Questions and Answers about the Sherman Island Seismic Test

A network of levees protects the Sacramento-San Joaquin Delta from flooding. These levees are built on or of soft, compressible, or sandy soils. The performance of these soils during an earthquake is poorly understood, and the subject is of intense scientific interest. Engineering researchers from the University of California, Los Angeles are working with the California Department of Water Resources to better understand the behavior of Delta soils during an earthquake.

What are the scientists doing?

The UCLA researchers will use a machine called an "eccentric mass shaker" to simulate earthquake shaking within a small area of Sherman Island in the western Delta. Using counterweights spun by an electric motor, the machine can generate tens of thousands of pounds of shaking force. For this test, the machine is mounted atop an earthen embankment, or model levee, created by the researchers. The researchers will use the shaker to simulate an earthquake and measure ground movement and water pressure within 300 feet of the test site.

What are they trying to learn?

The scientists hope to learn more about how the highly-organic peat soil beneath the levee embankment responds to the ground motion. They are not focused on the performance of the artificial levee itself, because they deliberately constructed it to be stronger than typical Delta levees. The peat soil of the Delta was created by decomposing wetland plants over thousands of years, and it underlies many of the Delta's 1,100 miles of levees. Little is known about how peat soil responds to earthquakes, and even less is known about how seismic energy flows through levees that rest on peat but are themselves made of a mixture of sand, clay or other types of soil.

Why should we care about seismic risk in the Delta?

Flooding from the failure of Delta levees could jeopardize towns, farms, wildlife habitat, highways, and key transmission and communication lines. The state's larger economy depends on Delta levees, too. That's because the federal and state water projects that move water from northern rivers to central and southern California pump water from the Delta. The water they pump reaches roughly 25 million people and three million acres of farmland. The levees surrounding the 65 islands of the Delta help keep the seawater of San Francisco Bay from encroaching too close to the water project pumps. Were multiple levees to slump or collapse in an earthquake, the flooding of the islands would draw salty ocean tides toward the pumps. State officials anticipate that water project operators would be forced to shut down the pumps to avoid contamination of aqueducts. The pump shutdown could disrupt water supplies to the Central Valley, Santa Clara Valley, and Southern California for weeks, months, or years.

What is being done to safeguard Delta levees?

Roughly one-third (385 miles) of Delta levees are officially part of a federal flood control project and therefore eligible for federal maintenance and rehabilitation funding. The rest of the levees are considered local levees, and they are the responsibility of local reclamation districts operated by landowners. The state, however, significantly offsets the costs associated with the improvement of the Delta levees. The state has committed approximately $300 million since 2005 to strengthen Delta levees. Voter-approved bonds provided much of that funding, and more such funding will be necessary to maintain the investment over the long term.

What were the results of last year's test?

A similar shaking experiment was conducted on Sherman Island in August 2011 on dry foundation soils. When the UCLA researchers analyzed measurements, they concluded that the motion did not cause significant settling of the dry peat underlying the model levee. The test results offer limited value to our understanding of the seismic risk to the levee system, because the soil was tested in a dry state, while the soil under Delta levees is saturated.

How is this year's test different?

Last year, the peat underlying the model levee was dry to a depth of six feet. This year researchers want to test wet peat, because it more accurately reflects the conditions under Delta levees, and saturated soil may respond differently to seismic energy. The researchers have built berms around the test site to hold water and allow it to soak into the ground.

Will the test damage levees on Sherman Island?

No. The energy generated by the "shaker" will dissipate before it reaches the levees that protect Sherman Island. During the August 2011 experiment, instruments placed near the levees were unable to detect the applied ground motion.

How soon will we know the results of this test?

The experimental data will be archived within six months of the test at a publicly accessible website (http://nees.org). Certain conclusions can be made immediately after testing, while others will require more detailed processing. It may require as long as a year to fully understand the test results. Examples of information that will be available immediately include:

- Whether the model levee sinks into the saturated peat during shaking;
- Whether the saturated peat generates excess water pressure during shaking, which could cause settlement in the days and weeks after testing;
- Whether the imposed ground motions are as large as anticipated for an earthquake in the Delta.

Conclusions that will require more time include:

- How much the embankment settles following shaking, since this process may take weeks or months;
- The nature of the energy transfer between the model levee and the underlying peat, as this will require detailed interpretation of the experimental data.

How definitive or useful will the test results be for helping us understand the seismic risk to Delta levees?

