Climate Change Commission
CITY AND COUNTY OF HONOLULU
650 South King Street, 9th Floor • Honolulu, HI 96813

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Charles Fletcher, Ph.D., Vice Chair
Rosanna Alegado, Ph.D.
Victoria Keener, Ph.D.
Bettina Mehnert, FAIA, LEED AP, O+M

SPECIAL MEETING AGENDA
Monday, May 21, 2018
3:00 p.m.
Saunders Hall, Room 116
University of Hawai‘i at Mānoa
2424 Maile Way
Honolulu, HI 96822

1. Call to Order
2. Roll Call
3. Discussion of the draft Climate Change Brief
4. Discussion of the draft Sea Level Rise Guidance
5. Public Input for Matters Not on the Agenda
6. Announcements
7. Adjournment

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PURPOSE
The Honolulu Climate Change Commission, in order to establish the factual basis and broad impact of climate change, adopts this climate change brief. This document delineates at the global, regional, and local scales, conclusions of the peer review scientific community with regards to impacts to physical, environmental, and socio-economic systems.

This document reinforces the need for an urgent and sweeping transformation in our energy sources, food systems, and land-use practices to achieve a decarbonized world economy. Mitigation of future climate change must be achieved to avoid the very worst aspects of global warming. In the words of Dr. Jim Hansen, former chief scientist at the NASA Goddard Institute of Space Science, “There is a possibility, a real danger, that we will hand young people and future generations a climate system that is practically out of their control… we have a global emergency. Fossil fuel CO$_2$ emissions should be reduced as rapidly as practical.”

Because many changes in global biophysical systems have been irreversibly set into motion, and these threaten the health and welfare of human populations, it is important that communities such as the City and County of Honolulu take bold steps to build sustainability and resilience in the face of a rapidly changing climate.

The role of the Honolulu Climate Change Commission is to gather the latest science and information on climate change impacts to Hawai’i and provide advice and recommendations to the mayor, City Council, and executive departments as they look to draft policy and engage in planning for future climate scenarios. This white paper provides a benchmark for the climate commission, attesting to our concern, underpinning our decisions and recommendations, and serving to educate those we serve.

INTRODUCTION
Excess heat, trapped by the anthropogenic greenhouse gases carbon dioxide, methane, nitrous oxide, and others in the atmosphere, is causing dramatic changes in ecosystems, weather patterns, and other climate-dependent aspects of Earth’s surface. Hawaii, and other Pacific islands are impacted, and these impacts will grow in coming decades.

Scientists are warning that human population growth, widespread destruction of natural ecosystems, and global warming are pushing Earth’s ecosystems and resources toward irreversible damage and that we are in the midst of Earth’s sixth mass extinction.

Unrelenting impacts to Earth’s ecosystems and natural resources have led researchers to conclude that our planet is perched on the edge of a tipping point, a planetary-scale critical transition resulting from human impacts. These changes include the following.

CARBON DIOXIDE
- Carbon dioxide levels in the air have passed 400 ppm compared to a natural level of 280 ppm – an increase of over 40%. This is the highest level in millions of years.
- Today, release of planet-warming carbon dioxide is ten times faster than the most rapid event in the past 66 million years, when an asteroid impact killed the dinosaurs.

TEMPERATURE
- Global temperature has risen approximately 1°C (1.8°F) from the late 19th Century.
- The likely range of global temperature increase is 2.0–4.9°C, with median 3.2°C (5.76°F) and a 5% (1%) chance that it will be less than 2°C (1.5°C).
- The last time it was this warm was during last interglacial time (ca. 125,000 years ago) when global mean sea level was 6.6 m (20 feet) above present.
- Atmospheric humidity is rising.
- The global water cycle has accelerated.
- Air temperature over the oceans is rising.

HAWAI’I – LOCAL AND REGIONAL IMPACTS
- In Hawai’i, the rate of warming air temperature has dramatically increased in recent decades. Currently, the air is warming at 0.3°F (0.17°C) per decade, four times faster than half a century ago. This can lead to heat...
waves, expanded ranges for pathogens and invasive species, thermal stress for the natural flora and fauna of the islands, increased demands for electricity, and increased wildfires and potential threats to human health. Rapid warming of the highest elevations can impede precipitation, the source of our freshwater.

