Coalition to Mitigate the Impacts of Sea Level Rise

The Ala Wai Canal during the King Low and High Tides of Jan 2-4, 2022

Waikiki is wedged between the restless seas and the Ala Wai Canal, which is fed by the rising ocean, polluted storm drains, the mountain runoff from high above, as well as an occasional Kona low storm. With an expected 3-foot sea level rise in the future, Waikiki will largely cease to exist as we know it now. Will the Ala Wai Canal without a flood control side channel advance its demise?

The Ala Wai Canal was inspected/photo documented during the King high and low tides of Jan 2-4, 2022, from a lay person's perspective because of the public's disconnect between published science pertaining to continuing sea level rise (SLR) and the ongoing permitting and construction in areas such as Waikiki that are expected to be flooded/inundated in the not-too-distant future by a 3- to 4-foot sea level rise.

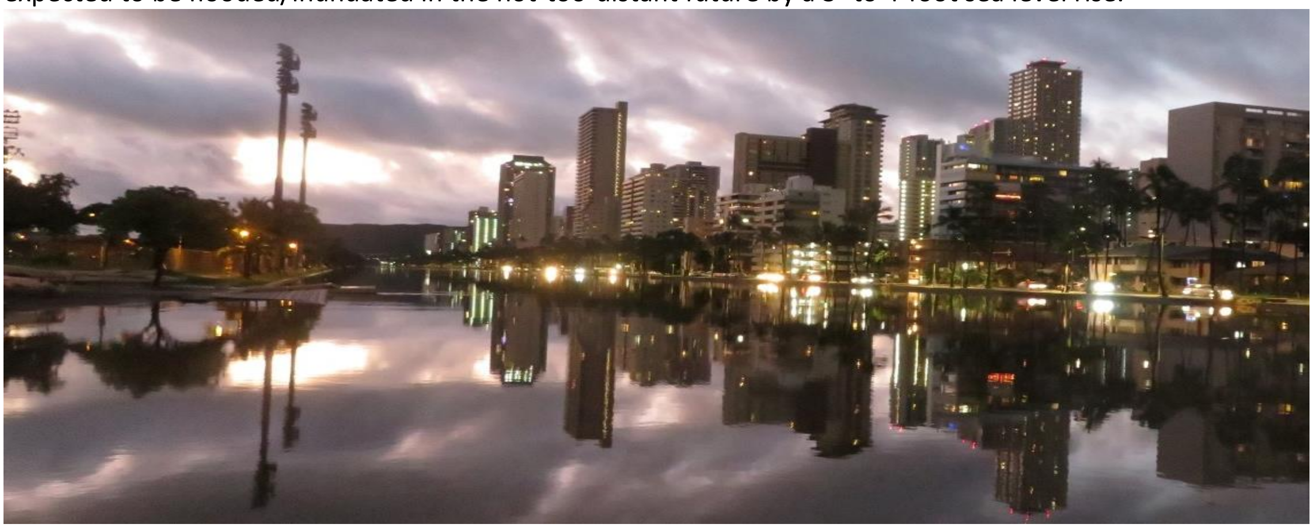


Photo 1 - Clouds from a Kona low storm mirrored in Ala Wai Canal during early morning King Tides (1-4-2022 7:30 am).

Map 1 - Waikiki and the Ala Wai Canal with street system (Google Earth). Photo spots in red are indicated by Photo #'s.

Jan. 2, 2022 11:24 am - O.33-ft. Preliminary Low Tide (Predicted 0.01 ft.)

Photo 2 - 11:27 am. No rain yet. No pollution from storm drain. **Photo 3** - 12:02 pm. Pollution plume- 24 minutes of rain. **Paoakalani Ave**. Storm drain outlet at **0.33-ft.** low tide. Water level 19" to top of storm drain outlet, 65" to water level.

Photo 4 - 11:37 am. No rain yet. No clearly visible pollution from drain. **Photo 5** - 11:37 am. Debris along canal banks. **Lili`uokalani St.** storm drain outlet at **O33-ft.** low tide. 18" to top of storm drain outlet, 63" to water level.

Photos 6, 7 - A downpour started 11:38am with moderate-to light rain continuing for the next hour. A dark pollution plume (often with floating debris) extended from storm debris outlets soon thereafter despite rains the last four days.

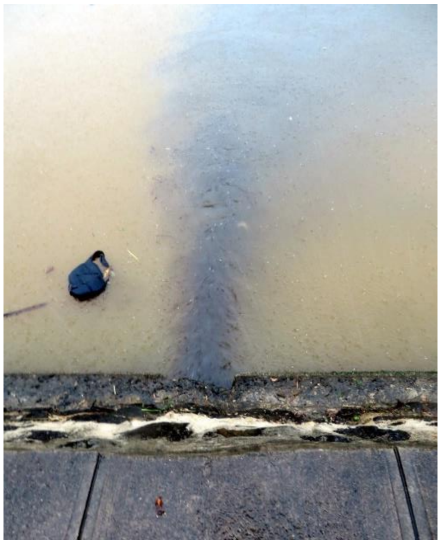


Photo 8 - Outlet pollution plume at 7 minutes of rain. **Photo 9** - Pollution plume in middle of canal at 7 minutes of rain.

