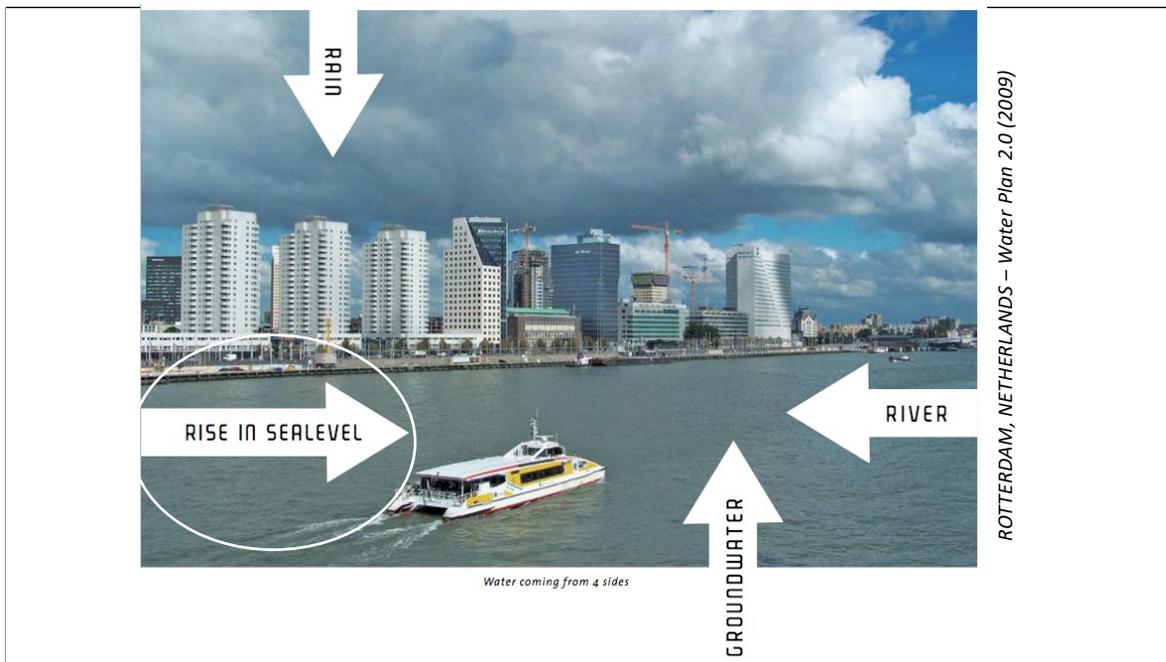




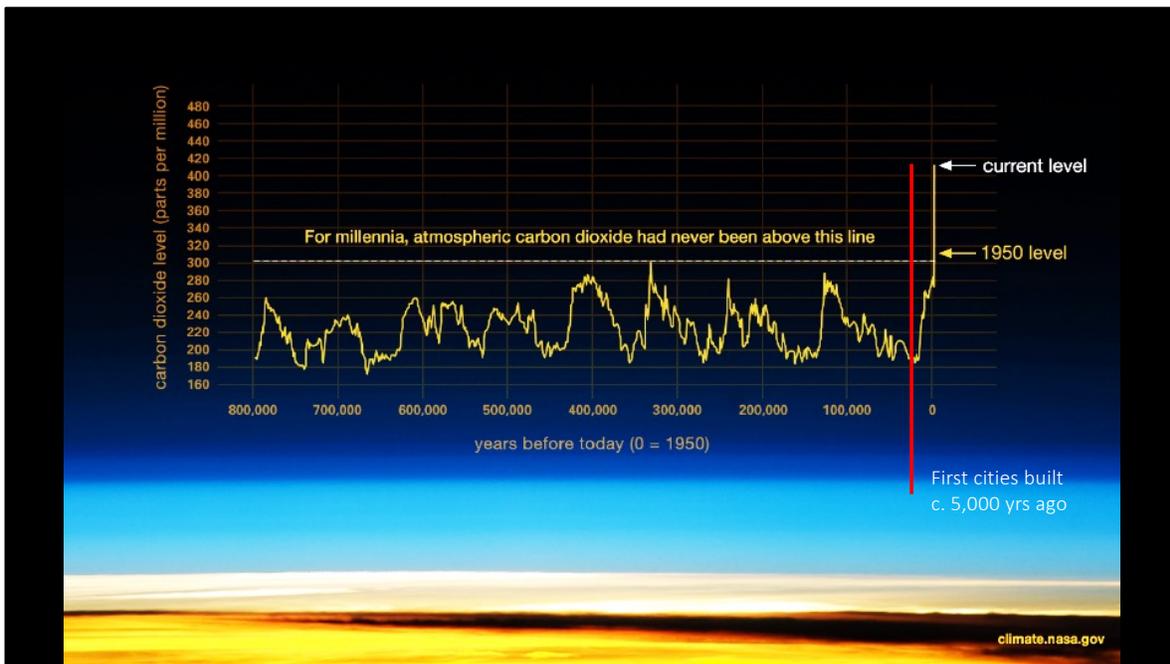
SEA LEVEL RISE : Impacts on Richmond

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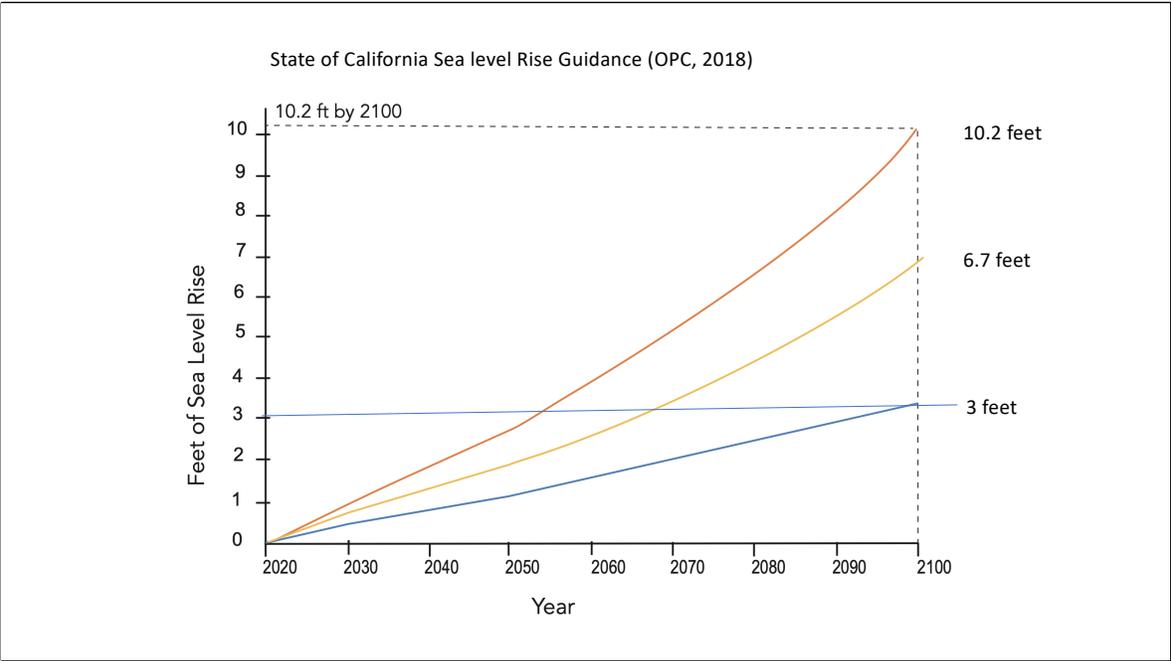




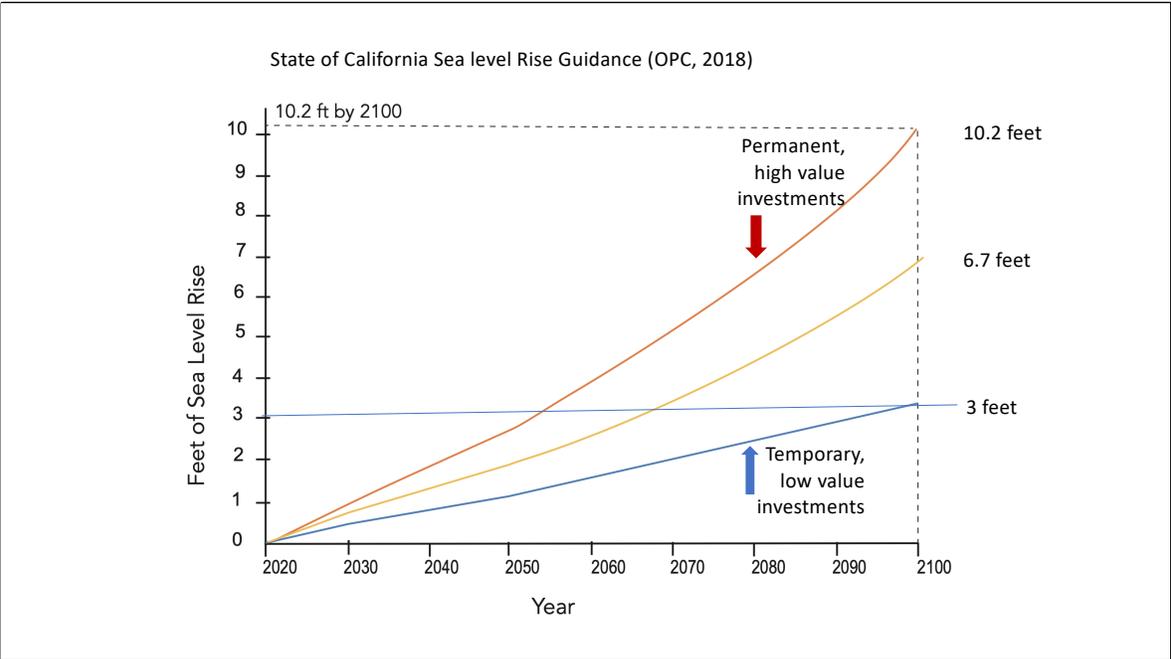
Dutch planners recognize that flooding will come from four directions as sea level rises: from the sea, from below, from rainstorms upriver, and from local rain.



