Example Sector-Scale Findings from the ART Subregional Project in Alameda County, CA

Vulnerabilities are grouped according to related sectors: Community Land Use, Transportation, Utilities and Shorelines. (These include most of the sectors for which there are assessment questions.)

The vulnerabilities are also identified by type -- Information, Governance, Functional and Physical -- which coincides with how the assessment questions are organized.

The broad types of consequences of each vulnerability to society, equity, economy and environment are also noted.

Overarching Vulnerabilities

Possible consequences for all Overarching vulnerabilities include: Public health and safety; people where they live, work, recreate and commute; equity; all scales of economy, ecosystem services.

INFORMATION	O1. Information about the effects of sea level rise on groundwater levels and salinity intrusion is insufficient for assessing vulnerability and risk, supporting identification of priority issues, and developing adaptation responses.
INFORMATION	O2. There is limited availability of and access to regionally relevant, current and historic weather data needed to understand flood risk.
INFORMATION	O3. Flood risk maps rely on historic flooding to determine coastal hazard zones and do not factor in sea level rise. Additionally, many communities do not have access to recent coastal hazard (100-year flood) maps or the underlying data that could support shoreline adaptation planning.
INFORMATION	O4. There is a limited understanding of how dynamic baylands habitats such as tidal marshes, intertidal mudflats, and subtidal areas will respond to accelerating sea level rise, or how these habitats will be affected by shoreline adaptation responses (e.g., structural solutions such as levees) that may change tide, wave or sediment conditions.
GOVERNANCE	O5. Proactive management of baylands to improve their resilience to sea level rise and storm events involves confronting regulatory requirements related to state and federal threatened, endangered, and special status species. Maintenance, upgrade, repair and restoration of baylands require review and authorization from multiple state and federal agencies, often with limited work windows and restrictions on the type of actions that can be taken.
GOVERNANCE	O6. Capital investment planning, design, and funding for new infrastructure or for substantial repairs and improvements to existing infrastructure do not consider sea level rise impacts. Infrastructure designed to remain in place for longer spans of time and that is not built or rebuilt to be resilient to flooding and salt-water exposure will need to be protected or retrofitted long before the end of the expected life of the infrastructure. Resources to maintain or improve existing infrastructure are limited, and investments needed in the future to address sea level rise will affect financial resources, economic opportunities, and communities.
GOVERNANCE	O7. Many of the plans, policies, and practices that guide community development, land use planning, emergency planning, and capital investments do not consider sea level rise or the adaptation responses that will be necessary to reduce the vulnerabilities and risks associated with sea level rise.
GOVERNANCE	O8. Non-profit, faith, and community-based organizations play a critical role in building and maintaining community resilience. Many of these organizations do not have the capacity to fully participate in climate planning efforts. Government agencies and organizations also lack the capacity and processes to engage non-governmental organizations in planning and decision-making to ensure the robust, sustained partnerships that will be necessary to address climate change in an equitable, environmentally conscientious, and economically feasible manner.
FUNCTIONAL	O9. Proper functioning of utilities, which themselves are vulnerable to sea level rise and storm events, is essential for communities to effectively respond during a disaster, and for communities, businesses, the airport, seaport, parks and recreation areas, and natural shorelines to function on a day-to-day basis.
FUNCTIONAL	O10. Some assets along the Bay shoreline function as a continuous corridor, or as a series of linked segments, and impacts to one segment of the Bay shoreline can compromise the function of the other segments. This is especially true of the system of natural and structural shorelines along the Bay edge; energy, gas, and pipelines infrastructure; and for long, linear ground transportation assets such as the Bay Trail and the regional rail network.
PHYSICAL	O11. Changes in groundwater levels due to sea level rise may increase the risk of liquefaction during an earthquake. Residences, utilities and other infrastructures that are not designed for these conditions are likely to be damaged during an earthquake. Long, linear infrastructure such as utility pipelines, surface roads, and rail lines are highly susceptible to damage during earthquakes, particularly due to liquefaction. Much of the airport is built on Bay fill, which has a high liquefaction potential. During an earthquake, liquefaction could cause damage to runways and other infrastructure, and could cause the perimeter levee to fail.
PHYSICAL	O12. Public health, safety, and welfare are at risk from sea level rise and storm events, particularly where the land uses are predominately residential, e.g., single-family, multi-family, and senior housing. These communities were developed in a manner that makes protecting them from future flood risks extremely challenging. It is likely that planning for future growth in the region will follow this past pattern without consideration of future flooding, increasing the number of people at risk.

