LAURIE JOHNSON CONSULTING

Urban Planning ● Risk Management ● Disaster Recovery

M_w8.8 Maule Earthquake
February 27, 2010

Photo: Laurie Johnson

Resources

- GeoEngineering Extreme Event Reconnaissance (GEER) investigation (www.geerassociation.org)

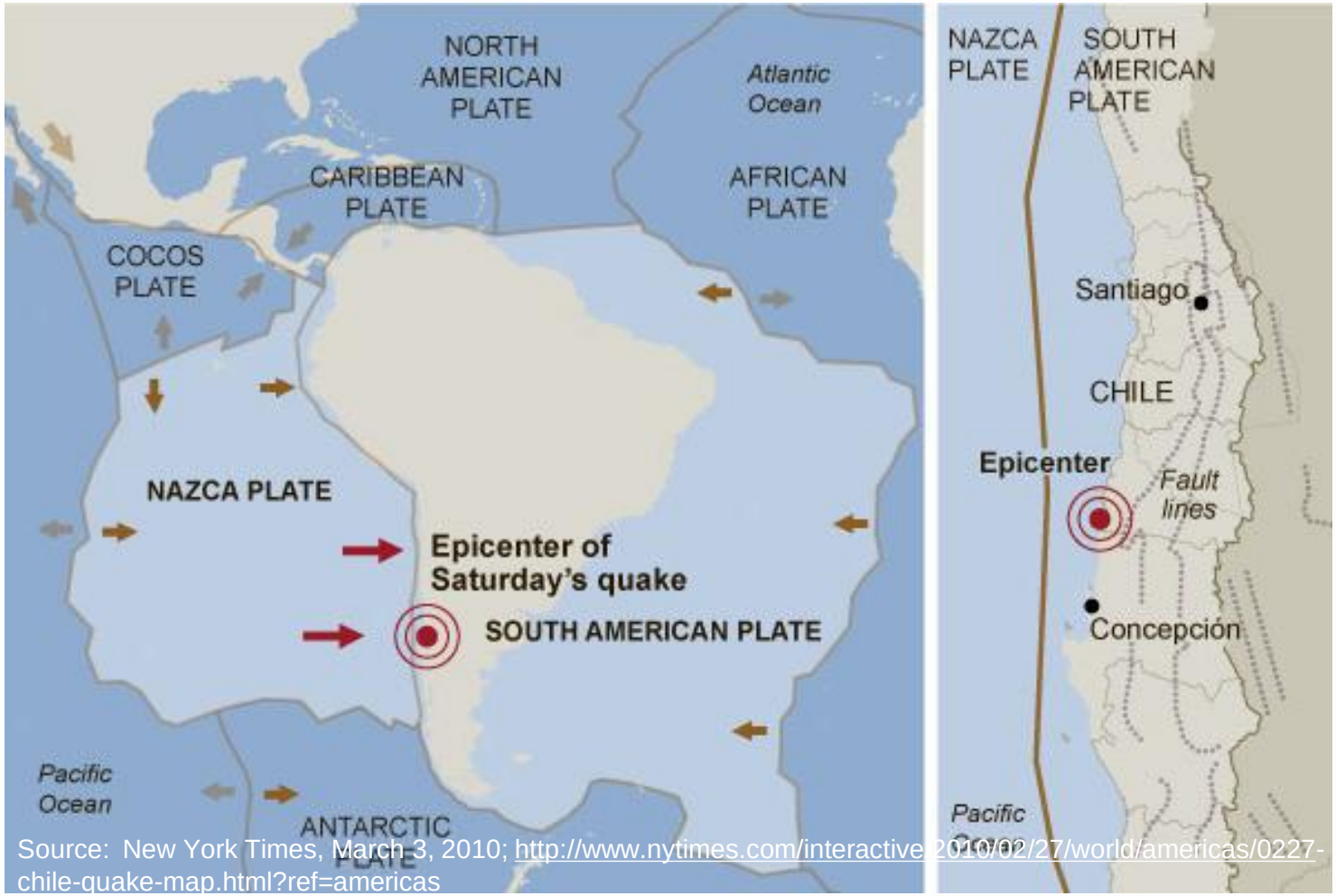
- Learning from Earthquakes reconnaissance and Earthquake Clearinghouse, Earthquake Engineering Research Institute (www.eeri.org)

- Pacific Earthquake Engineering Research Center reconnaissance reports (www.peer.berkely.edu)

- Technical Council on Lifeline Earthquake Engineering (TCLEE) (www.eeri.org)

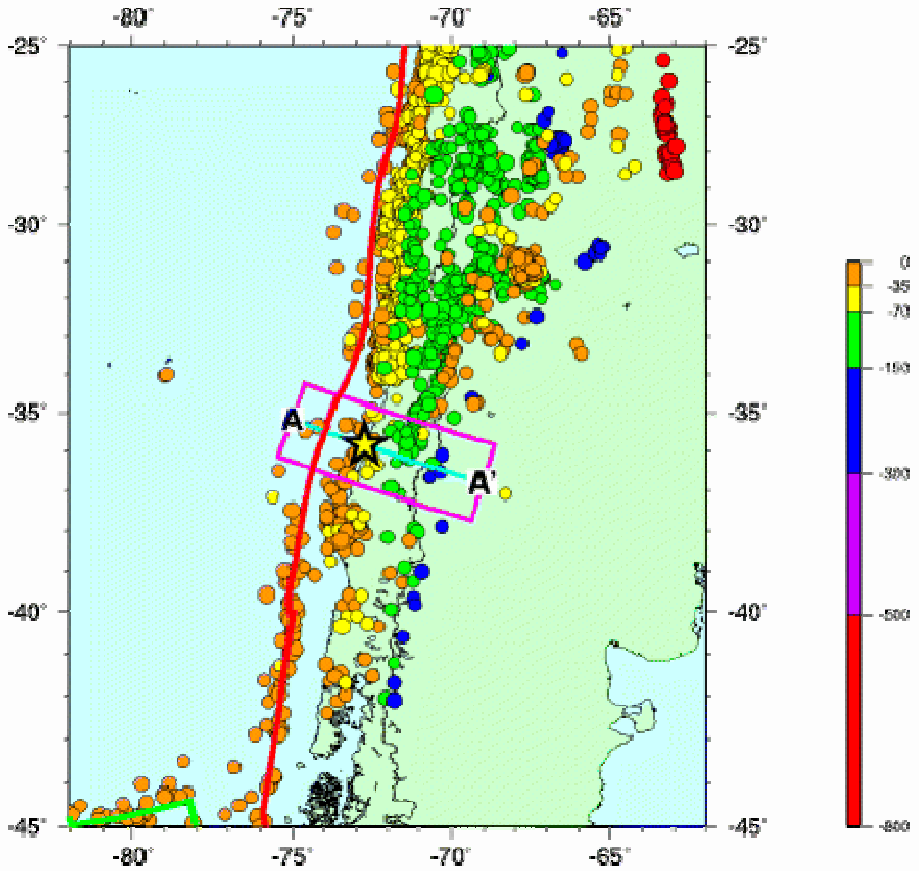
USGS National Earthquake Information Center (www.earthquake.usgs.gov/earthquakes/)

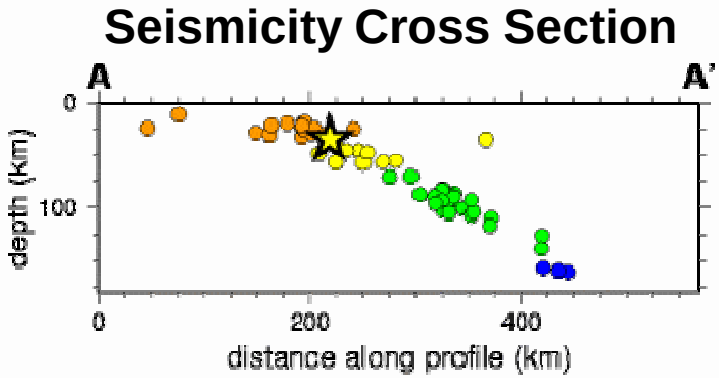
M_w8.8 earthquake struck at 3:34 am, Saturday, February 27



