Synthesizing Vulnerability and Risk: The Define Step

ADAPTING TO RISING TIDES PROJECT

DECEMBER 2013

The Adapting to Rising Tides (ART) project assessed the vulnerability and risk of shoreline and community assets by considering the underlying causes and components of vulnerability to sea level rise, storm events, and rising groundwater. The assessment also characterized the potential consequences to society and equity, the environment, economy and governance.

Once the ART assessment was complete, it became clear that the results needed to be organized and communicated in a manner that would support developing adaptation responses. The transition from the Assess to the Plan step in adaptation planning can be challenging. Often ranking, scoring or prioritization is suggested as the means to negotiate this shift. These approaches can have the unintended consequences of leaving important vulnerabilities behind, and reducing the transparency and clarity of the overall planning process. This transition was so critical that the ART project added a separate step to the adaptation planning process – the Define Step (see Figure 1). The objective of the Define Step is to organize the assessment findings, both within and across asset categories, create materials that clearly communicated the key issues and outcomes of the assessment, and ease the transition from assessing vulnerabilities into response planning.

By organizing and communicating the assessment findings, the project created a foundation that supported the development of adaptation responses that when implemented will build shoreline and community resilience. Two steps were taken. The first was to classify vulnerabilities and risks into categories that would help asset managers and decision-makers understand the defining characteristics of an issue (e.g., its timing, scale, responsibility for management, etc.). This step better supports an informed discussion about issues and the potential actions that could be taken to address them.

FIGURE 1. ART Planning Process

The second step was to summarize the assessment findings within and across the twelve asset categories evaluated. This was a key step that facilitated the identification of shared vulnerabilities among asset categories, eliminated redundancies, and highlighted the unique vulnerabilities of specific asset categories. The summarized assessment findings were then used to develop adaptation responses for the ART project area (subregion).

The remainder of this report presents the summarized findings of the ART assessment, highlighting the overarching vulnerabilities found across all asset categories evaluated, and the consequences of those overarching vulnerabilities on society and equity, the environment, economy and governance. In addition, the role of geographic and jurisdictional scale in assessing vulnerability and risk is discussed, and a number of recommendations on this issue are resented.

Key Planning Issues

The ART assessment revealed a number of overarching vulnerabilities that cut across most of the asset categories. These overarching vulnerabilities fell into five main themes: information gaps, emergency preparedness and response, population characteristics, certain land uses, and networked infrastructure. Taken together, these five themes define vulnerability in the ART subregion. These themes are also found across the entire Bay region at most planning scales.

Information Gaps

There are significant gaps in the quality and availability of information necessary to understand vulnerability and risk in the ART subregion. These include gaps in data and information regarding both the social and physical dimensions of vulnerability and risk (which are discussed in the sections that follow).

There is a very limited understanding of how groundwater and salinity levels along the shoreline will respond to a rising Bay. Groundwater rise and salinity intrusion will likely increase the vulnerability of many residences, utilities and other infrastructure that are not designed for these conditions. Additionally, rising groundwater may also increase the potential for liquefaction during an earthquake. Residences and other land uses built on the shoreline are not designed for this condition, and are likely to be at greater risk to seismic events as groundwater levels rise.

The tidal and managed marshes that

Overarching Vulnerability Themes

Information Gaps – there are significant gaps in the quality and availability of information necessary to improve the understanding of vulnerability and risk.

Emergency Preparedness and Response – plans, policies and practices that guide emergency planning do not consider sea level rise or future storm events that could affect areas not currently at risk of flooding.

Population Characteristics – young children, the elderly, people with special 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 are especially vulnerable to flooding and storm events.

Certain Land Uses – residential land uses of all types, facilities that serve at risk less mobile or medically dependent populations, and animal facilities or shelters, zoos, and farms are particularly difficult to protect, evacuate, or rebuild.