Eventually, researchers plan to develop methods that can be applied to real Delta levees for the purpose of evaluating liquefaction potential of sandy levee materials. These methods could be used for 1) estimating the amount of settlement anticipated in the peat as a function of ground motion intensity, and 2) estimating the amount of energy transmitted from the peat into Delta levees. Liquefaction of Delta levees is the biggest seismic threat in the Delta, and engineering evaluation procedures already exist for estimating liquefaction-triggering potential and post-liquefaction deformation potential.

The findings from this Sherman Island test will augment these evaluation procedures to make them more accurate for application to sandy levee fills resting atop soft peat soils. (The procedures were originally developed for more typical soil conditions.) The results of this testing will allow us to better estimate the level of ground motion required to trigger and define a levee response. The corrections we develop, in part from this testing, will not change the scientific consensus that seismic hazard in the Delta is a significant problem, but it will help us to better understand the magnitude of the hazard.

Who is paying for the experiment?

The study is funded by the National Science Foundation through the George F. Brown Network for Earthquake Engineering Simulation.

Myth: The Delta is a non-seismic region.

There are no records of an earthquake causing levee failure in the Sacramento-San Joaquin Delta, and long-time residents may never have felt an earthquake.

But that does not mean the region is not seismically active.

Our roughly 160 years of experience with Delta levees is not enough time to truly understand seismic hazard, and the span of a person's life is essentially meaningless to the issue. Consider two recent events as an illustration:

- A magnitude 7 earthquake struck Haiti in January 2010, killing over 300,000 people. The previous large earthquake in the region occurred in 1770.
- The 2011 magnitude 9 Tohoku Earthquake generated strong shaking and a deadly tsunami that devastated Japan. The previous event of this size occurred in 869 AD.

Both of these earthquakes were preceded by similar events hundreds of years prior, long before any living person was born. To characterize seismic hazard based on the experiences of local residents or written history in a place as recently settled as California would be dangerous.

Instead, scientists try to understand the hazard by characterizing earthquake faults that might shake a particular site, and then estimating the effects of various earthquake scenarios (i.e., ground shaking, tsunami).

Thorough seismic hazard analyses have been performed in the Delta by highly qualified scientists, and we know with certainty that the Delta has been strongly shaken in the past and will be strongly shaken in the future. We don't know precisely when strong shaking will occur again, but we know it will happen eventually and we can characterize the probability that a certain level of shaking will be exceeded in a particular year. We also know that earthquakes are rare events, and the lack of strong shaking during the existence of the man-made levees and the lifetimes of local residents is not surprising.

Myth: The peat soils in the Delta will dampen the shaking

The peaty organic soils that underlie many Delta levees are extremely soft and compressible compared with more traditional inorganic soils. Some have argued that these peat soils are incapable of transmitting large ground motions and that the peat will "damp out" or "dampen" the incoming seismic waves, thereby protecting the levees.

There are several problems with this argument:

- Large ground motions have been transmitted through peat soils during past earthquakes in other parts of the world.
- Physical model studies and numerical simulations specific to Delta peat indicate that the soil profiles in the Delta will likely amplify strong ground motions rather than dampen them.
- Arrays of underground and surface ground motion sensors in the Delta have shown significant amplification of ground motion during past weak earthquakes.

Japanese scientists (Tokimatsu and Sekiguchi, 2006) analyzed the readings of three ground motion sensors in close proximity that recorded the 2004 Mid Niigata Prefecture earthquake. One of the sensors was on a profile that contained a layer of peat, one was on rock, and one was on inorganic soil. The sensor on peat recorded a stronger ground motion than the other two stations, with a peak acceleration of 1.3 g. This is a very large ground motion that could easily damage Delta levees. Furthermore, the peat clearly did not dampen out the ground motion because it produced stronger ground motions than the inorganic soil conditions.

(Seismologists use "g" to represent the acceleration of gravity, with 1 g equivalent to the same force that pulls an object to the ground. For example, a 200-pound person experiencing 1 g would be pushed horizontally with 200 pounds. Their feet would move more than their upper body, and they would most likely be knocked off their feet.)

At the University of California, Davis, another research team (Arulnathan et al., 2001) performed centrifuge model tests of Delta peat. They found that the peat deposits amplified the ground motions imposed on the base of the container. The peat amplified small motions and large motions in a nearly identical manner. Numerical simulations of these tests reasonably reproduced the experimental results. Furthermore, weak ground motions recorded in the Delta during small magnitude earthquakes showed that the ground surface motion was significantly higher than the deeper ground motions (Curras, 2003).

