Delta Stewardship Council

A CALIFORNIA STATE AGENCY

DELTA ADAPTS: CREATING A CLIMATE RESILIENT FUTURE

EQUITY TECHNICAL MEMORANDUM

MAY 2021

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CONTENTS

FIGURES

TABLES

Acronyms and Other Abbreviations

AB	Assembly Bill
ACS	American Community Survey
AEP	Annual Exceedance Probability
ART	Adapting to Rising Tides
BCDC	Bay Conservation and Development Commission
CalBRACE	California Building Resilience Against Climate Effects
CalEnviroScreen	California Communities Environmental Health Screening Tool
CalEPA	California Environmental Protection Agency
CHAT	California Heat Assessment Tool
CCHVIz	Climate Change and Health Vulnerability Indicators
CDP	Census Designated Place
CDPH	California Department of Public Health
DAC	Disadvantaged Community
DCI	Distressed Communities Index
Delta	San Francisco-San Joaquin Delta, including the Suisun Marsh
DUC	Disadvantaged Unincorporated Community
GGRF	Greenhouse Gas Reduction Funds
GIS	geographic information system
HHAI	Heat-Health Action Index
HHE	Heat Health Event
HPI	Health Places Index
MPO	Metropolitan Planning Organization
MTC	Metropolitan Transportation Commission
NOAA	National Oceanic and Atmospheric Agency
OEHHA	Office of Environmental and Health Hazard Assessment
OPR	Governor's Office of Planning and Research
ROI	Regional Opportunity Index
RTP	Regional Transportation Plan
SACOG	Sacramento Area Council of Governments
SB	Senate Bill
SDAC	Severely Disadvantaged Community
SJCOG	San Joaquin Council of Governments
SoVI	Social Vulnerability Index
SWRCB	State Water Resources Control Board
VA	Vulnerability Assessment

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Chapter 1. Background

1.1 Purpose

Equity is just and fair inclusion into a society in which all can participate, prosper, and reach their full potential (OPR 2017a, PolicyLink 2018). The Governor's Office of Planning and Research identifies the following equity challenges for climate change policy: "addressing the impacts of climate change, which are felt unequally; identifying who is responsible for causing climate change and for actions to limit its effects; and, understanding the ways in which climate policy intersects with other dimensions of human development, both globally and domestically" (OPR 2017a). Put another way, climate equity means acknowledging that those who have benefitted least from the economic activities that cause greenhouse gas emissions are often most vulnerable to the impacts of climate change (IPCC 2014, Roos 2018, Shonkoff et al. 2011, Stallworthy 2009).

By Executive Order, State agencies must consider the most vulnerable populations when incorporating climate change into planning and investment decisions (EO B-30-15). The Delta Stewardship Council intends to incorporate equity into the Delta Adapts: Creating a Climate Resilient Future (Delta Adapts) initiative by identifying the communities and populations that are most vulnerable to climate hazards in the Delta and developing adaptation strategies that recognize and remedy these inequities. The primary purpose of this memorandum is to identify data sources, methods, and best practices to ensure that equity is addressed in the first phase of the initiative, the vulnerability assessment (VA).[1] The information generated in the VA will inform engagement and planning priorities in the second phase of the initiative, the adaptation strategy.

Local agencies have similar requirements to incorporate equity (pursuant to Senate Bill 1000)[2] and address climate change (pursuant to Senate Bill 379)[3] in their general plans. While some

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[1] This memo also seeks to identify an approach to Delta Adapts that incorporates environmental justice concerns, to the extent that such concerns are linked to the climate change impacts within the scope of the study. The Council's first Five Year Review of the Delta Plan identified environmental justice as one of four key planning topics and emerging issues requiring more information and analysis to inform potential future actions (Council 2019). While Delta Adapts will not comprehensively address this need, this memo recognizes the connections between climate equity and environmental justice and identifies data sources and methods that could support future, broader environmental justice efforts.

[2] Compliance with SB 1000 requires local agencies to identify goals, policies, and objectives to reduce risks to *disadvantaged communities*, defined as areas disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, exposure, or environmental degradation, or with concentrations of people who are of low income, high unemployment, low levels of homeownership, high rent burden, sensitive populations, or low levels of educational attainment (*Cal. Health & Saf. Code* § 39711).

[3] Compliance with SB 379 requires local agencies to identify the risks that climate change poses, the geographic areas at risk, and feasible climate adaptation and resiliency strategies to avoid or minimize those risks (*Cal. Gov. Code* § 65302).

local agencies within the Delta have already met these obligations by adopting environmental justice elements or updating safety elements in their general plans, others are still working toward compliance with this new set of requirements. Therefore, this memo seeks to identify data sources and methods that are also useful in addressing SB 1000 and SB 379.

1.2 Conceptual Model and Definitions

The Integrated Climate Adaptation and Resiliency Program (ICARP) Technical Advisory Council (TAC) developed and adopted the following definition of the *most vulnerable populations* to assist local and state agencies in implementing the Executive Order (OPR 2018)[4]:

> "[T]hose which experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with, adapt to, or recover from climate impacts. These disproportionate effects are caused by physical (built and environmental), social, political, and/or economic factor(s), which are exacerbated by climate impacts. These factors include, but are not limited to, race, class, sexual orientation and identification, national origin, and income inequality."

This definition aligns with the Intergovernmental Panel on Climate Change (IPCC) definition of vulnerability: "Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (2014). The IPCC defines adaptive capacity as, "The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (2014). In simplified terms, exposure, sensitivity, and adaptive capacity interact with one another to increase vulnerability to climate change (**Figure 1**).

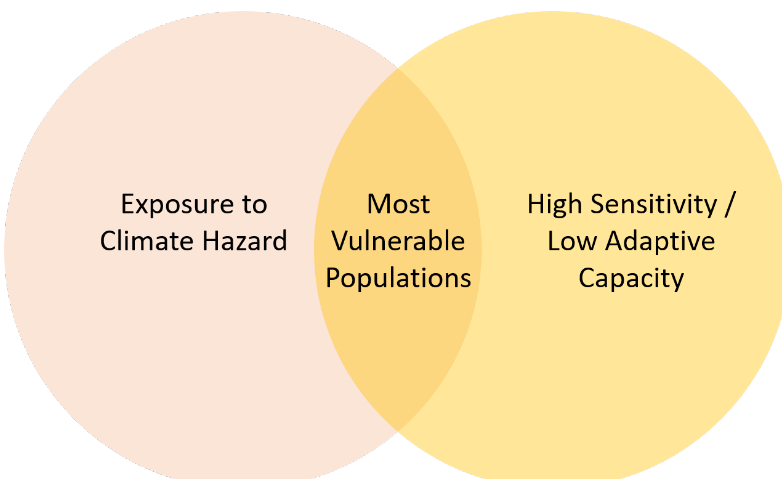

Figure 1. Conceptual Model of Vulnerability

Any person exposed to a climate hazard is vulnerable. Exposure is the presence of people (or other assets) in places and settings that could be affected by climate change hazards (IPCC

[4] Related, codified definitions are summarized in Appendix A.

2014). However, some individuals may have physiological or socioeconomic characteristics that increase their sensitivity to a particular climate change hazard (Raval et al. 2019). Similarly, some individuals, neighborhoods, or communities may have greater ability or opportunity to adjust to future hazards or respond to the consequences of those hazards (IPCC 2014). The *most vulnerable populations* are those that are exposed, are highly sensitive, and have low adaptive capacity (**Figure 1**).

Direct exposure is not a prerequisite for a person or neighborhood to be vulnerable to the impacts of climate change. For example, the neighbors of households that experience flooding may be indirectly affected by the loss of social networks (Paterson et al. 2018) or by consequent changes in occupancy rates and property values (Kunreuther et al 2018). Whole communities may lose access to workplaces, schools, or critical community facilities due to flood impacts in a single neighborhood (Kunreuther et al 2018). Thus, a person or community that is not exposed to a climate change hazard could still be highly vulnerable if they are highly sensitive or lack the resources or opportunities to prepare for and respond to the impacts.

Exposure is typically a function of the physical environment, such as the height of nearby levees and the likelihood that water levels will exceed that height; or urban density and the likelihood that local temperatures will reach unhealthy levels. Sensitivity and adaptive capacity tend to be a function of health and socioeconomic characteristics, such as the income that a household would need to access medical treatment, evacuate, or secure alternative shelter. In general, this memo will refer to sensitivity and adaptive capacity jointly as *social vulnerability*.

This conceptual model is not intended to imply that environmental and social vulnerability are independent of one another. Ample research demonstrates that the physical environment has been shaped by policies and attitudes towards particular socioeconomic groups. Redlining and discrimination, reinforced by market forces, have created conditions in which many low-income communities and communities of color reside and work in more hazardous environments (Bartlett 1998, CSIWG 2018, Rothstein 2017, Shonkoff et al. 2011) and experience significant health disparities (McCall 2018, OPR 2017b). Thus, social vulnerability is also closely linked to place, and is spatially explicit (Raval et al. 2019).

1.3 Climate Change Stressors and Hazards

Delta Adapts has identified three primary climate stressors: sea level rise, changes in precipitation and hydrologic patterns, and changes in air temperature. Chapter 3 of the VA describes each of the climate stressors in detail.

These climate stressors are expected to create a variety of climate hazards for populations in the Delta. Chapter 3 of the VA identifies four climate hazards as having increasing impacts to the Delta: extreme heat, wildfire, drought, and flooding (**Figure 2**). Increased air temperatures will cause more frequent and intense extreme heat events; changes in temperature, precipitation, and hydrology will increase the risk of drought and wildfire; and sea level rise and changes in precipitation and hydrology will both increase the risk of levee overtopping, and consequent flooding.

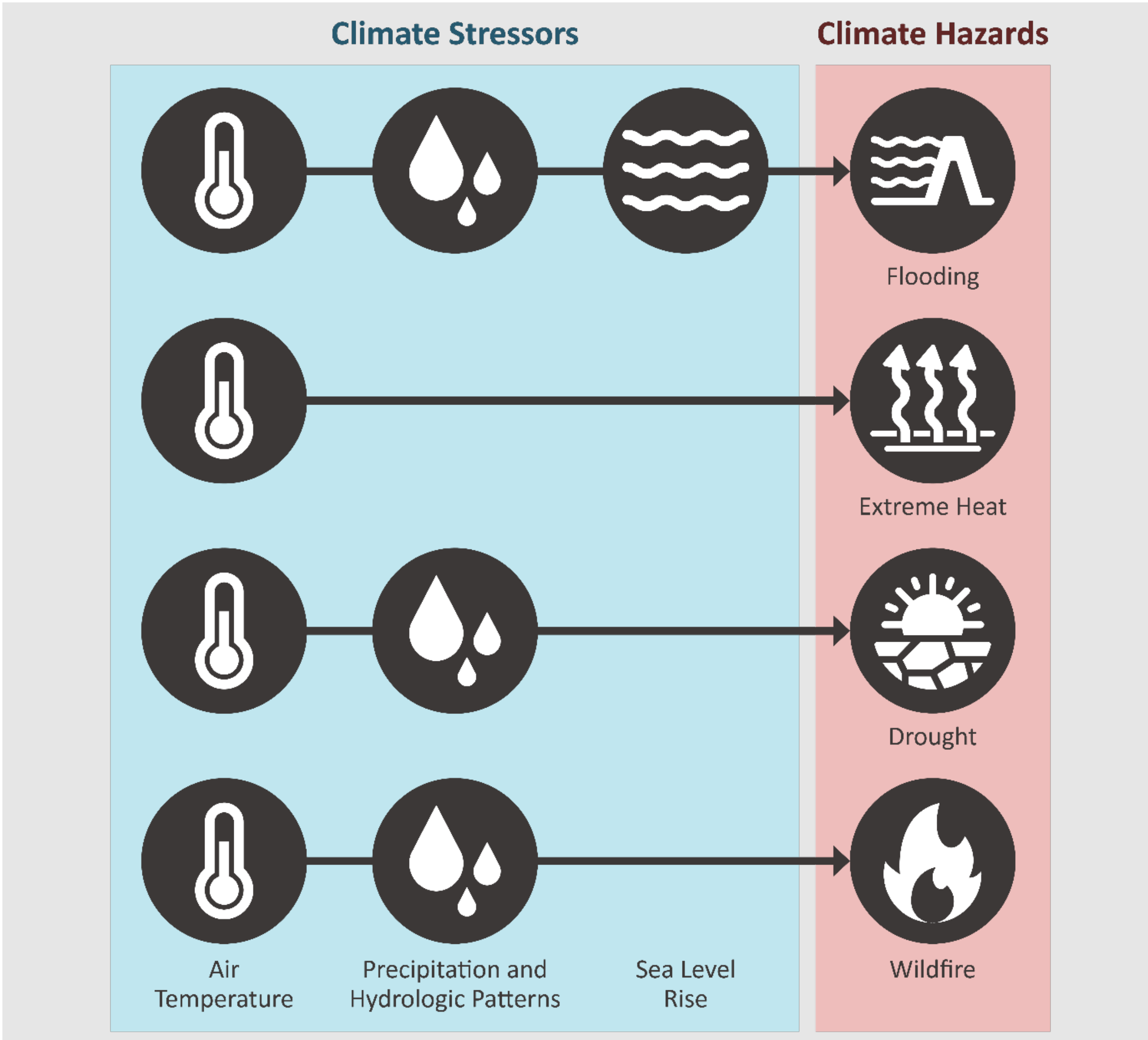

Figure 2. Relationship Between Climate Stressors and Hazards Evaluated in the VA

This memo will investigate the factors that increase sensitivity or reduce the capacity to adapt to three of these climate hazards: flooding, extreme heat, and wildfire. Drought will not be evaluated in this memo because its effects extend to a different scale than the other hazards; the effects of drought in the Delta are felt far beyond the Delta - throughout the Delta watershed, the San Joaquin Valley, the San Francisco Bay Area, and in Southern California communities. The potential equity implications of drought are discussed qualitatively in the **Water Supply Technical Memorandum** and the **Crop Yield and Agricultural Production Technical Memorandum**.

1.3.1 Flooding

Much of the Delta is protected from tidal inundation and/or riverine flooding by levees. Levees create residual flood risk for the people and property located behind them, as they are only designed to protect landside development against a specific peak water level (NRC 2013). Over time, land subsidence, land cover change, deferred maintenance, and changes to upstream flood control systems have increased residual flood risk in the Delta to among the highest in the nation (Burton & Cutter 2008, DWR 2012, NRC 2013). Based on federal levee accreditation criteria and existing flood insurance studies, a majority of land in the Delta currently has a 1 percent or greater probability of flooding each year (**Figure 3**). Climate change will further exacerbate these risks. Sea level rise will interact with changes in precipitation and hydrology to increase the frequency of extreme water levels and the risk of levee overtopping and failure throughout the Delta (Knowles et al. 2018).

Flooding has both immediate and long-term public health impacts. Flooding can lead to death or injury by drowning, hypothermia, electrocution, and trauma from debris and falls (Bell et al. 2016, Paterson et al. 2018). Individuals experiencing homelessness and emergency response workers have greater exposure to these immediate risks (OPR 2017b). Drowning is more likely to result from flash flooding than from slow-onset flooding (Paterson et al. 2018), but even slow-onset flooding can be deadly to individuals who do not have adequate warning information or the capacity to evacuate. Income levels affect how people perceive flood risks, and their willingness and ability to evacuate in response to warnings (Bell et al. 2016). Linguistically isolated households may not be as aware of flood risks or receive timely warnings (Bell et al. 2016). In addition, households that lack access to a vehicle, as well as young children, older adults, people with disabilities, and people living in nursing homes, prisons, and other institutions have less ability to evacuate on their own, and are therefore more vulnerable (Bell et al. 2016, OPR 2017b, Roos 2018).

Power outages caused by flooding can cause carbon monoxide poisoning (Bell et al. 2016). Flooding that causes power outages, damages health care infrastructure, or displaces people can also exacerbate existing heath conditions by making it more difficult to access medication and treatment (McCall 2018, Paterson et al. 2018), resulting in both immediate and chronic health impacts. People with cancer, cardiovascular disease, hypertension, diabetes, kidney disease, and chronic respiratory disorders experience greater health effects after flooding (Bell et al. 2016, Paterson et al. 2018).

Older adults are more likely to have existing, chronic medical conditions, and are therefore more sensitive to flood events (Bell et al. 2016). Low-income people and people of color also have higher baseline rates of chronic medical conditions that increase their sensitivity to the effects of flooding. It is important to note that these population health disparities are the result of long-term, cumulative, social and economic factors - not intrinsic differences based on race (OPR 2017b).

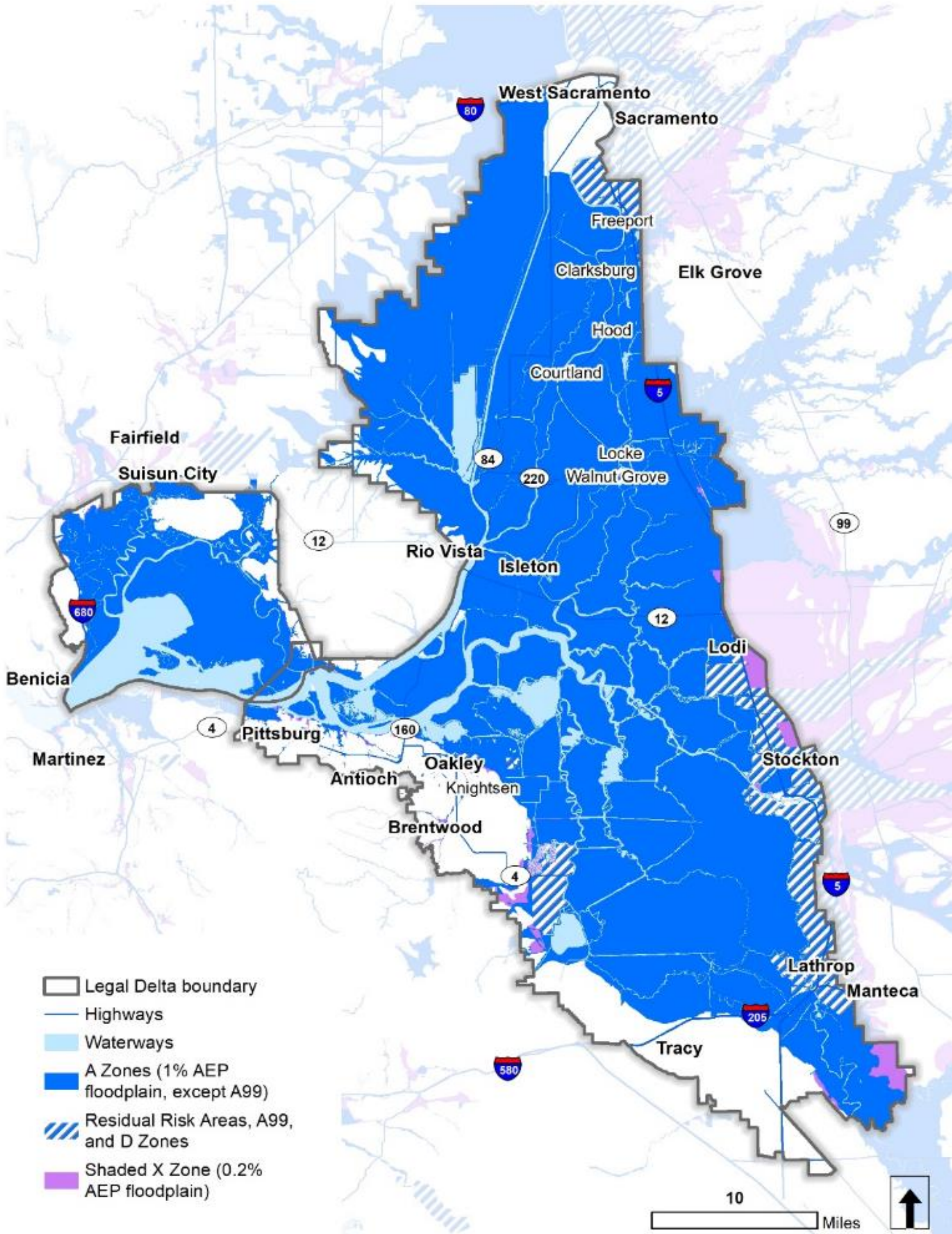

Figure 3. Existing Flood Hazards in the Delta

Data Source: FEMA 2020. The 1 percent Annual Exceedance Probability (AEP) floodplain is more commonly known as the 100-year floodplain. The 0.2 percent AEP floodplain is more commonly known as the 500-year floodplain. Hatched areas are protected by levees with varying levels of accreditation and protection.

