ASSOCIATION OF BAY AREA GOVERNMENTS
RESILIENCE PROGRAM

Housing and Community Risk Multiple Hazard Risk Assessment

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1. Introduction

Project Introduction and Purpose

In the Bay Area, retaining housing is crucial to expediting and ensuring an effective disaster recovery. Limiting catastrophic housing damage and keeping residents in their homes not only helps people who may lack the resources to effectively recover from a disaster, but keeps communities intact. Understanding where the most vulnerable housing types are located, especially those that house vulnerable community members, is a crucial first step to gain a more comprehensive understanding of multi-level risk within the region and to better understand where mitigation needs to be prioritized. For the region as a whole to become more resistant to disasters, jurisdictions need comprehensive, actionable strategies to reduce vulnerabilities and build more resilient communities. The Bay Area Housing and Community Multiple Hazards Risk Assessment, is a multi-agency project led by the Association of Bay Area Governments (ABAG) and the Bay Conservation and Development Commission (BCDC), designed to better characterize both the structural and community components of vulnerability, as well as develop strategies to address these specific vulnerability characteristics. The purpose of this project has been to:

- Understand the characteristics of San Francisco Bay Area housing and communities are likely vulnerable to earthquakes and sea level rise related flooding.
- Identify and assess housing and community vulnerability at regional and community scales.
- Develop strategies that reduce housing and community vulnerability to help the region meet its resilience, sustainability, prosperity, and equity goals.

During the time frame of the U.S. Geological Survey's funding for this topic, the project defined vulnerability indicators to identify areas of high risk from natural hazards, structural risks to housing stock, and social risks to communities, then mapped these risks to better understand where they overlap, revealing areas vulnerable to multiple risks. Indicators were first developed and mapped at a block group level across the whole region, but then refined or elaborated on at a local scale through case study work with individual communities and workshops with community representatives. A suite of strategies developed by ABAG, BCDC and a consulting firm, AECOM, provide a set of tools communities can use to reduce vulnerability of existing communities, minimize vulnerability in areas of new development, and improve post-event recovery.

The analysis was conducted with a sole focus on housing and the residents who live in it. There are many other factors aside from housing integrity that influence a resident's ability to stay in a home, including impacts to infrastructure and availability of utilities, availability of jobs, and access to resources that fulfill daily needs, such as grocery stores, hardware stores, medical and childcare facilities. While these factors are extremely important, they

are only touched upon briefly in this project and may be included in future analysis.

Partners

Funding from the U.S. Geological Survey's (USGS) Earthquake Hazards Program External Research Support program leveraged additional resources from the U.S. Environmental Protection Agency's (EPA) Smart Growth Implementation Assistance program, Federal Emergency Management Agency (FEMA), and the California Strategic Growth Council (SGC). ABAG's Resilience Program and Planning & Research Department and BCDC's Adapting to Rising Tides Program led the project. AECOM provided significant consultant support in the development of strategies. An advisory group of over twenty federal, state, regional and local government officials, academics, representatives of community organizations, and private businesses participated in defining risk indicators and in reviewing and suggesting strategies. Staff from the cities of East Palo Alto, Santa Rosa, San Rafael, Richmond and Berkeley were participants in the case study portion of the research.

Background

The nine-county San Francisco Bay Area (Bay Area), home to approximately seven million people, is the nation's fifth most populated metropolitan or urbanized area. Its economy, culture, and landscape support prosperous businesses, vibrant neighborhoods, and productive ecosystems. Yet the Bay Area is also vulnerable to natural hazards such as earthquakes, flooding, and sea level rise.

Earthquakes in the Bay Area result from accumulation of energy as the Pacific Plate slides past the North American Plate. Previous earthquakes such as the 1906 earthquake caused extensive damage in San Francisco, Oakland, San Jose and Santa Rosa. More recently, the 1989 Loma Prieta earthquake caused extensive damage in the Santa Cruz Mountains, as well as in Oakland and San Francisco tens of miles away. Additionally, many moderate to great earthquakes (over Magnitude 6.0) have affected the Bay Area; 22 such events have occurred in the last 160 years — for an average of one every seven years. Most recently, in August 2014, the City of Napa and surrounding communities experienced a magnitude 6.0 earthquake, causing significant structural damage to housing and the downtown area, and non-structural damage to many wineries. Future large earthquakes are a certainty, and the overall probability of a magnitude 6.7 or greater earthquake in the greater Bay Area is 63 percent (Uniform California Earthquake Rupture Forecast, 2008). Earthquakes can cause significant ground shaking as well as liquefaction in areas with loose and saturated soils, which are common along the Bay shoreline and ancient riverbeds, especially in areas that are composed of artificial fill. Both ground shaking and liquefaction can cause extensive damage to the built environment.

In addition to earthquakes, the Bay Area is also vulnerable to flooding, which is projected to increase as sea levels rise due to climate change, often in the same locations. Flooding can be caused by high riverine flooding, inadequate drainage systems, extreme astronomical Bay tides, such as King Tides, or extreme tides due to storm surges, or a combination of these. The extent and duration of flooding may be exacerbated by sea level rise, both in areas with existing flooding and in areas that currently do not flood. According to current projections (National Research Council, 2012), climate change could cause the Bay to rise by 12 to 24 inches by mid-century and by 36 to 66 inches by the end of the century. This means that today's floods will likely be the future's high tides, and areas that currently flood every 10 to 20 years could flood much more frequently. Neighborhoods, businesses, and entire industries that currently exist on the shoreline may be subject to this flooding and the many other cascading impacts that may result from it. These areas are home to more than 250,000 residents who may be directly affected and many others, including workers, who may be indirectly affected by reduced access to important services, such as transit and commercial centers, health-care facilities, and schools.

The consequences of earthquakes and flooding on Bay Area communities will be even greater in the future, as the population is projected to grow from seven million to nine million by 2040[1]. Furthermore, approximately 80 percent of the Bay Area's future housing needs (as well as 66 percent of new jobs) will be accommodated in Priority Development Areas (PDAs) identified in Plan Bay Area[2], a Sustainable Communities Strategy to meet the greenhouse gas reduction goals of Senate Bill 375 (SB 375)[3]. According

1 http://planbayarea.org/plan-bay-area.html

2 Plan Bay Area is a long-range integrated transportation and land-use/housing strategy through 2040 for the San Francisco Bay Area http://onebayarea.org/plan-bay-area.html

3 California Air Resources Board, Sustainable

to Plan Bay Area, PDAs are defined as locally designated areas within existing communities that have been identified and approved by local cities or counties for future growth. PDAs are areas of focused growth, and therefore are of regional importance. Likewise, areas surrounding PDAs are also expected to experience significant development in the future. It is critical to protect these areas of long-term investment through implementing resilience strategies to ensure that future growth is smart, safe, and sustainable in the face of the hazards we face as a region.

The consequences of earthquakes and flooding for residential land uses are particularly significant. The vulnerability of the region's current housing and limitations on the capacity to recover are weak links in the region's resilience. In the wake of a major disaster, many homes in the region may be seriously damaged and residents displaced. Earthquake-induced liquefaction could cause costly damage to building foundations, while flooding could make many homes (of any type) in existing or future flood zones uninhabitable. Significant damage to housing could force residents to move to other areas of the region or to leave the region permanently. Businesses without employees or customers may also be forced to move elsewhere.

Multiple studies have shown that population loss after a disaster significantly slows recovery time. In the Bay Area, much of the older, more affordable housing stock is at risk, and many residents may not have the resources to stay and rebuild if their homes are significantly damaged, as housing rebuilding can take years. Past disasters have also demonstrated that low-income or rental housing often gets demolished and rebuilt as market rate housing, permanently changing community and regional demographics. Not only is much of the region's housing vulnerable, but in many communities there are residents such as the elderly, low income populations, people without automobiles, or renters that may lack access to information and services, financial means, or the physical capacity to prepare for, respond to, and recover from hazard events. The problem is significantly exacerbated when communities with these characteristics live in fragile housing stock. Thus, keeping housing intact is fundamental to community stability. In the aftermath of natural disasters, the recovery of the region's economy is interdependent with the recovery of the region's housing. If residents can stay in their homes, they will be better able to participate in the rebuilding of their neighborhoods and cities, go to work and support local business, and improve the recovery trajectory of the entire region.

If new development is targeted for areas that are likely to be impacted by earthquakes and/or current or projected future flooding, it makes sense to manage that risk, for example by reducing the amount of housing in hazard-prone zones, or constructing homes in a way that reduces their vulnerability to these hazards. Furthermore, in the case of future flooding, potential solutions may include the planning and construction of protective defense structures. In addition to identifying and addressing strategies to strengthen the resilience of existing communities, this project develops strategies that can help reduce the vulnerability of new development in the Bay Area, so that sustainable growth is not only smart, but also safe.

Project Outcomes

This project includes an analysis of the characteristics of Bay Area housing and communities that increase their vulnerability to earthquakes and flooding, identification and assessment of housing and community vulnerability at regional and community scales, and strategies developed to reduce housing and community vulnerability to help the region meet its resilience, sustainability, prosperity, and equity goals. Each of these major tasks is described in further detail in subsequent sections. An Appendix to the report includes summaries of the 40 strategies developed by the project. The strategies are responsive to the project vulnerability analysis, helping to reduce vulnerability and build resilience in existing communities as well as provide guidance for future growth, such as new development, infill development, or significant modification to or conversion of existing development. The strategies geared towards existing development can help communities that are already at risk, while strategies geared towards future development in PDAs and other areas of growth can reduce potential vulnerability of new residential development in the Bay Area.

