Resources & context for building resilience in the Bay Area

RESILIENT BY DESIGN
BAY AREA CHALLENGE

Briefing Book

Introduction by Shaun Donovan

San Francisco Bay is a natural treasure; and has long captured the imagination of our nation. This region boasts natural assets from the Golden Gate Bridge and vineyards in Napa to salt flats ringing the South Bay. The Bay Area has long attracted migrants and immigrants from around the country and around the world, and has nurtured innovative social, political, and economic movements throughout its history. From the Gold Rush to Silicon Valley, from social movements of the 1960s to climate justice leaders today, the Bay Area's residents have lead the way in addressing the most challenging issues facing our times.

As the residents of the Bay Area have struggled and thrived, the balance between a critical ecological system and growing urban area has always been fragile. Human activities have severely limited wildlife habitat, wetlands and marshland around the Bay. Fortunately, over the last 20 years, that tide has begun to shift, with a much greater understanding of the benefits of a healthy bay, and investment in bay restoration.

Unfortunately, as the region slowly integrates this greater knowledge into planning and development efforts, the rapidly accelerating effects of climate change are threatening our local communities, the baylands and shoreline, and our critical infrastructure. We know we are facing a future of more extreme weather events and rising sea levels. We know these rapid changes threaten to overwhelm the resilience of the Bay's ecosystems. Vulnerable shoreline communities that have already faced systemic inequities are likely to be hardest hit by climate change. San Francisco Bay's shoreline ecosystems will be on the front lines of sea level rise and can play a role in protecting human communities.

To protect our local communities and economy from devastating impacts, and enable San Francisco Bay and its wildlife to survive and thrive, we can't rely on our current systems. We're just not prepared for these increasing threats that are hard to predict, cut across jurisdictional boundaries and exacerbate existing challenges that are both physical – i.e. seismic risks - and social — i.e. regional economic inequality. We must find ways to accelerate our commitment to reinstating, enhancing and replicating the natural processes that make this ecosystem and this region resilient.

Resilient by Design gives the Bay Area an opportunity to proactively prepare for sea level rise and other climate change impacts. People are looking to California now to provide leadership in how we protect our communities and adapt to climate change. Through the open and collaborative process of Resilient by Design, the solutions we generate together can provide a national model. Resilient solutions "by Design" will enliven the public's imagination and ensure that the final projects provide technical solutions to climate threats, but also address multiple community concerns and enhance lives today and for generations to come.

The original Rebuild by Design, launched after Hurricane Sandy, was an innovative and successful new model for disaster recovery. Resilient by Design takes the concept to the next level, preparing for disaster before it happens through not just planning but actual implementation of on the ground projects. If we in implementing this project in this context, without the significant disaster recovery funds that were available after Hurricane Sandy, Resilient by Design can serve as a detailed model for regions throughout the country and the world looking to prepare for the coming effects of climate change.

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Support for this Report:
The Rockefeller Foundation

Book and infographic design:
Shawn Hazen | HazenCreative.com

Special thanks also to Naomi Feger and Cristina Toms from the Regional Quality Control Board for their comments and contribution to the regulatory framework content.

About Resilient by Design | Bay Area Challenge
Resilient by Design | Bay Area Challenge is a collaborative research and design project that brings together local residents, public officials and local, national and international experts to develop innovative solutions to the issues brought on by climate change that our region faces today. It was modeled on New York Rebuild by Design, a successful program pioneered by The Rockefeller Foundation in partnership with the U.S. Department of Housing and Urban Development. This program will forge close ties with The Rockefeller Foundation's 100 Resilient Cities network, which is seeking to help 100 cities build resilience to thrive in 21st-century. Resilient by Design will leverage the network's existing resources and institutional knowledge to accomplish shared goals across the Bay Area.

About the San Francisco Estuary Institute
The San Francisco Estuary Institute (SFEI) provides independent science to assess and improve the health of the waters, wetlands, wildlife and landscapes of San Francisco Bay, the California Delta, and beyond. Additional resources for the RBD Challenge are available at sfei.org/rbd

About Resilient Communities Initiative
The Resilient Communities Initiative (RCI) is a coalition of environmental justice and community-based organizations in the San Francisco Bay Area creating a national model for resilience planning led by communities that are most impacted by climate change. The RCI was founded in 2013.

COVER PHOTO: DENNIS HEARNE

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About This Document

The Resilient by Design Bay Area Challenge Briefing Book is intended as a reference guide for Design Teams as they embark on the Challenge. The aim is to provide compilation of useful existing resources and context pertaining to resilience in the Bay Area. While not comprehensive, we hope this document will serve as starting place for inquiry and a source of inspiration. We are excited to be on this journey with you.

The Challenge

GRAPHIC: ADAPTED FROM IPCC

The seas are rising.

Here in California and across the globe, communities are feeling the impacts of climate change. Extreme weather events are increasing, and trends in precipitation and temperature are quickly departing from those that existed as human life emerged on this planet. Many scientists have now begun to refer to this new climate era as the Anthropocene, a distinct geomorphologic epoch shaped by human activity.[1] While the continued transition away from fossil fuels and onto renewable energy sources continues to be critical, dovetailing climate mitigation and climate adaptation has become imperative.

Climate change has presented an opportunity to reimagine our relationship to the natural world and to each other. As we plan for the impacts of climate change in the Bay Area, we must seek transformational change toward true long-term prosperity. This transformation will require confronting our shared history, and centering social equity in our decision-making practices. When solutions center social equity, they are best positioned to result in positive outcomes across social-ecological systems.

The Resilient by Design Bay Area Challenge views climate adaptation as a tremendous opportunity to facilitate innovation. Our goal is to implement an iterative and collaborative design process that creates the opportunity for community collaboration at every stage. We believe that the best climate resilient design is informed by both professional expertise and local knowledge, and that planning for real world implementation should be central to this practice. By building on the work already happening at the community, city, and regional level, we can transform the process by which we arrive at built environment solutions to climate change.

What is resilience?

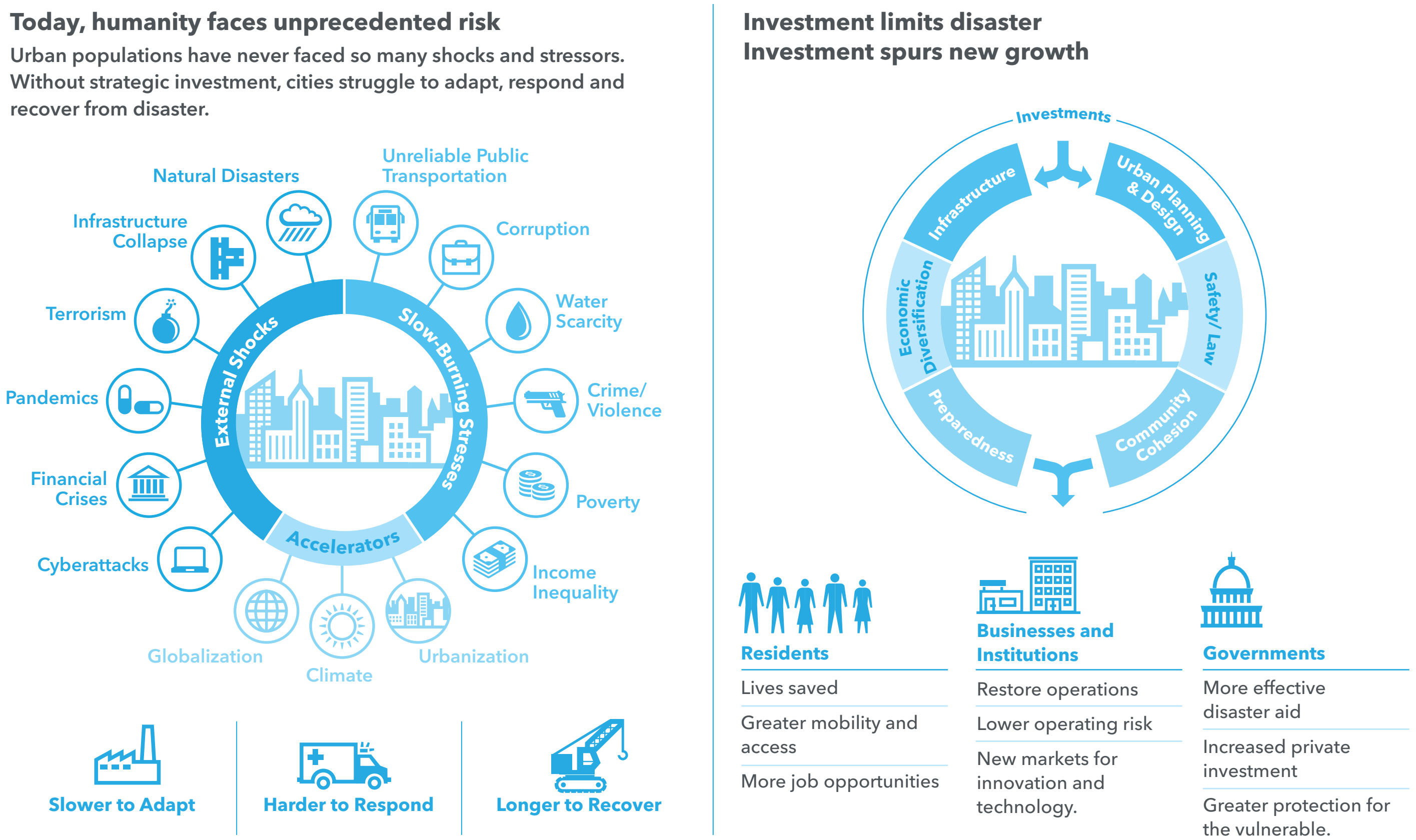
'Resilience' is the capacity of individuals and systems to respond to, thrive, and adapt in the face of chronic stressors and acute shocks.[2] The concept of resilience is rooted in ecology, the study of the complex systems that create the fabric of life on our planet. As our knowledge of ecosystem processes has deepened, we have gained better insight into the adaptive and dynamic systems at work. While a beach or a forest can seem frozen in time, ecosystems and landscapes are ever-changing processes. They are systems of systems that create a whole. Simply put, no system of living things is ever static.

Social-ecological and urban-regional systems are no different. As we seek to address the complex problems that our neighborhoods, cities, and regions face, it is critical that we find new ways of harnessing our collective capacity for creative thinking and innovation. The changing nature of our world requires solutions as complex as the problems we need to solve.

Many frameworks and approaches have emerged to describe and plan for adaptive and resilient city systems. The Rockefeller Foundation's 100 Resilient Cities defines Urban Resilience as "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience."[3] Resilience is thus key to responding to climate change impacts.

RESEARCH QUESTION

How can building resilience at the community level be scaled to address regional challenges?



GRAPHICS: ADAPTED FROM IPCC

FIGURE 1:
THE RESILIENCE DIVIDEND

PHOTO: MARISA VILLARREAL

Climate Adaptation in California

From the landmark climate change Assembly Bill 32 in 2006 to Governor Brown's recent agreement with China, California has positioned itself as an international leader on climate change. More recently, California has doubled down on its commitment to combatting climate change by signing new climate emissions reduction goals with China through utilizing clean energy investments. In 2009, California began a statewide Climate Adaptation Strategy leading to the 2014 Safeguarding California Plan. The 2017 Update is in process now.[4] Governor Brown signed Senate Bill 246 in 2015 to form a Climate Adaptation and Resilience Program to coordinate adaptation at state, regional and local levels.

The 2013 California Climate Assessment outlined major areas of concern for climate impacts in the state, including drought, wildfire, and sea level rise. There are several major data sets being used to model the impacts of sea level rise locally. See the *Sea Level Rise and Flooding* section for further information.

Additionally, California Indian Tribes are creating climate adaptation plans that consider a wider history of landscapes and ecosystems that span thousands of years, that consider a wider ecosystem approach, and that seek to protect culturally significant physical features, medicines, subsistence foods and other culturally imperative resources that rely on fragile threatened and interconnected bay area aquatic habitats. Co-management of environmental resources is preferred by many California Tribes who seek balance when faced with threats to cultural continuance because of climate change.

Key adaptation planning documents and processes

Federal

The EPA previously released recommendations around climate resilience and adaptation planning solutions for local communities. The Climate Adaptation Resource Center may provide some helpful framing for the broader national context of climate adaptation. *https://www.epa.gov/arc-x/planning-climate-change-adaptation*

State

Cal-Adapt is an excellent resource for state level recommendations and policy considerations around adaptation and resilience. On the website, you can browse climate impacts research as well as download data and explore community challenges. *http://beta.cal-adapt.org/*

Local

There are many climate resilience and adaptation planning processes underway in the Bay Area. Among them are the following:

→ Bay Area Rapid Transit (BART) Climate Adaptation Pilot Assessment Report Summary can be found here: *https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA0074_Research_Report_Summary.pdf*

- Operational Landscape Units: The San Francisco Estuary Institute is conducting research funded by the San Francisco Regional Water Quality Control Board to define practical, science-based landscape units focusing on watershed, creek and baylands processes for the Bay Area. Called "Operational Landscape Units", these units include baylands and shoreline areas. These approximately 30 OLU's will facilitate a geographically-specific set of integrated adaptation strategies to address issues of both the natural and built environment. The project is in early stages, and will run through 2018. *http://resilience.sfei.org*

- Mapping Our Future: 2013 study of 350 respondents, Bay Localize (now Rooted in Resilience) found community members wanted to be involved in planning decisions around resilience, and want associated funding and professional development opportunities. *http://www.baylocalize.org/files/EquityReportFinal041213v11.pdf*

- Resilience Atlas: The Resilience Atlas is an interactive mapping platform that visualizes the past, present and future conditions of the Bay's edge and surrounding watersheds by combining layers of information, such as shoreline infrastructure, shoreline change over time, and sea level rise. The project aims to aid regional planning efforts, restoration managers, government organizations, nonprofits, and citizens and serve as a repository of scientific analysis. *http://resilienceatlas.sfei.org*

- The Adapting to Rising Tides program of the San Francisco Bay Conservation and Development Commission (BCDC) is a comprehensive toolkit created to aid in decision-making processes around climate adaptation solutions. They provide data, strong analysis, and helpful guidance on reaching climate adaptation solutions. *http://www.adaptingtorisingtides.org/*

- The Association of Bay Area Governments (ABAG) Resilience Program, now a part of the Metropolitan Transportation Commission (MTC), has created an adaptation clearinghouse for local governments to submit their resilience and adaption planning documents. *http://resilience.abag.ca.gov/*

- ABAG also provides helpful analysis on the impacts of seismic and flooding risk to housing stock and potential mitigation strategies. *http://resilience.abag.ca.gov/projects/stronger_housing_safer_communities_2015/*

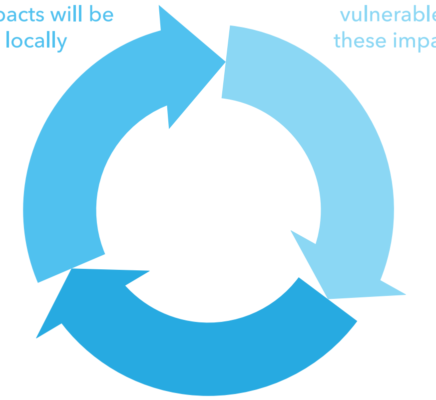
- The Climate Readiness Institute has created a Climate Adaptation Planning Clearinghouse which can be a useful guide to additional planning processes underway." *http://www.adaptationclearinghouse.org/organizations/climate-readiness-institute-sf-bay-area.html*

Tribal

- Many Bay Area Indian Tribes are also undergoing climate adaptation planning processes which will be explored in the collaborative research phase.

FIGURE 2: THE RESILIENT COMMUNITIES INITIATIVE APPROACH TO RESILIENCE PLANNING

Climate risk is a function of exposure to impacts, vulnerability to them, and ability to adapt. The task of climate adaptation planners is to understand the interactions between three sets of complex information:



Impacts of climate change will be felt both as acute events, such as natural disasters, and also as gradual changes, such as rising food prices. Climate adaptation planning needs to prepare for both types of change. Climate vulnerability is heavily influenced by income, race, health conditions, age, living conditions/location, occupation, language barriers, and related factors. Identifying highly vulnerable populations is a complex task in the Bay Area, a region with a majority of people of color, immigrants from around the world, and vast disparities in wealth and health outcomes.

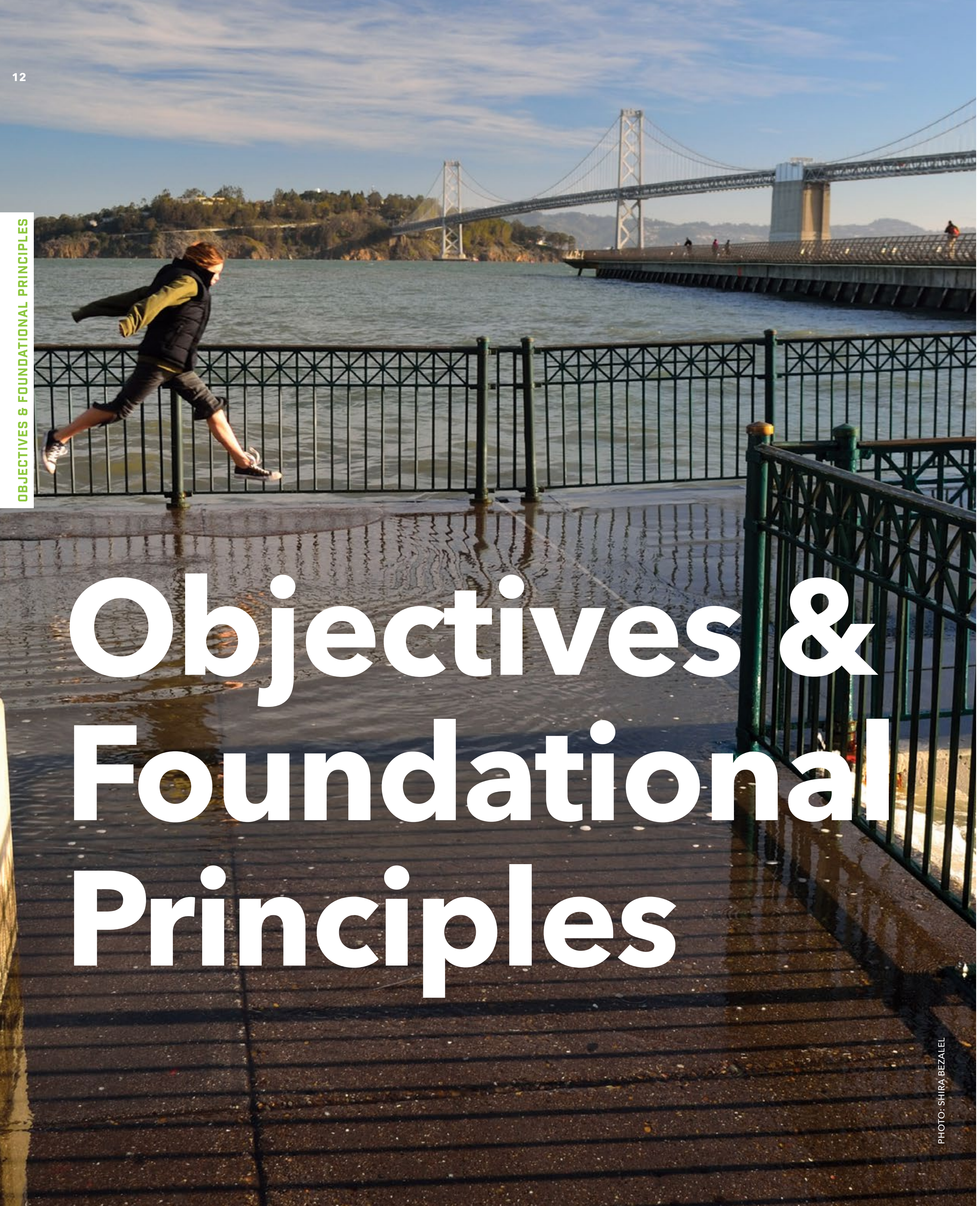
PHOTO: KARL NIELSON

Resilience is equity

Planning for climate resilience starts with understanding the vulnerabilities our communities and ecosystems face. While the impacts of climate change will touch everyone's lives, people who are most marginalized will be hit hardest. Resilience outcomes will therefore be tied heavily to the pre-existing vulnerabilities in a particular neighborhood or local jurisdiction. As Breakthrough Communities describes, "*Hurricane Katrina and Superstorm Sandy highlighted how extreme weather events caused by climate change exacerbate inequities caused by society's racism and classism, and how those inequities play out in survival, recovery and resilience.*"[5]

In planning for climate adaptation, it is critical that these underlying vulnerabilities be addressed, and that the process of planning for resilient solutions be grounded in community self-determination. NOAA's U.S. Climate Resilience Toolkit describes it this way: *"In climate adaptation, the higher vulnerability and risk of damage from storms for some populations is an issue of social equity. Additionally, the exclusion of people or groups from full participation in making decisions about climate adaptation based on their income, neighborhood, or social status is a social equity issue."*[6]

Planning for resilience with communities that are most vulnerable to the impacts of climate change is critical to the success of climate adaptation efforts overall. The Resilient Communities Initiative has created a set of best practices that can serve as a helpful guide to the process of embarking on outreach to communities that are most-impacted by climate change.



Objectives & Foundational Principles

PHOTO: SHIRA BEZALEL

CHALLENGE OBJECTIVES:

The challenge seeks local, regional, and international knowledge to create ten design projects that will:

- Combine implementable and creative design-driven ideas with technical expertise
- Reflect rigorous research and a strong understanding of ecosystems, local community, and government challenges
- Inspire collaboration, connection, and coordination across the region
- Prepare communities for the future by addressing ecological, economic, and social vulnerabilities that exist today.

Addressing multifaceted, dynamic issues through collaboration, coordination, and connection

Planning for sea level rise will require coordination and connection across many regional jurisdictions and complex local contexts. Managing and planning for resilience draws on the understanding of complex adaptive systems and seeks dynamic, multi-faceted solutions. Whereas often the goal in addressing ecological or societal issues is to narrow the scope of the problem enough to find a simple solution, resilience requires expanding the scope of the problem to achieve solutions with more dimensionality. By understanding complex problems in a complex system, we can better identify solutions that solve for many challenges at once.

Prepare communities for the future by addressing our shared history, and ecological, economic, and social vulnerabilities that exist today

Understanding history, context, and current vulnerability is critical to addressing current and future challenges. The 100 Resilient Cities Resilience Framework describes this principle as "reflective." "Individuals and institutions that are reflective use past experience to inform future decisions, and will modify standards and behaviors accordingly. For example, planning processes that are reflective are better able to respond to changing circumstances."[7]

The history of the Bay Area is rich with lessons to inform our current practice. A critical piece of understanding our shared history is confronting the roots of systemic racism and addressing the enduring reproduction of marginalization in our city and regional systems. The challenges we face in planning for the sustainability of our bay ecosystems are similar to those we face in planning for equity and prosperity in our neighborhoods. As Breakthrough Communities explains, "The same policies that drove segregation and disinvestment in communities of color also generated suburban sprawl, excess driving and air pollution that threaten our health and contribute to the climate crisis. Because social inequality and environmental decline share common roots, they must be tackled together to find shared solutions."[8] Before solutions can be reached and a better future can be forged, it is critical to acknowledge both positive and negative aspects of our shared history, and work toward community cohesion.

RESEARCH QUESTION

What are the best tools for conducting vulnerability assessments at the community level?

Acknowledging place and the First Nations of the Bay Area

The Resilient by Design Bay Area Challenge will be taking place on the ancestral homeland of some 80 Tribes, including descendents of the Ohlone (also referred to as "Costanoan") and the Miwok people.[9] The majority of Bay Area Tribes are not state or federally-recognized, thus they "receive none of the rights, benefits, compensations or protections afforded to Indian Tribes under US laws."[10] It is important to acknowledge those indigenous to this place: how they survived disease and centuries of policies that resulted in genocide, displacement, and persecution[11] and the ways in which they still survive and thrive throughout the Bay Area today. In the context of climate change, resilience, and the Bay Area, "place" is deeply connected to a powerful relationship between the Indigenous people and the land they come from, especially as it relates to "ancestral knowledge, cultural memory, and historical significance."[12] Despite colonialism and the history associated with it, those indigenous to the Bay Area continue to actively organize and advocate for their needs that almost always exist at the nexus of land and Indigeneity.

When considering this historical context, it is important to recognize that the repression of Bay Area Indigenous peoples is connected to the ongoing repression of the natural physical and aquatic landscapes, originally maintained by Bay Area Tribes. Communities who live in the Bay Area are more vulnerable to changes in climate change in part because of the destruction of these previous features and systems.

RESEARCH QUESTION

How can Traditional Ecological Knowledge (TEK) inform resilience solutions at the regional and local scale? What ways is TEK creating resilience currently?

Ceremony at 2011 Sogorea Te' Occupation (Sogorea Te' Land Trust, 2017.)

PHOTO: CALIFORNIA INDIGENOUS ENVIRONMENTAL ALLIANCE

Integrating social and ecological systems through rigorous research and a strong understanding of ecosystems, local community, and government challenges

Despite being a highly urbanized and altered estuary[13], the San Francisco Bay has great potential for nature-based, multi-benefit design solutions integrated with the highly urbanized shore. The San Francisco Bay retains a vast core area of wetlands—some that are diked and others that are natural tidal marshes. These marshes have great value as self-maintaining shields for the shoreline. They knock down waves and reduce erosion during high water events. With sufficient sediment available, they can grow vertically with sea level rise and continue providing services, requiring little to no maintenance. Tidal wetlands also provide many other benefits, including nutrient processing, primary productivity, contaminant sequestration and breakdown, recreation opportunities, and support for threatened and endangered wildlife. Thus, they offer more value than many engineered, single-benefit solutions that require ongoing maintenance and retrofitting. Optimal designs for San Francisco are likely to fall along a continuum from fully natural to completely constructed. Although natural processes cannot always be restored, they can often be enhanced or emulated, presenting many opportunities to create innovative approaches.

PHOTO: KARL NIELSON

A remarkable alignment among scientists, government agencies and nonprofits around how to incorporate nature-based solutions was recently achieved for San Francisco Bay. Over 100 scientists and other experts, guided by a steering committee of government entities, created *The Bayland Goals,* a report on how to rethink bay wetlands restoration and shoreline design as the climate changes.[14] This report offers 10 regional-scale recommendations and smaller-scale recommended actions for each segment of the shoreline, as well as the scientific bases for these guidelines.

The regional recommendations from the 2015 Bayland Goals Update to guide future Estuary restoration and enhancement projects include:

- **Restore** estuary-watershed connections
- **Design** complexity and connectivity into the Baylands landscape
- Restore and **conserve** complete tidal wetlands systems
- **Restore** baylands to full tidal action prior to 2030
- **Plan** for the Baylands to migrate
- Actively **recover**, conserve, and monitor wildlife populations
- Develop and **implement** a comprehensive regional sediment management plan
- **Invest** in planning, policy, research and monitoring
- **Develop** a regional transition zone assessment program
- **Improve** carbon management[15]

Considering the significant proportion of the Bay that is surrounded by marshes and mudflats and the significant efforts to restore these natural areas over the last five decades, there has been a considerable amount of attention paid to how critical wetlands will evolve in the future and the role they may play future adaptation strategies. The role of natural and nature-based features (NNBF)[13] is being closely examined in the Bay and there are a number of pilot projects in the Bay that will provide useful information on how natural features may contribute to the resilience of the shoreline. BCDC's Innovative Wetland Adaptation Techniques Project (BCDC 2013)[18] provides a recent overview of the role that the natural shoreline can contribute to adaptation strategies.

