

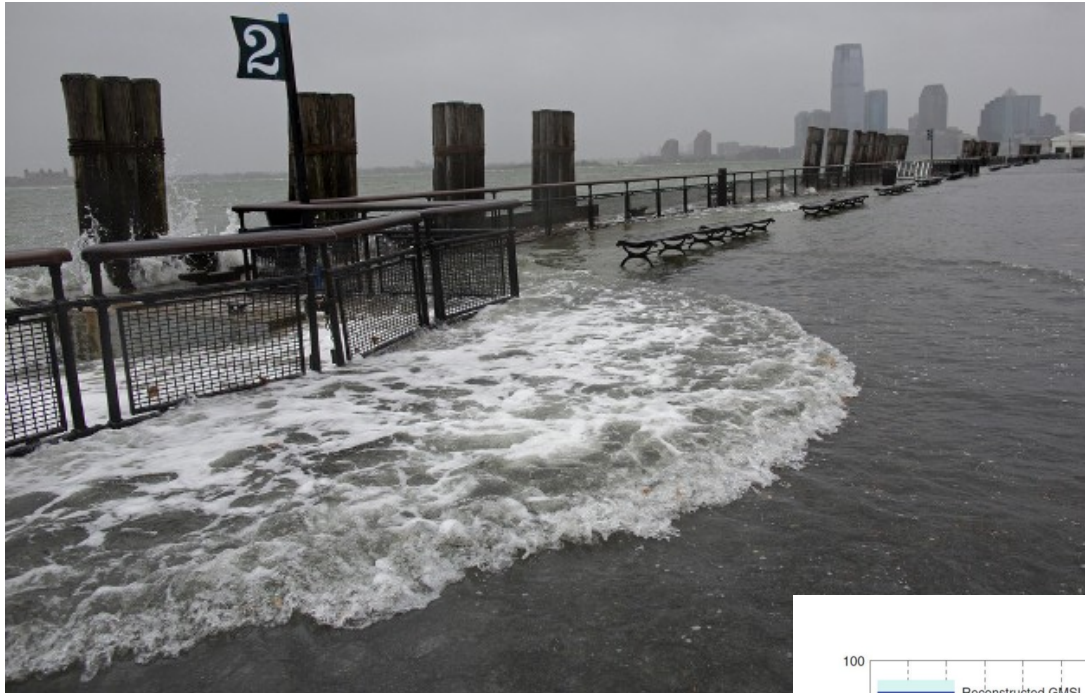
Future San Francisco Bay Shorelines and Regional Interdependence



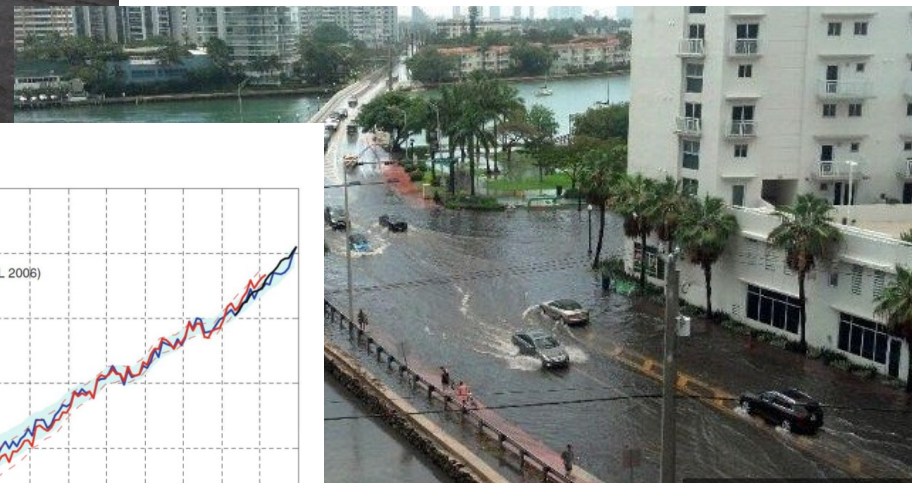
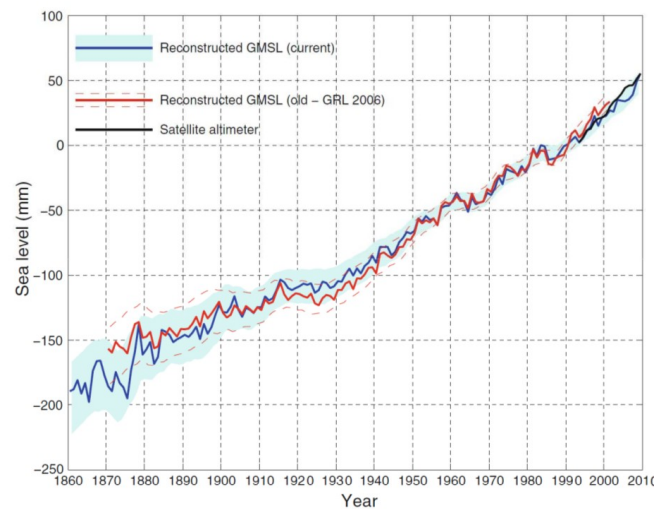
Mark Stacey
RISER Project
UC-Berkeley, UC-Davis, NYU, USGS
Sponsor: NSF-CRISP

Bay Area Regional Collaborative
Board Meeting
June 15, 2018

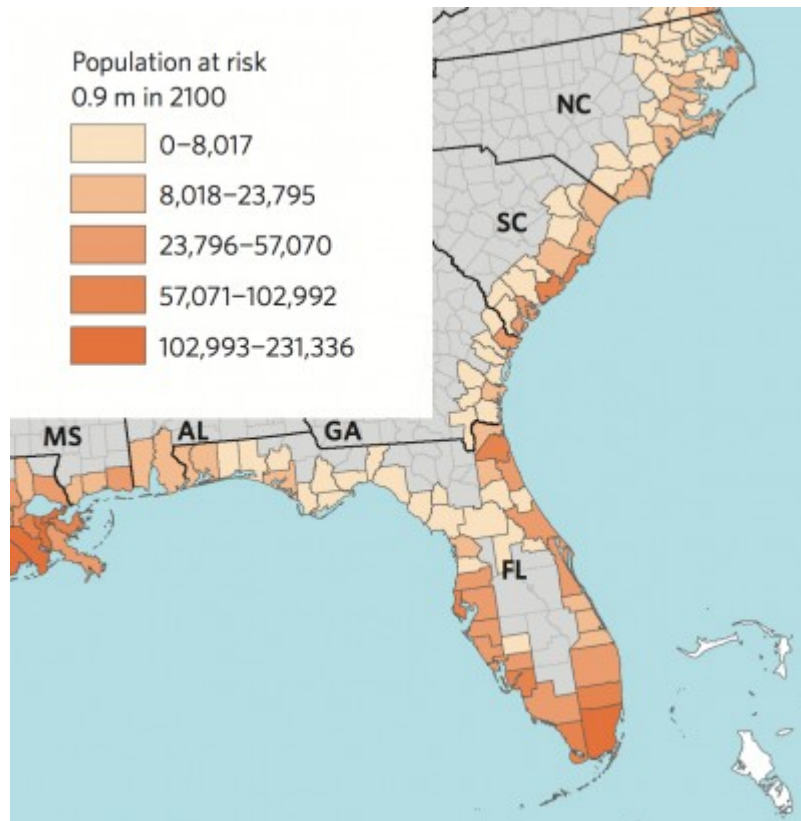
Coastal Flooding: An Emerging “Nuisance”?



- Increasing frequency, increasing cost

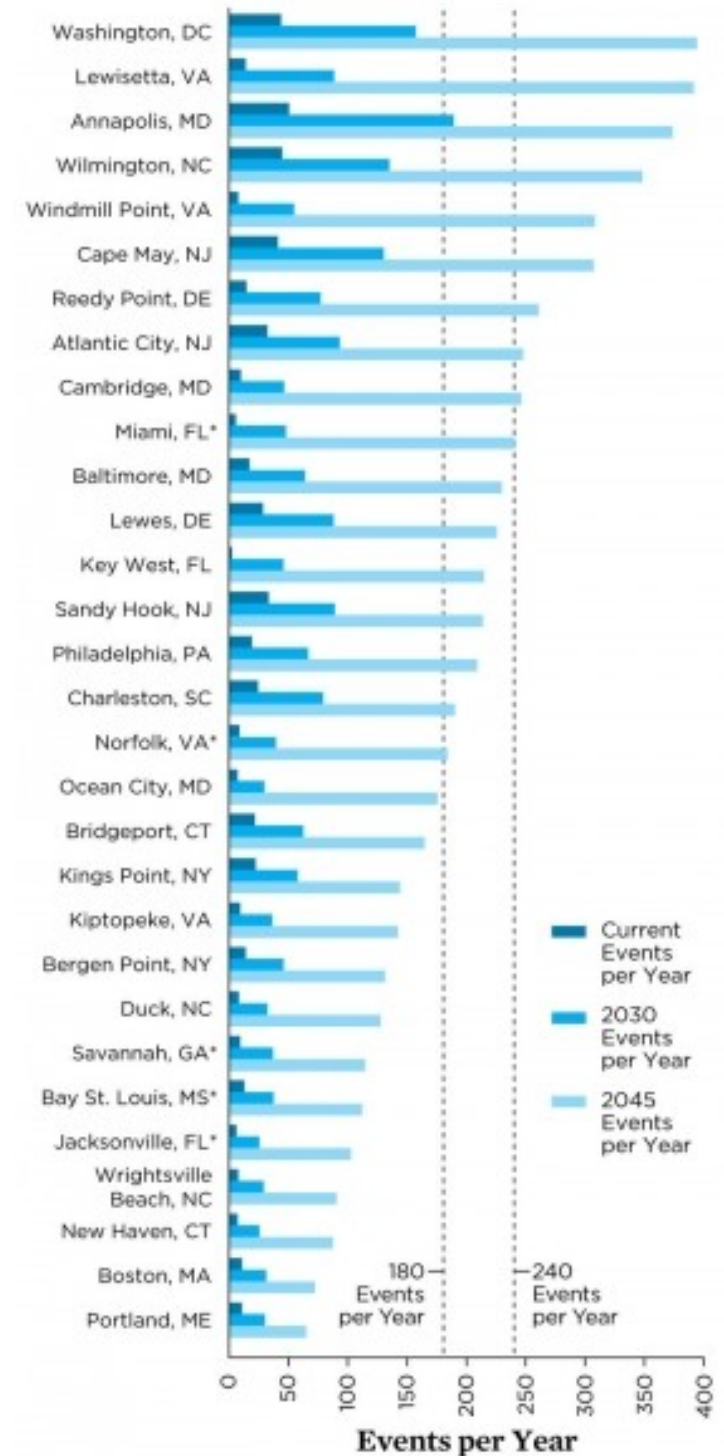


Coastal Populations



- Recent studies documented millions in the US that are vulnerable to flooding from future sea level rise
 - Disruption of infrastructure systems expands footprint

Tidal Flooding Today, in 2030, and in 2045

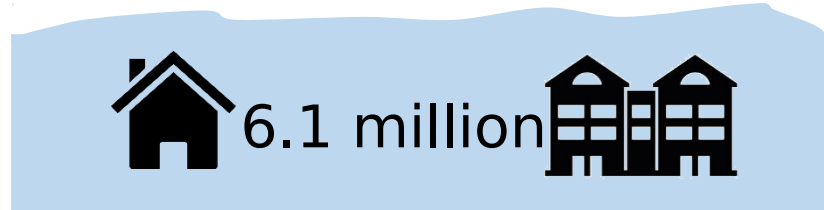
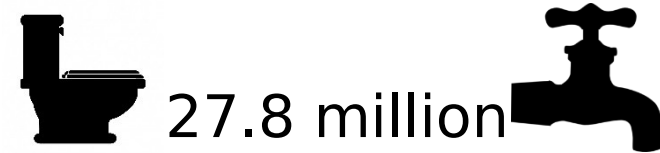


Coastal Infrastructure Disruptions

3ft SLR

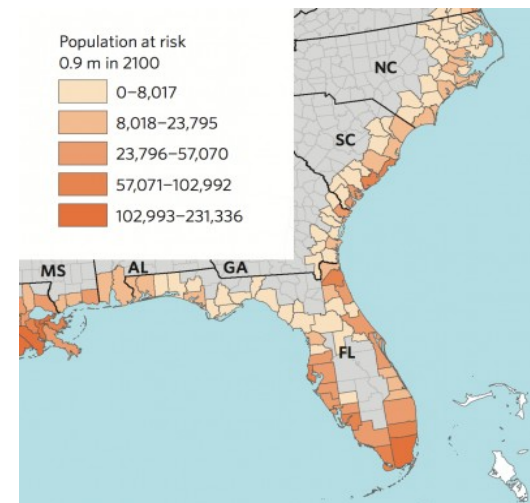


6ft SLR



Direct flooding data from Hauer et al. (2016)

- Accounting for wastewater infrastructure increases footprint of coastal flooding by a factor of more than 4



“Nuisance Flooding”: San Francisco Bay



- Tidal inundation already occurring along SF waterfront and at Tam Junction in Marin County
 - January (annual peak) high tides inundate currently
 - Future: daily high tides?

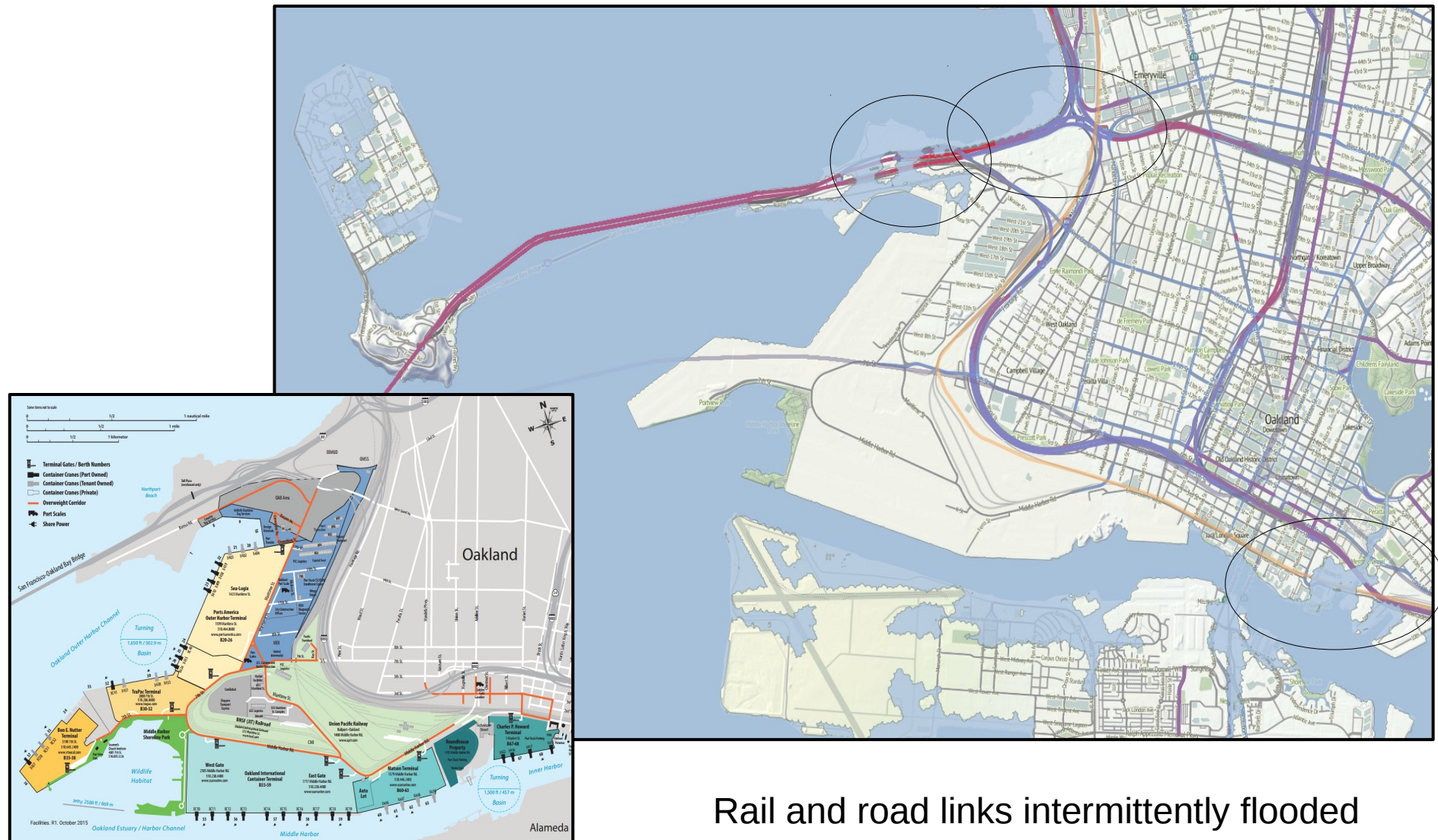
More than a “nuisance”

- Critical elements of regional, national and global transportation system disrupted



