Sea Level Rise Vulnerability Assessments: An Emerging Issue at Cleanup Sites

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Battelle Chlorinated Conference

June 2024

Agenda

1 **Background**

Climate Change Hazards, Adverse Effects, and Vulnerabilities

Sea Level Rise (SLR) Projections and Guidance

SLR Vulnerabilities at Cleanup Sites

2 **Types of “Flooding” Sources**

Inland Flooding (Fluvial and Pluvial)

Coastal Flooding

Groundwater Rise

3 **Case Study**

Sea Level Rise Vulnerability Assessment for a Diesel UST Site

Conclusions

Summary

Future Work

Background:

An Emerging Issue for Cleanup Sites

A few headlines on this emerging topic….

THE DAILY CALIFORNIAN
Wednesday, April 20, 2022

NEWS

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CITY FRIDAY, AUGUST 6, 2021

Community groups in Richmond file lawsuit against state for inadequate toxic waste cleanup

Los Angeles Times

CLIMATE & ENVIRONMENT

More than 400 toxic sites in California are at risk of flooding from sea level rise

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KQED

State Regulators Scrutinize Climate Plan for Controversial Richmond Housing Development

By Ezra David Romero Jan 12 Save Article

Climate Hazards, Flooding Source(s), and Potential Vulnerabilities/Failures

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Climate Hazards*
Extreme temperature events
Extreme precipitation events
Drought
Sea level rise (SLR)
Storm surge (and waves)
Hurricane
Wildfire
Erosion/scour
Saltwater intrusion
Landslides
Tides (stressor not affected by climate change)
Subsidence (stressor indirectly affected by climate change)

<u>Key Terms:</u>

CVA: Climate Vulnerability Assessment

SLRVA: Sea Level Rise Vulnerability Assessment

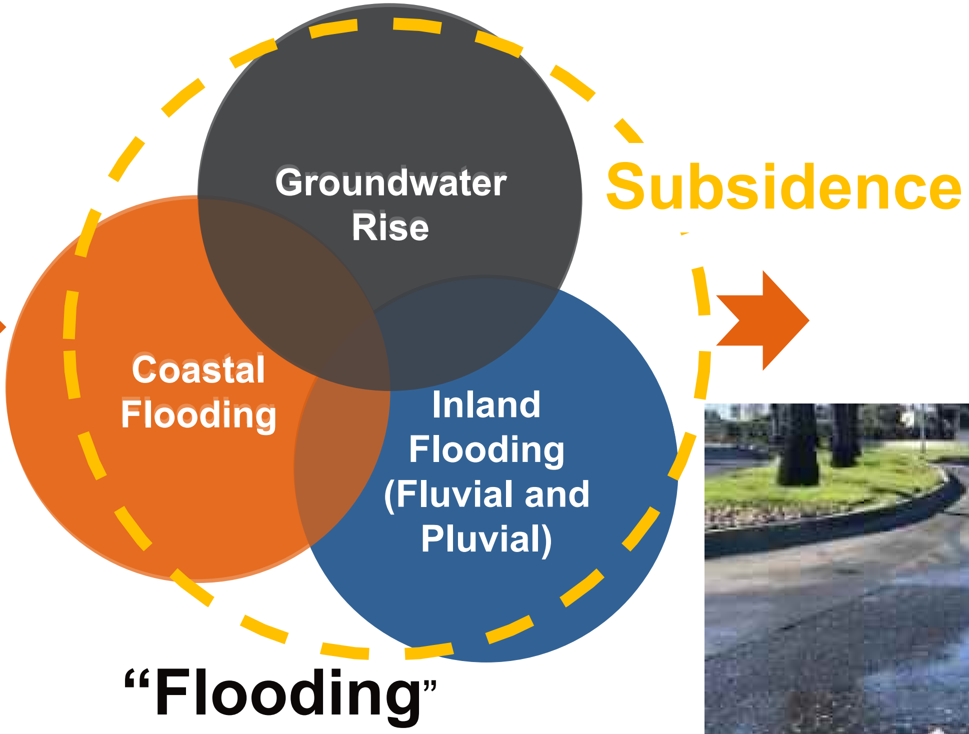

Photo sources: Tides project, sfgate.com

* Adapted from EPA 2023

Sea-Level Rise Projections and California Guidance

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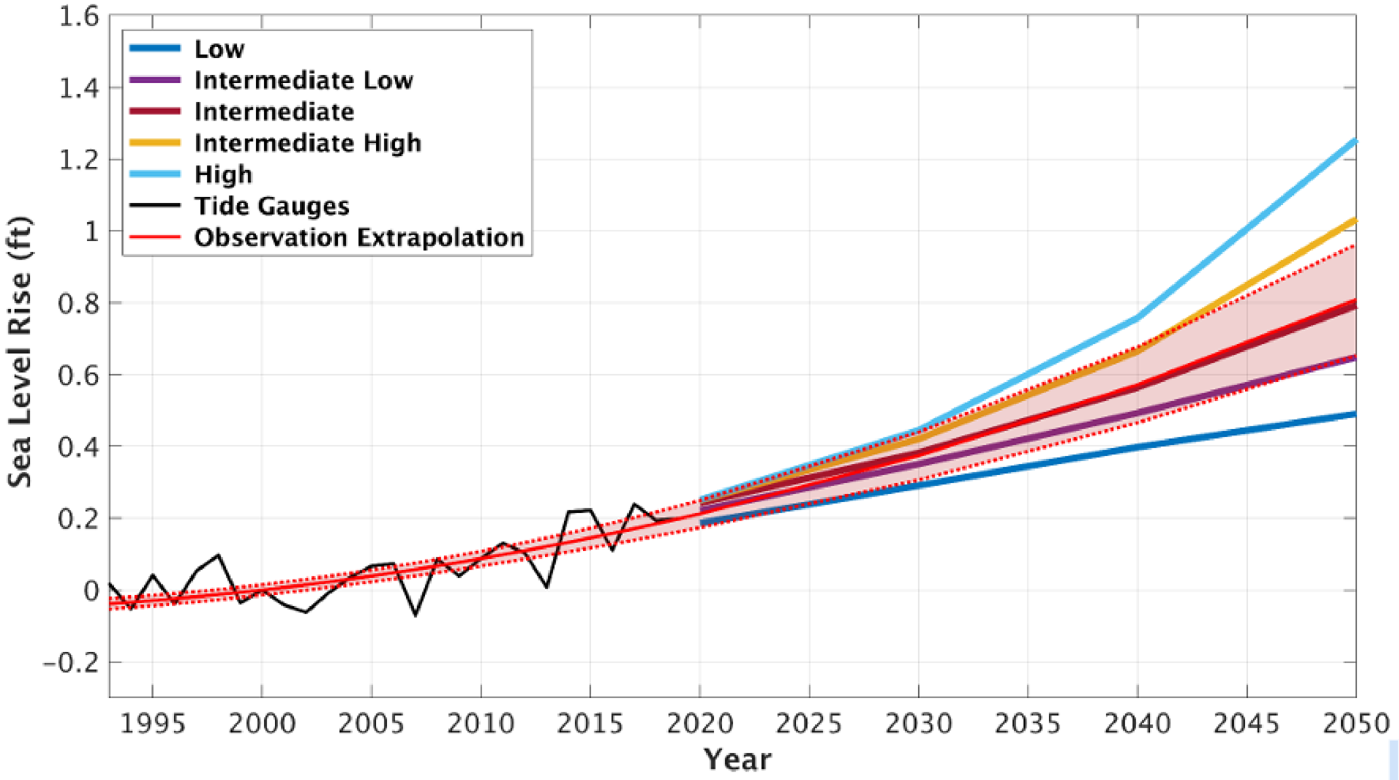
Provides local SLR increase estimates for California. Provides probabilities of SLR to meet or exceed a certain threshold **for various future emissions scenarios**.