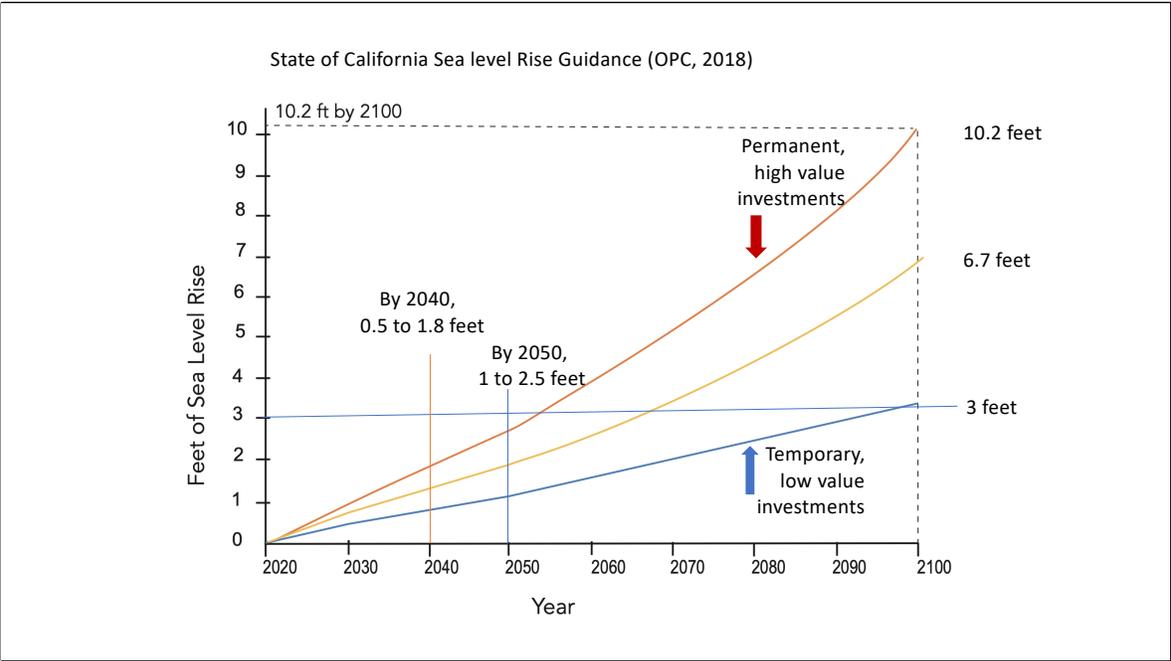
NASA data showing how much CO₂ is in the atmosphere today vs in the last 800,000 years (Homo sapiens has been around for the last 150,000)



These are the rates and magnitudes of sea level rise that the State recommended for planning in 2018.

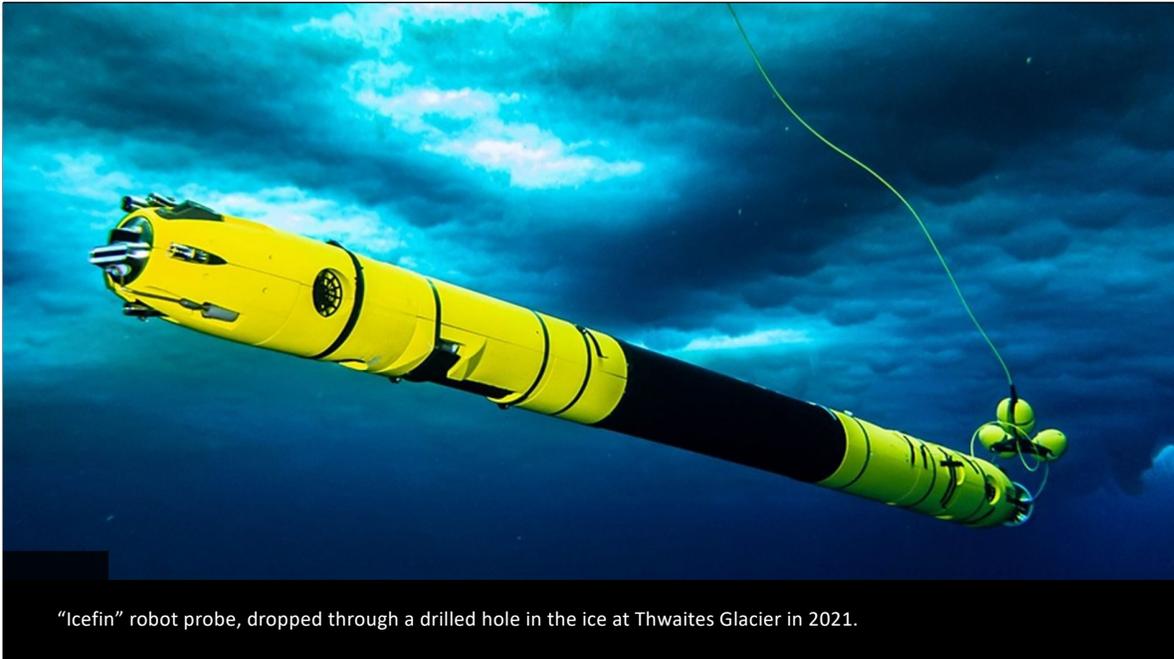


If an investment is long term (like multi-storey housing, or a highway, or a sewage treatment plant) one should use the high sea level rise projection line (red) for planning; if it's a temporary or low-value investment, it's OK to use the low sea level rise projection line (blue).



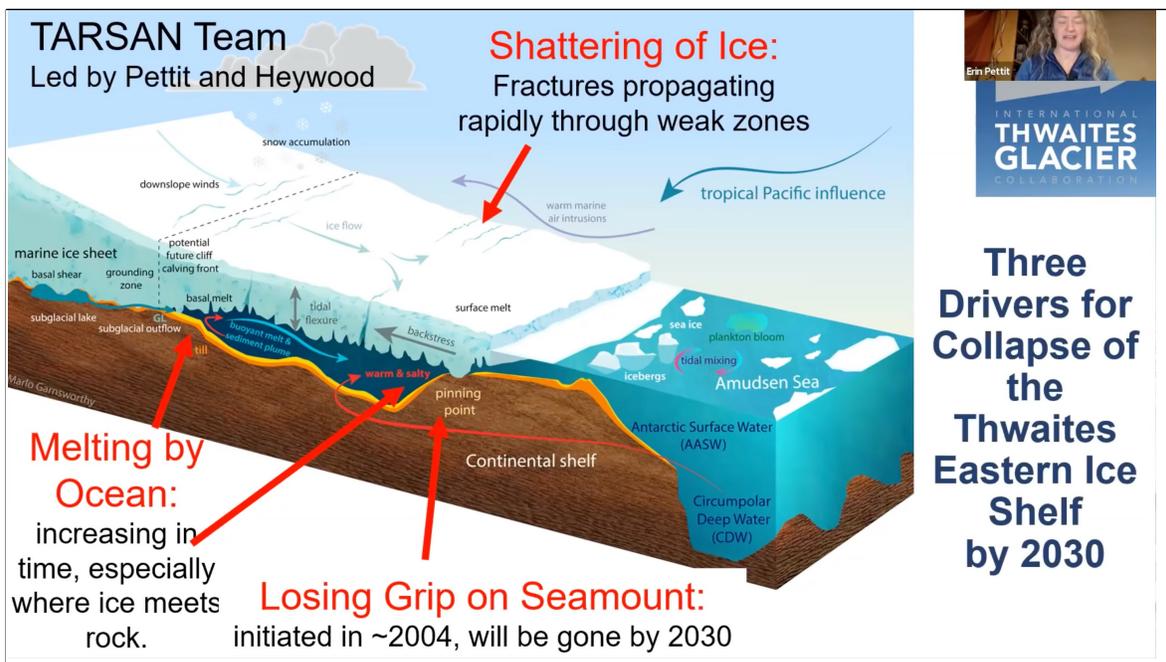
By 2040 the high tide could be 0.5 to almost 2 feet higher; by 2050, tides could be between 1 and 2.5 feet higher.

What's new in sea level rise research?



"Icefin" robot probe, dropped through a drilled hole in the ice at Thwaites Glacier in 2021.

Photo from BBC coverage of Thwaites research trip with Bethany Schmidt, 2021



Scambos, Pettit et al news conference at American Geophysical Union meeting, 2021 – this research showed that the Thwaites Glacier has extensive cracking on the surface, and may start to collapse as soon as 2030. It would take 100-500 years for it all to melt, but it could add another 3 feet or so to sea level rise by 2100 if it happens quickly.

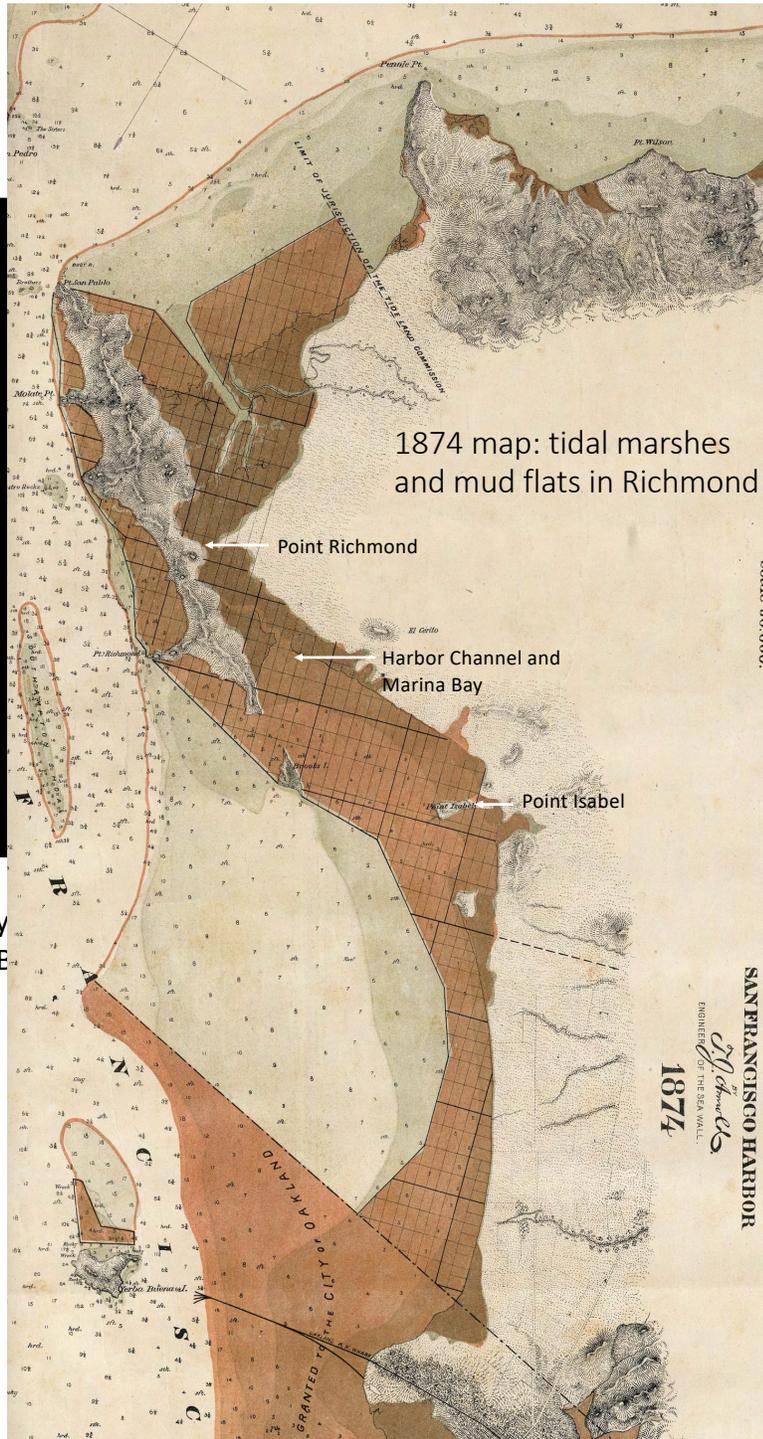
Mixed news about sea level rise:

