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Innovation or Inundation: The Political Economy of Sea Level Rise in the San Francisco Bay Area

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by

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Important Terms and Definitions

100-year flood – a flood event that has a 1 percent chance of occurring every year. Talking about sea level rise is often linked to projections on a 100-year flood because they determine the standards for planning, insurance and environmental regulations.

Adapting to Rising Tides (ART) – regional collaborative planning project in the San Francisco Bay Area to promote local and community adaptation to sea level rise and inundation from storm events. This project is led by the San Francisco Bay Conservation and Development Commission (BCDC) and the National Oceanic and Atmospheric Administration (NOAA).

Association of Bay Area Governments (ABAG) – a 50 year old membership organization of all the cities and counties in the Bay Area. ABAG includes 101 cities and 9 counties. The organization meets every few months to talk about issues within the Bay Area. They serve as the regional planning agency for the Bay Area, with a resiliency unit, an estuary partnership, land use planning, transportation units and more.

Bay Area Conservation and Development Commission (BCDC) – a membership organization with representatives from every agency who is interested in the San Francisco Bay. They work to protect and enhance the Bay through responsible use and governance that includes all three local, state and federal governments.

California State Coastal Conservancy (SCC) – a non-regulatory state agency that works with local governments, public agencies, nonprofit organizations and private landowners in an entrepreneurial way to protect, restore and enhance California's coasts and provide access to the beach.

Climate change adaptation – efforts that a society undertakes to prepare and adjust for future climate change impacts. These can be structural or non-structural.

Climate change mitigation – actions that reduce the magnitude of climate change into the future. Mitigation usually includes reductions in anthropogenic greenhouse gas emissions.

Greenhouse gas emissions (GHGs) – gases that trap heat in the atmosphere such as carbon dioxide, methane, nitrous oxide and fluorinated gases. Over the last century, global concentrations of manufactured greenhouse gases have all risen exponentially and are now over 400 parts per million (ppm).

Economic valuation – a framework to determine the quantitative value of the goods and services provided by an environmental resource as an input into decision-making processes for a sustainable future.

Ecosystem services – the benefits that people receive from functioning ecosystems. There are four categories of ecosystem services: provisioning services, regulating services, cultural services and supporting services.

El Niño/La Niña Southern Oscillation (ENSO) – a natural phenomenon that causes variations in regional climate patterns due to fluctuating ocean temperatures in the equatorial Pacific Ocean. El Niño cycles occur when sea surface temperatures are warmer than usual, resulting in enhanced storms and precipitation along California's coast during the winter months. La Niña cycles occur when sea surface temperatures are cooler than normal, creating drier precipitation conditions.

Externality – an effect resulting when an action performed by a privately benefiting party produces social benefits or costs. Externalities that benefit society are positive, while those that harm society are negative.

Inundation – an excessive covering of land-based regions of earth's surface by water.

King tide – a tide that is unusually high compared to normal conditions. This is not a scientific term, but has come to be used by nations within the Pacific Ocean that experience these high tides, which only occur a few times annually.

National Oceanic and Atmospheric Administration (NOAA) – a scientific agency in the US Department of Commerce that serves as an international leader on scientific and environmental issues pertaining to the ocean and the atmosphere. NOAA seeks to provide reliable information with the hopes that people can understand and prepare for environmental changes in the future.

Resilience – the ability to bounce back and recover quickly from a disaster or misfortune. A community's ability to withstand, cope with, manage and recover their stability after a crisis.

San Francisco Planning and Urban Research Association (SPUR) – a civic planning and member supported nonprofit organization established in San Francisco in 1910. SPUR undertakes work in eight program areas: community planning, disaster planning, economic development, good government, housing, regional planning, sustainable development and transportation.

Sea level rise (SLR) – a side-effect of global climate change that results from thermal expansion of the oceans and a loss of the world's land-based glaciers and ice caps caused by melting and breakage.

Chapter 1.
Introduction

Inundation has two meanings. Its first definition relates to the notion that people, ideas and things accumulate over time to create an overwhelming abundance of these phenomena. Not only is this the case with population growth, but the potential for human knowledge has increased exponentially through the development of language and literature. The second version of inundation refers to an excessive covering of water over land-based areas of the earth's surface, another term for flooding. These two definitions are closely related in that the recent inundation (abundance) of technologies into human societies that release greenhouse gas emissions is creating an adverse potential for the inundation (flooding) of coastal cities worldwide, and vice versa. Henry Cisneros, a Risk Committee member of the *Risky Business Project* suggests that "a broad range of issues impact real estate, construction, and urban development. Obviously coastal inundation is one of those" (Risk Committee 2014).

This paper focuses on the San Francisco Bay Area region as an intersection between human-induced climate change and the threats of sea level rise on coastal cities. Global climate change is a warming of Earth's temperatures due to a dramatic rise in total greenhouse gas emissions since the mid-1900s (Angier 2014; Nicholls et. al. 1999). In May of 2013 concentrations of carbon dioxide reached and surpassed 400 parts per million, the highest they have been since 3 million years ago (Folger 2013). Increased emissions from burning fossil fuels is a problem because greenhouse gases trap heat in the atmosphere, exacerbating environmental disasters. Global sea level rise is one such environmental disaster associated with climate change that is expected to become much worse in the near future. Reporter Justin Gillis from *The New York Times* wrote that "the increase of these and other gases from human activity has caused the planet to warm by about 1.5 degrees Fahrenheit since the preindustrial era, which is causing land ice to melt all over the world. The oceans are rising at what appears to be an accelerating pace, and heat waves and torrential rains are intensifying" (Gillis 2014).

In the World Economic Forum's Global Agenda report for 2014, inaction on climate change was ranked fifth out of ten for the top ten most significant global trends. It is no surprise that sea level rise has been making noise recently in the news and elsewhere. Sea level rise threatens natural habitats as well as man-made environments. By the end of the 21st century, 22% of the world's coastal wetlands could be lost (Nicholls et. al. 1999). Coastal erosion from rising sea levels will impact cities' potential for tourism due to damage of tourism infrastructure and losses of sandy beaches, which account for 34% of the world's coastlines (Mather 2007). Over the past century, the global average rate of sea level rise since 1900 was 1.7 millimeters per year (mm/year) (Church et. al. 2013; NOAA). Since the beginning of 1990, this rate has increased to 3.2 mm/year, showing an accelerating rate of sea level rise worldwide (Church et. al. 2013; NOAA). To think of sea level rise differently, the World Economic Forum presents information on projected sea level rise by 2100. A population of 1.3-million people live within the low prediction of a 0.7-foot high tide line, while 7.8 million people live below the high estimate of 6.6-feet of sea level rise (World Economic Forum 2013). Climate scientist and emeritus director at NASA Goddard Institute for Space Studies, James E. Hansen, was quoted in *The New York Times* recently saying: "the public doesn't see that much yet, but there's more in the pipeline. We are pumping energy into the ocean at a rapid rate; that energy is accumulating, and its biggest impact is going to be on ice shelves. The sea level will go up many meters. That means all coastal cities will be doomed if we stay on fossil fuel business as usual" (Dreifus 2014).

There are many reasons why cities are often the focus in talking about sea level rise and vulnerability to climate change. Cities are areas with concentrated populations where many economic, social, political and commercial activities occur (Awuor 2008). It also happens to be the case that many large cities are located along the coast. In 1999, 21% of the world's population lived within 30 km of the coast (Nicholls et. al. 1999). This also means that through time, more people are becoming susceptible to sea level rise and climate change impacts along the coast. As a result, many coastal cities are in the beginning stages of researching their risks to climate change and planning for various disaster scenarios in the future (Awuor 2008; Climate Central 2014).

Analyzing sea level rise from a global context before narrowing in on the Bay Area sheds light on the extensive severity of the situation worldwide. Some coastal cities face very similar challenges associated with sea level rise, while some face different ones. Kenya, South Africa and Australia are similar to the Bay Area in that they all contain coastal cities with important economies and infrastructural development close to the shore that are being threatened by rising seas. However, the environmental impacts and important adaptation strategies are slightly different. This comparison is useful when thinking about adaptation to sea level rise in a specific geographic location because it allows planners and decision makers to look critically at examples of strategies elsewhere that either work or fail. In the Bay Area, it is possible to implement adaptation measures that have been successful in other places to continue developing as a leader of environmental action. Emphasis on local planning is extremely important because every city or local jurisdiction is going to have a combination of vulnerabilities to the impacts of rising seas. This model of action will serve useful in the Bay Area to understand and organize adaptation strategies.

With a population of 700,000, the city of Mombasa, Kenya is at risk from the impacts of climate change. About 17 percent of the city's area could be submerged by a sea level rise of 0.3 meters (Awuor 2008). As the largest sea port in Africa, Mombasa has two harbors that serve as a major hub for the trade and the transport of goods into other regions throughout Africa (Awuor 2008). If sea level rise hits Mombasa in a hard way, a large portion of its land could become uninhabitable. Water logging and salt stress would also make the land an unviable option for farming and agriculture. A study performed by Awuor (2008) suggests that coastal flooding, erosion, storm damage, saltwater intrusion into freshwater sources, sedimentation fluctuations, decreased sunlight penetration in bodies of water, and loss of biodiversity and coral reefs are all potential impacts from sea level rise.

South Africa is also particularly susceptible to impacts from global climate change, notably sea level rise. This is partly because numerous microclimates and fluctuations in wind and storm patterns frequently occur due to South Africa's location at the confluence of the Indian and Atlantic Oceans near Cape Agulhas (Gyory 2004). Rapid development along the South African coast means that the country has a high incentive to protect their coasts and property from flooding and erosion. Approximately 30% of South Africa's 53 million inhabitants live along the coast (Kavonic 2013). The eastern coastal city of Durban, with a population of 3.5 million, has experienced a 2.7mm/year rate of sea level rise between 1970 and 2003 (Mather 2007). The urban city of Cape Town, with almost 4 million people, is also notably threatened by sea level rise and other climate change scenarios such as water scarcity due to reduced rainfall. While it is in the early stages of planning, one way to combat sea level rise that is being talked about in South Africa is through the implementation of coastal setbacks. This is a way to make smart decisions surrounding new development into the future, as coastal setback lines establish specific restrictions on distance and elevation for development along the coast (Kavonic 2013). In the city of Cape Town and the Western Cape region, recommendations on strategies for mitigation encourage reductions in greenhouse gas emissions (Climate Adaptation Report).

Australia is another example of a country that is at risk from sea level rise, as it is completely surrounded by the ocean. Furthermore, the country contains the world's largest coral reefs, which serve as a home to a plethora of plant and animal species. Increasing water temperatures and melting ice caps threaten these coral reef ecosystems. More water entering the ocean can yield changes in salt concentrations of the oceans and alter the potential for light penetration on these marine habitats (Church et. al. 2008). Recognizing this threat, many parts of Southern Australia and Melbourne are already underway in their implementation of adaptation measures to combat various impacts of sea level rise (Climate Adaption Report). In the city of Melbourne, short-term and long term planning measures include revisions in requirements for future infrastructure projects along the coast, improvements in storm water infrastructure to adapt to increased flooding, and preparation of a long term *Sea Level Rise Adaptation Action Plan*, which will contain the most recent projections of sea level rise (Climate Adaptation Report).

The United States is as susceptible to the effects of sea level rise as coastal cities and regions around the world. Sea level rise will impact such major metropolises as New York City, Washington DC, Miami and Seattle, among many other coastal communities within the United States. In an age of urbanization, humans tend to migrate towards cities where there are more opportunities for employment and higher standards of living (Creel 2003; White et. al. 2005). Three-quarters of these large cities are located along the coast, so human exposure to flood risk is only going to increase as more people move to coastal cities (UNEP). For this reason, it is important to understand which cities in the United States will need to plan for a future of rising seas and increasing harmful impacts from climate change.

Climate Central, an independent climate research and science organization, used historic flood statistics presented by the National Oceanic and Atmospheric Association (NOAA) to estimate New York City's risk to local sea level rise (Climate Central 2014).[1] According to the 2013 US Census, the greater New York City metropolitan area contains about 19.9 million people, of which 8.5 million reside within the City itself. Within this greater metropolitan area, there are more than 2,400 km of shoreline (Gornitz et. al. 2001). Various estimates conclude that a median level of 3.9 feet of sea level rise will occur by 2100 (Climate Central 2014; Gornitz et. al. 2001). Extreme values indicate that the 100-year flood height is closer to 5.9 feet above Mean Higher High Water (MHHW), suggesting that the risk of experiencing floods above 6 feet will become very likely (Climate Central 2014). This is concerning for New York City because there are so many buildings and people concentrated in a condensed geographical area. Whereas the average rate of sea

[1] These projections are part of the *Surging Seas* project, which enables people to interactively search for data and maps projecting sea level rise and flooding in the US. Available: http://sealevel.climatecentral.org/, accessed November 19, 2014.

level rise in eastern North America is 1.3 mm/year, it is 2.73 mm/year in New York City (Gornitz et. al. 2001). In terms of the potential costs associated with sea level rise, about $90.5 million of assets and 7.8 percent of the population in New York would be at risk from a 9-foot flood event (Climate Central 2014).

Also along the East Coast of the United States, the District of Columbia, Maryland, Virginia and Delaware are at risk from flooding and rising sea levels in the future. According to Montgomery (2014), about $42 billion of property in this region are within 5 feet of the local high tide line. Cities in the region are currently at very different stages in planning and implementation for sea level rise. The District of Columbia has just begun assessing its future risks, while the city of Baltimore is currently working with the Federal Emergency Management Agency (FEMA) to plan for a catastrophic 500-year flood event in which inundation would be 7 feet deeper than the anticipated 8-foot storm surges by the end of the century (Montgomery 2014).

Moving down the coast, Miami, Florida is in a particularly precarious location that is being looked at with a close eye based on the harmful effects that sea level rise might have. Senator Bill Nelson, in an NBC report on fighting sea level rise in Florida, said that the sea level has already risen between 5 to 8 feet over the last 50 years (NBC 6 South Florida). Florida is unique in that the whole state is at risk from sea level rise, with about 75 percent of the state's population living along the coast (NBC 6 South Florida). In Miami, planning for sea level rise is in the beginning stages and it is expected that over $500 million of spending will be used on maintaining and rebuilding pump infrastructure to combat high tides. However, massive underground pump infrastructure and sea walls in Miami Beach are not going to be enough in the future, suggesting that mitigating climate change from its source by reducing emissions will be necessary (NBC 6 South Florida).

Along the West Coast, Seattle, Washington faces challenges to rising sea levels. While sea levels have risen 6 inches in the last century, they are expected to rise much faster in the future. Baseline projections suggest that Seattle will likely experience 6.5-7 inches of sea level rise by 2015 and 24 inches by 2100 (SPU; Tobin 2014). Similar to the Bay Area, inundation in Seattle will likely occur more frequently from tidal flooding, storm surges and "king tides" before permanent sea level rise becomes an issue (SPU). The state of Washington serves as a leading example because the Department of Ecology, the University of Washington's Climate Impacts Group, the Washington Sea Grant and other local partners are working to synthesize reports and resources to facilitate community planning (Tobin 2014).

California, according to the relevant scholarly literature and governmental reports, should prepare for sea level rise all along its heavily populated coast (Cayan 2009; Climate Adaptation Report; Heberger 2009; Williams 2009). Among the areas expected to be the most threatened is the San Francisco Bay Area. The focus of this paper is on the San Francisco Bay Area and why it is an important area to study when it comes to climate change adaptation and mitigation. Sea level rise is one side effect of climate change which threatens the Bay Area. This region has the tendency to be overlooked when comparing sea level rise impacts to other cities or regions within the United States, where many East Coast cities tend to be the focus. Because of this, sea level rise in the Bay Area tends to be understudied on a national scale. This region contributes $630 billion to the nation's $16.8

trillion economy, or 3.75 percent of GDP, making it an important area to learn more about given its vulnerability to climate change and the potential hit to the US economy if it gets harmed by sea level rise.