In addition to informing the next update of Plan Bay Area (due in 2017), these strategies could potentially inform the next update of the Bay Area's Local Hazard Mitigation Plans[4], due for an update in 2016. These strategies could also inform updates to the Safety Elements of local

Communities and Climate Protection Act of 2008, http://www.arb.ca.gov/cc/sb375/sb375.htm

4 ABAG Regional Hazard Mitigation Plan, http://resilience.abag.ca.gov/mitigation/

Table 2-1: Housing Vulnerability Research

Hazard	ABAG/BCDC Previous Work	External Resources
Ground shaking	Shaken Awake! Estimates of Uninhabitable Dwelling Units and Peak Shelter Populations in Future Earthquakes Affecting the San Francisco Bay Region, ABAG, 1996	Safe Enough to Stay, SPUR, 2012 Seismic Retrofit Incentive Programs: A Handbook for Local Governments, FEMA, 2013 Earthquake Risk in Residential Buildings, David Bonowitz, 2005 Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings with Weak First Stories (FEMA P-807), FEMA, 2012 Seismic Evaluation and Retrofit of Existing Buildings (ASCE 41-13), ASCE, 2014 Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154, Edition 2), FEMA, 2002 Here Today – Here Tomorrow: The Road to Earthquake Resilience in San Francisco (ATC 52-1A), Applied Technology Council, 2010 The Apartment Owner's Guide to Earthquake Safety, City of San Jose Residential Seismic Safety Program, August 1998
Liquefaction	The Real Dirt on Liquefaction, ABAG, 2001 and 2011	
Flooding		Selecting Appropriate Mitigation Measures for Flood-prone Structures (FEMA 551), FEMA, 2007 Homeowners Guide to Retrofitting (FEMA P-312), FEMA, 2009

government General Plans. Further discussion of the strategies is included in Chapter 3.

2. Vulnerability Analysis

Methodology

The vulnerability analysis drew from the in-house expertise of ABAG and BCDC staff, from previously published reports and academic articles, and from the experience and knowledge of members of our advisory committee. The advisory committee included a mix of nationally and internationally recognized experts on the physical and social aspects of disaster preparation and response, federal, state, regional and local government officials dealing with issues of sustainability and safety, and community advocates with experience with vulnerable communities (See Appendix B for a list of the participants).

The vulnerability analysis addressed three hazards, including ground shaking, liquefaction, and current and projected future flooding. These hazards are described in the following section. By focusing the project on these three hazards, we were able to identify specific vulnerabilities and explore strategies designed to reduce these vulnerabilities in some depth within a very limited budget.

ABAG and BCDC investigated two different types of vulnerability: housing vulnerability and community vulnerability. Housing vulnerability is defined as fragile housing that is likely to experience significant structural damage in the event of a hazard to a degree that residents may have difficulty remaining in the home following the disaster. Indicators of housing vulnerability include structural characteristics that increase fragility and more aggregate indicators of the presence of these characteristics (such as building age). Community vulnerability is defined as characteristics that make residents less likely to be able to prepare for, respond to, and recover from a major disaster such as earthquakes or flooding. Community vulnerability indicators are based primarily on studies or reports using US Census data.

Similar approaches were used for developing indicators of these two different types of vulnerability. For each type, we built a large initial list of vulnerability indicators in-house, using internal experience and previously published reports and articles. These were compiled into descriptive

Table 2-2: Community Vulnerability Research

Dimension of Vulnerability	Measure	Effect on Vulner-ability	Type of Action Informed	Reference
Household Capacity				
Housing cost burden	% households monthly housing costs relative to income	↑	Prep, Resp, Rec	2, 4, 7, 8
Transportation cost burden	% households monthly transportation costs relative to income	↑	Prep, Resp, Rec	8
Renter households	% non-owner occupied housing	↑	Prep, Resp, Rec	1, 2, 3, 6, 7
Socioeconomic Status				
Household income	% households with income less than <50% AMI	↑	Prep, Resp, Rec	1, 3, 8
Education	% persons without a high school diploma > 18 years	↑	Prep, Resp, Rec	1, 2, 3, 6, 7
Community services				
Community services	Number of public facilities that could provide shelter (schools)	↓	Resp, Rec	2
Civic organizations	Community service organizations, e.g. food banks, shelters, CBOs/NPOs	↓	Resp, Rec	
Access to a public venue	Density or distance to a public venue that would serve as a gathering place or central location for emergency response (public park, facility, open space)	↓	Resp.	3, 4
Racial/Cultural Compo-sition	% non-white	↑	Prep, Resp, Rec	7, 8
Information and Mobility Challenges (for preparation and response planning)				
Transit dependence	% households without a vehicle	↑	Prep/Resp	1, 3, 5, 7, 8
Non-English speakers	% households where no one ≥ 15 speaks English well	↑	Prep/Resp	1, 3, 6, 8
Age - Young children	% young children < 5 yrs	↑	Prep/Resp	3, 6, 7, 8
Age - Elderly	% elderly, > 75 years	↑	Prep/Resp	3, 6, 7, 8

1. Cumulative Impacts: Changing Regulatory Culture to Address Environmental Injustice and Environmental Racism, Communities for a Better Environment, 2009
2. Resilience Capacity Index, Kathryn A. Foster, University of Buffalo Regional Institute, State University of New York, http://brr.berkeley.edu/rci/
3. Mapping Our Future: A work plan for public engagement & equity in Climate Adaptation Planning in the San Francisco Bay Area, Bay Localize for the Joint Policy Committee, 2013
4. STAR Community Rating System, Version 1.0, October 2012 (subset of objectives and measurable outcomes)
5. California Department of Public Health (CDPH) Climate Health Indicators
6. Cumulative Impact Indicators, Equity Issue Brief: Advancing Environmental Justice through Sustainability Planning, Pastor et al. for the Sustainable Communities Initiative
7. Life and Death from Unnatural Causes, Health and Social Inequity in Alameda County, Aug. 2008
8. MTC Communities of Concern, Plan Bay Area Equity Analysis Report, March 2013

Table 2-3: Description of Hazards used in the Vulnerability Analysis

Hazard	Description	Source
Ground Shaking	MMI VIII or above, from expected ground shaking from a M7.8 (San Andreas fault) M6.9 (Hayward fault)	USGS, 2013 Shakemaps available at: http://gis.abag.ca.gov/website/Hazards/?hlyr=northSanAndreas http://gis.abag.ca.gov/website/Hazards/?hlyr=haywardSouthNorth&co=6001
Liquefaction	Moderate Hazard	The Real Dirt on Liquefaction, A Guide to the Liquefaction Hazard in Future Earthquakes Affecting the San Francisco Bay Area, ABAG, 2001 http://resilience.abag.ca.gov/wp-content/uploads/2010/10/Lq_rept.pdf
	High Hazard	
Flooding	Current 100-year flood zone	FEMA National Flood Insurance Program (NFIP) rate maps, 2012 https://msc.fema.gov/portal
	Future, 24"	NOAA Sea Level Rise and Coastal Flooding Impacts Viewer, 2014 http://coast.noaa.gov/slr/
	Future, 36"	
	Future, 48"	

lists with the definition, source, previous uses, and any limitations. The advisory committee described above reviewed the lists and suggested additions and deletions to assist in compiling a list of measurable indicators that captured the breadth of vulnerability present within the Bay Area efficiently and with minimal overlap. There were two stages of "operationalizing" these indicators; first mapping the indicators regionally at the block group level and then developing community profiles (case studies) to investigate the indicators at a local scale. We held a workshop presenting the regional analysis and three profile communities to exemplify the use of the indicators at both scales, and obtain input on the relevance of different indicators at different scales, and to understand what additional information was needed at the local scale beyond what was informative at the regional scale.

Our understanding of housing vulnerability built on previous ABAG efforts as well as other published research on the performance of Bay Area housing past disasters (shown in Table 2-1, page 4) that helped identify common characteristics that predicted poor structural performance in a disaster. As each hazard type affects structures differently, we looked at fragile housing characteristics separately for each hazard.

An understanding of community vulnerability was built on a parallel project at ABAG sponsored by HUD, where communities vulnerable to housing shortfalls and displacement of low income residents were identified, as well as on earlier work done by BCDC in the Adapting to Rising Tides Project, and a set of communities of vulnerability indicators developed by the Metropolitan Transportation Commission for their work on Communities of Concern in the Plan Bay Area Equity Analysis Report. We augmented and modified this previous research based on academic and federally sponsored research designed to identify community vulnerability to disasters. Sources for each indicator are shown in Table 2-2 (page 5).

Members of the advisory committee provided feedback on both the housing and community vulnerability indicators during convened meetings as well as in written responses. After the initial convening of the advisory group, separate working groups formed to address housing and community vulnerabilities. These working groups addressed both the best way of conceptualizing the measures and narrowed down the indicators to factors for which data was available and for which interpretation was clear. The indicator frameworks differed for housing and community vulnerabilities. Because different hazards affect structures differently, the housing vulnerabilities are directly correlated with a specific hazard. In contrast, community vulnerabilities are independent of the type of hazard and are based on the characteristics of the individuals, households, and neighborhoods in the community that will require special attention in planning for resilience.

Hazard Statements

The vulnerability analysis considered three hazards: ground shaking, liquefaction, and flooding. The specific hazard scenarios used in the analysis are summarized in Table 2-3

Table 2-4: Definition of Liquefaction Hazard

MMI Value	Liquefaction Susceptibility Catetory		
	Moderate	High	Very High
VII – Strong	Moderately Low Hazard	Moderately Low Hazard	Moderate Hazard
VIII – Very Strong	Moderate Hazard	Moderate Hazard	Moderate Hazard
IX – Violent	High Hazard	High Hazard	High Hazard
X – Very Violent	High Hazard	High Hazard	High Hazard

Source: The Real Dirt on Liquefaction, A Guide to the Liquefaction Hazard in Future Earthquakes Affecting the San Francisco Bay Area, ABAG, 2001

(above) and are described below.

Different earthquakes cause differing levels of ground shaking throughout the region. In order to map the hazards that would have the greatest impacts across the greatest geographic area, we selected shaking scenario maps from two previously modeled earthquake scenarios – a Magnitude[5] 7.9 scenario on the San Andreas Fault and a Magnitude 7.0 scenario on the Hayward fault – and determined areas likely to experience ground shaking hazard levels of MMI VIII or above in these scenarios. These are the two faults with the greatest probability of creating a Magnitude 6.7 or greater earthquake in the Bay Area (31% probability for the Hayward fault and 21% probability for the San Andreas Fault). They are also the faults that are capable of producing the largest earthquakes in the Bay Area, affecting the largest geographical areas and the largest number of residents, impacting areas within the Bay Area where housing is most concentrated.

