Stakeholder Advisory Group

Board of Water Supply
City & County of Honolulu

Thursday April 25, 2019

Dr. Charles H. Fletcher, III (Chip)

Associate Dean for Academic Affairs and Professor of Earth Sciences
School of Ocean and Earth Science and Technology (SOEST)
University of Hawaiʻi at Mānoa
Vice-Chair of the Honolulu Climate Change Commission

CLIMATE CHANGE PANEL DISCUSSION

Global Sea Level Has Been Rising for Over a Century


Jason 3
2016
OSTM/Jason 2
2008
Jason 1
2001
TOPEX/Poseidon
1992–2006

Sea Level Rise has Accelerated

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PNAS Proceedings of the National Academy of Sciences of the United States of America

Keyword, Author, o

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NEW RESEARCH IN Physical Sciences Social Sciences

Climate-change–driven accelerated sea-level rise detected in the altimeter era

R. S. Nerem, B. D. Beckley, J. T. Fasullo, B. D. Hamlington, D. Masters, and G. T. Mitchum

PNAS published ahead of print February 12, 2018 https://doi.org/10.1073/pnas.1717312115

Edited by Anny Cazenave, Centre National d'Etudes Spatiales, Toulouse, France, and approved January 9, 2018 (received for review October 2, 2017)

Article Figures & SI Authors & Info PDF

Significance

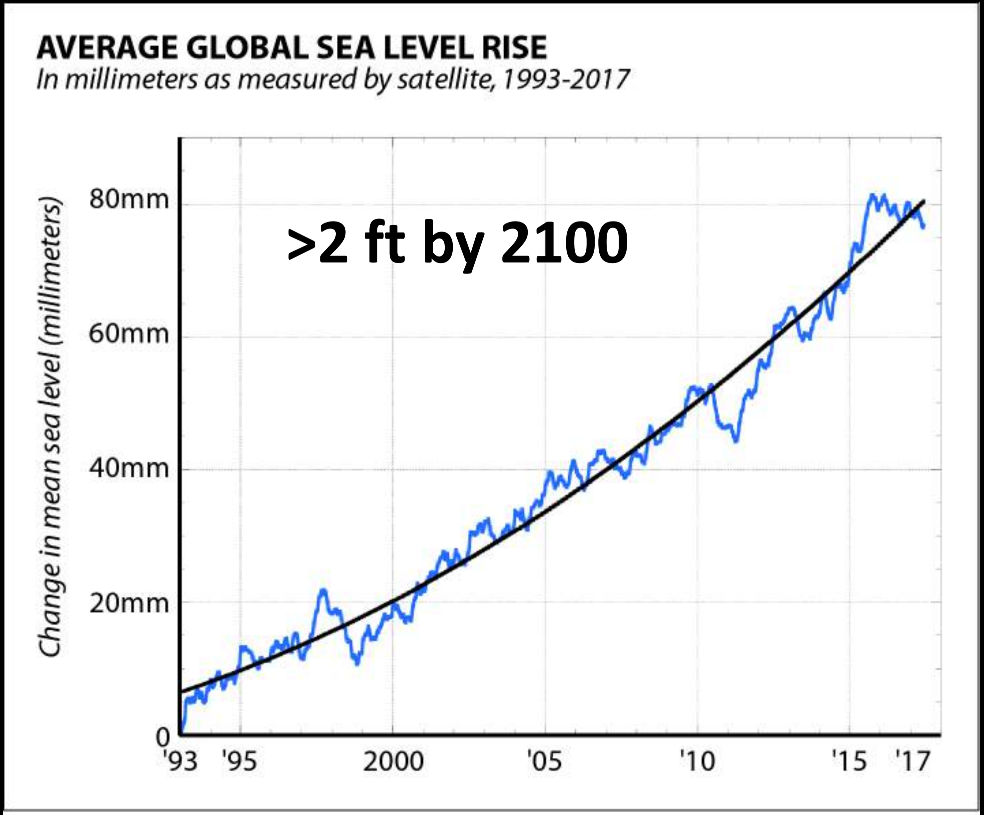
Satellite altimetry has shown that global mean sea level has been rising at a rate of ~3 ± 0.4 mm/y since 1993. Using the altimeter record coupled with careful consideration of interannual and decadal variability as well as potential instrument errors, we show that this rate is accelerating at 0.084 ± 0.025 mm/y^2, which agrees well with climate model projections. If sea level continues to change at this rate and acceleration, sea-level rise by 2100 (~65 cm) will be more than double the amount if the rate was constant at 3 mm/y.

Abstract

Using a 25-y time series of precision satellite altimeter data from TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3, we estimate the climate-change–driven acceleration of global mean sea level over the last 25 y to be 0.084 ± 0.025 mm/y^2. Coupled with the average climate-change–driven rate of sea level rise over these same 25 y of 2.9 mm/y, simple extrapolation of the quadratic implies global mean sea level could rise 65 ± 12 cm by 2100 compared with 2005, roughly in agreement with the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5) model projections.

sea level acceleration climate change satellite altimetry

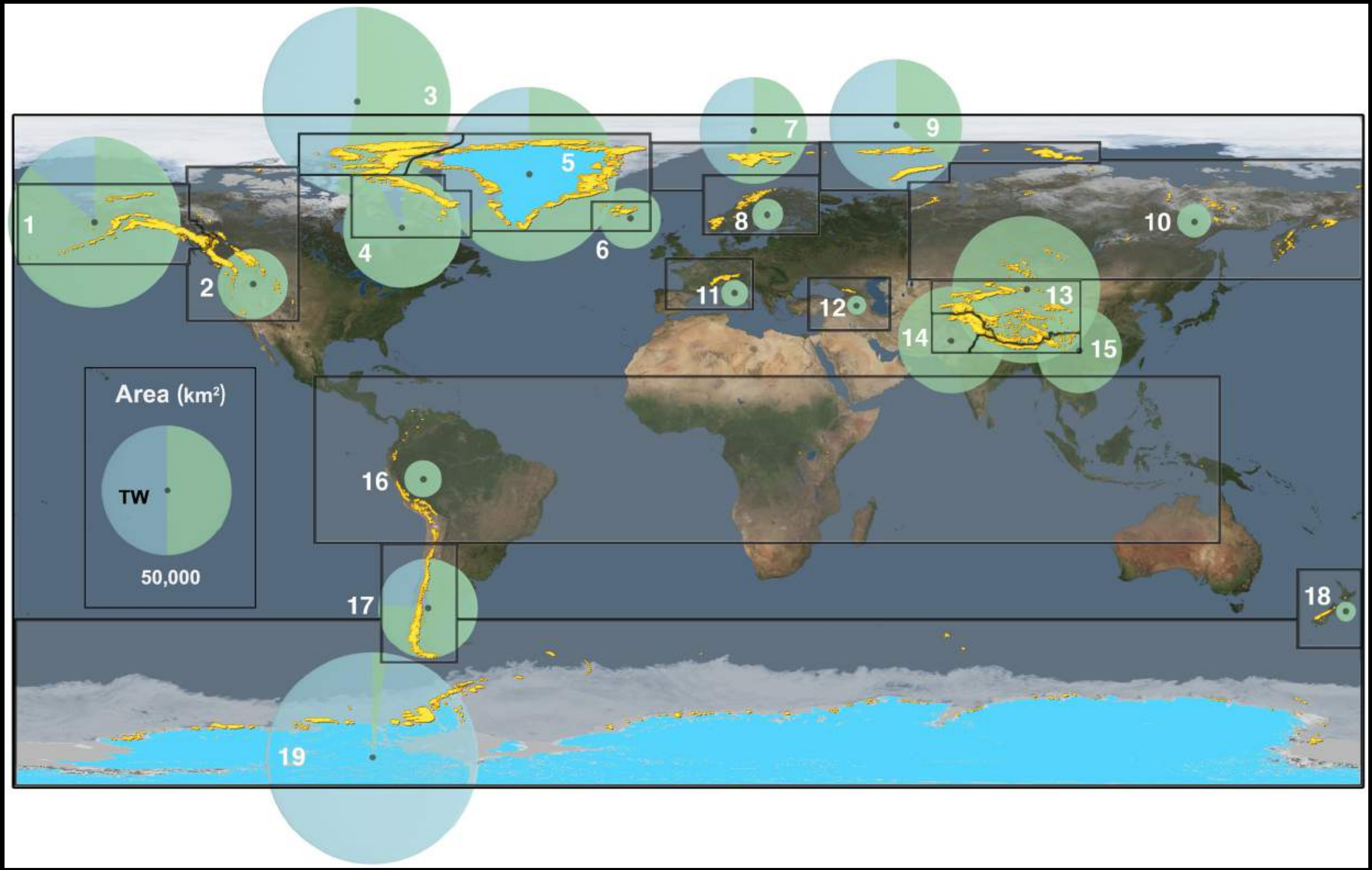
Satellite altimeter data collected since 1993 have measured a rise in global mean sea level



