gis based relative tsunami hazard maps for northern california, humboldt and del norte counties

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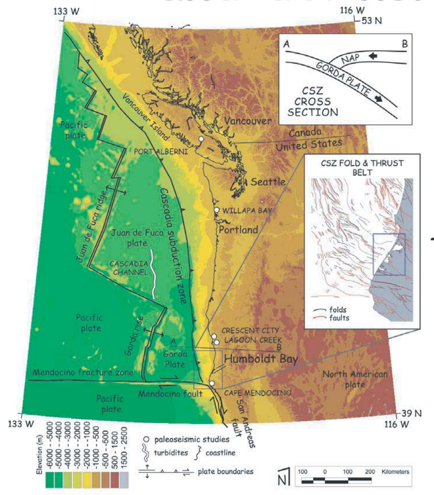


Humboldt Bay

1964 tsunamigenic car melange, Crescent City, Del Norte County, California.

Tsunami hazard maps are generated using a geographical information systems (GIS) approach to depict the relative tsunami hazard of coastal Humboldt and Del Norte Counties in northern California. Maps are composed for the Humboldt Bay, Eel River, and Crescent City regions and are available online at http://www.humboldt.edu/~geodept/earthquakes/rctwg/toc.html . In contrast to previous mapping efforts that utilize a single line to represent inundation, hazard is displayed gradationally. A 2.5D surface is constructed to represent this hazard. Elevation, normally used for 2.5D surfaces, is substituted with hazard units. Criteria boundaries are used to separate regions of increasing hazard. Criteria boundaries are defined based on numerical modeling, paleoseismic studies, historical flooding, FEMA Q3 flood maps, and impacts of recent tsunamis elsewhere. Zones are constructed to further adjust the criteria with respect to a physically determined variable hazard (e.g. proximity to open ocean). A triangular irregular network (TIN) is constructed using hazard criteria boundaries as breaklines. Fabricated points are necessary to construct a hazard surface and are placed where criteria boundaries diverge or where hazard is nonlinear between criteria boundaries. Hazard is displayed as a continuous gradational color scale ranging from red (high hazard) through orange (medium), yellow (low) to gray (no hazard). The maps are GIS based to facilitate ready adaptation by planners and emergency managers. The maps are intended for educational purposes, to improve awareness of tsunami hazards and to encourage emergency planning efforts of local and regional organizations by illustrating the range of possible tsunami events.

1 **Hazard area boundary criteria** are initially defined for each zone based on elevation.

Zone	Description	High	Moderate	Low	None
Open Coast	Everywhere within 2km of coast	0 - 3 m elev	3 - 10 m elev	10 - 35 m elev	above 35 m elev
Coastal Estuary	Low lying flat topography of river valleys and bottomlands	0 - 1.5 m elev	1.5 - 6 m elev	6 - 15 m elev	above 15 m elev
Bay	Low lying flat topography adjacent to Humboldt Bay	0 - 1.5 m elev	1.5 - 3 m elev	3 - 5 m elev	above 5 m elev
Special Study Zone	Area studied by PG&E	0 - 3 m elev	3 - 7.5 m elev	7.5 - 20 m elev	above 20 m elev
Uplands	All other areas inland of Open Coast zone				all elevations

hazard criteria table 1 — Criteria for each hazard zone are chosen in relation to elevation and attenuation.

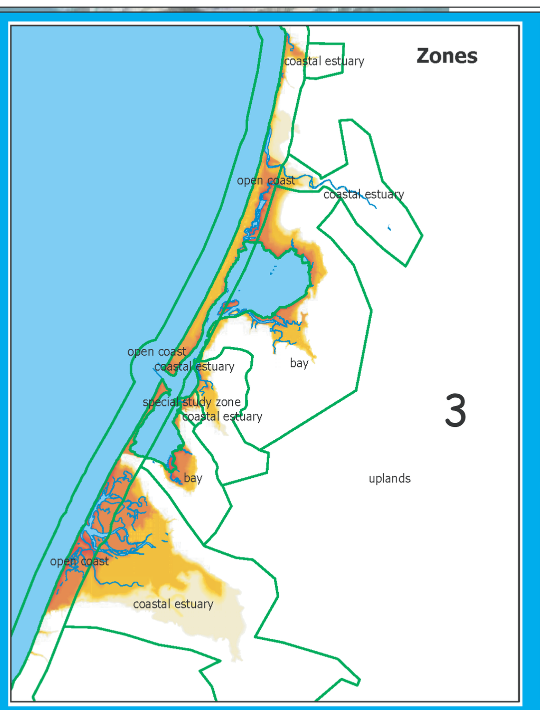
10 m DEM 2 — Elevation grid (DEM) is used for elevation control and generation of elevation contours.