- The frequency of gale-force winds is increasing in the western and south Pacific but decreasing in the central Pacific.\textsuperscript{15}
- Average daily wind speeds are slowly declining in Honolulu and Hilo, while remaining steady across western and south Pacific sites.\textsuperscript{16}
- Hawai‘i has seen an overall decline in rainfall over the past 30 years, with widely varying precipitation patterns on each island. The period since 2008 has been particularly dry.\textsuperscript{17}
- Both extreme heavy rainfall events and droughts have become more common, causing increased runoff, erosion, flooding, and water shortages.\textsuperscript{18} (needs confirmation)
- The numbers of consecutive wet days and consecutive dry days are both increasing in Hawai‘i.\textsuperscript{19} (needs confirmation)
- Stream flow in Hawai‘i has declined over approximately the past century, consistent with observed decreases in rainfall.\textsuperscript{20}
- The frequency of intense El Niño’s are projected to double in the 21st century, with the likelihood of extreme events occurring roughly once every 10 years instead of once every 20.\textsuperscript{21}
- Strong El Niño years in Hawai‘i bring more hot days, intense rains, windless days, and spikes in sea surface temperature.
- More frequent tropical cyclones are projected for the waters near Hawai‘i. This is not necessarily because there will be more storms forming in the east Pacific; rather, it is projected that storms will follow new tracks that bring them into the region of Hawai‘i more often.\textsuperscript{22}
- Globally averaged sea surface temperature (SST) increased by about 1.8°F (1.0°C) over the past 100 years. Half of this rise has occurred since the early 1990s. Regionally averaged SST trends follow the globally averaged trend. Over the last 5 years almost the entire tropical Pacific and in particular areas along the equator have seen temperatures warmer than the average over the last 30 years.\textsuperscript{23}
- In Hawai‘i, extended periods of coral bleaching caused by heat stress did not first occur until 2014 and 2015, respectively, as part of the 2014–17 global scale bleaching event that was the longest ever recorded.\textsuperscript{24}
- Models predict that ocean warming will cause annual coral bleaching for some areas, like the central equatorial Pacific Ocean, as early as 2030 and almost all reefs by 2050. This will not only devastate local coral reef ecosystems but will also have profound impacts on ocean ecosystems more broadly. Ultimately it will threaten the communities and economies that depend on a healthy ocean.\textsuperscript{25}
- The mean sea level trend at the Honolulu tide station is 0.055 in (1.41 mm) per year with a 95% confidence interval of ±0.008 in (0.21 mm) per year based on monthly mean sea level data, 1905 to 2015. This equivalent to a change of 0.46 ft (14.0 cm) over the past century.\textsuperscript{26}
- Future mean sea level rise estimates are somewhat higher in Hawai‘i and other Pacific islands, where due to regional effects, sea level is projected to be on the order of 20%–30% above the global mean.\textsuperscript{27}
- Over 70% of beaches in Hawai‘i are in a state of chronic erosion. This is likely related to long term sea level rise as well coastal hardening.\textsuperscript{28}
- The frequency of high tide flooding in Honolulu since the 1960’s, has increased from 6 days per year to 11 per year.\textsuperscript{29}
- Nearly 30 years of oceanic pH measurements, based on data collected from Station ALOHA, Hawaii, show a roughly 8.7% increase in ocean acidity over this time.\textsuperscript{30}
- Increasing ocean acidification reduces the ability of marine organisms to build shells and other hard structures. This adversely impacts coral reefs and threatens marine ecosystems more broadly.\textsuperscript{31}

