California Integrated Seismic Network

Strategic Plan: 2011 - 2016

Caltech
CGS
CalEMA
UC Berkeley
USGS, Menlo Park
USGS, Pasadena

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1 Executive Summary

Large earthquakes are inevitable in California. The degree to which future losses of life and property in the State from these earthquakes can be mitigated depends on our collective understanding of the earthquake problem and our investment in learning how to mitigate the earthquake effects. Seismic monitoring is the foundation upon which earthquake understanding, response operations and mitigation practices are built.

This strategic plan is an assessment of the needs for and a framework of the strategy to develop and operate an integrated seismic network for the State of California. A modern statewide earthquake monitoring and reporting system is fundamental to obtaining timely and accurate seismic information, the cornerstone of an effective earthquake response and mitigation strategy for the State. This California Integrated Seismic Network (CISN) will organize and manage the collection and distribution of seismic information and develop and provide new products and services. The CISN also constitutes one of the eight regions within the Advanced National Seismic System (ANSS) structure, and it participates fully in ANSS activities.

Rapid earthquake notification and automatically generated maps of the distribution of damaging shaking levels (ShakeMap) provide critical information to speed response in the aftermath of large earthquakes. Through modernization, the CISN will provide these products on a statewide basis. In addition, many buildings and other structures throughout California were designed without adequate knowledge of the level of strong ground motions to be expected from a major earthquake. The CISN will collect and distribute strong-motion information that will enable the engineering community to monitor how structures actually perform during strong earthquakes. Finally, many fundamental scientific questions about earthquakes remain unanswered: for example, what controls the magnitude of an earthquake, what controls where the earthquake rupture will terminate, and what are the limits on extreme ground motions. The CISN will collect, archive and provide the seismological data necessary to address these research questions as well.

The focus of the CISN preparation and publication of reliable earthquake information of all forms. To achieve this, we expend major efforts to maintain, operate and modernize a robust seismic network infrastructure throughout the state. During the first ten years of CISN operations important steps have been taken towards integration, standardization, and improvements in robustness. It is the mission of CISN to extend the modern seismic network infrastructure statewide, to streamline operations, and to integrate those operations into a coherent system to produce the best earthquake information as quickly as possible. Toward this goal we strive to ensure that the CISN networks and operations be supported and operated in the long term in a way that improves the safety of the people of the State of California before, during and after future earthquakes.

2 The California Integrated Seismic Network

Advances in technology have made it possible to integrate separate earthquake monitoring networks into a single seismic monitoring system. Before the California Integrated Seismic Network (CISN) was formed, each of the existing networks in California collected seismic information that served some of the needs of the State, but no single network satisfied all of them. Integrating the separate monitoring efforts into a single system gives researchers and users access to a complete and well-organized knowledgebase. The CISN provides the organizational framework to coordinate earthquake-monitoring operations. The CISN constitutes the California region within Advanced National Seismic System (ANSS). It is governed by a memorandum of agreement (MOA) among its core members (USGS Menlo Park, USGS Pasadena, Caltech, CGS, and UC Berkeley) with the Governor's California Emergency Management Agency (CalEMA) as a participant, and also a client for near real-time seismic data (see Appendix A). In addition, other seismic networks operating within and bordering the state are contributing members of the CISN.

2.1 Mission of the CISN

The mission of the CISN is to operate a reliable, modern, statewide system for producing information about earthquakes within the state for the benefit of public safety, emergency response, and loss mitigation. The activities necessary to support this task include earthquake monitoring, research, archiving of all forms of earthquake data, and the distribution of information to a variety of clients and customers. The CISN seeks to mitigate the impact of future earthquakes by collecting, processing, and disseminating critical earthquake information in a timely way.

2.2 Goals

The CISN has adopted the following primary goals toward achieving this mission:

- To operate and maintain a reliable and robust, statewide seismic monitoring system to record earthquake ground motions over the relevant range of frequencies, amplitudes and shaking levels;
- To rapidly distribute information about earthquakes after their occurrence to a broad spectrum of knowledgeable users, so as to improve the State's emergency response capability and to better inform the public;
- To create and maintain an easily accessible archive of California earthquake data, including waveform data and derived products, to stimulate engineering applications and further the seismological understanding of the locations and causes of future earthquakes throughout the State; and
- To develop new algorithms for analyzing earthquake data and create new user products by applying the latest research and technological discoveries.

2.3 Objectives

The CISN has identified the following specific objectives for realizing these goals:

- To continue integrating current monitoring networks into a statewide system with redundant data retrieval, storage and processing capabilities through improved communications systems, software, and standardized methodologies;
- To expand the capabilities of the statewide, integrated seismic network by increasing station density, improving instrumentation, enhancing data processing systems, and increasing the speed of reporting;

- To continue to improve the robustness of data retrieval, processing, and reporting capabilities at each processing center so that there is no single point of failure in the statewide network, particularly after a major earthquake in any part of the State;
- To continue to develop and incorporate new seismological algorithms and technologies that utilize improved data fidelity and spatial density in the network to provide more user-relevant products;
- To implement a statewide, virtual, seismic data center so that data access for technical researchers, emergency professionals, and the public is seamless and the data are in formats suitable for each group; and
- To identify and train potential users in the use of new products from the CISN.

