* J.C. Stepp, *Reporter*, J. Davis, W. Holmes, S. Nishenko, W. Petak, G. Nordensen**

**USGS Liaison Members -- J. Dieterich, R. Page, D. Schwartz, R. Updike**

1. **EHRP GOALS in 5 Year Plan should be stated more clearly:**
   - Goals should be directed to the user community and clearly stated in language that links with the user need.
   - Goals should be general and may be independent of time - a longer time horizon than the 5-year plan should be identified.
   - The plan should identify time-specific objectives, activities and tasks that will be implemented to achieve the stated goals (see text).
   - A useful structure for the plan is the following:

| GOALS | OBJECTIVES | ACTIVITIES | TASKS |
|---|---|---|---|
| G1 | O1 | A1 | T1 |
| | | | – |
| | | A2 | T1 |
| | | – | – |
| | O2 | A1 | T1. |
| | | – | – |
| G2 | O1 | A1 | T1 |

2. **EHRP PRODUCTS for the USGS program are:**

**A. Foundation (Basic) Products;**

- Seismicity maps, catalogs, and databases
- Active fault maps, slip rates, and paleoseismic histories
- Crustal strain rates and earthquake deformation
- Urban geologic/geotechnical databases
- Strong ground shaking measurements

- Post-earthquake investigations

**B. Integrated Products**

- Seismotectonic models
- Long-term probabilistic earthquake forecasts
- Ground failure susceptibility maps
- Strong ground shaking estimates
- Probabilistic hazard maps for ground shaking, ground failure, and building damage
- Earthquake scenarios
- Real-time earthquake alerts, warnings and information

**C. Outreach Products**

- Professional education
- Public information/education materials

**D. Partnership Products, e.g.**

- Regional and National Loss estimates

**3. Program Balance recommendations are:**

- The appropriate mix of resources between "Products for Earthquake Loss Reduction", "Earthquake Information", and "Earthquake Research" allocated to these elements is a dynamic of the EHRP. It should vary among program goals and objectives and should grow out of the planning of activities and tasks to meet the goals and objectives.
- The appropriate balance for Earthquake Information is a balance between: 1) strong motion data acquisition in densely urbanized areas, 2) regional networks (weak motion), and 3) global networks (teleseisms), which provides the basic data and dissemination activities upon which the EHRP depends. Basic support must be maintained. Partnering arrangements to leverage and maximize EHRP resources need to be implemented.
- General Priorities for elements of "Earthquake Research" in the 5 Year Plan are:
  - High priority elements:
    - Physics of earthquake rupture
    - Long-term hazard assessment
    - Real-time hazard assessment
  - Low priority element:
    - Earthquake Prediction

General Priorities for elements of " Earthquake Effects " in the 5 Year Plan are:

- High priority elements:
  - Source effects
  - Wave propagation

- Site-specific shaking hazard
- Ground failure
- Response of structures (partnering arrangements)

- Moderate priority elements:
  - Tsunamis (Effort should be consistent with the level of exposure to the hazard).

4. **The proper roles for the USGS in loss estimation and risk assessment are :**
   - **Loss and risk estimation methodologies** integrate hazard, facility inventory, and facility-specific fragility. It is suggested that the USGS should have the lead role in the development of hazard, including development of geologic/geotechnical site information. Development of loss estimation methodology and conduct of risk assessments should be involve partnering arrangements between the USGS and other organizations (FEMA, OTHERS).
   - **Loss scenario studies** also involve integration of hazard, facility inventory and fragility. State and local government and private sector involvement is essential. Partnering arrangements are essential. USGS should provide hazard scenarios and work with the product user.
5. **Partnering between Federal, State, and Local Governments and the Private Sector recommendations are:**
   - The USGS should be proactive in developing partnering arrangements at every level.
   - The EHRP should be viewed as providing basic hazard information needed by federal, state, and local governments and private sector organizations to develop and implement earthquake safety measures.

## "NSHMP WORKING GROUP" RECOMMENDATIONS FOR THE NATIONAL SEISMIC HAZARD MAPPING PROJECT

**Members -- M. Power, Chair, J. Hunt, Reporter, D. Kim, M. Peterson, R. Smith.**

**USGS Liason Members – A. Frankel, J. Boatwright, K. Haller, E.V. Leyendecker, E. Roeloffs.**

Recommendations regarding Products and Issues of the "NSHMP Working Group" are given in question-answer format as discussed in workshop.

## I. PRODUCTS

1. *Please develop a list of important USGS EHRP products needed by the user community and provide a general ranking according to priority.*

   Please see the attached lists of possible products of the National Seismic Hazard Mapping Project: A, high-level integrative products; and B database or foundation products. H indicates highest priority. M indicates an important activity but, from a timing standpoint, of less immediate need than those of H. Seismic hazard maps including site effects are important but need geology data bases (Item B.2) before they can be effectively implemented. NA indicates that the Mapping Working Group did not address that possible product.

2. *Are the "Products for Earthquake Loss Reduction" for the EHRP clearly specified in the 5-year plan?*

   They are reasonably well specified. Possibly, a more formal division between high-level integrative products (list A attached) and database or foundation products (list B attached), would be useful, both types of products being of great potential value to the user community. Products should be available in hard copy as well as digital form. The draft plan emphasizes the use of the maps for the 1997 NEHRP provisions published by BSSC. However, the potential or actual use in other provisions (e.g. potential use in AASHTO Specifications, actual use ATC-33 Seismic Rehabilitation Guidelines) and by many other federal agencies and other agencies and organizations should be mentioned as well. The need for interaction with these user groups should also be indicated.

3. *What additional products should be added to the 5-year plan?*

Overall products seem to be covered; see following list of seismic hazard mapping related products. These products and major elements of the EHRP are cross referenced in a subsequent section entitled *Major EHRP Program Elements and Products.*

**High-level, integrative products**

1. National probabilistic seismic hazard maps and associated products (hazard curves, uniform hazard spectra, uncertainties, de-aggregation...). *High priority*
2. Regional probabilistic seismic hazard maps with site amplification. *Medium priority*
3. Local probabilistic seismic hazard maps with site amplification and 3D basin effects. *Medium priority*
4. Site amplification maps for selected urban areas. *Medium priority*
5. Maps of expected ground motions for scenario earthquakes including site amplification and 3D basin effects. *Medium-high priority*
6. Tables of soil amplification factors (frequency/amplitude dependent) that are regionally specific (e.g., WUS and CEUS). *High priority*

**Database or foundation products**

1. Active fault database with slip rates, recurrence times, magnitudes. *High priority*
2. Surficial geology and shallow Vs maps of urban areas. *High priority*
3. National earthquake catalog (including historic events) with consistent moment magnitude determinations. *High priority*
4. Regionally-specific attenuation relations. *High priority*
5. Ground deformation database from GPS, etc. *Medium priority*
6. Detailed 3D models of Vs, Vp, Qs, Qp for sedimentary basins in urban areas. *High priority*
7. Intensity maps for earthquakes in U.S. above certain magnitude threshold. *Medium priority*

**NSHMP**

*Are the "Products of the NSHMP" clearly specified? If not, please indicate how they might be better emphasized.*

Please see responses to above questions under EHRP.

## II - ISSUES

**A) GOALS** - Are the goals of the National Seismic Hazard Mapping Project (NSHMP) as expressed in the 5-Year Plan clearly specified? If not, how can they be improved.

The goals are reasonably well stated. The recent effort of the NSHMP has been a great success both from a technical standpoint and from the standpoint of user interaction and user acceptance of the maps developed by USGS. It also illustrates the benefits of working with the earth sciences community at large (cooperative efforts with state agencies and interaction with private practitioners). The success of this project should be highlighted in the plan, indicating what has been accomplished and what are the logical next steps.

**B) PROGRAM BALANCE**

*What is the appropriate balance for the overall EHRP program between "Products for Earthquake Loss Reduction", Earthquake Information" and Earthquake Research"? How should the balance be modified to best meet the Earthquake Hazard Mitigation needs of society?*

The Working Group strongly believes that the National Seismic Hazard Mapping Project should be well supported and merits an increase in the percentage of available resources. The value and effectiveness of this project has been well demonstrated in the past 2 to 3 years.