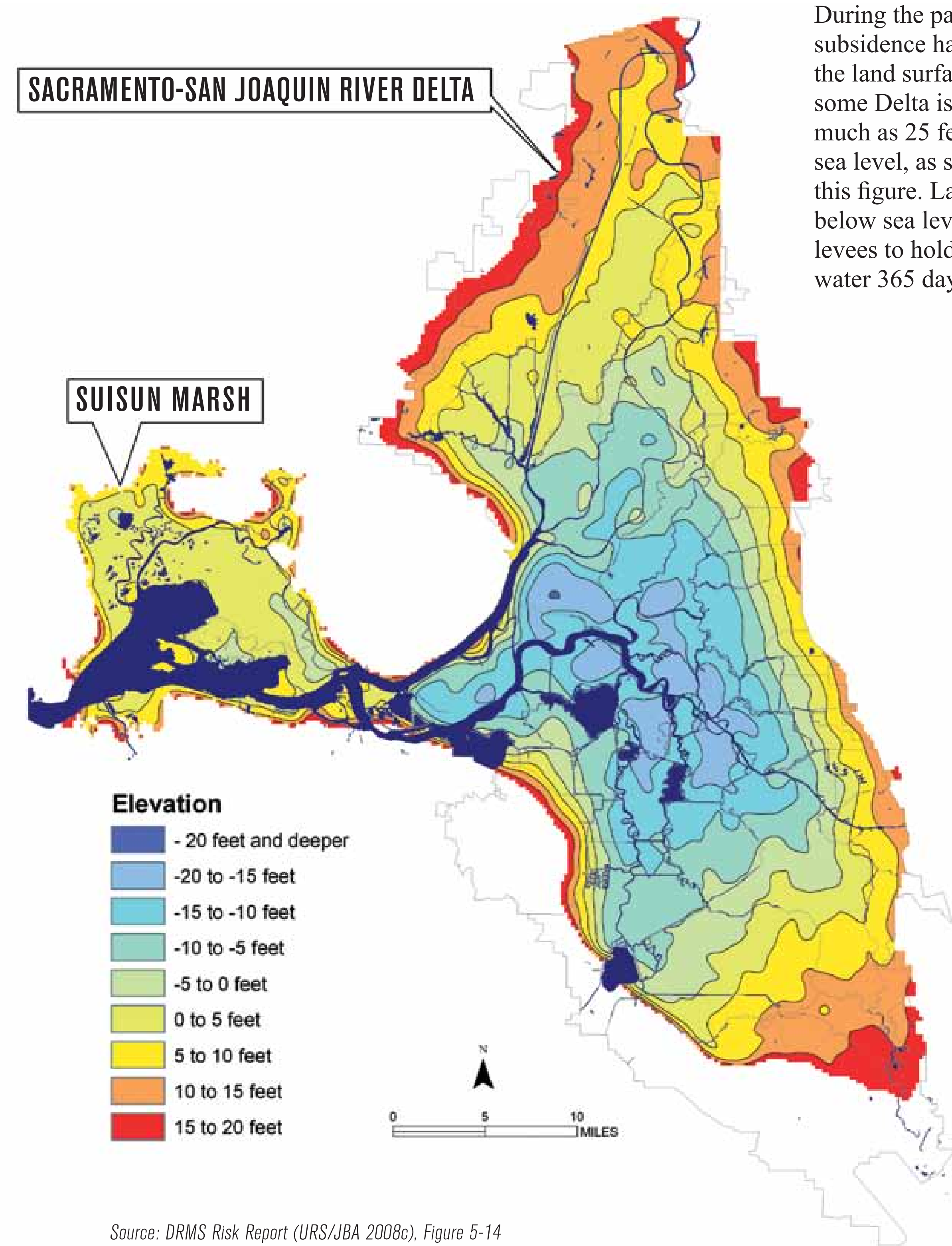
An abundance of data indicates that the peat soils in the Delta are capable of transmitting large ground motions. No research studies have indicated that the peat will dampen out strong motion.

Myth: Uncertainty about the seismic risk argues for doing nothing to address it.
Some would argue that because the seismic risk in the Delta is uncertain, there is no need to try to mitigate such an event. To paraphrase this argument: "We don't know when or where an earthquake will strike, we don't know how severe the shaking will be, so why waste so much money fixing the levees to an earthquake-proof standard?"

Although the seismic hazard is uncertain, we can quantify that uncertainty to help guide decision-making. For example, according to the Delta Risk Management Strategy report published by the California Department of Water Resources in 2009, there is a one percent annual probability that ground shaking will exceed 0.15 g near the western edge of the Delta. This level of ground motion could induce liquefaction in Delta levees, thereby causing a breach.