2.4 Current CISN Earthquake Information Products

In its first ten years of operations, the CISN has made considerable progress toward statewide integration and toward providing useful earthquake information. The CISN currently produces a variety of products for users ranging from the general public through emergency responders to earthquake engineers and scientists.

Table 1: CISN Earthquake Information Products

Product	Description
Rapid Earthquake Information (RecentEqs and Earthquake Notification System)	Time, location and magnitude, as well as other key parameters for all significant earthquakes in California. This information is published within minutes and updated as improved information becomes available. *Distributed through the web; for emergency responders and the media we also provide the information and products via other up-to-date communication paths.*
CISN Display	This software package is for agencies and institutions with an urgent need for immediate earthquake information. It receives data from all seismic networks operating in the United States, including the NEIC. Earthquake locations, magnitudes, and time of occurrence are displayed on a map, and the program can be set to notify users. CISN Display displays ShakeMaps and provides links to available earthquake products on the web, including loss estimates from HAZUS, tsunami warnings, and other information related to the quake. The display may be customized using and open source GIS mapping tool. *For more information see http://www.cisn.org/software/cisndisplay.htm.*
ShakeMap	Maps showing the distribution of ground motion and shaking intensity, based on ground motion measured at seismic stations. They are useful as a tool for guiding emergency response operations and damage assessments. They are available within minutes of a major earthquake and are updated as additional information becomes available. *Distributed electronically through the web and through CISN Display.*
Internet Quick Reports	Reports and archives of strong motion records of engineering interest. For significant earthquakes, data for these reports are collected and processed rapidly to facilitate their use in engineering. They include strong motion records from all the CISN partners, as well as data from structures, response spectra, and other relevant information. They may be accessed by the engineering community and the public. *Available online at the CESMD (http://www.strongmotioncenter.org)*

Seismic Waveform Archives	An archive of seismological data for all recorded earthquakes. Ground motion records from all CISN partners, including strong motion stations, are analyzed and archived for easy access to facilitate seismological use of the data. *Available online at the NCEDC (http://www.ncedc.org) and the SCEDC (http://www.data.scec.org)*
Earthquake Catalogs	Earthquake catalogs are available for Northern and Southern California. Event lists may be created by a variety of parameters including time, location and magnitude, in a variety of formats including KML for Google Earth. *Available online at the NCEDC (http://www.ncedc.org) and the SCEDC (http://www.data.scec.org)*
ShakeCast	This tool, based on ShakeMap, aids in rapid assessment of potential earthquake damage. In addition to delivering ShakeMap information to users, the package allows users to define locations of interest and set shaking levels which trigger automatic notifications. The program can integrate with GIS systems.
Seismological Algorithms	The CISN has implemented improved seismological algorithms for characterizing ground motions and rapid reporting of near real-time earthquake parameters, including mechanisms, seismic moment, depth, rupture information, and other source parameters for moderate to major earthquakes.
User Workshops	Training documents and workshops covering the uses of the CISN products for disaster response and mitigation. This outreach effort focuses on emergency responders, contingency planners, public information media representatives and others.

2.5 Current CISN Operations

During the past ten years the CISN has also made progress toward its goals of operating infrastructure that supports its objective of reporting earthquake information that is reliable and robust, and unified throughout the state. The table below describes several operational elements in which major milestones have been achieved. Although seismic stations have been added in the state (see Table 3), the number and distribution of seismic stations remains well below the number and type required for a high capability of producing the best quality of earthquake information from all parts of the state. From the perspective of improving the quality and equipment at our seismic stations, the American Recovery and Reinvestment Act (ARRA) has proven a great boon. By the end of September 2011, most of the almost ancient data loggers operated in the CISN will have been replaced with modern models. A number of the seismic stations will also have been renovated and/or remodeled.

Table 2: Improvements in CISN Operations

Milestone	Description
AQMS Software	In 2009, the ANSS Quake Management Software (AQMS, formerly CISN Software) became operational statewide, the result of nine years of planning, discussion, programming and testing. This software is also now being installed at other ANSS regional networks.
Center for Engineering Strong Motion Data	The Center for Engineering Strong Motion Data (CESMD) has been implemented at the EEMC as a joint effort of CGS and USGS. Procedures have been developed and implemented to convert strong motion records recorded at seismic stations operated by the NCEMC and the SCEMC to V0 format and automatically contribute them to the CESMD.