**ECOSYSTEMS, FOOD, AND HUMAN HEALTH**

- Humans are causing the climate to change 170 times faster than natural forces.\textsuperscript{32}
- Tree lines are shifting poleward and to higher elevations.\textsuperscript{33}
- One-third of burnt forests experience no tree regeneration at all.\textsuperscript{34}
- Species are migrating poleward and to higher elevations.\textsuperscript{35}
- Spring is coming sooner to some plant species in the Arctic while other species are delaying their emergence amid warm winters. The
changes are associated with diminishing sea ice.  
- Air temperature over land is rising.  
- Global wind speed has accelerated.  
- Spring is coming earlier.  
- The lower atmosphere (troposphere) is warming.  
- The tropics have expanded.  
- Warmer winters with less snow have resulted in a longer lag time between spring events and a more protracted vernal window (the transition from winter to spring).  
- Plants are leafing out and blooming earlier each year.  
- Climate-related local extinctions have already occurred in hundreds of species, including 47% of 976 species surveyed.  
- Plant and animal extinctions, already widespread, are projected to increase from twofold to fivefold in the coming decades.  
- Rising CO₂ decreases the nutrient and protein content of wheat, leading to a 15% decline in yield from mid-century.  
- By 2050, climate change will lead to per-person reductions of 3% in global food availability, 4% in fruit and vegetable consumption, and 0.7% in red meat consumption. These changes will be associated with 529,000 climate-related deaths worldwide.  
- Without changes to policy and improvements to technology, food productivity in 2050 could look like it did in 1980 because, at present rates of innovation, new technologies won’t be able to keep up with the damage caused by the climate change in major growing regions.  
- Certain groups of Americans— including children, elders, the sick and the poor—are most likely to be harmed by climate change.  
- Climate change is harming human health now. These harms include heat-related illness, worsening chronic illnesses, injuries and deaths from dangerous weather events, infectious diseases spread by mosquitoes and ticks, illnesses from contaminated food and water, and mental health problems.  
- Global warming is changing life on Earth on a global scale.

EXTREME WEATHER
- The global percentage of land area in drought has increased about 10%.  
- The global occurrence of extreme rainfall has increased 12%.  
- Heavy downpours are more intense and frequent.  
- Extreme weather events are more frequent.  
- Half a degree Celsius of global warming has been enough to increase heat waves and heavy rains in many regions of the planet.  
- Storm tracks are shifting poleward.  
- The number of weather disasters is up 14% since 1995-2004, and has doubled since 1985-1994.  
- In Australia, record setting hot days outnumber record setting cold days by a factor of 12 to 1.  
- Extreme heat waves are projected to cover double the amount of global land by 2020 and quadruple by 2040, regardless of future emissions trends.  
- New records continue to be set for warm temperature extremes. For instance, in the U.S. during February, 2017 there were 3,146 record highs set compared to only 27 record lows, a ratio of 116 to 1.  
- Nine of the ten deadliest heat waves have occurred since 2000 causing 128,885 deaths around the world.  
- Nearly one third of the world’s population is now exposed to climatic conditions that produce deadly heat waves.  
- Atmospheric humidity is rising.  
- The global water cycle has accelerated.  
- Extreme weather is increasing.  
- If global temperatures rise 2°C (3.6°F), the combined effect of heat and humidity will turn summer into one long heat wave. Temperature will exceed 104°F every year in many parts of Asia, Australia, Northern Africa, South and North America.  
- If global temperatures rise 4°C (7.2°F), a new “super-heatwave” will appear with temperatures peaking at above 131°F making large parts of the planet uninhabitable including densely populated areas such as the US east coast, coastal China, large parts of India and South America.

ICE
- Greenland is losing ~286 billion tons of ice annually, Antarctica is losing ~127 tons, and alpine glaciers are losing over 200 billion tons of ice annually.  
- West Antarctic ice sheet is in “unstoppable” retreat.  
- Melting on Greenland has accelerated.
OCEANS

- Cloud cover over Greenland is decreasing at 0.9 +/-3% per year. Each 1% of decrease drives an additional 27 +/-13 billions of ice melt each year.74
- Alpine glaciers have shrunk to their lowest levels in 120 years and are wasting two times faster than they did in the period 1901-1950, three times faster than they did in 1851-1900, and four times faster than they did 1800-1850.75
- Continental ice sheets are shrinking.76
- Arctic sea ice is shrinking (13% per decade) as a result of global warming.77
- Winter Arctic sea ice was the lowest on record in 2017.78
- In the Arctic, average surface air temperature for the year ending September 2016 was the highest since 1900, and new monthly record highs were recorded for January, February, October, and November 2016.79
- Rapid warming in the Arctic is causing the jet stream to slow and develop large planetary waves.80
- Regions of Earth where water is frozen for at least one month each year are shrinking with impacts on related ecosystems.81
- Extreme warm events in winter are much more prevalent than cold events.82
- Global snow cover is shrinking.83
- The southern boundary of Northern Hemisphere permafrost is retreating poleward.84
- Large parts of permafrost in northwest Canada are slumping and disintegrating into running water. Similar large-scale landscape changes are evident across the Arctic including in Alaska, Siberia, and Scandinavia.85
- In North America, spring snow cover extent in the Arctic is the lowest in the satellite record, which started in 1967.86