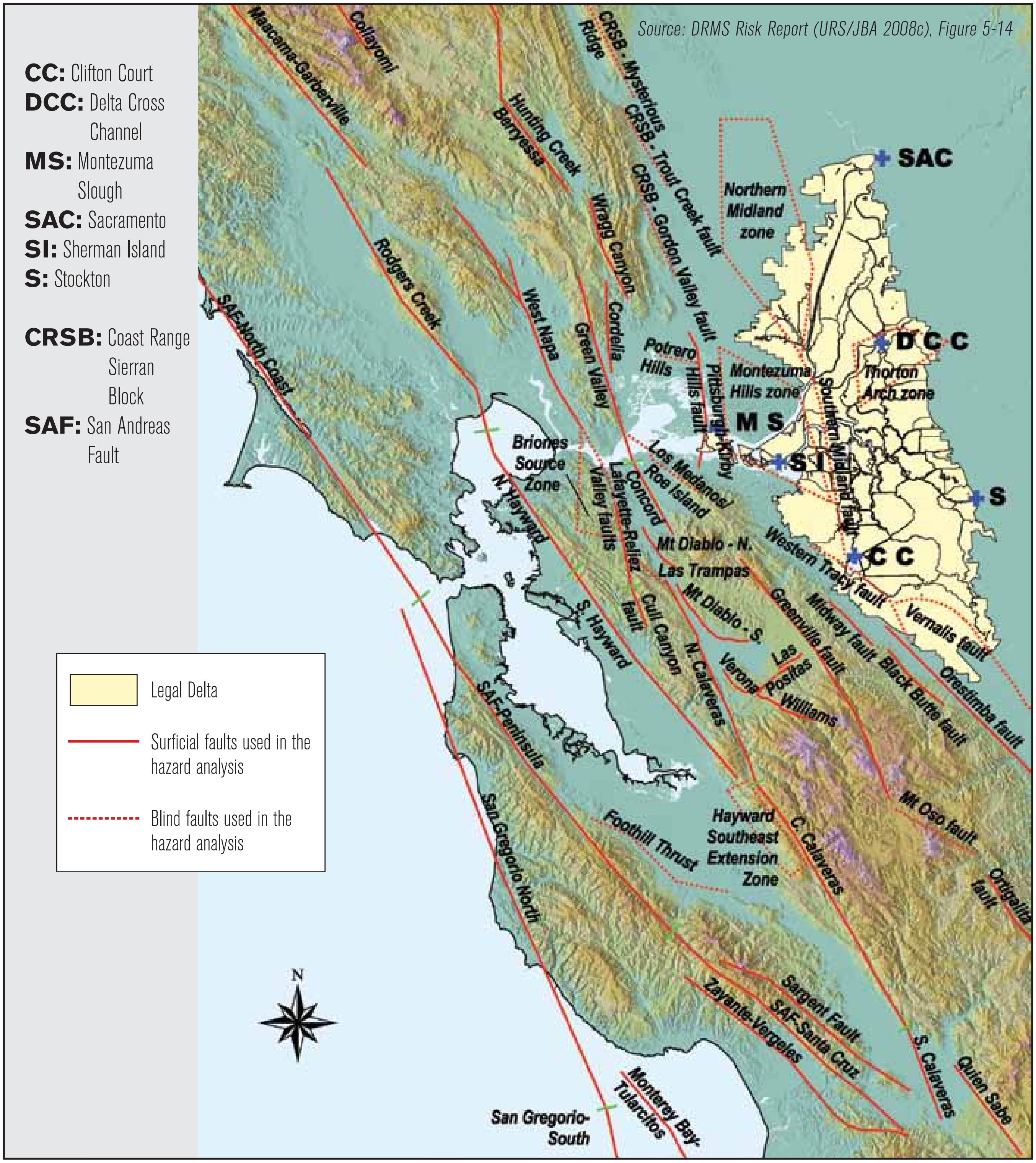
Not knowing when or where an earthquake will strike does not justify inaction.

During the past century, subsidence has lowered the land surface of some Delta islands as much as 25 feet below sea level, as shown in this figure. Land that is below sea level requires levees to hold back water 365 days a year.



