Assessment of Tsunami Risk and Exposure to California's Coastal Communities

using FEMA's Hazus Tsunami Model and ESRI Demographic Data

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FEMA

California Tsunami Program

The **California Tsunami Program** has completed a **statewide tsunami risk assesment** of **20 coastal counties**. Statewide **building loss** estimates are greater than **$12 billion***.

ENTERING TSUNAMI HAZARD ZONE

The **California Tsunami Program** is a collaboration between the California Governor's Office of Emergency Services and the California Geological Survey. We partner with the National Weather Service and other agencies to lead the State's efforts to assess tsunami hazard and risk throughout California's coastal communities.

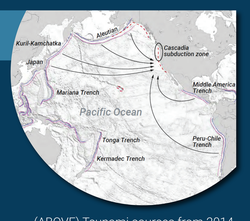
Our Program uses FEMA's Hazus Tsunami Model and demographic data to develop tsunami risk and exposure summary reports for support of tsunami preparedness, mitigation, and response planning activities statewide and at the county level. Our mission is to make California more tsunami resilient by creating tsunami hazard and risk maps, guidance, and educational material for the general public and local officials.

FEMA Hazus Tsunami Model is a Valuable Decision-Support Tool

TSUNAMI HAZUS RISK

FEMA's Hazus Version 6.0 Tsunami Model is a valuable decision-support tool for use in disaster risk management. It provides lead agencies and decision-makers a way to estimate potential casualties, structural losses, and economic impacts from tsunami hazards. In addition to tsunami, Hazus models impacts for earthquakes, hurricanes, and flooding (coastal and riverine).

The FEMA Hazus building inventory database leverages the U.S. Army Corps of Engineers National Structure Inventory 2022 (NSI). The NSI is enhanced with attributes from parcel data, HIFLD critical infrastructure, and other local data sources for use in the Hazus model.



Hazus Data and Methods

Hazus study regions were created for each county and aggregated with the building inventory and population data from FEMA. Hazard data is from California's 975-year average return period probabilistic tsunami hazard analyses (PTHA).

Building related damages were estimated using Hazus damage functions and tsunami hazard input parameters of median momentum flux and median depth. Resulting loss estimates include costs for repair and replacement of damaged buildings and costs associated with loss of function.

Casualties were estimated using input parameters for first wave arrival and time of tsunami warning and Hazus integrated methods based on the USGS Pedestrian Evacuation Analyst Tool, which evaluates evacuation travel times using only roads as travel pathways for each Census block. Disaggregated maximum contributing tsunami events from the PTHA data were used to determine travel times for the first wave arrival input parameter. Parameters used to model the variation in a population evacuation departure response to a tsunami warning were modified for three different evacuation departure delay times.

Hazus Evacuation Input Parameters

		Evacuation Departure Delay Time (minutes)		
	Dominant Source	**Good**	**Fair**	**Poor**
Near Source[1]	CSZ	2.5	5	10
Distant Source[2]	Alaska Aleutians	5	15	30

[1]Assumes time of earthquake is time of warning (natural warning).
[2]Assumes 60 minutes after earthquake before evacuation warning (official warning) is provided to community (e.g. WEA).

(LEFT) Evacuation Parameters: Table showing parameters used for input to the Hazus Tsunami Model for estimates of pedestrian evacuation for population exposed to tsunami flood.

The Hazus Tsunami Model does not include estimates for damage and losses for structures associated with ports, harbors, or other maritime related facilities; damage to infrastructure, roads, or essential facilities; and estimated quantities of debris.

(ABOVE) Tsunami sources from 2014 science and/or knowledge. Cascadia source characterization in line with National Seismic Hazard Mapping sources.

Disclaimer: This information is prepared to assist cities, counties, and tribal areas understand their risk and exposure to tsunami hazards. These data are intended for local jurisdictional, coastal assessment uses only; they are not legal documents and do not meet disclosure requirements for real estate transactions nor for any other land-use or regulatory purpose.

Custom Risk Reports and Visualizations

The **California Tsunami Program** has developed **customized reports and visualizations**, for **State**, **County**, and other **lead agencies** to support **science-based emergency management decision-making strategies** for **tsunami planning** and **response**.

The tsunami hazard exposure and loss results produced from these assessments are a first-of its-kind for California and provide consistent population exposure and loss estimates using the best-available methods and data.

(ABOVE) Design concept of an online dashboard created using the Esri Platform. The dashboard will be used to summarize and display Hazus Tsunami Model results for each of the 20 coastal counties.