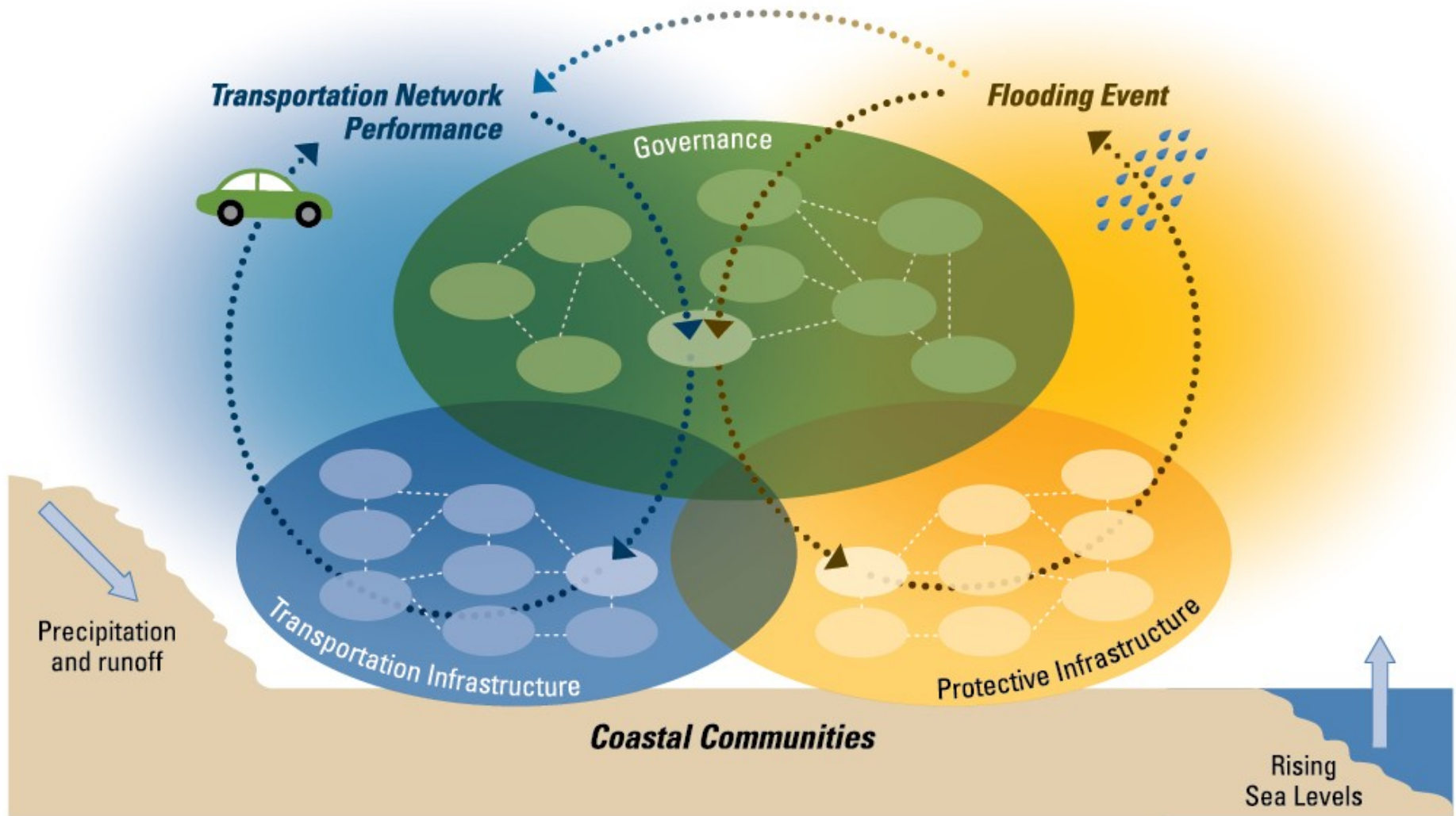
Shorelines as the transition

- Port of Oakland vulnerability most pronounced in linkages to land-based transportation



Rail and road links intermittently flooded

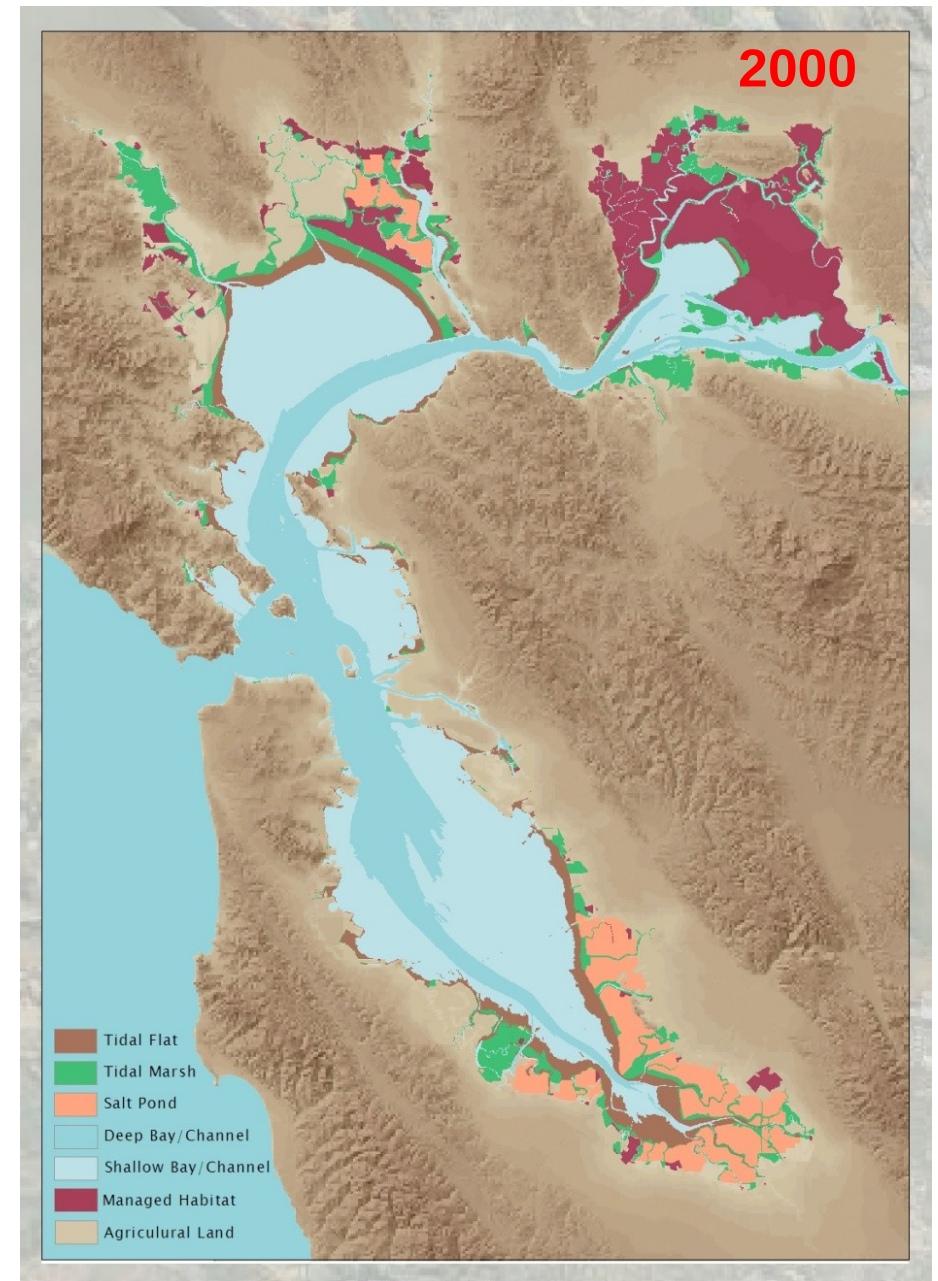
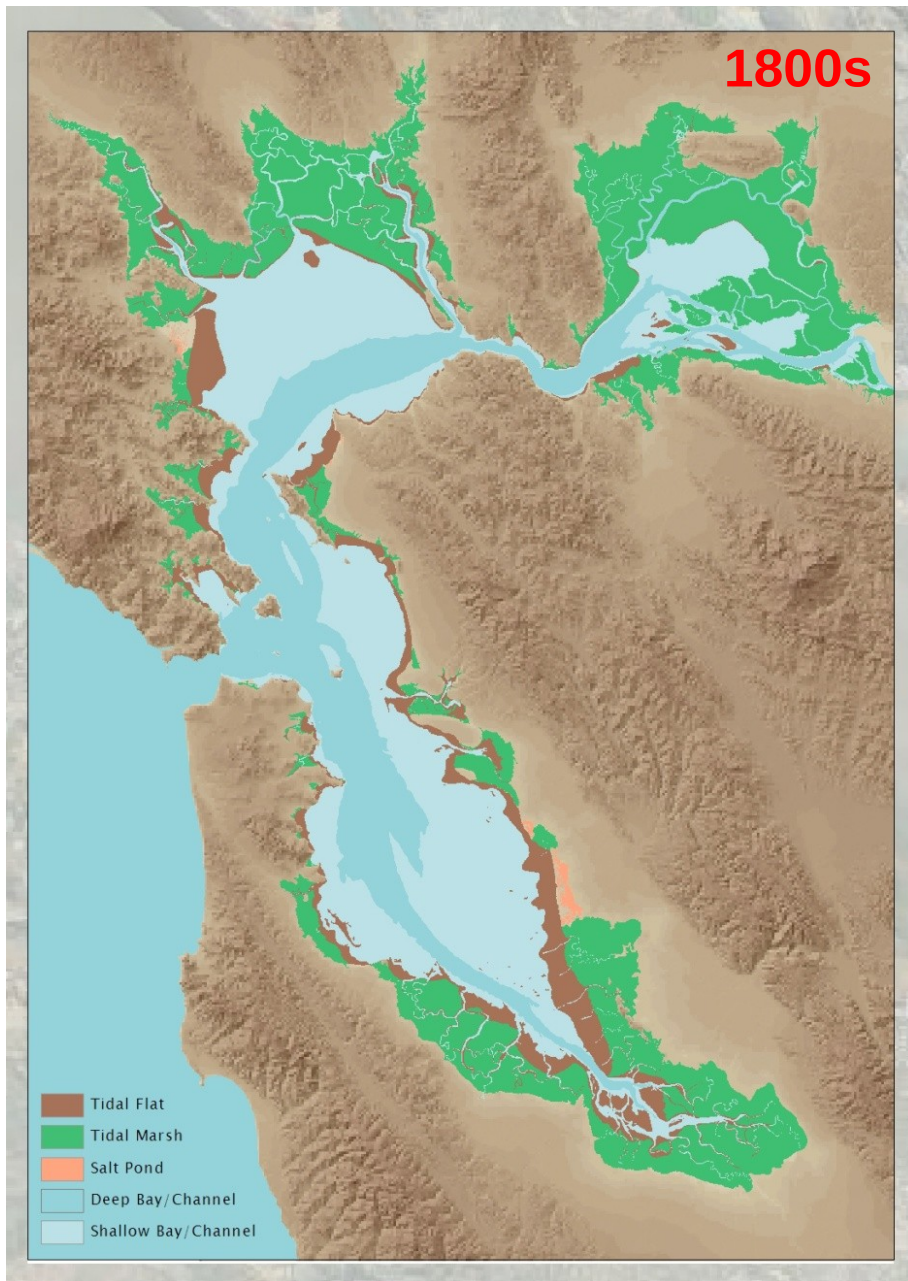
Challenges to Coastal Community Resilience



- RISER Project integrates hydrodynamic model of flooding, behavioral model of traffic flows and empirical evaluation of decision-making network
 - Driven by scenarios for environmental forcing and shoreline configurations

Important Theme: Local-regional Linkages and Network Effects Create Interdependencies

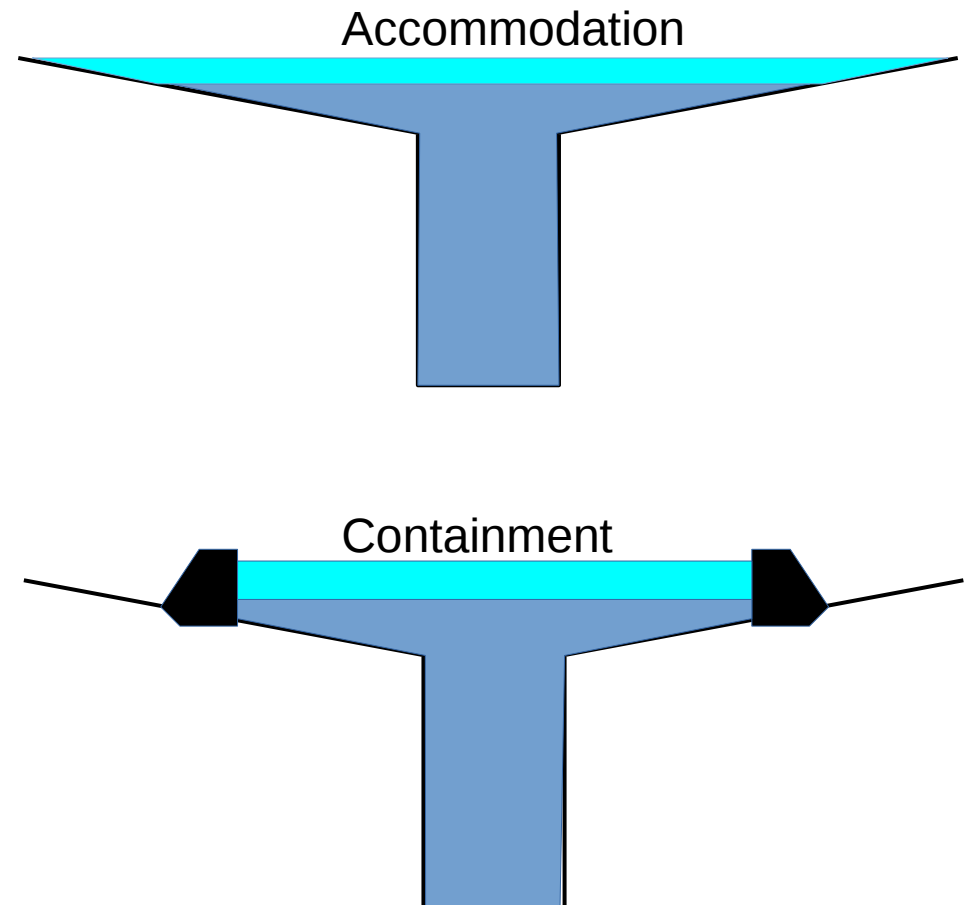
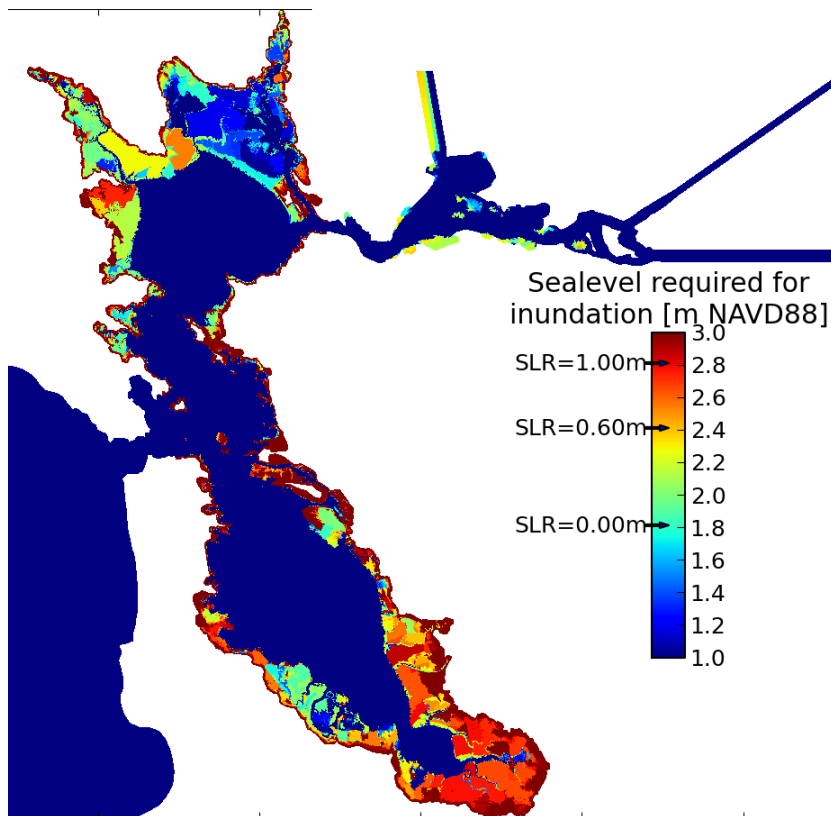
Changes to SF Bay Shorelines



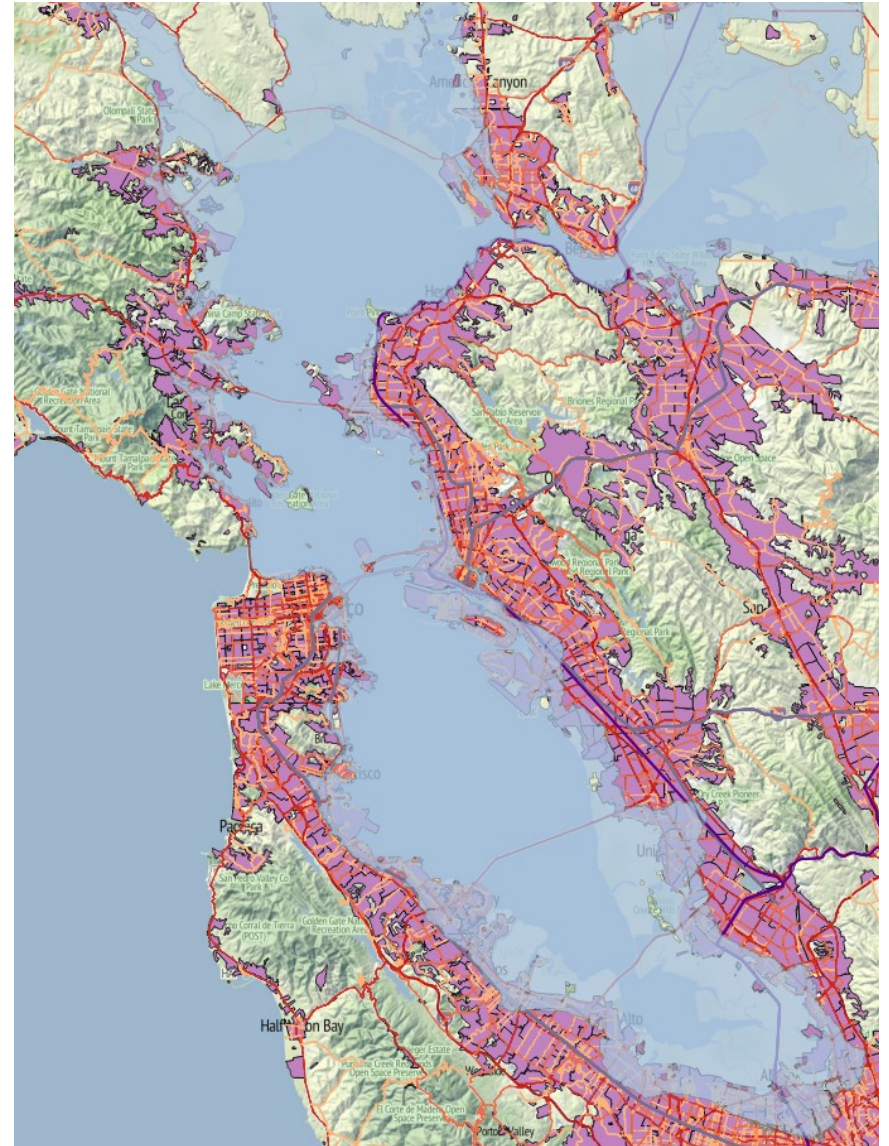
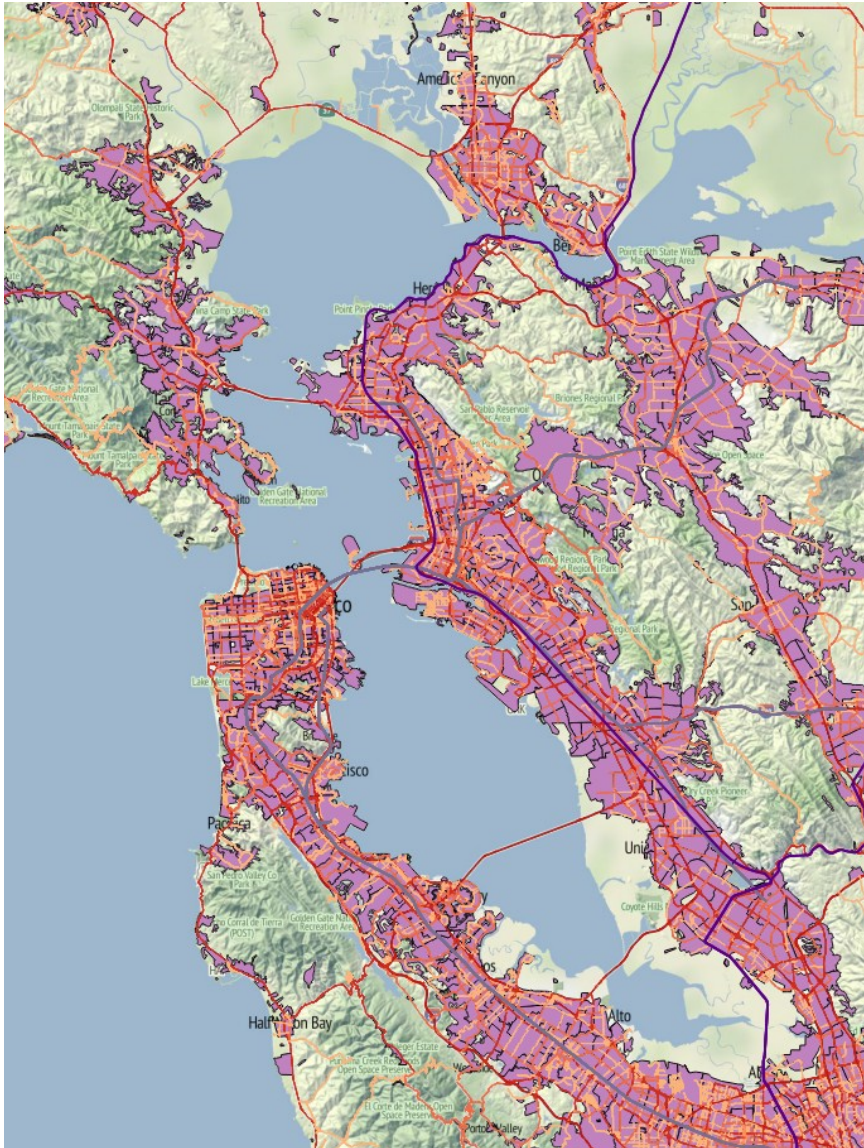
- History of 'reclamation' transforming to 'restoration'