1	SETTING	Unique geophysical, biological, and cultural aspects of a landscape that determine potential constraints and opportunities for resilience
2	PROCESS	Physical, biological, and chemical drivers, events, and processes that create and sustain landscapes over time
3	CONNECTIVITY	Linkages between habitats, processes, and populations that enable movement of materials and organisms.
4	DIVERSITY & COMPLEXITY	Richness in the variety, distribution, and spatial configuration of landscape features that provide a range of options for species
5	REDUNDANCY	Multiple similar or overlapping elements or functions within a landscape that promote diversity and provide insurance against loss
6	SCALE	The spatial extent and time frame at which landscapes operate that allows species, processes, and functions to persist
7	PEOPLE	The individuals, communities, and institutions that shape and steward landscapes

FIGURE 3:
SFEI's Landscape Resilience Framework is designed to facilitate application of resilience principles to urban design, conservation planning and ecosystem management by detailing the seven dimensions of a landscape that contribute to resilience. When combined, these seven principles embody the most critical considerations when planning for ecological landscape resilience.[16]

CHART 7: ADAPTED FROM GARE

FIGURE 4:
GOVERNMENT ALLIANCE FOR RACIAL EQUITY RACIAL EQUITY TOOLKIT

STEP 1 — Set Outcomes
Leadership communicates key community outcomes for racial equity to guide analysis.

STEP 2 — Involve Stakeholders & Analyze Data
Gather information from community and staff on how the issue benefits or burdens the community in terms of racial equity.

STEP 3 — Determine Benefit and/or Burden
Analyze issue for impacts and alignment with racial equity outcomes.

STEP 4 — Advance Opportunity or Minimize Harm
Develop strategies to create greater racial equity or minimize unintended consequences.

STEP 5 — Evaluate. Raise Racial Awareness. Be Accountable.
Track impacts on communities of color over time. Continue to communicate with and involve stakeholders. Document unresolved issues.

STEP 6 — Report Back
Share information learned from analysis and unresolved issue with Department Leadership and Change Team.

Principles to sustain biodiversity and ecological functions

Ecosystems with the capacity to adjust and reassemble in response to significant changes are increasingly important to maintain biodiversity and ecological functions across our landscapes in the context of an uncertain future. Seven key mechanisms exist that contribute to the resilience of ecosystems, as defined by *Landscape Resilience Framework* report, which can be used to provide a holistic framework to consider potential actions likely to confer ecological landscape resilience. These principles include: setting, process, connectivity, diversity/complexity, redundancy, scale and people. When combined, these seven principles embody the most critical considerations when planning for ecological landscape resilience.[19]

Merging local, regional, and international knowledge with technical expertise toward implementable and creative design-driven ideas

Closely linked with understanding our history and social-ecological context is the practice of merging local knowledge with professional expertise. While historically professional expertise has been valued higher in the dominant narrative than local knowledge, that knowledge is critical to developing solutions to multifaceted problems that work for communities. Planning processes that value and integrate local knowledge can be more responsive to community needs and are much more likely to result in real world implementation.

In the Bay Area, several sea level rise and hazard mitigation planning processes are already integrating knowledge sharing processes between experts and community. For example, Shore Up Marin's community tours bring city, county and other experts together with community members to tour impacted areas and share information with one another. Their current collaboration with Marin County Public Works and Marin City Community Service District on the Marin City Flood Study has been a particularly promising effort. Processes like these can serve as examples for potential engagement tactics.[20]

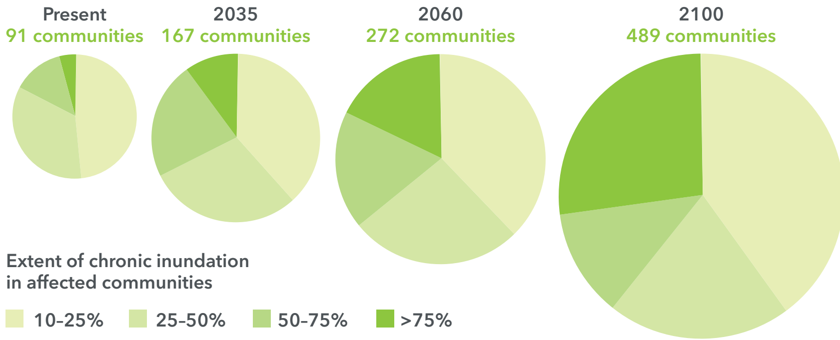


FIGURE 5:

INCREASING EXTENT OF CHRONIC INUNDATION

As sea level rises, the number of communities facing chronic inundation grows, as indicated here by the area of each circle. The extent of inundation within those affected communities grows as well. Of the 91 communities grappling with chronic inundation today, only four experience frequent, disruptive flooding of 75 percent of more of their land area (darkest blue wedge). In the intermediate scenario, 489 communities face chronic inundation by 2100, and more than 130 of them will see 75 percent or more of their land flooded twice per month, on average.

GRAPHIC: ADAPTED FROM UNION OF CONCERNED SCIENTISTS. PHOTO: KARL NIELSON

Equitable planning and development practice

Devising decision-making processes that center equity in their outcomes is critical to the success of this project and to the resilience of our region. Communities that are most marginalized are at higher risk implications of climate related disasters and chronic stressors. Because of this, it is critical that our development, processes, and implementation seek to remove barriers to participation and engage communities that will be most impacted by climate. By creating a collaborative and iterative process at every stage, we will ensure that solutions are more closely aligned with the issues faced by people who stand to lose or gain the most through these interventions. Additionally, solutions focused on creating positive outcomes for groups that are the most marginalized can yield the best outcomes for everyone.

When it comes to the political and social dynamics that have shaped our land use policy, planning, and development, race and access to decision-making are together key determinants. This is due in part to explicit and implicit exclusion of people of color from regional and city planning processes. The Bay Area exhibits highly racialized geographies, and is becoming increasingly 'resegregated' as housing pressures force low income and communities of color out of urban areas into outlying areas.[21] Because of the persistent nature of racism within our institutions, it is critical to consider the ramifications of any large-scale decision making on communities of color. The Government Alliance on Race and Equity (GARE) provides a strong framework and set of tools for equitable governance and decision-making processes. They frame their approach to racial equity in this way:

Why Lead With Race?

The Alliance leads with race, with the recognition that the creation and perpetuation of racial inequities has been baked into government, and that racial inequities across all indicators for success are deep and pervasive. We also know that other groups of people are still marginalized, including based on gender, sexual orientation, ability and age, to name but a few. Focusing on racial equity provides the opportunity to introduce a framework, tools and resources that can also be applied to other areas of marginalization. This is important because:

- *To have maximum impact, focus and specificity are necessary. Strategies to achieve racial equity differ from those to achieve equity in other areas. "One-size-fits all" strategies are rarely successful.*
- *A racial equity framework that is clear about the differences between individual, institutional and structural racism, as well as the history and current reality of inequities, has applications for other marginalized groups.*
- *Race can be an issue that keeps other marginalized communities from effectively coming together. An approach that recognizes the inter-connected ways in which marginalization takes place will help to achieve greater unity across communities.*
- *It is critical to address all areas of marginalization, and an institutional approach is necessary across the board. As local and regional government deepens its ability to eliminate racial inequity, it will be better equipped to transform systems and institutions impacting other marginalized groups."*[22]

The same must be true in planning for climate resilience. In May of 2017, the National Association of Climate Resilience Planners released their Community-Driven Resilience Planning Framework, which provides a useful guide to engagement at the local level. They identify integrating equitable planning practices and building community power as central to planning for resilience.[23] Their framework outlines steps to take toward centering community needs, and reaching solutions that offer multifaceted solutions to complex and entrenched problems.

Climate Change and the San Francisco Bay Area

GRAPHIC: ADAPTED FROM IPCC

Responding and adapting to the impacts of climate change is at the core of this Challenge. This section will give an overview on climate change impacts faced in the Bay and corresponding consequences. The following sections will examine the Bay's history and current context to deep our discussion of climate resilient design solutions in the Bay Area.

FIGURE 6:
THE IPCC'S FOUR KEY FINDINGS

There is a 95% certainty that human activities are responsible for global warming

Carbon dioxide is at an 'unprecedented" level not seen for at least 800,000 years

Sea level is set to continue to rise at a faster rate than over the past 40 years

Over the last two decades, the Greenland and Antarctic ice sheets have been melting and glaciers have receded in most parts of the world[24]

Climate change and other risks

Bay Area communities face a range of natural hazards, including flooding, wildfires, earthquakes, landslides, and drought. Adaptations to these challenges will require flexible management approaches and an integrative perspective which considers the impacts of climate change on the Bay's estuarine-river system from changing watershed and ocean factors. Safeguarding water quality, native species, critical infrastructure and vulnerable communities while promoting energy efficiency, water conservation, and health and wellbeing should all be considered in planning for resilience.

RESEARCH QUESTION

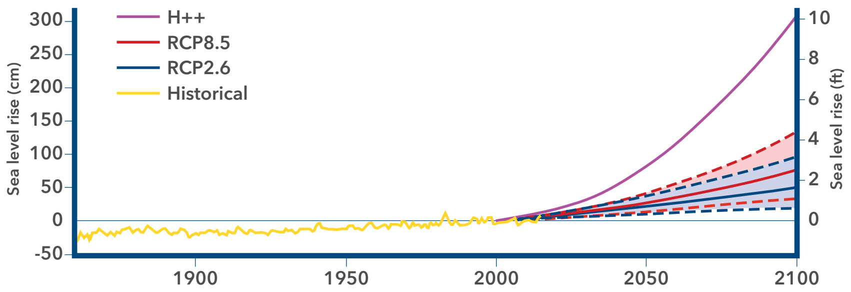
How does risk perception in regard to climate resilience planning vary across jurisdictions and sectors with decision making power?

The following sections highlight some of the most relevant risks to guide design thinking for the Resilient by Design Bay Area Challenge, which include sea level rise and storm surge; combined tidal-fluvial flooding; groundwater flooding; heat and drought; water quality degradation; and seismicity and liquefaction.

It is important to note that this is not an exhaustive list, but rather a glimpse into the relevant areas of concern for the purpose of this design challenge. Many of the concerns and hazards described below are interconnected and pose amplified risks when overlapping in geography. Depending on the nature of the site analyzed, it may be necessary to analyze additional hazards outside of these categories before moving forward with a design idea or approach.

Sea level rise and flooding

As the atmospheric concentration of carbon dioxide (CO_2) continues to rise[25], sea level rise and flooding will disrupt our city and regional systems with



increasing frequency. In order to just stabilize the concentrations of CO_2 in our atmosphere, an almost immediate halving of carbon emissions would be required with additional cuts necessary to maintain stability.[26] While emissions reductions must be achieved, even with continued success many of the Earth's stores of carbon and methane may still be headed for our atmosphere. 'Climate tipping points' or positive feedback processes including ocean CO_2 absorption decline, loss of global ice cover, and thawing permafrost may lead to even faster warming in the coming decades.[27] With global demand for energy continuing to rise, there is not yet a clear end in sight for rising greenhouse gas emissions.

According to a recent report, emissions of the last decade position us along the highest scenario considered by the last IPCC report, RCP 8.5.[28] If current emission trends continue through this century, Bay sea levels will likely rise 0.6-1.1 feet by mid-century and 1.6-3.4 feet by 2100 (Figure 8). There is a 1-in-20 chance that San Francisco will see a sea level rise of more than 4.4 feet by 2100 and a 1-in-200 chance that it will rise more than 6.9 feet (Table YY). Sea level will continue rising beyond 2100.

Total water level

In addition to sea level rise, a number of other factors influence water level including fluvial flooding, which together add to determine the Total Water Level (Figure 9). Storm surge, wave set-up and run-up are of great concern, as current projections show up to 3 feet of additional water level rise in the San Francisco Bay during storm events. El Niño/La Niña also influence Total Water Level, as the region receives about a foot of variation with fluctuations in temperature between the ocean and atmosphere. As the Total Water Level rises, the Bay will see an increase in 'nuisance flooding', flooding that causes inconvenience to the public.

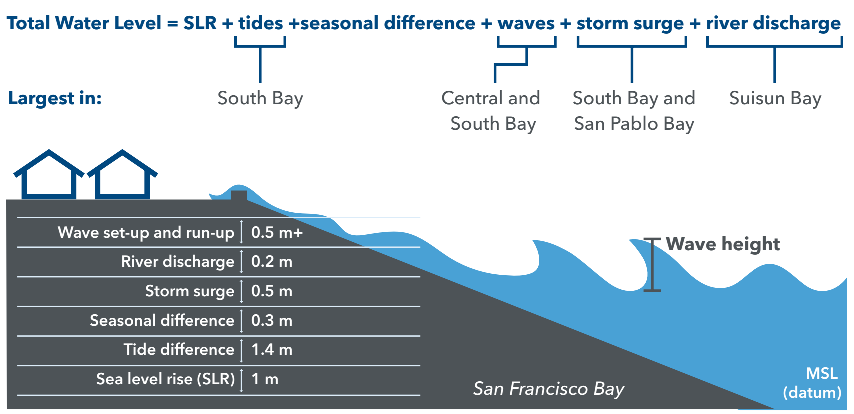


FIGURE 7:
RELATIVE SEA LEVEL RISE IN SAN FRANCISCO BAY
(from Griggs et al, 2017)[29]
An "extreme" sea level rise scenario (called "H++"), considered unlikely but increasingly plausible, was included in Griggs (2017) in addition to the IPCC scenarios used in the past. This reflects recent research suggesting that some parts of the Antarctic ice sheet may begin to collapse much sooner, governed by different processes than those which would drive rapid mass loss. The world is not presently following the H++ scenario, but this does not exclude the possibility of getting onto this path later in the century, and, of course, sea level will continue rising beyond 2100.

FIGURE 8:

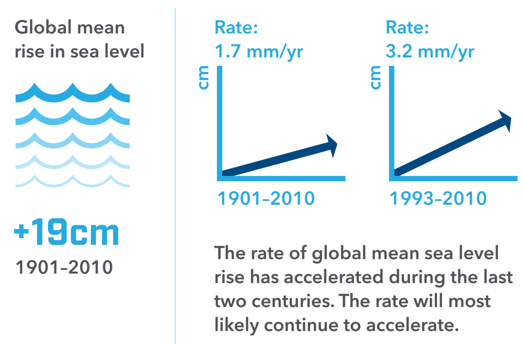
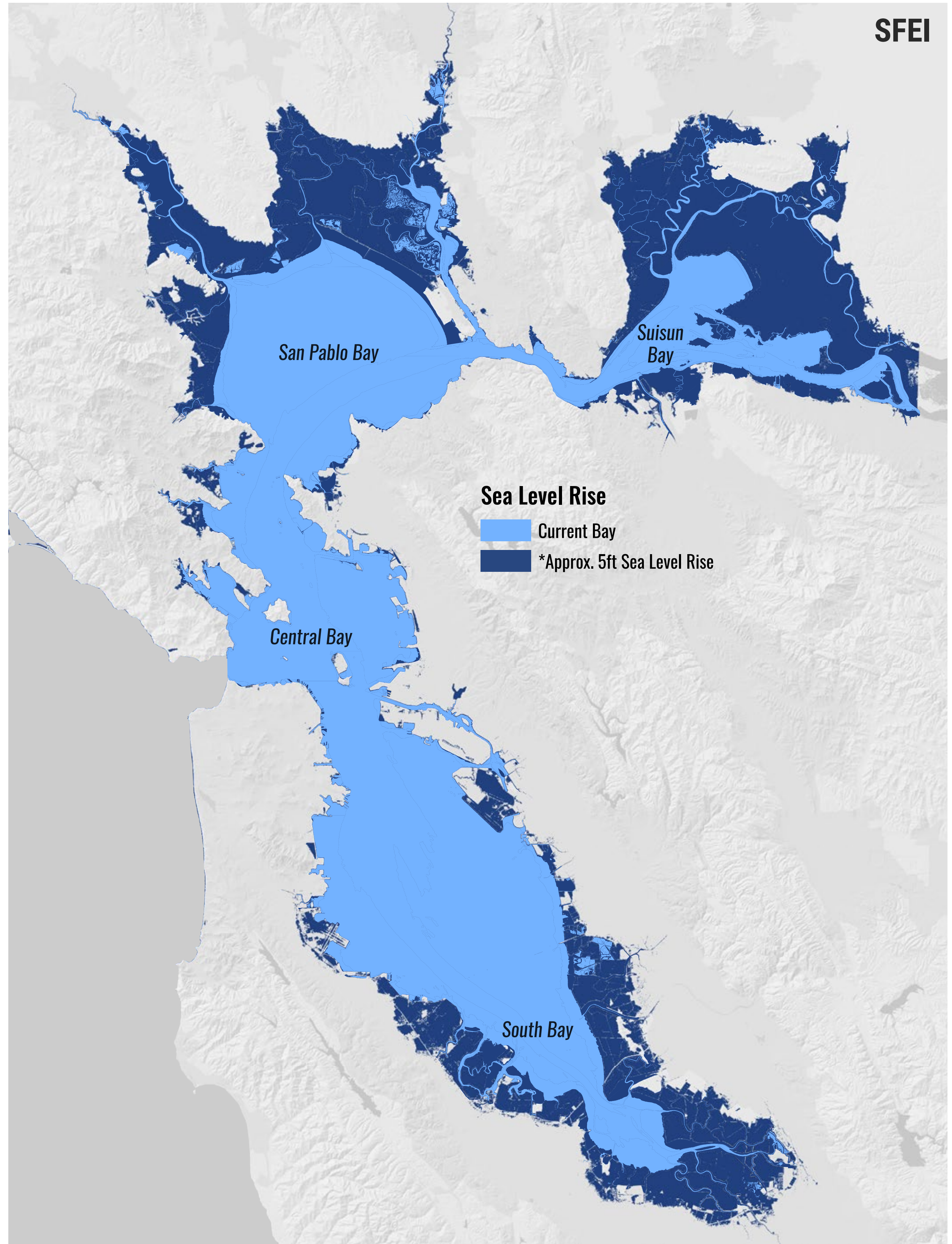


FIGURE 9. LEFT:
COMPONENTS THAT MAKE UP TOTAL WATER LEVEL IN THE BAY

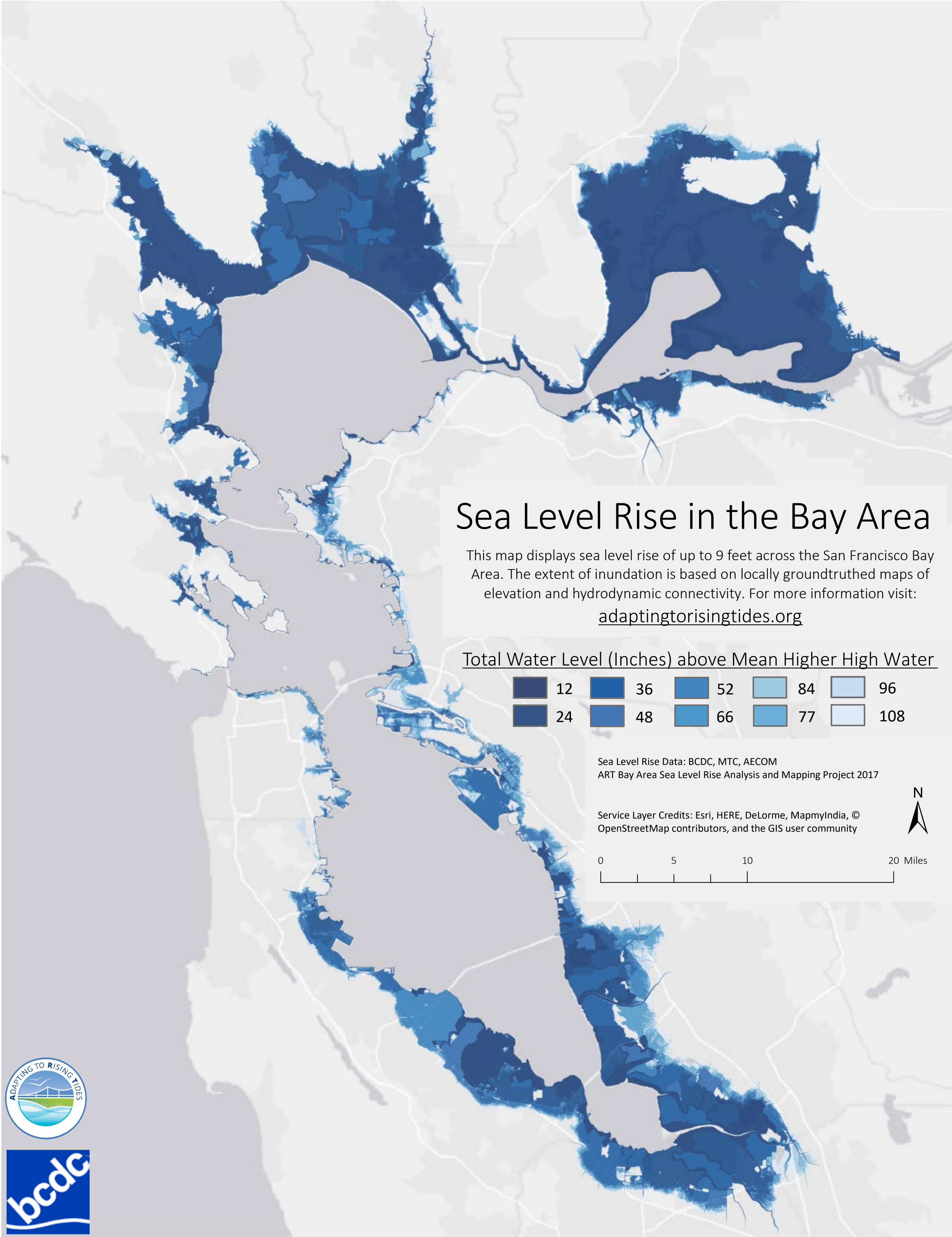
FIGURE 10, OPPOSITE:
SEA LEVEL RISE IN THE BAY AREA
This map is for illustrative purposes only. It does not include storm surge, levees, or combined flooding.

FIGURE 7: ADAPTED FROM RISING SEAS IN CA REPORT. FIGURE 8: ADAPTED FROM IPCC. FIGURE 9: ADAPTED FROM USGS

MAP: SFEI

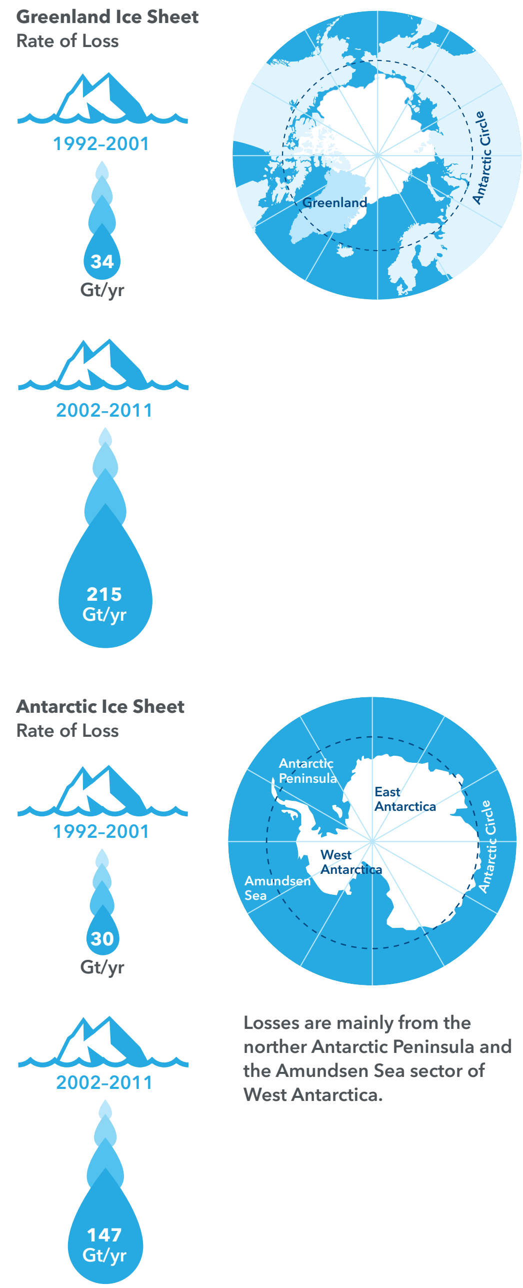


CLIMATE CHANGE & BAY AREA



GRAPHIC: ADAPTED FROM IPCC

FIGURE 11:



Losses are mainly from the norther Antarctic Peninsula and the Amundsen Sea sector of West Antarctica.

There are various helpful sea level rise viewers available online. With each viewer, care has to be taken to understand the assumptions or limitations behind the date used in the viewer. Some viewers and vulnerability assessments use a simple bathtub model of water inundating the land as sea level rises. Others account for the Total Water Level as mentioned above. The treatment of how water is routed by levees and berms also differs between viewers. The recent Our Coast Our Future viewer for San Francisco Bay includes both static (i.e. tides and global sea level rise) and dynamic components of water levels (i.e., storm surge and wave set-up and run-up), as well as explicitly models the flow of the flood waters. For more details, explore NOAA's Sea Level Rise Viewer and Our Coast Our Future's Flood Map to visualize the projected impacts of different sea level rise and storm surge scenarios for specific areas within the Bay.

Sea level rise will also impact the health of Bay wetlands. Wetlands provide many benefits such as habitat for abundant wildlife, open space for recreation, and clean water. Wetlands can provide protection from sea level rise and storm surge events by attenuating wave energy and absorbing water. Although many efforts are underway to restore wetland systems in the Bay, there are additional needs for sufficient migration space and sediment and organic matter inputs in order to keep pace with sea level rise. In the absence of sufficient space, sediment, and organic matter, many of the current wetlands and future restoration projects could be lost to rising tides, leading to a decrease in flood protection for communities and the loss of habitats for native species.

Combined tidal-fluvial flooding

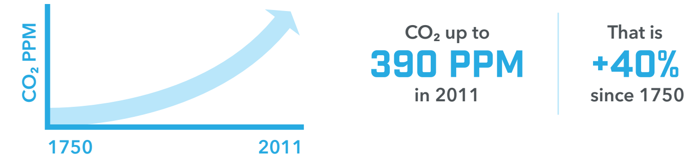
Flood risks along creeks from storm events may increase due to more frequent extreme high sea level events leading to backwater effects along flood-prone areas. The head of tide will move further inland up the creeks and, during storm events, the higher tidal levels will reduce flow capacity in the creeks and increase the risk of flooding.

