Rising seas and shallow groundwater

Understanding vulnerability, preparing for high water

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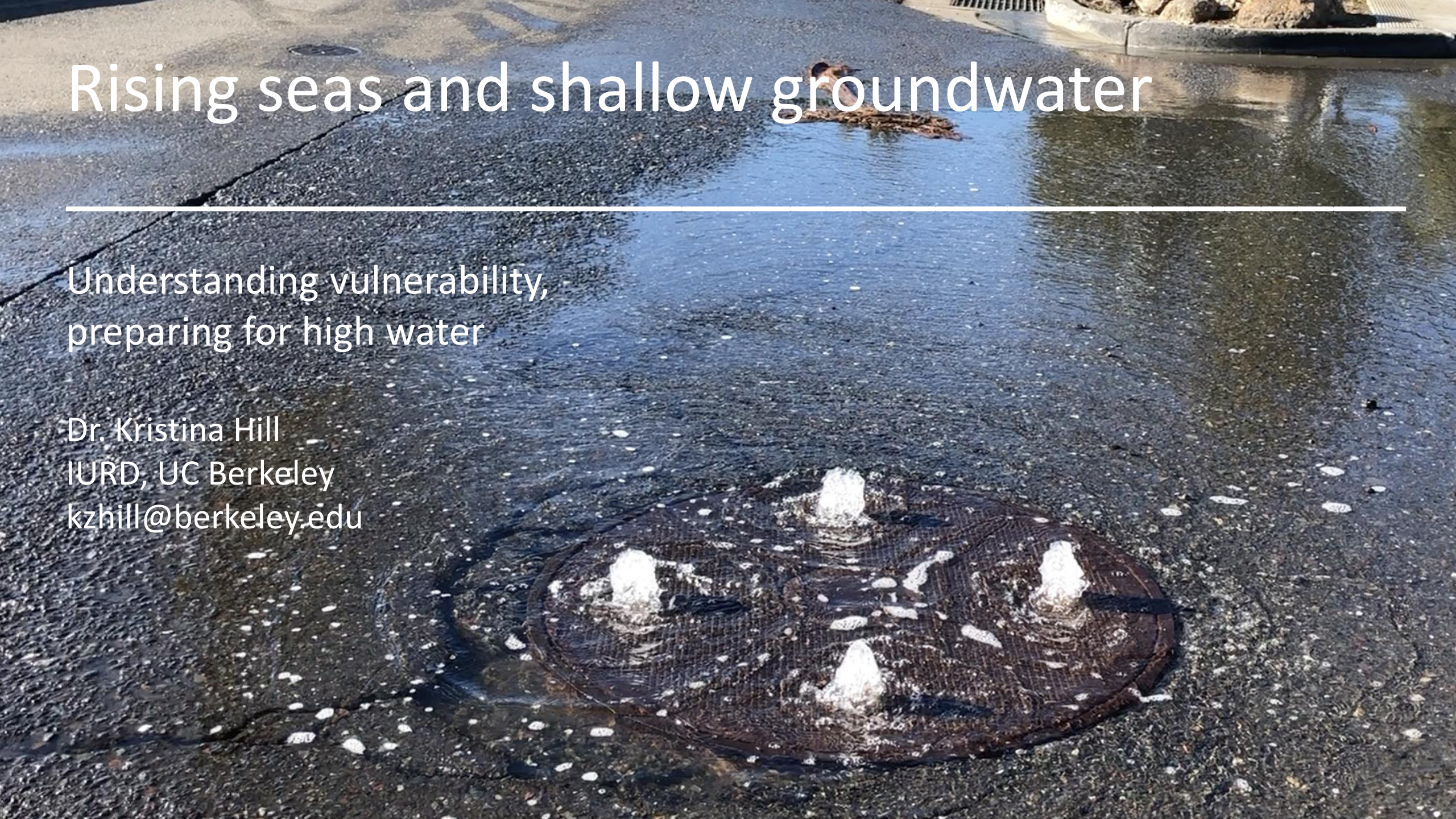
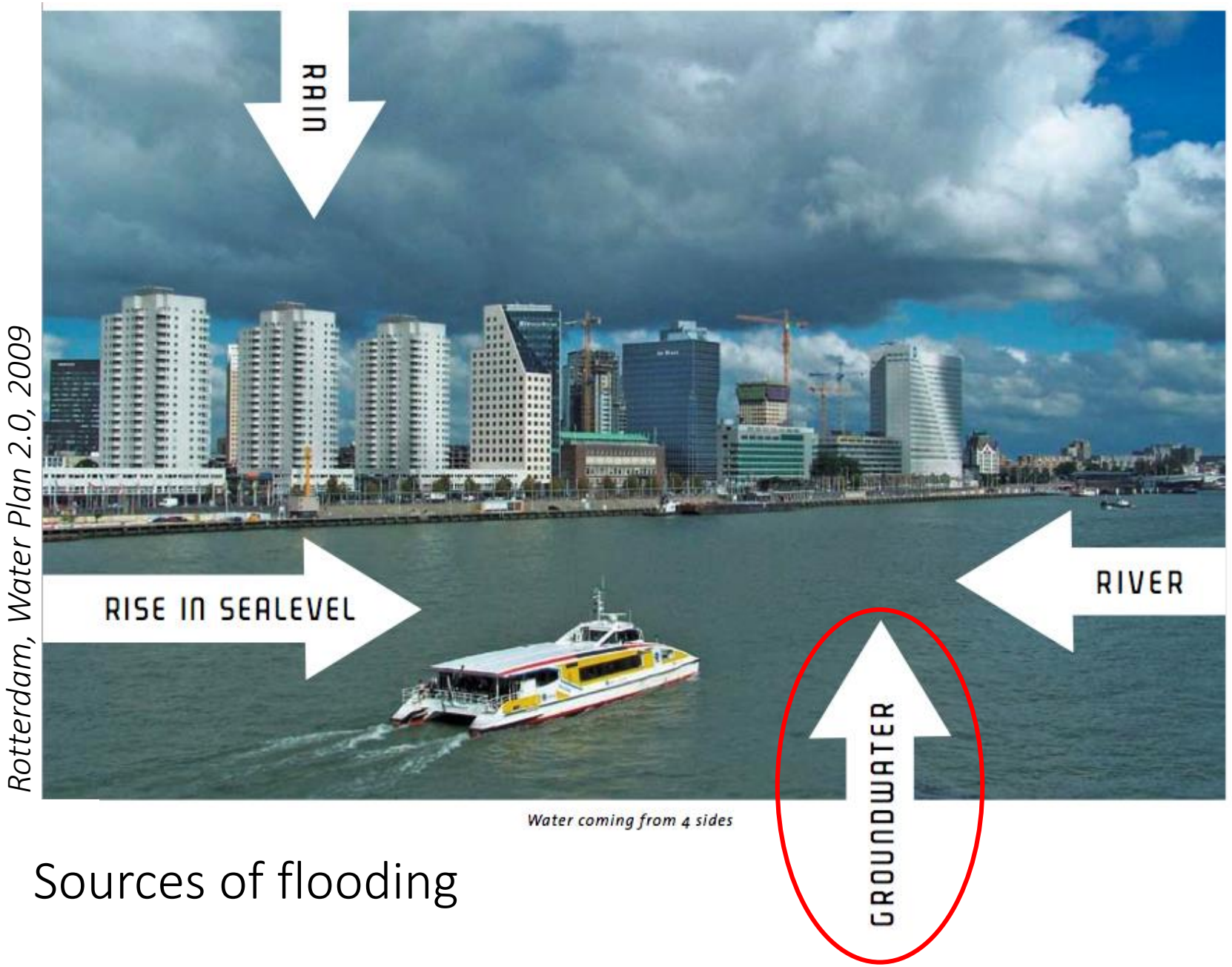
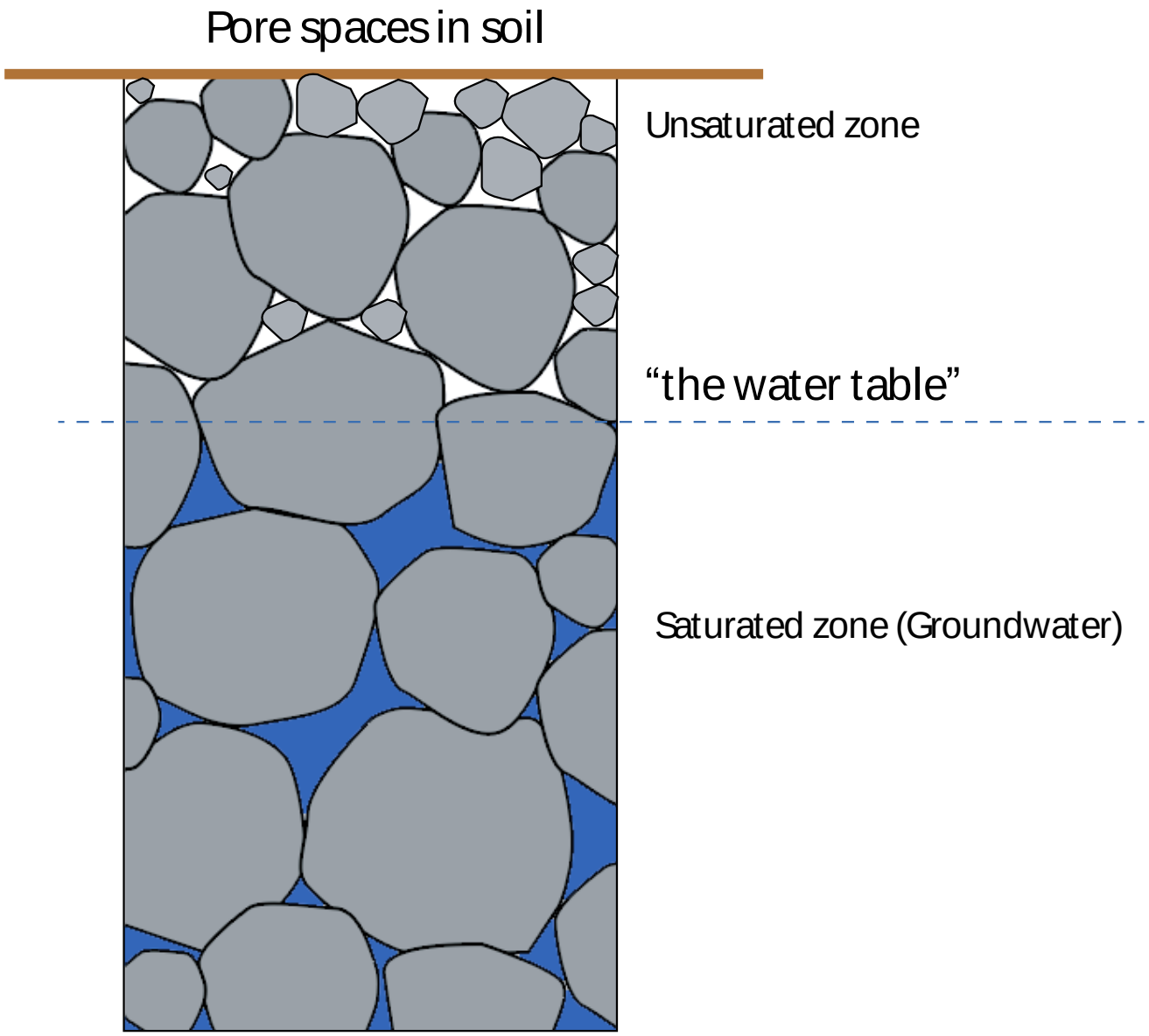