Community Land Use

community land use | contaminated lands | hazardous material sites

INFORMATION	C1. Up-to-date information regarding the characteristics of communities, including the locations and specific needs of certain populations, is generally not available or easily accessible when needed for emergency response. Collecting and maintaining this type of information requires coordination with non-profit, community, and faith based groups to ensure accuracy of information and to provide a trusted partner to help communities understand the importance of these efforts. *(Consequences: Public health and safety; people where they live and work; equity)*
INFORMATION	C2. There is a lack of centrally coordinated information systems for contaminated lands and hazardous material sites which is needed for effective emergency and adaptation planning, and for setting remediation, monitoring and enforcement priorities to reduce risks. *(Consequences: Public health and safety; people where they live and work; equity; ecosystem services)*
GOVERNANCE	C3. There are no effective regulatory or financing mechanisms to prioritize the remediation of contaminated lands that will be affected by sea level rise. Additionally, these sites may not provide the most appropriate redevelopment opportunities, further diminishing any incentive to conduct cleanup activities. *(Consequences: Public health and safety; equity; local economy; ecosystem services)*
GOVERNANCE	C4. Neighborhoods are informal networks whose function depends on the relationship among the individuals and services within them. These informal connections are easily severed during disasters and are often difficult to rebuild once disrupted. Neighborhoods without a strong social network, where residents do not know each other, or are not invested in the overall community good, are especially vulnerable to sea level rise and storm events. *(Consequences: Public health and safety; people where they live, work and commute; equity; local and regional economy)*
GOVERNANCE	C5. Certain populations within the subregion are especially vulnerable to sea level rise and storm events. These include young children, the elderly, people with mobility or medical needs, people without automobiles, renters, people without insurance, the linguistically isolated, people at or below poverty level and caretakers of young children, the elderly and animals. *(Consequences: Public health and safety; people where they live, work and commute; equity; local and regional economy)*
GOVERNANCE	C6. Planning and resources are inadequate to address contingencies and secondary impacts associated with widespread or long-lasting sea level rise or storm event impacts, especially if residential neighborhoods, elder care facilities, or similar land uses are affected. In addition, out-of-date emergency plans, lack of compliance with existing plans, and poor coordination among local, regional, and state authorities increases vulnerability of populations, facilities, and services. *(Consequences: Public health and safety; people where they live, work and commute; equity; local and regional economy)*
FUNCTIONAL	C7. Certain land uses and facility types within the subregion are particularly difficult to protect, evacuate, and rebuild due to the critical functions they serve. These include residences, elder care facilities, hospitals, childcare facilities, schools, and animal shelters. *(Consequences: Public health and safety; people where they live and work; equity; local and regional economy)*
FUNCTIONAL	C8. Community facilities such as hospitals, long-term care facilities, and those that serve at-risk, less mobile or medically dependent populations, are vulnerable since the individuals they serve cannot easily be evacuated or sheltered and require on-site care, specialized equipment, and a high level of coordination. *(Consequences: Public health and safety; people where they live)*
FUNCTIONAL	C9. Facilities that provide key community services are vulnerable if they cannot maintain operations, if connections to services such as power, clean water, and safe food supplies are not available, or if they cannot be easily accessed. This is of particular concern for facilities that play a role in emergency response and recovery such as schools, hospitals, shelters, and nursing homes. *(Consequences: Public health and safety; people where they live and work; equity)*
PHYSICAL	C10. Most residences, employment sites, and community facilities are highly susceptible to damage from sea level and groundwater rise because of their construction methods or materials. When flooding damages these structures, the release of hazardous materials including paints, cleaners, oils, batteries, pesticides, asbestos, and medical waste can occur. *(Consequences: Public health and safety; people where they live and work; equity; local and regional economy; ecosystem services)*
PHYSICAL	C11. Sites that generate, treat, store, or transport hazardous materials are particularly vulnerable since flood damage could cause a release of potentially harmful materials. *(Consequences: Public health and safety; people where they live, work and recreate; equity; local economy; ecosystem services)*
PHYSICAL	C12. Essential mechanical and electrical equipment in buildings are highly water and salt sensitive, and are often located below-grade or on the ground floor. *(Consequences: Public health and safety; people where they live and work; equity; local and regional economy)*
PHYSICAL	C13. Structures with habitable space below grade are vulnerable to sea level rise, storm events, and elevated groundwater. *(Consequences: Public health and safety; people where they live and work; equity)*