OCEANS

- The Atlantic Meridional Overturning Circulation has decreased 20%. The North Atlantic has the coldest water in 100 yrs of observations.87
- Air temperature over the oceans is rising.88
- Sea surface temperature is rising.89
- The oceans are warming rapidly.90
- Sea level is rising and the rate of rise has accelerated.91
- Today global mean sea level is rising three times faster than it was in the 20th Century.92
- Between 1993 and 2014, the rate of global mean sea level rise increased 50% with the contribution from melting of the Greenland Ice Sheet rising from 5% in 1993 to 25% in 2014.93
- We have already committed to a long-term future sea level 1.3 to 1.9 m higher than today and are adding about 0.32 m/decade to the total: ten times the rate of observed contemporary sea-level rise.94
- Over 90 percent of the heat trapped by greenhouse gases since the 1970’s has been absorbed by the oceans and today the oceans absorb heat at twice the rate they did only 18 years ago.95
- Excess heat in the oceans has reached deeper waters,96 and deep ocean temperature is rising.97
- Sea surface temperatures have increased in areas of tropical cyclone genesis suggesting a connection with strengthened storminess.98
- Oxygen levels in the ocean have declined by 2% over the past five decades because of global warming, probably causing habitat loss for many fish and invertebrate species.99
- Marine ecosystems can take thousands, rather than hundreds, of years to recover from climate-related upheavals.100
- Marine ecosystems are under extreme stress.101
- The world’s richest areas for marine biodiversity are also those areas mostly affected by both climate change and industrial fishing.102
- The number of coral reefs impacted by bleaching has tripled over the period 1985-2012.103
- By 2050 more than 98% of coral reefs will be afflicted by bleaching-level thermal stress each year.104
- Scientists have concluded that when seas are hot enough for long enough nothing can protect coral reefs. The only hope for securing a future for coral reefs is urgent and rapid action to reduce global warming.105
- Average pH of ocean water fell from 8.21 to 8.10, a 30 percent increase in acidity. Ocean water is more acidic from dissolved CO₂, which is negatively affecting marine organisms.106
- Dissolved oxygen in the oceans is declining because of warmer water.107
- Production of oxygen by photosynthetic marine algae is threatened at higher temperatures.108

SUMMARY

According to Raftery et al. (2017) the likely (66%)
range of global temperature increase over this century will be 2.0–4.9°C, with a median 3.2°C and a 5% (1%) chance that it will be less than 2°C (1.5°C).

What will this >3°C world look like?

- A global scale refugee crisis develops, as large parts of tropical continents become no longer habitable;
- Heat waves every summer in the middle latitudes that render the outdoors intolerable;
- Massive wildfires;
- Sea level, 10-15 m (30-50 ft), that will continue rising over many centuries;
- By 2050 wheat demand increases 60%, while actual yield decreases 15%;
- By 2100, 50% more people to feed, 50% less grain to give them;
- Among the world’s major aquifers, 21 out of 37 are receding, from India and China to the United States and France;
- Extreme weather disasters, massive floods, heat waves, great tropical cyclones, megadrought, and torrential rainfall will be widespread.

Ironically, with the ongoing global revolution in clean power, all this suffering and dystopia will be taking place in a world of solar panels, wind mills, electric cars, and cleaner air.

**GLOBAL OUTLOOK**

The U.S. Energy Information Administration forecasts global energy use to the year 2040. They project the following patterns: coal sustaining a 20-year-long plateau, natural gas plentiful and growing, carbon-free wind and solar growing rapidly in percentage terms but not fast enough to bring emissions down in absolute terms, and petroleum holding its own as the main source of energy for transportation, despite the arrival of electric vehicles.

With populations growing and developing nations getting richer, total energy consumption will keep climbing despite gains in energy efficiency. Fossil fuels will hold a 77% market share, and as a result greenhouse gas emission will increase in parallel. The EIA (2017) projects worldwide emissions of carbon dioxide from the burning of fossil fuels will grow 16% by the year 2040. This is far away from the necessary 50% decrease per decade necessary to meet the Paris Agreement target of 2°C (Figure 1).

**Figure 1.** The EIA (2017) forecasts a 16% rise in carbon dioxide emissions by 2040 (red circle). This is consistent with warming to 3 to 4°C by the end of the century. According to the Intergovernmental Panel on Climate Change (IPCC, 2013), the only pathway to stabilizing warming at 2°C is to employ negative emissions in the second half of the century (Global Carbon Project, 2017).

