Through the Looking Glass: Revamping the Vapor Intrusion Conceptual Site Model in Response to Climate Change

GSI ENVIRONMENTAL

International Conference on Remediation of Chlorinated and Recalcitrant Compounds

Denver, Colorado

4 June 2024

Chase Holton, Ph.D., PE

Agenda

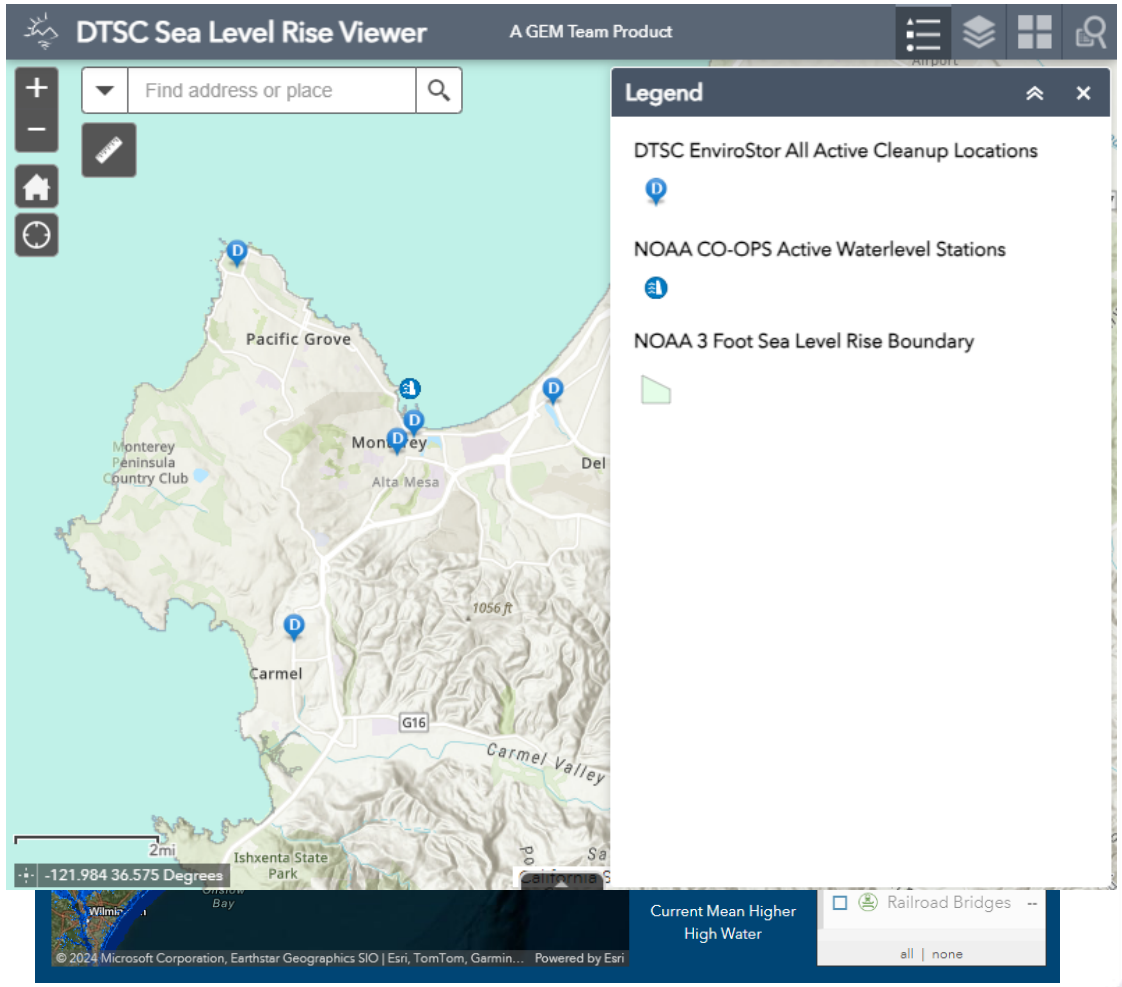
- Background
- Climate Hazards and the Vapor Intrusion Conceptual Site Model
  - Sea Level Rise and Groundwater Level Fluctuation
  - Indoor Air Exchange Rates
- Summary and Recommendations

Agenda

- Background
- Climate Hazards and the Vapor Intrusion Conceptual Site Model
  - Sea Level Rise and Groundwater Level Fluctuation
  - Indoor Air Exchange Rates
- Summary and Recommendations

Sea Level Rise and Contaminated Sites

- Studies highlight potential risks to coastal sites due to sea level rise:
  - EPA[1] identified 56 TSDFs susceptible to “high” SLR scenario
  - Hill et al.[2] identified 326 US Superfund sites and >5,000 sites in the San Francisco Bay region vulnerable to “intermediate” SLR scenario



[1]U.S. Environmental Protection Agency (2023), Effects of Coastal Sea Level Rise on US Hazardous Waste
[2]Hill, K., Hirshfeld, D., Lindquist, C., Cook, F., Warner, C. S. (2023), Rising Coastal Groundwater as a Result of Sea-Level Rise Will Influence Contaminated Sites and Underground Infrastructure

CRA Tools and Guidance


UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OLEM Dir. No. 9355.1-120

MEMORANDUM

SUBJECT: Consideration of Climate
Federal National Prioritie

FROM: Larry Douchand, Director
Office of Superfund Rem

TO: Regional Superfund Nati

PURPOSE

This memorandum[1] recommends approa
Agency) regions to consider when evalu
and implementation process for sites pr
(NPL) in accordance with the Comprehe
Liability Act of 1980, as amended (CER

Consideration of climate resilience in th
manner consistent with CERCLA as wel
Pollution Contingency Plan (NCP)[3] and
memorandum[4] supplements the Agency'
resilience activities, tools, considerations
however, it does not amend or modify th
should not be treated as a new criterion

[1] This document provides recommendations to regional staff
which provides the blueprint for CERCLA implementation,
those provisions or regulations, nor is it a regulation itself.
community and may not apply to a particular situation based
based on the statute and the regulations, and EPA decision m
from the recommendations where appropriate.
[2] 42 USC §9601 et seq.
[3] 40 CFR Part 300.
[4] The scope of this document is consistent with recommend
November 18, 2019 (GAO-20-73). https://www.gao.gov/prod
[5] For additional information, see https://www.epa.gov/superf

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

1. Purpose
2. Background
3. Performing a Climate Screening
4. Climate Vulnerability Assessment
5. Summary
6. Acknowledgements
7. Notice and Disclaimer
8. Selected Resources
9. Cited References

Appendix A. Determining if a Climate Vulnerability Assessment Is Needed at Your Site

Appendix B. Previous Efforts Related to Climate Change and Adaptation

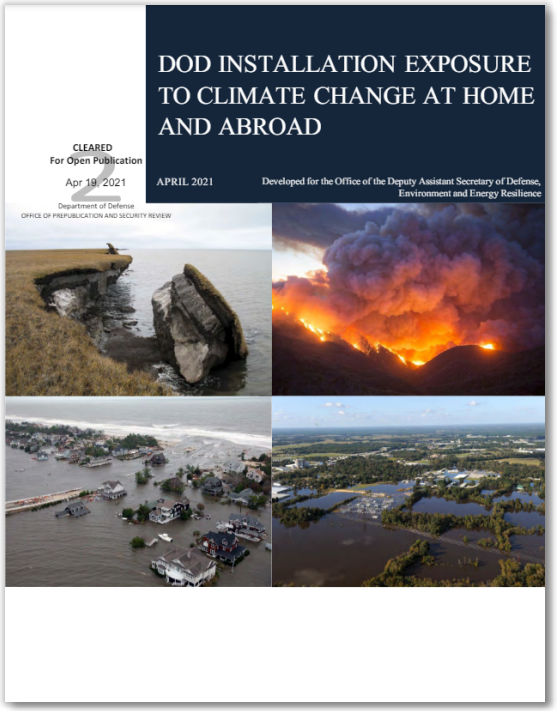
The Technical Support Project Engineering Forum issue papers provide information on remediation technologies or technical issues of interest. The information is not guidance or policy.