2018 Update: 1 mention of "contaminated soil"
2024 Draft Update: 7 mentions of "contaminants"

Year	Low	Int-Low	Intermediate	Int-High	High
2020	0.2	0.2	0.2	0.2	0.3
2030	0.3	0.4	0.4	0.4	0.4
2040	0.4	0.5	0.6	0.7	0.8
2050	0.5	0.6	0.8	1.0	1.2
2060	0.6	0.8	1.1	1.5	2.0
2070	0.7	1.0	1.4	2.2	3.0
2080	0.8	1.2	1.8	3.0	4.1
2090	0.9	1.4	2.4	3.9	5.4
2100	1.0	1.6	3.1	4.9	6.6
2110	1.1	1.8	3.8	5.7	8.0
2120	1.1	2.0	4.5	6.4	9.1
2130	1.2	2.2	5.0	7.1	10.0
2140	1.3	2.4	5.6	7.7	11.0
2150	1.3	2.6	6.1	8.3	11.9

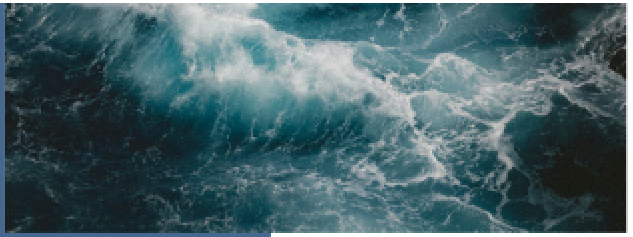


OPC, 2024: ***State of California Sea-Level Rise Guidance****.*

https://opc.ca.gov/2024/01/draft-slr-guidance-2024/

Vulnerability Assessment Guidance

2017, Updated in 2023 | 2023 | 2023



Sustainable Remediation: Climate Change Resiliency and Green Remediation

A guide for Cleanup Project Managers to:

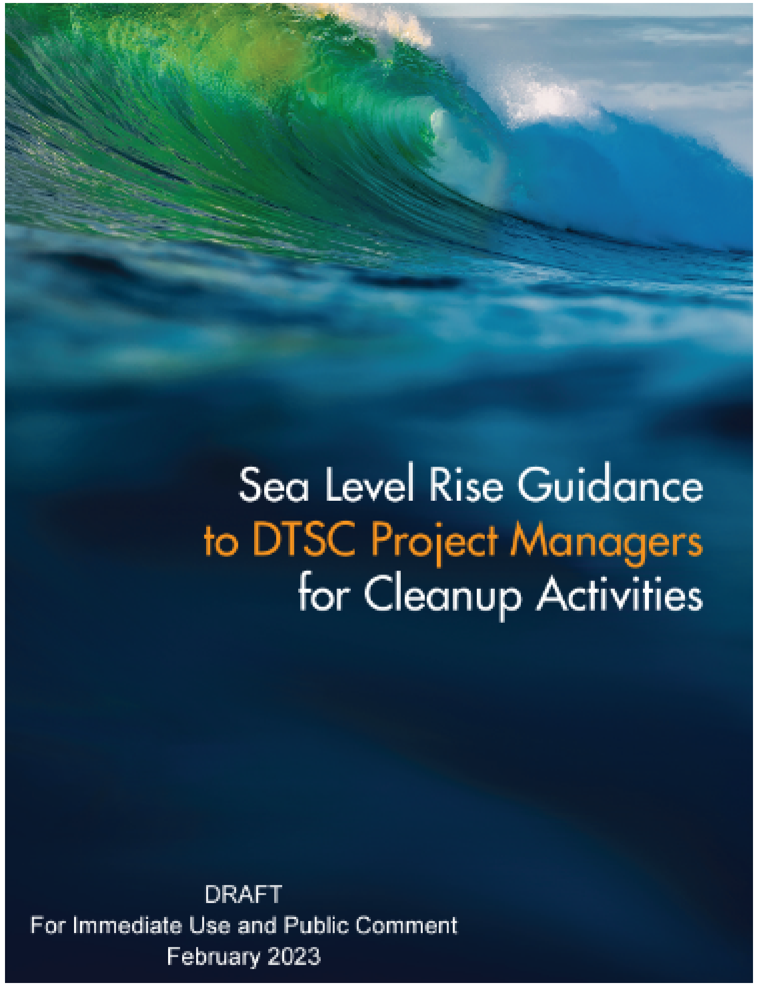
Increase resiliency of cleanup remedies to climate change impacts
-and-
Increase benefits and reduce impacts from the MTCA Cleanup Process

Toxics Cleanup Program
Washington State Department of Ecology
Olympia, Washington

Revised: January 2023
First published: November 2017

Publication 17-09-052

DEPARTMENT OF ECOLOGY
State of Washington



EPA United States Environmental Protection Agency

EPA 542-R-23-002
November 2023

Engineering Forum Issue Paper

The groundwater treatment plant and storage tanks at the American Cyanamid Superfund site, constructed on elevated land outside the 500-year floodplain, avoided floodwaters in 2021. Photo Credit: Mark Schmidt.

Conducting Climate Vulnerability Assessments at Superfund Sites

Contents

The Technical Support Project Engineering Forum issue papers provide information on remediation technologies or technical issues of interest. The information is not guidance or policy.

"The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes; it is a function of the character, magnitude, and rate of climate variation to which a system is exposed; its sensitivity; and its adaptive capacity."
— U.S. Environmental Protection Agency, 2021
https://semspub.epa.gov/work/HQ/100002993.pdf

1. Purpose

The U.S. Environmental Protection Agency (EPA) Office of Superfund Remediation and Technology Innovation (OSRTI), in collaboration with the Technical Support Project (TSP) Engineering Forum, developed this issue paper to document the lessons learned in conducting climate vulnerability assessments (CVAs) at sites on the National Priorities List (NPL). While developed for Superfund, this process is program neutral and may be used as a guide for performing CVAs at contaminated sites managed under other cleanup programs. Vulnerability assessments may be performed at all site types, by all site leads and at all stages of a cleanup. This issue paper may be used by all stakeholders wanting to replicate the CVA process applied in the Superfund Remedial Program.