DEMOGRAPHIC POPULATION PROFILES

ESRI forecasts for 2023, 2028, 2017-2021, 2023.

POPULATION AND BUSINESSES

Daytime Population: 684,098
Total Employees: 462,018

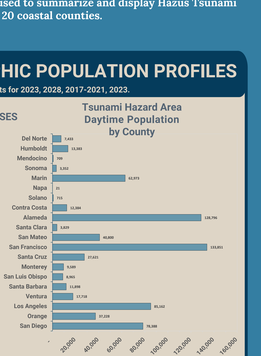
AT RISK POPULATION

Households With Disability: 27,904
Pop. 65+: 77,507

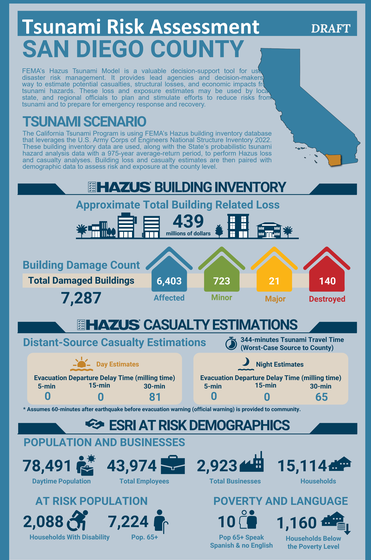
POVERTY AND LANGUAGE

Households Below Poverty Level: 14,298
Pop. 65+ Speak Spanish & No English: 366

Tsunami Hazard Area Daytime Population by County



We used Esri's Advanced Demographic At-Risk Population Profile data to provide detailed datasets for each coastal county's Tsunami Risk Assessment infographic. The advanced demograhic data includes more up-to-date data and metrics than what is available through standard demographics, such as Census data. Above we show a statewide demographic profile of those exposed to tsunami hazards within the state's Tsunami Hazard Area extent for Evacuation Planning.



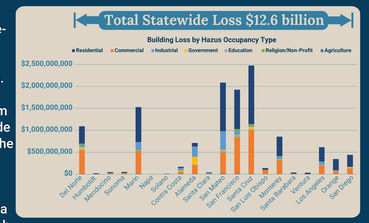
(ABOVE) An example Tsunami Risk Assessment infographic that summarizes Hazus building losses, casualty estimates, and at-risk demographic information. These 1-page summary sheets will be developed for all 20 coastal counties in California using results from this project. Feedback on content and layout from coastal partners will help us tailor custom infographic summaries that can be used for tsunami mitigation and response planning.

*Hazus Building Loss and Casualty Estimates

Hazus Tsunami Model results were exported using the open source Hazus Export Tool and Microsoft SQL Server Management Studio. Data were summarized and used to create custom reports. Demographic information of the population exposed to tsunami hazard were summarized from Esri data.

The Hazus Tsunami exposure and loss results produced from these analyses are a first-of its-kind for California and provide consistent population exposure and loss estimates at both the local and State-level using the best available methods and data.

The Hazus Tsunami results are paired with demographic data from Esri to create summary reports and dashboards for each California County. These reports support planning and response at both the local and State-level by providing a snapshot of the population and potential building related losses due to tsunami in California.



(ABOVE) Building Losses by Hazus Occupancy Type: Graphic showing the building related losses in dollars for structures according to the General Occupancy type as defined in the Hazus Tsunami Model and the NSI database.

(BELOW) Building Damage Counts: The Hazus Tsunami Model provides estimates of building damage counts for the number of buildings whose damages in dollars are classified as Affected, Minor, Major, or Destroyed.

Affected: less than 5% of value
Minor: 5%-30% of value
Major: 30%-50% of value
Destroyed: more than 50% of value

Value is derived from the structural and non-structural elements of a building and do not include land value.

These damage classifications can also be related to tagging nomenclature (red, yellow, green) used in post-disaster inspection of buildings.

Total Building Damage Counts

County	Affected (Green Tag)	Minor (Green Tag)	Major (Yellow Tag)	Destroyed (Red Tag)
Del Norte	460	247	94	654
Humboldt	359	9	6	42
Mendocino	30	29	3	11
Sonoma	76	77	74	20
Marin	6,937	2,366	271	397
Napa	116	0	0	0
Solano	68	18	1	2
Contra Costa	1,711	78	7	8
Alameda	5,286	189	5	17
Santa Clara	545	6	0	0
San Mateo	13,837	656	207	1,415
San Francisco	5,318	1,218	73	714
Santa Cruz	1,076	923	159	1,800
Monterey	234	92	7	12
San Luis Obispo	987	763	220	500
Santa Barabara	549	153	0	31
Ventura	2,202	111	0	55
Los Angeles	7,348	996	9	34
Orange	9,134	701	7	405
San Diego	6,403	723	21	140
Total	**62,676**	**9,352**	**1,107**	**6,257**

