Appendix A:

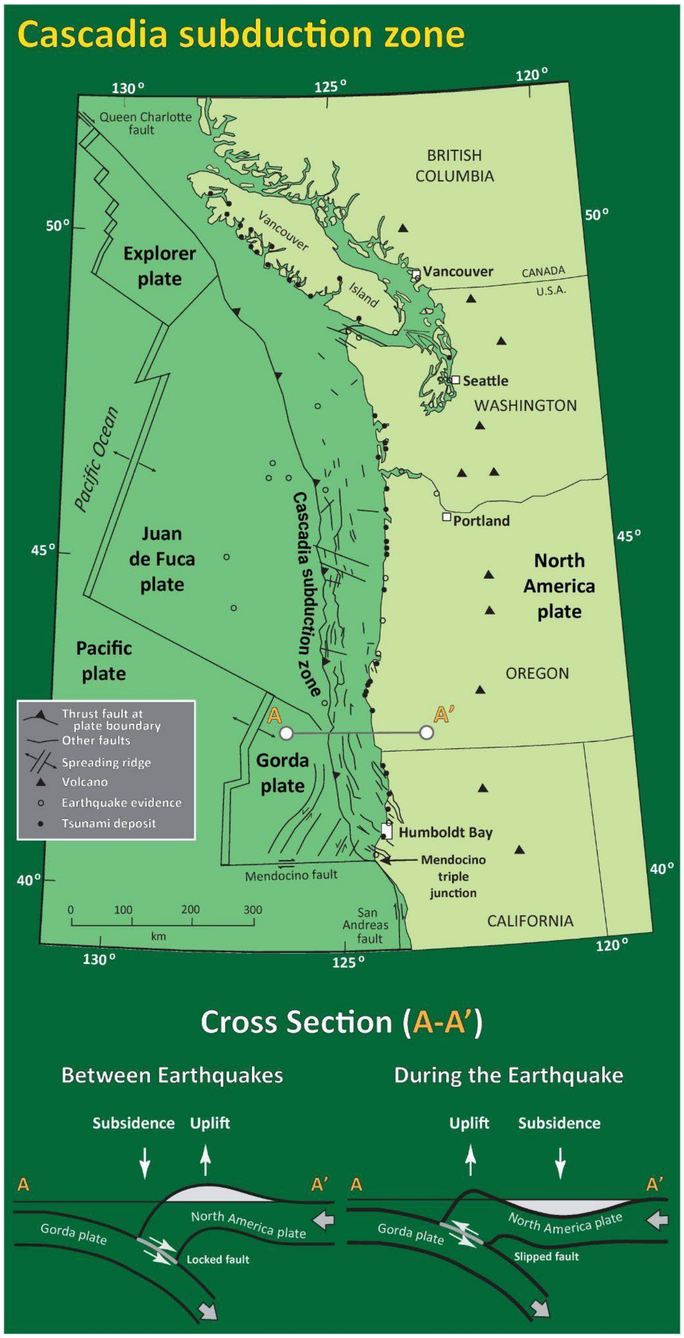
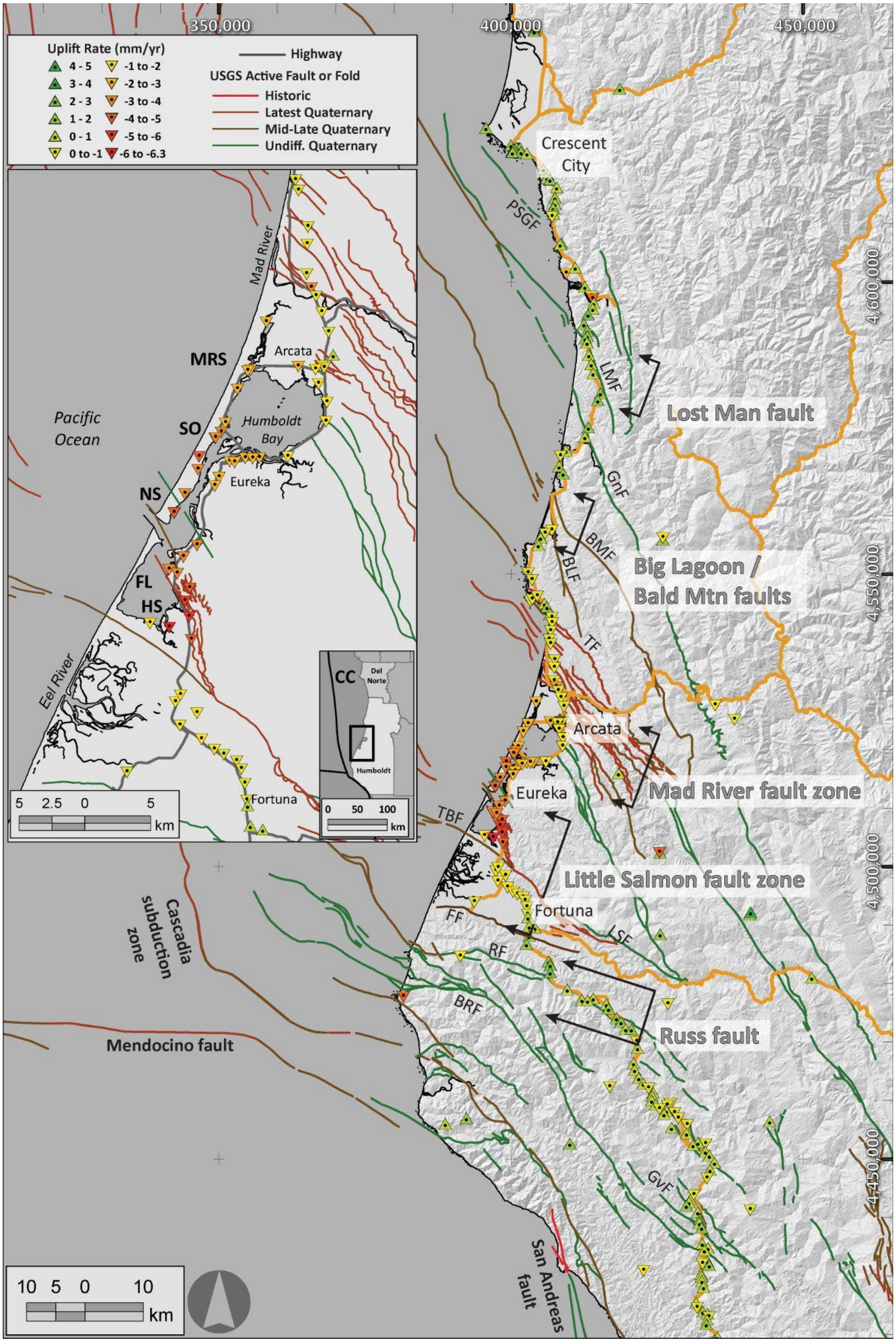


