The Climate Emergency

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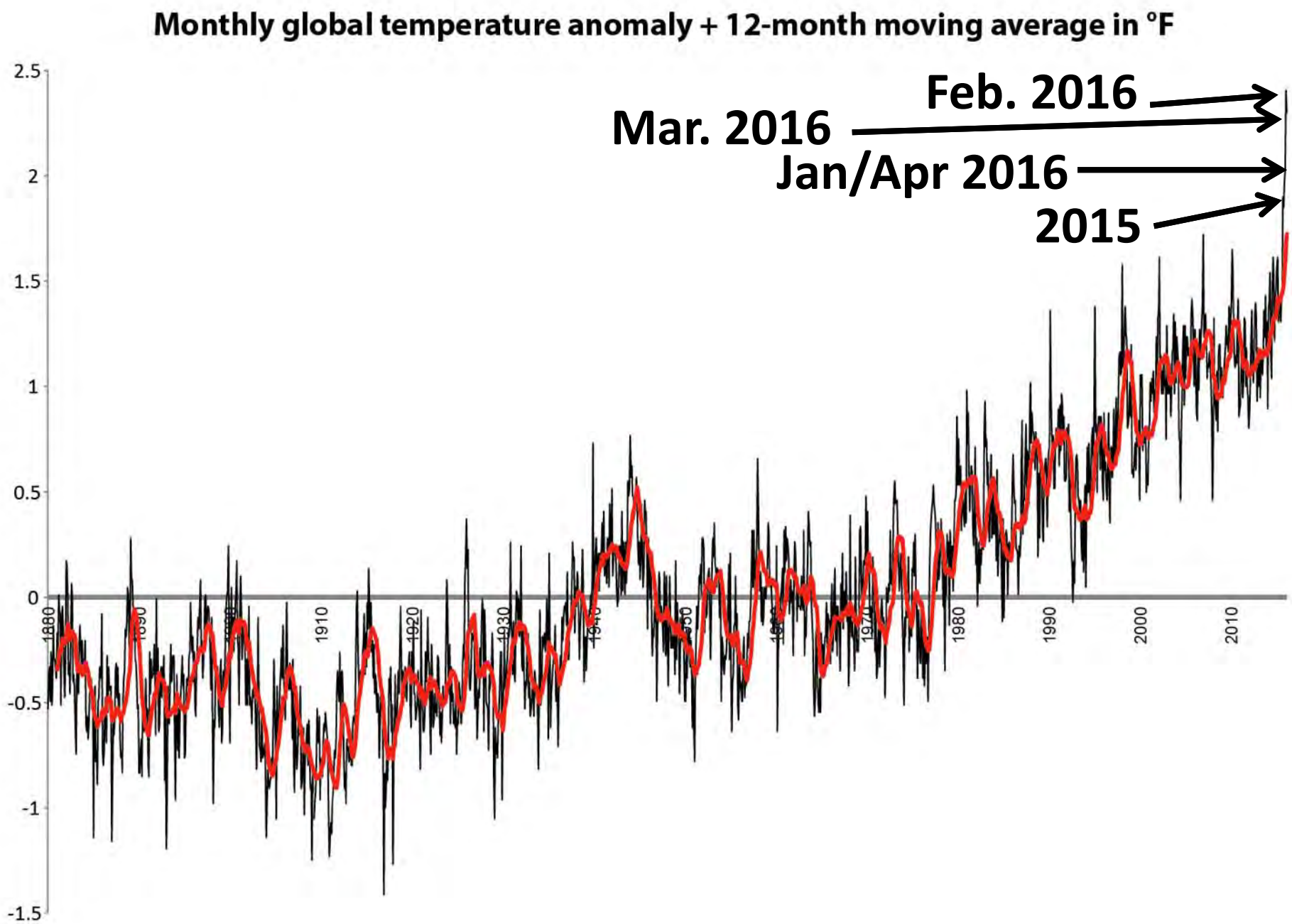

Monthly global temperature anomaly + 12-month moving average in °F
Feb. 2016
Mar. 2016
Jan/Apr 2016
2015
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
1910
1920
1930
1980
1990
2000
2010

What we're seeing has no precedent

- 2014 was the hottest year to date
- 2015 smashed records by 20%
- 2016 has 98% probability of setting new record
- The past 8 months have been the warmest months ever
- 15 of the top 16 warmest years have occurred since 2000
- Carbon dioxide levels in the atmosphere grew more in past 12 months than at any time in the past 56 years.
- U.S. Energy Information Administration foresees continued dominance for coal, gas and oil with 34% rise in their use by 2040

http://www.eia.gov/forecasts/ieo/

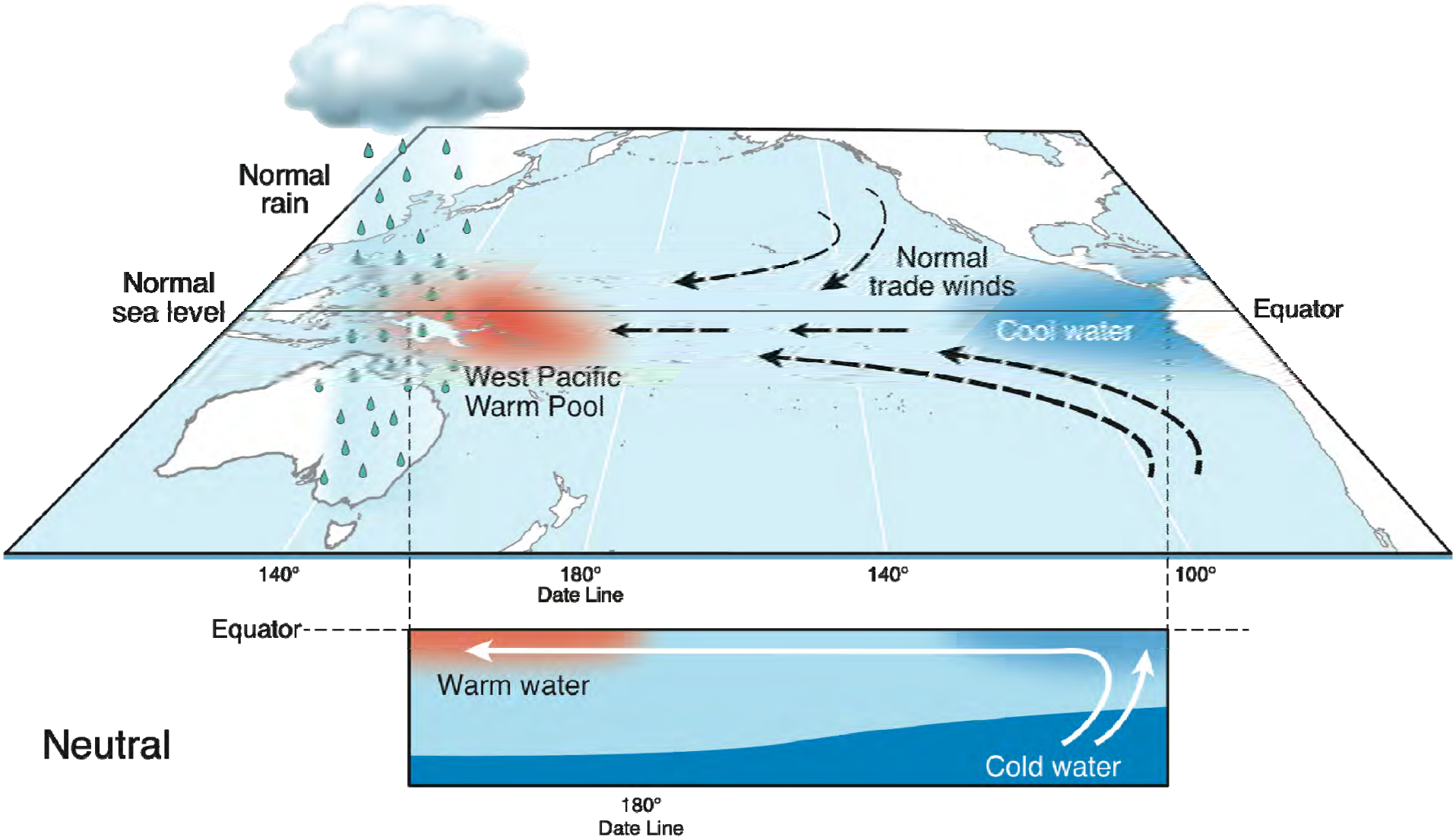
What will the future look like?

- Heat Waves
- Extreme Rain
- Failure of Trade Winds
- Active Hurricane Season
- Large Winter Waves
- Drought
- High Ocean Temperature
- Coral Bleaching

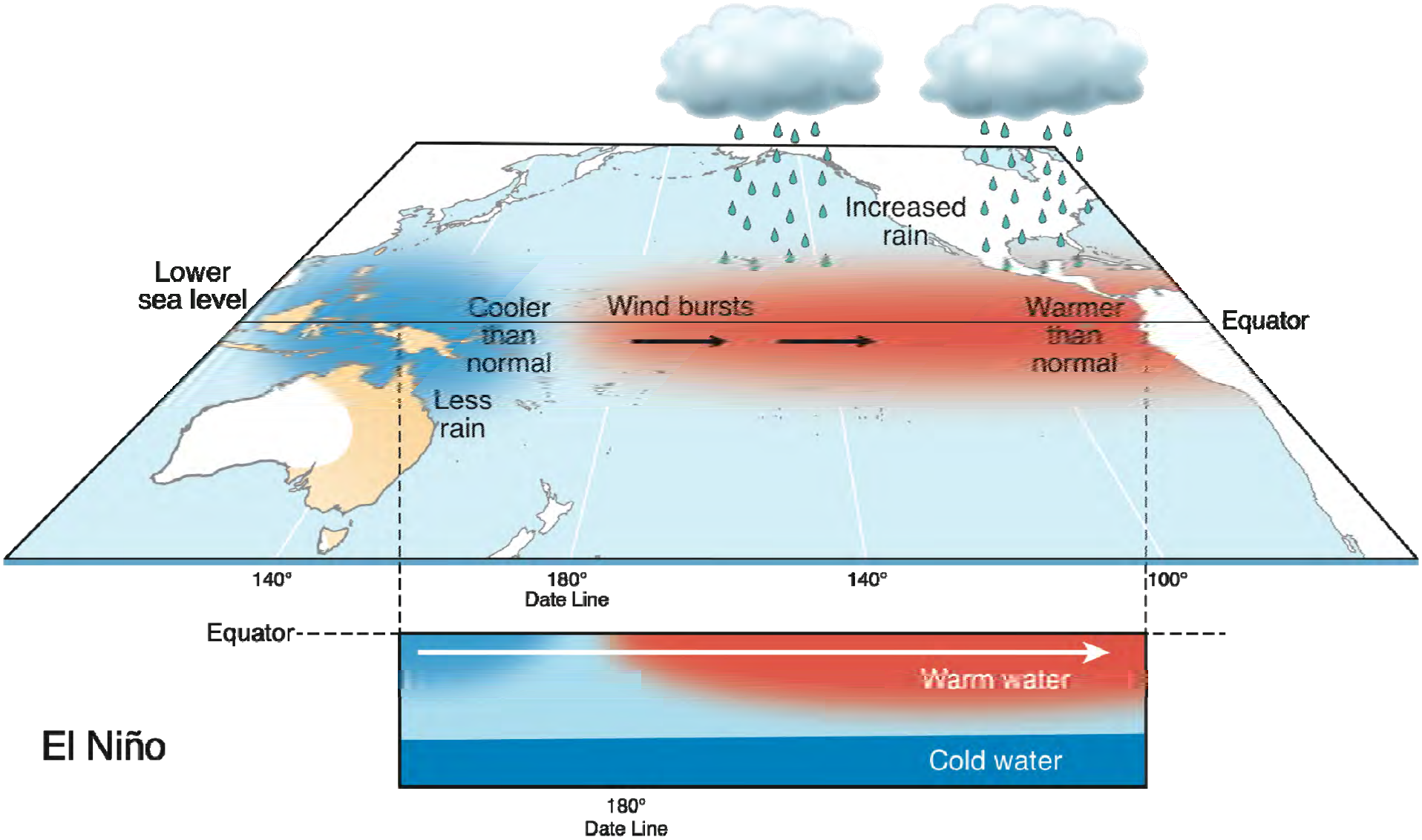
El Niño

- More El Niños
- They will be more powerful

Cai, W. et al. (2015) Increasing frequency of extreme El Niño events due to greenhouse warming. *Nature Climate Change* **4**, 111–116 (2014) doi:10.1038/nclimate2100
Kossin et al., 2014 The poleward migration of the location of tropical cyclone maximum intensity, Nature, 509, 349–352 (15 May)
Murakami, H., et al., 2013 Projected increase in tropical cyclones near Hawaii, Nature Climate Change, May 5, DOI:10.1038/NCLIMTE1890


Normal
rain
Normal
sea level
Normal
trade winds
Equator
Cool water
West Pacific
Warm Pool
140°
180°
Date Line
140°
100°
Equator
Warm water
Cold water
180°
Date Line

Neutral


Lower
sea level
Cooler
than
normal
Less
rain
Wind bursts
Increased
rain
Warmer
than
normal
Equator
140°
180°
Date Line
140°
100°
Equator
Warm water
Cold water
180°
Date Line

El Niño

Heat Waves

- In Hawaii
  - 2015 temperature was 1.2^{o}F above normal
  - 25 record-setting warm days and 4 record setting cold days
  - High heat stressed the HECO grid with calls in the past 2 years to turn off our air conditioning at home
- Record hot days now outnumber record cold by a factor of 12 to 1.
- 140,000 deaths around the world since 2000

Emergence of Heat Extremes attributable to anthropogenic influences. GEOPHYSICAL RESEARCH LETTERS 16 March 2016, : A.D. King, et al., DOI : 10.1002/2015GL067448
Seneviratne, S.I., Donat, M., Mueller, B., Alexander, L. ,2014, No pause in the increase of hot temperatures, Nature Climate change, p. 161-163, http://www.nature.com/nclimate/journal/v4/n3/full/nclimate2145.html
Coumou, D., Robinson, A., 2013 Historic and future increase in the global land area affected by monthly heat extremes. Environmental Research Letters; 8 (3): 034018 DOI: 10.1088/1748-9326/8/3/034018

Extreme Rain

King Street

- August, September, November had 11 days of record-setting rainfall causing flooding
- 2015 had 9 months of below average rainfall
- Currently we are in a declared state of drought
- Global drought has increased 10%
- Global extreme rainfall has increased 12%

J.Lehmann, D.Coumou, K.Frieler. Increased record-breaking precipitation events under global warming. Climatic Change, 2015; DOI: 10.1007/s10584-015-1434-y

BILLINGHAM BLVD

Food

- Global wheat provides 20% of human protein.
  - Rising CO_2 decreases nutrient and protein content.
  - By 2050 demand will increase by 60% (9 billion people)
  - But wheat yields will decline by 15%.
- Food prices are projected to double by 2030
  - Local food production is critical
  - Dependent on irrigation

Springmann, M. et al. *Global and regional health effects of future food production under climate change: a modelling study*. The Lancet, March 2, 2016 DOI: 10.1016/S0140-6736(15)01156-3

Myers et al, 2014 *Increasing CO_2 threatens human nutrition*, Nature 510, 139-142.
Feng et al, 2015 *Constraints to nitrogen acquisition of terrestrial plants under elevated CO_2*, Global Change Biology, DOI: 10.1111/gcb.12938

Future Rain?