Accommodation and Containment: SF Bay

- Management question: where, and to what extent, do we accommodate the rising water associated with sea level rise?
 - Implications for hydrodynamics and infrastructure function



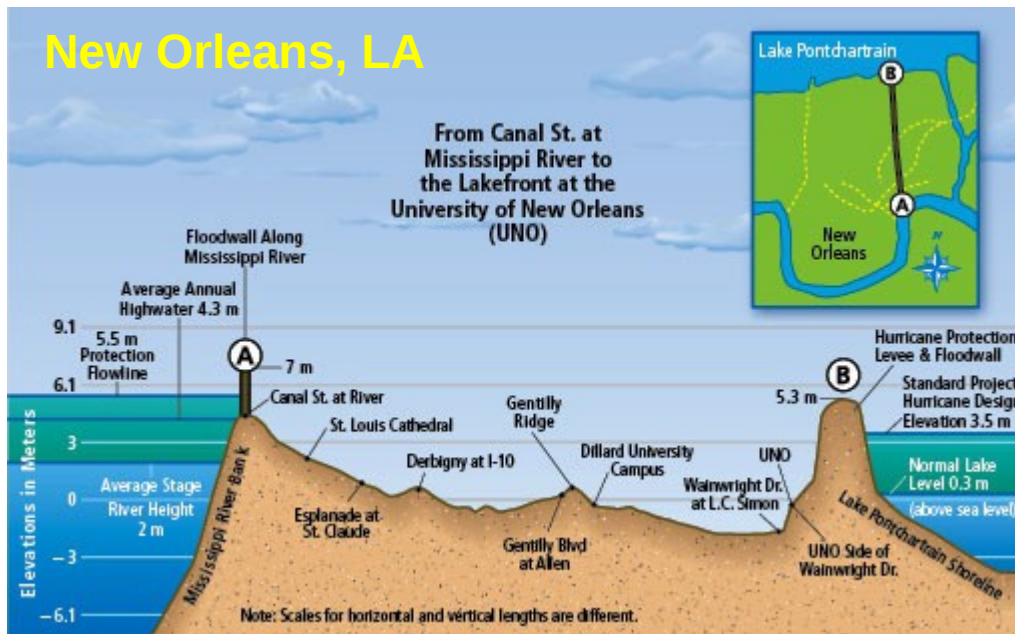
Accommodation in an urban estuary



- Decisions demand consideration of interacting vulnerabilities

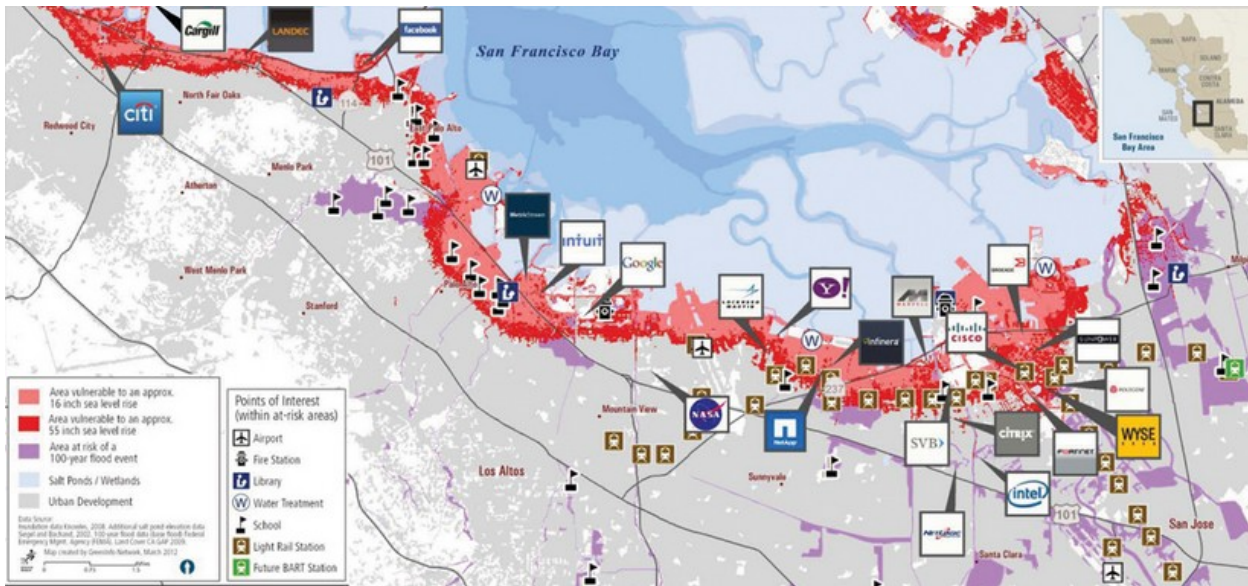
Individual Community Decision-Making

- Individual actor likely to extend protections vertically over time
 - Addresses near-term threat with incremental investment
 - No accounting of regional benefits (or costs) of alternative actions

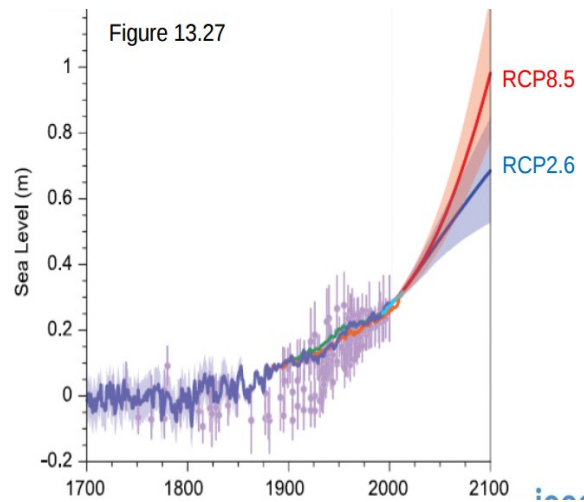


Challenge: Governance structures

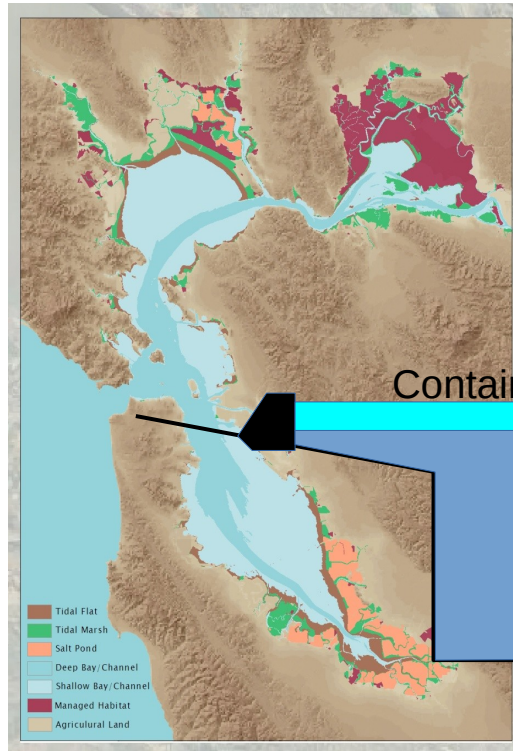
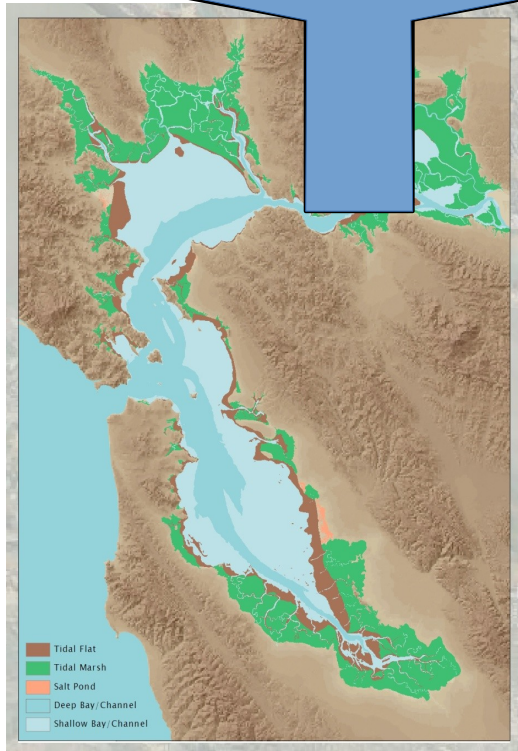
- Jurisdictions at range of scales with overlapping responsibility
 - Property owners, cities, county, state
 - Airports and transportation network
 - Cross-cutting agencies: Bay Conservation and Development Commission, e.g.



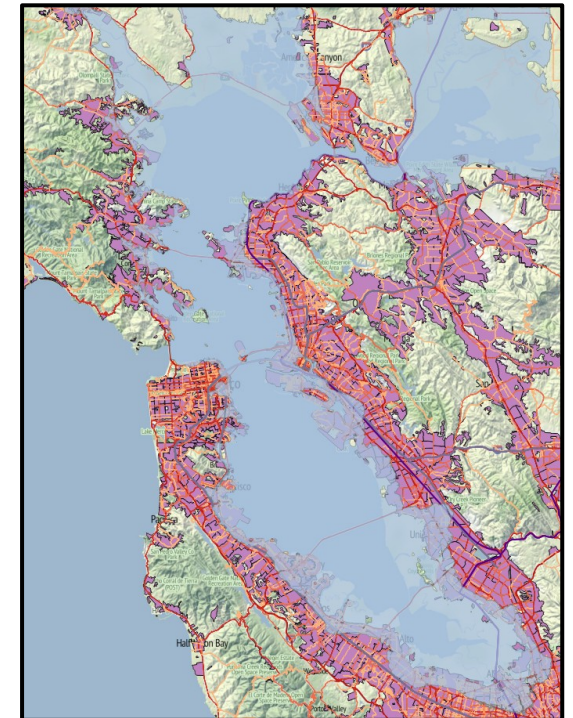
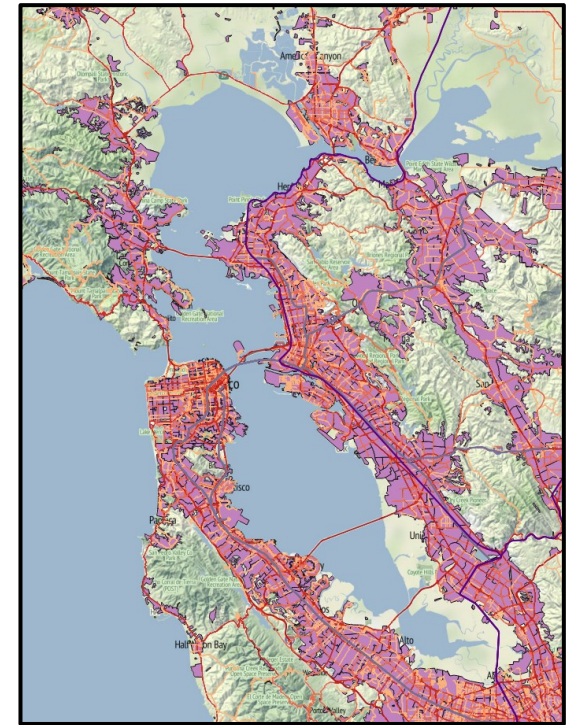
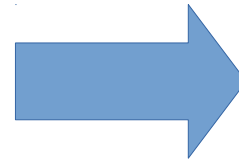
Shoreline and Sea Level Scenarios



Accommodation

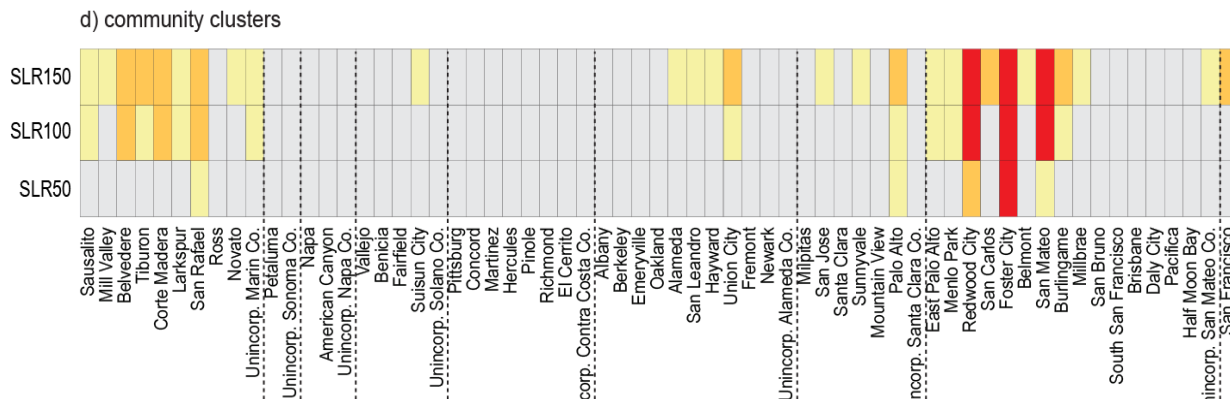
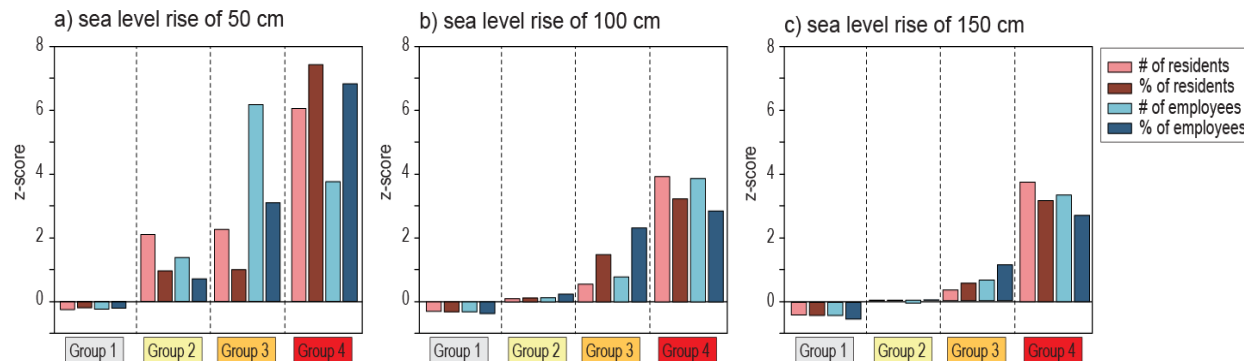
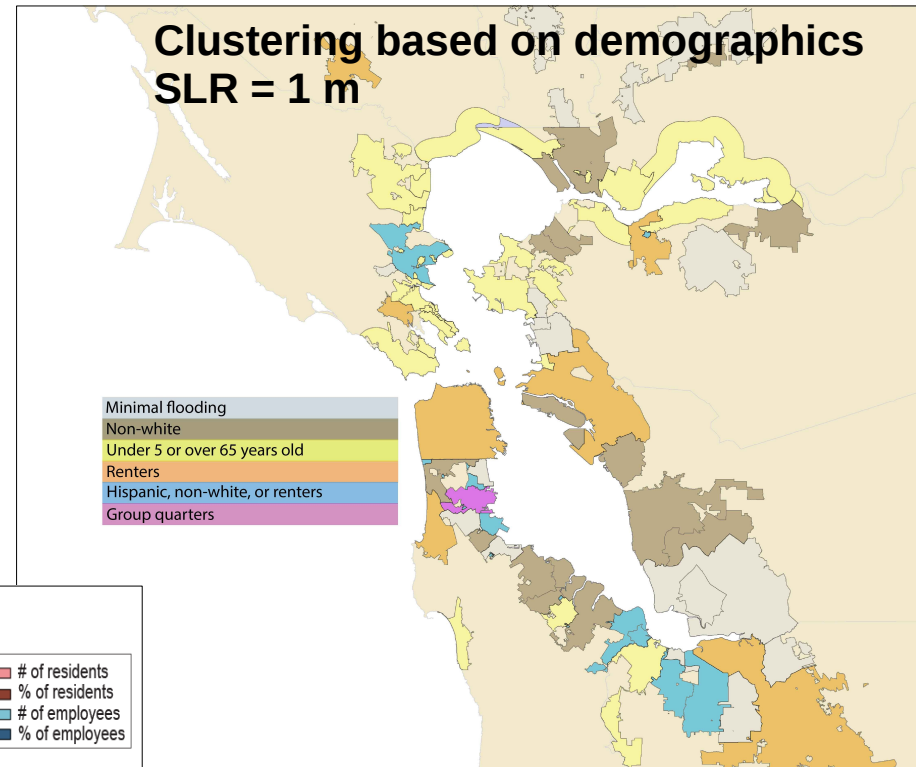