SOURCE: Steve Nerem/University of Colorado, Boulder InsideClimate News

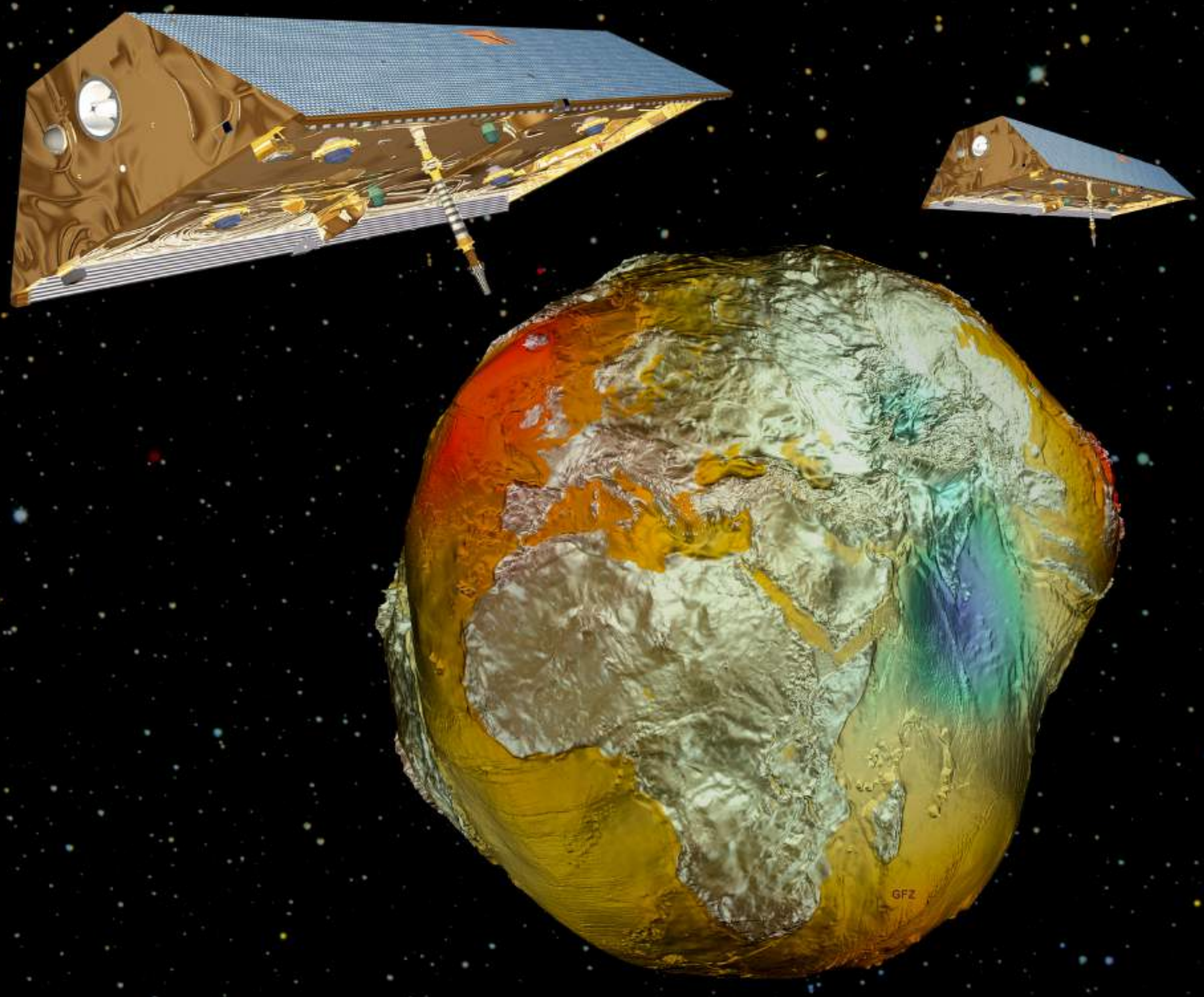
665 Billion Tons of Ice Melt Each Year

Greenland 37% Mountain Glaciers 34% Antarctica 29%

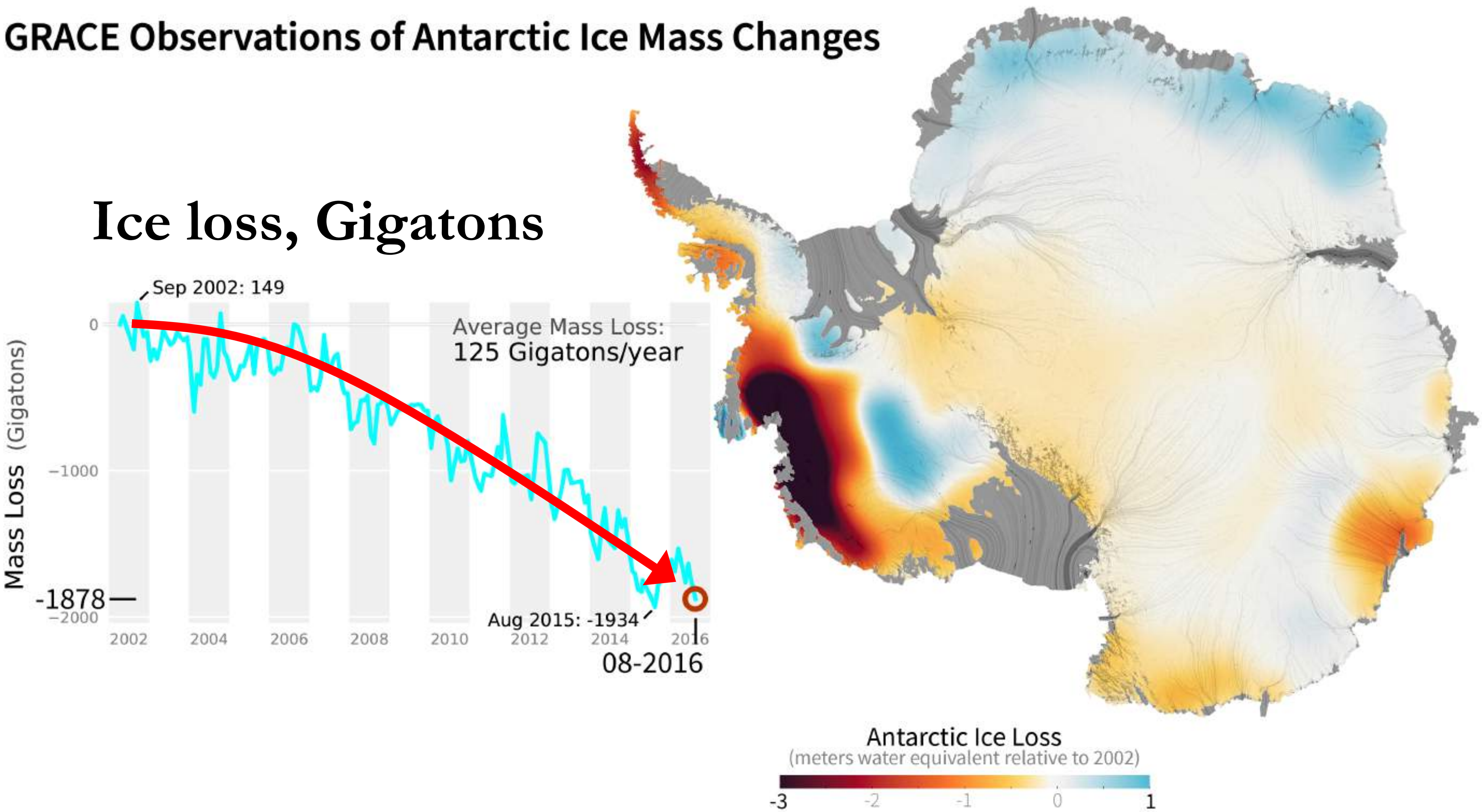


Bamber, J.L., et al (2018) The land ice contribution to sea level during the satellite era, Environ. Res. Lett. 13 https://doi.org/10.1088/1748-9326/aac2f0

GRACE – Gravity Recovery & Climate Experiment, 2002-2017

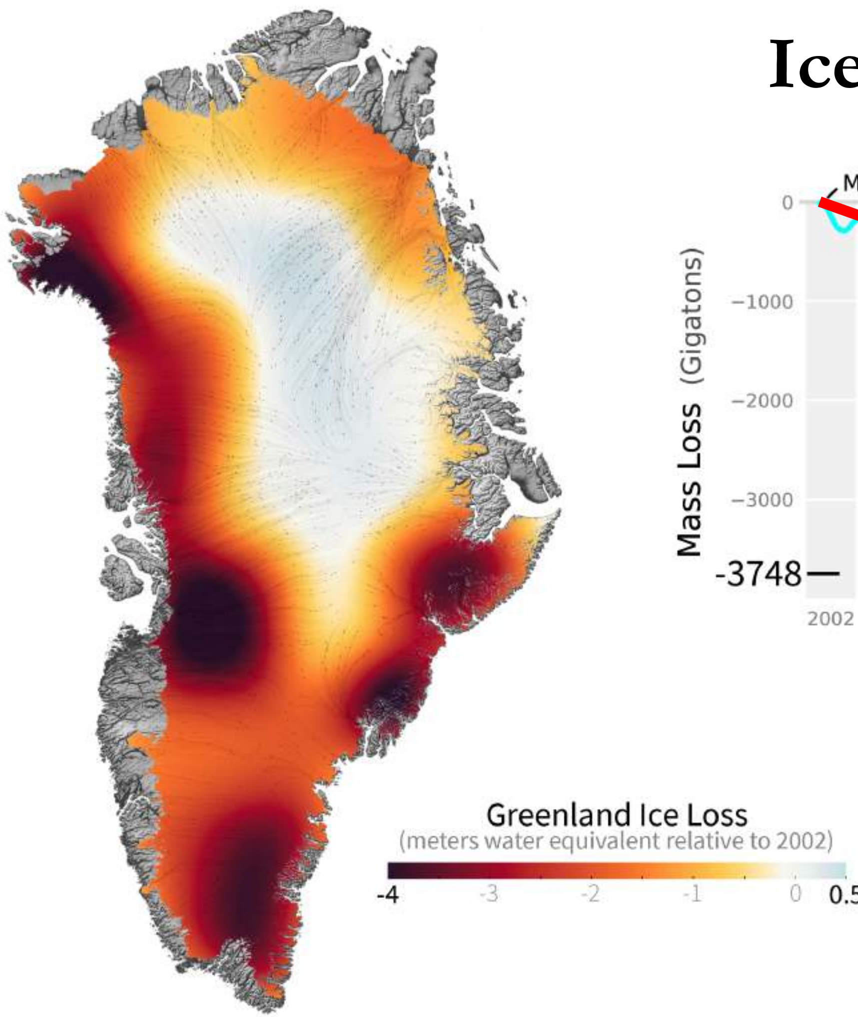


Antarctic ice melt has 'tripled over the past five years'

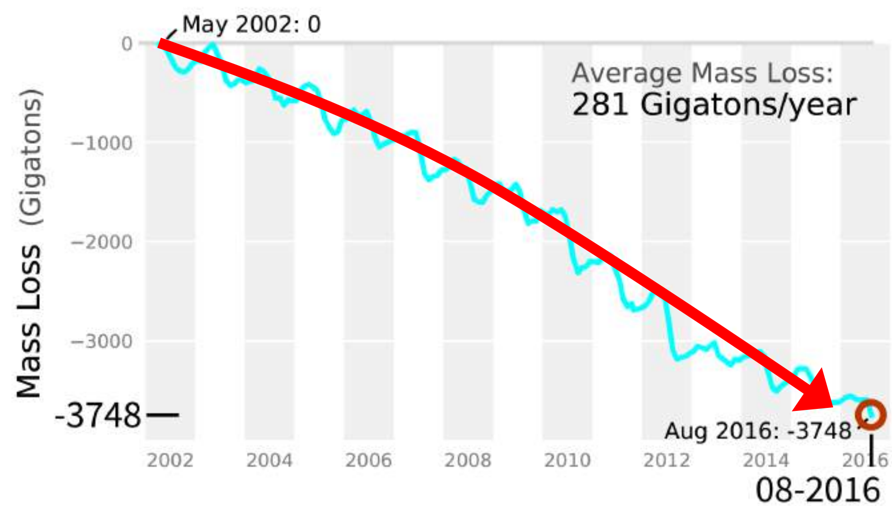


The IMBIE team (2018) Mass Balance of the Antarctic Ice Sheet, *Nature*, 558, pages219–222, https://doi.org/10.1038/s41586-018-0179-y

Greenland faces a 66% chance that melting will become unstoppable at 1.8°C

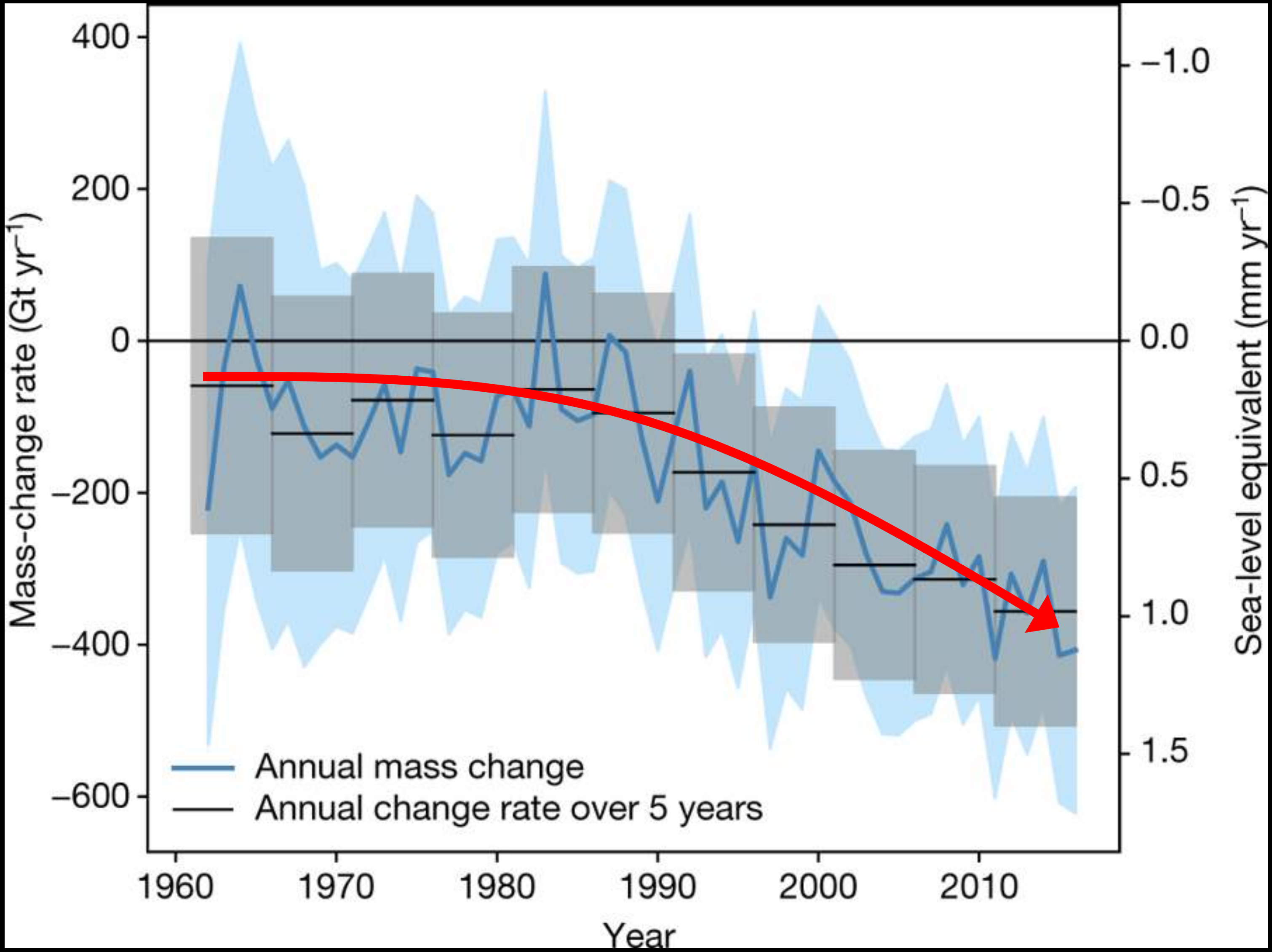


Ice loss, Gigatons



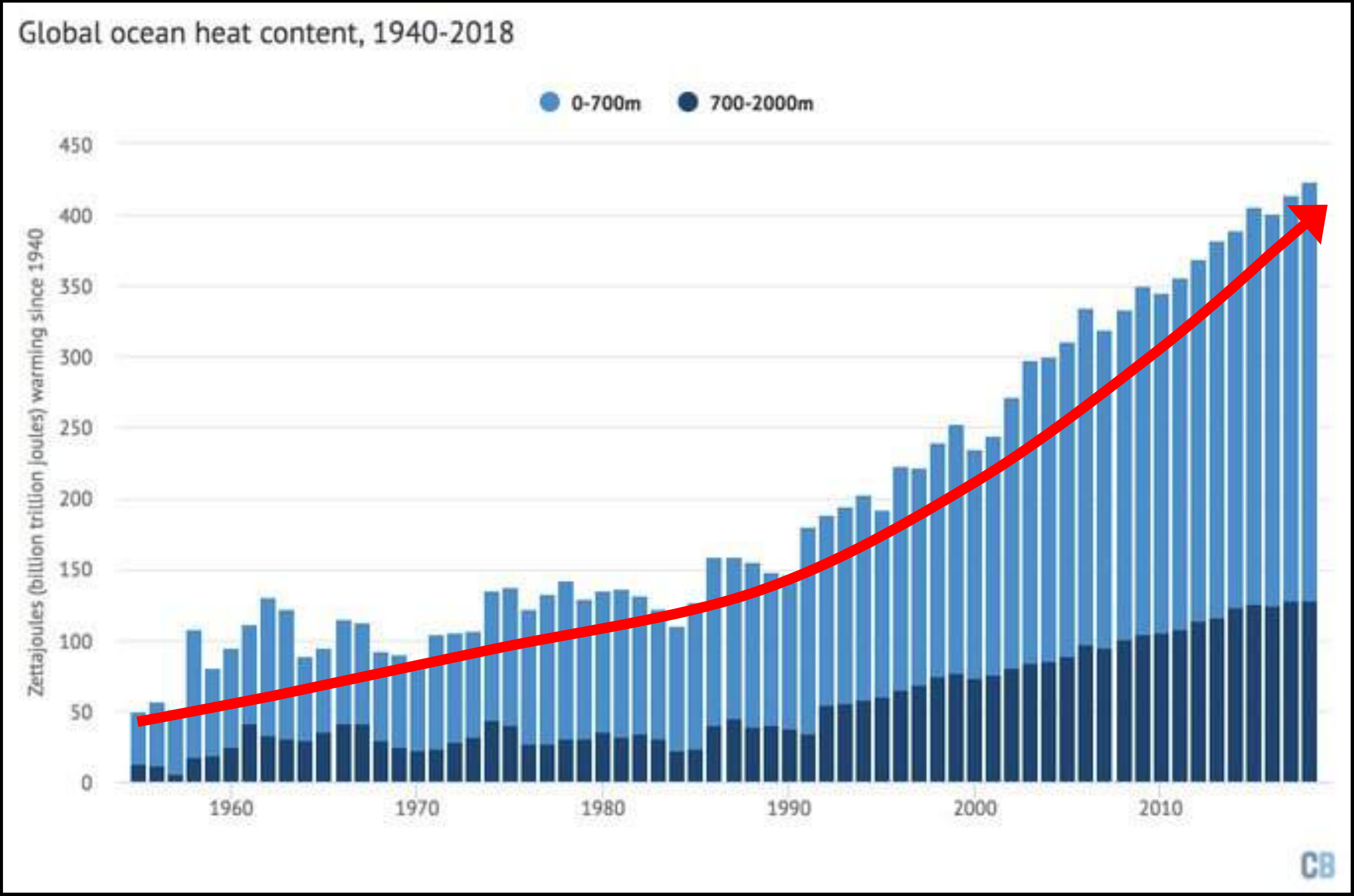
Trusel, et al., 2018 Nonlinear rise in Greenland runoff in response to post-industrial Arctic warming, 104, *Nature*, v564, 6 December: https://doi.org/10.1038/s41586-018-0752-4

Mountain Glaciers lost 9,625 billion tons of ice since 1961, raising sea level almost 1 ft



M. Zemp et al. Global glacier mass changes and their contributions to sea-level rise from 1961 to 2016, *Nature* (2019). DOI: 10.1038/s41586-019-1071-0

The ocean is 40% hotter than previously thought.