- In Hawaii, future rainfall still unclear
  - Decreased winter rain in dry areas
  - Longer and drier dry season
  - Greater demand on irrigation

Elison Timm, O. et al., 2014. Statistical Downscaling of Rainfall for the Hawaiian Islands using CMIP3 and CMIP5 Model Scenarios. Asia-Pacific Data-Research
IPRC http://apdrc.soest.hawaii.edu/projects/SD/ (03/19/14)
Chu, P.-S., Y.R. Chen, and T.A. Schroeder. 2010. Changes in Precipitation Extremes in the Hawaiian Islands in a Warming Climate. Journal of Climate 23(18):4
doi:10.1175/2010JCLI3484.1

Increased Storminess

- Record 15 TC in 2015
- TC paths shifting to the north.
- TC more violent.
- Greater frequency in El Niño years.
- More strong El Niño years.

Tippett, M. and Cohen. M. Tornado outbreak variability follows Taylor's power law of fluctuation scaling and increases dramatically with severity. Nature Communications, 2016; 7: 10668 DOI: 10.1038/ncomms10668

Cai, W. et al. (2015) Increasing frequency of extreme El Niño events due to greenhouse warming. *Nature Climate Change* **4**, 111–116 (2014) doi:10.1038/nclimate2100

Kossin et al., 2014 The poleward migration of the location of tropical cyclone maximum intensity, Nature, 509, 349–352 (15 May)

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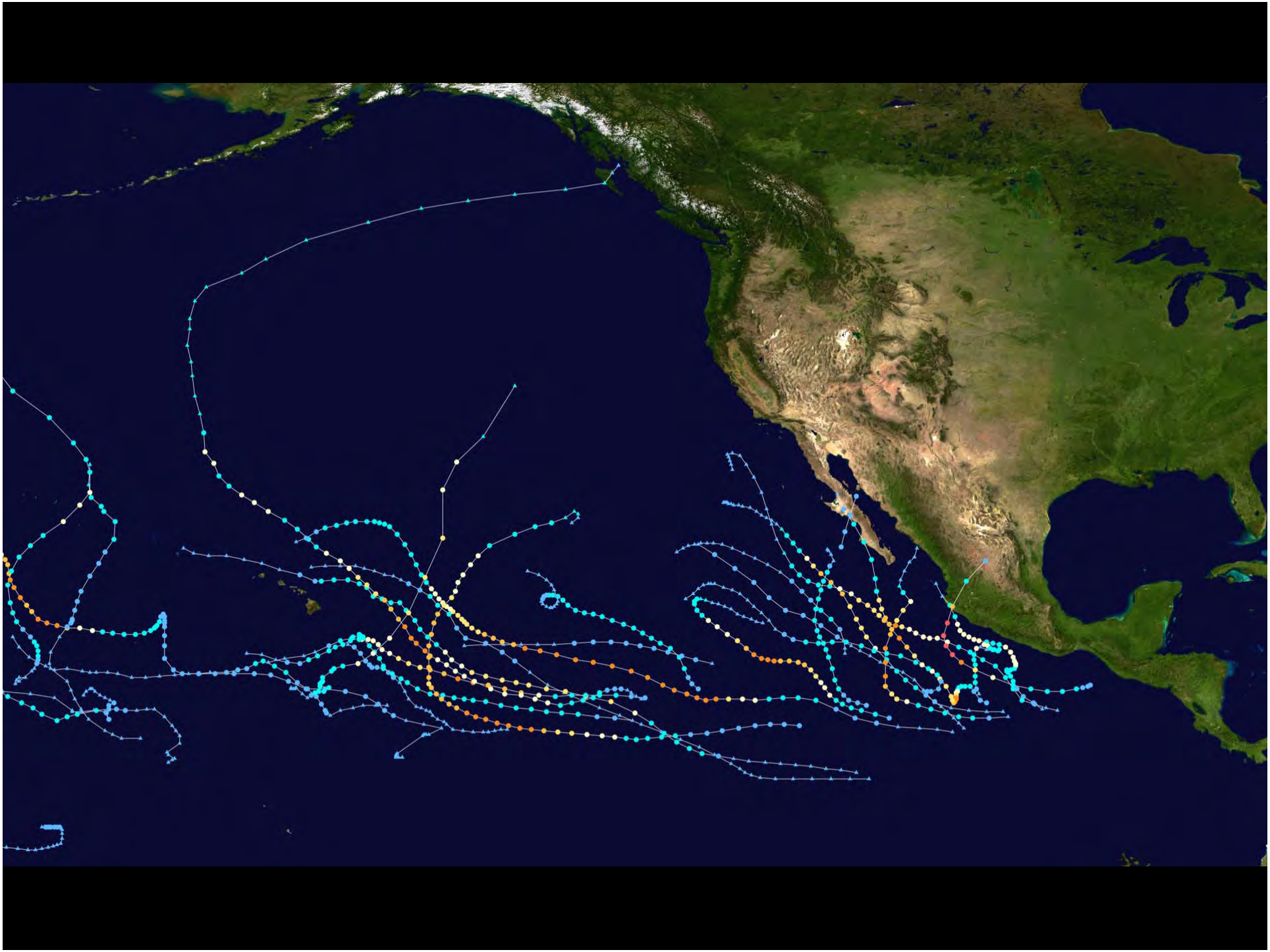


Congressional Budget Office

Hurricane damage will “increase significantly in the coming decades” due to climate change.

CBO – Potential Increases in Hurricane Damage in the United States: Implications for the Federal Budget: https://www.cbo.gov/publication/51518

Large winter waves

Greater Risk

- 335 weather-related disasters/year
  - up 14% from 1995-2004
  - twice as many as 1985 to 1994

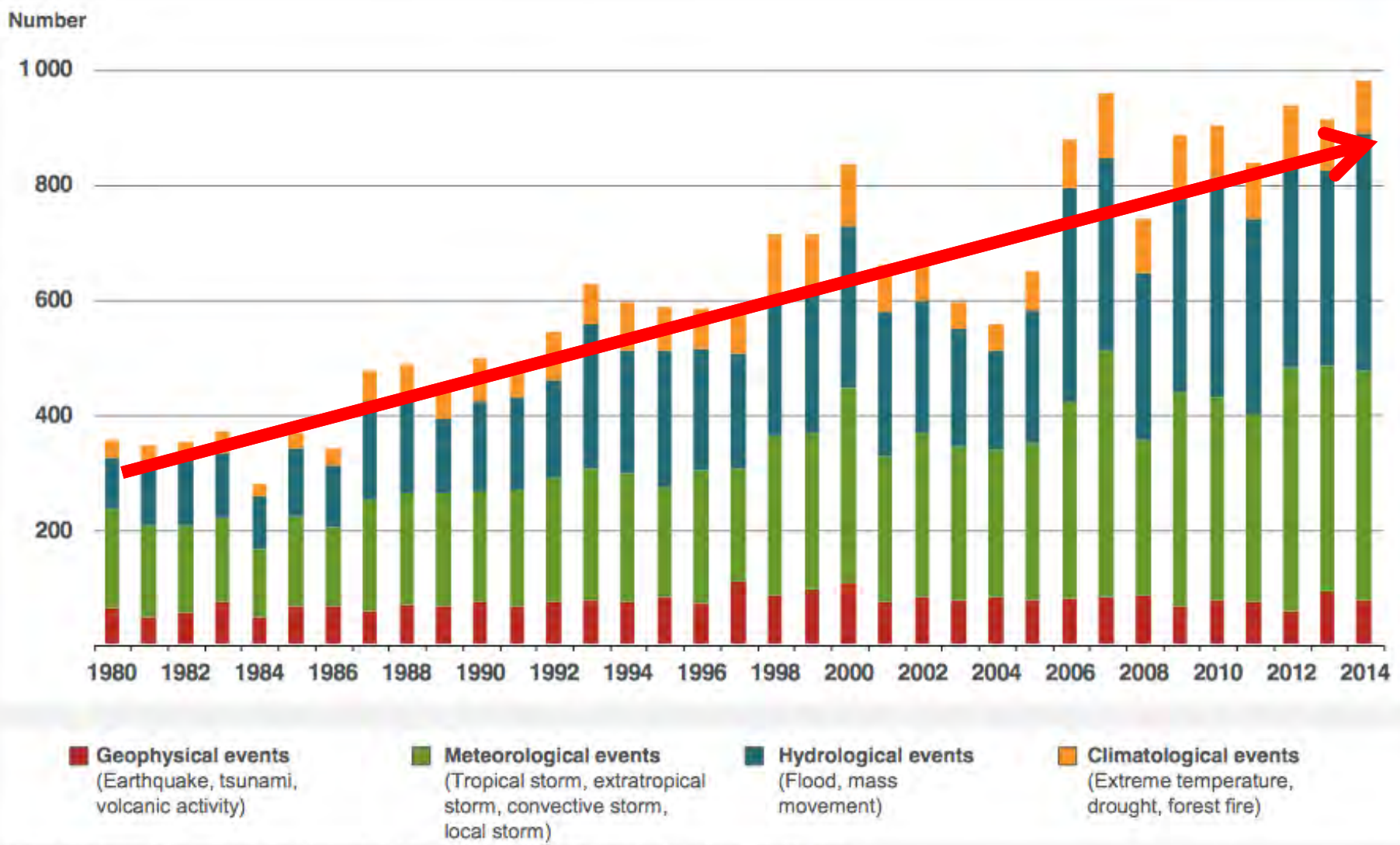
Centre for Research on the Epidemiology of Disasters, UN International Strategy for Disaster Reduction http://reliefweb.int/report/world/human-cost-weather-related-disasters-1995-2015
J.Lehmann, D.Coumou, K.Frieler. Increased record-breaking precipitation events under global warming. Climatic Change, 2015; DOI: 10.1007/s10584-015-1434-y
P. W. Thorne, J. R. Lanzante, T. C. Peterson, D. J. Seidel, K. P. Shine, "Tropospheric Temperature Trends: History of an Ongoing Controversy," Wiley Interdisciplinary Reviews: Climate Change 2010, doi: 10.1002/wcc.80.

NatCatSERVICE

Loss events worldwide 1980 – 2014

Number of events

Munich RE



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NatCatSERVICE

Natural loss events worldwide 2015
Geographical overview

Munich RE

- **Geophysical events** (Earthquake, tsunami, volcanic activity)
- **Meteorological events** (Tropical storm, extratropical storm, convective storm, local storm)
- **Hydrological events** (Flood, mass movement)
- **Climatological events** (Extreme temperature, drought, forest fire)

