ANNUAL PROJECT SUMMARY

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OPERATION OF THE JOINT EARTHQUAKE NOTIFICATION SYSTEM IN NORTHERN CALIFORNIA:
Collaborative between UC Berkeley
and the U.S. Geological Survey, Menlo Park

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INVESTIGATIONS UNDERTAKEN

In northern California, the BSL and the USGS Menlo Park collaborate to provide the timely and reliable earthquake information to the federal, state, and local governments, to public and private agencies, and to the general public. This joint earthquake notification system provides enhanced earthquake monitoring by building on the strengths of the Northern California Seismic Network, operated by the USGS Menlo Park, and the Berkeley Digital Seismic Network (BDSN), operated by the UC Berkeley Seismological Laboratory.

During this reporting period, the BSL worked with the USGS Menlo Park to enhance and improve earthquake reporting in northern California. Particular areas of activity include:

- improvements on moment tensor codes
- ShakeMap installation
- version numbers - QDDS and last mag message
- reporting M_w

Current Capabilities

In 1996, the BSL and USGS began collaboration on a joint notification system for northern and central California earthquakes. The current system merges the programs in Menlo Park and Berkeley into a single earthquake notification system, combining data from the NCSN and the BDSN. Figure 1 illustrates the distributed nature of the current joint notification system in northern California.

On the USGS side, incoming analog data from the NCSN are digitized, picked, and associated as part of the Earthworm system (*Johnson et al.*, 1995). Preliminary locations, based primarily on phase picks from the NCSN, are available within seconds, while final locations and preliminary coda magnitudes (M_d) are available within 2-4 minutes. Earthworm reports events - both the "quick-look" 25 station hypocenters (without magnitudes) and the final solutions (unreviewed, with coda magnitudes) to the Earlybird alarm module in Menlo Park. This system sends the Hypoinverse archive file to the BSL for additional processing, generates pages to USGS and UC Berkeley personnel, and distributes information via the Quake Data Distribution System (QDDS).

Once an event is declared, additional Earthworm processing at the USGS generates ground motion amplitudes from NCSN and NSMP stations and loads them into a database. A process known as ShakeMapFeeder extracts amplitudes from the database and pushes them to the ShakeMap system (*Wald et al.*, 1999) implemented in Menlo Park.

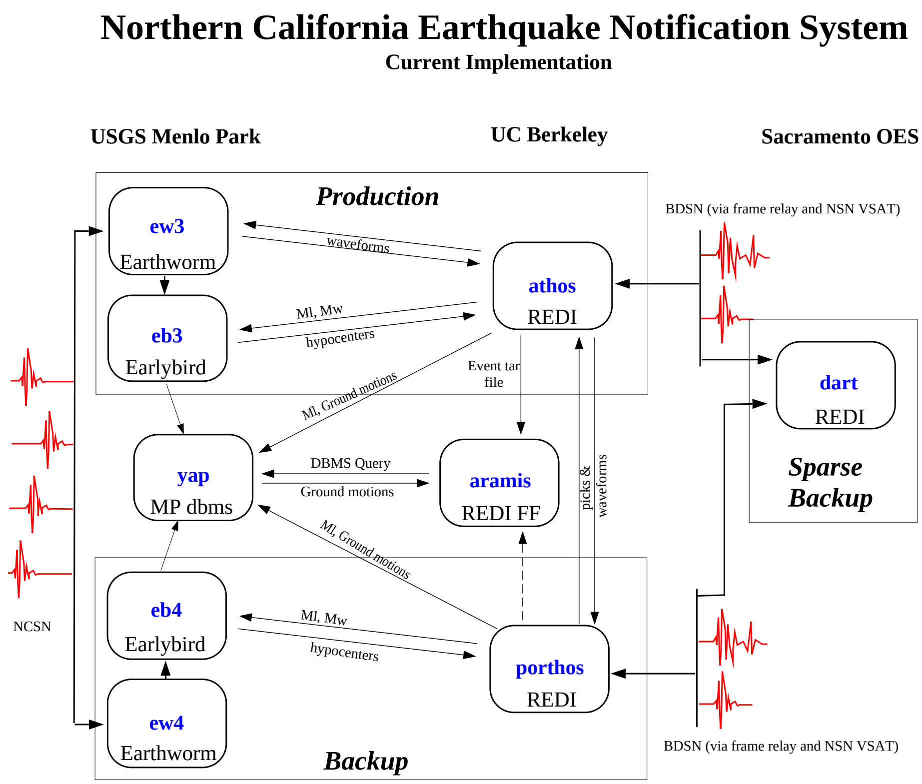

Figure 1: Schematic diagram illustrating the connectivity between the real-time processing systems at the USGS Menlo Park and UC Berkeley. This figure also illustrates the newly added finite-fault and ShakeMap capability, which is handled on a separate system, as well as the independent processing system in Sacramento.

On the UC Berkeley side, the Hypoinverse archive file is normally used to drive the REDI processing system. The REDI processing is divided into two systems - routine or standard processing (local magnitude, ground motion amplitudes, and moment tensors) - and the finite-fault processing added last year (Figure 2). Each REDI system provides several stages of processing, and the attributes of events such as magnitude, the "age" (time since origin), and number of associated phases are used to determine the appropriate processing. The REDI stage structure allows processing to be scheduled (for example, wait 5 minutes after the origin time before scheduling a moment tensor computation) as well as prioritized (for example, process the magnitude 6 before the magnitude 2).

In abnormal situations, such as when communication links between the BSL and the USGS are disrupted, the BSL can drive the REDI system using events detected based on BDSN data alone. The BSL has implemented the same association algorithm used in the Earthworm system in Menlo Park, using Murdock-Hutt phase detections and/or picks from an Earthworm picker.

Standard Processing

Stage 0 of the standard processing provides initial event handling. It can accept either Hypoinverse files from the USGS (the normal source of event information) or events generated from the local associator. If the preliminary magnitude estimate is less than 3.0, no additional processing is performed and event information is distributed if appropriate.

Stage 1 is initiated for all events with preliminary magnitudes greater than 3.0 and for events with no preliminary magnitude. In this stage, broadband waveforms are processed to produce Wood-Anderson synthetics and estimates of local magnitude are generated. This stage uses the preliminary magnitude and a distance criterion to decide which channels to analyze.