Photos 10, 11 - 11:51 am. Pollution from outlet at 13 minutes of rain continuing to extend into Ala Wai canal.

Photos 8-11 -_Kanekapolei St. Storm drain outlet at **O.33-ft.** low tide

Photo 12 - No visible pollution at 11:33 am before onset of rain. **Photo 13** - Storm drain #2 outlet at 12:00 Noon

Ohua Ave. at **0.33-ft.** low tide. Water level to top of side bank = 64" before onset of rains.

Pollution plumes from other storm drain outlets along the Waikiki (Makai) side of the canal.

Photo 14 - **Kai'ulani Ave.** storm drain outlet-11:53 am **Photo 15** - Outlet across the street from 2421 Ala Wai-11:54 am

----

Photos 16, 17 - Storm drain outlets along the Makai east end of Ala Wai Canal

----

Photo 18 - Ala Wai Golf Course mauka banks at **0.33 ft.** low tide during a short Kona low storm downpour at 11:56 am on Jan. 2, 2022. The Ala Wai Canal can already spill over these banks during high tides and threatening Kona storms.

Jan. 4, 2022 5:42am 2.86-ft. Preliminary High King Tide (Predicted 2.49 ft.)

Photo 19 - Jan. 2, 2022: 12:08 pm.
36" clearance 32 min. after **0.33-ft.** low tide **Kapahulu/Ala Wai Blvd. drain outlet**

Photo 20 - Jan 4, 2022: 5:46 am.
6"-7" clearance at **2.86-ft.** King Tide.

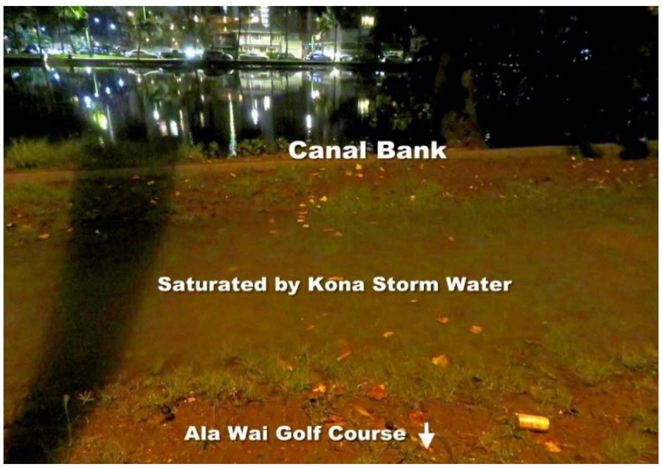
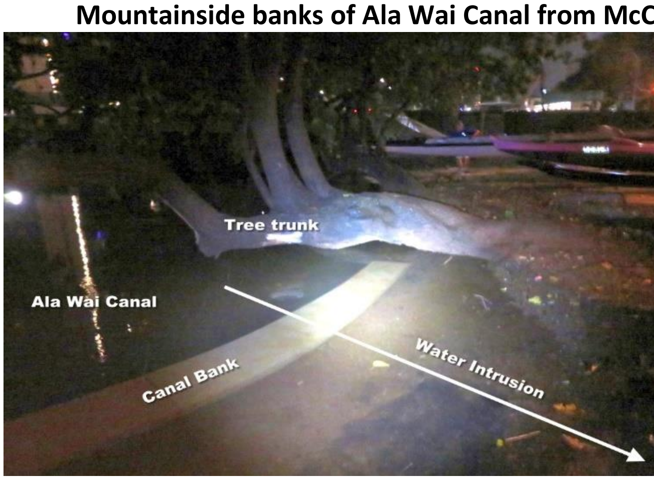
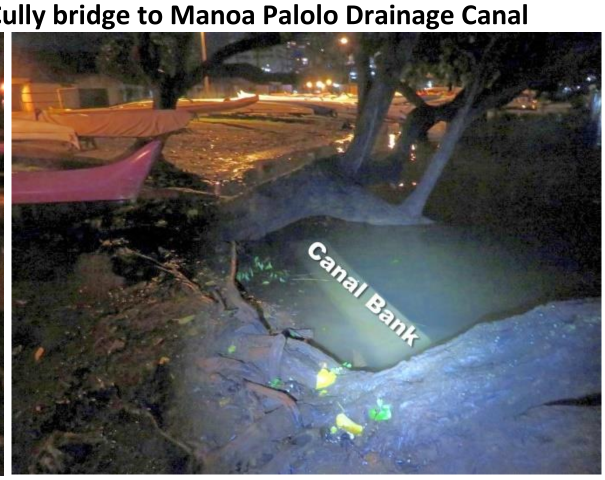


Photo 21 - Ala Wai Golf Course H.Q.- 5:30 am.
Water level 22" below eroded bank at **3.84-ft** King Tide.