Containment



Shared Experiences

- Inundation map merged with census data
 - Clusters based on similarities between communities
 - Clustering varies with time (sea level) and data considered

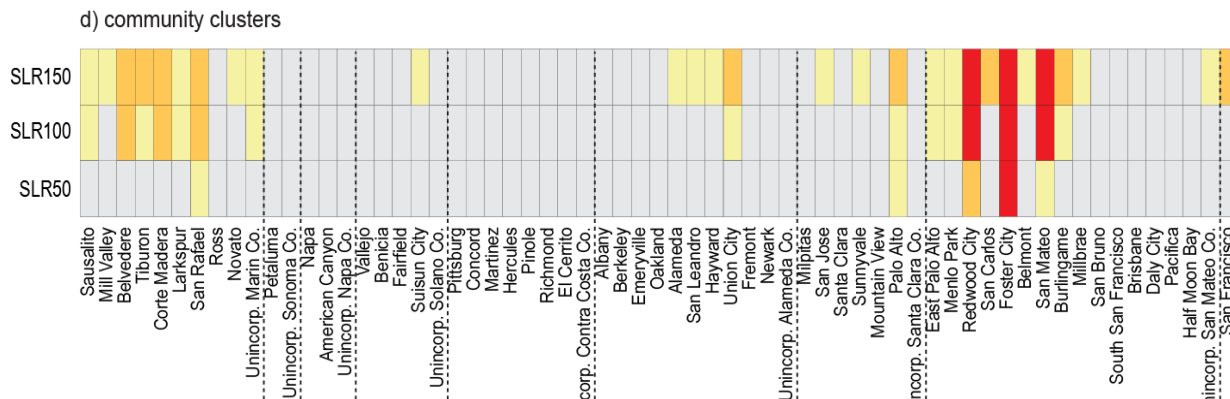
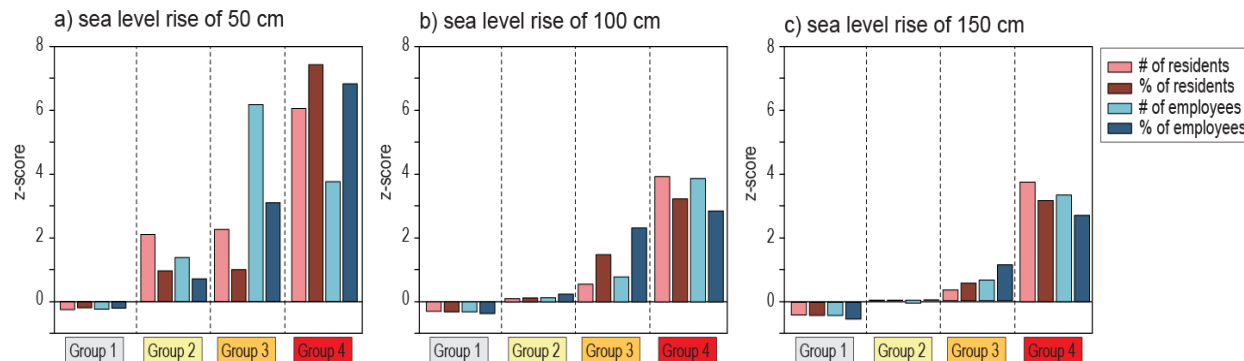
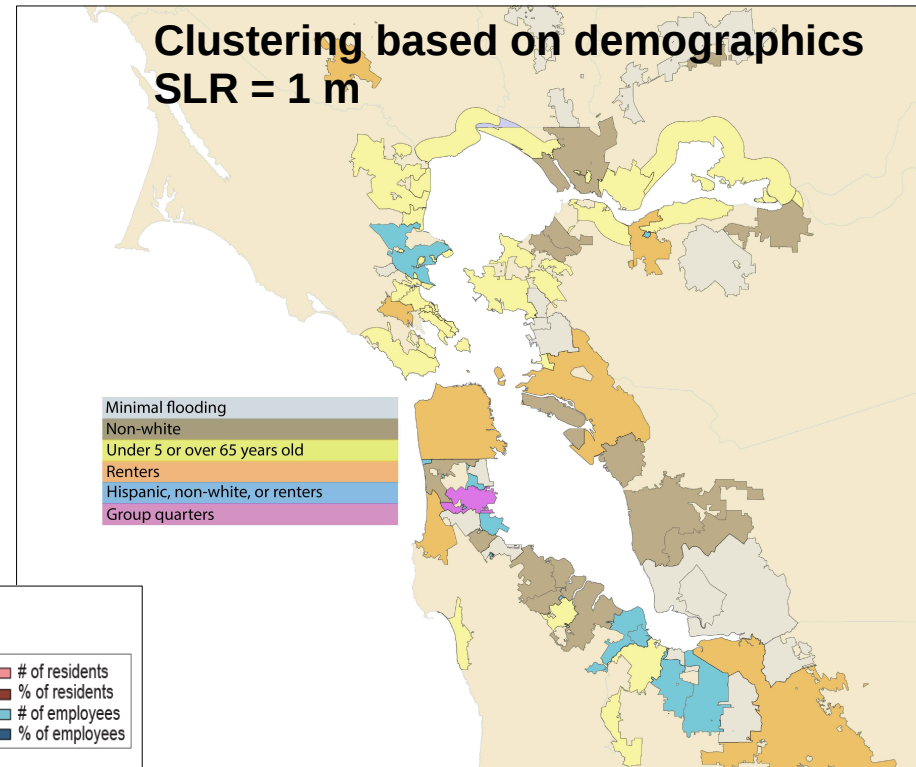


Time development of clusters

Hummel et al., in press at *Regional Environmental Change*

Shared Experiences

- Inundation map merged with census data
 - Clusters based on similarities between communities
 - Clustering varies with time (sea level) and data considered



Time development of clusters

- Regional Opportunity
 - Communities with similar risks may benefit from sharing knowledge
 - Future clustering may motivate unanticipated connection

Hummel et al., in press at *Regional Environmental Change*

Interdependent Vulnerabilities

- Disruption by flooding on Berkeley water front
 - 90% capacity reduction
- Behavioral model adjusts traffic patterns
 - Model built from cell phone data
- Travel time increases:
 - Green: 0%
 - Orange-Yellow: 0-50%
 - Red: >50%

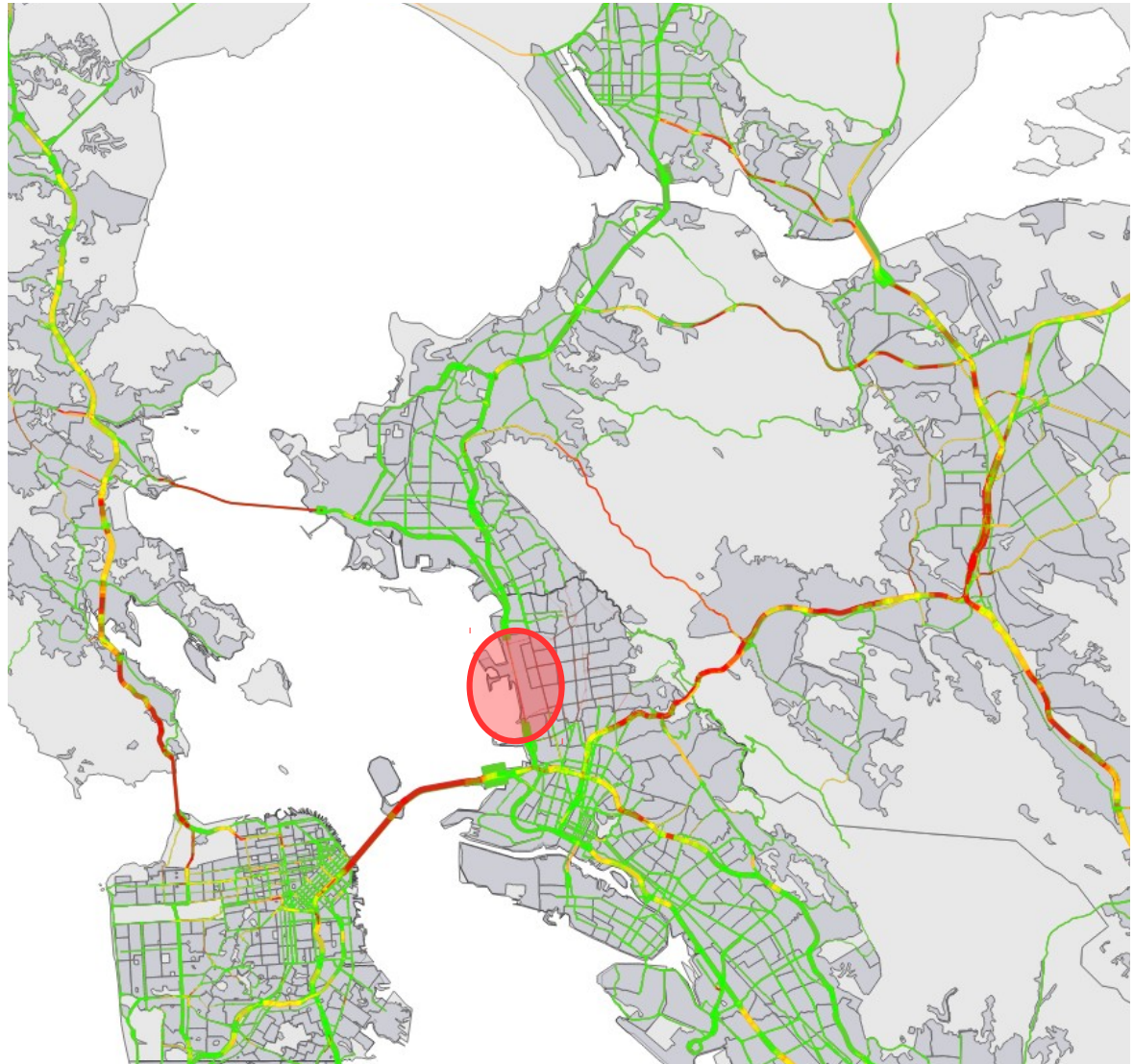
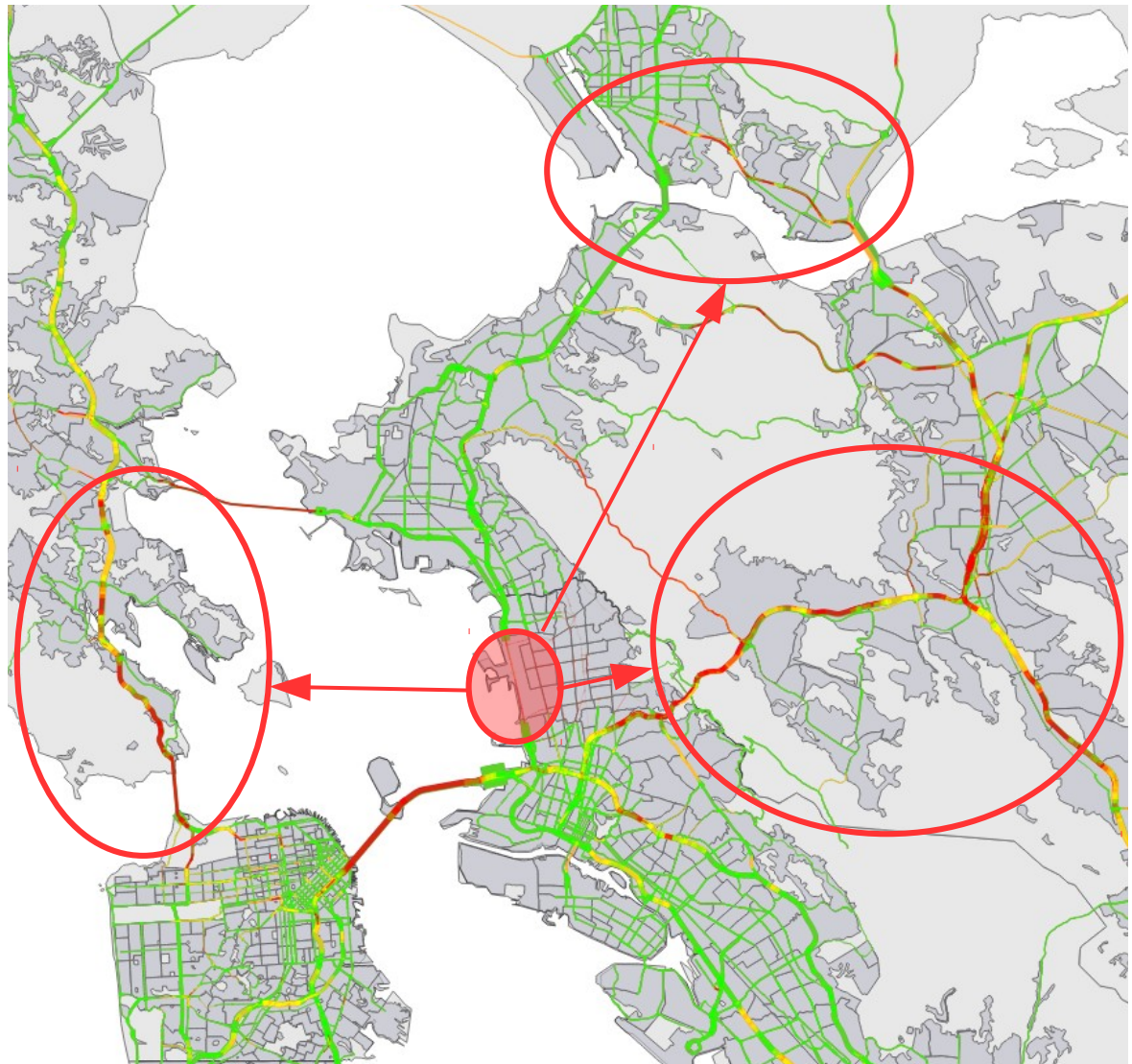


Figure from Sheehan and Pozdnukhov, unpublished

Interdependent Vulnerabilities

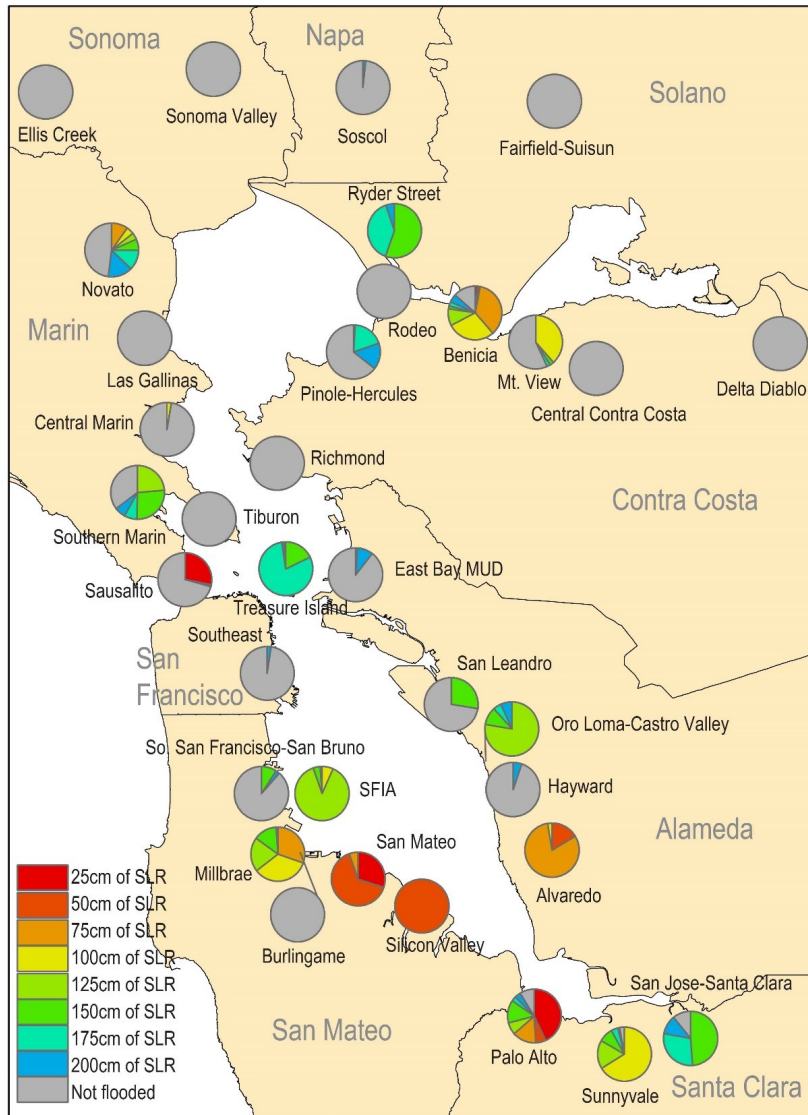
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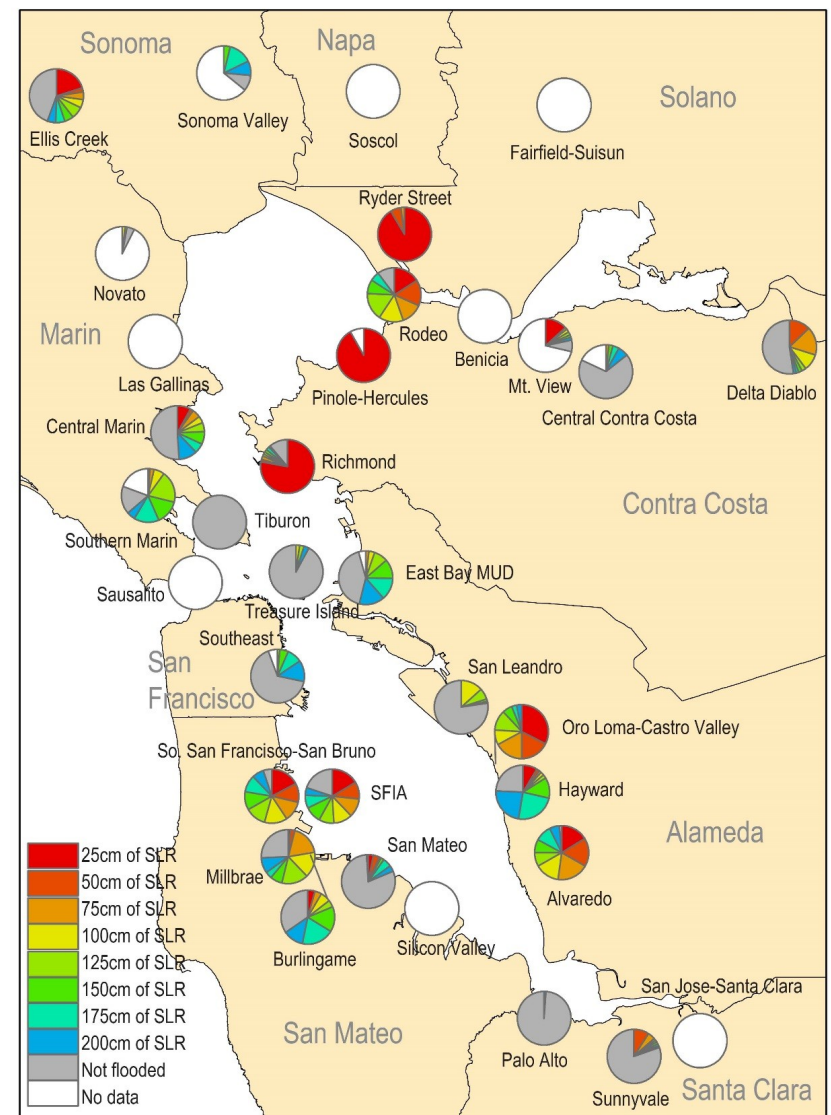
- Regional Costs due to Local Vulnerability
 - Localized inundation event creates regional changes in travel times and costs
 - Creates incentive for regional investment in local protections