- In the next 30 years, sea level could rise as much as it did in the last 100 years (**that's only about 1 foot, so it's good news**; it could have been higher)
- Between 2050 and 2100, sea level could still rise very quickly to a **worst-case level of 6 - 10 feet**, because observations from Antarctica are very worrying (cracks above and below Thwaites glacier, and lowest-ever surrounding sea ice amounts in 2022-23)
- We'll know a lot more by 2030, if not sooner

<https://www.youtube.com/watch?v=uBbgWsR4-aw> Erin Pettit et al 2021 Thwaites collapse likely after 2030

BBC. <https://www.bbc.com/news/science-environment-64640796>

Where is Richmond most vulnerable to permanently higher tides?



1874 map: tidal marshes and mud flats in Richmond

Point Richmond

Harbor Channel and Marina Bay

Point Isabel

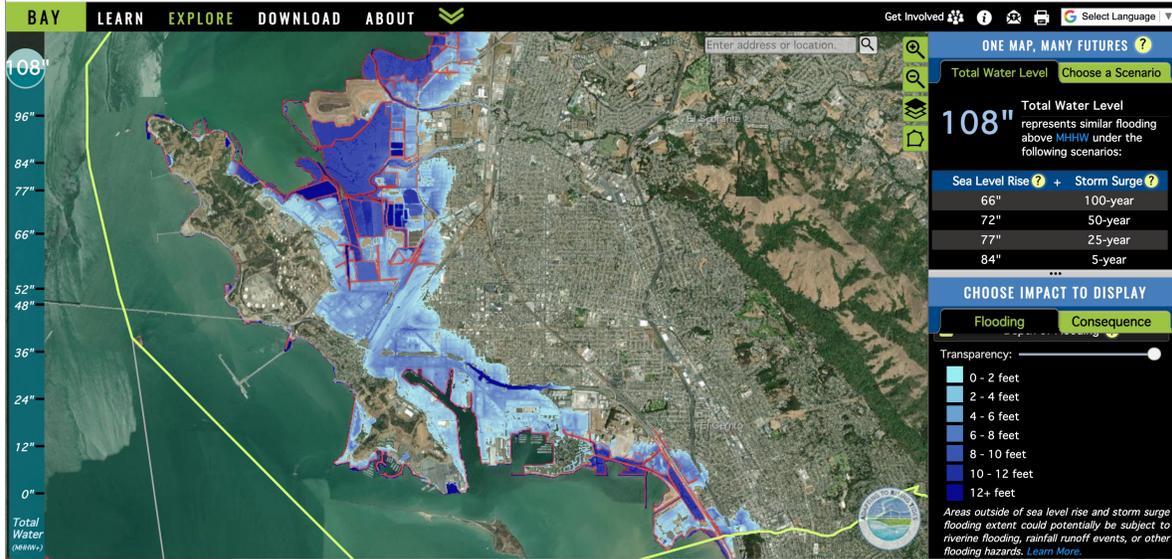
Scale 1:60,000.

SAN FRANCISCO HARBOR
ENGINEER OF THE SEA WALL
1874

Historically along the E

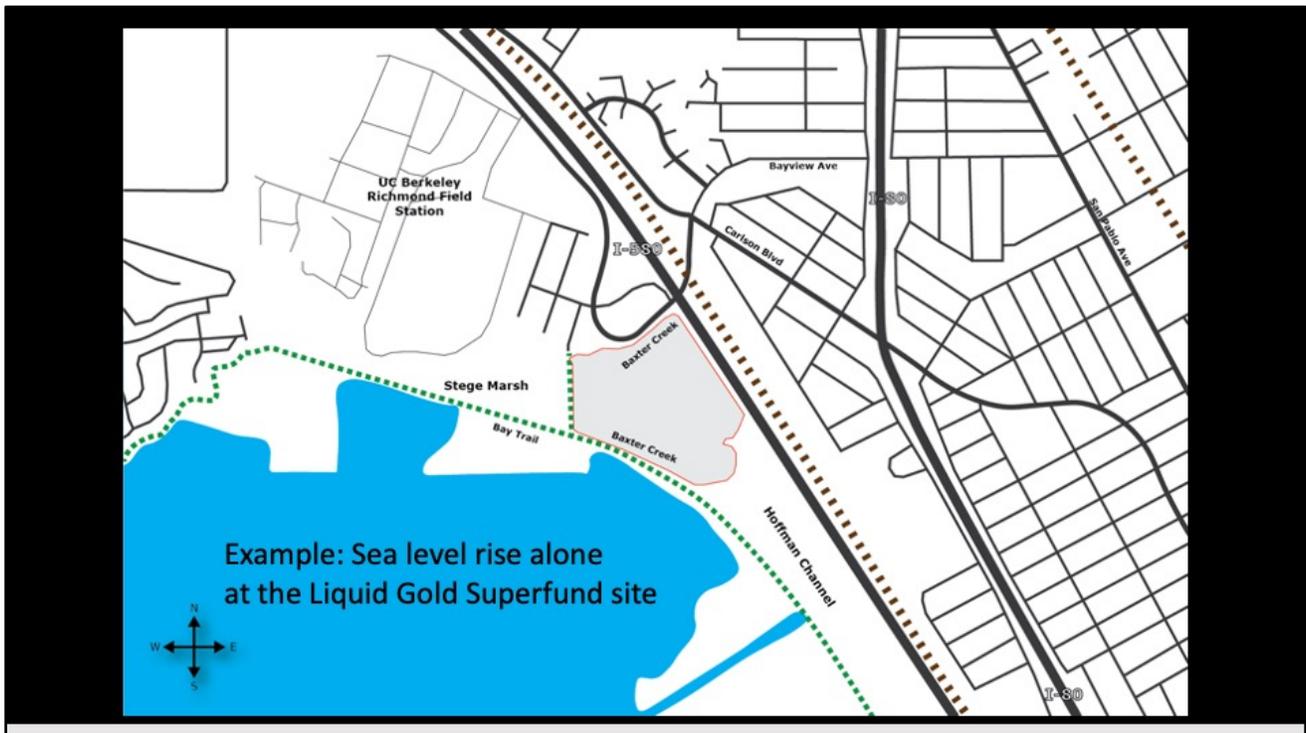
re and the hills

At some future point, Richmond will see 9 feet of sea level rise. (BCDC Bay Area Flood Viewer)

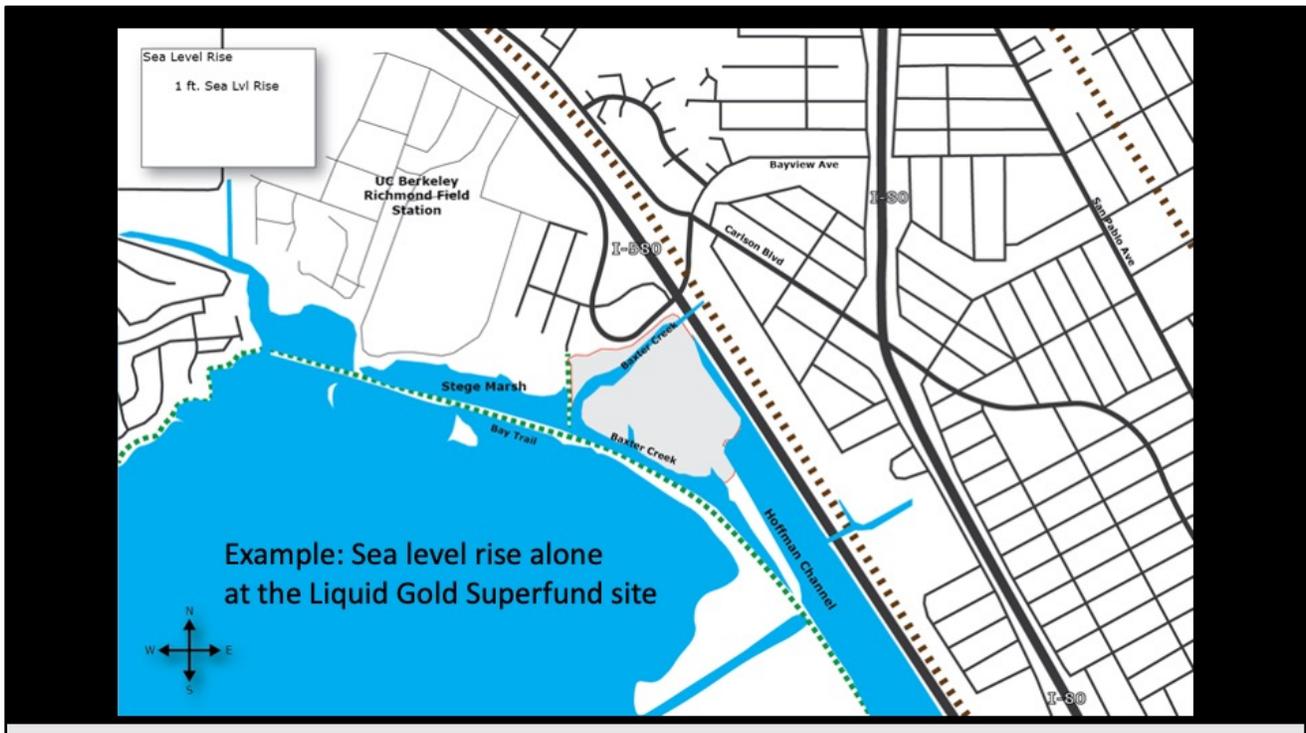


Many sea level rise researchers think we are now committed to 9-10 feet of sea level rise, at some point (maybe 300-500 years, maybe sooner). This can't be reversed by reducing emissions, so it's a reality that the city will need to prepare for over time.

