

GROUNDWATER + SEA LEVEL RISE

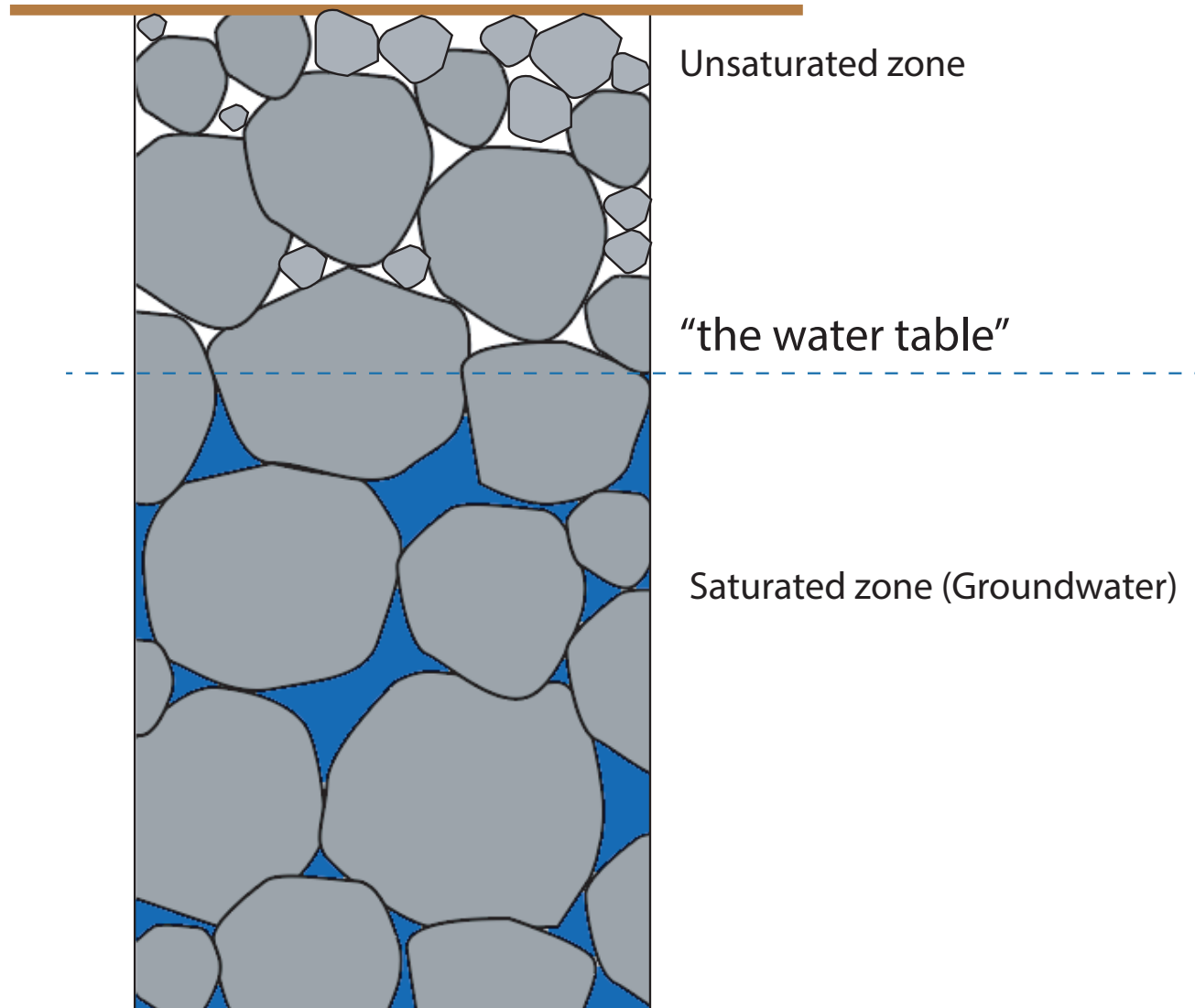
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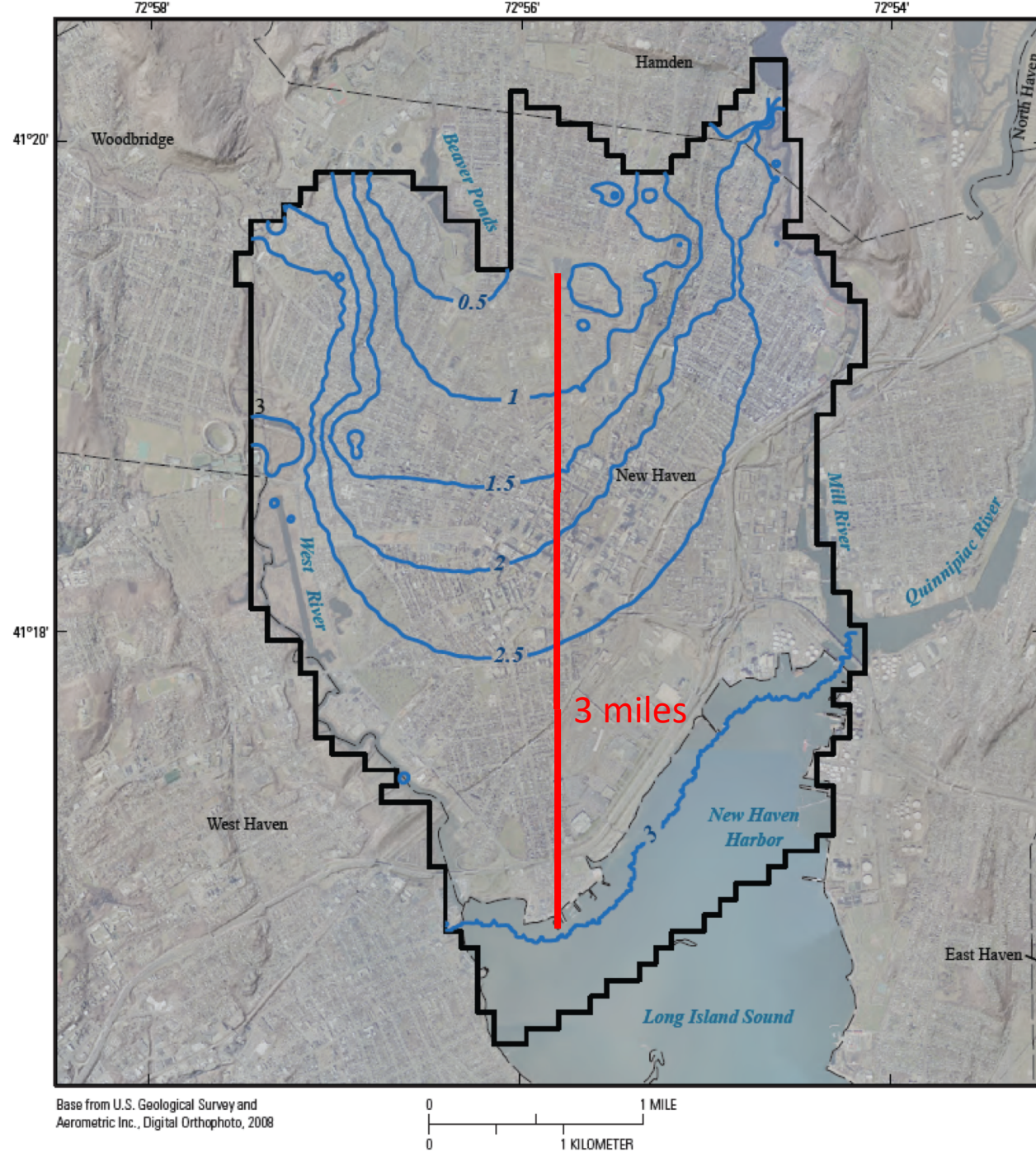
Pore spaces in soil



Groundwater is water from rainfall that is stored in the soil.