The ground shaking hazard analysis only includes homes that are likely to be exposed to MMI VIII and greater ground shaking, as they are the most likely to be significantly damaged, thus displacing residents. MMI of VIII was chosen because previous research indicates that at MMI VIII, the number of homes red-tagged[6] jumps significantly. While damage will occur at lower levels of ground shaking, it is less likely to force residents from their homes.

Liquefaction hazard levels were determined based on liquefaction susceptibility combined with shaking intensity (MMI) using the correlation outlined in Table 2-4 (above). For the purpose of this project, moderate or high liquefaction hazard areas were examined using MMI from the future earthquake shaking scenario maps for the two

5 Magnitude (M) and Intensity (MMI) measure different characteristics of earthquakes. Magnitude measures the energy released at the source of the earthquake. Magnitude is determined from measurements on seismographs. Intensity measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment and is measured using the Modified Mercalli Intensity Scale (MMI).

6 A red tag means that a building is unsafe to occupy.

Table 2-5: Special Flood Hazard Area Zones

Zone A	No Base Flood Elevations determined
Zone AE	Base Flood Elevations determined
Zone AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined
Zone AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
Zone AR	Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently declassified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
Zone A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined
Zone V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
Zone VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined

Source: https://www.fema.gov/floodplain-management/flood-zones

Table 2-6: Matrix showing combinations of Sea Level Rise and Extreme Tide Level

		Extreme Tide Level						
Sea Level Rise*	**Water Level above MHHW**	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
+0	0	12	18	24	30	36	42	48
+6	6	18	24	30	36	42	48	54
+12	12	24	30	36	42	48	54	60
+18	18	30	36	42	48	54	60	66
+24	24	36	42	48	54	60	66	72
+30	30	42	48	54	60	66	72	78
+36	36	48	54	60	66	72	78	84
+42	42	54	60	66	72	78	84	90
+48	48	60	66	72	78	84	90	96

* All values are in inches above Mean Higher High Water (MHHW) (NAVD 88).

Color Code	Map Scenario (inches above MHHW)
	24
	36
	48

Source: AECOM. Adapting to Rising Tides Alameda County Shoreline Vulnerability Assessment Report, Draft May 2014.

scenarios outlined above (a San Andreas or Hayward event), as they are the most likely to cause major building damage that displaces residents from their homes.

Any amount of flooding has the potential to displace residents from their homes, as even short duration flooding can undermine building structures or create unsafe living conditions due to mold growth and contamination. Current flooding scenarios are based on published National Flood Insurance Program (NFIP) rate maps. This analysis included all Special Flood Hazard Areas subject to inundation by the one percent annual chance flood (Zones A, AE, AH, AO, AR, A99, V, and VE[7]), as shown in Table 2-5 (page 7).

Future flooding scenarios are based on three regional inundation maps developed by NOAA Coastal Services Center[8]. These three inundation maps are used to represent future flooding from different combinations of sea level rise and tide levels, including the daily high tide (Mean Higher High Water, or MHHW) and a range of extreme tides that could occur during coastal storm surge events. The possible combinations are shown in Table 2-6 (above).

Caveats and Uncertainties

The hazards selected for the analysis have been simplified and do not represent the full spectrum of catastrophic risk projected for the Bay Area. The analysis was designed to reveal a general understanding of the greatest concentrations of vulnerability on a regional scale, and to apply vulnerability indicators effectively. More detailed analysis will need to be conducted at a local level using site-specific hazards. In the case of ground shaking risk, while the faults selected represent the majority of risk in the Bay Area region, there are several other faults that may significantly affect housing within the Bay Area. Additionally, jurisdictions may have more detailed soil analysis that represents a greater understanding of liquefaction risk, or have historical records of past

7 The one percent annual flood (100-year flood), also known as the base flood, is the flood that has a one percent chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include the Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the one percent annual chance flood.

8 NOAA Sea Level Rise and Coastal Flooding Impacts Viewer, http://coast.noaa.gov/slr/

liquefaction patterns. In the case of flooding, jurisdictions may choose to include additional flooding hazard areas due to on-the-ground knowledge of the existence and condition of flood control structures or significant inland flooding risks. The vulnerability analysis could also apply to other hazards not included in this initial development of the approach, such as dam inundation, wildfire, or secondary hazards such as earthquake-induced landslide or fire following earthquake. This analysis can be incorporated at the local level through the Hazard Mitigation Planning process.

Indicator Development

Measureable indicators were developed to identify characteristics that represent multi-faceted vulnerability throughout the Bay Area, including indicators of housing vulnerability and indicators of community vulnerability. Several guidelines were used to assist in the indicator development process.

These guidelines emphasized that indicators should:

1. Be numerically measurable. The data must be quantified in some way that indicates relative severity or concentration in a given area as compared to another given area.

2. Be based on data that is accessible and available. Many indicators could potentially provide great insight; however without supporting data, they are not useful. We make note of desirable data that is not currently available. Accessible and available information is defined as:

    - Regionally, publicly available: The data is consistently available for all (or most) parts of the Bay Area, and it is not proprietary or private data. The data is available such that others can replicate the analysis without special privileges.

    - Geo-referenced: The data must have a geographic location assigned to it so it can be mapped. The analysis is a spatial analysis; therefore spatial data must be available.

    - Reasonable scale: The data must be manageable in scale; too much detail can cause problems in extracting the right message, and too little detail may make the data lose meaning.

    - High quality: The data is consistent and reliable, the margin of error is acceptable, and the format is clear and usable. The data is accurate and data sets are largely complete (though some projection is acceptable).

3. Be representative of efficient, comprehensive coverage of vulnerability. Minimize overlaps or highly correlated indices to capture the most comprehensive measures of vulnerability with the fewest number of indicators.

4. Directly impact vulnerability. The indicator directly affects one of three primary factors of vulnerability: exposure, sensitivity, or adaptive capacity[9]. The indicator can either directly increase or decrease vulnerability.

5. Clear as to how and why the indicator impacts vulnerability and at what scale (individual, community, or organizational/institutional)[10]. Unclear correlations between the indicator and its impact on vulnerability are not useful or defensible.

6. Be able to guide strategy development and lead to effective policy. For each indicator of vulnerability, there should be a correlated, feasible action that can impact that indicator and reduce the vulnerability it represents.

7. Represent the highest priorities for vulnerability reduction. They should target the most significant and impactful characteristics that have the greatest potential to improve resilience.

Housing Vulnerability

Regional housing vulnerability was determined based on the eight potentially fragile building types commonly found in the Bay Area, as defined in Table 2-7 (page 10). The presence of vulnerable housing is indicated if 30 percent or more of housing units in a block group are a fragile housing type located in an area of ground shaking, liquefaction, or flooding hazard.

9 Assessing Climate Change Vulnerability & Risk. Adapting to Rising Tides, Bay Conservation and Development Commission, 2011.

10 Quantifying Social Vulnerability: A methodology for identifying those at risk to natural hazards. Geoscience Australia, 2014

Table 2-7: Definition of Fragile Housing Type Correlated with Hazard Type

Hazard Type	Fragile Housing Type	Definition
Ground Shaking MMI XIII or above	Hillside	Located in a "zone of required investigation" for earthquake-induced landslide
	Single family cripple wall	Contains a crawl space and/or stairs leading up to the front door
	Single family house over garage	Garage with living space above it that lacks interior walls and may be unable to support the living space above it
	Unreinforced masonry	Masonry buildings that lack any structural support aside from mortar
	Multi-family cripple wall	Contains a crawl space and/or stairs leading up to the front door
	Multi-family weak story or open front	Contains large openings on the first floor, typically for parking or commercial space, with residential units on the upper floors
	Multi-family non-ductile concrete	Concrete structures lacking steel reinforcement to add ductility, or the ability to bend without breaking
Moderate Liquefaction Hazard	Insufficient foundation to withstand liquefaction, e.g., less than 10 floors	Foundation that lacks piles and may be subject to cracking or sliding due to liquefaction
High Liquefaction Hazard		
Current flood zone	All housing types	All housing types can be damaged if exposed to flooding and can be rendered uninhabitable
Future flooding with sea level rise		

Several Bay Area-focused reports (see Table 2-1, page 4) were reviewed to understand what structural characteristics of vulnerability are likely to be present in construction types typically found in the Bay Area. Next, staff convened the Housing Indicator Working Group. Through discussion with the group, it was quickly determined that structural characteristics of vulnerability were highly dependent upon the type of hazard. The group then identified the most vulnerable housing types for each hazard. The fragile housing typology is designed to identify subsets of the Bay Area housing stock that are likely to possess characteristics that increase their vulnerability. This method identifies only what are deemed as the most fragile common housing structure types found within the Bay Area due to likely poor structural performance in an earthquake (i.e., those conditions most likely to cause housing to be red-tagged, requiring either demolition or extensive and lengthy repairs). This method considers critical combinations of material, system, etc. that indicate high fragility. As key data such as structure type (wood frame, concrete, etc.) is not widely available, proxies such as size, age, number of stories, and location that are associated with the most common fragile housing types are used. As different hazards interact with building types differently, hazards including liquefaction, ground shaking, and flooding are examined separately. The Working Group developed Table 2-8 (page 11) to identify the detailed characteristics that indicate presence of the eight identified fragile housing types.

Each fragile housing type was mapped at the block group level with data from the County Assessor and the American Community Survey using a series of queries to narrow down the housing type using the indicators shown in Table 2-8 (page 11) to identify block groups with the characteristic combinations associated with each fragile housing type. Only block groups exposed to the identified hazard level for ground shaking, liquefaction, and flooding are flagged; vulnerability is a combination of exposure and fragility. Block groups are identified as potentially vulnerable if 30 percent or more of the housing units within the block group are flagged as a potential fragile housing type. While isolated building damage or low levels of building damage are potentially devastating to individual residents, concentrations of damage are far more likely to stall recovery and impact entire communities. This methodology does not account for mixed neighborhoods that may contain several fragile housing types, none of which individually reach the 30 percent concentration, but combined may make up 30 percent or more of the housing stock. This more fine-grained analysis must be done at a local scale. Figure 2-1 (page 12) shows the results of the housing vulnerability analysis. This map is also available onlineathttp://resilience.abag.ca.gov/projects/housing-and-community-risk/.