Source: New York Times, March 3, 2010; http://www.nytimes.com/interactive/2010/02/27/world/americas/0227-chile-quake-map.html?ref=americas

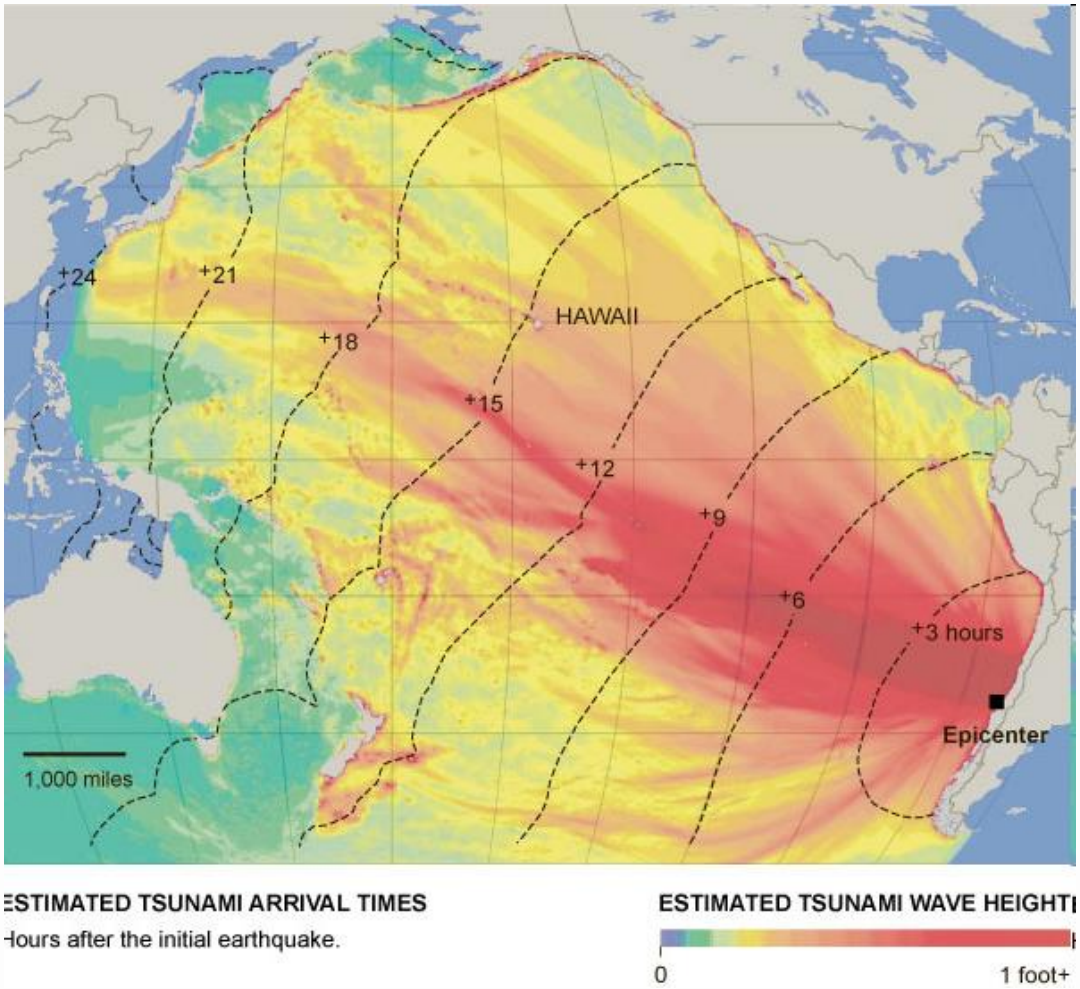
Over 458 Aftershocks (as of March 29), including several over M_w6.5





Source: http://neic.usgs.gov/neis/eq_depot/2010/eq_100227_tfan/neic_tfan_c.html).

Tsunami warning issued for entire Pacific; hit Chile < 30 minutes, heights up to 3 meters

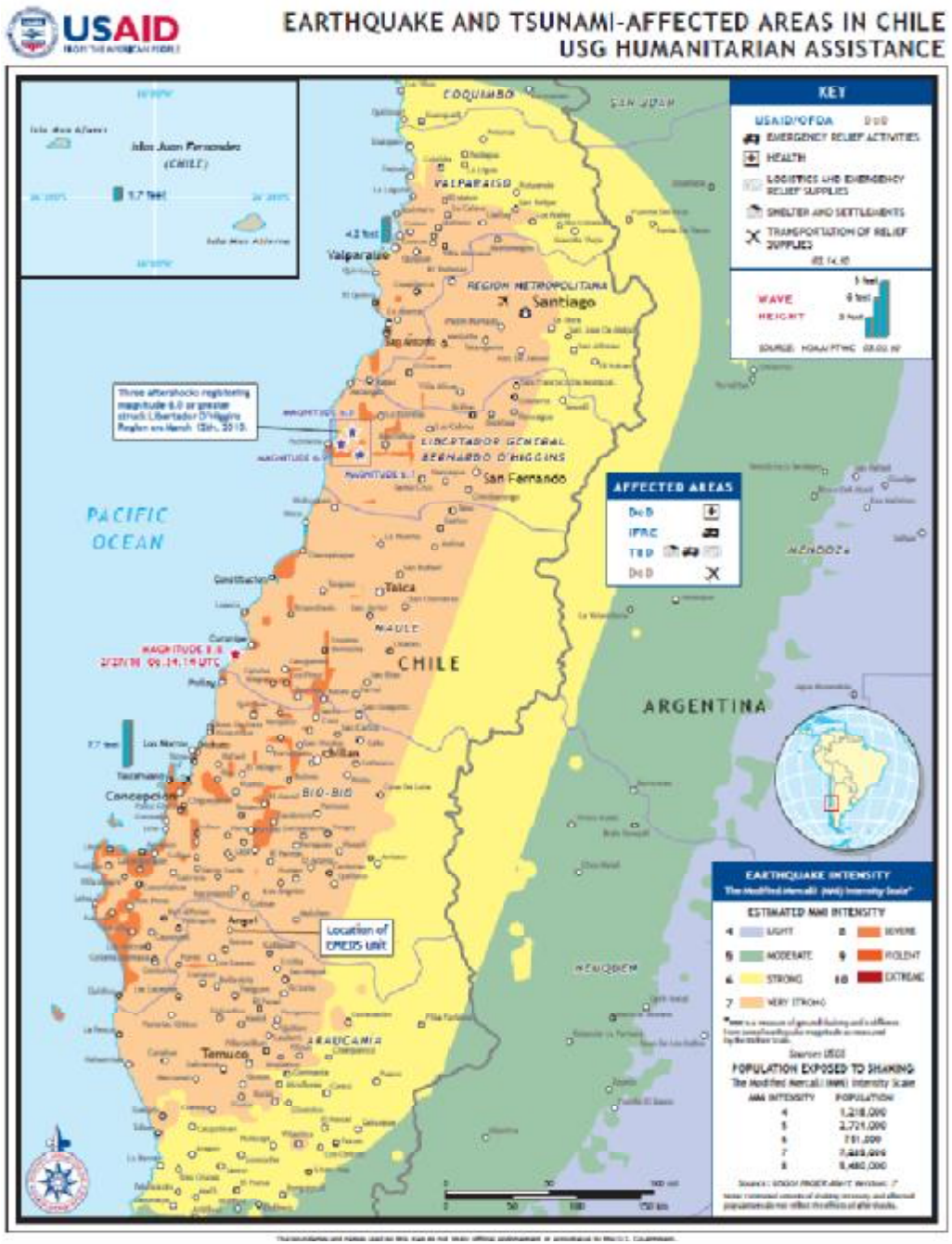


Source: New York Times, March 3, 2010; http://www.nytimes.com/interactive/2010/02/27/world/americas/0227-chile-quake-map.html?ref=americas

Chile – Country Overview

- National population: 16.76 million (2008)
- Upper middle income (globally), comparable with Argentina, Costa Rica, Czech Republic and Poland
- Major industries (impact region) – Fishing, shipping, mining, refineries, forestry, winemaking, agriculture Unemployment – 8.5%
- National debt – 4.1% of GDP
- GDP – US$146 billion (2006) (#40 globally)
- GDP per capita – US$8,865 (2006)
- People below poverty – 18%
- Literacy rate – 98%