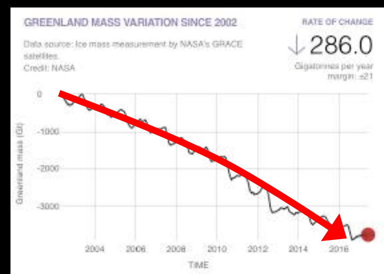


Cheng, L., et al. (2019) How fast are the oceans warming? *Science*, 2019 DOI: 10.1126/science.aav7619; Cheng L. J. Zhu, and J. Abraham, 2015: Global upper ocean heat content estimation: recent progress and the remaining challenges. Atmospheric and Oceanic Science Letters, 8. DOI:10.3878/AOSL20150031. ; Glecker, P.J., et al. (2016) Industrial era global ocean heat uptake doubles in recent decades. Nature Climate change. doi:10.1038/nclimate2915

How high will SL rise by 2100?

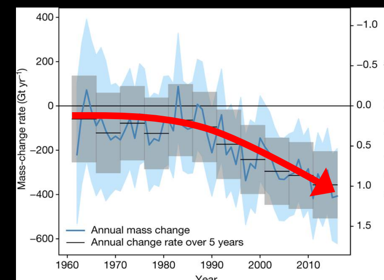
Antarctic ice loss

+



Greenland ice loss

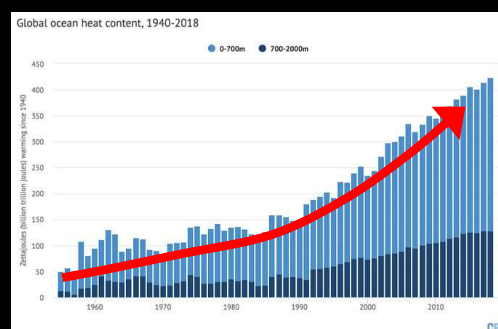
+



Mountain glacier ice loss

= 0.8m

0.8m +



Thermal expansion

= <u>1m by 2100</u>

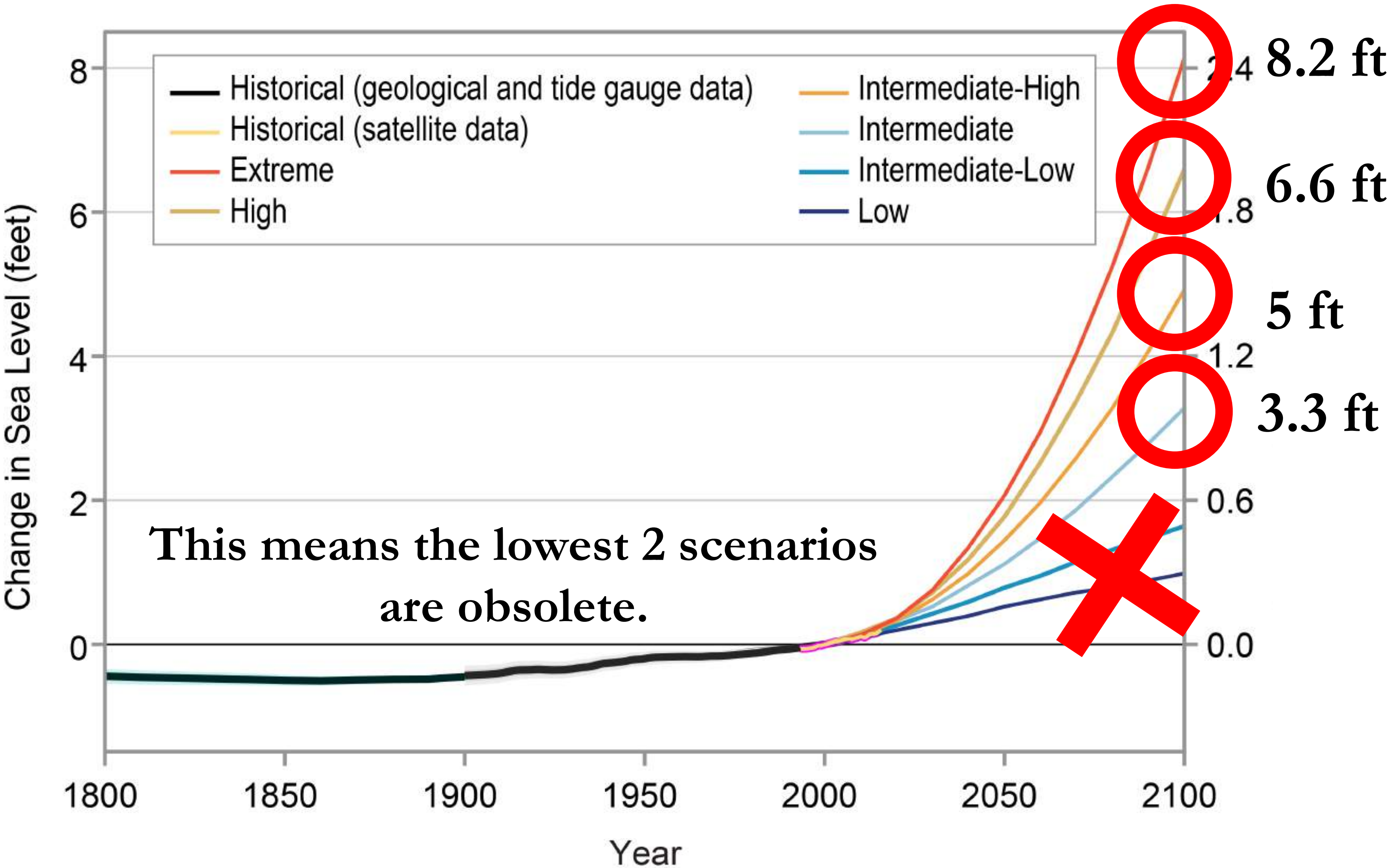
E. Rignot (2019) pers. comm.: http://sites.nationalacademies.org/SSB/SSB_191179

https://science2017.globalchange.gov

How High Sea Level?

- *Very likely* to rise 0.3–0.6 feet by 2030
- 0.5–1.2 feet by 2050
- 1.0–4.3 feet by 2100
- Emissions now and over the next 20-30 yrs have little effect on SLR in the first half of the century
- But significantly affect SLR for the second half of the century
- Emerging science on Antarctica suggests, for high emission scenarios, a SLR exceeding 8 ft by 2100 is physically possible
- It is *extremely likely* that SLR rise will continue beyond 2100 (*high confidence*).

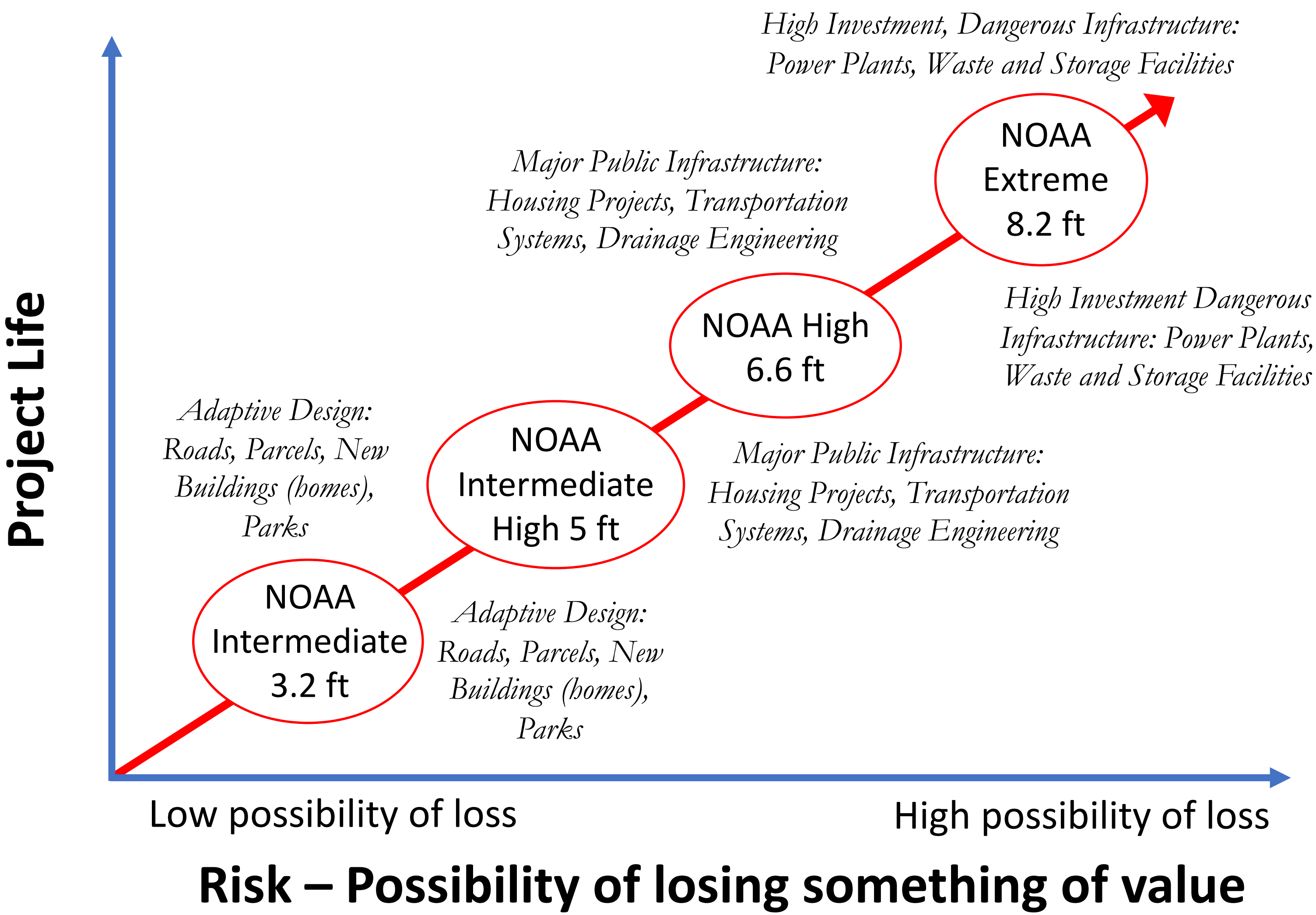
NOAA & 4thNCA SL Scenarios



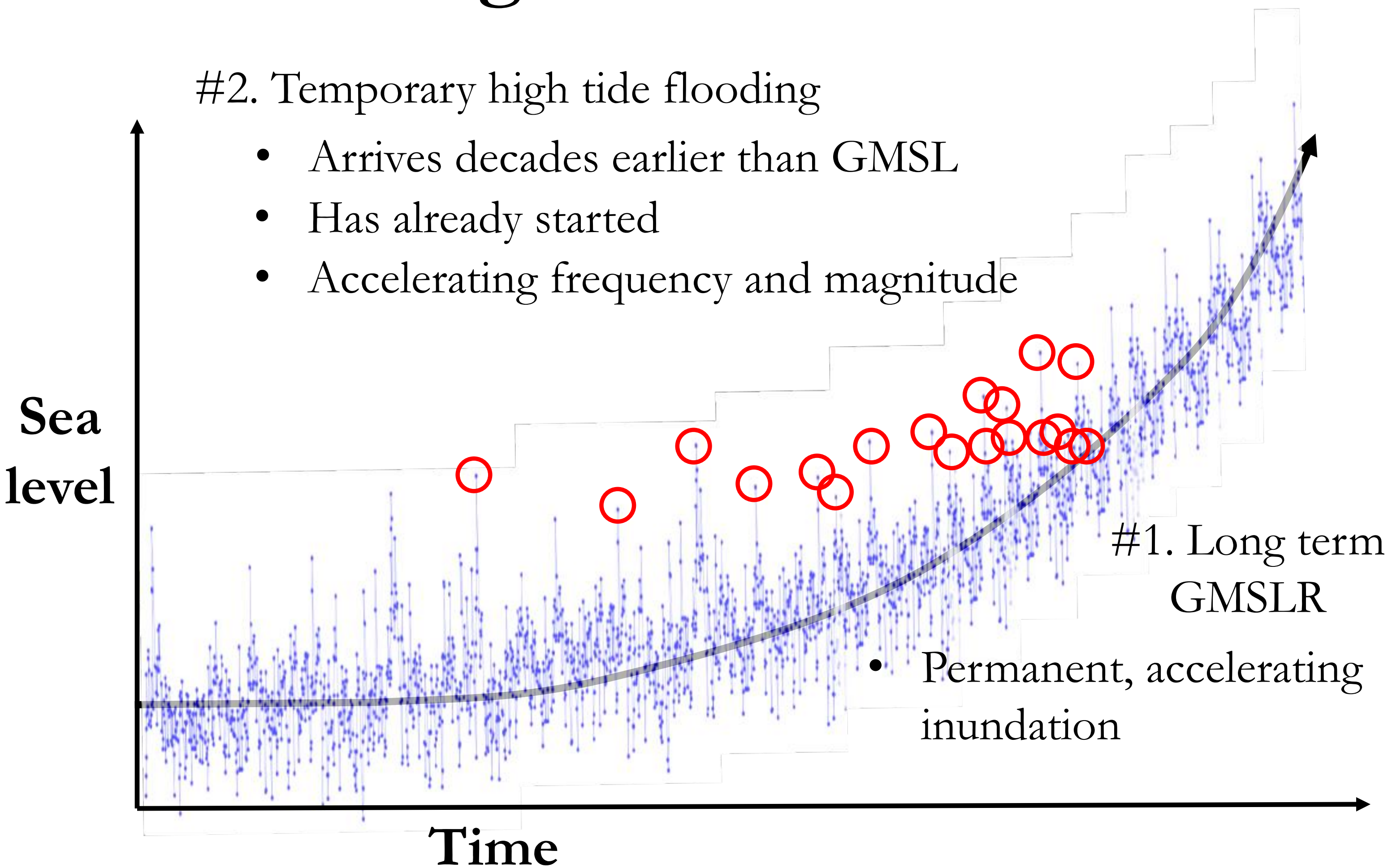
Sweet, W.V., et al. 2017 Sea level rise. In: *Climate Science Special Report: Fourth National Climate Assessment, Volume I*[Wuebbles, D.J., et al. (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 333-363, https://science2017.globalchange.gov/chapter/12/