The “water table” refers to the shallowest layer of that water, which often lies just below the surface of the soil.

Why is **rising** groundwater a
new problem?

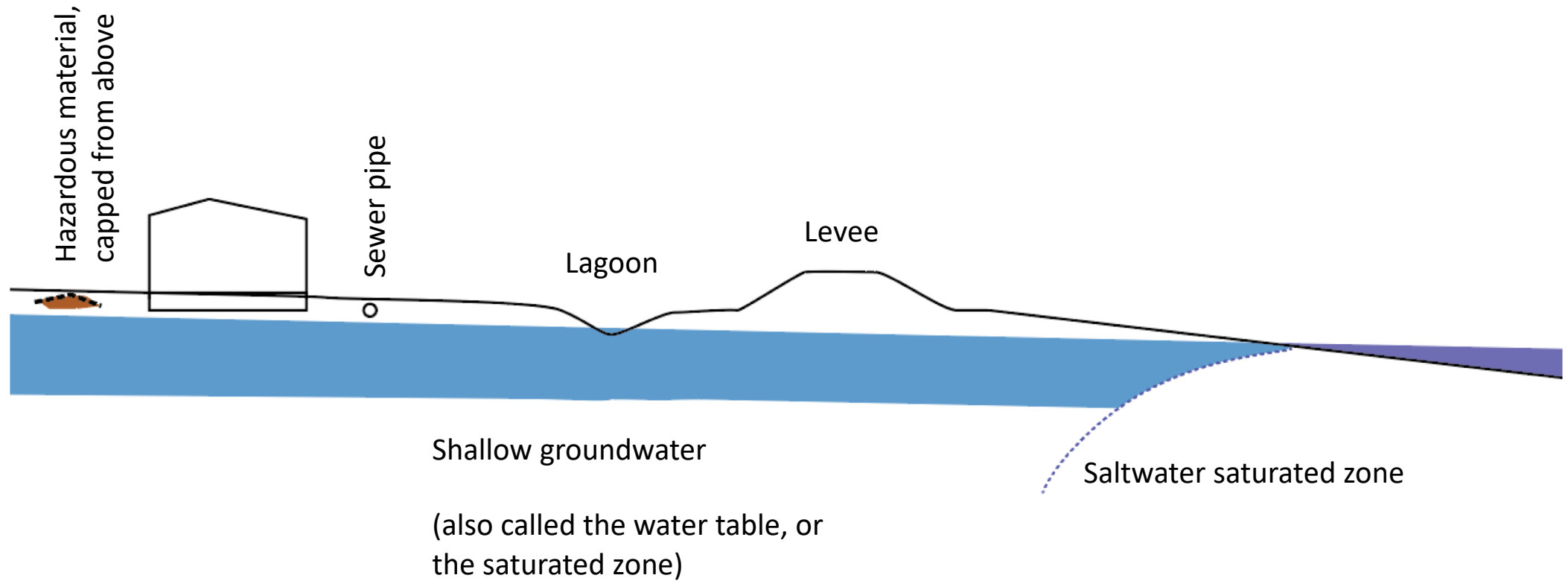


USGS study of New Haven, CT, 2012

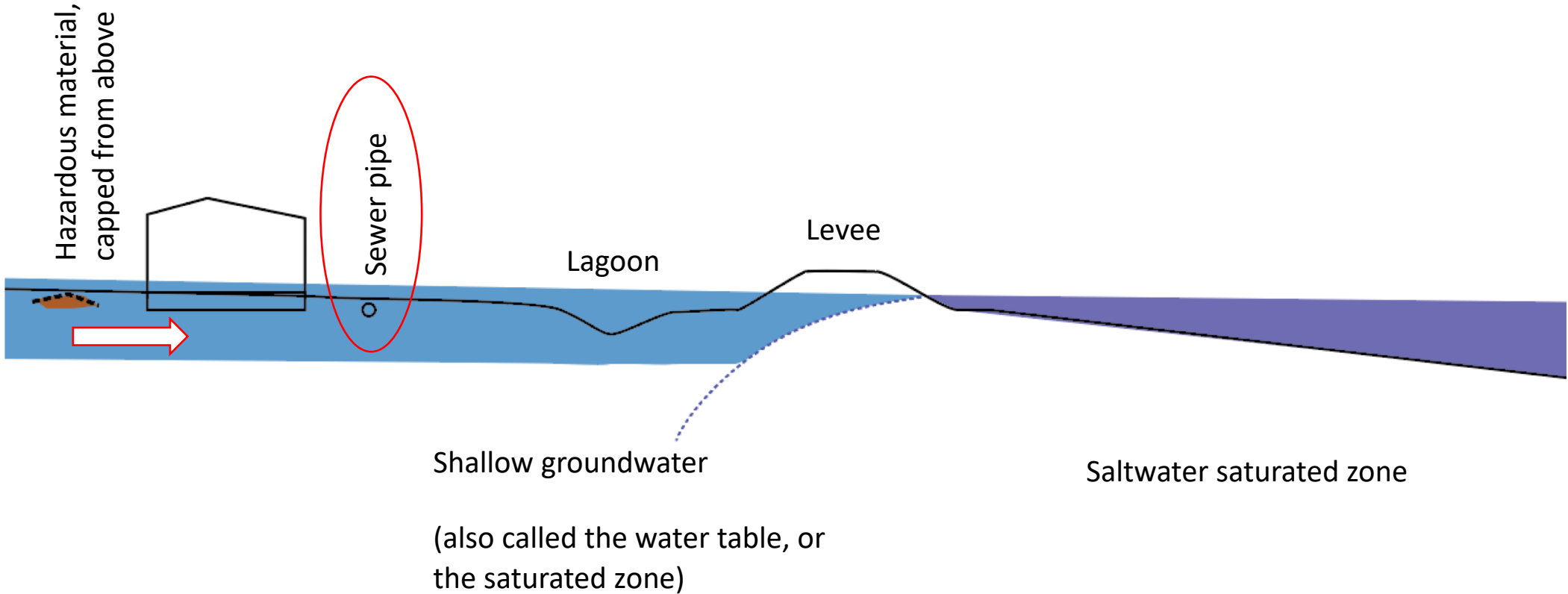
- Based on data from 13 wells
- Used MODFLOW to simulate groundwater rise and discharge
- Found that increases in groundwater levels are likely to extend 3 miles from the shoreline with 3 feet of sea level rise

Bjerklie, D.M., Mullaney, J.R., Stone, J.R., Skinner, B.J., and Ramlow, M.A., 2012, Preliminary investigation of the effects of sea-level rise on groundwater levels in New Haven, Connecticut: U.S. Geological Survey Open-File Report 2012-1025,

Existing conditions



If sea level rises 3 feet, then shallow groundwater rises 3 feet, within about a half a mile of the bay - maybe farther inland as well.