attenuation zones 3 — Elevation criteria are adusted in relation to proximity of open ocean.

use existing data 4 — FEMA q3 zone A flood insurance maps and 1994 NOAA modeling data are used to edit hazard criteria boundaries.

hazard TIN 5 — Generate a triangulated irregular network (TIN) using hazard units for z-values

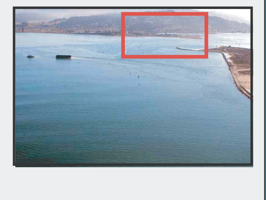
check previous modeling 6 — Results from previous wave heght estimates are compared to check the reliablity of this method.



Open Coast: open coastline directly exposed to the ocean; includes all areas within 2 km of the coast; vulnerable to inundation and high velocity tsunami waves.

Bay: margins of Humboldt Bay and lagoons more than 2 km from the coast; vulnerable to rapid changes in water level, fluctuating currents and flooding.

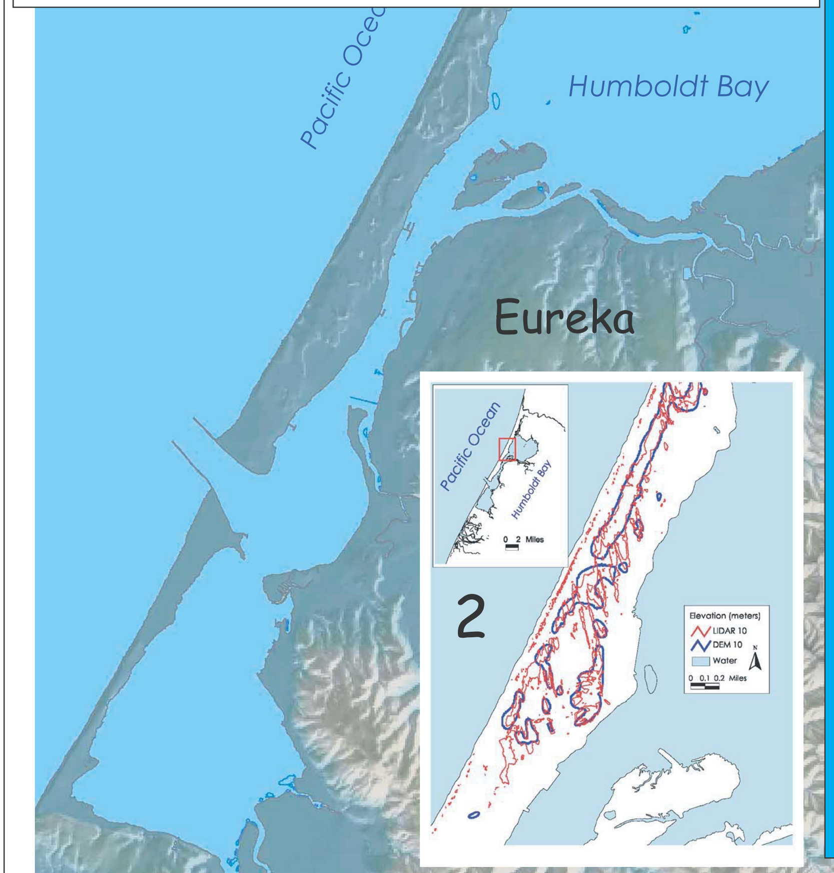
Special Study: Pacific Gas and Electric Company Power Plant and King Salmon opposite the mouth of Humboldt Bay; vulnerable to both Open Coast and Bay effects. Studies of the tsunami hazard have been conducted by PG&E.