Wastewater Infrastructure Vulnerabilities

Surface Water Flooding



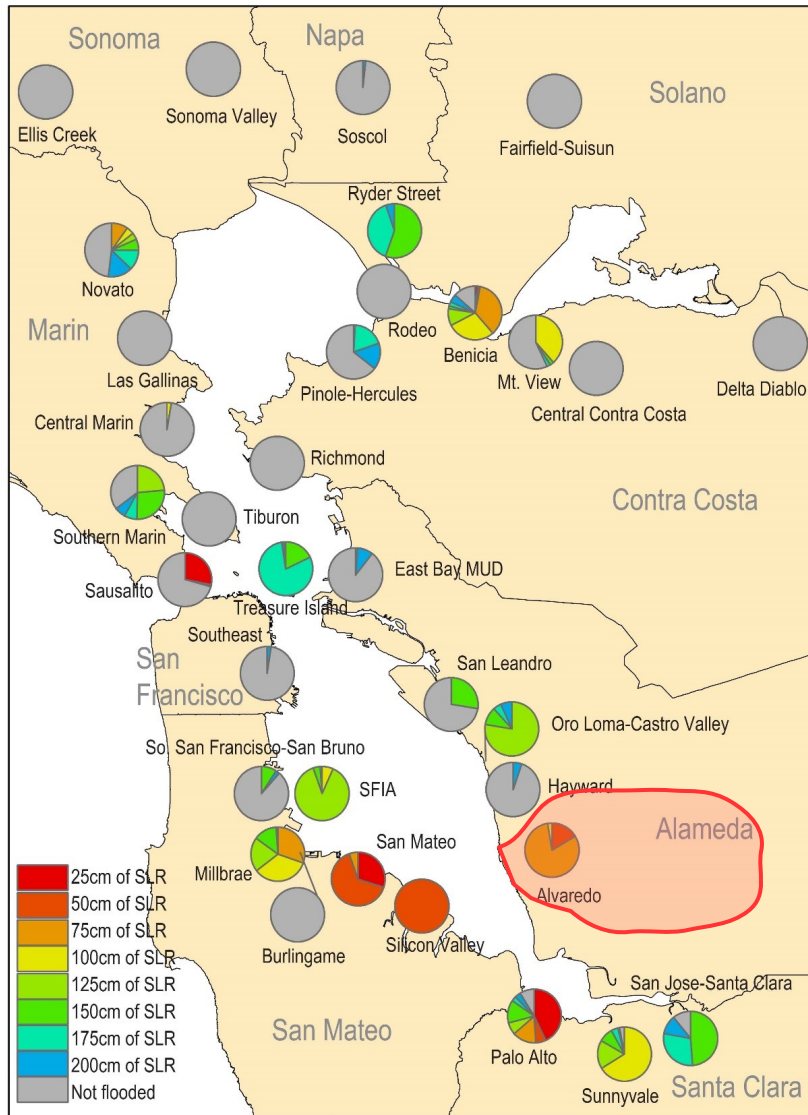
Groundwater Flooding



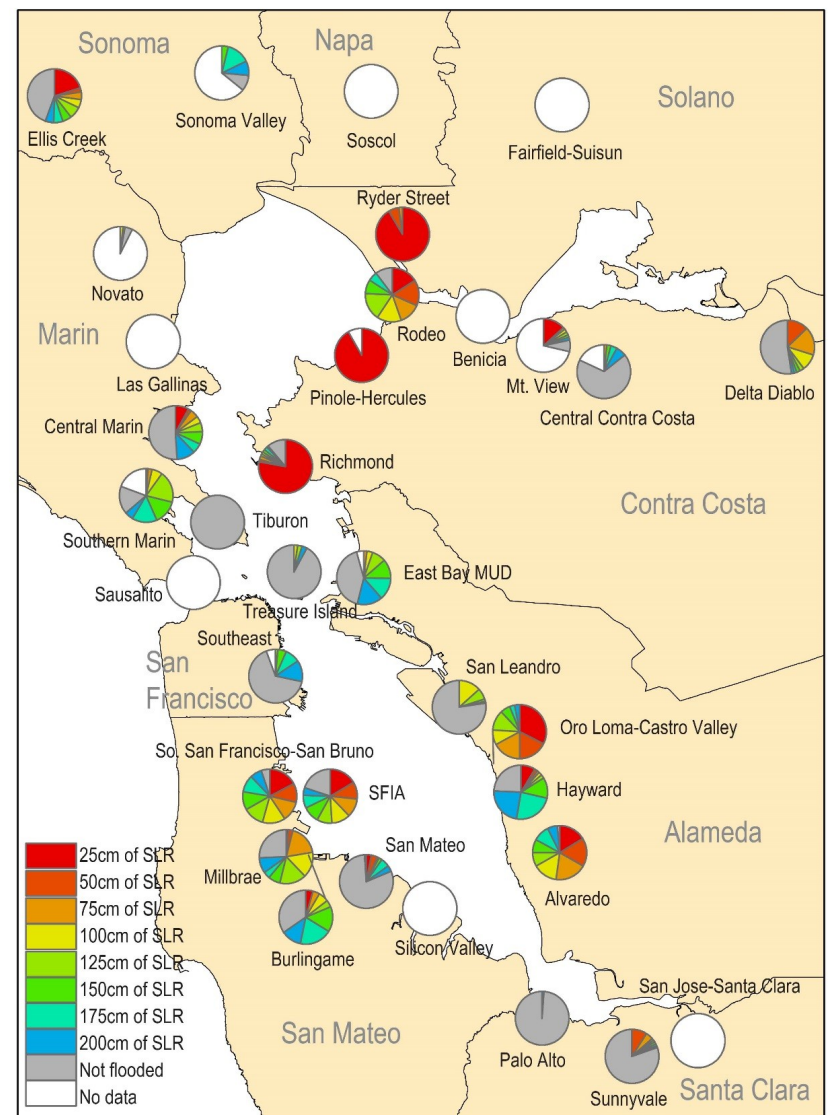
From Hummel et al., in press at *Earth's Future*

Wastewater Infrastructure Vulnerabilities

Surface Water Flooding

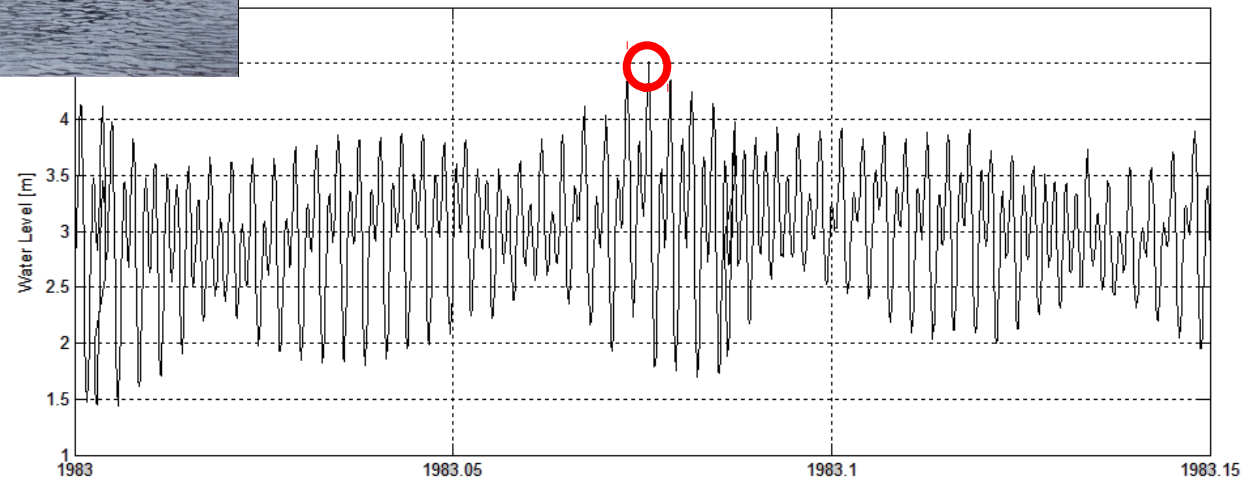
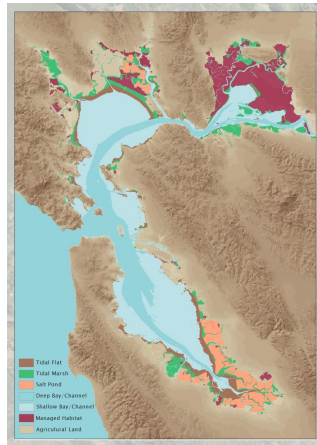
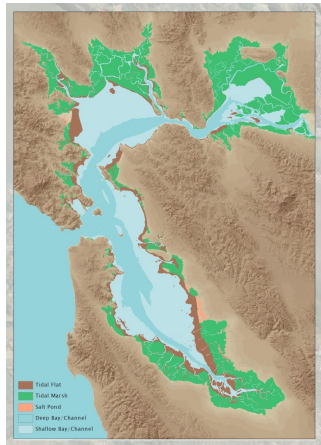


Groundwater Flooding



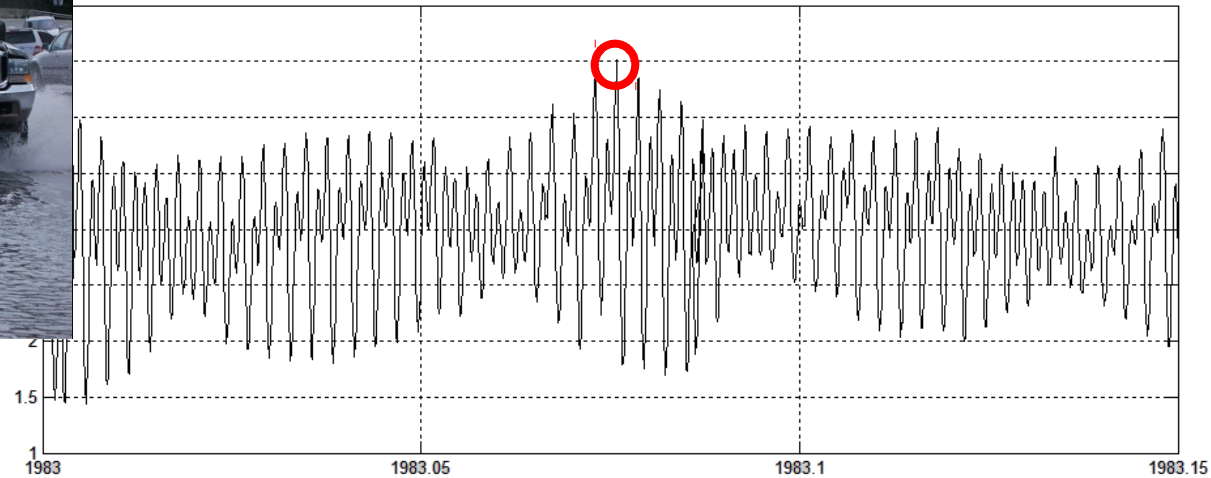
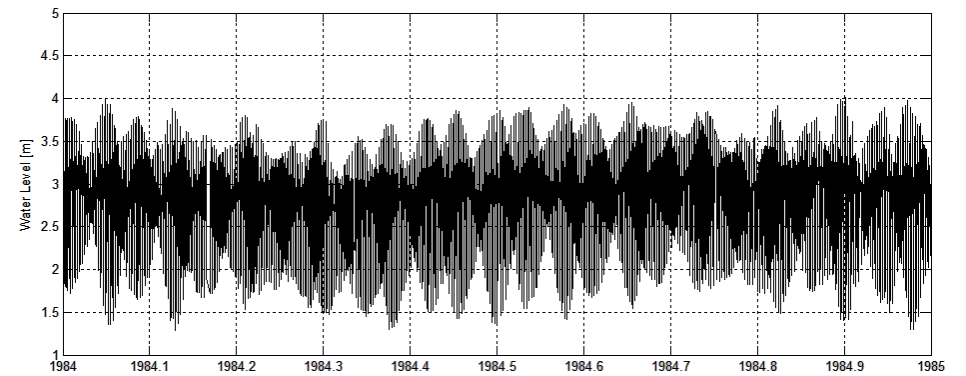
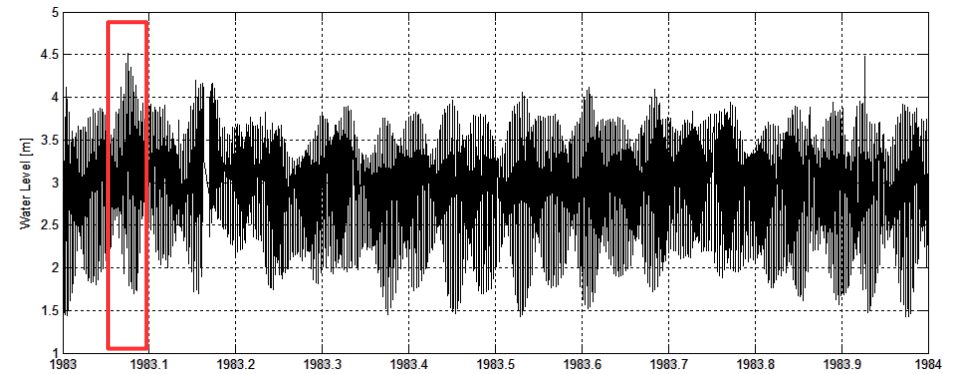
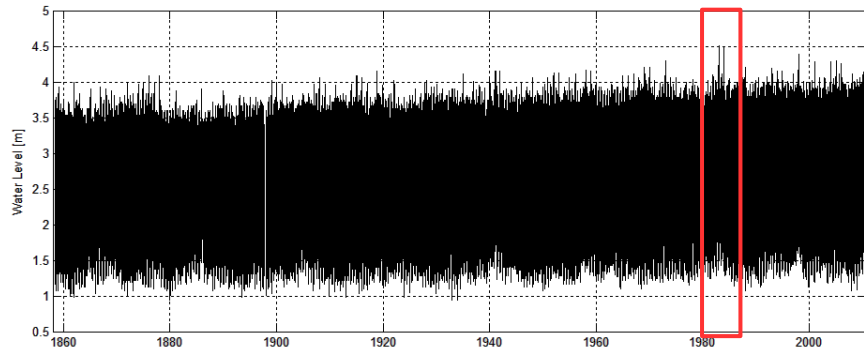
Lack of redundancy in wastewater network means vulnerabilities at key locations (WWTPs) create disruption for population served by facilities

Importance of the tides in SF Bay



- Tides dominate signature of high water events
 - Need to consider interaction of tides with the basin

Importance of the tides in SF Bay

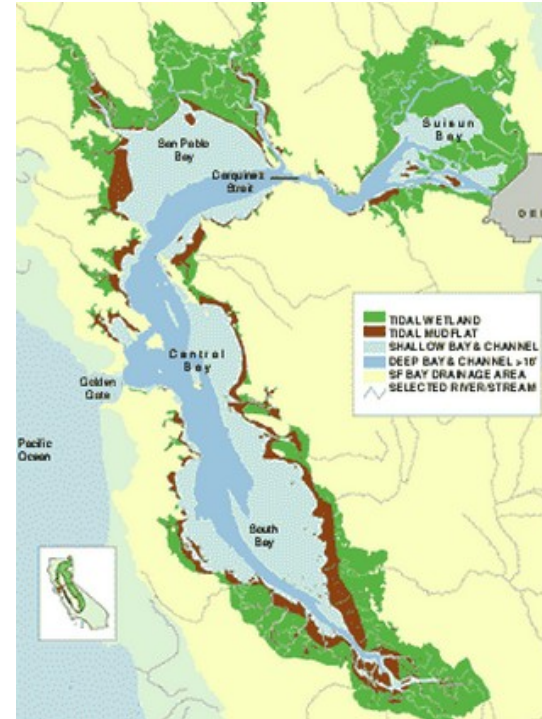


Tides in basins: Amplification v. Dissipation

- Tides can be amplified in basins
 - Set by interplay of tidal forcing and bathymetry and shorelines
- Friction and interaction with perimeter dissipate tidal energy
 - Wetlands, topography and shallow regions
- San Francisco Bay experiences both
 - South Bay: Amplified
 - North Bay: Dissipated