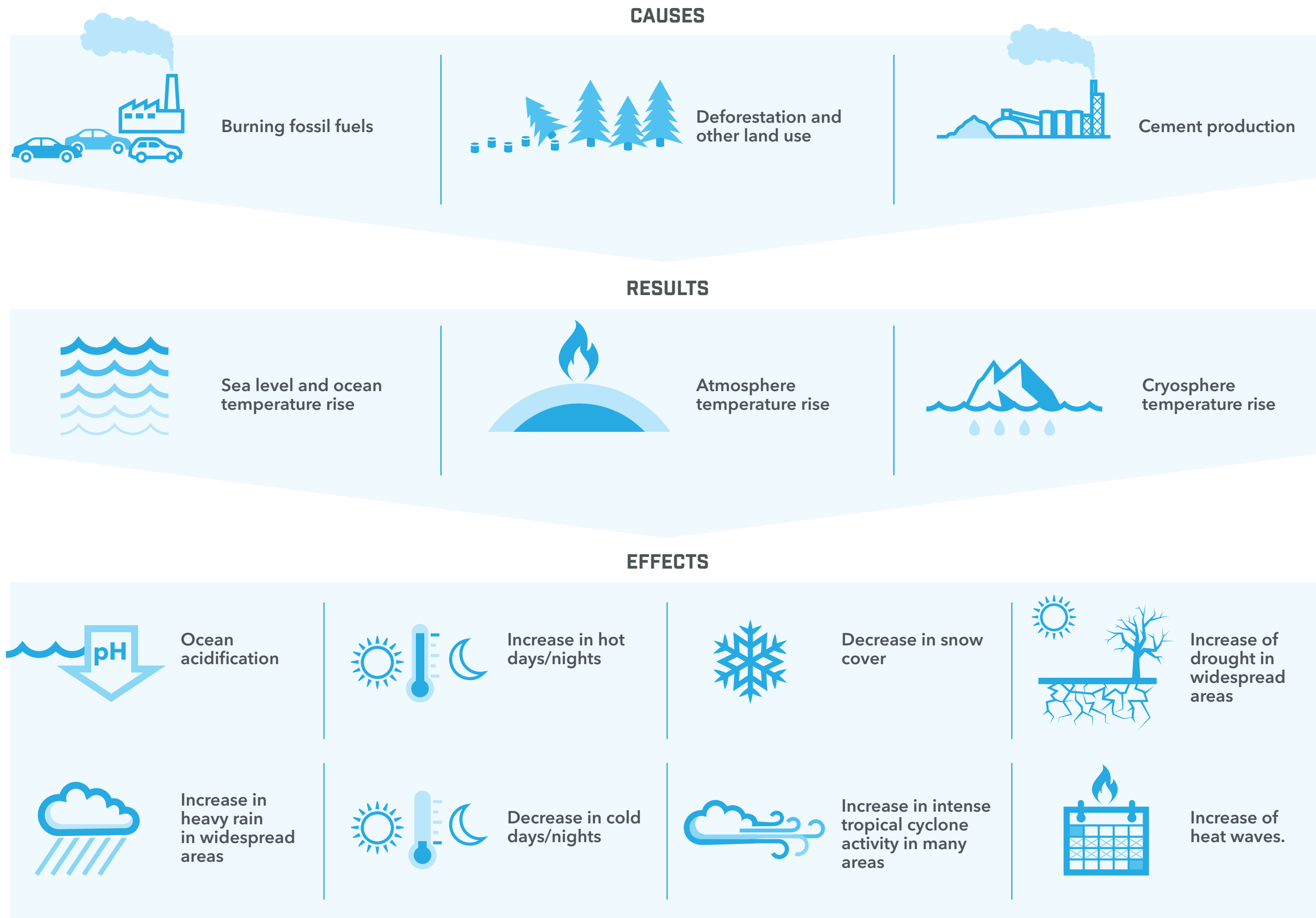
In addition, the duration of flooding events is likely to increase as extreme water levels increase and precipitation and storm surge events become more intense. More intense storms would produce higher peak flows in urbanized areas. This may result in increased in-channel erosion as sediment is scoured and vegetation washed out. Increased frequency of landslides and sediment erosion into flood control channels may be expected. Increased wildfire during the extended dry periods may also increase erosion that further reduces channel capacity. Increased storm intensity may also increase landslides and sediment transport into creeks.

Groundwater inundation

In addition to tidal and fluvial flooding, low-lying bay areas may also be vulnerable to groundwater inundation or localized flooding due to a rise of the groundwater table with sea level. The groundwater table close to the Bay typically lies above mean sea level and fluctuates with astronomical tides and El Niños. Amplitudes decrease exponentially with distance from the shoreline. Short-term, cyclic water-level changes in observation wells in the East Bay baylands are a pressure response to tides in San Francisco Bay. As sea level rises, the water table will rise and could eventually break out above the land

FIGURE 12:
CONCENTRATIONS OF CO_2 AND OTHER GREENHOUSE GASES HAVE INCREASED IN THE ATMOSPHERE.





GRAPHIC: ADAPTED FROM IPCC

surface creating new wetlands and expanding others, changing surface drainage, saturating the soil, and inundating the land depending on local topography. Flooding could start sporadically but will be especially intense seasonally when high tide coincides with rainfall events.

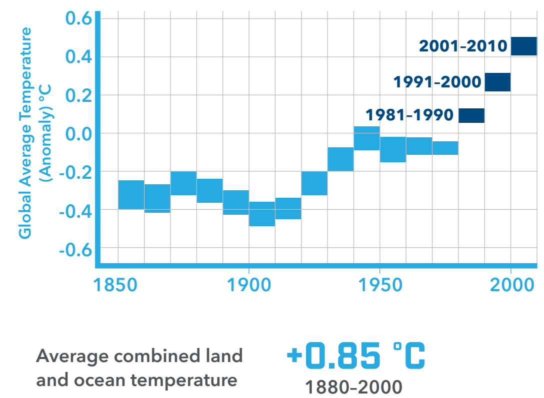
Heat and drought

Climate change will alter regional patterns for temperature and precipitation, which will pose uncertain impacts to endemic species within the Bay and surrounding rivers. Average daily air temperatures are on the rise, causing higher evapotranspiration rates, which create uncertainties for snowpack reserves and future water supply. Similarly, average daily water temperatures are on the rise, causing long-term concerns for native species if temperatures surpass a specific threshold linked to high mortality rates. Examples of vulnerable endemic species include Delta smelt (*Hypomesus transpacificus*) and Chinook salmon (*Oncorhynchus tshawytscha*). Projected increases in estuarine salinity and decreases in suspended sediment concentrations will

GRAPHIC: ADAPTED FROM IPCC

FIGURE 13:

Each of the last 3 decades has been warmer than all preceding decades since 1850.



also have uncertain impacts on endemic species and habitats.[30] Fish travel long distances through the Bay and Bay Delta into upper basin river and stream systems which means the health of the Bay and the Delta effects more than just the Bay Area. Similarly, all Tribes from the Bay Area throughout the Sacramento and San Joaquin River Basins may be affected as traditional foods are further threatened. Because of this inclusion of Tribes from the upper watersheds in climate adaptation planning is critical.

Water quality

Pollutants in water and sediment pose a threat to the health and survival of species at all levels of the Estuary's food web. In an effort to protect them, water quality laws and regulations require that the Estuary be clean enough to support abundant, diverse native communities of plants and animals. However, human activities continue to add contaminants to the ecosystem via municipal and industrial discharges, agricultural and urban runoff, and other pathways. A multitude of legacy and emerging pollutants – including mercury, pesticides, pharmaceuticals, and waste – pose ongoing challenges. Thoughtful strengthening of regulations, restoration, enhancements and urban design, particularly the implementation of green infrastructure, can greatly reduce pollutant loads from the watershed to the Bay. There are a variety of tools available to regional planners to help site these types of projects.

The water quality in freshwater aquifers close to the Bay's edge as well as the Bay itself are at risk from sea level rise and other stressors exacerbated by climate change. Near the Bay's edge, groundwater reserves are more likely at risk of saltwater intrusion, typically a result of over-pumping. In some instances, sea level rise could pose pollution risks to the Bay by saturating subsurface contaminants suspected to persist from historical contamination sites such as the superfund site at Alameda Naval Air Station. In addition, leaching from landfills positioned around the Bay's edge have potential to further decrease water quality.

Legacy pollution and site contamination

Legacy pollution, a term used to describe pollutants that were historically common in industrial practices before their negative impacts were understood, is another threat to water quality in the Bay.[31] The main sources of legacy pollution are from historical mining, manufacturing and agricultural activities. Manufacturing to support wartime operations was especially active in the Bay Area during World War II, and these operations commonly used persistent pollutants such as PCBs, dioxins, furans and heavy metals.[32] Many of these pollutants persist in the environment and will continue to pose a threat to human and ecosystem health unless cleanup efforts are pursued.

Numerous contamination sites exist in the Bay Area, and sea level rise could exacerbate mobilization of these pollutants. These contamination risks are an important factor when considering sea level rise adaptation strategies. Brownfield and Superfund sites are two common types of contamination sites, but terms used to describe contamination sites vary based on remediation status, the organizations involved in cleanup efforts and the type of contamination.[33] Brownfield sites are generally properties that have the presence or potential presence of a contaminant, pollutant or hazardous substance in need of remediation before development can take place. States or Tribes are typically the main entities involved in brownfield remediation and public programs exist to aid remediation efforts. When the federal government is or plans to be involved in a cleanup of contaminated land that is abandoned or uncontrolled, the site is designated as a Superfund site.[34] Superfund sites undergo screenings and assessments to determine if the environmental or human health risk is enough to qualify it for the National Priorities List. If placed on the National Priorities List, the site will eventually receive federal funds to conduct remediation efforts.[35]

Liquefaction

There is a greater than 70% chance that at least one major earthquake of magnitude 6.7 or greater will strike somewhere in the Bay Area within the next 25 years.[36] The risk posed by such a quake is amplified in areas built upon bay mud or artificial fill, which are susceptible to land liquefaction. Seismic precautions need to be taken where appropriate and any land uses on bay mud or bay fill need to be evaluated for increased risks due to the nature of the development. For example, the Bay has numerous inactive landfills around its margin, some of which have been be built in liquefaction zones. Sea level rise and seismic activity could undermine the integrity of the liners engineered to keep capped pollutants within landfills from entering the Bay or groundwater reserves. Excavation of landfill material would likely be very expensive and difficult to achieve without leaching toxic pollutants in the process, leading to increasing challenges to safeguard Bay water quality and human health.

Economic risk and development

Sea level rise and increased extreme storm and flooding events pose the threat of significant economic losses in the Bay Area. The California's *Flood Future Highlights* document indicates that in the Bay Area Region, structures valued at $130 billion are located within a 500-year floodplain. Additionally, over one million Bay Area residents live within a 500-year floodplain, and these numbers are likely to increase due to expected growth in population and development in the region. Thus, a change in flood risk is a potential significant effect of climate change that could have great implications for the region.

In 2015, the Bay Area Council Economic Institute, California State Coastal Conservancy, AECOM, and other partners released the report *Surviving the Storm*, which concluded that within the Bay Area hydrologic region a 150-year storm event, under present-day sea levels, would cause an estimated $10.4 billion in economic damages, almost the same as the Loma Prieta Earthquake. The analysis used this 'megastorm' scenario to illuminate vulnerabilities and economic impacts from severe flooding events, especially those occurring at high tide. A critical note is that this analysis did not incorporate future sea level rise in its modeling, only storm surge, rainfall, and combined flooding data.[37]

The total economic impact modeled used five key categories to assess potential vulnerability; structural damage, content damages (based on average contents by building type), air transportation delays, road transportation delays, and electricity service interruption.

FIGURE 14:
SUMMARY OF DAMAGES (MILLIONS OF DOLLARS)[35]

Damage Category	Estimated Damages
Structural damages	$5,932
Content damages	$4,180
Air transportation delay damages	$86
Road transportation delay damages	$78
Electricity service interruption costs	$125
Total	**$10,401**

FIGURE 15:
STRUCTURAL AND CONTENT DAMAGE ESTIMATES (MILLIONS OF DOLLARS)[36]

County Name	Structural Damages [1]	Content Damages [2]	Structural and Contents Damages [3]=[1]+[2]
Alameda	$394	$345	$739
Contra Costra	$448	$310	$758
Marin	$715	$487	$1,202
Napa	$22	$14	$36
San Francisco	$0	$5	$5
San Mateo	$680	$412	$1,092
Santa Clara	$3,586	$2,553	$6,140
Solano	$84	$52	$137
Sonoma	$2	$1	$3
Total	**$5,932**	**$4,180**	**$10,112**

FIGURE 16:
DEFINING LOWER-, MIDDLE AND HIGHER-WAGE JOBS IN THE BAY AREA[45]

The following terms will be used throughout this report to describe primary segments of the income spectrum:

Lower-wage: Less than $18 per hour (or less than about $36,000 per year)

Low-wage: Less than $11.25 per hour

Moderate-wage: $11.25 to $18 per hour

Middle-wage: Over $18 per hour and up to $30 per hour (or between $36,000 and about $62,000 per year)

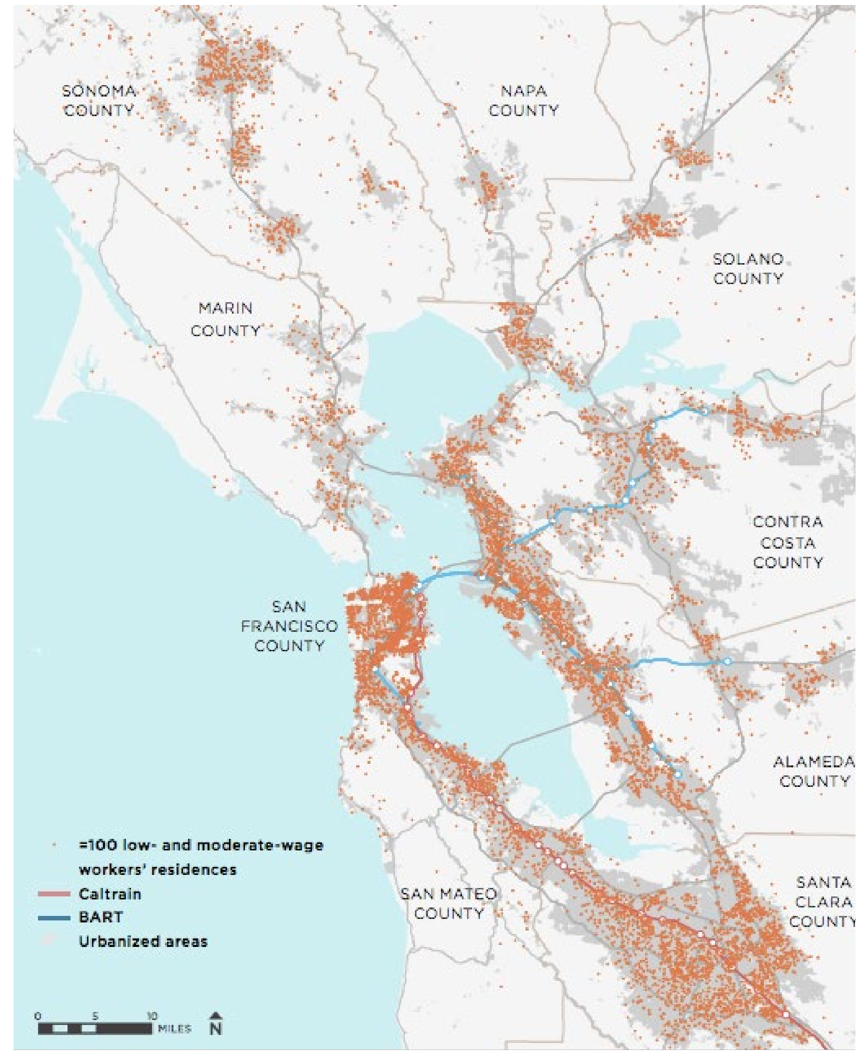
Higher-wage: Over $30 per hour (about $62,000 per year)

Note that both low-wage and moderate-wage jobs are considered lower-wage jobs. Throughout this report, the term "lower-wage jobs" is used as a proxy for all jobs that pay less than $18 per hour.

FIGURE 17:
SPUR'S MAP OF LOWER-WAGE WORKERS' PLACE OF RESIDENCE[46]

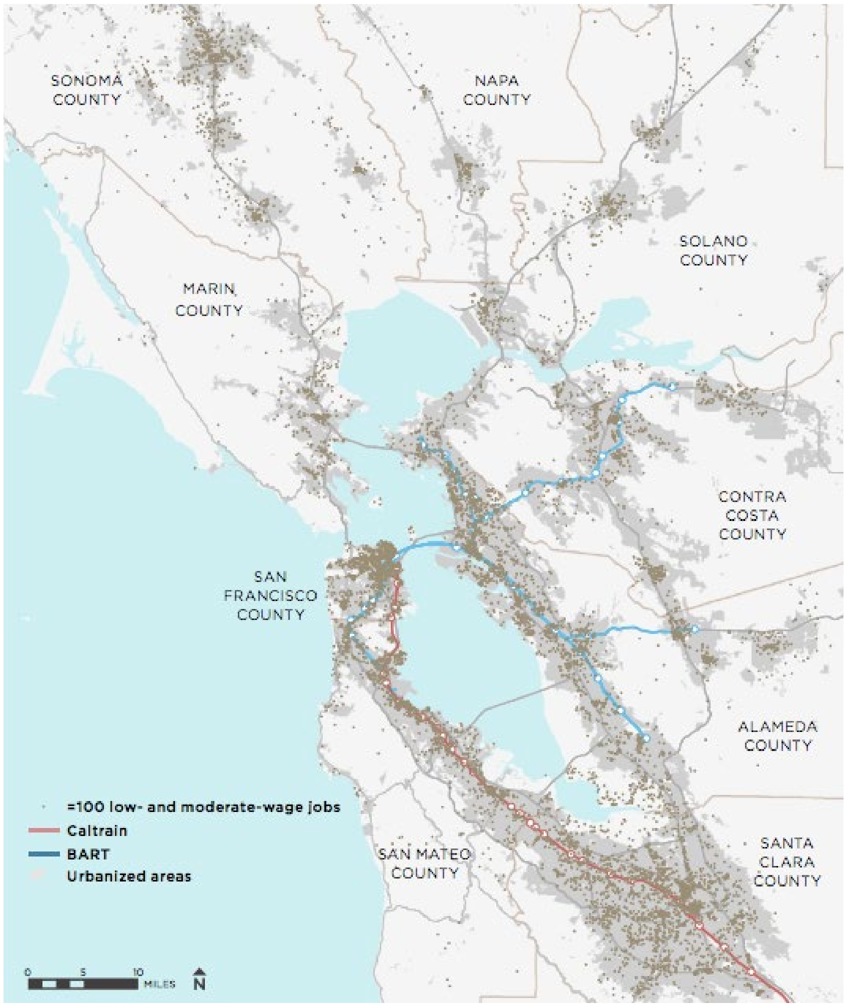
"Lower-wage workers live in every part of the Bay Area and are not concentrated in certain neighborhoods. The density of lower-wage workers in areas like San Francisco mirrors the overall greater population density in those parts of the region."[XX]

MAP: SPUR



California boasts the 6th largest economy globally.[40] According to numbers this July, the golden state boasts the 7th highest increase in gross state product and far exceeds the next closest state in GSP overall. The growth of the Bay Area is one piece of this continued increase in GSP. Recent economic growth in the Bay Area can be tied in large part to the rapid expansion of the tech industry, which has indirectly accelerated the growth of real estate and banking in the region. Jobs continue to grow in the Bay, with the highest increase in Oakland.[41] Unemployment levels have reached the lowest levels since the 1990's.[42]

Understanding the spatial relationships between low and middle income workers and their places of work can inform opportunities to build resilient solutions and economic vitality for the region.[43] The Bay Area has become more unequal, with the lowest and highest wage jobs growing, while middle-wage jobs are on the decline. A strategy developed by SPUR and the Economic Council highlights the need for 'pathways to the middle' or strategies to improve the growth of middle-income workers.[44]



MAP: SPUR

FIGURE 18:
SPUR'S MAP OF LOWER-WAGE WORKERS PLACE OF WORK[44]

"Jobs that pay low wages are located throughout the region and are closely correlated with where higher wage jobs are located."[47]

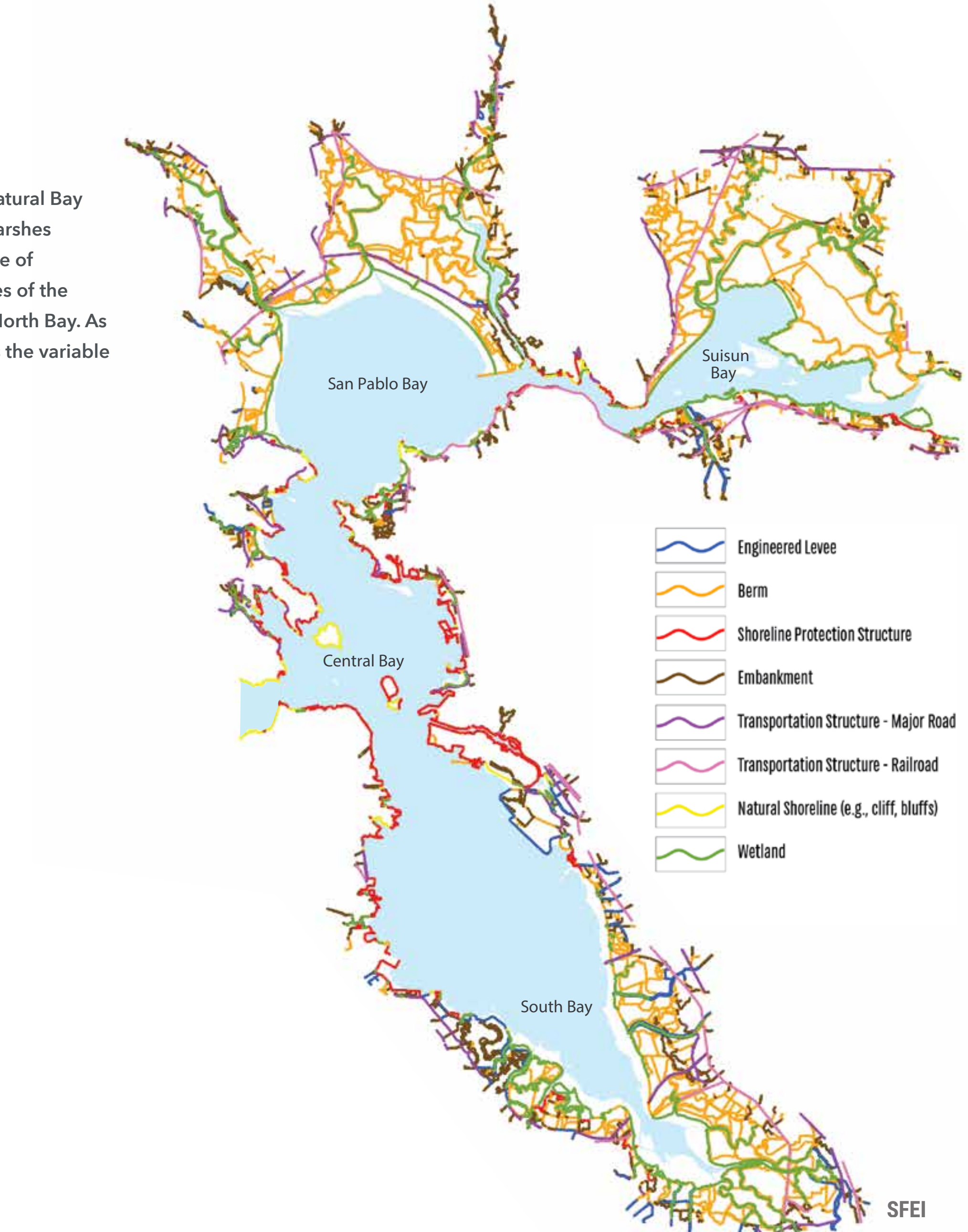
County Name		Value of Structures and Contents Exposed	Value of Crops Exposed	Total Exposed Value
Alameda County	100-year event	$5,600,000,000	$290,800	$ 5,600,290,800
	500-year event	$16,700,000,000	$447,000	$16,700,447,000
Costra Costa County	100-year event	$4,900,000,000	$48,400,000	$4,948,400,000
	500-year event	$8,700,000,000	$62,000,000	$8,762,000,000
Marin County	100-year event	$5,600,000,000	$677,400	$5,600,677,400
	500-year event	$9,300,000,000	$679,100	$9,300,679,100
Napa County	100-year event	$1,500,000,000	$336,900	$1,500,336,900
	500-year event	$1,900,000,000	$342,200	$1,900,342,200
San Francisco County	100-year event	N/A	N/A	N/A
	500-year event	N/A	N/A	N/A
San Mateo County	100-year event	$13,800,000,000	$3,000,000	$13,803,000,000
	500-year event	$19,200,000,000	$3,000,000	$19,203,000,000
Santa Clara County	100-year event	$15,200,000,000	$50,500,000	$15,250,500,000
	500-year event	$84,300,000,000	$68,400,000	$84,368,400,000
Solano County	100-year event	$2,500,000,000	$95,400,000	$2,595,400,000
	500-year event	$7,600,000,000	$133,900,000	$7,733,900,000
Sonoma County	100-year event	$2,100,000,000	$8,200,000	$2,108,200,000
	500-year event	$3,300,000,000	$8,400,000	$3,308,400,000
Nine-County Bay Area	100-year event	$51,200,045,500	$206,805,100	$51,406,850,600
	500-year event	$151,000,045,500	$277,168,300	$151,277,213,800

FIGURE 19:
FLOOD HAZARD EXPOSURE IN THE NINE-COUNTY BAY AREA[48]

MAP: SFEI

FIGURE 20:
CURRENT MAP OF BAY SHORE INFRASTRUCTURE

The San Francisco Bay has a diversity of natural Bay shore types ranging from mudflats and marshes to bluffs and beaches. Similarly, the degree of urbanization varies from the crowded cities of the South Bay to the agricultural zone in the North Bay. As a consequence, the shoreline type reflects the variable setting around the Bay.[49]



Threats to infrastructure

Sea level rise and storm surge also threaten to inundate critical infrastructure, which could have widespread implications across the Bay. For example, many wastewater treatment plants are located along the shoreline or at the edge of the baylands, leading to future uncertainties in sewage disposal, nutrient flows and water quality impacts. Highways are also of great concern as intermittent or permanent inundation could delay emergency vehicles, overcrowd other transit systems and interrupt economic activities. The San Francisco, Oakland and San Jose International Airports are located in low-lying areas adjacent to the Bay, posing major economic concerns as these airports generate billions of dollars in annual business revenues and provide hundreds of thousands of jobs. Infrastructure in low-lying areas often relies on built bay shore features, such as levees and berms, to reduce flood risk. Some infrastructure may be more vulnerable than others depending on the age, height, location, future maintenance and original design intent of the existing bay shore features (Figure 20).[50]


MAP: KARL NIELSON

Transportation

The Adapting to Rising Tides program of BCDC has assessed potential vulnerabilities of transportation infrastructure in the Bay Area. MTC, BCDC, CalTrans and BART partnered to create technical reports and a briefing book that describe some of the vulnerabilities already identified, and potential impacts of a disruption on communities that rely on these modes of transportation. Three major areas of concern emerged from this study: the Bay Bridge touchdown focus area, Oakland Coliseum focus area, and the Hayward shoreline. The challenges faced in these three focus areas can illuminate potential vulnerabilities for other sites as well. Each area exhibits a confluence of resilience challenges that must be addressed including protecting critical infrastructure, managing for sea level rise across multiple land use typologies, and protecting community assets.[51]

Transportation infrastructure, access and equity

In planning for resilient transportation infrastructure, it is important to address the needs of vulnerable populations that rely on or could benefit from access to public transportation. Access to transportation can improve outcomes for health and wellbeing in disadvantaged communities. If the impacts and needs of disadvantaged communities are not considered, new transportation infrastructure interventions can reinforce 'racialized geographies' and widen inequality in access to food, jobs, housing, and other basic needs.[52]

PolicyLink, the Prevention Institute, and the Convergence Partnership issued a report on health and equity in transportation policy that illuminated key strategies for improved outcomes for communities. They outlined a useful set of criteria for assessing the equity of transportation projects and gave recommendations for increasing the positive impact for communities.[53]

Where climate adaptation interventions involve changes to transportation infrastructure, PolicyLink's criteria can serve as a helpful guide for building resilience in social-ecological systems.