Sharing Waveform Data	NCEMC and SCEMC have been exchanging waveforms from a subset of stations for many years. From a core group of 26 seismic stations, data now go directly to both the NCEMC and the SCEMC (Figure 3). Since 2010, event waveform gathers for moderate to large events include waveforms from throughout the state. CISN is implementing statewide sharing of parametric data such as picks and amplitudes.
CISN T1 Ring	A high-speed robust ring of data communication links connects the CISN partners to each other and to CalEMA.
Ground Motion Exchange	The CISN established standards and protocols to rapidly prepare and exchange strong ground motion parameters (PGA, PGV, various SA values). This exchange of ground motion valuses allows all three centers to produce robust ShakeMaps
Magnitude Reporting	The CISN partners have reviewed the process for determining local magnitudes and put in place a method that is now uniform throughout the state.

3 CISN Plans and Activities for 2011 – 2016 and Beyond

The CISN consists of a group of institutions with capabilities and experience in effective delivery of critical seismic information to decision-makers and direct users throughout the State of California.

3.1 Complete Statewide Integration to Ensure System Robustness

The CISN is committed to operating a robust system that will reliably acquire and distribute earthquake information. This is essential if earthquake information is to be of use to the emergency response community and the public. In addition the failure to record a significant event means that the seismological and earthquake engineering communities lose valuable data for conducting research to improve public safety. Despite attention to these points in reaching this stage of development, single-points-of-failure remain to be addressed.

Now that the AQMS software is in place, within the CISN, we are establishing and improving reliable reporting of reduced data streams between the processing centers of the CISN. In addition, the CISN will exchange data with neighboring ANSS partners, like the Pacific Northwest Seismic Network, to mutually enhance earthquake monitoring. Finally, data will be transmitted to the USGS National Earthquake Information Center (NEIC) so that this national facility can serve as an additional backup capability.

The CISN has incorporated seismic data from the NSF-funded Earthscope project elements USArray, SAFOD, and PBO in routine processing. In particular, the temporary deployment of USArray stations during 2004-2008 in northern California enhanced the CISN monitoring capabilities and provided an opportunity to leverage some of the NSF investment into permanent stations. The permanent deployment of borehole seismometers in PBO and the SAFOD borehole provides new opportunities to study seismicity in selected areas in California.

Specific activities the CISN will complete in this area are:

- Regularly review and resolve single-point-of-failure issues associated with data acquisition, processing, and product distribution;
- Identify, and if feasible, implement redundant communications paths that permit more robust transmission capabilities for both data and products;
- Develop and implement procedures for exchanging data between Centers;

- Expand the set of seismic stations reporting to multiple centers to facilitate statewide processing;
- Exchange real-time data streams with ANSS partner networks, including the NEIC and tsunami warning centers in Alaska and Hawaii;
- Improve protocols for exchanging data and backup product distribution with NEIC in Golden, Colorado; and
- Develop and implement procedures for backup publication of rapid earthquake information.

3.2 Network Density and Operations

In the ten years since the formation of the CISN, the number of seismic and engineering stations has increased, though still remaining well below the number needed set forth in the ANSS planning document (USGS Circular 1188 (http://pubs.usgs.gov/circ/1999/c1188/), 1999). In addition, many existing stations within the CISN are now being modernized using ARRA funding. Finally, seismic monitoring in California has profitted from the deployment of borehole stations as part of the Plate Boundary Observatory program (PBO, http://pboweb.unavco.org/). Table 3 summarizes the number of seismic stations currently being operated in the CISN.

Table 3. CISN Instrumentation Plan

	Southern California		**Northern California**		**Statewide**
	Existing	Additional Needed	Existing	Additional Needed	Total
Urban Strong Motion (SM)	680	650	520	550	2400
Broadband + SM[1]	170	60	55	195	480
Short Period (SP) + SM	16	90	91	89	286
Analog SP [2]	133	0	283	0	291[3]
Borehole	15	35	38	22	110
Geotechnical Arrays	17	20	18	20	75
Buildings	125	105	110	100	440
Bridges	30	50	50	40	170
Dams	15	20	15	20	70
Others	5	6	5	4	20

1 Includes Anza stations
2 Includes UNR, DWR, and PG&E stations
3 Includes existing UNR, DWR SP stations and CI and NC stations after upgrade to digital short-period and strong motion capability. The number of these stations is expected to decrease as the equipment is upgraded to digital.

Nonetheless, California still lags in the number of stations needed to provide the same high quality of earthquake information throughout the state. Thus, we continue to target instrumentation improvements. Our California plan, shown in Table 3, considers the need for six classes of seismic stations and structures instrumentation across the State:

1. Urban stations with digital strong motion accelerometers (Figure 1);

2. Regional stations with broadband sensors and strong motion accelerometers, and digital (real-time) telemetry (Figure 2);
3. Regional or urban seismic stations with a single component vertical short-period seismometer, a triaxial strong motion accelerometer, and digital telemetry;
4. Regional short-period stations with analog telemetry to some central collection site;
5. Stations with sensors installed in boreholes for monitoring in urban areas, near faults, and other regions of seismic interest with digital telemetry; and
6. Strong motion instrumentation of selected buildings, structures, and lifelines.