Figure A.1. Cascadia subduction zone. Map showing tectonic plate boundaries, major cities, and Humboldt Bay (modified from Chaytor et al., 2004; Nelson et al., 2006). The lower panel shows how the land moves vertically between (interseismic) and during (coseismic) earthquakes (modified from Plafker, 1972).



350,000
400,000
450,000
4,600,000
4,550,000
4,500,000
4,450,000
Uplift Rate (mm/yr)
4 - 5
3 - 4
2 - 3
1 - 2
0 - 1
0 to -1
-1 to -2
-2 to -3
-3 to -4
-4 to -5
-5 to -6
-6 to -6.3
Highway
USGS Active Fault or Fold
Historic
Latest Quaternary
Mid-Late Quaternary
Undiff. Quaternary
Mad River
Arcata
MRS
Pacific Ocean
SO
Humboldt Bay
Eureka
NS
FL
HS
Eel River
Fortuna
CC
Del Norte
Humboldt
0 50 100 km
5 2.5 0 5 km
Crescent City
PSGF
LMF
Lost Man fault
GnF
BMF
BLF
Big Lagoon / Bald Mtn faults
TF
Arcata
Mad River fault zone
Eureka
TBF
Little Salmon fault zone
Fortuna
FF
LSF
RF
BRF
Russ fault
Cascadia subduction zone
Mendocino fault
GvF
San Andreas fault
10 5 0 10 km

Figure A.2. Geodetic Results. Vertical land-level change in coastal northernmost California. Vertical land motion rates are symbolized with color relative to rate magnitude. Inverted red triangles represent negative uplift and non-inverted green triangles represent positive uplift. Shaded relief shows how topography varies across the landscape in the Humboldt Bay region. USGS active fault and fold database is plotted relative to most recent activity documented for each fault (red = historic; red-brown = Latest Quaternary; Brown = Mid- to Late-Quaternary; Green = Undifferentiated Quaternary). Fault zones are designated: BLF – Big Lagoon fault; FF – Ferndale fault; GF – Grogan fault; LSF – Little Salmon fault; LMF – Lost Man Creek fault; RF – Russ fault; and TF – Trinidad fault. Inset: Tide gage site map, Humboldt Bay region. CC – Crescent City; FL – Fields Landing; HS – Hookton Slough; MRS – Mad River Slough; NS – North Spit; and SO – Samoa.

Appendix B:

Research Questions or Foci from Disciplinary Sections

MARINE & COASTAL SCIENCE

Research Questions

1. Would ocean water move underneath potentially new and higher barriers that are intended to protect property and infrastructure? Answering this question is not only important to the communities living around Humboldt Bay, but if the answer is “no” then marine habitats would be threatened for the reason described above. If “yes”, then repositioned barriers and marine habitats will have to be considered.
2. How will the distribution of the three intertidal habitats in Humboldt Bay change if the present set of dikes and seawalls are repositioned? Present modeling studies about rSLR in Humboldt Bay (e.g., Shaughnessy et al. 2012, Gilkerson 2013, and Stillman et al. 2015) do not include manipulations of dike position, although estimates for salt marsh area are made based on the 1860 perimeter of the bay.
3. What are the habitat requirements of oyster leases and could they be considered a 4th intertidal habitat during the planning process? Rather than continuing the process of renewing and/or expanding oyster leases at the potential expense of eelgrass beds and dependent waterfowl (Merkel and Gilkerson 2017), the repositioning of barriers presents an opportunity to build these leases into the management of the bay.
4. How would the repositioning of upland barriers alter water and sediment circulation in Humboldt Bay? Water circulation drives gradients of temperature, salinity, nutrient levels and sediment across estuaries - all of which affect the development and productivity of habitats.