"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.

- ***Consideration of Climate Resilience in the Superfund Cleanup Process for Non-Federal NPL Sites*** (EPA, 2021)
- ***Conducting Climate Vulnerability Assessments at Superfund Sites*** (EPA, 2023)

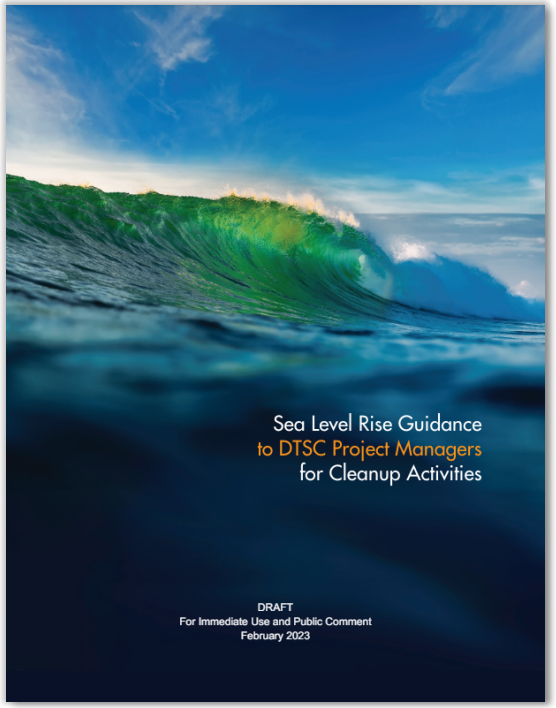

CLEARED
For Open Publication
Apr 19, 2021
Department of Defense
OFFICE OF PREPUBLICATION AND SECURITY REVIEW

DOD INSTALLATION EXPOSURE TO CLIMATE CHANGE AT HOME AND ABROAD

APRIL 2021

Developed for the Office of the Deputy Assistant Secretary of Defense, Environment and Energy Resilience

- ***DoD Climate Assessment Tool*** (Gade et al., 2020)
- ***DoD Installation Exposure to Climate Change at Home and Abroad*** (Pinson et al., 2021)


Sea Level Rise Guidance
to DTSC Project Managers
for Cleanup Activities

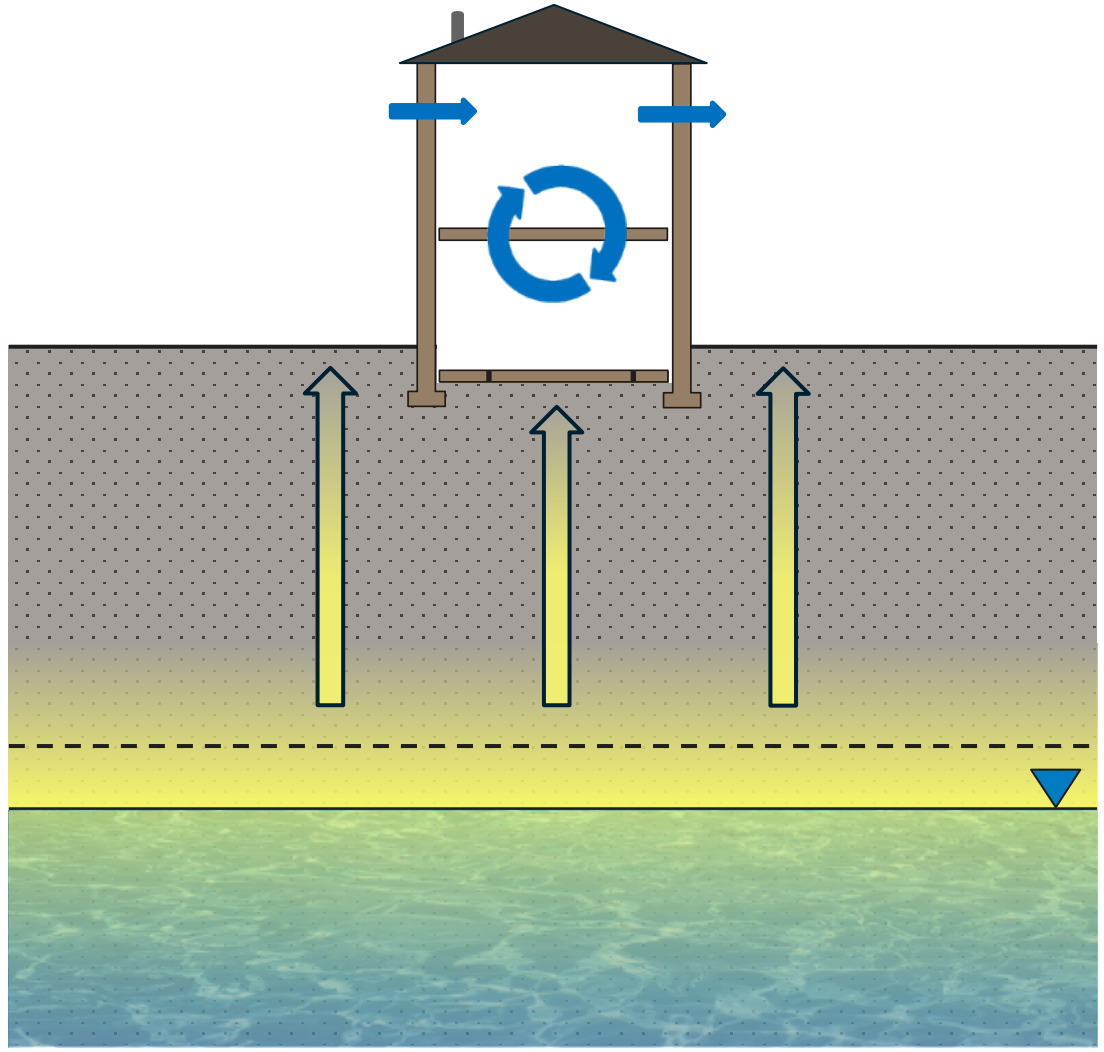
DRAFT
For Immediate Use and Public Comment
February 2023

- ***Draft Sea Level Rise Guidance to DTSC Project Managers for Cleanup Activities*** (DTSC, 2023)

Agenda

- Background
- Climate Hazards and the Vapor Intrusion Conceptual Site Model
  - Sea Level Rise and Groundwater Level Fluctuation
  - Indoor Air Exchange Rates
- Summary and Recommendations