Our plan is to locate approximately one strong motion station in each zip code in the State, with modifications based on specific recommendations by the Strong Motion Instrumentation Advisory Committee (SMIAC). We will also target instrumentation of urban structures , again guided by recommendations from SMIAC to the California Geological Survey Strong Motion Instrumentation Program (CSMIP) and ANSS guidelines. The selection of zip codes as a way to distribute strong motion instruments strikes a balance between a broad geographic spread of the instruments and a concentration of instruments in urban settings where ground response and building response are especially critical to public safety.

In many cases upgraded regional stations will replace short period seismic instruments; they will provide broadband waveforms for source and wave propagation analysis. They will also capture valuable data from earthquakes that occur outside the urban areas. These stations will make it possible to monitor many regions of high seismic risk (e.g., urban areas adjacent to major late Quaternary faults), the Long Valley volcanic region, regions with active seismicity and scientific interest (e.g., Imperial Valley and Eastern California Shear Zone, creeping section of the San Andreas fault, Cape Mendocino and the Gorda plate subduction zone), and regions risk is high (e.g., locked sections of the San Andreas fault). However, the number of broadband stations planned for the CISN is smaller than the number of analog short-period seismic stations currently operating in the state. To maintain the existing capability of seismic monitoring and to meet the above monitoring goals, the CISN plans to supplement the broadband regional stations with approximately 200 stations each equipped with a vertical, short-period seismometer, a tri-axial accelerometer and digital recording.

At present there are more than 50 borehole stations operating in California. These sites provide valuable data on earthquakes for several reasons. In urban areas, seismic noise generated by cultural activities renders most seismic stations useless except for recording earthquakes above M3. This noise is greatly reduced in borehole installations, so that smaller earthquakes can be recorded in critical locations. In addition, recording downhole and surface motions can provide valuable information about site amplification, soil nonlinearity, and attenuation of energy. Seismic instrumentation, including geophones and in some locations also strong motion sensors, is also installed in boreholes that contain strainmeters, such as along the Hayward fault.

While USGS Circular 1188 does not explicitly address borehole installations, CISN has a target of about 110 stations to be installed in boreholes across the entire state. Borehole stations record data that enable seismologists to record much smaller earthquakes than observable from surface stations. Because the number of earthquakes increases by a factor of 10 for each unit increase in magnitude, the greater number of quakes provides a rich data source to investigate the interval of time between repeating earthquakes that reflects the strain rate in the fault zone. Seismograms recorded in boreholes are simpler because the signal is not influenced by the freefield effect at the surface, and thus are invaluable for research on source properties and predicting ground motions. Finally, borehole stations are much quieter, and thus collect essential data for detecting the possible presence of fault zone seismic tremor and other subtle geophysical signals.

It is important to note that the plan in Table 1 does not include the instrumentation needed to provide reliable early warning uniformly in California. While the current infrastructure provides certain capabilities, additional instrumentation – both broadband and strong-motion sensors, with reliable real-time telemetry – will be needed to support earthquake early warning uniformly throughout the state.

3.3 Statewide Earthquake Product Archive

To operate as an "integrated" seismic network, the CISN must coordinate the acquisition of data, reporting activities, and products of each of the individual reporting networks so that the CISN appears seamless. Many tasks along this path have been completed in the past ten years. The data produced by the CISN has become fundamental to improving understanding of earthquake source processes, the causes of earthquakes, the propagation of seismic energy, and seismic hazard.

The CISN centers maintain long-term archives of earthquake data for earthquake engineers, seismologists, land-use planners, and other users. The archives contain complete sets of seismograms for each earthquake, processed in a uniform (and clearly described) way. Complete sets of records are added to the archive quickly after an earthquake. However, at the present time, the NCEMC and SCEMC are each hosting and serving data for its own region; there is no single location where data users can go to retrieve data, earthquake parameters or other related information for a past event.

During the next five years, we will develop and implement tools to unify the user interface, so that the CISN presents a seamless face for the access of data and earthquake information. The statewide archive system that is envisioned uses software that directs the user to the catalog quickly, then permits efficient downloading of records and supporting data (processing information, site conditions, etc.).

3.4 New Earthquake Information Products

An important element of the CISN is the co-existence of operations and research. The research tools and results of today often translate into the real-time earthquake data products of tomorrow. Recent examples of such migration include ShakeMap and algorithms for the automated determination of the fault rupture parameters. As new algorithms become available, software will be developed and implemented by the CISN to improve data processing and information distribution. Two particular algorithms are currently under development.

3.4.1 Earthquake Early Warning

When an earthquake starts, two types of seismic waves are radiated, P-waves which are faster but generally do not produce damage, and S-waves which move the ground horizontally and generally cause the strongest shaking. Most damage is caused by S-waves or the waves following still later. By recognizing and characterizing the size and location of an earthquake, based on the P-waves, earthquake early warning (EEW) can sometimes provide a few seconds to tens of seconds warning before the ground starts shaking.