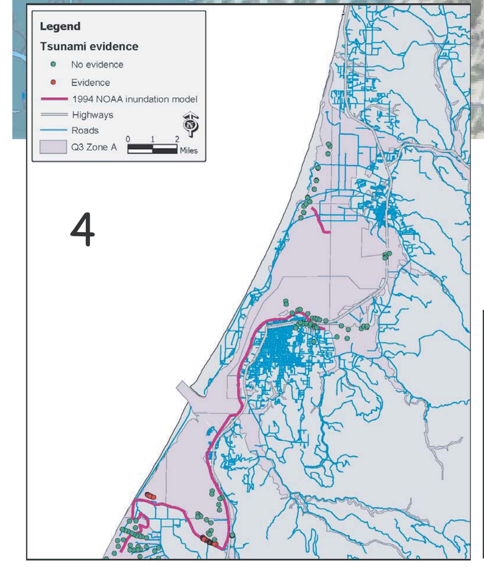
Coastal Estuary: coastal flood plain areas from the end of the Open Coast Zone to elevations inland of 35m; vulnerable to tsunami river bores; flooding potential strongly dependent on ambient tide and water levels.

Attenuation zones: used to adjust hazard in relation to attenuation due to proximity to wave hazard.

Upland: All areas more than 2km inland from the coast not included in the Bay or Coastal Estuary Zones; not vulnerable to tsunami hazards but will be affected by other earthquake effects if a large Cascadia earthquake occurs.

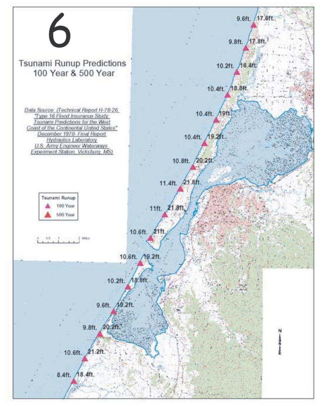


Elevation control: 10 meter DEM vs. 3 m LIDAR
LIDAR data allow better elevation constraints for hazard assessesment.



FEMA Q3 flood maps, NOAA, 1994 inundation modeling, and paleoseismic investigations: hazard criteria boundaries are adusted to mainatin consistency with these previous efforts 4

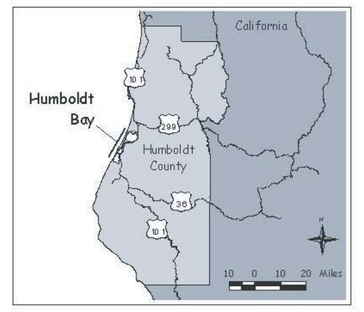
Triangulated Irregular Network (TIN), with hazard units as a source of z-values, is constructed with hazard criteria boundaries as breaklines and fabricated points as mass points. Fabricated points are placed to adjust the hazard surface in relation to topography not represented by breaklines. 5



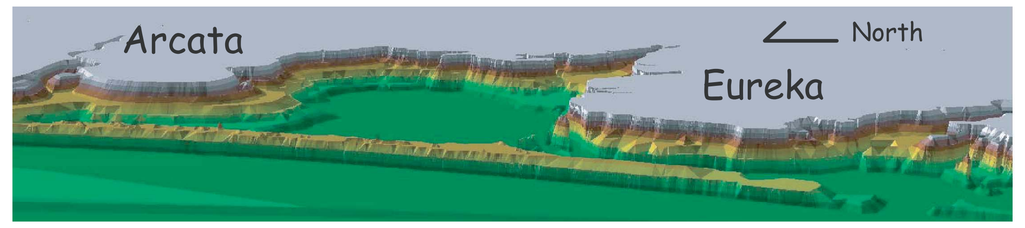
Garcia and Houston, 1975, model estimates are consistent with the hazard TIN. 6

tsunami hazard humboldt county

paleotsunami deposit, Hookton Slough, Humboldt Bay, California (Patton, 2004)