Table 2-8: Characteristics used to identify Fragile Housing Types in the Bay Area

Hazard	Hazard Level	Location	Units[3]	Stories[3]	Age[3,4]	Conclusion	Notes
Ground Shaking	MMI VIII[2] or above	Hillside	N/A	N/A	N/A	Possible landslide hazard	Hillside homes may also have structural damage due to ground shaking
		Not hillside	1-2 unit	N/A	Built before 1940	Possible cripple wall	Bedroom communities, rare in city centers and dense suburbs[1] Older, more established regions such as San Francisco and Alameda counties[2]
				2-3 stories	Built between 1920 and 1970	Possible house over garage	Dense pre-1950's suburbs like San Francisco Post 1950's suburbs with attached multicar garages1 Highly prevalent in more recently urbanized areas such as Santa Clara and Contra Costa counties2
			Multi-unit	3-5 stories	Built before 1920	Possible cripple wall	Pre-1920's neighborhoods[1]
					Built before 1933	Possible unreinforced masonry	1% of total regional housing stock, most significant in San Francisco and Alameda counties[2]
					Built before mid-1970s	Possible weak story or open front	Pre-1950: mixed or high density suburban neighborhoods (Berkeley, San Francisco) Post-1950: also found in large subdivision developments (Fremont, Hayward) [1] Pre-1940: Significant in older cities – over 10% in San Francisco Post-1940: Fairly prevalent, especially in San Mateo county[2]
				3 stories or above	Built between 1950 and 1971	Possible non-ductile concrete	High-density suburban neighborhoods[1]
Liquefaction	Moderate or High Hazard	N/A	N/A	Less than 10	N/A	Possible catastrophic foundation damage	Structural irregularities may also influence performance of buildings in liquefaction areas. New construction may follow new guidelines to limit these irregularities; more research is needed
Flooding	24", 36", or 48" flooding or FEMA 100-year flood plain	N/A	All	All	All	Possible loss of habitability after flooding	Mobile homes may be more susceptible to significant damage; however mobile home data is difficult to find at a regional level. Wave action may also influence damage.

[1] David Bonowitz, Structural Engineer, Working Group Member notes, 1/21/14

[2] Shaken Awake! Estimates of Uninhabitable Dwelling Units and Peak Shelter Populations in Future Earthquakes Affecting the San Francisco Bay Region, ABAG, 1996

[3] County Assessor Data

[4] American Community Survey

Figure 2-1: Fragile Housing in Flood, Liquefaction, and/or High Shaking Areas

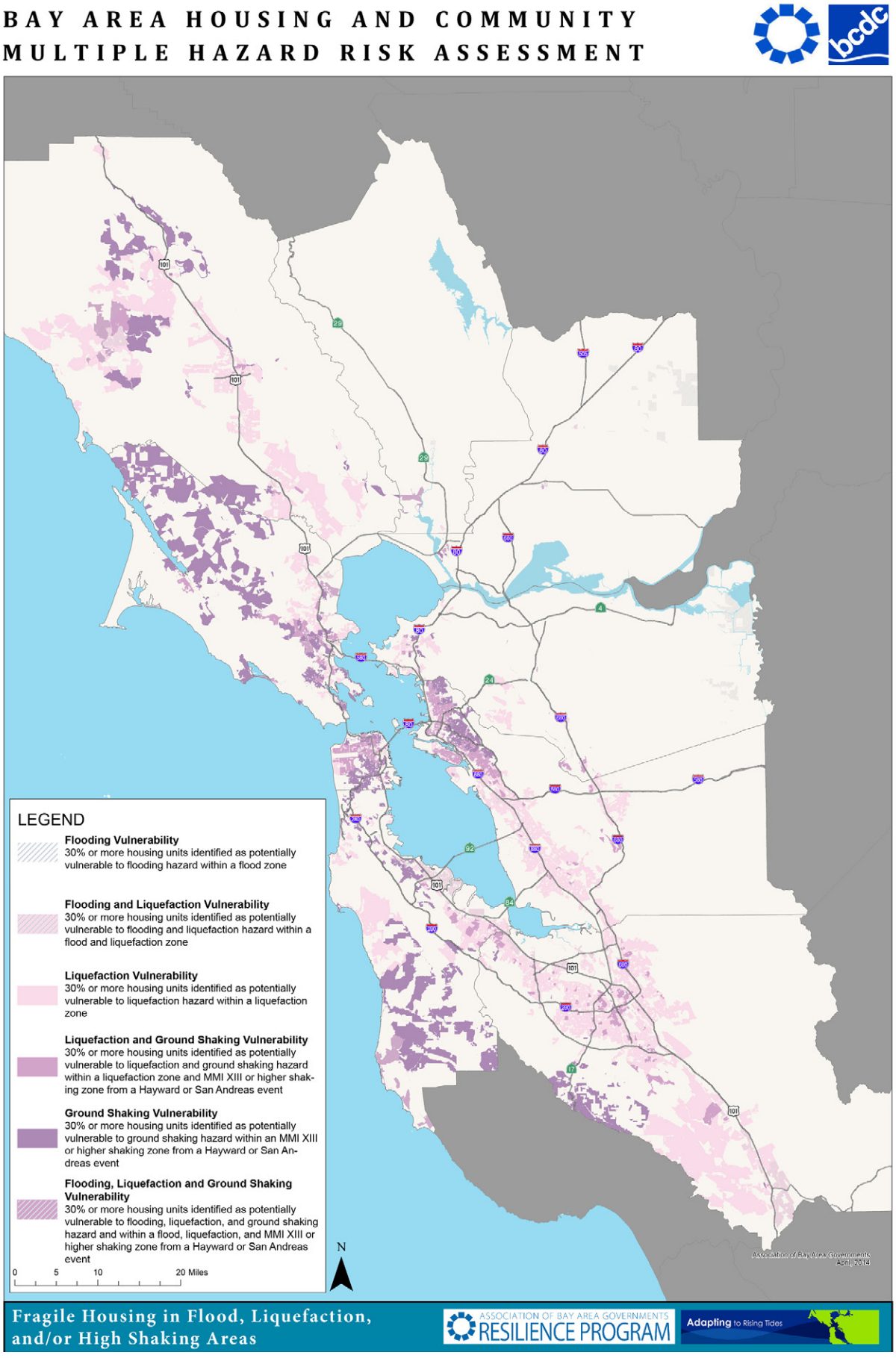

Figure 2-2: Communities at Risk in High Hazard Areas

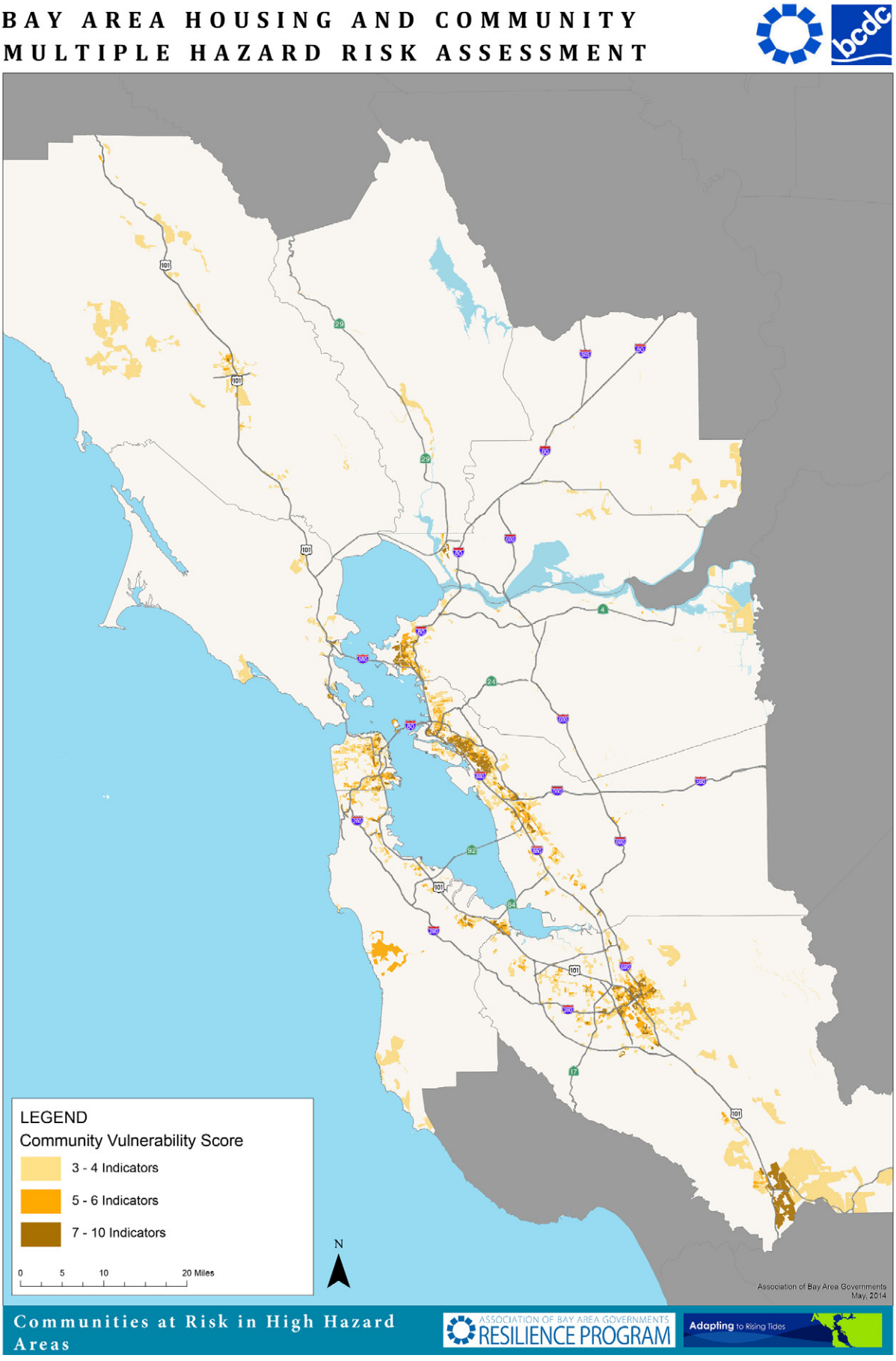

Table 2-9: Indicators of Community Vulnerability

Indicator	Measure	Percentage or amount per block group	Score
Housing cost burden	% household monthly housing >50% of gross monthly income	>15%	1
Transportation cost burden	% household monthly transportation costs >5% of gross monthly income	>15%	1
Home ownership	% not owner occupied housing	Mean + 1 standard deviation	1
Household income	% households with income less than <50% AMI	>30%	1
Education	% persons without a high school diploma > 18 years	Mean + 1 standard deviation	1
Racial/Cultural Composition	% non-white	>70%	1
Transit dependence	% households without a vehicle	>10%	1
Non-English speakers	% households where no one ≥ 15 speaks English well	>20%	1
Age - Young children	% young children < 5 yrs.	Mean + 1 standard deviation	1
Age – Elderly	% elderly, > 75 years	>10%	1
		Total Possible Score	10

Community Vulnerability

Community vulnerability was determined using ten indicators that represent characteristics of individuals and households that affect their ability to prepare for, respond to, and recover from a disaster. These indicators collectively present a picture of a community's vulnerability. A concentration of these indicators is assumed to influence the recovery of a community.