Vapor Intrusion Conceptual Site Model



5 Indoor air exchange and mixing

3 Diffusion through vadose zone

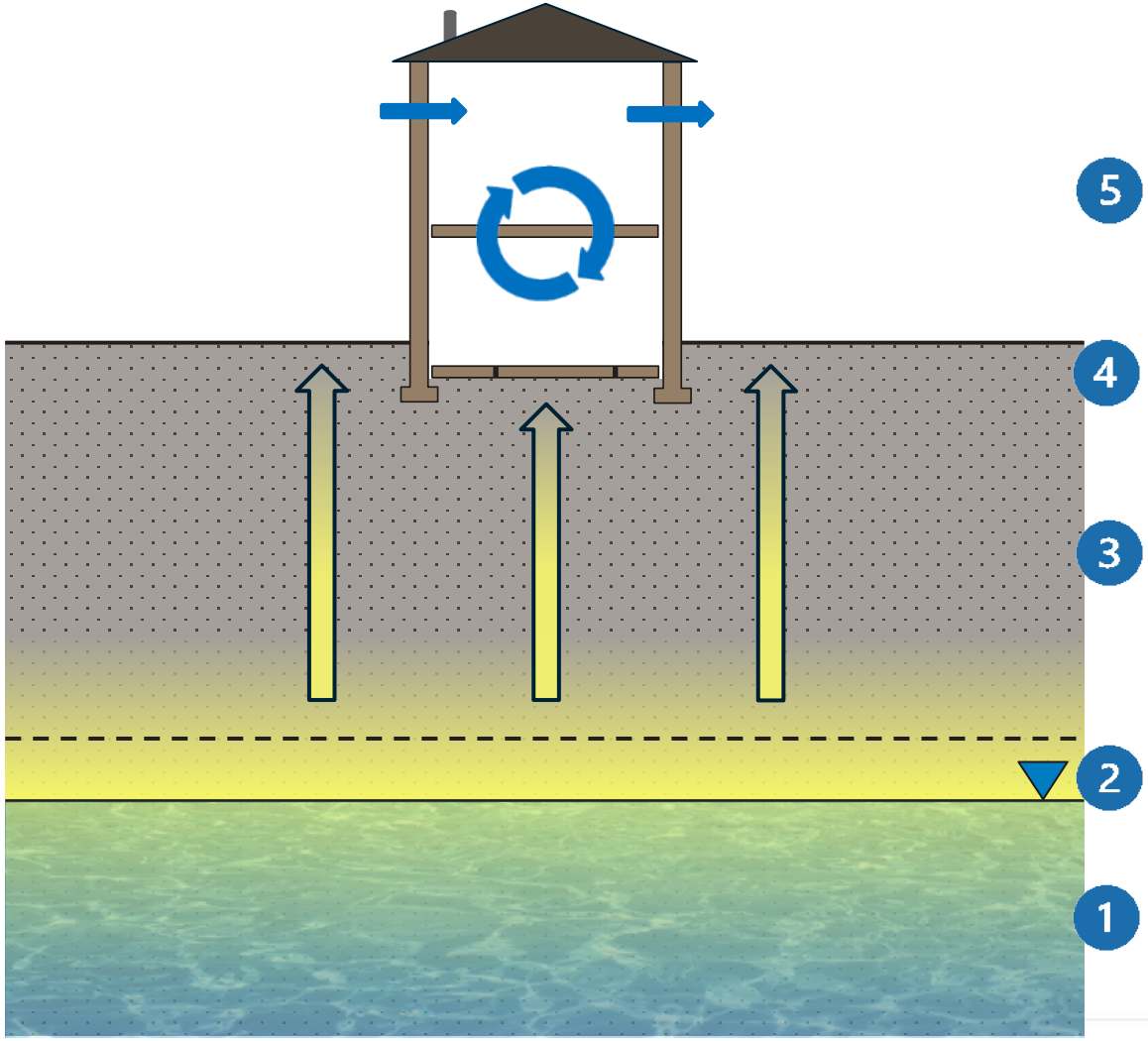
4 Vapor entry via diffusion and advection through cracks, openings, and conduits

2 Partitioning across capillary fringe

1 Contaminated groundwater

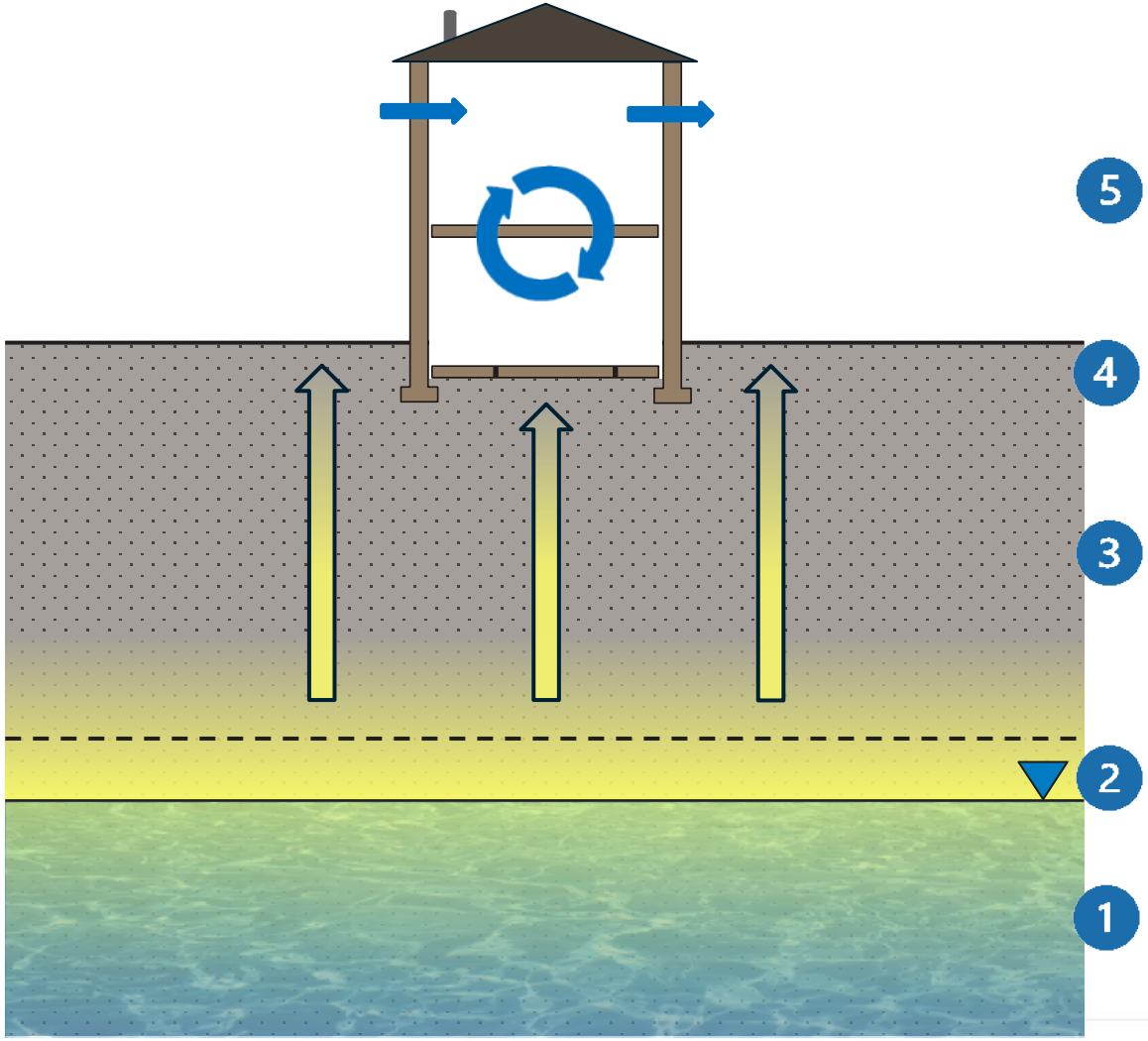
Climate Hazards

- Drought
- Coastal Flooding
- Riverine Flooding
- Heat
- Energy Demand
- Land Degradation
- Wildfire
- Historical Extreme Conditions