**C) SPECIFIC QUESTIONS**

*1. Should the USGS be working on loss estimation methodology and seismic RISK assessment?*

Yes. The emphasis should be on defining the seismic hazard ground motions working cooperatively as partners with FEMA/NIBS on the overall methodology. The overall loss

estimation methodology is composed of four major parts, i.e., the seismic hazard, site characterization, definition of the built environment involved in the loss estimation, and the built environment response to the earthquake ground motions. The USGS, FEMA, and other involved groups should work together to ensure the parts are integrated appropriately. Each group needs to understand the input and output from each other to ensure the final results are meaningful. Also it is recommended that cooperative activities with the states, counties, and cities be established to implement the loss estimation methodology in their respective areas. These are the groups who benefit most from these studies, therefore they should be willing to participate.

2. *Should the USGS be working on earthquake loss scenario studies?*

Yes. The earthquake loss scenario studies are needed for the loss estimation studies discussed in a) above.

3. *Should the USGS be an active participant in building code development?*

Yes. USGS should continue to participate in industry committees and cooperative projects which are developing seismic ground motions and seismic design information for use in the building codes. This participation should be a high priority and should be increased in groups such as BSSC, ASCE, SEAOC and other state structural engineering organizations, code committees, and ATC. This participation is important to identify and understand the user needs and to create cooperative relationships. These activities will improve the user's understanding of the USGS products and their vital importance in the development of the building codes and will help to focus USGS research.

4. *What are the needs of the user community?*

The needs of the user community should be identified through various modes of interaction with that community. It is recommended that user need workshops be held to more clearly identify the user needs and that workshops be specifically identified and included in the five year plan.

5. *What database products should the USGS provide?*

The databases used for developing the seismic ground motion maps should be provided to the users. The consistency of the databases should be improved and a consistent computer platform should be used for the databases. The databases for site conditions in urban areas are very important and a high priority should be given to accumulating these site conditions into available databases. The databases should also be available in hard copy. The availability of these databases should be publicized more to make everyone aware of their existence and importance.

6. *What high-level products (e.g., hazard maps) should the USGS develop?*

The national seismic hazard ground motion maps should be developed along with regional and urban maps with site effects. The urban area maps with site effects should have more priority than the regional maps with site effects and should be developed in cooperation with the states, counties, and cities in these urban areas. There should be interaction with FEMA and others (states, counties, cities, universities, etc.) to establish consistent guidelines for determining the site conditions.

7. *How should the USGS cooperate better with state agencies to improve seismic hazard maps? How should the USGS cooperate better with regional scientific entities (e.g.,*

*SDEC, CDMG) and federal agencies (e.g., FEMA, NRC, DOE) to improve seismic hazard maps?*

It strongly emphasized that cooperation is vital. The recent national mapping program, which held regional workshops to obtain input from the state agencies, regional scientific entities, other federal agencies, and the scientific and engineering community at large, is a good example of improving the cooperation. These type of workshops and feedback workshops on the results should be continued. Specific workshops with state geologists could be held to obtain all the important information which they have collected. Also specific federal interagency workshops could be held to determine what each federal agency is doing, what their ground motion mapping needs are, and how research and mapping programs can be coordinated.

8. *How can the USGS improve the national seismic hazard maps(short-term)?*
   - i. fault parameters
   - ii. earthquake catalogs
   - iii. attenuation relations
   - iv. other

The USGS could improve the consensus of the fault parameters outside of California. Future mapping efforts should quantify the understanding of the uncertainties in the input parameters used for mapping, including seismic sources, seismicity, and attenuation and their effects on the hazard. The adequacy of earthquake catalogs should be evaluated and the possibility of developing a moment magnitude catalog for the eastern U.S. investigated. A systematic approach should be taken to evaluate the mapping input parameters, methodologies, and uncertainties through workshops, independent review panels, and implementation in the next generation of maps.

9. *What novel technology/modeling can be used to improve national/regional/local hazard maps in the long-term?*
   - i. GPS
   - ii. 3-D basin modeling
   - iii. Sress change/fault interaction

It is recognized that the above items are important, but it is considered that, for purposes of developing maps, these items have a lower priority than the areas discussed in h) above. More detailed information on the site conditions (basin structure and properties) is needed before the 3-D basin modeling can be effectively utilized in providing regional or local estimates of ground motion.

10. *Should the USGS be working to develop consensus ground motion attenuation relationships?*

Yes. Consensus does not mean developing one attenuation relationship, but improved consensus on which and how many relationships to use along with consensus on the uncertainties associated with the relationships.

11. *How can the USGS get its results to be used better?*

The USGS can improve the use of its results through workshops to obtain input for developing the results, feedback workshops to understand the results, interaction with the

users through participation in industry committees and on projects oriented toward user needs, being more proactive on educating policy makers about the importance of the results, improved publicity of the results, and support of specific activities that are designed to enhance the transfer of USGS research results into engineering practice.

*12. Should the USGS develop detailed site response maps of selected urban areas?*

Yes, as discussed above, with emphasis on initially collecting the data to define the site conditions.

*13. Should the USGS develop local seismic hazard maps with site response included?*

Yes, as discussed above, with emphasis on initially collecting the data to define the site conditions.

*14. Should the USGS be collecting surficial geology information and shallow VS in urban areas?*

Yes, as discussed above this should have a high priority.

*15. Should more seismic instrumentation be deployed in urban areas? What kind?*

The working group did not specifically address this question because it is not directly related to the mapping program. The working group supports the need for more instrumentation because this is the only way to obtain the information necessary to test the research and theoretical modeling of ground motions, site effects, and effects of ground motions on the built environment.

*16. What should be the balance of funding between the urban hazards and other aspects of the Program?*

The working group understands the shortage of funds and recognizes that decisions need to be made on how to balance the funds for all the important parts of the program. The working group did not feel qualified to provide specific recommendations on how to balance the funding. However, the working group believes that high priority and increased funding should be given to the national seismic hazard mapping program.

*17. Please add critical issues for discussion as appropriate.*

For lack of time, the working group did not address this item.

*18. SUMMARY - What changes would you make in the draft 5-year plan?*

The working group recommends that information be added in the introduction of the plan to explain the recent successes such as the new national seismic hazard maps, involvement of users, cooperative efforts with others, etc. Also, it is recommended that workshops to identify user needs be specifically identified and included in the plan. It should be made clear that there are many potential users of the national maps, not just NEHRP. Workshops and other means of interaction will help to identify the needs of other agencies and organizations and educate them on the nature of the maps that have been produced. It should also be stated that a task is to begin to extend the national mapping to regional and urban area mapping incorporating site effects.

It may be useful to more formally distinguish between major integrative products, such as national maps, and database or foundation products, such as compilations of faults and fault parameters; earthquake catalogues; databases, models and parameter values used in national mapping (documentation); site conditions; etc. Both types of products are of great potential value to the engineering/earth sciences community.

## "NSMP WORKING GROUP" RECOMMENDATIONS FOR THE NATIONAL STRONG MOTION PROGRAM

**Members -- B. Bolt, Chair, C.B. Crouse, Reporter, N. Abrahamson, C. Rojahn, D. O'Connell, P. Somerville.**

**USGS Liason Members – R. Borcherdt, M. Celebi, A. McGarr, W. Mooney, J. Mori.**

1. **Enhance the capability for the collection, processing and dissemination of strong-motion accelerogram data from significant earthquakes.**
   - The USGS should strive toward a goal of disseminating strong motion data within months (in the case of analog records) or days (in the case of digital telemetered records) after a major earthquake.
   - Because approximately 90% of the USGS accelerograph network consists of analog instruments, the USGS should establish an aggressive schedule for replacing these instruments with digital accelerographs with remote (telemetry) access capability. Priority for this replacement should be given to urban areas in California where the likelihood of a moderate to large earthquake is relatively high. The analog instruments should be redeployed to other areas if feasible.
   - The USGS should acquire proper hardware to process analog accelerograms and not rely on outside vendors for this task.
2. **Increase instrumentation in regions of moderate to high seismicity outside California so that strong motions from all magnitude 6 or greater earthquakes will be recorded.**
   - The USGS should give priority to urban areas in implementing this recommendation.
   - An executive order requiring all new federal buildings to be instrumented with a minimum number of accelerographs (e.g. 3) should be pursued. This order might apply to those areas where the ground-motion hazard, as mapped by the USGS, exceeds a specified threshold. Cooperative arrangements with other U.S. government agencies should be sought to assist in carrying out the order.
3. **Convert old analog data to digital or electronic format.**
   - The USGS has compiled useful data on seismic hazards throughout the U.S. during the NEHRP program. Examples of these data include maps of liquefaction and landslide hazards in urban areas. Also, written observations of damage and felt reports, collected by the USGS through surveys following major earthquakes, may

be useful in calibrating loss estimation algorithms. These analog data should be converted to electronic format.