- ○ **Loss events**
- ◯ **Selection of catastrophes**

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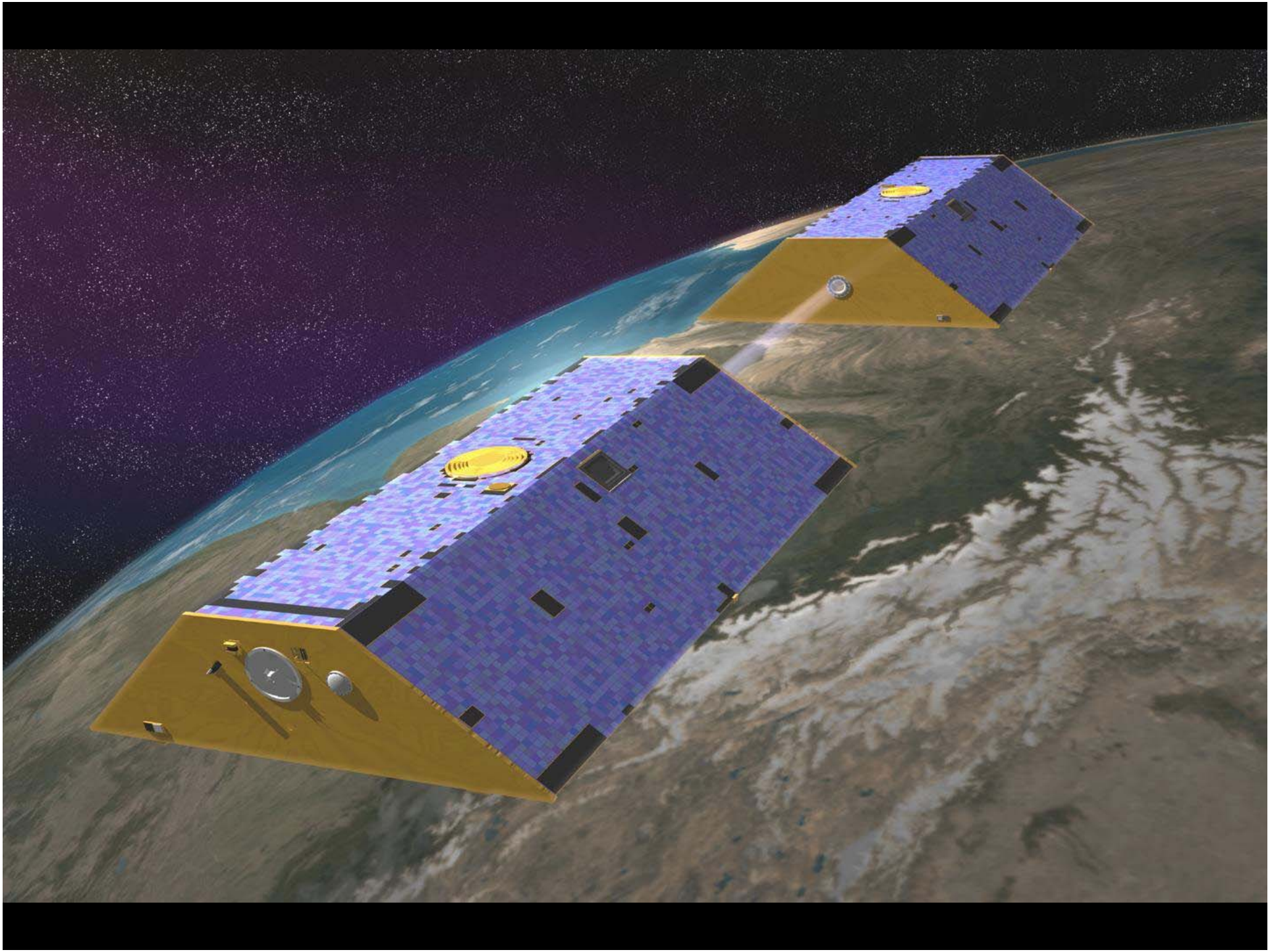
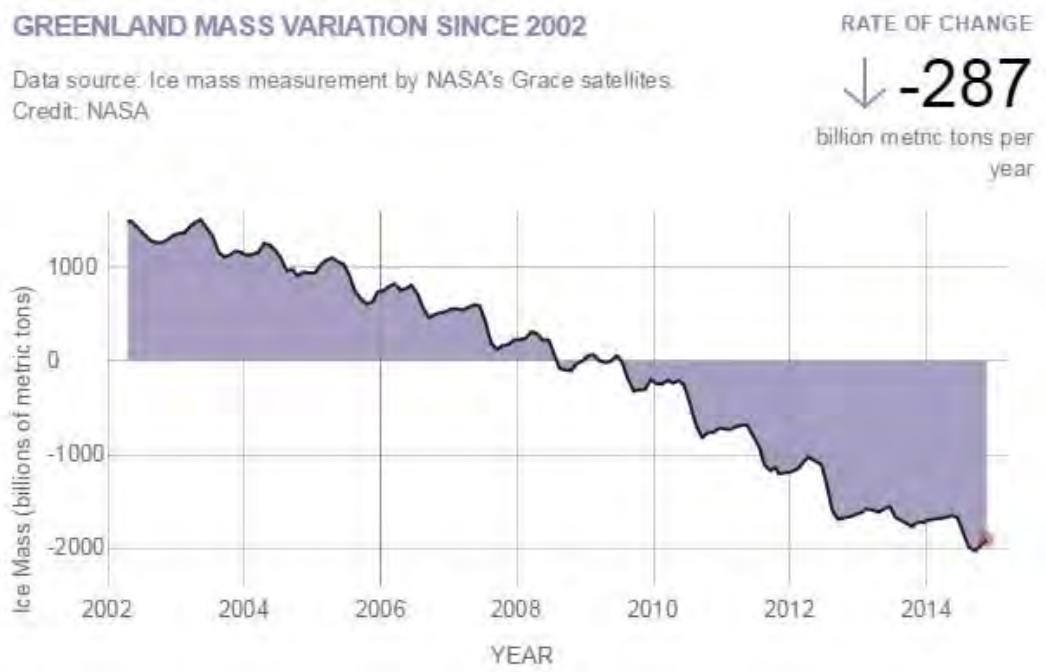
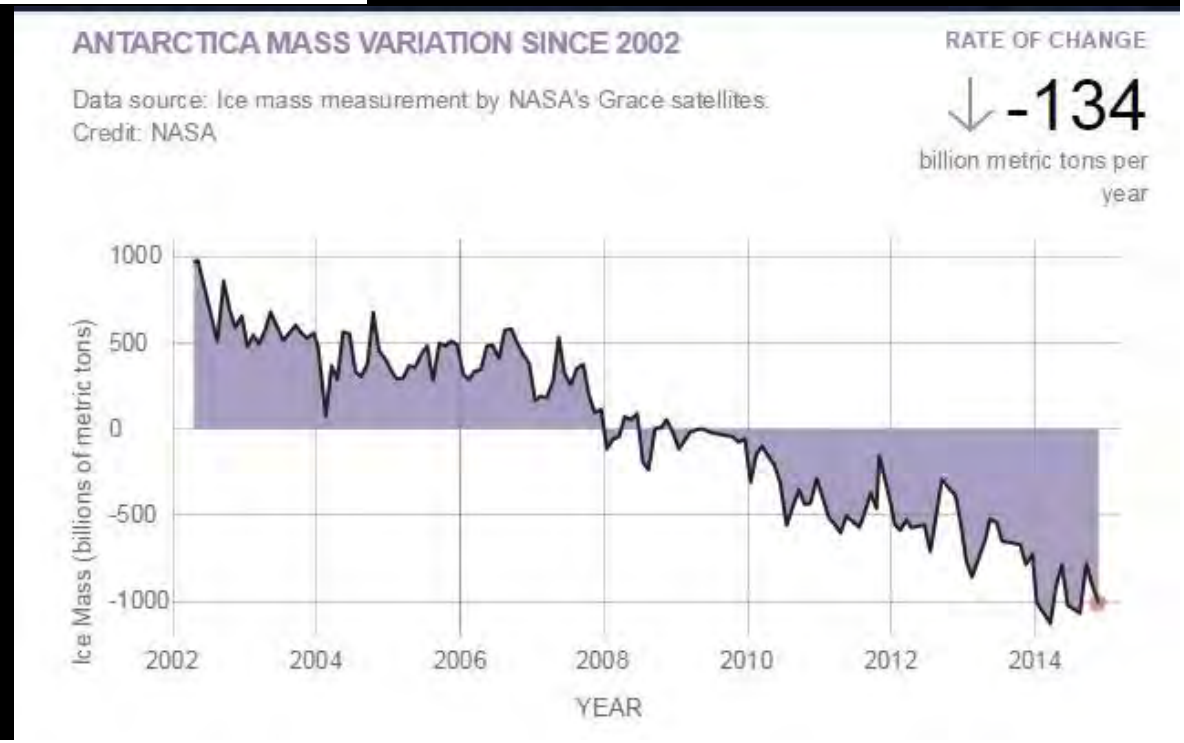
Sea Level Rise

- NASA December, 2015
  - “Given what we know now about how the ocean expands as it warms and how ice sheets and glaciers are adding water to the seas, it's pretty certain we are locked into at least 3 feet [0.9 meter] of sea level rise, and probably more.”
- Coastal erosion
- Wave flooding
- Groundwater inundation
- Drainage failure
- Hurricane and tsunami vulnerability





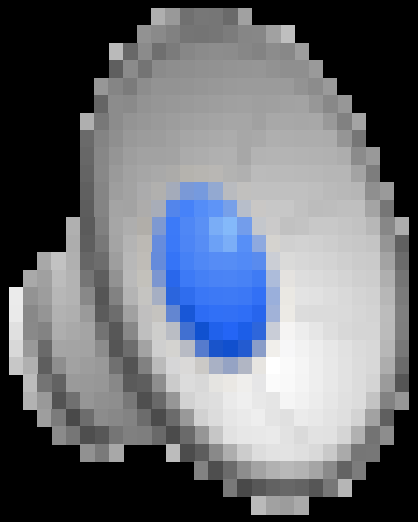
Greenland and Antarctica are both losing ice very rapidly



