The California Strong Motion Instrumentation Program

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CGS Strong Motion Instrumentation Program

EACH YEAR CALIFORNIA EXPERIENCES thousands of earthquakes. Although most of these earthquakes are too small to be felt by humans, the larger but less frequent events pose significant risk to both life and property. Fortunately, California boasts one of the largest and most sophisticated networks in the world for recording and disseminating earthquake shaking data.

The California Strong Motion Instrumentation Program (CSMIP) in the Department of Conservation's California Geological Survey (CGS) was established in 1972 to obtain vital earthquake data for the engineering and scientific communities through a statewide network of strong motion instruments. CSMIP is a core member of the California Integrated Seismic Network (CISN), a collaboration of organizations that monitor earthquakes in the State and collect data to support improvements to earthquake resilience.

The information gathered by CSMIP is provided to seismologists, engineers, building officials, local, state, and federal governments, and emergency response personnel. Within minutes of an earthquake, emergency operation centers can access ShakeMaps and other earthquake products. At specific sites rapid health assessments aid post-earthquake response efforts. Beyond the immediate value, the data are used to develop seismic design provisions in building codes and inform scientists and engineers internationally about how shaking affects buildings, infrastructure, and the ground.

STRONG MOTION NETWORK

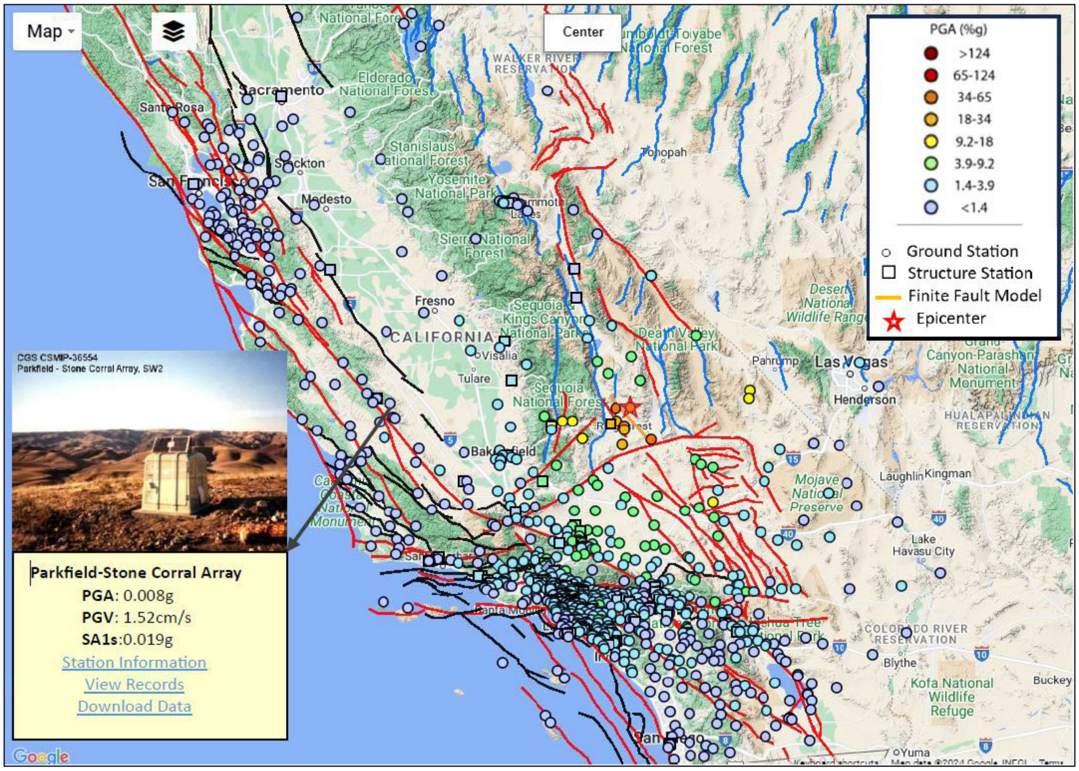
CSMIP installs state-of-the-art earthquake monitoring devices called accelerographs at various locations throughout California to measure the ground shaking (i.e., ground-response stations). Accelerographs are designed to record acceleration of ground shaking with respect to time that could cause a more sensitive seismograph to go off-scale. When activated by earthquake shaking, the devices produce a record from which important characteristics of ground and structural motion (acceleration, velocity, displacement, response spectra, and duration) can be understood and utilized.