Sources of flooding

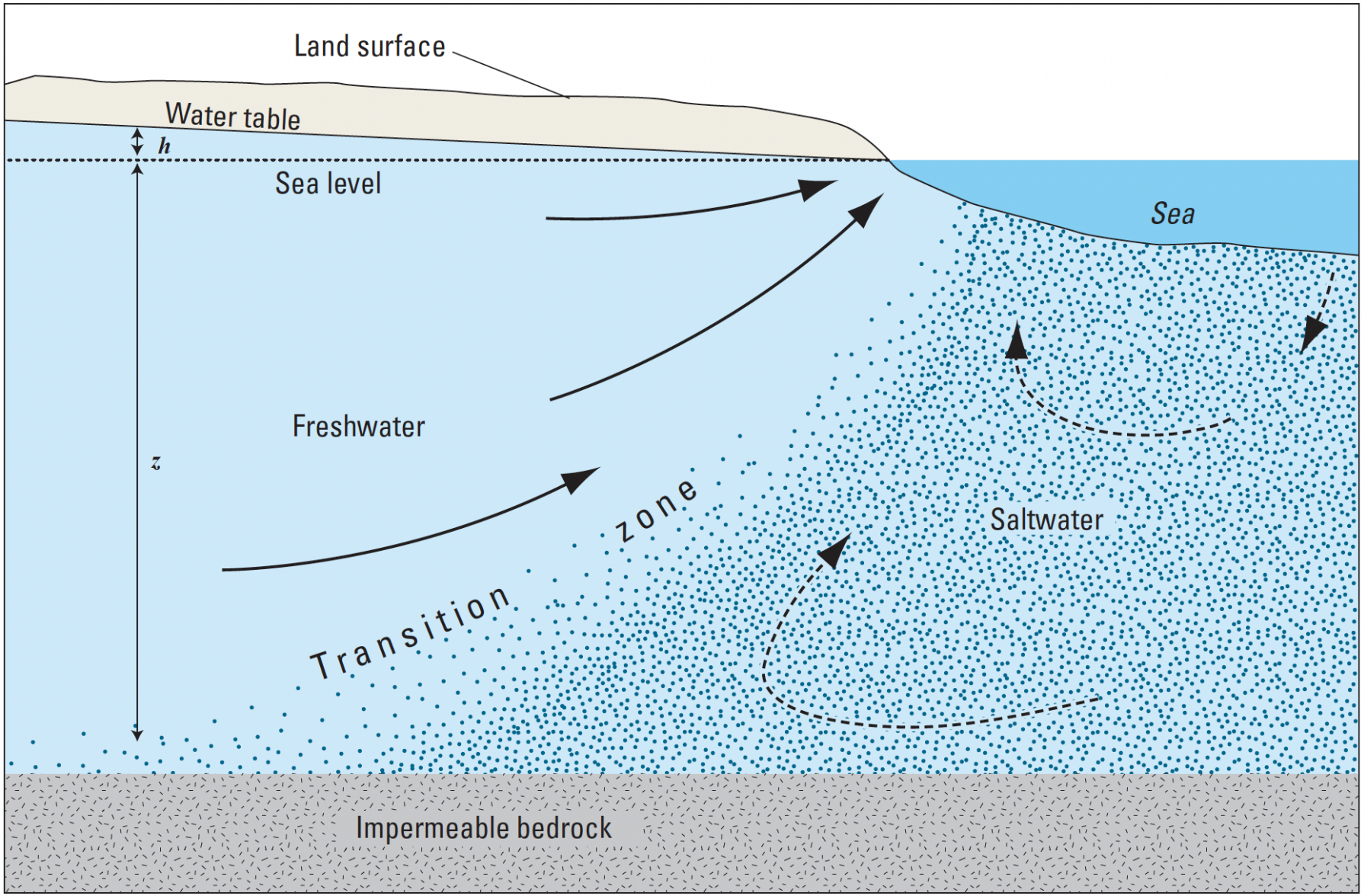
What is shallow groundwater?