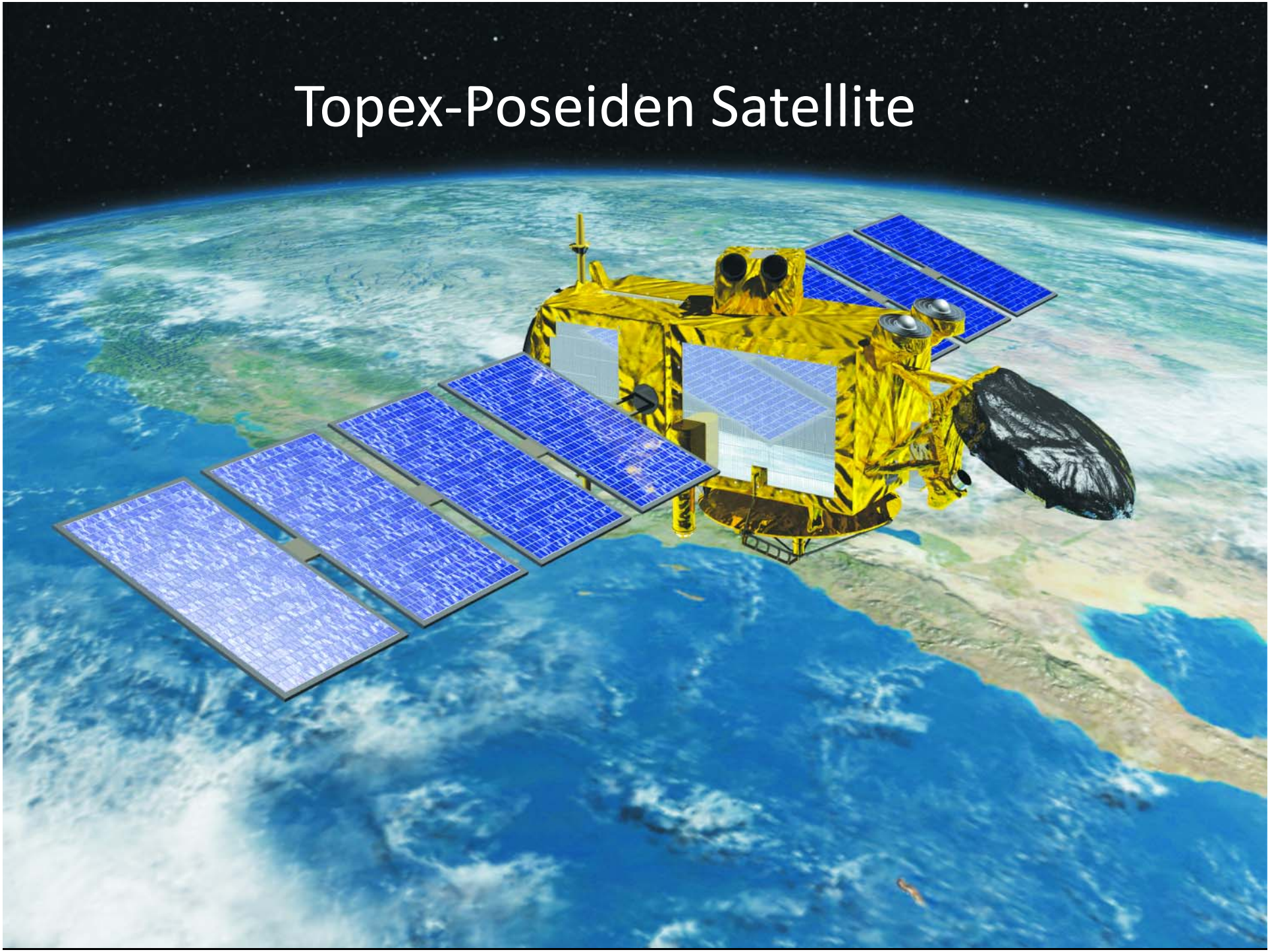
Greenland is melting

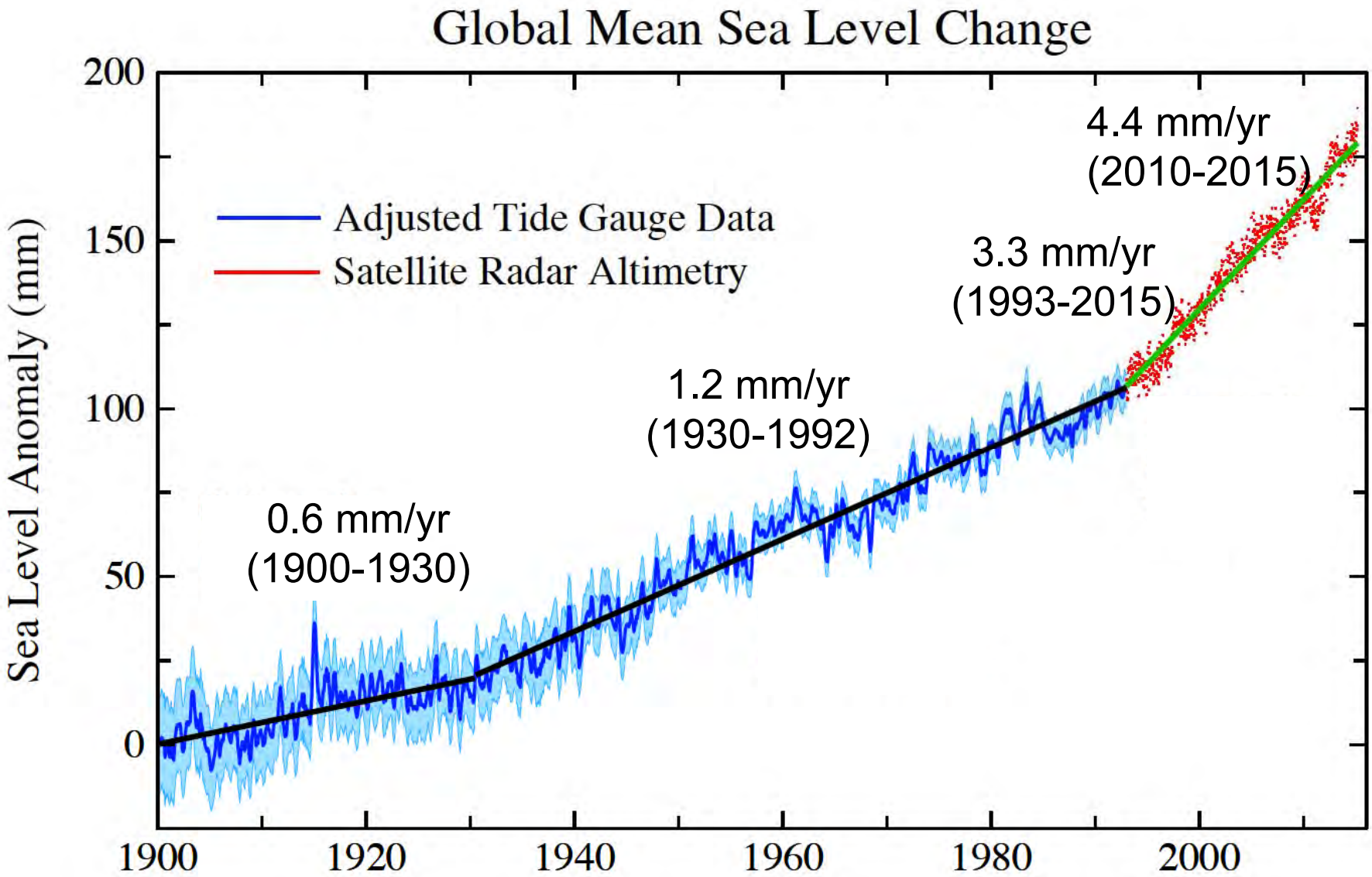
West Antarctica is collapsing

NBC news West Antarctic collapse



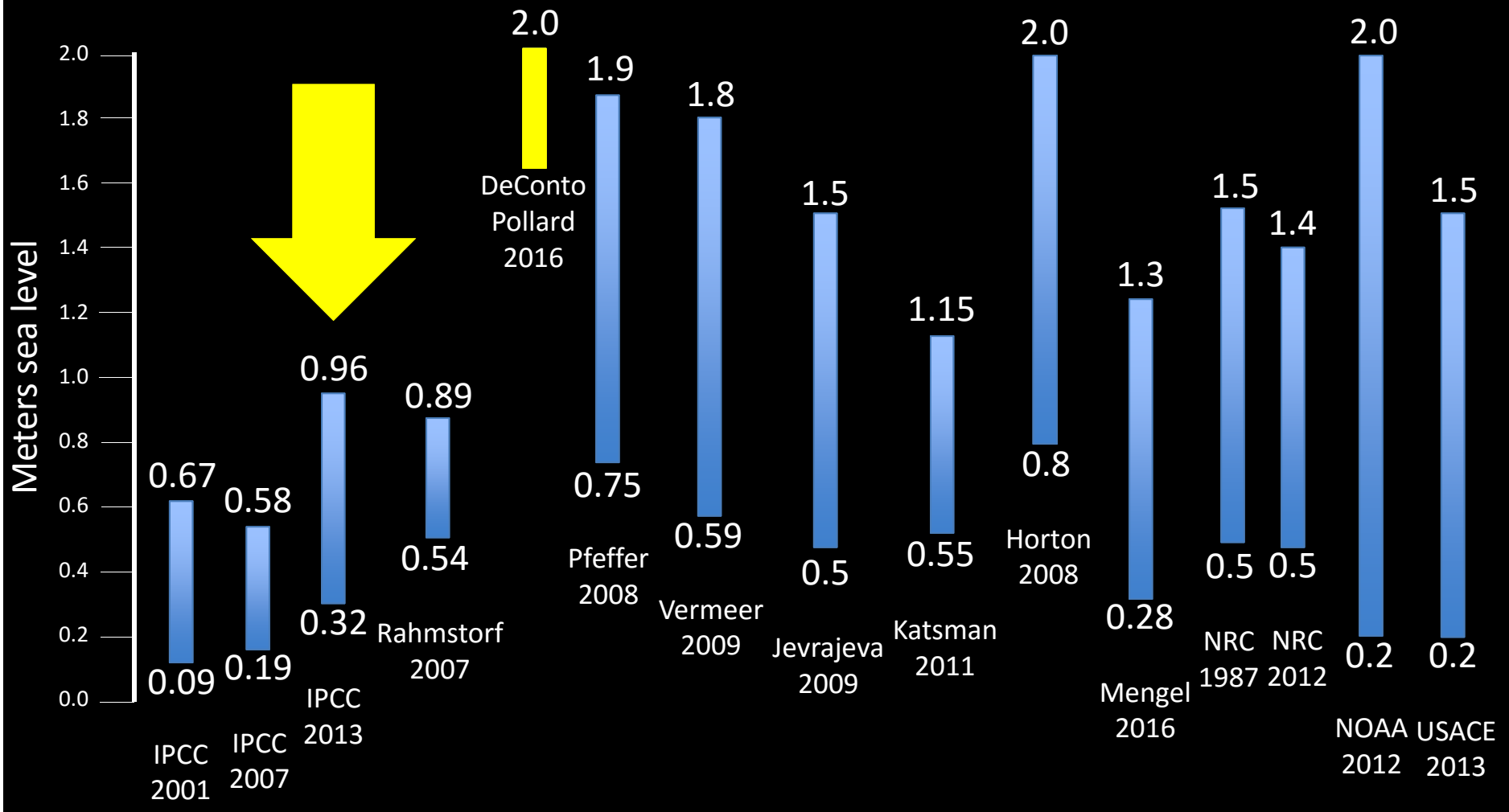
Topex-Poseiden Satellite



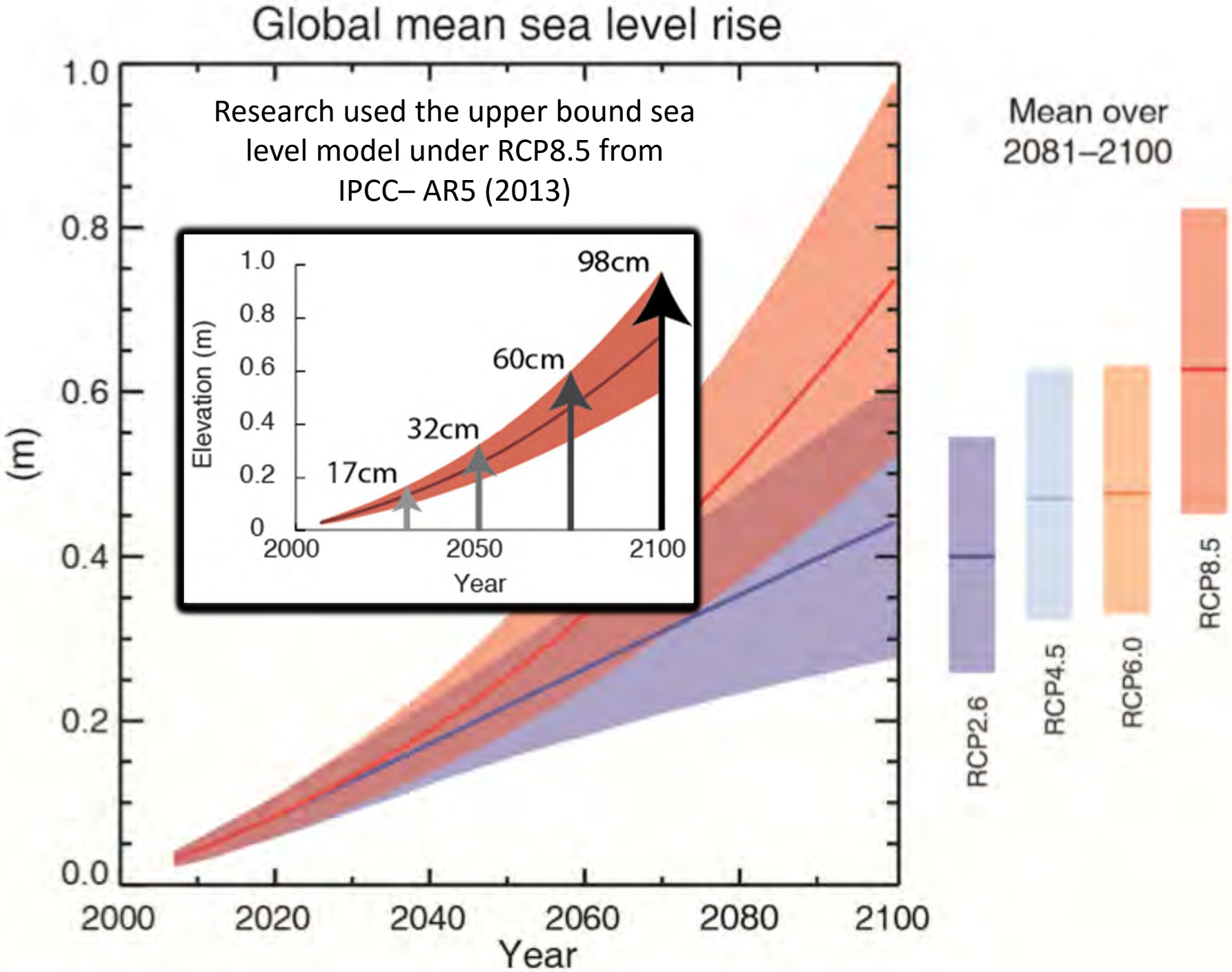


Hansen et al., 2015; Church and White, 2011; Nerem et al., 2010; Hay et al., 2015; Yi et al., 2015

Estimates of sea level rise



Procedures to evaluate sea level change: Impacts, Responses, and Adaptation. Technical Letter, no. 1100-2-1, 30 June, 2014.
http://www.publications.usace.army.mil/Portals/76/Publications/EngineerTechnicalLetters/ETL_1100-2-1.pdf


Global mean sea level rise
Research used the upper bound sea level model under RCP8.5 from IPCC– AR5 (2013)
Mean over 2081–2100
(m)
1.0
0.8
0.6
0.4
0.2
0.0
2000
2020
2040
2060
2080
2100
Year
Elevation (m)
1.0
0.8
0.6
0.4
0.2
0
2000
2050
2100
Year
17cm
32cm
60cm
98cm
RCP2.6
RCP4.5
RCP6.0
RCP8.5

Groundwater Inundation

Storm drains
back up at high
tide.