Source: DRMS Risk Report (URS/JBA 2008c), Figure 5-14

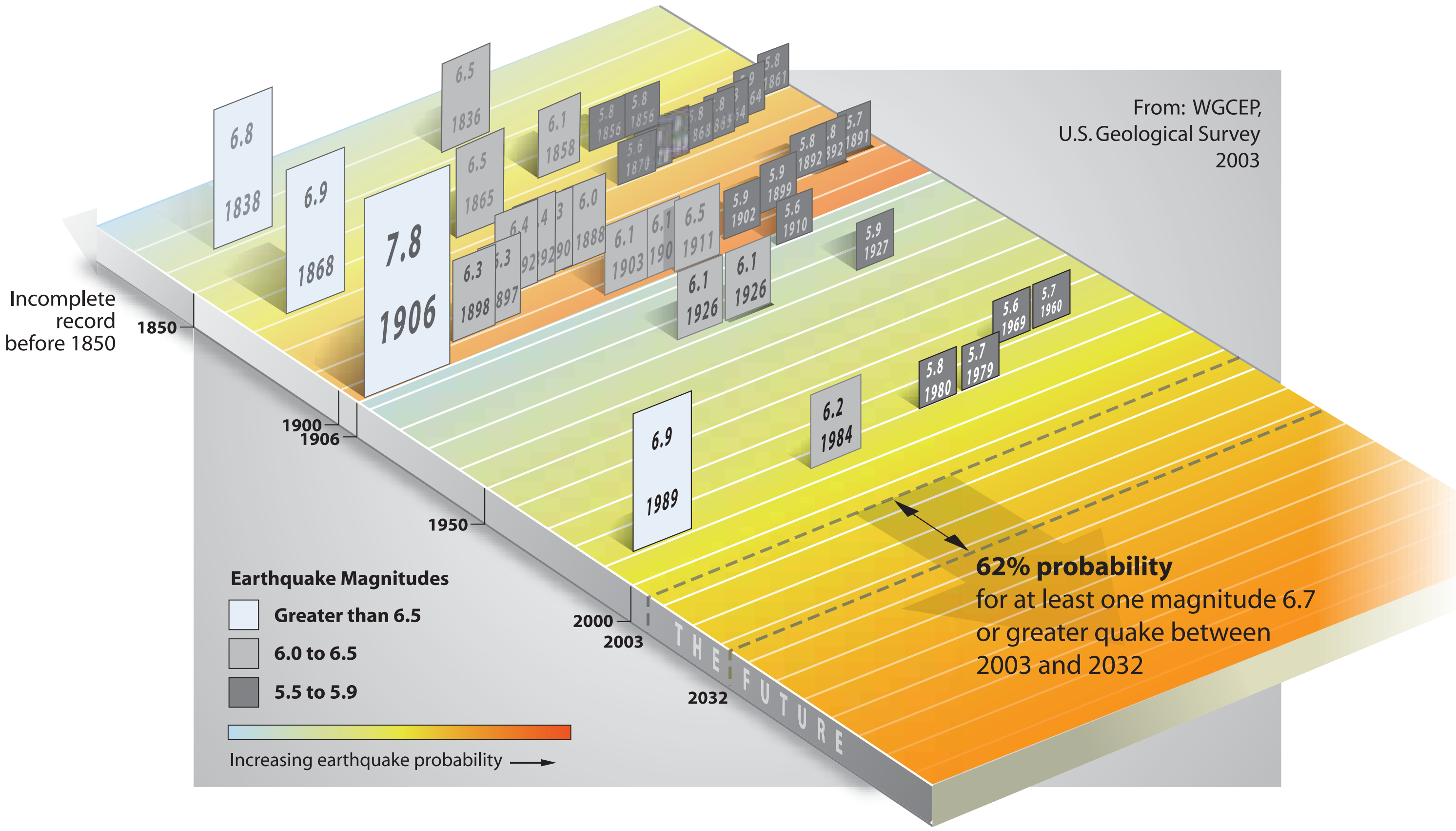
Faults and seismic sources in the vicinity of the Delta Region



Seismic risk in the Delta Region is characterized as moderate-to-high because of many active faults in the San Francisco Bay Area. This figure illustrates the locations of faults in and near the San Francisco Bay Area and the Delta Region.

Past and future earthquakes in the San Francisco Bay Area and the Delta Region

Source: DRMS Risk Report (URS/JBA 2008c), Figure 13-8



Seismic risk in the Delta Region is characterized as moderate-to-high because of many active faults in the San Francisco Bay Area. This figure shows that area seismic activity during the last 100 years is significantly less than what was experienced during the 1800s and the first part of the 1900s. Seismic experts predict increased seismic activity in the future similar to that which occurred up to the first part of the 1900s.

Cross-section of typical Delta levee

Source: DWR 2013