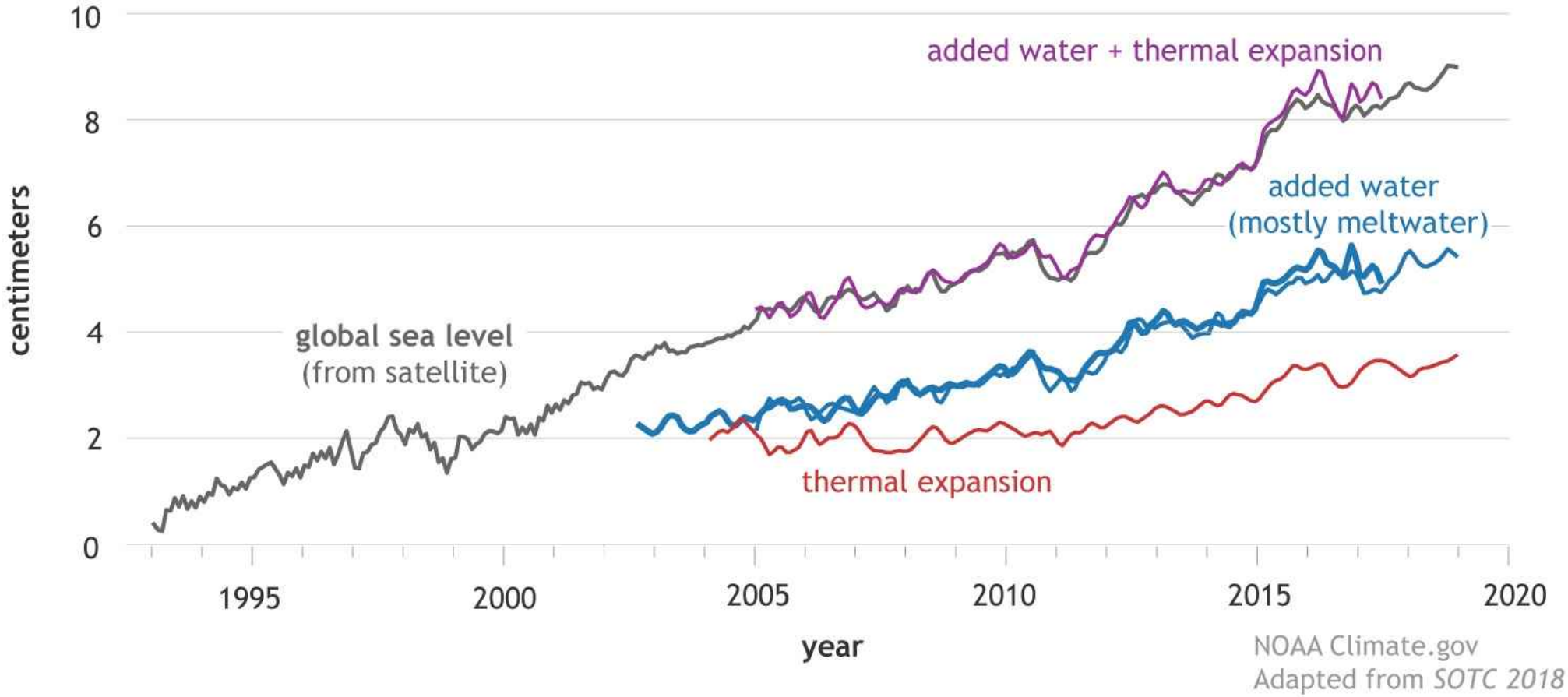
Climate Hazards

- **Drought**
- **Coastal Flooding**
- **Riverine Flooding**
- Heat
- Energy Demand
- Land Degradation
- Wildfire
- **Historical Extreme Conditions**

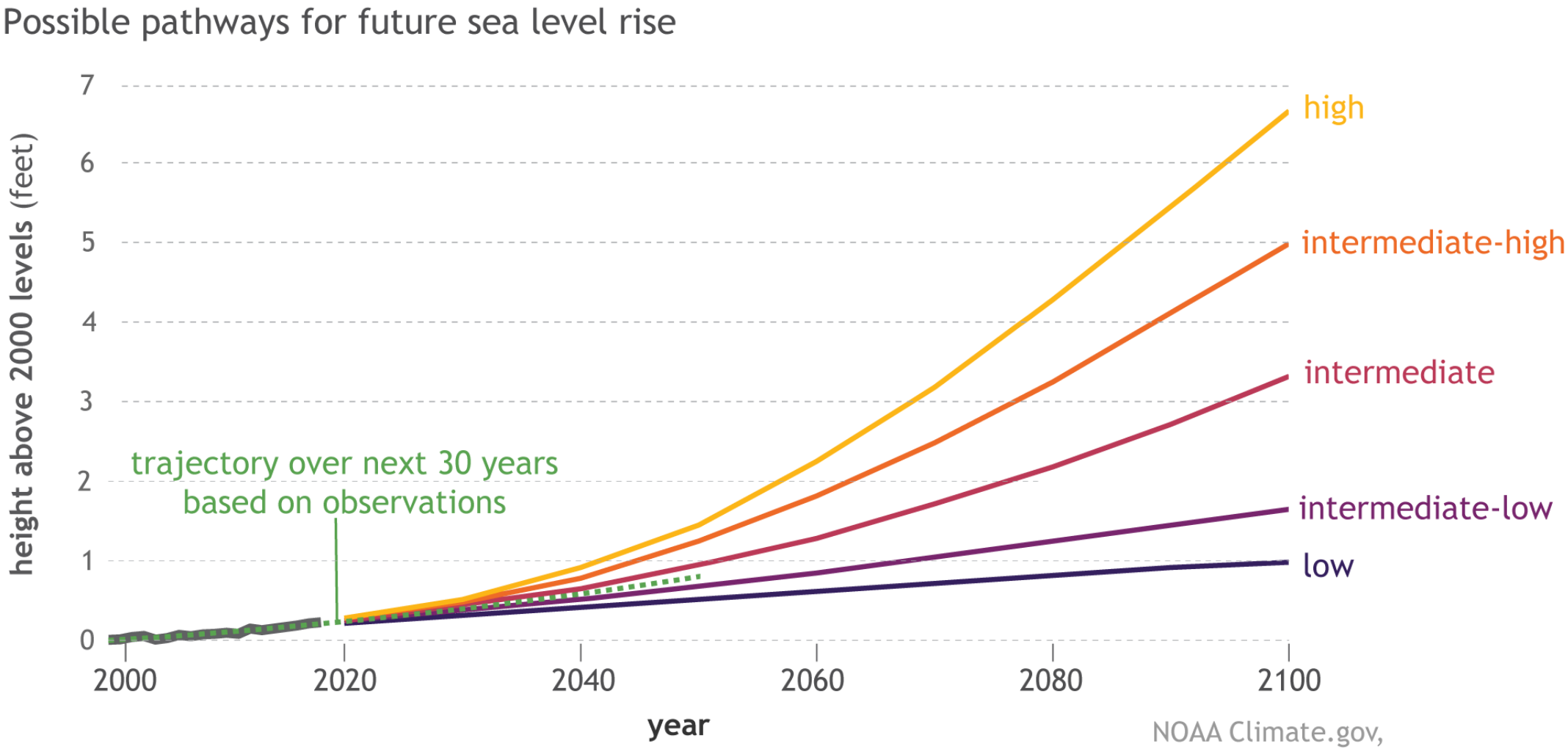


Sea Level Rise

Contributors to global sea level rise (1993-2018)