In addition, CSMIP installs earthquake monitoring devices in structures such as buildings, hospitals, bridges, dams, utilities, and industrial facilities. These devices are predominantly accelerographs, but some stations also include sensors which directly measure the relative displacement between two points of the structure. Sites are selected by a governing committee comprised of engineers and scientists representing industry, government, and universities. These sites are chosen based on scientific significance and include factors such as population density, geology, structure type, and seismic hazard level. The program currently has more than 1,375 active stations, including 942 ground-response stations, 272 buildings, 26 dams and 82 bridges, with the total number of sensors exceeding 10,000.

DATA PRODUCTS AND APPLICATIONS

Shortly after an earthquake in California, the Strong Motion Recovery and Analysis (SARA) system receives data recorded by California Integrated Seismic System (CISN) stations. CSMIP automatically processes and disseminates the strong-motion data and the related visual products via the Center for Engineering Strong-Motion Data (CESMD) for use in post-earthquake response, and for scientific and engineering research applications. The CESMD is an internationally utilized joint center of the USGS and the CGS, providing a single access point to quality-controlled strong-motion data from CSMIP, the USGS National Strong-Motion Project (NSMP), the USGS Advanced National Seismic System (ANSS), and other affiliates.

California Geologic Data Map Series Map No. 8. February 2024. This map shows the locations of CSMIP network stations differentiated by the type of the station; Ground, Building or Bridge/Dam. Also displayed are inset photographs of ten stations.

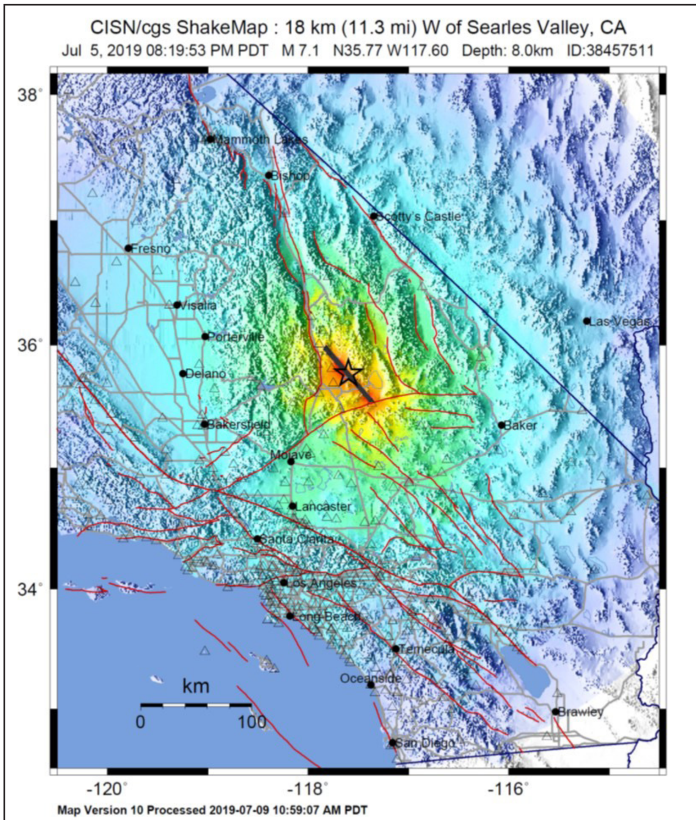


An example of the CESMD interactive map for the M7.1 Ridgecrest earthquake of July 2019 showing the spatial distribution of stations that recorded the earthquake. Ground stations are represented by circles and structural stations by square symbols. The color-codes in the stations correspond to ranges of peak ground acceleration in percent of gravity (%g) experienced at those locations. The fault overlay on the map is represented by colored lines – blue: normal fault; black: reverse fault; red: strike slip fault.

Inset: Screenshot of seismic station information popup. Such popups provide links to view station information, earthquake records, and waveform data.

The CESMD works closely with ANSS and with the Consortium of Organizations for Strong-Motion Observation Systems (COSMOS) to engage with the strong-motion networks in the U.S. and other countries. It is currently serving data from more than 40 countries via its Engineering Data Center (EDC) and the Virtual Data Center (VDC) portals. Through the VDC, the CESMD provides access to significant ground strong-motion records from data providers worldwide. In addition, the CESMD strives towards the completeness of station information such as site geology parameters, structural design characteristics, and sensor locations, all of which are critical for the analysis and interpretation of recorded data.