Exposure to floodwaters increases the risk of infection, pneumonia, gastrointestinal disease, and other diseases (Paterson et al. 2018). LGBTQ+ individuals, immigrants, and individuals without health insurance are less able to access treatment for these conditions, and are therefore more vulnerable (McCall 2018, OPR 2017b).

Increased incidence of post-traumatic stress disorder, depression, and increased stress levels have also been linked to flood events. Mental health effects can persist for years after an event (McCall 2018). Flood events are linked to increases in pre-term births and low birth weight infants due to increased stress among pregnant mothers (Bell et al. 2016).

People experiencing homelessness are more vulnerable to flooding because they have higher rates of underlying health conditions and generally lack access to health care (OPR 2017b). People experiencing homelessness may live in their vehicles, which are the most common location of flash flood fatalities (Terti et al. 2016). People experiencing homelessness also frequently reside in informal encampments within or near drainageways and waterways and may not have information or warning about flash floods (Moreno et al. 2020). Encampments near drainageways and waterways can also increase the risk of flooding. Unsecured property and other debris from encampments can blow or wash into drainageways and block flow, increasing flood stages upstream (Moreno et al. 2020). Encampments that are dug into earthen embankments and levees can increase erosion and risk of levee failure (Moreno et al. 2020). Thus, there are feedback effects between homelessness and flood risk, a relationship of growing concern to the Central Valley Flood Protection Board and levee maintenance districts.

Flooding also damages homes, schools, and community infrastructure, displacing households, interrupting business, and disrupting children's education (Bell et al. 2016). People living in mobile homes are more vulnerable to disasters such as flooding due to both their structural properties and the tendency for low-income households to occupy this housing type (Cutter et al. 2000, Fothergill & Peek 2004, Kusenbach et al. 2010). Mobile home foundations may not be designed for flood forces, and even with a reinforced foundation, structures must be properly anchored to the foundation to withstand a flood. Although construction standards for manufactured and mobile homes have improved over time, mobile home residents tend to be disproportionately impacted by flood events (Baker et al. 2014, FEMA 2009, Kusenbach et al. 2010, Terti et al. 2016).

Communities' and individual households' ability to access resources to recover from floods (such as insurance, public assistance, private loans, and home buyouts) has been found to vary based on race (Elliott et al. 2020) as well as less-tangible factors, such as a community's shared sense of place and history (Finch et al. 2010). Lower income households and renters have fewer resources to repair damage or procure temporary and replacement housing (Cutter et al. 2003).

While a variety of tools and studies are readily available to understand social vulnerability to flooding from sea level rise along California's coastline and in the San Francisco Bay Area, none of these extend inland to the Delta (see Raval et al. 2019 for a comprehensive inventory). Burton and Cutter (2008) developed an index to measure social vulnerability to levee failure in the Delta, but, due to data availability, did not include Contra Costa or Solano County. Moreover, no existing social vulnerability studies account for the exposure of Delta communities to flooding under future conditions that include both sea level rise and changes in precipitation and hydrology.

Delta Adapts will model sea level rise throughout the Delta and Suisun Marsh, and produce detailed information about the exposure of leveed islands to overtopping due to sea level rise, as well as the combined effects of sea level rise and high flow events. The Council is well-positioned to leverage this exposure information, in combination with existing indicators of social vulnerability, to identify the populations that are most vulnerable to flooding.

1.3.2 Extreme Heat

Extreme heat events cause more deaths in the United States than any other natural hazard (Bell et al. 2016) and are an existing public health concern in California (McCall 2018). The 2006 heat wave in California caused an estimated 147 deaths statewide; 13 of these were in Sacramento County and 17 in San Joaquin County (Ostro et al. 2009). Climate change will increase the frequency of extreme heat events, and associated mortality risk (Hoshiko et al. 2010, Ostro et al. 2011, Steinberg et al. 2018).

The built environment plays a significant role in extreme heat events. In urban areas, impervious surfaces and scarcity of vegetation create microclimates, or “urban heat islands” that are hotter than surrounding rural areas (Altostratus Inc. 2015, Oke 1989, Oke 1982) (Figure 4). Even within heat islands, temperatures can vary spatially, resulting in hotspots of land surface temperature (Huang et al. 2011). Low-income communities and communities of color are overrepresented in urban areas that have higher rates of impervious cover and less tree cover and are therefore more likely to be exposed to the urban heat island effect (Shonkoff et al. 2011).

Exposure to extreme heat can cause cramps, syncope (fainting), edema, and heat exhaustion, which are all readily treatable conditions if a person is able to quickly relocate to a cool environment and rehydrate. If a person does not have immediate access to a cooler environment at the onset of heat stress and exhaustion, and is not able to recover, these conditions may become more serious and progress to heat stroke. Heat stroke can cause death from cardiac failure, suffocation, and kidney failure (McCall 2018).

Older adults are considered the age group most sensitive to extreme heat events, especially those with impaired cognitive ability, immune system, body temperature regulation, and mobility (Hajat et al. 2007, Knowlton et al. 2009, Kovats et al. 2004). Children and infants are also highly sensitive to extreme heat events since they are still developing physically and emotionally (Ebi & Paulson 2007, Gamble et al. 2016). During the 2006 California heat wave, young children and adults older than 65 experienced higher rates of adverse health effects. Acute kidney failure, electrolyte imbalance, and inflammation were the most common heat-related health effects among the elderly (Knowlton et al. 2009).

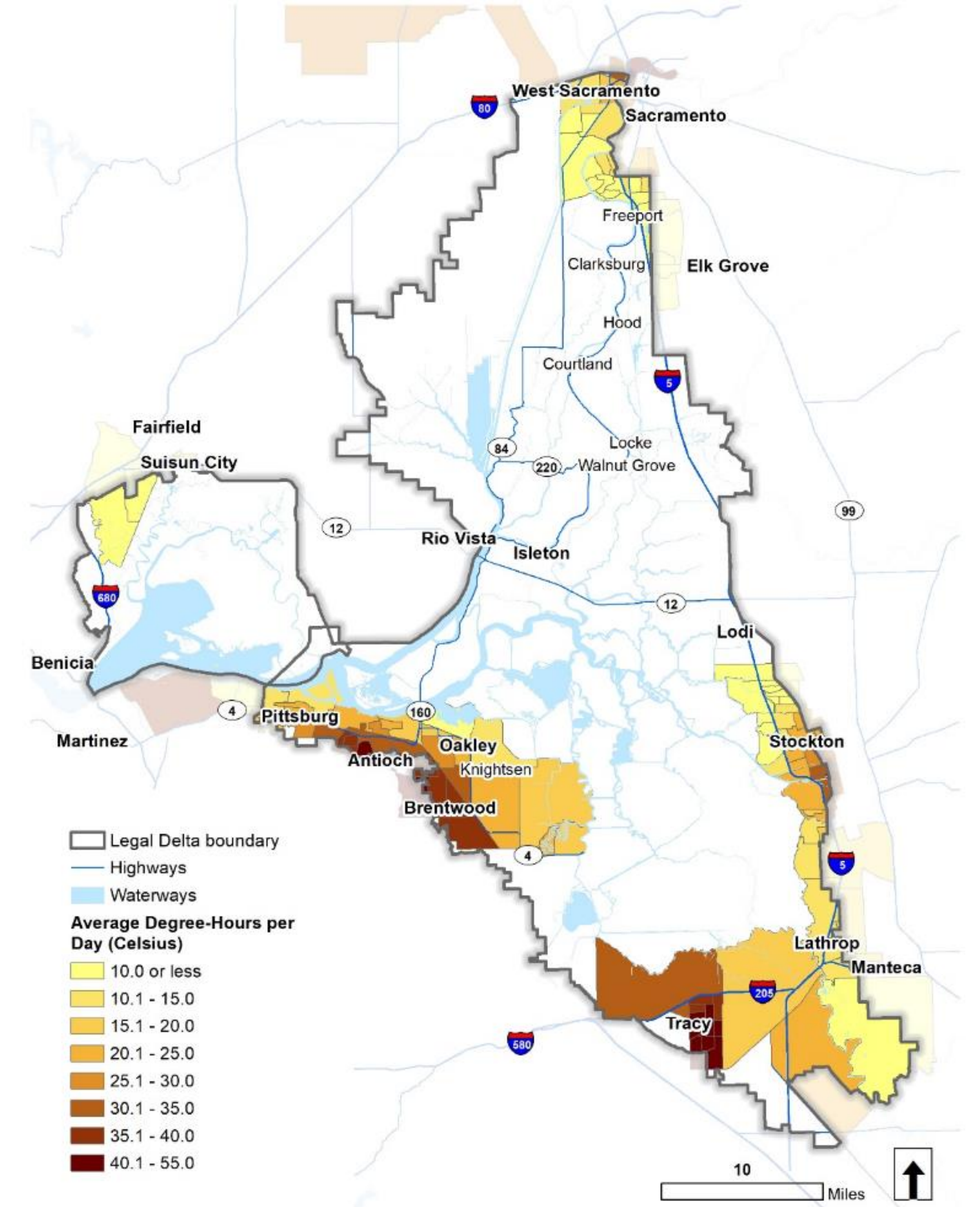

Figure 4. Existing Urban Heat Island Effects in the Delta

Data Source: CalEPA 2015

Extreme heat can also increase hospitalization for other conditions, including pneumonia, stroke, diabetes, and respiratory disease (McCall 2018). Extreme heat can increase ozone formation and air pollution, further aggravating existing respiratory disease among sensitive individuals (McCall 2018). Individuals suffering from chronic illnesses, such as diabetes, cardiovascular diseases, and asthma, are more sensitive to these effects. Mental illness can also cause heightened sensitivity to extreme heat events from medications that interfere with self-regulation of body temperature

(Gamble et al. 2016, OPR 2017b). Because there are disproportionately high levels of health conditions among low-income communities and people of color, these groups are disproportionately impacted by extreme heat (OPR 2017b, Shonkoff et al. 2011). As with flooding, LGBTQ+ individuals, immigrants, and individuals without health insurance may face more difficulty accessing care for these conditions (Fowler et al. 2010, OPR 2017b).

People who work outdoors, such as farm workers and construction workers, are more exposed to extreme heat and are more sensitive because body temperatures are elevated during strenuous activity (Gamble et al. 2016). Between 1992 and 2006, crop workers represented 16 percent of occupational deaths in the U.S. from exposure to environmental heat (Centers for Disease Control and Prevention 2008).

The primary adaptation strategies individuals use to combat extreme heat are air conditioning, or evacuating to a cooling center or other, cooler location (Shonkoff et al. 2011). Individuals experiencing homelessness are highly vulnerable because they are unlikely to have access to either adaptation mechanism (OPR 2017b). Incarcerated populations are susceptible to heat-related illness since many correctional facilities do not provide adequate air conditioning (Motanya & Valera 2016, OPR 2017b). Fewer African Americans, Latinos, and people living in poverty have home air conditioning (Shonkoff et al. 2011). Renters without air conditioning may not have the option of installing it (OPR 2017b). Low-income people who do have access to air conditioning may not be able to afford higher energy costs associated with using air conditioning during peak demand (Gamble et al. 2016, OPR 2017b). Households without access to a vehicle are less able to evacuate and are therefore more vulnerable (OPR 2017b, Shonkoff et al. 2011).

A variety of existing studies and tools have projected extreme heat events under various climate change scenarios (CDPH 2019a, Steinberg et al. 2018) and developed indices to measure the social vulnerability of California communities to extreme heat, including those in the Delta (Cooley et al. 2012, Steinberg et al. 2018). Thus, there is ample data available to identify the populations in the Delta that are most vulnerable to extreme heat. The applicability of each of these tools to the VA is discussed in the **Existing Vulnerability Indices** and **Revised Approach** sections, below.

1.3.3 Wildfire

Wildfire has become a major public safety threat in California due to decades of fire suppression, build-up of dead plant material, and development at the wildland-urban interface (WUI). Existing wildfire risk in the Delta is low relative to other parts of the state, though several large fires have occurred at the edges of the Delta in recent years. Several moderate Wildfire Hazard Severity Zones are designated at the edges of the Delta: in rural areas of Solano County between Suisun Marsh and Cache Slough; east of the Sacramento River, between Hood and Elk Grove; and at the southeastern Delta boundary between Clifton Court and Antioch (Figure 5).

The California Department of Forestry and Fire Protection (CAL FIRE) was recently directed to prepare an assessment of community wildfire vulnerability in California (Executive Order N-05-19). CAL FIRE's analysis accounted for exposure risk, as well as community sensitivity and adaptive capacity to wildfire. The analysis confirmed that, relative to other parts of the state, the Delta has very low wildfire vulnerability (CAL FIRE 2019).

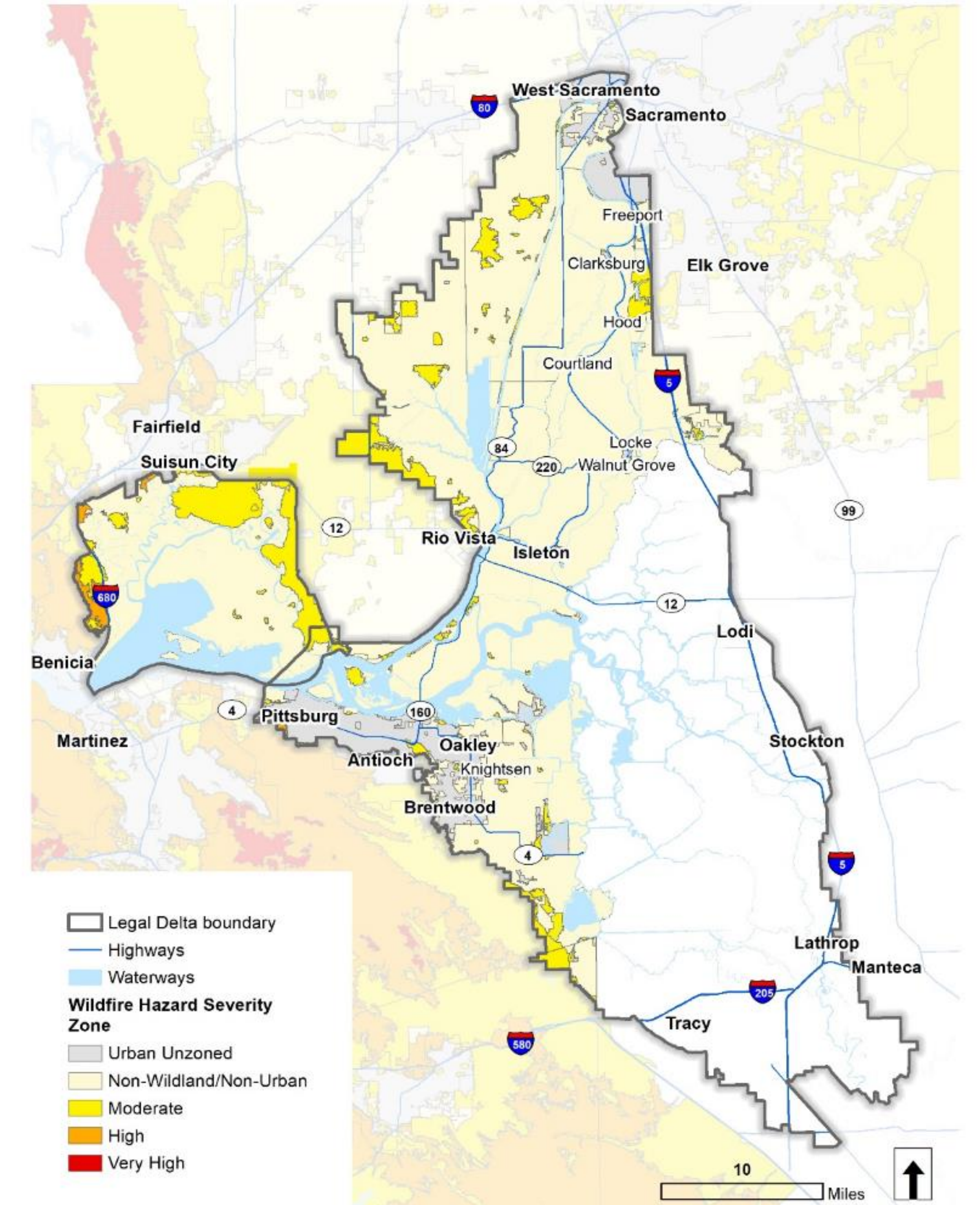

Figure 5. Existing Wildfire Hazards in the Delta

Data Source: CalFIRE 2020

Climate change projections indicate that the Delta will not experience a significant increase in exposure to wildfire. However, climate change is projected to increase wildfire frequency and severity in areas surrounding the Delta, by stressing forests, altering wind patterns, and lengthening fire season (Westerling & Bryant 2006). Wildfires in other parts of the state can create hazardous air quality conditions downwind, affecting the health of Delta residents.

Exposure to wildfire smoke is highly dependent on the fire location, wind, temperature, and humidity, and is difficult to predict on a daily basis let alone at a climatic scale (Stone et al. 2019). However, recent data indicates that northern California has among the longest duration and highest levels of fine particulate matter from large fires (Rappold et al. 2017), suggesting the Delta may have relatively high exposure in the future.

Wildfire smoke is a significant source of fine particulate matter, carbon monoxide, ozone, and toxic chemicals (Lipsett et al. 2008, McCall 2018). Toxic chemicals in wildfire smoke, such as formaldehyde and benzene, are believed to contribute to long-term adverse health impacts such as heart and lung disease, and cancer (Stone et al. 2019). Infants, children, pregnant women, older adults, and people with existing heart and lung conditions are particularly sensitive to these air pollutants.

Particulate matter inhalation has been linked to increased hospitalizations for cardiovascular conditions, stroke, asthma, bronchitis, and other respiratory conditions (McCall 2018) and premature death (Stone et al. 2019). Similar to the populations sensitive to extreme heat, people with existing cardiovascular disease, asthma, and chronic obstructive pulmonary disease (COPD) are particularly sensitive (Stone et al. 2019). Older adults, children, and pregnant women are physiologically more sensitive to smoke inhalation (Stone et al. 2019). Children’s lungs are still developing, and they breathe in more air per pound of body weight than adults (Lipsett et al. 2008, Stone et al. 2019). Children are more likely to be exposed to wildfire smoke because they spend more time outside and engage in more physical activity. Pregnant women’s exposure to smoke during the 2003 Southern California wildfires was linked to lower birth weights (Breton et al. 2011, Holstius et al. 2012).

As with the other climate change hazards described above, low-income communities and people of color are likely to be disproportionately impacted by wildfire hazards because these populations suffer from high rates of various health conditions (Stone et al. 2019). Reducing exposure to wildfire smoke requires adaptation measures similar to those recommended for extreme heat: staying indoors, using air conditioning (or air filters), or evacuating (Stone et al. 2019). Housing quality can also be a significant factor in a household’s exposure to harmful components of wildfire smoke in indoor air (Joseph et al. 2020). Low socioeconomic status households are more likely to live in buildings of lower quality and are less likely to have access to air conditioning or other air filtration systems, and are thus more likely to be exposed to poor indoor air quality during wildfire smoke events (Joseph et al. 2020; Stone et al. 2019). Thus, the same populations face increased exposure and reduced adaptive capacity to wildfire smoke: outdoor workers, individuals experiencing homelessness, low-income households, renters, African Americans, Latinos, and households that lack vehicle access (Stone et al. 2019). Smokers may also fail to take protective measures, and may therefore be vulnerable, due to perceptions that they will not be affected (OPR 2017b).