4. **Establish an Advisory Board to assist the USGS in the planning and implementation of the NSMP.**
   - Model the concept after the State of California strong motion instrumentation program (CSMIP) which has several panels of experts that advise the CSMIP.
5. **Recommendations regarding strong ground motion products (P. Somerville).**
   A. **Strong ground motion products needed by the Earthquake Engineering community.**
      1. **Probabilistic response spectral maps and suites of time histories** for use in base-level design and for code provisions, multiple probability levels required for performance based design, and maps that use empirical and/or numerical ground motion models.
      2. **Suites of time histories that use broadband numerical simulations** which permit hazard deaggregation and account for site and basin response.
      3. **Response spectral maps and time histories for scenario earthquakes** for use in planning and mitigation and for maps that use empirical and/or numerical ground motion models.
      4. **Response spectral maps and time histories of past significant earthquakes** for use by engineers seeking to explain damage and for mitigation activities, for both immediate post-earthquake reconnaissance and mitigation, and for long-term research.

   B. **Justifications for these products.**
      1. WHY TIME HISTORIES? Engineers need time histories for performance based design in the next generation of building codes.
      2. WHY MULTIPLE GROUND MOTION PROBABILITY LEVELS? Engineers need them for performance based design in the next generation of building codes
      3. WHAT IS PERFORMANCE BASED DESIGN? Design based on actual behavior of buildings, including non-linear effects associated with yielding of the structure that require time history input because they are difficult to represent adequately using response spectrum input.
      4. WHERE IS PERFORMANCE BASED DESIGN BEING USED NOW?
         - SEAOC - Vision 2000 (next generation of building codes)
         - Prop. 122 - Recommended Methodology for Seismic Evaluation and Retrofit of Existing Concrete Buildings
         - SAC Steel Building Project - Guidelines for the Repair, Modification and Design of Welded Steel Moment Frame Strctures.
         - Design and retrofit of bridges and dams.

5. WHY BASIN RESPONSE?

- Basin response was probably responsible for most of the damage in west Los Angeles and Santa Monica during the 1994 Northridge earthquake (e.g. I10 collapse).
- Basin edge effects were probably responsible for the narrow belt of extreme damage in Kobe during the 1995 Kobe earthquake.

## SUMMARY OF PROGRAM ELEMENTS, AND RECOMMENDED PROGRAM PRODUCTS AND PRIORITIES

*(WORKSHOP DISCUSSION).*

Several comments during the course of the workshop indicated that a strong correlation should be identified between elements of the USGS component of the EHRP and products produced by the program. A direct correlation between major elements of the program and products of the program as discussed and assigned priorities by workshop consensus is provided in the following table. These elements and products are consistent with those summarized by R. Page, USGS EHRP program coordinator. The products are classified as *High-level Integrated* and *Basic or Foundation* products. Priorities are assigned as *High, Medium,* and *Low.*

| Major Program Elements | Products | | |
|---|---|---|---|
| | Type | Priority | Name |
| **I Characterization of Earthquake Source Zones** | | | |
| (N. Calif., S. Calif, Pacific NW, Alaska, Nev., Utah, Cen. Miss. Valley, Eastern US) | | | |
| **1. Seismology (Seismicity) Studies -- *(Eqk. Info.)*** | Basic | | Regional seismicity catalogs and maps |
| A. Regional Networks | | | |
| B. U.S. National Network | **Basic** | **High** | **National earthquake catalog (incl. historic events) with consistent moment magnitudes for Mw > 3.0** |
| C. Global Network (NEIC) | | | Global earthquake catalog |
| D. Earthquake Intensity Surveys | Basic | Med. | Intensity maps for earthquakes in US |
| **2. Geodetic (Tectonic deformation) Studies *(Eqk. Info.)*** | | | |
| Strain Networks | Basic | Med. | Ground deformation data base from GPS, etc. |
| **3. Geologic Seismic Source Characterization** | **Basic** | **High** | **Digital active fault data base** |
| (Recurrence interval, ... *Research Studies*) | | | **(fault traces, recurrence times, slip rates, magnitudes ...)** |
| | Intgr. | | Regional earthquake probability assessments |
| | **Intgr.** | **High** | **National probabilistic/deterministic seismic source zone maps re 1997 code provisions** |

## II Measurement and Estimation of Strong Motion

**1. Strong-Motion Measurement** ***(Eqk. Information)***

National Strong Motion Network ~ 550 stations

(33 states and Caribbean)

| | | | |
|---|---|---|---|
| A. Deploy and maintain instrumentation to record ground shaking for public safety, engineering, and research in each urban area with significant seismic risk. | **Basic** | **High** | **Strong ground motion recordings of all major damaging US earthquakes in densely urbanized areas** |
| B. Deploy and maintain instrumentation to record response of structures for public safety, engineering, and research in each urban area with significant seismic risk. | **Basic** | **High** | **Strong motion recordings of significant structures and lifelines for all major damaging US earthquakes in densely urbanized areas** |
| C. Coordination of other federal and state programs and partnerships | **Basic** | **High** | **Strong motion recordings meeting partner program objectives of all major damaging US earthquakes** e.g. COE Dams, VA Hospitals, FHWA bridges, .... |
| **2. Strong-Motion Dissemination** ***(Eqk. Info.)*** National Strong Motion Data Center | **Basic** | **High** | **Rapid dissemination of strong motion recordings via Internet, ftp, ... for disaster response, recovery, engineering, and research.** |

**3. Site-Specific Strong-Motion Estimation** ***(Research Studies)***

| | | | |
|---|---|---|---|
| A. Source Modeling Studies | Intgr. | | Earthquake source rupture models |
| B. Ground Motion Attenuation Studies | **Intgr.** | **Med-H.** | Regionally specific attenuation relationships |
| C. Site Amplification Studies | **Intgr.** | **High** | **Site amplification factors (frequency/amplitude dependent)** |
| | Intgr. | Med. | Site-specific, strong-motion time histories for scenario eqks. |
| D. Ground Failure Studies | | | |
| E. Structural Response Studies | | | |

| | | | |
|---|---|---|---|
| **4. Data Base Development for Regional Estimates** | | | |
| A. Seismic and Geotechnical Logging at Strong Motion Site (SF, LA, SLC,Seattle,Anchorage, Memphis, ...) | **Basic** | **Med.-H** | **2 & 3 D models for Vs, Vp, Qs, Qp for urban sedimentary basins** |
| B. Geologic Q Maps in High Risk Urban Regions (soils map | **Basic** | **High** | **Surficial geology and shallow Vs data bases and maps for urban areas** |
| **5. National Seismic Hazard Mapping Project** | **Intgr.** | **High** | **NationalSeismic Hazard Maps and associated products (BSSC Design maps, hazard curves, uniform hazard spectra, uncertainties, de-aggregation,...)** |
| **6. Regional Seismic Hazard Mapping Methodology Projects** Probabilistic and Scenario Estimates of Ground Shaking Amplification Capability, Liquefaction Suseptibility, & | Intgr. | Med. | Regional probabilistic seismic hazard maps with site amplification and 3 D basin effects |
| Landslide Suseptibility Mapping (SF, LA, SLC,Seattle,Anchorage, Memphis, ...) | Intgr. | Med. | Local probabilistic seismic hazard maps with site amplification and 3 D basin effects |
| | Intgr. | Med. | Demonstration maps for high risk regions Amplification Capability, Liquefaction Suseptibility Landslide Suseptibility |

## III Outreach and Mitigation Policy Development

| | | | |
|---|---|---|---|
| Public Education Efforts | **Intgr.** | **High** | **Workshops, Public forums, Code contributions, ...** |

## RECOMMENDATIONS REGARDING EHRP PRODUCTS NEEDED FOR NATIONAL ESTIMATES OF EARTHQUAKE LOSS (*HAZUS*)

**Recommendations of R. Volland, G. Jamieson, and S. Nishenko**

23A

# Federal Emergency Management Agency

Washington, D.C. 20472

14 January 1997

**Memorandum**

TO: R. Page, Coordinator, Earthquake Hazards Program

FROM: R. Volland, Director, National Earthquake Program
G. Jamieson, Chief, Branch of Risk Assessment
S. Nishenko

RE: USGS Earthquake Hazards Program Five Year Plan

Having read the draft version of the USGS Five Year Plan for the Earthquake Hazards Program, there are a few comments that we at FEMA would like you to consider for the final version.