High Tide, Miami - $400 M in pumps and cisterns

Ft. Lauderdale

Del Rey Beach

Boca Raton

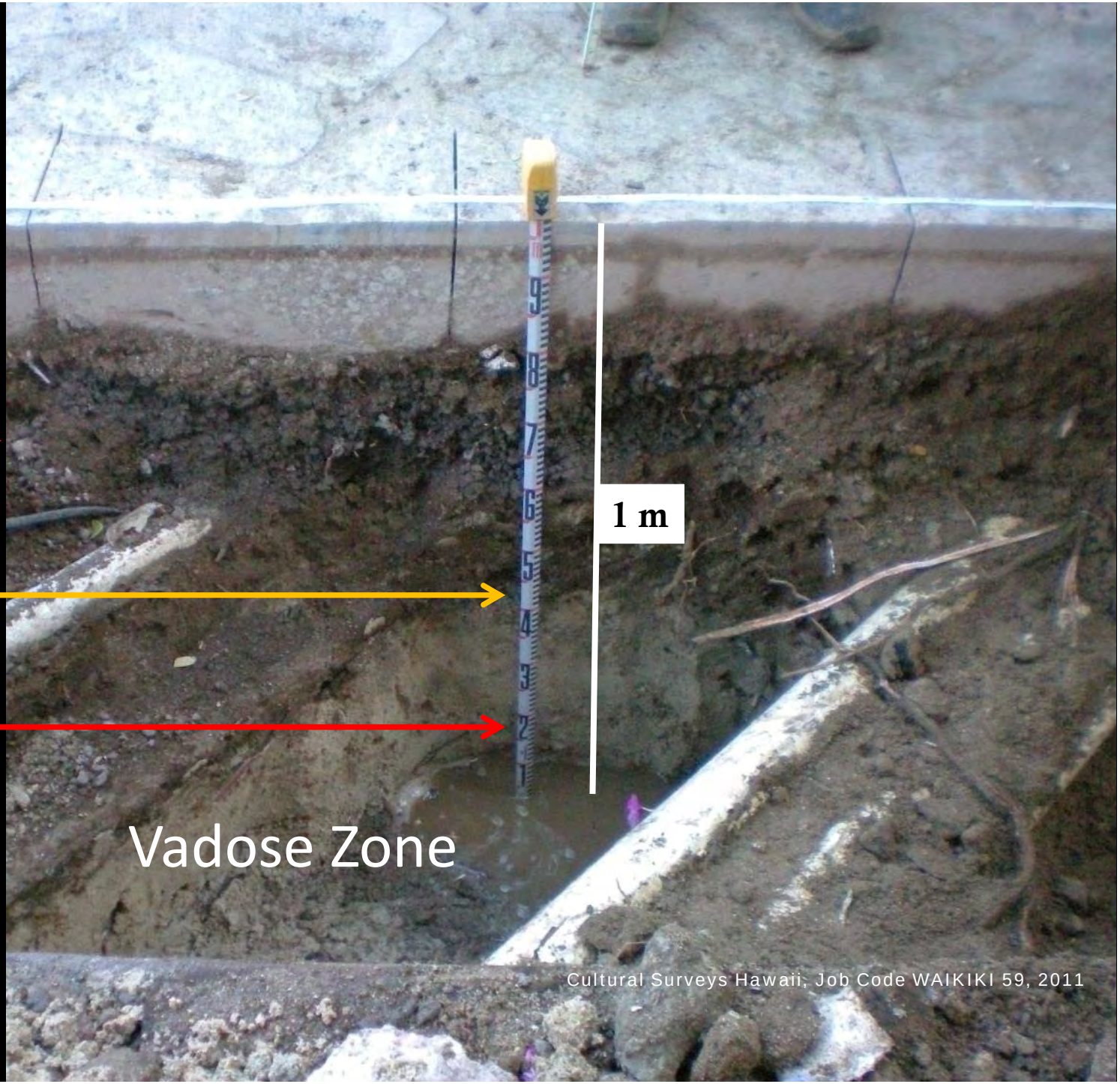
Key West

Vadose Zone

Ground Level

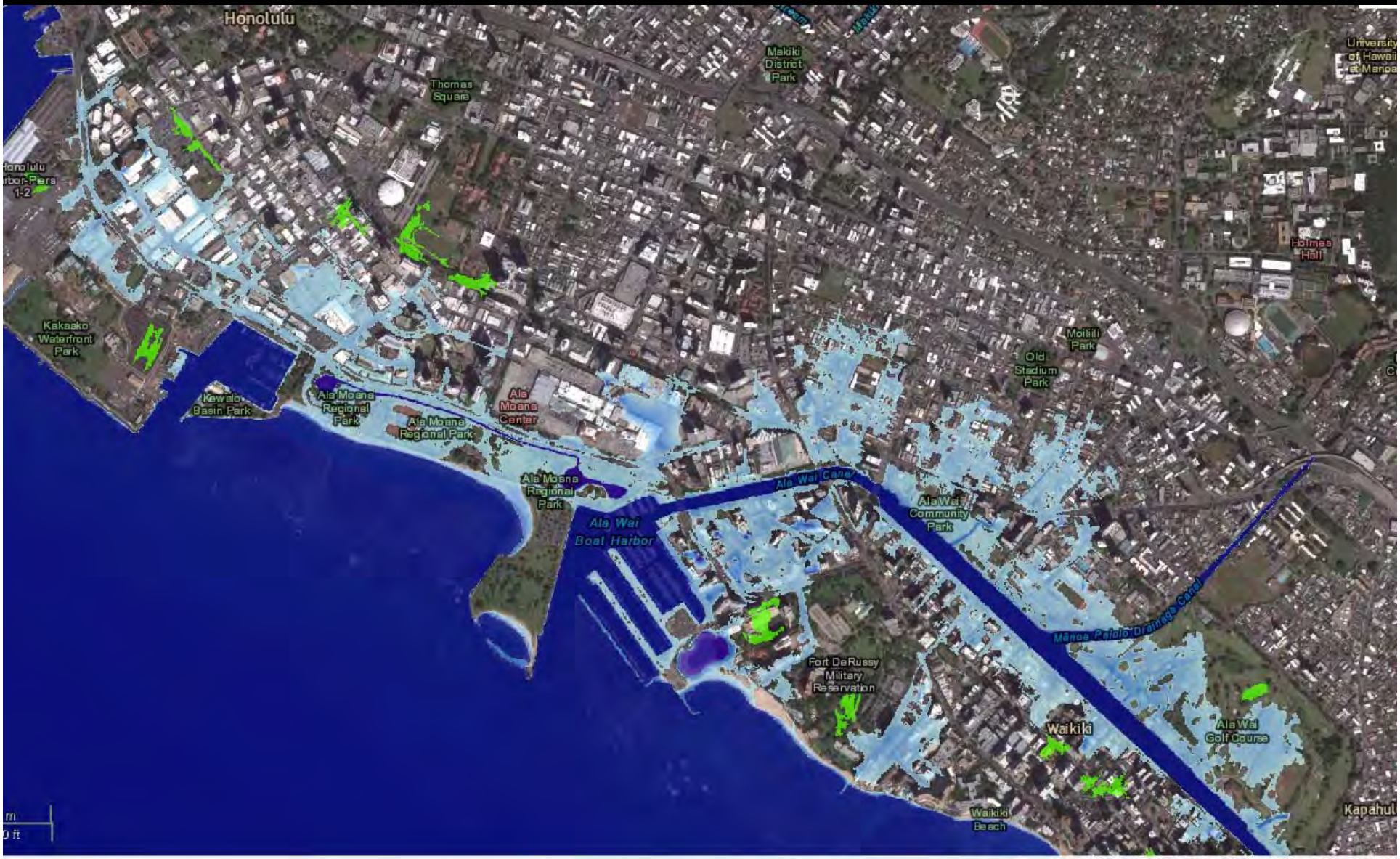
Water Level
0.33 m (MHHW)

Water Level
0 m (MSL)



HONOLULU ZOO

Fort DeRussy


Honolulu
Thomas Square
Makiki District Park
University of Hawaii at Manoa
Honolulu Harbor Piers 1-2
Kakaako Waterfront Park
Kewalo Basin Park
Ala Moana Regional Park
Ala Moana Regional Park
Ala Moana Center
Ala Moana Regional Park
Ala Wai Canal
Ala Wai Boat Harbor
Ala Wai Community Park
Old Stadium Park
Moiliili Park
Holmes Hall
Manoa Palolo Drainage Canal
Fort DeRussy Military Reservation
Waikiki
Ala Wai Golf Course
Waikiki Beach
Kapahulu

Ewa Beach – Wave Inundation

Ewa Beach – Wave Inundation

Hawaii Kai, Oahu 2100
Erosion and Flooding

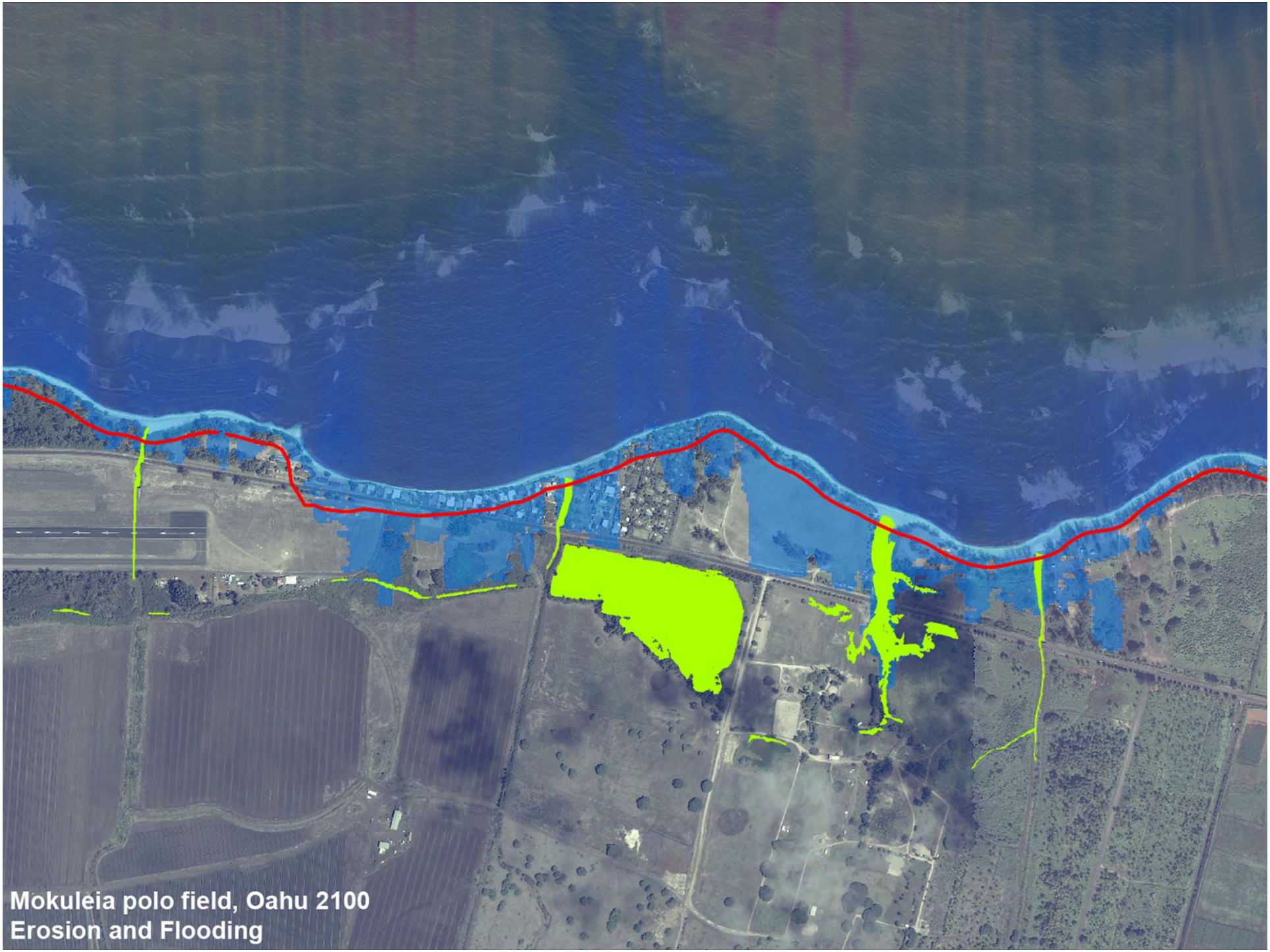
Kahala, Oahu 2100
Erosion and Flooding

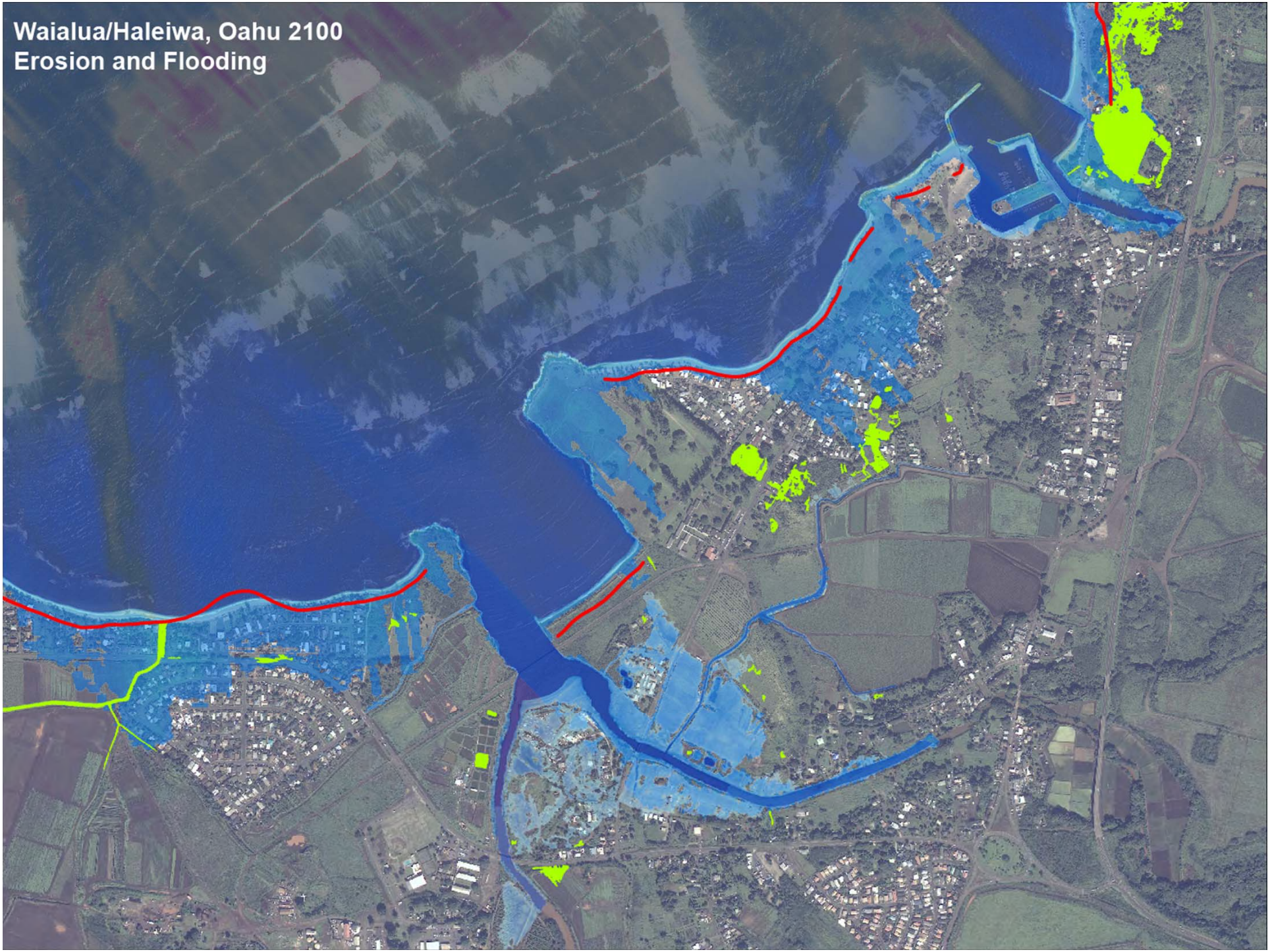
Sand Island, Oahu 2100
Erosion and Flooding