Following a three year test of EEW algorithms in the CISN, a prototype end-to-end system is now being implemented. For the foreseeable future, this system will remain a prototype, as the density of seismic stations in the state is not sufficient to reliably produce warnings.

As part of the development process, CISN is reviewing the hardware and software infrastructure that will be required for a system which can reliably publish EEW alerts.

3.4.2 GPS in Earthquake Monitoring and Characterization

In a large earthquake, such as a repeat of the 1857 Fort Tejon or 1906 San Francisco earthquake, offsets at the fault is expected to be as much as 10 m. In such an event, high sampling rate (1 sample per second or more) data from Global Positioning System (GPS) receivers will provide important information about the event, including potentially rapid information on the fault offset, how the offsets vary along-strike, and the total length of the ruptured fault. These measures are important input into the evaluation of event size, and can be an independent source of such information to augment seismic data. As the number of high-quality GPS stations throughout the state has increased to several hundred, with regional networks and the Plate Boundary Observatory, CISN's goal is to integrate processed GPS station position streams into the existing realtime seismic signal processing systems, so that GPS data can be used and additional earthquake information products made available.

GPS is especially well-suited to observation of the static displacements that occur in a large to great earthquake, from centimeters to larger 3D displacements. High-rate GPS has also been demonstrated to be capable of observing the waveforms of 3D displacement during the high dynamic portion of the earthquake shaking. Also importantly, GPS can observe the slower post-seismic deformations such as fault afterslip, including motions on both deep and shallow parts of the fault. Such slower fault motions can be important to engineering considerations for re-construction of critical lifeline infrastructure, that is, so that continuing motions over the days to years following a major earthquake can be anticipated in the restoration of these important lifelines.

4 Organization of CISN

The CISN is governed by a memorandum of agreement (MOA) among the core members (USGS Menlo Park, USGS Pasadena, Caltech, CGS, and UC Berkeley) with the CalEMA as a participant (see Appendix A). The MOA describes the CISN organizational goals, products, and management.

4.1 Leadership Structure and Responsibilities

The organizational aspects of the CISN address both geographical issues as well as disciplinary issues that build on the strengths of the participating institutions. For instance, the institutions in northern and southern California are best suited to monitor and report on earthquakes in their regions, while the California Geological Survey and USGS earthquake engineering component complements these activities statewide by focusing on recording engineering data from the largest earthquakes in the state.

4.1.1 Steering Committee

The CISN Steering Committee will oversee the program. The Steering Committee will be composed of two members from each of the core institutions, a representative of California Governor's Office of Emergency Services, and the chair of an Advisory Committee to the CISN. One of the USGS Menlo Park representatives will be the National Strong Motion Program Coordinator. The Chief Scientist, Earthquake Hazards Team, USGS in Menlo Park will also be a member of the CISN steering committee.

The Steering Committee will be responsible for policy decisions about data exchange and distribution, and for developing guidelines and spending priorities to be used in joint applications for funding. The CISN Steering Committee will review the program annually to assess the progress, organizational structure and the contribution of the member institutions, and to recommend adjustments where necessary. The Steering Committee will approve the formation and dissolution of standing committees to address specific CISN activities. The Steering Committee will have the authority to amend the Memorandum of Agreement. The chair of the Steering Committee will rotate among the five institutions. There will be a vice chair who will be the chair in the following term. The chair and vice chair of the Steering Committee will never be from the same management center or same sector (e.g. academic, federal or state).

The Steering Committee will select one member to be the Regional Coordinator to ANSS and another as the Alternate Coordinator. The Regional and Alternate Coordinators will never be from the same management center or same sector. The Regional Coordinator will be responsible for the interaction of the CISN with other regions of the ANSS and to represent the interests of the CISN. The terms of the Regional Coordinator and the Alternate Coordinator will be one year and can be renewed. The Alternate Coordinator will be an ex officio member of the ANSS National Implementation Committee if permitted by the ANSS.

4.1.2 CISN Program Management Group

A CISN Program Management Group (PMG), consisting of five members of the Steering Committee, one from each core institution, will meet regularly to coordinate the implementation of the CISN tasks by the member institutions. The PMG will have authority within its agency to carry out the goals of the CISN, and will report to the Steering Committee on a regular basis, no less than quarterly, on the progress of the CISN.

The PMG will oversee efforts to integrate and standardize operations through the activities of the CISN Standards Committee, which is tasked with examining issues related to implementing common software, such as waveform and parametric exchange, station naming conventions, and robust recovery of information following network interruptions. The PMG will coordinate with the ANSS to ensure that CISN efforts contribute to the goals of the ANSS, while also meeting the immediate needs of the CISN (Appendix A).