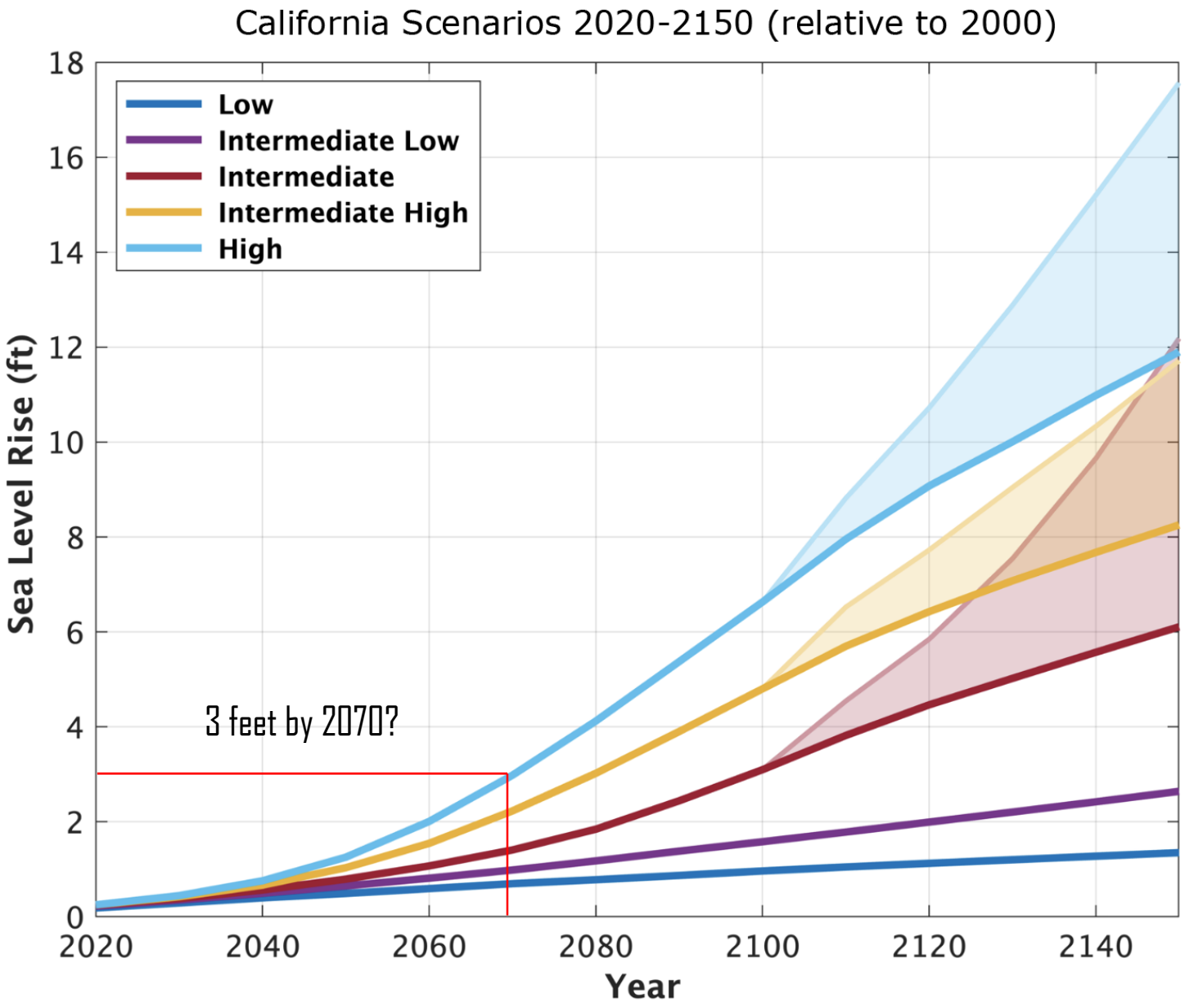
Shallow groundwater is water from rainfall that is stored in the soil.

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

A US Geological Survey cross-section with the interface between fresh groundwater and saltwater



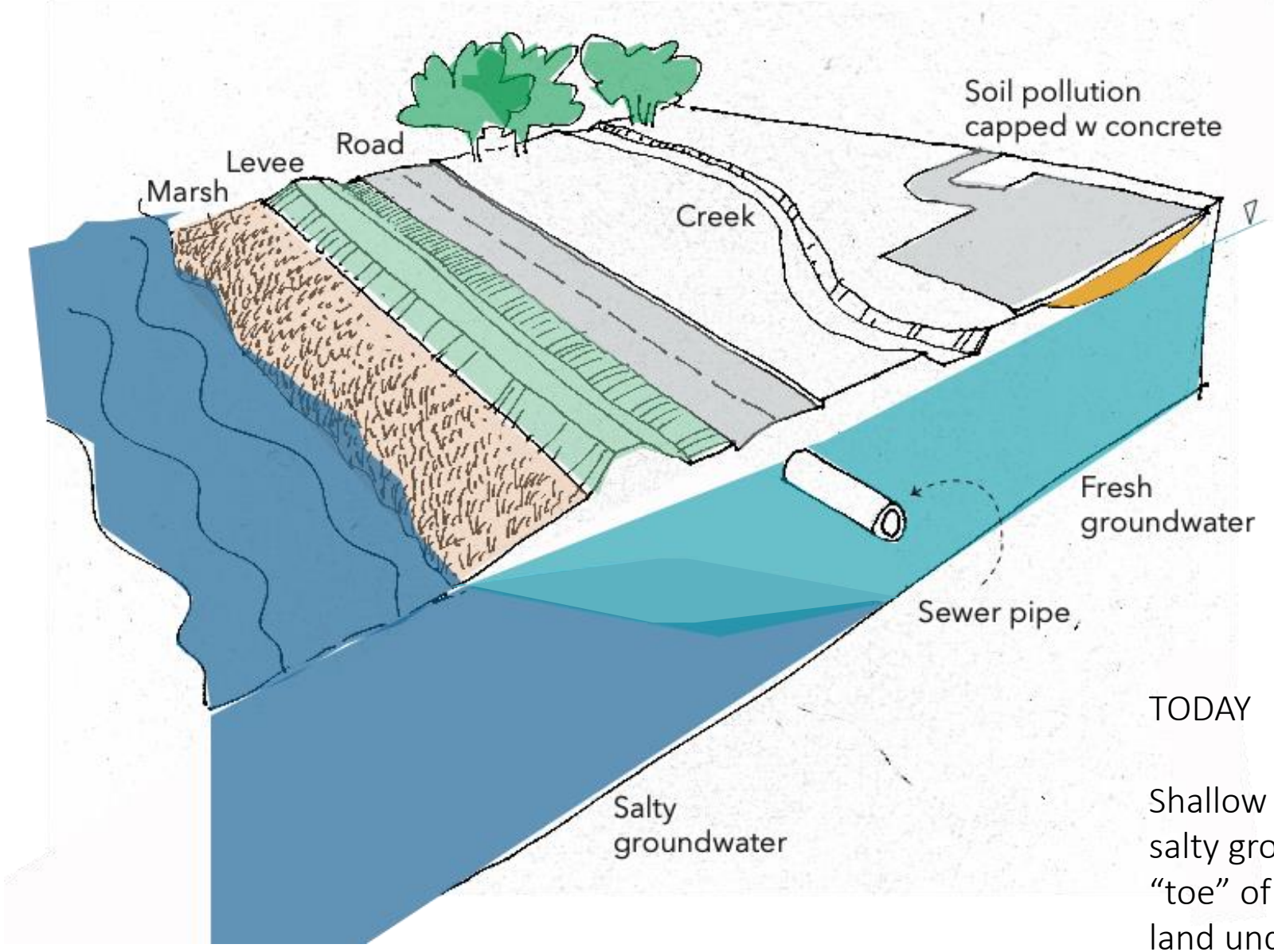
D. Bjerklie et al, "Preliminary Investigation of the Effects of Sea-Level Rise on Groundwater Levels in New Haven, Connecticut," USGS Open File Report 2012-1025