Example Case Study: Landfill Features and Infrastructure of Interest

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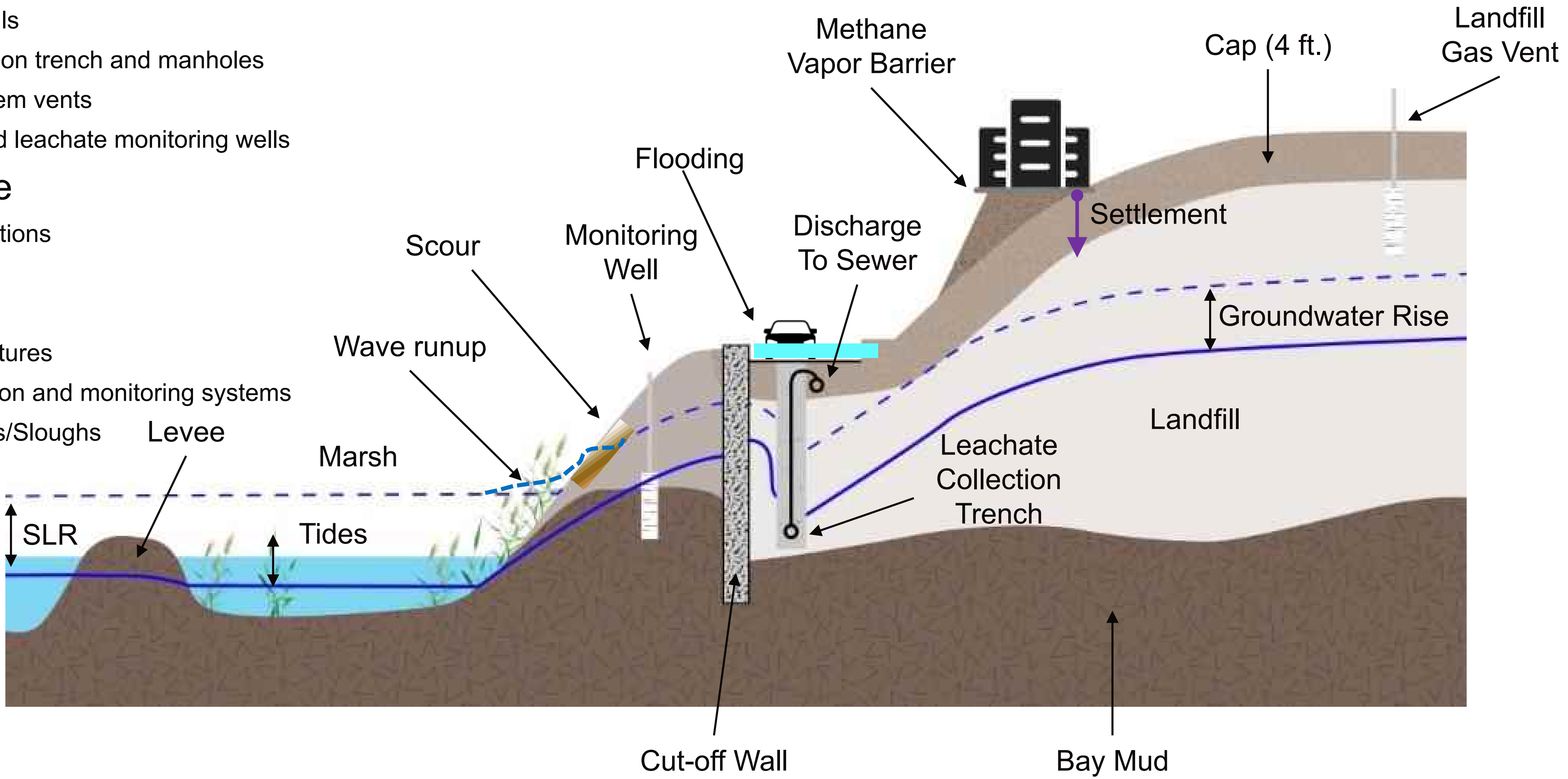
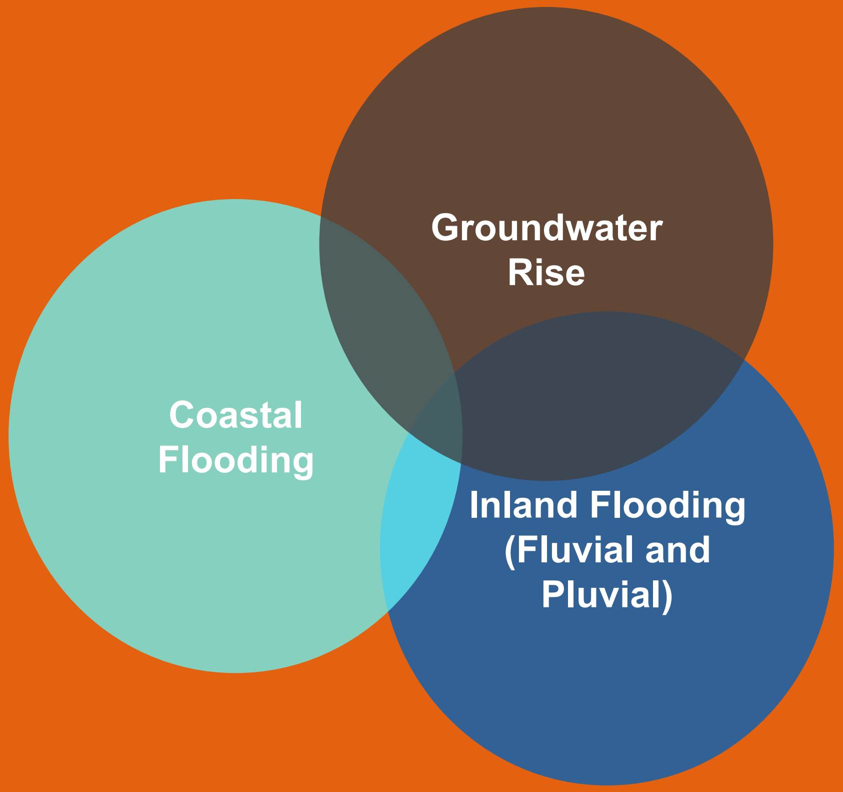
- Landfill Features
    1. Landfill extent
    2. Cap
    3. Cut-off/slurry walls
    4. Leachate collection trench and manholes
    5. Landfill gas system vents
    6. Groundwater and leachate monitoring wells
- Site Infrastructure
    1. Buildings/foundations
    2. Roads
    3. Sewers
    4. Storm drains/features
    5. Methane mitigation and monitoring systems
    6. Levees/Wetlands/Sloughs



Slide source: Lucas.Goldstein@arcadis.com

Flooding Sources:

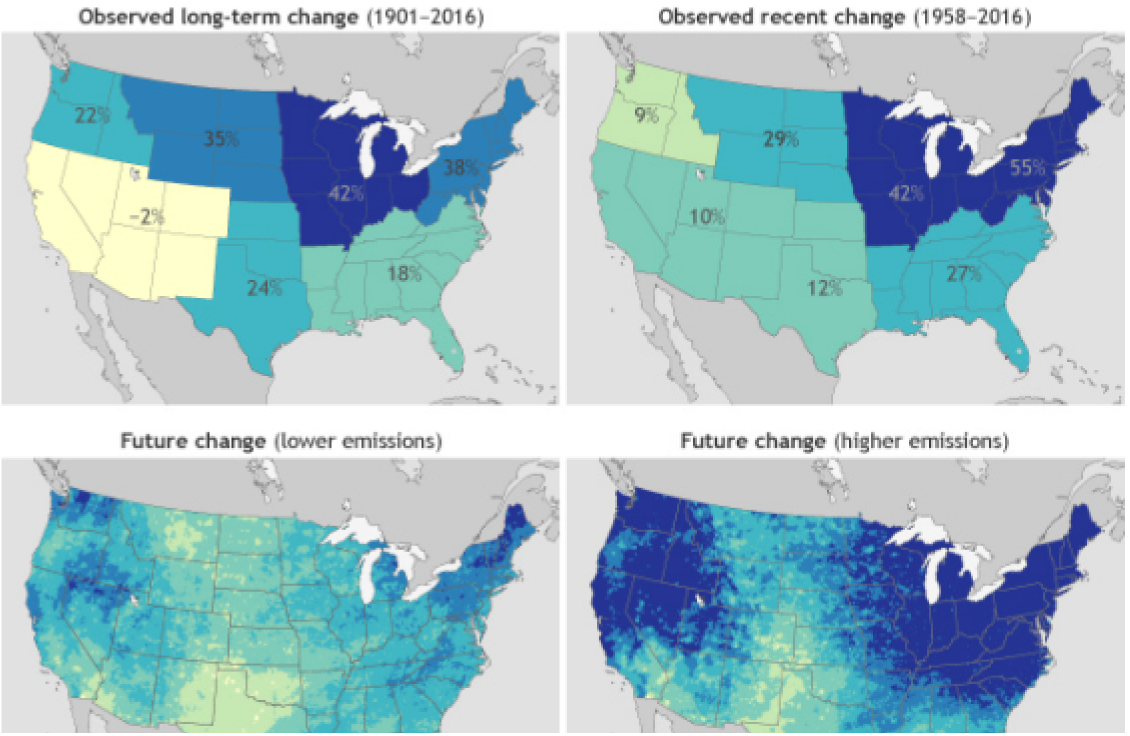
Inland Flooding, Coastal Flooding, and Groundwater Rise