Stage 2 generates ground-motion amplitudes for use in ShakeMap and other applications. Stage 2 currently generates estimates of peak ground acceleration, peak ground velocity, and peak ground displacement from BDSN acceleration records, but does not produce estimates of spectral acceleration.

Stage 3 performs the automated moment tensor analysis. In this stage of REDI processing, both the waveform modeling method of *Dreger and Romanowicz* (1994) and the surface wave inversion technique of *Romanowicz et al.* (1993) are run for every qualifying event (earthquakes with M_L greater than 3.5). Each algorithm produces an estimate of the seismic moment, the moment tensor solution, the centroid depth, and solution quality. The REDI system uses the individual solution qualities to compute a weighted average of moment magnitude, to compare the mechanisms using normalized root-mean-square of the moment tensor elements (*Pasyanos et al.*, 1996), and to determine a total mechanism quality.

In 2000-2001, two new stages were added to standard REDI processing. Stage 4 extracts the waveform data required for the finite-fault processing and Stage 5 packs the event up and ships it to the REDI finite-fault system running on aramis.

Finite-Fault Processing

During 2000-2001, the estimation of finite-fault parameters was migrated from the development platform to the REDI operational environment, new modules were developed to use the finite-fault parameters to simulate near-fault strong ground motions, and the results integrated into the generation of ShakeMap (*Dreger and Kaverina*, 2000; *Dreger and Kaverina*, 1999).

In Stage 0, waveform data are prepared for inversion and rough estimates of the fault dimensions are derived using the empirical scaling relationships of *Wells and Coppersmith* (1994). Using these parameters to constrain the overall dimensions of the extended source, the stage tests the two possible fault planes obtained from the moment tensor inversion over a range of rupture velocities by performing a series of inversions using a line-source representation. In addition to the identification of the fault plane and apparent rupture velocity, this stage yields preliminary estimates of the rupture length, dislocation rise time, and the distribution of slip in one dimension.

Stage 1 combines the results of the line-source inversion with the directivity-corrected attenuation relationships of *Somerville et al.* (1997) to simulate ground motions in the near-source region.

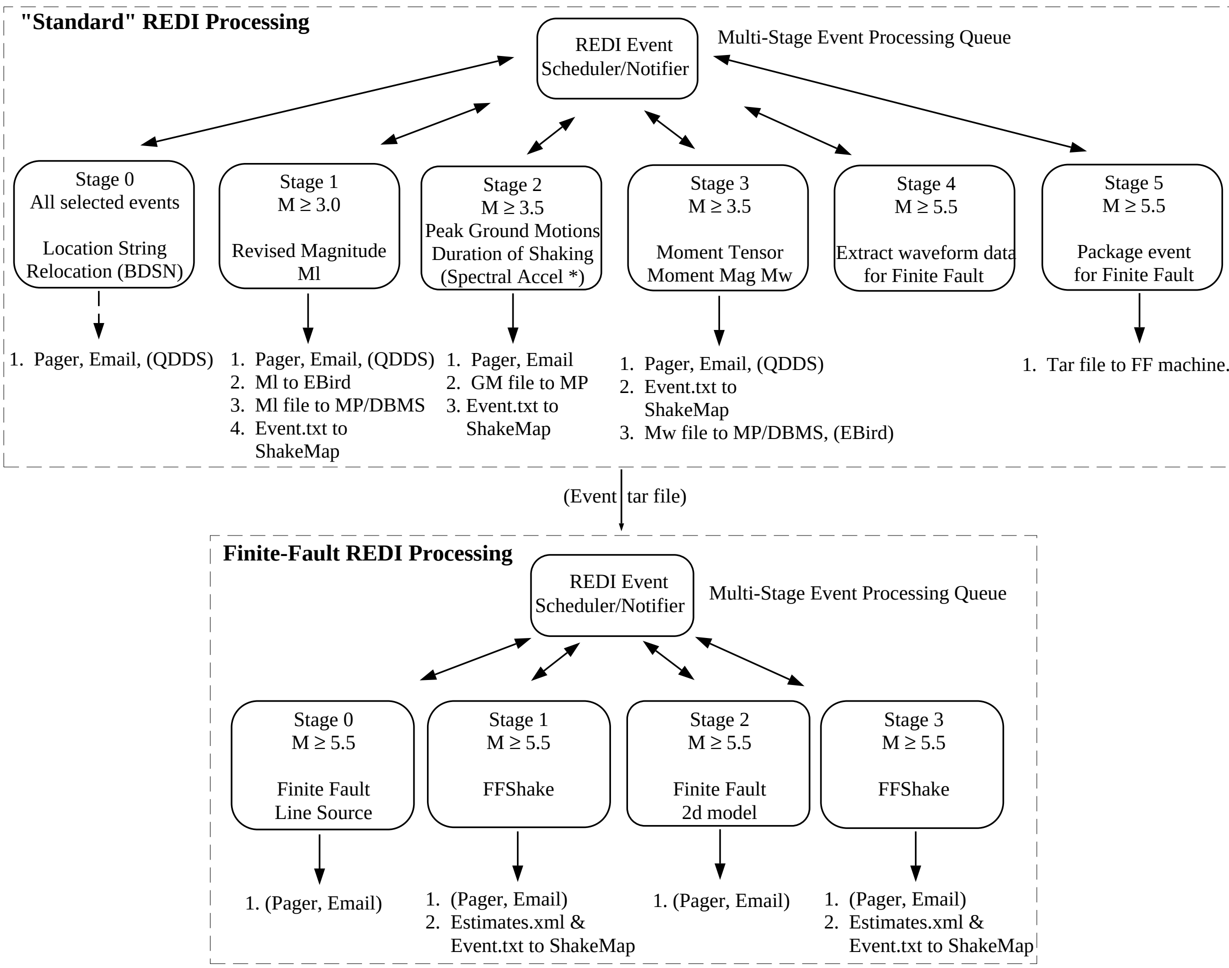

Figure 2: Diagram showing the two levels of REDI processing. The Standard processing is conducted on the two main data acquisition systems and includes the computation of M_L, ground-motion processing, and the determination of the seismic moment tensor. The Finite-fault system is an extension of REDI processing. Items in parentheses are planned expansions.