Current California scenarios, 2024 State Guidance

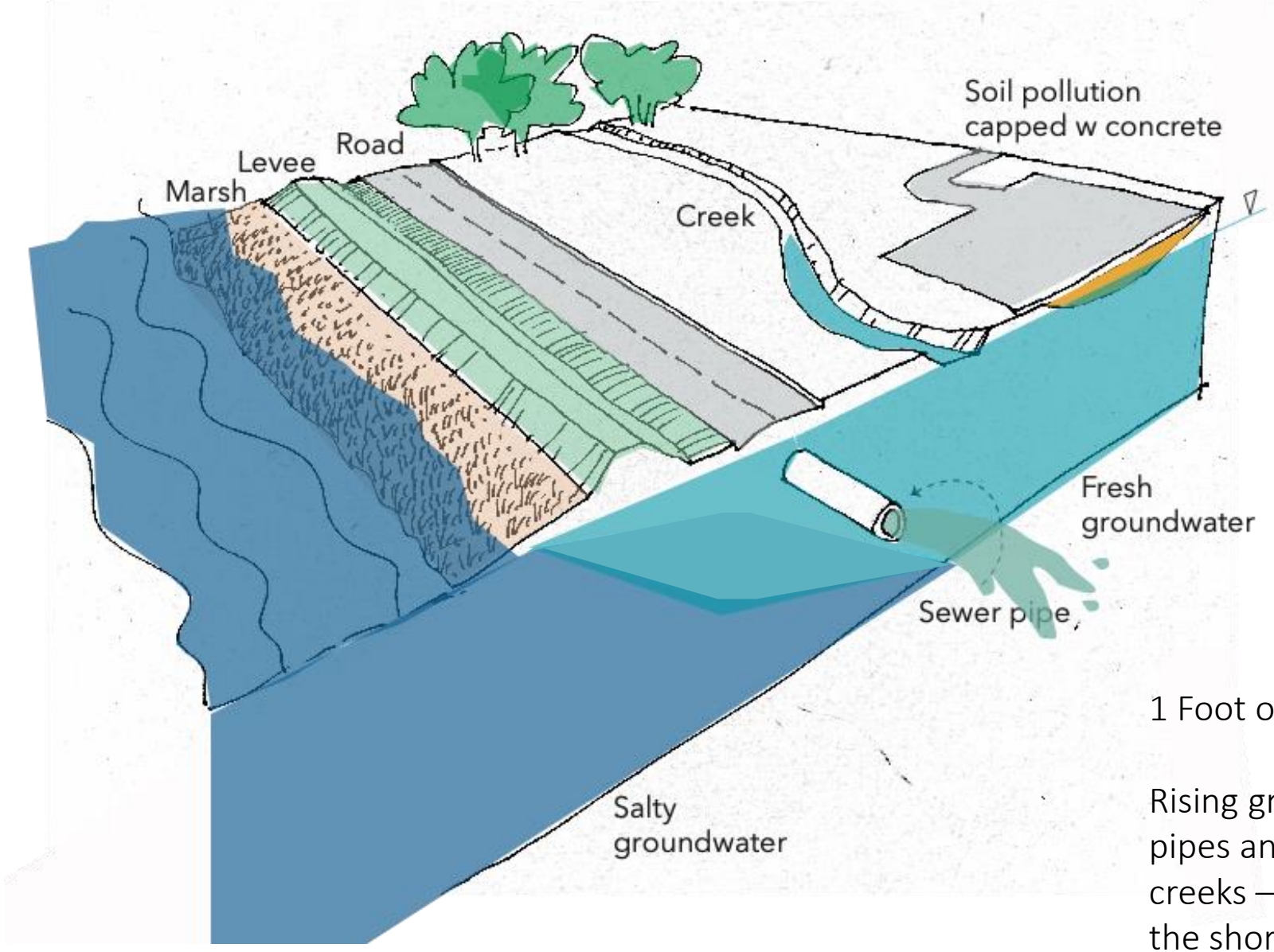
NASA 2023

Levees won’t prevent shallow groundwater from rising on the landward side



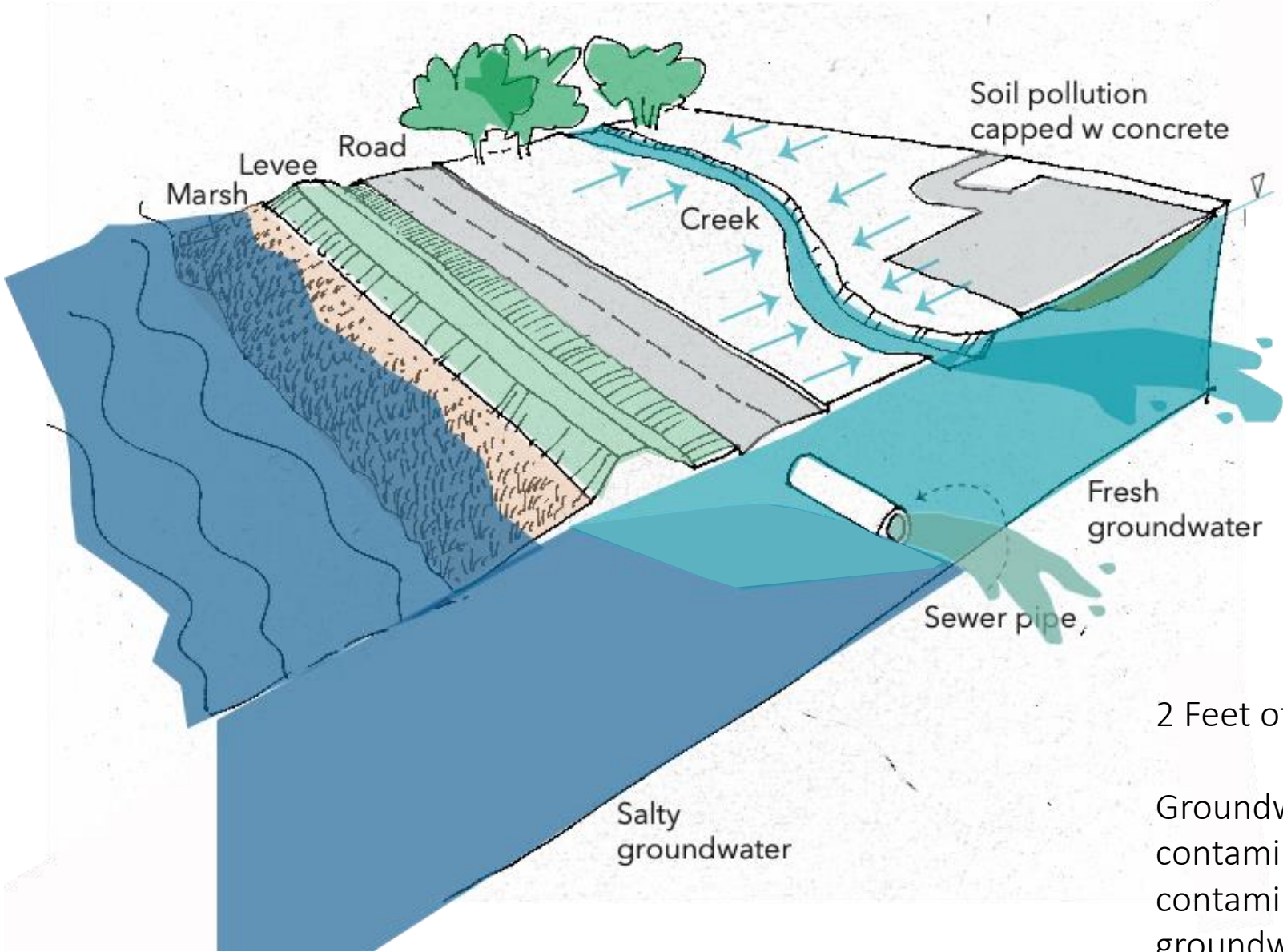
TODAY

Shallow groundwater sits on top of salty groundwater, which is like the “toe” of the ocean poking into the land underground.