Photo 22 -Seaside Ave. Canal staircase 6:01 am.
Water level 19"-20" below walkway at **3.84-ft** King Tide (and storm outflow from Manoa-Palolo FC Canal).

Mountainside banks of Ala Wai Canal from McCully bridge to Manoa Palolo Drainage Canal





Photos 23, 24 - **Ala Wai Community Park/McCully Bridge**: Jan. 4, 2022: 6:15 am - Water rising above the canal banks.

Photos 25 - 6:16 am - Early morning paddlers (arrow) perhaps unaware of polluted Ala Wai Canal. **Photo 26** - 6:49 am.

Photo 27 - 6:54 am - At the McCully Bridge, the water has risen over the canal banks and is extending onto the Ala Wai Community Park.

Photo 28 - 6:55 am - Ala Wai canal banks mountainside (Mauka). **Photo 29** - 6:55 am - Canal banks oceanside (Makai).

Photo 30- 7:00 am - AlaWai Park Trail bridge… **Photo 31** - 7:00 am…leading over drainange canal.

Photo 32 - 7:01 am – Flooded Ala Wai Canal banks along the Ala Wai Neighborhood Park.

Photo 33 – 7:23 am - Flooded Ala Wai Canal banks along the Ala Wai Community Park.

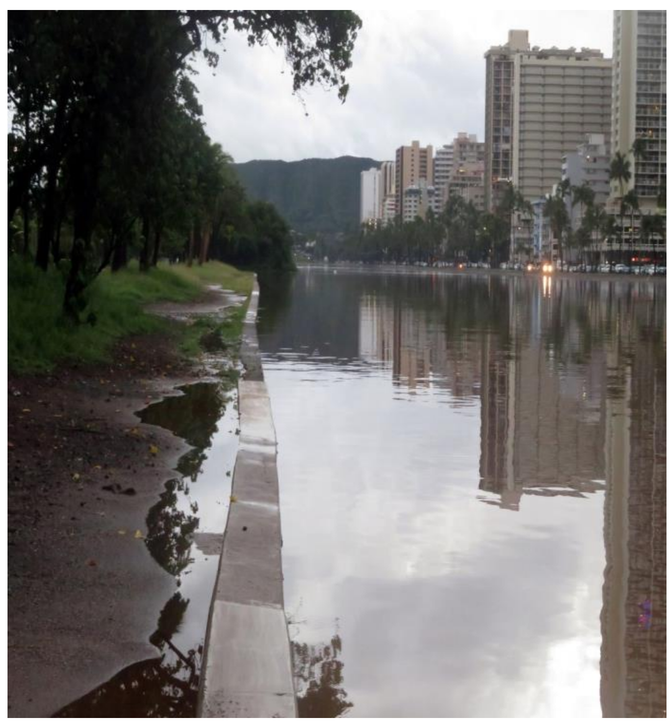


Photo 34 - 7:01 am - Ala Wai Park Trail near Ala Wai Commuity Garden. **Photo 35** - 7:07 am - Flooded canal banks.

Photo 36 - 7:09 am - Flooded Ala Wai Canal side banks near the Ala Wai Community Garden.

Photo 37 – 7:09 am – Flooded canal banks as the Manoa-Palolo Flood Control Canal discharges into Ala Wai Canal. Storm runoff from earlier rain showers in the mountain watersheds (prior to about 4:30 am) kept the water level elevated above the 5:42 am, **2.86-ft.** King High Tide even 90 minutes later.

Photo 38 - 7:14 am – Manoa-Palolo Drainage Canal flooded side banks as it discharges into the Ala Wai Canal acoss from Lewers Ave. and just downstream of Seaside Ave.

Photo 39 - 7:15 am **–** Manoa-Palolo Drainage Canal flooded side banks as it discharges into the Ala Wai Canal.

Photo 40 - 7:17 am - Ala Wai Dog Park.

Photo 41 - 7:17 am - Flooded Manoa-Palolo Drainage Canal banks.

Photo 42- 7:17 am - Flooded park walkway

Photo 43 – Flooded Manoa-Palolo Drainage Canal banks.

Photos 44-45 - 7:18 am - Manoa-Palolo Drainage Canal overflowing onto the park's infrastructure and walkways.

OVERVIEW

The water level of the Ala Wai Canal. Flood Control Channel (Canal) provides a visual evaluation of the movements of the tides to everyone, and was therefore chosen for a photo-documented evaluation of the King High and Low Tides of January 2-4, 2022.