As with the rest of the planet, two factors contribute to rising sea levels in the Bay Area: increased melting of ice caps like those in Antarctica and Greenland, and thermal expansion of Bay and ocean surface water as temperatures continue to rise (Gleick and Maurer 1990; Sanchirico 2009; SPUR). San Francisco will be among those places bearing the brunt of elevated seawater. The San Francisco Bay is susceptible to both sea level rise and excess storm surge, which can create unusually high tides during the winter called king tides (Goldzband, personal interview, 2014 July 30). King tides are a unique occurrence determined by gravitational pulls of the sun and the moon when they are in alignment (California King Tides, NBC 6 South Florida). These tides are especially noteworthy in California during the winter because they makes water levels rise, giving a good indication of what future sea level rise will look like. The combination of increased storm surge and sea level rise on top of low lying development that has been filled in makes cities around the Bay significantly more susceptible to flooding.

Since the early 20th century, Bay sea levels have risen 8 inches (Schueneman 2013). According to the San Francisco Bay Conservation and Development Commission (BCDC), sea levels are predicted to rise 16 inches by 2050 and as much as 55 inches by 2100 (SFBCDC 2009). However, uncertainties and revised estimates associated with sea level rise suggest that the Bay Area could start seeing dramatic increases in sea level in as early as the next 15 years (Tam 2012). California is often viewed as more susceptible to low probability catastrophic events associated with sea level rise than other regions in the United States (Risk Committee 2014). This is partly because California's coastline is more exposed to rising seas from the melting of the Antarctic ice sheet than the global average (Risk Committee 2014).

Addressing these risks is a political challenge for local and state government agencies in the San Francisco Bay Area. When thinking about politics, this refers to the way that decisions are made in a region and why they are either hindered or facilitated. These barriers are something that must be overcome considering how many people and how much infrastructure is at risk. One report released by the Pacific Institute finds that approximately 140,000 people representing 2 percent of the Bay Area's population are currently at risk from a 100-year flood event. If sea levels increase by 1.4 meters this number would jump to 270,000 people at risk from a 100-year flood event (Heberger et. al. 2012).[2] Residential cities situated along the coast of the Bay, government agencies, private businesses, San Francisco and Oakland international airports, major highways, public transportation like Bay Area Rapid Transit (BART) and Caltrans, and other important infrastructure like waste treatment plants that drive California's economy are all at risk of being flooded in the future (Heberger et. al. 2012). As a result, sea level rise is making the news and grabbing the attention of people throughout the Bay Area because there is property at stake that could be lost due to coastal flooding and sea level rise (Temple 2013; Tere & Roberts 2014). Sea level rise is expected to produce more frequent flood events,

[2] 1.4 meters is equivalent to 55 inches of sea level rise.

which will cause worse damage to areas that are already at risk from flooding and will place more areas at risk by creating a larger coastal floodplain (Heberger et. al. 2012).

Uncertainties associated with sea level rise and its slow moving nature make it hard to plan long-term policy decisions. Hansen adds that the reason climate change is "a really dangerous situation is that the climate system does not respond quickly to the forces we apply to it. That means that we have not witnessed the impact of the gases we've already added to the atmosphere. We're waiting for the public to see enough to demand effective government response" (Dreifus 2014). Given the vast amount of wealth, knowledge and environmental awareness, the Bay Area has an incredible capacity to overcome challenges to adaptation and sea level rise. By analyzing the potential impacts and challenges associated with sea level rise in the Bay Area, this paper seeks to contribute to an existing body of literature by answering the question: what economic and policy decisions will help the region proceed down a path towards successful climate adaptation?

It has come to the point where local governments, agencies and land use professionals need to start making policy decisions to prepare for the future. This may be challenging politically because there are so many pressing needs that government agencies deal with. Understanding why this is difficult and why policy takes so long to implement is the first step in being able to change the way people approach climate issues that are knocking on our door. Executive director Larry Goldzband from the San Francisco Bay Conservation and Development Commission (BCDC) suggests that "the hardest thing – and I say this every time I talk about sea level rise – the hardest thing about sea level rise right now is that we don't know how to talk about it." This paper aims to speak about sea level rise in a way that everyone can understand, with the hopes that people can begin to see more clearly what it means to live in an age where environmental disasters are a reality and how we can start to prepare for that future. The next chapter addresses background on the physical and geographical features of the Bay Area that make the region particularly susceptible to sea level rise, followed by chapters that discuss the economics and politics of sea level rise through a planning and policy framework.

Chapter 2.

The Bay Area: Physical and Geographic Realities Influencing Sea Level Rise

The Bay Area is the largest estuary located on the West Coast of North America, a major hub for business, and serves as a home to over 7 million people (Bay Area Census). Natural features within the Bay Area have driven development and shaped the layout of what we see today when you look at a map (Figure 1). Using the San Francisco Bay Area as a case study for sea level rise is helpful for people directly involved with the region like homeowners and businesses, but also for those around the world who are interested in understanding the actions that are being taken to prepare for climate change scenarios in various locations.

The Bay Area is a region that is geographically, politically, and economically different from other large coastal cities. Geographically speaking, the region contains 101 cities that surround the San Francisco Bay. Politically, there are 9 different counties and many other local government entities that have some sort of influence or control. Economically, the Bay Area is a powerhouse with a GDP of $535 billion in 2011 and $594 billion in 2012 (BACEI; Marinucci 2013). With the second most Fortune 500 companies in the United States[3], the region's current economy is worth approximately $630 billion, placing it 21st among national economies (Terplan 2014). As a result of all the valuable assets that are close to the shore in the Bay Area, sea level rise will have a harmful and destructive impact on local habitats, economies, communities and building infrastructure such as offices, houses and many forms of transportation.

[3] New York is number one with the most Fortune 500 companies in the US.

When analyzing sea level rise in the Bay Area, it is first important to note that dramatic sea level rise is technically not occurring right now (Rapport, personal interview, 2014 August 12). Historically, sea levels have been consistently rising in the San Francisco Bay at a slow and steady rate of 2 mm/year (SPUR 2009). This tide gauge data, taken near the Golden Gate Bridge, translates to a sea level rise of just 8 inches over the past century (Heberger et. al. 2012; Rapport, personal interview, 2014 August 12; SPUR 2009). While rates over the last 150 years were pretty slow, recent rates of global sea level rise in the past 10-15 years have increased to 3 mm/year (SPUR 2009). This means that sea levels will continue to rise into the future. The next concern is at what rate and how fast.

2.1. Geography of the Bay Area

In order to understand how sea level rise will impact the Bay Area in the future, one must achieve a grasp of the natural and physical layout of the region. As mentioned, the Bay Area is the largest estuary on the West Coast of North America. The region is filled in by ocean tides and freshwater from the Sierra mountain range (Nelson-Embry 2012). The development of this large watershed is the result of the compression of the Coast

Figure 1. USGS satellite map of the San Francisco Bay Area.

Range Mountains that caused uplift of surrounding mountains and hills along the western coast of the Bay closest to the Pacific Ocean (Elder 2013). It is only open to the Pacific Ocean where the Golden Gate Bridge connects Sausalito in the north with San Francisco in the south. This means that cities located within the San Francisco Bay itself are not directly subject to ocean surges and currents. In this sense, the Bay is like a large bathtub with mountains blocking the ocean from most of the Bay (Figure 1).

The Sacramento-San Joaquin Delta, located north of the Bay Area, is a region that provides water to more than half of California's population. This Delta is known to be hydraulically reliable, containing over 1,700 km of levees (Jeffrey & Robert 2005). The area contains tons of tiny stream systems in and around the Bay, with headwaters coming down from the surrounding hill and mountain formations (Elder 2013). During the spring and summer months, Delta islands have the potential to become flooded, causing failures of levees and ground subsidence (Jeffrey & Robert 2005). Not only does this endanger native aquatic plant and animal species by disrupting their habitats, but it also impedes population demand for water. Flooding of this kind can bring brackish water into the Delta, making it more expensive to provide clean water to California residents. Sam Schuchat, Executive Director of the California State Coastal Conservancy, similarly suggests that:

> Because of the Bay Area's peculiar geography, sea level rise is actually going to go quite far inland. Sacramento is only 19 feet above current sea level. Our water system is very dependent on the Delta, which is below sea level in most places now. Already the salinity is moving up the Delta and the freshwater parts are getting brackish (Schuchat, personal interview, 2014 July 29).

Sea level rise has the potential to exacerbate the degradation of water quality in the Delta, harming people who rely on it as a resource. This is especially threatening for California today, where drought conditions are at a record high and water supply is scarce already.

Regions within the Bay Area are also reliant on wetlands and salt marshes as a natural cushion for storm surge and flood protection. Coastal wetlands are valuable because they provide a number of ecosystem services to their surrounding environment. Services aside from flood protection include waste assimilation, carbon sequestration, habitats for fisheries and nature conservation purposes (Nicholls et. al. 1999). In the 1800s, 780 km^2 (78,000 hectares) of tidal wetlands and marshland bordered the Bay (Brown 2003). Today, only 10,000 hectares remain, signifying a 70-93% loss of wetlands in the area (Callaway 2011). Coastal wetlands in the Bay Area are at risk of being destroyed from sea level rise, presenting a high cost to society in terms of loss of biodiversity, ecosystem functioning and diminished flood protection if they were to disappear. Climate change and rising sea levels will have large effects on the remaining wetlands in the area, challenging future restoration projects such as the South Bay Salt Pond Restoration Project (Callaway 2011).

Sea level rise presents various risks to cities along the Bay. One such risk would be the impact rising sea levels will have on people and residential areas. Impact on local cities can be predicted based on the geographical layout of the Bay. Schuchat adds more on the geography of the Bay Area and why sea level rise is different in this region compared to other places in the United States:

> What's unique about the Bay Area in the context of California and in the context of the west coast is you've got 500 miles of shoreline that is heavily built up and industrialized except where there are salt ponds. If there weren't salt ponds in the south Bay that would have all been filled in too. And it's a gently sloped alluvial fan from the Coast Range Mountains down to the ocean. In that sense this geography is a little bit more like some east coast cities, except that we're in the Bay not exposed to the open ocean, which makes a difference in terms of storms and wave energy (Schuchat, personal interview, 2014 July 29).

Certain cities in the Bay are located on a slightly higher incline gradient than other cities, which are at or below sea level. Knowles (2010) developed a Bay-wide regional elevation data set by gathering data from various sources, with the hopes of assessing more clearly potential inundation caused by an acceleration of sea level rise (Figure 2). Sea level rise will impact cities and counties disproportionately in the Bay Area. San Mateo County has been deemed the most vulnerable to sea level rise in the Bay Area, with numerous low lying cities on the Bay side and the ocean side (Peterson, personal interview, 2014 July 22). San Mateo County accounts for approximately 40 to 45 percent of all people at risk from coastal inundation in the Bay Area (Heberger et. al. 2012). Other counties that will be affected more intensely include Alameda, Marin and Santa Clara counties (Heberger et. al. 2012). This makes cities like Palo Alto to the west of the Bay and Hayward to the east of the Bay much more susceptible to rising tides than cities which are located on higher ground.

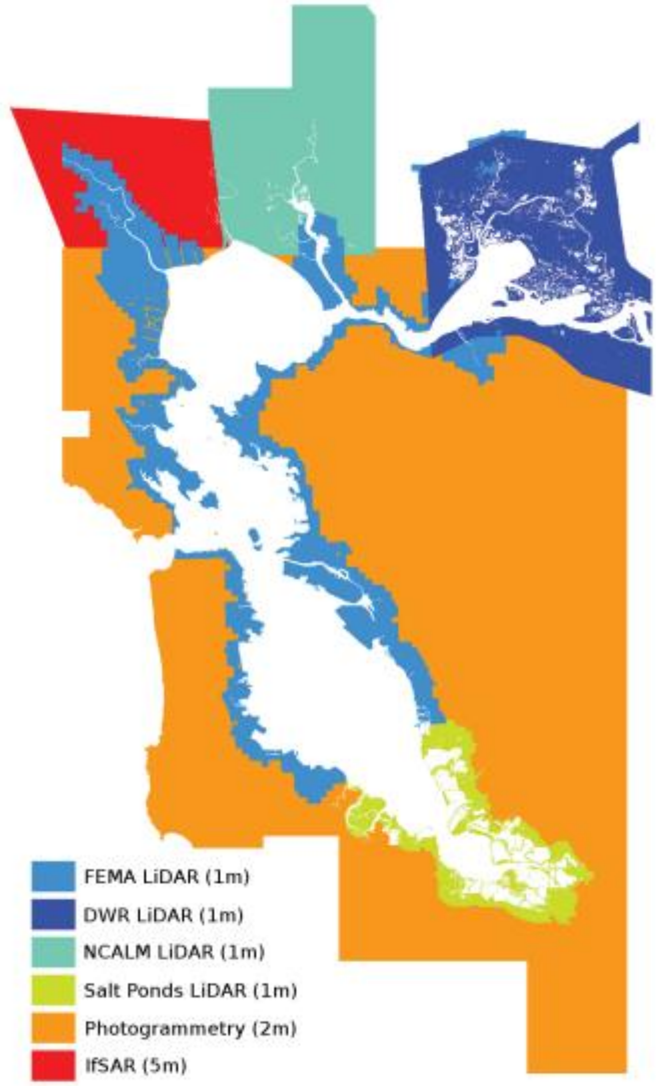

Figure 2. Elevation data by Knowles (2010).

Sea level rise also has the potential to alter seismic conditions in the Bay Area. The Bay Area is located within a network of multiple active fault lines, which have shaped the geography of the region. According to USGS, tectonic motion occurs via a series of subparallel faults between the Pacific and North American plates. The Bay Area contains the infamous San Andreas Fault line as well as 6 fault zones that include: Calaveras, Concord-Green Valley, Greenville, Hayward, Rodgers Creek and San Gregorio (Figure 3; Figure 4). What this means is that if an earthquake occurs in the Bay Area, a large amount of damage would be done to infrastructure caused by ground movement. Ezra Rapport, Executive Director of the Association of Bay Area Governments (ABAG), argues that this damage could be exacerbated by sea level rise because:

> If sea levels rise you increase the liquefaction zone, so you're going to have more impacts further out where you don't normally have liquefaction today. Liquefaction means that the soil conditions liquefy and [buildings] tend to fall down in those conditions, unless they have been built with some very deep piers. So sea level rise makes seismic conditions worse in the Bay Area because a lot of what we've built on is landfill. The Bay has been filled in quite a bit and the fill itself is not engineered fill so it is not stable and is subject to liquefaction (Rapport, personal interview, 2014 August 12).

The zone of liquefaction would increase in size under sea level rise, causing the ground to move around more loosely in an earthquake. Under these conditions, the combination of an earthquake and sea level rise could cause a lot more property damage than usual. Rapport adds that "the San Francisco sea wall that protects the Embarcadero is not seismically engineered, it's a hundred years old. So if that goes because of an earthquake and we've had sea level rise, or even without sea level rise, the whole downtown of San Francisco would be flooded."