There is a fundamental need for this plan to provide a clear outline as to how USGS activities contribute to and fit into the overall NEHRP/ NEP agenda. As it reads now, the USGS plan appears to be a stand alone document. This plan needs to clearly identify partnerships, that build on the strengths of the various NEHRP agencies, to achieve the national goal of earthquake loss reduction. The USGS has played a crucial role in helping develop the FEMA/NIBS loss estimation technology (HAZUS). This should be used as an example of interagency cooperation. FEMA and the USGS have a long history of cooperation - we should use this to our best advantage and demonstrate to Congress that the USGS 5 year plan is part of a cohesive national strategy. Some additional examples and ideas for the next 5 years are presented in the following section.

Projects that FEMA would like to collaborate with the USGS in developing, and products that we would like to see introduced over the next 5 years include,

- The ability to account for site amplification of earthquake ground motions, as well as liquefaction, landsliding, and lateral spreading are key to the successful application of HAZUS. A national soils map, initially at 1:100,000 scale and eventually at a finer scale as dictated by local requirements, would be a significant step forward in this regard.

- A national ranked list of urban areas at risk from earthquakes. This would incorporate hazards information from the national probabilistic shaking maps with building inventory and infrastructure information to develop a quantitative assessment of earthquake risk at the national level.

## II. Recommendations of R.V. Whitman ( Chm. Project Working Group, HAZUS).

Date: Mon, 13 Jan 97 19:58:35

From: rwhitman@MIT.EDU (Robert V. Whitman)

To: 5-year@rsgl.er.usgs.gov

Subject: Comments re 5-year plan

I want to thank you again for the invitation to attend the meeting later this week. I really agonized over the decision, since I feel the USGS effort is important and that I should help support planning for it - but one more cross-country trip at this time just isn't feasible.

These comments reflect my particular interest in the FEMA/NIBS methodology (HAZUS) for estimating losses from future earthquakes. I note the 5-year plan calls for producing "maps of expected building damage distributions for scenario earthquakes in selected high-risk urban areas". The desire to have such scenarios produced (for moderate-risk as well as high-risk regions) was the reason that FEMA initiated and funded the development of HAZUS. The USGS has supported the development of HAZUS in several ways: Roger Borcherdt played a key role on the technical oversight committee; Paula Gori provided invaluable liason to several offices of the USGS; and many products of USGS research were used in the "potential earth science hazards" module of PESH. As we move into the use of HAZUS by states, cities and regions, it will be very important that this co-operation between FEMA and the USGS continue. I understand that the USGS is considering use of HAZUS in connection with the recently launched effort to evaluate natural hazard risks for the Puget Sound region.

I will subdivide my comments as follows:

**Co-operation re scenarios for a few high-risk urban areas:**

1. Presumably the parts of HAZUS of greatest potential use to the USGS in its studies are the modules for predicting damage to buildings and other structures and (to a lesser extent) to components of lifelines. (The methods for structuring inventory and the data bases for inventory, already built into HAZUS, should also be of great value.)
2. I know that researchers at the USGS have in the past developed damage functions, and also have collected data concerning damage during several earthquakes. It would be natural for USGS people to want to develop further their past work concerning vulnerability of buildings.
3. It would be unfortunate, I think, to have competing methods evaluating building damage and loss. However, the building damage and loss functions in HAZUS are new, having been developed on new principles, and there is need for evaluating, calibrating and evolving these functions. There is ample room for working together in this regard. It will not hurt to have urban officials realize that there is considerable uncertainty as to just how individual structures or the building stock as a whole will respond to a specified ground shaking.

4. HAZUS aggregates buildings into census tracts, and this leads to some potential difficulties in interfacing with very detailed maps of ground shaking distribution, liquefaction potential, etc. The first high-risk urban earthquake loss scenario will also be a good opportunity to explore how best to minimize or reduce these difficulties.

(2) **Needs arising from FEMA-assisted efforts to apply HAZUS in many states, regions and cities:**

1. One major requirement for the application of HAZUS is maps reflecting potential for amplification of earthquake ground motions, liquefaction susceptibility and landslide susceptibility. It is hoped that HAZUS will be used in many parts of the country during the next few years, which means that "soil effects" maps must be prepared for many areas. For initial studies, such maps do not require the detail that has characterized maps the USGS has prepared (for example) for the Bay Area. USGS contributions to this effort would be of enormous benefit, since the current lack of suitable maps is possibly the greatest obstacle to the hoped-for program of initial loss estimates. It would appear that much can be done by adapting and massaging information on maps of surficial geology that already exist for most if not all areas of interest, but considerable judgement from established earthquake geotechnology experts will be necessary. Please consider including such an effort in your 5-year program.
2. Another particular short-term need is greater consensus re appropriate attenuation equations for use in the Eastern United States. While we have opted to use in the first release of HAZUS the equations selected by the USGS for the effort on behalf of the BSSC, I personally am not satisfied that these equations fulfill our need for best estimates of spectral ordinates.
3. There is another, perhaps somewhat longer term need in regard to probabilistic seismic hazard maps. I believe that aleatory uncertainty was considered in producing these maps, but that epistemic uncertainties were not factored into the calculations. HAZUS has plans to use the current USGS probabilistic seismic hazard maps as the basis for a crude probabilistic analysis of losses. As the probabilistic analysis within HAZUS is refined to reflect uncertainties in building losses given some ground shaking, it will become necessary to factor in epistemic uncertainties in the ground shaking corresponding to some specified mean recurrence interval.

I would be glad to try to amplify on these comments should you so desire. Thank you for the opportunity to comment.

## INDIVIDUAL RECOMMENDATIONS REGARDING NATIONAL SEISMIC HAZARD MAPPING PROGRAM

### RECOMMENDATIONS OF JEFF KIMBALL;

Department of Energy
Germantown, MD 20874-129-0

January 13, 1997

Robert A. Page, Coordinator, Earthquake Hazards Program
Mail Stop 905
United States Department of the Interior
United States Geological Survey
Reston, VA 22092

Dear Dr. Page:

Thank you for the opportunity to provide my views on the United States Geological Survey (USGS) Earthquake Hazards Program 5-year plan. My views focus on those aspects of the 5-year plan that I am most familiar with, the National Seismic Hazard Maps and the ongoing efforts to quantify ground motion attenuation throughout the United States. Both of these aspects are visible in the draft plan, and in my view should continue to get high priority attention in the next 5 years.

While the USGS should be proud of its accomplishments related to updating the National Seismic Hazard Map in 1996, more work needs to be done. Your plan recognizes this in committing to update on a periodic basis these maps, and to have improved maps available for the Year 2000 National Earthquake Hazards Reduction Program (NEHRP) Recommended Provision for the Development of Seismic Regulations for New Buildings. The job of integrating and incorporating the elements of regional and local geoscience data and input, and to make concerted efforts to attract input and critique from the broad scientific community, is both time consuming and resource intensive. Your near-term planning should focus on determining if the current approach for obtaining this information is appropriate or should be enhanced. Additionally, while the past regional workshops were clearly a success, there remains a number of technical issues that need evaluation and input from the scientific community.