FFShake computes peak ground acceleration, peak ground velocity, and spectral response at 0.3, 1.0, and 3.0 sec period, which are the values used in ShakeMap, for a grid of pseudo-stations in the vicinity of the epicenter. The predicted ground motions are automatically incorporated in ShakeMap updates as described below.

In Stage 2, the second component of the finite-fault parameterization uses the best-fitting fault plane and rupture velocity from Stage 0 to obtain a more refined image of the fault slip through a full two-dimensional inversion. If line-source inversion fails to identify the probable fault (due to insufficient separation in variance reduction), the full inversion is computed for both fault planes. In the present implementation, the full inversion requires 20-30 minutes per plane, depending on the resolution, on a Sun UltraSPARC1/200e.

Stage 3 completes the cycle by simulating the near-fault strong ground motion parameters by convolving the velocity structure response with the finite-fault slip distribution. As in Stage 1, FFShake computes peak ground acceleration, peak ground velocity, and spectral response at 0.3, 1.0, and 3.0 sec period for a grid of pseudo-stations in the vicinity of the epicenter and pushes these ground motions to the ShakeMap system.

ShakeMap

As part of the development of the finite-fault project, the BSL worked with the USGS Menlo Park to install ShakeMap V2.0 at UC Berkeley. Although USGS personnel had done most of the work to adapt the program to northern California, development was required to integrate the ShakeMap package into the REDI environment. In the process, BSL staff identified and fixed some minor bugs in the software.

The motivation for this effort is the desire to integrate the ground motions predicted from the finite-fault inversions into the ShakeMap generation. The goal is to provide updated ShakeMaps as more information about the earthquake source is available. Versions 2.0 and higher of ShakeMap are structured to allow the use of different estimates files, that is, to incorporate ground motions predicted by alternate means.

As shown in Figure 2, the REDI processing system is integrated with the ShakeMap software at several levels. ”Event.txt” files are generated at several stages - these files tell the ShakeMap software to wake-up and process an event. A ShakeMap is generated following Stage 2 in the Standard processing and updated if a revised estimate of magnitude is obtained following Stage 3.

For events which trigger the finite-fault processing, estimates of ground motions based on the results of the line-source computation and the full 2D inversion are produced in the FFShake stages. ”Estimates.xml” files are generated and pushed to the ShakeMap package. The output of the line source computation produces what we call an ”Empirical ShakeMap”, while output from the 2D inversion produces a ”Conservative ShakeMap”.

Figure 3 illustrates the three different methodologies with examples from an M6 earthquake which occurred in the Mammoth Lakes region in May 1999. Very few data were available to constrain these maps. This event is somewhat small for this methodology, but the impact of the successive improvements in the ground motion estimates is clearly illustrated.

Future plans include the continued testing and refinement of the procedure, working with the USGS group toward integration into the authoritative ShakeMap method for northern California and other regions, and development of additional capabilities based on the incorporation of BARD GPS data. Figure 4 shows the typical processing times associated with the current implementation.

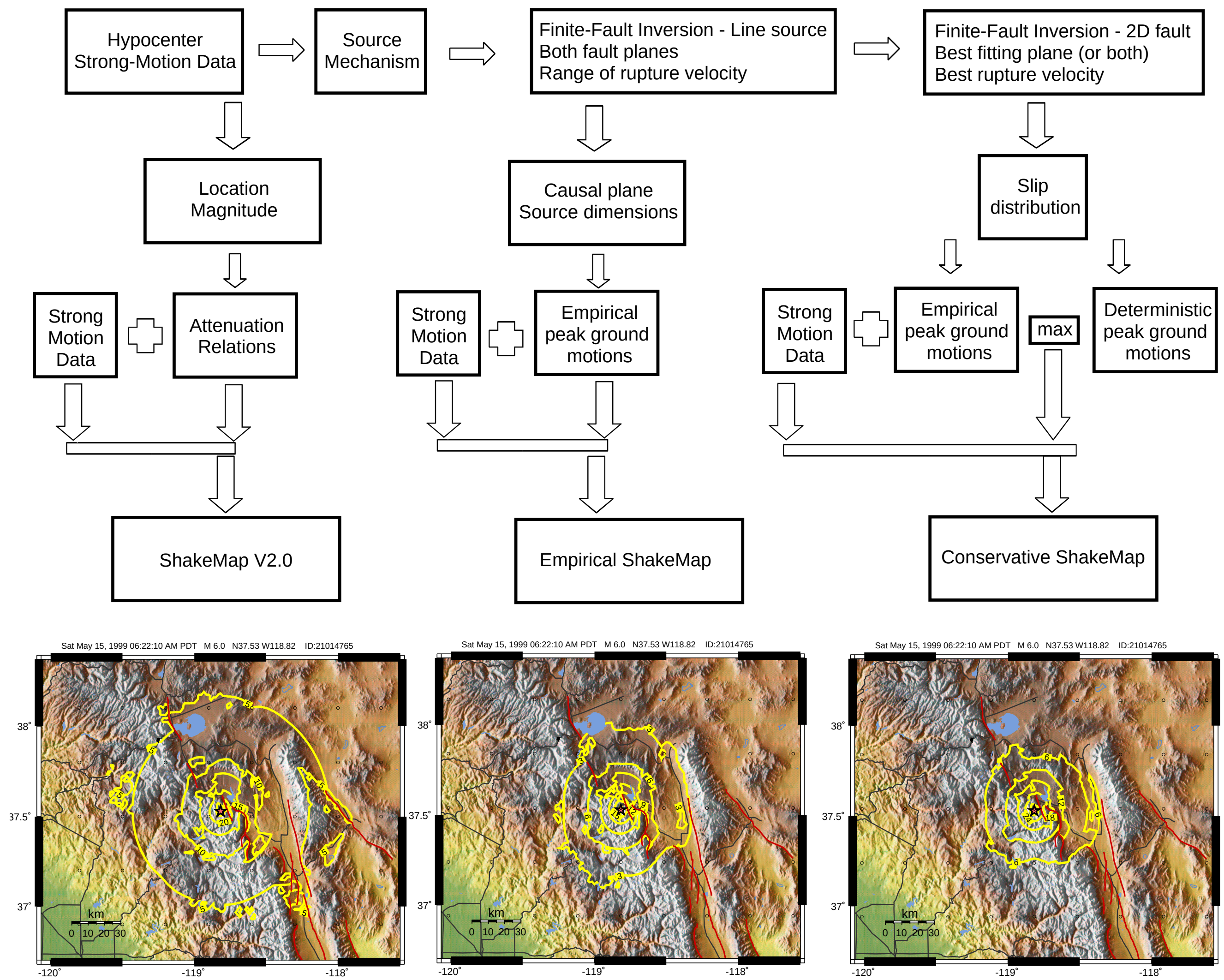

Figure 3: Summary of the three levels of ShakeMaps produced by the REDI system, with an example for an M6 earthquake in the Mammoth Lakes region. Note that the contour intervals vary from plot to plot.