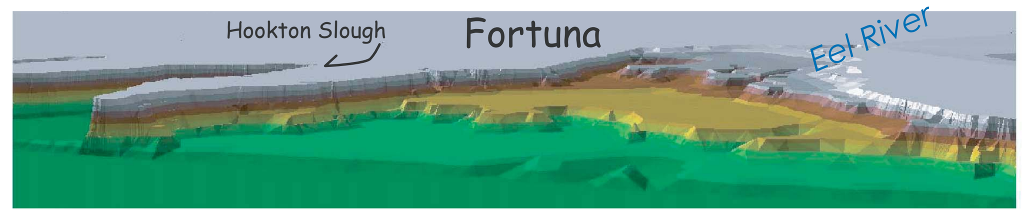


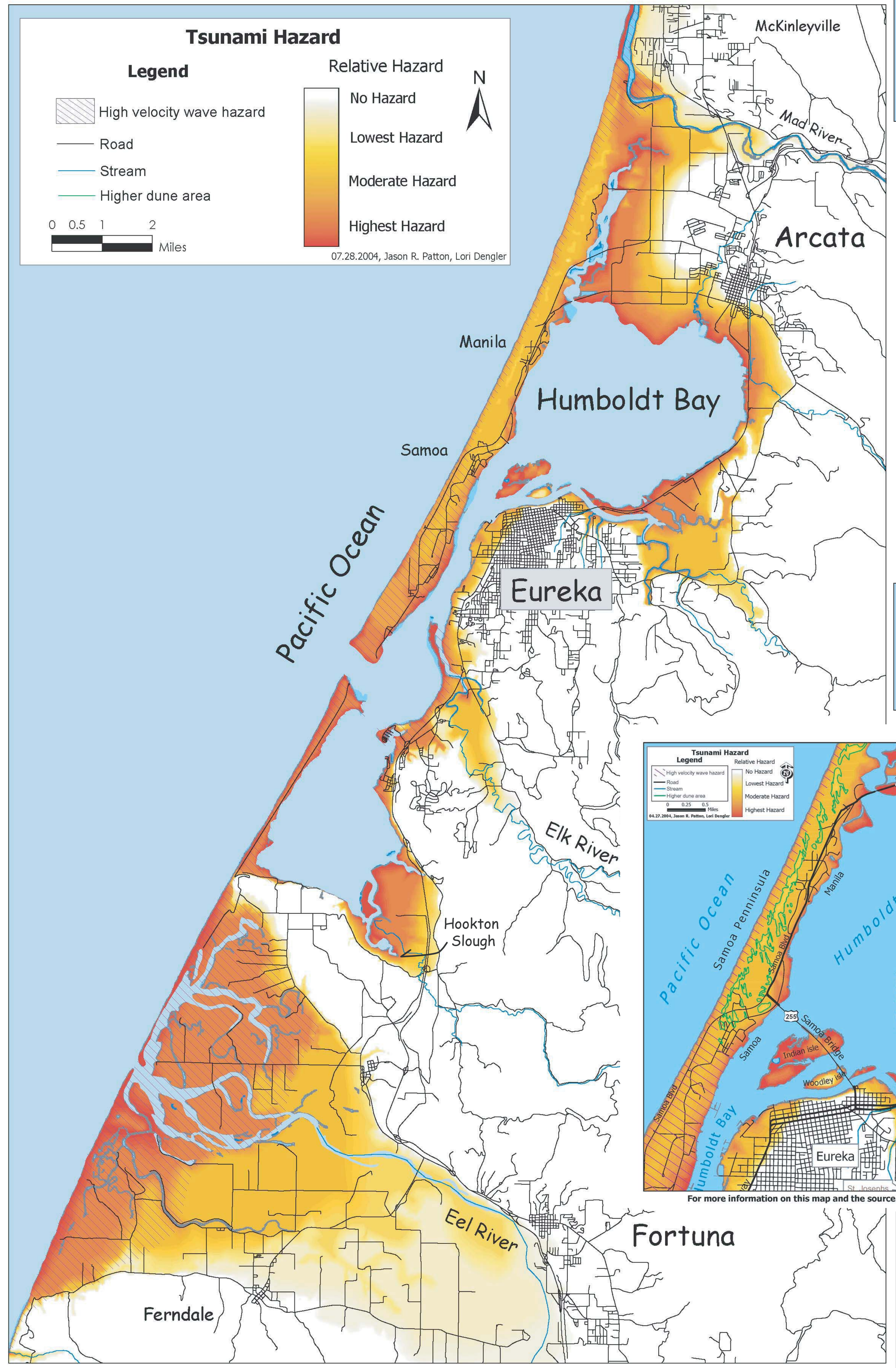
Vibra Core
depth below ground surface (cm/in)
up