"Specifically, healthy, equitable transportation policy:

→ Supports the development of accessible, efficient, affordable, and safe alternatives to car travel, and especially to driving solo. These alternatives enable everyone to walk more, travel by bicycle, and use public transportation more—in other words, to get around in ways that improve health, expand access to opportunity, and reduce toxic pollutants and greenhouse gas emissions.
→ Works hand in hand with sustainable land use planning. Together, they encourage and support high-density, mixed-use, mixed income metropolitan development and affordable housing with good access to transportation options. Together, they focus, particularly, on underserved and economically isolated communities.
→ Recognizes that income is important to health, and that good transportation has an impact on family income. Healthy, equitable transportation policy support systems that connect all people, especially low-income and underserved communities, to employment and other opportunities. It also encourages hiring low-income residents of color for well-paying jobs in

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transportation construction, maintenance, and service.

- Understands the importance of ensuring equal representation. All community members, regardless of race, gender or geographical location should be equitably represented and involved in making decisions which impact their communities, their infrastructure and their options for travel.
- Recognizes that access to healthy foods is integral to good health and that transportation systems are integral to food production and distribution. Healthy, equitable transportation policy explicitly addresses food access issues, including transportation to grocery stores and food transport practices."[54]

Storm and wastewater management

Wastewater and storm water management systems will increasingly face threats from sea level rise, storm surge, and increased precipitation. The first of these threats is the overwhelming of pipe and pump capacity. Additionally, seawater could cause premature corrosion of pipes that are not meant to handle salt water.[55]

Water pumps and treatment systems rely on uninterrupted power in order to maintain proper function. If there is disruption in the power grid due to storm surge, high winds, or other weather-related disturbance and there is no alternative generation available, there may be dual threats of interrupted water and power infrastructure simultaneously. Additionally, water pumps that protect low-lying areas from flooding or storm surge inundation may be knocked out as well, increasing flood risk. Frequent flooding can exacerbate these issues, especially when chronic drainage issues are preexisting.

The gravity systems that drain stormwater from urban areas will also become less effective as bay levels rise. Stormwater discharges and pipes may allow backflow and serve as conduits for flood water. Flap gates that prevent the back flow of flood waters will remain closed for longer, resulting in ponding of water in local drainage systems. The potential impacts could be severe if flood conveyance channels and storm drains are overwhelmed, which will lead to the increase of flooding in low-lying areas.[56]

The combination of increased flood flows and higher water levels could result in the need to raise levees and flood walls in many places. This may increase the risk to communities and infrastructure as they become lower relative to the crest of the flood protection structure. If the structure does fail then the depth of water, and the consequent damage, may be greater. Changes may also be made higher up in the watershed to alleviate some of the combined flooding issues that may occur more frequently. For instance, flood-plain restoration and reconnection, off-line detention higher up in the system and the increased use of pumping may alleviate some of these issues. All approaches will require increased coordination between different jurisdictions.[57]

Housing

Displacement and gentrification are long-standing, growing threats to San Francisco Bay Area stability, diversity and sustainability. In planning for resilience, understanding this dynamic is critical. Causa Justa :: Just Cause, a grassroots organization that advocates for equitable communities, defines gentrification as a decline in low income residents of color relative to higher-income workers willing to pay higher rents, and notes the same populations have been targeted by past racial discriminatory redlining and urban renewal projects, as well more recently by predatory lending.[58]

UC Berkeley's Urban Displacement Project defines displacement as, "when housing or neighborhood conditions actually force moves." According to their 2015 study, 48% of Bay Area neighborhoods were affected. They linked transportation investments as well as regional housing and job market changes to displacement and found more stable at-risk neighborhoods resisting the trend "largely due to strengths of local housing policy, community organizing, tenant protections and planning techniques." For example, between 1990 and 2011, Oakland and San Francisco African American populations dropped by half, while the number of Latino households in the Mission decreased by 1,400 and white homeownership more than doubled.[59]

As a result, the Bay Area has experienced widespread 'suburbanization of poverty' as lower-income residents are forced out of urban centers due to rising costs of housing and other necessities.[60] Some of the fast-growing sites of increasing poverty are vulnerable to sea level rise, and lack characteristics of neighborhoods that foster social cohesion. Urban Habitat released a report, *Race, Inequality, and the Resegregation of the Bay Area*, exploring the changing demographics across the region. Their overall conclusions show a clear pattern of low income and communities of color shifting to outer parts of the region. Overall, poverty is increasing in outer regions and at higher rates within Black and Latino poplutations in these areas.[61] Causa Justa :: Just Cause identifies participatory planning processes and local efforts to stabilize communities and prevent displacement as critical to building long-term prosperity.[62]

In 2015, the California Legislative Analyst's Office released a report outlining causes of the overall rising cost of housing in California relevant to the Bay Area context. First, the demand for housing in California especially in coastal areas is not sufficient to meet the demand of people who want to live there. Their analysis suggests that the number of homes built impacts the price of housing, and that higher rates of home building result in lower housing costs.[63] Additionally, barriers to increasing density in coastal areas and high cost of building materials also contribute to increasing costs. Some of these barriers can be linked to resistance to increasing density at the local level and lack of local incentives for increasing home building rates.[64]

Investment without Displacement

The Investment Without Displacement network of the Six Big Wins Coalition argues that to effectively protect disadvantaged communities, urban infill or transit investments must be implemented in such a way that does not cause displacement of existing communities. The same is true for bayfront development or built environment interventions around climate adaptation.

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While disadvantaged communities can benefit from investments, if their neighborhoods are not kept affordable at diverse income levels then community members are forced out by rising rents and property taxes as their neighborhood improves. Additionally, displacement patterns cause more greenhouse gas emissions by replacing low-income urban transit users with wealthier car-owners who use transit less frequently, and pushing former transit users to regional peripheries where they are forced to buy cars. Displacement also causes traumatic disruption of communities that have complex patterns of interdependence and threatens extended family support networks, harming social cohesion. The Investment Without Displacement network offers a clear understanding of how social equity and environmental goals overlap, aiming to keep deeply rooted communities in place, and getting people to drive less.[65]

Homeless tents in West Oakland.

PHOTO: FABRICE FLORIN/FLICKR

Homelessness and climate impacts

The homeless population in the Bay Area is uniquely vulnerable to climate change and sea level rise. Given that they reside outdoors and frequently near bodies of water, they are on the frontlines of flooding impacts,[66] heat emergencies and water shortages. Like residents of disadvantaged communities, homeless populations are experiencing a preview of impacts that will affect more of the population as the climate crisis progresses.

Many of the homeless population in the Bay Area have organized into ad hoc encampments with loose social and governance structures. Conditions are worse than refugee or disaster recovery camps. Ironically, because of how homeless populations are underserved, they may not have access to basic amenities such as running water, sanitation or adequate facilities for garbage and recycling. This can lead to a vicious cycle where trash can make its way into waterways, increasing flood risk and reducing water quality, then floods can sweep away more trash and possessions to further clog waterways and lead to more severe flooding. There are also frequent fires. To prevent these kinds of problems, the City of Oakland has begun regular trash collection at homeless encampments.[67]

Challenges faced by Bay Area First Nations

The majority of Tribes in the Bay Area are not federally recognized, nor do many of them have land bases, in the form of reservations or rancherias. The path to federal recognition and gaining a land base is a lengthy, costly, and complex process. Some Tribes have been engaged with this process for the last few decades if not longer. Take for example, the Muwekma Ohlone Tribe who has been engaged in the federal recognition process since 1995 and has yet to get recognized.[68] In addition, the Federal Relocation Act of 1956, which was a part of the larger Indian termination policy era, numerous Native Americans were moved to select U.S. cities, including San Francisco, San Jose, and Oakland. Many of today's inter-tribal elders and their descendants in the Bay Area were relocated during these "efforts to force assimilation."[69] National statistics on Native Americans are alarming: one in four Native Americans live in poverty and face a unique set of health problems, including high rates of diabetes, alcoholism, and youth suicide.[70]

> "We still have a whole history of colonization that we're trying to heal from. Dealing with the trauma of that, and actually re-awakening a whole generation of people to the fact that they're indigenous. That there are obligations to this land that we still have to do as indigenous people. We have to bring back those songs, those healing dances, that language back, so that we can actually engage the land again in the healing process. That's not just for us, it becomes an obligation for us to deal with this for all the people that now live here." --Corrina Gould (Chochenyo and Karkin Ohlone; Co-founder of IPOC and the Sogorea Te' Land Trust)

There are research and ongoing initiatives that address historical and contemporary trauma through culture, community, and land as interventions.[71] An example of this is through the Native American Health Center of the Bay Area and their work with evaluating "community-defined evidence-based practices", which is a part of a larger movement, that affirms the effectiveness of cultural practices (which include traditional ceremonies, dance, and medicine) in increasing and cultivating the wellness of Native American communities.[72] Indigenous communities in the Bay Area have expressed needs for reclaiming ancestral land and sacred spaces, having places to gather in community, heal, and practice culture; and places to practice subsistence and stewardship.

Bay Area History and Context

PHOTO: SPUR

Regional environmental setting

Evolution and formation of the San Francisco Bay

The San Francisco Bay is part of a larger estuary that extends from the South Bay, Central Bay, San Pablo Bay, Suisun Bay, and inner Delta (Figure 23). Geology, sea level rise, ocean and tidal currents, waves, rivers, sediment transport, and biology shape the shoreline of the San Francisco Bay. More recently, intense modifications by people, including the filling, draining and diking of wetlands together with extensive urbanization and farming have transformed the Bay and its ecology.

Geology, topography, and tectonics

From a geologic perspective, the Bay is a very young feature. It formed less than 10,000 years ago, when rising seas entered the Golden Gate--a gap in the outer Coast Range--and interior valleys (Figure 22). The Bay's varied geology has led to a varied shoreline. In some places steep ancient headlands thrust into the Bay and its deeper waters, leaving little room for intertidal habitats. Elsewhere, wide valleys and alluvial fans have filled with more recent alluvium, creating broad, gently sloping plains with wide intertidal zones occupied by mudflats, marshes, and salt pannes (Figure 23). The hills that frame the Bay generally run parallel to major fault lines, most notably the Hayward and San Andreas faults (the latter generating the famous 1906 San Francisco earthquake) (Figures 24 and 25).

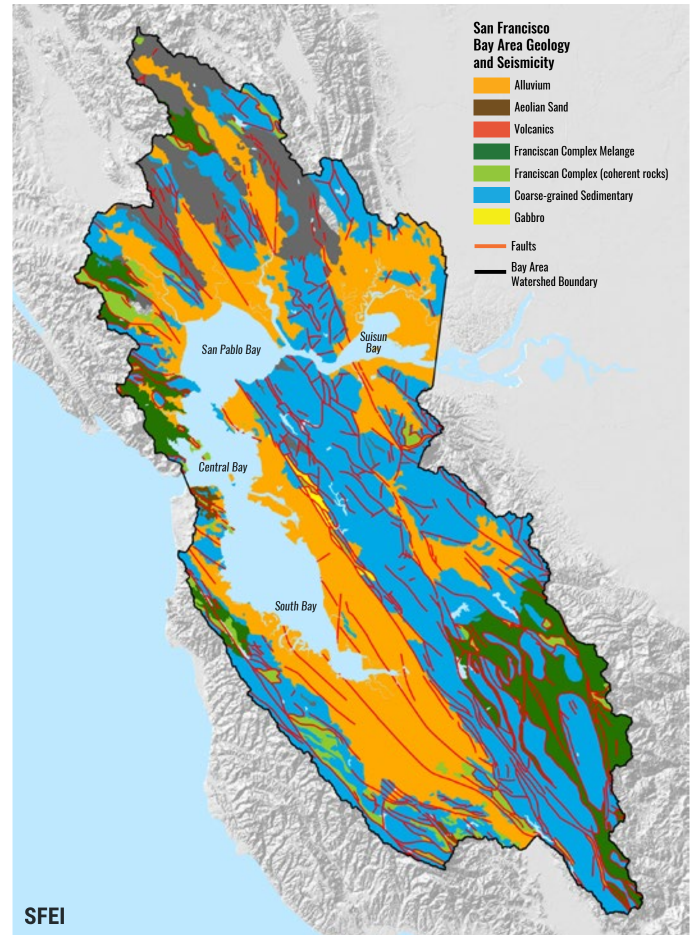
FIGURE 22:
SHORELINE CHANGE OVER 15,000 YEARS.
Since the last ice age, the seas have been moving steadily up and inland. The rate of advance inland along marsh edges is mediated by local factors such as sediment supply, shoreline modification and hydrodynamics (adapted from Cohen and Laws 1992).[73]

MAP: SFEI

MAP: SFEI

FIGURE 23:
The San Francisco Bay is part of a larger estuary, where brackish and freshwater mix, that extends from the Golden Gate to the inner Delta.

MAPS: SFEI



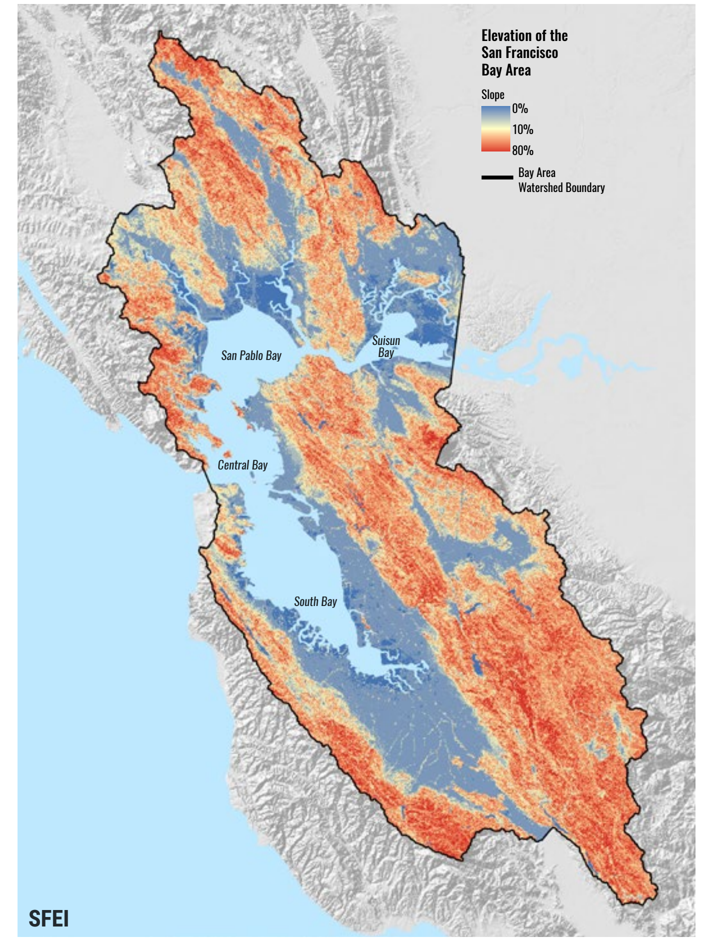


FIGURE 24, ABOVE LEFT:
GEOLOGIC MAP OF THE SAN FRANCISCO BAY AREA.

FIGURE 25, ABOVE RIGHT:
FAULT MAP AND SLOPE MAP OF THE SAN FRANCISCO BAY AREA.

Climate

The San Francisco Bay Area experiences a Mediterranean climate, characterized by hot dry summers, and mild rainy winters. The diverse topography of the Bay Area creates numerous microclimates in the region, with varying amounts of wind, rain, fog and heat throughout the year.[74] On average, between 1890 and 2010, the occurrence of large events in the San Francisco Bay Area increased based on regional rainfall patterns, and this trend is projected to continue with climate change (however, the magnitude of these trends will depend on local rainfall patterns since rainfall trends are very heterogeneous throughout the region).[75] As climate change progresses, the Bay Area may experience warmer, drier summers and fluctuating wet winter conditions.[76] The impacts of climate change will likely alter stream flows and could have negative implications on native fish species and other wildlife.[77] Other climate change trends for the Bay Area may include increasing water temperatures, prolonged growing seasons and earlier snowmelt runoff.[78]

RESEARCH QUESTION

With consideration to climate change, does the change in frequency and intensity of rain storms result in channel degradation or aggradation?

Watershed processes: freshwater delivery and sediment supply

The Bay is the downstream end of an extensive estuary, where salt water from the Pacific meets freshwater flowing down from the Central Valley and from dozens of local streams that fringe the Bay. In total, the water from nearly half

MAP: SFEI

FIGURE 26:
***Changing Channels,* a 2017 report by SFEI on regional guidance for developing multi-benefit flood control channels at the Bay interface, identified 25 of 33 creeks considered as having the potential for channel reconnection for bayland habitat support based on the extent of current undeveloped lands adjacent to the channel. Reconnecting these creeks to existing or restored adjacent baylands would allow sediment from the watershed and sediment scoured from the channel to be distributed across the baylands area that has been "opened" to these flows.[79]**

of California's land area ultimately drains into the Bay. These freshwater flows drive important gradients in salinity that extend from the Golden Gate, where the salt content of the water is usually equal to that of seawater, to upstream to the headwater rivers and creeks, where the water is fresh, as well as transporting coarse and fine sediment downstream to the Bay where it settles in marshes, beaches, mudflats, and shoals.

With pronounced change in sediment supplylikely to occur in the future and in the context of accelerated sea level rise, the Bay is now generally considered to be sediment-starved. This is problematic, because sediment carried into the Bay by rivers and creeks provides substrate for marsh development and is an important component in the transport of nutrients within the Bay ecosystem. Though the majority of freshwater (close to 95%) delivered to the Bay comes from the Central Valley, in recent years the majority of suspended sediment (>60%) has come from the smaller local tributaries.[80] This represents a shift from historical conditions, when the Bay's suspended sediment supply was dominated by contributions from the Central Valley (a change largely driven by the exhaustion of sediment flowing through the system unearthed during the Gold Rush, dam construction, and river armoring).[81] This shift increases the need to rethink the interfaces between local creeks and bayland habitats as well as how we manage dredged sediment. Reconnecting creeks to existing or restored adjacent baylands would allow sediment from the watershed and sediment scoured from the channel to be distributed across the baylands area that has been "opened" to these flows,[82] promoting the delivery of precious sediment to where it is needed most (Figure 5).[83] However, it is important to keep in mind that there are limitations to how sediment can be used depending on contaminants that may exist within sediment sources. Permitting challenges may arise if sediment quality does not adhere to federal, state and local water quality regulations.

RESEARCH QUESTION

How much sediment is needed for current Bay marshes to keep pace with sea level rise?

Tidal processes

The Bay experiences mixed diurnal tides, meaning there are two unequal high tides and two unequal low tides approximately every 25 hours. Mean range of tides (the difference between mean high water and mean low water) at the Golden Gate Bridge is approximately 5.5 ft. As one moves from there to the Delta along the northern axis of the Bay, tidal range generally decreases. By the time one reaches Sacramento, the tidal range has decreased to about 1 ft. The opposite happens when one moves from the Golden Gate bridge towards the South Bay. Because the South Bay is a closed basin, tidal range is amplified to 8.5 ft at its southern end. Variation in tidal range and tidal prism-- a related measurement of the amount of water moving into and out of an area with the tides-- impacts the quantity and quality of intertidal habitats. Tides transport nutrients, sediment, salt, and other materials to and from the baylands; create gradients of moisture and energy; and provide the physical means for fish and other aquatic organisms to move across tidal habitats at high tides. The spring-neap cycle, driven by the gravitational pull of the moon, lead to the highest (spring) and the lowest (neap) tides each month. The highest astronomical tides of the year, referred to as king tides, usually occur in the winter months and provide a proxy for visualizing higher water levels in the future with sea level rise.

HISTORY & CONTEXT

Salinity gradients

Estuaries form where freshwater runoff from the land mixes with saltwater from the ocean, creating a brackish salinity regime where suspended sediment and nutrient-rich particles tend to accumulate.[84] Salinity and gradients in salinity influence the type and extent of habitats in the San Francisco Bay Estuary and are an important factor in understanding ecological pattern and process. Salinity gradients also drive currents which can increase circulation and hasten flushing in the Bay, factors which are important for water quality and the movement of sediment in the Bay. Freshwater flows and tidal action are the primary factors that affect the salinity gradients throughout the Bay, causing salinity gradients to vary by region (Figure 6). Seasonal freshwater variability between the dry and wet seasons cause temporal changes in salinity gradients, and the magnitude of those changes are driven by watershed size, storm frequency and duration, and snowmelt runoff. Suisun Bay receives large freshwater flows from the Sacramento and San Joaquin rivers, which increase in late fall as the wet season begins and continue to increase during the winter, peaking in spring from snowmelt runoff from the Sierra Nevada mountain region and declining to low levels during the onset of the summer dry season.[85] In contrast, the South Bay generally has a much higher salinity, receiving less watershed runoff during the wet season due to smaller contributing watersheds and some urban runoff during the dry season but no snowmelt runoff other than the flows from Suisun Bay. High salinity also occurs near the Golden Gate since the salt content is close or equal to that of seawater due to the proximity to the Pacific Ocean.[86]

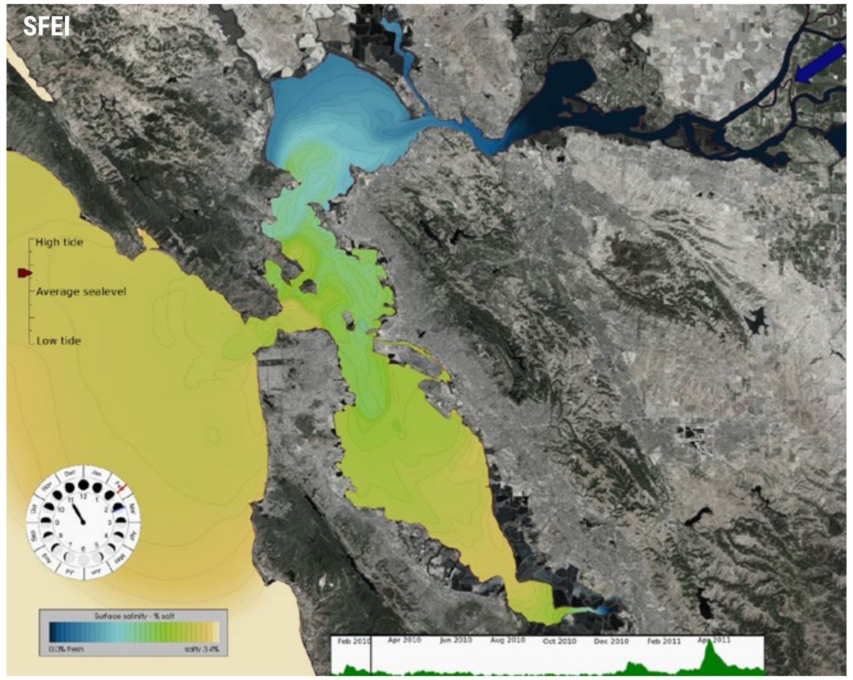


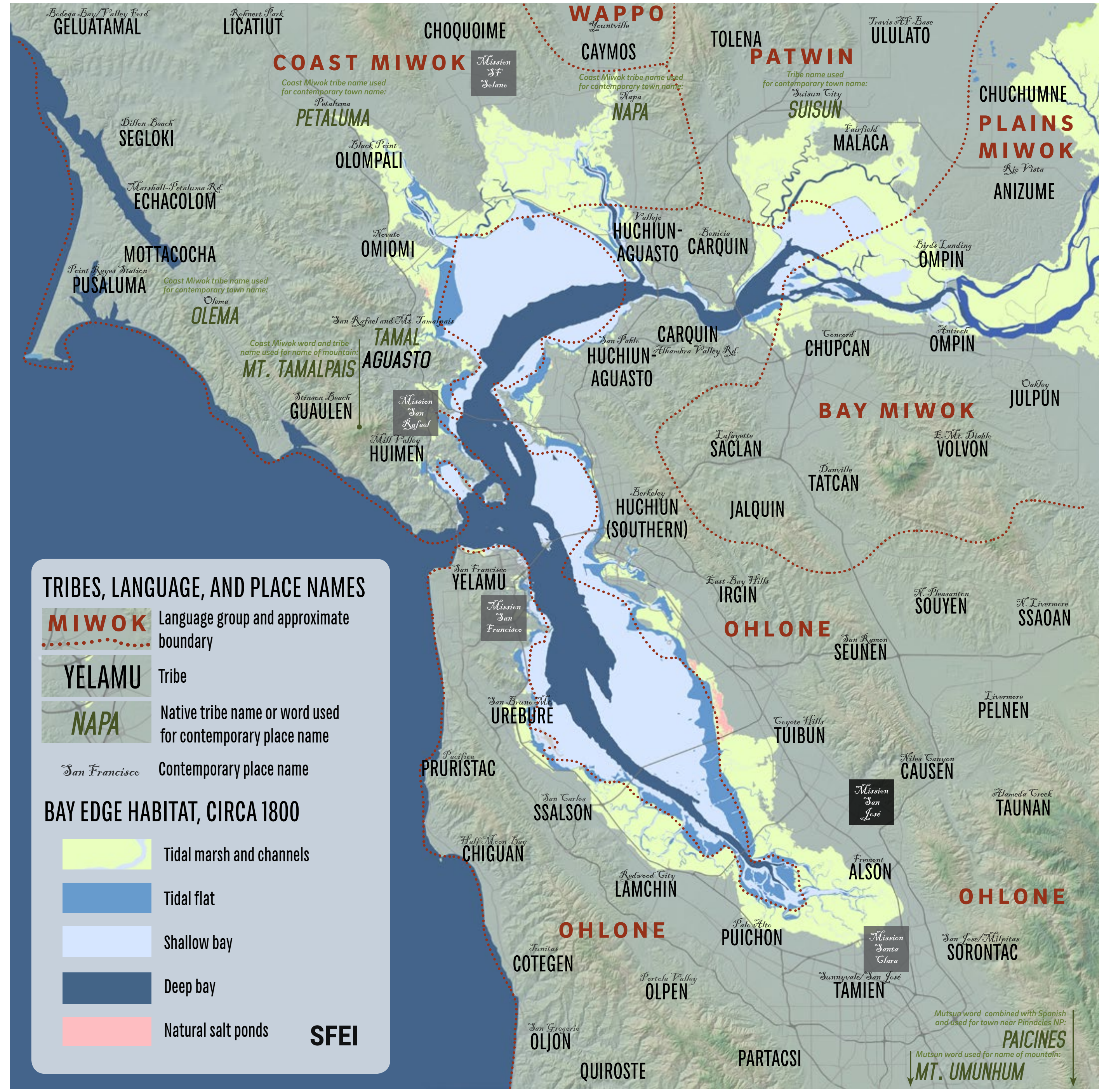
FIGURE 27:
SALINITY GRADIENTS
Still from a sequence showing surface salinity in San Francisco Bay, as predicted by a computational model, during a large rainfall event in February 2010. This model combines data on freshwater flows, tides and the geography of the Bay to predict currents and salinity in the Bay, essentially a weather forecast for the water instead of the atmosphere. The full simulation can be viewed at resilience.sfei.org.[87]