SLR Scenario Planning

decision-making under conditions of uncertainty



SLR Flooding: Nuisance and Permanent

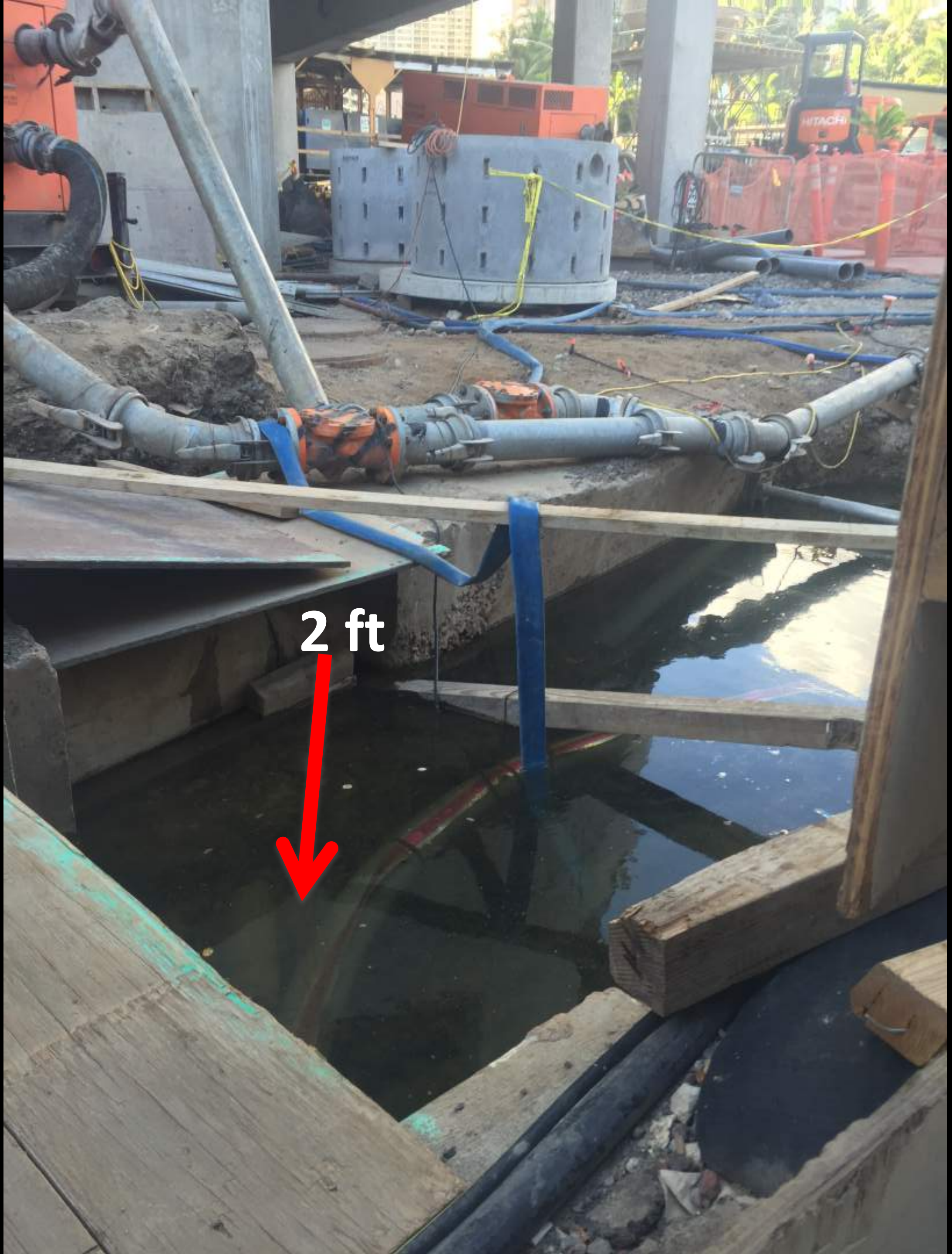


Disruptive High Tide Flooding by Mid-Century

Storm Drain Backflow at High Tide

Disruptive High Tide Flooding by Mid-Century

Groundwater Inundation



Rain + High Tide = Flooding

Disruptive High Tide Flooding by Mid-Century

Groundwater Pollution

Summer wave run-up 2ft

Summer wave run-up 3ft

Coastal Erosion and Beach Loss

Department of Transportation

- 140 miles
- 120 bridges
- 10-15% all roads
- $7.5M per lane mile
- $14M per bridge
- $15B total

Sunset Beach
3 ft of SLR

Waikiki at 1m SLR

Article | OPEN | Publi

Modeling
reveals up
compared
methods

TOP 100
– READ ARTICLES –
2018
OFFICIAL AUTHOR
SCIENTIFIC REPORTS

Tiffany R. Anderson, (... no &
Jade M.S. M. S. Delevau

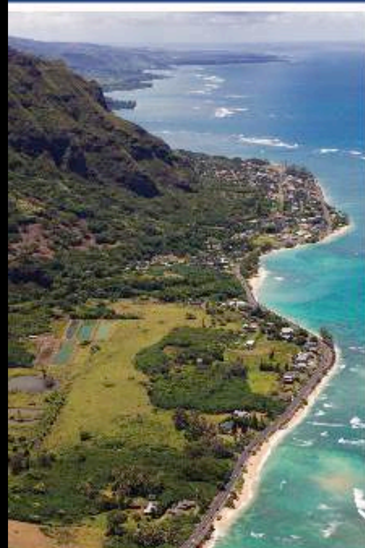
Scientific Reports **8**, Arti

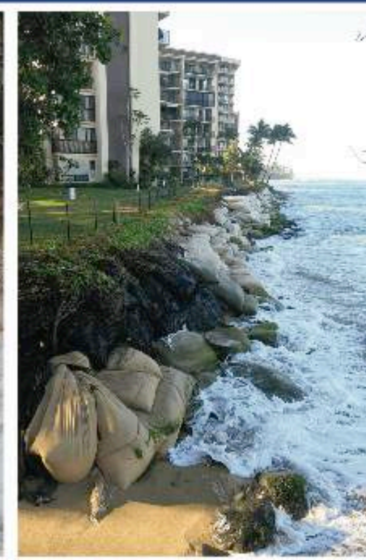
https://www.nat

Abstract

Planning community resilience to sea level rise (SLR) requires information about where, when, and how SLR hazards will impact the coastal zone. We augment passive flood mapping (the so-called "bathtub" approach) by simulating physical processes posing recurrent threats to coastal infrastructure, communities, and ecosystems in Hawai'i (including tidally-forced direct marine and groundwater flooding, seasonal wave inundation, and chronic coastal erosion). We find that the "bathtub" approach, alone, ignores 35–54 percent of the total land area exposed to one or more of these hazards, depending on location and SLR scenario. We conclude that modeling dynamic processes, including waves and erosion, is essential to robust SLR vulnerability assessment. Results also indicate that as sea level rises,

Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report



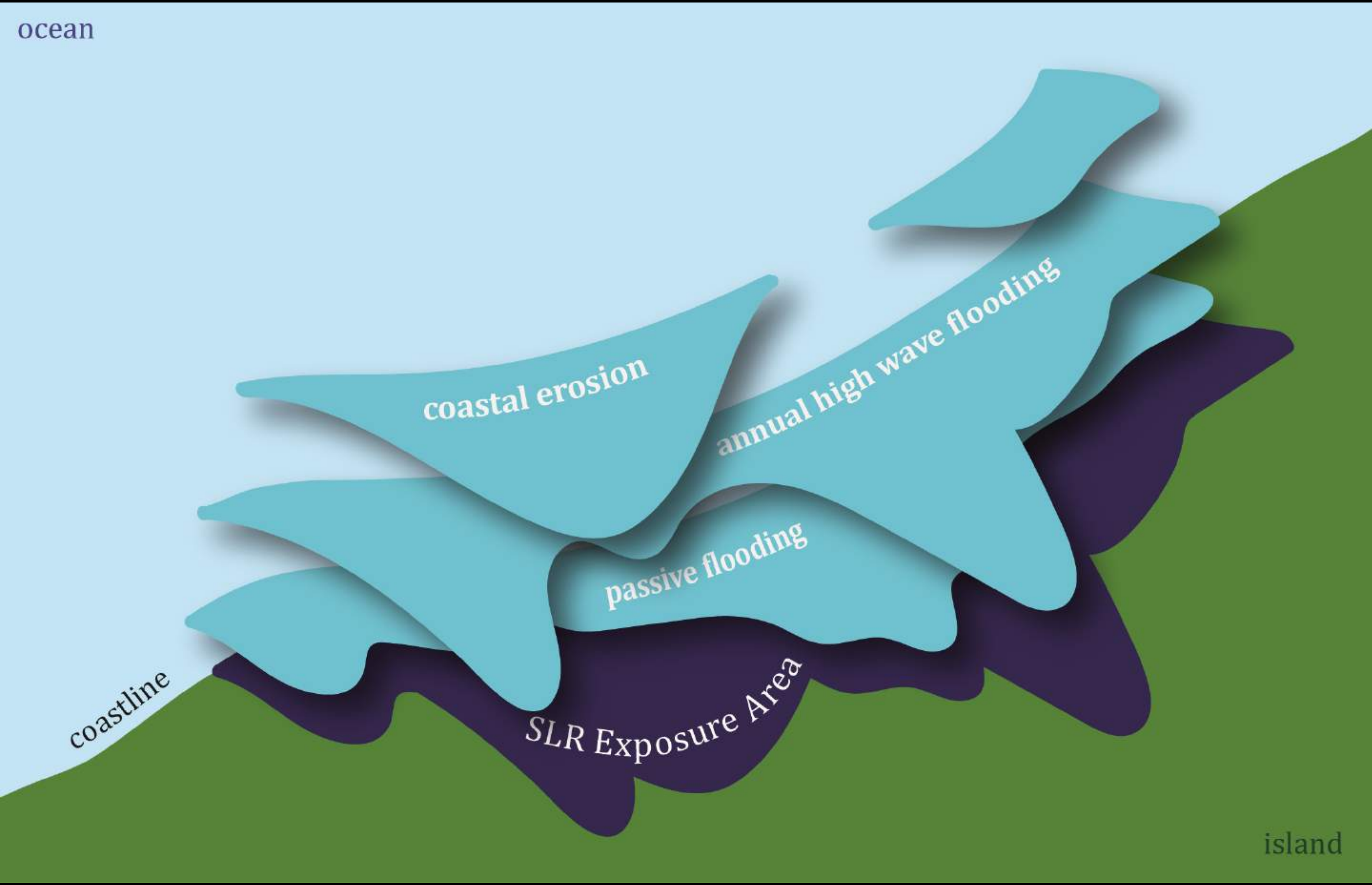


State of Hawaii, Office of Planning

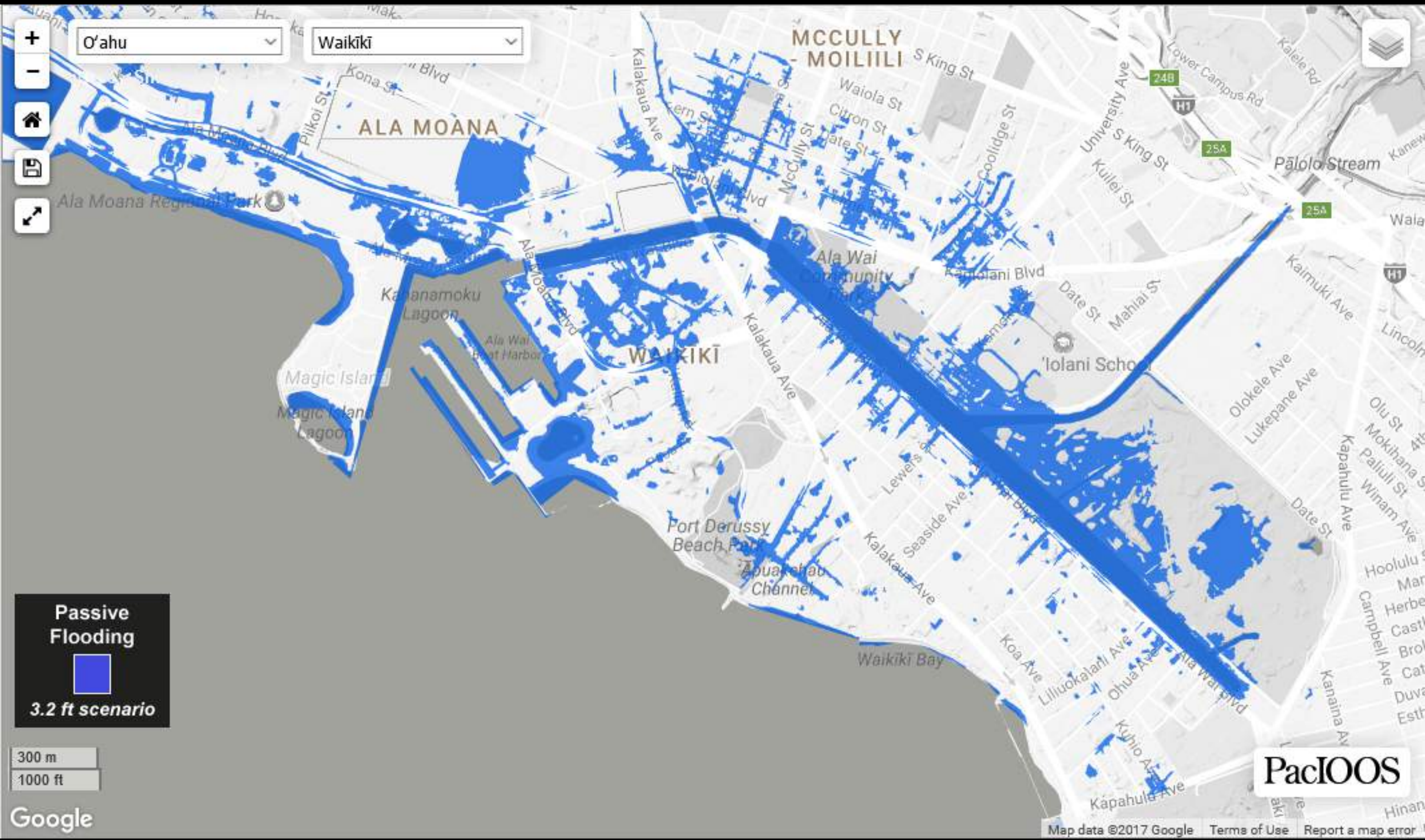
TETRA TECH

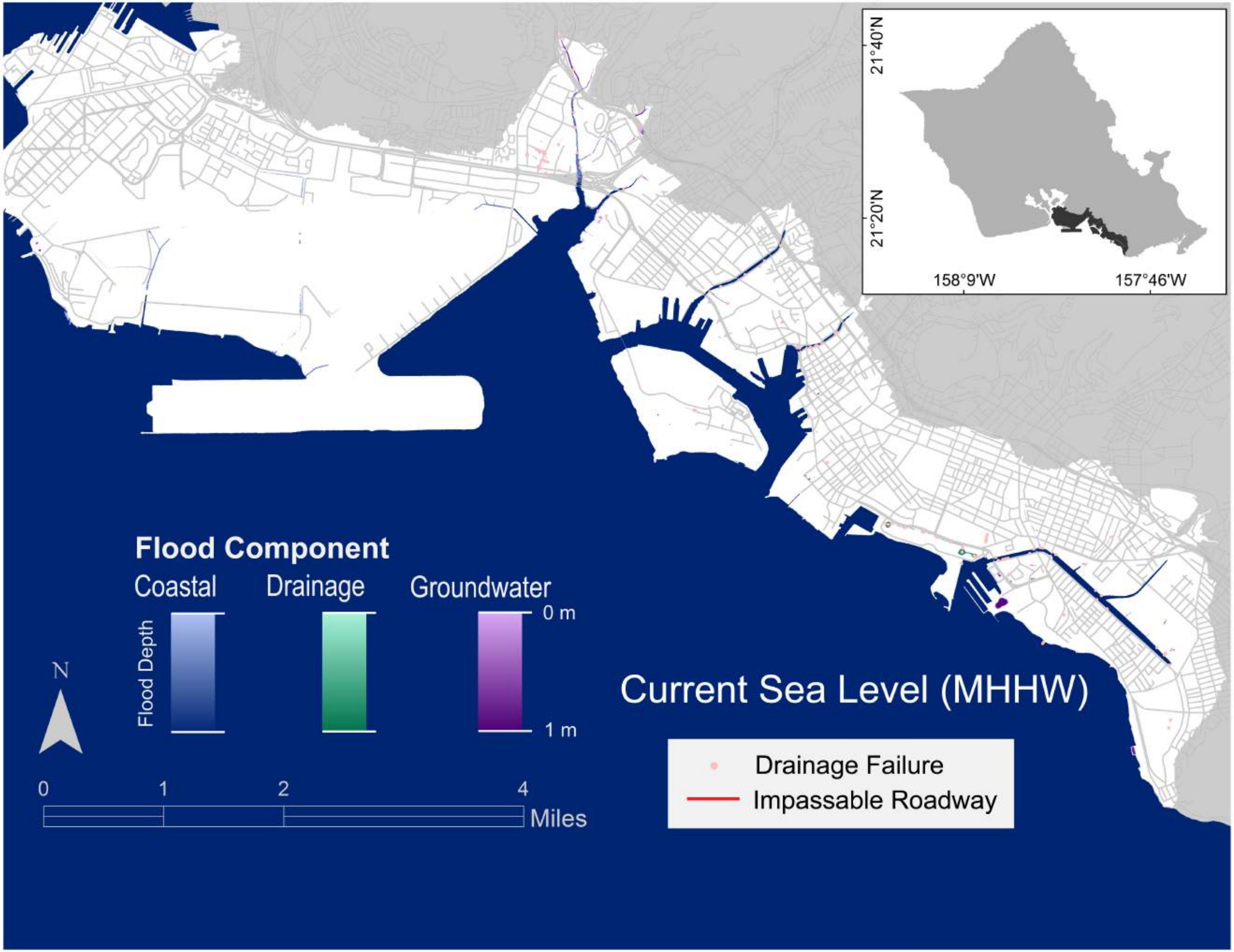
SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY

PICSC

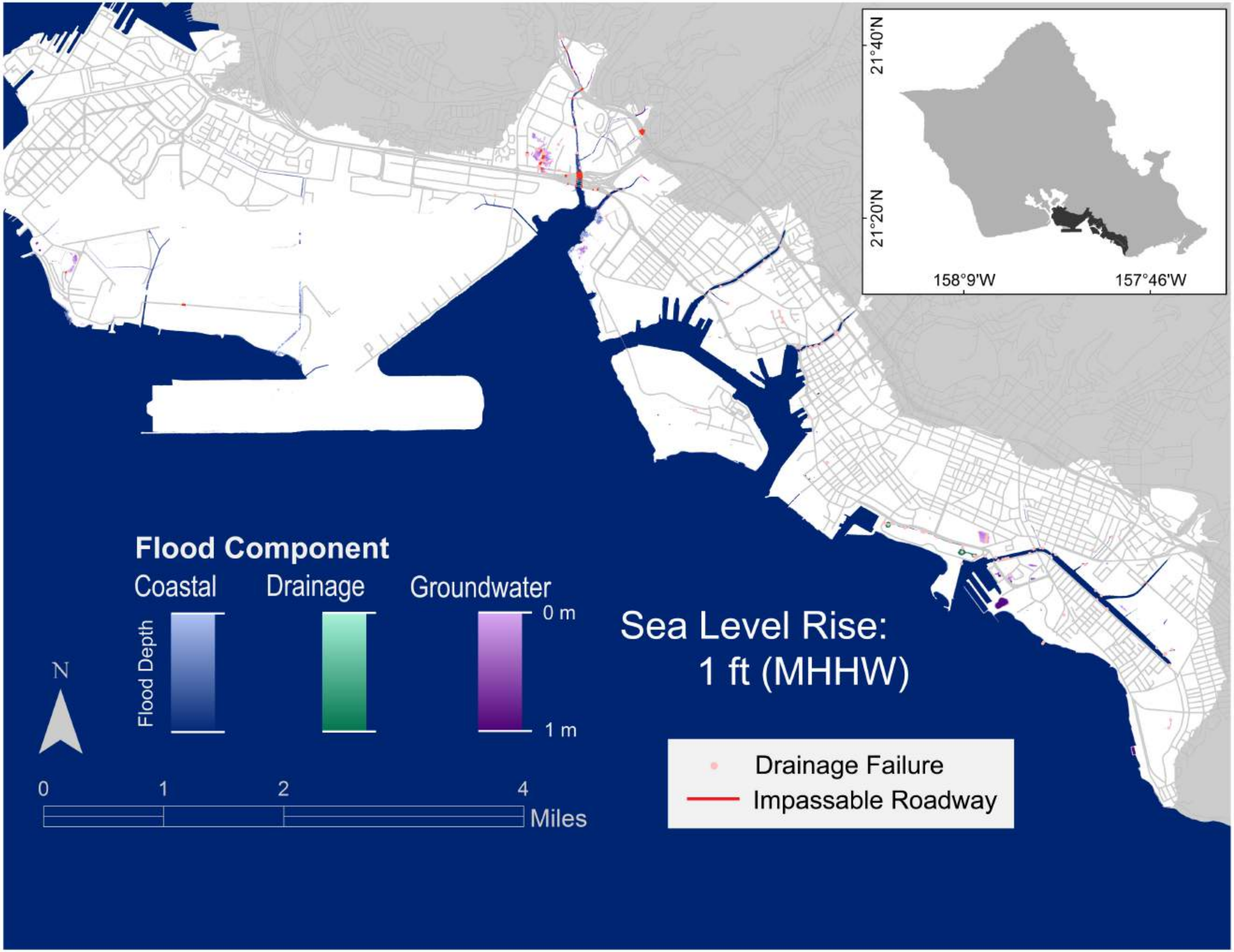

ocean
coastal erosion
annual high wave flooding
passive flooding
SLR Exposure Area
coastline
island

The 3.2SLR-XA
Location of both King Tide Flooding and Permanent Inundation





21°40'N
21°20'N
158°9'W
157°46'W
Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
1
2
4
Miles
Current Sea Level (MHHW)
Drainage Failure
Impassable Roadway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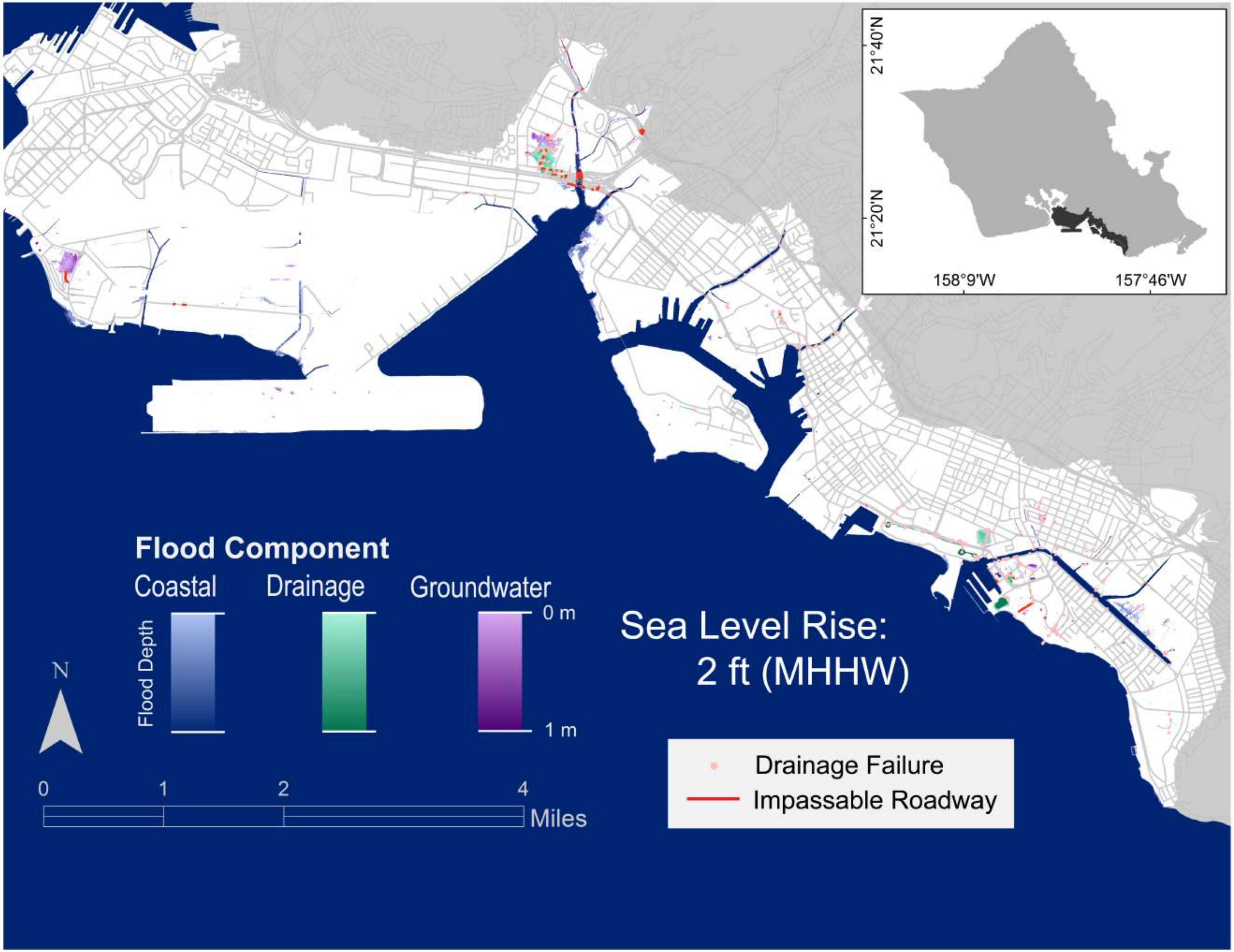
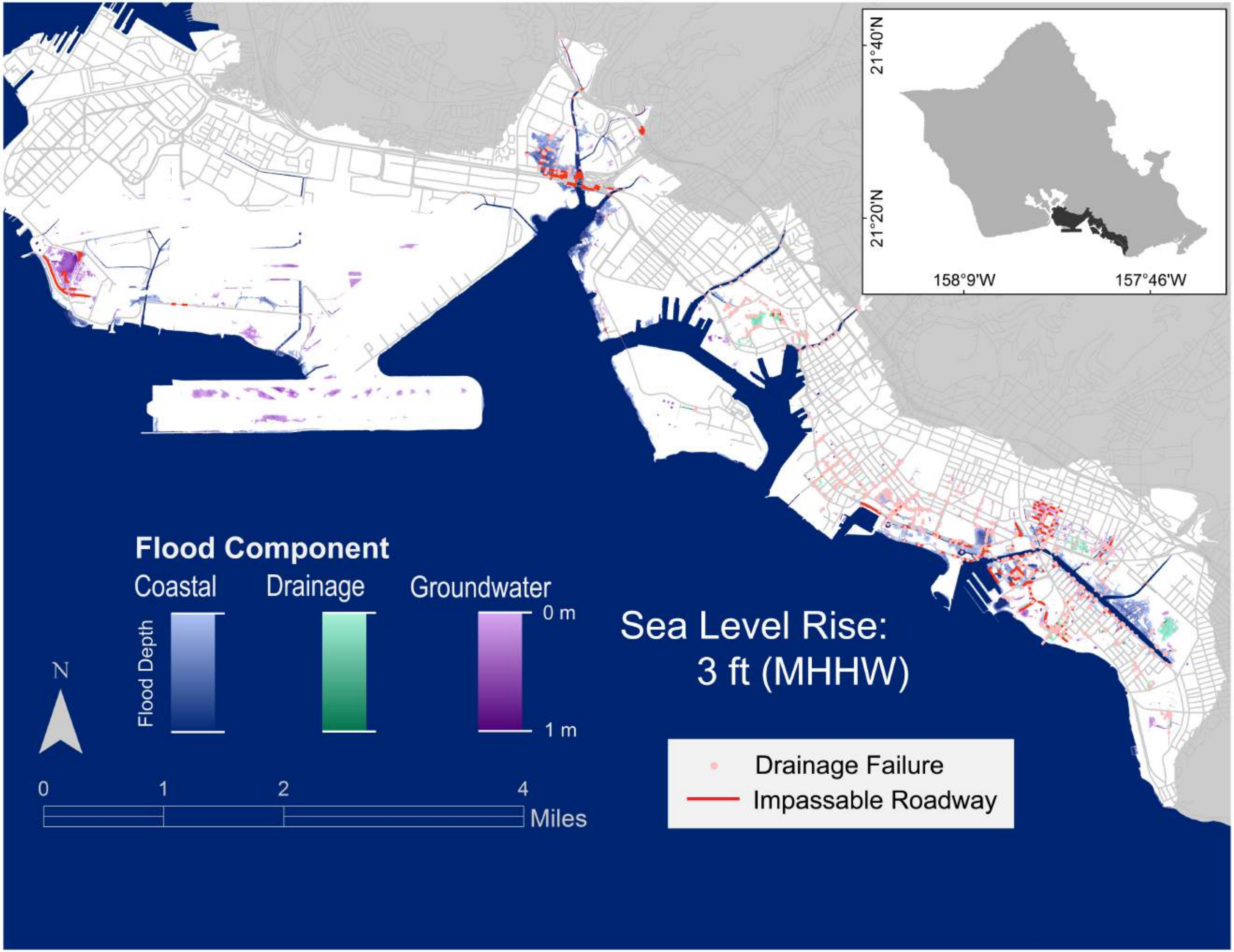
Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
1
2
4
Miles
Sea Level Rise:
1 ft (MHHW)
Drainage Failure
Impassable Roadway