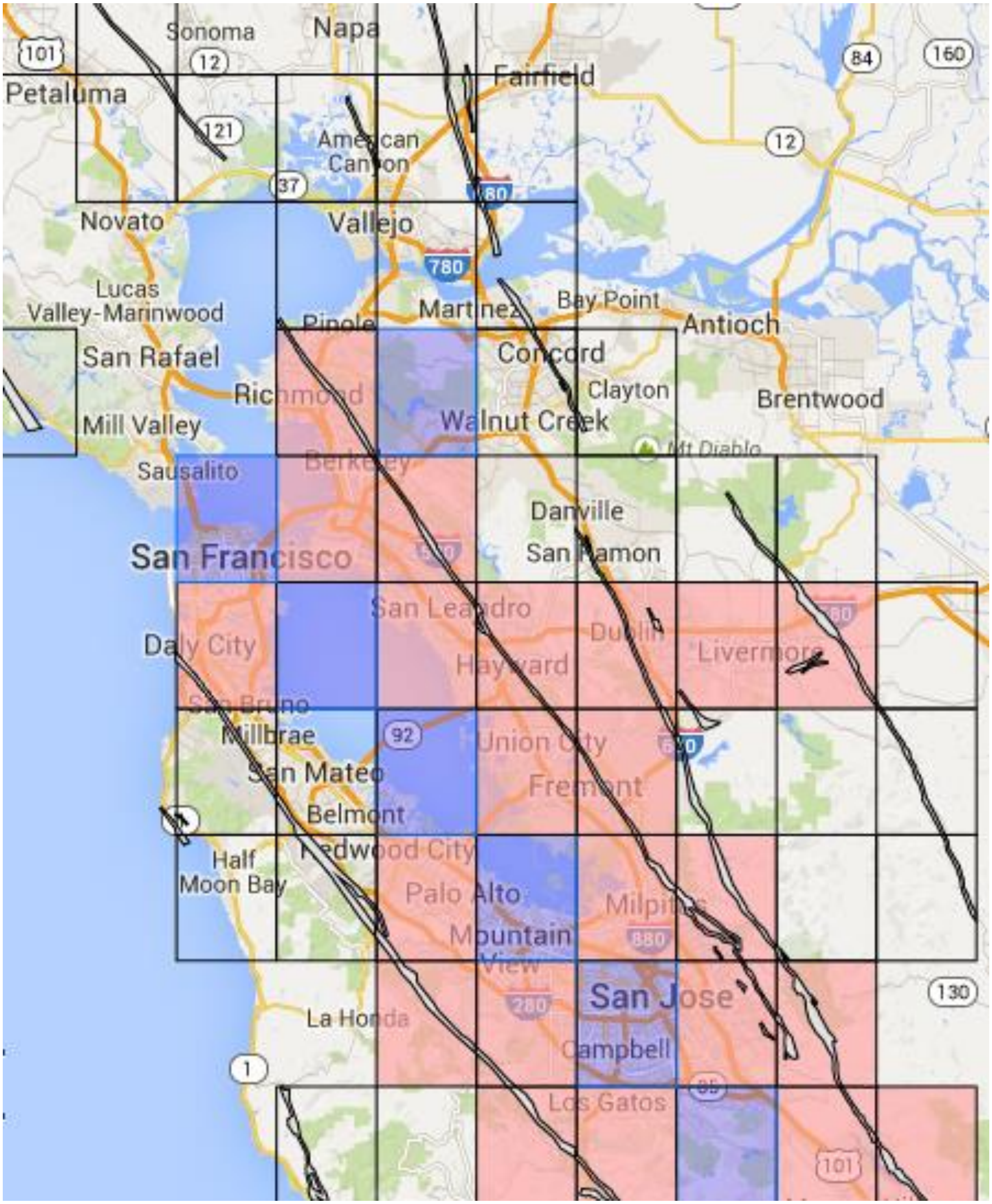

Figure 3. California state earthquake fault zones in the Bay Area produced by the California Geological Survey. Black lines denote earthquake fault zones. Blue boxes depict landslide and liquefaction zones. Red boxes denote fault zones containing landslide and liquefaction zones as well.

Figure 4. Detailed mapping of the Hayward Fault Zone produced by USGS.

2.2. Astronomical and Atmospheric Factors: Tides

The Sun, the Moon and Earth all affect gravitational pulls that impact tides and sea levels in the Bay Area (Heberger et. al. 2012). Tides constantly alter sea levels in the Bay Area, depending on the time of month and year as gravitational pulls change. As more water enters the oceans due to the melting of land-based ice, these forces have the potential to alter tidal ebbs and flows. This system is important to understand because sea level rise increases water levels and tidal forces cause fluctuations of water levels in the Bay Area.

A study by Holleman and Stacey (2014) points to a link between rising global mean sea level and increasing tidal amplitudes. Focusing on peak sea level over mean sea level as a driver of inundation, a coupling between coastal forces of the ocean, tidal energy, and inundation is investigated (Holleman & Stacey 2014). Holleman and Stacey (2014) argue that increasing the depth of a basin caused by inundation decreases the frictional effects of the basin's interior and can yield altered tidal amplification. Tidal amplification is an increase in the range of tidal flows creating higher and lower tides at each extreme. Using a hydrodynamic model of the San Francisco Bay, the authors conclude that flooding of low-lying areas will introduce more friction and intertidal regions within the Bay that will serve as energy sinks for tidal waves. This means that tidal amplification could decrease under sea level rise conditions:

> The coupling between sea level rise, tidal amplification and inundation is important and must be taken into account for accurate assessment of future restoration and mitigation questions. In many estuaries and bays, rising sea level in the coastal ocean will lead to newly inundated areas. To a degree this inundation can mitigate sea level rise by decreasing tidal amplification within the basins (Holleman & Stacey 2014).

To address sea level rise in the Bay Area in the future, it will be important to consider this coupling effect to determine whether or not tidal ranges could amplify or dampen. In contrast, some are of the opinion that "combined effects of sea level rise and potentially increasing tidal ranges will have far-reaching impacts on coastal inundation as many low-lying areas either become uninhabitable or require massive mitigation measures to fend off higher sea levels" (Holleman & Stacey 2014). Whether or not this is true will be a determining factor in coastal management decisions and for this reason it is important that people understand this relationship between sea level rise and tides.

Paying attention to tides as they relate to sea level rise speaks to the differences in impacts that cities and regions in the Bay Area will face. Tidal exchanges arise if parts of a flooding tide come from ocean water entering the Bay for the first time. This process is beneficial for other features in the Bay Area as tidal exchanges help provide nutrients, maintain salinity and push water to far out places in the Bay (Travis et. al. 2007). Peterson speaks to the different impacts of sea level rise in the Bay Area:

> The San Mateo coast is going to be the most impacted and the difference is San Mateo County gets [sea level rise] on both the ocean side and the Bay side. The force on the ocean side will cause extensive erosion and they are already losing buildings along the Pacifica coast. On the Bay side, it's going to be more from the overall rise so you don't have the same kind of wave energy. To the extent that tidal exchanges get more extreme that will have many impacts as well. One of the challenges is even if you walled off certain areas, there's still the tidal flows. Creeks and places like the airport can get flooded from behind so they'd have to put in tide gates (Peterson, personal interview, 2014 July 22).

Flooding from behind would reduce the adaptive capacity of infrastructural projects that seek to protect the shoreline. Thus, tidal energy may be a problem along the coast and along the Bay in terms of potential damage to infrastructure. These tidal flows appear to affect each side of the shoreline differently, which is why Peterson addresses the option for tide gates. Preventing flooding in creeks is important because many of these waterways feed directly into the Bay. This is good for protecting local residents from flooding along the creeks, but would eventually impact people and structures along the shore. If a tidal exchange from the ocean is too strong, tide gates could help slow down this flow and prevent flooding from behind or underneath.

Shoreline "hardening" tactics, such as the barrier infrastructure that Peterson speaks of, cannot be the only solution to managing sea level rise because tidal action is still going to occur. In some cases tides will become amplified as the tidal prism, or volume of water between mean high tide and mean low tide, decreases (Holleman & Stacey 2014). There have to be more complex solutions to help protect the Bay from such forces. This belief corresponds with Holleman and Stacey (2014), who suggest that the use of shoreline "softening" to complement and restore tidal action to the area could have many benefits such as "re-establishing highly productive marsh ecosystems, improving water quality, and even mitigating flood risks. These projects often increase the area available to tidal action and introduce softer, natural shorelines and slough networks that are effective at dissipating tidal energy."

The Bay Area, because of its geography, low-lying infrastructure, and weather, experiences what are called "king tides." During the winter months, king tides raise water levels dramatically compared to the summer months. This is an unscientific term that originated in nations within the Pacific Ocean to describe an unusually high tide, like a perigean spring tide. The Moon's perigee is the point at which the Moon is closest to Earth in its 28-day elliptical cycle. Spring tides usually occur twice a month when the new or full

Moon, the Sun and Earth all align, allowing the Sun's gravity to pull ocean tides up higher than normal (Woo 2014). If the Moon's perigee aligns with a spring tide, then a perigean spring tide forms. These usually only occur three to four times each year. If alignment occurs at the same time that the Moon is closest to Earth, then a slight boost in gravity creates a king tide (Woo 2014). King tides are not affected by climate change. However, high tides will have a more destructive impact when infrastructure and housing are closer to mean sea level in the future. Factoring in high waters from king tides plus other climatic conditions that raise sea level supports the notion that a future of higher mean water and inundation is not far out.

2.3. Climate Change Effects

Astronomical forces, climatic conditions and meteorological effects create fluctuating sea levels in the San Francisco Bay (Heberger et. al. 2012). More severe weather patterns, changes in thermohaline ocean circulation, thermal expansion and melting of ice caps exacerbate sea level rise (Adger, et. al. 2005; Holleman & Stacey 2013). These important factors are only going to increase in frequency due to climate change's positive feedback system of increasing temperatures and lower albedos. Climate change encompasses numerous processes that are interconnected and it is important to understand how these drivers interact with sea level rise. Among these processes are changes in the greenhouse effect, the Sun's energy reaching Earth and the reflectivity of Earth's atmosphere and surface (EPA).

When asked what the future would look like for the coastal cities being affected by climate change, Schuchat notes that "here we are in the drought of the century in what is shaping up to be yet again the hottest summer in California history. We have now learned that the west Antarctic ice sheet is definitely melting and there is no stopping it. The only question now is how quickly and how soon" (Schuchat, personal interview, 2014 July 29). This speaks to the grave implications that climate change has on the natural and built environment.

A common phenomena known as El Niño/La Niña-Southern Oscillation (ENSO) occurs along the west coast of the United States. El Niño years result in more extreme storms that often impact peak sea levels in the Bay during the winter months (EPA). La Niña conditions are the opposite, creating drier than normal conditions along the coast. Climate and weather conditions such as this have an impact on sea levels through increased storm surge and erosion. The Pacific Decadal Oscillation (PDO) is a long-lived El Niño weather pattern occurring because of Pacific climate variability (NOAA). These extreme ENSO conditions are usually marked by variations in sea surface temperatures as either warm or cool. These oscillation cycles can factor into higher tides in the San Francisco Bay caused by variations in climate and surface temperatures during a given year (NOAA).

2.4. Sedimentation and Subsidence

Mountains such as the California Coast Ranges started forming because of compression along the San Andreas fault system some 6 million years ago (Elder 2013). These topographical and sedimentary features had an impact on early estuary and valley formations in the Bay, as river systems began transforming the Bay Area into a network of local and regional watersheds. The watersheds provide outlets for excess water that flows into the Bay during heavy storm periods, absorbing some of the potential for sea level rise.

Natural factors within these watersheds like "soil saturation, tide levels, river flows and sediment levels can make a difference between moderate and severe flooding" (EESI 2012).

Sediment buildup is a feature of the San Francisco Bay Area. Traveling through tidal marshes, channels, sloughs and islands in the Sacramento-San Joaquin Delta, sediments make their way down to the Bay Area via intertidal processes, tectonic subsidence and sea level rise (Jeffrey & Robert 2005). Bedrock that lies underneath the many watersheds in the area contribute to most of the sediment load entering the San Francisco Bay (Elder 2013). Historically, sedimentation began occurring due to replacing Delta land with farm land. During the 19th century, the Sacramento-San Joaquin Delta experienced a large period of hydraulic mining, causing sediment build-up to travel into the San Francisco Bay (Jeffrey & Robert 2005). In a period of widespread land reclamation of island marshes in the Delta, levees were built and man-made channel networks constructed (Jeffrey & Robert 2005). This has made it so that the Delta and surrounding regions are all below sea level by some degree. Furthermore, land drainage for agriculture has caused the water table to fall below sea level as land has sunk down, increasing risks of flooding if levees fail or sea level rise hits (Ingebritsen & Ikehara).

Subsidence, which increases with human activity, is known to impact coastal flooding by producing a localized sea level rise effect (Nicholls et. al. 1999). An example of this is in the Santa Clara Valley, a region that expands over the southwest part of the San Francisco Bay and is now known as the densely populated "Silicon Valley" (Ingebritsen & Jones). This region experienced land subsidence resulting from a history of groundwater pumping and water extraction to spur an agricultural economy. Groundwater pumping only increased during the rapid development in the region in the 1900s. The Santa Clara Valley was the first region in the United States to be recognized as subsiding due to groundwater extraction (Ingebritsen & Jones). Throughout this region, water was being extracted at a faster rate than it was being replaced, resulting in extreme cases of ground subsidence near San Jose. This problem caused many square miles of land to fall below the high-tide level during the mid-1900s (Ingebritsen & Jones). In an effort to prevent catastrophic consequences, the area is now lined with dikes and flood-control levees to control stream channels. During storms, discharge has to be captured and then pumped out and over levees to prevent flooding (Ingebritsen & Jones). While water pumping is being managed more carefully now and aquifers in the region have been recharged, land subsidence has permanently increased the region's risk to flooding, especially if levees break. This will become an even larger problem in the future as sea levels increase and the potential for saltwater intrusion[4] and flooding becomes more likely.

2.5. Implications of Natural Factors on Adaptation in the Bay Area

From previous sections we have learned about the physical features of the Bay Area that make it an important place to study in terms of sea level rise. Among some of these factors are astronomical and climatic phenomena such as king tides and El Niño weather patterns, respectively. Other features of the Bay Area include an history of excessive groundwater pumping that has caused land subsidence and sinking, the environmental degradation of wetlands due to development and the potential for earthquake risk. Finally, the infrastructural layout of the Bay Area makes it hard to implement regional adaptation

[4] Saltwater intrusion occurs when saltwater moves into a freshwater aquifer. In the case of sea level rise, this can impact groundwater and coastal ecosystems by harming freshwater species or contaminating groundwater supplies (USGS).

plans very easily. This is because there are 101 different cities, 9 counties and over 150 different private and government entities touching the Bay that all have some vision of how they want their portion to be regulated. In the Bay Area, local cities and counties have land use control and authority over development in their jurisdictions (ABAG).

The consequences of astronomical and climatic effects may not necessarily be harmful on their own, because king tides and El Niño events are seasonal and temporary. However, as sea level rise gets added into the mix, it amplifies the amount of inundation experienced because you have more than one stressor raising sea levels in the Bay. In defining sea level rise, Rapport addresses the features of different types of flooding in the Bay Area:

> There are flooding challenges that we live with now with respect to what are called king tides or combinations of king tides which are gravitational, with El Niño effects which are climatic, and also potential storm surges. So if you add all three together you end up with some pretty significant flooding but it's temporary flooding because a king tide ebbs and flows. So it's not as consequential necessarily as something like sea level rise, which is permanent (Rapport, personal interview, 2014 August 12).

This makes adaptation planning tricky because of the uncertainty associated with temporary flooding and the potential consequences of permanent inundation in the future. Goldzband approaches the timing of the issue differently, by suggesting that even without sea level rise, the combination of El Niño and king tides could cause large water backups in the region:

> What's really worrying right now is not the rising Bay, what is worrying is an El Niño coming in on the first weekend of the year, when the king tide hits. In this scenario a king tide hits, so you have a foot more than you normally have on a high tide. Then you've got a storm coming in and the storm is not going to make the water rise, but what the storm does around the Bay, because the Bay is a big bathtub, is all this water comes flowing in from outside of the Bay and where can it go? It can't go anywhere because all the sewer outfalls and all the storm drains flow right into the Bay. So you've got a higher Bay with water that can't go anywhere, which means all of a sudden you get huge backups going around (Goldzband, personal interview, 2014 July 30).