Indicators were selected based on regionally relevant research and best professional judgment as described earlier. Key themes that emerged included age-related vulnerabilities, language and ethnicity vulnerabilities, cost-burdened residents, housing tenure issues, and access to resources. A number of indicators were identified that fit these key themes; correlations were run to identify repetitive indicators, and then staff and the Community Indicator Working Group selected the final ten indicators from the larger candidate list.

Indicators were measured and scored using the method developed by the Metropolitan Transportation Commission (MTC) to identify Communities of Concern (CoC)[11]. This is meant to identify block groups with higher than average concentrations of the particular indicator and therefore may have higher concentrations of vulnerability. In this method, individual block groups received a score of 1 point for each indicator that is greater than a certain percentage of the block group population determined to have an impact on vulnerability (as defined by the MTC CoC). The percentage varies by indicator. For example, block groups with greater than 10 percent of individuals over 75 years would receive a score of 1. For indicators that were not identified in the MTC CoC and therefore did not have a pre-identified percentage, block groups received a score of 1 point for each indicator that is greater than the mean for the region plus one standard deviation (this is consistent with the method used by the MTC CoC process). This identified block groups with higher than average concentrations of a particular indicator, which implies there is a greater level of vulnerability. The total possible score each block group could receive ranged from 0 to 10. The indicator methodology established for this project is based on previous studies and prior research and are for planning purposes only. This approach should not be used in project review or environmental assessment. See Table 2-9 (above).

Each indicator was mapped at the block group level, and then a score was determined for each block group by adding together the number of indicators identified. Block groups were then were grouped into three bins – those with 3-4 indicators, 5-6 indicators, and 7-10 indicators. Block groups with a score of less than three were determined to have minimal vulnerabilities, while block groups with a score of seven or more have the highest vulnerability level.

11 MTC defines communities of concern relating to minority residents (70%), low-income residents 90%), residents who do not speak English well or at all (30%), households with no car, senior age 75+, persons with a disability, single-parent households, cost-burdened renters.

Figure 2-3: Communities at Risk in Fragile Housing and Exposed to Hazards

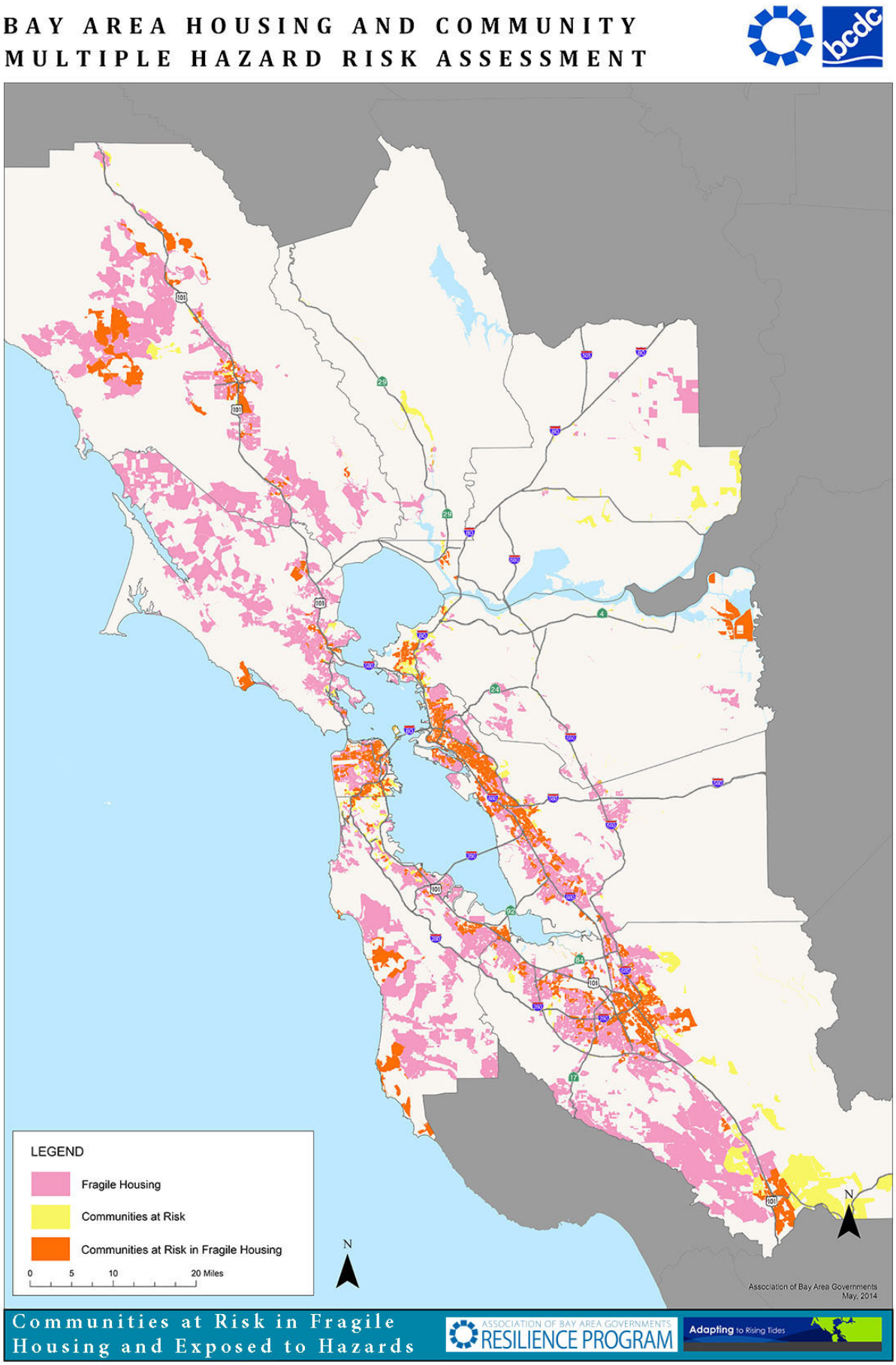

Table 2-10: Description of Final Four Maps produced for the Analysis

Hazard(s)					Areas potentially exposed to ground shaking, liquefaction, current and future flooding
Hazard(s)	+	Community Vulnerability	=	Communities At Risk	Communities exposed to hazards that are less able to prepare, respond and recover
Hazard(s)	+	Vulnerable Housing	=	Fragile Housing	Housing exposed to hazards that will likely be significantly damaged
Communities At Risk	+	Fragile Housing	=	Communities At Risk in Fragile Housing	Communities exposed to hazards that are less able to prepare, respond and recover that are potentially living in fragile housing

The analysis conducted through this process is a high level, regional screening for vulnerability and does not reflect qualitative characteristics that may increase or decrease vulnerability, such as community cohesion and high social capital (community capacity). The Community Indicator Working Group discussed many proxies for community cohesion, such as the presence of churches, neighborhood groups, and social services in a neighborhood. However, this data was difficult to obtain at a regional or even community scale, and the connection between the presence of these services and facilities and the actual community capacity is neither obvious nor easily measured. Local jurisdictions will need to account for how community capacity might moderate (or mitigate) vulnerability in determining the resilience of the neighborhoods within the community. Figure 2-2 (page 13) shows the results of the community vulnerability analysis. This map is also available onlinehttp://resilience.abag.ca.gov/projects/housing-and-community-risk/.

Final Mapping and Assessment

The final mapping and analysis consists of three analysis maps. The final maps are summarized in Table 2-10 (above).

The final maps represent block groups within the Bay Area that are likely to be exposed to hazards and also have housing and community characteristics that indicate higher vulnerability, or are more likely to be affected to the degree that residents will have trouble preparing for, responding to, and recovering from a major disaster. These are areas where residents are more likely to be displaced and will likely undergo the most change, negatively affecting the current residents. Local jurisdictions can use this analysis to zoom in on areas that require more nuanced vulnerability assessment, including more accurate fragile housing inventories and a more detailed understanding of community vulnerability that incorporates a qualitative understanding of community capacity. The Communities at Risk in Fragile Housing map (Figure 2-3, page 15) is also available online at http://resilience.abag.ca.gov/projects/housing-and-community-risk/.

Mapping housing and community indicators at a block group level presented some notable issues. For example, block groups with minimal population but large borders that were flagged, making it appear as though vulnerable populations existed in areas that were, in reality, largely open space (an example of this is the Presidio in San Francisco or Point Reyes in Marin County). Many Working Group members expressed concern that this could be confusing and misleading and cause concern about areas that in fact are not residential. In response, staff developed a masking layer to exclude certain unpopulated or lightly populated areas. The mask layer includes blocks with no households, airports, conservation easements, State-protected areas, large landmark areas, and areas with no hazards (as defined previously).

Summarizing Vulnerability

Twelve key issue statements summarizing the types of vulnerabilities emerged in the analysis and represent what the project team, Working Groups, ands takeholders feel are the primary vulnerability issues that Bay Area housing and communities face. These issues are based on performace of housing and communities in past disasters as well as observations within many communities in the Bay Area. These statements, along with the Fragile Housing, Community Vulnerability, and Communities at Risk in Fragile Housing, can be used to help jurisdictions understand their particular risk profile and identify key strategies for addressing that risk. The key issue statements are summarized below.