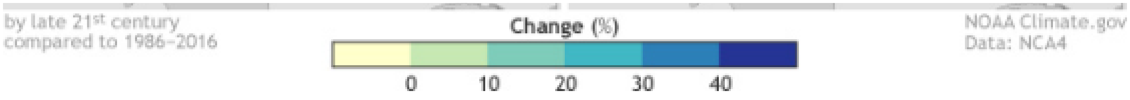
Inland Flooding

Pluvial flooding (also known as flash flooding due to extreme precipitation)

Inland flooding can be combined with coastal flooding in coastal-inland transitioning areas ([Bilskie et al. 2021](#))



[Prepare for more downpours: Heavy rain has increased across most of the United States, and is likely to increase further | NOAA Climate.gov](#) PUBLISHED JULY 10, 2019

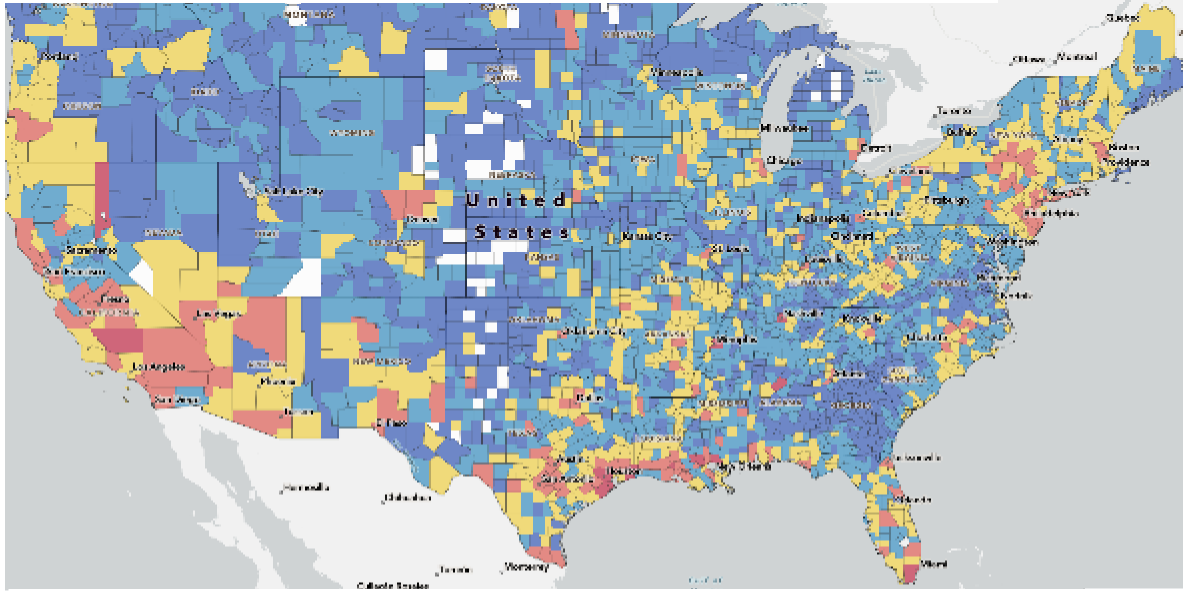


Fluvial (riverine) flooding in non-coastal areas

Occurs when rivers exceed the capacity of their natural or constructed channels

based on historical data

Riverine Flooding Risk Index by FEMA



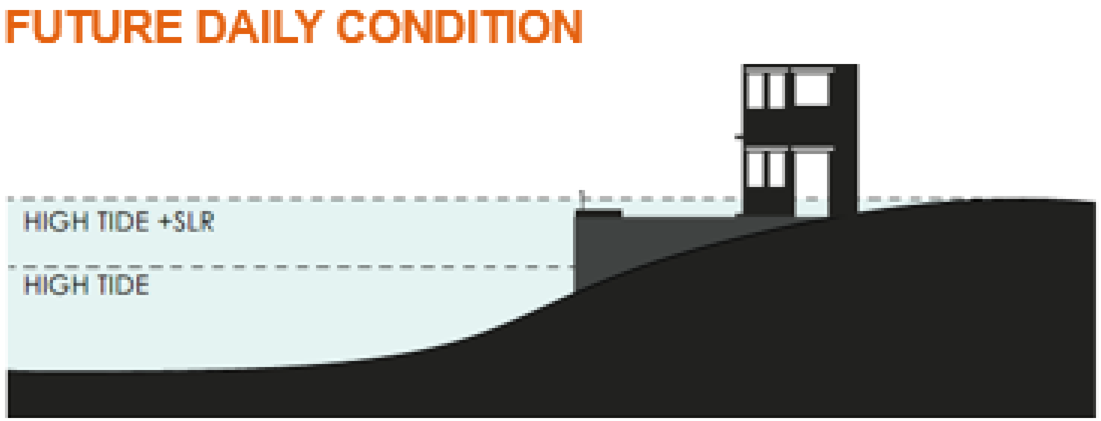
https://hazards.fema.gov/nri/map

Coastal Flooding

Nuisance (daily) flooding (also known as "high-tide flooding").

Occurs when **sea level rise causes either surface water or groundwater to regularly exceed the ground surface**.

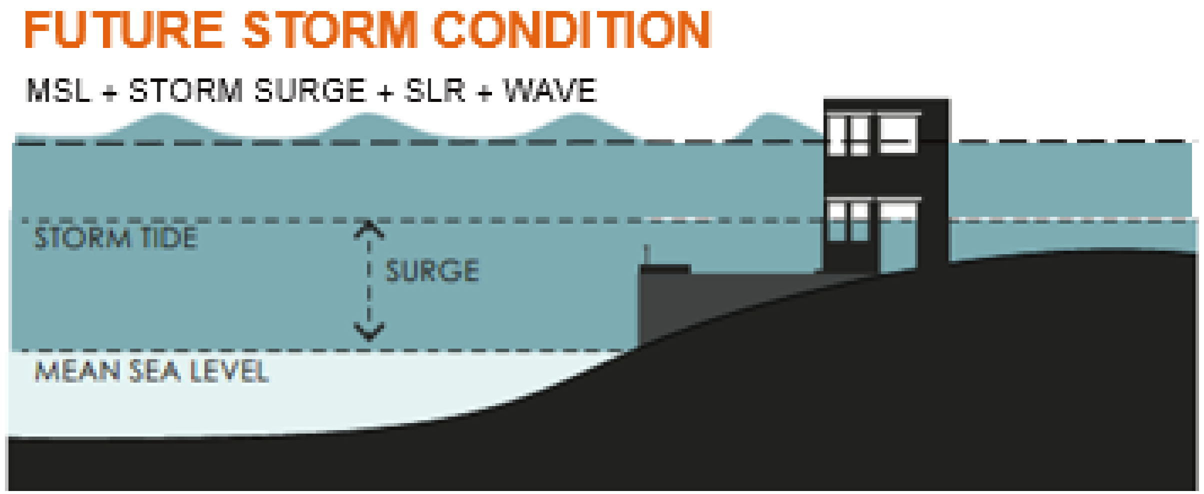
Does not include any of the dynamic components of the flood elevation such as storm surge or wave action.



Temporary (storm) flooding - event based-flood hazards

Associated with a coastal storm (storm surge + wave action)

Temporary flooding can occur sporadically but can typically be forecasted weeks to months in advance based on weather forecasts. Duration of temporary flooding ranges but the duration of the high-water surface elevation will typically be less than 6 hours.