In Rapport's scenario, long-term permanent sea level rise is the frame of reference and the fear is that people will not be able to adapt in time. While in Goldzband's example, natural events are going to be more of an impact in the short-term so there is increasing need to address these seasonal events.

A document on climate adaptation and transportation released by the Environmental and Energy Study Institute (EESI), in partnership with the Center for Clean Air Policy (CCAP), discusses different recommendations for assisting transportation professionals in climate adaptation. These can be applied to a wide range of adaptation plans. What is noteworthy among these priorities is that an assessment of climatic and natural factors is an important piece of information that guides adaptation planning and decisions (EESI 2012). The next chapter discusses all of the possible strategies for climate adaptation in the future, given these climate factors driving sea level rise.

Chapter 3.
Possible Strategies for Adaptation

A number of solutions exist to control sea level rise from intensifying the physical impacts mentioned above, such as tidal energy or astronomical climatic patterns. Adger et. al. (2005) argue that these adaptation solutions are in some sense reactive, in that they are triggered by major events like earthquakes, but also anticipatory, meaning they are rooted in some idea about what future environmental conditions will look like.

There are multiple frameworks through which to analyze the benefits and costs of adaptation strategies. The first set of actions fall under the category of "hard" or "gray" solutions, while the second category contains "soft" or "green" infrastructure and technologies. Another framework, presented by the Adapting to Rising Tides (ART) project, utilizes four categories of adaptation: structural, nonstructural, asset-specific and regional adaptation (ART 2011). Structural measures are the physical projects that mitigate impacts of sea level rise. Nonstructural measures are the non-physical actions like changing policies and regulations. Asset-specific measures are those related to specific assets like transportation. Regional adaptation measures are those that protect many different assets and communities at the same time. The use of timing as an organizing principle is another category for assessing adaptation measures. ART defines adaptation measures that are framed around timing as either "opportunistic" or "proactive." Opportunistic measures are strategies that are embedded during the normal lifetime of an asset, while proactive measures are applied before the end of an asset's lifecycle in anticipation of a stressor like sea level rise (ART 2011). Using these frameworks, possibilities for adaptation are compared based on their feasibility and economic and environmental impacts.

Shoreline management decisions can be labeled either “hard” or “soft” when planning for sea level rise. Adaptation that is “hard” generally means that the strategy uses specific technologies or actions that involve capital goods and large investments (Hallegatte & Dumas). Hard structures control for flooding and erosion (Grannis 2011). Holleman and Stacey (2014) add that shoreline “hardening” can also significantly change dynamics in a basin after they are implanted. On the other hand, “soft” adaptation and management decisions are non-structural (NOAA). Shoreline “softening” can also be called restoration, because it usually seeks to reverse harmful effects of “hard” projects (Holleman & Stacey 2014). It has been argued that soft adaptation strategies manage uncertainty better than hard ones (Hallegatte & Dumas).

Soft adaptation strategies overlap directly with “green” infrastructure in that they mimic natural forms of protection (Grannis 2011). According to Foster et. al. (2011), “green” infrastructure and technologies achieve sustainability and resilience. Green and soft adaptation strategies are similar in that they both seek to reduce the harmful impacts of traditional hard or “gray” flood infrastructure. Green infrastructure is likely more expensive than gray infrastructure, but the economic and environmental analysis that helps people make these investment decisions is still new and uncertain (Britain 2013). Green infrastructure does provide a great range of benefits and contributes more to long-term resilience. In terms of climate adaptation, soft and green initiatives are linked to an ability to regulate and mitigate impacts of climatic conditions like sea level rise by filtering out air pollutants, protecting people from flooding and storm surges, and reducing erosion (Brittain 2013). These projects vary in scale from individual properties to cities and regions. For the sake of adaptation in the context of the San Francisco Bay Area, city and regional adaptation strategies are the focus as broader solutions that benefit multiple people. According to the EPA, "gray" infrastructure are the traditional practices for flood and stormwater management. In the context of climate adaptation, these are the large, engineered infrastructural projects (Talberth & Hanson 2012).

3.1. Hard Solutions:

Tidal Barriers

Tidal barriers or barrages can be large dams, gates or locks that would manage tidal flows entering and leaving the San Francisco Bay (Tam 2009, Travis et. al. 2007). One of the proposed benefits to tidal barriers is that they can help harness tidal energy to reduce carbon emissions. Barriers might also be beneficial because they can protect large areas of land from flooding and also protect everyone with one technological solution (Tam 2009). This would lessen the need for piecemeal strategies in specific areas and eliminate social equity or priority considerations for other land use solutions.

However, there are also many downfalls to using a barrier to adapt to sea level rise. Travis et. al. (2007) note that the tidal currents in the Bay are about half the speed and half the height necessary for efficient energy generation. Furthermore, sea level rise would decrease the tidal range meaning that there would be less available energy from tides to generate power (Travis et. al. 2007). It has been suggested that building a barrage (Figure 5) in the Bay Area across the Golden Gate as an alternative to shoreline protection projects would cost double or triple the $25 billion required to build the Three Gorges Dam in

Figure 5. Proposed tidal barrage in the Bay, produced by BCDC.

China, making it one of the most expensive adaptation strategies available. According to Travis et. al. (2007), building a tidal barrage in the Bay would also have many ecological consequences by affecting fresh and salt water mixing, sedimentation, wetlands, wildlife, endangered species, coastal erosion and flooding. In terms of flooding, future storm surge and sea level rise would reduce the drainage ability of excess water through the barrage. There might also be some unintended economic consequences of building a barrage, such as delaying access to ports, which bring in over $10 billion of revenue each year (Travis et. al. 2007).

Politically, assembling all the necessary requirements to construct a barrage is limiting. Numerous stakeholders would be involved in the decision making process such as the environmental community, Bay Area residents, port agencies, energy companies and local businesses, all of which might oppose or support such a project for various reasons.

Governmental agencies would also have regulatory jurisdiction and be involved with the project, namely the US Army Corps of Engineers, BCDC, US Environmental Protection Agency, US Fish and Wildlife Service, NOAA and the California Department of Fish and Game (Travis et. al. 2007). This means that the project would have to go through a plethora of different policy approvals, all in line with various regulations in regard to land use, public access, environmental considerations and more. There are also unknowns with this type of adaptation, such as the extent of upstream flooding that could occur with a barrier that holds back ocean storm surges from dissipating through the larger surface area of the Bay (Tam 2009).

Armoring

Coastal armoring are forms of linear protection that fix a shoreline in its existing spot (Tam 2009). This form of protection is regarded as the most frequently used tool for protecting assets close to the shoreline in the Bay. Armoring can be either hard or soft, depending on its intended use and what kind of protection is needed. Coastal armoring is done up and down the California coastline to protect beaches and property from erosion and other impacts. Two forms of harder armoring strategies are building levees and seawalls:

Levees

Levees are used to protect assets that are very low to the ground. In the case of the Santa Clara Valley, which contains many streams that can flood into the region, levees have been put in place to protect cities from flooding (Ingebritsen & Jones). Levees have also been used in various other places within the Bay Area to protect development and agriculture.

Seawalls

Seawalls are another form of hard engineering strategies that protect the Bay Area from wave and tidal action. Ocean Beach, in San Francisco utilizes a large seawall.

Armoring has benefits and costs. First, armoring is reliable and is the oldest form of flood protection. People know what is required for armoring and how much of an effect it will have on surrounding areas. It is also versatile and can be used in concert with other adaptation strategies to protect against sea level rise. Armoring serves two purposes at the same time: protection against storm surge and protection against sea level rise. While armoring is not necessarily a sustainable solution for long-term adaptation, it can be useful as a transitional strategy to help protect key infrastructure before other measures are implemented. Once put in place, armoring is only able to withstand certain storm sizes or rises in sea levels. If the water level is higher than the armored shore, then flooding can occur. Armoring can also adversely impact local environments like beaches or wetlands (Grannis 2011).

Furthermore, armoring is only as strong as its annual maintenance and monitoring. If it is not engineered up to standard, major catastrophes like expansive flooding can cause systems to fail or break. Structural shorelines are vulnerable to seismic conditions in this scenario. If an earthquake occurs, these structures could overtop or fail, placing many other assets at risk. During a seismic event liquefaction could damage pre-existing shoreline protection, similar to the damage that occurred along the Embarcadero freeway and seawall during the 1989 Loma Prieta earthquake. There is also the issue that armoring does not always protect against flooding from behind. If a storm occurs on top of a high tide then flooding could still occur.

3.2. Soft Solutions:

Wetland restoration

Wetlands are a form of living shoreline that make up a large portion of the Bay. Wetlands are important to the functioning of the Bay Area because they provide a natural habitat for species. They also prevent flooding by absorbing water like a sponge, and releasing it slowly into groundwater or other habitats. Wetlands control flooding by slowing down water movement and spreading it out. There are many different types of wetlands in the Bay Area: tidal basins, marshes, mud flats, rocky shores and pebble beaches. Living shorelines such as wetlands also add ecosystem services to a society. Among these ecosystem services include pollution filtration, carbon sequestration and recreation. Unfortunately, a history of filling, pumping, armoring and reclamation activities have caused wetlands along the Bay to shrink to approximately 5 percent of their original size (Tam 2009). The downside to wetlands is that they require a large surface area. They also require continuous regulation and monitoring in the beginning stages of their development because they take time to become functional on their own.

Restoration of coastal wetlands are considered to be structural measures. One concern for the implementation of wetlands in the San Francisco Bay is that the modified hydrology of the basin and the surrounding rivers might limit restoration (Tam 2009). If there is not enough sediment to keep up with rising tides, then their ability to adapt to sea level rise might be hindered. Wetlands require extra space to grow and expand in a natural way. An important step to promoting the sustainability of wetlands into the future would be to provide room between development and the natural shoreline to serve as a buffer, allowing wetlands to grow without being impeded. Flood protection of this kind could have high returns depending on how much flood attenuation wetlands would provide in a future with sea level rise. Of course, the sad part is that wetlands in the Bay will likely never grow back to what they once were pre-development.

One major trade-off to wetland restoration is that allowing wetlands to grow without restriction could mean that quite a bit of surrounding shoreline development would have to be abandoned. This is because wetlands grow outwards and require space to grow and function fully. Houlahan et. al. (2006) argue that wetlands must be managed alongside their surrounding areas instead of in isolation and that having a land buffer in between helps reduce wetland damage. Land near wetlands should be regulated in such a way that allows the wetlands to grow and prosper. The implication of this is that it makes sense to have a buffer zone between development and wetlands. Grannis (2011) suggests that buffers require land owners to leave property in its natural state to support wetland functioning. Less people would be able to live along the shoreline and development would be set farther back in this scenario.

Living shoreline projects such as wetland restoration are more difficult and costly than hard shoreline options like armoring. Moving property inland to accommodate for expanding wetlands is expensive and it triggers involvement from all levels of government who have regulatory review over the permitting process (Grannis et. al. 2014). This leads to the next soft adaptation strategy known as managed retreat.

Managed Retreat

Managed retreat, or relocation from the shore, is one strategy that might be an inevitable consequence of sea level rise in the future. This means that people would have to leave their homes and move inland or to higher ground in the face of rising seas and excessive flooding. As a form of long-term adaptation, retreat from the shore can be planned or managed. In the case that planning does not occur before a major flood event, retreat might be catastrophic with peoples' houses completely destroyed. Managed retreat involves either abandoning, destroying or relocating property that is too close to the shore. Not only does this address existent property, it also prohibits development in places that are known to be susceptible to sea level rise and flooding.

An uncertainty associated with managed retreat is how expensive it will be. Costa may differ based on how developed a city is. If a city is highly developed, managed retreat would be more expensive, causing a decrease in property values in the area. In some cases retreat may be less expensive than hard infrastructural projects, which might only be temporary if continually rising sea levels force people to relocate in the future anyways. Managed retreat is also the most politically difficult to undertake because many factors are involved in making a decision to relocate property. Legally, it presents a challenge because not everyone is going to want to leave their properties. There are also equity issues as many people do not have the financial resources or the capacity to move. These considerations make managed retreat one of the more politically difficult solutions for sea level rise adaptation, despite being one of the more necessary ones in the long-term. From the discussion above, future living shoreline projects like wetlands might not even be possible without retreat to provide a buffer zone.

Armoring

The softer forms of shoreline protection include beach nourishment, offshore breakwaters and groins. According to Tam (2009), beach nourishment occurs when sand is used to restore beaches that have eroded by building larger sand dunes. Offshore breakwaters are structures that are built parallel to a beach to reduce wave action. Groins are colloquially termed "riprap" and describe large rock walls that span across beaches to prevent coastal erosion. Aside from utilizing a large seawall, Ocean Beach in San Francisco also uses beach nourishment and dune regulation.

These soft armoring strategies provide coastal protection by replenishing or mimicking natural shorelines (Grannis 2011). This is important because they provide natural habitats and flood control. To implement these, Grannis (2011) suggests that governments create permitting programs that require the use of these sustainable green projects wherever possible. This is because they can help reduce environmental impacts of hard shoreline armoring. They are also sometimes less expensive that hard armoring.

However, soft armoring will not work in every area because it relies on natural considerations like geological conditions and flood dynamics (Grannis 2011). It would not be wise, for example, to utilize soft armoring in areas that are subject to heavy erosion. One downside to soft armoring is that it requires regular maintenance and monitoring to keep serving its purpose. For example, beaches require a constant source of sediment, which turns into a continuous cost to keep replenishing it. Beach restoration can also harm sea floors, which must be dredged to put in the sand (Grannis 2011). Soft armoring also presents a challenge because landowners sometimes to not believe that it could protect their property as well as hard infrastructure from flooding.

Embed planning within building codes

Building codes in the Bay Area are specific regulations on which types of infrastructure projects are allowed and what requirements they must fulfill. This is important when considering earthquake or flood risk, because any new infrastructure that is built in the Bay Area must be constructed in a way that allows it to withstand environmental disasters. Changing building codes are advantageous for structures to better cope with floods and rising seas. Adapting building codes to require a certain base height above sea level is an example of adaptation that is nonstructural, but eventually turns into a structural development.

One form of modified development would be to raise buildings appropriately so that there is room for water to go up. According to Tam (2009), this either involves raising the land or pre-existing development. The advantage to this is that it allows things to be built in areas that are vulnerable to flooding. In the case of the Bay Area, elevating large low-lying structures that cannot be moved as easily like airports could be a tool to retrofit development temporarily. This is only a short-term strategy because it alters the shoreline. Tam (2009) suggests that elevated development would need just as much protection as low-lying infrastructure, so "its advantage is merely that it is not threatened by sea level rise for a longer time."

Eventually, coastal development could have resilient design requirements that coincide with other green infrastructure, while limiting the amount of hard coastal armoring (Grannis 2011). However, design requirements are hard to enforce because they require technical capacity and knowledge from building inspectors. According to Grannis (2011), the California Adaptation Strategy "recommends that state agencies collaborate with local governments to consider amending building codes ‘to require that coastal development incorporate features that are resilient to SLR.’” Federal Emergency Management Agency (FEMA) makes relationships like this possible by providing financial assistance to local governments that do implement resilient design structures such as elevating or moving buildings (Grannis 2011).