Sources: CIA World Factbook, 2008; Government of Chile, 2010



- Strong shaking lasted over 90 seconds
- Shaking intensities VII or greater affected 12 million people
- "State of catastrophe" declared for 6 of Chile's 15 regions

Source: U.S. Agency for International Development, March 14, 2010, http://www.reliefweb.int

Maule Earthquake Impacts

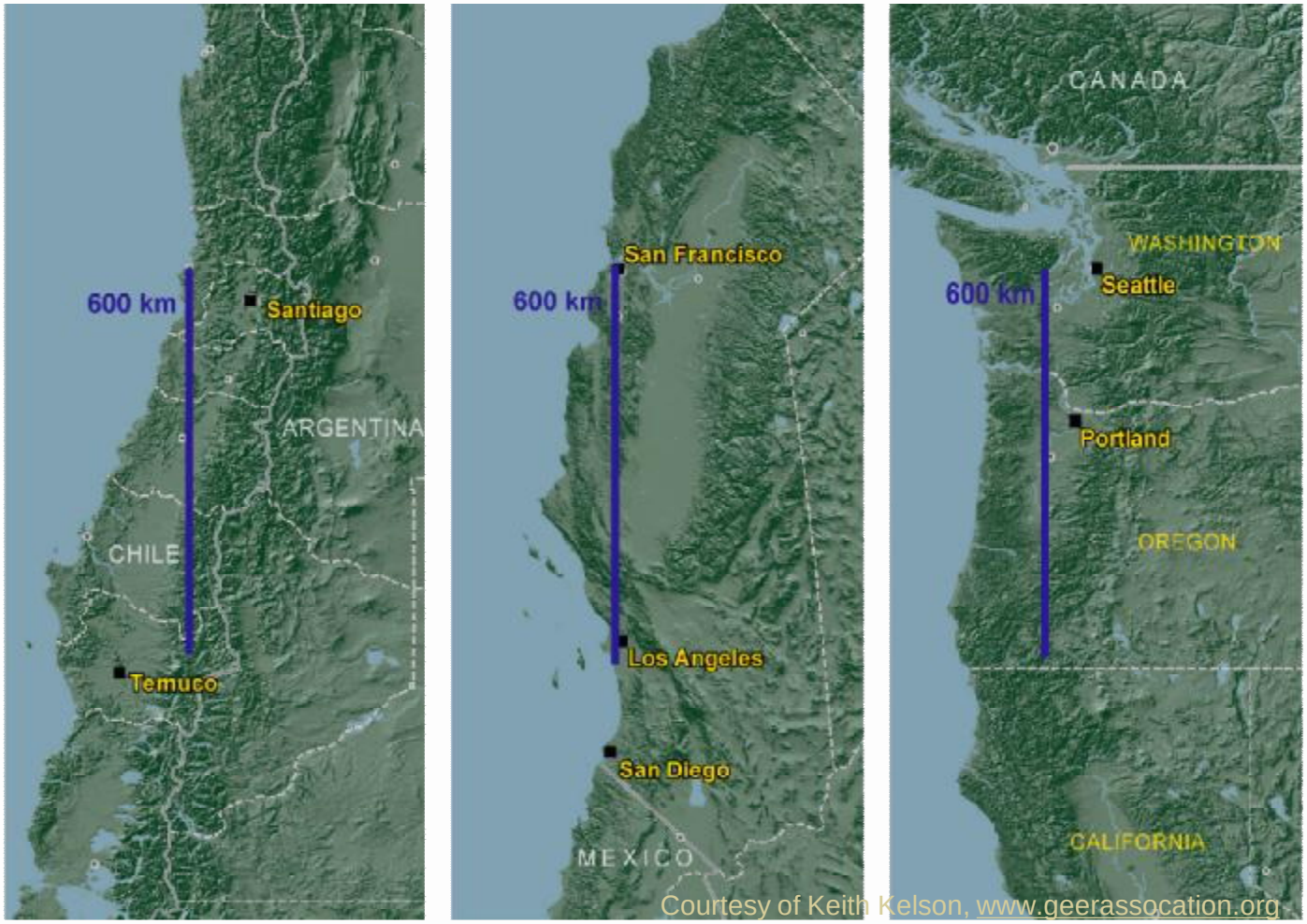
- 521 Deaths; 56 still missing
- 1.8 million people directly affected (1/8 Chiles total pop)
- At least 30 cities and towns badly damaged
  - Greater Concepcion (>890,000 pop) 2nd largest conurbation
- 81,000 housing units destroyed; additional 109,000 housing units sustained major damage
- Infrastructure and social service systems all sustained heavy damage, especially along coast and central valley
- Total economic losses: ~ US$30 billion
- Insured losses: ~ US$8 billion