Networked Infrastructure – assets that act as a continuous corridor are highly vulnerable as disruption to one segment can cause cascading, secondary impacts to adjoining segments or even farther away.

comprise the natural shorelines that in many cases protect communities and infrastructure from flooding are themselves at great risk from sea level rise. Marshes around the Bay are not predicted to keep pace with sea level rise solely through vertical accretion, especially in light of the Bay's declining suspended sediment supply. In the ART subregion there is a significant lack of space for marshes to shift landward, and therefore they could be lost to "coastal squeeze." The understanding of how these natural, dynamic systems will respond to sea level rise is a growing but still very limited, and there is a lack of information on how they will be affected by changes in the shoreline, and in particular by structural solutions such as levees and berms that can change tide, wave or sediment conditions. The extent to which natural shoreline systems will be resilient to sea level rise, the amount of proactive management or intervention required, and the potential for other actions to affect these areas, are not well understood and create a regional research need.

The ART project also found that information on the **ownership, location and condition of energy, pipeline, telecommunication, and stormwater infrastructure** is particularly difficult to obtain, as it does not currently exist or is not publically available, up-to-date, or easily accessible. While some utility information will likely remain restricted for security reasons, the subregion and the region as a whole would benefit from access to basic information that supports vulnerability and risk assessments and adaptation planning.


Photo: ART project

A lack of centrally coordinated, up-to-date, accurate information about **hazardous material sites and contaminated lands** is a barrier to planning for future flood risks. Many commercial and industrial land uses generate, treat, store or transport hazardous materials, and a number of shoreline parks in the subregion are built on closed landfills. These types of land uses are particularly vulnerable as flooding could result in a release or mobilization of potentially harmful materials. While it was possible to find publically available data on the location of hazardous materials sites and contaminated lands, the information is provided by a variety of local, regional, state and federal agencies each with their own definitions and authorities. Furthermore, the available information was often technical and not easily translated into how sensitive the sites would be to flooding. Together these information challenges proved to be barriers to defining the specific vulnerability of these types of facilities and land uses.

Lastly, although **flood risk maps** are being updated for shoreline communities around the Bay, these efforts identify current risk and do not evaluate future changes due to sea level rise. While the underlying data developed for these efforts will be extremely useful in informing analyses of future flood risk, most shoreline communities neither have easy access to the information nor the capacity or resources to fully leverage its potential power. In addition, access to **historic weather observations** at a scale appropriate to inform an understanding of past flooding as an indicator of future risk is very limited.

Emergency Preparedness and Response

Most of the plans, policies and practices that guide emergency planning either in the ART subregion or elsewhere do not consider sea level rise or future storm events that could affect areas not currently at risk of flooding. Additionally, these plans do not always identify the specific needs of community members, or

include strategies for managing those needs.

The crucial information necessary to improve these plans is not always available, correct, up-to-date, or easily accessible. This information includes the location of at risk community members that need specialized equipment or evacuation procedures because they are less mobile or medically dependent, the location and needs of facilities and individuals who care for animals (shelters, zoos, pet owners), the status of hazardous material sites or contaminated lands, and the characteristics and condition of shoreline protection infrastructure. Collecting, maintaining and assuring the quality of this type of data requires a sustained effort, and requires coordination among public, public, and non-profit sectors. For example, public agencies could work with community or faith-based organizations that are in frequent contact with the community members and could help bridge the gap in information about those most at risk. It is important to recognize, however, that community partners can have a hard time finding the capacity and resources to fully participate in these or other types of sustained efforts. In addition, existing planning and collaborative processes are often not designed to fully engage these organizations, and this can pose barriers to building and maintaining the robust, sustained partnerships necessary to address future vulnerabilities and risks in an equitable, environmental, and economically feasible manner.

Plans and resources are generally inadequate to address contingencies and secondary impacts associated with widespread or long-lasting storm event flooding, especially if certain land uses, such as residential neighborhoods, nursing homes, or hazardous or contaminated sites, are affected for any length of time. Many of the facilities that play a role in emergency response and recovery, such as schools, hospitals, and shelters are themselves vulnerable to sea level rise and storm events. If these facilities cannot maintain operations because their connection to utilities, clean water, and safe food supplies are disrupted, response and recovery efforts will be slowed. In addition, if these facilities cannot be safely accessed because roads are flooded, the communities that rely on them will be at greater risk.