Floating Infrastructure

Floating development is when buildings are built such that they float on the surface of the water. This strategy has developed recently as sea level rise presses the need for more innovative forms of adaptation. This would be a form of soft adaptation, because it seeks to minimize interference with natural factors along the coast. It is also adaptive because floating buildings are receptive to fluctuations in sea levels (Tam 2009). This is an added benefit because it is hard to predict how high sea levels will rise into the future. Floating development reacts well to the uncertainties of environmental phenomena in the Bay Area and it is resilient to earthquake activity. The main disadvantage with floating structures, as presented by Tam (2009) is that they do not bode well in high wind and wave conditions, such as along the ocean coast.

Adaptation to sea level rise is going to be necessary. In the future, it will have to occur with urgency and on many different scales. Adger et. al. (2005) suggest that adaptation strategies which require large-scale investment are “likely to be triggered through extreme events that raise the consciousness of climate change within policymaking.” It has also been argued that the potential for successful adaptation will depend on whether or not cities have the capacity to adapt. In many instances, this capacity is represented by money available for adaptation and since it is not distributed evenly then some areas will have a higher capacity for success than others.

Chapter 4.
Addressing a Future with Sea Level Rise

The potential costs of sea level rise can be significantly reduced with government policy that addresses climate change adaptation to better prepare cities for sea level rise. The reality is that in the San Francisco Bay Area, higher waters are slowly encroaching on developed areas and pose a threat to the ecological diversity and economic importance of the region. This section distinguishes adaptation strategies that should be implemented based on their anticipated timeframe. This usually means either for the short-term or the long-term. This section picks out the likely strategies that should be utilized in both the short-term and the long-term.

4.1. Short-Term Adaptation

Sea level rise affects cities disproportionately, as those directly along the coast will come into contact with higher water and feel its damages sooner than those further inland. Cities that are farther away from the shore have a longer time-frame to work with in terms of adaptation (Tam 2012). Local governments are the ones that make land use decisions, but in the future it will be important to ensure that adaption is coordinated on a regional scale. This is going to be difficult because cities and counties may have different visions or priorities for adaptation. The following strategies are the most important regulation initiatives in a short-term time-frame of up to 15 years:

Reinforcement of Infrastructure in the San Francisco Bay Area

Buildings and infrastructure such as highways and airports close to the shore are the most vulnerable to sea level rise and will have the largest economic impact if destroyed. In

1990, property at risk from a 1 meter increase in sea level in the Bay Area was valued at $48 billion for existing commercial, residential and industrial infrastructure (Gleick 2008). These estimates do not include transportation infrastructure, which would add more value to the threatened areas. San Francisco International Airport and Oakland International Airport are located right along the water in the Bay, plus many roads and highways, railways like BART and Caltrans, 21 wastewater treatment facilities and more (Table 1). If people cannot commute to work or their building is flooded, then the economy will experience losses in worker productivity due to delays and expensive transportation costs (Tam 2012).

Vulnerability assessments are the main tool for implementing policy to determine which buildings should move inland and which buildings can be reinforced more sufficiently to withstand rising sea levels (ART 2011). The vulnerability assessment measures a building's risk relative to its capacity to adapt (Tam 2012). By measuring predicted sea level rise and overlaying that with a city's building layout or demographic information, we can determine that buildings which are likely to get flooded within the next half century must be relocated while others can afford to be protected. Such forms of protection include elevation of property, floating development on top of the water and designing buildings so they can withstand floods or storms (Schueneman 2013).

This is a necessary step in short-term adaptation because it will help for planning in the future. Rapport suggests that "adaptation planning in the short-term means reviewing the datasets for where the assets are located and if they are at risk" (Rapport, personal interview, 2014 August 12). Doing such an analysis would ensure the most cost-effective

Table 1. Infrastructure in Bay Area at risk from sea level rise, data gathered from ART.		
Assets	**Vulnerabilities**	**Consequences**
Businesses: Google, Facebook, WhatsApp, LinkedIn, Yahoo, Twitter, YouTube, Pinterest, Spotify, Reddit, Instagram, Citi, Intuit, Cisco, Chegg	Sea level rise, flooding, subsidence, liquefaction potential	Economic decline, lost days of work, lower wages, decreased tourism, lower utility, social networks decrease, education
Hazardous Material Sites: laboratories, manufacturing facilities, gas stations, transportation operation maintenance facilities	Wind waves, storm events, tidal flooding, rising groundwater, facility vulnerability	Release hazardous materials, expose people to hazardous materials, health and safety, water quality, wildlife and habitats, high cleanup costs, economic impacts
Ports: Oakland, Redwood City, Richmond and San Francisco	Less access to maritime facilities, rails that serve the seaports, interstate access sensitive, rising groundwater, liquefaction, levee failure	Less imports and exports, agricultural products spoil, delays, closures, contaminants released in Bay and groundwater, air pollution, employment, lower shipping capacity
Residential: housing, schools, local businesses, parks and recreation	High tides, storm event flooding, liquefaction, drainage systems, shoreline erosion, damage to property	Damage and closures, reduced recreation, less access, impact commuters, disruption to education, economic decline, higher insurance costs, limited mobility
Transportation: Bay Area Rapid Transit (BART); Bay Bridge; Bay Trail; Caltrans; Hayward-San Mateo Bridge; Ferry terminals in Alameda; Oakland and Harbor Bay Island; Interstates 80, 101, 580, 880, 980; State routes 61, 92, 185, 238; Passenger and freight rails; Oakland International Airport; San Francisco International Airport, San Jose International Airport	Access to transportation, low elevation, some transportation built on Bay fill, liquefaction potential, perimeter levees, flooding, saltwater intrusion, storm event flooding	Employment cargo movement, lower economic activity, groundwater contamination, increased emissions, disruptions to transportation, commuters, congestion, slow evacuation, less movement of goods and services, lower wages, poorer air and water quality

<u>Energy Utilities:</u> PG&E: power plants, substations, transmission and distribution lines; Dynegy: oil-powered peaking plant; Northern California Power Agency: Natural gas peaking plant, diesel-powered reserve plant	Wind wave flooding, deep storm flooding, water sensitivity, corrosion, groundwater intrusion, liquefaction potential, strong currents, shutdown plans	Insufficient power generation, power outages, pollution from hazardous materials, business closures, losses in productivity and revenue, pollution of natural habitats, species loss
<u>Stormwater Management:</u> drains, pipes, pump stations, outfalls	Flood events, rain and high tide coincidence, sea level rise, encroachment from Bay water, water entering pipes with insufficient capacity, saltwater corrosion, backup power if power systems fail, reduced infiltration capacity	Homes, transportation networks, flooding, backups in system, redistribute contaminants, sensitive habitats, pump failures, employment, economic impacts, energy and maintenance costs
<u>Wastewater Management:</u> East Bay Municipal Utility District (EBMUND), East Bay Dischargers Association (EBDA)	Storm event flooding, high tide, low electricity capacity, sensitive to water, damage, low capacity to handle flows, large, expensive, complex, liquefaction risk	Properties and neighborhoods, wastewater services worse, untreated wastewater released into Bay, pollution, chlorinated water, raw sewage, public health risk, losses of tourism, fishing and other economies

approach to adaptation because you only want to protect development that will be able to withstand higher thresholds of sea level rise. To guide cities in planning for the correct amount of partial retreat from the coasts and building reinforcement, government should continue to assist Bay Area communities through collaborative planning efforts and regional vulnerability assessments. This has already been done for the potion of Alameda County along the shoreline under the ART project, and it should be done for every county within the Bay Area to get a true sense of what it takes for communities to become resilient to sea level rise. Vulnerability assessments help minimize the externalities and costs that would occur from relocating infrastructure, which causes extra greenhouse gasses, pollutants and effluents to be emitted into the environment during construction projects.

Create Regional Plans and Organize the Roles of Government

Rising sea levels in the Bay Area yield environmental and socioeconomic costs. These can be societal impacts based on changes necessary for adaptation, such as retreat from the coast or large financial burdens associated with infrastructural projects. There are also environmental impacts on local habitats and species as beaches or wetlands get damaged. Some regions in the South Bay such as the Santa Clara Valley, and the city of San Jose in particular, have sunk 13 feet below sea level due to practices of groundwater extraction and loss of marshes during the 1960s (Ingebritsen & Jones; Tam 2009). The same thing is the case for the Sacramento-San Joaquin Delta region, which experienced land subsidence due to channeling and diking of the Delta for agriculture and water (Ingebritsen & Ikehara; Tam 2009). Cities in these regions will feel the effects of sea level rise sooner than others, and will need to adopt policies that make sense in a shorter time-frame, while also planning for long-term strategies.

Regional government and institutions should encourage vulnerability assessments for counties in the Bay Area. This is an important step in successful adaptation because it lays out appropriate and feasible strategies to address sea level rise for each part of the Bay. Creating a vision would then allow cities to delegate roles of adaptation management to stakeholders and other actors involved. Some of the responsibility will fall on the various public agencies surrounding the Bay that control water supply and wastewater, airports, seaports, transportation and development decisions that impact their specific region (Tam

2009). If local governments partner with their surrounding jurisdictions, then coordinated planning can take place to ensure that maladaptation does not occur. In the context of sea level rise, maladaptation means adaptation measures put in place that could end up creating more costs than benefits. This relates to the notion that if one city ends up building a seawall, there could be spillover effects from sea level rise if other cities do not.

Any program or policy that goes towards planning for sea level rise will have a monetary cost and the question is where the money will come from. Households will most likely be opposed to spending huge amounts of money on taxes or on adaptation that is not sustainable into the future. One way to figure out what residents are willing to spend their money on is to figure out peoples' willingness to pay for various strategies. This would provide a gauge on what forms of adaptation are most important to local residents. The downside is that people often understate their willingness to pay, so it is hard to tell if the results are entirely true. In any case, it is necessary to modify how shorelines are governed to give government agencies like BCDC and the California Coastal Commission more authority to come up with collaborative planning solutions for sea level rise (Tam 2012).

Making regional adaptation plans through locally established policies for addressing sea level rise is something that has to occur in the short-term, because the Bay Area is going to start experiencing sea level rise by mid-century. These plans will provide the vision of how adaption should progress within the Bay Area to address the long-term effects of sea level rise, bearing in mind that the pre-eminent land use authority belongs to local governments within the Bay Area. Given the potential for increases in sea level greater than 1.4 meters by 2100, long-term goals should be established as well, which often require more money and time. It is still uncertain how fast and far sea levels will encroach on communities located in the Bay Area, but it is better to be prepared for the worst possible outcomes than be unprepared.

4.2 Long-Term Adaptation

Short-term adaptation strategies are better suited to local adaptation strategies, especially in places that are at high risk from storm surge or higher tides. When thinking about a long-term time-frame under permanent sea level rise, it makes sense to have a more coordinated vision for how the Bay Area should plan and implement adaptation measures to become resilient. Resiliency relies on a continuous effort by land use planners to maintain adaptation into the future as sea levels keep rising. Regional and state-wide planning would promote this long-term goal. Wetland restoration and managed retreat are important initiatives for a long-term time-frame beyond 15 years:

Wetland Restoration

In the long-term, the services provided by wetlands such as the sponge effect or the ability to absorb flooding to a large extent will be crucial. Cities that do have wetlands in their area, like Redwood City and Menlo Park, should implement wetland restoration programs to prevent sinking or loss of land along the coast. Wetlands provide valuable ecosystem services to Bay Area that are capable of absorbing water associated with sea level rise, waves and storm surges. This will manage flooding and protect surrounding developed areas, while also benefitting the environment by restoring the Bay and sequestering carbon to mitigate impacts of climate change (BCDC 2008).

A study implemented by the United States Geological Survey found that flow speeds in the Bay will be higher once sea level rise hits. Higher levels of water and winds will create taller and more powerful waves, causing erosion and threatening recreational land uses (Tam 2009). These costs will impact safe shipping at seaports in the Bay (Tam 2009). To combat this, wetland restoration and soft shoreline armoring become important solutions to absorb higher mean water levels. Restoring natural ecosystem services via living shorelines is a path towards long-term sustainability because it helps mitigate climate change. In talking about mitigation in concert with adaptation, more and more people are starting to recognize the value and environmental importance of these living shorelines as essential for the health of the Bay (Grannis 2011).

However, mandating certain adaptation measures from the top or creating a uniform policy strategy for all areas is not politically, environmentally or financially appropriate (Tam 2009). For example, cities in the Bay that do not have wetlands to restore should not invest their money into a program for that purpose because it would be an inefficient allocation of money. Along the same lines, beach nourishment would not do well in places that experience high erosion. While soft shoreline adaptation strategies may not be implemented in every city of the Bay Area, there are ways to plan coordinated shoreline restoration with other necessary long-term adaptation strategies like managed retreat. In this sense, governance needs to be coordinated in a way that promotes regional and state agencies to work directly with their local governments in a collaborative way to help spur them along the adaptation process.

Managed Retreat and Relocation

An important part of managed retreat in the long run is understanding the lifecycle of hard infrastructural assets that are surrounding the Bay Area. These can be anything from power plants that need to be phased out to a building that needs to be modified to fit into updated building codes. Rapport suggests that for long-term planning, what is important is "thinking through how much you're going to depreciate the assets so that you have financing capability when you are rebuilding something to put it in a place that is safer" (Rapport, personal interview, 2014 August 12).

Once these values are determined by vulnerability assessments and other informational projects, policymakers can begin to regulate new infrastructure. For managed retreat, a buffer needs to be created in between natural shoreline protection and building infrastructure. This buffer would establish a certain distance from the shore where development is unsafe, saving money from reactive armoring efforts and ensuring protection from rising sea levels.

There are political challenges to relocating property. Adaptation is ultimately going to be expensive. Starting early can ease local governments into this inevitable process. Grannis (2011) address the importance of coordinated efforts for adaptation in California:

> The California Adaptation Strategy recommends that state agencies coordinate with local governments to consider 'policies and funding to facilitate easements to (a) relocate developments further inland, (b) remove development as hazards encroach into developed areas, or (c) facilitate landward movement of coastal ecosystems subject to dislocation by SLR and other climate change impacts' (Grannis 2011).

Understanding the economics of sea level rise will help sort out some of these political challenges and guide the framework for making coordinated adaptation decisions into the future.

Chapter 5.
Economics of Sea Level Rise in the Bay Area

Rising seas are one of the most salient effects of climate change on human populations. This can be analyzed through different lenses such as economic impacts, political impacts, social impacts, environmental impacts and more. To fully understand the components of sea level rise in the Bay Area, it is important to make sense of each problem individually first before analyzing how they relate. This chapter talks about the economics of sea level rise, focusing on its associated economic costs and risks. The chapter concludes by defining the terms of resiliency, adaptation and mitigation, which will lay the groundwork for analyzing sea level rise from a political lens.

5.1 Economics of Sea Level Rise

Sea level rise is one of the many interconnected externalities of greenhouse gas emissions. Those who release emissions into the atmosphere, either directly or indirectly through consumption choices, are contributing to an accumulating pool of emissions that get dispersed throughout the world. People who are not heavy emitters of greenhouse gases are then negatively impacted by the side effects that occur when fossil fuels build up in the atmosphere, such as sea level rise. Sea level rise will be exacerbated by more greenhouse gases raising world temperatures, regardless of where in the world they are emitted. Excessive GHG emissions are market failures and are a big reason why adaptation and mitigation are so difficult. This is important to think about with adaptation because, as Goldzband suggests, assessing these externalities facilitates environmental decision making:

> Environmental decisions are economic decisions because environmental costs are exogenous costs. I mean they're externalities, and you know that from your microeconomics class. Air pollution is an externality, and so the question is how much are you willing to pay to deal with those externalities? The decisions that we are going to have to make around here are going to be economic decisions and my hope is that we can also include the value of the environmental assets in there somehow. But it's all economics (Goldzband, personal interview, 2014 July 30).