Joint Base Pearl Harbor Hickam, Oahu 2100
Erosion and Flooding

Barbers Point, Oahu 2100
Erosion and Flooding

Makaha Beach, Oahu 2100
Erosion and Flooding


Mokuleia polo field, Oahu 2100
Erosion and Flooding


Waialua/Haleiwa, Oahu 2100
Erosion and Flooding

Sunset, Oahu 2100
Erosion and Flooding

Hauula, Oahu 2100
Erosion and Flooding

Marine Corps Base Hawaii, Oahu 2100
Erosion and Flooding

Waimanalo, Oahu 2100
Erosion and Flooding

Elevate and yield to water

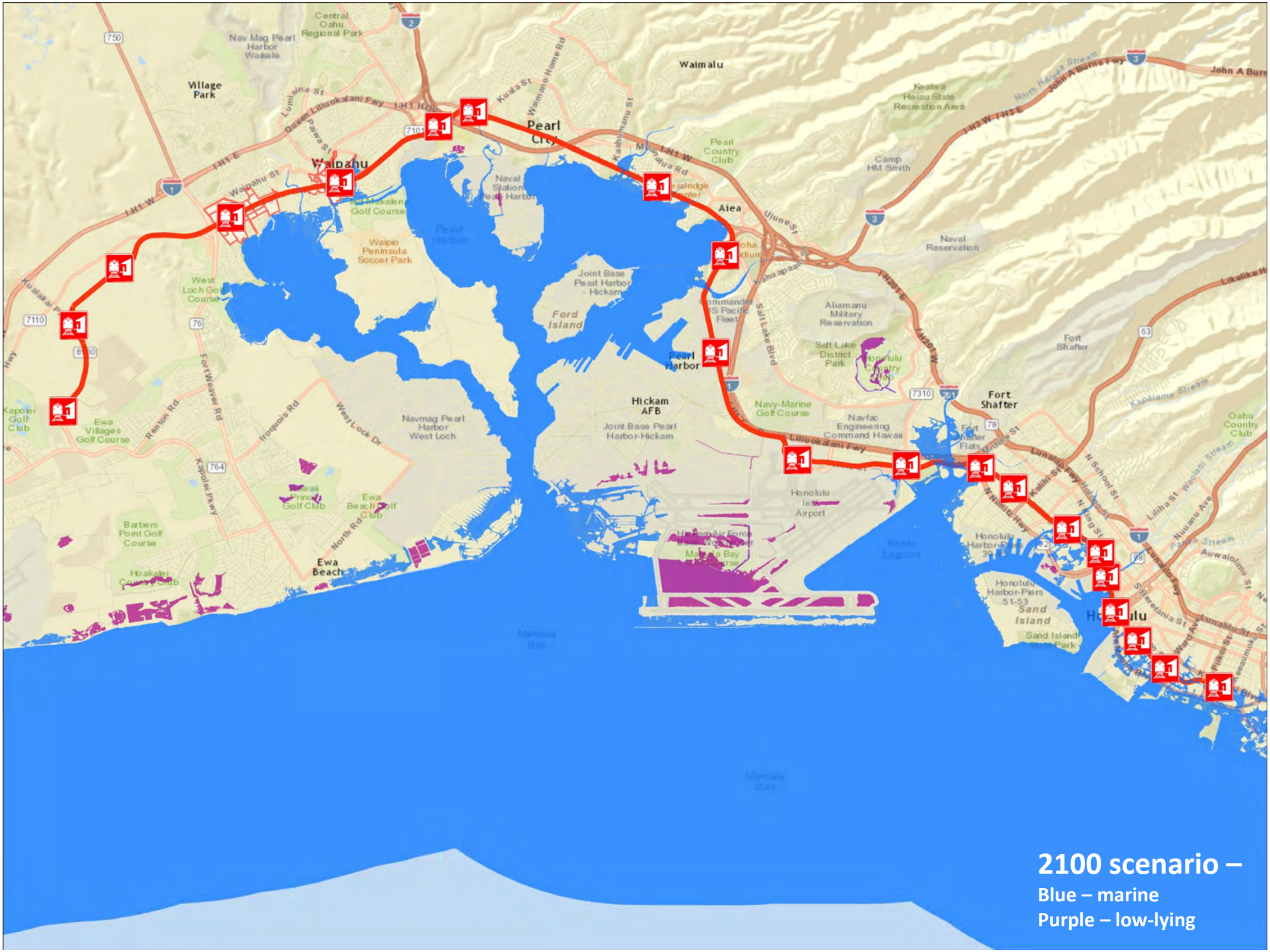
Waging war with water is a fight you never win.

Wave Run-Up, Erosion, and Groundwater Flooding – OAHU

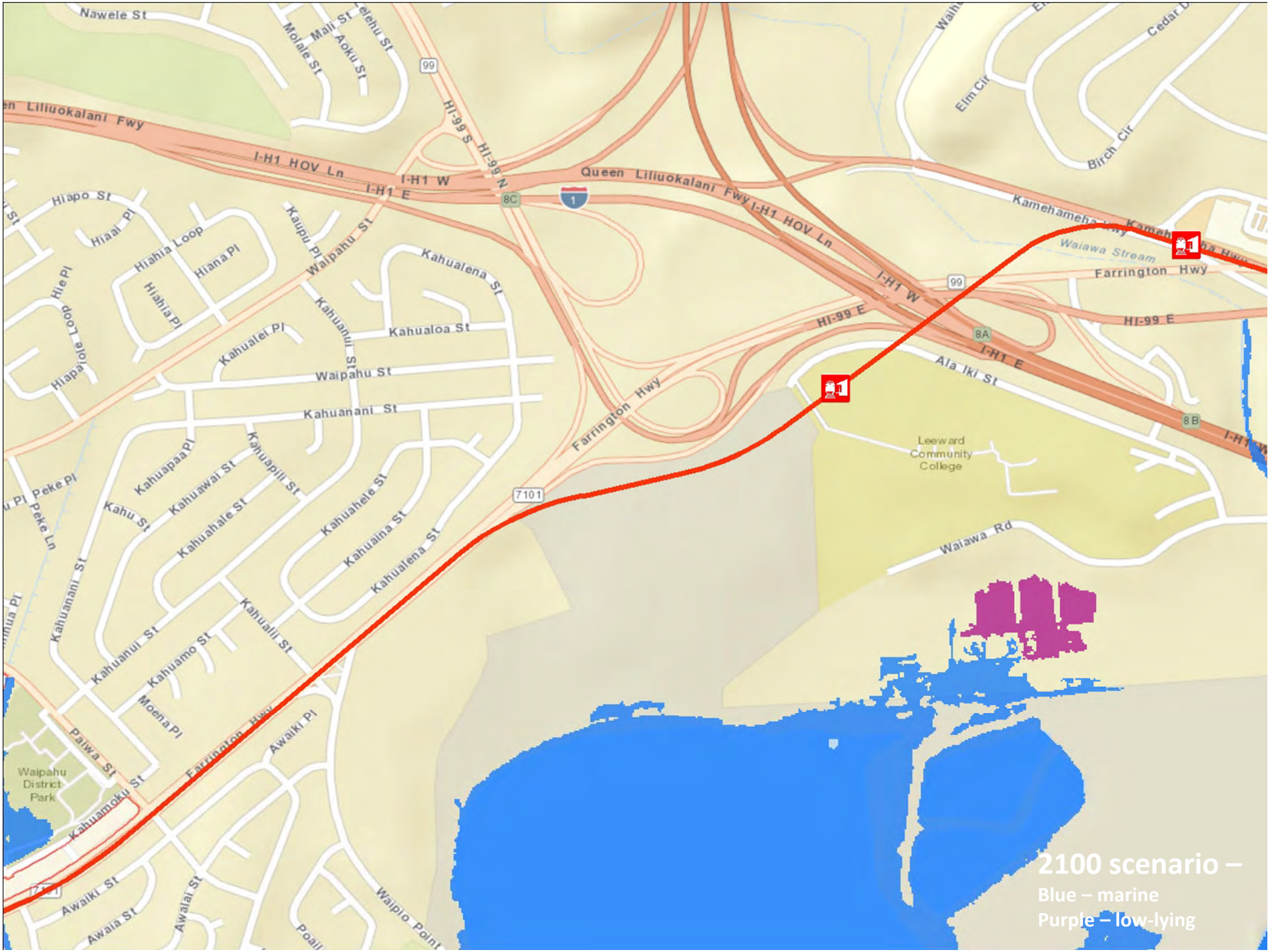
2050 scenario –

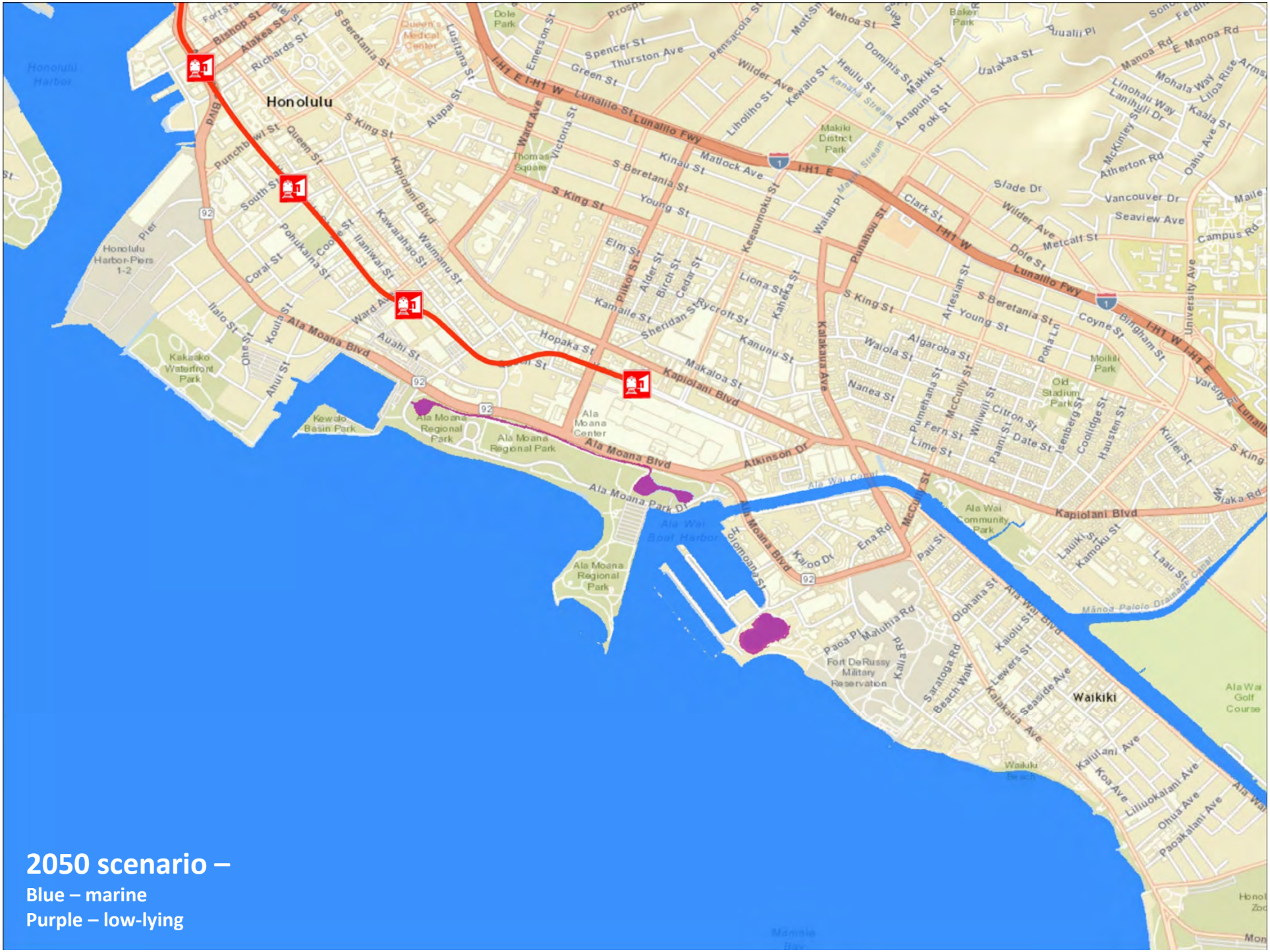
Blue – marine

Purple – low-lying


Waimalu
Pearl City
Waipahu
Aiea
Pearl Harbor
Hickam AFB
Fort Shafter
Ewa Beach
Village Park
Joint Base Pearl Harbor - Hickam
Ford Island
Naval Station Pearl Harbor
Waipio Peninsula Soccer Park
Navmag Pearl Harbor West Loch
Honolulu Intl Airport
Honolulu Harbor-Piers 51-53
Sand Island
Aliamanu Military Reservation
Salt Lake District Park
Navy-Marine Golf Course
Navfac Engineering Command Hawaii
Naval Reservation
Camp HM Smith
Pearl Country Club
Keaiwa Heiau State Recreation Area
Central Oahu Regional Park
Nav Mag Pearl Harbor Waikele
West Loch Golf Course
Ewa Villages Golf Course
Barbers Point Golf Course
Hoakalei Country Club
Ewa Beach Golf Club
Oahu Country Club
Honolulu
Kapalama Stream
Waiawa Stream
Auwaiolimu St
Lunalilo Fwy
Likelike Hwy
John A Burns Fwy
Queen Liliuokalani Fwy
Kamehameha Hwy
Salt Lake Blvd
Kaahumanu St
Kuala St
Waimano Home Rd
Waipahu St
Fort Weaver Rd
Renton Rd
Iroquois Rd
West Loch Dr
Kapolei Pkwy
North Rd
Kalihi St
N School St
N King St
Liliha St
Beretania St
Ward Ave
Pilkoi St
Keeaumoku St
Kuulakai Pkwy
Kapolei Golf Club
Mamala Bay
Keehi Lagoon
2100 scenario –
Blue – marine
Purple – low-lying

2050 scenario –
Blue – marine
Purple – low-lying
Nawele St
Molale St
Mali St
Aoku St
Lilliuokalani Fwy
I-H1 HOV Ln
I-H1 W
I-H1 E
HI-99 S
HI-99 N
Queen Liliuokalani Fwy
Elm Cir
Cedar
Birch Cir
Kamehameha Hwy
Waiawa Stream
Farrington Hwy
HI-99 E
Ala Iki St
Leeward Community College
Waiawa Rd
Hiapo St
Hiaai Pl
Hiahia Loop
Hiana Pl
Hiahia Pl
Hie Pl
Hiapaiole Loop
Kaupu Pl
Waipahu St
Kahualena St
Kahuanui St
Kahualoa St
Kahualei Pl
Kahuanani St
Kahuapaa Pl
Kahuawai St
Kahuapili St
Kahuahale St
Kahuahele St
Kahuaina St
Kahualena St
Kahualii St
Kahuamo St
Moena Pl
Peke Pl
Peke Ln
Kahu St
Paiwa St
Kahuamoku St
Waipahu District Park
Awaiki Pl
Awaiki St
Awaia St
Awalai St
Waipio Point