21°40'N
21°20'N
158°9'W
157°46'W
Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
Sea Level Rise:
2 ft (MHHW)
N
0
1
2
4
Miles
Drainage Failure
Impassable Roadway



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21°20'N
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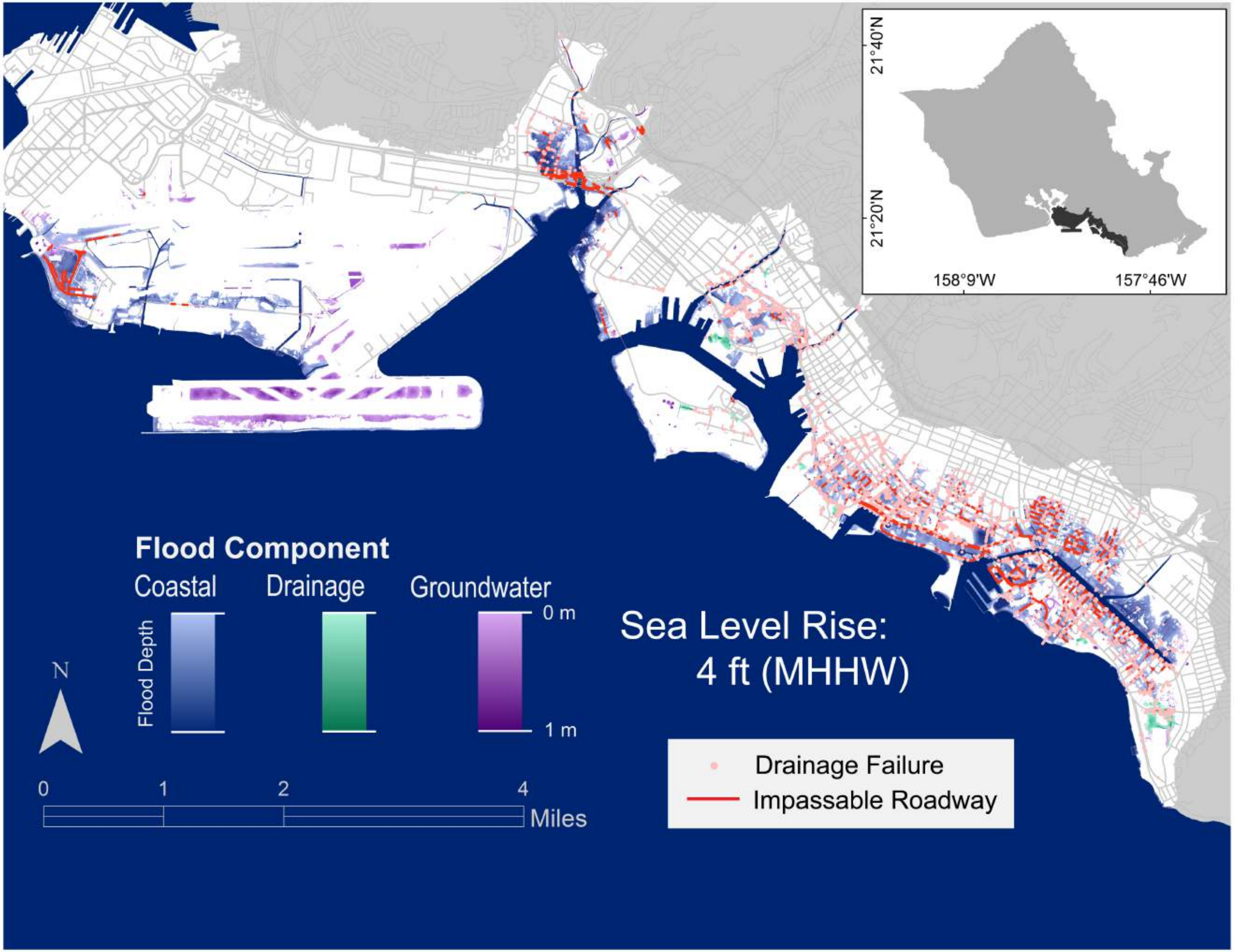
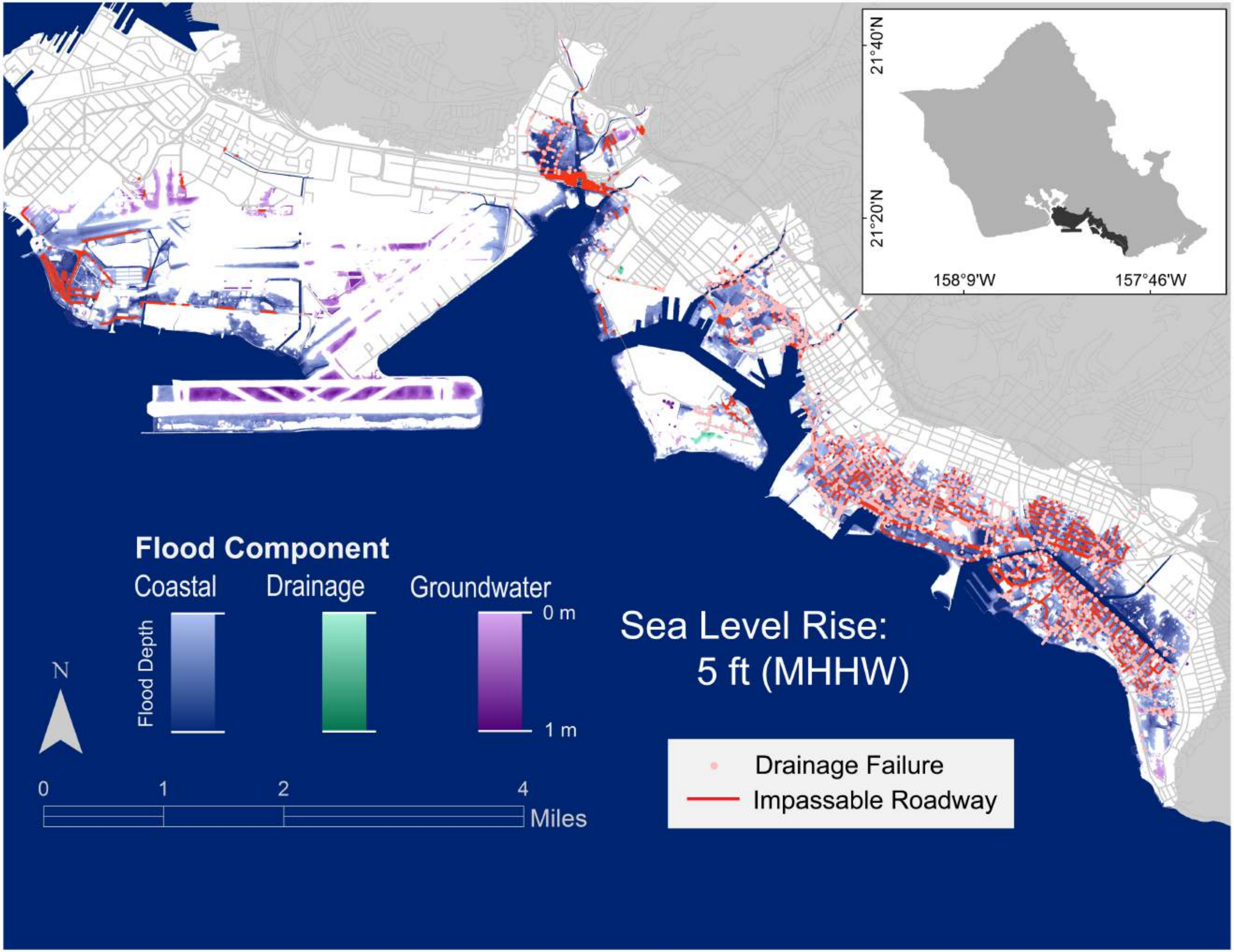
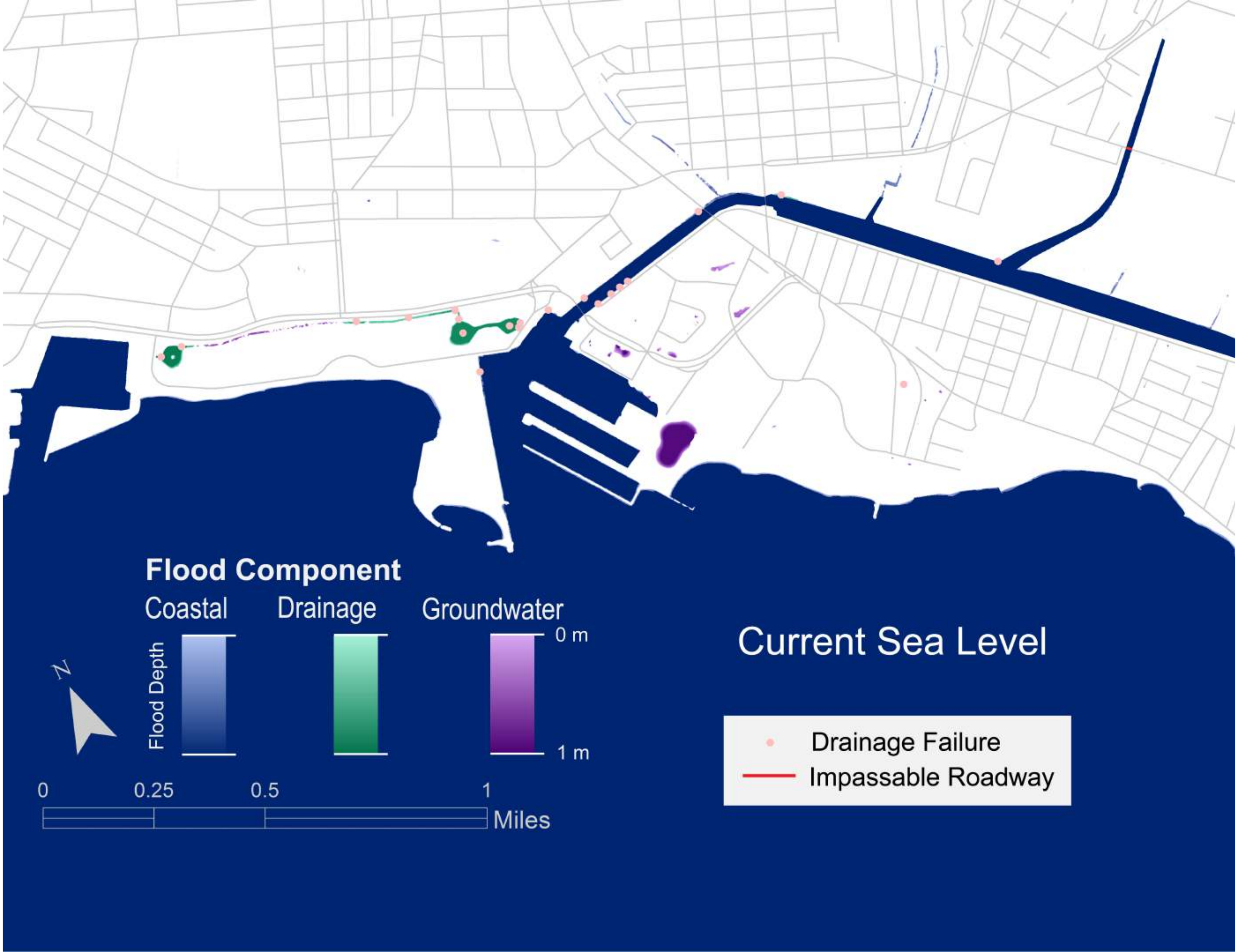
157°46'W
Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
Sea Level Rise:
3 ft (MHHW)
N
0
1
2
4
Miles
Drainage Failure
Impassable Roadway