Transportation

ground transportation | airport | seaport

INFORMATION	T1. There is a lack of detailed, easily accessible and well coordinated transportation infrastructure information which is necessary for vulnerability and risk assessments. *(Consequences: Public health and safety; people where they live, work, recreate and commute; equity; all scales of economy)*
GOVERNANCE	T2. The number and relationships of public agencies and private entities that own and operate transportation assets complicates planning and implementing improvements or use changes. Due to the function and physical characteristics of these assets, numerous agencies and organizations will be affected by the temporary disruption and permanent loss, or adaptation responses for, transportation assets. *(Consequences: Public health and safety; people where they live, work, recreate and commute; equity; all scales of economy; ecosystem services)*
GOVERNANCE	T3. The capacity to plan for sea level rise and storm event impacts on transportation infrastructure in a timely manner is limited due to the current lack of financing and regulatory mechanisms. *(Consequences: Public health and safety; people where they live, work, recreate and commute; equity; all scales of economy; ecosystem services)*
GOVERNANCE	T4. Public agencies and private entities that own or manage transportation assets do not have control over the surrounding land, road, or transit that provide access to their facilities or services, or in some cases provide protection against flooding. Ensuring that access to these facilities remains viable and that current levels of flood protection are maintained will require cooperation that goes beyond the agencies operating the transportation infrastructure. This is of particular importance to regionally and nationally significant infrastructure such as the Oakland International Airport, the Port of Oakland seaport, the interstate system, and lifeline facilities. *(Consequences: Public health and safety; people where they live, work, recreate and commute; equity; all scales of economy; ecosystem services)*
FUNCTIONAL	T5. Alternative routes have limited additional capacity to accommodate re-routed commuter traffic (e.g., buses or carpools) or goods movement. If significant roadways or nodes are disrupted, re-routing would result in heavy congestion that could overwhelm the region's roadways and interstates as well as non-motorized transportation corridors (bike and pedestrian). *(Consequences: Public health and safety; people where they live, work and commute; equity; all scales of economy; ecosystem services)*
FUNCTIONAL	T6. The temporary disruption or permanent loss of public transportation assets due to sea level rise and storm events, and the lack of sufficient alternatives, could leave residents in some communities unable to travel on a day-to-day basis, compounding evacuation challenges during an emergency. *(Consequences: People where they live, work and commute; equity; local economy)*
FUNCTIONAL	T7. The rail system lacks redundancy, and fixed stations and maintenance yards serve long, linear lengths of track. The interconnected nature of rail and the lack of redundancy mean that damage at any point in the system can disrupt commuter and goods movement system-wide, causing significant economic effects in the region, particularly if there is a loss of service to the seaport or airport. Repair or relocation of rail infrastructure may require significant investment to ensure public safety and security. *(Consequences: Public health and safety; people where they live, work and commute; equity; all scales of economy)*
FUNCTIONAL	T8. Certain communities or facilities are linked by only one or two access-ways (e.g., road, rail, or transit) and could become isolated during disasters. For example, the majority of access roads to the Port of Oakland's seaport and Oakland International Airport are vulnerable, and if they flood they could isolate these regionally significant facilities. *(Consequences: Public health and safety; people where they live, work and commute; equity; all scales of economy)*
FUNCTIONAL	T9. The Port of Oakland seaport exports a significant amount of perishable goods, such as agricultural products. Sea level rise and storm events could delay and disrupt the movement and delivery of these goods. *(Consequences: All scales of economy)*
FUNCTIONAL	T10. The seaport facilities in the San Francisco Bay region do not have sufficient capacity to handle additional cargo if operations at the Port of Oakland seaport were disrupted by sea level rise and storm events. *(Consequences: All scales of economy)*
FUNCTIONAL	T11. There is not sufficient commercial airport runway capacity in the San Francisco Bay Area to serve as a short- or long-term alternative to Oakland International Airport if it were damaged or disrupted due to sea level rise or storm events. *(Consequences: All scales of economy)*
PHYSICAL	T12. Many high-cost and critical elements of transportation infrastructure are highly vulnerable to flooding because they are located at or below grade (tubes, tunnels, ventilation), in low-lying areas (airport runways, storage and maintenance facilities), or on top of levees (rail alignments). *(Consequences: Public health and safety; people where they live, work and commute; equity; all scales of economy)*
PHYSICAL	T13. Water- and salt-sensitive electronic and mechanical components and power supplies critical to the continued function of transportation infrastructure are often at or below grade and therefore are vulnerable to sea level rise, storm events, and elevated groundwater levels. *(Consequences: Public health and safety; people where they live, work and commute; equity; all scales of economy)*
PHYSICAL	T14. Certain assets such as bridges across tidal streams or in the Bay, and infrastructure located under the wharves at the Port of Oakland seaport, may be increasingly vulnerable to high water levels and wave erosion during storm events, which can disrupt asset function, cause scour, require additional maintenance, and potentially shorten asset life span. *(Consequences: Public health and safety; people where they live, work, recreate and commute; all scales of economy)*