4.1.3 CISN Advisory Committee

The CISN Advisory Committee is composed primarily of users of CISN data and serves to provide advice to the Steering Committee and Program Management Group on directions and goals. The Advisory Committee represents the interests of structural and geotechnical engineers, seismologists, emergency managers, industry, government, and utilities. The Steering Committee approves the members of this Advisory Committee from nominations made by each management center or CalEMA. The Advisory Committee will have fifteen members, representing the constituency of each management center, CalEMA, USGS, and FEMA. The chair of the

Committee is elected by the membership, and serves a one-year term, renewable. The term of membership on the Advisory Committee will be three years, renewable.

4.2 Partnerships and Funding

Existing sources of funding provide many of the infrastructure items needed by CISN. The core members of the CISN have agreed to cooperate in this effort because of the obvious benefit to the State and the Nation. Because of this agreement, any new sources of funding for the CISN will have increased effectiveness because they will be directed to the area of most critical need.

The Federal Government through the USGS provides funds for seismic monitoring in California both through internal and external programs. These funds are used for core operations of earthquake monitoring in southern and northern California. The USGS office in Menlo Park works with UC Berkeley to maintain a comprehensive program of monitoring and archiving in northern California. The USGS office in Pasadena is located on the Caltech campus and shares responsibilities with Caltech in operating the seismic network in southern California. The USGS external program also provides funds to Caltech, UC Berkeley, and UCSD for operations and earthquake catalog production. The USGS and NSF fund the Southern California Earthquake Center (SCEC), which in turn provides funding for the Southern California Earthquake Data Center (SCEDC). The USGS through the ANSS funds expansion and modernization of seismic instrumentation throughout the state.

The State of California provides funding directly to the CISN through CalEMA. It also provides core funding for the CGS/CSMIP program. The State, through the University of California at Berkeley, provides core support for the Berkeley Seismological Laboratory, including partial support for the operation of the Berkeley Digital Seismic Network. Funds are being used to support the operations of CISN. Additional funding has been provided by the Federal Emergency Management Agency’s Emergency Management Performance Grants (EMPG) and the Hazard Mitigation Grant Program (HMGP) through California CalEMA for emergency response enhancements to CISN.

In addition to the core members, several organizations contribute data that enhances the capabilities of the CISN. Contributing members of the CISN include: University of California, Santa Barbara, University of California, San Diego, University of Nevada, Reno, University of Washington, California Department of Water Resources, Lawrence Berkeley National Lab, Lawrence Livermore National Lab, and Pacific Gas and Electric.

4.3 Management Centers

To facilitate coordination of activities between institutions the CISN has formed three management centers located in Pasadena, the San Francisco Bay Area, and Sacramento. These centers are referred to as:

- **Southern California Earthquake Management Center:** (Caltech/USGS Pasadena)

- **Northern California Earthquake Management Center:** (UC Berkeley/USGS Menlo Park)

- **Earthquake Engineering Management Center**: (CGS CSMIP/USGS NSMP)

4.3.1 Northern and Southern Earthquake California Management Centers

These centers operate as twin earthquake processing centers. Both centers acquire data from remote stations for statewide earthquake monitoring. Each center has a reporting region for which it is the primary source of data. Each center will also have a statewide reporting capability and be able to report in case of failure on earthquake activity in the adjacent region. Each center operates facilities for archiving and public distribution of data. Data users will be able to obtain all data from either center based on the concept of virtual data centers.

The centers will exchange waveform data in real-time directly from selected remote stations as well as by center-to-center exchange. In addition, the centers will exchange parametric data in near-real time from center to center. The goal will be to maintain adequate coverage in the boundary regions between the reporting areas and to provide backup over the whole region by recording subsets of stations.

4.3.2 Earthquake Engineering Management Center

The Earthquake Engineering Data Management center has the responsibility for producing engineering data products. The California Department of Conservation’s Strong Motion Instrumentation Program (CSMIP) in the California Geology Survey will operate the engineering management center in cooperation with the USGS/National Strong Motion Program (NSMP). The Engineering Management Center will provide data from CSMIP and NSMP strong motion stations. It will also assemble strong motion data sets for the earthquake engineering community using data from all CISN stations. Further, the Engineering Center will provide strong motion records, from their stations, of small earthquakes for seismological and site response studies. The engineering center will serve as limited back up for the statewide earthquake notification system. By using data from its own stations combined with strong motion parametric data from both northern and southern California centers it will be able to produce ShakeMaps coordinated with and in parallel with the other centers.