While almost everyone agrees that sea level is rising, and faster than anticipated, uncertainties still remain as to the timing of just 3.2-feet (1 meter) sea level rise before 2100 as indicated on Map 2 (PacIOOS), which the state uses for future planning decisions. Four feet or greater sea level rise, as now being predicted by the latest extensive research, is visualized on the NOAA sea level rise maps such as Map 3. There is also growing uncertainty about projected SLR by the late 21st century, as it may even greatly exceed 4 feet if global warming rises to and exceeds 1.5 degree Celsius.

While libraries of research have been and are still being produced pertaining to climate change and sea level rise, let us focus on just some of the latest studies pertaining to Honolulu, largely carried out by local researchers, and see how it pertains to Waikiki where development in continuing as if there is no tomorrow.

Even much before sea level would rise to 3 feet, "minor/nuisance" flooding could already bring Honolulu partially to a standstill when it occurs. For example, researchers,[1] studying the 2017 King Tides where *a combination of anomalously high mean sea levels and seasonally high tides contributed to record water levels reaching more than 1.15 feet (0.35 m) above the mean higher high water (MHHW) datum at Honolulu* and flooded immediate coastal Honolulu, then established this as their sea level rise threshold KT2017 - 1.15 feet (0.35 m) MHHW model.[2] Their research demonstrated that Honolulu is more likely than not to experience its first year with more than 50 minor flooding days above this 1.15-feet (0.35m) sea level rise threshold by 2035 and more than 100 minor flooding days by 2045. In later interviews, lead scientist Thompson pointed out that because high-tide floods involve a small amount of water compared to hurricane storm surges, there is a tendency to view them as a less significant problem overall. *"But if it floods 10 or 15 times a month, a business can't keep operating with its parking lot under water. People lose their jobs because they can't get to work. Seeping cesspools become a public health issue."*

Combining oceanic and astronomical causes of flooding, the Thompson group pointed out in 2021 that in the mid-2030s, every U.S. city will experience rapidly increasing numbers of high-tide floods (nuisance or sunny day floods) when lunar cycles (monthly new and full moon) will amplify rising sea levels caused by climate change.

Based on Thompson's high tide KT2017 1.15 ft. (0.35 m) flood threshold, a further study included storm-drain backflow (reverse flow through the municipal drainage system) and groundwater inundation (underground water table pushed to the surface) in addition to direct marine type flooding (ocean water sweeping over the shoreline).[3] The study applied its simulation method to *"Honolulu's primary urban center based on its high density of vulnerable assets and present-day tidal flooding issues."* Map 4 (Fig 2-Research Report) shows the study area and outlines Honolulu's Cesspool, Storm-Water Inlet, Storm-Water Conduit, and Roadway Infrastructure. However, the study stressed that it did not include simulation of rainfall induced flooding.

---

[1] Thompson, P. R., Widlansky, M. J., Merrifield, M. A., Becker, J. M. & Marra, J. J. A statistical model for frequency of coastal flooding in Honolulu, Hawai'i during the 21st century. *J. Geophys. Res. Ocean*. 2018JC014741

[2] Mean higher high water (MHHW) is defined as the average of daily maximum water levels during the U.S. National Tidal Datum Epoch (NTDE, 1983–2001) and is roughly equivalent to local high tide line and captures spatial variation in both mean sea level (MSL) and tidal amplitudes

[3] *Sea-Level Rise induced Multi-Mechanism flooding and contribution to Urban infrastructure failure*. by Shellie Habel,[1] Charles H. Fletcher,[1] Tiffany R. Anderson[1] & Philip R. Thompson[2] [[1]University of Hawai'i at Mānoa, School of Ocean and Earth Science and Technology, Department of Earth Sciences, [2]University of Hawai'i at Mānoa, Sea Level Center]. Published in NATURE 2020 3-2.

The study found that more than a quarter of flooding is attributed to groundwater inundation alone, while a combination of the three types will eventually account for more than half of the projected flooding generated by climate change. As explained by the authors, it occurs as the rising ocean lifts Oahu's caprock aquifer, an underground lens of brackish and polluted water that floats on a base of higher-density saltwater connected to the ocean. During high-tide events, the groundwater then breaks the surface to create temporary urban wetlands that grow even larger when high tides and rainfall coincide. Within just a few decades, such wetlands will then become permanent and will require costly engineering, where feasible, for municipalities to continue to function. While some coastal erosion could be contained by seawalls, they cannot stop flooding because of such groundwater inundation.

As part of the study, the UH Sea Level Center then developed a statistical model with predicted tide and projected magnitudes of local sea level rise. In doing so, it considered three more sea level rise scenarios in addition to the Thompson KT2017 1.15 ft. (0.35 m) flood threshold scenario. This first scenario indicated that infrastructure failure was already occurring during periods of high tides, as illustrated by backflow of gravity drainage, by traffic slowdowns along submerged roadways, and by partial inundation of active cesspools, as nearly 90% of cesspools in the study area are already likely inundated during present-day king tide events[4].