Rappold et al. (2017) developed the Community Health-Vulnerability Index (CHVI) to measure vulnerability to wildfire smoke at a national level. The underlying health data for the index are not publicly available, but the structure of the index provides a useful starting point for the Council to understand vulnerability to wildfire smoke within the Delta. Given the close relationship between vulnerability to wildfire smoke, and vulnerability to air pollution (fine particulate matter, in particular) other tools that were developed to focus on air pollution can help supplement information on social vulnerability to this climate change hazard (CDPH 2019a, OEHHA 2017).

1.4 Existing Data and Studies

1.4.1 Existing Vulnerability Indices

A multitude of existing vulnerability indices are available, and potentially useful as screening tools or data sources for identifying the most vulnerable populations with respect to climate change in the Delta (Raval et al. 2019). Of these, Council staff identified and evaluated eight indices with publicly available data for applicability to Delta Adapts, drawing primarily from state guidance (OPR 2018, OPR 2017a). **Table 1** summarizes and compares the main characteristics of each index. Detailed descriptions of each index are provided below.

Table 1. Index Characteristics

Index	Spatial Resolution	Indicators	Domains
CalEnviroScreen	Census tract	20	(4) pollution exposure, environmental effects, sensitivity, socioeconomics
CHAT / HHAI	City, county, census tract	16	(1) heat / (3) social, health, environmental
CCHVIz	County, census tract	21	(3) climate change exposure, sensitivity, adaptive capacity
DAC Mapping Tool	Census place, tract, block group	1	(1) income
DCI	City, county, zip code	7	(1) economic distress
HPI	Census tract	25	(8) economics, education, healthcare, housing, social, neighborhood conditions, environment, transportation
ROI	County, zip code, census place, tract	33	(6) education, economic, housing, transportation, health, civic life
SoVI	County, census tract, block group	29	(8) wealth, race, age, health insurance, special needs, employment, gender

1.4.1.1 CalEnviroScreen

Available at: https://oehha.ca.gov/calenviroscreen

The California Communities Environmental Health Screening Tool (CalEnviroScreen) was developed by the Office of Environmental and Health Hazard Assessment (OEHHA) for CalEPA to guide public investments and policy decisions to benefit communities that are most burdened by environmental contamination and pollution (OEHHA 2017). State agencies are encouraged to use CalEnviroScreen to comply with EO B-30-15 (OPR 2017a). In addition, local agencies are encouraged to use CalEnviroScreen to comply with SB 1000 (OEHHA 2017, OPR 2018). The index was vetted through a public process and is in its third iteration (Version 3.0).

The index is calculated from 20 different indicators across four domains: exposure, environmental effects, sensitivity, and socioeconomic factors. Indicators were selected to represent widespread concerns related to pollution in California, based on data sources available for the entire state (OEHHA 2017). Pollution burden indicators were selected to relate to issues that may be potentially actionable by CalEPA boards and departments (OEHHA 2017). For each indicator, OEHHA provides a literature review summarizing its relevance to health, and a summary of data sources, methods, and limitations. Each indicator is normalized across all census tracts in the state.

OEHHA developed a weighting scheme for the index based on scientific evidence of the relative contribution of each domain to environmental justice (OEHHA 2017). The exposure and environmental effects domains are averaged to calculate a pollution burden score, with the exposure score weighted twice that of environmental effects. The sensitive population and socioeconomic domains are averaged to calculate a population characteristics score. Finally, the pollution burden and population characteristic scores are multiplied. OEHHA (2017) documents several reasons for this weighting scheme, including evidence in the scientific literature of effect modifiers that multiply the effects of pollution burden by 3 to 10 times; and based on established risk assessment and scoring methods.

Data are publicly available for download as shapefiles (for use in geographic information systems [GIS]) or tabular/spreadsheet formats for both the overall index scores and for individual indicators. OPR (2018) and Seim (2019) identify and recommend specific indicators from CalEnviroScreen for use in local general plans and Delta Adapts, respectively.

Census tracts with scores in the top quartile statewide are eligible to benefit from an earmarked share of Greenhouse Gas Reduction Funds (GGRF) under AB 1550, which requires that 25 percent of funds be allocated for projects located in and benefitting disadvantaged communities as identified by CalEPA (*Health & Saf. Code* §39711[a]). Tracts in the Delta with scores in the top quartile are concentrated in the South Delta, particularly in Stockton, Lathrop, Manteca, and Tracy (Appendix B, Figure B-1). Tracts in portions of Pittsburg, Antioch, Oakley, Sacramento, and West Sacramento also fall within the top quintile.

SB 1000 uses the same definition of disadvantaged communities as AB 1550 (*Gov. Code* §65302[h]). Thus, using CalEnviroScreen to identify focal communities for Delta Adapts would align with both local government planning needs and potential funding sources.

1.4.1.2 California Heat Assessment Tool

Available at: https://www.cal-heat.org

The California Heat Assessment Tool (CHAT) was developed for California's 4th Climate Change Assessment on behalf of the California Natural Resources Agency, to provide information about vulnerability to extreme heat events (CEC 2020).

Various dimensions of extreme heat events, including absolute and relative maximum and minimum daily temperatures, and duration, all contribute to health impacts. CHAT is based on the combination of these dimensions that has the greatest statistical relationship to local increases in emergency room visits. The statistical relationship is then used to forecast future Heat Health Events (HHEs) using an ensemble of downscaled climate change projections and models (Steinberg et al. 2018). CHAT defines HHEs as "any event that results in negative public health impacts, regardless of the absolute temperature" (CEC 2020).

CHAT provides an online interface in which users can view the annual number of projected HHEs, and the individual dimensions of extreme heat events, at a census tract level. Users can also download projections in tabular format.

CHAT also developed and published a Heat-Health Action Index (HHAI) that identifies social vulnerability to extreme heat. The index is calculated from 16 different indicators across three domains: social (including indicators such as poverty, linguistic isolation, and educational attainment); health (e.g. asthma rates, low birth weight infants); and environmental (e.g. impervious cover and tree canopy). Indicators were identified from the California Building Resilience Against Climate Effects (CalBRACE) program (which developed CCHVIz, discussed in the next section) and from CalEnviroScreen. Transit-access and urban heat island effects were identified as contributing factors but omitted from the index because available data only covered urban areas (Steinberg et al. 2018).

A principal components analysis was used to group indicators into domains and to determine each domain's contribution to variation in heat vulnerability. The domain weights were then used to calculate a social vulnerability score for each census tract, with final scores scaled from 1 to 100. Data sources and methods are summarized in Steinberg et al. (2018).

Based on CHAT, the Delta is projected to experience a moderate number of HHEs compared to other parts of California. However, the HHAI identifies four census tracts in Stockton[5] and one tract in West Sacramento as highly socially vulnerable to heat (CEC 2020) (Figure B-2).

1.4.1.3 Climate Change & Health Vulnerability Indicators

Available at: https://discovery.cdph.ca.gov/ohe/CCHVIz

Climate Change & Health Vulnerability Indicators (CCHVIz) is a data visualization tool developed by the California Building Resilience Against Climate Effects (CalBRACE) program. CalBRACE is a

[5] Based on the HHAI, Census tract number 6077000100 in Stockton has the highest social vulnerability to heat in the state, with a score of 100.

project of the California Department of Public Health (CDPH) that provides resources and technical assistance on climate adaptation to public health departments in California (CDPH 2019a). CCHVIz was developed to help state and local agencies plan to meet the needs of the communities most at risk of harm from climate change (CDPH 2019b). In addition, OPR recommends CCHVIz as a resource for complying with SB 1000 (OPR 2018).

CCHVIz is based on the concept that overall community vulnerability to a particular climate change hazard is a function of exposure, sensitivity, and adaptive capacity, which aligns with the definition of vulnerable communities in OPR guidance (2018). CCHVIz consists of a set of 21 indicators that represent exposure, sensitivity, and adaptive capacity to one or more climate change hazards. For each indicator, CDPH provides a literature review summarizing its relevance to health, and a summary of data sources, methods, and limitations.

The “Vulnerability” visualization tool allows users to select an exposure indicator and a sensitivity or adaptive capacity indicator in order to view the resulting vulnerability at a county level. However, the tool does not calculate an overall vulnerability score, and does not provide for visualizing combinations of more than two indicators at a time. Therefore, CCHVIz does not account for the cumulative effects of multiple sensitivity factors and cannot be used on its own to screen for the most vulnerable populations.

CCHVIz may be more useful to the Council as a source of individual indicator data, rather than as an index. The “Single Indicator” tool allows users to select an indicator and visualize or download the scores at a census tract level relative to all tracts in the state. The six exposure indicators include projected extreme heat days, ozone concentration, particulate matter concentration, drought, projected sea level rise, and wildfire. There are 11 sensitivity indicators and four adaptive capacity indicators. OPR (2018) and Seim (2019) identify and recommend specific indicators from CCHVIz for use in local general plans and Delta Adapts, respectively.

1.4.1.4 Disadvantaged Communities Mapping Tool

Available at: https://gis.water.ca.gov/app/dacs

The California Department of Water Resources (DWR) developed the Disadvantaged Communities (DAC) Mapping Tool to help screen communities in California for Proposition 1 Integrated Regional Water Management (IRWM) funding. The tool is also intended as a resource for local governments to fulfill their responsibilities related to the California Water Plan and the Sustainable Groundwater Management Act (SGMA) (DWR 2019).

The DAC Mapping Tool is based on a definition of disadvantaged community that differs markedly from that used to develop CalEnviroScreen and to comply with SB 1000. For the purposes of the DAC Mapping Tool, “‘Disadvantaged Community’ means a community with a median household income less than 80 percent of the statewide average” (Pub. Resources Code §75005[g]). This is the same definition as that of a low-income community in the Health and Safety Code (§39713[d][2]). Under AB 1550, five percent of GGRF must be allocated to projects located within, and benefiting individuals living in these low-income communities. Thus, using the DAC Mapping Tool to identify focal communities for Delta Adapts would align with projects that were awarded Prop 1 IRWM or GGRF funding, as well as with potential future GGRF or other DWR grant awards.

With only a single indicator, the DAC Mapping Tool does not account for the cumulative effects of multiple sources of disadvantage or vulnerability. Communities are identified as either above or below the 80 percent median household income threshold ($51,026 for the 2012-2016 ACS 5-year average). The index and threshold were developed by legislation, not through a scientific, peer-reviewed process. However, other analyses have found this indicator to be a strong predictor of environmental health outcomes (Delany et al. 2018).

Based on the 2016 tool, disadvantaged communities are distributed throughout the Delta and Suisun Marsh, suggesting that the Delta has many economically disadvantaged communities relative to the state as a whole. Tracts in Stockton, Pittsburg, Antioch, Fairfield/Suisun Marsh, West Sacramento, Sacramento, and Tracy are identified – as well as tracts in the unincorporated areas of Sacramento and San Joaquin Counties (Figure B-3).

1.4.1.5 Distressed Communities Index

Available at: https://eig.org/dci

The Distressed Communities Index (DCI) was identified for evaluation because it was referenced in public comments submitted to the Council by Restore the Delta and the Environmental Justice Coalition for Water with regard to environmental justice (Restore the Delta and EJCW 2017).

The Economic Innovation Group (EIG) created the Distressed Communities Index (DCI) to measure place-based economic opportunity before and after the Great Recession, and to understand how the distribution of opportunity in the U.S. has changed over time. EIG is a think-tank that conducts economic research and advocates for public policy to reduce economic inequality, create jobs, and encourage entrepreneurship. The EIG highlights the U.S. Treasury Department's Opportunity Zones program as a good example of public incentives for private investment in distressed areas (EIG 2019). However, the DCI itself does not appear to be the basis for any existing funding or investment programs. Therefore, using this index for Delta Adapts would not have the benefit of aligning with state and local programs.

This is the only index evaluated that consider the direction of change over time. The index is calculated from seven socioeconomic indicators including educational level, housing vacancy, adults not working, poverty, area median income as a percentage of state median income, change in employment, and change in the number of business establishments. Scores for each indicator are ranked, normalized, and averaged to calculate the overall DCI score. Indicators are weighted equally in the overall score. Scores are calculated at the scale of cities, counties, congressional districts, and zip code tabulation areas. The DCI defines the most distressed areas as those with the highest 10 percent of distress scores. Notably, Stockton is ranked among the top 10 most distressed cities in the Unites States (EIG 2016, p 26).

Data are not available for download but can be viewed through a variety of interactive maps. The "U.S. Zip Codes by State" visualization tool allows users to select a state in order to view the DCI scores at the zip code level and its rank relative to all zip codes in the state. The EIG does not provide a scientific justification for the selection of indicators or the equal-weighting scheme, and does not appear to be peer reviewed, but a summary of the methodology is publicly available (EIG 2016).

1.4.1.6 Healthy Places Index

Available at: https://healthyplacesindex.org

The California Healthy Places Index (HPI) was developed by the Public Health Alliance of Southern California in partnership with Virginia Commonwealth University's Center on Society and Health. The purpose of the index is to target California Department of Public Health (CDPH) projects and resources to areas with the greatest cumulative extent of deprivation (Delany et al. 2018). State agencies are encouraged to use HPI to comply with EO B-30-15 (OPR 2017a). In addition, local governments are encouraged to use HPI to implement SB 1000 guidance in their general plans (OPR 2018). Thus, using HPI to identify focal communities for Delta Adapts would align with local government planning needs.

The index is comprised of 25 indicators that fall within eight thematic domains: economics, education, healthcare, housing, social, neighborhood conditions, environment, and transportation. Indicators were selected based on their relationship to public health and health outcomes, as identified in the scientific literature, then screened for a statistically significant correlation to life expectancy at birth, prior to inclusion in the index. Data sources and methods are summarized. Each indicator is normalized across all census tracts in the state.

Thematic domain scores are calculated as the arithmetic average of the z-scores of individual indicators. The index weights domain scores based on their statistical contribution to life expectancy. The economic domain is weighted most heavily (32 percent); the healthcare, housing, and environment domains were each assigned the minimum weight (5 percent) (Delany et al. 2018). Tracts in the bottom quartile are identified as the most disadvantaged, or those with the least opportunity to improve their health conditions (Delaney et al. 2018). Tracts with scores in the bottom quartile are located at the edges of the Delta and Suisun Marsh, including portions of Fairfield/Suisun Marsh, Pittsburg, Stockton, Sacramento, and West Sacramento (Figure B-4).

HPI data are publicly available for download in GIS or tabular/spreadsheet formats for both the overall index scores and for individual indicators. OPR (2018) and Seim (2019) identify and recommend specific indicators from HPI for use in local general plans and Delta Adapts, respectively.

A Steering Committee of 20 public health practitioners and researchers advised on the development of the index, and a Communications Committee comprised of community organizations, researchers, and staff advised on reframing the index through an asset-based lens and increasing the accessibility and transparency of the inputs. The index was updated in 2017 to include more recent data and incorporate new methods to predict health outcomes (Delany et al. 2018). The index is in its second iteration (Version 2.0).

1.4.1.7 Regional Opportunity Index

Available at: https://interact.regionalchange.ucdavis.edu/roi/webmap/webmap.html

The UC Davis Center for Regional Change created the Regional Opportunity Index (ROI) to help banks, policymakers, advocates, and other organizations target resources and policies to communities with high levels of vulnerability (UC Davis 2019). State agencies are encouraged to use ROI to comply with EO B-30-15 (OPR 2017a). In addition, a Delta-specific version of the ROI was developed to inform the Delta Protection Commission's updates to the Economic Sustainability Plan (ESP) (Benner 2015).

The ROI is comprised of 33 indicators selected to represent educational, economic, housing, transportation, health, and civic life opportunities. These six categories of opportunity, or domains, were identified based on their relationship to community development and well-being (UC Davis 2016). Data sources and methods are summarized. Each indicator is normalized across all census tracts in the state.

Domain scores are calculated as the geometric average of the scaled z-scores of individual indicators. The ROI actually consists of two indices: "people" and "place." These represent the joint influence of social variables and the built environment on opportunity – a structure that aligns with OPR's definition of vulnerable communities. The final "people" and "place" index scores are the geometric means of their component domain scores.

ROI ranks census tracts based on quintiles for each index, with the bottom quintile representing the least opportunity. Stockton, Pittsburg, Antioch, Sacramento, and West Sacramento all have tracts that offer the least opportunity on the "people" index (Figure B-5). Several rural tracts in the Central and South Delta (Contra Costa and San Joaquin Counties) have the lowest opportunity on the "place" index, along with many of the same urban tracts that ranked poorly on the "people" index (Figure B-6).

ROI data are publicly available for download in tabular/spreadsheet formats for both the overall index scores and for individual indicators. Seim (2019) identifies and recommends specific indicators from ROI for use in Delta Adapts.

1.4.1.8 Social Vulnerability Index

Available at: https://coast.noaa.gov/digitalcoast/data/sovi.html

The Social Vulnerability Index (SoVI) was developed in 2003 by Susan Cutter, at the University of South Carolina, to enable science-based comparisons of hazard vulnerability among diverse places. The National Oceanic and Atmospheric Agency (NOAA), one of the Council's federal partners, has identified SoVI as a resource for state and local coastal adaptation planning. The index was included in the Council's evaluation because there are two examples of its use within the region. The Bay Conservation and Development Commission (BCDC) used SoVI for its initial Adapting to Rising Tides (ART) vulnerability analysis (Nutters 2012). Burton & Cutter (2008) applied SoVI to understand social vulnerability related to levee failure in the Delta.

The index is based on a conceptual model that relates hazard potential to place-based social factors, including experience and perception of hazards as well as economic, demographic, and housing characteristics (Cutter et al. 2003). For the original index, 42 indicators were selected based on a relationship to social vulnerability in the literature, and a principal components analysis was used to identify and rank the top contributors to vulnerability. The analysis identified 11 factors, or domains, and combined the indicators that comprised each of these factors to produce the composite SoVI score. Final scores were represented as z-scores. Development and application of SoVI is documented in numerous peer-reviewed publications.

The University of South Carolina's Hazards and Vulnerability Research Institute has updated SoVI multiple times. The earliest version used Decennial Census data and was available at the block group level. A 2010 iteration of the tool adjusted and reduced the number of indicators to 29, spread across 7 domains, at the census tract level (HVRI 2019). The 2006-2010 version of SoVI is available to download in both GIS and tabular/spreadsheet format from NOAA's Digital Coast website (NOAA 2019). A 2014 version for the tool is available only at the county level.

The 2010 SoVI statewide data does not identify many locations within the Delta or Suisun Marsh as highly socially vulnerable (1.5 standard deviations above the statewide mean). Only a handful of block groups in West Sacramento, South Sacramento, Stockton and Pittsburg are flagged in this category. Burton & Cutter (2008) used a different classification scheme to rank social vulnerability within the Delta (Yolo, Sacramento, and San Joaquin Counties only): tracts scoring in the top quintile relative to the Delta. Based on this threshold, tracts with the highest social vulnerability were those in Stockton and unincorporated areas in the South Delta (Figure B-7).

1.4.2 Additional Data Sources

Nearly all of the indices evaluated above are calculated at the census tract level. The geographic nature of these indices is an important consideration because it assumes that the spatial units represent discrete communities that share common characteristics. Census tracts are drawn based on population (tracts may contain between 1,200 and 8,000 people) such that more populous areas (e.g. Stockton and Sacramento) tend to have more, smaller tracts than less populous areas. In rural and unincorporated areas with lower population density, local characteristics are averaged across much wider areas. Thus, socially vulnerable communities within those larger areas may be "averaged out" when looking at indices or metrics at the census tract level.