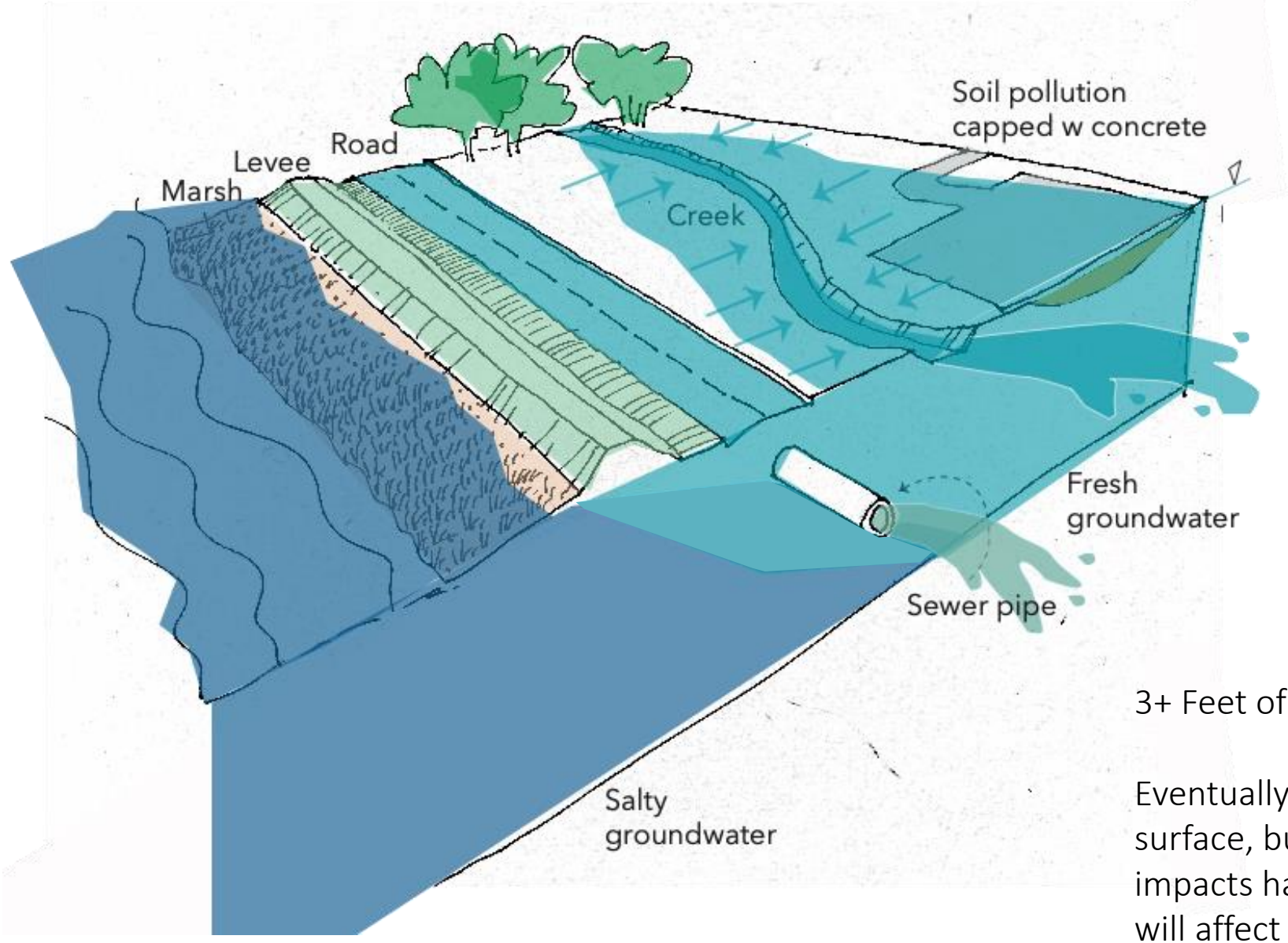
1 Foot of sea level / groundwater rise

Rising groundwater can enter sewer pipes and create higher flows in creeks – even if a levee was built at the shoreline. Shallow water under roads increases maintenance costs by reducing pavement durability.



2 Feet of sea level / groundwater rise

Groundwater can come up into contaminated soils, causing the contaminants to move on or in the groundwater. It can even change directions of flow.



3+ Feet of groundwater rise

Eventually flooding emerges at the surface, but by then, most of the impacts have already occurred that will affect land value.


Veterans Court in Alameda
High astronomical tide, 2022
Bubbling manhole

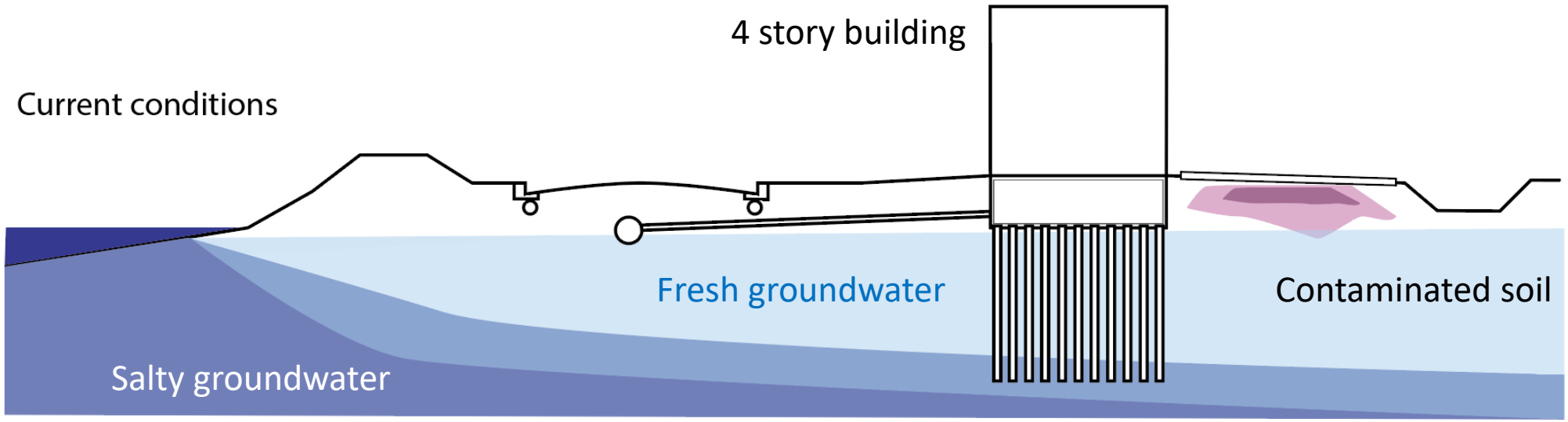
Groundwater infiltration into a storm or sanitary sewer pipe reduces the capacity of the pipe to do its work.

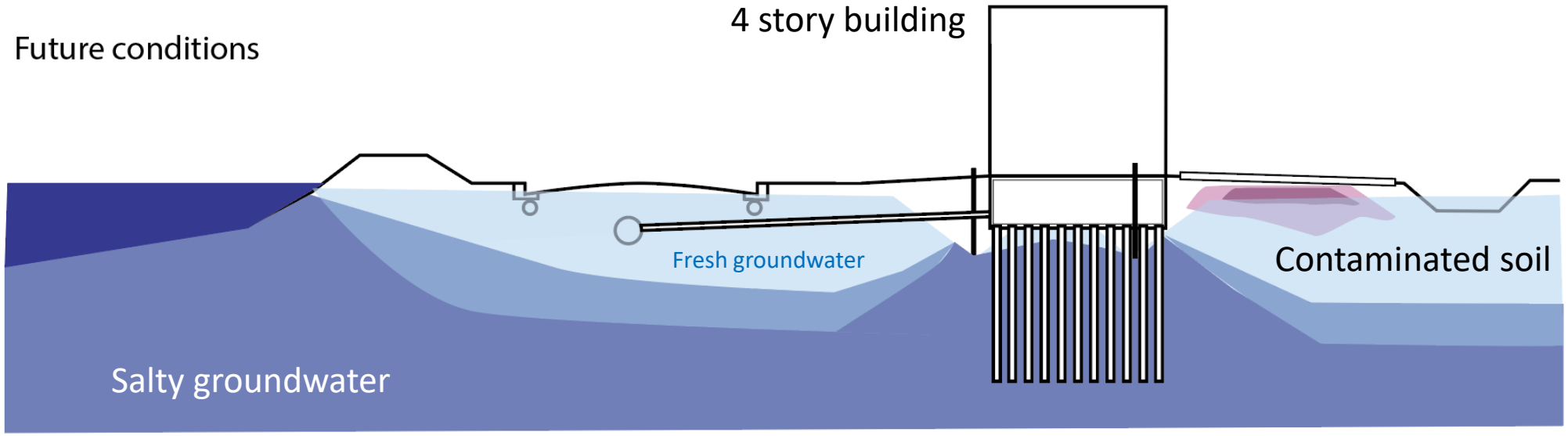
Source: American Public Works Association

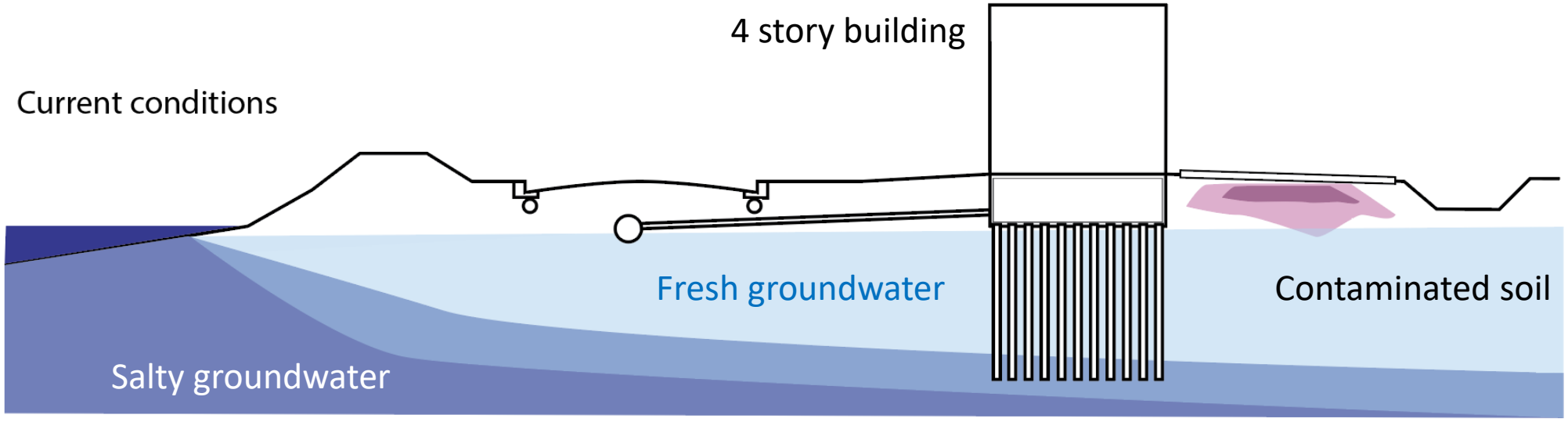
Building and infrastructure foundations will corrode much faster in unexpectedly salty groundwater.