City of Palo Alto Shallow Groundwater Map

Map created: April 2016
 Authors: B. Wenzlau, L. Erban, P. Eberspacher, B. Han
 Terradex, Inc.

Palo Alto Groundwater with contaminant plumes

Terradex, 2016

Methodology.

Contours: Depth to water (DTW) data is provided by the City of Palo Alto's database of soil borings. The locations of borings are shown as black circles on this map. DTW in these borings, where available, is averaged in square grid cells measuring ~1300 ft on each side. Spatially averaged DTW is contoured in 5 ft increments shown on map.

Hydrographs: Depth to water (DTW) data is provided by the California State Water Resources Control Board through its GeoTracker GAMA groundwater information system, available at: <http://geotracker.waterboards.ca.gov/gama/>.

These data are plotted in hydrographs 1-5 at right for a selection of monitored wells, which are also identified by their "Well ID" from GAMA. No attempt is made here to correct DTW data for well riser heights, which may increase DTW by a small, but unknown amount.

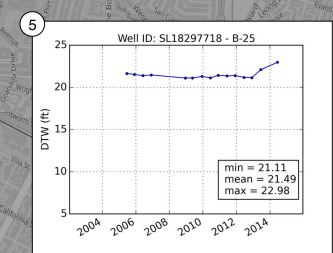
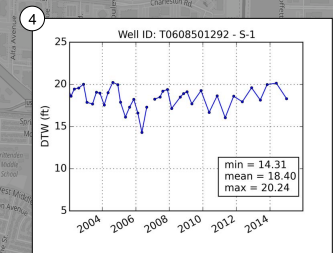
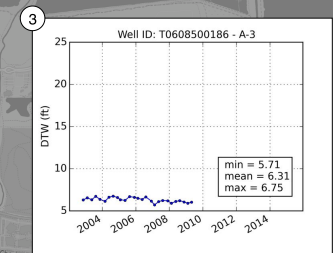
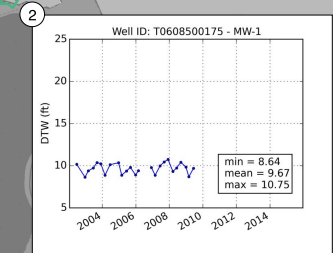
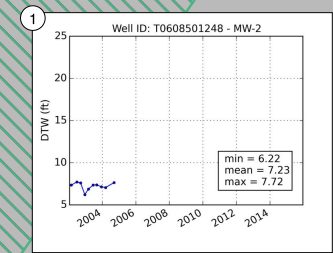
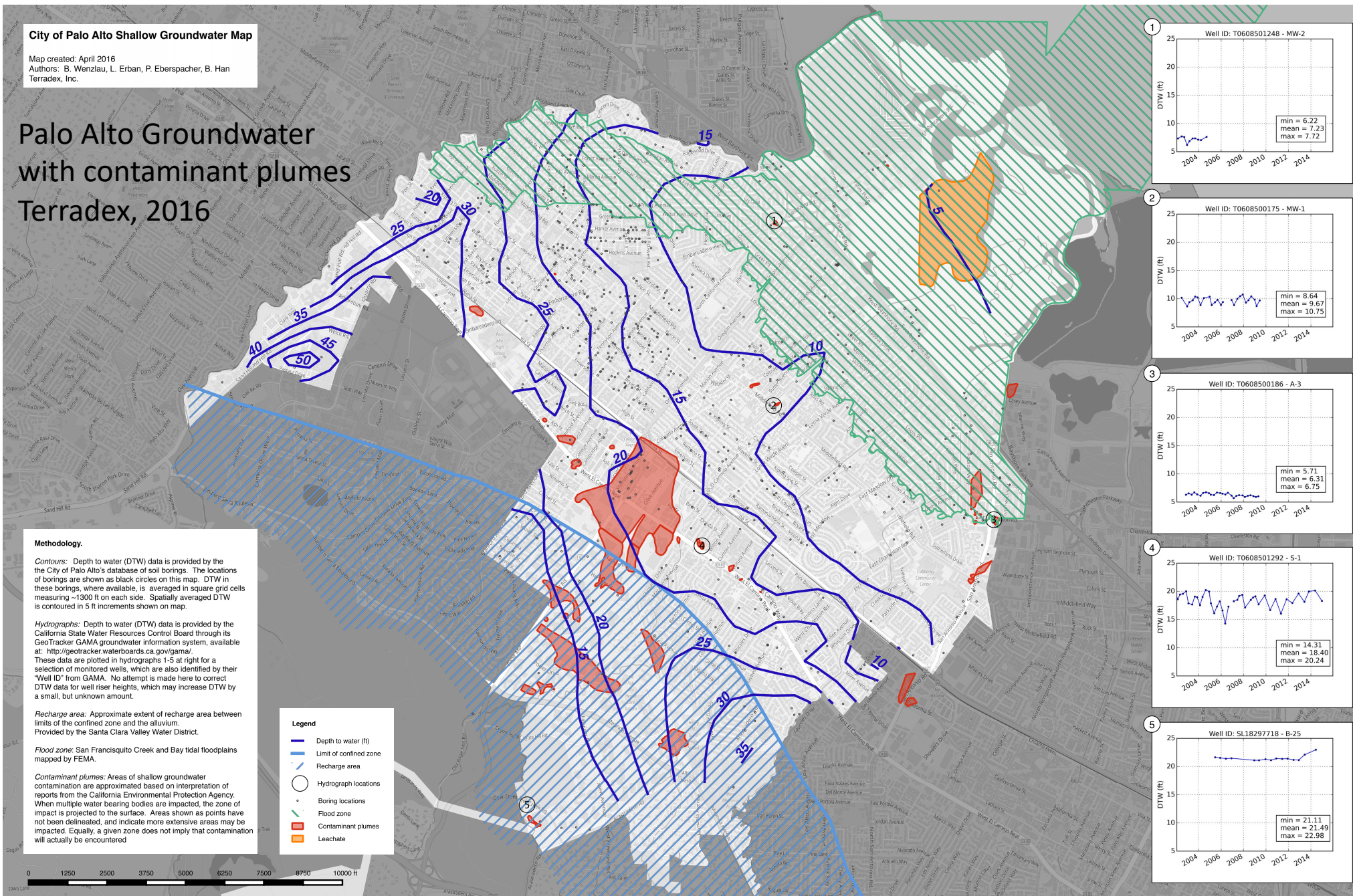
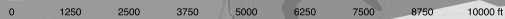
Recharge area: Approximate extent of recharge area between limits of the confined zone and the alluvium. Provided by the Santa Clara Valley Water District.