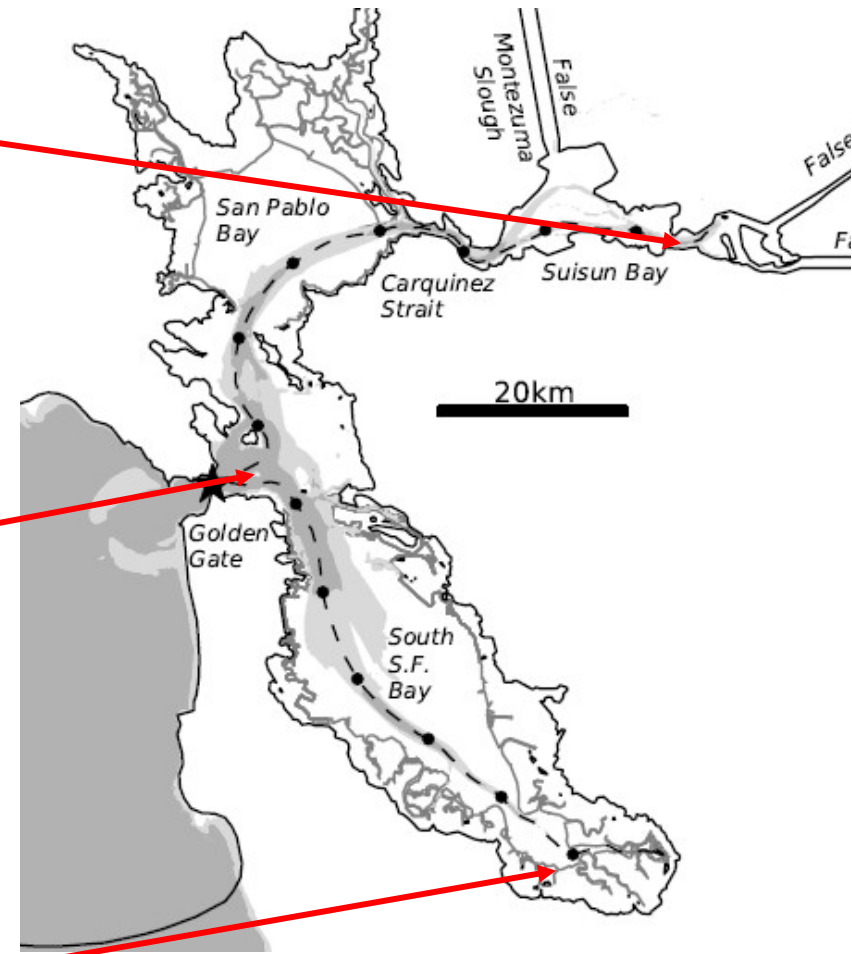
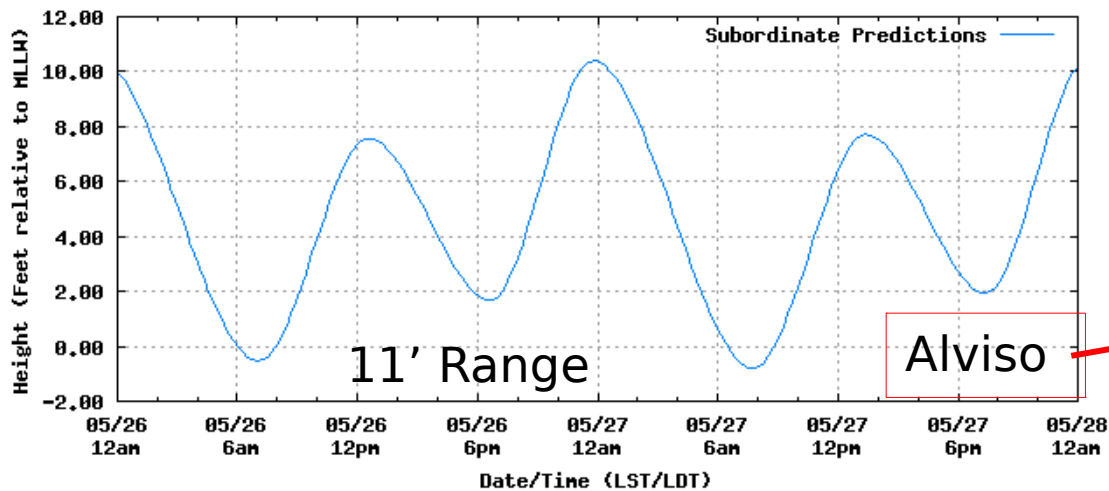
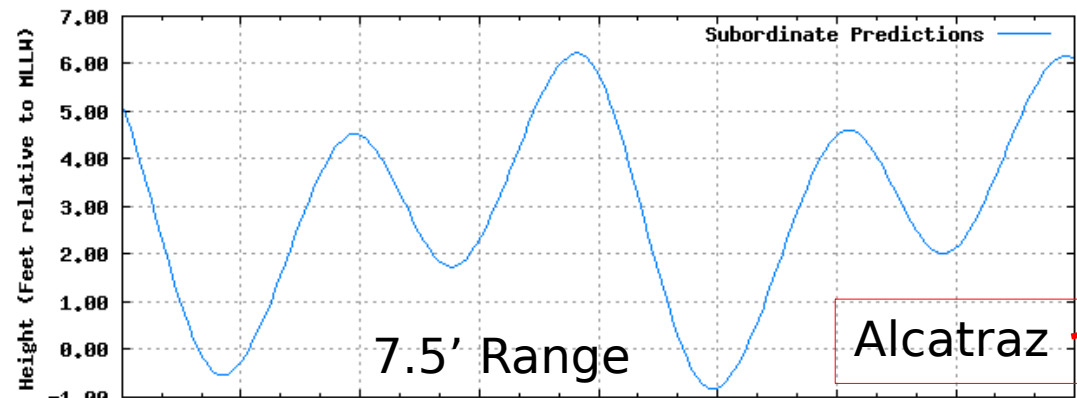
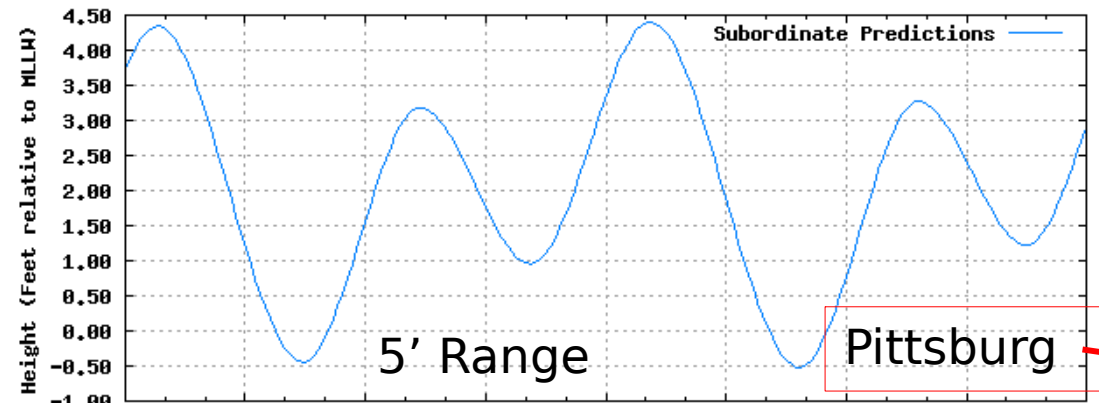


Bay of Fundy, Low and (nearly) High Tide

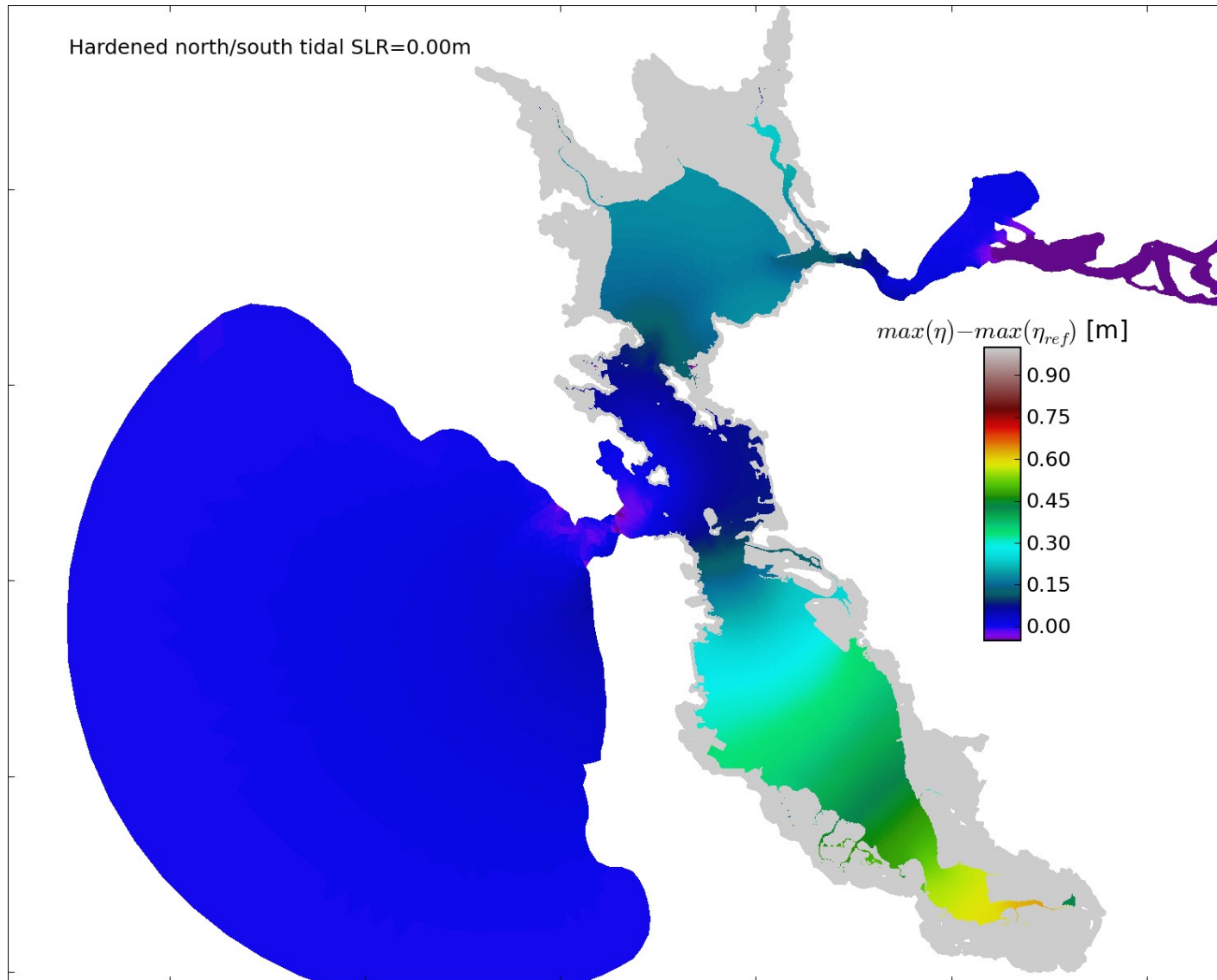


Historical SF Bay

Examples: SF Bay



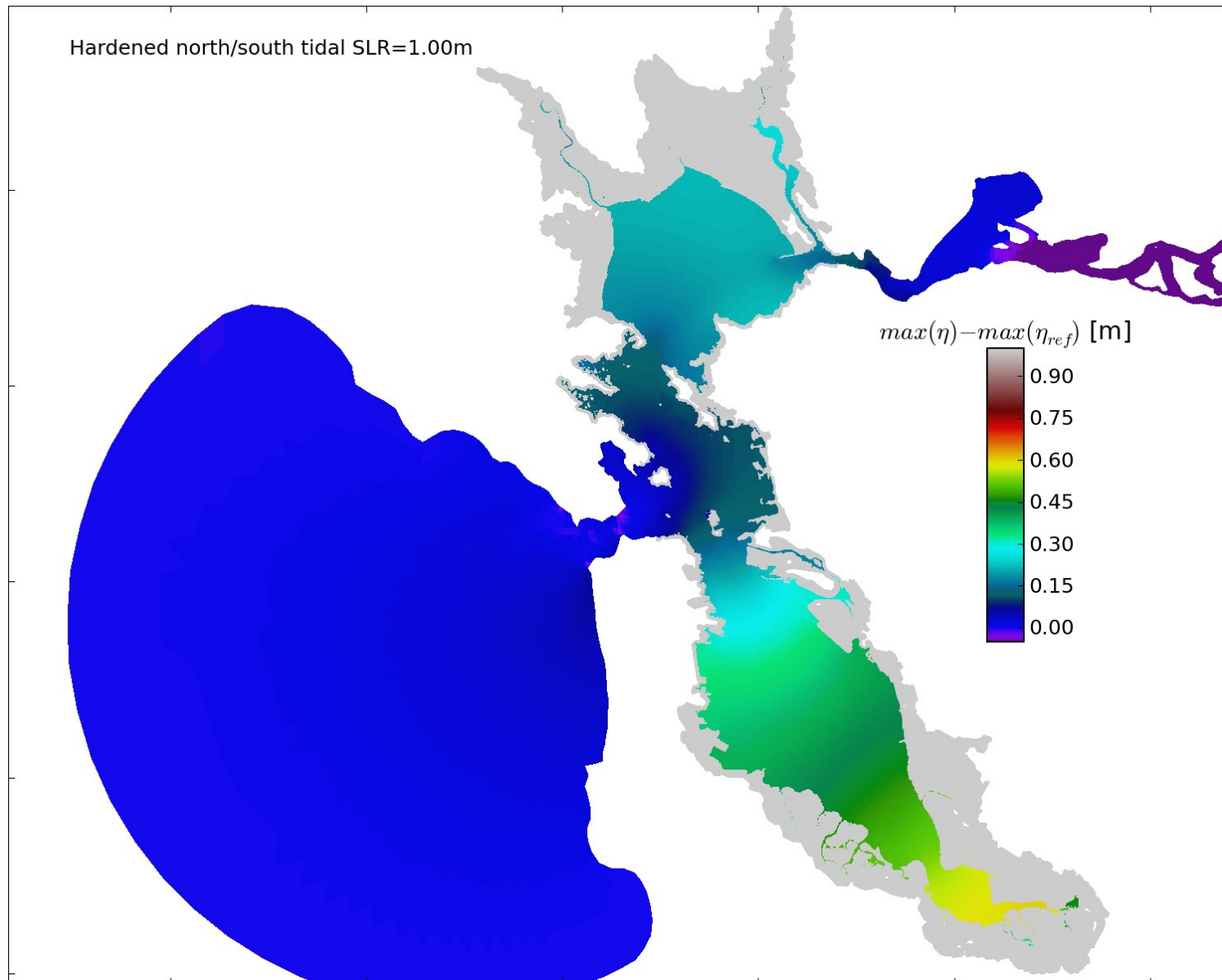
Current conditions with tidal forcing



Colors show water elevation *above* high water level in ocean (M2 tides)