At their Minor Flood Threshold of 0.82 ft. (0.25m) and 1.73 ft. (0.52 m) by 2050 and 2100 (NOAA predictions 2030s, 2060s), infrastructure failure included 200 locations where drainage inlets lose all capacity for drainage and begin acting as conduits for flooding, which represents near doubling relative to the KT2017 simulation (Map 5 – Report Figure 4). Such failures include all drainage inlets along Ala Moana Blvd. from Kewalo Harbor Basin to Kahanamoku Harbor basin as visually documented by us (CMISLR) during the Dec 5, 2021 King High Tide and also the drainage inlets along Ala Wai Canal during the Jan. 4, 2022 King High Tide. Their research also documented that as *water levels advance from the minor to moderate flood threshold, flooded area and infrastructure impacts escalate markedly.* The researchers therefore pointed out that the design of flood management strategies required to mitigate these impacts necessitate site-specific consideration of each mechanism to avoid the potential of being rendered ineffective.

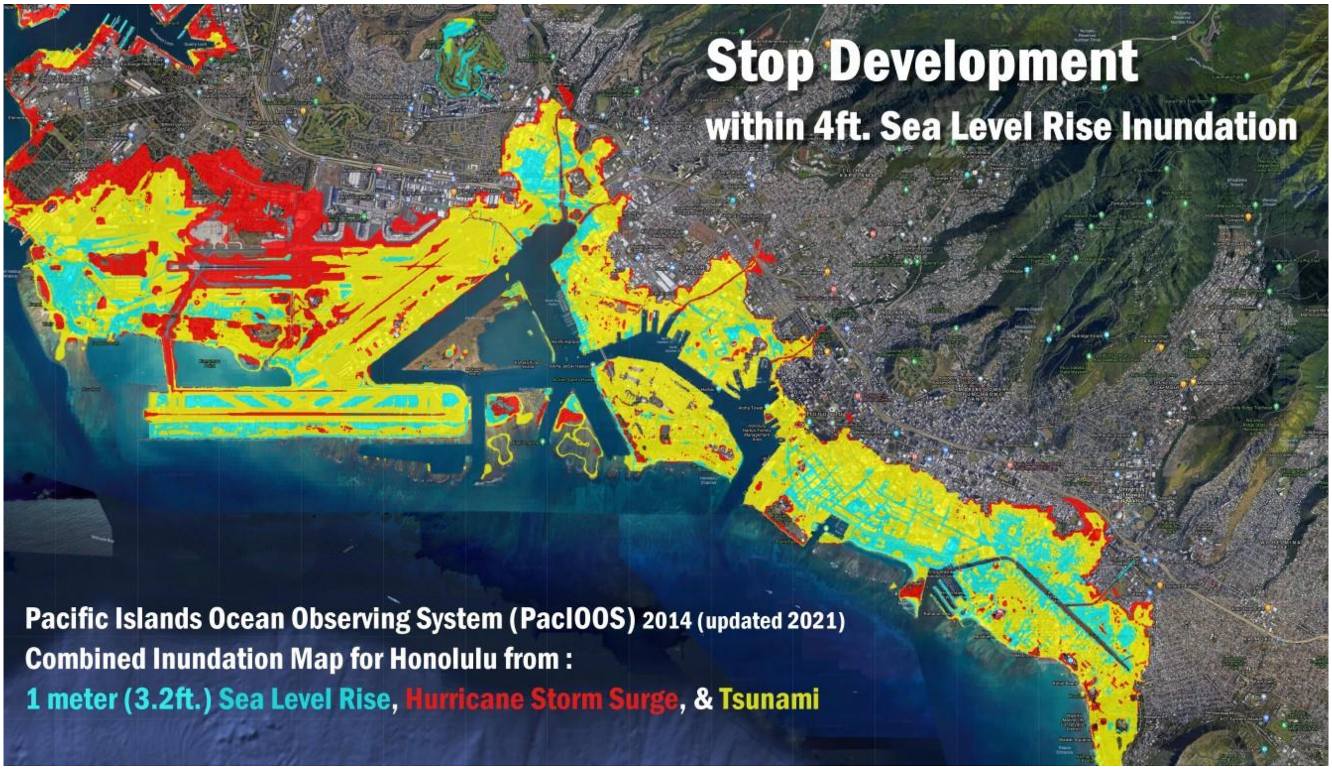
At their Intermediate Flood Threshold of 1.3 ft. (0.4 m)and 2.7 ft. (0.82 m) by 2050 and 2100 (NOAA 2020s and 2050s), respectively, simulated infrastructure failure was significantly magnified with the number of failed storm drains increasing to 860, a fourfold jump from the minor threshold; the length of dangerous roadway conditions increasing to 9.19 km (a nearly seven-fold jump from the minor threshold), and cesspools flooded to the ground surface more than doubled.

At the Major Flood Threshold of 1.87 ft. (0.57 m) and 6.33 ft. (1.93 m) in Honolulu by 2050 and 2100, respectively, more than half of the expansive total area flooded was identified as resulting from triple-mechanism flooding with many infrastructures unlikely remaining in their current locations.