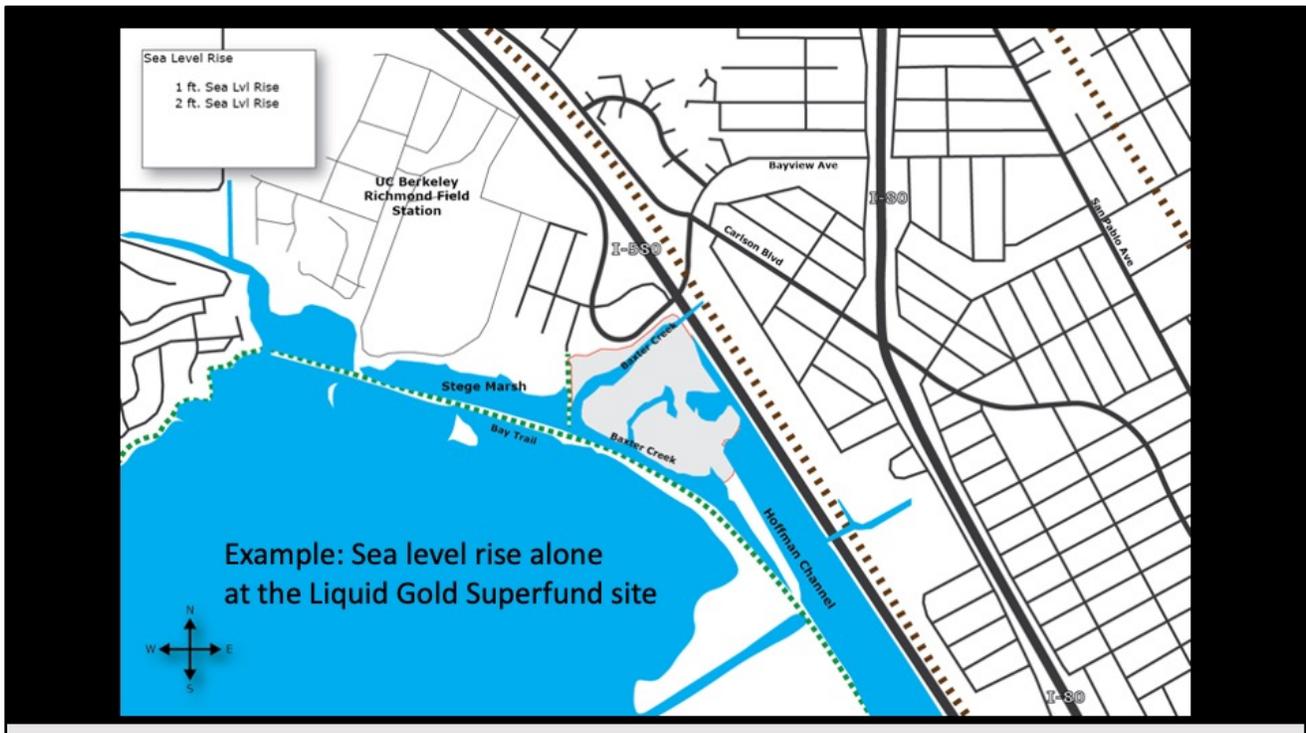




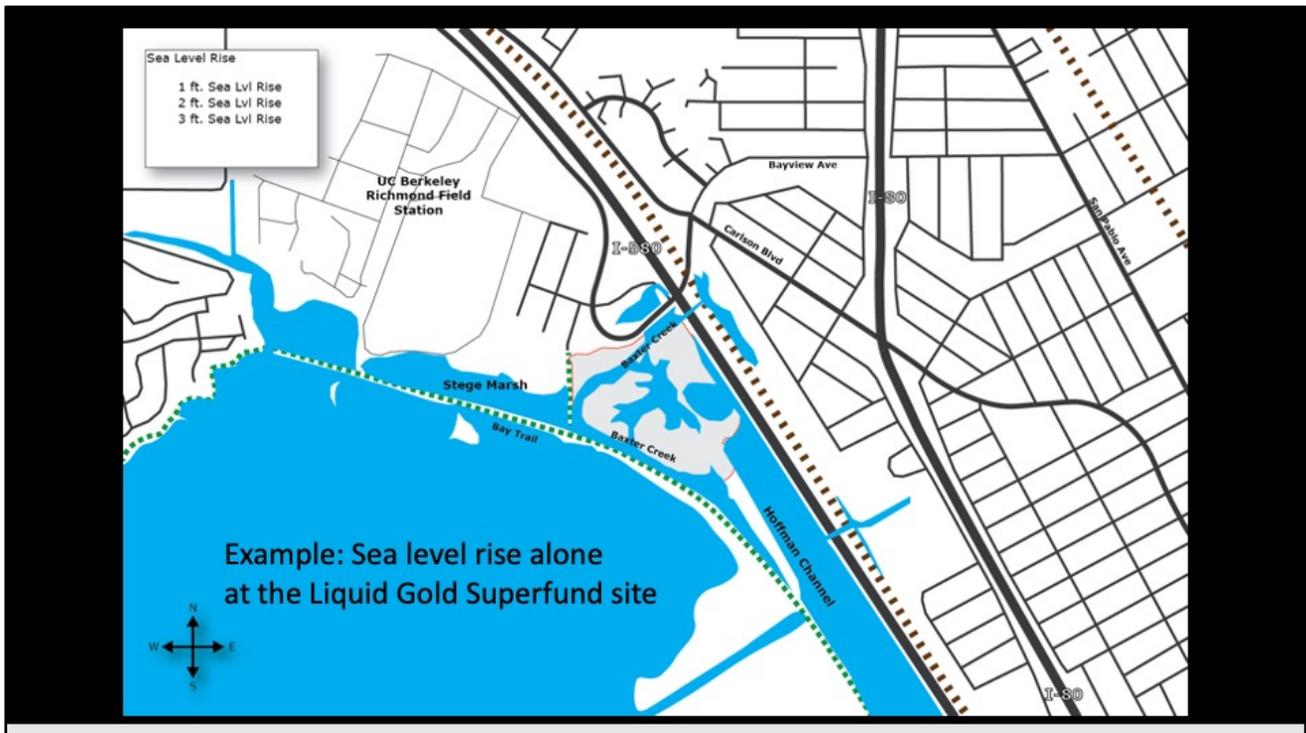
My students at UC Berkeley made this map to show how vulnerable the Liquid Gold Superfund site is to sea level rise alone – and groundwater is even higher, so it's even more at risk from rising groundwater. Let's see how it will be affected by a foot or more of sea level rise.



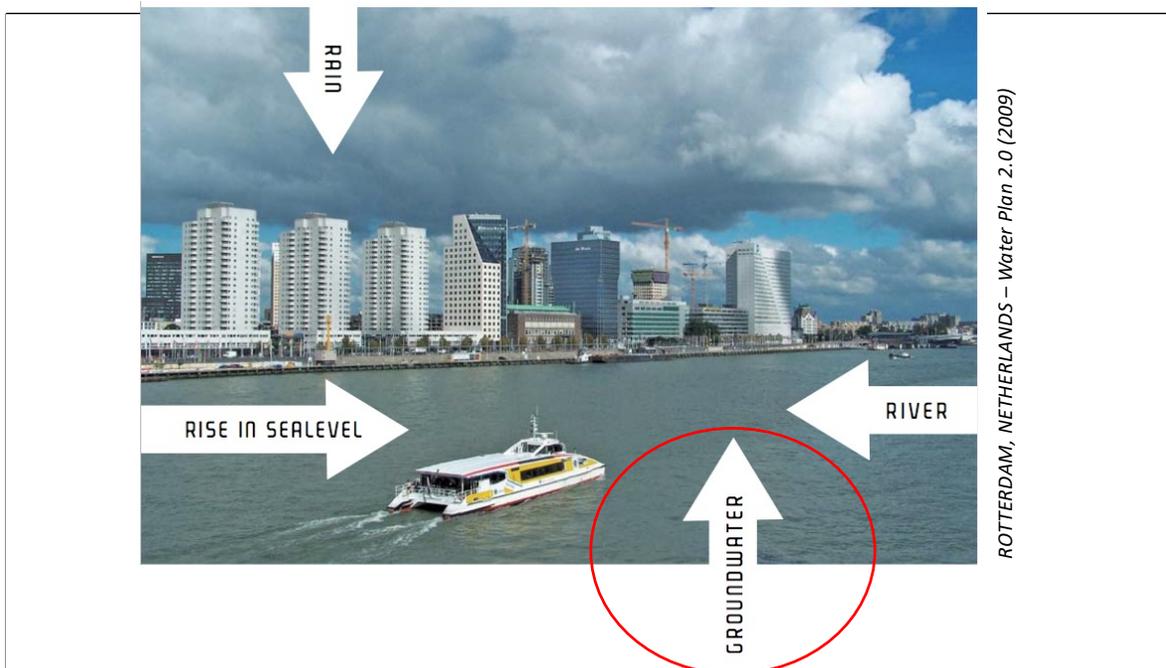
Here's the beginning of flooding on this site – at just 1 foot of sea level rise. This is clearly one of the most vulnerable Superfund sites to surface flooding in the region, maybe on the whole west coast.



Here's more flooding, at 2 feet.



And here's three feet.



The Dutch use this kind of diagram to remind people that sea level rise is only one component of compound flooding – which will come from local rain, rain far away up river, groundwater, and lateral flooding from saltwater high tides.