Sources: Ministry of Interior May 2010; EQECAT 2010; RMS 2010

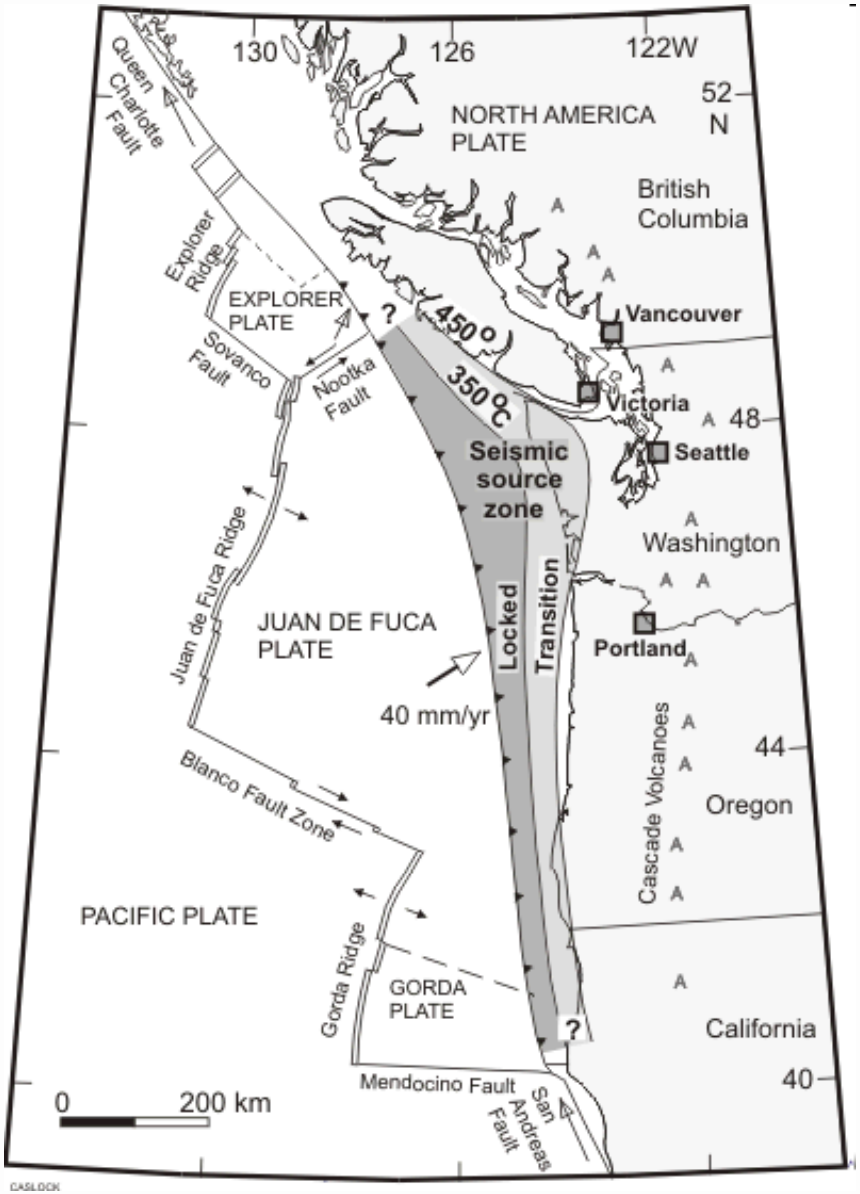
Earthquake and Tsunami Science Insights

Laurie Johnson PhD AICP

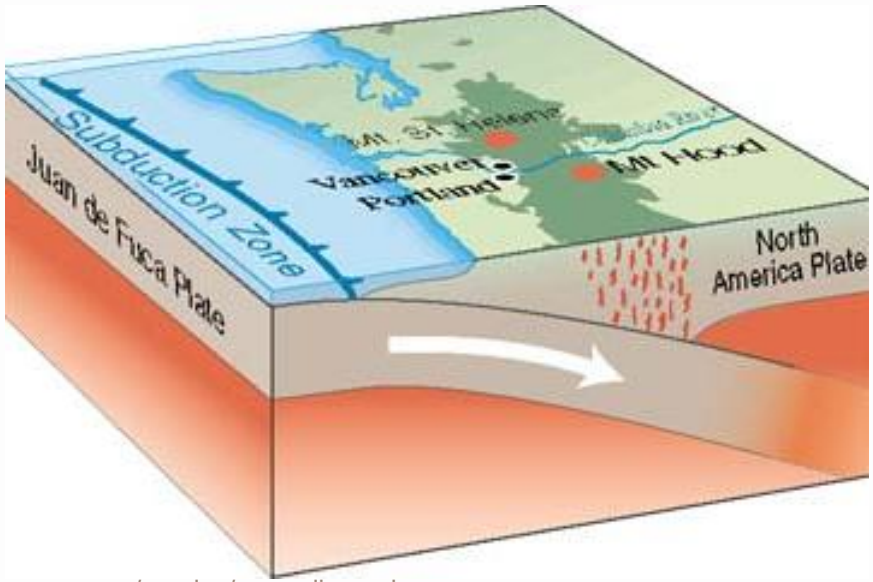
Comparable impact area along the U.S. West Coast



Courtesy of Keith Kelson, www.geerassocation.org



- Cascadia Subduction Zone
- 10% to 14% probability of M9 or higher in next 50 years
- Tsunami of up to 30 meters (100 feet)



Source: Natural Resources Canada and U.S Geological Survey; http://gsc.nrcan.gc.ca/geodyn/cascadia_e.php
http;//en.wikipedia.org/wiki/File:Cascadia_subduction_zone_USGS.png#filehistory

M7.2 Cape Mendocino Earthquake and Tsunami (1992)

- Main shock: M7.2, April 25, 1992, 11:06 am, near small town of Petrolia, Humboldt County, California
- 2 Aftershocks: M6.5 and M6.7, morning of April 26
- 25 km of uplift (1 meter max) along coast
- Tsunami (1 foot max height) recorded along West Coast and Hawaii; reached near-field coast (1 min), Humboldt Bay (20 min), and Crescent City (50 min)

Photos and sources: www.usgs.gov; wikipedia.org

2009 Warning of M8 to 8.5 earthquake centered in the Maule region of Chile

Interseismic strain accumulation measured by GPS in the seismic gap between Constitución and Concepción in Chile

J.C. Ruegg[a,*], A. Rudloff[b], C. Vigny[b], R. Madariaga[b], J.B. de Chabalier[a], J. Camp
E. Kausel[c], S. Barrientos[c], D. Dimitrov[d]

[a] Institut de Physique du Globe (IPGP), Paris, France
[b] Laboratoire de Géologie, Ecole Normale Supérieure (ENS), CNRS, Paris, France
[c] Departamento de Geofísica (DGF), Universidad de Chile, Santiago, Chile
[d] Bulgarian Academy of Sciences, Sofia, Bulgaria

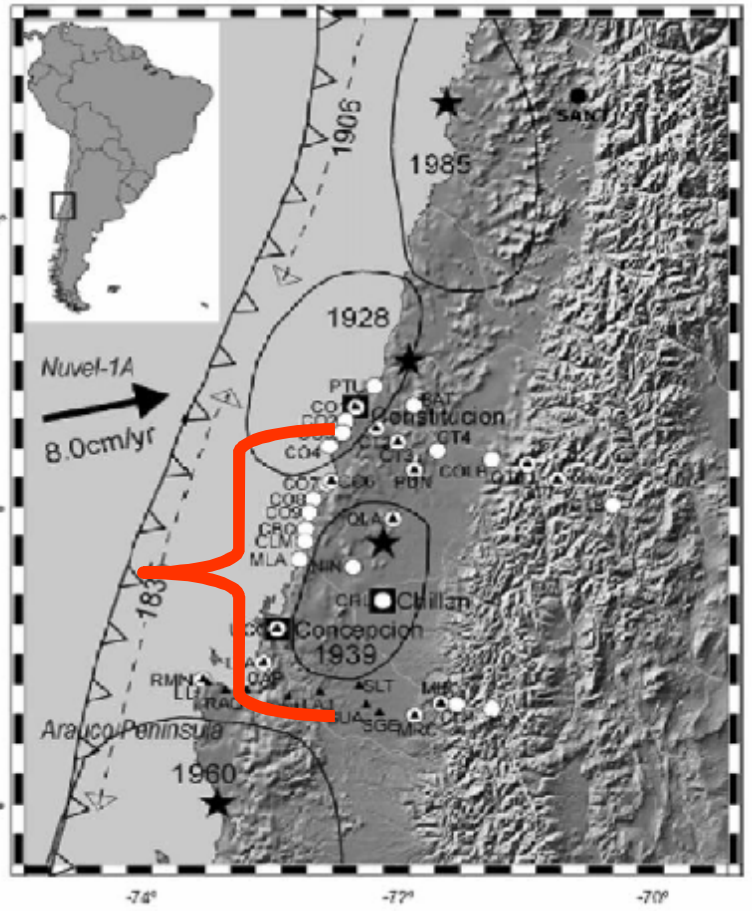
ARTICLE INFO

Article history:
Received 30 March 2007
Accepted 10 February 2008

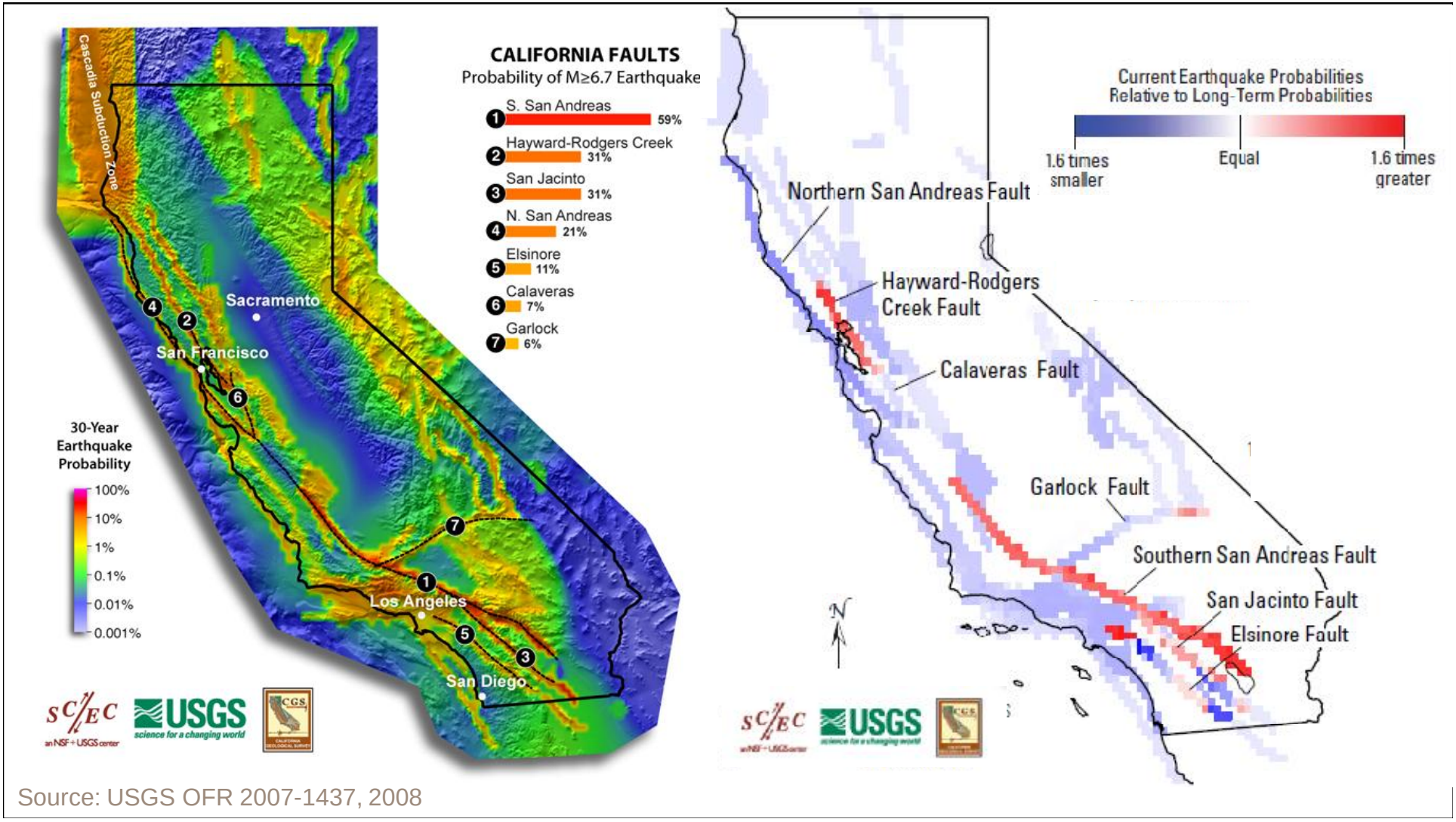
Keywords:
GPS
Tectonics
Seismic gap
Subduction
Coupling