Nawele St
Molale St
Mali St
Aoku St
Lelehu St
99
Lliliuokalani Fwy
I-H1 HOV Ln
I-H1 W
I-H1 E
HI-99 S
HI-99 N
Queen Liliuokalani Fwy
8C
1
Hiapo St
Hiaai Pl
Hiahia Loop
Hiana Pl
Hiahia Pl
Hie Pl
Hiapaiole Loop
Kaupu Pl
Waipahu St
Kahualena St
Kahuanui St
Kahualoa St
Kahualei Pl
Waipahu St
Kahuanani St
Farrington Hwy
7101
Kahuapaa Pl
Kahuawai St
Kahuapili St
Kahuahale St
Kahuahele St
Kahuaina St
Kahualena St
Peke Pl
Peke Ln
Kahu St
Kahuanani St
Kahuanui St
Kahuamo St
Kahualii St
Moena Pl
Paiwa St
Waipahu District Park
Kahuamoku St
Awaiki Pl
Awaiki St
Awaia St
Awalai St
Waipio Point
Elm Cir
Birch Cir
Cedar
Kamehameha Hwy
Waiawa Stream
Farrington Hwy
HI-99 E
8A
Ala Iki St
8B
Leeward Community College
Waiawa Rd
2100 scenario –
Blue – marine
Purple – low-lying



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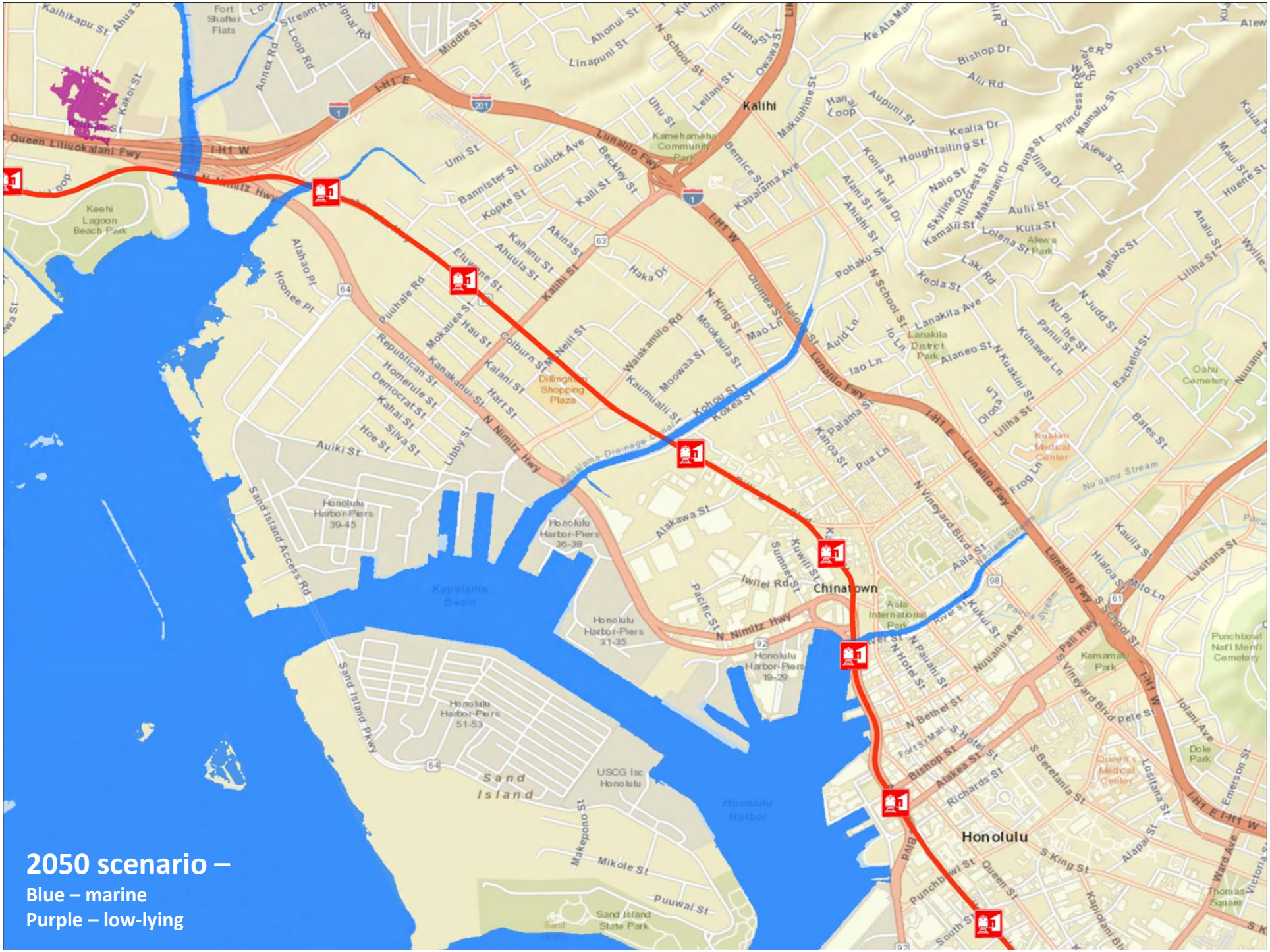
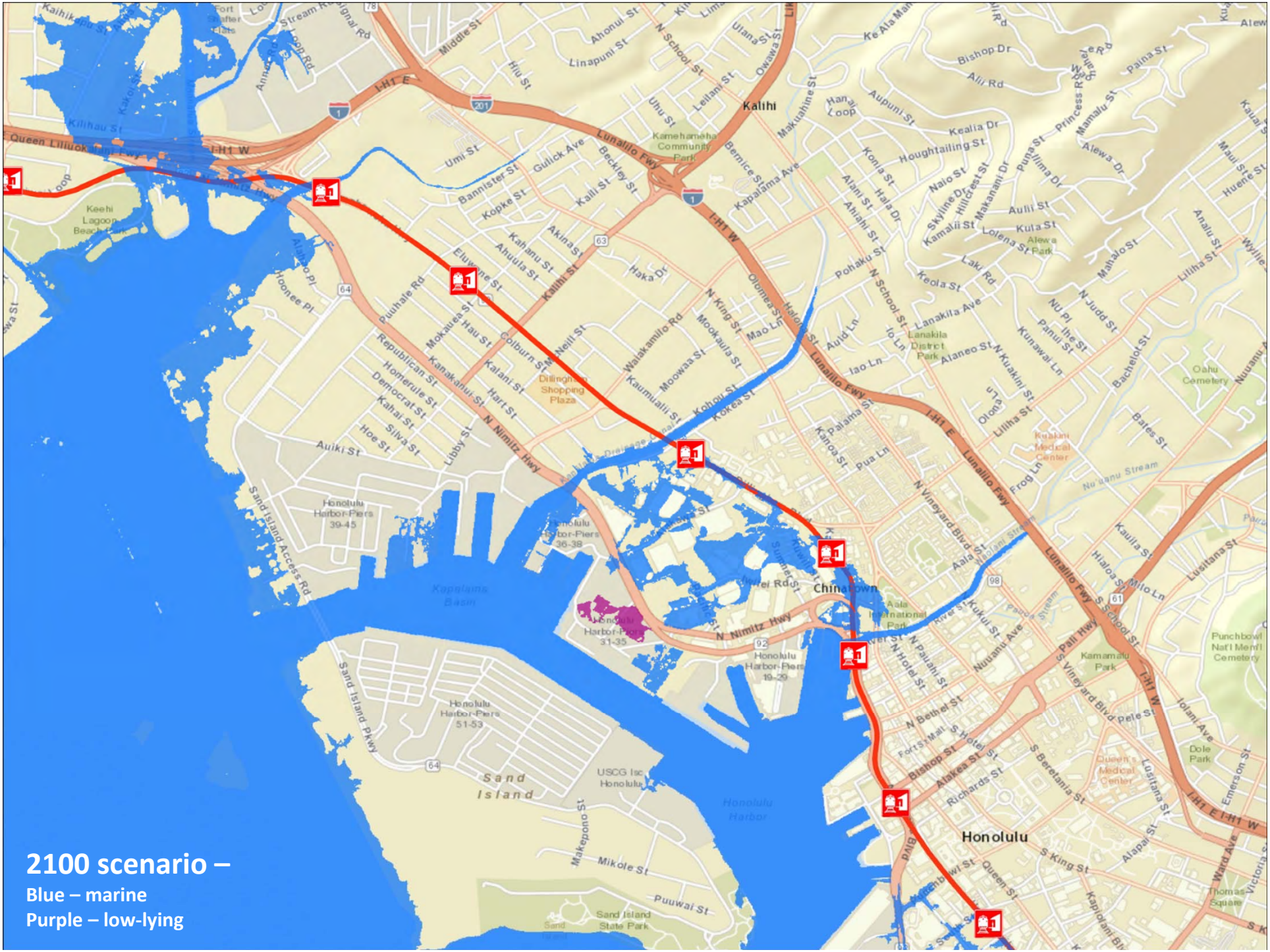

2050 scenario –
Blue – marine
Purple – low-lying
Kalihi
Chinatown
Honolulu
Sand Island
Honolulu Harbor
Kapalama Basin
Keehi Lagoon Beach Park
Kamehameha Community Park
Dillingham Shopping Plaza
Lanakila District Park
Alewa Park
Aala International Park
Kamamalu Park
Dole Park
Thomas Square
Sand Island State Park
Honolulu Harbor-Piers 39-45
Honolulu Harbor-Piers 36-38
Honolulu Harbor-Piers 31-35
Honolulu Harbor-Piers 19-29
Honolulu Harbor-Piers 51-53
USCG Isc Honolulu
Queen's Medical Center
Punchbowl Nat'l Mem'l Cemetery
Oahu Cemetery
Queen Liliuokalani Fwy
I-H1 E
I-H1 W
Lunalilo Fwy
N Nimitz Hwy
Pali Hwy
Vineyard Blvd
Nuuanu Ave
Bishop St
Alakea St
Richards St
S King St
Beretania St
Punchbowl St
Queen St
South St
Ala Moana Blvd
Sand Island Access Rd
Sand Island Pkwy
Makepono St
Mikole St
Puuwai St
Kapalama Drainage Canal
Nu'uanu Stream
Iwilei Rd
Kalihi St
Kaili St
Kapalama Ave
Kokea St
Mokauea St
Kaumualii St
Mookaula St
Moowaa St
Waiakamilo Rd
Dillingham Blvd
Middle St
Ala Moana Blvd
Kaiulani St
Lusitana St
Punchbowl St
Alapai St
Ward Ave
Iolani Ave
Dole St
Emerson St
Bachelot St
Liliha St
Kuakini Medical Center
Alaneo St
Lanakila Ave
Keola St
Laki Rd
Houghtailing St
Kealia Dr
Aupuni St
Bishop Dr
Alii Rd
Paina St
Mamalu St
Alewa Dr
Kula St
Aulii St
Mahalo St
Analu St
Huene St
Maui St
Kaua St
Kaiulani St
Hialoa St
Milo Ln
Frog Ln
Kunawai Ln
Pauoa Stream
Kapalama Basin