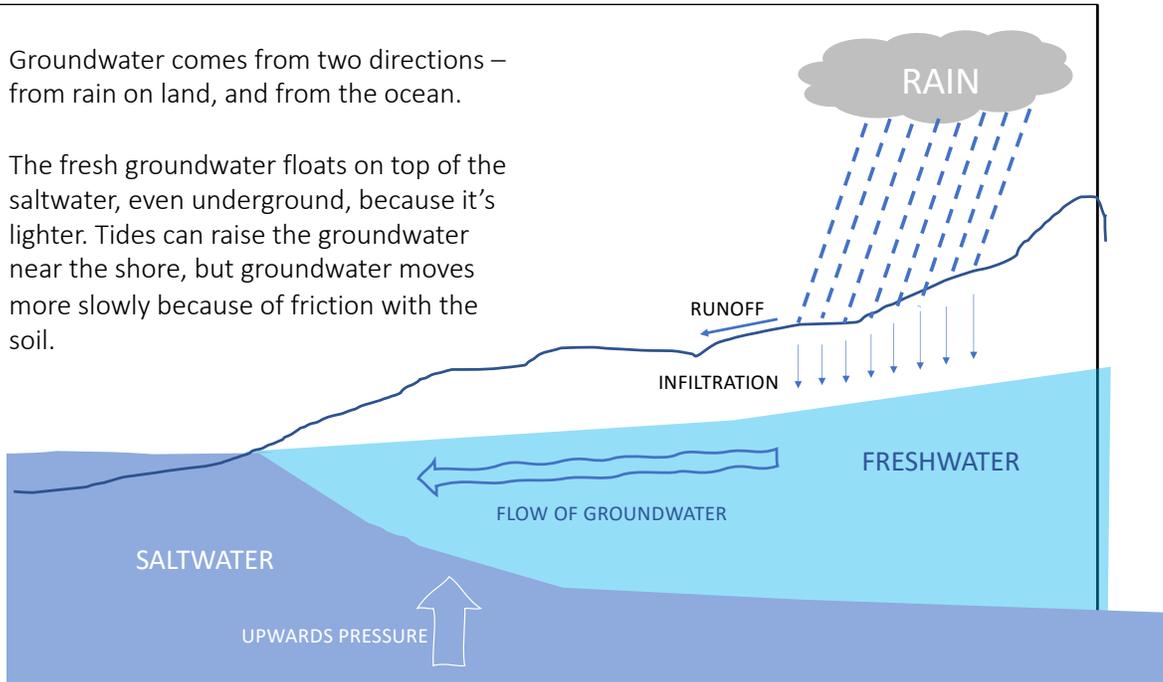
What is “shallow groundwater”?

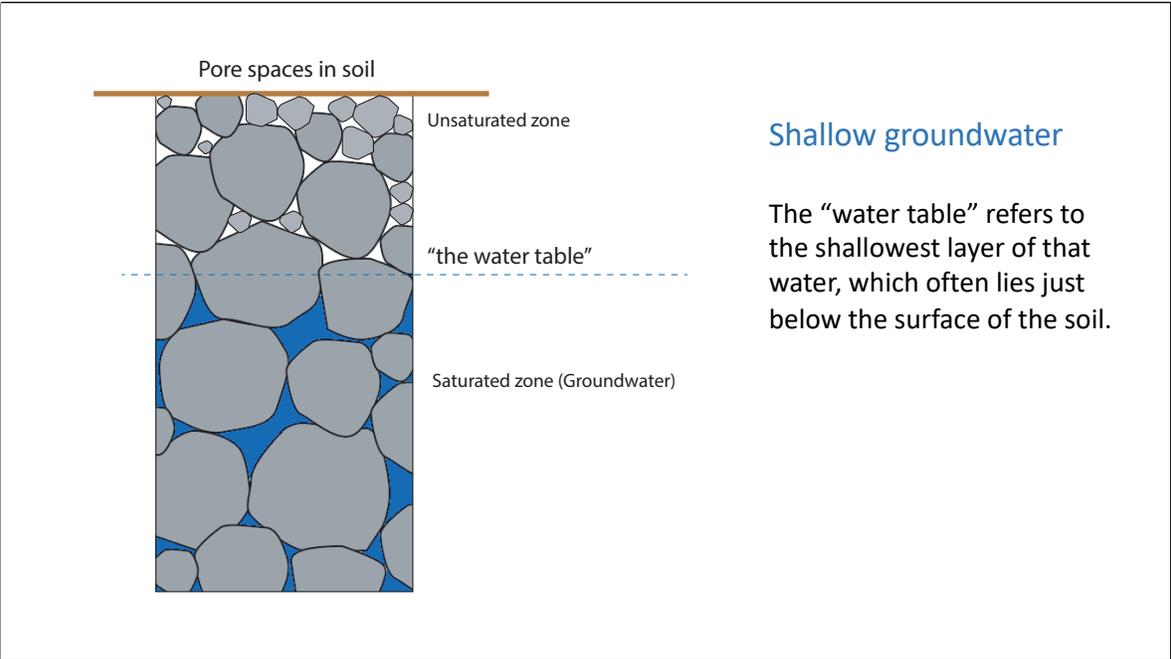


Shallow groundwater is that water you come to when you dig a hole at the beach. It's not the groundwater we drink or even use for irrigation. Close to the shore, it rises and falls with the tides – just much slower. And it flows out sideways through the soil towards creeks and the Bay.

Groundwater comes from two directions – from rain on land, and from the ocean.

The fresh groundwater floats on top of the saltwater, even underground, because it's lighter. Tides can raise the groundwater near the shore, but groundwater moves more slowly because of friction with the soil.





Shallow groundwater

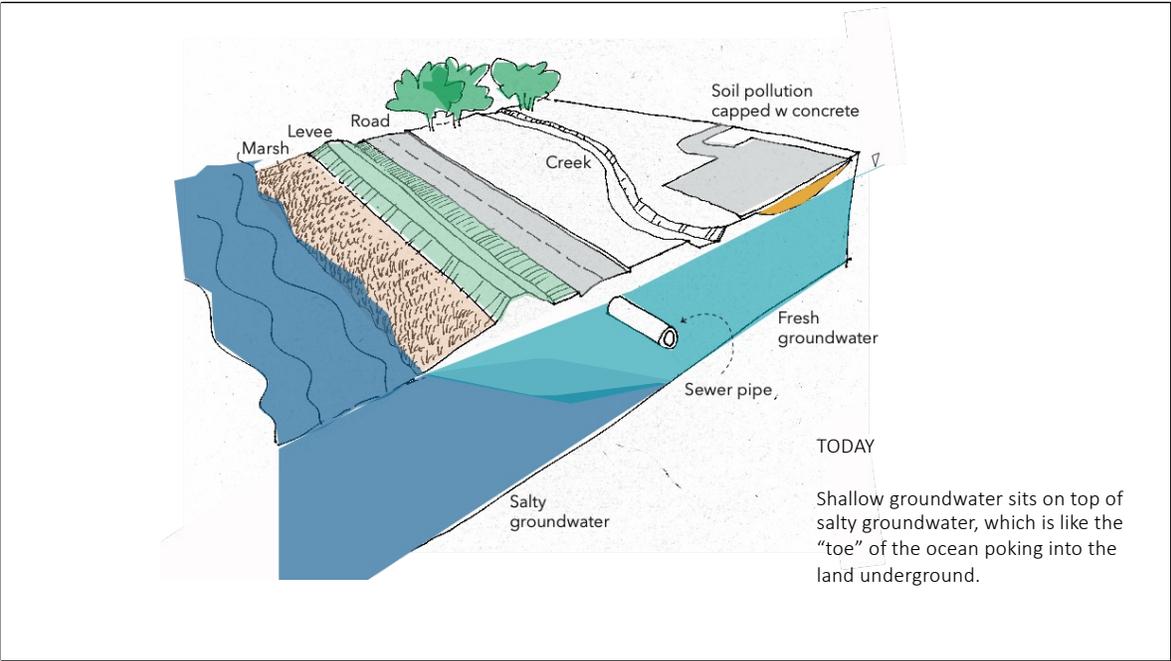
The "water table" refers to the shallowest layer of that water, which often lies just below the surface of the soil.

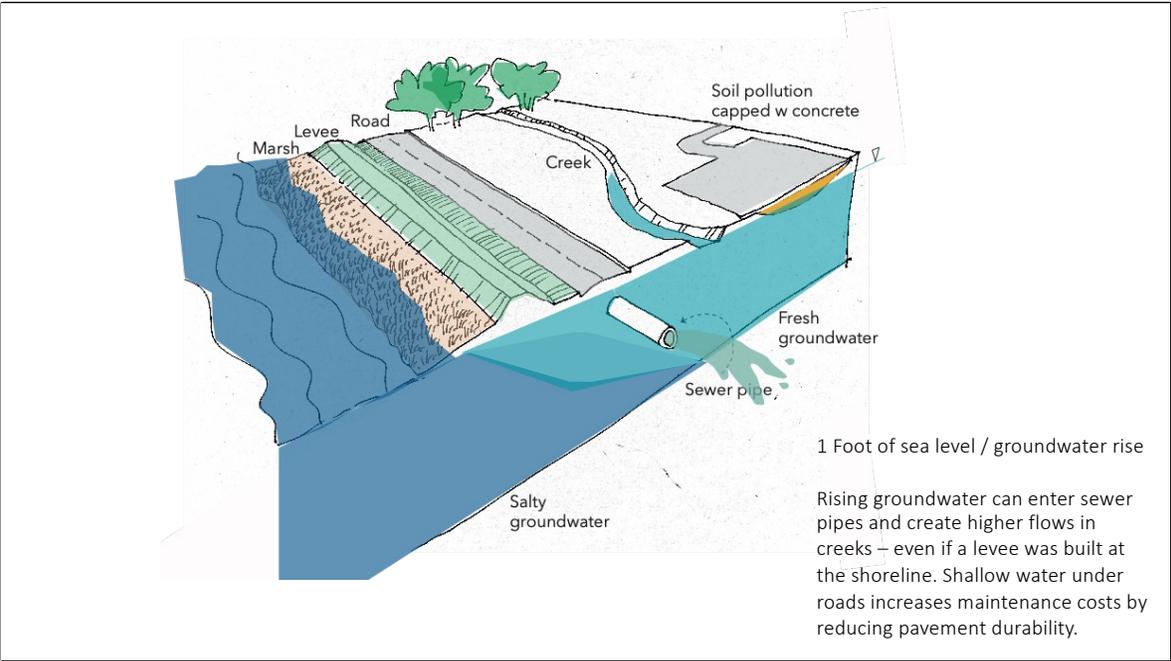
Groundwater infiltration into a storm or sanitary sewer pipe

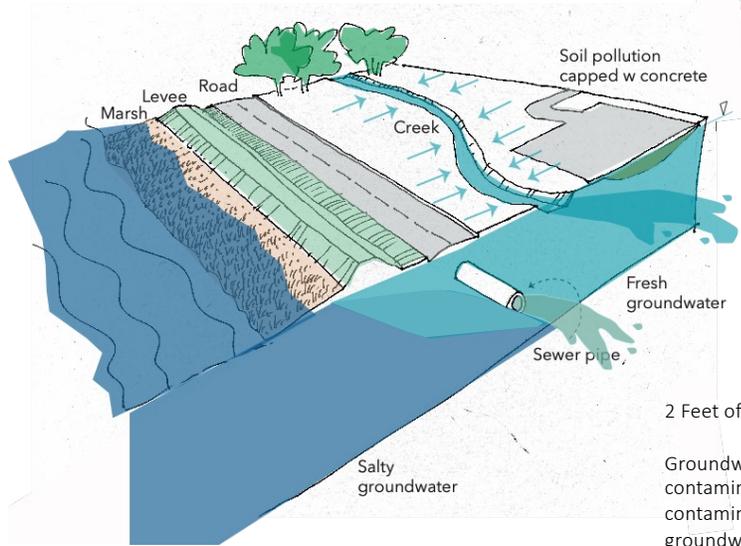


Source: American Public Works Association

The typical problem of high groundwater is that it gets into sewer pipes, so they have less capacity to carry away sewage or rain water. That can cause a home's sewer system to back up, or flooding at the surface.