ABSTRACT

The Concepción–Constitución area [35–37°S] in South Central C
since no large subduction earthquake has occurred there since
tioning system (GPS) measurements were carried out in this are
a network of about 40 sites, including two east–west transect
Argentina border and one north–south profile along the coast.
the Nazca/South America relative angular velocity (55.9°N, 95.2
(2008, this issue) which predicts a convergence of 68 mm/year c
36°S. With respect to stable South America, horizontal velocities
to 10 mm/year in the Cordillera. Vertical velocities exhibit a co
about 10 mm/year on the coast and slightly positive or near zer
Horizontal velocities have formal uncertainties in the range of 1–
3–6 mm/year. Surface deformation in this area of South Central
elastic loading on the subduction interface at depth. The best fit to
a locking depth of 55 ± 5 km and a dislocation corresponding to
the northern area of our network the fit is improved locally by
convergence motion of about 68 mm/year represents more than
the last big interplate subduction event in this area over 170 years
win). Therefore, in a worst case scenario, the area already has a p
as large as 8–8.5, should it happen in the near future.



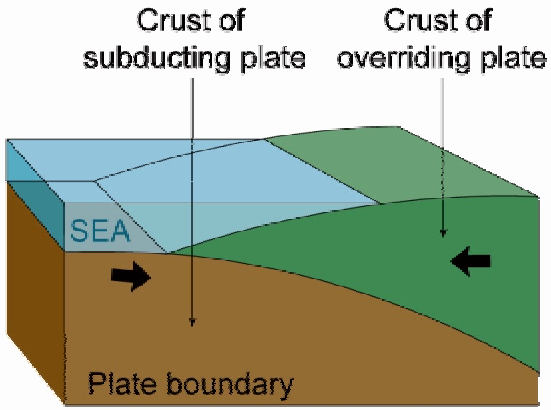
2007 Forecast: M6.7 California earthquake in next 30 years



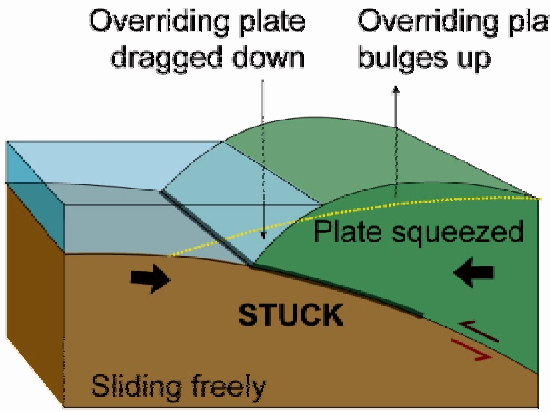
Source: USGS OFR 2007-1437, 2008

M7.2 Baja California (April 4, 2010)

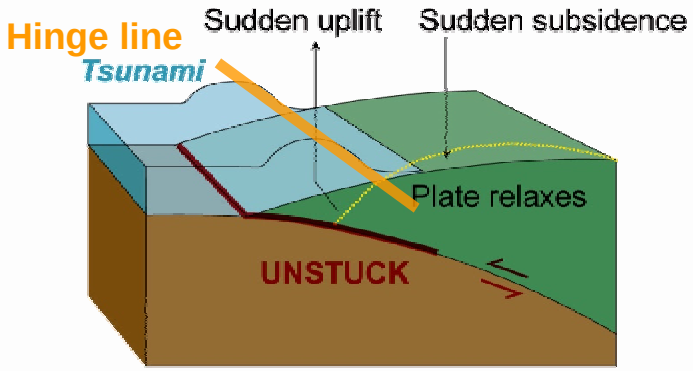
Relationship between earthquakes and tsunamis in a subduction zone



One tectonic plate descends, or "subducts," beneath an adjoining plate. But it does so in a stick-slip fashion.



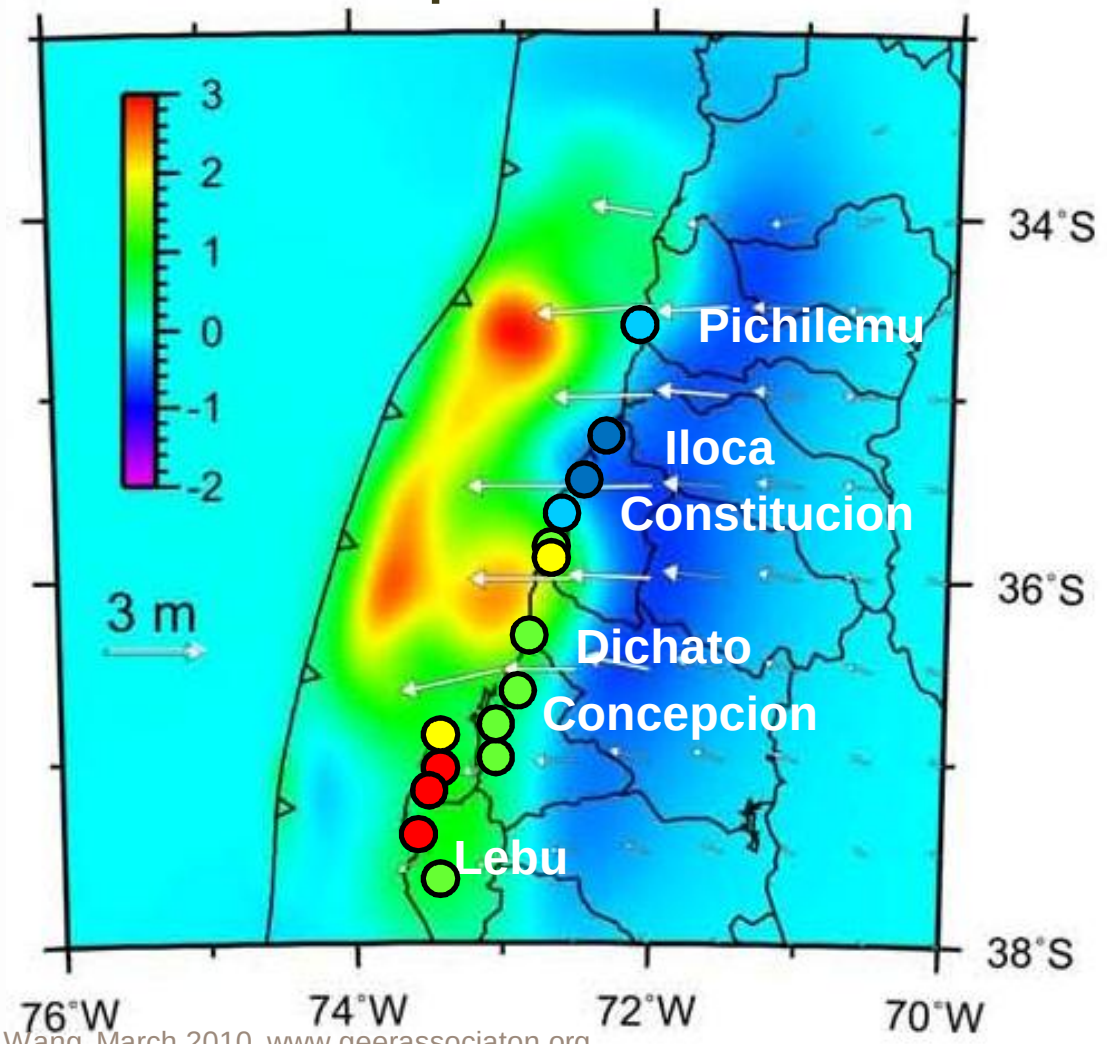
BETWEEN EARTHQUAKES plates slide freely at great depth, where hot and ductile. But at shallow depths, they stick together. Slowly squeezed, the overriding plate thickens.