5. Are sedimentation rates in local estuaries and on the outer coast sufficient to keep pace with global SLR and the rapid local tectonic downward movement of the land? Studies of local marine habitat responses to rSLR (Shaughnessy et al. 2012, Gilkerson 2013, and Stillman et al. 2015) have made simplistic assumptions about sedimentation rates because they are difficult to measure but are likely to be temporally and spatially variable.
6. How will rSLR interact with other aspects of climate change to affect the structure of marine habitats and species? It is an oversimplification to think that marine habitats and species will only react to rSLR. A few examples:
    a. For linear, riverine estuaries (e.g., Mad River, etc.) rSLR by itself suggests that a salt water wedge could penetrate further upriver, especially if drought conditions decrease discharge rates. But the latter could also allow the formation of a perched beach (i.e., sand dam) at the river mouth thereby creating a lagoon estuary (i.e., high salinity and temperature, low dissolved oxygen) during the summer that switches back to an oceanic winter estuary when the beach is breached by storms (Largier et al. 2015, Shaughnessy et al. 2017).
    b. The eelgrass plant, which creates entire habitats in certain types of estuaries, can go locally extinct in deep water because it is vulnerable to low light. But the increased CO_2 concentration due to ocean acidification could allow it to persist in deep water longer if the increasing seawater temperatures don't offset this carbon gain by causing higher rates of plant respiration (Palacios and Zimmerman 2007).
    c. Coho and Chinook salmon juveniles can rear in estuarine habitats such as eelgrass beds, mudflats and deeper channels, and in oceanic nearshore habitats such as sandy beach surf zones. The impact of rSLR, increasing water temperatures and wave height, and stronger water stratification could severely impact their growth, use and movement among habitats in nearshore environments, and survival to adulthood (Reimers 1973, Halloran 2020, Marin Jarrin et al. 2022).

7. What are the best conservation practices for preserving the ecosystem functions of marine habitats that are responding to SLR? The high diversity of estuarine types (Shaughnessy et al. 2017) and watershed activities on the North Coast suggests that a mixture of conservation practices could be more effective than one approach for all locations (Palumbi 2001). In some marine habitats like Humboldt Bay, it may be more effective to manage watershed activities (e.g., pollution, suspended sediments) and bolster traditional ecological practices rather than creating exclusionary spaces.

ENGINEERING

Possible areas of focus could be in the following areas:

1. Sediment transport and streamflow data gathering within the watershed, to better characterize existing conditions and changes observed.
2. Groundwater monitoring and modeling within the basin
3. Wave and energy modeling
4. Coastal sediment monitoring and modeling to determine erosion and accretion in Wigi
5. Designs for dredging protocols, living shorelines, constructed wetlands, ecolevees, and other protection plans for critical infrastructure.

SOCIAL SCIENCE, PLANNING, POLICY, AND LAW

Emerging from these state and local developments, future research questions include:

1. What is the sociocultural context and sense of place among coastal communities facing SLR and will that interact with SLR planning?
2. What are local knowledge, values, and priorities related to SLR? Where are areas of conflict and overlap? How can SLR planning processes draw from these community perspectives?

3. How and under what circumstances should permitting for sea level rise adaptation projects, such as living shorelines or road elevation projects, be streamlined? What are the equity and justice considerations of modernizing federal, state, and local laws and regulations to accommodate quicker permitting timelines for sea level rise adaptation projects?
4. Similarly, what are the ecological and species considerations of sea level rise adaptation planning? For example, how will we address contradictions in law when critical habitat protected under the Endangered Species Act may be disturbed by living shoreline construction critical for protecting Highway 101 from sea level rise flooding? Or when groundwater inundation threatens critical habitat with saltwater intrusion? Who is legally liable in such instances?
5. What are the legal duties and responsibilities of state and local? agencies to respond to climate adaptation needs? For example, is the duty to maintain a submerged road a legal or political question, given the state's guidance rather than policy direction on sea level rise adaptation?
6. How will the inland migration of tidelands impact state jurisdiction of public trust lands, and how might the landward migration of tidelands impact how sea level adaptation projects are prioritized, managed, and governed? (See California Coastal Commission, 2022).
7. What are the most effective governance systems to support equitable SLR planning and adaptation across multiple jurisdictions and scales?
8. How can we develop equitable and community-based SLR adaptation strategies in our region?
9. What are the most effective and equitable means to engage the public, specifically residents of at-risk locations, in planning for the future of their places?
10. What are the opportunities for communities and governments to co-create adaptation/resilience plans?
11. What are the equity implications of future SLR and how can policy and planning seek to address or overcome these?
12. How can the Humboldt Sea Level Rise Initiative support emergent regional sea level rise collaboratives and entities with research, outreach, funding, and support?

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