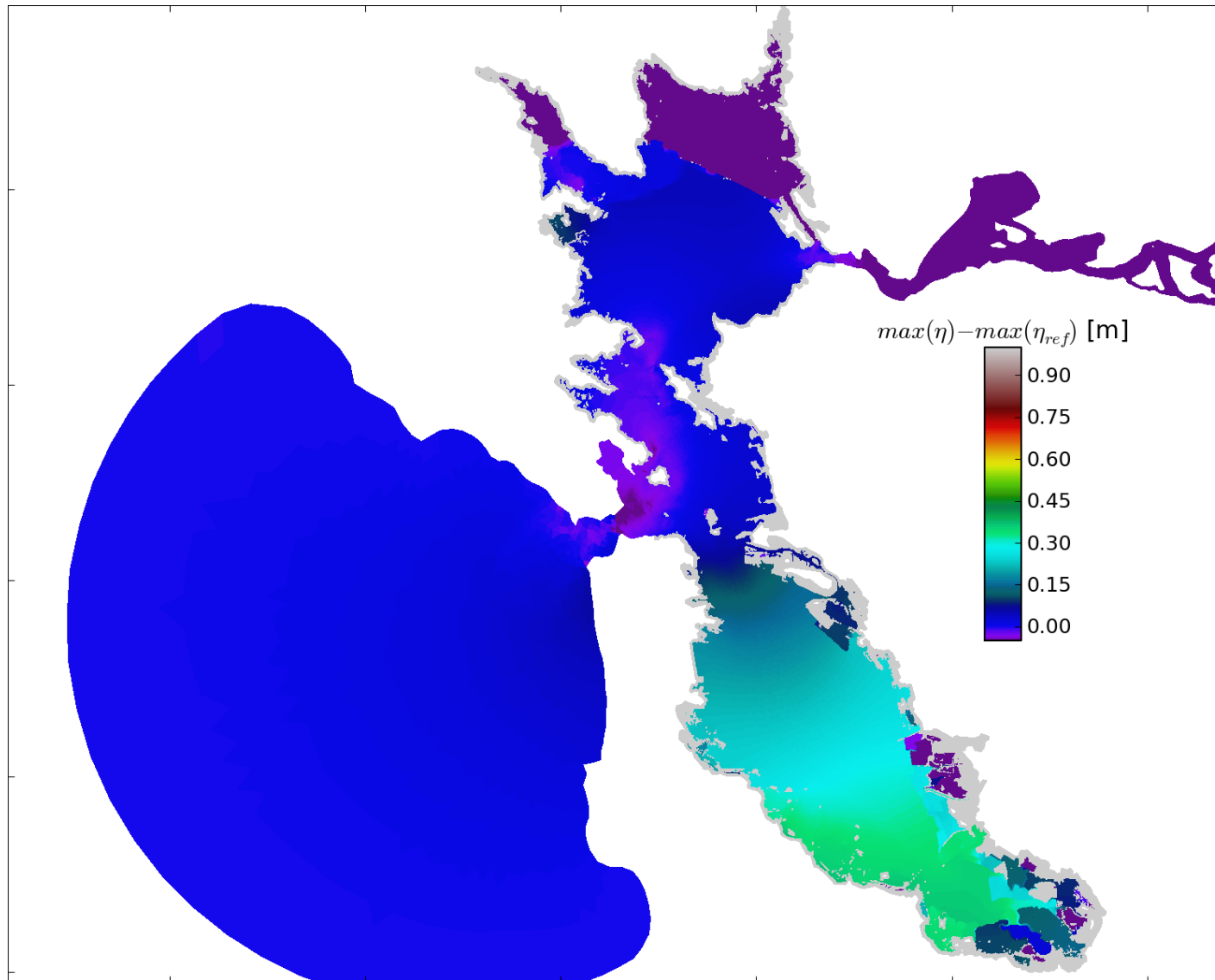
Gray areas show extent of grid

Full Containment, 1 meter SLR



Very similar to current conditions. SLR adds linearly to current water levels

Full Accommodation

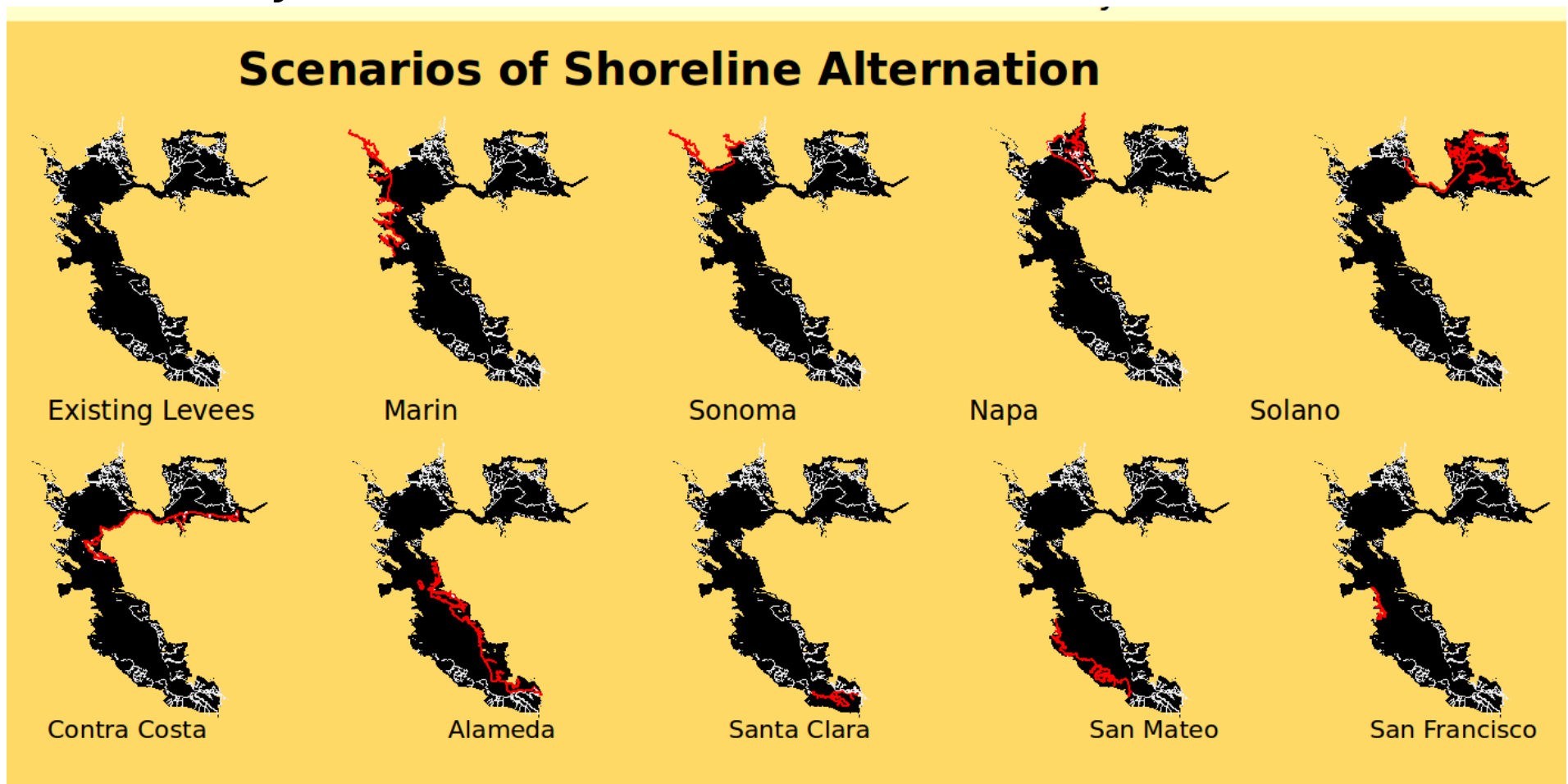


Water level in south bay is only 40-45 cm above ocean water level.

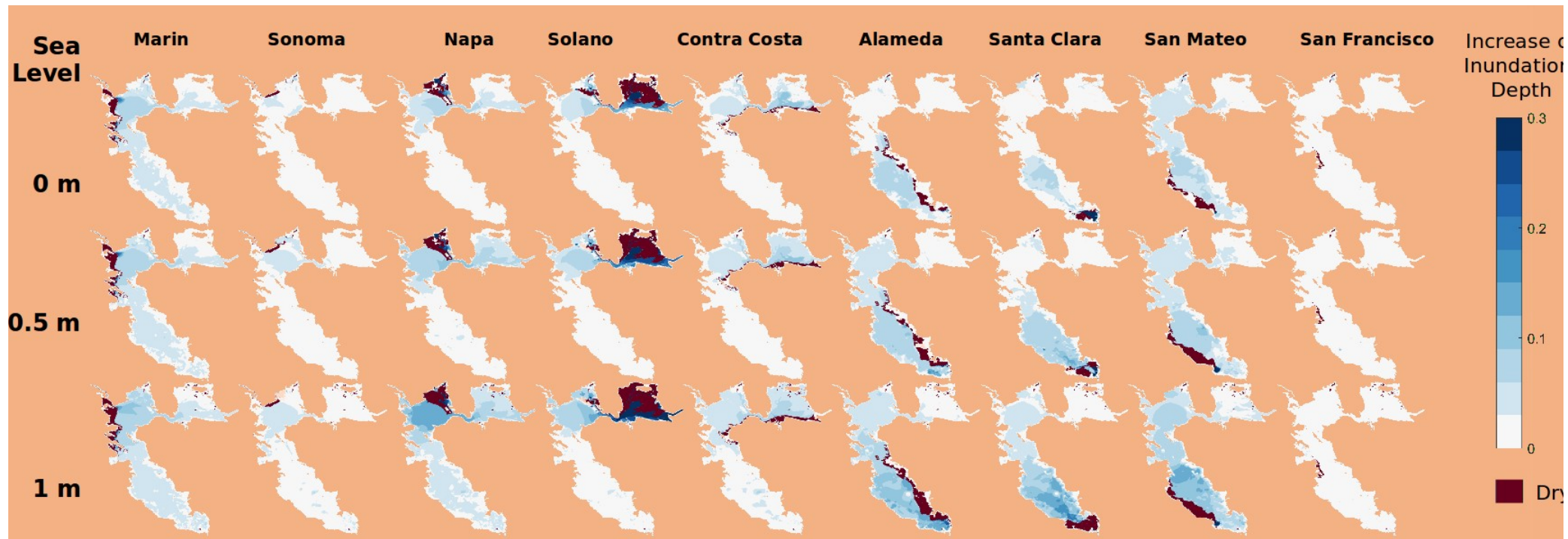
With full containment (previous), was ~60 cm above ocean water level.

County-by-county protective measures

- Existing topography/levees in white
 - Red lines show hardened shorelines for 9 county-by-county scenarios



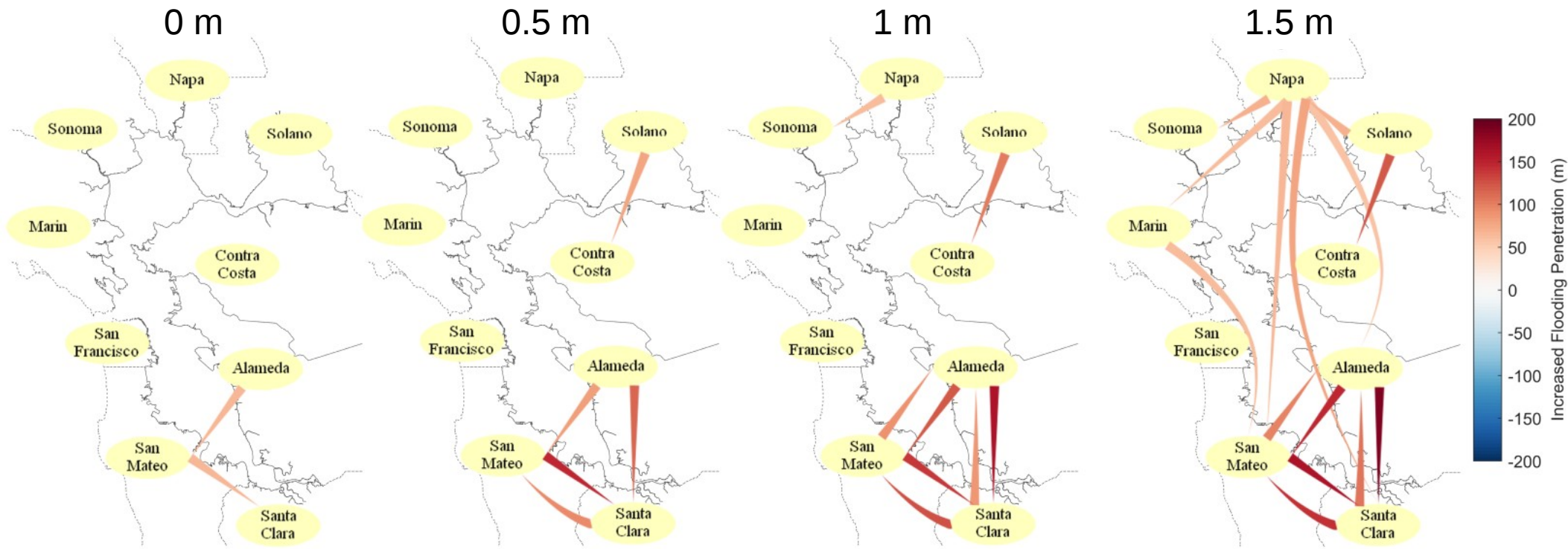
Water level response to county actions



- Shades of blue show how water level increases when walls are raised

Interdependent Adaptation

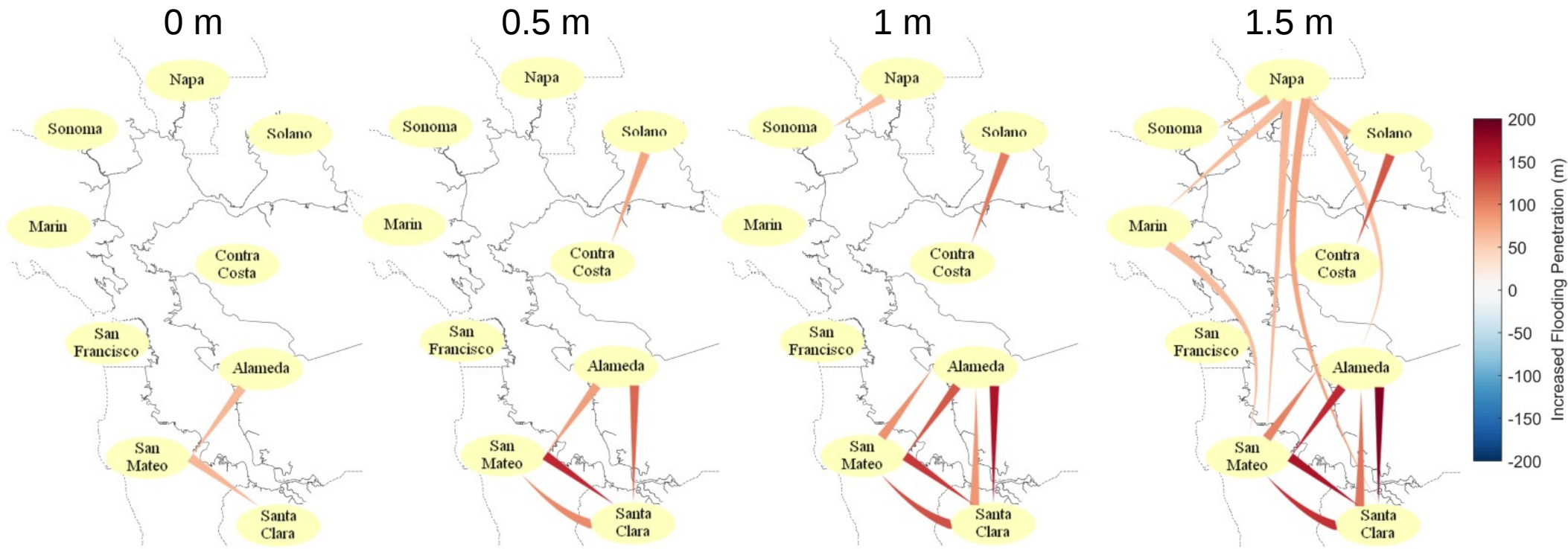
- Defining direct influence of action by one county on flooding in another
 - County-by-county shoreline protective action
 - Quantify change in flooding in other counties for 4 SLR scenarios



From Wang et al., in press at *Earth's Future*

Interdependent Adaptation

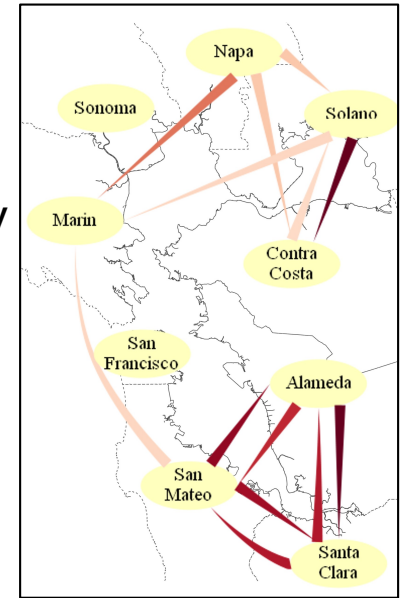
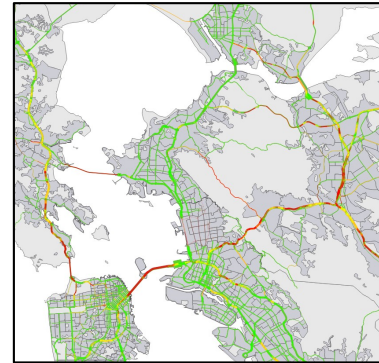
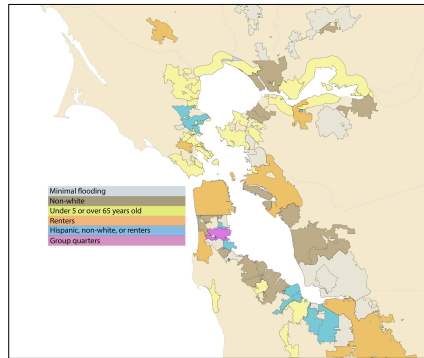
- Defining direct influence of action by one county on flooding in another
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- Regional Impacts of Local Actions
 - Direct interactions means counties planning activities must account for others
 - Strongly motivates coordinated actions

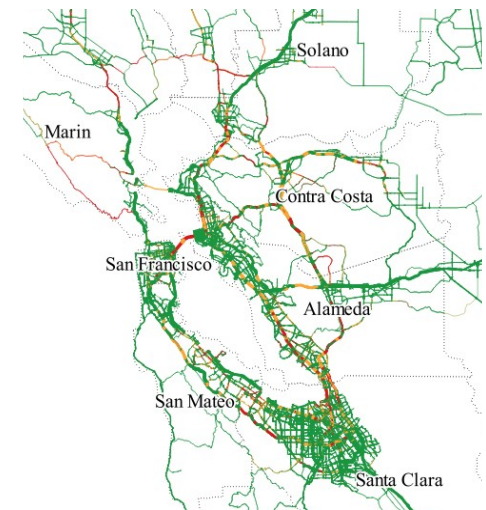
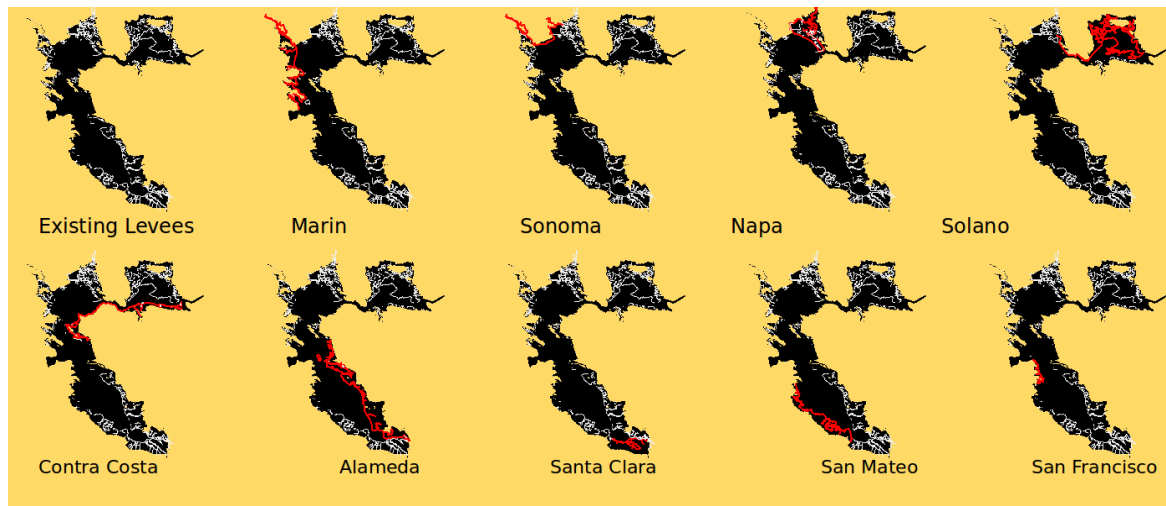
Regional Coordination in SLR Adaptation

- Summary of interdependencies
 - Shared Experience: Value of sharing knowledge
 - Interdependent Vulnerability: Regional cost from local vulnerability
 - Interdependent Adaptation: Regional impacts of local actions



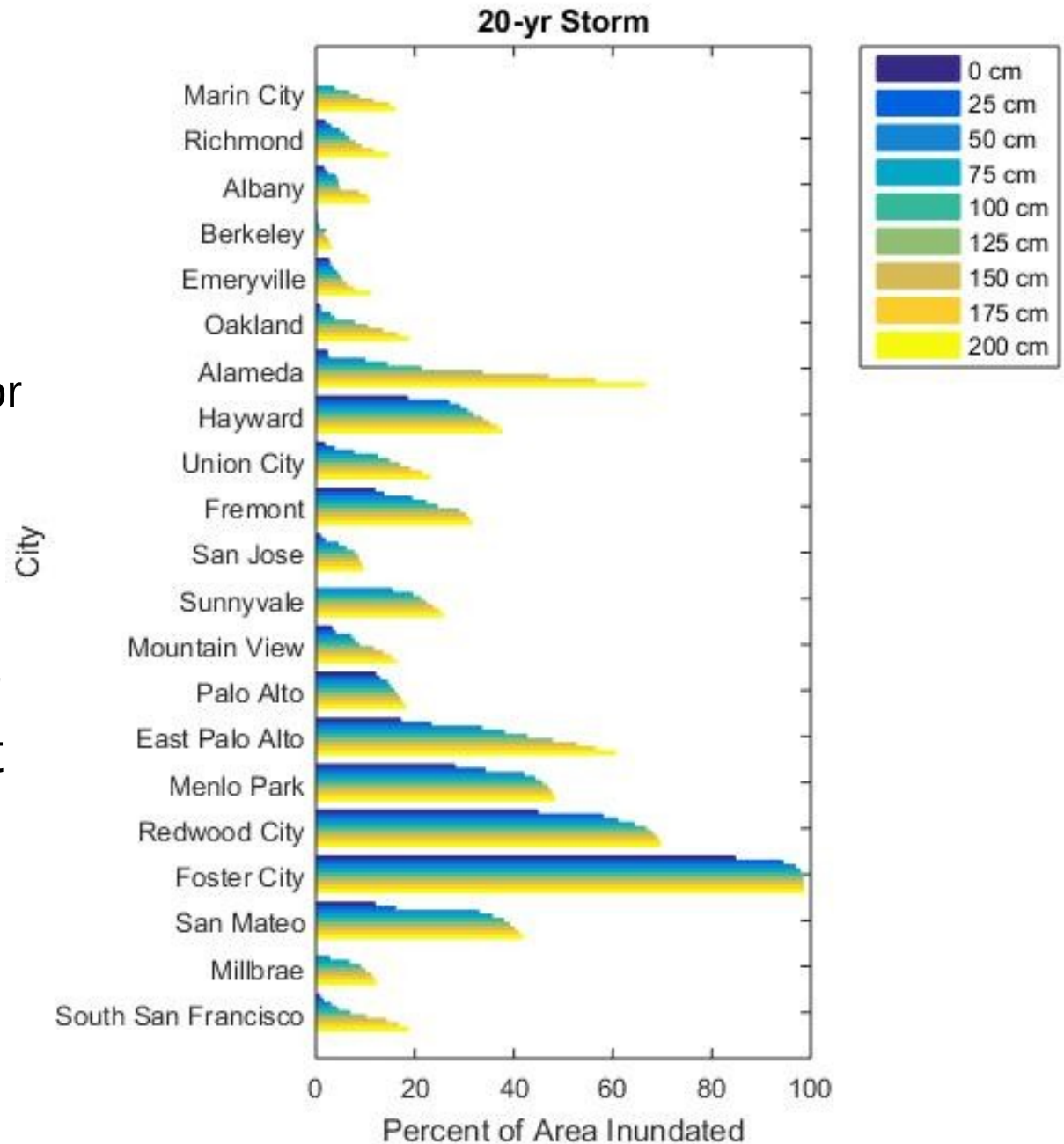
Lubell et al., In preparation for
Nature Climate Change