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4 Ullah, H., et al. (2018) Climate change could drive marine food web collapse through altered trophic flows and cyanobacterial proliferation. *PLOS Biology*; 16 (1): e2003446 DOI: 10.1371/journal.pbio.2003446


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76 Rignot, E., et al. (2011)
78 See http://nsidc.org/arcticeaice/health/
90 Wang, G., et al. (2017) Consensuses and discrepancies of basin-scale ocean heat content changes in different ocean analyses, Climate Dynamics. DOI: 10.1007/s00382-017-3751-5
104 Heron, S.F., et al. (2016)


There has been considerable research on the global and local implications of accelerating sea level rise. This brief by the City and County of Honolulu Climate Change Commission builds on the findings from the State of Hawai‘i Climate Mitigation and Adaptation Commission (2017), Sweet et al. (2017), USGCRP (2017), and Sweet et al. (2018) to provide more specific policy and planning guidance on responding to sea level rise by the City & County of Honolulu (hereafter “City”).

Summary of Key Findings by the City Climate Change Commission:

1. The research finds that, relative to the year 2000, global mean sea level (GMSL) is very likely (90-100% confidence) to rise 0.3–0.6 ft (0.09-0.18 m) by 2030, 0.5–1.2 ft (0.15-0.36 m) by 2050, and 1.0–4.3 ft (0.3-1.3 m) by 2100 (USGCRP, 2017).
2. Future emission pathways have little effect on projected GMSL rise in the first half of the century, but significantly affect projections for the second half of the century.
   a. Table 1 (supplementary information) provides estimates of projected GMSL under NOAA scenarios (Sweet et al., 2017).
3. Global carbon dioxide emissions are projected to grow 16 percent by the year 2040 (EIA, 2017).
   a. The likely range of global temperature increase is 3.6-8.8°F (2.0–4.9°C), with median 5.8°F (3.2°C) and a 5% chance that it will be less than 3.6°F (2°C) and a 1% chance that it will be less than 2.7°F (1.5°C) by the end of this century (Raftery et al., 2017).
4. Simulations show that under these conditions, melting of the Antarctic ice sheet could raise global sea level by up to 10 ft (3 m) by the year 2300 and continue for thousands of years thereafter (Golledge et al., 2015). Melting of other ice sources, and oceanic thermal expansion, could more than double this.
   a. Research indicates that on multiple occasions over the past three million years, when global temperatures increased 1.8 to 3.6°F (1 to 2C), melting polar ice sheets caused global sea levels to rise at least 20 ft (6 m) above present levels (Dutton et al., 2015).
5. Emerging science regarding Antarctic ice sheet stability suggests that under high emission pathways, a GMSL rise exceeding 8 ft (2.4 m) by 2100 is physically possible (USGCRP, 2017).
6. Regardless of emissions pathway, it is extremely likely (95-100% confidence) that GMSL rise will continue beyond 2100.
7. High tide flooding will arrive decades ahead of any GMSL rise scenario.
   a. Table 2 (supplementary information) provides estimates of when minor high tide flooding will arrive in Honolulu 6, 12, and 24 days per year (Sweet et al., 2018).
   a. Urbanized coastal areas become increasingly vulnerable to four types of flooding during high water and high wave events:
      1) Saltwater flow across the shoreline.
      2) Saltwater intrusion of drainage systems.
      3) Groundwater inundation.
         a) Intrusion of in-ground sewage systems.
         b) Intrusion of buried assets that are not sealed.
         c) Formation of new wetlands, initially concurrent with high tide.
      4) Rainstorms, especially concurrent with high tide.
   b. Shoreline retreat.
      1) This leads to land loss (coastal erosion) in the back-beach area.
2) If the back-beach area is composed of sand-rich dunes, sandy paleo shoreline deposits, or high wave sand berms, the released sand nourishes the retreating beach.

3) If the back-beach area is hardened, a beach is prevented from retreating. This leads to beach erosion, beach narrowing, and beach loss. Hardening has caused at least 5.4 mi of beach loss on Oahu (Fletcher et al., 2012).

c. Saltwater will intrude streams and coastal wetlands, increasing the salinity of the environment and threatening low-lying agriculture (e.g., kalo farming) and wildlife sanctuaries.

d. Wave, and eventually still water overtopping of Loko I’a kuapā (fishpond walls) will increase.
   1) Interior circulation will change (including at mākāhā).
   2) Upland discharge into the pond will change.
   3) Fishpond connections to the shore will become unstable.

e. Wave energy at the shore will increase.
   1) Muddy shore deposits may be released.

f. Damaging flooding will increase when hurricanes, tsunamis, and seasonal high waves strike.

g. Annual high waves, which arrive in Hawaii seasonally, will flood further landward and cause more damage, as sea level continues to rise.