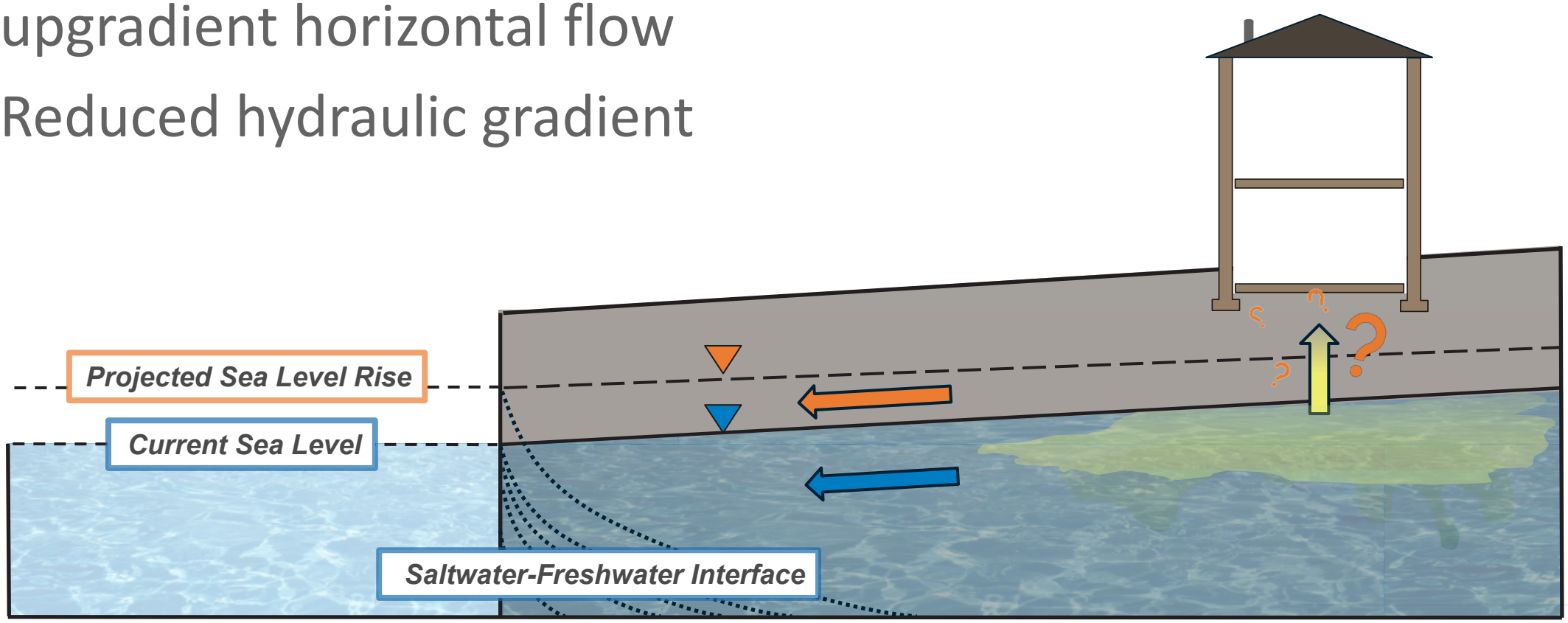
Sea Level Rise Projections



NOAA Climate.gov,
adapted from Sweet et al., 2022

VI Conceptual Site Model with Sea Level Rise

- Groundwater table rise from upgradient horizontal flow
- Reduced hydraulic gradient



Groundwater Level Fluctuation

Rising

- Reduced distance between capillary fringe and building
- Short-term increase in vapor flux due to soil vapor displacement

Falling

- Increased distance between capillary fringe and surface
- Short- to medium-term increase in vapor flux due to greater air entry into deeper and possibly more contaminated regions

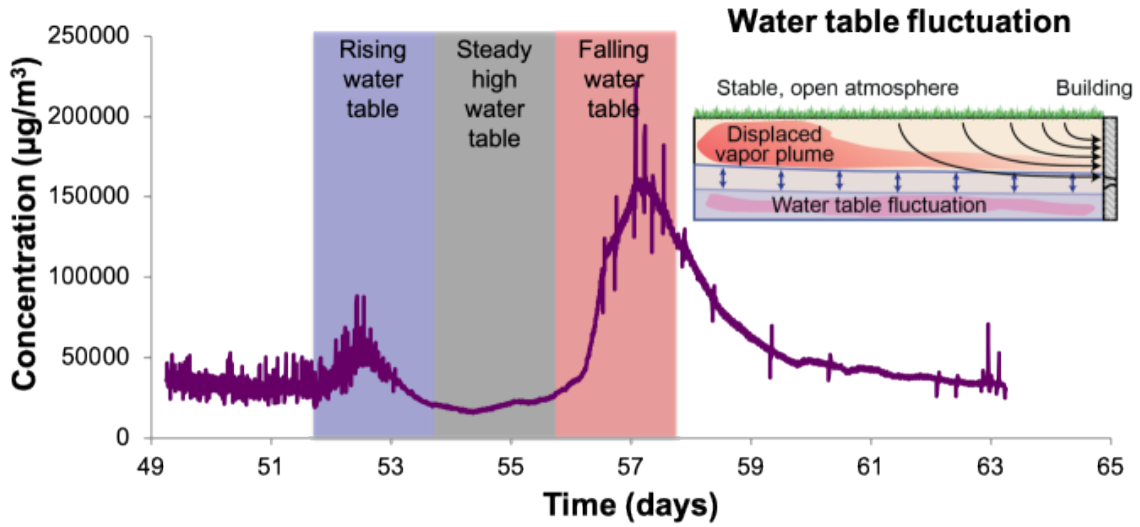
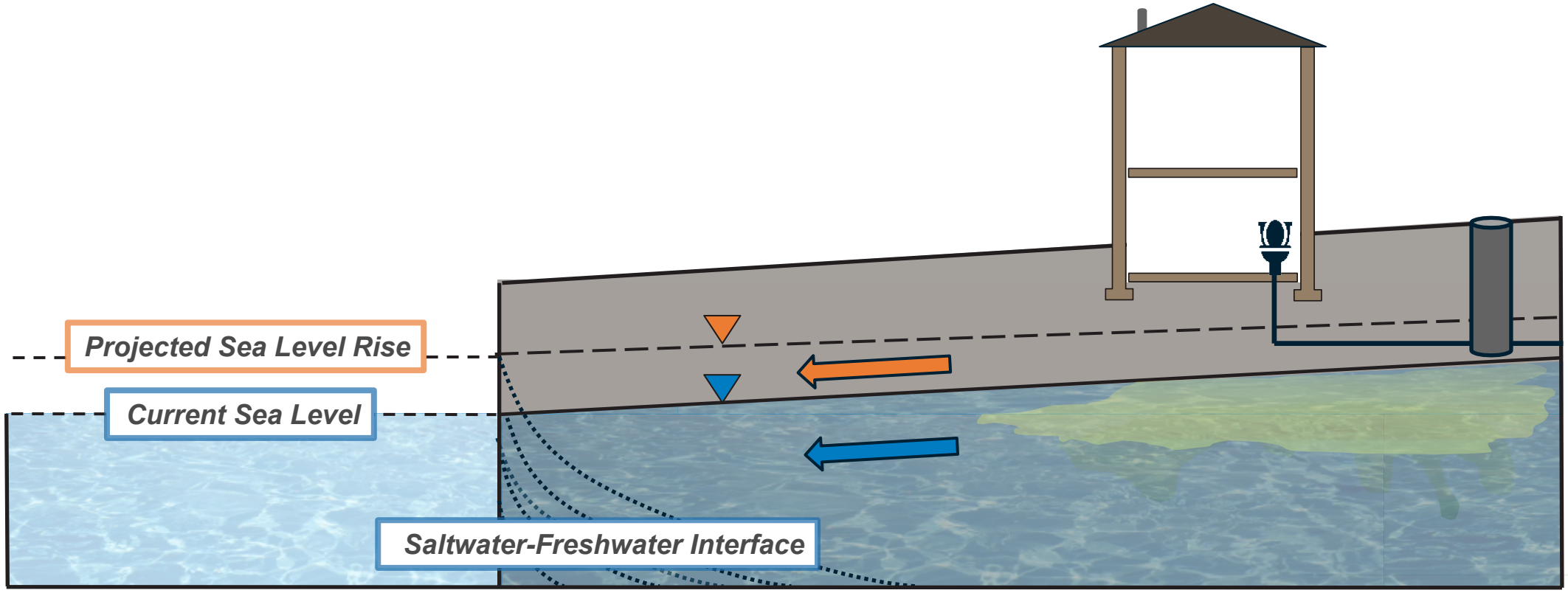