Another potential shortcoming of the existing vulnerability indices is a reliance on readily available environmental and demographic data as proxies for the factors that increase sensitivity or reduce capacity to adapt to specific climate change hazards. Several of the indices acknowledge that relevant factors were omitted due to lack of geographic coverage or reliable updates (OEHHA 2017, Steinberg et al. 2018, UC Davis 2016). This section identifies additional data sources and methods that are available to fill these gaps.

1.4.2.1 Census Block Groups and Places

Many of the demographic and economic indicators used to capture sensitivity and adaptive capacity in the indices described above are based on data from the American Community Survey

(ACS), an annual survey conducted by the Census Bureau to supplement the Decennial Census. Most of the data available at the census tract level are also available for census block groups. Block groups are statistical divisions of census tracts, drawn to contain between 600 and 3,000 people. Thus, indicators that are available at a block group scale can capture more spatial variation than tract-level information.

Similarly, most of the data are also available for incorporated places and Census Designated Places (CDPs), which can collectively be queried as “places.” CDPs are named, unincorporated areas that have a concentration of people, housing, and commercial structures (Census Bureau 2019). ACS data are available at the place-scale for nine of the 11 legacy communities in the Delta.[6] Thus, some demographic indicator data could be queried at this scale and used to better understand the spatial variation in specific elements of vulnerability. Because the ACS is based on a sample rather than population survey, there is a margin of error associated with the data. The margin of error is larger for smaller geographic areas and for shorter time periods. Therefore, use of ACS data at this scale would require quality control to ensure that there is a reasonable confidence interval around the estimate.

1.4.2.2 Disadvantaged Unincorporated Communities

Even CDP data may fail to capture the spatial granularity of vulnerable populations in California. PolicyLink, working with California Rural Legal Assistance, found that many of the most disadvantaged communities in the rural San Joaquin Valley were not identified as places or delineated as CDPs by the Census Bureau (Flegal et al. 2013). These communities often lack basic infrastructure and safe housing, characteristics that OPR identifies as increasing vulnerability to climate change (OPR 2017b). Flegal et al. (2013) contend that these areas are disadvantaged precisely because they are often unmapped and unnamed, lacking data and representation to attract funding and services. London et al. (2018) cite other historical factors, including growth management frameworks that focused local and state funding, infrastructure, and development in incorporated urban areas.

PolicyLink developed a methodology for mapping and identifying these disadvantaged unincorporated communities (DUCs) using Census data, local parcel data, and aerial imagery (Flegal et al. 2013). The method identified unincorporated areas with a density of at least 250 parcels per square mile, located within block groups with a median household income less than 80 percent of the statewide average. The approach was carried out within the San Joaquin Valley and identified 51 DUCs within San Joaquin County. Several of these are located within the Legal Delta, including New Hope, Terminous, and Thornton (Figure B-8).[7] This data was recently used to identify gaps in the provision of safe and affordable drinking water (London et al. 2018).

[6] Locke is included as part of the Walnut Grove CDP geographic area, and Ryde is not available as a CDP.

[7] CDP data is available for Terminous and Thornton.

The Contra Costa Local Agency Formation Commission has identified Bethel Island as a DUC (Contra Costa LAFCo 2019).[8] No DUCs have been identified in the remaining counties within the Legal Delta (Alameda LAFCo 2018, Yolo LAFCo 2018, Solano LAFCo 2015).

1.4.2.3 Community Surveys and Workshops

There are also precedents for conducting surveys to collect supplementary information about community sensitivity and adaptive capacity at alternative scales. For example, the State Water Resources Control Board (SWRCB) funds income surveys in small, unincorporated communities in order to determine eligibility for funding for water system improvements. Thus, the legacy town of Locke (which does not have its own CDP) was determined to have a median household income of $22,000, which is well below the “disadvantaged” threshold of 80 percent of state median household income (RCAC 2018).

Surveys can also be used to understand more qualitative aspects of sensitivity and adaptive capacity. For example, the cohesion and willingness of local residents to work together has been identified as a contributor to community adaptive capacity (Kusel 2019, Norris et al. 2008) but is not regularly or readily measured. The Sierra Institute for Community and Environment asked workshop participants to rate their community’s financial, social, human, cultural, and physical capital on a Likert scale. The researchers then used the survey data to develop an index of community capacity (Kusel 2019). While the Sierra Institute project was focused on rural counties in the Sierra Nevada Mountains, the methodology could be replicated to understand community capacity to adapt to climate change within the Delta.

1.4.3 Local and Regional Plans

A variety of existing plans and studies have applied the indices and indicators described above to identify vulnerable populations within the Legal Delta. The Council reviewed these plans and studies both as precedents for Delta Adapts, and as opportunities to align the Delta Adapts approach and focus areas.

1.4.3.1 Regional Transportation Plans

Under Title VI of the Civil Rights Act and Executive Order 12898, Metropolitan Planning Organizations (MPOs) are required to evaluate whether their Regional Transportation Plans (RTPs) benefit low-income and minority communities equitably, and whether transportation investments have any disproportionate negative effects on minority and/or low-income populations. While these requirements differ from those of EO 15-B-30, the MPOs with jurisdiction in the Delta all incorporate additional indicators of vulnerability into their screening approach. Their approach to applying these indices and indicators to a transportation equity analysis may be informative for the purposes of Delta Adapts.

There are three MPOs with planning areas that include land within the Delta and Suisun Marsh: the Sacramento Area Council of Governments (SACOG), the San Joaquin Council of Governments

[8] CDP data is available for Bethel Island.

(SJCOG), and the Metropolitan Transportation Commission (MTC). In accordance with federal and state guidance, all three MPOs use indicators based on race and ethnicity, and the federal poverty level to identify concentrations of minority and low-income households, respectively (**Table 2**).

Table 2. Low-Income, High-Minority Indicators in RTPs

Indicators	SACOG Draft 2020 MTP/SCS	SJCOG 2018 RTP/SCS	MTC Plan Bay Area 2040
Households earning less than a threshold relative to the federal poverty level	More than 45% of households; 200% of poverty level	More than 30% of households; 100% of poverty level	More than 30% of households; 200% of poverty level
Hispanic and non-White households	More than 70% of households	More than 75% of households	More than 70% of households
Spatial resolution	Census block group	Census block group	Census tract

The federal poverty level accounts for household size and family composition, whereas measures of median household income (such as the indicator used by the DAC Mapping Tool) may be confounded by such factors. SACOG and MTC focus on areas with concentrations of households earning less than 200 percent of the federal poverty level, to account for their higher cost of living relative to the rest of the nation (MTC-ABAG 2017, SACOG 2019).

Based on these indicators, several communities in the Delta are identified as low-income or high-minority. In the SACOG region, Isleton and the unincorporated areas of Sacramento County downstream are flagged as low-income, along with portions of West Sacramento (SACOG 2019). The block group that includes Walnut Grove and Locke is flagged as high-minority, along with portions of West Sacramento and the Pocket in Sacramento. Other block groups in West Sacramento are flagged as both low-income and high-minority. SJCOG identifies many block groups in the southern half of Stockton as both low-income and high-minority. Large portions of Lathrop along Highway 5 are identified as low-income, along with several block groups in Tracy and Manteca (SJCOG 2018). MTC identifies low-income and high-minority tracts in Pittsburg, Antioch, and Oakley, and low-income tracts in Rio Vista, Brentwood, and Bethel Island (MTC-ABAG 2017, Map 4).

Each of the MPOs also incorporate additional indicators of vulnerability into their screening approach (Table 3). These factors have all been found to compound the disadvantages already faced by low-income communities and communities of color, and to increase vulnerability to climate change (OPR 2017b). For example, all three MPOs flag areas with higher concentrations of linguistically isolated households. As described earlier in this memo, OPR guidance notes that linguistically isolated households are more vulnerable to climate change impacts, such as flooding and extreme heat events, because they have more limited access to or understanding of emergency alerts, health warnings, and safety information than the general population (OPR 2017b). This factor is compounded by low socioeconomic status, among other factors (OPR 2017b).

Because vulnerability increases when multiple factors are present, the MPOs screen for the communities with multiple, overlapping concentrations of these indicators (Table 3).

Table 3. Other Indicators of Vulnerability in RTPs

Indicators	SACOG Draft 2020 MTP/SCS	SJCOG 2018 RTP/SCS	MTC Plan Bay Area 2040
Number of indicators required to flag area	4	Range (1 to 4)	3, and low-income
Older Adults aged 75 or more	Top quintile in region	Above County average	More than 10% of households
Linguistically Isolated Households	Top quintile in region	Above County average	More than 20% of households
Single Parent Households with Children under the age of 18	Top quintile in region	Above County average	More than 20% of households
Less than a High School Diploma or GED for the population aged 25 or more	Top quintile in region	*Not included*	*Not included*
Households that spend 50% or more of their income on housing costs	Top quintile in region (renter and owner households)	*Not included*	More than 15% of renter households
Households with at least one person with a disability	Top quintile in region	*Not included*	More than 25% of households
Zero-vehicle households	*Not included*	Above County average	More than 10% of households

SACOG's screening approach did not identify any vulnerable communities within the Delta (SACOG 2019). SJCOG identifies block groups primarily within Stockton that meet all four of its criteria (SJCOG 2018). MTC's approach identifies a high concentration of census tracts within Pittsburg and Antioch, with the highest levels of disadvantage in Pittsburg (MTC-ABAG 2017, Map 2).

Finally, all of the MPOs used CalEnviroScreen to screen for vulnerability. SACOG included any block groups within tracts with scores in the top quartile. SJCOG included any block groups within tracts with scores in the top quartile of CalEnviroScreen, if those block groups were also either low-income or high-minority. SJCOG used this additional screening method because such a high share of block groups in its planning area have high CalEnviroScreen scores (SJCOG 2018). MTC uses CalEnviroScreen, as well as HPI and the Communities Air Risk Evaluation tool, to evaluate the vicinity of communities of concern to sources of air pollution, such as heavy truck traffic (MTC-ABAG 2017, Map 33).

1.4.3.2 Adapting to Rising Tides

The Bay Conservation and Development Commission's (BCDC) Adapting to Rising Tides (ART) program builds on MTC's approach to identifying Communities of Concern (ABAG and BCDC 2014). ART brings together local, regional, state and federal agencies and partner organizations to identify how current and future flooding will affect communities, infrastructure, ecosystems, and the economy in the Bay-Delta Estuary (BCDC 2019). Two recent ART projects cover portions of the Delta and Suisun Marsh: the ART Bay Area Regional Sea Level Rise Vulnerability and Adaptation Study and the ART East Contra Costa Vulnerability Assessment & Adaptation Project.

BCDC first updated the set of indicators used to identify Communities of Concern in order to screen communities specifically for natural disasters, including flooding and earthquakes. Between 2014 and 2017, BCDC updated the approach again to focus on vulnerability to sea level rise. The final set of indicators included housing tenure, age, income, citizenship status, vehicle access, disability status, single parent families, race/ethnicity, linguistic isolation, educational attainment, and housing cost burden (BCDC 2020). Census block groups which score in the 70th percentile for at least eight indicators or in the 90th percentile for at least six indicators are considered the most vulnerable (BCDC 2020). For the vulnerability analysis, BCDC mapped exposure to 12 and 36 inches of sea level rise, and highlighted communities where projected sea level rise overlaps with high social vulnerability (BCDC 2020).

In addition to the regional vulnerability analysis, the Bay Area Regional Health Inequities Initiative (BARHII) was contracted to select two communities for a deeper level of engagement in the adaptation planning process. BARHII used sites identified through the ART vulnerable communities assessment process, and supplemented these with sites identified through other, complementary programs. Sites were scored across a variety of indicators, including HPI score, life expectancy, displacement, sea level rise exposure, seismic/housing risk, extreme heat, and local capacity (BARHII 2018). Ultimately, the team selected East Palo Alto and East Contra Costa County for focused outreach, partnering with two community-based organizations to lead public workshops with local residents.

ART's approach to planning for the most vulnerable populations is a particularly valuable precedent for Delta Adapts, as it shares a focus on vulnerability to flooding. The Council is a partner on the ART East Contra Costa project, and aligning Delta Adapts with this project's approach would help each initiative integrate the findings of the other.

1.4.3.3 Local General Plans

The Council also seeks to ensure that its approach aligns with existing local and regional planning initiatives and can inform and support future local and regional planning efforts – particularly compliance with SB 379 and SB 1000.

The City of Stockton was the first local agency within the Legal Delta to update its general plan after SB 1000 went into effect. The Envision Stockton 2040 General Plan uses CalEnviroScreen as the basis for identifying disadvantaged communities (City of Stockton 2018). Areas that scored in the top quartile within the Delta include Trinity/Northwest Stockton, South Stockton, the Port area, portions of the Industrial Annex, and portions of Westin/Van Buskirk.

The City also analyzed and identified Disadvantaged Unincorporated Communities in its Sphere of Influence, following the PolicyLink approach and OPR guidance (City of Stockton 2018). Several of these DUCs are within the Legal Delta, including Boggs Tract, the East Interstate 5 Community, the Holt Ave/Pershing Ave Community, the Pershing Ave Community, and the West Interstate 5 Community (City of Stockton 2018).

Sacramento County adopted an Environmental Justice element in December 2019. The general plan element identified four environmental justice communities using CalEnviroScreen in combination with low-income and high-minority block groups (based on SACOG's methodology) (Sacramento County 2019). None of the environmental justice communities identified in the plan element are located within the Delta (Sacramento County 2019).

Several other local agencies are in the process of updating their general plans, and as such, are working to identify disadvantaged communities and develop their environmental justice goals, policies, and objectives. Contra Costa County, the City of Manteca, and the City of Pittsburg are all using CalEnviroScreen as the basis for identifying disadvantaged communities (City of Manteca 2019, Contra Costa County 2019, De Novo Planning Group 2019).

1.4.4 Data Gaps

Several of the indices and plans reviewed above are applicable to the climate change hazards that Delta Adapts will study. However, each has some limitation that also limit its utility for the VA.

Many vulnerable populations are not well captured by existing indices and indicators. For example, homelessness, gender identity, and sexuality are not tracked by the Decennial Census nor ACS and are not captured in any of the indices reviewed (Roos 2018). The health information that would inform population sensitivity to extreme heat and wildfire smoke is suppressed at smaller geographic scales, for privacy reasons.[9] Thus, existing indices that include health indicators must choose between conducting a county-level analysis (Rappold et al. 2017), applying county-level information to smaller geographic units (Cooley et al. 2012), or limiting the

[9] The public health effects of wildfire smoke exposure is a topic of growing interest, and currently research initiatives may provide more fine-grained data while Delta Adapts is ongoing. The University of California's Wildfire Induced Air Pollution Mitigation & Assessment Symposium (UCOP 2020) highlighted several research projects that Council staff will track and incorporate as timing allows.

analysis to a smaller set of health indicators that are available at the tract scale (Delaney et al. 2018, OEHHA 2017, Steinberg et al. 2018).

There are other data sources that could be used to supplement these indices and provide a more customized picture of social vulnerability to flooding, extreme heat, and wildfire in the Delta. Census block group and CDP data could provide finer-scale information for a more limited number of demographic indicators. However, not all indicators of sensitivity and adaptive capacity are available at these scales. Health indicators that are available at the census tract scale could be assigned to the block groups that each tract contains, but this type of downscaling does not work for CDPs, which cross census tract boundaries.

The ART social vulnerability index most closely aligns with the VA objective to identify the populations most vulnerable to flooding, but only covers Contra Costa County. The index could be extended to the other five Delta counties using readily available ACS data. CHAT/HHAI mostly closely aligns with the VA objective to identify the populations most vulnerable to extreme heat. However, the index is only available at the census tract scale, which may not capture variation in social vulnerability among the more rural, unincorporated areas of the Delta. CCHVIz, CalEnviroScreen, and HPI all contain indicators that are highly relevant to understanding vulnerability to wildfire smoke, but combine them with other indicators that are applicable to other types of environmental hazards. This may skew the results away from the populations most vulnerable to wildfire smoke.

The limitations of available spatial data underscore the importance of incorporating other types of information and input directly from community members (OPR 2017b, Raval et al. 2019, Roos 2018). The VA will not fill all data and knowledge gaps identified above but proposes an approach to mitigate for information gaps with local knowledge and input. This approach is discussed in the next Chapter.

CHAPTER 2. METHODS

2.1 Equitable Engagement

In accordance with best practice (Raval et al. 2019, Roos 2018), OPR guidance (2018, 2017b) and the Council's Public Participation Plan (Council 2020), the Council intends to engage with local stakeholders to ensure that the analysis methods (described in this Chapter) are sound, that information and data are accurate, that findings reflect on-the-ground conditions, that the adaptation strategies adequately consider vulnerable populations, and that the overall process is inclusive. Engagement will occur primarily through direct communications with community-based organizations (CBOs) and service providers. Engagement will occur throughout the Delta Adapts process.

The Council has identified at least six points at which information could be shared and feedback generated from outreach and engagement with CBOs and service providers. During the VA phase of Delta Adapts, these touchpoints include providing input on assets and social vulnerability, and reviewing and commenting on the draft VA. During the adaptation strategy phase, these touchpoints include helping to develop potential adaptation strategies, assisting with public outreach, reviewing and commenting on the draft adaptation strategy, and partnering with the Council to help implement adaptation strategies. The Council will engage with community-based organizations and service providers throughout both phases of the Delta Adapts process.

During the VA, the Council will consult and involve these stakeholders, by requesting feedback and making a concerted effort to ensure goals and concerns are incorporated (Council 2020, IAP2 2019). The results described in later sections of this memo represent feedback provided during the first two touchpoints described above.

During the adaptation strategy, the Council intends to engage more deeply with select CBOs for specific focus areas. On the spectrum of public participation, this level of engagement is expected to fall between "involve" and "collaborate" (Council 2020, IAP2 2019). The Council will seek to answer the questions on OPR's Equity Checklist to ensure that any policy, initiative, program or budget resulting from Delta Adapts advances equity and considers the most vulnerable populations (2017b).

In addition to Council-initiated outreach and engagement, the Council intends to align with concurrent outreach and engagement processes that are occurring at the local and community level within the Delta. Aligning with complementary planning initiatives and projects will help to minimize meeting fatigue, conserve resources, and align the outcomes of Delta Adapts with the outcomes and recommendations of other planning efforts. The Council has identified a preliminary list of such complementary planning initiatives and projects (Table 4).

Table 4. Complementary Planning Initiatives

Community	Complementary Planning Initiatives
City of Antioch	ART East Contra Costa Project City of Antioch Climate Action Resilience Plan
City of Lathrop	City of Lathrop General Plan Update
City of Manteca	City of Manteca General Plan Update
City of Oakley	City of Oakley General Plan Update
City of Pittsburg	ART East Contra Costa Project City of Pittsburg General Plan Update
City of West Sacramento	City of West Sacramento Climate Action Plan Update
Contra Costa County	ART East Contra Costa Project Contra Costa County General Plan Update

The opportunities to engage with stakeholders and members of the public through these complementary planning initiatives and projects are not likely to align with the Delta Adapts phases of work and are not expected to occur at the same frequency and depth as the Council's direct communications with CBOs and service providers. The level of engagement will be dictated by each complementary planning initiative's approach but is likely to trend closer to the "inform" end of the spectrum of public participation (Council 2020, IAP2 2019). The Council will seek to provide meaningful information about Delta Adapts to assist participants in understanding how it relates to, and in some cases could inform, the complementary initiative.

A summary of outreach and engagement with CBOs, service providers, and complementary planning initiatives will be included in supporting documents for the VA and adaptation strategy reports.

2.2 Assessing Vulnerability

As summarized in the **Conceptual Model and Definitions** section above, vulnerability is a function of exposure, sensitivity, and adaptive capacity. The VA will evaluate the exposure of a variety of assets, including Delta residents and communities, to flooding, extreme heat, and wildfire using the exposure data summarized in Table 5.