9. State of the art modeling reveals a critical elevation in GMSL rise between 2 and 3.2 ft (0.6-1 m).
   a. This is a critical point where there is a rapid increase in land exposure to hazards on low-lying coastal plains such as characterize the urbanized south shore of Oahu.
   b. This is a dangerous elevation range, where reacting after the fact to establish adaptation strategies is likely to be less successful and costlier than taking proactive measures.

10. The research finds that high tide flooding in the 3.2SLR-XA; at least two dozen times per year, will occur by mid-century and as early as 2028:
   a. “Minor” (Sweet et al., 2018) high tide flooding occurs decades before GMSL rise impacts.

11. The research finds that it is reasonable to set as a planning benchmark up to 6 ft (1.8 m) of GMSL rise in the later decades of the century, especially for critical infrastructure with long expected lifespans and low risk tolerance.

Given the tools available to planners, stakeholders and policy-makers with the Hawai‘i Sea Level Rise Viewer, the NOAA SLR Viewer, and the Climate Central–Surging Seas Risk Finder, the Honolulu Climate Change Commission, pursuant to Revised Charter of Honolulu Section 6-107(h), recommends:

1. That the Mayor, City Council, and executive departments of the City utilize the 2017 Hawai‘i Sea Level Rise Vulnerability and Adaptation Report (hereafter “Report”) and online Viewer, for baseline planning activity and infrastructure assessment and development.
   a. The City must recognize that climate change poses significant, dangerous, and imminent threats to the perpetuation of Hawaiian culture, island residents and visitors, natural resources and environments, the economy, and government functions and planning.

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1 Here we use the term “3.2SLR-XA” to represent the SLR-XA (an acronym that stands for sea level rise-exposure area) as mapped by the Hawai‘i Sea Level Rise viewer: http://www.pacioos.hawaii.edu/shoreline/slr-hawaii/

1 Hawai‘i Sea Level Rise Viewer: http://www.pacioos.hawaii.edu/shoreline/slr-hawaii/

1 NOAA Sea Level Rise Viewer: https://coast.noaa.gov/digitalcoast/tools/slr

1 Surging Seas Viewer: https://riskfinder.climatecentral.org/county/honolulu-county.hi.us?comparisonType=postal-code&forecastType=NOAA2017_int_p50&level=3&unit=ft
b. Negative impacts of climate change will tend to exacerbate socio-economic inequality in our community with amplified impacts among under-served populations.

c. Sea level rise challenges physical, environmental, and socio-economic systems.
   1) Managing these systems should be guided by specific design principles for separate zones threatened by 3.2 ft (1 m) and 6 ft (1.8 m) of sea level rise.
      a) The principle of risk reduction should guide management of physical systems.
      b) The principle of green networks should guide management of environmental systems.
      c) The principle of place-making should guide management of socio-economic systems.