Image from ***Vapor Intrusion of Entrapped NAPL Sources and Groundwater Plumes: Process Understanding and Improved Modeling Tools for Pathway Assessment*** (Illangasekare et al., 2019, *SERDP Project ER-1687*)

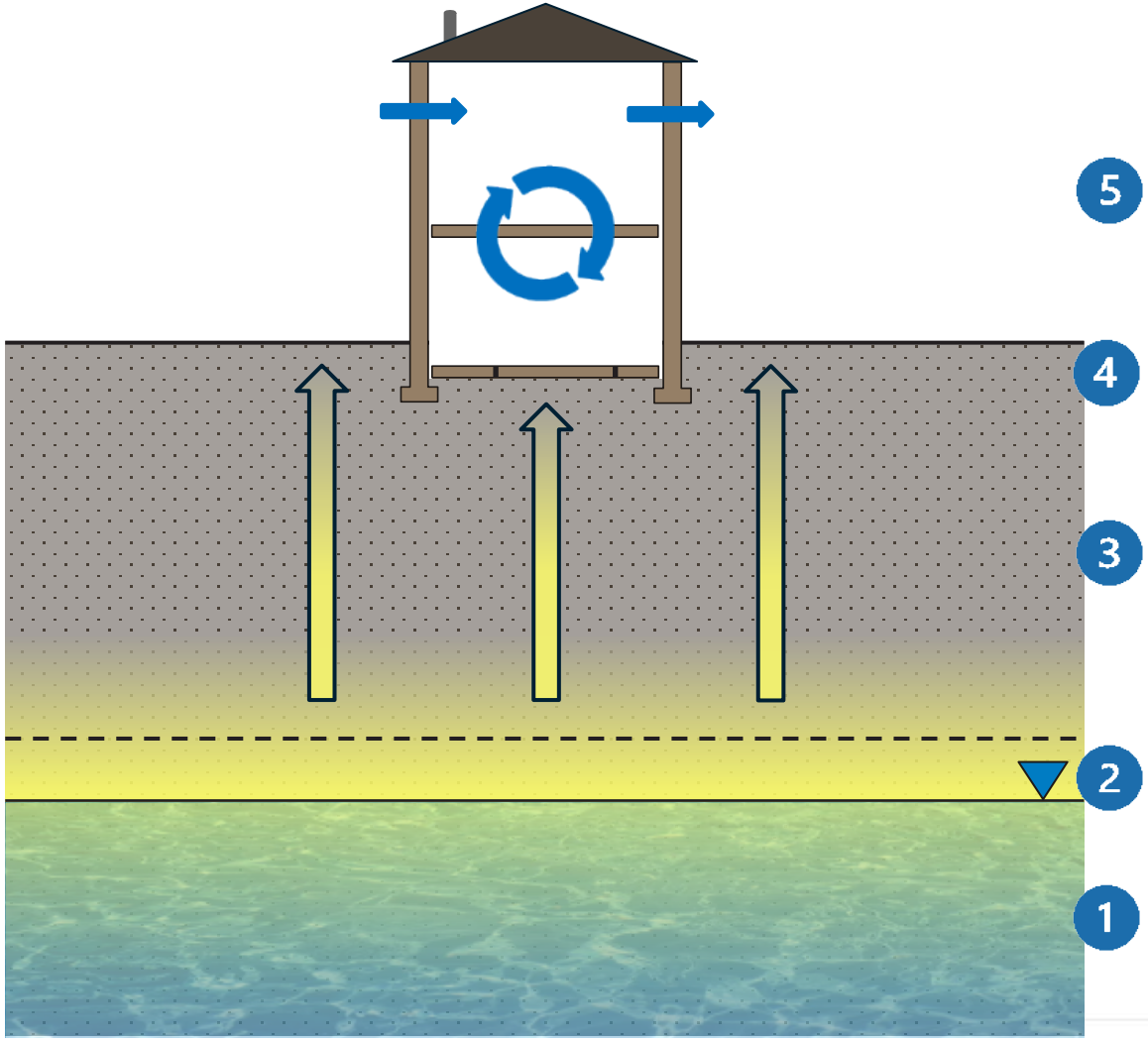
VI Conceptual Site Model with Sea Level Rise

- What about conduit VI pathways?