Many significant transportation assets in the ART subregion do not have adequate alternatives, or the alternatives have limited capacity to accommodate additional traffic. For example, disruption of I-880 between Oak Street and 23rd Avenue in Oakland, or I-80 between the Bay Bridge Toll Plaza in Oakland and Powell Street in Emeryville, would result in heavy congestion that could overwhelm not only the subregion but also the region as a whole. Disruption to the road network will also affect public transportation, both directly for bus service and indirectly for BART, passenger rail, and the ferry system. The lack of adequate alternatives could leave residents in some communities isolated during emergencies or disasters. This vulnerability is even greater for communities or facilities that are only linked to the transportation network by one access-way, or a limited number of roads or transportation providers.

In many cases, those that own or manage the transportation assets that are critical during an emergency or disaster do not have control over the lands that provide access to their facilities, or the shoreline that protects them. For example, both passenger and general aviation operations at the Oakland International Airport rely on local roads and interstates. Key roadways leading to the airport, including Airport Drive, Hegenberger Road and I-880, are owned and managed by other agencies, while the shoreline that protects these roads is owned and managed by yet other agencies. Ensuring the airport remains viable during an emergency will require cooperation that goes beyond the Oakland International Airport, to those that own and manage the shoreline and the transportation facilities that provide protection and access. The need for coordination and decision-making among so many may pose significant management challenges that could increase the vulnerability of the airport and the facilities and services that are dependent on it, co-located with it, or nearby.

Population Characteristics

Certain community members tend to be especially vulnerable to flooding and storms, including young children, the elderly, people with special 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. These community members may lack access to information and services, financial means or the physical capacity necessary to prepare for, or respond to, flooding or other hazards. Historic responses to disasters have demonstrated that specific community needs must be considered in planning and policy-making to build resilience and protect public health and safety.

Photo: M. Wolfe

According to the 2000 U.S. Census data, approximately one-third of the households exposed to storm events in the ART subregion are renter occupied. Renters are generally less likely than owners to have the means to prepare the buildings they live in to withstand flood events. In addition, as many as 20 percent of the residents exposed to storm events in the ART subregion are low income as defined by households earning less than 200 percent of the national poverty level. Low-income residents may have reduced means to prepare for, respond to, and recover from flood events. Lastly, there were approximately 300 residents living in nursing institutions in the ART subregion that could be exposed to storm events by the end-of-century. As this number was based on 2000 U.S. Census data, and because the number of seniors is increasing over time it is highly likely that there are more elderly residents at risk then the assessment suggests.

Overall, communities and neighborhoods with a strong social network (social capital), where residents know each other and are invested in the overall community good, can reduce their vulnerability to flooding and storm events. For example, linguistically isolated

Community members most likely to be vulnerable include those with the following characteristics:

- The elderly
- Young children
- Caretakers of young children or the elderly
- Linguistically isolated households
- Low income households
- People with mobility or medical needs
- People without automobiles
- People without insurance
- Renter-occupied households
- Pet owners and other caretakers of animals

populations, e.g. households without a member over age 14 that “speaks English well” are often at risk because they may not have access to critical information about preparing for, or responding to, flood events.

A strong social network can alleviate this risk by ensuring all community members, even those that are linguistically isolated, are provided the information they need. Social networks are, however, informal and are built on the relationships of those that live, work, and use the services within the neighborhood. These connections can be easily severed, in particular if homes are not quickly inhabitable or services are not quickly reopened after a disaster. Once disrupted, social networks are often difficult if not impossible to rebuild.

Certain Land Uses

The ART assessment demonstrated that certain land uses are highly vulnerable because they are particularly difficult to protect, evacuate, and rebuild due to the critical functions they provide, the community members they serve, or the types of activities that occur at these sites. Public health, safety and welfare are most at risk where people live and sleep, including residential land uses of all types (single-family, multi-family and senior housing). In addition, facilities such as hospitals, long-term care facilities and those that serve at-risk, less mobile or medically dependent populations are highly 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 for safe and effective evacuation. Lastly, other land uses, for example contaminated lands and hazardous material sites, can threaten public health, safety and welfare in the event they are flooded and are therefore not only vulnerable, but can cause cascading or secondary vulnerabilities in the adjacent neighborhoods and communities.

Within the ART subregion there are a number of senior residences, skilled nursing facilities, residences and an animal shelter at risk of flooding as sea level rises. Most shoreline communities have been developed without consideration for protecting against future storm events or sea level rise inundation. This will likely make protecting some of these communities more difficult. Additionally, there is a lack of adequate resources to address the effects that widespread or long-lasting flooding would have on certain uses within communities. For example, relocating or retrofitting elder care facilities or residential neighborhoods is very difficult and creates significant social and economic disruption. This combination of factors places these land uses at particular risk.