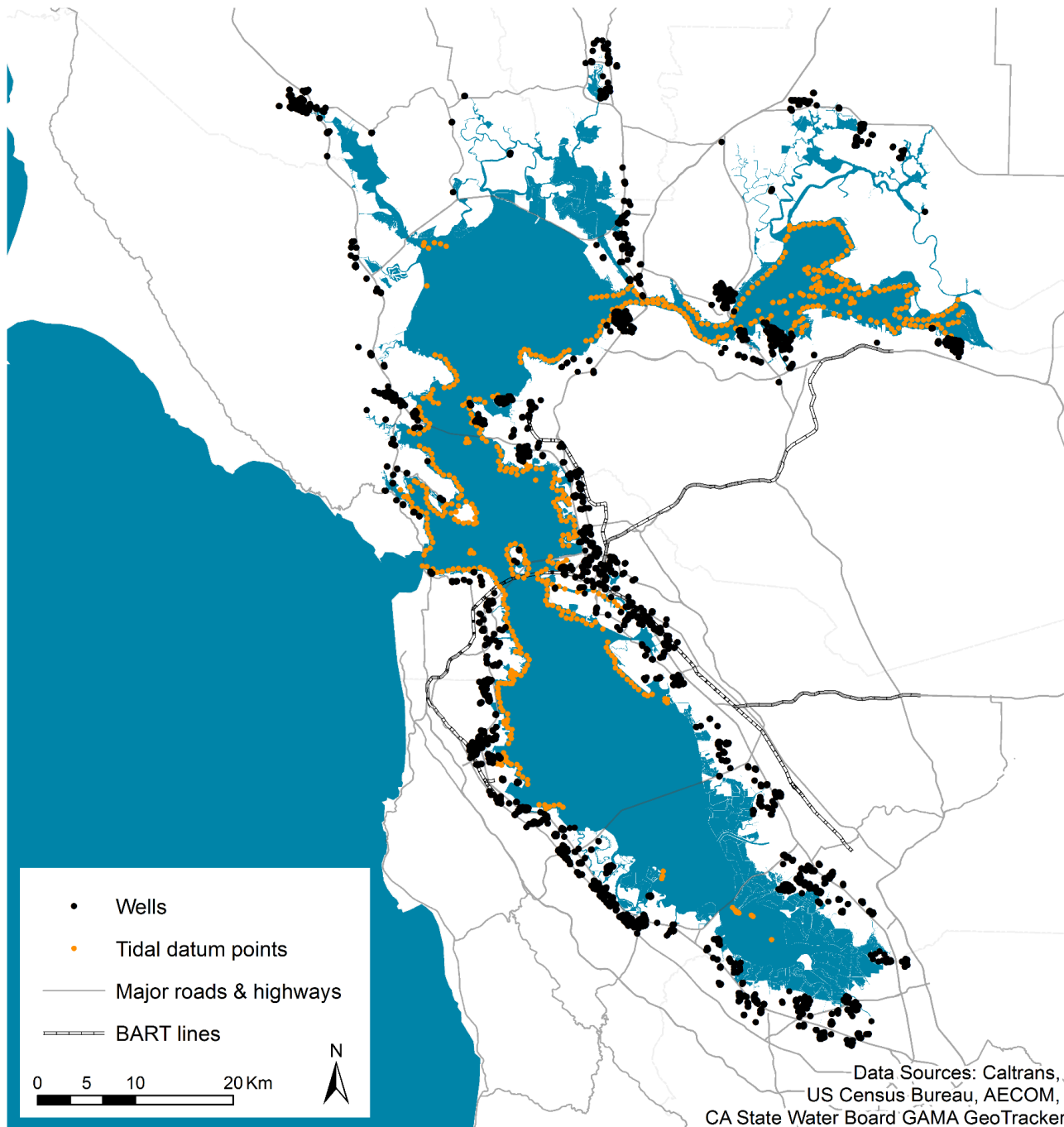
Flood zone: San Francisco Creek and Bay tidal floodplains mapped by FEMA.

Contaminant plumes: Areas of shallow groundwater contamination are approximated based on interpretation of reports from the California Environmental Protection Agency. When multiple water bearing bodies are impacted, the zone of impact is projected to the surface. Areas shown as points have not been delineated, and indicate more extensive areas may be impacted. Equally, a given zone does not imply that contamination will actually be encountered

Legend

- Depth to water (ft)
- Limit of confined zone
- Recharge area
- Hydrograph locations
- Boring locations
- Flood zone
- Contaminant plumes
- Leachate





State Water Board, GAMA dataset of groundwater monitoring wells

Number of GAMA wells we used = 10,777

We sampled *maximum* groundwater elevation

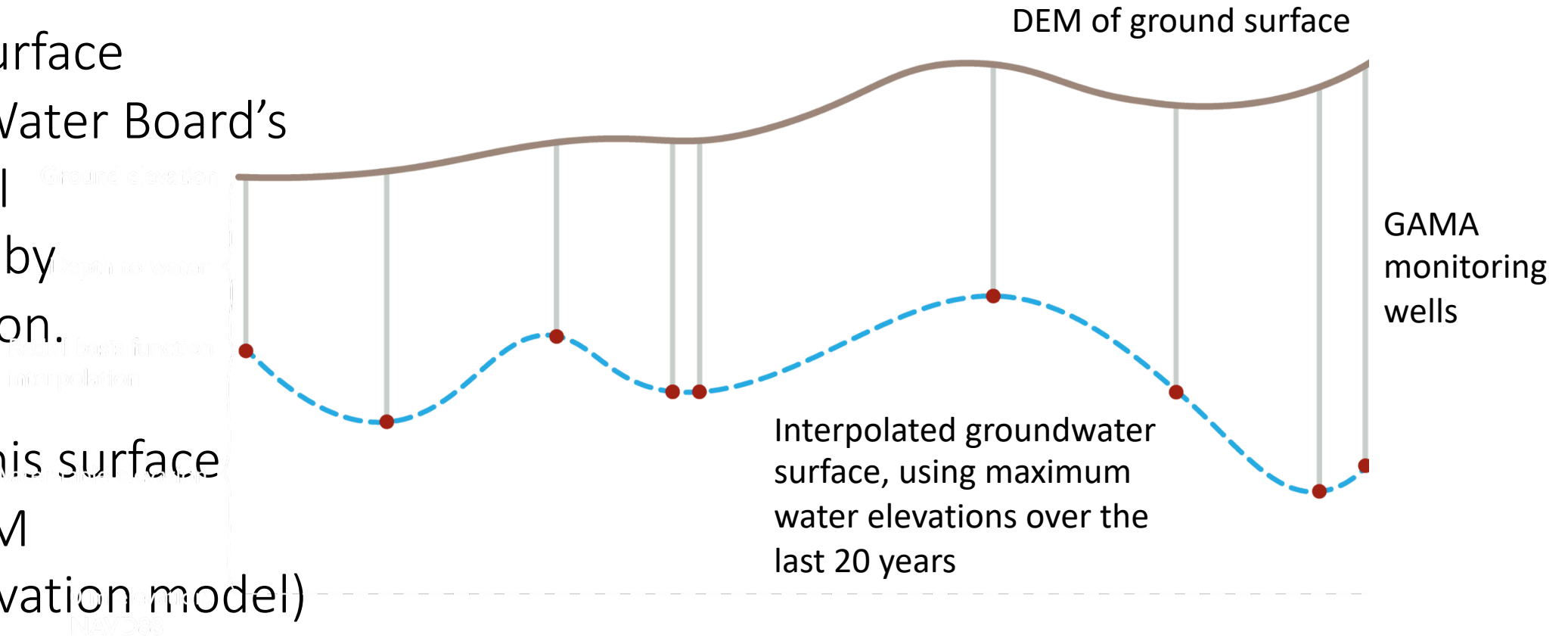
Median depth-to-water for this dataset = 1.75 m