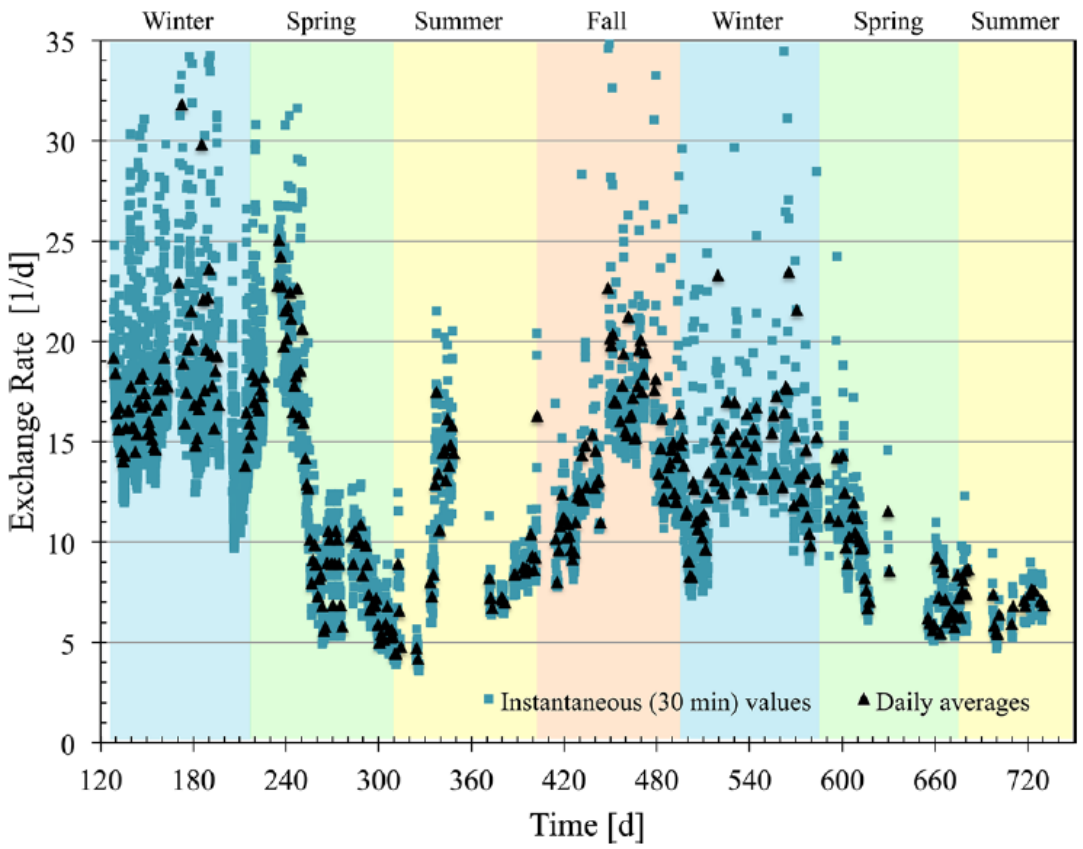


Climate Hazards

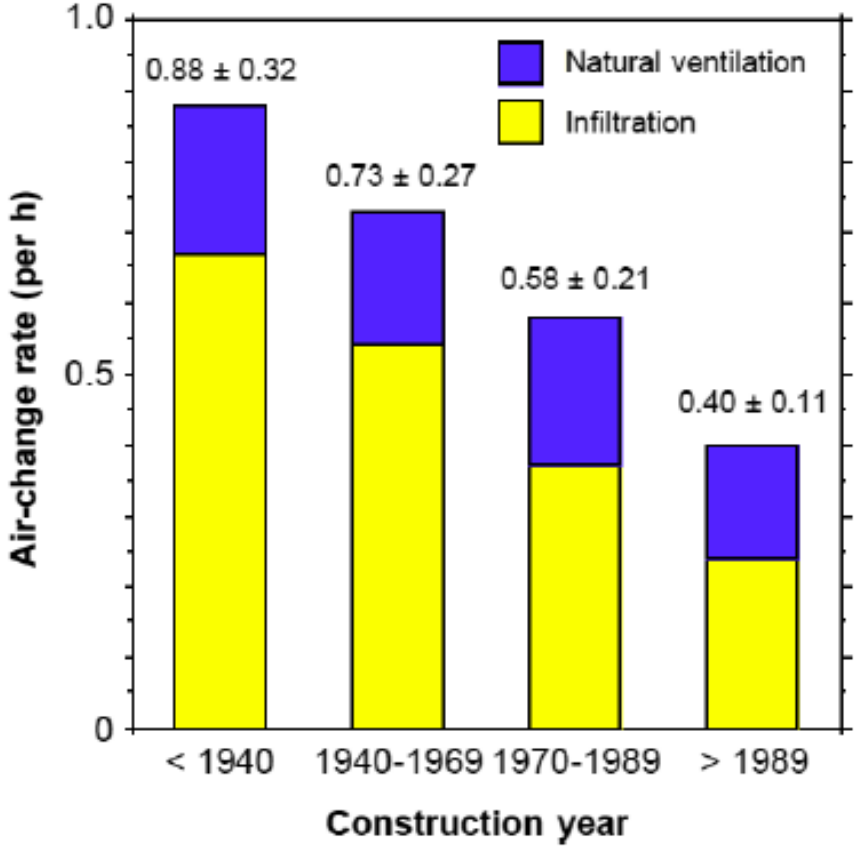
- Drought
- Coastal Flooding
- Riverine Flooding
- **Heat**
- **Energy Demand**
- Land Degradation
- **Wildfire**
- Historical Extreme Conditions



Indoor Air Exchange Rates



Indoor air exchange rate at ASU VI Research House, typically 0.6 to 1.0 hr^{-1} daily averages, 0.4 to 1.5 hr^{-1} instantaneous values (Figure 3, Holton et al., 2013)



Estimated mean air-change rate for the US housing stock, by year of construction (Figure 3, Nazaroff, 2020, *Residential air-change rates: A critical review*)

Agenda

- Background
- Climate Hazards and the Vapor Intrusion Conceptual Site Model
  - Sea Level Rise and Groundwater Level Fluctuation
  - Indoor Air Exchange Rates
- Summary and Recommendations

Summary and Recommendations

- Climate hazards should be considered as part of long-term site management.
- Groundwater table fluctuation can increase the risk of vapor intrusion but not for all CSMs
- Regional SLR and GWR projections should be verified with local data.
- Next steps…

QUESTIONS?

GSI ENVIRONMENTAL

In the news...

Rising Groundwater Could Release Toxic Chemicals From More Than 100,000 Contaminated Sites Across U.S.

Rising sea levels threaten hazardous waste facilities along U.S. coast

Jared Whalen, Andrew Freedman

A Hidden Climate Danger Threatens Coastal Communities

More than 132,000 sites in the US, many of them in low-income neighborhoods, are susceptible to rising groundwater that could release toxic chemicals. By Todd Woody

Rising groundwater threatens thousands of toxic sites in the Bay Area

New study highlights the growing "threat from below" as climate change raises coastal groundwater levels By Kara Manke

How rising groundwater caused by climate change could devastate coastal communities

Higher sea levels will push the water table up with them, causing flooding, contamination, and all manner of unseen chaos.