low angle oblique views of hazard surface

color is arbitrary and is not intended to represent gradational hazard





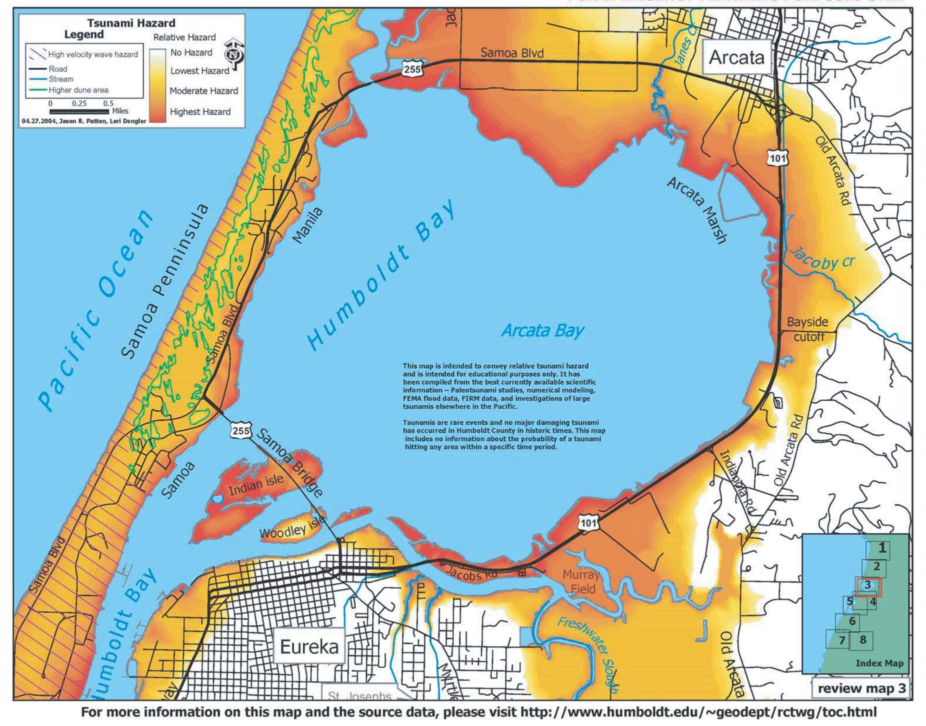
Tsunami Hazard TIN
The Humboldt Bay and Eel River Valley regions are shown with relative hazard represented gradationally by color.

Positive Issues:
· The TIN permits the gradtional display of hazard.
· The TIN can be adjusted in relation to new data.
· The TIN allows easy interpretation by government officials, emergency planners, and most importantly, the general public.
· The TIN represents the most recent available data.
· The TIN construction process is easily adaptable as even better data become available.

Negative Issues:
· The TIN is time consuming to generate relying upon manual input of data.
· The TIN incorporates subjective reasoning, limiting the reproducibility.

Successes:
· The Humboldt County Office of Emergency Services (OES) has adopted a series of maps based on the tsunami hazard TIN as a basis for portions of their tsunami hazard mitigation plan.

SHEET 3: FOR EMERGENCY PLANNING PURPOSES ONLY



For more information on this map and the source data, please visit http://www.humboldt.edu/~geodept/rctwg/toc.html

Next Step:
· A set of rules will be designed to define an elevation GRID to represent tsunami hazard.
· The hazard GRID can reflect attenuation without subjective zones.
· Once data are prepared for production, the GRID can be generated in little time.
· The entire process is repeatable and can be modified as additional data become available.

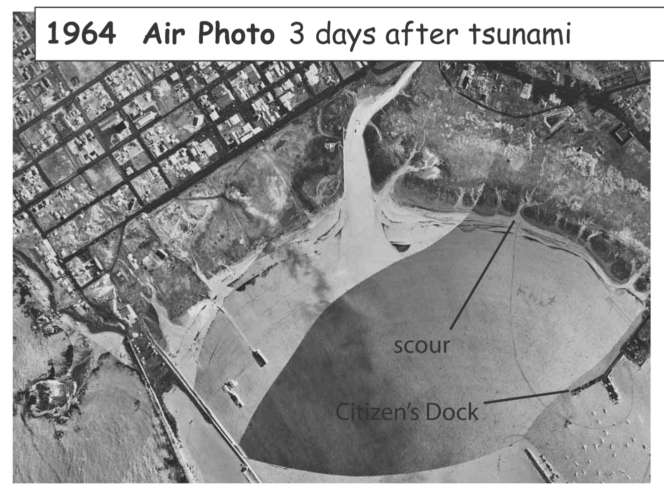
tsunami hazard del norte county

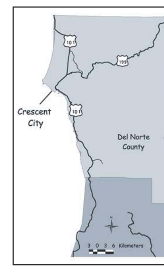
Flooding at Citizen's Dock Road, Crescent City, from the 1960 Chielan tsunami