DURING AN EARTHQUAKE the leading edge of the overriding plate breaks free, springing seaward and upward. Behind, the plate stretches; its surface fails. Vertical displacements set off a tsunami.

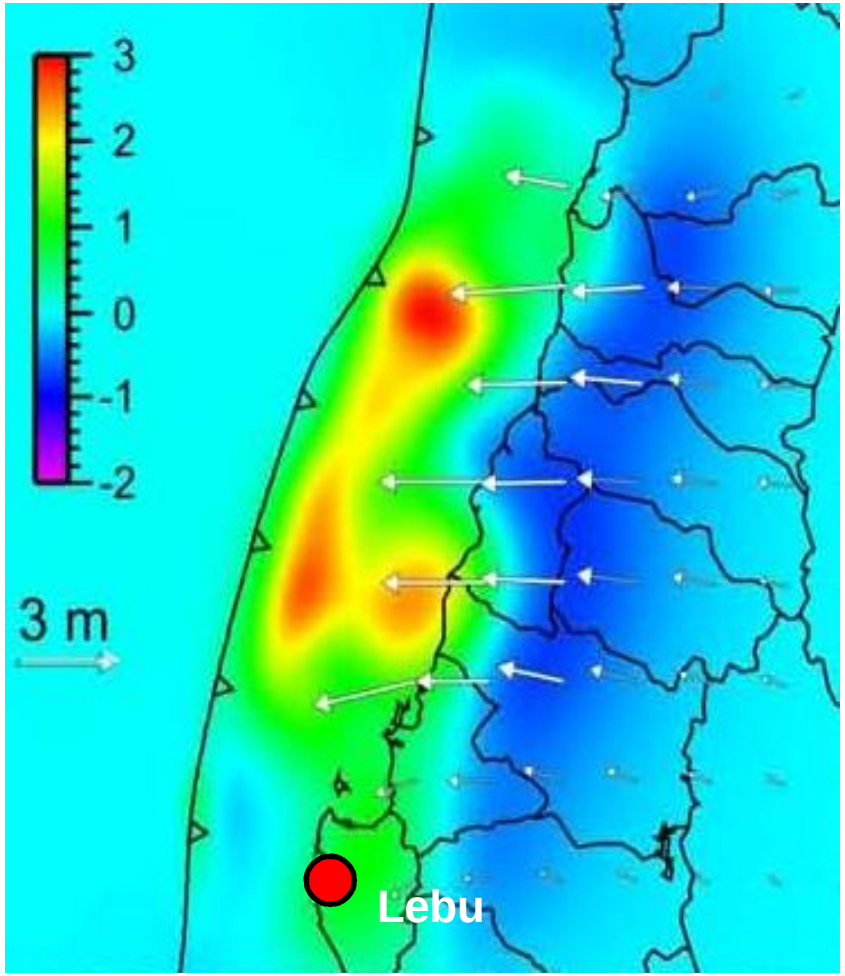
Courtesy of Keith Kelson, after Atwater et al. (2005), www.geerassociation.org

Resulting uplift and subsidence along coast; also, horizontal displacement



Source: Model from K. Wang, March 2010, www.geerassociaton.org

Tectonic uplift >2 meters in Lebu



Source: Model from K. Wang, March 2010, Photos courtesy K. Kelson, www.geerassocation.org

View of Concepcion from across Bio Bio River, Photos: Laurie Johnson

Engineering and Lifeline Insights

Laurie Johnson PhD AICP

Seismic provisions in Chile's building codes saved lives and met performance objectives

Structures built between 1985 and 2009

Buildings that Collapsed	4 (approx)
Buildings to be Demolished	50 (estimate)
Number of 3+ story buildings	9,974
Failures of 3+ story buildings	0.5%
Number of 9+ story buildings	1,939
Failures of 9+ story buildings	2.8%

Source: Jack Moehle, www.peer.berkeley.edu; Courtesy of R Lagos, Chile

Still, there were a few spectacular failures and questions of design, construction quality, and enforcement

Rio Alto apartment building, Concepcion; Photo courtesy of Jack Moehle, www.peer.berkely.edu

Some structures on soft or poorly compacted soils had extensive damage

- Included modern, engineered structures in Santiago, central valley, and along coast
- Areas with higher water tables and near waterways–rivers, lakes, lagoons, bays, and beaches, most susceptible

Ciudad Empresarial, NortheastSantiago;
Sources: Google Earth; Photos: GEER Reconnaissance, www.geerassociation.org

Significant nonstructural losses even when buildings undamaged

- Nonstructural systems very comparable to U.S. – nonstructural walls, ceiling tiles, M/E/P equipment and distribution systems
- Code-specified nonstructural protection not enforced

Hospitals in Talca

and Los Angeles; Photos courtesy of W. Holmes, www.eeri.org

Refineries: Aconcagua (west of Santiago) and Bio-Bio (near Concepcion)

- Both refineries initially shut down (e.g. loss of power, check critical elements, appraise possible damage); only minor, non-critical structural damage
- Aconcagua (98,000 bpd capacity) had only minor damage and restarted in 10 days
- Bio-Bio (130,000 bpd capacity) sustained relatively minor damage but with more substantial effects
- Damage from fallen heater refractory
- Ground failures damaged floating roof tank and steel crude oil pipeline
- Gasoline and diesel is being imported into the service area
- 3 to 7 months estimated to restore operating capacity

Source: Modified ASCE TCLEE Chile web report, May 2010; www.eeri.org; Photo: Laurie Johnson

Ports

- Ground displacements to quay walls, sheet pile walls, wharf structures and pile foundations

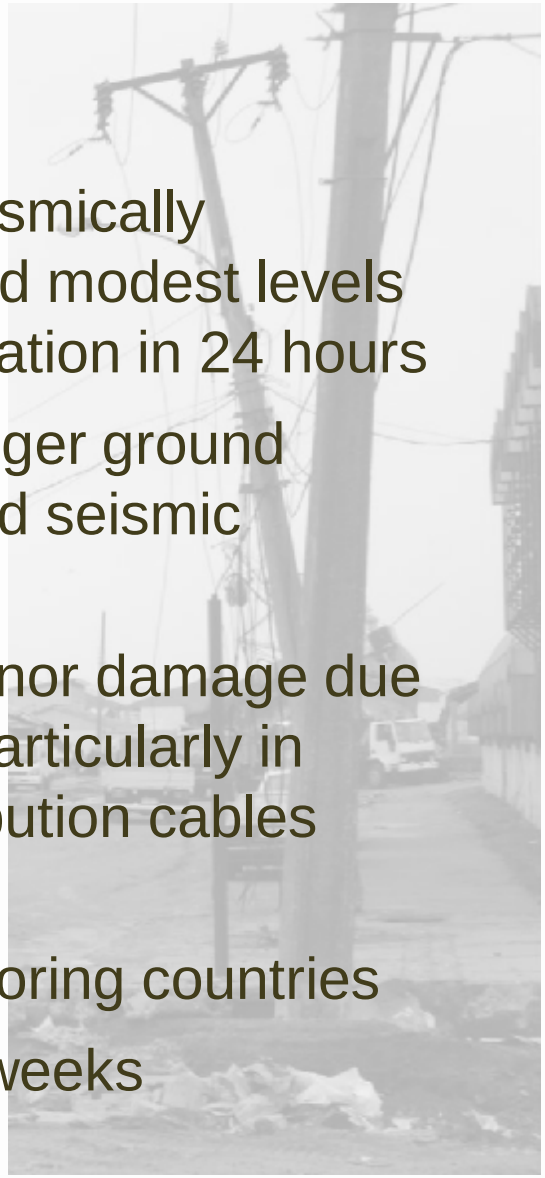
Commercial ports in Coronel and Valparaiso. Photos: GEER Reconnaissance, www.geerassociation.org