Coastal cities are built in a “dry crust” of land 5-10’ thick. As groundwater rises, that dry crust will get wetter, softer, and saltier.

People will start pumping to protect their buildings.




Future conditions
4 story building
Fresh groundwater
Contaminated soil
Salty groundwater


Current conditions
4 story building
Fresh groundwater
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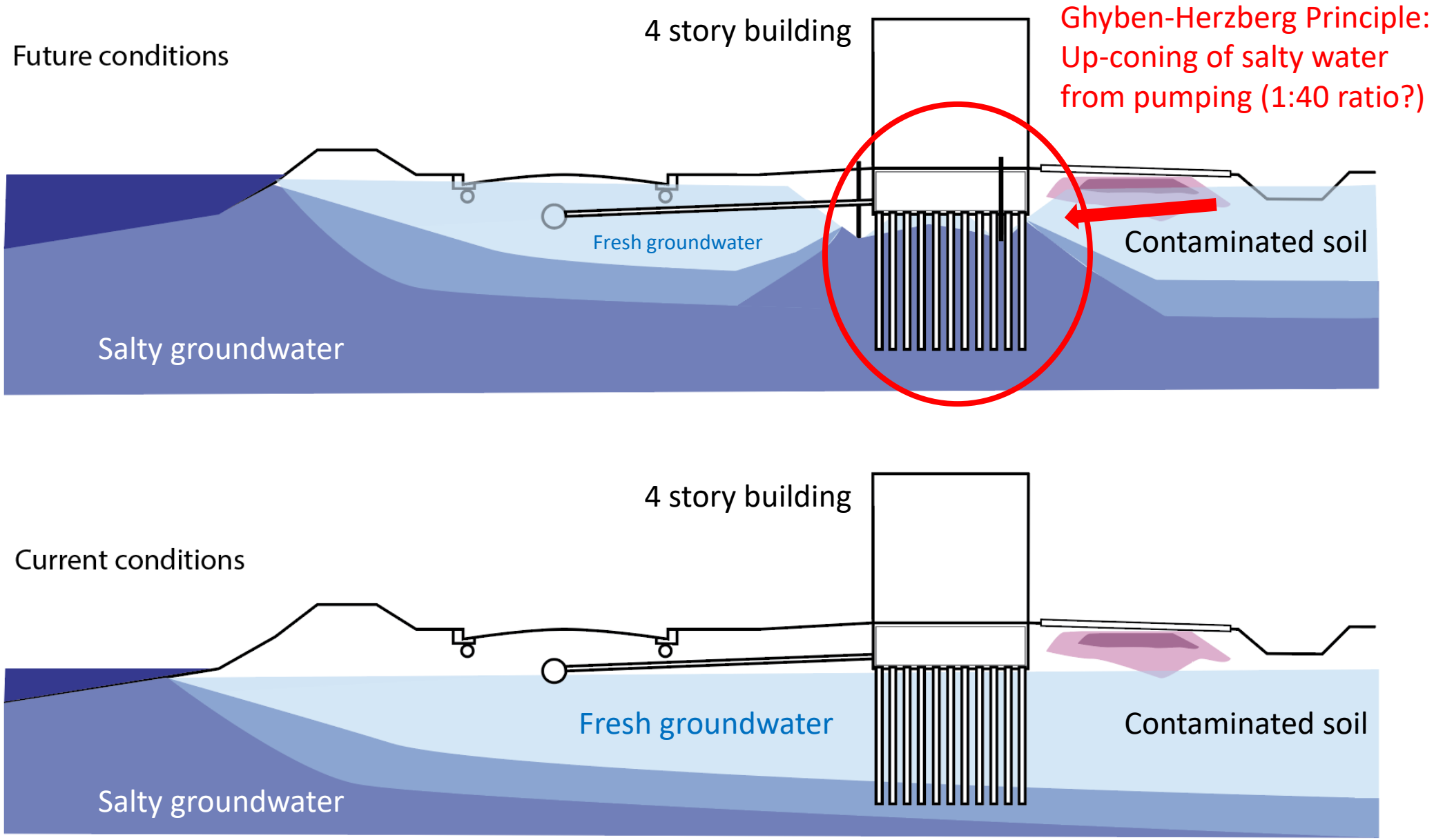
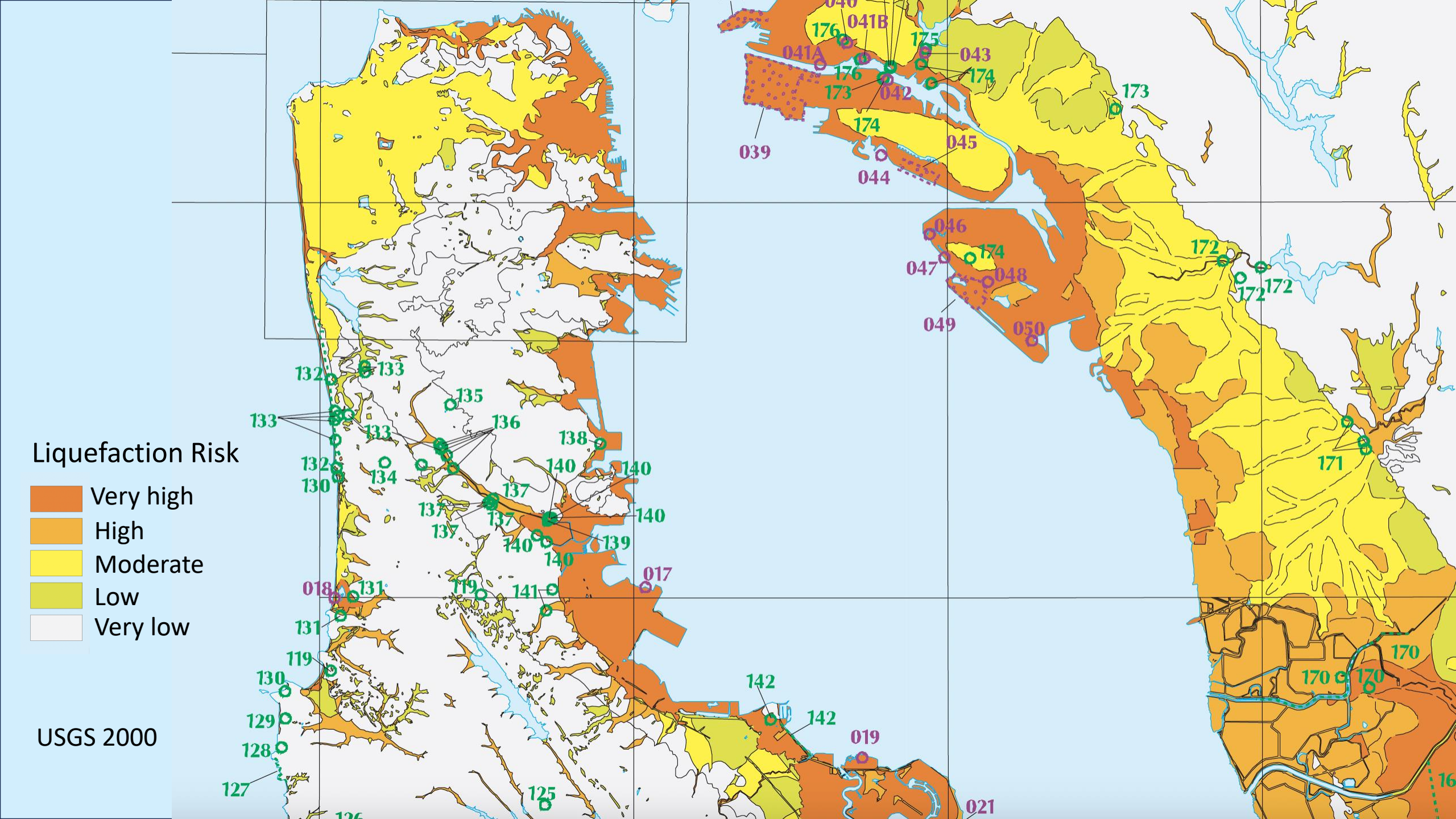

Future conditions
4 story building
Ghyben-Herzberg Principle:
Up-coning of salty water
from pumping (1:40 ratio?)
Fresh groundwater
Contaminated soil
Salty groundwater
Current conditions
4 story building
Fresh groundwater
Contaminated soil
Salty groundwater

Pumping needs to be regulated to prevent weakening of foundations and potential contamination of indoor air.