2100 scenario –
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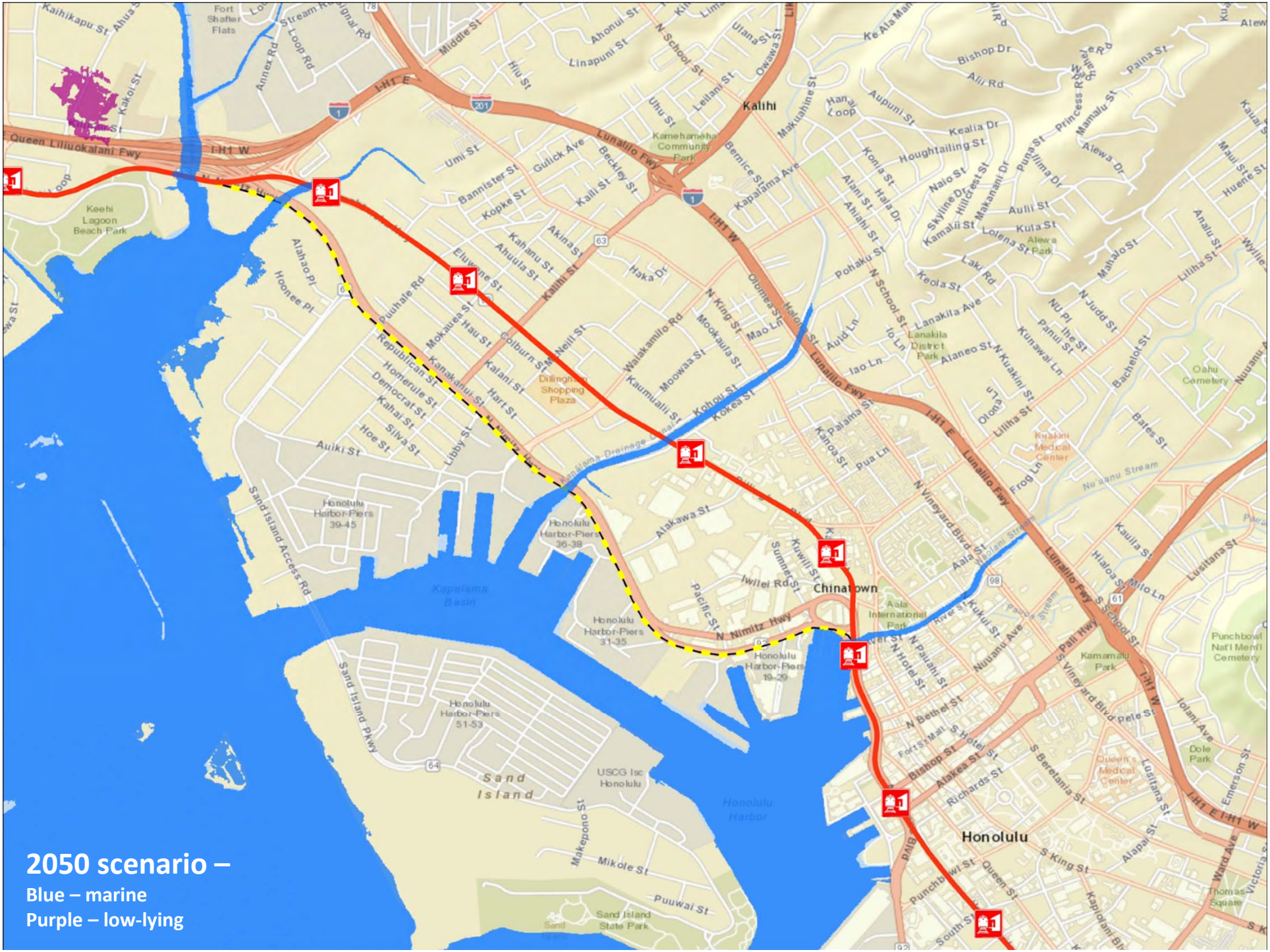
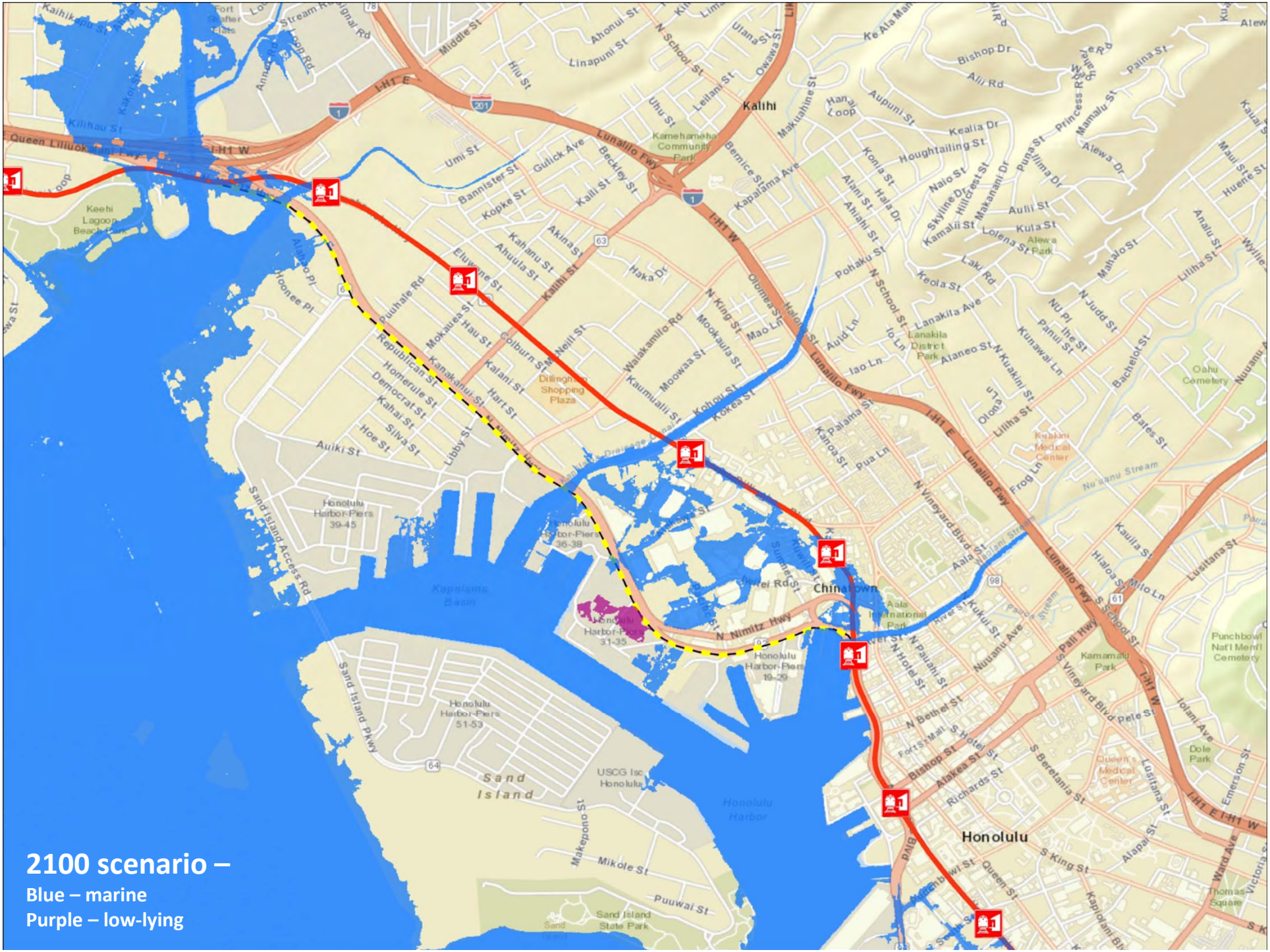
Honolulu Harbor-Piers 39-45
Honolulu Harbor-Piers 36-38
Honolulu Harbor-Piers 31-35
Honolulu Harbor-Piers 19-29
Honolulu Harbor-Piers 51-53
USCG Isc Honolulu
Sand Island State Park
Aala International Park
Kamamalu Park
Dole Park
Punchbowl Nat'l Mem'l Cemetery
Oahu Cemetery
Queen's Medical Center
Kuakini Medical Center
Thomas Square
Nu'uanu Stream
Lunalilo Fwy
I-H1 E
I-H1 W
N Nimitz Hwy
Sand Island Access Rd
Sand Island Pkwy
Queen Liliuokalani Fwy
Middle St
Bishop St
Alakea St
Richards St
Queen St
King St
Beretania St
Vineyard Blvd
Pali Hwy
Nuuanu Ave
Punchbowl St
Ala Moana Blvd
Kapiolani Blvd
Ward Ave
Makepono St
Mikole St
Puuwai St
Kaliuwa St
Kaliuwa Pl
Hoonee Pl
Alaiko Pl
Kilihau St
Kaihikapu St
Umi St
Bannister St
Kopke St
Gulick Ave
Beckley St
Kaili St
Akina St
Kahanu St
Ahuula St
Eluwene St
Kalihi St
Haka Dr
Puuhale Rd
Mokauea St
Hau St
Kanakanui St
Republican St
Homerule St
Democrat St
Kahai St
Silva St
Hoe St
Auiki St
Libby St
Hart St
Kalani St
Colburn St
Neill St
Waiakamilo Rd
Mookauia St
Moowaa St
Kaumualii St
Kohou St
Kokea St
N King St
Mao Ln
Olomea St
Halona St
Palama St
Kanoa St
Pua Ln
Laurel Rd
Summer St
Kuwili St
Aala St
N Vineyard Blvd
N Pauahi St
N Hotel St
N Beretania St
N Bethel St
Fort St Mall
S Hotel St
Alapai St
Kukui St
River St
Nuuanu Stream
Kaiulani St
Lusitana St
Iolani Ave
Pele St
Emerson St
Ala Moana Blvd
Kapiolani Blvd
Ward Ave
Victoria St
Bachelot St
Bates St
Lilliha St
Kuula St
Mahalo St
Aulii St
Houghtailing St
Keola St
Lanakila Ave
Alaneo St
Kunawai Ln
Pohaku St
Ahihi St
Alani St
Konia St
Hala Dr
Naio St
Kealia Dr
Aupuni St
Bishop Dr
Alii Rd
Paina St
Mamalu St
Alewa Dr
Pua St
Princess St
Kaua St
Maui St
Huene St
Analu St
Wylie St
Kaiulani St
Hialoa St
Milo Ln
Frog Ln
Olona Ln
Iao Ln
Auld Ln
Io Ln
Kuakini St
Kaiwa St
Kaiwa Pl
Ke Ala Mahi
Makuahine St
Owawa St
Ulana St
Leilani St
Uhu St
Hiu St
Linapuni St
Ahonui St
N School St
Kaiwa St
Kaiwa Pl
Kaiwa St
Kaiwa Pl


2050 scenario –
Blue – marine
Purple – low-lying
Kalihi
Chinatown
Honolulu
Sand Island
Keehi Lagoon Beach Park
Kamehameha Community Park
Dillingham Shopping Plaza
Honolulu Harbor-Piers 39-45
Honolulu Harbor-Piers 36-38
Honolulu Harbor-Piers 31-35
Honolulu Harbor-Piers 19-29
Honolulu Harbor-Piers 51-53
Kapalama Basin
Honolulu Harbor
Sand Island State Park
Lanakila District Park
Kamamalu Park
Dole Park
Thomas Square
Queen's Medical Center
Punchbowl Nat'l Mem'l Cemetery
Oahu Cemetery
Nu'uanu Stream
Queen Liliuokalani Fwy
I-H1 W
I-H1 E
Lunalilo Fwy
N Nimitz Hwy
Pali Hwy
Sand Island Access Rd
Sand Island Pkwy
Middle St
Kalihi St
Bishop St
Alakea St
Nuuanu Ave
Vineyard Blvd
Punchbowl St
Queen St
S King St
Beretania St
Richards St
Iwilei Rd
Alakawa St
Mikole St
Puuwai St
Makepono St
Kapalama Drainage Canal


2100 scenario –
Blue – marine
Purple – low-lying
Kalihi
Honolulu
Chinatown
Sand Island
Honolulu Harbor
Keehi Lagoon Beach Park
Kamehameha Community Park
Dillingham Shopping Plaza
Lanakila District Park
Alewa Park
Kapalama Basin
Honolulu Harbor-Piers 39-45
Honolulu Harbor-Piers 36-38
Honolulu Harbor-Piers 31-35
Honolulu Harbor-Piers 19-29
Honolulu Harbor-Piers 51-53
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Thomas Square
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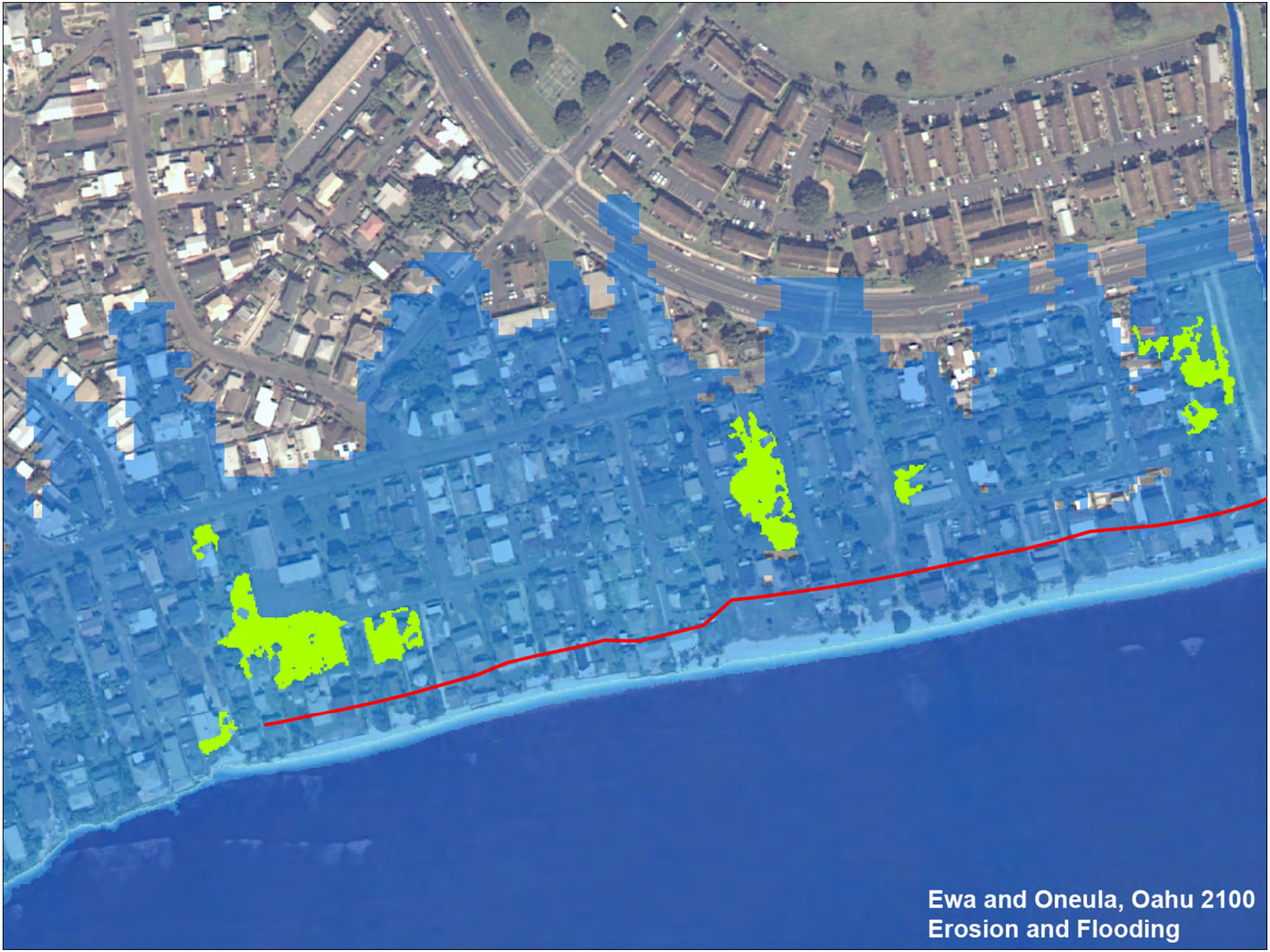
Lunalilo Fwy
I-H1 E
I-H1 W
N Nimitz Hwy
Sand Island Access Rd
Sand Island Pkwy
Queen Liliuokalani Fwy

Ewa and Oneula, Oahu 2050
Erosion and Flooding

Ewa and Oneula, Oahu 2100
Erosion and Flooding

Ewa and Oneula, Oahu 2050
Erosion and Flooding


Ewa and Oneula, Oahu 2100
Erosion and Flooding

Honolulu, Oahu 2100
Erosion and Flooding