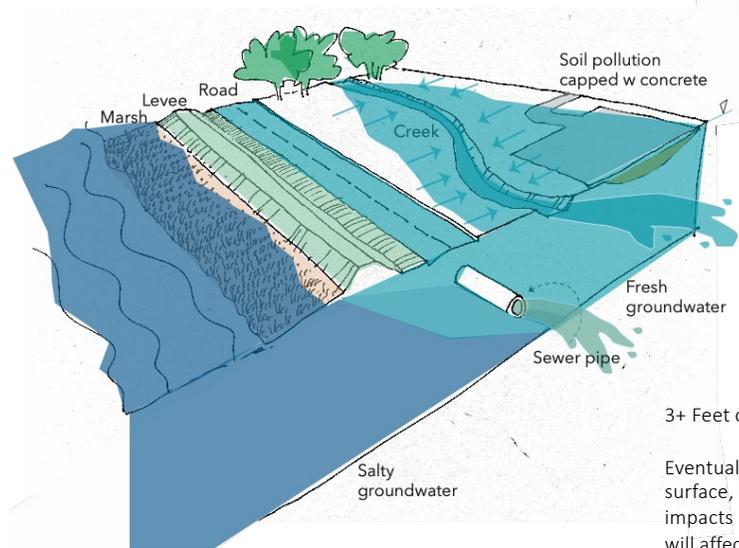






2 Feet of sea level / groundwater rise

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

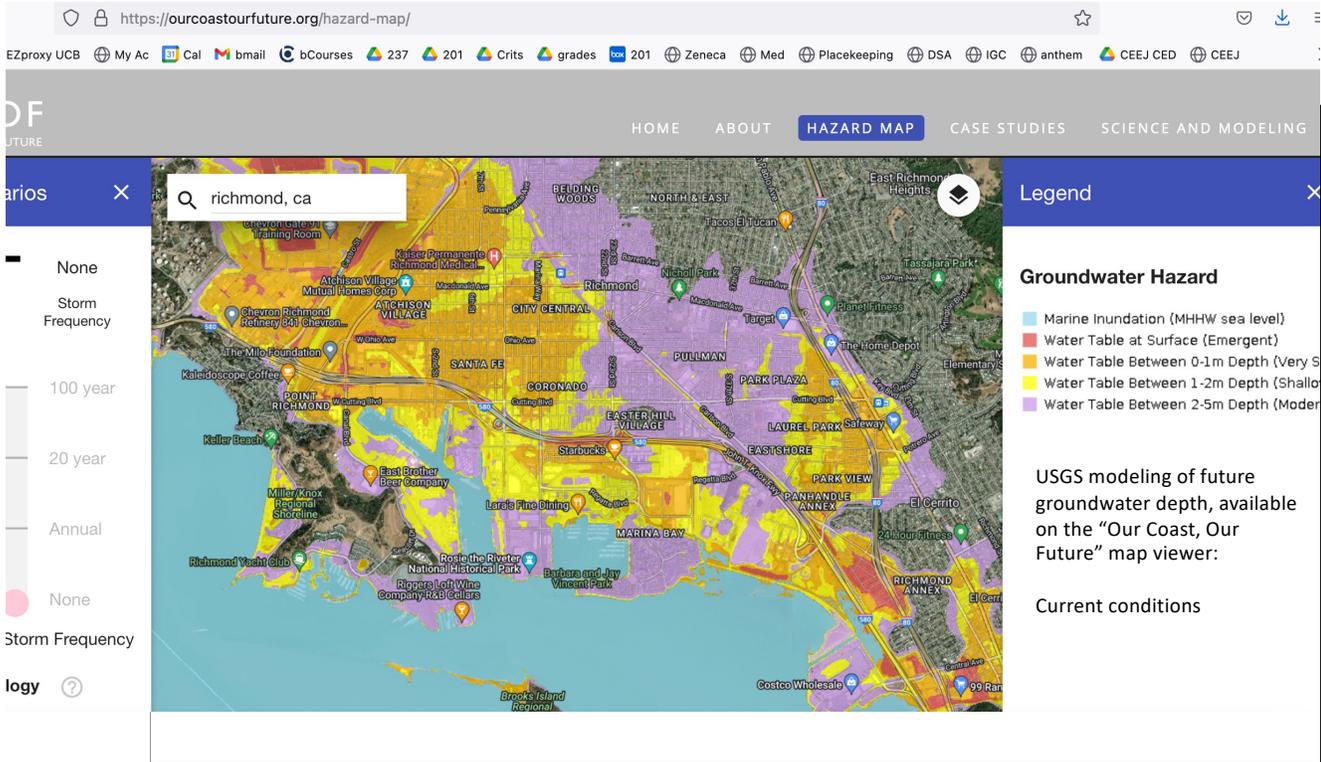
Eventually flooding emerges at the surface, but by then, most of the impacts have already occurred that will affect land value.



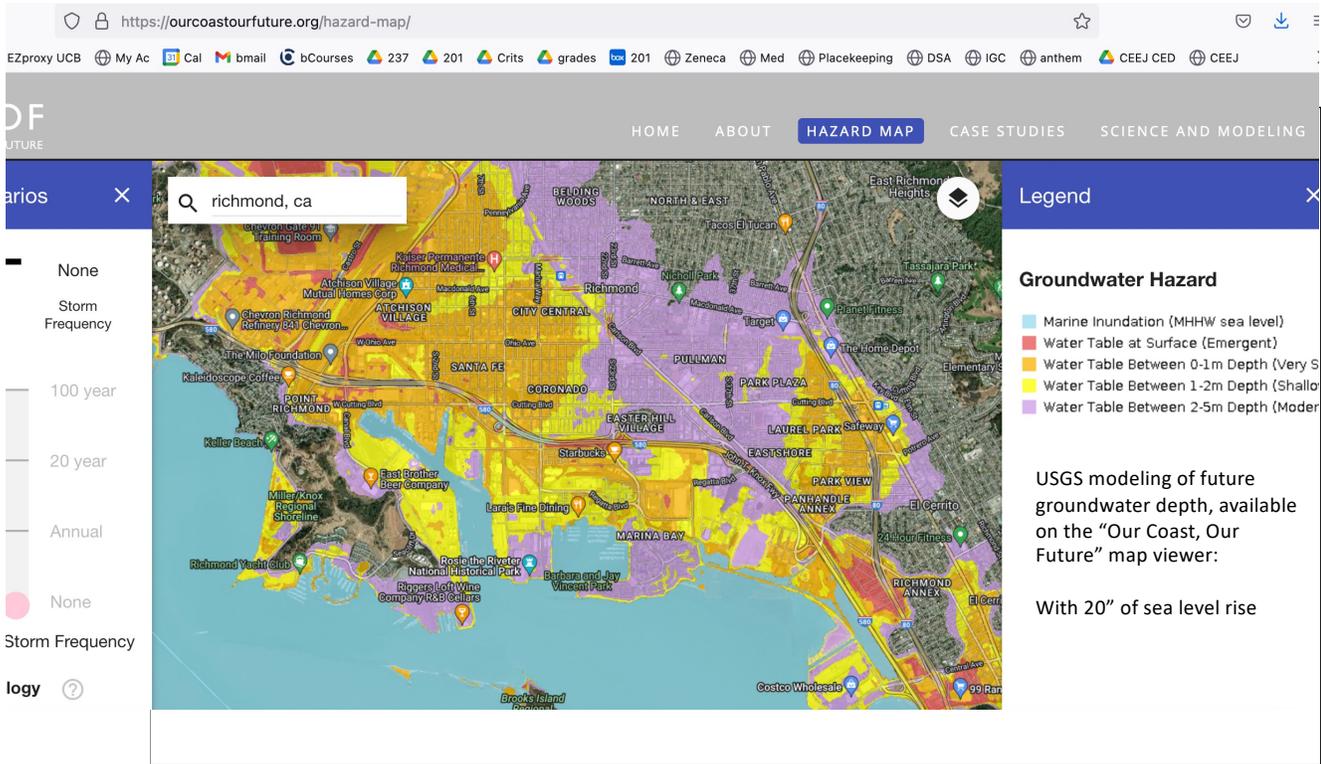
January 2021 King Tide, San Leandro

Shallow groundwater already comes up through a maintenance hole in San Leandro during the highest tides of the year.