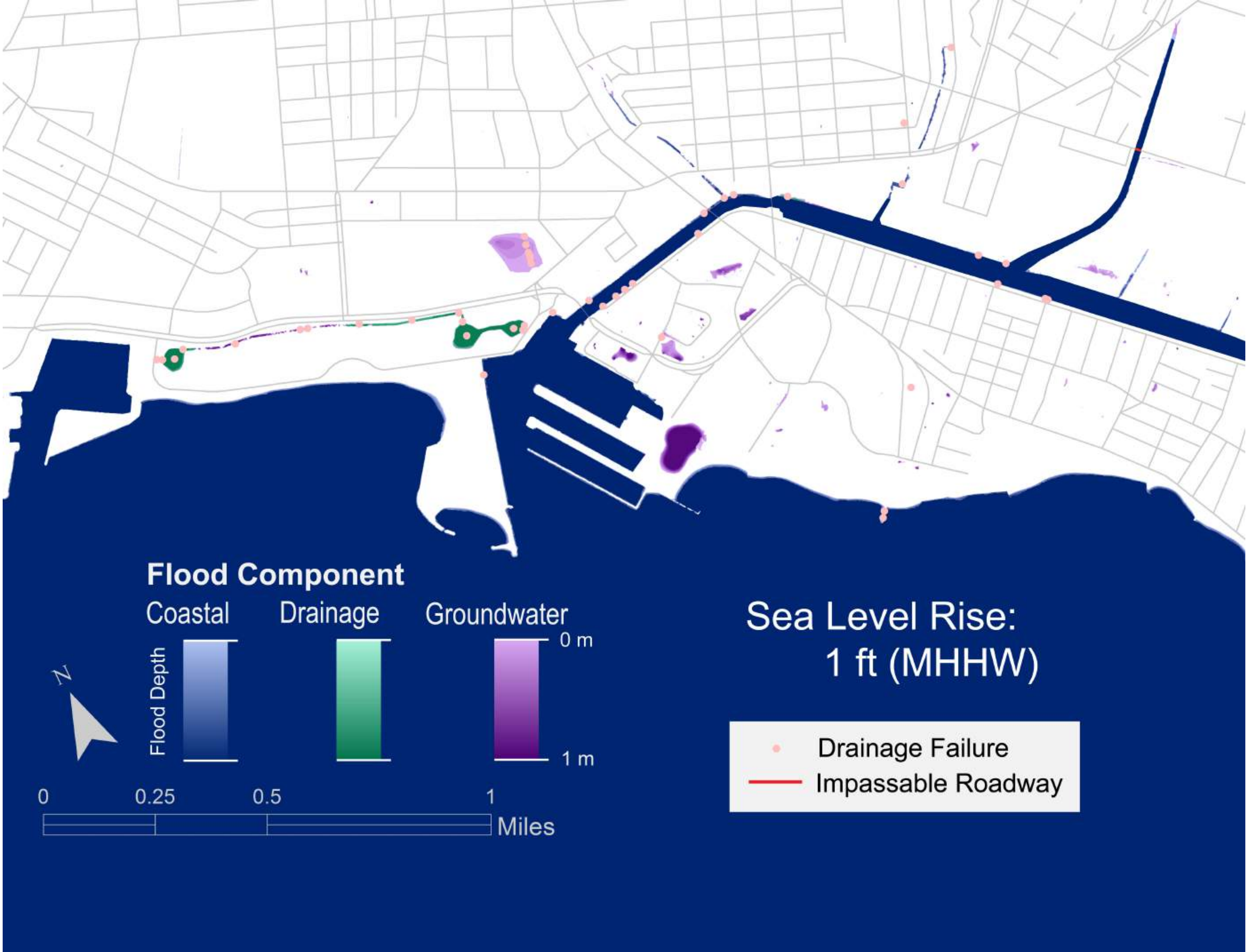
21°40'N
21°20'N
158°9'W
157°46'W
Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
1
2
4
Miles
Sea Level Rise:
4 ft (MHHW)
Drainage Failure
Impassable Roadway



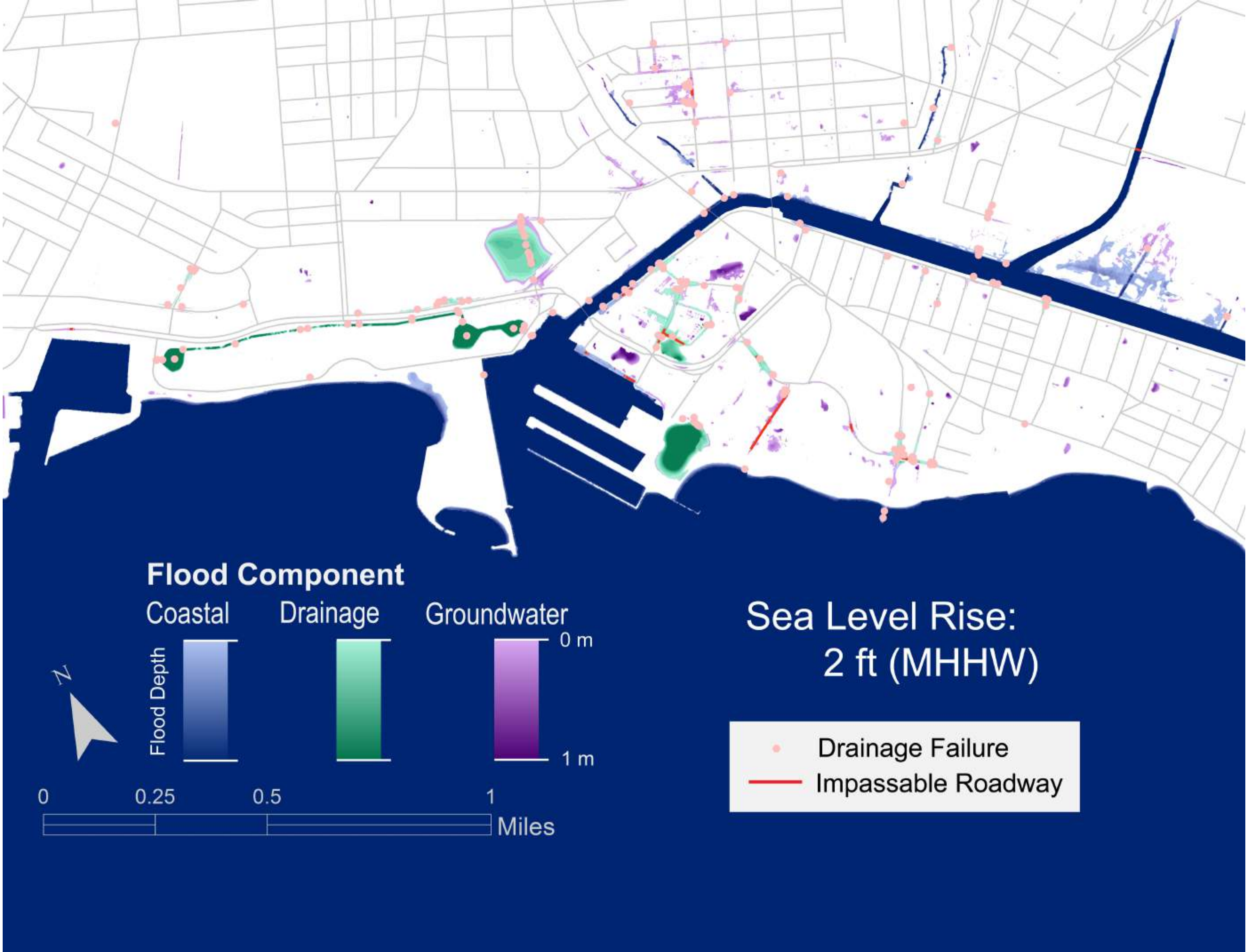
21°40'N
21°20'N
158°9'W
157°46'W
Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
1
2
4
Miles
Sea Level Rise:
5 ft (MHHW)
Drainage Failure
Impassable Roadway



Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
0.25
0.5
1
Miles
Current Sea Level
Drainage Failure
Impassable Roadway



Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
0.25
0.5
1
Miles
Sea Level Rise:
1 ft (MHHW)
Drainage Failure
Impassable Roadway