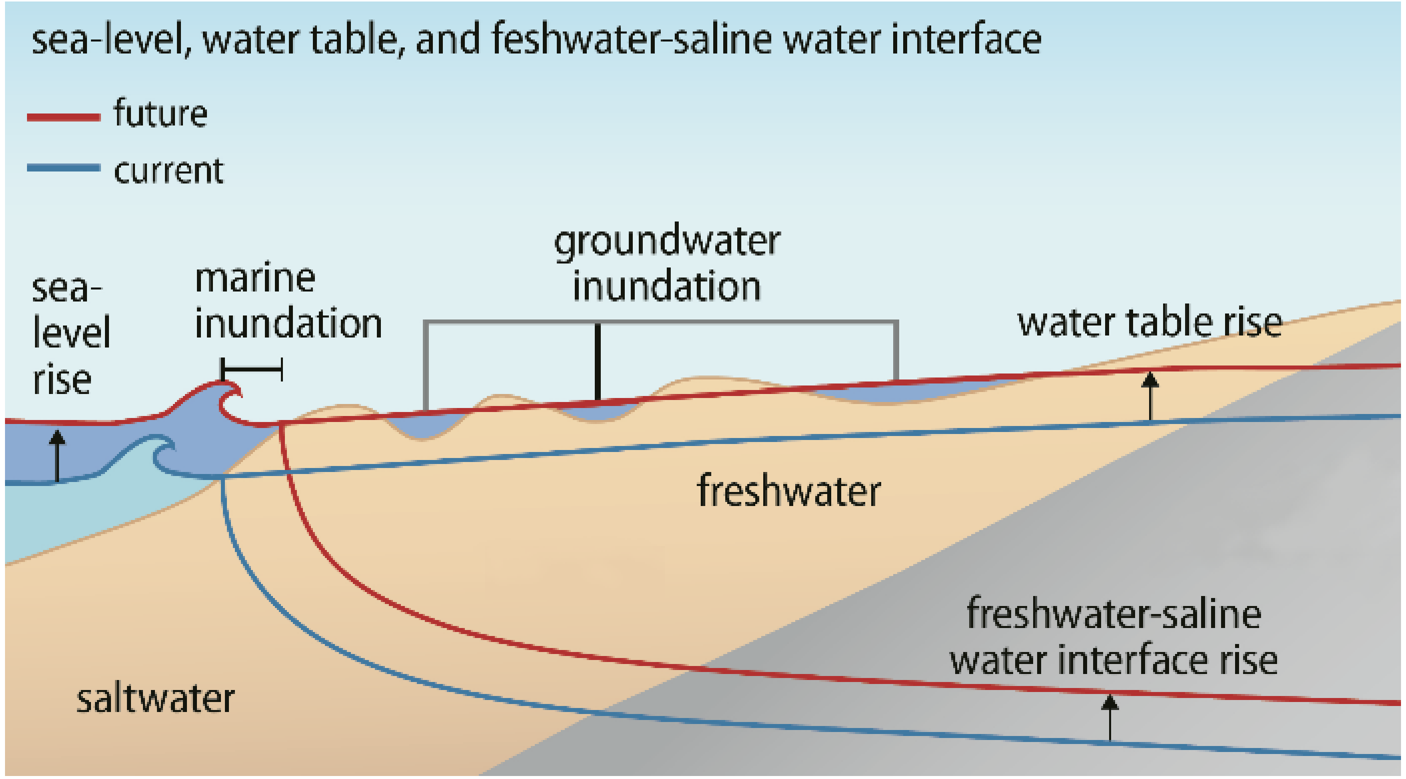


Rain contribution is not shown. Based on site studies, e.g., Bilskie et al. (2021), it is expected to be negligible in coastal areas; however, it can be important in a transition zone, such as estuaries or bays.

Source: adapted from NYC Planning (2013): Urban Waterfront Adaptive Strategies

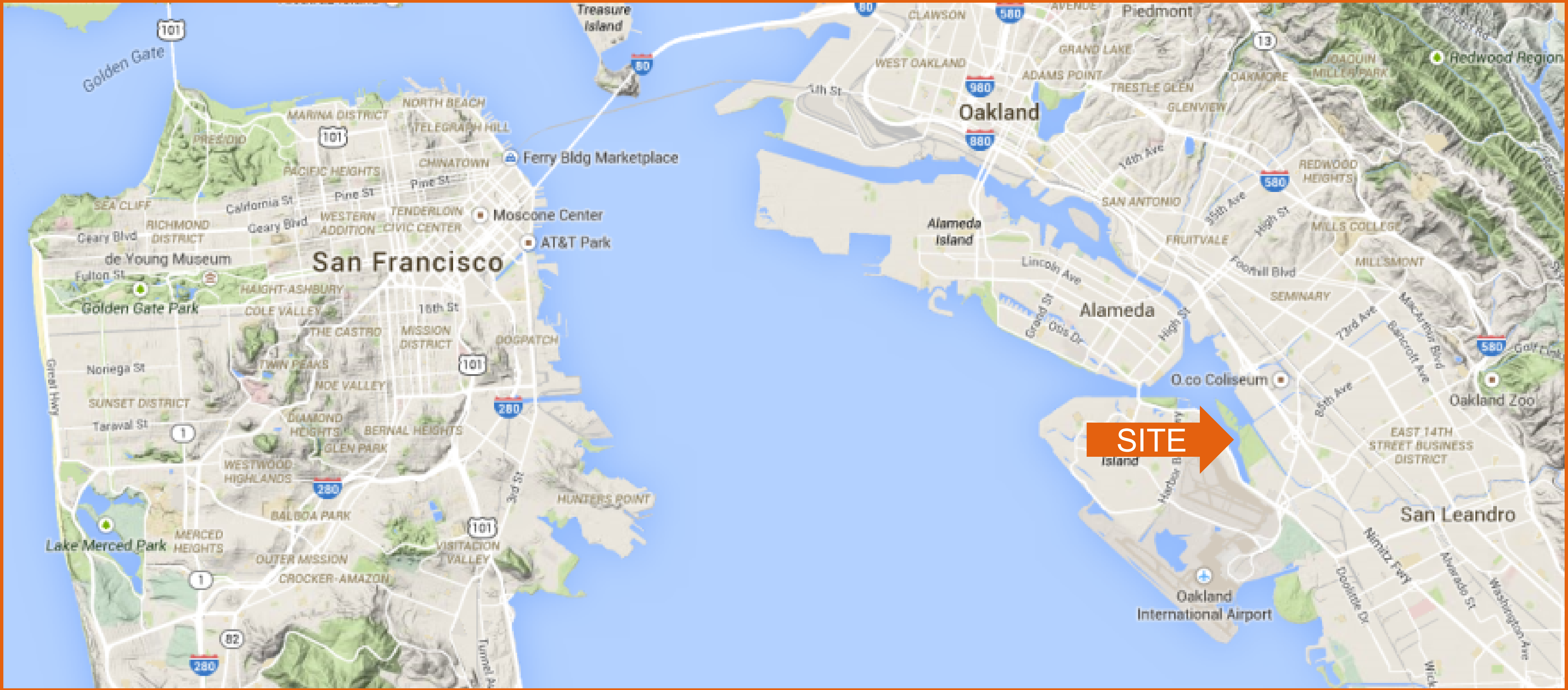
Groundwater Rise

- Near the coast (≈1km), the water table may rise with SLR – actual rise depends on lithology, topography, and preferential conduits.
- Groundwater flooding is slow compared to storm flooding, but chronic and hard to mitigate
- Potential impacts include:
  - Basement flooding
  - Increased corrosion of buried infrastructure
  - Reduced sewer capacity
  - Soil and foundation instability
  - Creation of wetlands
  - **Contaminated soil and groundwater plume mobilization**



(adapted from Rotzoll and Fletcher 2012)