MAP: SFEI

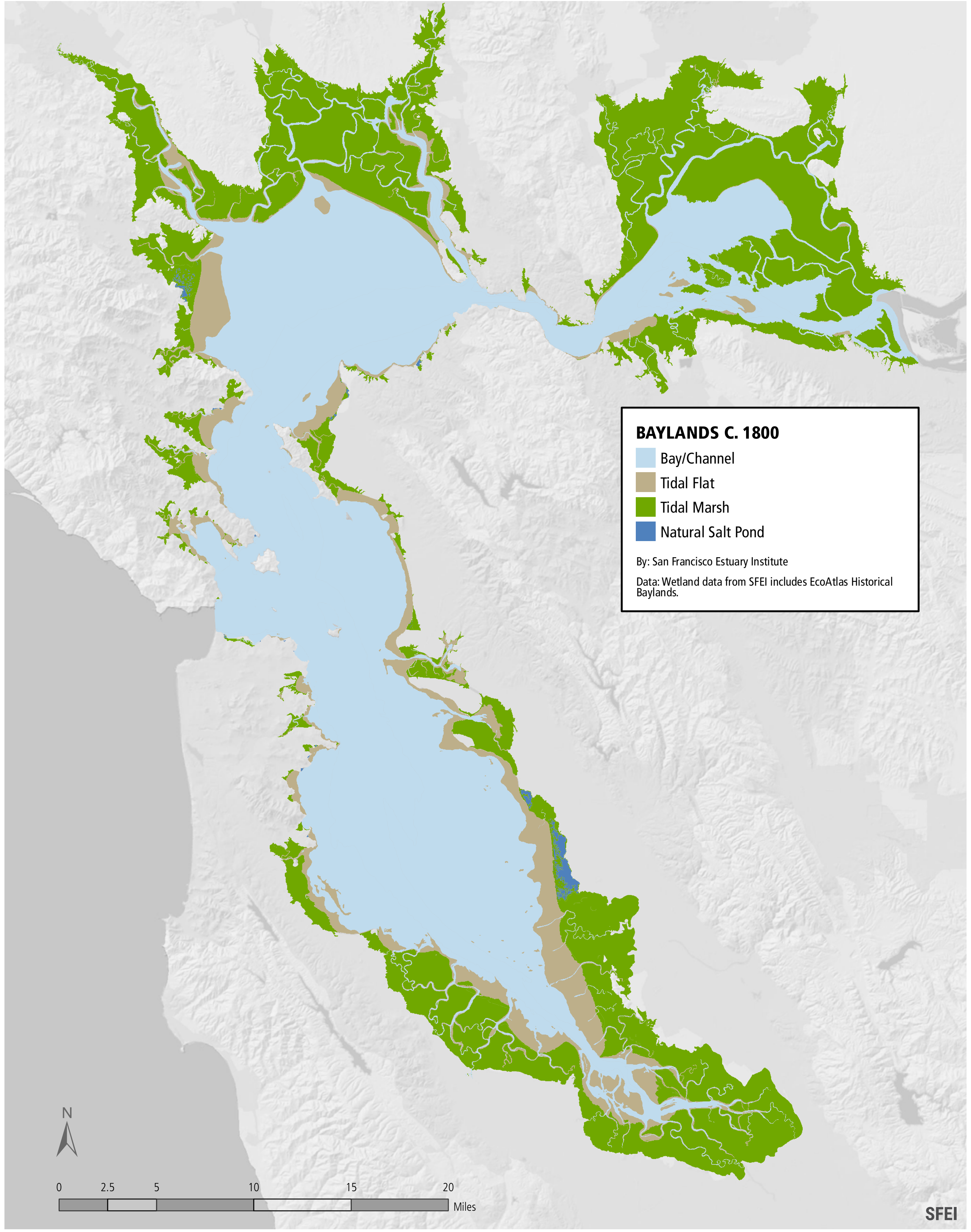
Indigenous peoples' ecosystem management practices

As far back as 15,000 years ago or possibly earlier, Native Americans inhabited the territory known today as California.[88] As sea level began to move steadily inland approximately 10,000 years ago during the end of the last ice age, the indigenous communities living in the region adapted to the changing shoreline and developed an intimate knowledge of the natural processes and functions of the baylands. In the 1700s, before European colonists arrived, the Bay Area was home to diverse indigenous communities as evidenced by approximately 78 different languages and 42 individual Tribes (Figure 7).[89] At the turn of the 1800s, there were more than 400 shellmounds (places that held villages, ceremonial sites, burial mounds, and were points to communicate with neighboring Tribes) that could be found along the shores of the Bay.[90] Many of the shellmounds lie next to the coastline.[91] Although precise estimates are not available, anthropologists suggest that 20,000 to 25,000 indigenous people lived in the Bay Area sometime before European colonization.[92,93] Native wildlife of the region, including mammals, mussels, oysters, fish, clams and water birds, were commonly harvested. Wild plants were also harvested including native fruits and nuts (such as acorns).[94] Fire management was also used to shape the landscape to control food plant production and maximize game though it was unlikely to have had a major impact on the baylands ecosystem as a whole.[95] It is important to consider the intergenerational nature of these ecological practices, which are still actively used by Indigenous communities in the Bay Area. Traditional Ecological Knowledge (TEK) can be described as "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmissions, about the relationships of living beings (including humans) with one another with their environment." This pool of knowledge can encompass Indigenous observations and narratives, which most often

FIGURE 28:
Map of historical Indigenous tribes, languages and place names in the Bay Area (ca. 1700). The Native Languages Map of the Bay was assembled for the Fisher Bay Observatory at the Exploratorium (exploratorium.edu) by the San Francisco Estuary Institute and Chuck Striplen. The map is based on extensive research by Dr. Randy Milliken and data from Far Western Anthropological Research Group, Inc. (farwestern.com). Members of the Federated Indians of Graton Rancheria, Amah Mutsun Tribal Band, and Muwekma Ohlone provided review of the map.



MAP: SFEI



MAP: SFEI

FIGURE 29:

Historical habitat extent of the San Francisco Bay Estuary (circa 1800).[93]

include intergenerational knowledge on resource management, patterns, and practices. TEK is an acknowledgement of the interconnectedness of all the things; and in doing so it provides a practical foundation for how individuals, families, and communities can be well and thrive on the land on which they are situated.

Change in historical baylands

Between 1800 and 1998, 79% of tidal marsh and 42% of tidal flats were lost to diking and filling (Figure 30). Today, urban development, agriculture, diked wetlands and managed ponds (including industrial salt ponds) dominate the baylands, a stark departure from historical conditions.[96] Although the existence of tidal marsh and tidal flats has changed dramatically since the 1800s, the physical processes that drive Bay habitat formation have largely remained the same. Understanding the historical conditions of Bay habitats offers insight into the physical conditions and processes (e.g., elevation, slope, tidal prism, sediment deposition, freshwater flows, salinity gradients, etc.) that drive the success of habitat restoration and enhancement efforts in San Francisco Bay.

Approximately 200 years ago, before European colonization, the baylands were dominated by two primary habitat types: tidal flats (including mudflats, sandflats, and shellflats), which covered 50,000 acres, and tidal marshes (including salt and brackish marshes), which covered 190,000 acres.[97] Extensive tidal marsh habitat existed along the margins of the North Bay, South Bay and Suisun Bay, with small pockets of tidal marsh in coves and protected areas in the Central Bay and Carquinez Strait. Tidal flat habitat existed in each of the Bay's four subregions, but the extent differed largely based on salinity levels because, under freshwater conditions, marsh vegetation tends to grow lower in the intertidal zone, reducing the width of the unvegetated flats. Suisun, the subregion with the largest freshwater influence, had little tidal flat habitat compared to the South Bay, the subregion with the highest salinity, which had a large portion of the Bay's tidal flat habitat. Tidal flats also existed in portions of the North Bay and Central Bay resulting from an active supply of sediment and an environment that promotes sediment deposition.[98] Other important historical baylands habitat types included sandy beaches, marsh pannes, tidal channels, and lagoons. The baylands also had strong connections to deeper subtidal habitats (such as eelgrass meadows, shellfish beds, and shoals) and upland habitats (such as riparian corridors, willow groves, wet meadows and vernal pools, and oak savannas), creating transition zones up to several miles wide that provided critical habitat, resources, and high-tide refuge for many species.[99]

In the 1850s, the diking and draining of tidal marshes around the Bay became common practice to make land for agriculture and salt production. As the population of the Bay Area grew throughout the 1900s, the filling of baylands to create land for development also became commonplace, leading to large losses in tidal marshes and tidal flats.[100] A legislative moratorium against filling the Bay was passed in 1961, which led to the creation of the Bay Conservation and Development Commission, a permanent state agency that regulates development along the shoreline.[101] Although stricter environmental regulations to protect the baylands evolved between the 1960s and 1990s that slowed losses in tidal

RESEARCH QUESTION

Broadly, what are the biggest drivers of land use change that have most impacted the shoreline?

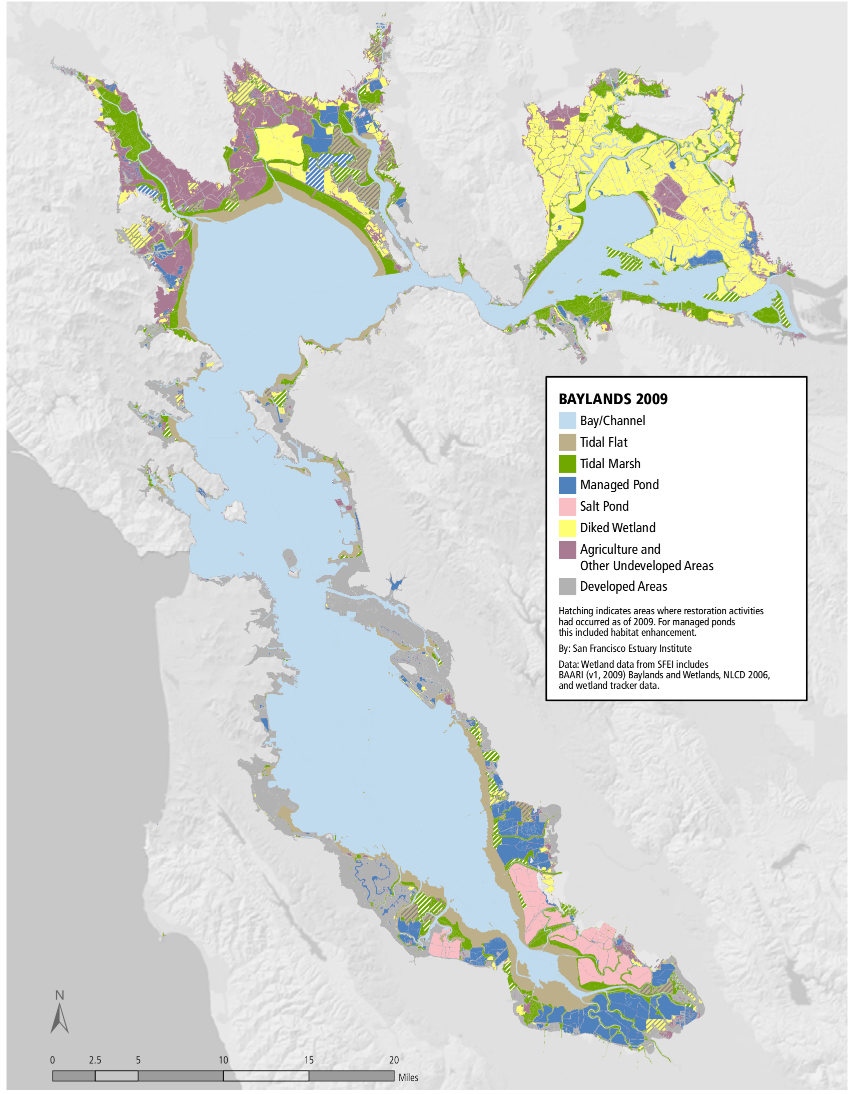


FIGURE 30:

Habitat extent of the San Francisco Bay Estuary in 2009.[104]

MAP: SFEI

marsh and tidal mudflat habitat, significant losses had already occurred. By 1998, approximately 150,000 acres of tidal marshes and 21,000 acres of tidal flats were lost compared to historical conditions (ca. 1800).[102] The remaining tidal marshes have generally become more fragmented and isolated, arranged in smaller patch sizes than were found historically with less "core" habitat, situated farther from other patches, and leveed off from upland habitats. These changes in habitat configuration likely reduce the quality of habitat for wildlife, compounding the problem of overall habitat loss.

Habitat loss and degradation is worrisome because the baylands provide some form of food, shelter, or other benefits to approximately 500 species of fish, amphibians, reptiles, birds, and mammals, and at least as many invertebrate and plant species.[103] At least 90 species of plants and animals found in the nine counties that border the Bay are endemic. At least 90 species living in and around the Bay are also listed as threatened or endangered under the Endangered Species Act. Among the most iconic of these species are the Ridgway's Rail and Salt Marsh Harvest Mouse—the conservation of these two species motivated much of the initial efforts to preserve and restore bayland habitats. The Bay is also a key location on the Pacific Flyway for migratory birds and a nursery for Dungeness crab, halibut, and Pacific salmon fisheries.

Although vast wetland areas have been lost since the 1800s, Bay wetland restoration efforts have significantly progressed since the inception of the 1999 Baylands Ecosystem Habitat Goals Project (Goals Project) and the more recent 2015 Baylands Ecosystem Habitat Goals Science Update (Science Update), which recommended reestablishing 100,000 acres of tidal wetlands in the Bay. Since the publication of the original Goals Project, approximately 12,000 acres have been restored and an additional 30,000 acres are in the process of being restored (Figure 30).[105] The Science Update identifies the latest scientific findings and recommended actions to support continued restoration and ecological enhancements in the face of increasing challenges from climate change and other urban stressors. Following the key guiding principles of the Goals Project, resilient ecological systems should be self-maintaining and highly functional, support native species over non-natives, and prioritize biological communities over individual species.[106] In 2016, voters in the nine Bay Area counties approved a $12-parcel tax, known as Measure AA, to fund over $500 million of bay enhancement and habitat restoration projects over the next 20 years, beginning in 2018.[107] Measure AA funding will further Bay wetland restoration and work towards improving the ecological integrity of the baylands.

HISTORY & CONTEXT

Historic Timeline of the Bay Area

Key moments in the formation of social-ecological systems in the Bay Area

TIMELINE: ADAPTED FROM SFEI

15,000 years ago

For 15,000 years or possibly longer, Native Americans inhabited the territory known today as California. Estimates by anthropologists suggest that the Bay Area was one of the most densely populated regions in North America. Although exact estimates are not available, 20,000 to 25,000 Native Americans likely inhabited the area before European settlers arrived.[108,109]

10,000 years ago

The San Francisco Bay (as we know it today) began to form approximately 10,000 years ago when the planet experienced a period of warming that marked the end of the last ice age. Mudflats and tidal marshes first formed around the edge of the Bay approximately 2,000 to 3,000 years ago.[110]

1770s

Europeans discovered San Francisco Bay and began to colonize San Francisco and surrounding areas through the establishment of Missions over the decades that followed. Over time, the Native American population was heavily impacted by disease, enslavement, and forced resettlement. Livestock grazing caused the first large-scale changes in natural habitats in the region.[111]

1848

The Gold Rush in the Sierra Nevada, which began in 1848, caused rapid population growth and development in the Bay Area. Hydraulic mining, which was a common method used to extract gold from the rivers and mountains, caused widespread erosion and downstream sedimentation. The use of mercury in gold processing and the establishment of nearby mercury mines led to mercury contamination of Bay waters and sediments in existence today.[112,113]

1850s

The diking and draining of tidal marshes around the Bay became common practice in the 1850s and 1860s to create land for agriculture and salt production. This practice is the main reason for the significant decrease in size of the Bay from historical conditions. Many of the agricultural areas adjacent to the baylands were converted to residential and industrial uses in the 20th century due to population growth.[114]

1900s–1950s

Throughout the first half of the 1900s, the Bay was generally considered a dumping ground for trash. Trash dumps located at the edge of the Bay became commonplace. Many still exist as landfills. Industrial waste, trash, and agricultural and urban runoff draining into the Bay led to significant water quality degradation, threatening the health and survival of species at all levels of the Estuary's food web.[115]

1930–1950

Racially restrictive land covenants. Land covenants restricting ownership of property by race are commonplace. Many of these land covenants have still not been removed from current deeds and other documentation.[116]

1934–1968

Redlining- Federal Housing Administration explicitly discriminatory lending practices. The practice of 'redlining' or racially discriminatory loan grade mapping is commonplace. Lending and access to capital in designated communities is severely restricted, which has had an enduring impact on the racial geographies of the Bay Area.[117]

1950s

By the 1950s, approximately 50,000 acres of tidal marsh remained in the Estuary, about one-quarter of the historical tidal marsh extent (Bayland Goals 1999). Habitat losses of this scale contributed to population declines of native fish and wildlife species that inhabit or rely on the the baylands such as the Ridgway's rail, California least tern, and Chinook salmon.[118]

1961

Plans unveiled in 1961 to fill 60% of the remaining Bay tidal marsh by 2020 catalyzed a campaign by Kay Kerr, Sylvia McLaughlin, and Esther Gulick to stop the rampant filling of the Bay and protect what remained of the Estuary's marsh habitats. Through creation of the "Save San Francisco Bay Association" and mobilization of Bay Area citizens, filling of the bay became illegal.[119]

1970s

The environmental movement began in the 1960s with the advent of Rachel Carson's "Silent Spring" and gained momentum through the 1970s with the inception of federal environmental regulations. The Clean Water Act was passed into law in 1972 to address growing public concern about water pollution. Shortly thereafter, in 1973, Congress passed the Endangered Species Act to protect native plants and animals in danger of becoming extinct.[120,121]

1998

By 1998, approximately 79% of tidal marsh and 42% of tidal flats had been lost to diking and filling. Tidal habitat restoration efforts in the Bay accelerated upon completion of the 1999 Baylands Ecosystem Habitat Goals Project. This was the first comprehensive vision of how to restore the baylands ecosystems. This report recommended a target of 100,000 acres of bay tidal marsh, a goal that continues to guide restoration projects today.[122,123]

2002

The South Bay Salt Pond Restoration Project began in 2002 to restore much of the converted salt ponds in South San Francisco Bay back to tidal marsh. When complete, the project will restore approximately 15,100 acres of tidal marsh, mudflat, and other wetland habitats.[124,125]

2007–2010

Mortgage crisis (and disproportionate impact on communities of color) 2007-2010. Following a legacy of inequitable housing access, communities of color are hit particularly hard by the impacts of the subprime mortgage crisis.[127]

2008

In 2008, the San Francisco Bay Restoration Authority was created through legislation sponsored by the Save the Bay Foundation. The goal was to raise and distribute regional funds towards wetland restoration projects.[126]

2015

The Baylands Ecosystem Habitat Goals Science Update, published in 2015, outlined new habitat restoration and enhancement guidelines to add to the original 1998 report. The Update incorporates the latest scientific understanding of climate change and other key drivers to maintain a resilient bayland ecosystem through 2100.[128]

2016

In 2016, voters in the nine Bay Area counties approved a $12-parcel tax to fund over $500 million of bay enhancement and habitat restoration projects over the next 20 years, beginning in 2018.[129]

Present

The Bay Area faces many challenges from sea level rise and other climate related issues that threaten critical infrastructure (e.g., roads, railroads, wastewater treatment plants, sewer systems, etc.), vulnerable communities, and important ecosystem functions. The Resilient by Design competition comes in an era marked by adaptive management, multi-benefit infrastructure, and re-envisioning our relationship to the baylands in an effort to support and adapt to a changing Estuary.

Environmental justice and resilience in the bay area

The Bay Area has a long and rich history of grassroots racial, social, and economic justice organizing that has won many victories, helped launch the national movements, and has brought about systemic changes in industry and government policies and practices. In considering the Bay Area context, it is important to touch on the history of key environmental justice fights in the region.

In the mid 1980s, the movement for environmental justice began to take its current shape in the Bay Area and across the country, with advocates fighting a long-standing pattern of systemic racism in the siting of toxic facilities in their communities, and the resulting impacts on health. As individual communities around California and around the country began to challenge the companies, policies and decisions that led to environmental pollution in local neighborhoods, in 1987 the Commission on Racial Justice of the United Church of Christ (CRJ-UCC) released a landmark report, "Toxic Wastes and Race in the United States"[130] which documented the racial and socio-economic characteristics of communities where hazardous waste sites were located. This document served as a powerful tool to highlight what communities fighting these issues across the country had asserted for decades – the disproportionate impact of pollution on communities of color and the need for addressing systemic racism in the siting of toxic facilities.[131] More recently, the CRJ-UCC has noted that, "Climate change and global warming bring an additional peril to communities of color or poor communities all over the world. Many who live near the coasts or in lower-lying areas will be the first to feel the effects of rising temperatures and oceans. They will not have the resources to make choices that others can make and may lose their homes and their livelihoods and will be displaced as environmental refugees."[132]

The environmental justice movement has worked not only to confront racism in government policies and industry decisions leading disproportionate impacts of pollution on low income communities, but also to highlight the failure of many environmental organizations to address these issues. In 1991, community leaders and grassroots activists from the Bay Area and across the country participated in the First National People of Color Environmental Leadership Summit in Washington DC. They joined in drafting and adopting the Principles of Environmental Justice.[133] Since then, The Principles have served as a defining document for the growing grassroots movement for environmental justice.

The preamble of The Principles stated clearly why so many people from diverse communities and Native Nations united to launch a national movement:

RESEARCH QUESTION

How can the principles of just and inclusive planning practice be upheld in community vulnerability assessment processes?

"WE, THE PEOPLE OF COLOR, gathered together at this multinational People of Color Environmental Leadership Summit, to begin to build a national and international movement of all peoples of color to fight the destruction and taking of our lands and communities, do hereby re-establish our spiritual interdependence to the sacredness of our Mother Earth; to respect and celebrate each of our cultures, languages and beliefs about the natural world and our roles in healing ourselves; to ensure environmental justice; to promote economic alternatives which would contribute to the development of environmentally safe livelihoods; and, to secure our political, economic and cultural liberation that has been denied for over 500 years of colonization and oppression, resulting in the poisoning of our communities and land and the genocide of our peoples, do affirm and adopt these Principles of Environmental Justice."

Environmental justice successes around the bay

Cleaning up toxic sites near homes and businesses and protecting communities against future risks is often a decades-long effort, placing a significant burden on local community leaders and neighborhood-based organizations to hold political and industry leaders accountable. Bay Area environmental justice organizers have persisted throughout the last few decades to ensure that accountability. These efforts have built up networks of activists and community leaders working to ensure development, adaptation and restoration projects incorporate community concerns and protect the region's most vulnerable residents. Examples of successful efforts include communities of color in Bayview-Hunters Point in San Francisco, who began organizing to confront government agencies and private industries that contributed to the many pollution sources plaguing their community to go unaddressed in the early 1980s. Their efforts eventually lead to the closure and cleanup of the PG&E Hunters Point power plant in 2006 after years of sustained effort.[134]

During this time fights also sprang up against oil refineries, chemical plants and other polluting industries in the East Bay, from West Contra Costa County to West Oakland and beyond.[135] Years of effort have led to some significant wins over time, from the closing the Chevron Ortho incinerator in the 1990s in Richmond to continued efforts, through both advocacy and legal action, to reduce the toxic impacts of Bay Area refineries.[136] In West Oakland earlier this year remediation finally began on the AMCO Chemical Superfund site, almost 30 years after it closed.[137] And along with mitigating the negative impacts of existing refineries, local community leaders are working proactively to move toward cleaner and more sustainable energy sources, to both reduce local air pollution impacts and reduce the overall climate impacts of fossil fuels.[138]

The story of the restoration of Dotson Family Marsh, formerly known as Breuner Marsh, which was dedicated earlier this year, captures the

HISTORY & CONTEXT

history of local community members tenaciously advocating for protecting their community's access to nature and open space, throughout years of development threats.[139] "Everybody neglects the need of low-income communities to access to quality of life," says Mr. Dotson, remembering the community using the adjacent open space for fishing, swimming and nature viewing.[140] Now the restored marsh restored marsh is designed to be a self-sustaining wetland complex that will filter polluted run-off and provide high quality habitat for threatened and endangered species. The park addition is designed to accommodate for sea-level rise resulting from climate change through 2080. This includes infrastructure design such as elevated trails and planning wildlife habitats so that even if some areas are submerged, the area can still sustain diverse species. The final restored area will also include interpretive exhibits and a 1.5-mile extension of the San Francisco Bay Trail, helping to close the remaining 10 miles of Bay Trail gaps within Richmond's current 32 miles of existing trail, and providing the first safe, non-motorized access to Point Pinole Regional Shoreline.[141]

Groups led by indigenous peoples in the Bay Area have built movements to advocate for the return and protection of native lands and for environmental remediation. In 2016, approximately 150 years after the Kashia Tribe in Sonoma County were forced to retreat inland to a tiny, water- poor reservation of just over 41 acres, the newly established Kashia Coastal Reserve restores ownership of coastal lands to the Kashia, protects important cultural sites, and provides a place to connect present and future generations of the Kashia with their heritage. The Tribe will manage the property as a demonstration forest and as a gateway for educating and engaging the public about the history and practices of native people in the area.[142]

The California Indian Environmental Alliance (CIEA) coordinated the language development and Tribal engagement of two new statewide beneficial uses which can protect water quality standards under the Clean Water Act: "Tribal Cultural Uses" and "Tribal Subsistence Fishing." These were adopted by the State Water Resources Control Board and approved by the EPA in 2017.