Appendix A: Memorandum of Agreement

Appendix B: Glossary

ABAG	Association of Bay Area Governments
ANSS	Advanced National Seismic System
AQMS	ANSS Quake Management Software
ARRA	America Recovery and Reinvestment Act
CISN	California Integrated Seismic Network
CalEMA	California Emergency Management Agency (formerly OES or Office of Emergency Services)
CESMD	Center for Engineering Strong Motion Data
CGS	California Geological Survey
CSMIP	California Geological Survey Strong Motion Instrumentation Program
EEMC	Earthquake Engineering Management Center
EEW	Earthquake Early Warning
EIDS	Earthquake Information Distribution System
EMPG	Emergency Management Performance Grants
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GPS	Global Positioning System
HAZUS	Hazards US
HMGP	Hazard Mitigation Grant Program
IRIS	Incorporated Research Institutions in Seismology
ISP	Internet Service Provider
NCEMC	Northern California Earthquake Management Center
NOAA	National Oceanic and Atmospheric Administration
NEIC	National Earthquake Information Center
NSF	National Science Foundation
NSMP	National Strong Motion Program
PBO	Plate Boundary Observatory
PMG	Program Management Group
SAFOD	San Andreas Fault Observatory at Depth
SCEC	Southern California Earthquake Center
SCEMC	Southern California Earthquake Management Center
SMIAC	Strong Motion Instrumentation Advisory Committee
USGS	United States Geological Survey

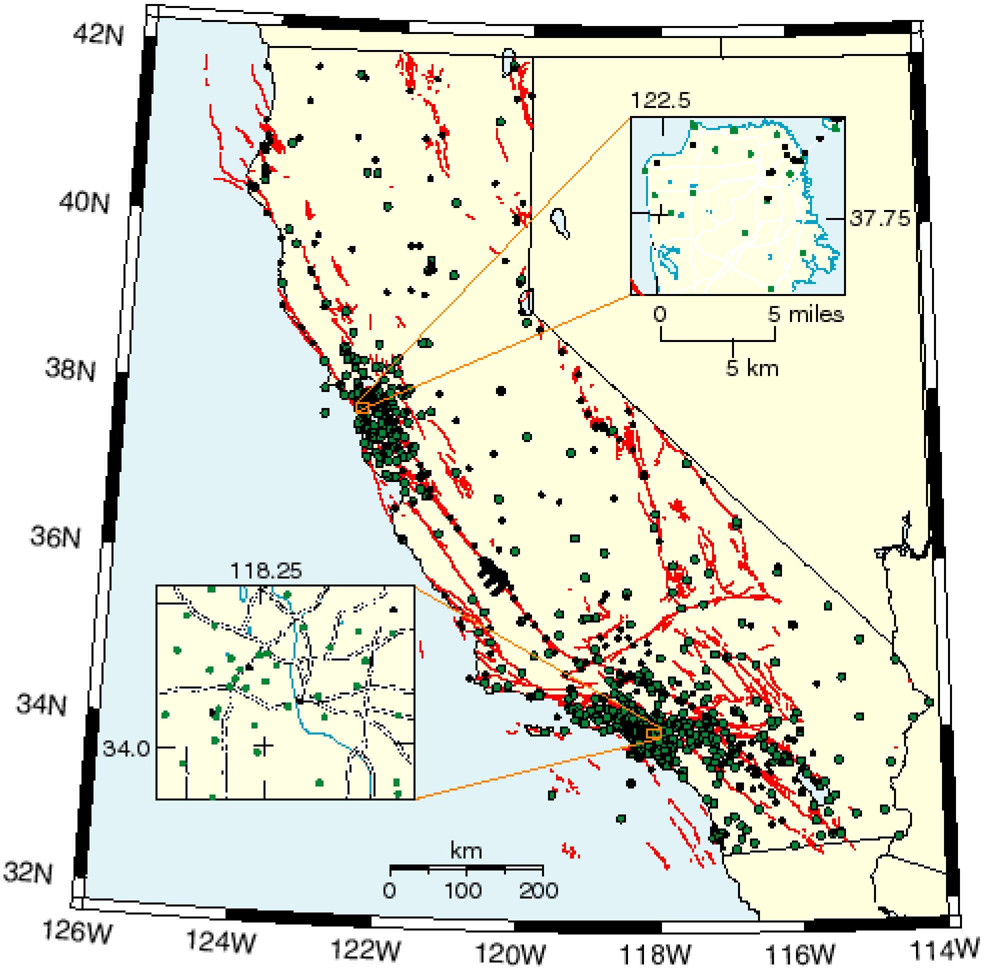

Figure 1. Distribution of strong motion instrumentation in California. Green symbols depict recorders with telemetry and which are suitable for use in ShakeMap. Black symbols depict recorders that are either instruments that are analog and/or do not have telemetry, or are located in structures. Insets show distribution of instrumentation in central Los Angeles and San Francisco. Major roads are shown in insets.