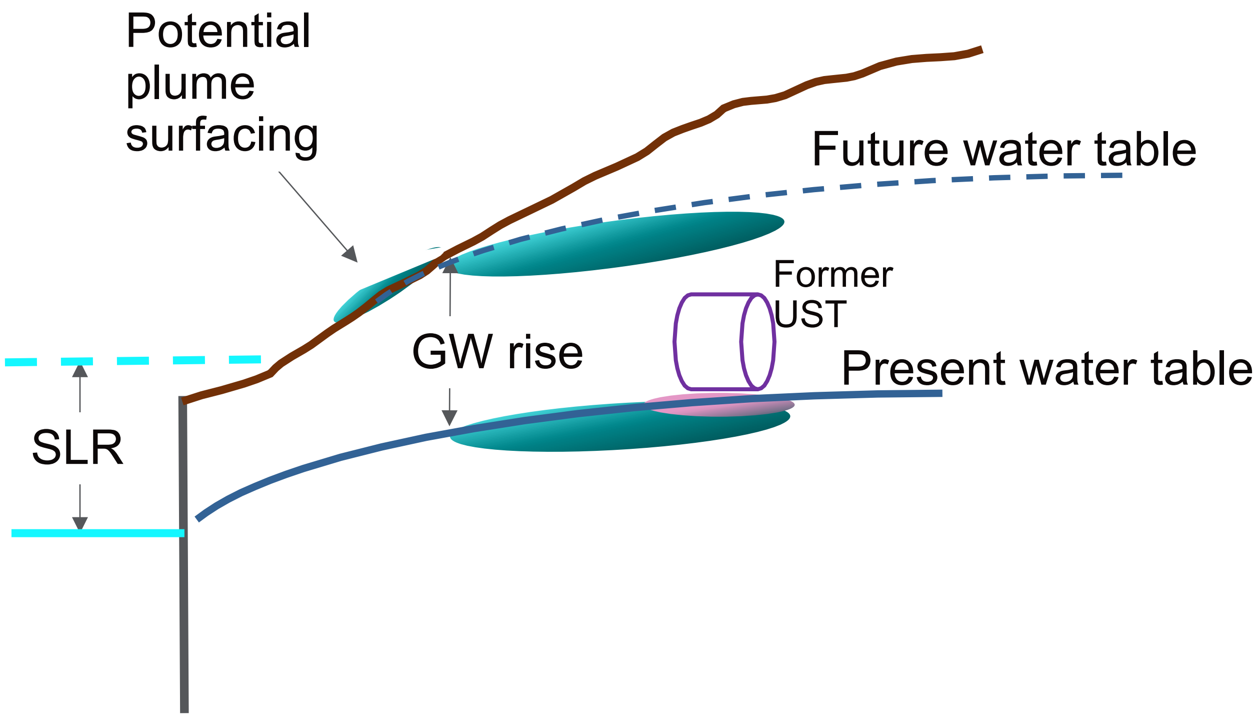
Case Study: Sea Level Rise Vulnerability Assessment of a Former Diesel UST Site



Site Summary

- Diesel USTs and source-area soils excavated in 1990s.
- 30 yeas of groundwater monitoring data and a site-specific fate and transport model indicated that both the dissolved plume and residual LNAPL are shrinking and expected to attenuate in approx. 30 years.
- Downgradient plume extent is 400 feet from drainage canal tidally connected to the SF Bay.
- Site meets California's low-threat closure criteria.

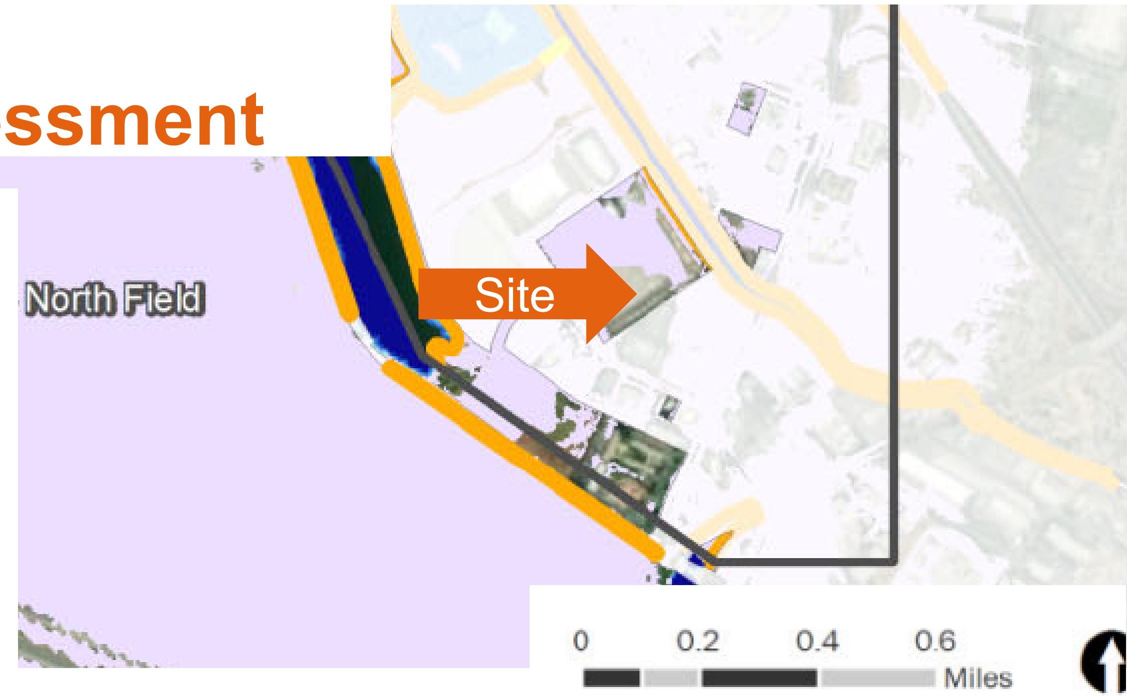
➢ **How will sea-level rise (SLR) affect the residual plume?**



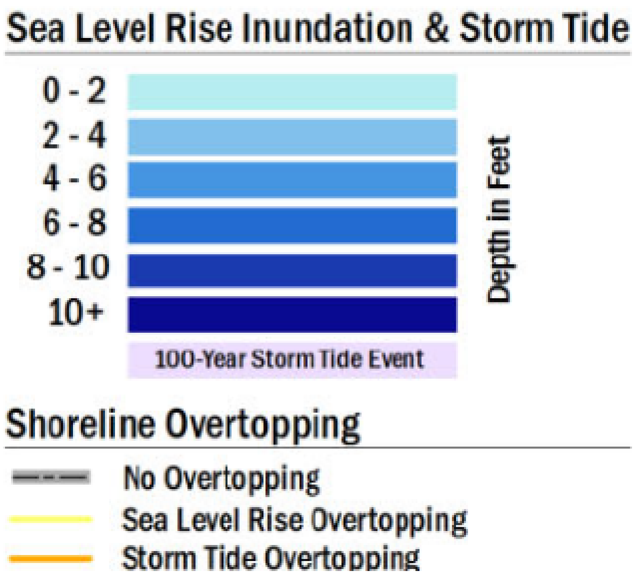
Conceptual site model; 10x vertical exaggeration

Previous (2019) SLR Vulnerability Assessment

Planning Time Horizon	Guidance Sea Level Rise Projections1	Port Assessment Mapping Scenario (closest match to existing ART SLR maps)
2030	0.8 feet Med-High Risk Aversion 0.5% Probability	1 foot
2050	1.9 feet Med-High Risk Aversion 0.5% Probability	2 feet
2100	3.4 to 6.9 feet Low to Med-High Risk Aversion 66% to 0.5% Probability	3 and 5.5 feet



YEAR 2050 SCENARIO: 2 FEET SEA LEVEL RISE + 100-YEAR STORM TIDE EVENT



Assessment methodology for general area of Site was limited to coastal flooding and used exiting reginal (ART) model. <u>No assessment (or mention) of groundwater rise.</u>