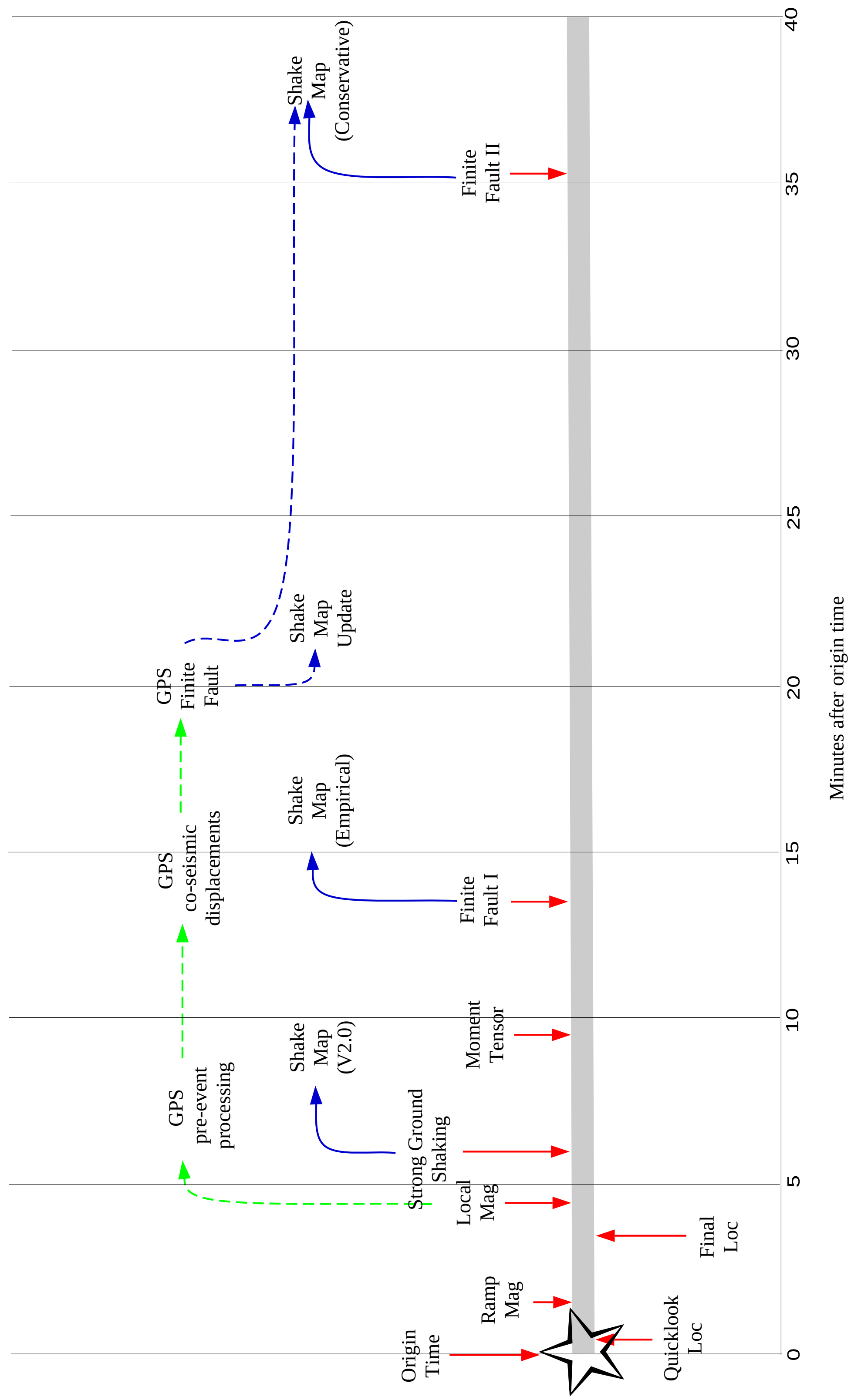

Figure 4: Illustration of the current (solid lines) and planned/proposed (dotted lines) development of real-time processing in northern California. The Finite Fault I and II are fully implemented within the REDI system at UC Berkeley and are integrated with ShakeMap. The resulting maps are still being evaluated and are not currently available to the public.

Implementation

At present, two Earthworm-Earlybird systems in Menlo Park feed two standard REDI processing systems at UC Berkeley (Figure 1). One of these systems is the production or paging system; the other is set up as a hot backup. The second system is frequently used to test new software developments before migrating them to the production environment. The REDI finite-fault processing is installed on a third system, which is always fed from the production system. A fourth system is installed in Sacramento as a stand-alone operation in order to provide a redundant notification facility outside of the Bay Area.

This structure has greatly expedited automatic earthquake processing in northern California. The dense network and Earthworm-Earlybird processing environment of the NCSN provides rapid and accurate earthquake locations, low magnitude detection thresholds, and first-motion mechanisms for smaller quakes. The high dynamic range data loggers, digital telemetry, and broadband and strong-motion sensors of the BDSN and REDI analysis software provide reliable magnitude determination, moment tensor estimation, peak ground motions, and source rupture characteristics. Robust preliminary hypocenters are available about 25 seconds after the origin time, while preliminary coda magnitudes follow within 2-4 minutes. Estimates of local magnitude are generally available 30-120 seconds later, and other parameters, such as the peak ground acceleration and moment magnitude, follow within 1-4 minutes (Figure 4).