2. That the City and County of Honolulu recognize the 3.2SLR-XA as marking the land area impacted by 3.2 ft (1 m) of sea level rise (mapped on the Hawai‘i Sea Level Rise Viewer) and the area that will be affected by minor and moderate high tide flooding.
   a. Revise the Special Management Area (SMA) boundary to include parts of the 3.2SLR-XA that are not in the SMA already.
   b. Establish a goal of redeveloping the 3.2SLR-XA as parkland, designed to naturally evolve to wetland with continued sea level rise.
      1) Include storm water management as a major goal of parkland and wetland in the 3.2SLR-XA.
   c. Develop special guidelines for all planning, permitting, decisions, and activities in the 3.2SLR-XA to promote managed retreat by mid-century.
      1) Limit or prohibit major renovation of existing development that would increase vulnerability and exposure in the 3.2SLR-XA.
      2) Impose strict building and flood proofing requirements.
      3) Prohibit public infrastructure if not specifically designed to withstand sea level rise impacts.
      4) Design these guidelines to incrementally increase the regulatory burden on all development and non-conservation land-use activities by 2050.
   d. Require disclosure of all lands in the 3.2SLR-XA.
      1) Disclosure on all real estate sales.
      2) Disclosure on Property Information Sheets.
      3) Disclosure on all real property assessment and registration documents and activities.
      4) Disclosure on all tax, loan, lien, and insurance documents and assessments.
   e. Ensure that major transportation corridors in the 3.2SLR-XA adapt to 3.2 ft (1 m) of sea level rise with flexibility to adapt to 6 ft (1.8 m) of sea level rise later in the century.
   f. In certain critical infrastructure or economic areas (e.g., Waikiki, Honolulu Harbor), establish specific strategies to adapt to 3.2 ft (1 m) of sea level rise in the 3.2SLR-XA. Incorporate flexibility to adapt to 6 ft (1.8 m) of sea level rise by later in the century.
   g. Implement consistent and predictable beach conservation policies in the 3.2SLR-XA.
      1) Establish as inviolate, existing CZM goals (environmental conservation, public access, open space).
      2) Establish set-back rules that:
         a) Promote dune (or storm berm) conservation;
         b) Promote retreat from the 3.2SLR-XA.
   h. Immediately add 2 new staff positions to DPP specifically for implementing the new rules and policies necessary to carry out these recommendations, and for reviewing the permit applications that result.

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1 See Project for Public Spaces, “What is placemaking?” https://www.pps.org/category/placemaking
1) Increase the number of staff positions commensurate to demand.
2) Add an “Adaptation Assessment Fee” (e.g., $2500) to all permit applications and other related demands on DPP staff time.
   i. Establish a partnership with the University of Hawaii, and other institutes of higher education, to train students in climate change adaptation, especially sea level rise adaptation (e.g., certificate program) for staffing local agencies, corporations, NGO’s, and other entities faced with managing the challenges of sea level rise.
3. That 6 ft (1.8 m) of sea level rise (available on the NOAA Sea Level Rise Viewer) be adopted as the basis for planning and to guide decisions on all new development and infrastructure that have an expected physical life extending into the second half of this century, or for any other reason are deemed to be development with low risk tolerance.
   a. Delineate and adopt the 6SLR-XA as a hazard overlay for planning and to guide decisions on all new development and infrastructure that has an expected physical life extending beyond mid-century.
   b. Emphasize resiliency to flooding (of all types) as major design elements of the 6SLR-XA. Design and construct retention basins in selected upper watersheds, and wetlands in low-lying regions.
   c. Model hazards in the 6SLR-XA using the most current climate change scenarios.
4. That all City departments be directed to use the Report, the 3.2SLR-XA, and the 6SLR-XA in their plans, programs, policies, and capital improvement decisions, to mitigate impacts to infrastructure and critical facilities triggered by sea level rise.
5. That the City Department of Planning and Permitting propose rule changes to include sea level rise in their permitting decisions and in shoreline setback calculations.
6. That the areas in the 3.2SLR-XA and the 6SLR-XA be adopted as hazard overlays for planning under the City and County General Plan, all Development Plans, and Sustainable Community Plans.
7. That implementing ordinances and regulations be established to carry out the intentions of the revised plans.
   a. New ordinances and regulations may include zone changes, land use ordinances, subdivision ordinances, sign regulations, special use permits, and others as applicable.
8. That the expectation of minor high tide flooding before mid-century be immediately integrated in all considerations within the 3.2SLR-XA permitting process.
9. That planners and other relevant parties use available Viewers to inform their decision-making to immediately support compatible activities and land uses within the 3.2SLR-XA and 6SLR-XA.

The Commission adopts the precautionary principle and a scenario-based planning approach and supports these recommendations as planning targets informed by the best available science. The Commission fully acknowledges that there is uncertainty in the timing and magnitude of sea level rise projections globally and for Hawai‘i. The Commission also acknowledges that these recommendations constitute a major additional obligation to agency staff. We therefore recommend that new resources be made available for the successful achievement of these recommendations. This is a living document that will be updated with increasing data.
Supplementary Information

Global Mean Sea Level will rise 3.2 ft (1 m) relative to the year 2000. NOAA (Sweet et al., 2017) has published scenarios that provide estimates, by decade, of when GMSL will hit this benchmark (Table 1).