While greenhouse gas emissions produce a negative externality that worsens the impacts of sea level rise, sea level rise also has the potential to lower certain positive or beneficial externalities within a society. In the Bay Area, houses are at risk of being flooded in the future. Slemrod and Bakija (2008) suggest that activities performed by homeowners can create positive externalities through activities like local engagement with communities or household maintenance that increases market value for property. Along similar lines, education of individuals would benefit broader societies as those people become economically productive and enter the workforce, lowering unemployment rates. These benefits would be eliminated should inundation threaten various entities that produce positive externalities for society. Protecting these assets and people from sea level rise will need to rely on many different types of adaptation in the future such as armoring in the short term and managed retreat as conditions get worse.

Risk and uncertainty are often used to describe the status of sea level rise and its potential impacts on coastal cities in the future. It is important not to get the two confused because decisions under knowledge of risk are different than they would be under uncertainty. In economics, risk is a calculable value for the probability that future events will occur or not (Rose 2001). Relating this definition to sea level rise, risk tends to be associated with the notion of vulnerability. If people are vulnerable to sea level rise by living along the shoreline, this implies some sort of calculated measurement that sea level rise is going to occur. Rahmstorf (2007) addresses the notion of uncertainty when talking about climate change and sea level rise. Economist Frank H. Knight states that uncertainty is different from risk in that "the likelihood of future events is indefinite or incalculable" (Rose 2001). Thus, uncertainty does not relate to a numerical value while risk is defined as a probability measurement. When planning for adaptation, it is imperative to understand all of these risks and vulnerabilities. Some regions in the Bay Area have a higher probability of being impacted by sea level rise sooner than others. These risk measurements help planners make decisions by prioritizing the most vulnerable areas first. Knowing probabilities and consequences associated with risk allow for better informed decision-making compared to uncertain conditions.

These concepts are important in talking about sea level rise because measurements and studies which aim at determining risk are still going to be uncertain. In the context of projecting and adapting to future sea level rise, Rahmstorf (2007) argues that sea level rise is hard to understand or predict because there are so many different mechanisms at play with different timescales. Among a few of these mechanisms are thermal expansion of the oceans as they absorb more heat, influxes of water into the ocean from melting glaciers and ice sheets, and fluctuating levels of water on land due to variable precipitation or climatic patterns (Rahmstorf 2007). These all occur at different rates, making it hard to predict how they will impact sea level rise altogether. Furthermore, the rates of sea level rise in particular places is more uncertain than the eventual amount of sea level rise. While global warming is understood as the driver of sea level rise, uncertainty becomes a limiting factor because we do not know when or how much sea levels will rise. Sea level rise estimates, which are continuously updated based on advancements in climate science and changes in greenhouse gas emissions, are likely to be different from what is actually experienced in the future (CEC 2012). It is smart to factor in uncertainty to think about other possible scenarios, but implementing adaptation measures under a veil of uncertainty could potentially cause maladaptation to occur.

Predicting sea level rise is an uncertain science, with numbers ranging from 0.2 to 1.4 meters of sea level rise by 2100 (BCDC; IPCC; Rahmstorf 2007). A future of rising sea levels places many communities and habitats in the Bay Area in danger due to damage from flooding. Economic value can be assigned to these features that are in hazardous regions along the coast where sea level rise is likely to occur. The notion of ecosystem services is one way to assign value to natural features within the Bay Area. Ecosystem goods and services are the benefits that nature and natural processes provide to people, a society or an economy. An obvious example of an ecosystem service in the San Francisco Bay Area would be benefits provided by the wetlands and salt-ponds located in the south near Santa Clara and Hayward Counties (Open Space Authority 2014). Wetlands provide services such as climate stability by sequestering carbon from the atmosphere, enhancing air quality and providing water regulation through natural irrigation and drainage services that help control water levels in the San Francisco Bay (Groot et. al. 2002). Larry Goldzband talks about the necessity of being able to evaluate the value of a wetland when thinking about how to adapt into the future:

> There is a growing body of literature trying to figure out what the economic value is of a wetland. One of the real keys here in the Bay, which is very different from the coast is that in a lot of places south of here – both down towards southern Alameda County, Santa Clara County and even up in San Mateo County – there are shallow areas where it would make sense to create or re-create marshland. What you do is you put in a smaller levee by sloping it much more gradually and you build it up with dredge materials, mud essentially. You plant stuff and you hope if it works that it grows faster, both up and back, than the Bay rises. That offers an amount of what is called the sponge effect, and that is an incredibly important thing (Goldzband, personal interview, 2014 July 30).

In assessing the impacts of sea level rise, it is not enough to say that approximately $60 billion of property will be damaged due to future inundation (BCDC). Not accounting for the economic value of wetlands within the Bay and other natural features that provide services to society would be missing a large portion of the costs associated with sea level rise. Loss of habitats, water resources, wildlife and other natural features of the Bay Area has the potential to drive economic productivity down. Since the 1930s, the state of Louisiana has experienced severe losses of about 1,900 square miles of coastal wetlands, which have made impacts from hurricanes much worse as a result (Farris 2005). Such was the case during Hurricane Katrina that hit Louisiana in 2005, which transformed another 30 square miles of wetlands into open water (Farris 2005). Losing this natural protection increases risk to more severe impacts from storms and flooding in the future. Promoting restoration of marshlands could diminish the impacts of sea level rise through the sponge effect, which helps regulate sea levels by absorbing excess water during flood events.

There are different ways to place value on these assets and services, a process which is already being done in the south Bay. One of the easier ways to think about economic valuation is to figure out if an asset were not there, what it would cost to society based on how much it is valued. If a wetland were not present then there would be foregone services that are important such as air purification so society would have to bear health costs or pay money to clean air that would otherwise be cleaned naturally. Turning to a study on the high value of nature in Santa Clara County supports this notion that natural features in the Bay Area are extremely valuable and could potentially be the most important form of adaptation.

Santa Clara County is the first county in the Bay Area to truly place a numerical value on the economic benefits of natural landscapes, many of which are at risk from climate change impacts like wildfire and sea level rise. This is important because it reinforces the need for an understanding of how valuable assets are before it is too late. The Open Space Authority released a report called *Nature's Value in Santa Clara County*, to provide the first-ever regional economic valuation of natural capital and ecosystem services in Santa Clara County (Open Space Authority 2014). The study captures economic benefits people receive from the County's natural capital such as open space, water resources and working landscapes. These features of an environment are important because they provide many ecosystem services like reduced fire and flood risk, which is helpful for regulating sea level rise.

The findings of the Nature's Valley study prove that the value of nature's assets in a region can be high and must be considered in circumstances where their survival is threatened. In Santa Clara County, the value of these ecosystem services spans from $1.6 to $3.9 billion annually. The study also found that the total asset value of natural capital in the area is somewhere between $162 and $386 billion. Comparing this to the County's total property value of $335 billion reinforces the notion that nature's capital is just as important as the built world, not only because it enhances quality of life in the area but also because if it were lost then society would bear expensive cost burdens. Losses of natural capital such as wetlands, open space and water resources in the Bay Area could become a reality due to climatic changes causing sea level rise, drought, water depletion and more. To combat this problem, investments in land and natural resources conservation would be sustainable alternatives to development and could provide high rates of economic return

(Open Space Authority 2014). Santa Clara serves as an example for other counties in the Bay Area by placing a value on nature's resources. In order to prepare for the future, communities should know how much value lies their assets and promote a balanced relationship between the built human environment and the natural environment.

5.2. Economic Impacts as a Measure of Costs

California is a prosperous state with more than 800 miles of coastline (EPA). Approximately eighty percent of California's GDP arises from coastal counties, which contain eighty seven percent of the population of the state as well (Risk Committee 2014). It is no coincidence that the state's GDP comes from the coast because that is where businesses and firms want to locate. People like living along the coast and without it GDP might be quite a bit lower than it currently is. This means it will be very important in the future to protect the many coastal assets that drive California's economy. To understand what will be harmed when sea level rise hits, we can look at the aggregate costs of all infrastructure and basic property that would be hit by various projections of future sea levels at different periods of time.

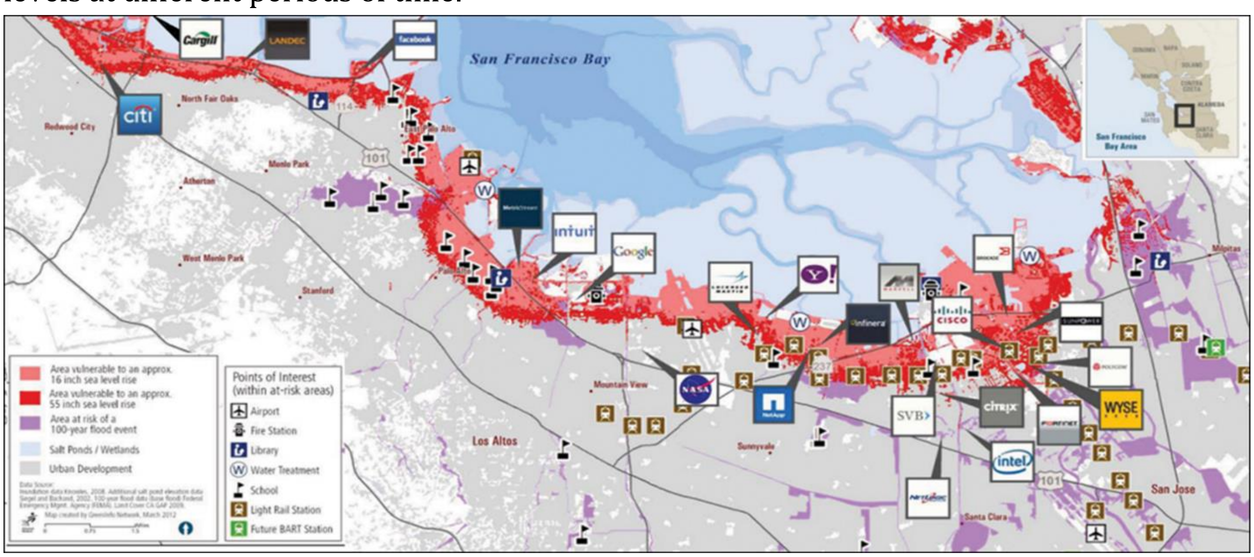

Figure 6. Assets in the south Bay at risk from sea level rise by southbayshoreline.org.

The majority of the coast of the San Francisco Bay is urbanized. Figure 6 displays major businesses and other points of interest that are at risk from sea level rise and a 100-year flood event in the south Bay Area; Figure 7 presents a zoomed out version of these vulnerabilities throughout the Bay. A 0.4 meter increase in sea level rise poses a threat to almost the whole western coastline south of San Francisco (Figure 7). At 1.4 meters of sea level rise, much more property surrounding the Bay becomes vulnerable. In the Silicon Valley, fortune 500 companies like Apple, Facebook, Google and Yahoo are all within projected sea level rise scenarios (Figure 6). In the event of a 100-year flood, many regions inland of the shore would become inundated too. When asked how economics plays a role in addressing sea level rise, Kelly Malinoswki, a sea grant fellow at The State Coastal Conservancy responds:

> I think generally the whole movement towards evaluating ecosystem services and putting a price on nature and on what we would lose economically is going to motivate people to take action. Economics is going to play a vital role in promoting and encouraging adaptation. Obviously the ports are at risk, the airports, the Embarcadero, businesses and then lost days at work. That's some of the economic valuation that's going on too saying that if this part of the highway is flooded then these people can't get to work and what hit to the economy is that. Putting a price on what we would lose is probably the main thing that will motivate people (Malinowski, personal interview, 2014 July 24).

Analyzing the damage that could be done to the economy will serve as a driver for action. Since wealthy areas like the Silicon Valley have a high risk to sea level rise, it would make sense for them to start investing in adaptation strategies. This would allow public and government funding to be directed towards low-income communities who need it more, to the extent that government should be involved in protecting private property.

It is hard to predict the economic impacts of sea level rise into the future. Various studies yield different levels of sea level rise, presenting different values and figures for the amount of property damage to be expected. BCDC suggests that if the Bay Area experiences

1.4 meters of sea level rise, over $60 billion of assets will be inundated (Goldzband, personal interview, 2014 July 30). According to the California Energy Commission, a 1meter rise in sea levels around the Bay could place $49 billion worth of property at risk of coastal inundation (Heberger et. al. 2012). Along the same lines, a 1.4 meter sea level rise would increase costs of property replacement to $62 billion (Heberger et. al. 2012). Many important economic assets that would be flooded are located in the Silicon Valley, where the land is very close to sea level.

Figure 7. Map created by GreenInfo Network, March 2012.

5.3. Economic Risk

Before diving into the various risks associated with climate change, one must understand and be able to define risk. In terms of climate change, risk can be defined as the likelihood that an event occurs combined with the severity of its impacts on society (Risk Committee 2014). These risks are often natural disasters such as severe storms or floods. Understanding risk and how to prepare for unfavorable outcomes is a necessary step in adaptation to sea level rise. Assessing the risks of sea level rise on the Bay Area can also lead to effective disaster management and public health planning.

Analyzing the economics of sea level rise in the Bay Area starts with assessing the risk and potential costs to local cities and counties who might face rising sea levels in the future. This process is called a risk assessment, whereby vulnerable assets are identified by some level of risk from sea level rise (ART 2011). The likelihood that sea level rise will occur is measured by estimating its probability (ART 2011).

Not only does sea level rise present a risk to physical assets that drive economic growth in the San Francisco Bay Area, but there are also costs to humans living along the coast as their property is put at risk. A person's house is usually the largest investment they own, so making a decision to live along the coast comes with a lot of extra risk involved. Matt Gerhart, Deputy Bay Program Manager at the California State Coastal Conservancy, brings up the idea that acknowledging risk is an important step in making smarter land use decisions in the future:

> It's *fundamentally a land use question* so it's essentially about siting things and how you make decisions about where you site things. This has come up a lot within the Bay Area and they're talking a lot about earthquake risks in concert with flooding risks. In an earthquake levees can actually fail and people don't really know how to manage the combination of the two. I mean everyone lives here

> in a pretty dangerous situation with earthquake risk and you just sort of get inured to it, you don't necessarily react to it. So the people who do risk management are very conscious about having specific ways to get people engaged (Gerhart, personal interview, 2014 July 23).

In order to think about protecting their property, people would first want to know what their susceptibility is to coastal hazards. It is true that people live with risk and those who live in the Bay Area choose to live there for calculated reasons. Framing the issue of sea level rise in a way that gets people involved and able to understand completely what the hazards are is a necessary step in being able to adapt. Sea level rise will only increase costs for people as they either have to retreat from the shoreline or take other preventative actions such as re-building their homes above sea level.

Livelihoods will certainly be impacted. In planning for a 100-year flood event, approximately 140,000 people are currently living in areas that are at risk of inundation (Heberger et. al. 2012). This is 2 percent of the region's entire population that will soon have to make decisions about how they want to live after significant sea level rise occurs. The scary part is that as sea levels rise, the amount of people living in vulnerable areas increases exponentially. Data suggests that a 0.5 meter rise in sea level will place an additional 20,000 people at risk, from the 140,000 baseline mentioned above, to bring the total to 160,000 (Heberger et. al. 2012). Jumping to a 1 meter and 1.4 meter increase puts 220,000 and 270,000 people in danger, respectively (Heberger et. al. 2012). This is almost double current levels of people who are vulnerable to a 100-year flood in the San Francisco Bay Area. This is just people living in flood zones.