Table 5. Exposure Data

Hazard	Metric	Data Source	Scale
Flood	Joint probability of levee overtopping due to sea level rise and inflows	Delta Stewardship Council flood model	Custom
Extreme Heat	Projected days with maximum temperatures exceeding the 98th percentile	Cal-Adapt	Census tract
Wildfire	None; wildfire smoke exposure is considered uniform within the Delta	Not applicable	Not applicable

In order to be consistent with the overall Delta Adapts initiative and avoid duplication of effort, the focus here will be on identifying communities with higher sensitivity and/or lower adaptive capacity to the three climate hazards, relative to other communities in the Delta, i.e. socially vulnerable communities. The exposure analysis will be conducted for all assets in the VA. The intersection of the exposure data with the socially vulnerable communities will highlight the *most vulnerable* communities for each climate hazard. The approach described below has been, and may continue to be, revised based on stakeholder input.

2.3 Preliminary Approach

The Council initially proposed to leverage the detailed research, expert review, and stakeholder input invested in CalEnviroScreen to identify social vulnerability in the Delta, rather than developing a custom index.[10] While CalEnviroScreen is focused on vulnerability to present-day environmental pollution and contamination, rather than vulnerability to climate change, it reflects the idea that communities facing socioeconomic disadvantages and environmental injustices are more vulnerable to additional shocks and stressors – including those caused by climate change.

The Council solicited input from CBOs, local agency staff, and subject-matter experts on the preliminary approach through:

- Direct phone calls and meetings with CBOs and service providers
- October 2, 2019 Stakeholder Work Group meeting
- October 10, 2019 Technical Advisory Committee meeting

All of the CBOs that were contacted for feedback on the preliminary approach were very familiar with CalEnviroScreen, and most expressed support for using it as the primary tool to identify communities with heightened vulnerability to climate change. In contrast, members of the Stakeholder Work Group and the Technical Advisory Committee noted that the factors that increase social vulnerability to climate change depend on the climate hazard, and the social

[10] This approach is documented in the October 3, 2019 draft version of this technical memo.

vulnerability index should reflect the specific hazards of interest. Multiple members suggested that CalEnviroScreen would not adequately capture community vulnerability to flooding because it was developed with a focus on environmental contamination and air pollution.

In addition, several members of the Stakeholder Work Group and the Technical Advisory Committee noted that a census tract-level index, such as CalEnviroScreen, did not provide a useful level of detail for the more rural portions of the Delta, particularly in Solano County. The members encouraged the Council to use more granular data sources, such as census places, to develop a more refined index.

2.4 Revised Approach

Based on the Stakeholder Work Group and Technical Advisory Committee input, the Council revised its approach and proposed to develop a custom social vulnerability index specific to the three climate change hazards of interest, using data at the smallest spatial scale available. As this scale remains coarse in more rural parts of the Delta, the approach recommends two additional datasets to represent socially vulnerable communities that are too small to be captured by the social vulnerability index. Finally, the approach identifies and describes other vulnerable populations that cannot be represented in the neighborhood-level social vulnerability index.

2.4.1 Indicator Selection

As evident in the review of existing vulnerability indices, there is no shortage of studies that have already reviewed public health literature and identified indicators of vulnerability. A comprehensive review of more than 40 vulnerability frameworks identified a set of indicators that have consistently been used to understand sensitivity and adaptive capacity across climate change hazards: young children, disability status, educational attainment, linguistic isolation, older adults (especially those living alone), poverty, race/ethnicity, renters, and household vehicle access (Raval et al. 2019).[11] ACS data for all of these indicators is available at the block group scale (Table 6).

[11] Some of the indices produced by state agencies have omitted indicators of race/ethnicity in order to avoid conflicts with Proposition 209, which prohibits grants awards on the basis of race (OEHHA 2017, Delany et al. 2018, Steinberg et al. 2018). The Council does not have grant-making authority and has chosen to include race/ethnicity in its index. Any other state or local agencies that use the VA and adaptation strategy to determine funding priorities in the future should be aware of this constraint.

Table 6. Indicators of Social Vulnerability to Climate Change, Block Group Scale

Indicator	Metric	Data Source
Children	% population under 5	2017 ACS, Table B01001
Ability	% households with 1 or more persons with a disability	2017 ACS, Table B22010
Educational attainment	% adults over 25 without a high school diploma or GED	2017 ACS, Table B15003
Linguistic isolation	% households that are limited English speaking households	2017 ACS, Table C16002
Older adults living alone	% households that have 1 member, age 65 years and over	2017 ACS, Table B11007
Poverty	% of households with income less than 200% of the federal poverty level	2017 ACS, Table C17002
Race and ethnicity	% households with 1 or more persons that are Hispanic and/or non-white	2017 ACS, Table B03002
Renters	% of housing units that are renter-occupied	2017 ACS, Table B25003
Vehicle access	% households without a vehicle	2017 ACS, Table B25044

Health disparities and existing medical conditions like asthma and cardiovascular disease were also identified in the literature review as factors affecting vulnerability to all three climate change hazards of interest. Five indicators that measure relevant health conditions are available at the census tract scale (Table 7).

Table 7. Indicators of Social Vulnerability to Climate Change, Tract Scale

Indicator	Metric	Data Source
Health insurance	% of individuals without health insurance coverage	2017 ACS, Table B27001
Asthma	Age-adjusted rate of emergency department visits for asthma per 10,000	CalEnviroScreen 3.0
Cardiovascular disease	Age-adjusted rate of emergency department visits for heart attack per 10,000	CalEnviroScreen 3.0
Birth weight	Percent low birth weight	CalEnviroScreen 3.0
Food access	At least 100 households are more than ½ mile from the nearest supermarket and have no access to a vehicle; or at least 500 people or 33 percent of the population live more than 20 miles from the nearest supermarket	US Department of Agriculture (USDA) Food Access Research Atlas

Asthma and cardiovascular disease were identified explicitly in the literature. Low birth weight was identified as an impact of all three hazards, rather than a factor affecting vulnerability. However, incidence of low birth weight is also a useful proxy for overall community health and a predictor of future health conditions like diabetes; thus, it is used in several of the indices reviewed for this initiative (Cooley et al. 2012, OEHHA 2017, Steinberg et al. 2018). Delaney et al. (2016) identified food insecurity as a statistically significant contributor to health outcomes. Food access was also raised as an important indicator of community health and access to services during discussions with CBOs.

2.4.2 Weighting Scheme

A variety of weighting schemes have been used to combine indicators into a single vulnerability score. Many indices developed by academic researchers use principal components analysis, a data analysis technique that assigns groups of variables to domains, generating statistically relevant weights for each domain (Burton & Cutter 2008, Cutter et al. 2003, Delaney et al. 2018, Rappold et al. 2017). In contrast, the indices developed by local and regional agencies in the Delta do not weight indicators or domains. All use a simple sum of the indicators' percentile ranks, or a sum of the number of indicators above a set threshold (BCDC 2018, MTC-ABAG 2017, SJCOG 2018, SACOG 2019). Based on advice from the Technical Advisory Committee, and a desire to be able to clearly explain the index to the general public, the Council also opted for a simple sum approach.

An individual block group or tract was assigned a score based on the number of indicators for which it is in the 70th percentile or higher.[12] The 70th percentile was selected as the threshold based on the review of existing vulnerability indices, many of which use the 70th or 75th percentile as a threshold (see section 2.4.1 Existing Vulnerability Indices and section 2.4.3 Local and Regional Plans). Separate scores were calculated based on indicators available at the block group level (Table 6) and indicators available at the tract level (Table 7). A combined score was also calculated, by assigning tract-level scores to the block groups they contained, using a spatial join. Because the inputs are at different scales, it is important to recognize that the precision of the combined score is overstated. However, there are twice as many indicators at the block group level, so the combined score is heavily weighted towards the more fine-scale information.

2.4.3 Other Vulnerable Populations

Council staff considered several other indicators highlighted in the literature and in CBO discussions that were ultimately not selected for inclusion in the social vulnerability index. While public health research indicates that these populations have heightened sensitivity and/or reduced adaptive capacity to climate change, the Council determined that they cannot be represented within the same spatial unit as the neighborhood/community. Instead, these populations will be mapped or described separately, as distinct vulnerable populations.

[12] The 70th percentile was not calculated for the Food Access indicator because it is binary; tracts are identified as either above or below defined distance and vehicle ownership thresholds.

2.4.3.1 Outdoor Workers

The share of the resident population employed in outdoor industries, such as agriculture and construction has been included in a number of vulnerability indices based on the increased exposure of outdoor workers to extreme heat and wildfire (Steinberg et al. 2018). The share of the resident population employed in extractive and service-sector jobs has been included in indices measuring social vulnerability to flooding based on the reduced adaptive capacity of those industries (Cutter et al. 2003). Despite the clear link between outdoor workers and vulnerability to extreme heat, the share of the population that works in outdoor industries was omitted from the Council's index because existing data sources are based on where workers live, rather than where they work and experience the greatest exposure (Roos 2018). Using this data in the social vulnerability index would create a spatial mismatch between the exposure of different locations in the Delta, and the population exposed in that location. This population will be described qualitatively in the VA to ensure that future adaptation strategies consider their needs.

2.4.3.2 Incarcerated and Institutionalized Populations

People living in nursing homes, prisons, group homes, and other institutions have less ability to evacuate on their own, and are therefore more vulnerable to floods, extreme heat events, wildfire, and other health hazards (Bell et al. 2016, OPR 2017b, Roos 2018). The ongoing COVID-19 emergency has highlighted the disparate vulnerability of people living in institutions, who are unable to take the precautionary health measures that are available to the general population and who cannot access support from family or community members outside of the institution. Institutionalized populations were omitted from the Council's index because it is the very lack of neighborhood and community connections that make these populations socially vulnerable (Roos 2018), not the characteristics of the neighborhood in which they are located. Instead of including these populations in the social vulnerability index, the VA will use the physical location of prisons and hospitals as a proxy. Other types of institutionalized populations that are not captured in the asset database will be discussed qualitatively in the VA to ensure that future adaptation strategies consider their needs.

2.4.3.3 People Experiencing Homelessness

Homelessness is consistently cited as a condition that increases vulnerability to flooding, extreme heat, and other public health and climate change hazards (Moreno et al. 2020, OPR 2017b, Raval et al. 2019, Roos 2018, Stone et al. 2019). Point-in-time counts from January 2019 identified 9,581 individuals experiencing homelessness in Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties (HUD 2019). More than 70 percent of these individuals were unsheltered at the time of the count. Most of the unsheltered individuals were adults, though six percent were under age 18. Of the those in transitional housing and emergency shelters, 33 percent were under age 18. Unfortunately, due to the transience of people experiencing homelessness, counts consistently underestimate this population. The share of this population that is living within the Delta is unknown, as data is not readily available for smaller geographic areas. This population will be described qualitatively in the VA to ensure that future adaptation strategies consider their needs.

2.4.3.4 Mobile Home Park Communities

Mobile home parks were identified in the literature review as particularly vulnerable to flooding due to the physical characteristics of the structures and their foundations. The literature review also indicated that, as a relatively affordable housing typology, mobile home parks are more likely to be populated by low-income households. Those living in mobile home parks dependent on small water systems, including groundwater-dependent systems, can also be vulnerable to degraded water quality and water supply shortages due to drought (Pacific Institute 2017; DWR 2021). A 2021 DWR study assessing the vulnerability of small water suppliers and self-supplied communities to drought and water shortages identified six high-vulnerability small water systems in the Delta, including Camino Mobile Homes, Marina Mobile Manor, and Russos Mobile Park in Contra Costa County (DWR 2021) (see the Water Supply Technical Memorandum for additional details on the DWR study and drought vulnerability of small, self-supplied communities and small water suppliers).

The Council developed a dataset of all mobile home parks in the Delta and Suisun Marsh based on a county-level query from the California Department of Housing and Community Development Codes and Standards Automated System (CASAS) (2020). The georeferenced mobile home park points were spatially joined to the social vulnerability index and median household income data (ACS 2017) to enable an evaluation as to whether these points represent more socially vulnerable communities in the Delta that may not be captured as well at the block group scale. The VA will evaluate the exposure of mobile home park communities to flooding based on this location data.

CHAPTER 3. RESULTS/DISCUSSION

3.1 Socially Vulnerable Communities

Based on the social vulnerability indicators available at the block group scale, scores ranged from zero to eight (Figure 6). A score of eight reflects the highest level of social vulnerability, meaning a block group has population and household characteristics in the 70th percentile of all block groups in the Delta and Suisun Marsh for eight of the nine total indicators. None of the block groups are in the 70th percentile for all nine indicators. The most socially vulnerable communities, those with at least seven indicators in the 70th percentile, are located in Stockton (11 block groups), Antioch (four block groups), Pittsburg (three block groups), West Sacramento (two block groups), Sacramento (two block groups), and Tracy (one block group).

These cities also contain block groups with moderately high social vulnerability scores, with six of nine indicators in the 70th percentile. The City of Brentwood also has one such block group (60133032041). Several rural block groups also have six indicators in the 70th percentile, including the block group containing Ryde and portions of Walnut Grove (60670099003), and the block group containing large unincorporated areas in San Joaquin County (60770039001). The least socially vulnerable communities are located in North Stockton, Discovery Bay, Brentwood, Suisun Marsh, and unincorporated areas in Solano and Yolo Counties.

Based on the social vulnerability indicators available at the tract scale, scores ranged from zero to four (Figure 7). None of the block groups are in the 70th percentile for all five indicators. Based on these indicators, the most socially vulnerable communities (with four indicators in the 70th percentile) are located in Pittsburg (six block groups), Antioch (two block groups), and Bay Point (one block group). The least socially vulnerable communities are located in North Stockton, Discovery Bay, Suisun Marsh, and unincorporated areas in Solano and Yolo Counties, eastern Contra Costa County, and western San Joaquin County.

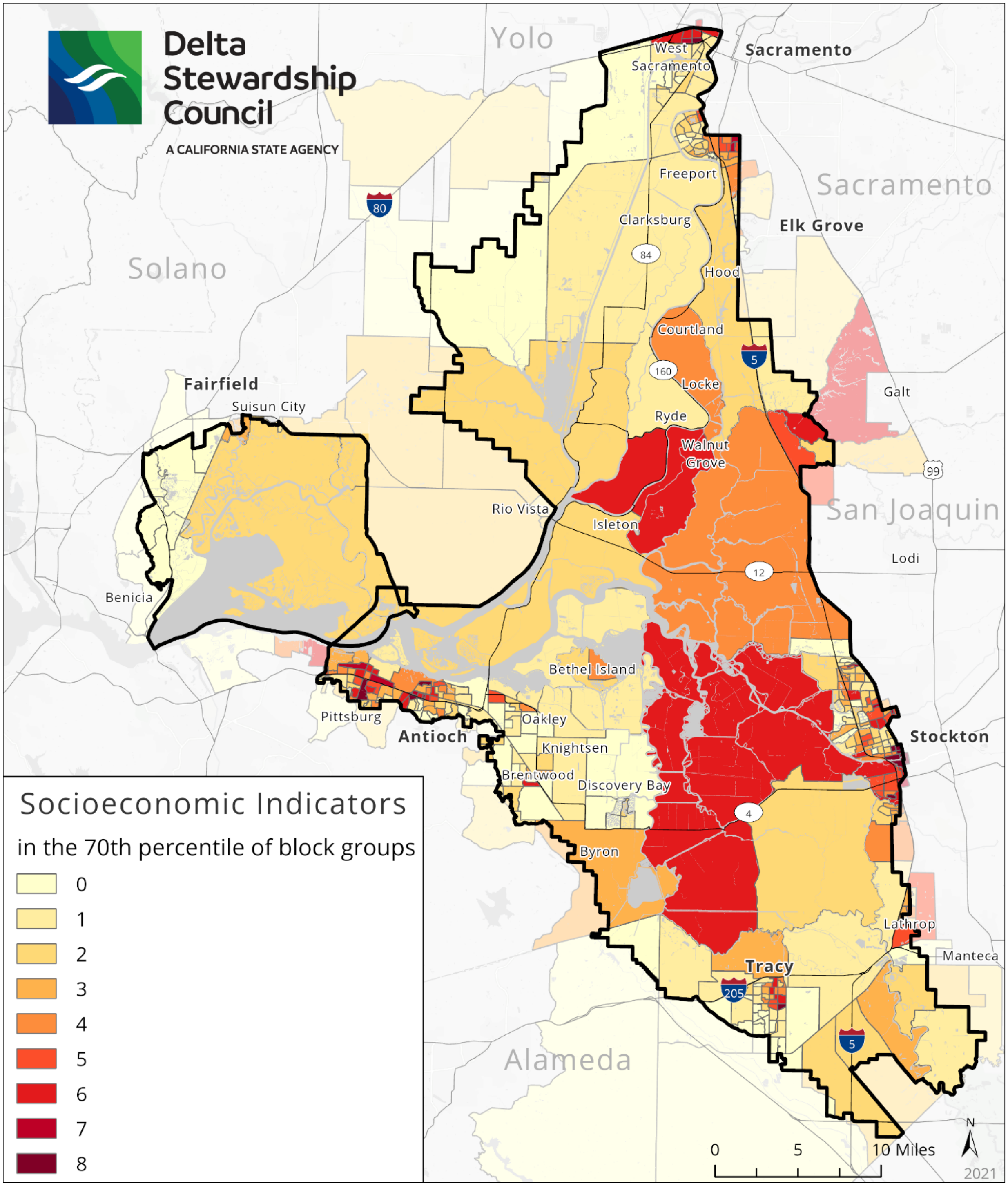

Figure 6. Number of Indicators with Values in the 70th Percentile of All Block Groups in the Delta

Source: Adapted from ACS 2017

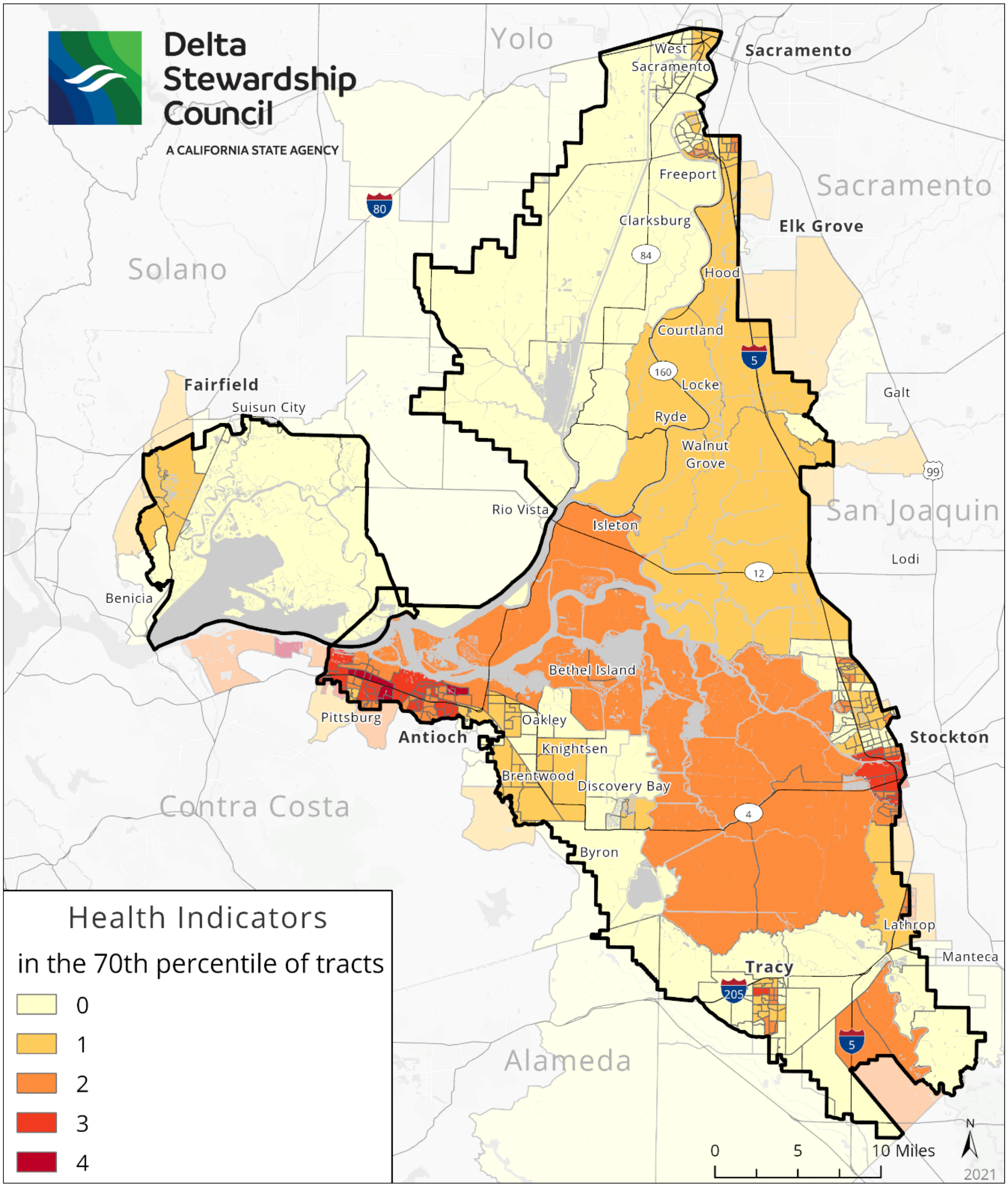

Figure 7. Number of Indicators with Values in the 70th Percentile of All Tracts in the Delta

Source: Adapted from ACS 2017, OEHHA 2017 USDA 2017.