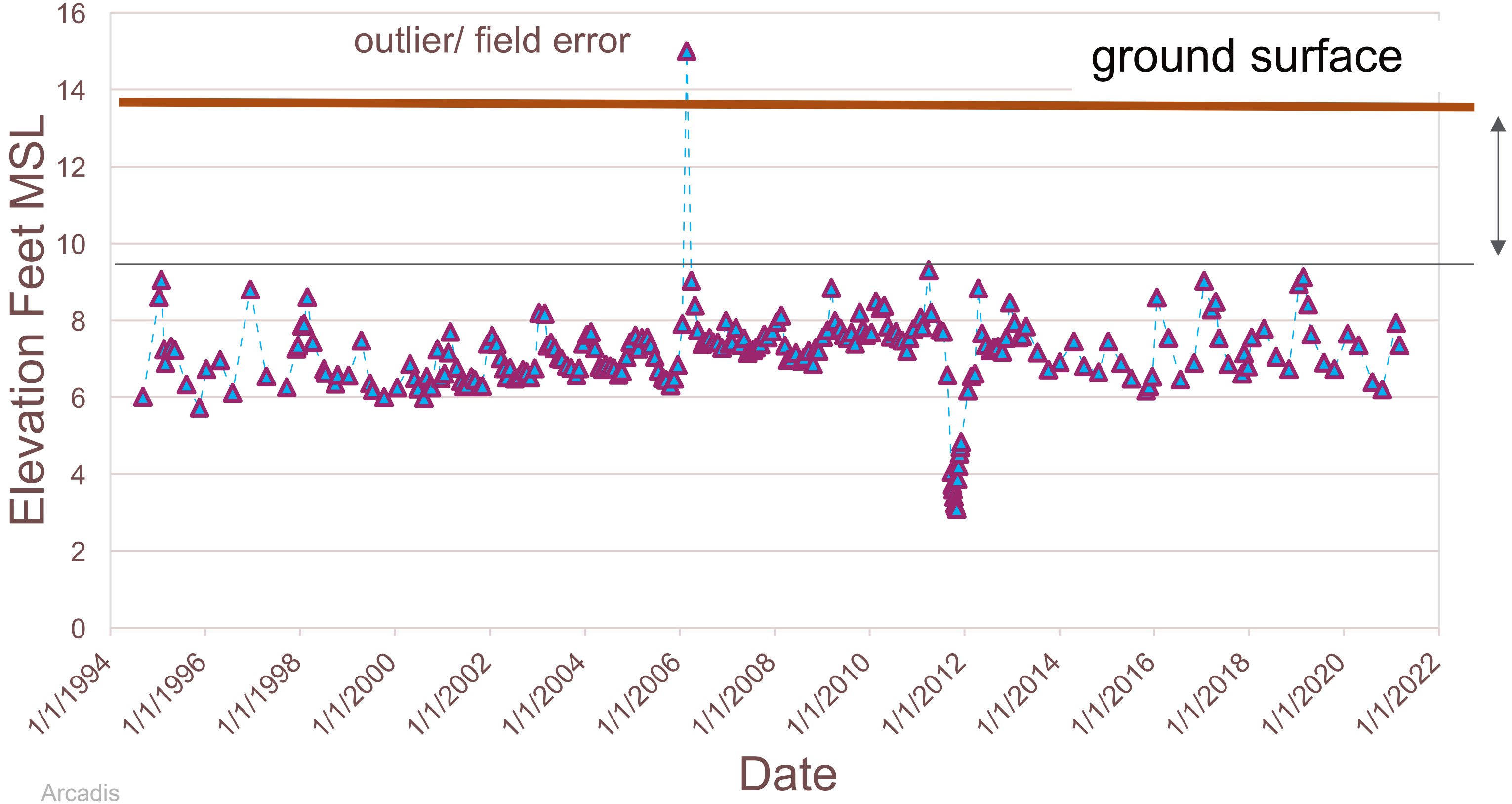
Initial Exposure for General Site Area

- Daily Tidal Inundation: MHHW + 5.5 feet (Year 2100)

Source: Port 2019

Approach 1: GW Rise Prediction using Flux-Controlled Model

- Conservative linear approach:
  - 1 ft SLR = 1 ft GW rise



Historical Minimum Vadose Zone Thickness (Feet)	Plume is vulnerable to surfacing after 4 feet SLR (in approx. 100 years using 0.5% probability scenario)
4 feet	

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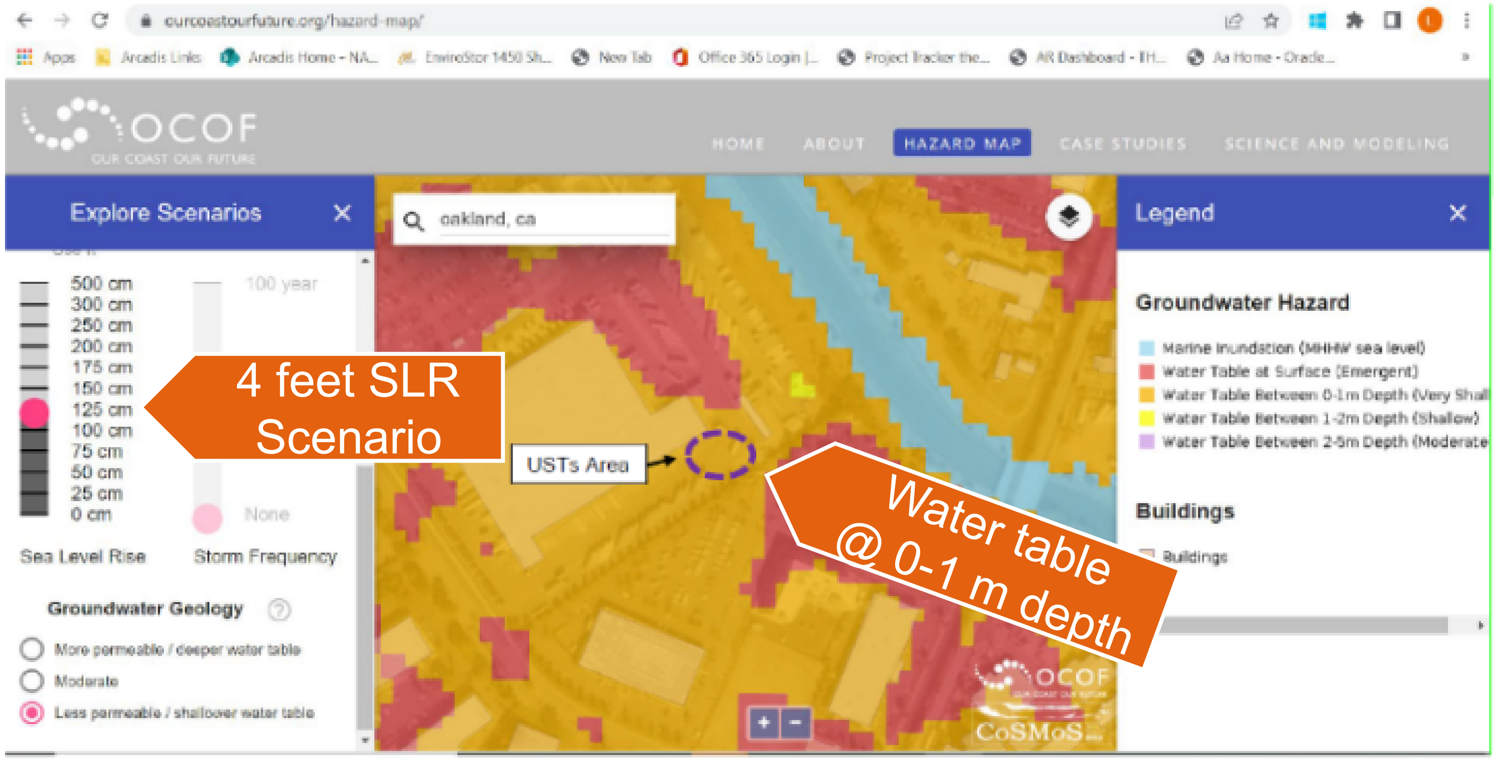
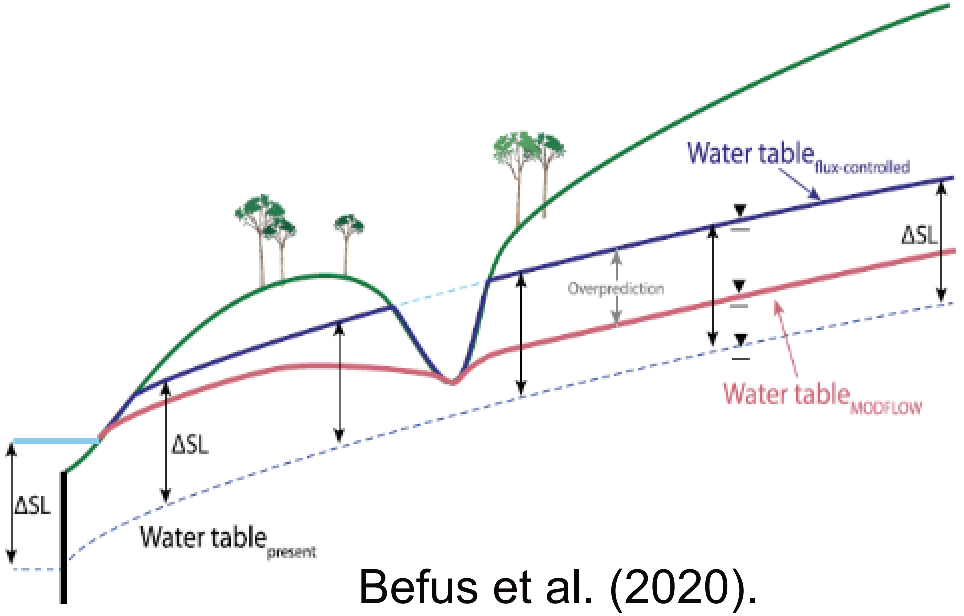
Approach 2: GW Rise Prediction using Regional MODFLOW Model