In essence the above discussion breaks down into three broad areas: (1) Identification of the technical issues which dominate the hazard results; (2) identification of those issues which need more work; and (3) arriving at the best approach to obtaining the information to addressing these issues. It has been my experience that the latter area, the approach or process to obtaining input, does not get enough attention when planning occurs. The challenge is to develop an approach that allows the USGS hazard map team to be both a processor and integrator of the relevant technical information involving the entire relevant

scientific community. It also means communicating meticulously and accurately the scientific community's level of knowledge as well as the lack of understanding to a wide range of users.

To address such issues may require the development of specific approaches/procedures for effective communication, expert interaction and debate, resolution of outlier opinions, and documentation of the scientific community state of information and knowledge.

To be clear, implementation of a more rigorous process will likely require more resources than has been previously allocated. You may ask is it worth it? From my perspective, given the fact that the national seismic hazard map directly impacts all building codes and should be considered by all seismic hazard users, the answer should be a resounding yes. Provided on the attachment are specific process and technical issues for your consideration in future seismic hazard mapping efforts, including thoughts and recommendations on how to enhance the process to obtaining seismic hazard input, from the scientific community.

There is one specific technical issue which is discussed in your 5 year plan which I think needs more attention and that is the issue of site response (site amplification). There remains considerable debate within the scientific community regarding the amount of non-linear behavior for soils, and the large amount of empirical data which appears to suggest linear behavior except for the very soft soils. Additionally, the current approach to quantifying site response in the NEHRP Provisions, while seemingly appropriate for the Western United States, is likely to be inappropriate for the East and may be unconservative (primarily because of the dramatically higher impedance contrast that exists between soil and rock in the East). Finally, the development of any urban hazard maps will need to include an assessment of site response. This assessment should be consistent with that included in the NEHRP Provisions. To address these issues it is my view that the USGS needs to take a more proactive role in the quantification of site response.

In closing, I want to thank you for the opportunity to present my views regarding priorities and opportunities for the USGS Earthquake Hazards Program.

Sincerely yours,

Jeffrey K. Kimball, Team Leader

Engineering Design Support Team

DOE, DP-45

## FOCUS AREAS RELATED TO THE NATIONAL SEISMIC HAZARD MAPS

The National Seismic Hazards Maps published in July 1996 represent a significant achievement with respect to updating the assessment of probabilistic ground motion within the United States. As stated in the draft 5-year plan, a mandate of the National Earthquake loss

reduction Program (NEP) and among the highest priorities for the USGS earthquake program is to update on a periodic basis a series of national probabilistic shaking hazard maps. I strongly endorse such a high priority for this effort. To strengthen this effort, it is recommended that the National Seismic Hazard Mapping task address the issues outlined below as part of developing the deliverable of updated maps by April 1999.

1. MORE FORMAL APPROACH TO OBTAINING INPUT FROM EXPERT COMMUNITY:

While the seismic hazard regional workshops should be considered a great success, future efforts should, using the existing hazard results, provide more specific focus on those aspects of the hazard input that are critical to quantifying the ground motion hazard following a more formal process for assessing seismic hazard input. The essence of this would be a documented description of the overall process that would be used to debate specific technical issues, gather appropriate input for hazard calculations, and feedback the updated hazard results with final agreement for the maps to be prepared by April 1999. By documenting the process you will be implementing, the roles and responsibilities of the various participants will be clearly described, including what is expected from each participant. his would allow the USGS leads to become more of a "gatekeeper or integrator" than being specifically responsible for developing "inputs",and would result in a more "engaged" scientific community, taking more ownerships of the inputs and the product. The downside to a more formal process is that it is likely to be more labor intensive that the previous workshops.

It is recommended that the USGS Seismic Hazard Map Team review the recently published report "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts", prepared by the Senior Seismic Hazard Analysis Committee (SSHAC, UCRL-ID-122160, 9/95, to be published as a Nuclear Regulatory Commission NUREG). The SSHAC report provides a framework for the process that could be followed in completing a probabilistic seismic hazard analysis (PSHA). Specifically, the SSHAC report addresses the integration and evaluation issues that should be considered and focuses on the process of integration required in a PSHA.

The USGS Seismic Hazard Map Team should start by assessing and identifying issues in the current effort which most influence the hazard results. The issues should be prioritized depending on the significance of the issue to the hazard results, the issue's technical complexity and level of uncertainty, and the amount of technical contention about the issue in the technical community. This step would provide the opportunity to make additional comparisons with existing PSHA studies and results, as input to identifying critical issues. Once this has been completed, a determination can be made regarding how best to address each issue. As part of this process it is recommended that the USGS identify and select a "process" peer review team, and have that team involved early on in the effort to revise the hazard maps (for example, the peer review team would be represented at all workshops),

For the most significant issues, it is recommended that an approach similar to the SSHAC report Technical Facilitator/Integrator (TFI) be implemented. In this case the USGS Seismic Hazard Map Team would be the TFI lead, with enhanced expertise as needed. The TFI has the responsibility and is empowered to represent the composite state of information regarding a technical issue raised by the scientific community. In this process, the expert community would also have specific roles and responsibilities. Some experts would have the specific role

of being a proponent of a specific hypothesis, will other experts would have the role of evaluators of a range of hypotheses and models. The overall precept of this approach is that a thorough and well documented expert interaction becomes the principal mechanism for integration.

The above process is outlined in the SSHAC report as a seven steps process: (1) Identification and selection of the technical issues; (2) identification and selection of the experts; (3) discussion and refinement of the technical issues; (4) training for elicitation; (5) group interaction and individual elicitation; (6) analysis, aggregation, and resolution of disagreements; and (7) documentation and communication.

Outlined below are several candidate technical seismic hazard issues which may require assessment in the development of the future seismic hazard map. For the Eastern United States issues the order of presentation is based on recommended priority.

2. EASTERN UNTIED STATES SEISMIC HAZARD ISSUES:

(a) Ground Motion Attenuation Models: The PSHA map results are directly dependent on the selection of ground motion attenuation models. Based on a review of recently published literature and the ground motion models used for the 1996 maps, there remains considerable uncertainty in the assessment of Eastern United States ground motion, particularly for response frequencies less than about 2 hertz. Figure 1 is provided to illustrate 1 hertz spectral acceleration for a moment magnitude 6.5 earthquake based on six recent ground motion models. Review of Figure 1 suggests that there remains considerable debate regarding the appropriate models for the East. The two models used for the 1996 maps tend to be the most conservative models for 1 hertz ground motion: Does this represent the consensus of the scientific community? The use of any of the alternative models would suggest that the 1 hertz probabilistic results may be overconservative. In any case, a more active debate needs to take place to determine which are the most appropriate models to use for the future PSHA maps.

(b) Special Zones - Seismic Sources Based on Tectonic Features: In general the input to the existing PSHA maps is based on various assumptions for smoothed seismicity. Based on input from the Memphis workshop, however, a special source zones for Eastern Tennessee was developed. The criteria for identifying such zones should clearly be described, and should be applied consistently throughout the Eastern United States. Under what conditions is it significant that a special source zones is added when compared to the smoothed seismicity assumptions?

(c) The Earthquake Catalog: One of the most important parameters in assessing the seismic hazard is the magnitude of the earthquakes in the catalog. In the East, the USGS primarily used the catalog of Seeber and Armbruster (1991), which is a refinement of the EPRI (1986) catalog. The assignment of earthquake magnitude for pre-instrumental earthquakes is critically dependent on the intensity-magnitude relationship used and on intensity-area estimates for these older events. It is not clear what type of critical review was performed on the utilized earthquake catalog, particularly the estimated magnitude for older earthquakes. Specifically a review of the confidence in assigned areas for different intensity levels of historic earthquakes should be undertaken to ensure that no bias exists that could impact activity rates, earthquake completeness intervals, and recurrence values. Additionally,

if multiple measure of magnitude are going to be used (Mw, Mblg), care must be taken to ensure that any intensity-magnitude conversions are implemented correctly.

(d) Special Zones - Seismic Sources, Activity Rates and Paleoearthquakes: In several locations either the recurrence interval for the characteristic earthquake or the identification of seismic source is based on field evidence for repeated episodes of liquefaction. While the field evidence for paleoliquefaction is compelling, the integration of this information into a PSHA must be done with care. For example, the magnitude of the earthquakes causing the liquefaction could span a wide range and may come from multiple seismic sources. For locations away from historic earthquakes, the question of completeness can logically be asked.