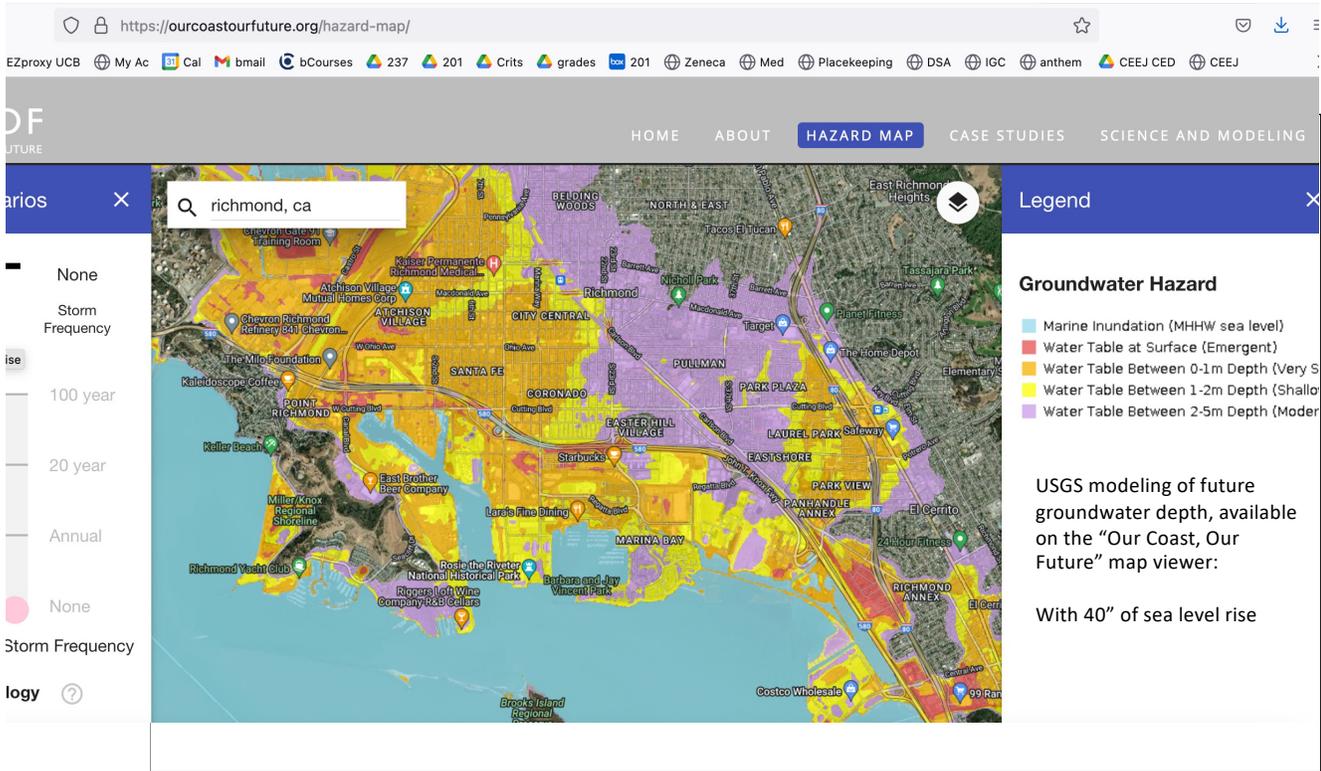
Where is Richmond most vulnerable
to rising groundwater?



The US Geological Survey has done a low-resolution model of how shallow coastal groundwater may rise with sea level for the entire state of CA. This slide shows current conditions. It's available through the Our Coast, Our Future (OCOF) mapping tool at ourcoastourfuture.org.



This slide shows about 20 inches (half a meter) of sea level rise pushing groundwater up as the orange and yellow areas expand.

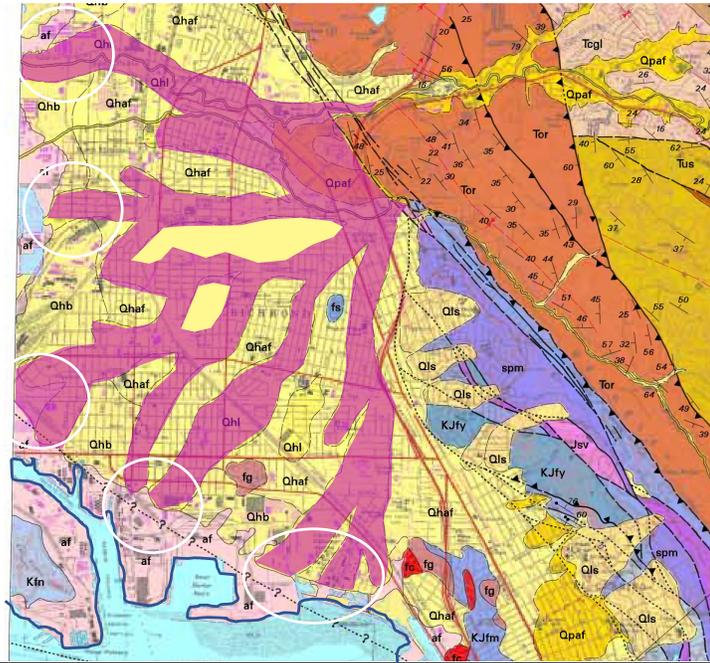


This shows the effect of 3' feet 4" inches of sea level rise (1 meter). You can see the red areas expanding, where groundwater would reach the surface. But even having the groundwater 3 feet below the surface effectively saturates the soil above. And the impacts can start to occur from just a few inches of increased elevation of the water table – most of the impacts will occur long before the water shows up at the surface.

Old riverbeds – shown here in dark pink - run under Richmond like fingers on a hand that extends from the hills to the Bay.

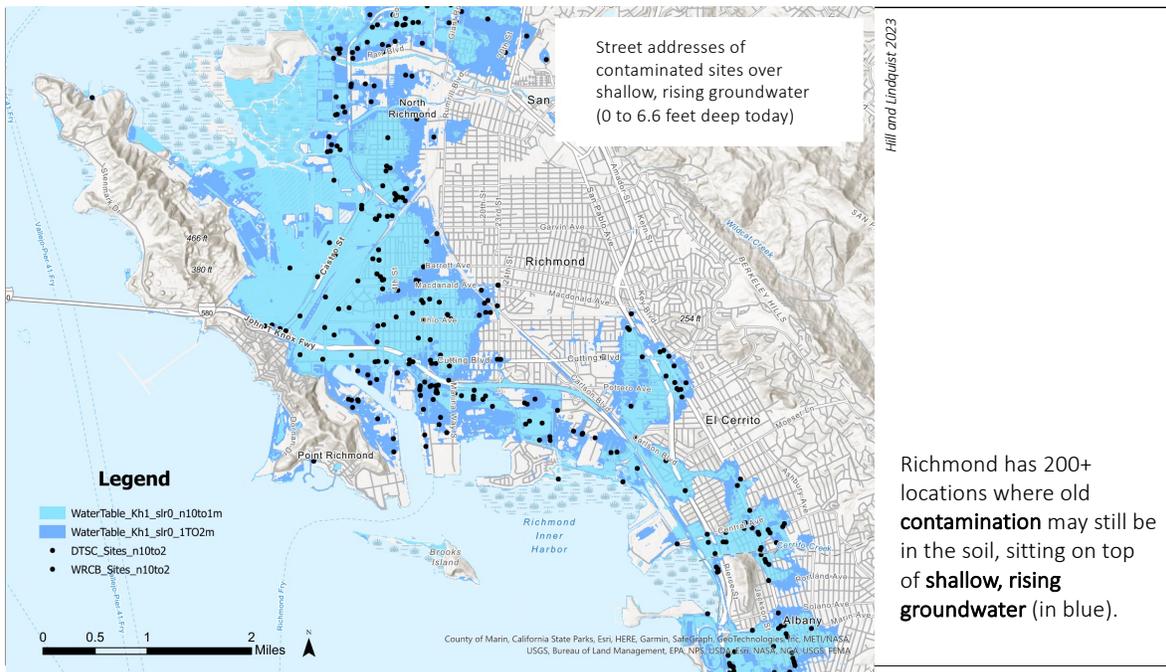
Gravels in those old riverbeds allow groundwater to flow through faster, which can make the water table higher where the “fingers” meet the urban fill at the shoreline.

That’s why land parcels at the end of the fingers are more vulnerable to rising groundwater, with those higher groundwater flows coming down from the hills.