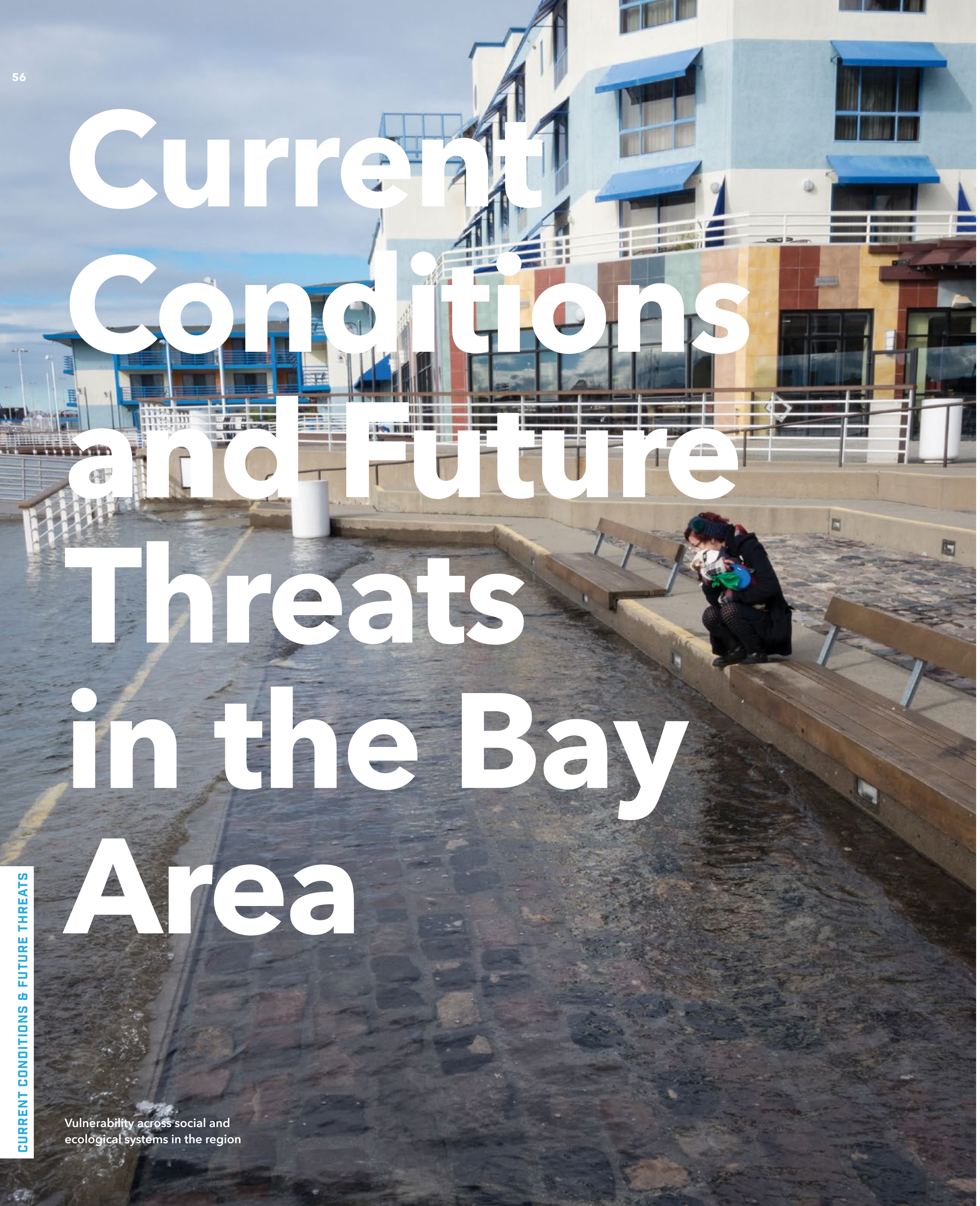
Looking toward the future

As a result of the power and victories of the environmental justice movement, environmental justice is recognized in many jurisdictions as a legal designation. In California law, "Environmental Justice" is defined as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. (Cal. Gov. Code, § 65040.12, subd. (e).) However, even where explicit environmental justice policies are present, implementation of and compliance with these policies and laws remains mixed.

More recently, environmental justice groups in the Bay Area have turned to climate adaptation planning to assert the values of climate justice, According to Breakthrough Communities, "a global climate justice movement is emerging, demanding fairness in the distribution of the benefits and burdens of climate change processes."[143] In step with this international movement, many social and environmental justice organizations in the Bay have become active in advocating for climate justice, equitable adaptation, and inclusive resilience planning advocacy. Likewise new groups and coalitions have formed to address the climate and flooding challenges of disadvantaged and environmental justice communities, including advocacy on hazard mitigation, flooding and emergency preparedness.

PHOTO: SPUR

Lake Merritt, Oakland.



Current Conditions and Future Threats in the Bay Area

Vulnerability across social and ecological systems in the region

Current ecosystems and ecological vulnerabilities

Bayland habitats and ecosystems

The tidal marshes, tidal flats and native wildlife are integral pieces of the San Francisco Bay's identity and provide multiple benefits to the region. Recreational value, flood protection, clean water, wave attenuation, and abundant wildlife support are some examples of the additional value the Bay's estuarine ecosystems provide to the people and wildlife in the region.[144] Significant change has taken place along the Bay shore. Much habitat has been lost, novel ecosystems such as diked wetlands and agricultural baylands have been created, and processes that sustain the baylands – such as sediment transport to build marshes and freshwater delivery to maintain gradients that promote biodiversity – have been disrupted. Changes in climate, with likely associated greater frequency and severity of storms, flooding, droughts and heat waves will further stress Bay ecosystems and their food webs.

Invasive species

As one of the most heavily invaded estuaries in the world,[145] invasive species are a large ecosystem management concern in the Bay. Invasive species, which refer to non-native plant and animal species which often possess characteristics (i.e., fast growth, quick maturation, large numbers of offspring) thought to damage native ecosystem dynamics by overwhelming and displacing native species.[146] With the potential to change habitat structure and outcompete native species for resources, invasive species can lead to conversion of native habitats to low-quality habitat types and dramatic reductions in endemic species populations.[147] Some of the most notable species in terms of impact on the Bay ecosystem include non-native cordgrass (*Spartina alterniflora*) and Asian clam (*Potamocorbula amurensis*). *Spartina alterniflora* was introduced from the east coast and has proliferated in the Bay by converting mudflat and small tidal channel habitats to dense marsh of generally low habitat value to many native species.[148] In 1986, *Potamocorbula amurensis* was introduced in the Bay and, since its filter feeding exceeds phytoplankton production rates, primary productivity levels experienced five-fold reductions in low-salinity areas within one year, dramatically altering ecosystem structure.[149] Although most invasive species are challenging to eliminate completely, long-term management efforts should outline strategies to reduce or control invasive species in Bay ecosystems to protect endemic species. Climate change presents additional challenges and unknowns with invasive species management since changing environmental conditions (e.g., air and water temperatures, Bay salinity and suspended sediment concentrations etc.) could lead to an expansion in habitat range for invasive species as well as less suitable habitat conditions for endemic species.

RESEARCH QUESTION

How will climate change impact the viability of both endemic and invasive species?

Natural processes governing the bayland habitats and ecosystems

Tidal baylands are dynamic and depend on their sustaining and interacting processes. Understanding and managing for these processes is of high importance as sea level rise becomes an increasing threat to bayland and marsh loss.

The dominant processes that govern the distribution of the complete tidal marsh ecosystem in space and time primarily include the rate of sea level rise, the supply of sediment, local topography, subsidence, wave energy, space for migration, and resident plant communities.

Processes that sustain or degrade marshes

Some definitions related to sustaining or degrading processes:

Migration: Movement of baylands to higher elevations, determined by rate of rise in sea level, supply of sediment, existing vegetation, local elevation gradients, hydrology and subsidence of marshlands.

Erosion: Loss of sediment from the outer surface of baylands; wave energy drives erosion typically at the border between tidal flats and subtidal area.

Progradation: When marshes and mudflats accrete sediment and organic matter, they horizontally extend into subtidal areas. The rate of this process depends on the rate of erosion, sediment supply and biological interactions.

Drowning: Wholesale loss of baylands due to submersion of lower elevation tidal habitat, resulting in habitat change (typically referring to change from tidal marsh to tidal flat, or tidal flat to subtidal habitat).

Accretion: Related to progradation, except referring to the vertical raise of tidal wetlands as a result of both organic and inorganic matter and sediment (similarly this refers to the conversion of tidal flat to tidal marsh or subtidal habitat to tidal flat).

As a side note, managed marsh systems that are not subject to equivalent tidal processes do not behave equivalently. Diked baylands, where water levels are heavily managed, do still endure subsidence and erosion. However, levees and water control structures constrain the resilience of these systems given their isolation and heavy modification. Disconnection from both sediment supply networks and exchange associated with tidal action may constrain these systems' capacity for adaptive change.[150]

GRAPHIC: ADAPTED FROM SFEI

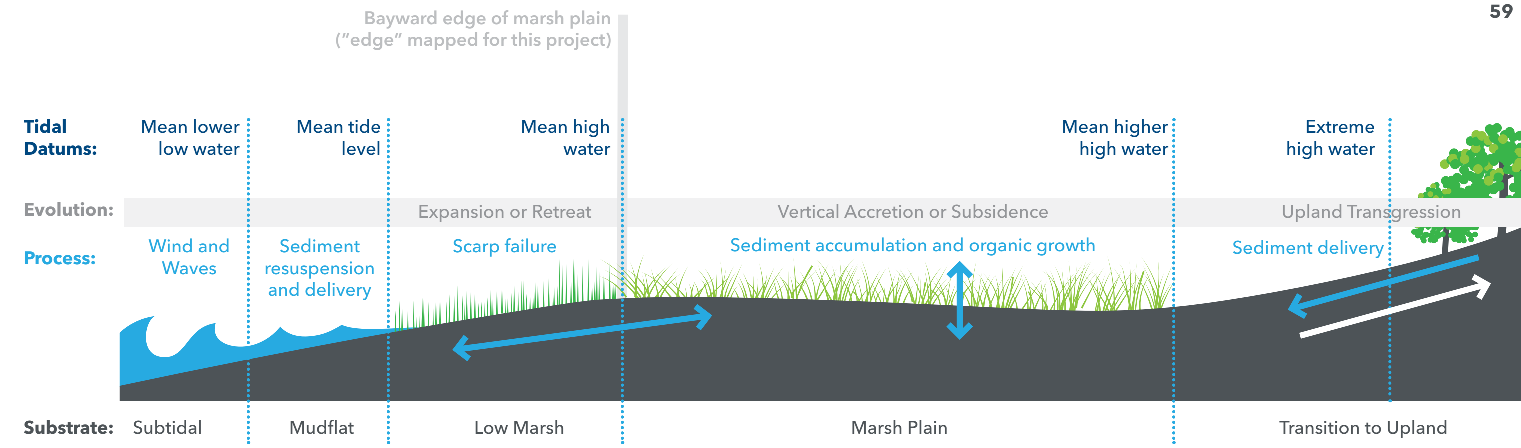


FIGURE 31:
CONCEPTUAL MODEL OF MARSH EVOLUTION.
This cross section stretches from subtidal reaches of an idealized shoreline through the marsh to the upland transition zone. It illustrates the different drivers and processes controlling the evolution of the marshes, and of the shoreline in particular.[151]

Components of a complete Baylands ecosystem

The baylands comprise a broad spectrum of habitat types. The full gradient encompasses subtidal eelgrass and oyster beds, tidal flats, tidal wetlands and the estuarine-terrestrial transition zone. Clearly delineating where one habitat ends and another begins is a challenging exercise, as these ecosystems exist based on complex and heterogeneous environmental gradients. Considering the ecosystem in totality, or as a "complete tidal wetland system," is useful (Figure 31). This way, the individual constituent habitats, their ecotones and their synergy in provision of ecological functions and services are all illustrated.[152]

Managed habitats, not described in full detail here, also can provide significant habitat value. These habitats, which include diked baylands, and managed ponds, cumulatively make up nearly 95,000 acres according to 2009 estimates.Managed ponds, in particular, can support abundant wildlife such as waterfowl. These habitats should also be considered when managing for complete tidal wetland systems.[153]

Subtidal habitats

Deep bays and channels can generally be characterized as the deepest portions of the Bay to 18 feet below mean lower low water (MLLW), while *shallow bay and channel* habitat transition from this point to the lowest elevation of the diurnal tides (MLLW).[154] The bay leans shallow – shallow water habitats make up about two thirds of the subtidal area, while deep bay habitat comprises the remaining third. These habitats serve as important habitat for large aquatic invertebrates, water birds and some marine mammals, and are used as migratory corridors by anadromous fish. Eelgrass beds exist in shallow bay habitats, which provide critical habitat many species of fish, invertebrates and birds, including spawning grounds for the Pacific herring and feeding grounds for least terns. The subtidal habitats (e.g., oyster beds and eelgrass) found in this zone also provide important regulatory processes by breaking up wind waves, acting as a protective buffer to other surrounding inland tidal habitats.[155] Subtidal and shallow bay and channel habitats may likely increase in extent with rising sea levels, depending on the rate of marsh accretion and sediment delivery to the baylands.[156,157]

Tidal flats (mudflat)

Tidal flats exist between the lowest elevations of the tides and Mean Tide Level (MTL), and range from sandflats, mudflats and shellflats depending on existing sediment, with mudflat being the most common. According to 2009 estimates, tidal flats encompass about 34,000 acres around the bay,[158,159] and occur more often in saline compared to brackish area.[160] Tidal flats are inundated twice daily by the tides, creating foraging habitat for different species during different parts of the day depending on inundation levels. Mudflats are colonized by a variety of invertebrates. Starry flounder, staghorn sculpin, longfin smelt and many other species of fish feed in this area during periods of high tide. During low tide, this zone becomes prime foraging grounds for shorebirds like the western sandpiper, dunlin and semipalmated plover. Wind waves and tidal action cause sediment resuspension and delivery in this zone which provides a means for marsh accretion and critical material flows between habitats. Mudflats also act as a buffer by attenuating wind waves before they reach adjacent tidal marsh.[161] The movement of this habitat will depend on the rate of sea level rise, sediment supply, vegetative structure and wind.[162,163]

Tidal marsh

Tidal marshes are wetlands in which inundation is governed by the tides. This habitat type is found in baylands between mudflats and the highest tidal extent, as well as the tidal-influenced sections of streams. Plant communities in this habitat type are driven by a variety of factors as discussed previously, including but not limited to salinity, rate of sedimentation, erosion and wave energy. Salinity is higher in the North, Central, and South bays, while more freshwater input creates more brackish tidal marsh in Suisun, stretches of the Petaluma and Napa rivers, as well as portions of the South Bay. Marsh extent varies by salinity, occurring lower in the intertidal zone in fresher waters. Tidal marsh is located in its largest patches in San Pablo Bay and the Petaluma River, and is relatively absent in the Central Bay.[164]

According to 2009 estimates, over 44,000 acres of tidal marsh habitats exist around the Bay.[165] These habitats can generally be considered in three zones delineated by tidal elevation and distance from shore. *Low tidal marsh* is found between the bayward marsh edge and mean high water, serving as marsh interface with the tidal flats and experiencing the highest levels of salinity. This area is frequently dominated by Pacific cordgrass. *Middle marsh (marsh plain)* is found in the intermediate zone, between mean high water and the even higher Mean Higher High Water. This plain is comprised of such vegetation as pickleweed and marsh gumplant. *High marsh* is found from this latter boundary to the highest margin of the marsh. The high marsh serves as an ecotone and transition into the adjacent uplands. Elevation drives the local extent of these zones – in higher slope areas such as the Central Bay, the zone is quite narrow, while in lower gradient areas such as Suisun, the zone could be longer than several hundred yards.[166]

Tidal marshes have a variety of important components including *tidal channels* and, sometimes, *pans* or pannes (natural ponds in the marsh plain). Tidal channels are filled as tides rise. Large channels often have smaller tributaries that spread water throughout the marsh. Channels tend to be more sinuous in flatter marshes, and denser in more saline marshes.

Richmond Mudflats. Photo courtesy SFEI.

Tidal Marsh. Photo courtesy SFEI.

Tidal marshes are zones of significant productivity. Such areas provide nursery habitat, food and refugia for a variety of fish and wildlife. The marshes of San Francisco Bay are also particularly unique in their biodiversity -- high levels of endemism are present in these communities. Fish species vary by locale – gobies, sculpin and three-spined stickleback are found in the North Bay, while topsmelt, gobies and staghorn sculpin are found in the Central and South Bay and smelt and salmon are found in Suisun. Bird species associated with these habitats include California black rail, Northern Harrier, Great Egret, as well as the Alameda, San Pablo and Suisun song sparrows. Small mammals include the salt marsh harvest mouse, salt marsh wandering shrew and Suisun shrew. Larger predators such as coyote occupy middle and high marsh. Even harbor seals spend time in tidal marsh, in particular in the South Bay.

Tidal marshes provide many important services, including carbon sequestration,[167] pollution and nutrient filtration/absorption, as well as protection from storm surge and flooding. Tidal marsh migration will depend on the rates of sea level rise and accretion of inorganic and organic matter.

GRAPHIC: ADAPTED FROM SFEI

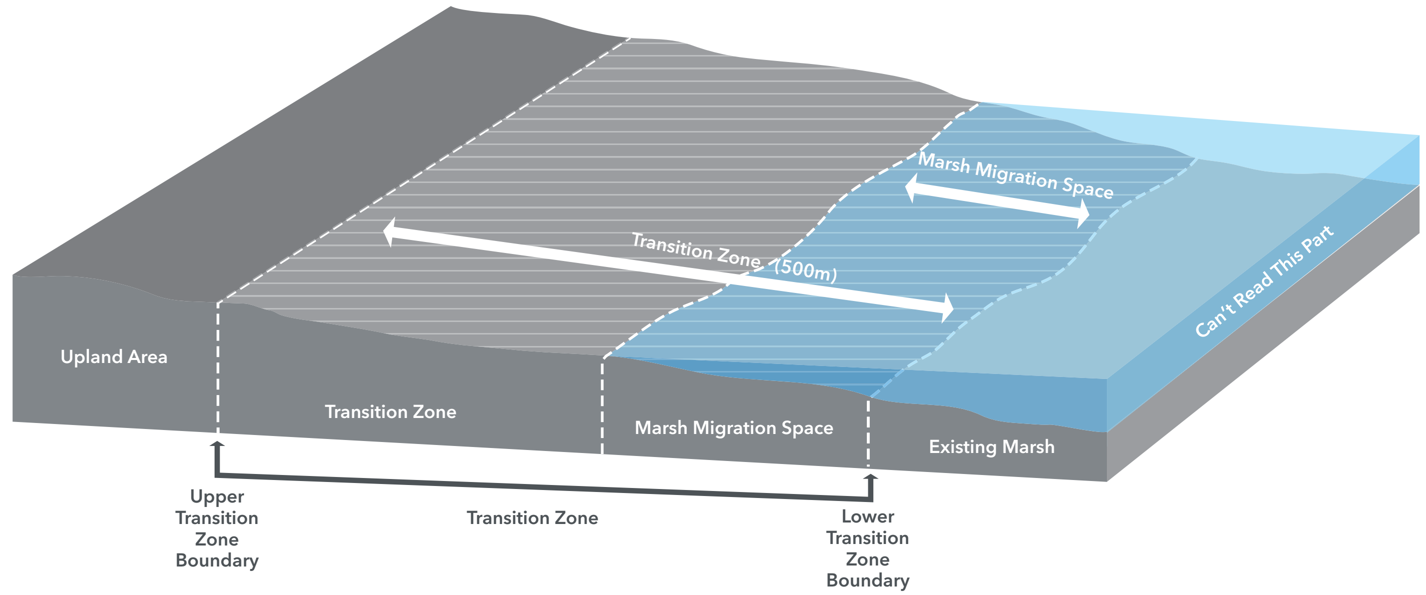


FIGURE 32:
CONCEPTUAL DIAGRAM OF COMPONENTS OF A TRANSITION ZONE
Showing areas for marsh migration (based on 0.6m of sea level rise), and transition space (approximately 500m) (SFEI draft 2017).[68]

Transition zone and uplands

The estuarine-terrestrial *transition zone,* or *t-zone,* is defined from the *Baylands Goals* 2015 update as "the area of existing and predicted future interactions among tidal and terrestrial or fluvial processes that result in mosaics of habitat types, assemblages of plant and animal species, and sets of ecosystem services that are distinct from those of adjoining estuarine, riverine, or terrestrial ecosystems."[169]

In general terms, the transition zone spans from between the wetlands under tidal action and the uplands not yet influenced by the tides (though these lands may be soon, depending on the rate of sea level rise) (Figure 32). Various factors can affect the width of the t-zone, including slope, hydrology,

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soil type and vegetation association. Further, the t-zone itself evolves and migrates over time. With sea level rise, current uplands will become future marshlands in areas of shallow-sloped topography. Managing land use to buffer t-zone migration space and managing sediment supply for wetlands reinforcement will help ensure resilient future complete tidal marsh ecosystems.[170]

The t-zone provides numerous ecosystem services: buffering - pollution control, invasive species control, erosion control; flood risk management; sea level rise accommodation as discussed; groundwater recharge; carbon sequestration; and support for wildlife - refuge from tides and predation, movement across habitat types and landscape complexity to support diversity. The exchange of freshwater to saltwater creates a gradient that promotes biodiversity. Many species of terrestrial and aquatic wildlife, including birds of prey and salmon, move between the baylands and its local watersheds. This link between baylands and local watersheds is important in provisioning many ecosystem services, including exchange of resources such as water, sediment, energy, plants and other animals.[171]

RESEARCH QUESTION

Where do opportunities exist to protect existing or create future transition zones that can accommodate marsh migration around the Bay as sea level rises? What function might transition zones fill under different scenarios of sea-level rise?

Adjacent uplands take many different habitat forms and comprise a mosaic depending on local geography and diverse vegetation is supported. Some common habitat types include riparian forest and willow groves along streams, and vernal pools, grasslands, oak savanna and woodlands and mixed evergreen forest. Upland habitats are an integral part of the baylands ecosystem as they provide important foraging, roosting, and breeding habitat for many species of amphibians, reptiles, birds, and small mammals that frequent the baylands. Uplands provide many similar services to the t-zone, including carbon storage in soils and vegetation, fresh water supply, flood risk reduction downstream, and production of wood and food such as cattle.[172]

Future threats to ecosystems

The baylands face numerous, severe threats in the coming decades. The region's ecosystems and the processes that sustain them have been lost, fragmented or degraded. Habitat loss and fragmentation continues under development and land conversion, and degradation continues with the spread of invasive species, emission of pollutants, and disruption of sustaining processes such as sediment and freshwater delivery. As a result, threatened and endangered species, as well as a general abundance and diversity of native wildlife are under threat. Climate change, driving rising sea levels and increased frequency and severity of stressful weather events and disturbances, threaten ecosystem integrity. The many services provided by our ecosystems – ranging from flood protection to pollution control – are at risk as a consequence.[173]

However, opportunities remain. Large-scale re-conversion efforts of salt ponds are occurring in the South Bay to restore vast acreage of lost tidal marsh, and more opportunities remain for future acquisition and restoration. Disrupted processes, also, can be improved. The use of dredged sediment for engineering, navigability or flood control projects can be delivered downstream to help build marshes at the Bay's edge.[174] Planning with foresight to address these threats by considering t-zone geography, holistic management across habitat types, sediment supply and freshwater delivery will create the most resilient future baylands.[175]

Social vulnerability

Social vulnerability

The terminology related to social vulnerability varies. In the context of hazard mitigation and resilience planning it often applies to populations with less capacity to prepare for, respond to, and recover from a harmful event, such as a flood. Examining social vulnerability indicators can be a powerful tool for developing climate resilience solutions that create positive outcomes for vulnerable communities. Assessing social equity to understand climate risk is complementary to environmental justice movement.

Approaches to understand and classify social vulnerability vary. Some of these approaches include map-based screening tools, which identify geographic locations with populations that exhibit characteristics of heightened vulnerability. Each of the screening tools includes data about population characteristics, and some include environmental hazard data. These data sets and associated viewers are primarily used in research and planning. In some cases, vulnerability designation is tied to funding sources. These tools represent just one method to locate areas that may need support and it does not serve as a comprehensive description of communities.

Social vulnerability screening tools and application to sea level rise in the SF Bay Area

Screening tools exist to help identify locations where more attention may be needed. Critical consideration in choosing the best vulnerability screening tool to use is necessary, as they are not all intended for the same use. Each has been designed to answer different research and policy questions. A description of these tools, their intended purpose, and where to access the data are included.

For evaluating social vulnerability to sea level rise, it is important to collect the data that is specifically relevant to flood risk. The San Francisco Bay Conservation and Development Commission (BCDC) Adapting to Rising Tides (ART) Program has created such a dataset through extensive stakeholder input and research, described in Section C. The data represents characteristics of individuals and households that may affect ability to prepare for, respond to, and recover from a flood event.

The BCDC social vulnerability dataset—Community Indicators for Flood Risk—makes calculations and determines thresholds based on data from the nine-county bay area region. Many of the other tools work at the state or national scale, and therefore generate percentiles of vulnerability for a given location relative to the rate in the state or country. When working with socioeconomic data—such as looking at income, housing costs—it is more accurate to compare Bay Area geographies with Bay Area geographies.

It is important that methods of computation used in the screening tool are clear and that the full range of data is available to the user—not just the data

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points which have met the screening tool's threshold or are above a certain percentile. In particular, local-scale analyses will benefit from having full access to the complete data to meet their diverse needs. Conducting supplemental analysis to the screening analysis can provide a more comprehensive understanding. The screening tools generate a total vulnerability "score," which may or may not satisfactorily represent vulnerability in any given location. Access to each individual data point may be beneficial in clarifying and deepening understanding. In some screening tools, the user is unable to disaggregate the data points, or unable to access the full dataset.

BCDC community indicators for flood risk:

Background and use:

The Resilience Program at the Association of Bay Area Governments and Adapting to Rising Tides (ART) Program at San Francisco Bay Conservation and Development Commission partnered on the 2015 Stronger Housing, Safer Communities project to better understand and characterize housing and community vulnerability to flooding and earthquakes, and to develop strategies to reduce these vulnerabilities. An advisory committee of recognized experts, including community advocates, developed criteria for vulnerabilities and strategies based on professional experience, local knowledge, and consultation of academic and federally sponsored research. Indicators were developed as a regional screening tool to help identify neighborhoods where community members may be at greater risk. This approach does not, however, reflect qualitative characteristics that may increase or decrease risks, such as community cohesion and social capital (i.e., community capacity). The indicators for community vulnerability were updated in 2016, will undergo another round of stakeholder review as part of the current ART Bay Area project, and will be continually updated as social vulnerability knowledge evolves. The total number of characteristics may increase depending on working group input and improvements in data availability. This methodology is appropriate for local to regional scale planning, but should not be used for project reviews or environmental assessments.

Description of data:

The Community Indicators for Flood Risk data is comprised of population characteristics uncoupled from environmental hazards. This allows for flexibility in evaluating exposure to a variety of hazards. Depending on the project, different overlays of sea level rise, FEMA flood zones, location of brownfields, and other flooding-related hazards can be applied to this community dataset.

Indicators were measured and analyzed using a triggering level methodology developed by the Metropolitan Transportation Commission (MTC) to identify Communities of Concern (CoC). The triggering level methodology identifies US Census block groups that have a concentration of individuals or households with a particular characteristic. The triggering levels, which are reported as a percentage, are determined for each indicator by calculating the regional mean + ½ standard deviation.