Photo: WLC Architects

Photo: Bay Trail

Residences and critical facilities, including those that serve the elderly or medically dependent, are not designed to withstand flooding, rising groundwater or saltwater intrusion. Essential mechanical and electrical equipment, such as fans, boilers, and pumps that are highly water and salt sensitive are often located below-grade or on the ground floor. Many of these structures are susceptible to damage from rising groundwater, and as sea level rises so will the risk of flooding of below-grade space that is either habitable or houses essential equipment. Long and short-term response and recovery efforts are particularly challenging for these land uses. Finding alternative housing or facilities with the capacity to serve the displaced within a reasonable distance from their social networks and community services can be difficult, if not impossible. Even temporary relocation can be disruptive, especially when the people who are displaced lose connections to their support systems and community services.

Many of the plans, policies and practices that guided community land use and capital investment planning in the past did not consider sea level rise and storm events. Therefore, our existing communities were built along the shoreline in a manner that makes them difficult to protect from future flood risks. Currently, very few plans and policies in the ART subregion or elsewhere in the region have been updated to include the consideration of sea level rise and future storm event impacts. This means that without a significant change at the local, regional, state and even federal levels it is possible that planning for growth in the region will follow past practices without considering future flooding, leading to an increased number of people at risk.

Networked Infrastructure

There are many assets in the ART subregion that function as networks connected as a continuous corridor, or as a series of contiguous segments. Disruptions to one segment cause cascading, secondary impacts in adjoining segments or even farther away. This is especially true for long and linear ground transportation assets like the Bay Trail and the regional rail system, utility infrastructure, and the system of shoreline protection along the Bay's edge.

As an example, much of the utility infrastructure in the ART subregion is interconnected and is often managed by different entities. For example, stormwater infrastructure is mostly managed by cities and discharges to flood control channels managed by the county. In addition, networked utility infrastructure often relies on other services and facilities (power, water, communication) that are also networked and owned and operated by others. These connections and dependencies mean that improving the resilience of utility networks will require close coordination of many public and private entities and an understanding of the relationships among the networks.

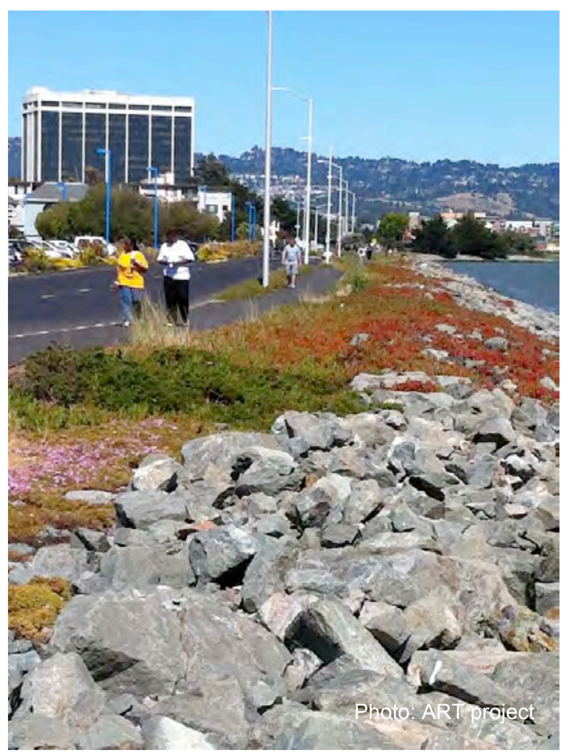


Photo: ART project

Most of the networked infrastructure in the ART subregion is essential to day-to-day community and economic functions, and is critical during an emergency or disaster. Ground transportation assets, including roads, heavy and light rail, and bike and pedestrian ways provide access to goods, services, jobs, schools, family, friends, and recreation. Utilities provide water, power, and means of communication. The shoreline, both natural and structural, provides access to the Bay and protects inland communities and job centers from flooding during extreme water levels that occur during storms.