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Time Benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate Scenario</td>
<td>end of the century</td>
</tr>
<tr>
<td>Intermediate High Scenario</td>
<td>decade of the 2080's</td>
</tr>
<tr>
<td>High Scenario</td>
<td>decade of the 2070's</td>
</tr>
<tr>
<td>Extreme Scenario</td>
<td>decade of the 2060's</td>
</tr>
</tbody>
</table>

Gravitational forces will cause regional sea level in the North Central Pacific to rise above the global mean (Spada et al., 2015). NOAA suggests planners use higher scenarios for large projects with low risk tolerance. This recommendation is also made by the US Army Corps.

High tide flooding will arrive decades ahead of GMSL. NOAA has published a model of high tide flooding for the Honolulu Tide Station (Sweet et al., 2018). Relative to MHHW, the threshold for minor high tide flooding is 1.7 ft (0.52 m), for moderate high tide flooding is 2.6 ft (0.8 m), and for major high tide flooding is 3.8 ft (1.17 m).

High tide flooding has never occurred at the Honolulu Tide Station as none of these thresholds has ever been crossed. Table 2 provides estimates of when minor high tide flooding will arrive in Honolulu 6, 12, and 24 days per year using the NOAA model.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>6 x per year</th>
<th>12 x per year</th>
<th>24 x per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate Scenario</td>
<td>2038</td>
<td>2041-2042</td>
<td>2044-2045</td>
</tr>
<tr>
<td>Intermediate High Scenario</td>
<td>2030</td>
<td>2033</td>
<td>2035-2036</td>
</tr>
<tr>
<td>High Scenario</td>
<td>2025-2026</td>
<td>2028-2029</td>
<td>2030-2031</td>
</tr>
<tr>
<td>Extreme Scenario</td>
<td>2024</td>
<td>2026</td>
<td>2028-2029</td>
</tr>
</tbody>
</table>

Because of the exponential nature of the NOAA sea level scenarios, the doubling time of high tide flooding is brief in all scenarios. High tide flooding events are likely to cluster around the summer solstice. High tide flooding will occur first in the 3.2SLR-XA as defined in the Hawaii Sea Level Rise Vulnerability and Adaptation Report (2017).

High tide flooding can take several forms. Beach erosion will be pronounced during high tide flooding events. Storm drain flooding will occur where marine water blocks drainage and spills out onto the street, or where runoff cannot drain and causes flooding around storm drain sites. Groundwater inundation will develop where the water table rises to break the ground surface and creates a wetland. At first this flooding is most common when high tide and precipitation occur simultaneously, but eventually occurs without precipitation at high tide. Rainfall that occurs at high tide when storm drains are blocked and the ground is saturated will lead to widespread flooding. Marine flooding will occur at high tide when seawater flows over the shoreline. Wave flooding will occur at high tide during typical seasonal swell events as waves run-up past the shoreline and into the backshore. Tsunami and storm surge occurring at high tide will cause greater flood damage than historically.
Modeling of sea level rise impacts on Oahu (Report) reveals the following:

1. Over the next 30 to 70 years, homes and businesses on Oahu’s shorelines will be severely impacted by sea level rise. Nearly 4,000 structures will be chronically flooded with 3.2 ft (1 m) of sea level rise (Figure 1).

2. Of the 9,400 acres of land located within the 3.2SLR-XA, over half is designated for Urban land uses, making O‘ahu the most vulnerable of all the islands.

3. With 3.2 ft (1 m) of sea level rise, almost 18 mi (30 km) of Oahu’s coastal roads will become impassible, jeopardizing access to and from many communities.

4. O‘ahu has lost more than 5 mi (8 km) of beaches to coastal erosion fronting seawalls and other shoreline armoring. Many more miles of beach will be lost with sea level rise if widespread armoring is allowed. In the Report, Chapter 5 (Recommendations) explores opportunities to reduce beach loss by improving beach protection policies.

5. A more detailed economic loss analysis is needed of Oahu’s critical infrastructure, including harbor facilities, airport facilities, sewage treatment plants, and roads. State and County agencies should consider potential long-term cost savings from implementing sea level rise adaption measures as early as possible (e.g., relocating infrastructure sooner than later) compared to the cost of maintaining and repairing chronically threatened public infrastructure in place over the next 30 to 70 years.

Figure 1. Sea level rise impacts on Oahu.
References and Additional Reading:


Anderson, T.R., et al. (in review) Modeling recurrent sea level rise stresses reveals 50% more land at risk. *Manuscript*