Standard deviation = 1.21 m

Methods

Create a surface from the Water Board's GAMA well point data by interpolation.

Subtract this surface from a DEM (digital elevation model) to create a map of depth-to-groundwater.

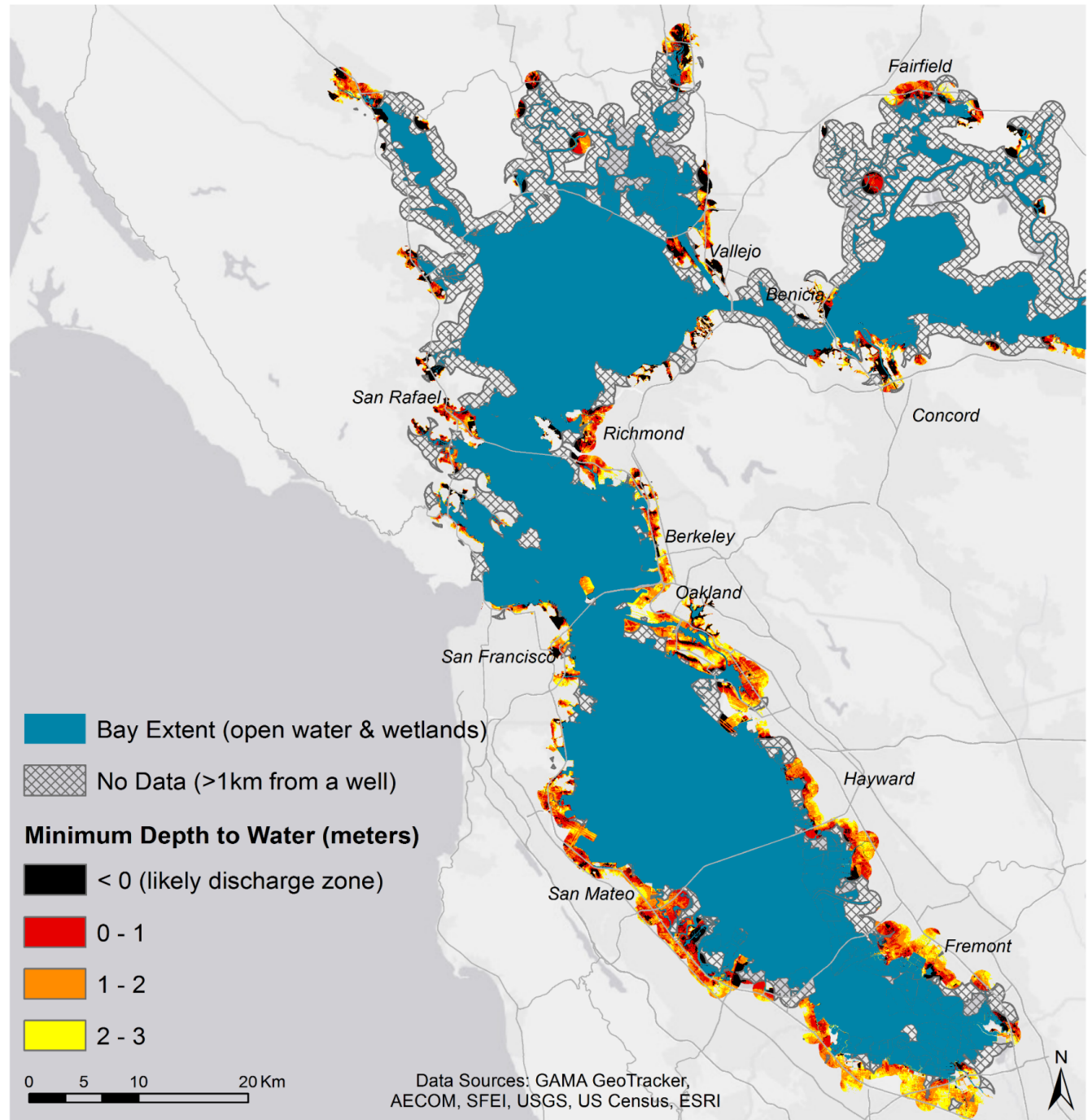


(Cross-section)

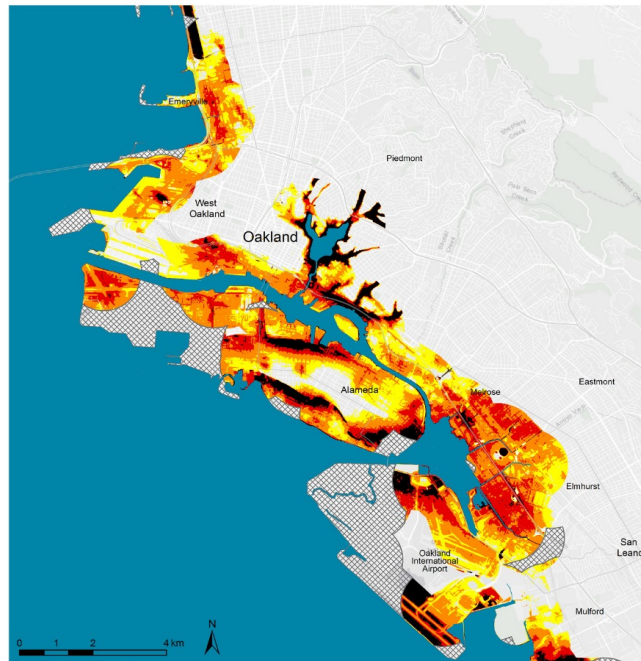
Resulting map of depth to shallow groundwater

Bay Area locations that will flood by groundwater as sea levels rise 3 feet, shown in red.