ArcGIS layers for each indicator are available for use in mapping and analysis and can be downloaded from the ART Program's Maps and Data Products page. For each block group, the layers contain the total count

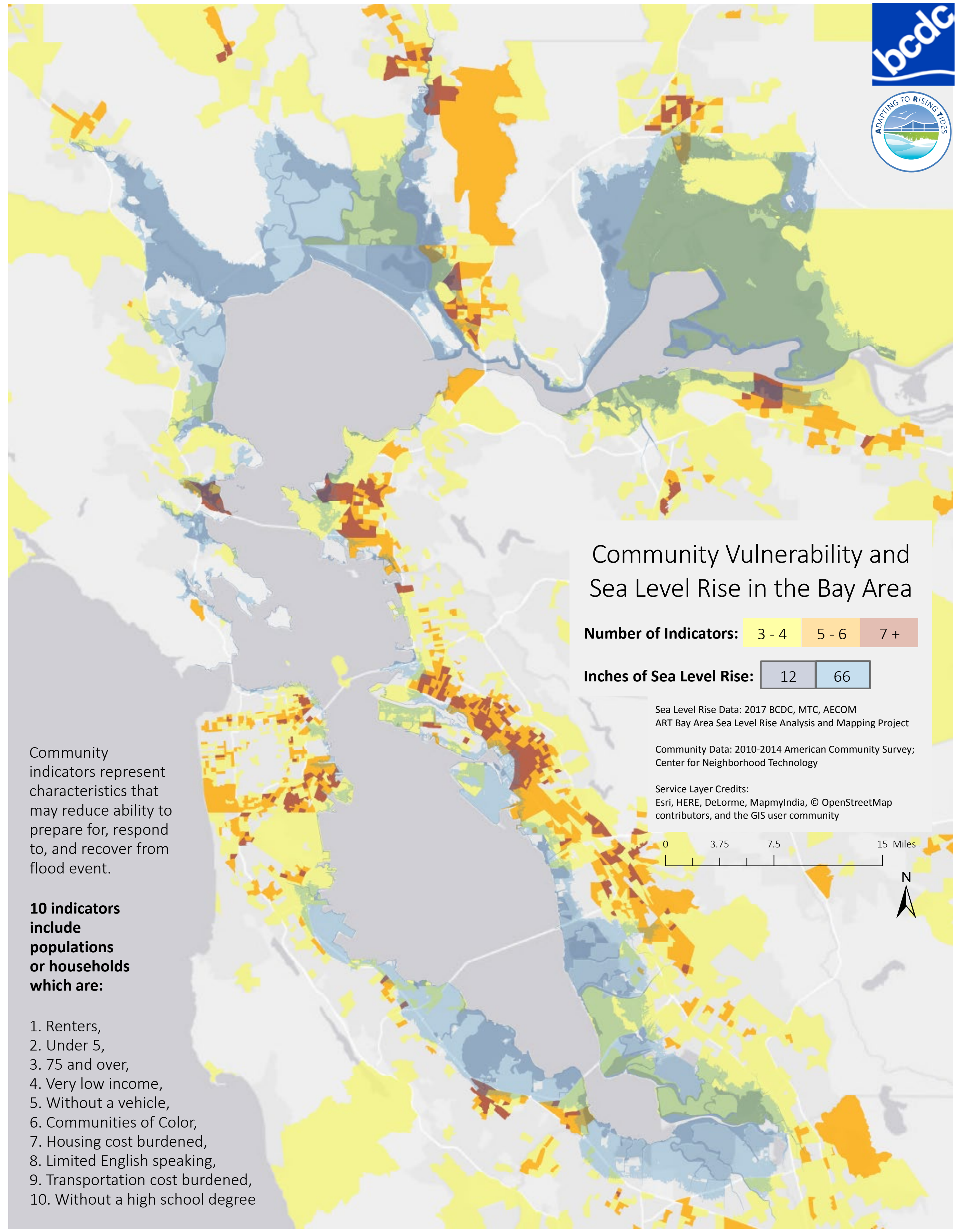
RESEARCH QUESTION

What will be the lasting impacts of this challenge? What types of community capacity building could be achieved?

FIGURE 33:

Mapping social vulnerability and sea level rise in the Bay Area. BCDC, MTC, AECOM

MAP: BCDC



of individuals or households with each indicator, the total population and number of households, the percentage of individuals or households with each indicator, and whether the percentage is at or above the triggering level (1=has met trigger, 0=has not), as well as the reliability of the data for each indicator (1=reliable, 0=not reliable). Reliable data is defined as having a coefficient of variation less than 40%. The database includes data as it was received from the census, so that other types of analyses can be performed in addition to the threshold screening methodology described above. Local-scale analyses will benefit from having access to all data, and not only those which have met the threshold.

The table below provides information about each indicator, including the measure used, the source of data, and the triggering level (reported as a percentage). In addition, an unweighted score of 1 was assigned to each indicator for use in composite mapping of block groups with 3 or more indicators.

TABLE: BCDC

FIGURE 34:
COMMUNITY INDICATORS FOR FLOOD RISK CHARACTERISTICS

Indicator	Measure	Source: 2010-2014 American Community Survey, unless otherwise noted	Percentage Per Block Group	Count
Language	% Households without a proficient English speaker 15 years and older	S1602: Limited English Speaking Households	≥ 14	1
Access to a vehicle	% Households without a vehicle	B08201: Household size by vehicles available	≥ 15	1
Housing cost burden	% Households spending greater than 50% income on housing	B25091: Monthly owner costs as a percentage of household income & B25070: Gross rent as a percentage of household income	≥ 35 renters &/or ≥ 19 owners	1
Race and ethnicity	% Persons of Color	B03002: Hispanic or Latino origin by race	≥ 68	1
Education	% Persons 25 years and older without a high school degree	B15003: Educational attainment for the population 25 years and over	≥ 19	1
Housing tenure	% Not owner-occupied households	B25003: Tenure	≥ 55	1
Transportation cost burden	% Households with high transportation costs	Center for Neighborhood Technology Housing and Transportation Affordability Index	≥ 18	1
Income	% Households with income less than 50% of Area Median Income	B19001: Median household income	≥ 33	1
Age	% Persons 75 and older	B01001: Sex by age	≥ 9	1
	% Persons under 5		≥ 8	1
Total				**10**

Additional community vulnerability screening tools:

1. **US Environmental Protection Agency EJSCREEN**:

Background and use:
Under Executive Order 12898, Federal Actions To Address Environmental Justice In Minority Populations and Low-Income Populations, all federal agencies "collect, maintain and analyze information assessing and comparing environmental and human health risks borne by populations identified by race,

TABLE: EJSCREEN

FIGURE 35:
SUMMARY TABLE OF ENVIRONMENTAL INDICATORS AND DATA SOURCES

Key Medium	Indicator	Details	Source	Data Year
Air	National-Scale Air Toxics Assessment (NATA) air toxics cancer risk	Lifetime cancer risk from inhalation of air toxics	EPA NATA	2011
Air	NATA respiratory hazard index	Air toxics respiratory hazard index (ratio of exposure concentration to health-based reference concentration)	EPA NATA	2011
Air	NATA diesel PM	Diesel particulate matter level in air, µg/m3	EPA NATA	2011
Air	Particulate matter	PM2.5 levels in air, µg/m3 annual avg.	EPA, Office of Air and Radiation (OAR) fusion of model and monitor data	2012
Air	Ozone	Ozone summer seasonal avg. of daily maximum 8-hour concentration in air in parts per billion	EPA, OAR fusion of model and monitor data	2012
Air/other	Traffic proximity and volume	Count of vehicles (AADT, avg. annual daily traffic) at major roads within 500 meters, divided by distance in meters (not km)	Calculated from 2014 U.S. Department of Transportation (DOT) traffic data, retrieved 2016	2014
Dust/ lead paint	Lead paint indicator	Percent of housing units built pre-1960, as indicator of potential lead paint exposure	Calculated based on Census/ American Community Survey (ACS) data, retrieved 2015	2010-2014
Waste/ air/ water	Proximity to Risk Management Plan (RMP) sites	Count of RMP (potential chemical accident management plan) facilities within 5 km (or nearest one beyond 5 km), each divided by distance in kilometers	Calculated from EPA's RMP database, retrieved 12/01/2015	2015
Waste/ air/ water	Proximity to Treatment Storage and Disposal Facilities (TSDFs)	Count of TSDFs (hazardous waste management facilities) within 5 km (or nearest beyond 5 km), each divided by distance in kilometers	Calculated from EPA's Resource Conservation and Recovery Act (RCRA) Info database, retrieved 08/16/2016	2016
Waste/ air/ water	Proximity to National Priorities List (NPL) sites	Count of proposed or listed NPL - also known as superfund - sites within 5 km (or nearest one beyond 5 km), each divided by distance in kilometers	Calculated from EPA's Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) database, retrieved 10/30/2015	2015
Water	Proximity to major direct water dischargers	Count of National Pollutant Discharge Elimination System (NPDES) major direct water discharger facilities within 5 km (or nearest one beyond 5 km), each divided by distance in kilometers	Calculated from EPA's Permit Compliance System/ Integrated Compliance Information System (PCS/ ICIS) database, retrieved 11/30/2015	2015

national origin or income." The US EPA uses diverse information to comply with this executive order, and published the EJSCREEN mapping tool and data to provide transparency on the process of evaluating environmental justice concerns. Additionally, making EJSCREEN data readily available—for use in research, decision-making, education, etc.—improves clarity between the EPA and the public by using consistent sources. EJSCREEN is intended to be used as a screening-level tool and does not definitively identify environmental justice issues in any specific location or label any areas as an "environmental justice community." It is not designed to measure cumulative impacts of additive environmental hazards, and not designed to quantify risk.

Description of data:
EJSCREEN includes 11 indicators for environmental hazard, 6 demographic indicators, and 11 environmental justice indexes, which combine each environmental hazard with demographic information. Data is reported out in percentiles, which are available both relative to the US and relative to each state. See tables below for data included.

EJSCREEN includes 6 indicators on demographics:

1. **Percent Low-Income**:
   The percent of a block group's population in households where the household income is less than or equal to twice the federal "poverty level."

2. **Percent Minority**:
   The percent of individuals in a block group who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino. That is, all people other than non-Hispanic white-alone individuals. The word "alone" in this case indicates that the person is of a single race, not multiracial.

3. **Less than high school education**:
   Percent of people age 25 or older in a block group whose education is short of a high school diploma.

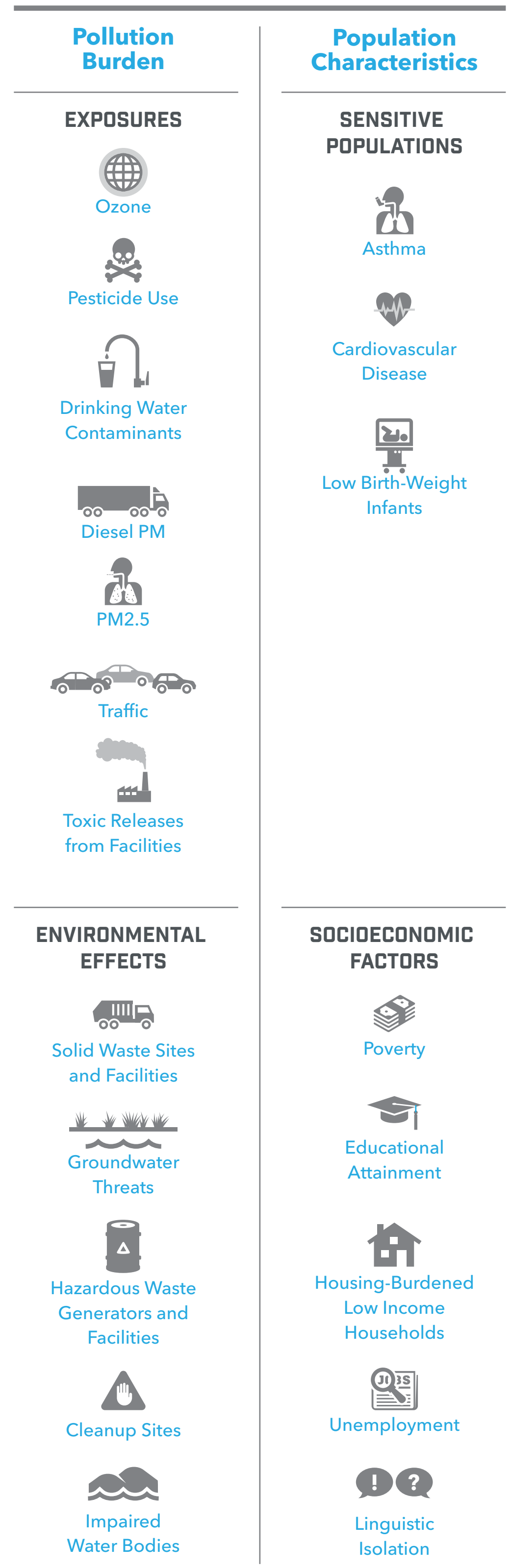
4. **Linguistic isolation**:
   Percent of people in a block group living in linguistically isolated households. A household in which all members age 14 years and over speak a non-English language and also speak English less than "very well" (have difficulty with English) is linguistically isolated.

5. **Individuals under age 5**:
   Percent of people in a block group under the age of 5.

6. **Individuals over age 64**:
   Percent of people in a block group over the age of 64.

GRAPHICS: ADAPTED FROM CALEPA

FIGURE 36:
POLLUTION BURDEN INDICATORS
Types of pollution burden indicators used by EPA EJSCREEN



❷ CA Environmental Protection Agency (CalEPA) and CA Office of Environmental Health Hazard Assessment (OEHHA) CalEnviroScreen
Background and use:
Passed in 2012, CA Senate Bill 535 (De León, Chapter 830, Statutes of 2012) directed funds from the State's cap and trade program[176] to benefit "disadvantaged communities"— at least 10% of funds given to projects located in these communities and at least 25% for projects that benefit them. The legislation designated CA Environmental Protection Agency (CalEPA) to develop a method for identifying "disadvantaged communities." Funding minimums were increased in 2016 that 25% of funds be for projects within disadvantaged communities, and another 10% of funds to de directed to low-income communities and households with CA Assembly Bill 1550 (Gomez, Chapter 369, Statutes of 2016). CalEPA created the CalEnviroScreen tool to geographically identify disadvantaged communities. In addition to identifying areas to distribute cap-and-trade proceeds, CalEnviroScreen informs other areas of CalEPA decision-making, such as prioritizing resources and cleanup actions, and in allocating other grants from state agencies.

FIGURE 37:
CALENVIROSCREEN FORMULA

* The Environmental Effects component is weighted one-half when combined with the Exposures component.

Description of data:
CalEnviroScreen 3.0 is the most recent version, released after a workshop-based engagement process in February 2017. Pollution burden and population characteristics are combined to generate a CalEnviroScreen score by census tract. The score for each census tract is relative to all other census tracts around the state, reported as a percentile. Twenty indicators in four themes are considered:

1. **Exposures**: Contact with pollution
2. **Environmental Effects**: Adverse environmental conditions caused by pollution
3. **Sensitive Populations**: Populations with biological traits that may magnify the effects of pollution exposures
4. **Socioeconomic Factors**: Community characteristics that result in increased vulnerability to pollution

③ Metropolitan Transportation Commission Communities of Concern

Background and use:

The Metropolitan Transportation Commission (MTC) is the regional transportation planning, financing, and coordinating agency in the Bay Area, and developed the Communities of Concern (CoC) designation through a regional equity working group process.[177] CoCs can exhibit vulnerabilities now and to future growth impacts, and inform the equity analysis of Plan Bay Area 2040 — the combined Sustainable Communities Strategy and Regional Transportation Plan for the San Francisco Bay Area, which works to reduce greenhouse gas emissions through transportation and land use required by SB 375, the Sustainable Communities Act (Chapter 728, Statutes of 2008). Additionally, in establishing local funding priorities for One Bay Area Grants, projects located in a CoC are "favorably considered."[178]

Description of data:

Communities of concern designation is given to census tracts that have a concentration of both minority and low-income residents, or that have a concentration of low-income residents and any three or more of the following six disadvantage factors: persons with limited English proficiency,[179,180] zero-vehicle households, seniors aged 75 years and over, persons with one or more disability, single-parent families,[181] and renters paying more than 50 percent of their household income on housing.[182] Concentration thresholds are between the regional average and one standard deviation for each disadvantage factor. Data is from the US Census American Community Survey 5-year estimates for 2005-2009 and 2010-2014.

Disadvantage Factor	Share of Regional Population 2009	Share of Regional Population 2014	Concentration Threshold
Minority	54%	59%	70%
Low-Income	23%	25%	30%
Limited English Proficiency	9%	9%	20%
Zero-Vehicle Household	9%	10%	10%
Senior	6%	6%	10%
People with a Disability	18%	9%	25%
Single-Parent Family	14%	14%	20%
Cost-Burdened Renter	10%	11%	15%

FIGURE 38:
CHARACTERISTICS FOR MTC COMMUNITIES OF CONCERN

④ Bay Area Air Quality Management District (Air District) Community Air Risk Evaluation (CARE) Program

There is a variety in the amount of air pollution, and therefore health impacts, that different communities around the bay endure. The goals of the CARE Program are to:

- → Identify areas where air pollution contributes most to health impacts and where populations are most vulnerable to air pollution. CARE Communities are designated in geographic locations where there are concentrations of high atmospheric air toxic/particulate matter and sensitive populations (seniors, children, and low income). Online mapping tool and data: http://www.baaqmd.gov/plans-and-climate/community-air-risk-evaluation-care-program
- → Apply sound scientific methods and strategies to reduce health impacts in these areas.
- → Engage community groups and other agencies to develop additional actions to reduce local health impacts. (http://www.baaqmd.gov/plans-and-climate/community-air-risk-evaluation-care-program)

⑤ CA Department of Water Resources (DWR) Disadvantaged Communities (DAC) and Economic Distressed Area (EDA) Mapping Tools

Background and use:

CA Proposition 50 and Proposition 84, and the corresponding creation of Integrated Regional Water Management (IRWM) planning groups, significantly altered California's approach to water management. As these programs evolved, a growing gap emerged between the activities of the traditional water community and the needs of disadvantaged communities and the people that live and work there. In response to these concerns, DWR initiated seven IRWM disadvantaged community grant projects, representing a diverse socio-economic landscape, to identify more effective means of engaging with and responding to the water-related needs of disadvantaged communities. The DWR Proposition 1 IRWM Disadvantaged Community Involvement Program is designed to ensure the involvement of disadvantaged communities (DACs), economically distressed areas (EDAs), or underrepresented communities (collectively referred to as DACs) in IRWM planning efforts. Grants awarded through Proposition 84 and Proposition 1 IRWM include requirements to benefit DACs and EDAs.

Description of data:

Proposition 84 IRWM Guidelines (2015) defines disadvantaged communities. Census Place, Census Tract, and Census Block Groups with annual median household income (MHI) less than 80% of the statewide level receive DAC designation, and census geographies with annual MHI less that 60% of the statewide level receive Severely Disadvantaged Communities (SDAC) designation. The tool used data from the US Census American Community Survey 5-year estimates for 2010-2014.

- → DAC mapping tool: http://gis.water.ca.gov/app/dacs/
- → DAC data download: https://d3.water.ca.gov/owncloud/index.php/s/zx1U3UA68Vv70uQ/download

Proposition 1, the Water Quality, Supply, and Infrastructure Act of 2014, defines EDAs[183]: "economically distressed area" means a municipality with a population of 20,000 persons or less, a rural county, or a reasonably isolated and divisible segment of a larger municipality where the segment of the population is 20,000 persons or less, with an annual median household income that is less than 85 percent of the statewide median household income, and with one or more of the following conditions as determined by the department:

1. Financial hardship.

2. Unemployment rate at least 2 percent higher than the statewide average.
3. Low population density.

→ EDA mapping tool: https://gis.water.ca.gov/app/edas/
→ EDA data download: https://d3.water.ca.gov/owncloud/index.php/s/KvE3fukHKCv9oZD/download

6 **Social Vulnerability Index (SoVI)** from University of South Carolina Hazards and Vulnerability Research Institute **SoVI®** measures social vulnerability to hazards using 29 socioeconomic variables, which are "primarily" from the US Census. Data are also obtained from the Geographic Names and Information System (GNIS), and model-based Small Area Health Insurance Estimates (SAHIE) published by the U.S Census Bureau. This version uses ACS 2010-2014 data and is available for counties. A previous version is available for 2010 Census Tracts. **SoVI®** uses the statistical procedure principal component analysis to generate social vulnerability scores. **SoVI®** is a comparative index and its scores are relative. The total **SoVI®** score is represented as a numeric value, but it has no inherent mathematical properties. Because the score is a relative score and not an absolute score it cannot be used to compare two places directly (e.g. a county with a **SoVI®** score of 10 does not have double the vulnerability of a county with a **SoVI®** score of 5). **SoVI®** scores are used to show the relative placement of a county relative to others on the continuum of scores with variable ranges. As such, **SoVI®** scores should be classed (e.g. by standard deviation) for mapping and analysis purposes or can be examined using percentile ranks. Explanation of methodology is available here: *http://onlinelibrary.wiley.com/doi/10.1111/1540-6237.8402002/abstract*

7 **US Center for Disease Control Social Vulnerability Index (SVI)**: Developed by the Geospatial Research, Analysis and Services Program in Agency for Toxic Substances and Disease Registry. SVI 2014 uses ACS 2010-2014 data. Looks at relative vulnerability of census tracts. Percentile rank between 0 and 1, and highlighted those ranked at .9 or more, meaning a tract with this percentile rank is more vulnerable for this variable, them, or overall ranking ("scored" for all 3) than 90% tracts. Ranked for the entire nation and by state—comparing only tracts within each state. Interactive mapping application, data, and documentation available: *svi.cdc.gov*

15 VARIABLES IN 4 OVERARCHING THEMES:

1. **Socioeconomic Status:**
   Below Poverty
   Unemployed
   Income
   No High School Diploma
2. **Household Composition and Disability:**
   Aged 65 or Older
   Aged 17 or Younger
   Older than Age 5 with a Disability
   Single-Parent Households

FIGURE 39:
VARIABLES USED IN SOVI®

TABLE: SOVI

Variable Name	Description
MDGRENT	Median gross rent for renter-occupied housing units
MEDAGE	Median age
MHSEVAL	Median dollar value of owner-occupied housing units
PERCAP	Per capita income
PPUNIT	Average number of people per household
QAGEDEP	% Population under 5 years or age 65 and over
QASIAN	% Asian population
QBLACK	% African American (Black) population
QCVLUN	% Civilian labor force unemployed
QED12LES	% Population over 25 with less than 12 years of education
QESL	% Population speaking English as a second language with limited English proficiency
QEXTRCT	% Employment in extractive industries (fishing, farming, mining etc.)
QFAM	% Children living in married couple families
QFEMALE	% Female
QFEMLBR	% Female participation in the labor force
QFHH	% Families with female-headed households with no spouse present
QHISP	% Hispanic population
QMOHO	% Population living in mobile homes
QNATAM	% Native American population
QNOAUTO	% Housing units with no car available
QNRRES	% Population living in nursing facilities
QPOVTY	% Persons living in poverty
QRENTER	% Renter-occupied housing units
QRICH200K	% Families earning more than $200,000 per year
QSERV	% Employment in service occupations
QSSBEN	% Households receiving Social Security benefits
QUNOCCHU	% Unoccupied housing units
QNOHLTH	% population without health insurance (COUNTY SoVI® ONLY)
HOSPTPC	Community hospitals per capita (COUNTY SoVI® ONLY)

TABLE: JAMA

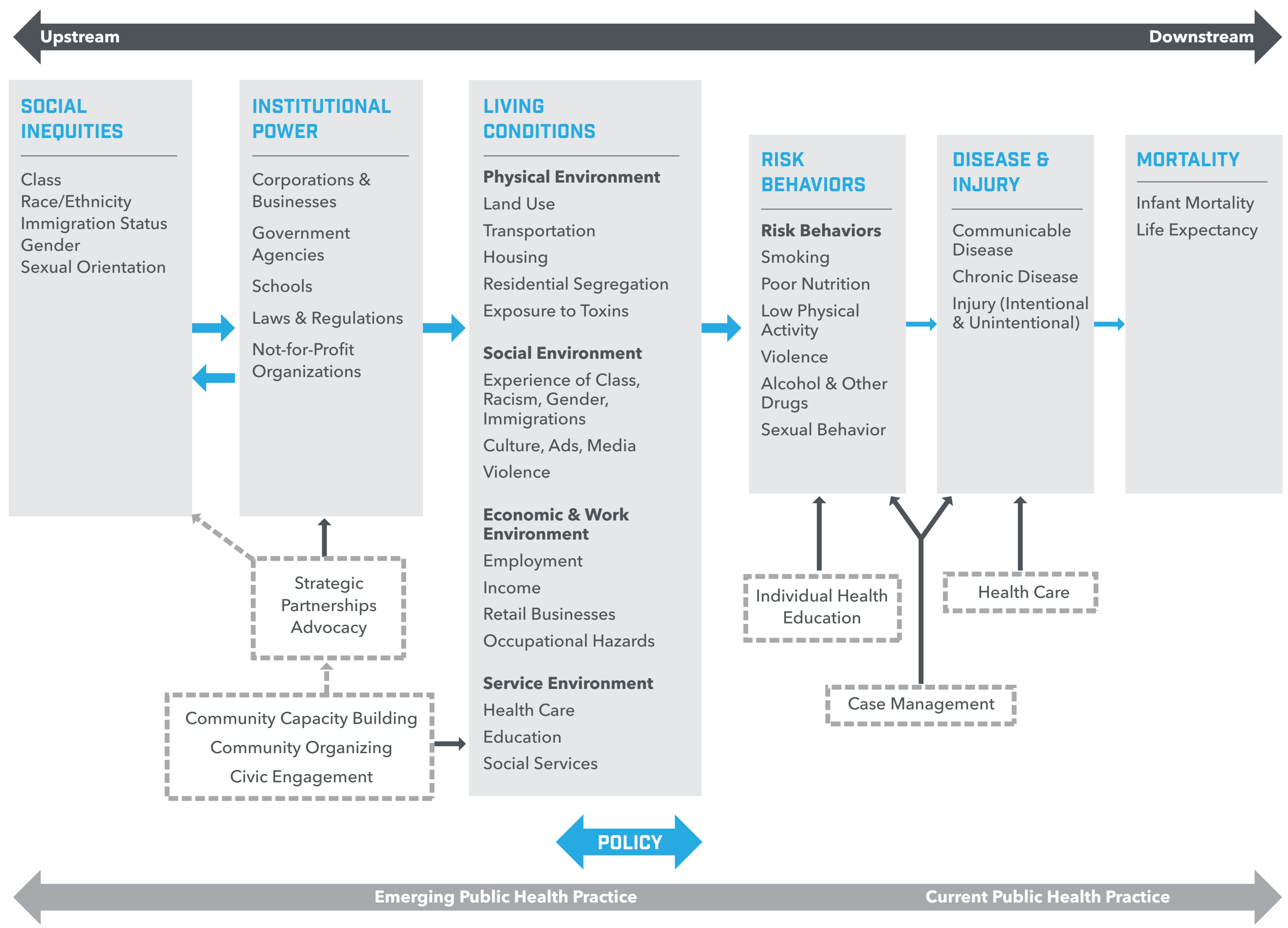
3. **Minority Status and Language:**
   Minority
   Speak English "Less than Well"
4. **Housing and Transportation:**
   Multi-Unit Structures
   Mobile Homes
   Crowding
   No Vehicle
   Group Quarters

Health inequity and outcomes frameworks

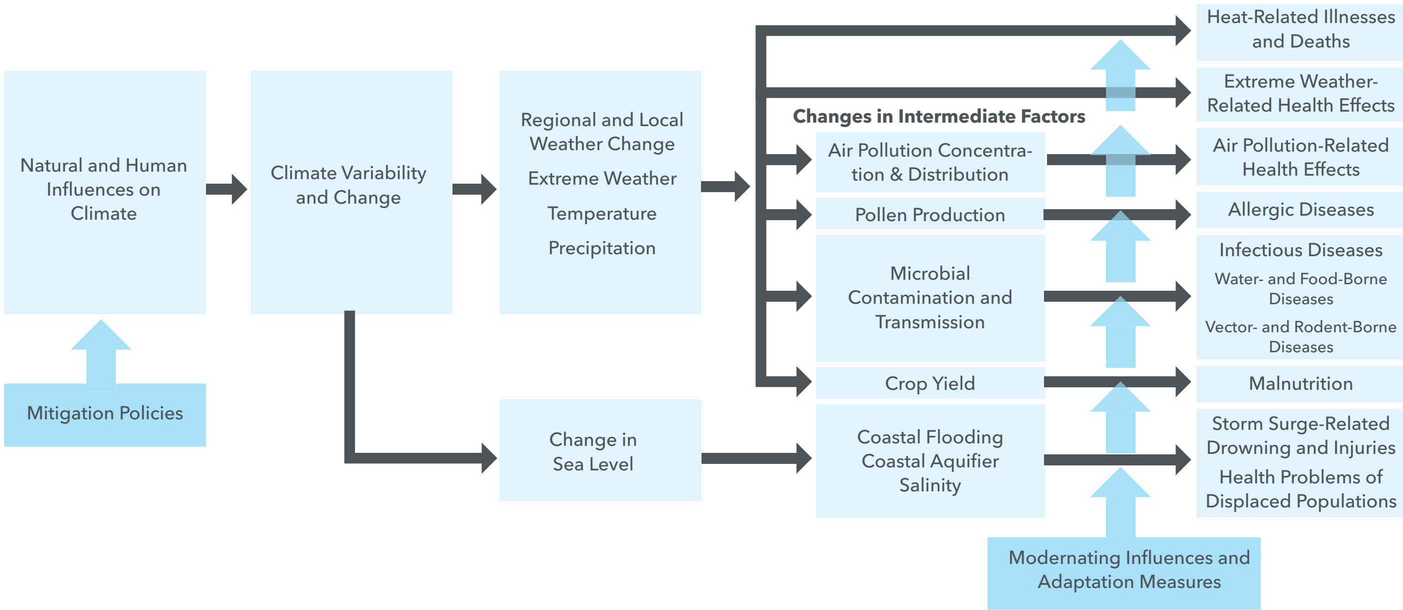
Climate change, including sea level rise, will pose significant health risks, especially to vulnerable populations. The process of designing for increased community resilience provides important opportunities to mitigate risk, optimize adaptation and thereby not only prevent adverse health outcomes but also promotes health and related social outcomes.