3. WESTERN UNITED STATES SEISMIC HAZARD ISSUE:

The documentation associated with the 1996 maps recognizes that more information needs to be provided related to slip rates for fault seismic sources. The process for obtaining slip rates should be more systematic and formal to ensure that the quality of all input, independent of the geographic location, is adequate. Slip rates used should be critically reviewed to ensure that the input is adequate. Issues such as short term versus long term rates of slip must be considered in a more regional context than simply accepting a value provided. Slip rates based on only the most recent slip rate. Specific criteria should be developed to select slip rates for faults.

## QUANTIFICATION OF SITE RESPONSE

The effects of local site soil conditions on earthquake ground motions are complex and important. The current approach contained in the 1994 NEHRP Provisions (to be retained in the 1997 Provisions) is to select the soil profile type based on the material properties within the top 100 feet of the surface. Site coefficients are provided depending on the soil profile type and level of ground motion. The site coefficients are primarily based on the work of the "Working Committee to Draft NEHRP Site-Dependent Response Provisions", and are described in Borcherdt (1994). Review of this work indicates that the site coefficients are dominated by Western United States (California) experience. A critical question is whether such results are appropriate for other regions, such as the Eastern United States, where the contrast between rock and soil is significantly larger than typically found in California.

In the East, the shear wave velocity for rock can range from over 10,000 feet/second for crystalline rock, to 4,000 to 7,000 feet/second for sedimentary rock. In general, both coastal plain soils, and glacial soils (such as till) are stiff soils with shear wave velocities ranging from 1,000 to 2,000 feet/second. In these instances the amount of soil amplification can be large, ranging from 3 to 8 depending on the specific site in question. Review of the NEHRP site coefficients would suggest that the amount of site amplification would be underestimated for the above Eastern situations. Additionally, because of the large impedance contrast, the actual depth of the soil is important in determining at what response frequency the site amplification will occur.

## RECOMMENDATIONS REGARDING NATIONAL STRONG MOTION PROGRAM

### I. Recommendations of K. Jacobs

To: borcherdt@samoa.wr.usgs.gov, afrankel@gldesg.cr.usgs.gov

From: jacob@ldgo.columbia.edu (Klaus Jacob)

Subject: Jan 16/17 workshops

Cc: rpage@usgs.gov

Dear Roger and Art:

I just informed Joyce Costello USGS-Reston that I will not be able to attend the earthquake engineering and risk workshop(s) Jan. 16-17 in CA. (as I had already indicated, at least to Art). I did commit myself to attending the Wrap-Around Workshop on Jan. 30-31 (despite partial conflict with BSSC annual meeting in Dallas, Jan 28-30). If I can provide any additional input in written form, I will try to work this into my full schedule.

In that spirit, here follows a partial list of some of my concerns:

- We need a ten (10!!) year plan for both urban and national strong motion data acquisition, data management and dissemination regarding sites on structures, soil/foundation systems, and in the free field; with specifics on scientific and engineering needs, and:
  - (a) what is technologically possible,
  - (b) scientifically needed; (with realistic cost estimate for a and b combined),
  - (c) what under current funding limitations will remain of (a) and (b), and what will NOT be possible to do that needs to be done, and
  - (d) what will be the likely impact and price paid by the public if it does not get done?
- We need a national standard seismicity catalog referenced to moment magnitude
- We need a national standard catalog of active and potentially active faults
- We need a standard catalog of geologically (paleoseismic) or otherwise inferred potential seismic sources (mines, reservoirs, quarries, volcanoes, slides, other).
- We need more detailed regionalized ground motion attenuation laws with a clear understanding of region-specific uncertainties as a function of distance, magnitude, depth and frequency.
- Quantification of ground motions at long periods, and for long duration
- Better handle on 1-D site vs. 2- and 3-D basin response
- How much nonlinear soil response is there: revisit NEHRP site amplification factors ?
- How to put data and products on the INTERNET?

  We need better and more intelligent on-line accessibility of ground motion data, allowing simultaneous (!) searches of diverse data bases. For this purpose

standardization of pertinent header information stored in relational data bases searchable with standard query language will be essential. This requires cooperative efforts from data collector-, data manager-, and data user- disciplines. An ordinary user should not need to know where the data are stored, and in what format. The search engine should be able to do it for him, with minimal user interaction (deselect).

Also, here are parts of recommendations from a recent US/Italy earthquake engineering workshop held at Columbia University in Dec 96, that may have some bearing on your deliberations:

**Ground Motions:**

- Research and data are needed for a better understanding of near field motions, including fault mechanisms and directivity effects.
- The capability to simulate ground motions on demand, via Internet access (given location, reoccurrence interval, and site class) will create a need for improved computational models for nonlinear dynamic response of structures.
- Tools need to be developed and standardized to optimize the selection of ground motion data from large retrieval sources.

**Modeling of Seismic Response:**

- Efforts need to be directed at improving the understanding of what critical ground motion constituents are the most significant on response of different types of structures in terms of potential destructiveness.
- Simple computational models for nonlinear dynamic analysis of structures need to be developed as the availability of time series ground motion data via Internet access will increase.
- Newly developed computer programs should permit a simplified display of response output data (stress, strain, displacement, failures, etc.)
- New computational models need to be developed for assessment of existing structures with undesirable or poorly understood behavior modes that are not inherent in newly constructed, code complying structures.
- Computational models need to be verified or confirmed with actual dynamic measurements taken from prototype structures with a detailed array of sensors.
- Full-scale ambient or large-amplitude testing of an actual building with extensive instrumentation could serve as a common test site for research on methods of measurement or computation of dynamic response.

**Vulnerability Studies:**

- Studies need to be done to quantify seismic vulnerability of urban building stocks.
- Improved inventories of building stocks are needed to improve the accuracy of urban vulnerability studies. Research needs to be done to develop new and

improved methods for generating and extrapolating building inventories using advanced technologies and new sources of information.

- Existing loss assessment methodologies should be compared and evaluated by testing in different cities and (internationally) in different countries.

Good luck with the workshops. I would appreciate being a "corresponding member". i.e. get drafts of the WS recommendations before finalizing. I will try to comment or make suggestions for changes. Is this possible and acceptable ?

Regards, Klaus

Klaus H. Jacob, Ph.D.

Senior Research Scientist

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## II. Recommendations of M. Celebi re: 5 YEAR PLAN

January 24, 1997

There are many issues raised on the DRAFT FIVE YEAR PLAN. In general, I believe the plan looks good. I would like to provide you with some thoughts, however.

The following quotes are from " ***Recommendations for the Strong-Motion Program in the United States***" published in 1987 by Committee on Earthquake Engineering of the National Research Council":

> Page 49: *"An effective national strong-motion program must be concerned with all phases of activities, including strong-motion instrument development, deployment and operation of instruments, processing, archiving and dissemination of data, the uses of data, strong-motion research, strong-motion applications, integration of activities of various governmental agencies, universities and corporations taking part in strong-motion activities, and identification of the amount of funding required for such a national effort and the source of funding."*
>
> Page 50: *" Plans for deployment of strong-motion instruments requires decisions as to whether they should be located in structures or in the free-field. Both kinds of data are needed by engineers, whereas seismologists prefer free-field data."*

The following quotes are from " Earthquake Prediction and Hazard Mitigation Options for USGS and NSF Programs" published in 1976 by NSF and USGS:

Page 51: *Under Activities for Subelement b: Acquisition of Strong-Motion Data: :*

1. *Improve the national-strong-motion instrumentation network by:*

   *(a) Replacing obsolete instruments,*

   *(b) Installing adequate instrumentation arrays in all seismic regions,*

   *(c) Developing arrays to measure the two and three dimensional distribution of ground motion.*

   *(d)* ***Instrumenting representative types of structures, particularly in the more active parts of the country.***

There are many other reports that are published between 1976-1997 that refer to the above "recommendations" to the USGS. Therefore, we should dwell upon what we can do to live up to these recommendations. Here are some thoughts on how we can proceed with expansion of the structural instrumentation program during the next five-years and beyond:

1. Expand our involvement with other federal agencies in persuading them to instrument new and existing buildings. This is particularly important in light of Executive Orders 12941 [Seismic Safety of Existing Buildings] and Executive Order 12699 [Seismic Safety of New Buildings]. The strategy for this can be as follows:

   (a) Instrument in Seismic Areas 3 and 4 only, federally owned and leased buildings on ***a selective basis*** that reflects the objectives of the strong-motion instrumentation of structures program. [Alternatively, the areas described by Leyendecker/Frankel maps as having the highest risk or highest PGA with 10 % probability of exceedence could be used]. 10 % of all significant lifelines in urban environments within areas 3 and 4 that are not instrumented by other programs should be instrumented. ***For information: There are approximately 84,000 federally owned and 5000 federally leased buildings in areas 3 and 4. The acquisition value of these buildings is $16 billion (does not include contents).*** This means that if 0.1 % of the buildings are instrumented, the number would reach to approximately 90.