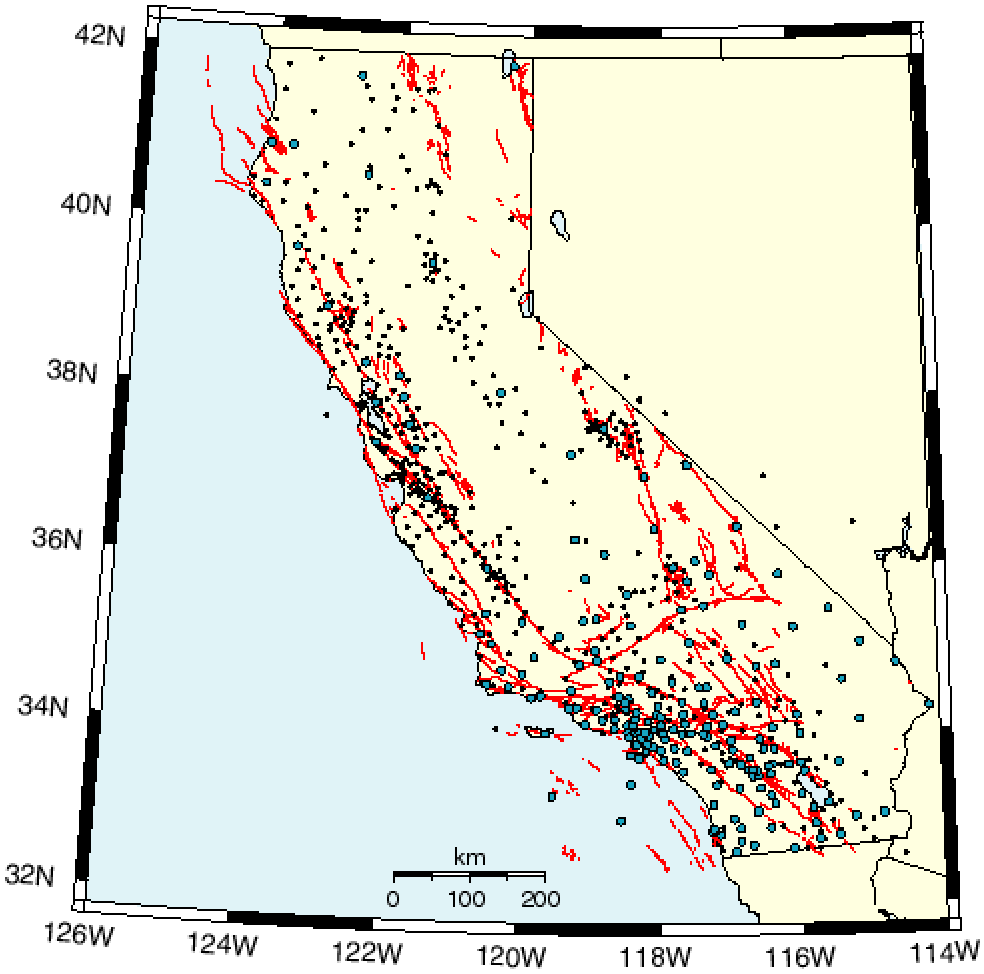

Figure 2. Distribution of weak motion instrumentation in California. Blue symbols depict stations with tri-axial broadband instruments with 24-bit digitizers and continuous digital telemetry. Black symbols depict stations with short-period seismometers using continuous analog telemetry.

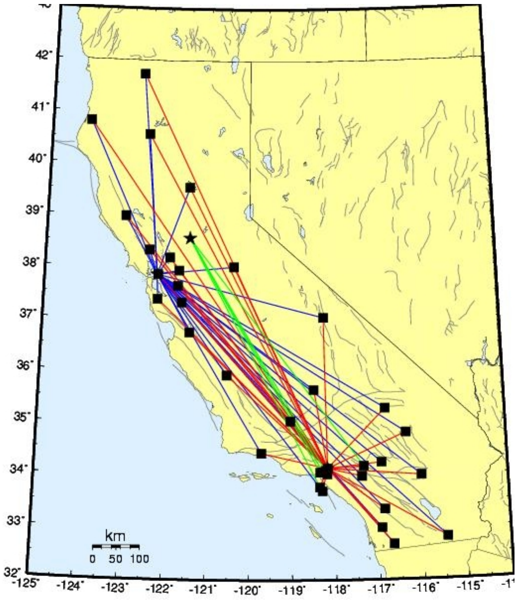

Figure 3. Diagram illustrating dual station data feeds to improve robustness.

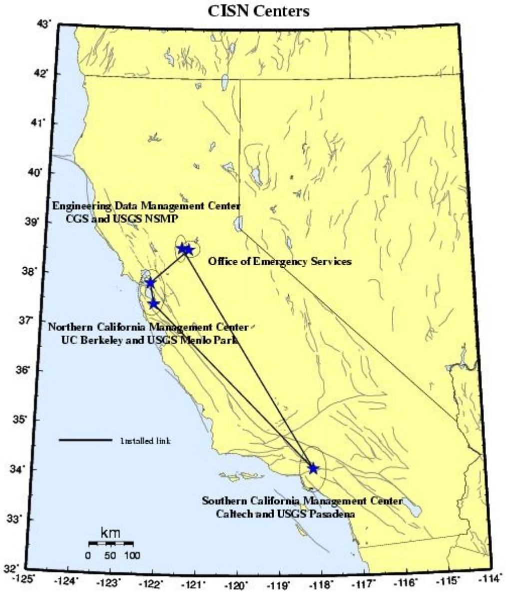

Figure 4. Diagram of the CISN backbone.