Strong-motion data products of engineering interest are made available to end users via the event-specific Internet Quick Report (IQR). While users can navigate the IQR to access event-specific products, the CESMD also provides a search engine and webservice data access tools to facilitate the utilization of bulk data products from a single event or multiple events. The data products provided via the IQR include raw and processed records and easily interpretable visual products such as spectral, ground and structural motion plots, the interactive station map, and a link to ShakeMap. In addition to displaying a spatial context of earthquake and recording stations, the dynamically generated interactive station map provides quick links to the station pages, record plots, and the downloadable data files. The stations on the interactive map are color-coded according to peak ground acceleration (PGA)



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	**<0.1**	**0.5**	**2.4**	**6.7**	**13**	24	44	83	>156
PEAK VEL.(cm/s)	<0.07	0.4	1.9	5.8	**11**	**22**	**43**	**83**	**>160**
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Wald, et al.; 1999

ShakeMap of the M7.1 Ridgecrest earthquake of July 2019. Colors represent the range of intensities from low (light blue) to high (red). Red lines and the star icon represent active faults and the earthquake epicenter, respectively.

values matched with the intensity scale used in ShakeMap. ShakeMap displays the intensity of ground shaking due to an earthquake. ShakeMap is useful for emergency services responding to earthquakes because recorded and estimated ground motions correlate to felt effects and expected damage distributions.

CSMIP provides real-time data to the USGS west coast ShakeAlert Earthquake Early Warning System. ShakeAlert detects earthquakes quickly and alerts people and automated systems through the MyShake application to take protective action in response to earthquakes.

Also, the program annually provides grants to researchers to fund projects that will utilize strong motion records, new types of seismic recording equipment, to provide innovative approaches to improve the seismic resilience of our communities. The ultimate goal of these projects is to accelerate the process by which lessons learned from earthquake data are incorporated into seismic monitoring and structural design practice. For example, the study of CSMIP building data led to improved formulas in the building code for calculating the resonant vibration period of buildings, a key parameter in earthquake-resistant design.