Contamination in soil

...can move when groundwater
rises into it from below

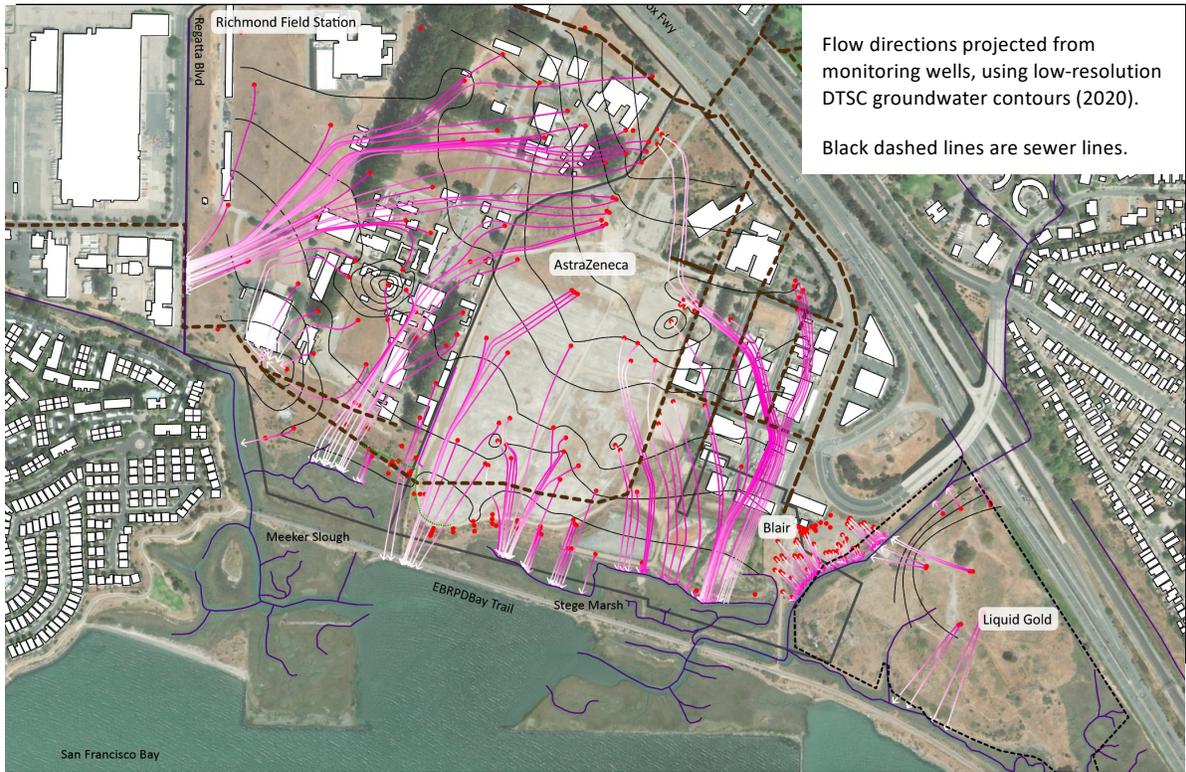


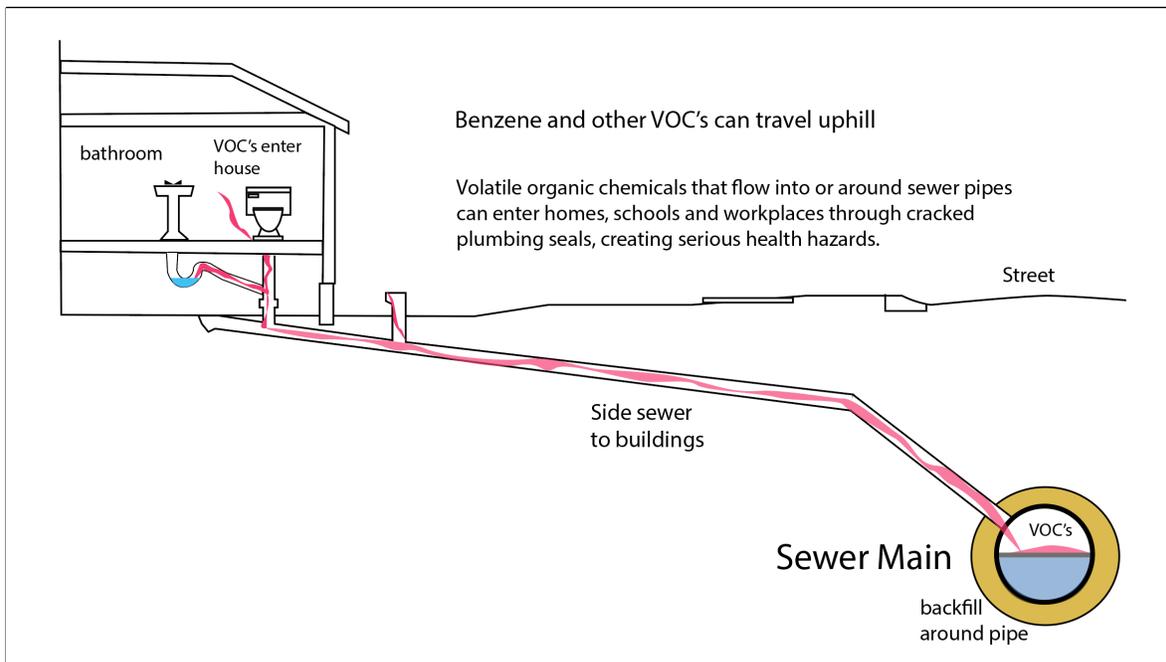
This is the set of sites (marked with black dots) that should be reviewed to identify hazards that could occur from rising groundwater.

South shoreline case study

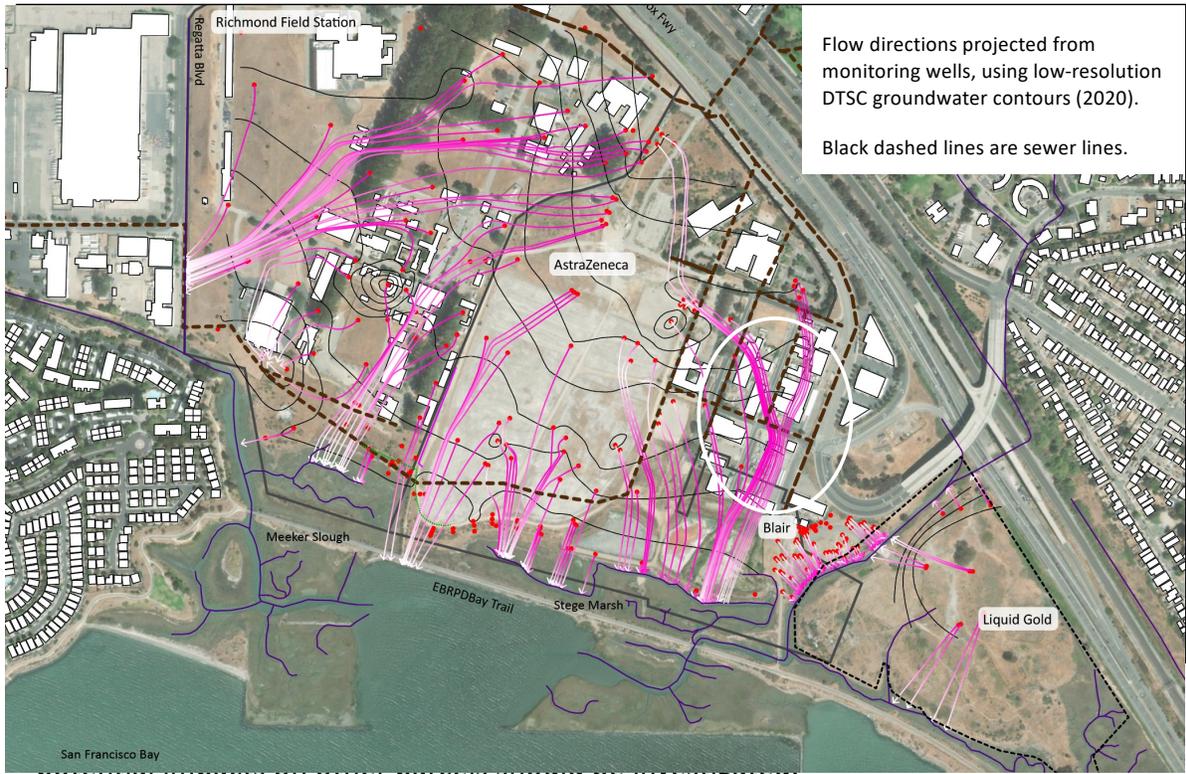
(UC Berkeley, 2020-2023)

Changing groundwater levels can change
the flow directions of contaminants underground





Contaminants in groundwater can travel in unexpected directions. The vapor component of volatile organic chemicals can travel up cracked pipes and even up the backfill (usually gravel or crushed rock) that surrounds pipes. This is a well known phenomenon in DTSC and the Water Board, but very few people in the public know about it. Old plumbing seals like the seal at the base of a toilet can be cracked, and allow these gases to enter homes, school, and businesses. While sinks have P-traps to prevent vapor intrusion, toilets have internal P-traps (p-shaped) so they are vulnerable at the base. Many people have developed serious illnesses as a result of vapor exposure alone.



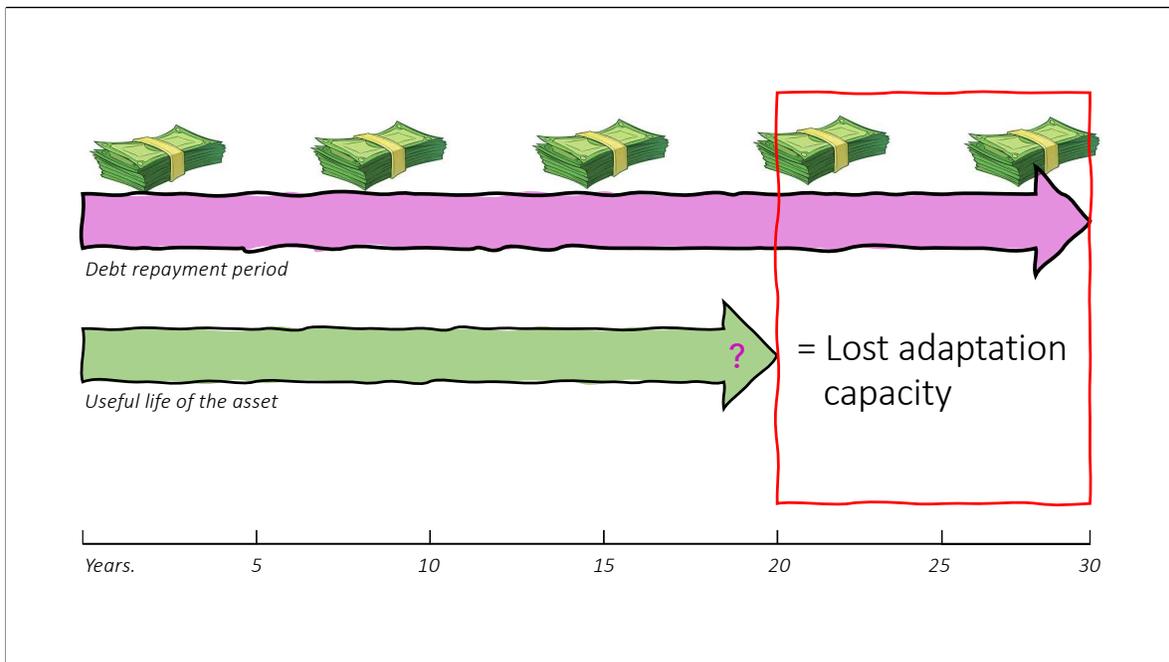
potential impacts on other parcels should be investigated.

Richmond faces significant risks to health, the environment, buildings, and infrastructure as a result of rising sea level.

This adds up to a resulting risk to the **property tax base** for coastal cities, and to a city's **bond rating** if no adaptation plans are made.

Impacts on Richmond from a rising sea level and rising shallow groundwater:

1. Underground pipes will be compromised (infiltration causes problems with storm sewers and sanitary sewers, which require more maintenance)
2. Increases risks of extreme earthquake shaking (liquefaction) on fill and former wetland soils
3. Increases probability of tidal inundation at contaminated sites
4. Increases likelihood that contamination underground will move towards sewer lines, potentially affecting people in buildings, as well as towards the Bay
5. As groundwater becomes more saline, the risk of foundation failures increases
6. Pavements will degrade faster over shallow groundwater, requiring more maintenance
7. Eventually, the risk of flooding at the surface increases. Levees or cut-off walls can increase the rate at which groundwater rises on the landward side. Pumping can increase the rate at which the land sinks, which happened in New Orleans.



If the debt repayment period for a public infrastructure investment exceeds its useful life, that represents a loss of adaptation capacity for the city. Investments made using bonds should be evaluated to make sure the useful life of the investment (roads, parks, etc.) meets or exceeds the period of bond repayment while the environment floods around it.



The city of Amsterdam was built in a shallow groundwater area. Canals and pumps are used to drain groundwater away and keep the blocks dry in between.



Canals can be a beautiful component of dense urban areas, as this image from Amsterdam shows.



New districts of Amsterdam and other Dutch cities are being built with floating homes, up to three floors high. This one is called Steiger Eiland, and it is an affordable housing development in a water body that is surrounded by levees (not on the open ocean). The future plan is to put prefabricated housing units onto shared decking, instead of having each structure float individually. Utilities are designed with the type of flexible joints that would be useful in an earthquake zone.

How to protect safety, support a high quality of life and conserve the value of public/private assets as these unavoidable changes occur?

Step 1: Start comparing the functional period of new infrastructure investments to their repayment period – this is critical, to avoid being stuck with useless debt.

Step 2: Make an Adaptation Plan: identify adaptation pathways for adding new development in the safest locations while transitioning away from conventional development in dangerous areas (consider Dutch-style housing precedents).

Step 3: Prepare for groundwater to rise at contaminated sites by excavating or treating soils before the contaminants get wet.