- Hazards can have significant impacts on communities that live in high hazard areas.

- Ground shaking can damage cripple wall and house over garage single family homes.
- Ground shaking can damage fragile first story, concrete, and cripple wall multi-family homes.
- Housing is generally built to life safety rather than shelter-in-place standards.
- Most foundations cannot withstand liquefaction.
- Most houses cannot withstand any amount of flooding.
- Houses with habitable space or critical equipment below-grade are at risk from flooding.
- Many community members have limited access to resources.
- Housing affordability is an existing challenge that could hinder recovery.
- Renters have limited ability to improve their housing resilience.
- Many community members have limited or inadequate information about hazards.
- Information on elderly and very young community members is limited.

These issue statements can be used in conjunction with the regional maps to frame a jurisdiction's approach to identifying local vulnerabilities and potential opportunities for action. This process is exemplified in the project's community profile approach, described next, which takes into account both the vulnerability measures and the key issues outlined in these statements.

Community Profiles

The regional analysis supplies a high-level screen to identify which areas are most likely to have multiple vulnerability factors. However, staff wanted to develop methodology to "zoom in" on certain areas to test the assumptions that the regional analysis made as well as to gather more nuanced and qualitative information on community capacity factors that may increase resilience, even if more quantitative measures indicate high levels of vulnerability. Therefore, the team developed nine community profiles to better illustrate vulnerability within specific communities.

Community profile areas were chosen based on the following criteria:

- Contains a mix of both planned development (such as a Priority Development Area) and existing development.
- Are exposed to a variety of hazards.
- Contain a range of fragile housing types and community indicators.
- Are distributed geographically throughout the Bay Area.
- City staff has an interest in working with the team and/or can utilize the profiles to further existing or future resilience work within the jurisdiction.

Profile boundaries were determined based on existing Priority Development Area boundaries, other specific plan boundaries (if they exist), block group boundaries, and natural geographical breaks such as freeways or major roads. Profiles focused on manageable portions of cities, not the entire city. The following communities were selected for the development of a comprehensive community profile:

- Oakland – Coliseum neighborhood
- Oakland – Bay Farm Island
- Richmond – Inner Harbor
- Berkeley – Adeline/San Pablo corridor
- East Palo Alto (entire city)
- San Francisco – Bayview neighborhood
- San Jose – Alum Rock corridor
- San Rafael – Downtown, Gerstle Park, West End, and Canal neighborhoods
- Santa Rosa – Roseland neighborhood

Profiles were developed beginning with online research to access basic information using publicly available sources. Information compiled included general descriptions of the profile area, a brief hazard statement based on the hazards criteria developed for the regional assessment, a summary of community vulnerability characteristics based on the

regional indicator assessment, as well as any additional demographic information gleaned from city documents, community assets such as churches, hospitals, or community centers, a summary of fragile housing based on regional indicator assessment and supplemented with local inventories, if applicable, and extensive ground-truthing through Google Street View, and any other information available on topics such as flood insurance, retrofit programs, and projections for future growth.

Several local maps were developed for each profile area as well, including profile and PDA boundaries, hazard exposure, fragile housing types, total community indicator score, and breakdowns of each community indicator into subgroups, including age (children under five and elderly over 75), language and ethnicity (non-English speakers and non-white), cost burden (housing cost burden and transportation cost burden), income and education (very low income and low high school graduation rate), and home and vehicle ownership (renter households and households with no vehicle).

Draft profiles were developed using this initial information. In most (but not all) cases, these profiles were presented at a meeting with the jurisdiction, where staff provided feedback and additional resources. Information from the meetings was integrated into the profiles. In many cases, jurisdictions provided additional information not available online, such as older or draft plans or ordinances not available on city websites. Some jurisdictions requested additional hazard layers, such as riverine flooding, or had more detailed information on city assets such as flood control structures. Some jurisdictions became very involved and requested multiple meetings to develop the profile in a format, and with information, that would benefit existing or future planning processes or to help develop a vulnerability narrative for use in political decisions. We also included notes on policy barriers and resource constraints, as applicable.

Staff went into this process expecting that the profiles would provide significantly more depth in understanding localized vulnerability; in actuality, while we did gather some additional information that provided some more nuanced context for our regional analysis, what we largely learned was how little data around vulnerability is actually known and collected in any meaningful way. Very few jurisdictions have detailed information on the vulnerability of their housing stock and even fewer have comprehensive detailed information. Those who have conducted inventories of vulnerable housing likely only have information on one fragile housing type. Most jurisdictions have no mechanism for tracking retrofits, so there is no comprehensive understanding of improvements made to the building stock. In the context of community vulnerability, many jurisdictions are aware of community services provided by nonprofits, but may not have a broader understanding of what these services provide or how residents' lives are impacted. The lack of data resulted in the development of several strategies to better address understanding vulnerability on a local, in-depth level to inform jurisdictions on how to address them.

3. Safe, Smart Growth Strategies

Strategy Development Process

Areas of the San Francisco Bay Area with the most vulnerable housing and communities identified through the process were summarized and illustrated with the maps in Chapter 2. Next, a suite of implementation strategies were developed to help local jurisdictions reduce the vulnerability of housing and populations in these areas to earthquake-induced ground shaking and liquefaction, and current and future flooding hazards, and plan for future growth in a way that minimizes new vulnerability.

ABAG and BCDC developed strategies focused on mitigating earthquake and flooding hazards in existing communities. These strategies focus on retrofitting existing housing and building resilience in already-established communities. The strategies developed by AECOM under the EPA-funded portion of the project are focused on mitigating earthquake and flooding hazards in future urban growth areas. These include, but are not limited to, Priority Development Areas (PDAs) as defined in the Plan Bay Area (ABAG, MTC, 2013) where urban infill, densification, and major conversion projects are expected over the next 36 years (by 2040). While the strategies are focused on new development, they may also provide co-benefits to existing vulnerable populations and housing and could address more than one type of vulnerability or hazard. Many future urban growth areas, including PDAs, will have a mix of established neighborhoods and new development, and therefore will need to consider a wide range of strategies.

An initial draft list of strategies was compiled by ABAG and BCDC staff, drawing from existing work, such as ABAG's Regional Resilience Initiative (2013) and BCDC's Adapting to Rising Tides project (2014). Using

the identified vulnerabilities and profiles, staff initially brainstormed a comprehensive list of potential strategies, and then organized them by which vulnerability type they responded to. While ABAG and BCDC staff developed strategies for existing housing and communities, AECOM was simultaneously developing strategies for future development.

Strategy development involved several rounds of content development and review between ABAG and BCDC staff, AECOM staff, and Advisory Committee members with specialized expertise who could assist with technical content development. Staff and AECOM eventually developed a list of forty draft strategies that were concise, discrete, and responded to the hazard, housing, and community risks identified in the vulnerability analysis phase and summarized in the key issue statements. A list of the draft strategies, along with a sample strategy format, and the key issue statements, were presented to the Advisory Committee in a workshop. Participants were invited to comment on the overall strategy list and respond in small groups to the format, and were invited to provide written comments on any or all of the draft strategies. After the workshop, the strategy list was refined and strategy content was further developed by staff.

Strategies are laid out with the following information:

- Title
- Short summary
- Summary table
    - Strategy lead
    - Scale of benefit
    - Applies to new or existing development
    - Hazard addressed
    - Community vulnerability addressed
    - Vulnerable housing type addressed
        - Type of action
        - Evaluation
        - Program, plan or policy
        - Code, regulation or ordinance
        - Coordination
        - Education and outreach
    - Prerequisites
    - Other related strategies
- Strategy description
- Governance or implementation issues
- Potential financing mechanisms (see table 3-3 for more description of financing mechanisms)
- Partners for implementation
- Examples or case studies where the strategy has been successfully implemented.

Table 5-1 (page 22) in the Appendix provides a summary list of the final strategies.

Financing Mechanisms

Consideration was given to identifying the most appropriate financing mechanisms that might be needed to implement the strategies. The strategies broadly fall into two categories:

- The first category comprises strategies related to planning, programs, and operations.
- The second category includes strategies related to capital expenditures.

Strategies in the first category can be implemented through existing departments and programs, sometimes at no additional cost, or through new or expanded programs for which a budget must be found. General fund resources, fee-based special purpose funds, or state, federal, or private grants are among the main sources of funds for these types of strategies.

Strategies in the second category involve capital projects, which, by and large, require a level of funding that is a few orders of magnitude greater than planning-level, programmatic, or operational strategies. Depending on the strategy, funding may come from the private sector (individuals, a development company, or professional

or philanthropic organizations), the public sector, or a cooperative effort among public and private actors.

Financing property-specific improvements and neighborhood-level or larger investments in infrastructure can be challenging in California. State legislation and ballot measures have put strict limitations on the ability of the State and local governments to raise the capital needed to implement projects (and to mandate repayment schemes for the borrowing that typically is necessary). These limitations—and crises arising from natural disasters and other events—have driven a lot of innovation in financing mechanisms. Although traditional mechanisms are still available, the aforementioned limitations make it difficult to use those mechanisms (specifically, selling bonds to raise capital that are paid back through an increase in property or sales taxes). Drawing from "existing" sales tax or property tax revenues from city and county general funds is generally considered untenable because of the existing fiscal constraints plaguing most California cities. Therefore, this overview discusses methods for locating new mechanisms of funding.

The applicability of different financing mechanisms depends on a variety of factors that include the following:

- The geographic extent of stakeholders that the investment is intended to address, such as:
  - An individual property
  - A neighborhood
  - A collection of neighborhoods
  - A city
  - A county
  - A utility's or transportation district's service territory
- The type of threat the investment is intended to address, such as:
  - Seismic-related
  - Flood-related
- The type of property or infrastructure asset the investment is intended to address
- The type of investment (e.g., investment in publicly shared infrastructure such as a roadway with multiple uses, or investment a levee primarily for flood control)
- The ability of beneficiaries of the investment to bear the costs of repaying whatever debt is taken on to make the investment
- The political and financial appetite of civic leaders, community leaders, individual business and residential property owners, tenants, and users of services to permit and ultimately pay for the investments.