Combined scores vary from zero to 11. The distribution of social vulnerability skews left (Figure 8) with a mean of 3.9 and a standard deviation of 2.8 (n=368). Approximately nine percent (n=34) of the block groups have a score of zero. In contrast, the combined number of block groups with scores greater than eight (n=28) makes up only eight percent of the total.

Social vulnerability index scores were used to categorize block groups into "moderate," "high," and "highest" levels of social vulnerability. Block groups with scores between zero and three were categorized as moderately vulnerable because they have few (or no) concentrations of interacting sensitivities or reduced adaptive capacity to the three climate hazards. Block groups with scores between four and seven were categorized as highly vulnerable because they have concentrations of several interacting sensitivities or reduced adaptive capacity. Finally, block groups with scores of eight or higher were categorized with the "highest" level of vulnerability, because they score in the 70th percentile for more than half of all 14 indicators.

Figure 8. Distribution of Block Groups by Social Vulnerability Index Score

Block groups are not evenly distributed among these categories (Figure 8). More than half of the block groups are moderately vulnerable (51 percent). The highly vulnerable block groups make up 37 percent of the total, and the highest level of social vulnerability contains 12 percent of block groups. Of the 45 block groups in this "highest" social vulnerability category, six block groups have the maximum score, meaning they score in the 70th percentile for 11 of the 14 total indicators. These blocks groups are located in Stockton and Pittsburg (Figure 9). The characteristics that make these communities highly vulnerable are described in detail below.

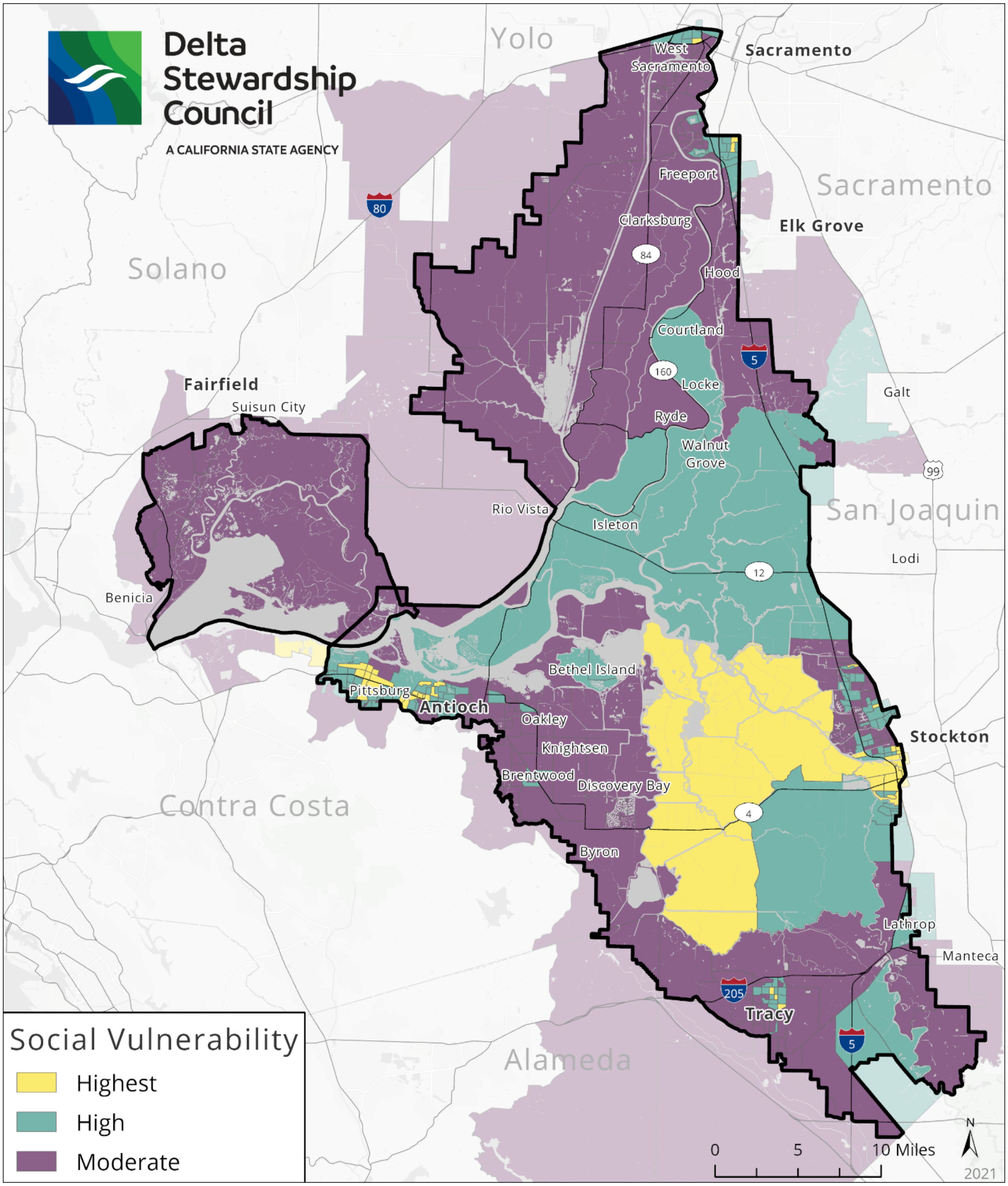

Figure 9. Geographic Distribution of Social Vulnerability in the Delta

Data Sources: ACS 2017, OEHHA 2017, USDA 2017.

3.1.1 Stockton

It is notable that the social vulnerability scores in Stockton correspond closely to both the distribution of CalEnviroScreen scores and historic redlining maps for the city (CalEPA 2021). Nearly all of South Stockton falls into the highest social vulnerability classification.

Two of the block groups in Stockton that have the highest social vulnerability score (770003001 and 770003002) are located within the "Gateway" to Stockton, on either side of the crosstown freeway (State Highway 4) and Mormon Slough. These block groups include the historic Little Manila, Chinatown, and Japantown communities. The characteristics that increase the vulnerability of this neighborhood are:

- 68 to **78 percent** of households are living below 200 percent of the federal poverty line
- 21 to **47 percent** of households have no access to a vehicle
- 41 to **44 percent** of adults in the community have less than a high school education
- 20 to **35 percent** of households are linguistically isolated, and
- 81 to **100 percent** of housing units are occupied by renters.

These communities are located within a census tract (77000300) in which:

- **37 percent** of the population lacks health insurance, and
- The rate of emergency department visits for asthma per 10,000, and the rate of low birth-weight infants are in the 70^{th} percentile among all Delta tracts.

These communities are also located within a census tract with a score of 99.9 in CalEnviroScreen 3.0 (the highest possible score is 100), meaning the community is already experiencing an extreme concentration of environmental justice challenges.

The other block group in Stockton with the highest social vulnerability score (770025032) is located north of French Camp Slough in the Van Buskirk/Conway Homes neighborhood. The characteristics that increase the vulnerability of this neighborhood are::

- **76 percent** of households are living below 200 percent of the federal poverty line
- **44 percent** of adults in the community have less than a high school education
- **11 percent** of the population is younger than, or age five
- **99 percent** of households are racial or ethnic minorities, and
- **42 percent** of households have at least one member with a disability.

This community is located within a census tract (77002503) in which:

- **18 percent** of the population lacks health insurance, and
- The rate of emergency department visits for asthma and heart attacks per 10,000 are in the 70^{th} percentile among all Delta tracts.

3.1.2 Pittsburg

The block groups in Pittsburg that have the highest social vulnerability score (133120001 and 133131013) are within the East Leland, East Central, and Loveridge districts of the city, along Railroad Avenue and State Highway 4. The characteristics that increase the vulnerability of these neighborhoods are::

- 18 to **20 percent** of households have no access to a vehicle
- 27 to **38 percent** of adults in the community have less than a high school education
- 16 to **18 percent** of households are made up of an older adult living alone
- 15 to **19 percent** of households are linguistically isolated
- 61 to **64 percent** of housing units are occupied by renters
- 78 to **91 percent** of households are racial or ethnic minorities, and
- 40 to **50 percent** of households have at least one member with a disability.

These communities are located within census tracts (13312000and 13313101) in which the rate of emergency department visits for asthma and heart attacks per 10,000, and the rate of low birth-weight infants, are in the 70^{th} percentile among all Delta tracts. Block group 133120001, roughly aligned with the Loveridge district, is located in a census tract with a score of 94.6 in CalEnviroScreen 3.0 (the highest possible score is 100), meaning the community is already experiencing an extreme concentration of environmental justice challenges.

3.1.3 Antioch

One block group in Antioch has the highest social vulnerability score (133050005). This block group is a residential part of the Downtown district that includes Prosserville Park, and Bridgemont and Del Rio Homes. The characteristics that increase the vulnerability of this neighborhood are:

- **65 percent** of households are living below 200 percent of the federal poverty line
- **20 percent** of households are made up of an older adult living alone
- **30 percent** of adults in the community have less than a high school education
- **18 percent** of households are linguistically isolated
- **72 percent** of housing units are occupied by renters
- **78 percent** of households are racial or ethnic minorities, and
- **42 percent** of households have at least one member with a disability.

This community is located within census tract (13305000) in which the rate of emergency department visits for asthma and heart attacks per 10,000, and the rate of low birth-weight infants, are in the 70^{th} percentile among all Delta tracts.

Although these six block groups have the maximum scores for social vulnerability, based on the Council's social vulnerability index, the conceptual model for this analysis identifies the most vulnerable populations as those at the intersection of exposure and social vulnerability (**Figure 1**). The VA will evaluate the exposure of Delta residents and communities to flooding, extreme heat, and wildfire. The block groups that are both highly exposed and highly socially vulnerable may differ from the shortlist of block groups described above.

3.2 Vulnerable Populations

3.2.1 Mobile Home Park Communities

Mobile home communities are scattered across the Delta, in both rural and urban areas (Figure B-10). There are 79 mobile home and residential recreational vehicle (RV) parks in the Delta. These parks have a combined total of 5,654 mobile home and RV lots (a proxy for total households, though there is no data on the share of lots that are occupied). Forty-two of the mobile home parks (3,336 total lots) are located in cities, including 15 in West Sacramento, eight in Tracy, and five in Oakley. The remainder, 37 mobile homes parks (2,318 total lots), are located in unincorporated areas, including six on Bethel Island, one in Hood, one in Isleton, and one in Freeport.

Although household-level data is not available, the spatial join analysis supports the idea that mobile home parks are more likely to be populated by socially vulnerable households. Mobile home parks in the Delta are located in block groups with social vulnerability index scores ranging from zero to 9, with a mean of 5 and a standard deviation of 2 (*n=79*). Although the maximum score for block groups containing mobile home parks is lower than the maximum score for all block groups, the average score is higher, and has a more normal distribution (Figure 10).

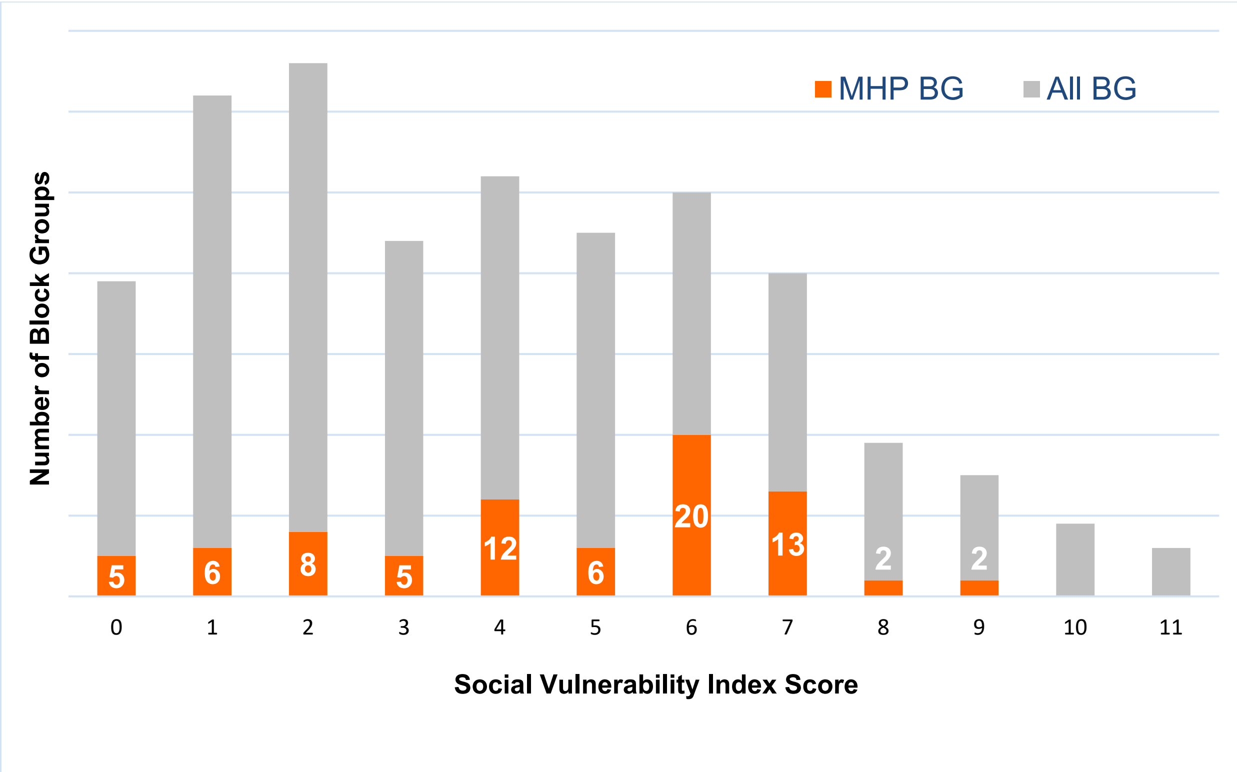

Figure 10. Distribution of Block Groups by Social Vulnerability Index Score

In addition, the spatial join found that mobile home parks are located in block groups that, on average, have a lower median household income (MHHI) as a percentage of State MHHI (66 percent) compared to all block groups in the Delta (92 percent) (Table 8). Recall that communities with MHHI less than 80 percent of the state level are considered disadvantaged communities (*Pub. Resources Code* §75005[g]). Mobile home parks in unincorporated areas and in eight of the ten cities in the Delta are located in block groups that, on average, would qualify as disadvantaged communities. Those located in Antioch, Isleton, Stockton, and West Sacramento would qualify as severely disadvantaged, below 60 percent of the state MHHI.

Table 8. Average MHHI of Block Groups as a Share of State MHHI, by Jurisdiction

Jurisdiction	Block Groups containing Mobile Home Parks	All Block Groups
Antioch	53%	83%
Brentwood	65%	128%
Isleton	56%	63%
Lathrop	78%	91%
Oakley	74%	110%
Pittsburg	72%	81%
Rio Vista	89%	74%
Stockton	52%	73%
Tracy	94%	107%
West Sacramento	39%	92%
Unincorporated areas	71%	109%
Total	**66%**	**92%**

While this analysis suggests that mobile home park communities may tend to be more socially vulnerable, it does not mean that all mobile home park communities are socially vulnerable. However, the specificity of the dataset provides higher resolution information about where vulnerable populations in the Delta may be located, particularly within larger block groups.

As discussed above in section 2.4.3.4, Mobile Home Park Communities, mobile homes residents are more vulnerable to flooding, not only because of potential socioeconomic factors, but because mobile homes are less resilient to flood forces than other housing types. In addition, those living in mobile home parks dependent on small water systems, including groundwater-dependent systems, can be vulnerable to degraded water quality and water supply shortages due to drought (Pacific Institute 2017; DWR 2021). A 2021 DWR study assessing the vulnerability of small water suppliers and self-supplied communities, including groundwater-dependent systems and communities, to drought and water supply shortages identified six high-vulnerability small water systems in the Delta, including Camino Mobile Homes, Marina Mobile Manor, and Russos Mobile Park in Contra Costa County (DWR 2021) (See the Water Supply Technical Memorandum for more details on the DWR study and for a discussion of drought vulnerability of small, self-supplied communities and small water suppliers).

The VA will evaluate the exposure of mobile home park communities to flooding in the Delta, to supplement the analysis that will be conducted using the social vulnerability index.

3.2.2 Other Vulnerable Populations

As described in the Revised Approach, above, the Council determined that not all of the identified populations with heightened sensitivity and/or reduced adaptive capacity to climate change can be represented by the social vulnerability index. These populations include outdoor workers, incarcerated and institutionalized populations, and people experiencing homelessness.

The vulnerability of outdoor workers and people experiencing homelessness will be described qualitatively in the VA, to ensure that future adaptation strategies consider their needs. The VA will evaluate the exposure of prisons and hospitals to flooding, extreme heat, and wildfires as a proxy for understanding the exposure of incarcerated and institutionalized populations. Other types of institutionalized populations that are not captured in the asset database will be discussed qualitatively in the VA to ensure that future adaptation strategies consider their needs.

The results of this evaluation will be described in the VA report.