Utilities

energy & pipelines | stormwater | telecom | wastewater

INFORMATION	U1. There is a lack of detailed, easily accessible, and well-coordinated information about the ownership, location, and condition of energy, pipeline, telecommunication, and stormwater infrastructure, which is needed for site- and asset-specific vulnerability and risk assessments. *(Consequences: Public health and safety; equity; people where they live and work; equity; local and regional economy; ecosystem services)*
GOVERNANCE	U2. The infrastructure that comprises wastewater, stormwater, and flood control systems is either interconnected (e.g., stormwater pipes connect to flood control channels) or affected by other systems (e.g., stormwater contributes to wet weather flows to wastewater treatment plants), but is owned and managed by different public and private entities. Even within a single utility, different departments are often responsible for interdependent functions (e.g., reducing versus handling wet weather flows). Due to these interdependencies, many assets will be affected by the temporary disruption or permanent loss of, or adaptation responses for, other assets that are owned and operated by different departments or entirely separate agencies. *(Consequences: Public health and safety; people where they live and work; equity; local and regional economy; ecosystem services)*
GOVERNANCE	U3. Existing operations, maintenance, and emergency response plans and procedures for utility infrastructure may be inadequate to address contingencies associated with storm events. *(Consequences: Public health and safety; people where they live and work; local and regional economy; ecosystem services)*
GOVERNANCE	U4. Cities and flood control districts have limited ability to increase revenues to address current stormwater and flood management needs, and sea level rise impacts will create a need for additional funding. *(Consequences: Public health and safety; people where they live and work; equity; local and regional economy; ecosystem services)*
FUNCTIONAL	U5. Wastewater treatment systems are large, expensive, and complex, and there is little to no redundancy within each system or the ability to connect across systems, making them highly vulnerable to sea level rise and storm events. *(Consequences: Public health and safety; people where they live and work; local and regional economy; ecosystem services)*
FUNCTIONAL	U6. Stormwater and flood control infrastructure is vulnerable to higher Bay water levels and rising groundwater levels that will reduce the capacity of these systems to collect, convey, and discharge flows. *(Consequences: Public health and safety; people where they live and work; all scales of economy; ecosystem services)*
PHYSICAL	U7. Many mechanical and electrical components of utility infrastructure are vulnerable to groundwater rise and/or salinity intrusion due to water- and salt-sensitivity. *(Consequences: Public health and safety; people where they live and work; all scales of economy; ecosystem services)*
PHYSICAL	U8. Certain critical utility infrastructure (e.g., cell towers, wastewater and stormwater pump stations) requires an uninterrupted power supply to function. *(Consequences: Public health and safety; people where they live and work; local and regional economy; ecosystem services)*
PHYSICAL	U9. Infrastructure such as pipelines, cables, and utility poles that are exposed to storm events are susceptible to damage. Scour and erosion can expose pipelines and cables, and pipelines can become buoyant when flooded, while high winds can topple utility poles and damage electrical wires, especially in flooded areas. *(Consequences: Public health and safety; people where they live and work; local and regional economy; ecosystem services)*