Road and bridge damage impacted response and regional transportation

- Critical issues of redundancy in central valley (Route 5) and Bio Bio River, Concepcion
- In Concepcion, only 1 of 3 bridges operational with a temporary crossing

Electrical transmission network performed reasonably well

- 220 kV and 500 kV transmission systems seismically upgraded in recent decades. Mostly sustained modest levels of ground motions (<0.25g). Ready for restoration in 24 hours
- Sub-transmission systems experienced stronger ground shaking (<0.45g) and sporadic damage. Good seismic anchoring of equipment and connections
- Low voltage distribution system sustained minor damage due to collapsed buildings and damaged poles, particularly in tsunami impacted areas. Underground distribution cables performed well.
- Mutual aid from other companies and neighboring countries
- Distribution system mostly restored within 2 weeks



Source: Modified ASCE TCLEE Chile web report, May 2010; www.eeri.org;
Photo: Talcahuano, by Laurie Johnson

Extensive setbacks to telecommunication performance and restoration

- Overhead lines heavily damaged in tsunami impacted areas. Some fiber optic cables severed along damaged bridges

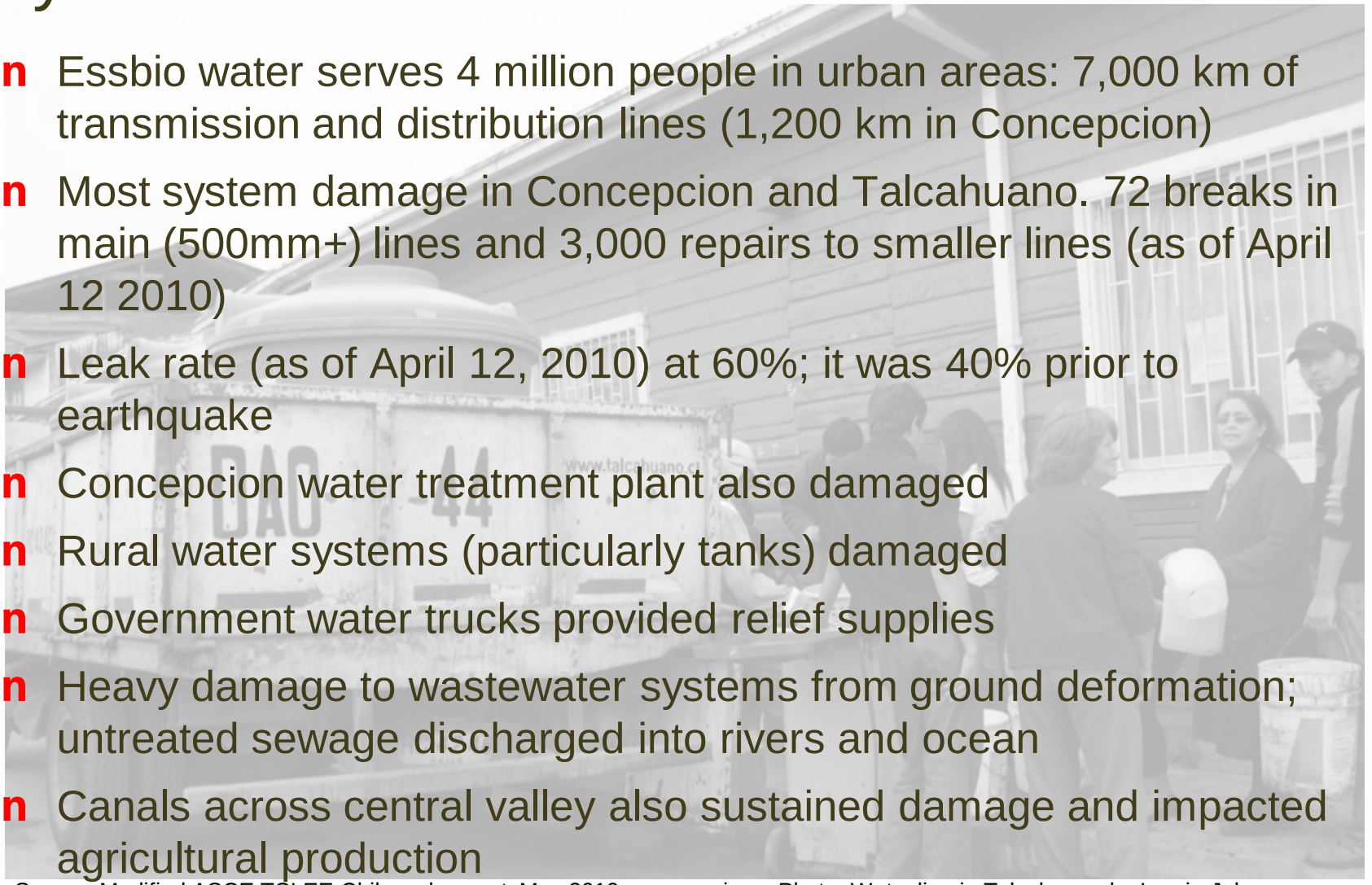
Source: Modified ASCE TCLEE Chile web report, May 2010; www.eeri.org; Photo: Telecom restoration in Pelluhue, Laurie Johnson

Extensive setbacks to telecommunication performance and restoration

- Overhead lines heavily damaged in tsunami impacted areas. Some fiber optic cables severed along damaged bridges
- Only critical offices (e.g. central offices, switching offices, and fiber backbone carrier offices) had backup power generators
- Majority of cell sites and remote offices had 3 to 4 hours and 8 hours of battery reserve power, respectively; ran out of power by late morning, Feb 27. Road and bridge damage limited access to these sites and ability to deploy portable generators
- Other disruptions caused by unanchored battery racks and shelves, fallen antennas, and tower installation collapses
- Both landline and wireless services restored in 7 days