   (b) Funding for this effort should be provided by individual agencies, GSA, FEMA and other sources. USGS should provide expertise and guidance, monitoring on a reimbursable basis and management and dissemination of acquired data.

2. In areas within 10 km of faults that can generate M>7 earthquakes, instrument 5 % of **all buildings** taller than 3 stories **or** single or double story buildings if not regular structures (e.g. tilt-up buildings, precast buildings etc). In addition 50 % of all lifelines in these areas should be instrumented.

   (a) There are large inventories of buildings within 0-10 km of the major faults [within the US] capable of generating M>7 earthquakes. This is particularly important because, very recently, the Structural Engineers Association of California (SEAOC) issued the 1996 edition of the ***Recommended Lateral Force Requirements and Commentary*** which has provisions for increasing the design base shear by 0-100 % depending on the 0-10 km distance of the building from the fault. This implies that the forecasting of performance of buildings within 0-10 km of major faults must be done more informatively. This requisite

information can be achieved only through acquiring and studying response data from buildings during earthquakes.

(b) This effort has to be carried out on a cooperative basis – with building owners and other sources (as was done in the past).

(c) In California, this effort has to be complementing CDMG's program where they instrument regular buildings and USGS instruments non-typical buildings.

3. All new or retrofitted buildings [in areas 3 or 4] that incorporate new technologies such as base-isolation, viscous elastic dampers, recently developed methods of design and construction). In California, in general, this effort falls outside the scope of CDMG as they dwell on instrumenting regular buildings.

4. Identify special areas such as (a) In San Francisco Bay Area (such as Lower Market Area in San Francisco, Emeryville, Marina District in San Francisco, South SF Peninsula, Oakland), (b) In LA Area (such as Sherman Oaks, Van Nuys, Downtown LA, Santa Monica, San Bernardino), (c ) In Pacific Northwest (Seattle, Portland), (d) in Central and Eastern US (Memphis [Tn], Cape Girardeau [Mo], Chareston [SC] and others) that are vulnerable and have high seismic risk. In these areas develop special instrumentation of structures program that reflect the risk associated with their specific seismic sources and site effects.

5. Develop special purpose experiments such as soil-structure interaction [SSI] and topographical experiments for which we have little or no detailed data in areasthat exhibit topographical features in built urban environments. These should be "national" experiments in nature as now being demanded by engineering profession. As has been done in the recent past, ultimate details of the selection criteria of structures to be instrumented should be developed through advisory committees in each region. The advisory committees should be representative of local engineering profession, academicians and local city and county government representatives.

**Some deliberations on Strong-motion data needs for IMPROVED Earthquake Resistant Design, Construction and Retrofit practices:**

Evolution of new technologies in earthquake resistant design, construction and retrofit practices requires systematic and efficient verification of the performance of structures built with the new technologies or retrofitted with new methods. Such verification can only be accomplished in essence by strategically deploying seismic sensors in such structures to record their performances during future events.

The severity of damages to numerous steel structures during the January 17, 1994 Northridge earthquake (Ms=6.7) and Kobe (Japan) earthquake of January 17, 1995 (Ms=6.8) is a perfect example which requires instrumentation of both the new generation design of mid-rise to high-rise steel buildings but also those that were repaired and/or retrofitted by methods developed for the particular damage problem. It is therefore essential to obtain data during future events for response studies to assess the effectiveness and revise and/or improve the new methods of design, construction and retrofitting.

**Critical Research in Structural Engineering**:

There are many facets of response of structural systems that are not well understood. In many cases, although theoretical solution are abound, actual response data is scarce or non-existent. One important aspect of structural response is the soil-structure interaction. In many cases, under specific geotechnical environment, certain structures will respond differently than if that structure was built as a fixed based structure on a very stiff (e.g rock) site condition. This alteration of vibration characteristics of structures due to soil-structure interaction can be both beneficial and detrimental for their performances. To date, the engineering community is not clear about the pros and cons of SSI. In Mexico City, during the Michoacan earthquake of Sept. 19, 1985, many structures were negatively affected due to SSI because the lengthening of their fundamental periods placed them in a resonating environment close to the approximately 2 second period of Mexico City lake bed. On the other hand, under different circumstances, SSI may be beneficial because it produces an environment whereby the structure escapes the severity of the response spectra due to shifting of its fundamental frequency. Certainly, in a basin such as that of Los Angeles area, SSI may cause both beneficial and detrimental effects in the response of structures. The identification of the circumstances under which SSI is beneficial or detrimental and the parameters is a necessity.

There are many urban areas in the United States as well as in other countries where hills are heavily built. There is now sufficient evidence to claim that there is such a phenomenon as the topographical effects.

**Personnel Needs and Line of Action for the next 5 years:**

The demand for additional personnel should not be underestimated or ignored. In addition to the current personnel of the strong-motion program involved in instrumentation of structures [one research civil engineer and seven technical staff], there is need for another research civil engineer who will have a hands on attitude and devote his time/energy to the basic instrumentation and structures program. Also there is need for at least 3 more technical staff that carry deployment aspects of both the structural instrumentation program and those for free-field ground instrumentation.

Realistically speaking, with the personnel at hand (even with additions), provided that funds are found through cooperative efforts and OFA sources, I suggest that we can instrument a maximum of 20 structures per year. In five years, this makes 100 [not bad at all]. (Remember that CDMG, with all their financial and personnel resources reached a number of approximately 150 in 10 years!).

Therefore, our objective should be to obtain steady annual allocation of funds [internal and OFA and other] for purchasing hardware for 20 structures per year for the next five years. My estimates for the hardware is approximately ($0.6 million/year based on an average of $30 K /structure).

## APPENDIX 1

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## APPENDIX 2

### Earthquake Engineering and Risk

### Workshop Agenda

Park Plaza Hotel
1177 Airport Blvd.
Burlingame, Ca 415-342-9200
January 16 -17, 1997

*Thursday, January 16,1997*

**8:30 Welcome, Introductions, Purpose and Goals**
(R. Borcherdt and A. Frankel)

**8:45 Background for 5 Year Plan** (R. Page)

**9:15 Preliminary 5 Year Plan** (E. Roeloffs)

**Program Summaries**

**9:30 Status of NEP and USGS EHRP Programs**
Brief Discussion (15 min)

**10:00 Status of National Seismic Hazard Mapping Project** (A. Frankel)
Active Fault data Bases (K. Haller, D. Schwartz)
Brief Discussion (15 min)

**10:45** *Coffee*

**11:00 Status of the National Strong-Motion Program** (R. Borcherdt)
Brief Discussion (15 min)

**General Review of Products and Issues**

**11:30 Earthquake Hazard Reduction Program** --- (R. Page)

**11:50 National Seismic Hazard Mapping Program** --- (A. Frankel)

**12:10 National Strong-Motion Program** — (R. Borcherdt)

**12:30** ***Lunch***

**1:30Working Group Discussions and**
**Development of Bullet Recommendations**

**3:15** *Coffee*

**3:15Continue Working Group Discussions and**
**Completion of Bullet Recommendation Summary**

**5:30 Adjourn**

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*Friday January 17, 1997*

**8:30 Oral Reports and Discussion of Working Group Recommendations**
**9:30 Develop Written Summary of Recommendations**
1) **Specify Products and Priorities**
2) **Specify Issues and Priorities**

**10:30** *COFFEE*

**10:45 Complete Written Summary of Recommendations**

**12:00 Closing comments**

**12:30 Adjourn**

## APPENDIX 3

### Products and Issues for the EHRP Working Group

**I — PRODUCTS**

1. Are the "Products for Earthquake Loss Reduction" for the **EHRP** clearly specified?
2. What additional products are needed? P
3. Please develop a list of important USGS EHRP products needed by the user community and provide a general ranking according to priority.