- Controlled by boundary conditions, local topography, and aquifer hydrogeology **Befus et al. (2020).**



Source: https://ourcoastourfuture.org/hazard-map/
(MHHWL Datum, Less Permeable Scenario)

Model for forecasts for present day and future day SLR conditions, Befus et al. (2020) presents both LMSL and MHHWL boundary condition datums.

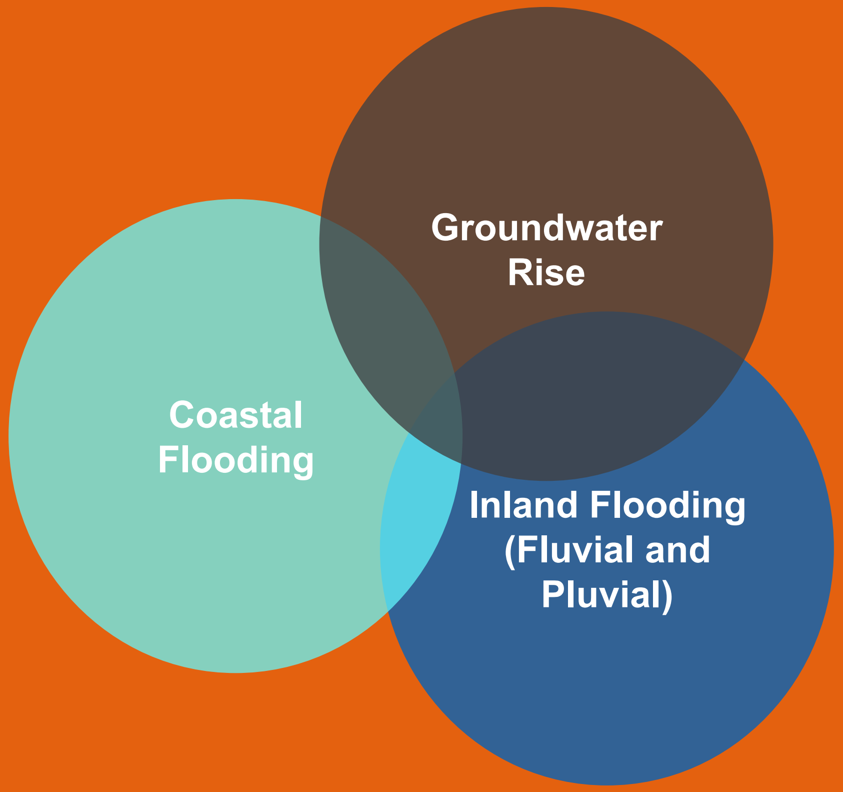


Befus et al. (2020).

Findings

- The flux-controlled and Modflow predictions yielded similar results.
- The residual diesel plume is not vulnerable to surfacing under the SLR projection of 2 feet of SLR by 2050.
- The flux-controlled approach may overestimate the risk of emergent groundwater in some areas; additional **site-specific** Modflow modeling will be needed to assess risk in areas further inland.
- Both approaches may overestimate the risk if preferential conduits or drainage system are present.
- The regulator agreed to move forward with the closure of the site.

Conclusions



Summary

- Climate vulnerability regulatory awareness and guidance are rapidly evolving; thousands of hazardous sites are potentially vulnerable and will require assessments (CVAs/SLRVAs).
  - Adaptation planning and/mitigation costs for cleanup sites will be significant; closed sites may be re-opened and sites currently under long-term management may require additional remediation or mitigation.
- Climate vulnerability assessments should consider all applicable Flooding Sources.
- Groundwater rise is of particular concern at cleanup sites because it can be difficult to mitigate.

Future Work: Climate Change and Environmental Justice

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New York

The New York Times

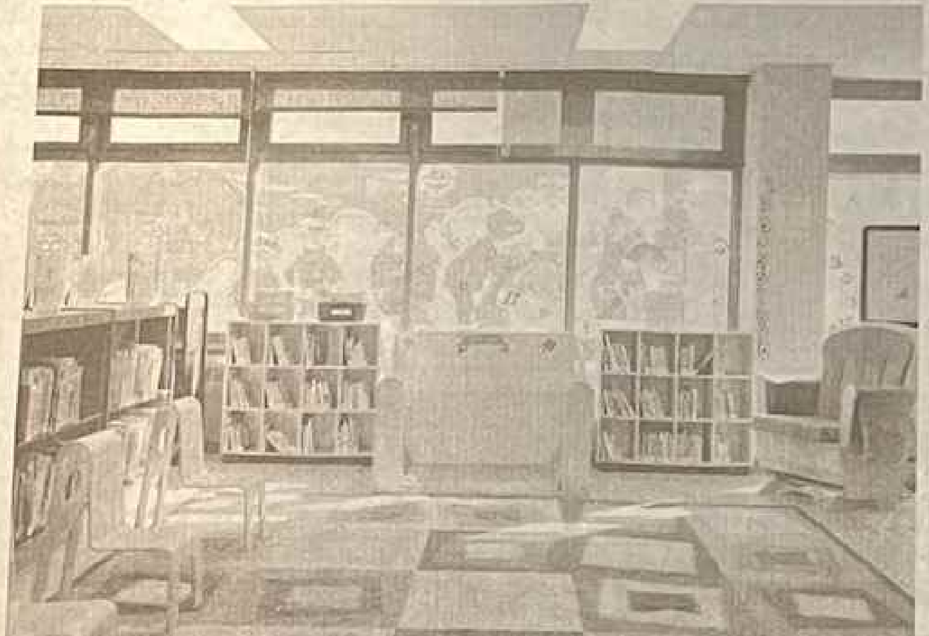
Storm Clouds in Vulnerable Neighborhoods

Social Inequality In New York City May Be Intensified By Climate Change

By HILARY HOWARD
Photographs by JADE DOSKOW

Some of the effects of climate change on New York City neighborhoods are clear, like extreme heat and persistent flooding.

But as city leaders explore which neighborhoods are most vulnerable to a warming world, they are also focusing on less obvious factors like poverty, chronic health conditions and language barriers that can deepen the impact of climate



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Abstract