Source: Modified ASCE TCLEE Chile web report, May 2010; www.eeri.org

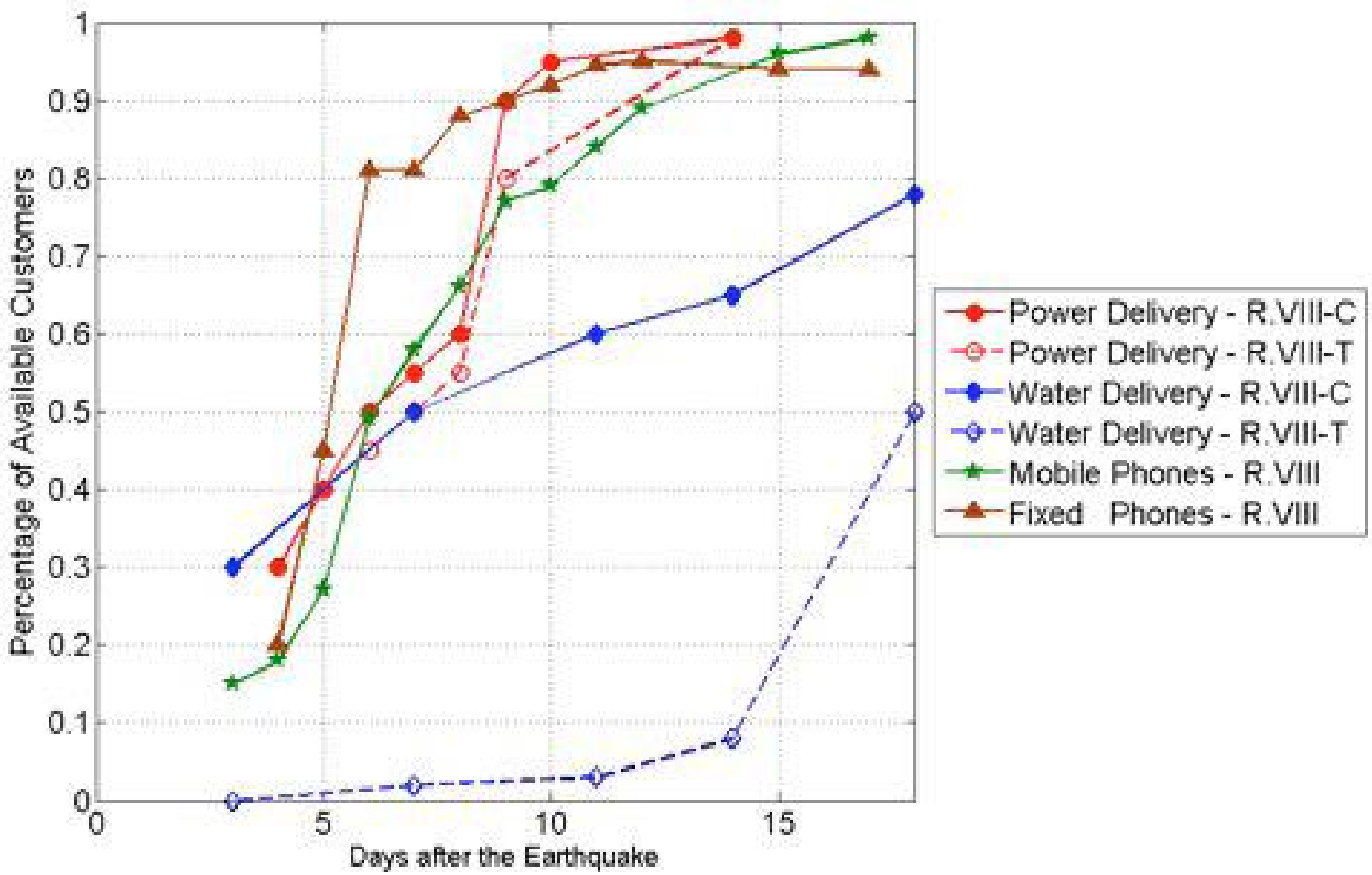
Heavy damage to water and wastewater systems in both cities and rural areas



- Essbio water serves 4 million people in urban areas: 7,000 km of transmission and distribution lines (1,200 km in Concepcion)
- Most system damage in Concepcion and Talcahuano. 72 breaks in main (500mm+) lines and 3,000 repairs to smaller lines (as of April 12 2010)
- Leak rate (as of April 12, 2010) at 60%; it was 40% prior to earthquake
- Concepcion water treatment plant also damaged
- Rural water systems (particularly tanks) damaged
- Government water trucks provided relief supplies
- Heavy damage to wastewater systems from ground deformation; untreated sewage discharged into rivers and ocean
- Canals across central valley also sustained damage and impacted agricultural production

Source: Modified ASCE TCLEE Chile web report, May 2010; www.eeri.org; Photo: Water line in Talcahuano by Laurie Johnson

Lifeline interdependencies increased loss of functionality and delayed restoration efforts



Source: Modified ASCE TCLEE Chile web report, May 2010; www.eeri.org

Socio-economic and Governance Insights

Laurie Johnson PhD AICP

Most casualties likely tsunami-related and tourists

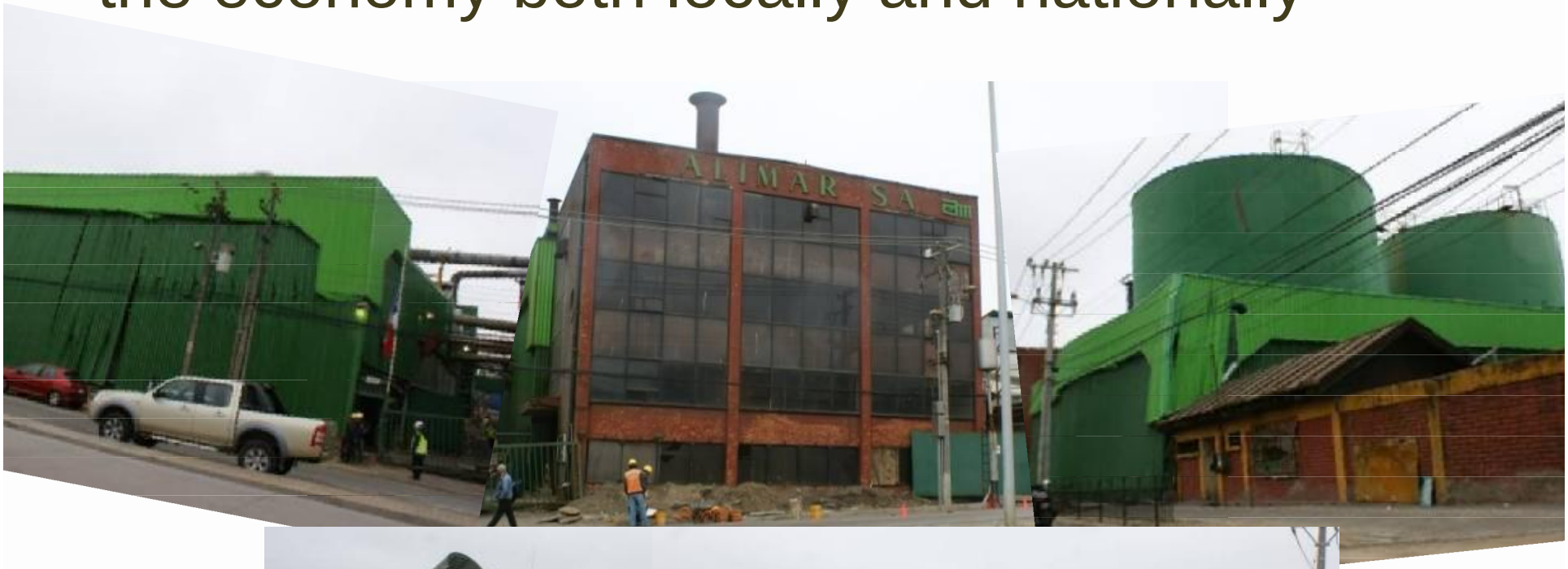
- Residents knew what to do and ran to hills
- Tsunami response plans and warning systems were inadequate, with incorrect signals and poor communications

Tsunami evacuation sign, Curanipe, and hillside path escape route, Pelluhue; Photos: Laurie Johnson

Long-term ripple effects in specific sectors

Port San Vicente, Talcahuano; Photo: Laurie Johnson

Fish processing plant closures are impacting the economy both locally and nationally



Port San Vicente, Talcahuano; Photos: Laurie Johnson

Additional post-disaster losses caused by looting and fires

- Looting and civil unrest erupted throughout the central region, even in areas with relatively little damage
- Recovery has stalled in some places as residents want to stay safely away

Concepcion city center and Talcahuano port area; Photos: Laurie Johnson

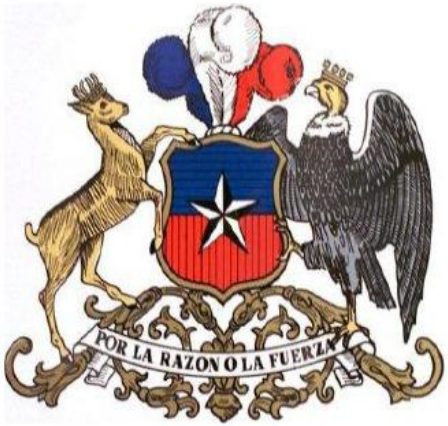
Key Insights

- Can we make better use of rupture forecasts issued in advance (e.g. Haiti, Chile, and the West Coast)?
- There will be lessons that translated into both modeling changes and code changes
- Many insights for risk management now, particularly in reducing risk of nonstructural and business interruption losses, warning and evacuation planning, and multi-level coordination

State of California

Republic of Chile

JOINT DECLARATION



State of California

Republic of Chile

JOINT DECLARATION BETWEEN THE STATE OF CALIFORNIA, UNITED STATES OF AMERICA, AND THE GOVERNMENT OF THE REPUBLIC OF CHILE ON COOPERATION IN EMERGENCY AND DISASTERS

THANK YOU!

laurie@lauriejohnsonconsulting.com