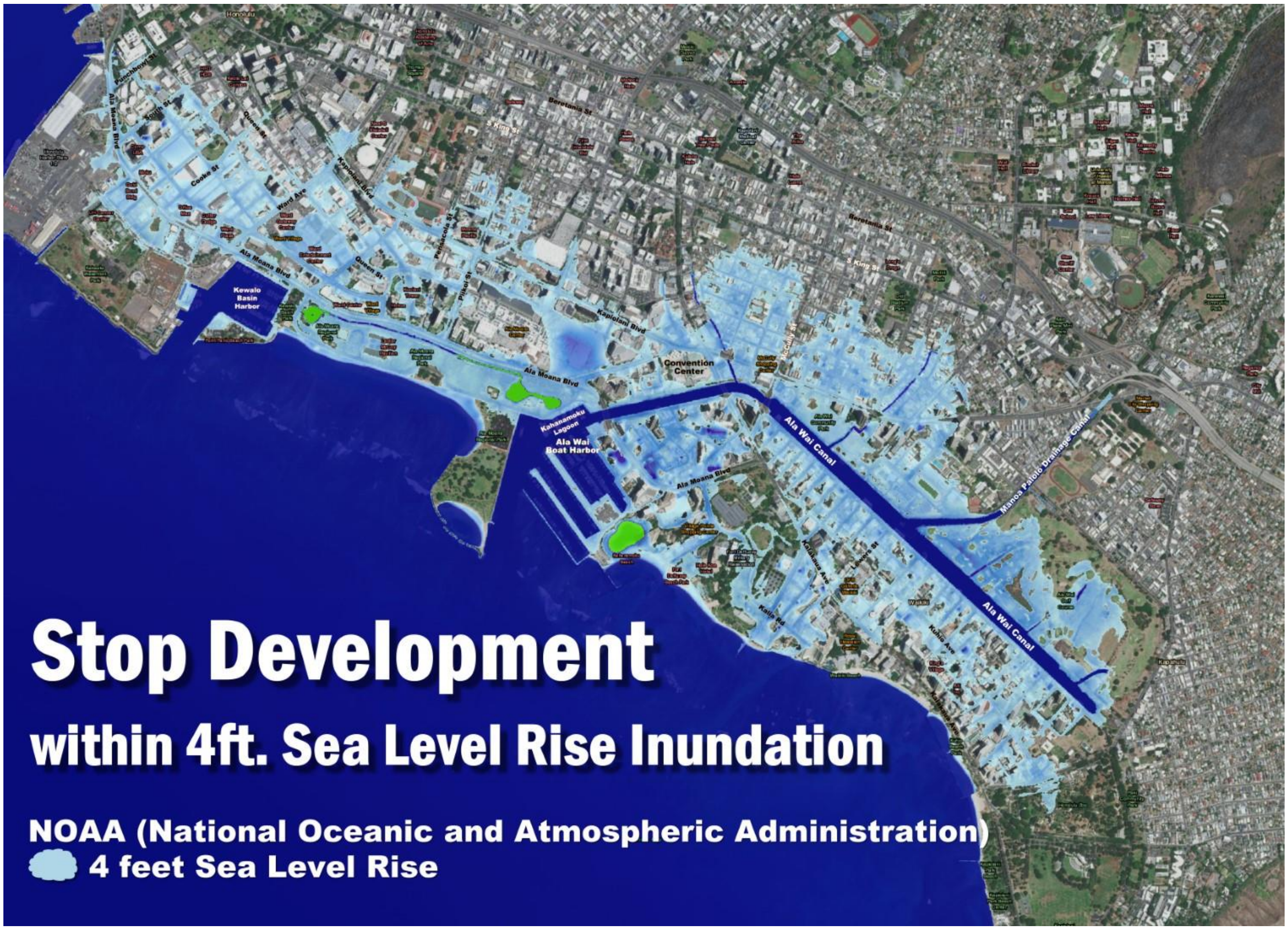
In summary, the authors pointed out that while the intermediate scenario was the primary focus to support general adaptation planning, the more extreme projections such as intermediate-high, high, and extreme should be used when designing projects that are highly sensitive to flood impacts (such as critical infrastructure, with no capacity to accommodate flooding, etc.).

[4] The scientific term for King Tides, the highest tides of the year, is perigean spring tides. In the Hawaiian Islands King Tides tend to occur during the summer (e.g., July and August) and winter months (e.g., December and January) when the moon is closest to the earth in its monthly orbit and the sun, moon and earth are in alignment.