Earthquake information from the joint notification system is distributed by pager, e-mail, and the WWW. The first two mechanisms push the information to recipients, while the current Web interface requires interested parties to actively seek the information. Consequently, paging and, to a lesser extent, e-mail are the preferred methods for emergency response notification. The *recenteqs* site has enjoyed enormous popularity since its introduction and provides a valuable resource for information whose bandwidth exceeds the limits of wireless systems and for access to information which is useful not only in the seconds immediately after an earthquake, but in the following hours and days as well.

RESULTS

Earthquake Monitoring

During FY2001-2002, nearly 8000 events were processed by the joint notification system in northern California. Most of these events were small earthquakes, although a number represent mislocated teleseisms, microwave glitches, or other blown events. Of the total, 260 events had an M_d greater than 3.0, 60 events had an M_L greater than 3.5, and 3 earthquakes with M_L greater than 5 were recorded. Figure 5 illustrates the distribution of events.

In general, the automatic systems are performing well. The use of the digital data to estimate M_L and M_w continue to be valuable contributions from the REDI system. For example, 5 events were reported with M_d ranging from 5.3 to 5.9 in the past year. All 5 had M_Ls ranges from 2.3 to 2.9.

The most interesting event was the May 14, 2002 Gilroy earthquake. This event occurred off the San Andreas fault on the Castro fault. The event generated the motivation to implement routine reporting of moment magnitude, as described below.

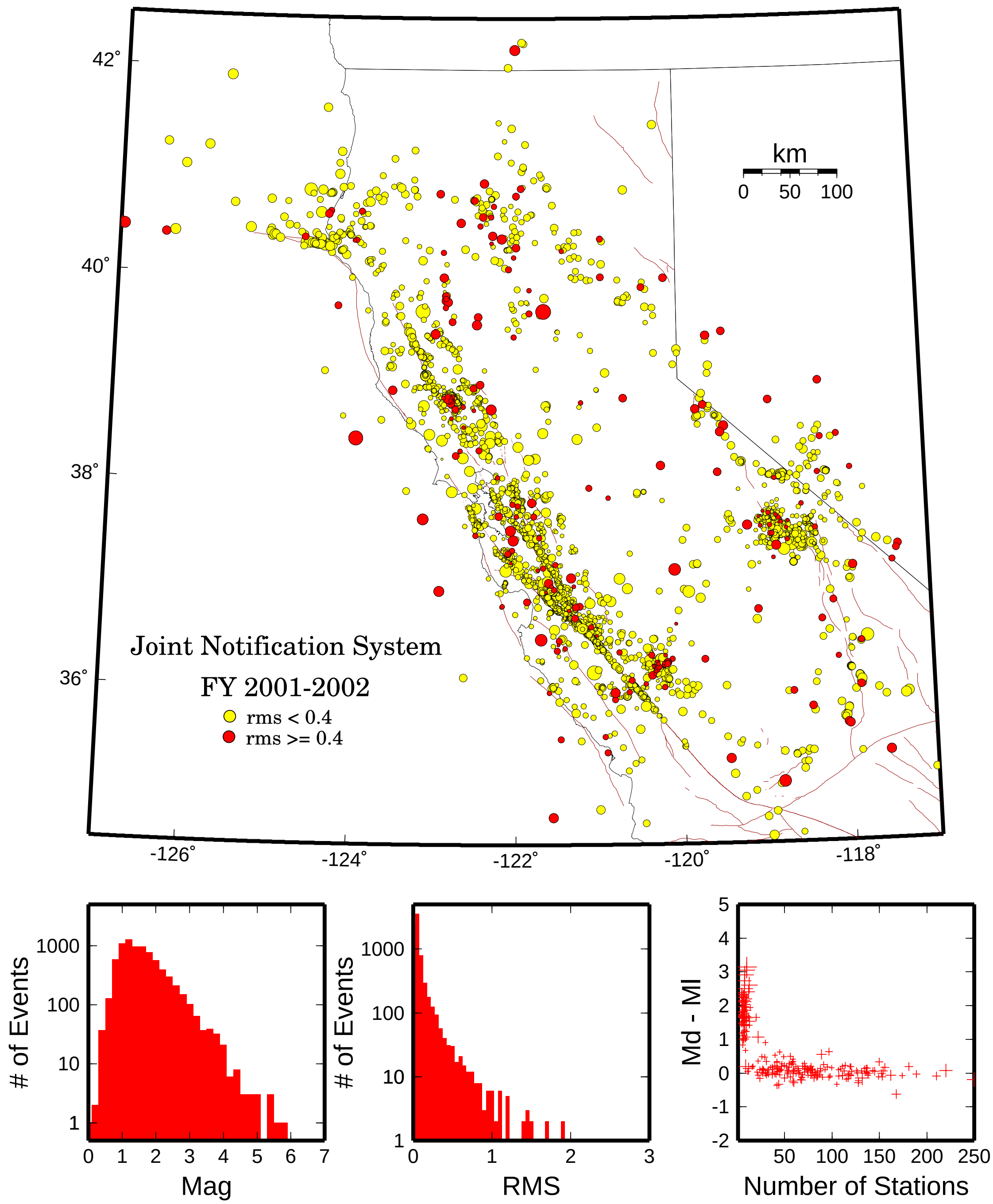

Figure 5: Map of northern and central California showing events processed by the joint notification system in FY 2001-2002. Some of these events were either teleseisms, microwave glitches, or other false events, as illustrated by the high RMS (yellow circles are events with RMS less than 0.4; red circles are RMS greater than or equal to 0.4).

DOI Internet shutdown

On Thursday, Dec. 6, 2001, the USGS was ordered to disconnect all external Internet connections by the Office of the Secretary of the Interior. The order included email as well as popular Web pages and lasted for 3 days.

BSL and USGS Menlo Park staff worked feverishly on the 5th and 6th to set up mechanisms for distributing earthquake information through UC Berkeley, using the private network which connects them. For several years, the recenteqs Web pages have been available through the NCEDC (`http://quake.geo.berkeley.edu/recenteqs/`) and this site was publicized broadly so that the public would be aware of the alternative resource. In addition, the BSL set up temporary redistribution hubs for QDDS messages from northern California so that the recenteqs maps at the NCEDC and at the SCEDC would have access to the earthquake messages. A similar setup through Caltech provided access to southern California events. Thirdly, the BSL worked with the USGS so that ShakeMaps generated in Menlo Park would be hosted on the NCEDC (`http://quake.geo.berkeley.edu/shake/`). Software was set up to allow BSL staff to send out email notification of earthquakes to USGS clients; USGS paging was unaffected.