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Chapter 5. Appendices

Appendix A: Definitions

Table A-1. Codified Definitions Related to Vulnerable Populations

Term	Definition	Source
Vulnerable communities	women; racial or ethnic groups; low-income individuals and families; individuals who are incarcerated or have been incarcerated; individuals with disabilities; individuals with mental health conditions; children; youth and young adults; seniors; immigrants and refugees; individuals who are limited English proficient (LEP); and Lesbian, Gay, Bisexual, Transgender, Queer, and Questioning (LGBTQQ) communities, or combinations of these populations	*Cal. Health & Saf. Code* §131019.5
Vulnerable places	places or communities with inequities in the social, economic, educational, or physical environment or environmental health and that have insufficient resources or capacity to protect and promote the health and well-being of their residents	*Cal. Health & Saf. Code* §131019.5
Access and functional needs population	individuals who have developmental or intellectual disabilities, physical disabilities, chronic conditions, injuries, limited English proficiency or who are non-English speaking, seniors, children, people living in institutionalized settings, or those who are low income, homeless, or transportation disadvantaged, including, but not limited to, those who are dependent on public transit or those who are pregnant	*Cal. Gov. Code* § 8593.3[b]
Disadvantaged community	an area disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, exposure, or environmental degradation, or with concentrations of people who are of low income, high unemployment, low levels of homeownership, high rent burden, sensitive populations, or low levels of educational attainment	*Cal. Health & Saf. Code* § 39711
Disadvantaged community	a community with a median household income of less than 80 percent of the statewide average	*Cal. Wat. Code* § 79505.5, *Cal. Health & Saf. Code* §116275[aa]
Severely disadvantaged community	a community with a median household income of less than 60 percent of the statewide average	*Cal. Health & Saf. Code* §116760.20
Disadvantaged unincorporated community	unincorporated inhabited territory, within which there reside 12 or more registered voters, that constitutes all or a portion of a "disadvantaged community," meaning a community with an annual median household income that is less than 80 percent of the statewide annual median household income	*Cal. Gov. Code* § 56033.5

Appendix B: Maps

Maps of all but two of the existing vulnerability indices described in this memorandum are provided in this appendix. The Climate Change and Health Vulnerability Indicators (CCHVIz) is not included in this appendix because it is not a composite index; there are separate maps and scores for each indicator. The Distressed Communities Index is not included because neither tabular nor spatial data is publicly available.

The maps in this section are all symbolized to highlight the census tracts that the index has designated as most vulnerable relative to all tracts in the State of California. Terminology and symbology vary to reflect the terminology and characteristics of the specific index shown.

Maps of Disadvantaged Unincorporated Communities (DUCs) in the Delta and in the San Joaquin Valley are also included for reference. These maps are not based on an index; communities are designated as DUCs if they meet income and population criteria.