Table 5-2 (page 27) in the Appendix lists examples of financing mechanisms, the agency normally responsible for administering the mechanism, the source of repayment used for the mechanism, and the scale at which the mechanism is typically applied. In addition, the table identifies whether or not the mechanism requires voter approval for implementation, thereby indicating the political viability of the mechanism. The last column identifies by strategy number, the adaptation strategies recommended in this report, which could be financed by the mechanisms listed in this table.

4. Conclusion

This project highlighted many issues previously unaddressed in the Bay Area. Primarily, the intersection between vulnerable communities and fragile housing was long suspected, but had never been made explicit. Improving resilience should focus on this intersection. For example, local jurisdictions should use the results of the regional analysis and the community profile approach to identify neighborhoods to target specific strategies to mitigate risks to communities living in fragile housing. The outcomes of this project should also assist the region to actively avoid increasing the number of communities at risk while still meeting ambitious growth and sustainability goals.

Much more information is needed to have a comprehensive understanding of vulnerability throughout the region. The region lacks a great deal of knowledge on the actual state of its housing, including construction type, condition, and retrofit status, that could significantly impact the housing vulnerability picture. Local jurisdictions also generally lack knowledge on the community and social connections that could help their residents be more resilient in the face of disasters. Understanding of the vulnerability of housing and communities is only one component of creating a more

resilient region – infrastructure performance and economic factors significantly impact how the region can prepare for and survive a major disaster. Lastly, this project only addressed specific hazards – other hazards such as wildfire, dam inundation, extreme heat, or tsunamis also affect the overall resilience of the region. Many of the strategies created by this project address these information gaps and suggest ways for the region to better understand the type of mitigation and adaptation actions that can provide the most impact in preparing for hazards. Some may also be used to address other hazard types.

Local jurisdictions are encouraged to conduct more in-depth local analysis based on this project, for example by considering the methods and outcomes of the regional analysis in their Local Hazard Mitigation planning process. Local jurisdictions can also begin using the strategies based on the initial regional analysis even without local analysis. The region can use the outcomes of this project to incorporate resilience into region-wide policies on planning for future growth through Plan Bay Area and in helping jurisdictions decide where and how to grow. Assistance implementing strategies will be provided to local jurisdictions by ABAG through its Regional Resilience Plan throughout 2015 and 2016.

The suite of strategies developed by this project are not intended as a one-time effort or a complete set of tools. As communities gain more experience with assessing vulnerability and implementing strategies they may have additional insights to offer on potential actions, or recommendations for modifying the strategies recommended here. ABAG's ongoing Resilience Program is one vehicle through which new lessons at the local level can be communicated to a broader audience.

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5. Appendix

Table 5-1: Strategy Summary List

Scale	#	Strategy Name	Strategy Snapshot
State-led Strategies			
S	1	Complete seismic hazard mapping of urban and urbanizing areas	Encourage the California Geological Survey (CGS) to complete mapping of seismic hazard zones for the portions of the Bay Area that are not currently mapped or in the process of being mapped with priority given to urban and urbanizing areas.
S	2	Evaluate current guidelines and the "state of practice" for mapping, evaluating and mitigating seismic hazards, particularly multi-hazard areas	Through its authority under the State Seismic Hazard Mapping Act, encourage the California Geological Survey (CGS) to work with regional and local agencies and the geology/geotechnical community in the Bay Area to evaluate current guidelines, as well as the current state of practice, for mapping, evaluating and mitigating seismic hazards, particularly in areas of expected growth that are also vulnerable to tsunami, flooding and permanent inundation.
S	3	Develop education program(s) to encourage homeowners and renters to purchase of hazard insurance	This strategy recommends creating targeted education programs that encourage homeowners and renters to better understand their risk and make more informed decisions about the purchase of earthquake insurance. This includes education about retrofitting versus insurance, understanding the site-specific hazards of their building, helping them understand what the costs versus benefits are of purchasing insurance, and what is and is not covered by hazard insurance policies.
S	4	Improve the quality assurance of non-engineered retrofits by developing a statewide retrofitting license for contractors, with contractor training and technical materials	Increase the number of skilled contractors, contractor knowledge, consistency in retrofit quality, and owner assurance and trust in non-engineered retrofits by developing a regional or statewide program to train and license or certify contractors in non-engineered seismic retrofits.
Region-led Strategies			
R	5	Establish a cooperative shoreline management program	Coordinate with government agencies, organizations, and land owners to establish and maintain a cooperative shoreline management program. This cooperative program could identify strategies for shared decision-making and funding to reduce current and future flood risks in a manner that benefits and balances issues of equity, economy, and environment.
R	6	Develop guidelines for the siting and design of transit-oriented development to reduce seismic and flood risks	Encourage the Metropolitan Transportation Commission to include an annex to its Station Area Planning Manual that contains guidelines for on-site planning and design techniques that could reduce risk to areas vulnerable to flooding, shaking, and liquefaction hazards. The annex would be consistent with the overarching purpose of MTC Resolution 3434 Transit-Oriented Development (TOD) policy for regional transit expansion projects, taking into account techniques to mitigate for the risk of introducing 42,000 new housing units along the region's major transit corridors.
R	7	Encourage innovative insurance solutions at the state and federal levels, and in partnership with the private sector	Lobby and advocate for the expansion of state- and federally-mandated catastrophe insurance programs, such as the California Earthquake Authority. Better insurance solutions could enhance mitigation efforts by offering incentives such as building permit rebates, lower premiums or deductibles for retrofitted homes, state-level tax incentives, and state and federal grants to fortify homes and business.
R	8	Advocate for changes to federal and state programs to improve multi-family rebuilding efforts	Lobby at the state and federal levels to ensure multi-family housing receive a fair and equitable share of financial and technical assistance during rebuilding and recovery efforts.

Scale	#	Strategy Name	Strategy Snapshot
R	9	Decrease reliance on grid-supplied power	Promote buildings that will maintain livable conditions in the event of extended loss of power or heating fuel. This can be done through incentives for residential energy efficiency retrofits, weatherization projects, building design standards that promote energy load reductions and on-site generated electricity or bi-direction energy sources, that make homes habitable when there are utility outages caused by disasters.
R	10	Host a regional "Smart and Safe" growth design competition	Develop a region-wide design competition to promote innovative approaches to resilient design and new solutions to building high-density, mixed-use community development or redevelopment in a safe and smart manner in areas that are susceptible to multiple hazards
Locally-led Strategies			
L	11	Develop locally-specific seismic hazard maps	Encourage local governments to develop locally specific seismic hazard maps to improve upon mapping resolution and, support more informed and nuanced decision-making about development and hazard mitigation, particularly in urban and urbanizing seismically hazardous areas.
Strategies that reduce development in the highest hazard areas			
L	12	Increase protection of critical facilities and lifelines in high hazard areas	Encourage local governments to require critical infrastructure and public-service facilities to be located or relocated outside high hazard areas, or that seismic- and flood-related mitigation and other protective measures be undertaken to enhance the structural integrity, overall performance, and functionality of facilities that must be located within high hazard areas. Emphasis should be given to ensuring the continuity of operations of critical facilities and lifelines essential to helping residents remain in their homes following a disaster and facilitating and expediting community and regional post-disaster recovery.
L	13	Reduce or prohibit development in the most hazardous areas while ensuring equity and beneficial use of these areas	Reduce or prohibit development in high hazard areas, incentivize relocation out of these areas, and reduce or prohibit rebuilding after a disaster. This strategy also works to create beneficial uses, such as open space, flood mitigation and recreation, for non-developable high hazard lands.
L	14	Establish overlay zoning districts to help facilitate safe and smart new development	Establish overlay zoning districts, such as a Planned Unit Development (PUD) overlay district, to cluster new development into lower hazard areas on a particular site while also establishing special conditions for development in high hazard areas.
L	15	Establish a Transfer of Development Rights program to redirect development from high hazard areas to preferred, low hazard areas	Amend local development codes to establish a Transfer of Development Rights (TDR) program, which could place permanent conservation or hazard mitigation easements on properties in high hazard areas, to prevent or minimize the vulnerability of new development to seismic and flood hazards.
Strategies to retrofit of fragile housing in seismic hazard areas			
L	16	Create a fragile housing inventory	Create and maintain a database that includes the type and location of fragile housing by building type and housing tenure (owner vs. renter), and the property's retrofit status. This would include developing and sustaining standardized, transferrable procedures for collecting and managing data. The inventory should contain, at a minimum, unreinforced masonry buildings, soft-story buildings, and non-ductile concrete buildings.
L	17	Develop soft story retrofit program	Develop voluntary of mandatory retrofit program(s) to address soft story housing in areas where it makes up a large percentage of a jurisdiction's housing stock (as a whole or for a specific vulnerable community). Pair programs with financing tools and incentives. Consider different incentives and financing tools for more vulnerable communities, such as low-income residents or renters. The program should consider how to handle compliance and enforcement standards, mechanisms for enacting the program, and which retrofit standards to use.