People commuting into counties and cities for work in the Bay Area are also vulnerable. Heberger et. al (2012) suggest that a 1.4 meter rise in sea levels will cause about 320,000 people to be at risk. However, employees who can no longer commute to their jobs due to impacts of sea level on transportation infrastructure are not considered. Both employees and workplaces will not be able to perform effectively after sea level rise gets worse.

Under the framework of ecological economics, if sea levels rise and communities have not adapted to survive, then cities in the Bay Area will lose inputs into production that drive its economy. Sea level rise will crush certain amenities such as recreation along beaches in the Bay or life support systems like storm protection due to loss of wetlands. While it is clear that the Bay Area faces serious economic threats in terms of climate change and rising sea levels, it is not too late to lessen or reverse some of these risks through adaptation and mitigation solutions. Adaptation and mitigation serve as complements because you cannot have one without the other. In a no-mitigation world, the risks from sea level rise increase and adaptation would become even harder under more extreme sea level rise scenarios.

5.4. Resilience and Adaptation

People live with risk every day. In the Bay Area, people live with earthquake risk as mentioned above and more recently other environmental risks such as sea level rise. These are examples of extreme events that have the potential to harm or displace many residents, resulting in billions of dollars of property damage. Resiliency has come up as a popular word used to help people talk about climate change and strategies for adapting to associated impacts (Foster et. al. 2011). Resiliency seeks to mitigate the impacts of a disaster on the economy and human populations after it has already hit. Foster et. al. (2011) suggest that cities and counties undergo certain adaptation practices such as "green" infrastructure solutions to increase their resilience to climate change impacts.

Resiliency in the Bay Area it is often linked with risk. When asked what resiliency means, Ezra Rapport responded that people "do face massive risk with seismic conditions in the Bay Area, so resiliency means an ability to bounce back after one of these natural events." Resilience is the ability to recover quickly from a natural event that could be harmful to a society. Expanding on this, we find that "the other idea of resiliency is when you do try to fix something along the shoreline you want to be able to increase the amount of resiliency over time. Once [sea level rise] gets started and we're able to measure it, we would want to be able to increase the protection over time so we'd be looking for that type of long-term solution" (Rapport, personal interview, 2014 August 12). This links with the adaptation suggestions talked about earlier. To build an adaptive capacity, planning for sea level rise must be a continuous process that is able to respond quickly to sudden changes and be able to return to stability.

Figuring out when to become resilient relates directly with adaptation. Adaptation can be defined as actions that occur in response to future anticipated threats associated with climate change. There is no set path for preparing for sea level rise, as many different strategies can lead to the same goal. Nadine Peterson of the California State Coastal Conservancy speaks to the challenge of making decisions when there are different solutions that would fall under the category of adaptation:

> I mean to me [adaptation] really means looking at alternatives and prioritizing actions based on economics, but also overall public benefits from alternatives. Looking at scenarios and saying: if [sea levels] go up this amount of inches what would be the implications and what are the various tradeoffs of different alternatives? Adaptation would be going through that to start weighing the pros and cons of each potential solution. Of course my fear is that there is going to be money thrown at protecting certain areas and not other areas, and using armoring even if it damages other people's property and natural resources (Peterson, personal interview, 2014 July 22).

To adapt, one must look at the potential damage that could be done after an earthquake, a flood event, and a king tide or another natural disaster to figure out how this damage could be lessened. The point is that timeframe matters when defining resiliency and adaptation, both of which are necessary steps in addressing the economics of sea level rise.

In the case of sea level rise, which would be permanent, costs are going to increase indefinitely because there are always things that can be done in the way of planning, mitigation and adaptation. This is why many government agencies in the Bay Area are interested in finding ways to reduce damage from sea level rise as much as possible:

> When you take a look at the economics of [sea level rise], you can easily determine that $62 billion of property damage does this and BART has infrastructure here by looking at maps. The interesting thing from my perspective is not just that, it's what can you do to minimize [those impacts]. And you can do any number of three or four different things: you can build big levees, you can build smaller levees that have habitat, you can build marshes, you can build a gate underneath the Golden Gate Bridge and people are talking about that (Goldzband, personal interview, 2014 July 30).

Under this framework, policy decisions naturally become opportunity costs where using one dollar to finance resiliency in an area means foregone spending in another area. Likewise, choosing to spend money on one certain type of project means that there will be less money available for other projects.

Some people might argue that it makes sense to spend money first where the most property damage is expected to occur. However, a decision of this type is limited to economic prioritization. This often leads to discussions about what is equitable or fair when planning for resiliency and climate adaptation. Decisions like which communities or cities should adapt first are tradeoffs that government officials, policymakers and stakeholders will have to make more frequently as sea level rise increases. High costs associated with becoming resilient, due to large financial investments, means that not everyone will benefit from adaptation measures. This can raise concerns over equitable distribution of funds (Heberger et. al. 2012). In the Bay Area, many coastal cities are low-income communities that have the potential to be more severely impacted by sea level rise. These poorer areas might not have the political influence or financial resources to facilitate their protection. It is important that policymakers, when planning adaptation for a future with sea level rise, consider the needs of underprivileged communities to promote environmental justice.

A report released in July by the Georgetown Climate Center (2014) addresses twenty different ways that states and local governments can become resilient and develop plans to address growing vulnerability to climate change. California is already underway in implementing the Climate Center's first suggestion in planning for resiliency, which calls for enhanced state hazard mitigation plans. The plan, which was approved by the Federal Emergency Management Agency (FEMA) in 2013 as an "Enhanced" State Mitigation Plan, aims to prepare California for long term threats of climate change (Georgetown Climate Center 2014). Developing an "Enhanced" Hazard Mitigation Plan is a huge milestone for California in addressing long term climate resiliency. It allows the state to be eligible for increased federal funding should a disaster occur. Since 2010, California has already received about $168 million in federal funding for natural disaster relief (Georgetown Climate Center 2014). Increased funding is going to be a necessary step in becoming resilient against sea level rise and other threats of climate change.

Adaptation focuses on the actions that are taken to make sure cities and communities are prepared for futures with sea level rise. In relating this with resiliency, planning should be implemented in a ways that increases protection of local communities in the Bay Area over time. This is an important factor in assessing the economics of sea level rise because it is a way to reduce vulnerability of the built and natural environments to inundation.

5.5 Mitigation

Mitigation is linked to discussions about climate adaptation as strategies that seek to reduce the severity or the hazards of sea level rise. Under the executive order of Assembly Bill 32 (AB 32), the state of California is hoping to reach a 90 percent reduction of emissions by 2050 (Rapport, personal interview, 2014 August 12). This is the comprehensive, statewide initiative to reduce greenhouse gas emissions. Governor Jerry Brown of California states:

> Here in California…we are pioneering climate change strategies across a broad front. We have a robust cap-and-trade system. We have a goal of one-third renewable energy in the electricity sector; we're already at 22 percent. We have the strictest building standards in the world. We have a goal of over a million electric vehicles; we've got our first 100,000! We have a certain momentum in California (Dreifus 2014).

This initiative serves as an important example for state-wide regulation plus regional and local cooperation towards a standard goal of emissions reduction and climate mitigation. This is an example of cooperative governance at various different levels of government, which is something that will be a key factor in addressing adaptation to sea level rise throughout the Bay Area. Malinowski adds that because of AB 32, there are multiple different action plans being implemented "because we have AB 32 at the state level, each of the counties have their own general plans and local coastal plans. Each of the cities have their own plans too. So it is all these different levels and people have to be taking action at the city level, the county level and the state level" (Malinowski, personal interview, 2014

July 24). Adaptation will need to mesh with local mitigation plans to reduce greenhouse gas emissions, which are mainly focused on transit and driving. This would ensure that adaptation does not make greenhouse gas emissions worse in the future.

5.6 Moving Forward

Much of the literature on climate change and sea level rise focuses on a timeframe from the present to 2100. This is because greenhouse gases, notably carbon dioxide, stay in the atmosphere well after they are emitted (Risk Committee 2014). Even if all greenhouse gas emissions were cut, enough carbon dioxide is in the atmosphere to dramatically shift climates and exacerbate communities up to the year 2050 (ART 2011). In terms of climate change, almost all of the damage up until the mid-21st century has already been done (Malinowski, personal interview, 2014 July 24). Planning for sea level rise 100 years from now seems like a long ways away for investors, policymakers and homeowners. However, the reality is that decisions made today will have a direct impact on the future risks of climate change. For example, if people continue to produce emissions at uncontrollable rates, it will increase rates of sea level rise faster. Using a semi-empirical model to estimate sea level rise, Rahmstorf (2007) suggests that people need to be prepared and able to respond quickly to the possibility of rapid sea level rise through adaptation and mitigation strategies. The next challenge is addressing the political barriers to making these measures possible.

Chapter 6.
Political Challenges of Planning for Sea-Level Rise

Formulating strategies to minimize sea level rise are rooted in the political debates surrounding the issue. As a result, clarifying the aforementioned environmental and economic lenses through which to understand sea level rise helps guide solution-based thinking. This section presents a discussion on the politics of sea level rise in the Bay Area, mainly stemming from personal interviews with members of local government agencies who are working to address sea level rise in some capacity. Integrating policy with the economic and the environmental issues of sea level rise provides a holistic approach to what can be done in the future to solve adaptation issues. Three challenges are analyzed in this section: the political complexity of making decisions in the Bay Area, financial challenges to funding adaptation, and prioritization of environmental justice issues. In the end, it is not just the role of government agencies and decision makers to be prepared for sea level rise – it is everyone's job.

6.1 Political Complexity in the Bay Area

Managing sea level rise is reliant on the ability of local, regional and state governments to formulate new policy decisions within the Bay Area. However, without local cooperation from landowners progress is still limited. When talking about the politics of sea level rise, this is a discussion about how people make decisions which may be rooted in policies that seek to help people adapt. A majority of these solutions, as mentioned earlier, involve land use planning that addresses parts of the coast that need to adapt to become resilient. These decisions almost always stem from local governments, who have control over land use in their jurisdiction. Making policy decisions of this sort is complex because private landowners, cities, regulatory agencies like the California Coastal Commission, BCDC, utilities and transportation authorities all play a part and have some decision-making control along the coastline of the Bay. Decisions regarding land use have to go through a number of hands before they are approved. It is imperative to understand the political challenges and processes that are involved so that planning can occur on a path of least resistance.

One political challenge in dealing with sea level rise is managing the roles and responsibilities of each tier of government. In the Bay Area, land use decisions are made on a local basis, but may face restrictions from regional or state authorities. Gerhart argues for organizing specific roles for each level of government:

> Local government is at the level where they have to do site-specific planning and community involvement. They are leaders on the ground in terms of who to work with and how. Eventually we need to have a two-tiered approach where we help folks early on who have some impetus and ability to act on their own by pushing them as leaders. Our projects have mostly been to work with jurisdictions that are proactively addressing [sea level rise] so that we can get them as far along as possible and have examples of success. In the places where nothing is happening I think there needs to be a more assertive effort over time by higher levels of government to provide tools to get those folks engaged (Gerhart, personal interview, 2014 July 23).

This two-tiered approach is an interesting idea that would encourage some actors to serve as an example for others. In situations where local actors are self-sufficient, they can partake in adaptation strategies more easily. The implication of this, is that many communities that do have the resources to plan for adaptation are wealthier communities. In this sense they are arguably more likely to be able to address sea level rise on their own compared to lower income communities. Where communities are struggling to plan and adapt, then regional or state government might want to get involved. Regional government plays a role in fostering a relationship amongst various local agencies in order to guide coordinated adaptation strategies that involve everyone.

Thus far, it is clear that local government is going to play a large role in cities' and counties' ability to become resilient to sea level rise through climate adaptation. The ability of local governments to cooperate on a region-wide initiative is important, because adaptation that occurs in some cities but not others does not mean that the Bay Area has fully adapted. Malinowski adds that "you could still do what you need to do in your city but because your neighbor didn't do what they needed you could be negatively impacted by that" (Malinowski, personal interview, 2014 July 24). For example, if one city walls off their portion of the Bay so they are not subject to storm surge, they might still feel lingering or spillover effects if their neighbors did not build one too. The hope is that the adaptation process would be continuous and each community that is threatened by inundation could be prepared for the future. One challenge lies in the notion that calculating economic, environmental and social costs and benefits from certain adaptive strategies serves as a "barrier to action for local governments" (Foster et. al. 2011).

Another challenge facing government when addressing risk to sea level rise is that it is hard to get people on board with the whole issue and actually accept that adaptation changes need to happen. People tend not to think of a future with permanently higher water levels so it is hard to imagine the changes that might occur and what they might look like. Sea level rise is not noticeable right now considering over the past century sea levels have gone up at a very slow marginal rate of 2 mm/year. Furthermore, many people do not anticipate or react to flooding until it happens. Gerhart speaks to the challenge of getting people engaged and aware that sea level rise poses a threat when it is not obviously visible or occurring now:

> This is a problem that isn't easy to see, it's not a problem that you think of everyday when you're walking by the Bay. I mean it's a worse version of the same problem we already have with fire risk and normal flood risk where you don't think about a flood until your backyard is wet. You don't think about the fires until they already hit so it's sort of all best practices kind of stuff. People think yeah sure somebody should be taking care of that but they don't see it so they don't worry about it (Gerhart, personal interview, 2014 July 23).

Until a natural disaster actually occurs, people are not inclined to prepare their houses for flood damage or invest money in property protection. This is a problem because under current climate change scenarios and projections, more severe storms and rare flood events are going to occur. By the end of the century sea levels will be permanently higher. Communities in the Bay Area must accept this notion that the probability of flood and sea level rise risk is increasing in order to start making changes for the future. This requires working together towards the same decision-making agendas to prepare for disasters before they occur and stepping away from individualistic, inward-looking models of action.

Providing a context for timing is another factor that makes defining sea level rise a tricky concept to understand. Planning for the long-term is something that people often shy away from because thinking about a far-out future is hard to imagine. It gets confusing when people talk about 100 years into the future, when planning for mid-century adaptation still needs to occur. Goldzband suggests that thinking 50 years in advance is hard enough, so how do we expect people to fathom 100 years from now. In this sense, making long-term decisions stems from some degree of uncertainty and there is the fear that people could do something to adapt that would make everyone worse off in the future. Gerhart adds that "the idea of planning 50 years ahead doesn't work for many people. There needs to be a role carved out in government to do that function, so they can chip away at it over time. I think a lot of people agree yeah you need to plan that far ahead, but they just don't have the resources, the time or the expertise" (Gerhart, personal interview, 2014 July 23). The key in this situation is to undertake manageable actions continuously to ensure that little things are done here and there, which will eventually add up to a more comprehensive group of actions.

6.2 Financial Barriers and the Role of Government

The largest barrier to adapting to sea level rise are financial constraints and the capacity actors have to take action. Federal, state, regional and local government, plus households are all restrained by financial challenges for funding adaptation. This is because most funding does not carry through an entire project (Grannis et. al. 2014). Addressing the funding issue is an important step to allow those who are involved in adaptation to become examples of success to continue the process.

The first problem government's face is that in order to even think of being able to adapt, communities need funding. However, this has to be done in a strategic way. There is only so much money available to direct towards adaptation, that governments must think about how much they are willing to spend and where. Gerhart suggests that funding certain groups to serve as leaders in adaptation would be a way to show what is working:

> Funding is going to be a huge issue. That's what The Conservancy would really focus on is getting funding to communities in need over time. I think we're trying to focus on certain leaders or groups who can lead now because they will provide examples of what to do. Right now you can throw money at [addressing sea level rise] but nobody really knows what to do. We really need other communities that are demonstrating how best to proceed (Gerhart, personal interview, 2014 July 23).