Shorelines

natural shorelines | structural shorelines | parks & recreation

INFORMATION	S1. Publicly available information about the ownership, elevation, and condition of structural shorelines is insufficient for conducting vulnerability and risk assessments and developing adaptation responses. *(Consequences: Public health and safety; equity; people where they live, work and recreate; equity; all scales of economy; ecosystem services)*
GOVERNANCE	S2. Landowners, agencies and facility managers do not always have control over the shorelines (structural and natural) that protect their vulnerable assets from flooding or storm event impacts. *(Consequences: Public health and safety; equity; people where they live, work and recreate; equity; all scales of economy; ecosystem services)*
GOVERNANCE	S3. Structural shorelines that lack dedicated funding and permit authorizations for maintenance and improvements, and which are not included in long-range capital improvement planning, are particularly vulnerable because shoreline managers cannot easily maintain or make repairs to address sea level rise and storm event impacts for these "at risk" structural shorelines. *(Consequences: Public health and safety; people where they live, work, recreate and commute; local and regional economy; ecosystem services)*
GOVERNANCE	S4. Existing inter-agency coordination, governance structures, and financing strategies are insufficient for planning and implementing the types of large-scale, phased, structural and/or natural shoreline projects that will be needed to address sea level rise and storm events. *(Consequences: Public health and safety; people where they live, work, recreate and commute; local and regional economy; ecosystem services)*
GOVERNANCE	S5. Planning and implementing improvements or changes in use at shoreline parks is complicated because parks are often owned and managed by different agencies. Some parks have multiple managers and owners, adding complexity to funding and decision-making. *(Consequences: Public health and safety; people where they live, work, recreate and commute; equity; local and regional economy; ecosystem services)*
FUNCTIONAL	S6. Many Bay Trail segments are vulnerable because they are situated on shoreline levees, cannot be used when flooded, and often have surface materials that erode easily. Because of the interconnected nature of the Bay Trail, disruption of one segment can affect the function of the entire Bay Trail. *(Consequences: People where they recreate and commute; equity; local and regional economy)*
FUNCTIONAL	S7. Shoreline access for people with limited mobility is especially vulnerable to sea level rise and storm events. *(Consequences: People where they recreate and commute; equity; local and regional economy)*
FUNCTIONAL	S8. Shoreline recreation areas with activities that depend on grass (sports fields, golf) are vulnerable to coastal flooding and saltwater intrusion. *(Consequences: People where they recreate; equity; local and regional economy)*
FUNCTIONAL	S9. Loss of sandy beaches due to sea level rise and storm events will diminish access to the Bay for certain water recreation activities (swimming, boardsailing, paddle boating). *(Consequences: People where they recreate; local and regional economy)*
FUNCTIONAL	S10. Birds and wildlife that rely on tidal marshes will be displaced by changing (i.e., downshifting) habitat and more frequent or permanent inundation. These changes will force them to forage and nest closer to people and infrastructure, such as roads and highways, and will reduce the amount of available high tide refugia. *(Consequences: People where they recreate; ecosystem services)*
PHYSICAL	S11. Depending on the type and design, structural shorelines will have varying sensitivity to sea level rise and storm events. Daily tides can cause wear and tear of varying degrees depending on type and design of shoreline, while overtopping during larger storm events can cause destabilization and failure. *(Consequences: Public health and safety; people where they live, work, recreate and commute; local and regional economy; ecosystem services)*
PHYSICAL	S12. Natural, non-wetland shorelines (e.g., sandy beaches, bluffs, and cliffs) are vulnerable to sea level rise and storm events, which cause erosion and land loss. *(Consequences: Public health and safety; people where they live, work, recreate and commute; local and regional economy; ecosystem services)*
PHYSICAL	S13. Tidal marshes will not keep up with sea level rise solely through vertical accretion, especially in light of the Bay's declining suspended sediment supply and the lack of space to shift landward. *(Consequences: Public health and safety; people where they recreate; local and regional economy; ecosystem services)*
PHYSICAL	S14. Managed marsh systems are particularly sensitive to sea level rise and storm events because they rely on water level control structures (tide gates, berms, and levees), some of which are already in need of repair. *(Consequences: Public health and safety; people where they recreate; local and regional economy; ecosystem services)*
PHYSICAL	S15. Stormwater drainage at shoreline parks and golf courses in low-lying areas will worsen with sea level and groundwater rise. *(Consequences: People where they recreate; local and regional economy; ecosystem services)*