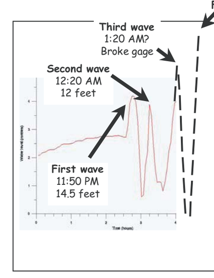
1964 Tsunami in Crescent City (from Magoon, 1966)

October 1962 Air Photo Two years before tsunami

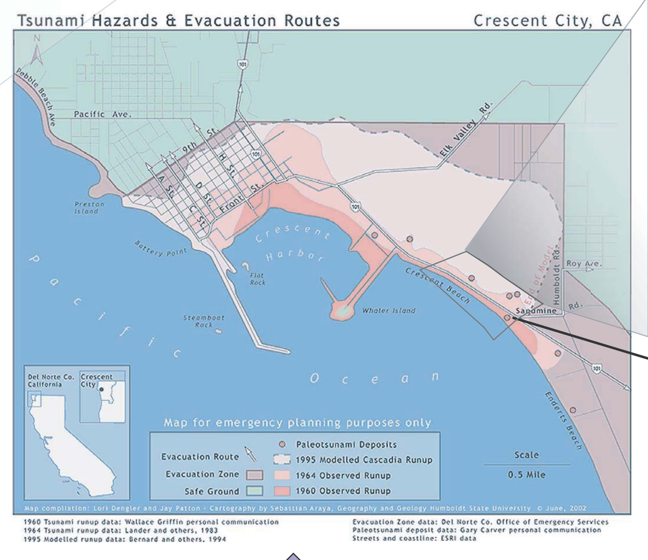
1964 Air Photo 3 days after tsunami

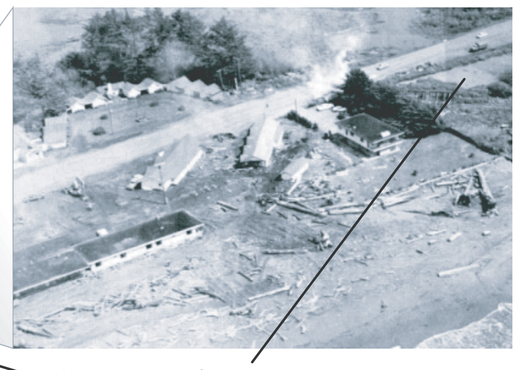




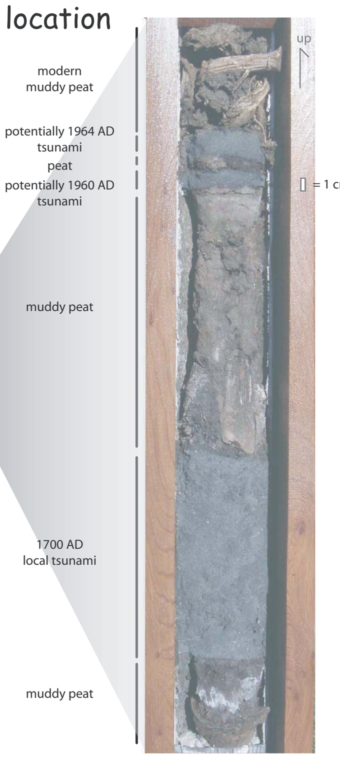


1964 Tide Gage water height in Crescent City. The instrument was destroyed as the thrid wave hit. Dashed line is reconstruction based on eye-witness accoutns and Magoon (1966).





drive core location



10 m DEM — Elevation grid (DEM) is used for elevation control.

elevation converted to hazard units — Based on numerical modeling and historical data, elevation units are converted to hazard units.