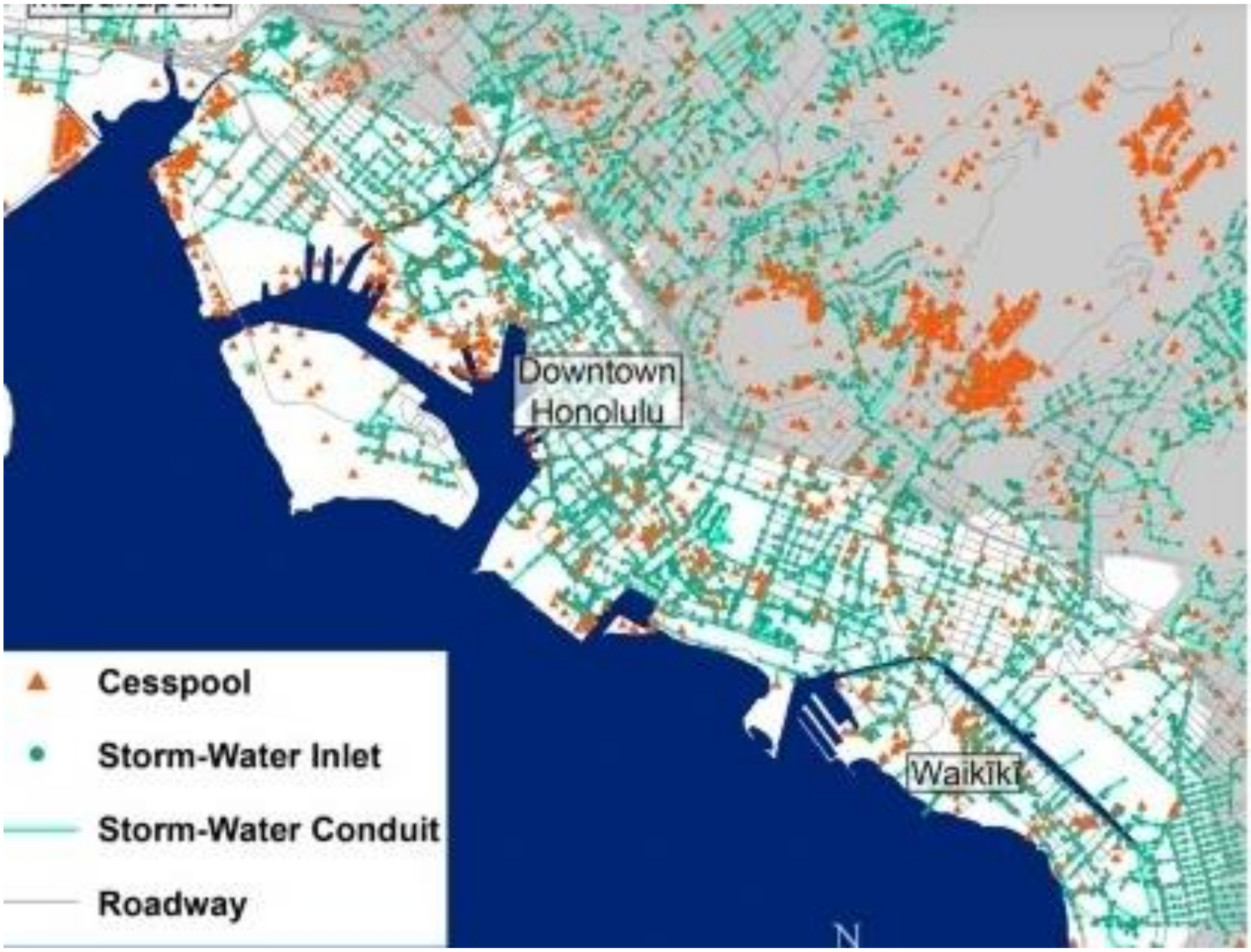
They also pointed out that the statewide assessment of SLR impacts conducted in 2017 employed the bathtub approach to represent flooding from a combination of phenomena including passive direct marine inundation, drainage backflow, and GWI; but the three mechanisms were not uniquely simulated. Alternate sea level rise (SLR)-induced flood sources of ground water inundation (GWI) and storm-drain backflow are therefore often overlooked in Hawaii's resiliency planning efforts, which has the potential to render flood management efforts increasingly ineffective as SLR continues. They also stressed that assessment of critical infrastructure reinforces the need to consider multi-mechanism flood scenarios in present-day municipal planning, owing to the extreme vulnerability of specific components that feature limited capacity to accommodate flooding. To mitigate SLR related impacts, simulations of multi-mechanism flooding such as they featured can be used to prioritize infrastructure upgrades, ideally as part of normal maintenance schedules.