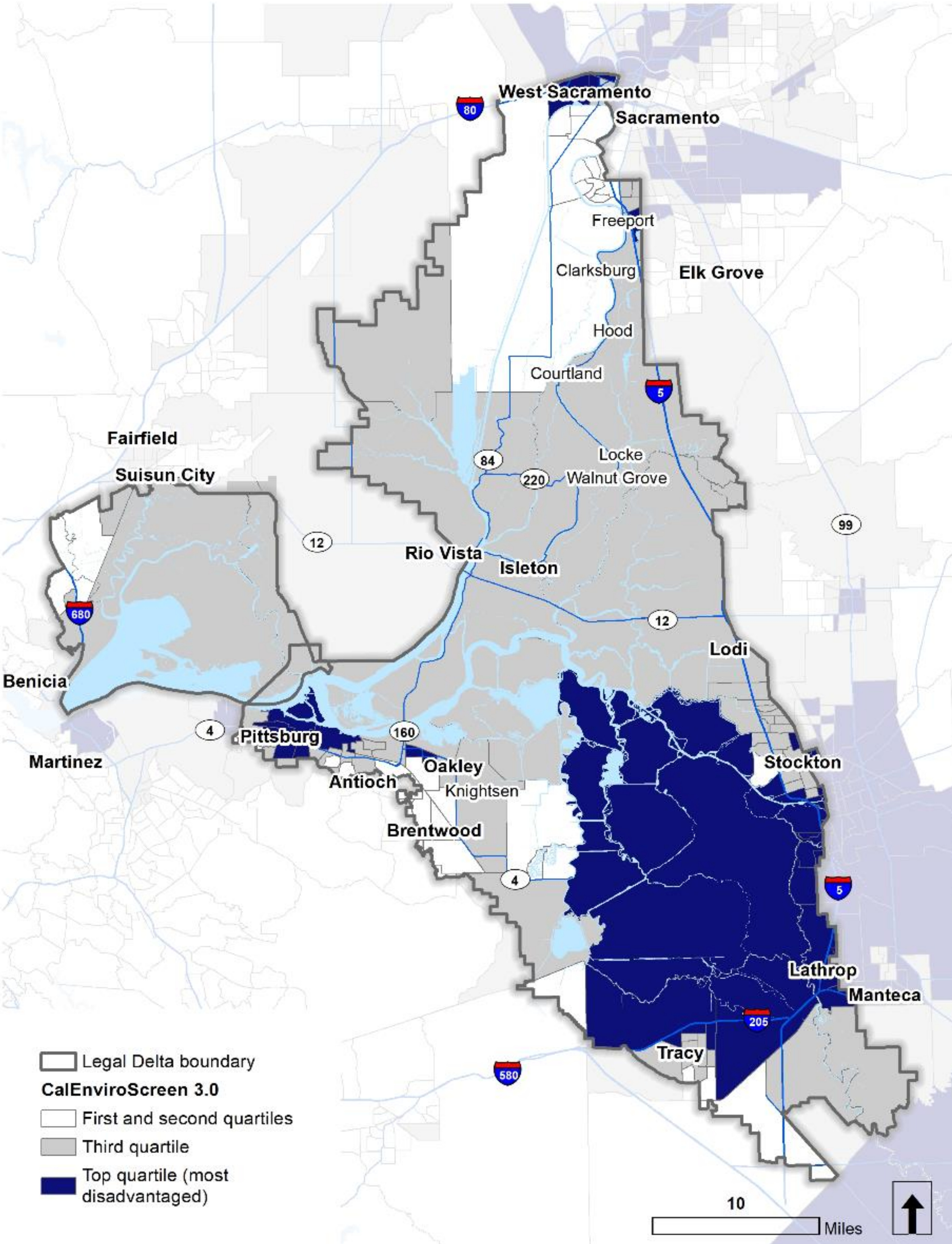

Figure B-1. CalEnviroScreen 3.0

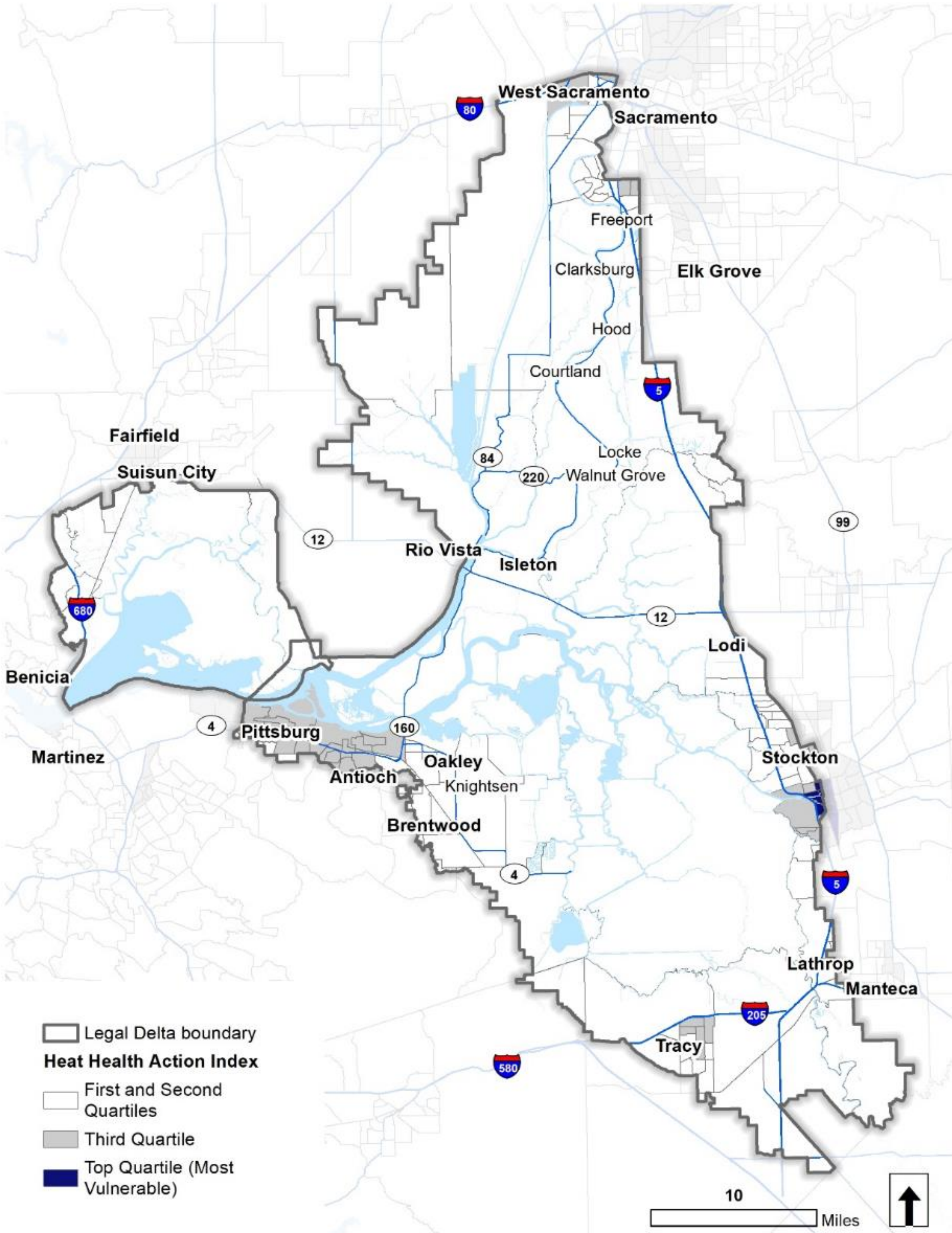

Figure B-2. California Heat Assessment Tool: Heat Health Action Index

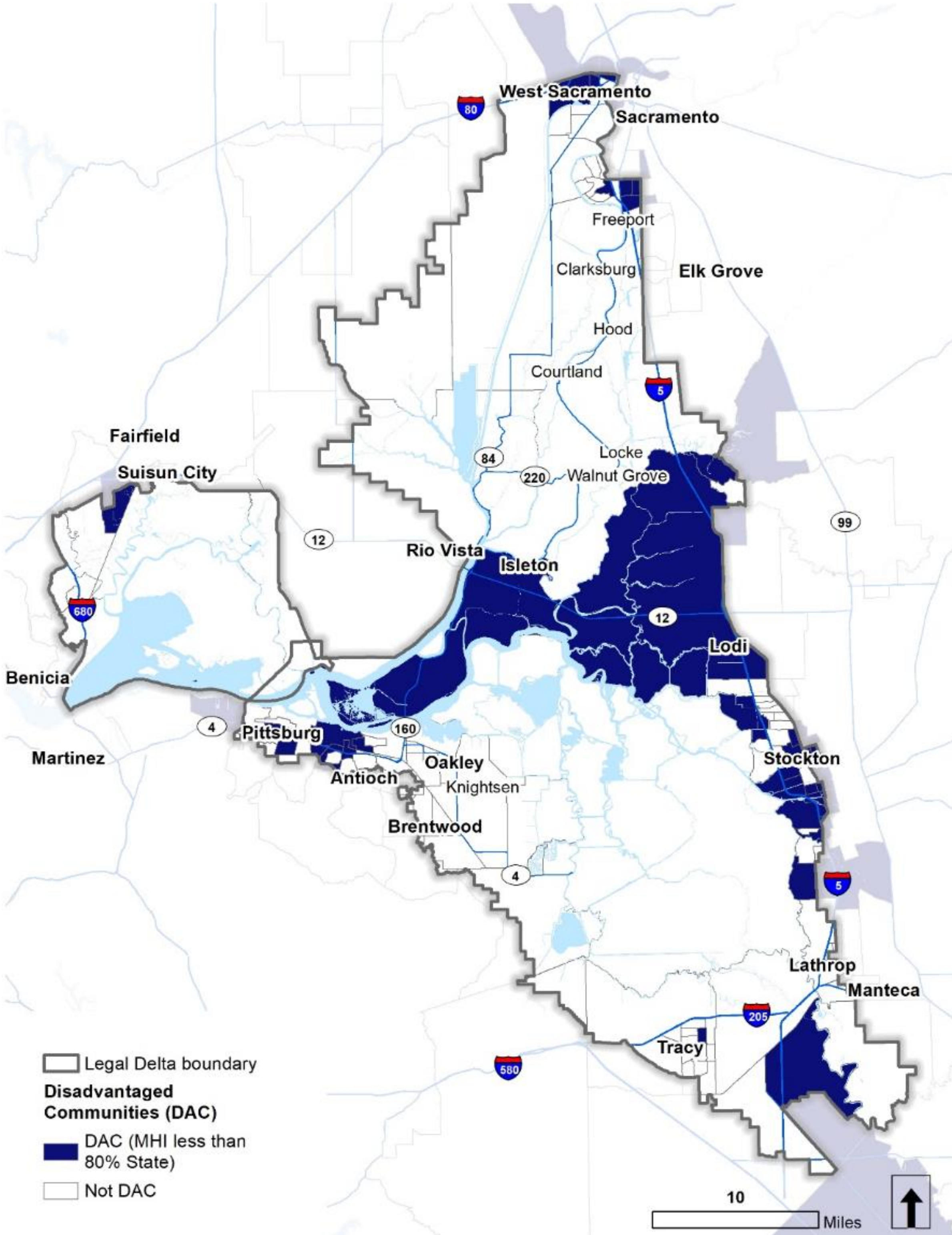

Figure B-3. Disadvantaged Communities Mapping Tool

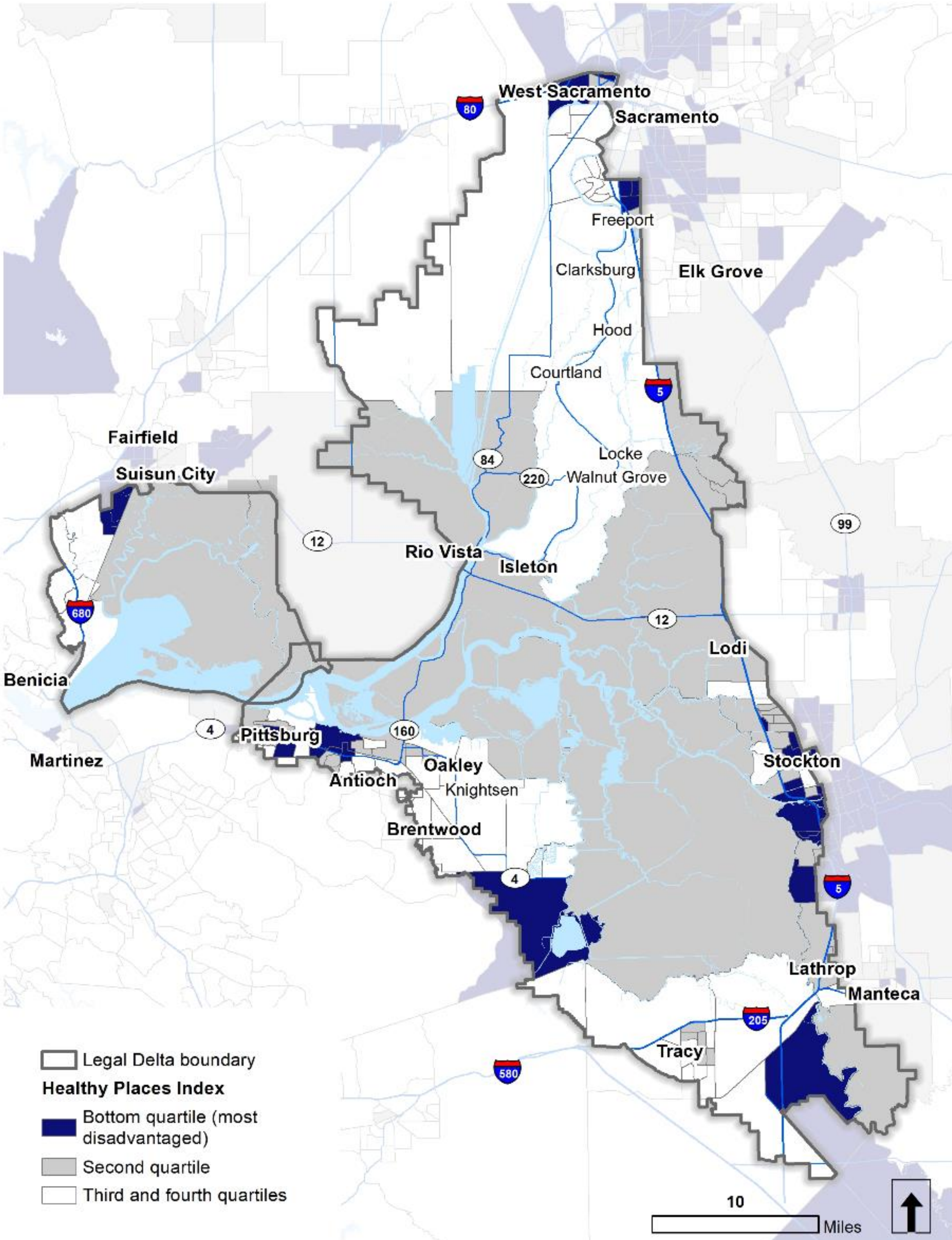

Figure B-4. Healthy Places Index

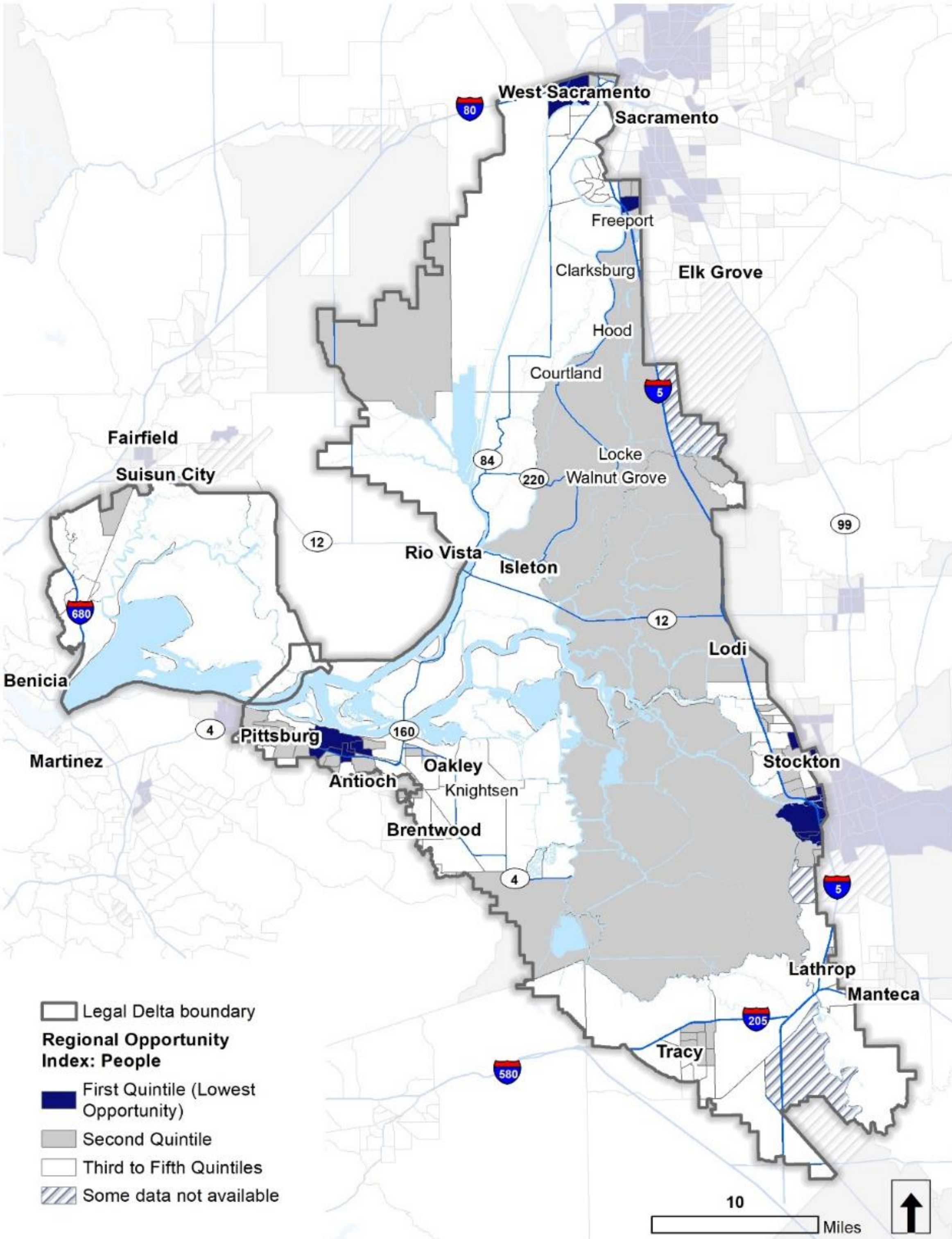

Figure B-5. Regional Opportunity Index: People

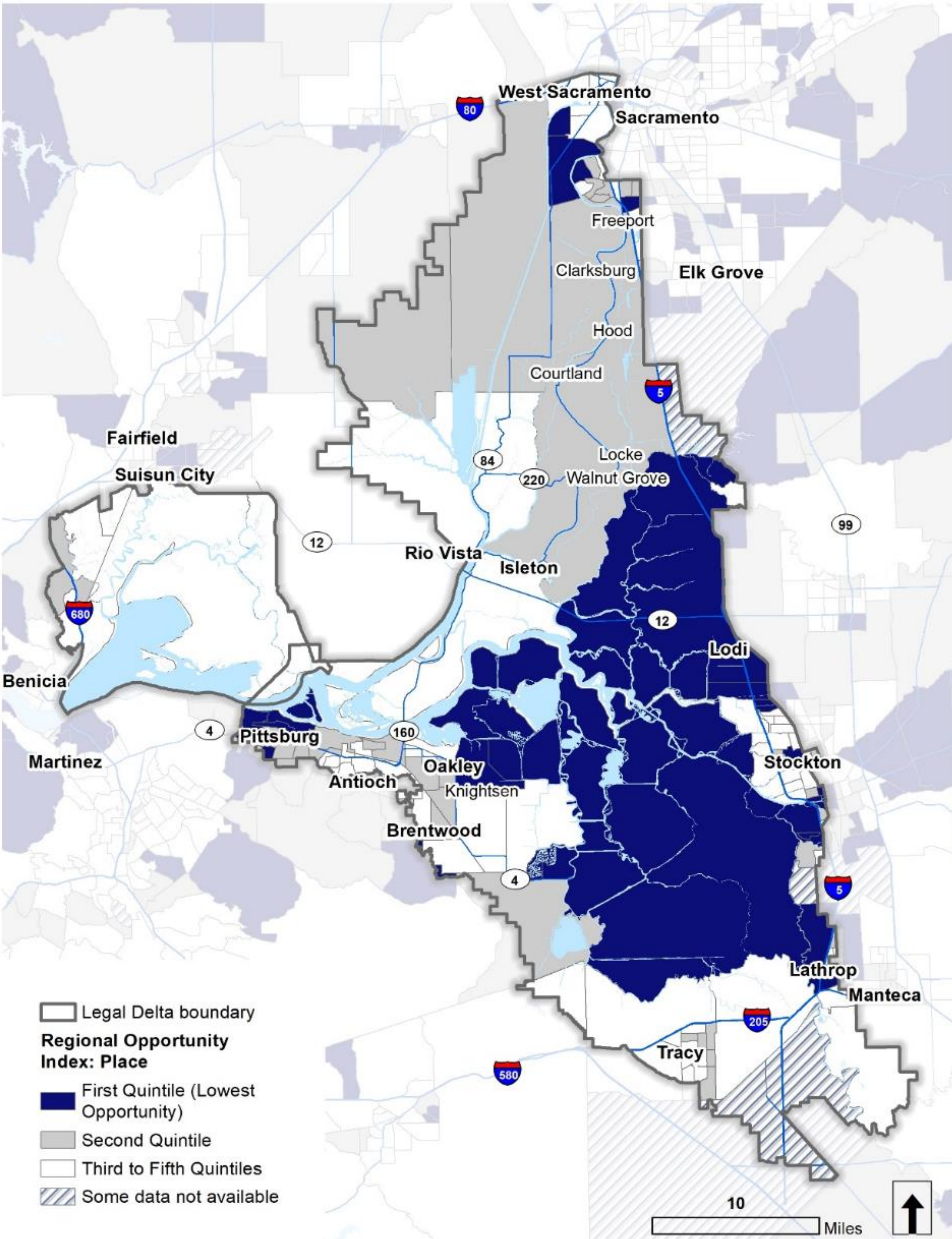

Figure B-6. Regional Opportunity Index: Place

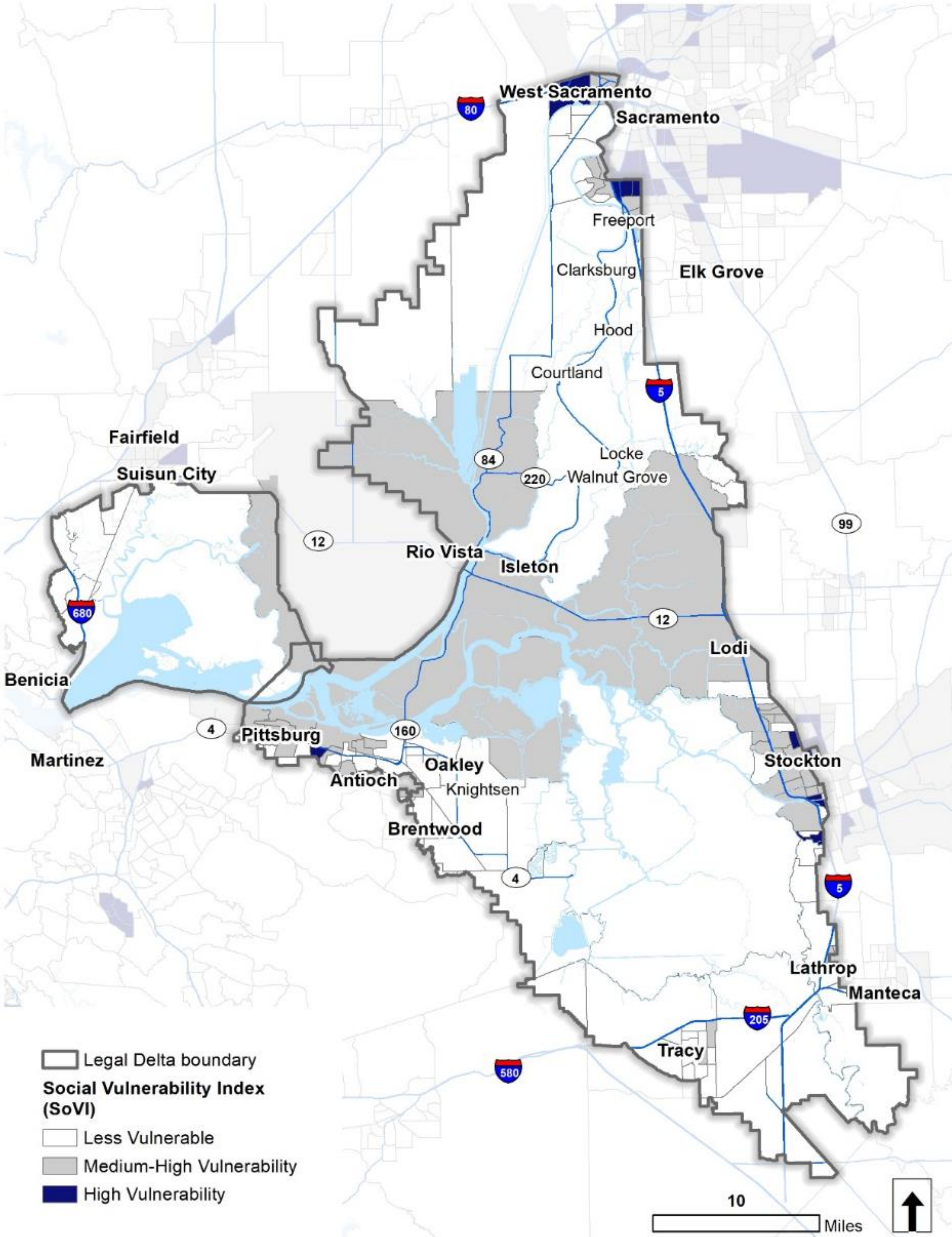

Figure B-7. Social Vulnerability Index (SoVI)

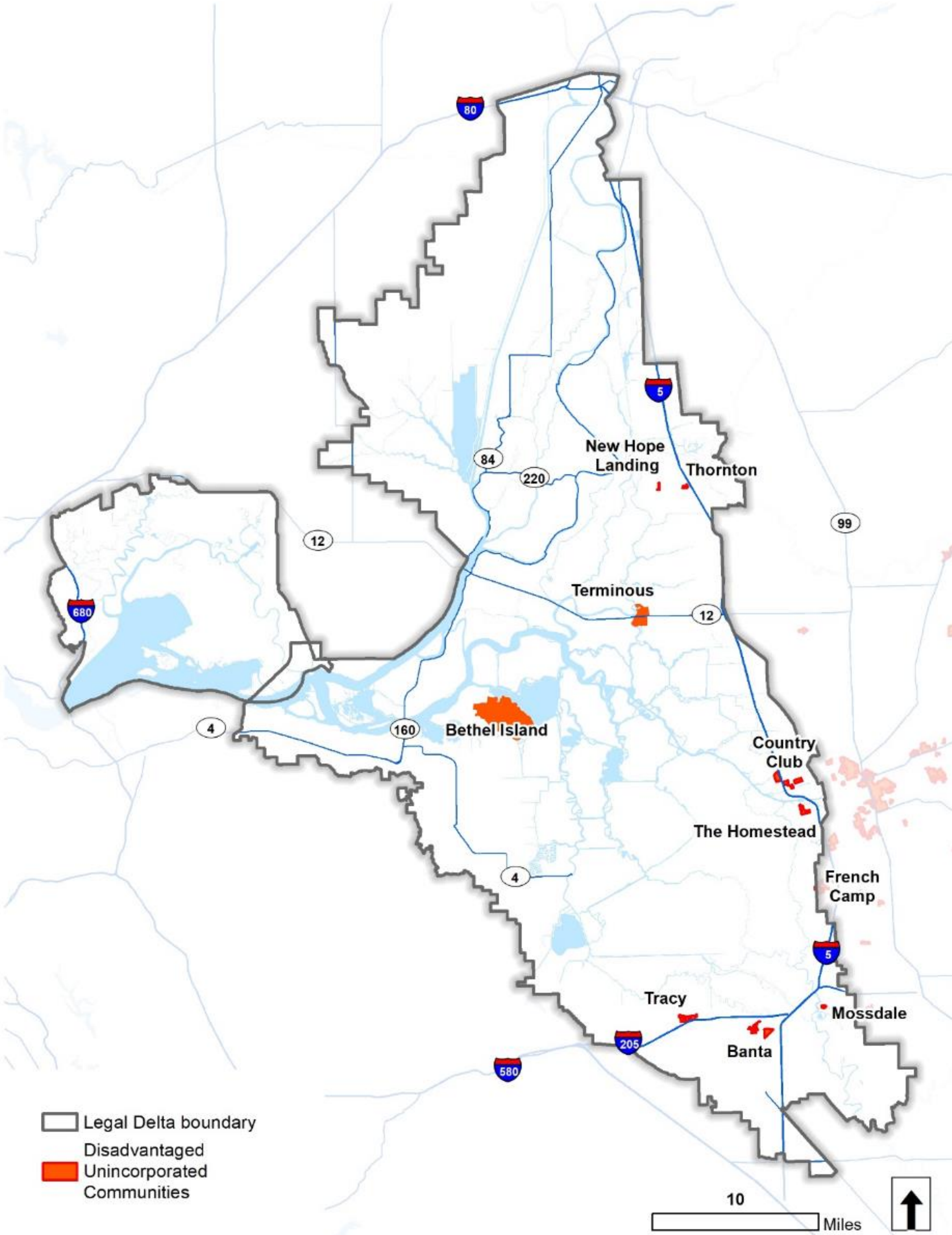

Figure B-8. Disadvantaged Unincorporated Communities in the Delta

Source: Flegal et al. (2013), London et al. (2018), Contra Costa LAFCo (2019)

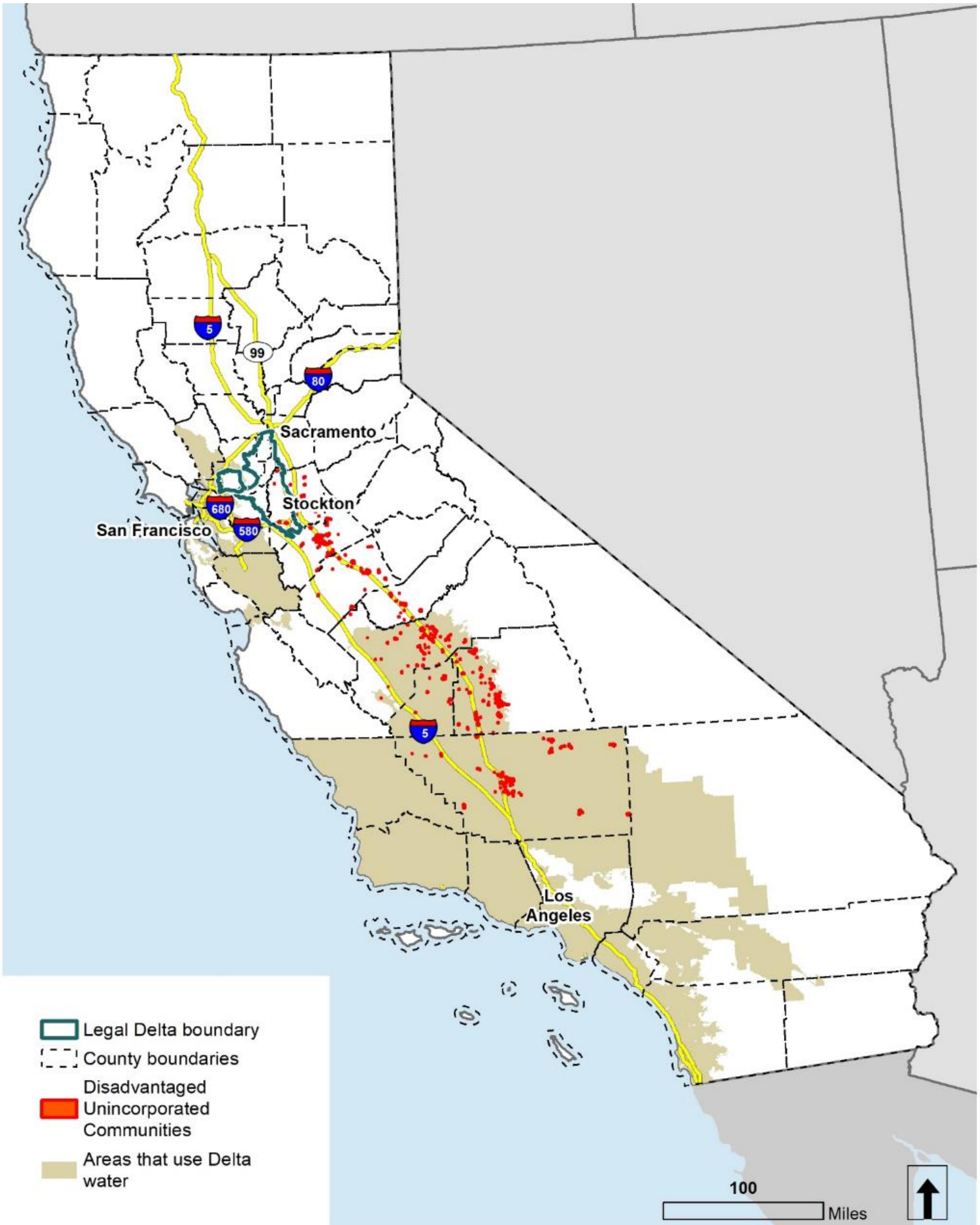

Figure B-9. Disadvantaged Unincorporated Communities in Areas that use Delta Exports

Source: Flegal et al. (2013), London et al. (2018)

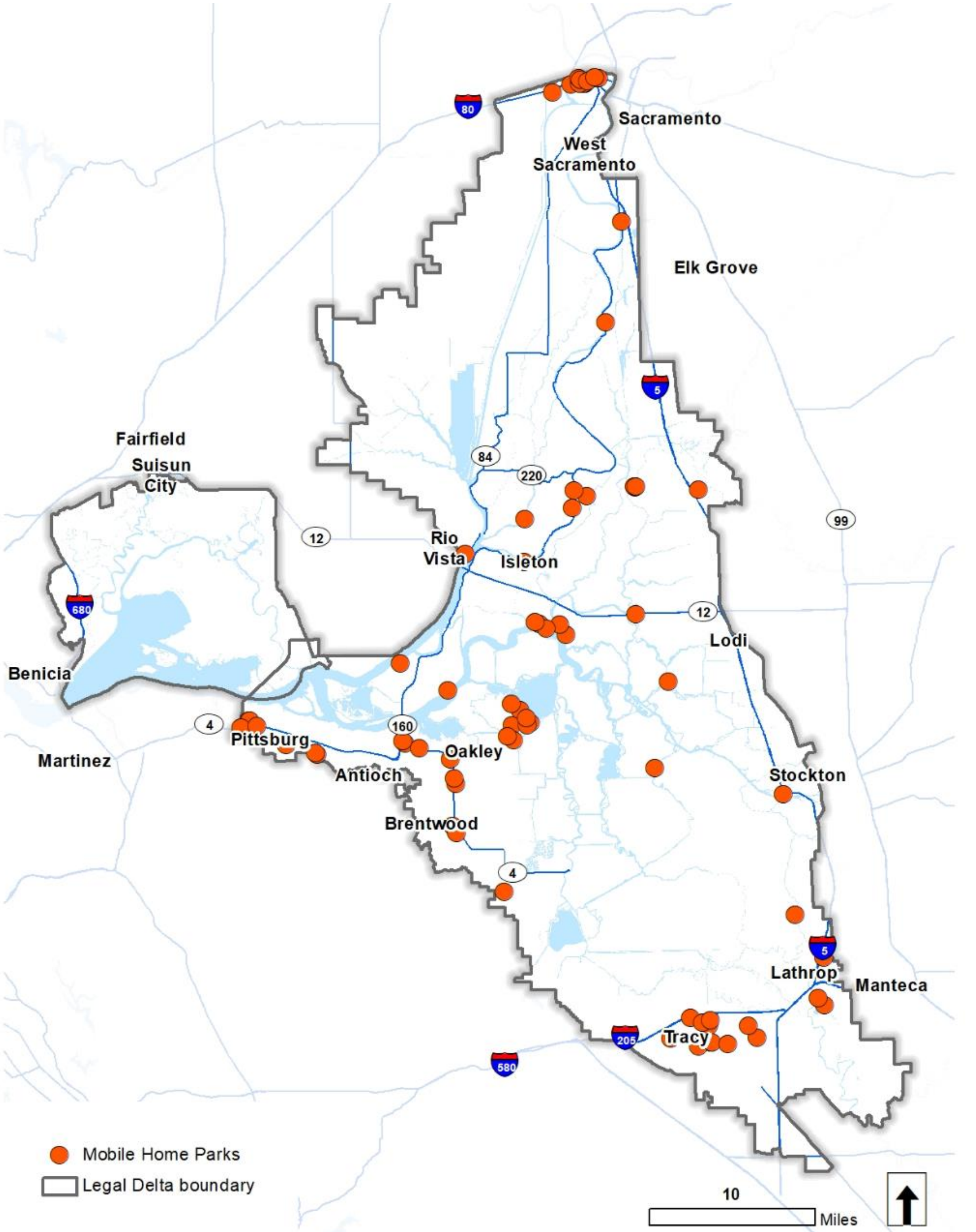

Figure B-10. Mobile Home Parks

Adapted from CASAS (2020)