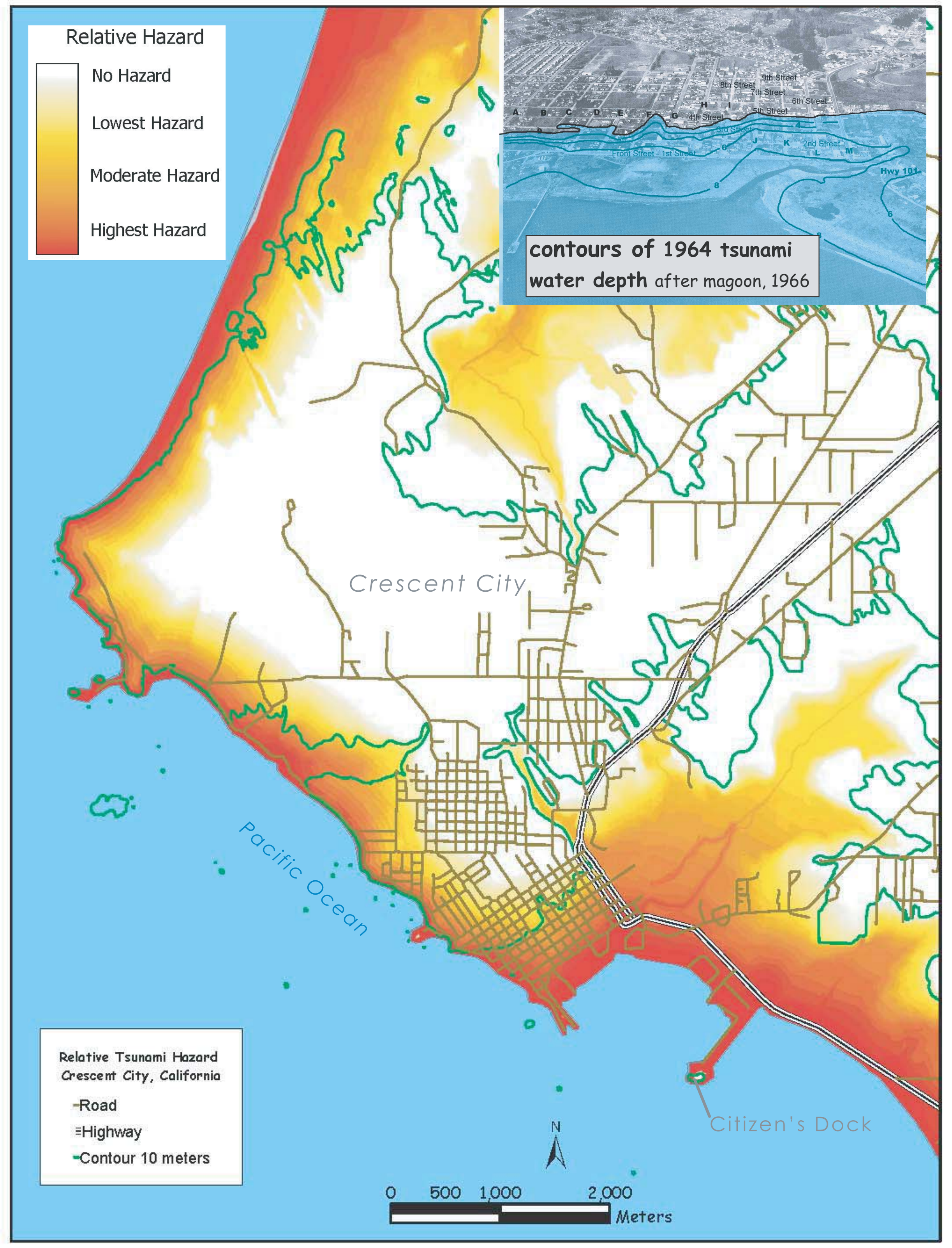
attenuation zones — Elevation criteria are adusted in relation to proximity of open ocean and proximity to low lying coastal valleys.

use existing data — FEMA q3 zone A flood insurance maps, 1994 NOAA modeling data, and historical observations are used to edit attenuation relations.

hazard GRID — The hazard GRID is generated with all constraints listed here and displayed with color ramp that denotes the gradational nature of tsunami hazard.

check previous modeling — Results from previous modeling efforts are used to check the reliablity of this method.

Drive Core
sediment drive core sampled from pond on south side of Crescent City. (Bob McPherson,)



Tsunami Hazard GRID
Crescent City is shown with relative hazard represented gradationally by color.

GRID vs. TIN:
· The GRID model is more objective.
· The GRID can be more easliy adjusted in relation to new data
· The GRID process can be rapidly modified as even better data become available
· The GRID represents the tsunami hazard more true to topographical form than the TIN (note hazard plateaus in oblique views of TIN).
· The GRID construction process can incorporate data from wave height modeling.

Continuing Issues:
· The GRID is limited by available data.

Next Step:
· A set of rules will be designed to define an elevation GRID to represent tsunami hazard.
· The hazard GRID can reflect attenuation without subjective zones.
· Once data are prepared for production, the GRID can be generated in little time.
· The entire process is repeatable and can be modified as additional data become available.

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