Plane, Hill, and May 2019

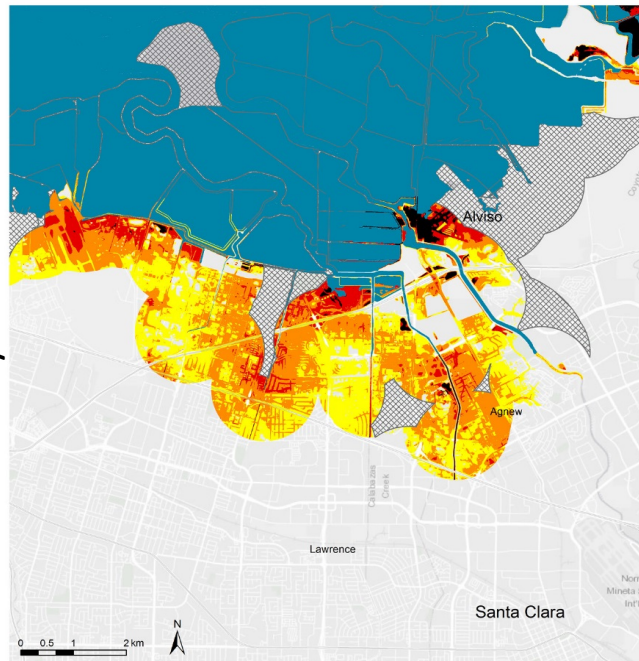


Oakland / Alameda



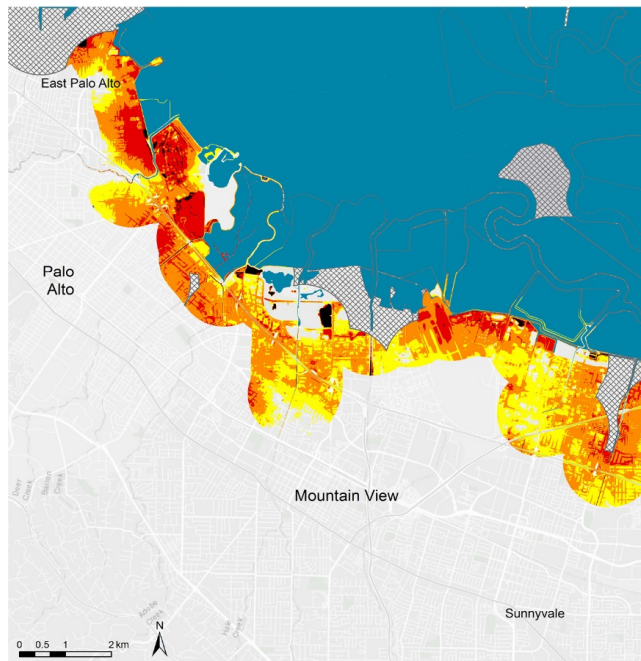
(a)

Alviso / San Jose

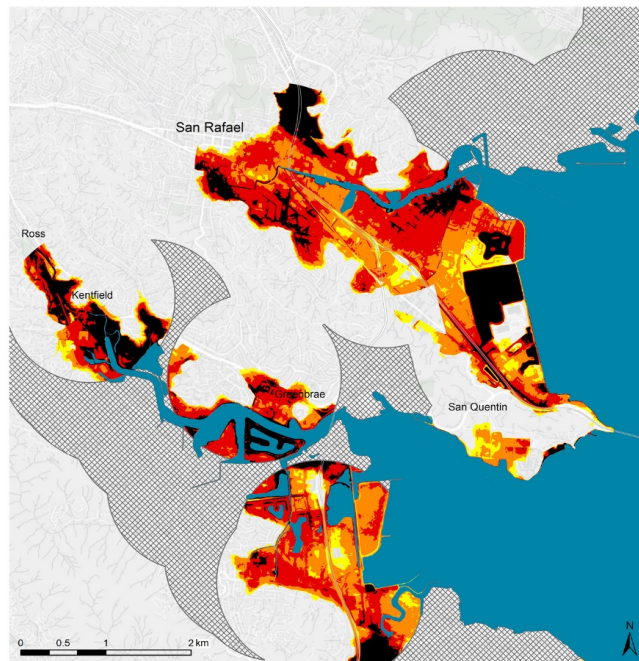


(b)

Sunnyvale / Palo Alto



(c)



(d)

Minimum Depth to Water (meters)

< 0 (uncertain)