The NCEDC Web server saw a doubling of hits during the days of the DOI Internet shutdown. The recenteqs Web pages became the 3rd most popular URL at the NCEDC and the ShakeMaps were not far behind at 20th (in November 2001, the recenteqs URL did not show up on the list of top 30 URLs at the NCEDC).

Following the restoration of Internet service, the BSL disabled the temporary QDDS hubs (although they were briefly reactivated when a second outage was threatened in May this year) but left the ShakeMap Web site in place at the NCEDC.

McCone generator failure

On March 7, 2002, a campus-wide power outage occurred when moisture seeped into a UC Berkeley electric substation. The power failed a few minutes before 5:00 PM local time. BSL staff immediately noticed that the McCone generator failed to start. Phone calls were made to Physical Plant and Campus Services (PPCS), but the extended nature of the outage prevented PPCS staff from responding for over two hours.

During this time, BSL staff made several attempts to bring the McCone generator online. The initial failure of the generator was traced to a weak battery. When BSL staff replaced the battery, the generator started up and then shut itself off after several minutes, due to a leak in the water pump.

As a result of the failure of the generator, the REDI system went off the air around 5:30 PM when the UPS system shut down due to a low battery condition (the UPS is designed to carry the electrical load until the generator comes online). A subset of critical computers were brought back online when a personal generator belonging to Bob Uhrhammer was brought in around 8:00 PM. A temporary fix to the generator was provided by PPCS around 8:30 PM, which allowed the rest of the processing system to be restored. The generator was not fully repaired until March 26th, 19 days after the power outage.

The failure of the McCone generator was due to poor maintenance. Similar to the situation in 1999, it failed due to problems in the power system combined with a leak in the water pump. The BSL is working with PPCS to establish a routine of regular load tests, which should improve screening for problems such as this, as well as working with other groups to relocate the critical activities to more robust campus facilities. Since the power outage, the McCone generator has had two load tests and passed with flying colors.

A future project for the BSL and the USGS Menlo Park is to establish combined notification by paging. Currently, each institution performs paging for its own set of clients. A combined system would allow either institution to perform paging to all clients and thus take advantage of the physical separation and separate infrastructure to enhance robustness.

System Development

In the past year, we have continued to work with the USGS Menlo Park to upgrade and improve the capabilities of the Northern California system. Perhaps the most significant development in the past year was the decision to eliminate a single-point-of failure for the generation of ShakeMaps in northern California.

ShakeMap

For the last several years, the ShakeMap system in northern California has been implemented in Menlo Park on a single machine The single instance of the ShakeMap program is in contrast to the other earthquake modules in northern California. As shown in in Figure 1, there are 2 of each system except for *yap*, the ShakeMap machine. Although the BSL has implemented ShakeMap as part of the REDI finite-fault processing, these ShakeMaps are viewed as experimental and are not currently distributed to the public.

In August 2002, BSL and USGS personnel met to discuss this potential weakness and to review other issues related to support of the ShakeMap products. The group decided to install a ShakeMap system at UC Berkely for redundant operation. The group also decided to expand responsibility for reviewing ShakeMaps following earthquakes. In the short term, Pete Lombard was identified as a BSL staff member to participate. The group also identified the need for additional tools to facilitate the review of ShakeMaps.

As part of this effort, the BSL began implementation of an Earthworm database and ShakeMap on the computer *shaker*. Pete Lombard worked with Lynn Dietz to modify the ”file flingers” in Berkeley, Menlo Park, and Pasadena to distribute ground motions from the NCSN, NSMP, PGE, Tremor, CSMIP (via CIT), TriNet, and the BDSN. The system on shaker is designed to be driven by the master or production system. The USGS and BSL have agreed that only one system (either yap or shaker) will distribute ShakeMaps to the webservers and clients at this time, but that the ”distribution system” will switch between MP and the BSL, depending on who is ”on-duty” for ShakeMap that week, i.e., when Pete is on duty, the primary ShakeMap system will be operating from UC Berkeley.

All of the work was initiated in September and a preliminary implementation of ShakeMap was completed in mid-October. It is important to note that between the August meeting and the completion of the work in October, the computer system *yap* at Menlo failed with disk errors early in the morning of Sept 15th, 2002, bringing down the northern California ShakeMap system and reinforcing the importance of redundant systems. In parallel with the implementation effort, Pete Lombard met with both Howard Bundock and David Wald to be trained for reviewing ShakeMaps following an earthquake.

Several issues still need to be addressed and will be the focus on ongoing work in the coming year. This includes:

- resolution of some differences between NC and SC
- synchronization of configuration files between the 2 NC systems
- mechanisms to monitor distribution of ShakeMaps
- development of review tools

Support for SNCL

Over the last year, we completed the implementation of full SEED channel names. In the past, the REDI system had used Station/Network/Channel (SNC) to describe a unique waveform channel. However, the evolution of the BDSN and expanded data exchange with other networks created the need to implement Location code or the full SNCL convention. In parallel, the NCSN has adopted the use of the SNCL convention, as it has provided ”tie-breaking” capability in decribing instrumentation at a site. To support the full SEED convention within REDI, a number of modules which handle waveform data and channel-specific information required changes.

Channel selection

Most of the REDI processing modules depend on raw waveform data. An important implementation within REDI has been a ”station-availability” file which modules read before requesting data. In practice, this file is used to remove stations with telemetry problems, sensor failure, or other difficulties from processing. Concurrent with the implementation of SEED SNLC, we extended the use of this file to the channel level. Individual channels may now be controlled for use in each REDI module. For example, a channel may be used for M_L estimation, but deemed too noisy for a moment tensor inversion. Similarly, this file also allows preferences to be set among multiple channels at a particular station. For example, the moment tensor and finite-fault codes normally use data from the broadband sensors, but will select data from the accelerometers if the broadband data are clipped.

Moment Tensor codes

As part of the changes for supporting SNCL, BSL staff put considerable time into recasting the moment tensor stage of REDI. For the last 5-6 years, the REDI moment tensor stage has run two methodologies for computing moment tensors. Both of these programs were developed at the BSL as part of the research environment and then migrated to REDI operations.