The Conservancy plays a really important role in promoting local adaptive capacity, because they are the agency that gives grants to people and groups who are working on climate adaptation under their Climate Ready Program. Nadine seconds this idea by adding:

> We need to support things that would help us look at the impacts of alternatives for protecting from sea level rise. We need to provide incentives for people to do the right things, which requires funding. That's what we're trying to do at The Conservancy is provide incentives to get people to plan ahead and hopefully look at 'green' options. However, the future is uncertain with regard to who is going to get funded to do what (Peterson, personal interview, 2014 July 22).

While this distribution of money still might not solve the problem of funding projects through their entirety, it is a step in right direction for making adaptation more accessible and manageable on a localized scale.

In some cases, local communities have to pool resources together and streamline funding from a variety of willing donors or other sources to successfully implement adaptation plans. One way to combat this issue is to find a way to help people who are doing things to adapt. In a report by the Georgetown Climate Center, Grannis et. al. (2014) argue that there are ways for federal agencies to provide funding to support state and local adaptation strategies. It is also important to understand that there will almost never be just one source of funding, especially for large scale adaptation plans that encompass multiple cities and counties. In this sense, local governments must be willing and able to make up the funding gap. Ways to do this are to leverage local funds by harnessing market tools such as public-private investment strategies. These could be lending money to local actors via a revolving loan fund or supporting private lending through a loan guarantee program (Grannis et. al. 2014).

Another debate about financing planning and adaptation for sea level rise addresses the issue of the distribution of funding. Local government only has so much it can direct towards projects and the reality in the Bay Area is that funding will have to be supplied in some places before others. Gerhart suggests that "funding is going to be very piecemeal. Some cities are either able to work the system and get what they need, or just have the funding already to build structural protection. The differential ability of cities is a big deal. For the Bay Area there's definitely cities that won't be able to keep up quite as well as others" (Gerhart, personal interview, 2014 July 23). Based on this idea, it appears that financing adaption will have to be chipped away at over time depending on which communities and counties are given money and when. Malinowski speaks to the idea that more private money could potentially be used as an investment into adaptation:

> Funding is hard because the state doesn't have a ton of money. I think private investment would be good, I mean the Silicon Valley area as you know has a lot of money. I am hoping that people there could at least contribute to adaptation in their region. I think if businesses and private investment, when there is money, would contribute that it would definitely further things because public money is always limited and stretched really thin over multiple issues (Malinowski, personal interview, 2014 July 24).

This is an important transition towards equity and funding distribution. If wealthy communities have their own resources and money to finance adaptation, it would benefit the rest of society for them to do so because then public resources could be directed to communities that truly need it.

Overall, there are high values to protecting shorelines but it is difficult to finance. This challenge becomes an issue because people are most likely not willing to bear these costs. Goldzband suggests that determining the value of an asset is more complex than figuring out how much it would cost if it were destroyed "because there are habitat values too that you can't just quantify. But even if you do that who pays for it?" (Goldzband, personal interview, 2014 July 30). The case study on economic valuation of Santa Clara County's natural features supports this notion that property damage due to sea level rise would be expensive and hard to repair because no one wants to bear the burden of high costs.

6.3 Prioritization and Environmental Justice

Another topic explored was the issue of prioritization and how governments make decisions. When there are multiple available options for addressing sea level rise, this necessarily implies that a certain level of prioritization must occur. From a governance perspective, there are two ways to view prioritization of sea level rise. The first has to do with the idea that sea level rise, among other environmental disasters, should be prioritized in terms of government policy planning in the future. The next question, if people do agree that sea level rise poses the highest risk to society in the future, would be how to prioritize actions in certain regions as opposed to other ones. This relates to an environmental justice framework, whereby adaptation for sea level rise might not always be reflected in an equitable manner. The good news is, policymakers do seem to be aware of these equity issues so hopefully funding in the future can be distributed evenly to facilitate adaptation.

In thinking about sea level rise as a priority relative to other environmental issues within the Bay Area, many people and policymakers are of the opinion that it is a huge concern. Sea level rise might be seen as getting more attention in the news and media as a side effect of the widespread attention that climate change receives. However, there are still people of the belief that other environmental hazards such as drought and fire might be a bigger risk for California in the future. Gerhart speaks to his concern about the lack of information about other environmental stressors and that they might not be getting enough attention:

> I am someone who thinks that [sea level rise] is probably not as significant an impact as some of the others relative to how much attention it gets. The Bay Area certainly has a lot of stuff in the way of sea level rise and it is a fundamental change. It's not like you can just deal with it and it goes away, it is just going to be that way. It's clear that it will have big impacts and that's why it's getting a lot of focus. People around a table know that sea level rise is going to affect them as opposed to other stressors that they are not as sure of. Not everybody is totally sure what is going to happen when it comes to fire risk, drought or water supply because there is just less information (Gerhart, personal interview, 2014 July 23).

Despite differing opinions on the severity of sea level rise compared to other environmental issues, planning will become more important in the future once it does get started. It also seems clear that people are prioritizing it in terms of adaptation because it is going to impact people and the economy in a large and permanent way.

The next idea of prioritizing sea level rise relates to decisions about where to implement adaptation measures first, based on the limited supply of public resources that can be directed to this purpose. Schuchat adds that spending could be prioritized based on a cost-benefit analysis, but would still be unequal:

> At any given point in time you've only got so much money, so we will have to prioritize. The problem with this is that benefit-cost assessments are always an imperfect and a somewhat subjective instrument. Politically you could do a cost-benefit analysis that says this is the community we should protect first, but then other communities are not going to care about your numbers. They are going to say 'why aren't you protecting us and you're protecting them instead?' (Schuchat, personal interview, 2014 July 29).

Ultimately it seems that helping communities adapt is going to be hard for policymakers to address without making some groups better off before others.

One of the relevant conversations surrounding sea level rise is how vulnerable different communities are to its impacts. As we know in the Bay Area, various factors such as elevation and access to financial resources will determine how funding gets prioritized.

According to the Pacific Institute's report, environmental justice concerns present a determining factor in a communities' vulnerability to sea level rise. This is because "vulnerability is a function of the magnitude of the impact, the sensitivity of the system to that impact, and the system's ability to adapt" (Heberger et. al. 2012). From an equity framework, this means that communities which are closer to sea level and have less capacity for resilience are worse off under sea level rise scenarios. Furthermore, "decisions about how to use public funds can lead to inequitable distribution of costs and benefits, whether they are based on economics (protect the most valuable assets) or utility (protect the largest number of people)" (Heberger et. al. 2012). Heberger et. al. (2012) present data showing that low-income communities will be disproportionately impacted by sea level rise and urging policymakers to make a conscientious effort to understand these environmental justice concerns. Rapport reinforces this idea by suggesting that:

> The ones who are usually most vulnerable are lower income people who are living in areas that have freeways or elevated freeways. People living on land that's not particularly desirable, which may be in the floodplain area, have a limited capacity to move. That's the equity side of government spending: to prioritize whatever spending there is to try to address problems that will affect poorer people because they have less resources to be resilient individually (Rapport, personal interview, 2014 August 12).

This is important for supporting environmental justice and helping communities that have less mobility become more resilient to sea level rise. Building off of these equity considerations, it appears that some adaptation decisions are being made in lower income communities in the Bay Area:

> The Conservancy has chosen to start with the community of Alviso because it is literally the furthest below sea level of any community around the Bay so they have the highest flood risk. On the other hand, it's not a wealthy community so the homes aren't worth as much. Therefore the cost-benefit calculus doesn't come out the way it would for instance if it were Atherton. In Southern California there are wealthier communities that live near the water. In the Bay Area it's the poorer communities that generally live near the water so they have less political clout (Schuchat, personal interview, 2014 July 29).

That communities living along the water tend to be poorer in the Bay Area is a really interesting aside. This means that it is even more important to factor in equity decisions.

6.4 Management and Leadership: Practical Implementation

The current problem of sea level rise in San Francisco should not be overlooked because it is one of the most burdensome side-effects of climate change on the region (Tam 2009). Since sea levels are going to rise at least 0.4 meters by mid to late century, establishing policy for planning and adaptation to sea level rise in the Bay Area is a top priority for local governments. In doing so, problems resulting from sea level rise like freshwater depletion, public health concerns, and biodiversity loss will be less severe. The role that influential leaders such as local government and stakeholders play in addressing sea level rise will be crucial. "The point of government is to allocate scarce resources. It is to organize society and the economy, to provide public goods and services, to allow for the flourishing of individual activity and exchange" (Englebert & Dunn 2014:213). This sections talks about some of the practical pieces of planning that are being implemented and how achieving small milestones on a continuous basis must become a reality.

Despite the natural realities of the Bay Area and its susceptibility to future sea level rise problems, these trends can be reversed or offset through flood protection (Nicholls et. al. 1999). In the late 20th century, adaptation measures were already occurring as a response to climate variability, without even considering sea level rise beforehand (Nicholls et. al. 1999). To determine what actions are needed to prepare for sea level rise in the Bay Area, people will need a solid grasp of what is at risk and already exists in the way of protection. Predictions and data on climate change can only make policy and management decisions more accurate in the long run. Under this argument, the research side of sea level rise will play a huge role in gaining better information so that people feel confident in making decisions (Gerhart, personal interview, 2014 July 23).

Mazmanian et. al. (2013) argue for a governing framework that would require infrastructural projects with a minimum 30-year lifespan to include minimum building standards that prepare for future climate change impacts as suggested by the Intergovernmental Panel on Climate Change (IPCC) immediate scenario. This view is in line with both Goldzband and Rapport's input on future development in the Bay Area. In order to ensure that cities prepare fully, buildings should be sited properly and old buildings phased out in a timely fashion to get the most value from them.

Some flood protection projects fall under the category of management actions that Holleman and Stacey (2014) call shoreline "hardening," where hydrodynamic barriers like seawalls and levees are built. One issue associated with shoreline hardening is that it alters the natural dynamics of the Bay by "decreasing the tidal prism" and causing "greater tidal amplification" (Holleman & Stacey 2014). Nadine Peterson addresses the future challenges associated with "hard" shoreline protection such as armoring:

> We're going to have a lot more armoring and I think the best we can do is try to get started early by showing that there are alternatives that won't be as damaging to the environment. There is a proposal by Mark Stacey, who is a researcher, to see if there is a model which would show if you put armoring here how it would affect sediment, water flows and energy elsewhere. That's the kind of thing we need to help us really start making choices rather than blindly going forward and saying okay we are going to protect this irrespective of the impacts (Peterson, personal interview, 2014 July 22).

Aside from being expensive, shoreline "hardening" is not always the most environmentally conscious approach to addressing sea level rise. Sometimes the goal with policy is to handle the situation in the most efficient way possible. Shoreline hardening is a natural consequence of this goal because it generates externalities that people might not realize until after the fact.

On the contrary, shoreline "softening" addresses attempts to reverse and restore potential damage by allowing natural shorelines to return. Peterson suggests that the steps for pursuing more soft adaptation measures involve "engaging stakeholders and looking at wide-ranging alternatives to consider environmental impacts as well as social and economic ones. Then providing incentives for people to do the greener option that will sustain us longer term" (Peterson, personal interview, 2014 July 22). Not only are green options in line with goals of sustainability, but they also do a better job of maintaining species diversity and restoring ecosystem habitats to their natural state. This brings up the idea that there needs to be specific incentives and directives from government higher up because otherwise local governments might move towards implementing shoreline hardening first, which can adversely affect other communities.

In instances where local governments do not have the capacity of capability to cooperate, regional strategies such as the ART project become extremely important. This project helps set the standards for areas and provides clear frameworks for how to prepare for the future. Goldzband describes the project as "a groundbreaking, nationally recognized, first of its kind project" that asks the question "how do we prepare individuals, neighborhoods, communities, private sector and local governments to actually understand and adapt to what will happen?" (Goldzband, personal interview, 2014 July 30).

The first step to making this happen relies on experts and people who are engaging with these issues on a daily basis to be able to answer questions in a way that allows everyone to become engaged. The Bay Area is already doing this in a large way and hopefully the region and California in general can continue to be leaders on environmental issues like sea level rise.

Chapter 7.
Conclusion

Discussions about sea level rise have increased exponentially over the years as facts about climate science and the future become clearer. Scientists are constantly coming out with new data and projections about which cities around the world are going to be hit with rising seas. From a national perspective, the Bay Area is just one of many cities vulnerable to inundation and sea level rise.

In 2014, the Risk Committee performed standard risk-assessments for various regions in the United States to determine potential impacts of climate change on communities and the economy under a business as usual trajectory. They evaluated cities based on their level of risk and as a result, the project became known as the Risky Business Project. It seeks to sketch out likely scenarios that would impact different sectors of the United States economy. These risks can be broken into property damage, climatic-driven changes and the impact of higher temperatures on society (Risk Committee 2014). The Risky Business Project found various conclusions rooted in the certainty that economies in the United States will face major risks from climate change (Risk Committee 2014). The study found that there is no single solution to dealing with the economic costs associated with climate change in the US. Instead, they argue that each region should adopt their own approaches to climate mitigation and adaptation that are most suited to their needs. This means that economic impacts of sea level rise will yield different strategies for dealing with associated risks in the Bay Area compared to elsewhere in the United States or the world.

The Bay Area is already making important progress on research, planning and adaptation. Given the successes of Adapting to Rising Tides as a pilot project, hopefully it can expand and create county and Bay-wide reports on the vulnerability and anticipated effects of rising seas. Large projects like this that involve local actors like BCDC and national groups like NOAA are so useful for making people aware of the need to prepare for adaption on a regional scale. Once regional plans and studies are done, then local action becomes more thoughtful or planned out in a strategic way. Regional wetland restoration projects such as the South Bay Salt Pond Restoration Project display examples of coordination between federal and state government, flood control districts, park districts and others towards a similar goal. Funding from various public and private entities like the US Fish and Wildlife Service, the US Army Corps of Engineers, NOAA, The Conservancy and more are making these local projects a huge success. The Ocean Beach Master Plan is another example of a long-term vision for the future of the Bay's coasts to protect beaches and other areas from flooding and sea level rise. One project that speaks to the ability of local governments to overcome inter-jurisdictional challenges is the San Francisquito Creek Flood Protection Project, which seeks to solve flooding challenges associated with the expansive watershed region within Santa Clara County. Highlighting certain success stories from projects in the Bay Area is important to encourage adaptation in other regions.

Having continuous conversations about sea level rise is another way to make people aware about the severity of the issues of climate change. Talking about sea level rise frequently will help get people engaged with the issues and understand why adaptation is important. It is easy to put off talking about important issues, but this is also problematic because it creates a barrier between knowledge and timely action.

Now is the time to start preparing and adapting for the future of the Bay Area in the midst of climate change. It will be important to continue updating data on sea level rise. Information spanning from modeling Antarctica's rate of ice melt to assessing which levees need to be updated should be released as it becomes available. This is because having the most relevant data ensures that the timing of projects and spending is efficient. One interesting area of study for the future will be figuring out how to bridge this gap between science and policy. When asked how policymakers can use science to get to the right decision making frameworks for addressing sea level rise, Rapport responds that that there is an emerging field called "climate services" which would form a bridge between scientists and decision makers in terms of how to understand, talk about and explain these issues further.

This paper sought to study sea level rise with the goal of learning how to talk about it more clearly and help people understand some of its underling features. Among these are geographical factors, viable adaptation strategies, economic impacts and political challenges to making decisions about how to prepare people and communities for sea level rise. Ironically, I leave having learned that this process is only in the beginning stages of what appears to be a long journey. Sea levels will go up and it is uncertain how fast. Thus, efforts to plan and adapt must be continuous and forever changing. Technology improves and so does our information, but it is how we act on this knowledge that matters. Pursuing innovative strategies for adaptation to sea level rise is a conscious decision to learn from the past and transition towards a brighter future.

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