Total Residential Building Damage Counts

County	Affected (Green Tag)	Minor (Green Tag)	Major (Yellow Tag)	Destroyed (Red Tag)
Del Norte	377	166	2	542
Humboldt	240	9	3	42
Mendocino	7	16	1	8
Sonoma	56	57	1	19
Marin	5,266	1,822	38	371
Napa	103	0	0	0
Solano	56	16	0	0
Contra Costa	1,211	33	2	4
Alameda	3,015	76	1	11
Santa Clara	341	3	0	0
San Mateo	12,001	549	36	1,199
San Francisco	4,083	954	1	668
Santa Cruz	878	726	23	1,545
Monterey	95	16	0	9
San Luis Obispo	816	655	33	436
Santa Barabara	473	151	0	28
Ventura	2,116	109	0	55
Los Angeles	6,394	875	1	28
Orange	8,296	609	0	404
San Diego	5,625	661	0	170
Total	**51,446**	**7,503**	**142**	**5,487**

Distant Source Tsunami Casualty Estimations

County	Evacuation Departure Delay Time (minutes)	5	15	30	5	15	30
	Tsunami Travel Time (minutes)	Daytime Casualty Estimates			Nighttime Casualty Estimates		
Mendocino		249	0	0	5	0	0	1
Sonoma - Outer Coast		255	0	0	0	0	0	2
Sonoma - Inner Coast		399	0	0	0	0	0	0
Marin - Outer Coast		271	0	0	10	0	0	8
Marin - Inner Coast		301	0	0	228	0	0	159
Napa[1]		404	—	—	—	—	—	—
Solano		379	0	0	0	0	0	0
Contra Costa		321	0	0	33	0	0	16
Alameda		325	0	0	188	0	0	87
Santa Clara[1]		417	—	—	—	—	—	—
San Mateo - Outer Coast		291	0	0	50	0	0	55
San Mateo - Inner Coast		335	0	0	246	0	0	139
San Francisco - Outer Coast		287	0	0	24	0	0	35
San Francisco - Inner Coast		300	0	0	472	0	0	103
Santa Cruz		276	0	0	131	0	0	95
Monterey		277	0	0	16	0	0	5
San Luis Obispo		285	0	0	29	0	0	66
Santa Barbara		305	0	0	7	0	0	5
Ventura		330	0	0	13	0	0	18
Los Angeles		322	0	0	197	0	0	117
Orange		351	0	0	60	0	0	69
San Diego		344	0	0	81	0	0	65
	Casualty Totals		0	0	1,845	0	0	1,045

[1] Assumes 60 minutes after earthquake before evacuation warning (official warning) is provided to community (e.g. WEA).
* Limited exposure of structures in the tsunami hazard area. Insufficient data for casualty analysis.

Local Source Tsunami Casualty Estimations

County	Evacuation Departure Delay Time (minutes)	2.5	5	10	2.5	5	10
	Tsunami Travel Time (minutes)	Daytime Casualty Estimates			Nighttime Casualty Estimates		
Del Norte		10	1,648	2,222	3,157	1,153	1,521	2,441
Humboldt		10	360	504	724	400	468	540
	Casualty Totals		2,008	2,726	3,881	1,553	1,989	2,981

* Assumes time of earthquake is time of warning (natural warning)

(ABOVE RIGHT) Distant and Local Source Tsunami Casualty Results: Tables summarize casualty estimates from the Hazus Tsunami Model for California counties. Casualties are the sum of projected injuries and fatalities resulting from the population (based on 2020 census data) exposed to the tsunami flood. The Hazus Tsunami Model estimates a 99% fatality rate and 1% injury rate for the population exposed to tsunami flood depths of 2 meters or greater and a 50% fatality rate and 50% injury rate for tsunami flood depths less than 2 meters.

Looking to the Horizon and Beyond

California will continue to update the tsunami loss estimates when Hazus software and data are updated and as California updates tsunami hazard data.

California Geological Survey is leading efforts to begin the development of methods for estimating tsunami damage and losses to maritime related structures and assets that could be incorporated into the Hazus Tsunami Model.

California is evaluating methods for improving casualty estimates by refining evacuation route pathways, including temporary populations, and evaluating evacuation travel times from individual structures.

Acknowledgments

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