GOLDEN GATE BRIDGE MONITORING

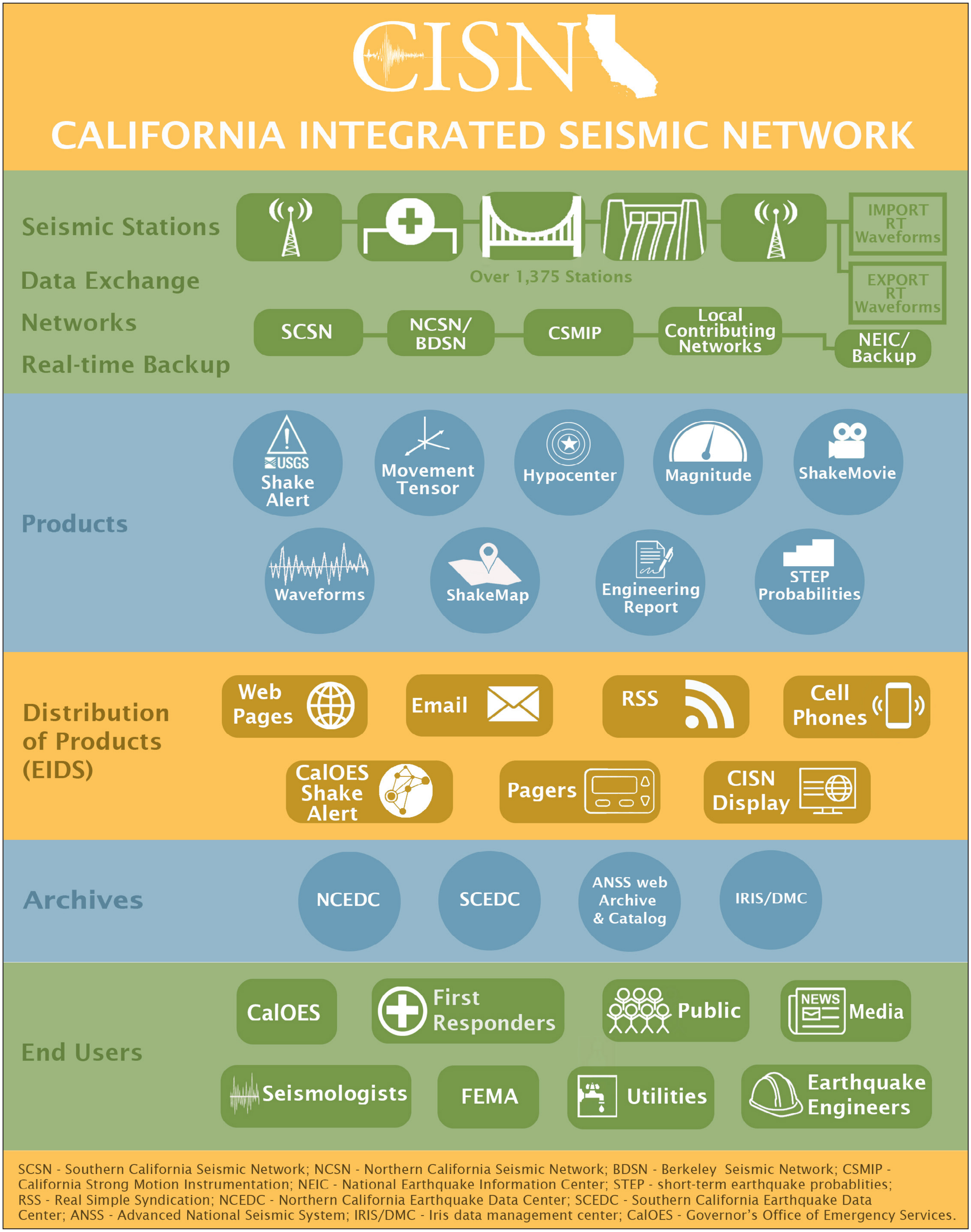
The Golden Gate Bridge (GGB) is an example of the use of data for post-earthquake response applications such as emergency mitigations. The bridge is constantly monitored by CSMIP for earthquake motions using strong-motion sensors distributed throughout the structure, all connected to data recorders by electrical cabling. The initial installation of instrumentation by CSMIP at the GGB occurred in 1995. At that time 69 accelerometers were installed on the bridge and three on the ground near the bridge. Four relative displacement sensors were also installed on the bridge at the time. As of today, the instrumentation at the GGB includes 100 accelerometers and 10 relative displacement sensors on the bridge, as well as two clusters of six accelerometers near the ends of the bridge The state-of-the-art central recorders and communication technology utilized in the seismic monitoring system at GGB allows for the rapid transfer of seismic data between the bridge and CSMIP.

To improve post-earthquake response efforts at the GGB, CSMIP recently initiated an effort to provide GGB engineers with information for their rapid structural health assessments immediately after an earthquake. Through this monitoring system, peak ground accelerations and important bridge response parameters are calculated and distributed to GGB personnel through an automated notification system. Equipped with this crucial information, on-site engineers are able to take urgent action seconds after a damaging earthquake.

For over 50 years, CSMIP has been collecting and disseminating valuable seismic data and associated products to increase public safety by enhancing rapid post-earthquake response capabilities and improving building codes for safer structures. In order to facilitate the utilization of seismic data products, the program is upgrading over 1,100 obsolete recorders with modern systems that can take advantage of faster communication methods. The upgraded equipment will allow these stations to provide data in real time and make possible advanced applications such as structural health monitoring of tall buildings, hospitals, and lifelines. The rapid delivery of earthquake information to emergency responders will ultimately help to save lives during the next damaging seismic event. For more information about the California Geological Survey's Strong Motion Instrumentation Program, visit our website https://www.conservation.ca.gov/cgs/smi/program.

CSMIP staff installing an earthquake monitoring device on the Golden Gate Bridge.

Schematic of the Golden Gate Bridge showing the locations of the sensors (red arrows) that contribute data to the bridge's automated notification system. Ground surface sensors are located near each end of the bridge. Sensors on the bridge are located at the top and bottom of each tower. The ground and bridge shaking data obtained by these sensors during an earthquake are used to produce notification messages which are rapidly distributed to Golden Gate Bridge personnel.



The CSMIP, funded by the state of California through the CGS, is one of the core members of the California Integrated Seismic Network (CISN). The CISN is California's partner to the Advanced National Seismic System.