It would also make sense to require foundation inspections, just as soft-story buildings face additional requirements.


Liquefaction Risk
Very high
High
Moderate
Low
Very low
USGS 2000

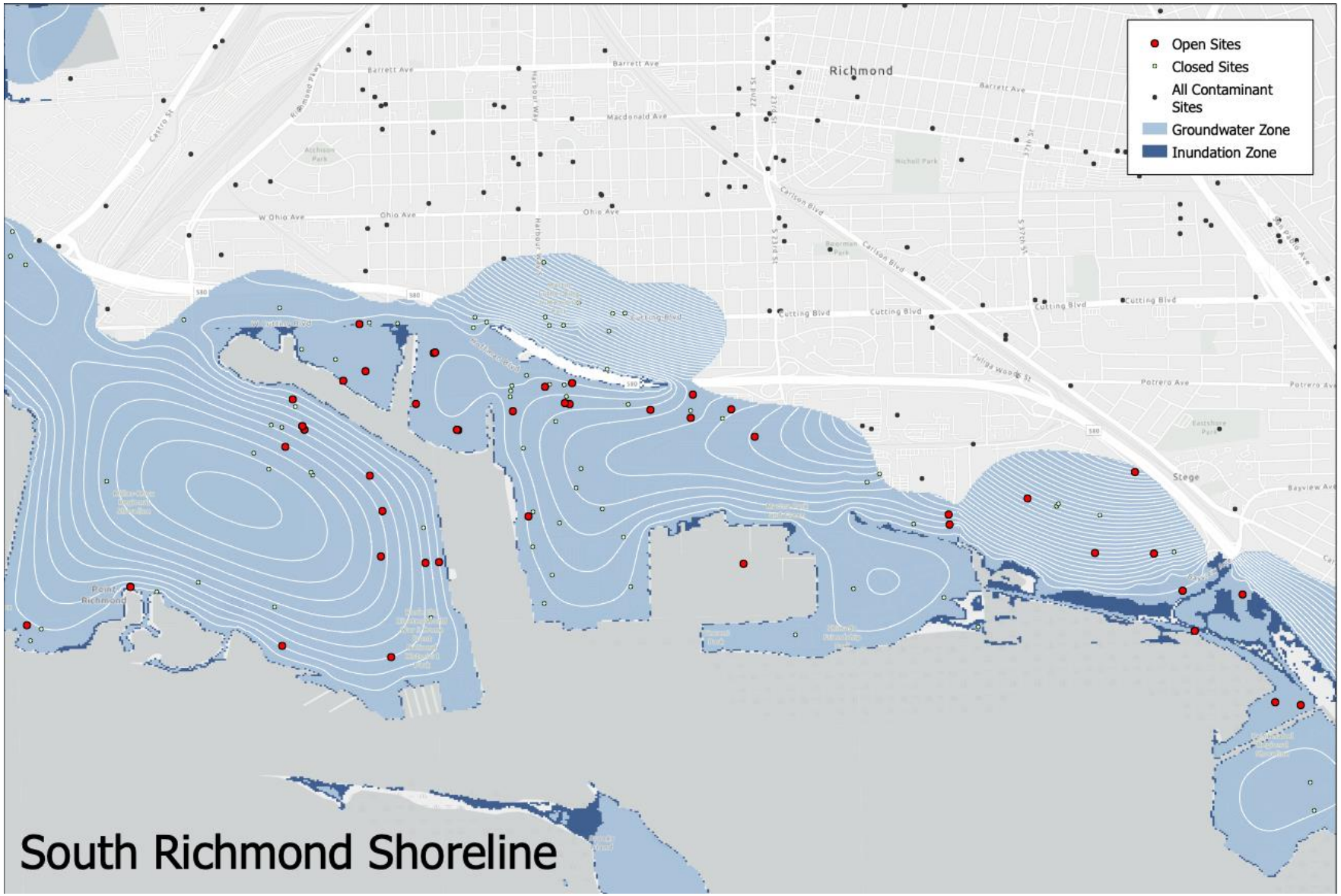
Higher groundwater can drive increased liquefaction risk

Christchurch, New Zealand

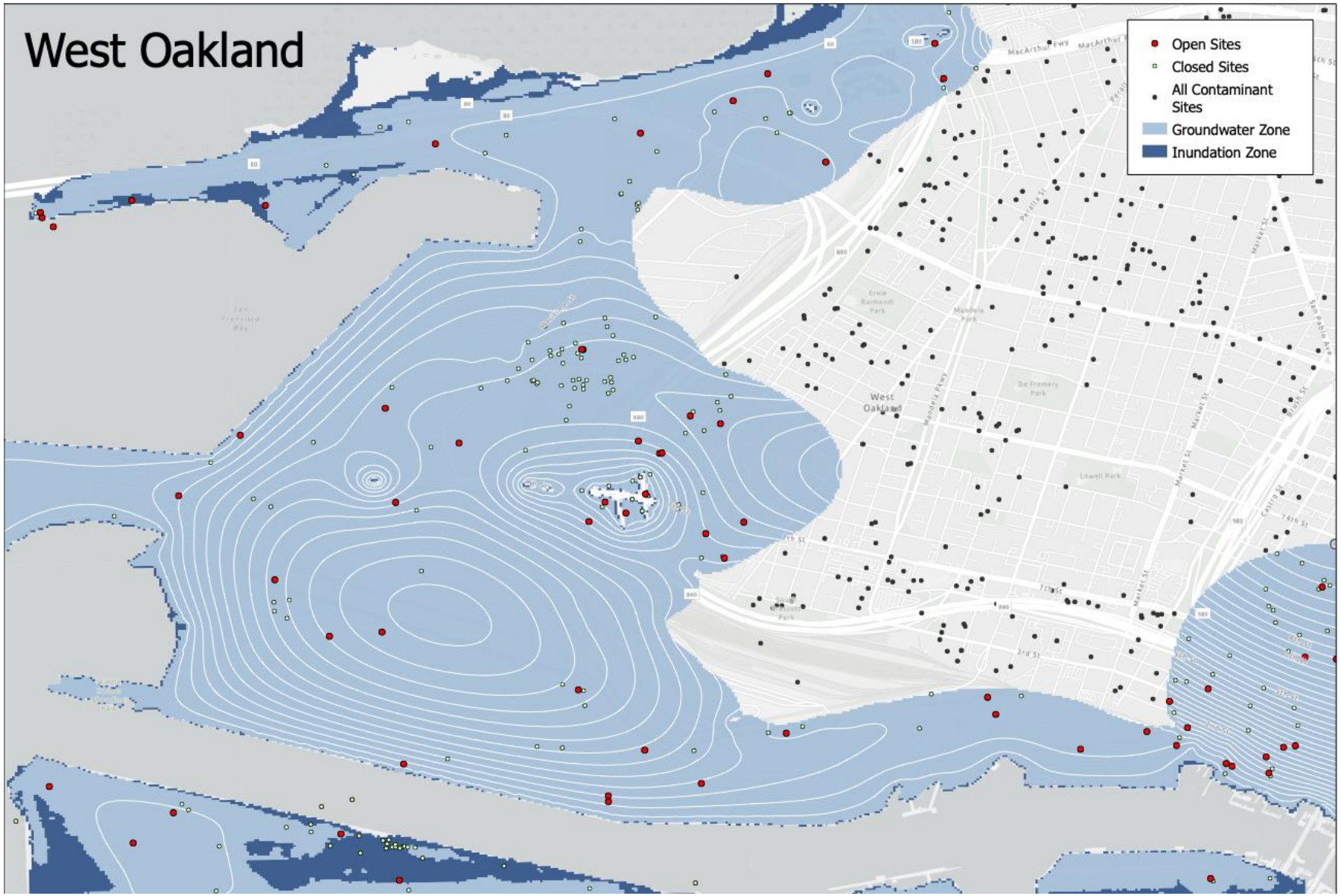
In 2023, we identified 1,840+ “open” contaminated sites above rising groundwater with 3.3’ of SLR in the San Francisco Bay Area.

We found a higher likelihood that these legacy contaminated sites would still be open in more socially-vulnerable neighborhoods.

Hill et al, in the peer-reviewed journal *Earth’s Future*, AGU, 2023



Light blue: 3 feet of sea level rise, groundwater within 10 ft of surface; dark blue: emergent.