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Scale	#	Strategy Name	Strategy Snapshot
L	18	Develop cripple wall retrofit program	Develop a retrofit program to address cripple wall housing in areas where it makes up a large percentage of a jurisdiction's housing stock (as a whole or for a specific vulnerable community). Pair programs with financing tools and incentives. Consider different incentives and financing tools for low-income homeowners or renters. The program should consider how to handle compliance and enforcement standards, mechanisms for enacting the program, and which retrofit standards to use.
L	19	Require hazard disclosure for renters	This strategy recommends the development of policies that require residential property managers and landlords to disclose hazard risk information to renters in a manner similar to that required when residential properties are sold, including if the property is listed on a fragile housing inventory.
L	20	Ensure that major upgrades and repairs to existing buildings address seismic and flood-related hazards.	Encourage local governments to develop and adopt special repair and upgrade standards for existing buildings that are not typically part of hazardous building abatement programs and are also potential candidates for conversion to mixed-use or higher-density residential use in areas of expected growth. This strategy focuses on reducing the risks posed by existing hazardous buildings by addressing both seismic and flood-related hazards at the time of upgrade (such as a mixed-use or residential conversion) or major repairs following a disaster.
Strategies to increase building standards for new construction in seismic hazard zones			
L	21	Assign higher seismic importance factor to new large scale residential buildings.	Amend the local building code to enhance structural and nonstructural design requirements for new large-scale residential buildings by adoption of increased seismic importance factor to improve their seismic performance level.
L	22	Enhance minimum design requirements for new small scale residential building foundations in liquefaction zones	Amend the local building code to require enhanced foundation design requirements for new small-scale residential development (e.g. single or two-family dwellings) and for significant modifications to existing small-scale residential development to limit foundation damage due to liquefaction.
L	23	Restrict use of significant structural irregularities in residential buildings	Amend the local building code to restrict the use of structural irregularities in the design of new residential construction as well as existing residential construction subject to significant modification in areas with high or moderate shaking and liquefaction potential.
L	24	Enhance minimum requirements for non-structural anchorage and bracing of interior partition walls in residential buildings	Amend the local building code to include enhanced non-structural anchorage and bracing requirements for interior partition walls in existing residential buildings in areas with shaking potential.
L	25	Develop and adopt guidelines for building utility connections to incorporate earthquake safety features	Amend the local building code to require that utility connections to buildings incorporate safety features to prevent adverse impacts from earthquakes. Develop guidelines on safety measures such as adequate displacement allowance for building utility connections, if there are no existing guidelines.
Strategies to address flooding hazards			
L	26	Participate in FEMA's Community Rating System	Encourage local governments to participate in FEMA's Community Rating System (CRS), a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum National Flood Insurance Program (NFIP) requirements by reducing local flood insurance rates.
L	27	Reduce flood risk through integrated watershed management	Develop a program to work with public and private landowners to decrease the risk of flooding by advancing watershed management projects that reduce and/or store runoff during rainfall events, including the installation of green infrastructure and Low Impact Development (LID) practices, and improve the condition in the floodplain, for example through floodplain restoration or improvement.

Scale	#	Strategy Name	Strategy Snapshot
L	28	Increase standards in local floodplain management ordinances beyond the minimum requirements of FEMA's NFIP program	Adopt a floodplain management ordinance that exceeds the minimum requirements of the NFIP to reduce potential risk from flood events that exceed the 100-year (1% annual chance) event. A strong floodplain management ordinance will ensure that land-use decisions account for current flood risks based on available information and assessments and consider more extreme events and/or future flood risk associated with sea level rise.
L	29	Require flood-proof construction methods and techniques within and adjacent to special flood hazard zones	Amend the applicable local codes to require flood-proof construction techniques in structures in special flood hazard zones, high hazard zones, and adjacent areas. Requiring flood-proofing techniques in these special flood hazard and high hazard zones could reduce the potential of damage to a structure and its contents in the event of a flood. Requiring the same level of flood-proofing in areas adjacent to these zones could reduce the potential for damage in areas that may be flooded in the future with sea level rise, or by flood events that exceed the FEMA 1% annual chance (100-year) flood conditions.
L	30	Revise minimum building elevation standards and maximum building height-limits for new development	Revise building standards to require that habitable building space and sensitive building components be elevated above current and future flood levels. In tandem, maximum building height limits may be increased to reduce conflicts where these codes are applied together.
L	31	Incorporate sea level rise guidance within the capital planning process	City and County departments submit projects for incorporation within the respective local government's capital plan. The goal of the capital plan to provide clear direction on how the local government's assets will be maintained and improved over time, and to identify and prioritize projects for funding within the multiyear capital plan timeframe. The capital planning process can require that all projects located within a specific sea level rise inundation zone boundary adhere to sea level rise vulnerability and risk assessment guidance and identify appropriate adaptation strategies.
Policy tools that support financing mechanisms			
L	32	Create geologic hazard abatement districts (GHADS) to fund hazard mitigation	Establish Geologic Hazard Abatement Districts (GHADs) as a mechanism for raising funds and defining responsibility for the prevention, mitigation, abatement or control of geologic hazards, including landslides, land subsidence, soil erosion, earthquake, fault movement or any other natural or unnatural movement of land or earth. GHAD related projects can include the mitigation or abatement of structural hazards that are partly or wholly caused by geologic hazards and they can include flood control structures.
L	33	Create Mello-Roos Community Facilities Districts to provide financing to property owners for resiliency improvements	Facilitate collaboration among local governments and property owners to form a district in which property owners opt in to participate, wherein the district would use capital raised by issuing bonds to make resiliency improvements, which is paid back through a property tax assessment.
Strategies to prepare for post-disaster recovery			
L	34	Create a pre-disaster rebuild and recovery plan	Make decisions about long-term disaster recovery, and implement as policy, such as when, where, and how rebuilding will occur after a natural disaster, which areas will be rebuilt according to existing plans and codes and which will be re-planned, whether rebuilt homes will be encouraged or required to be more likely to withstand the effects of future hazard events, and who will be in charge of coordinating and overseeing the recovery process through the development of a pre-disaster recovery plan.
L	35	Revise local plans and development codes to allow temporary land uses to facilitate and expedite post-disaster recovery	Revise local plans and development codes to permit interim or temporary land uses to support critical public facilities to facilitate and expedite recovery after a disaster event.

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Scale	#	Strategy Name	Strategy Snapshot
L	36	Develop and implement a shelter-in-place program	Develop a comprehensive shelter-in-place program to allow residents to remain in their homes after a disaster. Establish engineering criteria to determine shelter-in-place capacity, develop acceptable habitability standards for sheltering-in-place, and prepare and adopt regulations that allow for the use of these standards in a declared housing emergency period. Also develop plans for implementing the program, such as public training materials, coordinating with post-disaster evaluation procedures, and setting up neighborhood support centers.
L	37	Improve the resilience of rental units and ensure they are re-built after loss or damage due to a natural disaster	Adopt new policies, and strengthen existing policies, to improve the resilience of available rental units, and develop policies to ensure that rental units damaged during a natural disaster are replaced in kind (with a similar number/type) during rebuilding and recovery rather than being converted to owner-occupied properties.
L	38	Protect affordable housing during recovery	Develop a more fair community planning process for rebuilding affordable housing after a disaster, adopt policies to support the replacement of affordable housing units that have been damaged or demolished, and prioritize the deployment of interim housing in vulnerable communities.
Strategies for coordination with non-profit organizations and community organizations			
L	39	Create a community capacity inventory	This strategy recommends developing or enhancing an existing community capacity inventory by first defining the elements that should be included (such as critical facilities and community services), engaging NGOs and city agencies to utilize current work, and then developing and sustaining standardized, transferrable procedures for collecting and managing data. Partnerships with NGOs such as Code for America could yield an open-source, collaborative format for collecting and sharing this information.
L	40	Disseminate best available hazard and climate risk information through community-based organizations and non-traditional partners	This strategy recommends seeking opportunities to expand existing, successful community-based programs (e.g. programs on crime, blight, neighborhood beautification, education or other important community issues) in order to better communicate hazard and climate risk information to community members. An example of such an expansion would be the promotion of voluntary retrofits to building owners in coordination with the public health sector Healthy Homes educational campaigns.

Table 5-2: Potential Financing Mechanisms

Name	Administrator	Source of Repayment	Area of Application	Voter Approval Considerations	Applicable Strategies
City/County/ State Bond Program	City, County, Regional Agency, or State	General fund, sales tax, or hotel tax Service fees, property tax, tax increments	Citywide, Countywide, or Statewide	General obligation bonds require two-thirds voter approval. Revenue bonds require majority voter approval.	12, 20, 26
Parcel or Sales Tax	City, County, Regional, or State	Parcel tax or sales tax	Citywide, Countywide, Region-wide, or Statewide	Parcel or sales taxes require two-thirds voter approval	None
Tax-based Special Districts	Special District	Ad-valorem property tax	Districtwide	Tax-based special districts need two-thirds voter approval to be able to levy special taxes.	5, 9, 12, 14, 17, 26, 32, 33, 38
Fee-based Special Districts	Special District	Service fees	Districtwide	Fee-based special districts do not need voter approval to issue bonds for capital generation. Similarly, fees charged by special districts do not require voter approval as long as the fees are for a specific benefit, service, or product provided directly to the fee payer.	5, 6, 12, 26
Infrastructure Financing Districts	City or County	Property tax increments within the district	Districtwide	Property tax increments proposed by infrastructure financing districts require both local and countywide approval, where both jurisdictions forego general fund revenue to pay back infrastructure investments.	6, 14, 36
Joint Powers Authorities (also known as Public Financing Authorities)	Joint Powers Authority appointed by City or County	Income from public project projects (e.g. income generated by a Port Authority by leasing space to businesses)	Multi-city, Countywide, Region-wide, District	This mechanism requires multi-jurisdictional buy-in before it can be implemented.	None
Municipal Enterprise Funds	City, County, or utility	Users of Infrastructure Services (e.g., water, energy, etc.)	Citywide, Countywide, District	Fees charged by municipal enterprises do not require voter approval as long as the fees are for a specific benefit, service, or product provided directly to the fee payer.	12
Development and Construction Loans	Local or regional banks	Income from investment	Neighborhood wide	None	6, 14, 15, 20, 21, 22, 23, 24, 25, 26, 28, 29, 30
Individual Home Improvement Loans or Commercial Renovation Loans	Local or regional banks, local, regional, state, and federal agencies	Individual or business income	Individual property owner or individual business	None	12, 17, 18, 20, 22, 23, 24, 25, 26, 28, 29, 37, 38

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Name	Administrator	Source of Repayment	Area of Application	Voter Approval Considerations	Applicable Strategies
Revolving Loan Fund (RLF) Programs	Local, regional, state, and federal agencies	Income from investment, individual and business income	Citywide, neighborhood wide, individual households and businesses	None	12, 23, 24, 25, 26, 28, 29
Grant Programs	Local, regional state, or federal agencies, philanthropic organizations	None required	Citywide, neighborhood-wide	None	1, 2, 4, 5, 6, 10, 11, 12, 20, 22, 23, 24, 25, 26, 27, 28, 29, 35, 37, 38, 39, 40

Source: AECOM, 2014

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