Flood Component
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1 m
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Miles
Sea Level Rise:
2 ft (MHHW)
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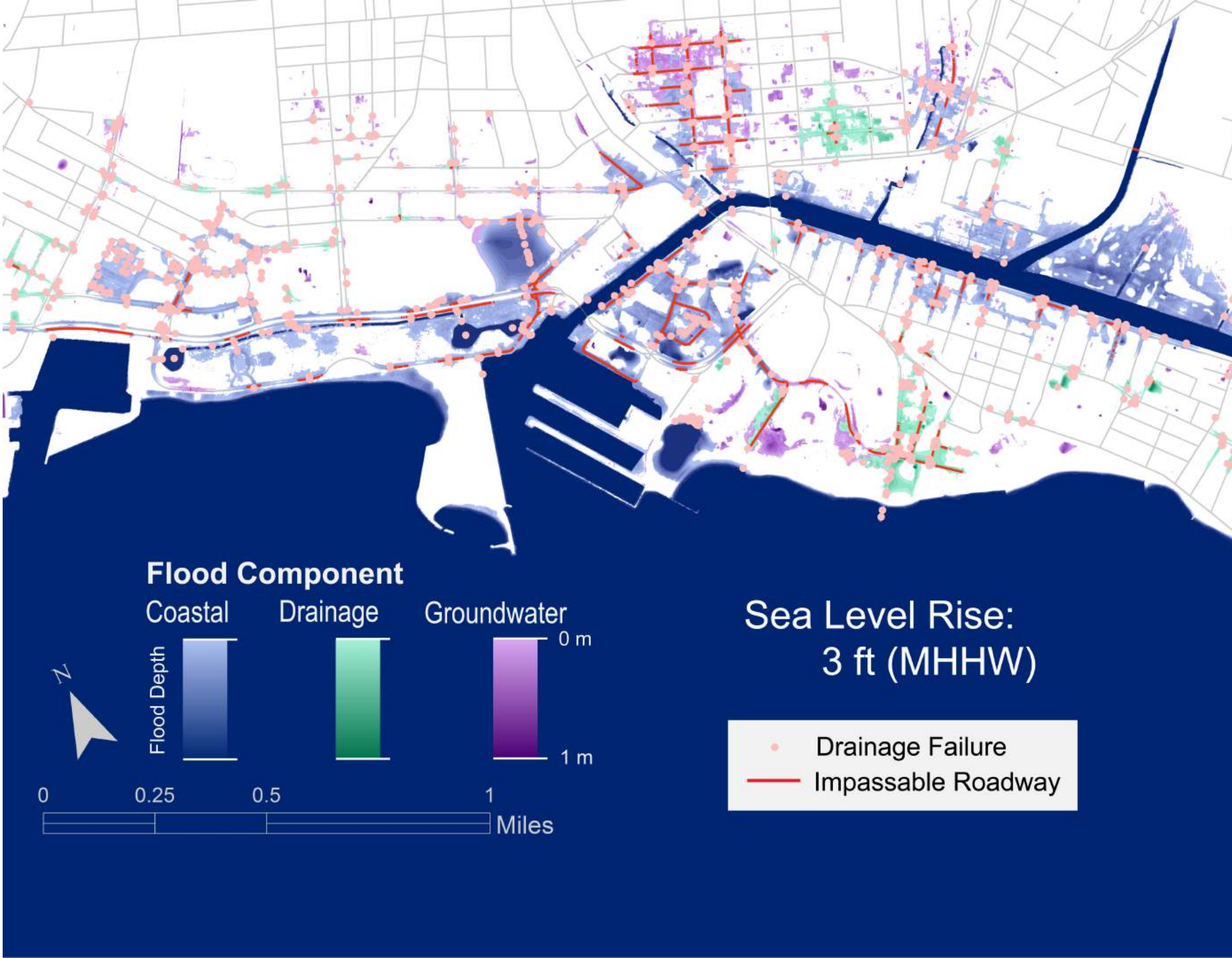
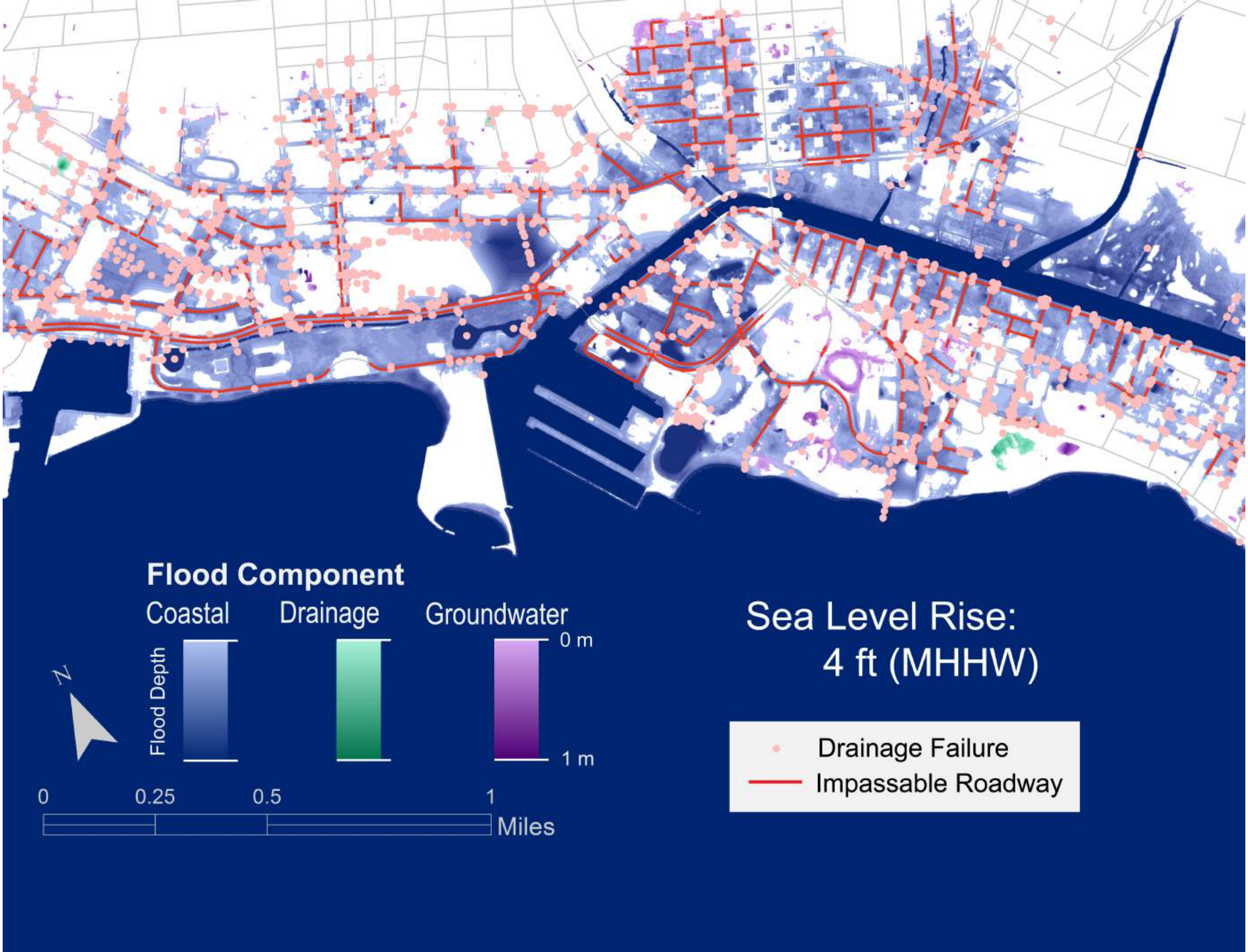
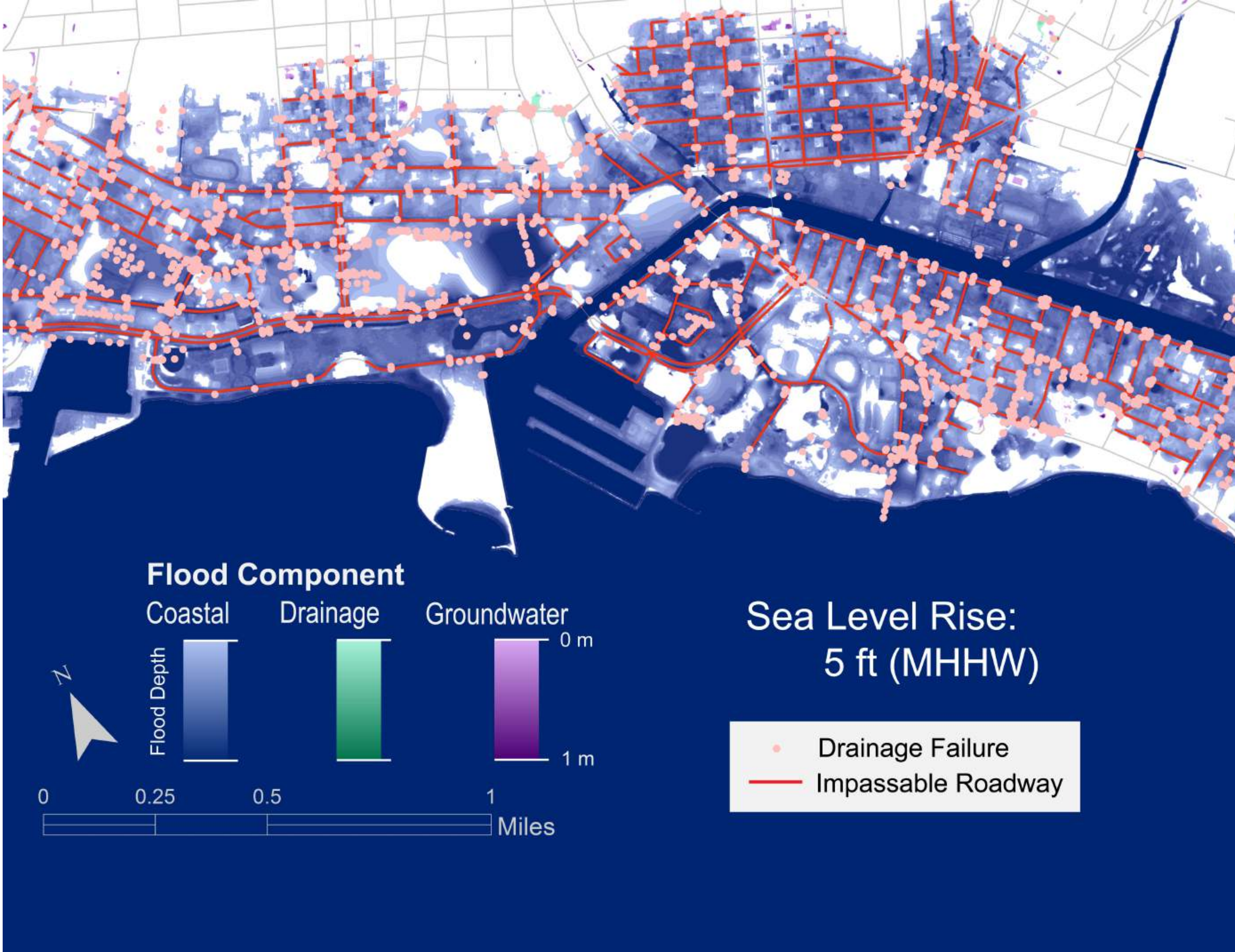
Impassable Roadway



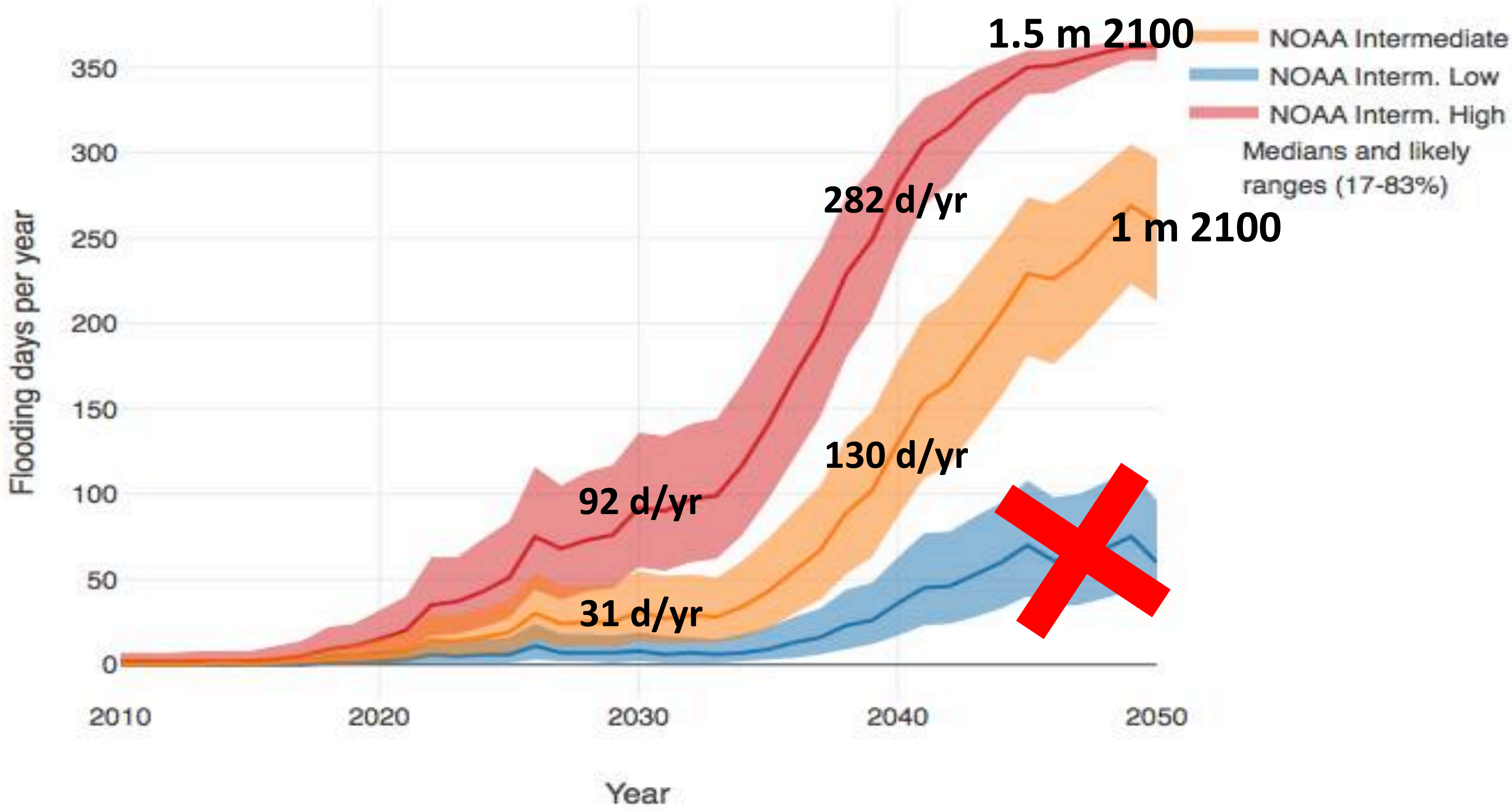
Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
0.25
0.5
1
Miles
Sea Level Rise:
3 ft (MHHW)
Drainage Failure
Impassable Roadway


Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
0.25
0.5
1
Miles
Sea Level Rise:
4 ft (MHHW)
Drainage Failure
Impassable Roadway



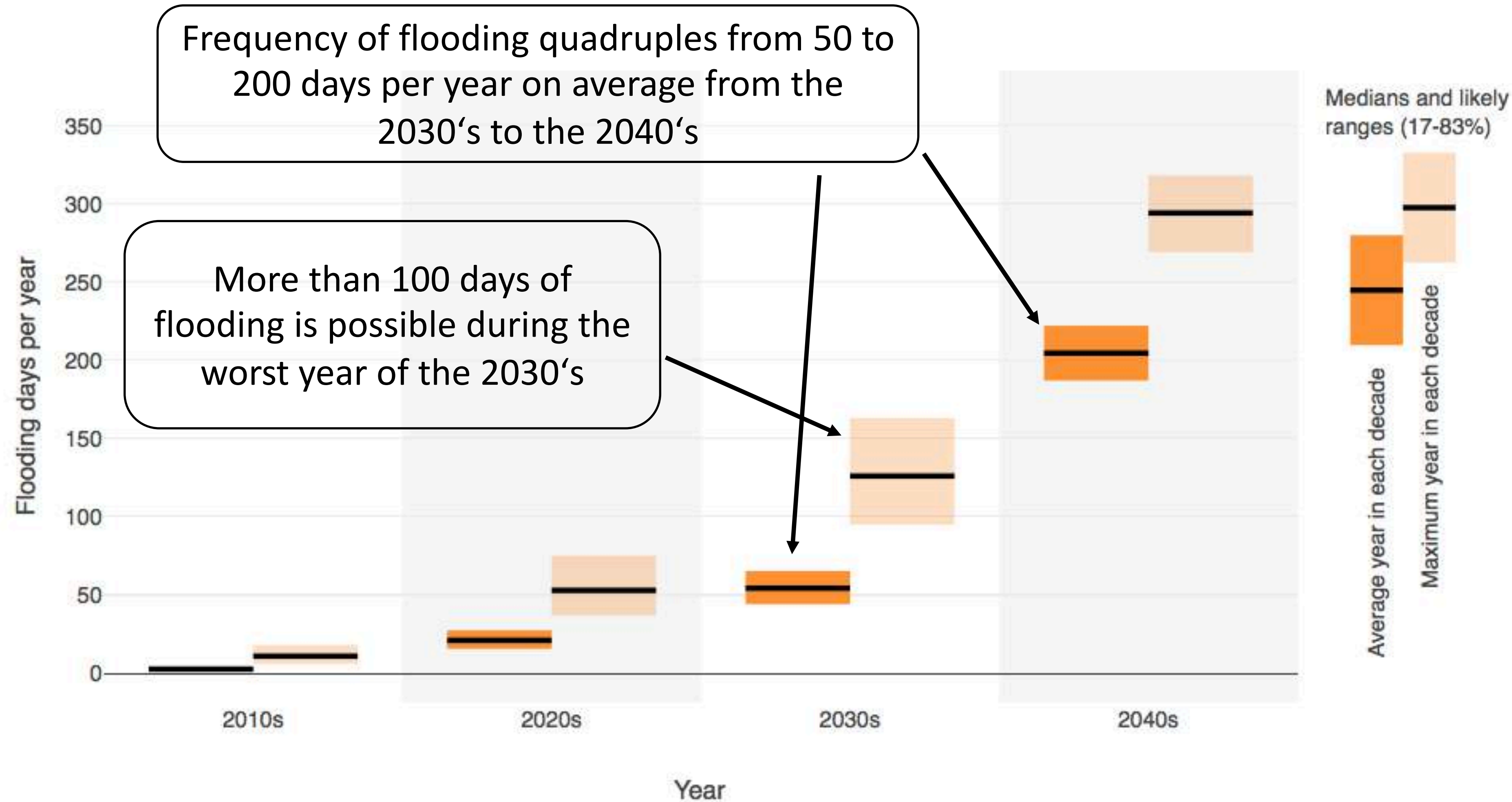
Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
0.25
0.5
1
Miles
Sea Level Rise:
5 ft (MHHW)
Drainage Failure
Impassable Roadway

High Tide Flooding in Coastal Honolulu by Decade



Thompson et al. (2019) A statistical model for frequency of coastal flooding in Honolulu Hawaii, during the 21st Century, JGR Oceans, 10.1029/2018JC014741
UH Sea Level Center: https://uhslc-flooding-test.soest.hawaii.edu

High Tide Flooding in Coastal Honolulu by Decade



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