0 - 1

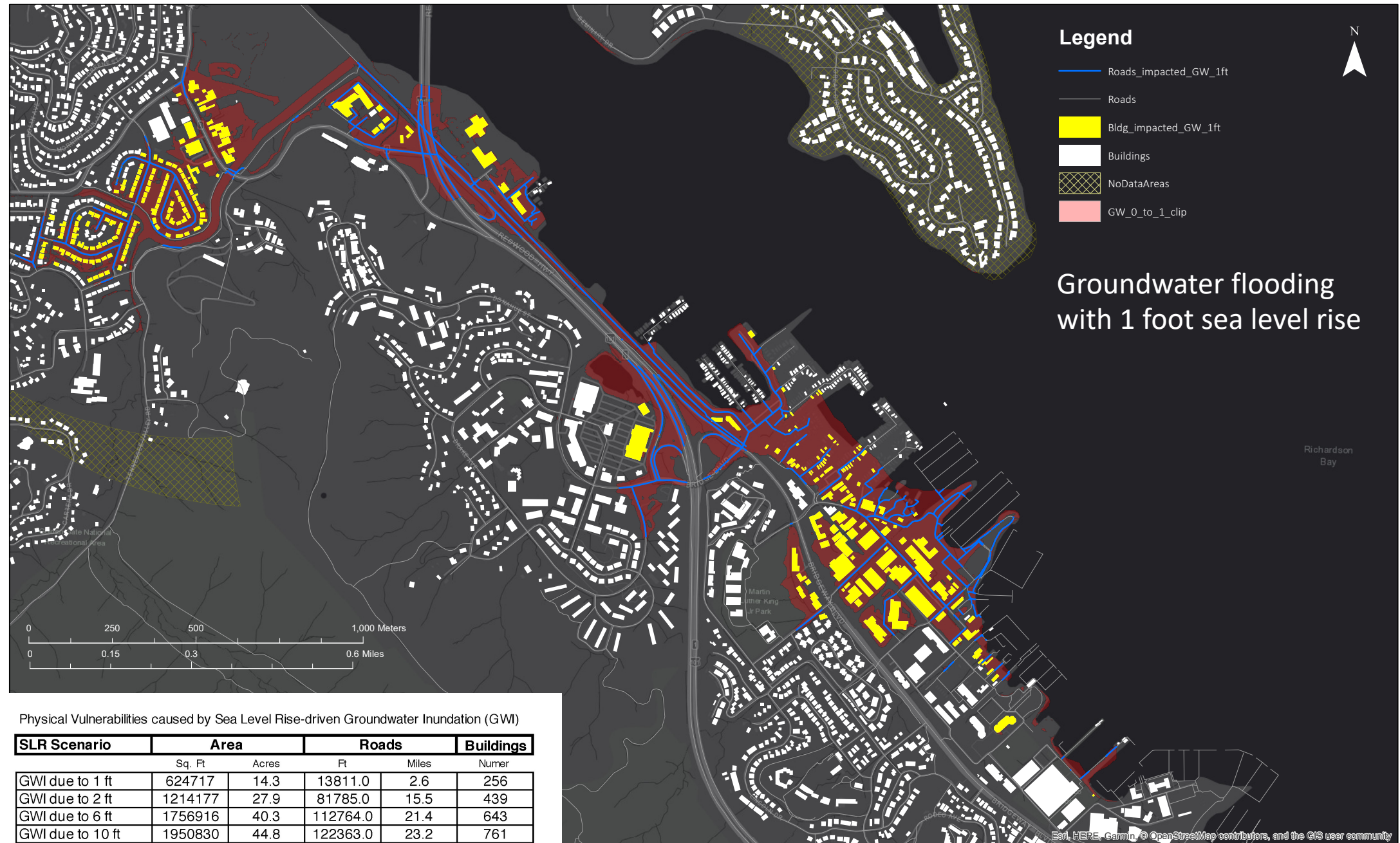
1 - 2

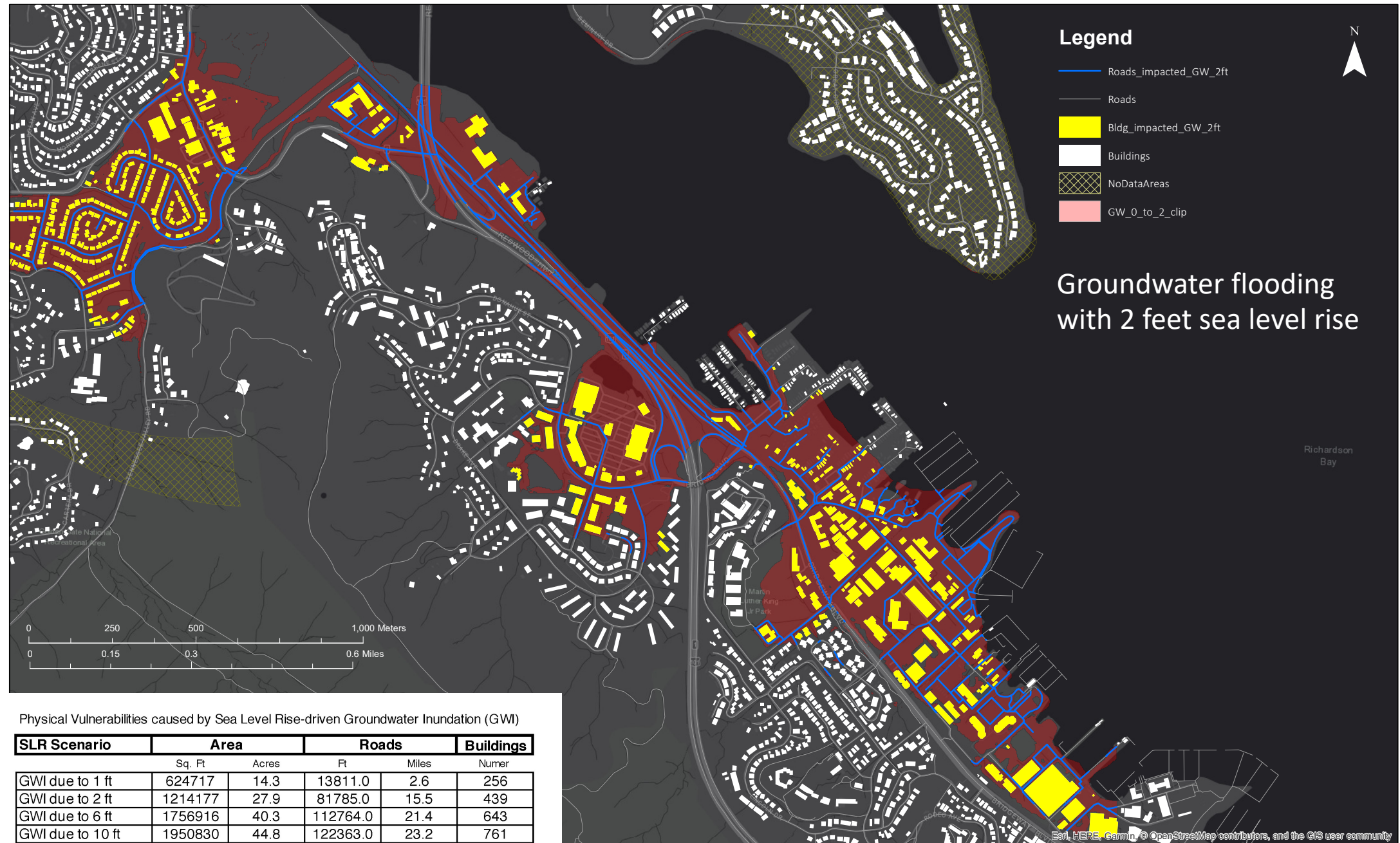
2 - 3

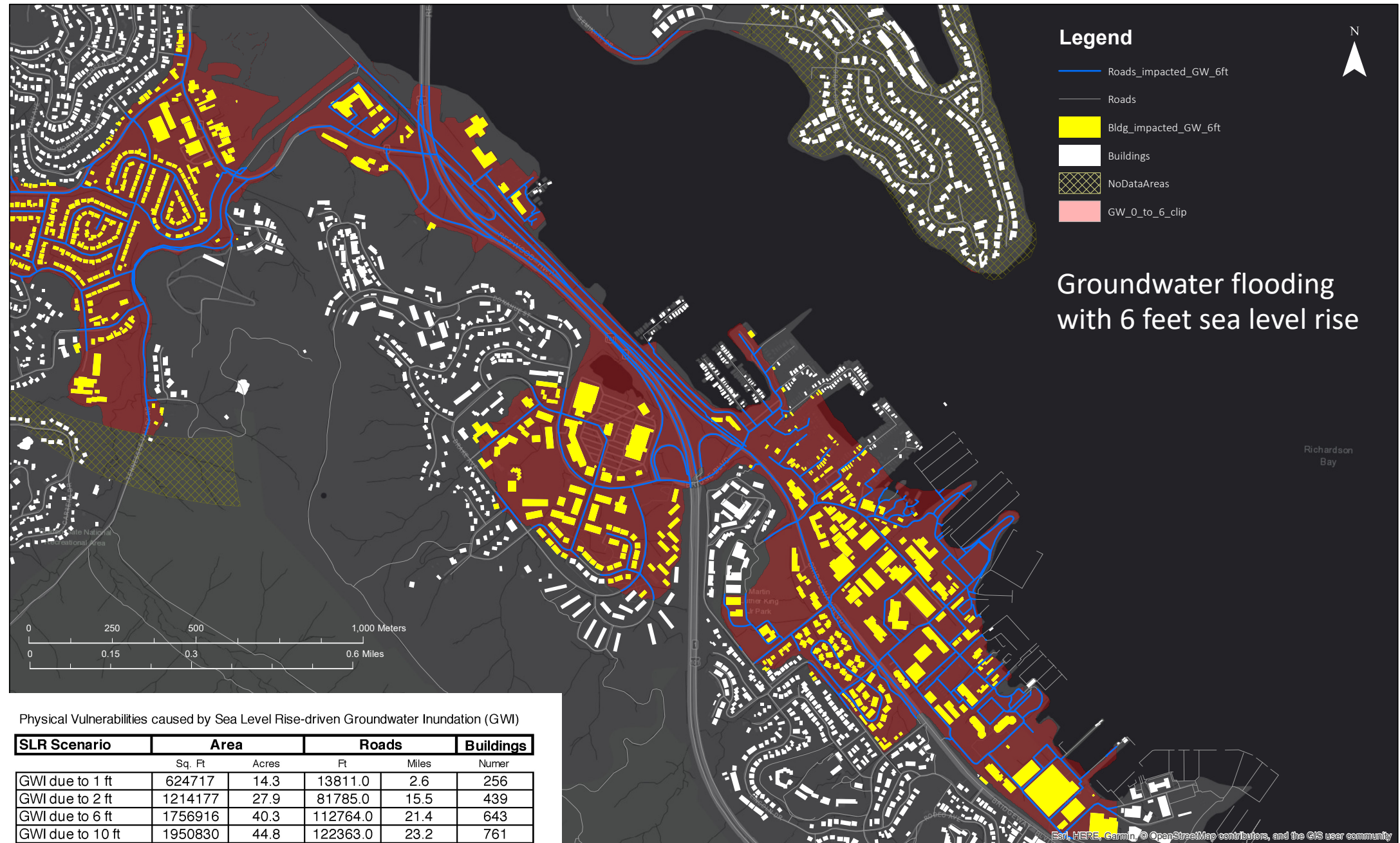
Bay Extent

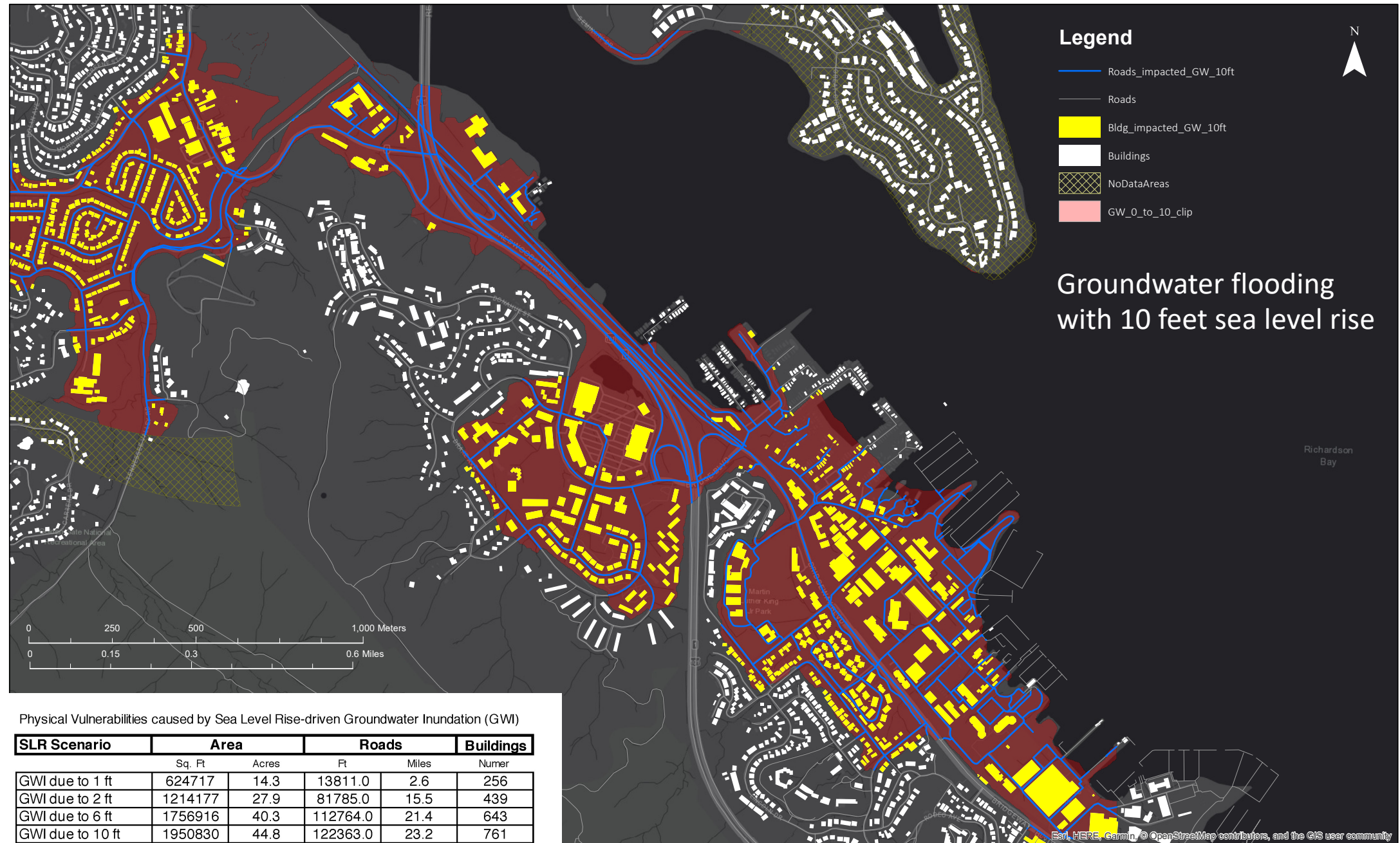
No Data (>1km from a well)

Data Sources: GAMA GeoTracker, AECOM, SFEI, USGS, US Census Bureau, ESRI









Flood risks **within 2/3 mile** of today's Bay shoreline
(2m DEM results – improving these now with a 0.5 m DEM) :

- 20,600 acres at risk of flooding by 1m SLR only
- 11,400 acres at risk of flooding by 1m SLR **and** groundwater
(ie, flooding will be deeper, coastal structures may not prevent emergent floodwaters)
- 26,000 additional acres at risk of flooding by emergent groundwater alone