**II — ISSUES**

1. **GOALS** -- Are the overall goals of the **EHRP** program as expressed in the 5 Year Plan appropriate? If not, how should they be modified?
2. **PROGRAM BALANCE** –
   a) Is the balance of the overall program appropriate between "Products for Earthquake Loss Reduction", "Earthquake Information" and Earthquake Research" correct? If not, how should the balance be modified to best meet the Earthquake Hazard Mitigation needs of society?
   b) Is the balance of the program for "Earthquake Information" correct? What proportion of personnel and funding resources should be devoted to strong-motion stations (free-field and structures) in densely urbanized areas, to regional networks with stations not in urban areas (weak motion), and to global networks (teleseisms)? Is the present allocation appropriate? If not, how should it be modified?
   c) Is the balance for the "Earthquake Research" component of the program appropriate between "Earthquake Occurrence" and "Earthquake Effects"? Are the most critical earth-science research problems for Earthquake Hazard Mitigation identified? Please indicate a priority list of critical research problems and the rough percentage of resources that seems appropriate for the solution of each.
4. **ACHIEVEMENT OF GOALS** – Are the goals in the 5 year plan realistic? Can they be achieved with the present balance and allocation of funding and personnel resources? Are the milestones for their achievement clear and realistic? If not, how can they be improved?
5. **Specific Questions** –
   a) What is the proper role for the USGS in regards to development of loss estimation methodologies and seismic RISK assessments as suggested in the NEP document?
   b) What is the proper role for the USGS in regards to the conduct of earthquake loss scenario studies?
   c) Does the 5 Year Plan suggest the proper emphasis to help resolve some of these issues? If not, how should it be modified?

d) Please add critical issues for discussion as appropriate

**III — General Comments**

Please comment on any topics or issues pertinent to the USGS conduct of a more effective **EHRP.**

## APPENDIX 4

**Products and Issues for the National Seismic hazard mapping Project Working Group**

**I --- PRODUCTS**

**EHRP**

1). Are the "Products for Earthquake Loss Reduction" for the **EHRP** clearly specified?

2) What additional products are needed?

3) Please develop a list of important USGS EHRP products needed by the user community and provide a general ranking according to priority.

**NSHMP**

1. Are the "Products of the **NSHMP"** clearly specified?
2. If not, please indicate how they might be better emphasized.

**II --- ISSUES**

1. **GOALS** -- Are the goals of the **National Seismic Hazard Mapping Program (NSHMP)** as expressed in the 5 Year Plan clearly specified? If not, how can they be improved?
2. **PROGRAM BALANCE** –

a) Is the balance of the overall program appropriate between "Products for Earthquake Loss Reduction", "Earthquake Information" and Earthquake Research" correct? If not, how should the balance be modified to best meet the Earthquake Hazard Mitigation needs of society?

b) Is the balance of the program for "Earthquake Information" correct? What percentage of personnel and funding resources should be devoted to strong-motion stations (free-field and structures) in densely urbanized areas, to regional networks with stations not in urban areas (weak motion), and to global networks (teleseisms)? Is the present allocation appropriate? If not, how should it be modified?

3. **Specific Questions** –

1. Should the USGS be working on loss estimation methodology and seismic RISK assessment?
2. Should the USGS be working on earthquake loss scenario studies?
3. Should the USGS be an active participant in building code development?
4. What are the needs of the user community?
5. What database products should the USGS provide?
6. What high-level products (e.g., hazard maps) should the USGS develop?

7. How should the USGS cooperate better with state agencies to improve seismic hazard maps? How should the USGS cooperate better with regional scientific entities (e.g., SCEC, CDMG) and other federal agencies (e.g., FEMA, NRC, DOE) to improve seismic hazard maps?
8. How can the USGS improve the national seismic hazard maps (short-term)?
   a. fault parameters
   b. earthquake catalogs
   c. attenuation relations
   d. other
9. What novel technology/modeling can be used to improve national/regional/local hazard maps in the long-term?
   a. GPS
   b. 3-D basin modeling
   c. stress change/fault interaction
   d. ????
10. Should the USGS be working to develop consensus ground motion attenuation relations?
11. How can the USGS better get its results used?
12. Should the USGS develop detailed site response maps of selected urban areas?
13. Should the USGS develop local seismic hazard maps with site response included?
14. Should the USGS be collecting surficial geology information and shallow Vs in urban areas?
15. Should more seismic instrumentation be deployed in urban areas? What kind?
16. What should be the balance of funding between urban hazards and other aspects of the Program?
17. Please add critical issues for discussion as appropriate.
18. SUMMARY. What changes would you make in draft 5-year plan?

**III --- General Comments**

Please comment on any topics or issues pertinent to the USGS conduct of a more effective **EHRP.**

## APPENDIX 5

**Product and Issues for the National Strong Motion Program Working Group**

### I --- PRODUCTS

**EHRP**

1. Are the "Products for Earthquake Loss Reduction" for the **EHRP** clearly specified?
2. What additional products are needed?
3. Please develop a list of important USGS EHRP products needed by the user community and provide a general ranking according to priority.

**NSMP**

1. Are the "Products of the **NSMP**" clearly specified?
2. If not, please indicate how they might be better emphasized.

### II --- ISSUES

1. **GOALS** -- Are the goals of the **National Strong Motion Program (NSMP)** as expressed in the 5 Year Plan clearly specified? If not, how can they be improved?
2. **PROGRAM BALANCE** –

a) Is the balance of the overall program appropriate between "Products for Earthquake Loss Reduction", "Earthquake Information" and Earthquake Research" correct? If not, how should the balance be modified to best meet the Earthquake Hazard Mitigation needs of society?

b) Is the balance of the program for "Earthquake Information" correct? What percentage of personnel and funding resources should be devoted to strong-motion stations (free-field and structures) in densely urbanized areas, to regional networks with stations not in urban areas (weak motion), and to global networks (teleseisms)? Is the present allocation appropriate? If not, how should it be modified?

3. **SPECIFIC QUESTIONS** –

a) Is the present **NSMP** meeting the needs of society for on-scale measurement of damaging earthquakes in densely urbanized areas of the United States? If not, why not?

b) Is the present **NSMP** meeting the needs of the research and engineering communities for on-scale measurements of the main shock to understand:

i) Physics of earthquake rupture,

ii) Near source radiation characteristics (Directivity, coherent pulses)

iii) Near-source Attenuation

iv) Non-linear site response

v) Soil-structure Interaction

vi) Structural Failure (e.g. steel moment frame)

vii) etc.

c) Is the present level of resources expended on the National Strong Motion Program adequate? Do personnel and funding levels for network maintenance and data management need to be restored to pre-EHRP (1977) levels? If effort continues at present level, what is likely cost to public?

d) Should the USGS continue to help coordinate other Federal, state and local strong-motion programs requesting assistance?

e) What proportion of program resources should be devoted to ground motion measurement and what proportion to measurements in structures?

f) Should the USGS continue to maintain instrumentation in structures? If not, how will this need to be accomplished in Federal structures and in areas outside California?

g) How can the current strong-motion data dissemination effort of the **NSMP** be improved to better meet the needs of the earthquake engineering community?

h) How should near-real time warning and near-real time measurements in urbanized areas be integrated into **NSMP** efforts?

i) Please add critical issues for discussion as appropriate.

j) Does the 5 Year Plan suggest the proper emphasis to help resolve some of these issues? If not, how should it be modified?

**III --- General Comments**

Please comment on any topics or issues pertinent to the USGS conduct of a more effective **EHRP.**