Just as environmental inequities follow the geographies of vulnerable populations, so does health inequity. The Bay Area Regional Health Inequities

FIGURE 40:
A PUBLIC HEALTH FRAMEWORK FOR REDUCING HEALTH INEQUITIES



CURRENT CONDITIONS & FUTURE THREATS



Mitigation Policies for Reduction of Greenhouse Gas Emissions

Energy Efficiency

Use of Renewable Energy Sources

Forest Preservation

Moderating Influences

Population Density and Growth

Level of Technological Development

Standard of Living and Local Environmental Condition

Preexisting Health Status

Quality and Access to Health Care

Public Health Infrastructure

Adaptation Measures

Vaccination Programs

Disease Surveillance

Protective Technologies

Weather Forecasting and Warning Systems

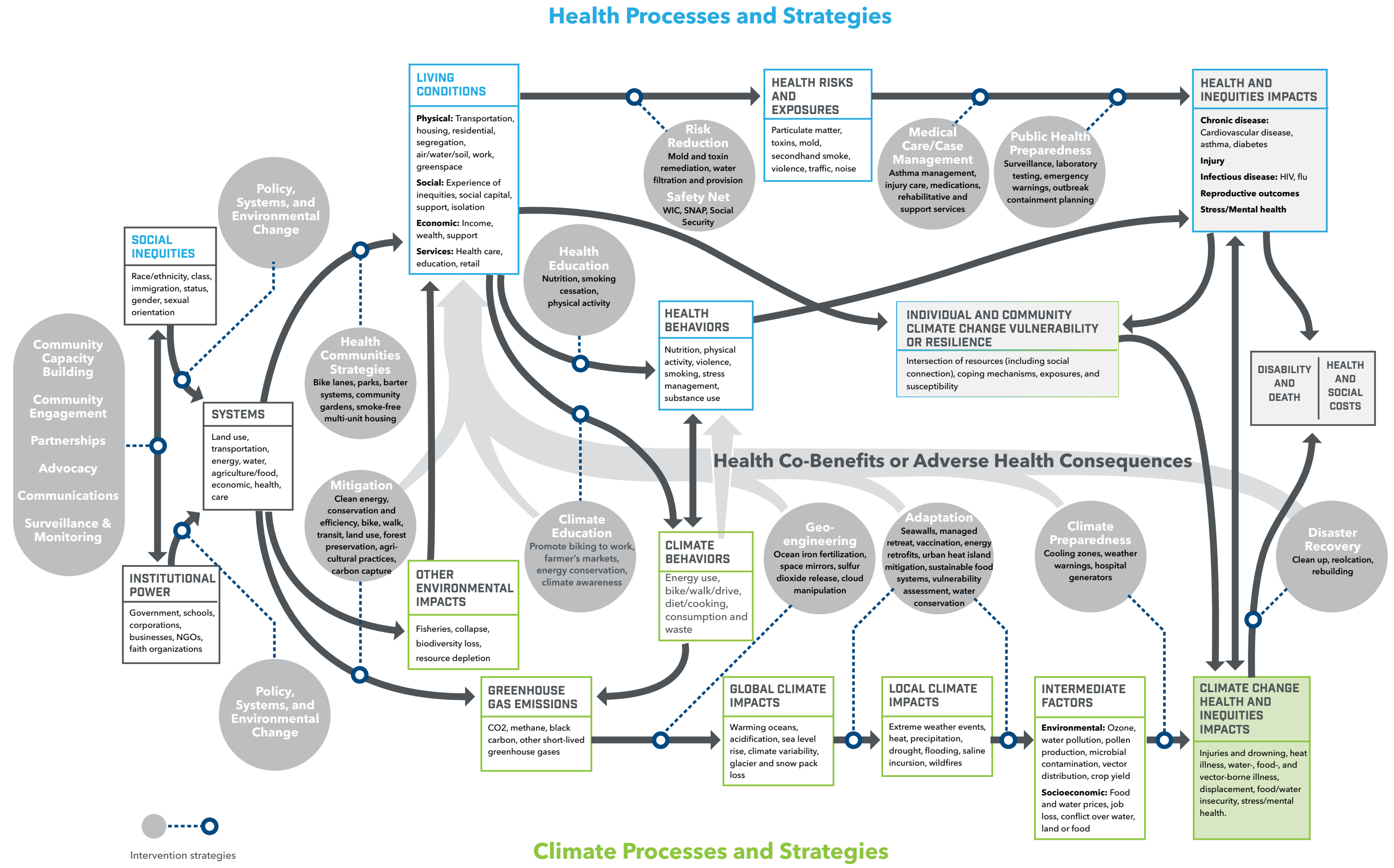
Emergency Management and Disaster Preparedness

Public Health Education and Prevention

Legislation and Administration

GRAPHIC: ADAPTED FROM BARHII

GRAPHIC: ADAPTED FROM HEALTHX DESIGN



Initiative has created a framework for articulating the inter-relatedness of health, social, and physical environment as it relates to inequity.

In shaping solutions to increase resilience in communities that exhibit characteristics of vulnerability, it is critical not only to ensure those communities are involved in the development and decision making, but also that the solutions leverage existing health science in order to target specific risk factors or predictors of adverse health consequences as well as those predictors of positive community health outcomes. An outcomes-based framework helps to align solutions with actual community needs, and creates a mechanism for accountability.

There are many important and emerging frameworks connecting health and social outcomes to climate change, equity, and built environment, the ones listed can serve as a starting place for understanding the interlocking impacts of climate, health, social inequity, and institutional power and for shaping resilience solutions that address these factors.

FIGURE 41:
CLIMATE CHANGE AND HEATLH FRAMEWORK

From the Journal of the American Medical Association (JAMA, 2004), Andy Haines, MD, MBBS and Jonathan Patz MD, MPH developed an influential framework in medicine for articulating how change and variability in climate will adversely impact health. They articulate intermediate factors or predictors that can be targeted to mitigate and adapt against to prevent adverse health outcomes.

FIGURE 42:

More recently, the Public Health Institute (PHI) and its Center for Climate Change and Health, based in Oakland, built on several existing frameworks, including the BARHII Health Inequities framework as well as the Patz and Haines, to develop a comprehensive framework for action. PHI has used this framework in the Bay Area, both at local, regional and state levels, to educate and advocate for greater health equity in the context of climate change.

Social cohesion

While vulnerability indicators can help prioritize community needs, a broader view of community assets and resilience is also critical. As Eric Klinenberg discusses in *Heat Wave: A Social Autopsy of Disaster in Chicago* social cohesion can have a significant mitigating effect on the impacts of climate change on communities. His research showed that while overall communities that have less access to capital and adequate housing fair worse in extreme climate events, some communities that exhibit these same characteristics are better equipped to care for their most at-risk. The difference is the presence of social cohesion.[184]

The influence of social cohesion on a community's capacity for resilience is critical to consider in shaping climate adaptation interventions. Solutions that drive forces that make social cohesion more difficult – such as gentrification, may lessen the communities underlying resilience to acute shocks and chronic stressors. Conversely, climate adaptation design interventions that promote social cohesion may have additional benefits to resilience.

CURRENT CONDITIONS & FUTURE THREATS

Natural and Nature-Based Climate Adaptation Strategies

Natural and Nature-Based Features

Considering the significant proportion of the Bay that is surrounded by marshes and mudflats and the significant efforts to restore these natural areas over the last 5 decades, there has been a considerable amount of attention paid to how these wetlands will evolve in the future and the role they may play future adaptation strategies. The role of natural and nature-based features (NNBF)is being closely examined in the Bay and there are a number of pilot projects in the Bay that will provide useful information on how natural features may contribute to the resilience of the shoreline.

The BCDCs *Innovative Wetland Adaptation Techniques Project* (BCDC 2013)[185] provides a recent overview of the role that the natural shoreline can contribute to adaptation strategies. For instance

Reduce nearshore wave energy

Low-crested berms constructed from coarse gravel or oyster shell are potential alternatives to conventional offshore breakwaters, e.g., rock or concrete armor units. Berms would be able to adjust to rising sea level by naturally rolling landward, driven by wave forces. They may also enhance rather than conflict with ecological and aesthetic objectives. A pilot project is currently under way in San Rafael.

Stabilize with a coarse beach

Coarse beaches are a natural and very effective form of shoreline protection that adjusts to local wind-wave conditions, including those during extreme events. Unlike typical engineered revetment systems, such as riprapped levees, adjustments in beach morphology are an inherent characteristic of the coarse beach system and not an indication of failure.

Recharge mudflat and marsh

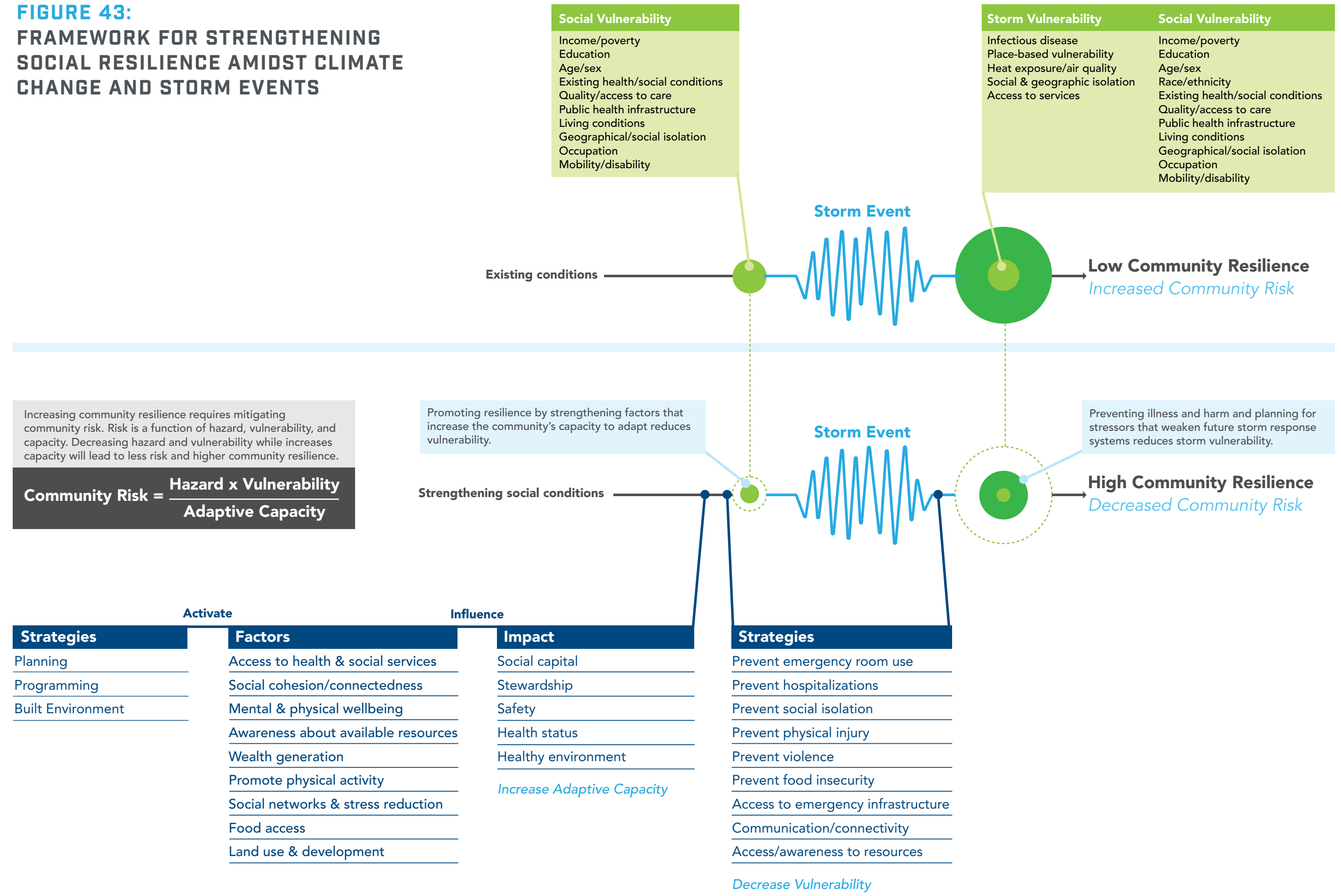
Many tidal marsh ecosystem services are a function of the elevation and inundation regime, and therefore are dependent on the marsh maintaining its position in the tidal frame. Vertical marsh accretion rates are dependent on the local supply of sediment. A number of methods have been suggested to increase the local concentration of fine sediment in the water column to support vertical marsh accretion. These recharging methods are not aimed at increasing the total sediment supply; rather the approach is to focus available sediment supply to specific locations.

Improve sediment pathways

Tidal channels link the baylands to the watersheds and Bay, acting both as pathways for nutrients and sediment and habitat for plants and wildlife. Mature, natural marshes tend to have complex dendritic channel networks; these have often been leveed and simplified. These channels convey turbid water into the marshes, allowing sediment deposition to occur at high water. The rate

GRAPHIC: ADAPTED FROM HEALTHX DESIGN

FIGURE 43:
FRAMEWORK FOR STRENGTHENING SOCIAL RESILIENCE AMIDST CLIMATE CHANGE AND STORM EVENTS



of vertical accretion therefore depends on the distance from a channel, and if channel density is low, parts of the marsh may be poorly supplied with fine sediment and thus have low rates of vertical accretion.

Increase transition zone

This measure creates an estuarine-terrestrial transition zone on fill slopes located landward of the existing tidal marsh and bayward of the flood risk management levee . There may be opportunities to fill man-made ponds (such as salt or oxidation ponds) located between the levee and the outboard marsh to avoid placing fill directly on wetland habitats. Transition zone slopes would create a habitat type that is missing in many parts of the Bay due to diking, and provide gently sloping uplands to allow for upland transgression, buffering the tidal marsh from coastal squeeze between a rising Bay and steep levee slopes.

Realign levees

Realignment of the flood risk management levee to a location further inland is complementary to the aforementioned transition zone slope measure as it provides additional space for upland transgression. Realignment would increase the distance between the Bay and shoreline development, allowing for the dissipation of wave energy over distances of several hundred feet or more and allowing the construction of much lower levees inland.

Bayfront Regulatory Considerations

Largely due to the lack of environmental protections for much of the modern Bay's history, major laws and regulations were passed protecting the Bay, the water quality within it, and the species that live around it. These were important for halting filling of the Bay (MacAteer Petris Act), halting the dumping of pollutants into the Bay (Clean Water Act), and protecting the endangered species that live in and around the baylands (Endangered Species Act).

These laws, and others, drive many of the regulations and requirements that are necessary when making changes to the shoreline, or incoming water bodies. However, the threat of sea-level rise changes the needs and the context around the regulatory environment. As stated by Lubell 2017, "fragmented permitting and administrative procedures require substantial time...to complete, which may delay or block implementation, increase costs, or produce conflicting recommendations."[185]

Here is a synopsis of the major agencies at play along the Bay shore, their jurisdictions, and the laws and permit requirements that govern them. The complexities around the regulatory environment in the San Francisco Bay should not be understated, and must be understood when proposing designs.

The National Environmental Policy Act (NEPA) (all federal agencies)
Requires federal agencies to assess the environmental impacts of their proposed actions and to avoid or mitigate those impacts.

California Environmental Quality Act (CEQA) (all state agencies)
Requires state and local agencies to identify the significant environmental impacts of their actions and to avoid or mitigate those impacts, if feasible.

US Rivers and Harbors Act (USACE)
Prohibits construction of obstacles to navigation of federal waters without federal congressional approval.

National Pollutant Discharge Elimination System (SWRCB, RWQCB)
Protects federal and state waters from impacts of discharges of contaminants from point sources.

US Clean Water Act Sections 404 and 401 (USEPA, USACE)
Protects federal waters from the impacts of dredging and discharges of contaminants.

Waste Discharge Requirements (SWRCB, RWQCB)
Protects state waters from impacts of point source discharges of contaminants exempt pursuant to Subsection 20090 of Title 27 and not subject to the Federal Water Pollution Control Act.

US Endangered Species Act (USFWS, NMFS)
Provides permits to protect federally protected species of plants and wildlife including anadromous and estuarine fishes.

Consolidated Dredging and Dredged Material Reuse/Disposal Application (DMMO) (BCDC)
Protects bayshore from impacts of dredging and dredged material disposal

McAteer-Petris Act (BCDC)
Establishes BCDC as regulatory agency charged with regulating fill and use of the Bay and bayshore.

San Francisco Bay Plan (BCDC)
Details the policies that guide BCDC's regulatory and planning work (i.e. bayfill, public access, climate change, etc) and maps that show these policy applications around the Bay and bayshore.

California Endangered Species Act (CDFW)
Provides permits to take state-protected species of plants and wildlife including anadromous and estuarine fishes.

California Building Code (all agencies)
Provides a minimum standard for building design and construction and provides specific requirements for seismic safety, excavation, foundations, retaining walls and site demolition, while also regulating grading activities, including drainage and erosion control.

Alquist-Priolo Earthquake Fault Zoning Act (all agencies).
Prohibits the location of structures designed for human occupancy across active faults and regulates construction within fault zones with regard to surface fault rupture.

The Seismic Hazards Mapping Act (all agencies).
Requires the State of California to identify and map areas that are at risk for these hazards and requires cities and counties to regulate development in the mapped seismic hazard zones.

Governor's Executive Order B-30-15 (all agencies)
Calls for state agencies to take climate change into account in their planning and investment decisions (forerunner to pending state law requiring local climate change plans).

Local codes and ordinances (cities, counties, and special districts)
Numerous and variable across municipalities and counties. Can include set-backs, building height limits, neighborhood reviews, etc.

GRAPHIC:SFEI

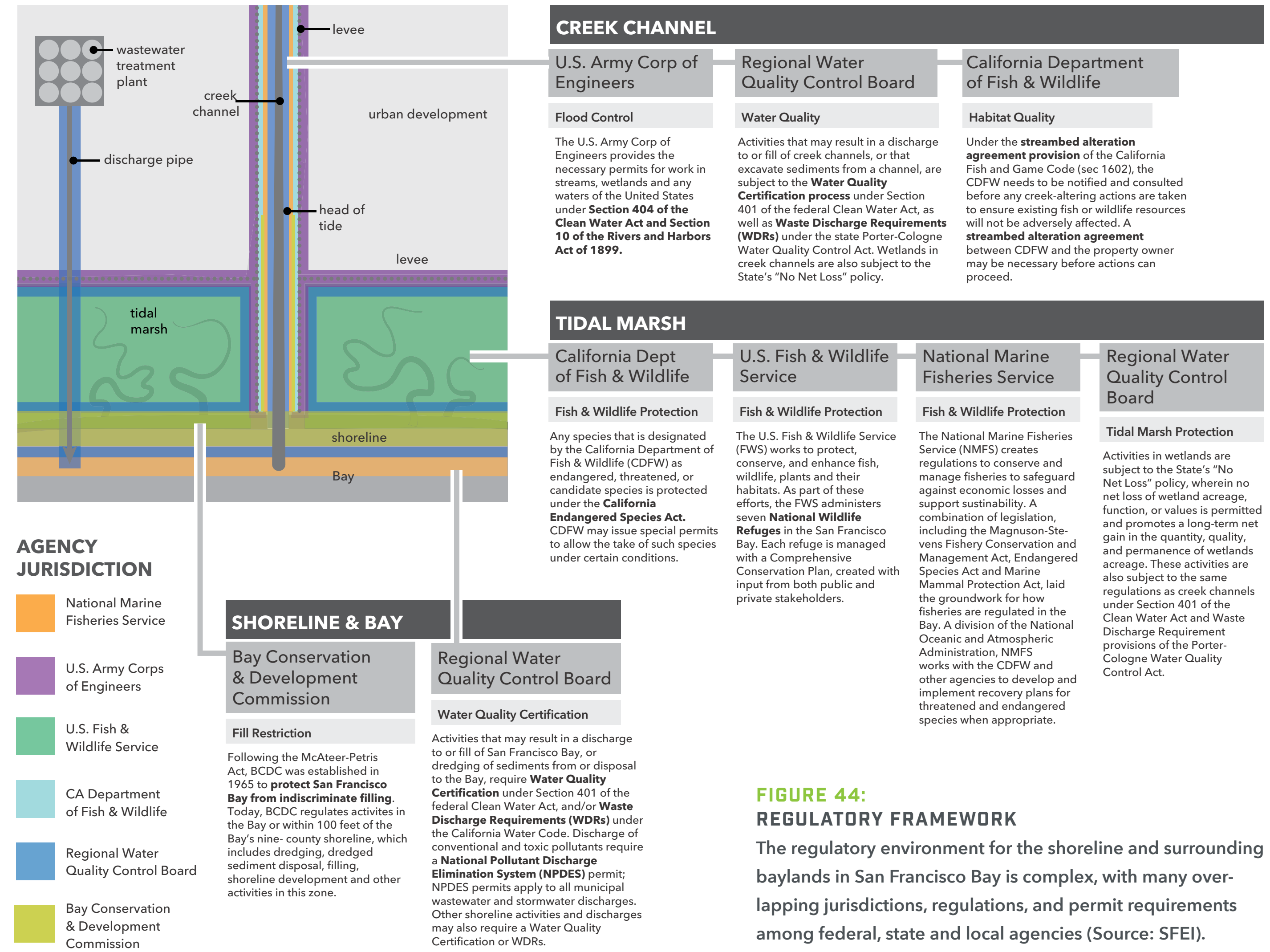


FIGURE 44:
REGULATORY FRAMEWORK
The regulatory environment for the shoreline and surrounding baylands in San Francisco Bay is complex, with many overlapping jurisdictions, regulations, and permit requirements among federal, state and local agencies (Source: SFEI).

Executive Order 13175: Reaffirms the Federal government's commitment to Tribal sovereignty, self-determination, and self-government. Its purpose is to ensure that all Executive departments and agencies consult with Indian Tribes and respect Tribal sovereignty as they develop policy on issues that impact Indian communities. This federal EO is in keeping with the Federal Trust Responsibility and treaties entered into by the federal government with Native American Tribes and affects all federal agencies as well as state agencies, programs or projects that receive federal funds.

Executive Order B-10-11: Requires that, "Every state agency and department subject to executive control is to encourage communication and Consultation with California Native American Tribes." Per this order, it is the policy of the State to work with Native American Tribes (federally and non-federally recognized) on a government-to-government basis to address issues concerning Native American Tribal self-government and Tribal trust resources. Because the IRWM program is administered by state agencies and involves other agencies that are funded by state and/ or federal funds the RWMG, whether a county, a water agency or other eligible lead agency, shall communicate and consult with federally and non-federally recognized Tribes within the IRWM region, or those that have historical use areas or cultural resources within the IRWM Region. In keeping with this EO, the policy of the state of California, the RWMG will uphold the right of Native American Tribes to self-govern and exercise inherent sovereign powers over their members, aboriginal territory, and resources.

SB 18: Requires cities and counties to notify and consult with California Native American Tribes about proposed land use planning decisions for the purpose of protecting Traditional Tribal Cultural Places at the earliest possible point in the planning process to avoid potential conflicts.

AB 52 (See CEQA above): Requirement amending Public Resources Code §21080.3.1 to require the CEQA lead agency to consider project effects on Tribal cultural resources and to conduct Consultation with California Native American Tribes at the earliest possible point in the planning process. Additional information on Tribal Consultation and AB 52 can be found through the links in Appendix A, which includes an example Tribal Consultation Policy that was developed by the Karuk Tribe and guidance from the Office of Planning and Research.

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[176] California Government Code § 65040.12 (e)

[177] CA Global Warming Solutions Act of 2006 (AB 32) authorized the cap-and-trade program. Funds generated from the program are used to continue reducing emissions and improve public health, quality of life, and economic activity through energy efficiency, public transit, affordable housing, and more.

[178] Metropolitan Transportation Commission Resolution No. 4217: Equity Framework for Plan Bay Area 2040. Approve the draft Equity Framework, developed with input from the Regional Equity Working Group. The Framework includes two components: 1) equity measures to analyze Plan Bay Area 2040 scenarios; and 2) the Communities of Concern that define disadvantaged communities for scenario analysis and the Plan. 2016.

[179] MTC Resolution No. 4035

[180] Populations above the age of 5 years that can speak less than "well" as defined by the US Census

[181] As a share of all families regardless of whether or not they have any children

[182] As a share of all households regardless of occupancy status (renter or owner)

[183] California Water Code § 79702 (k)

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Notes

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