- Consider interaction between shorelines and transportation infrastructure



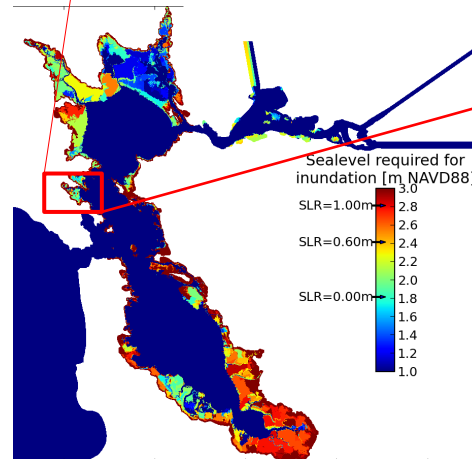
Barriers to Regional Action: Timing

- Different communities feel the threat of coastal flooding with different levels of urgency
 - For some it is immediate, for others it is decades away
- Regional coordination requires an understanding of shared vulnerabilities at a particular time of action or planning



Barriers to Regional Action: Socio-economics

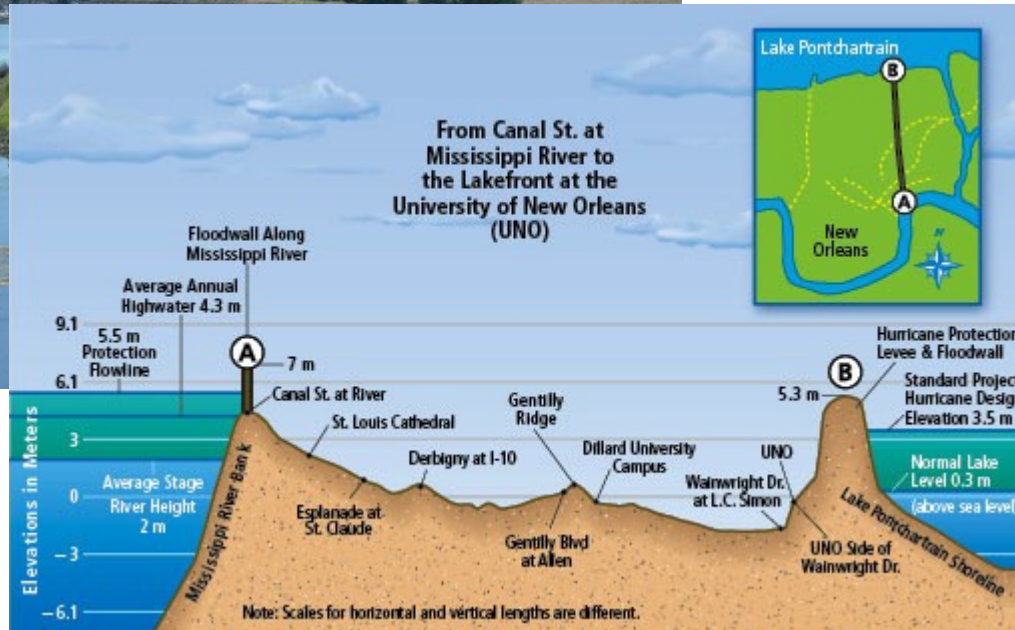
- Heterogeneity in socio-economic power
 - Many vulnerable bayfront communities have limited ability to invest for long-term
 - Interdependencies may create regional incentives for investment



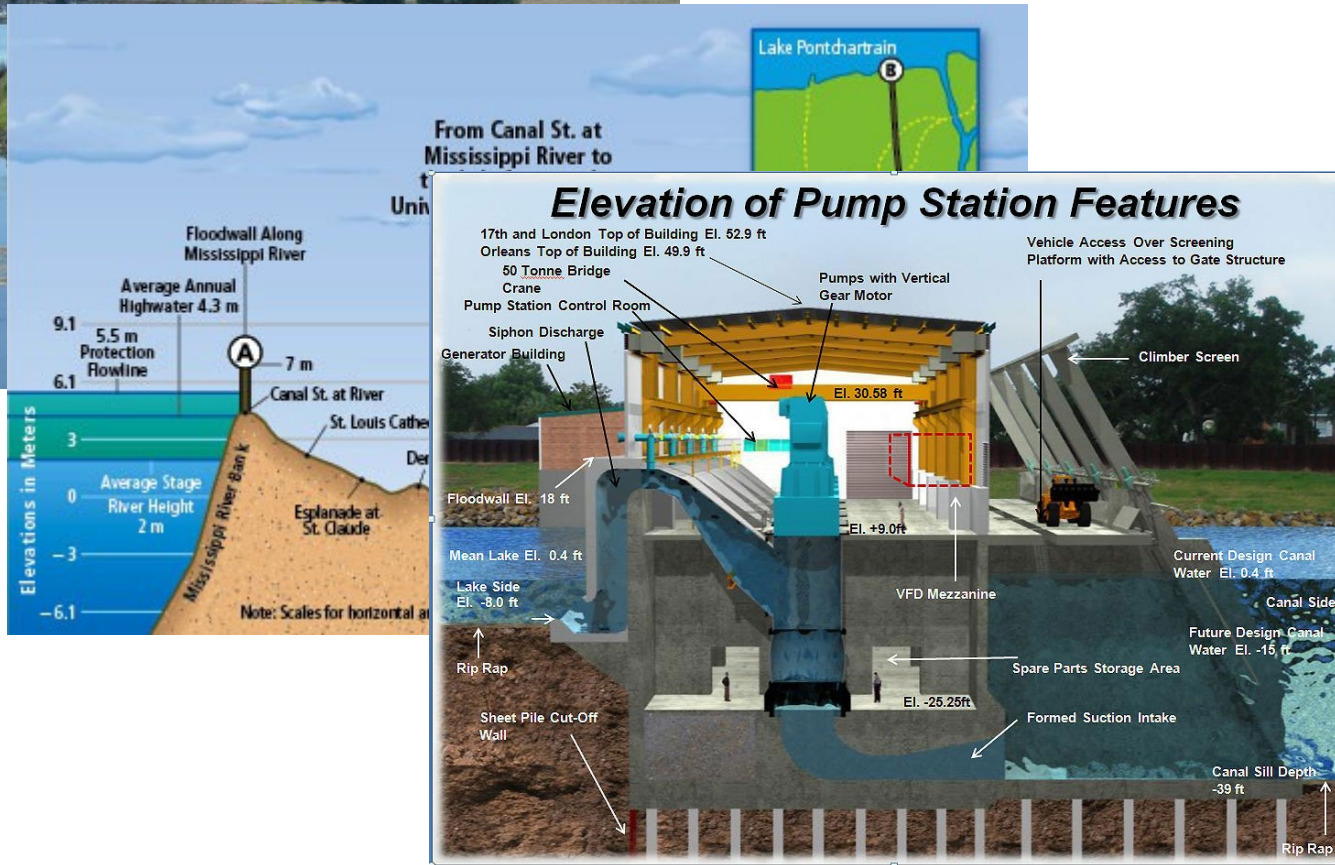
Path Dependency in Decision-Making



Path Dependency in Decision-Making

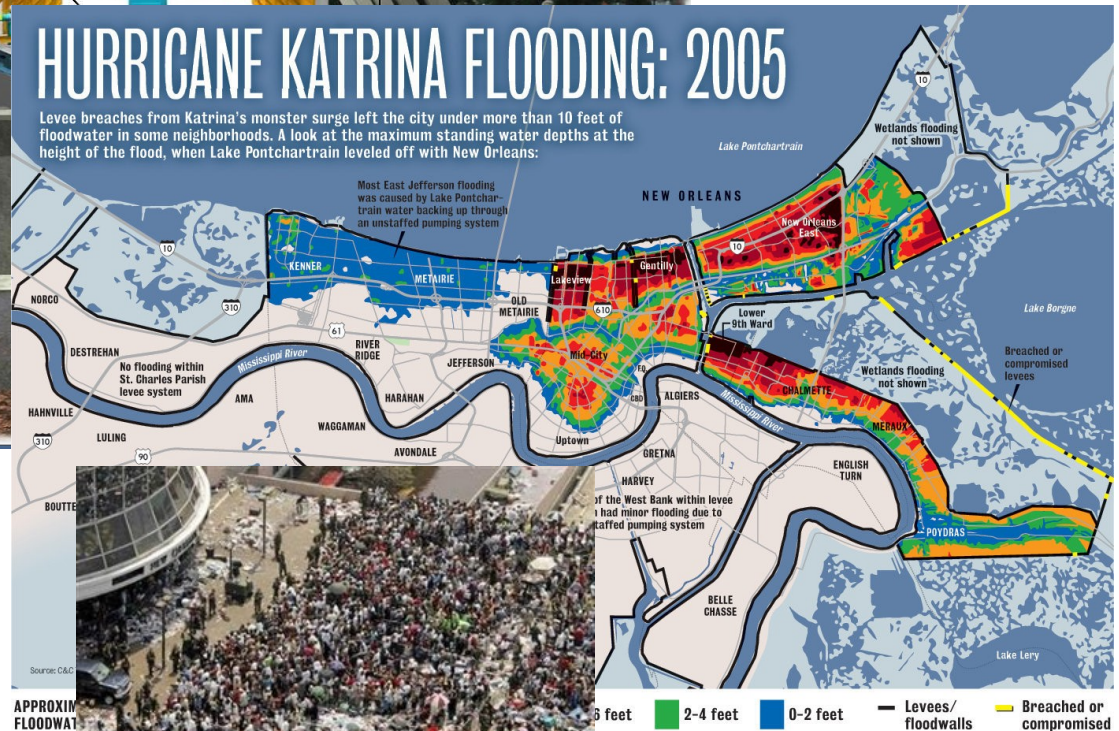


Path Dependency in Decision-Making

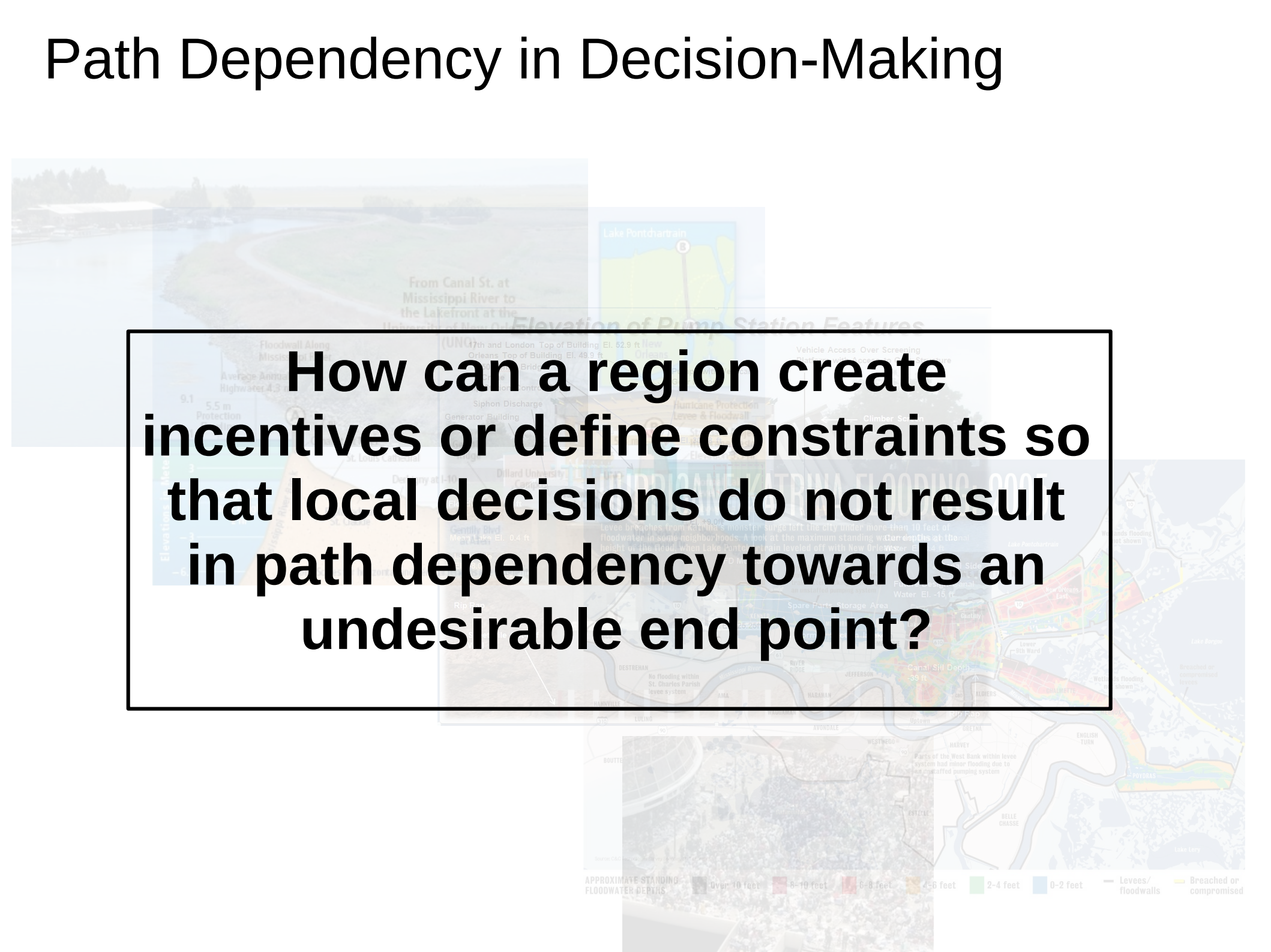


The image shows an aerial view of the Mississippi River floodwall on the left, with a large building and parking lot. On the right, a diagram illustrates the floodwall structure. The diagram includes the following labels and data:

- Floodwall Along Mississippi River**
- Average Annual Highwater 4.3 m**
- 5.5 m Protection Flowline**
- 9.1** (elevation)
- 6.1** (elevation)
- 7 m** (width)
- From Canal St. at Mississippi River to**
- Elevations**
- 17th and London Top of Building**
- Orleans Top of Building El. 49**
- 50 Tonne Bridge Crane**
- Pump Station Control Room**
- Siphon Discharge**
- Generator Building**



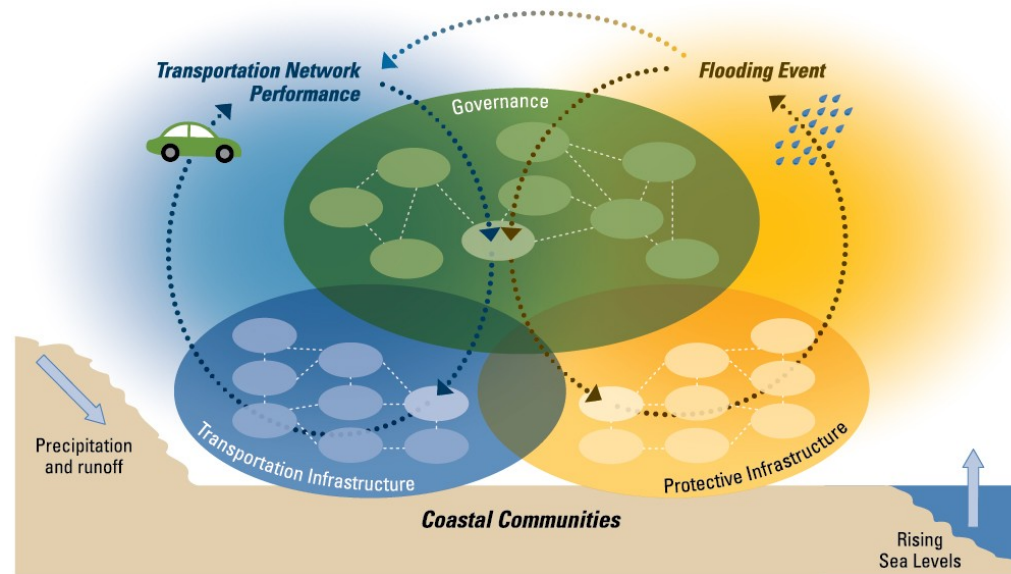
Path Dependency in Decision-Making

The background of the slide is a collage of various images related to flooding and infrastructure. It includes an aerial view of a flooded area, a map of Lake Pontchartrain, a map of New Orleans showing flood depths, and a map of the Mississippi River levee system. The text is overlaid on a semi-transparent black box in the center of the collage.

How can a region create incentives or define constraints so that local decisions do not result in path dependency towards an undesirable end point?

Opportunities and Challenges

Immediacy of threat to local communities creates inequities in response – Regional interdependence provides counterbalance.



Opportunities from Regional Analyses:

- Consider future scenarios
 - Move discussion beyond immediate threats and consider end state for region
 - Scenario-based approach can help eliminate “leader-follower” dynamics
- Establish local-regional interactions
 - Regional costs of local action or inaction (vulnerabilities)
 - Local impacts of regional strategies



Questions?