The original codes are a combination of scripts and programs in C and Fortran. Many parameters such as channel usage (for example, use of LHZ, LHN, and LHE) and sampling rates were hardwired. As part of this effort, we identified several problems to be addressed: rejection of clipped data, use of an instrument response API, use of the new channel selection files, support for SNCL, and generally get away from hardwired assumptions about data rates and channel orientation. In addition, we wanted to install a new velocity model for earthquakes in the Cape Mendocino area, developed by Fumiko Tajima and Doug Dreger.

After reviewing both the complete waveform and surface wave inversion codes, the BSL decided to focus on modifications to the complete waveform methodology. These programs are more self-contained that the surface wave codes and the original developer (Doug Dreger) is still at UC

Berkeley. The modifications were completed in mid-May. As part of the CISN efforts to standardize and calibrate software, the complete waveform codes were packaged together along with documentation and provided to the Caltech/USGS Pasadena.

In parallel, we also developed the tools to distribute the reviewed moment tensor solutions as *recenteqs* addons.

Version numbers

For some time, the BSL and the USGS have wanted to take advantage of their separated facilities to improve the robustness of northern California data distribution by QDDS. Since the development of QDDS, the USGS Menlo Park has been responsible for contributing events from northern California. However, the Internet shutdown of DOI in December 2001 provided motivation for the BSL to distribute the events messages as well.

M_w

The REDI system has routinely produced automatic estimates of moment magnitude (M_w) for many years. However, these estimates have not routinely used as the ”official” magnitude, due in part to questions about the reliability of the automatic solutions. However, in response to the 05/14/2002 Gilroy earthquake (M_w 4.9, M_L 5.1) and the complications created by the publication of multiple magnitudes, the BSL and USGS Menlo Park have agreed to use automatically determined moment magnitudes, when available, to supplement estimates of local magnitude (M_L).

We have taken steps to use M_w automatically and recently completed this work. However, additional work is ongoing to improve the reporting of M_w. As presently implemented, moment magnitude from the complete waveform inversion is reported if the correlation between the complete waveform and surface wave results is greater than 25% and if the quality of the complete waveform solution is 75% or better. The current standards are rather high - of the 60 or so earthquakes which qualified for moment tesnor processing in the past year, M_w was reported only 19. We are investigating improvements to the automated assessment of quality.

In parallel, the developments for reporting moment magnitude allow both the USGS and the BSL components of the joint notification system to report earthquake information to Web independently (currently, only the USGS component distributes information to the Web using QDDS). As a result of this development, both the USGS and BSL components will distribute information to the Web, enhancing the robustness of the Northern California operations.

Collaborations

An earthquake in eastern California motivated a review of boundaries between adjoining networks. Lind Gee and David Oppenheimer visited UNR in Sept 2001 to discuss this with colleagues at UNR and then expanded the discussion with colleagues in southern California. As a result of these discussions, the distribution polygons for *recenteqs* were modified. Figure 6 illustrates the new distribution polygon for northern California which will be used for QDDS, email, and paging.

As part of our collaboration with UNR Seismological Laboratory, we implemented the capability to ”forward” event messages from UNR over the REDI paging system in January. UNR sends Qpager format messages to the BSL via email, where a program extracts the message, evaluates the location, and then sends a page if the event is inside the UNR paging polygon.

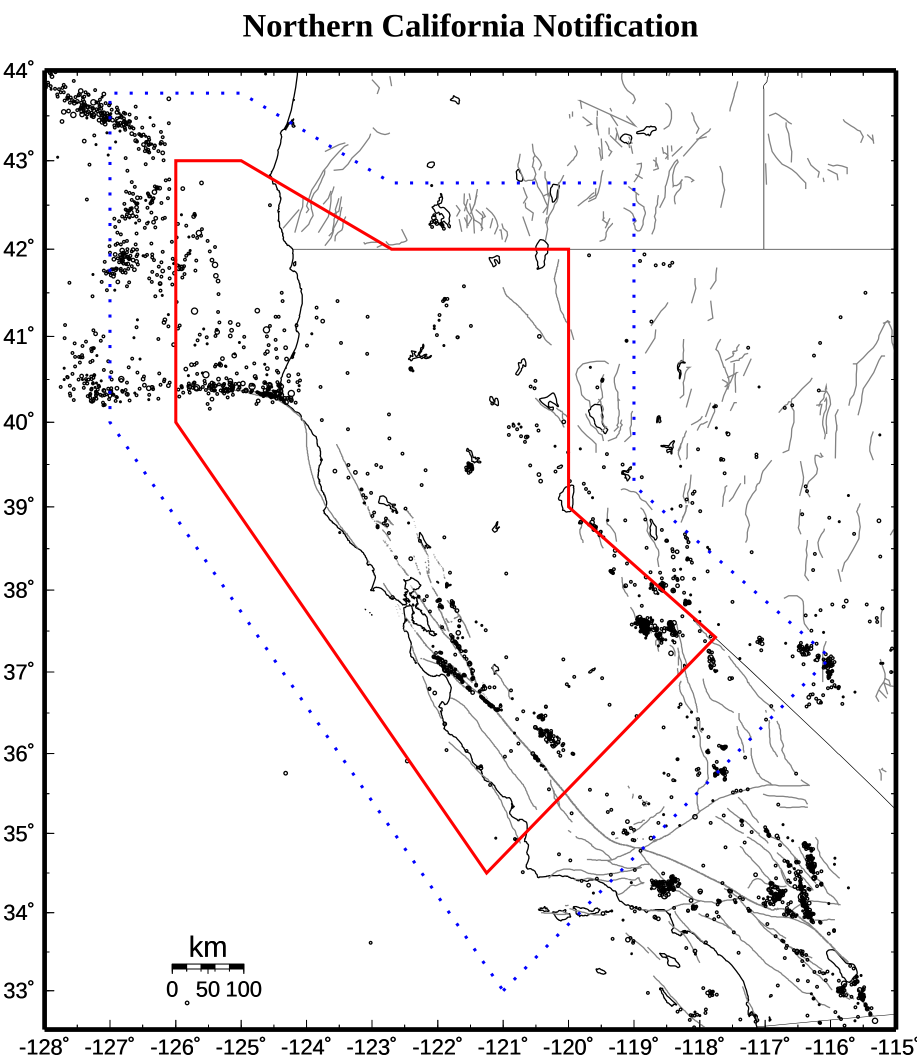

Figure 6: Map of northern California showing the polygon used for the distribution of earthquake information (red) and the REDI processing polygon (blue). The red polygon is used by the USGS Menlo Park and the BSL for distribution by QDDS, email, and pagers.