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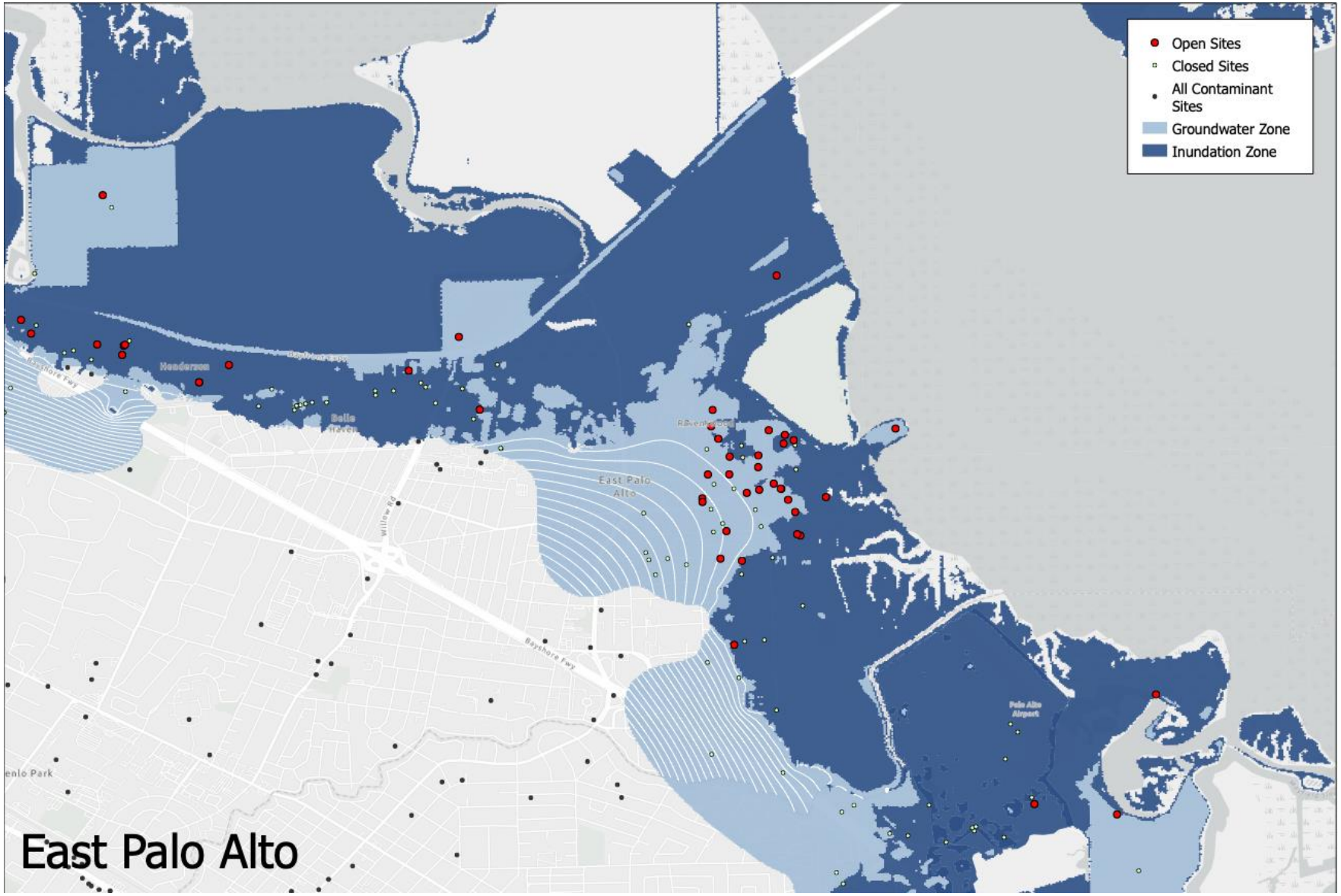

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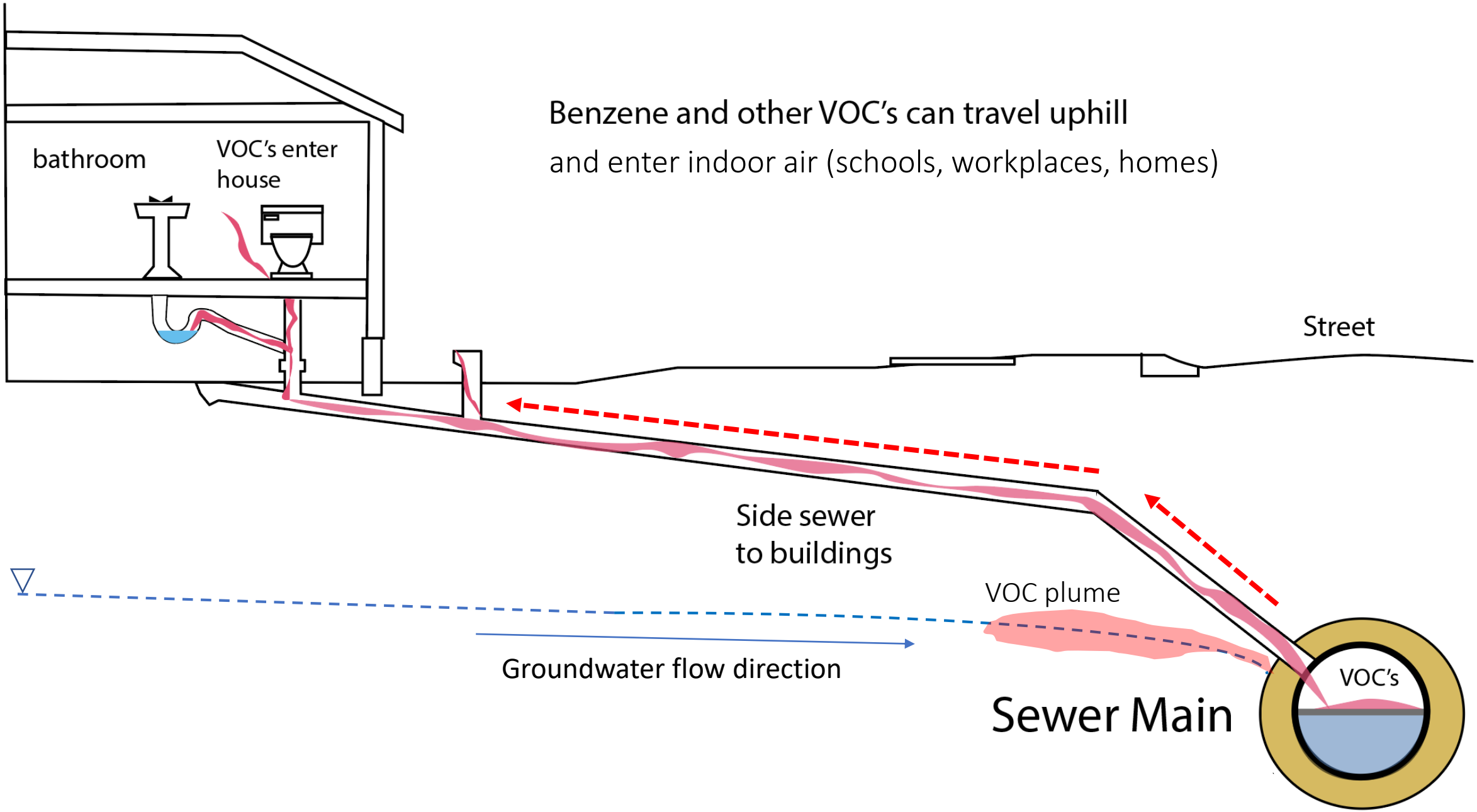
The **immediate risk** for **public health** is that higher groundwater or a change in flow direction could allow Volatile Organic Compounds (VOCs) to enter indoor air through a sewer connection.

Hill et al, in the peer-reviewed journal *Earth's Future*, AGU, 2023


Benzene and other VOC's can travel uphill
and enter indoor air (schools, workplaces, homes)
bathroom
VOC's enter house
Street
Side sewer to buildings
VOC plume
Groundwater flow direction
VOC's
Sewer Main

As of 2023, CA DTSC requires managers of contaminated sites to consider rising groundwater when they evaluate the vulnerability of those legacy sites to sea level rise.

Both DTSC and the Water Board are helping us develop a screening tool to prioritize sites for attention.

But the CA State Water Board, which manages more contaminated sites in the SF Bay Area, has not issued SLR / GWR guidance to its site managers.