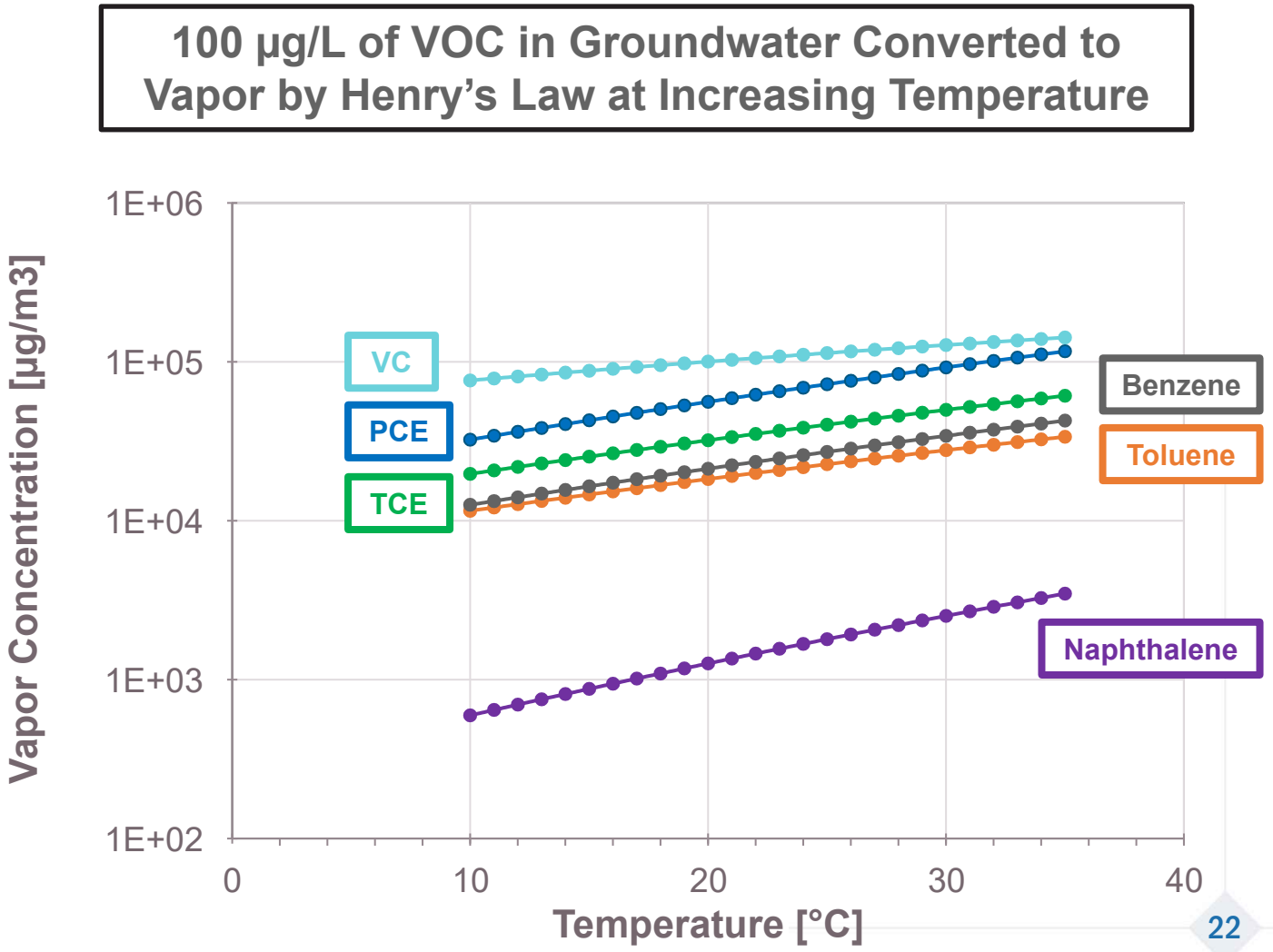
Rising groundwater levels are threatening clean air and water across the country

As subterranean water inches higher, so do threats to air and water.

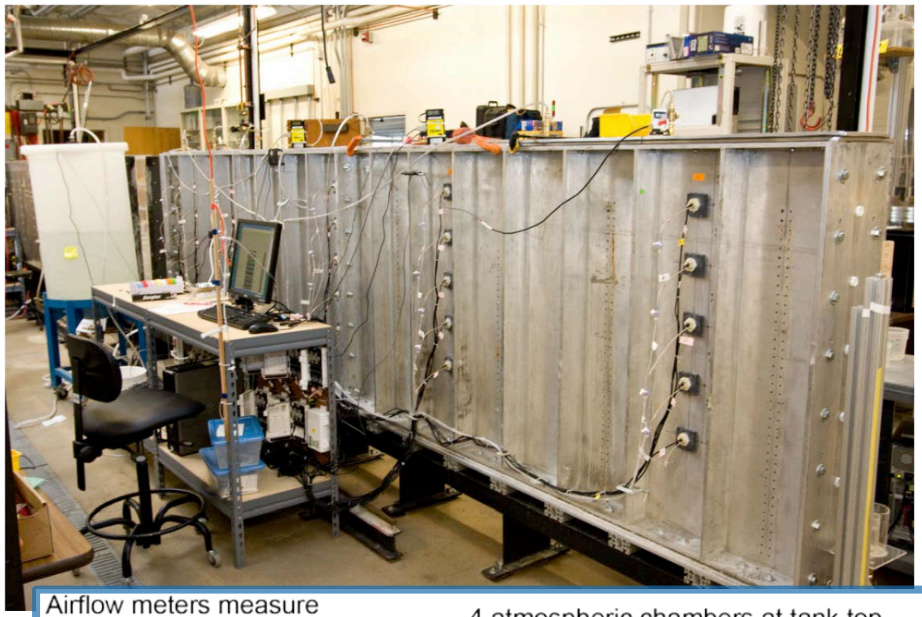
Julia Kane, Lina Tran, & Diana Kruzman

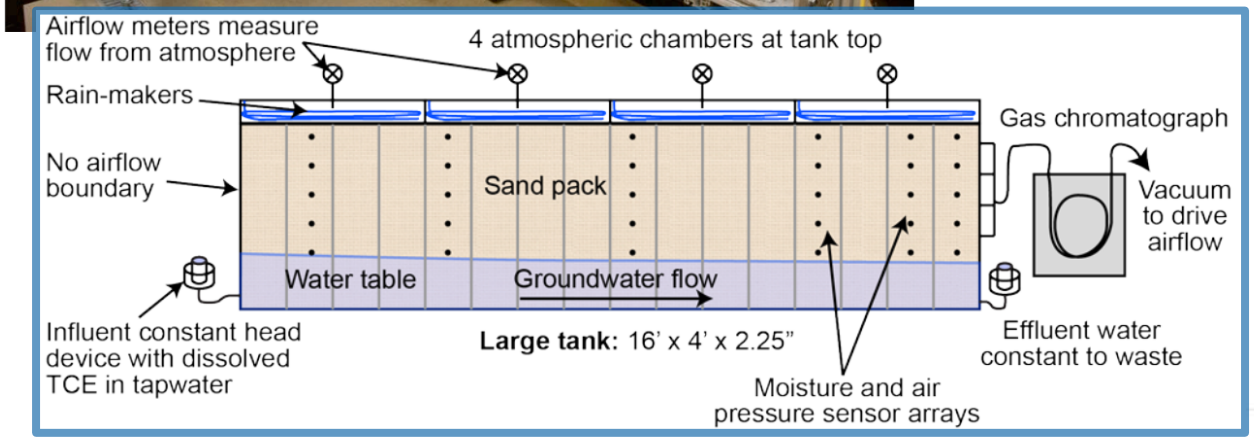
Climate Hazards

- Drought
- Coastal Flooding
- Riverine Flooding
- **Heat**
- Energy Demand
- Land Degradation
- Wildfire
- Historical Extreme Conditions



Groundwater Level Fluctuation (SERDP ER-1687)





Time Spent Indoors

Improving Your Indoor Environment

Did you know we spend about 90% of our time indoors?

- 90% of our time indoors?
  - National Human Activity Pattern Survey (NHAPS) found Americans spend 87% of their time indoors and 6% in vehicles (2001)
  - Two-year study (n = 9,386) completed between 1992 and 1994