Related Projects

CISN

The efforts of the California Integrated Seismic Network or CISN significantly expanded during the last year. The USGS Menlo Park and the BSL form the Northern California Management Center of the CISN. Both groups are involved in all aspects of the CISN, particularly in the issues of creating a statewide processing system.

The BSL and USGS Menlo Park are continuing to plan for the next generation of the northern California joint notification system, in the context of a statewide system. Figure 1 illustrates the current organization of the two systems. As described above, an Earthworm/Earlybird component is tied to a REDI component and the pair form a single ”joint notification system”. Although this approach has functioned reasonably well over the last 5 years, there are a number of potential problems associated with the separation of critical system elements by 30 miles of San Francisco Bay.

Recognizing this, we intend to redesign the northern California operations so that a single independent system operates at the USGS and at UC Berkeley. Figures 7 and 8 illustrate the planned configuration. Our discussions have proceeded to the stage of establishing specifications and determining the details required for design. In the last year, the BSL and the USGS Menlo Park have met several times to discuss designs for the proposed system. In October 2001, the BSL and the USGS Menlo Park held a meeting with representatives from the USGS Golden, USGS Pasadena, and Caltech to discuss the design.

In order to migrate to a design such as Figure 7, the BSL and the USGS Menlo Park need to enhance the communications infrastructure between their sites. Presently, data and information are shared on a dedicated frame-relay connection, with fallback to the Internet.

With OES funding, the BSL commissioned Telecommunications Design Services, Inc. to perform a feasibility study for a microwave communication link between Berkeley and Menlo Park. This study was conducted in June 2002 and a report delivered to the BSL and the USGS Menlo Park. The report concludes that a repeater site will be required, given the length of the path and the obstructions (buildings, bridges, etc.). According to the report, the Space Sciences Laboratory at UC Berkeley will be a good site for the repeater. The results of this study are under discussion between the BSL and the USGS. Further discussion is required before moving forward with issues of permission and purchase of hardware.

The USGS Menlo Park has placed effort in the development of statewide association and location algorthms, while the BSL has been looking at some of the software developed under the TriNet project with the goal of adapting it for northern California. Of particular interest are the codes which continuously process waveform data to create timeseries of pre-computed amplitudes (*Kanamori et al.*, 1999) such as Ml100 (local magnitude computed for a fixed distance of 100 km), Me100 (energy magnitude computed for a fixed distance of 100 km), peak ground acceleration, peak ground velocity, and spectral acceleration at 3, 1, and 0.3 seconds. The continuous processing of the amplitudes is advantageous in providing a steady computing load (as opposed to ”peaking” during an earthquake) and rapid access to the data of interest.

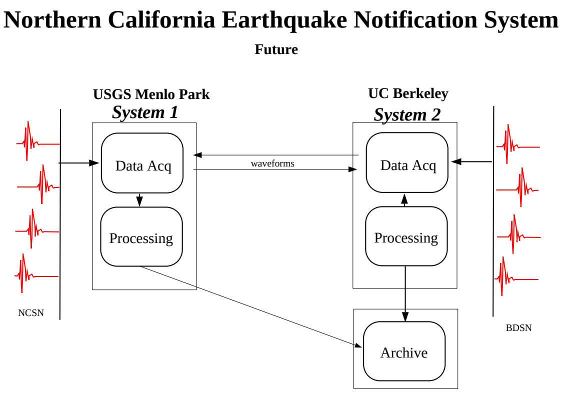

Figure 7: Future design of the Northern California Earthquake Notification System. In contrast with the current situation (Figure 1), the system is being redesigned to integrate the Earthworm/Earlybird/REDI software into a single package. Parallel systems will be run at the Berkeley and Menlo Park facilities of the Northern California Operations Center.

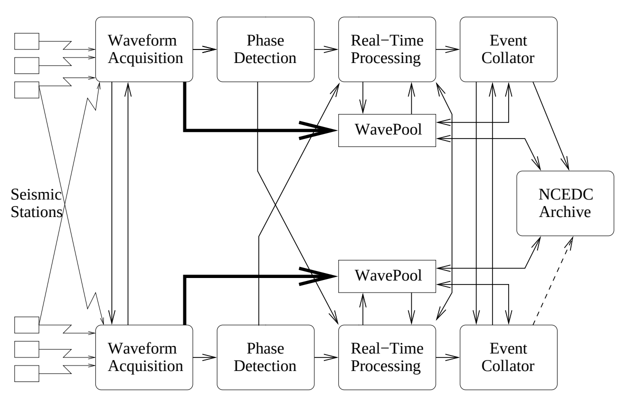

Figure 8: Illustration of the design currently being considered for the development of the Northern California Management Center.

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NON-TECHNICAL ABSTRACT

This project focuses on the development and implementation of hardware and software for the rapid assessment of earthquakes. The Berkeley Seismological Laboratory collaborates with the USGS Menlo Park to monitor earthquakes in northern California and to provide rapid notification to public and private agencies for rapid response and assessment of earthquake damage. In the past year we improved the robustness of the computation of ShakeMaps through the establishment of parallel ShakeMap system at the BSL and improved the codes for the determination of the seismic moment tensor. We have also participated in discussions with the USGS Menlo Park to develop plans for improving the Northern California Seismic System, as part of the California Integrated Seismic Network.

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MEETING PRESENTATIONS

CISN, The California Integrated Seismic Network: status and perspectives Eos Trans. AGU, 82 (47), Fall Meet. Suppl., S12C-0612, 2001

DATA AVAILABILITY

Data and results from the REDI project are available at the Northern California Earthquake Data Center (*//www.quake.geo.berkeley.edu*) For additional information on the REDI project, contact Lind Gee at 510-643-9449 or lind@seismo.berkeley.edu.