Map 2 – PacIOOS 1-meter (3.2 ft.) Sea Level Rise, Hurricane Storm Surge, & Tsunami Inundation

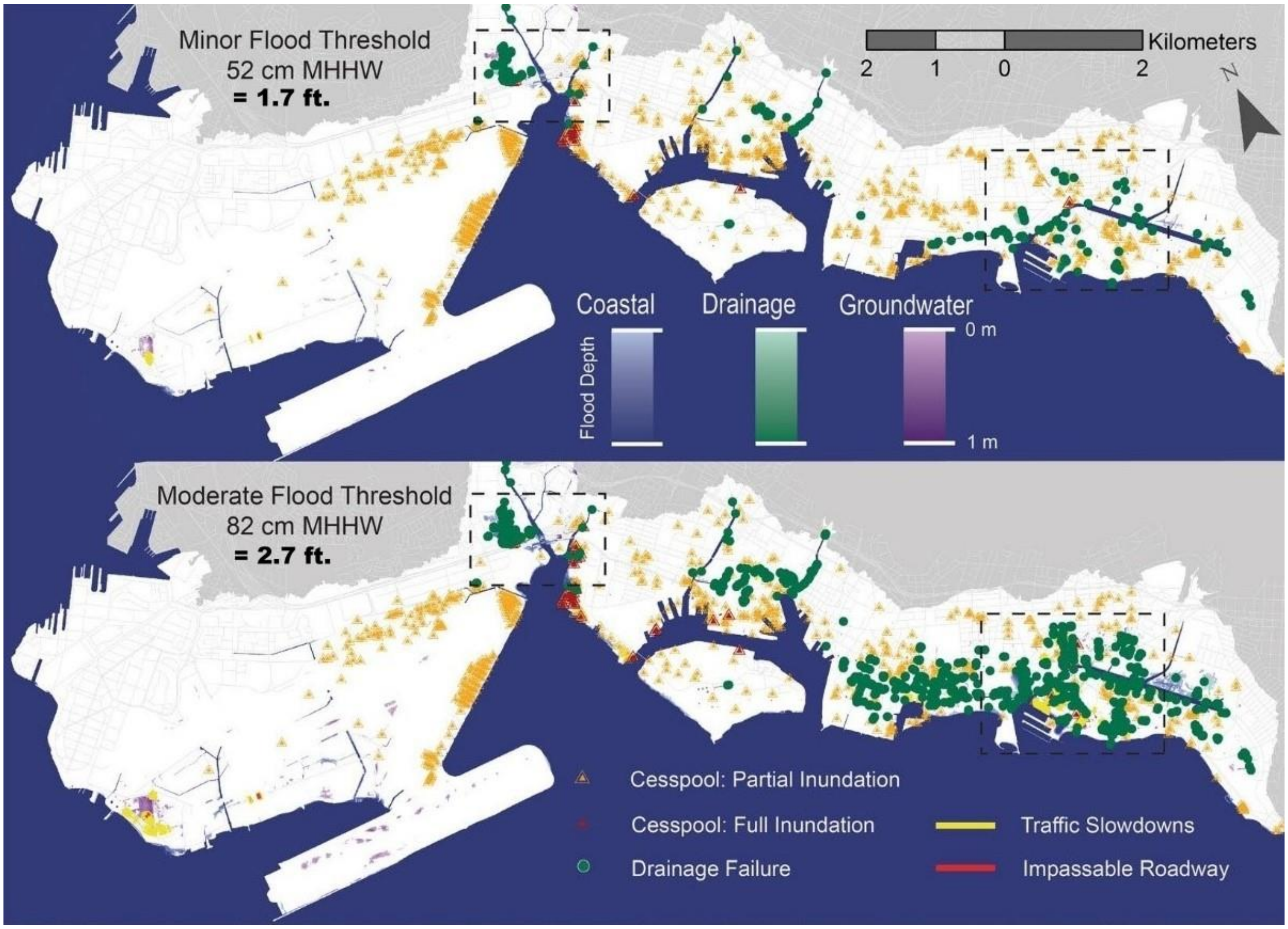


Map 3 – NOAA Four Feet Sea Level Rise Map - Kaka`ako-Waikiki



Map 4 – Honolulu Cesspool, Storm-Water Inlet, Storm-Water Conduit, Roadway Infrastructure

(Fig. 2 in *Sea-Level Rise induced Multi-Mechanism flooding and contribution to Urban infrastructure failure* by Shellie Habel,[1] Charles H. Fletcher,[1] Tiffany R. Anderson,[1] & Philip R. Thompson[2] [[1]University of Hawai'i at Mānoa, School of Ocean and Earth Science and Technology, Department of Earth Sciences, [2]University of Hawai'i at Mānoa, Sea Level Center]. Published in NATURE 2020 3-2.



Map 5-Flooding and infrastructure failure across the primary urban center: minor and moderate flood thresholds
(Fig. 4 cropped - in *Sea-Level Rise induced Multi-Mechanism flooding and contribution to Urban infrastructure failure* by Shellie Habel,[1] Charles H. Fletcher[1], Tiffany R. Anderson[1] & Philip R. Thompson[2][[1]University of Hawai'i at Mānoa, School of Ocean and Earth Science and Technology, Department of Earth Sciences, [2]University of Hawai'i at Mānoa, Sea Level Center]. Published in NATURE 2020 3-2.