The ART assessment revealed that the characteristics of networked infrastructure range from fairly rigid or fixed to more flexible and modular. These differences were most obvious when considering adaptive capacity, that is the ability of different assets or asset components to accommodate or adjust to sea level rise and storm events. As an example, rail assets in the ART subregion are part of the regional rail system that consists of long, linear track running within existing, limited, right-of-ways that are served by fixed stations and maintenance yards. The entire rail system is fixed, and making changes to any one component of the network will require changes in many adjacent segments. In addition, disruptions that occur in one segment will have widespread and cascading consequences on the function of the entire system, affecting the entire rail networked including the loss of cargo and passenger service for the duration of the event and during any necessary recovery activities. On the other hand, the ART assessment found that, in general, telecommunication infrastructure is fairly modular, and that there is the capacity to improve redundancy system-wide in order to maintain service, using mobile temporary structures known as COWs (cell on wheels), when a portion of the larger network is disrupted.

he network of structural and natural shorelines that protect communities and infrastructure from flooding or storm events are generally not owned or managed by the people and properties that they protect. As such, those that rely on shoreline protection are not always included in decisions about, or funding for, their maintenance, repair or upgrade. In addition, because shorelines often lack dedicated funding and permit authorizations for ongoing maintenance or improvements owners and managers cannot easily maintain or make repairs to address storm event impacts, let alone prepare for sea level rise.

Consequences of the Identified Vulnerabilities

Sea level rise and storm events will have consequences on public health and safety; people where they live, work, commute and recreate; equity; ecosystem services; and the local and regional economy. Based on the overarching vulnerabilities and those identified more specifically for the twelve asset categories, there could be significant financial and personal consequences to those that live and work in the ART subregion, including the loss of life and personal items, loss or damage to residences and businesses requiring temporary or permanent relocation, and dislocation from jobs, schools, and other important community services and ties. Flooding of facilities that generate, treat, store or transport hazardous materials could significantly harm public health and safety and the function of nearby ecosystems. Flooding of residences and commercial establishments can have similar, and potentially even more widespread consequences, if it leads to a release of household hazardous materials such as paints, cleaners, oils, batteries, pesticides, asbestos, or medical waste.


Photo: H.A.R.D.


Photo: Wikimedia Commons

The magnitude of the consequences to the residents, households, and communities along the shoreline varies depending upon age, health, income, vehicle ownership, pet ownership and other characteristics. Of the approximately 17,321 residents of the ART subregion that live in areas that would be exposed to a storm event (i.e., a 100-year extreme event) with 16 inches of sea level rise, 34 percent have high vulnerability and 50 percent fall within the middle range based on the social vulnerability index (SOVI)[1]. Some of the key characteristics considered in the SOVI that increase vulnerability include renter-occupation, linguistic isolation, lack of a vehicle, and low-income.

By virtue of the role shorelines play in providing storm and flood protection, damage to structural and natural shorelines would put people who live and work in the subregion as well as significant infrastructure at risk.

[1] The Social Vulnerability Index (SOVI) is a comparative metric that helps users examine differences in social vulnerability. The SOVI method was applied to Census 2000 block groups for all coastal states by the University of South Carolina with funding from South Carolina Sea Grant and NOAA Coastal Services Center. SOVI information and data is available at: www.csc.noaa.gov/digitalcoast/data/sovi.

The societal and economic consequences of these impa[2]cts would be enormous. Using current population and property assessment values, a storm event with 16 inches of sea level rise that causes portions of the shoreline protection system to overtop could potentially affect 17,300 residents, 18,300 employees, and a half billion dollars worth of property damaged based on replacement costs only. Beyond storm and flood protection, the shoreline plays a key role in providing ecosystem, recreational, economic and transportation benefits not only to the ART subregion, but also to the region as a whole. For the many areas around the Bay shoreline that are managed for multiple purposes, sea level rise and future storm events will have the consequence of challenging owners and managers to maintain and enhance these systems to ensure they continue to provide the same suite of benefits.

Lastly, there will be societal, economic and environmental losses due to damage and disruptions to key infrastructure, services, and businesses that would affect not only the communities in the ART subregion, but the entire region as well. For example, damage or disruption of many of the networked assets assessed, including transportation, utility and shoreline systems, will have consequences that spread from the ART subregion to the greater region, and even beyond in the case of nationally and internationally significant assets such as the interstates, the rail corridors, the seaport, and the airport.

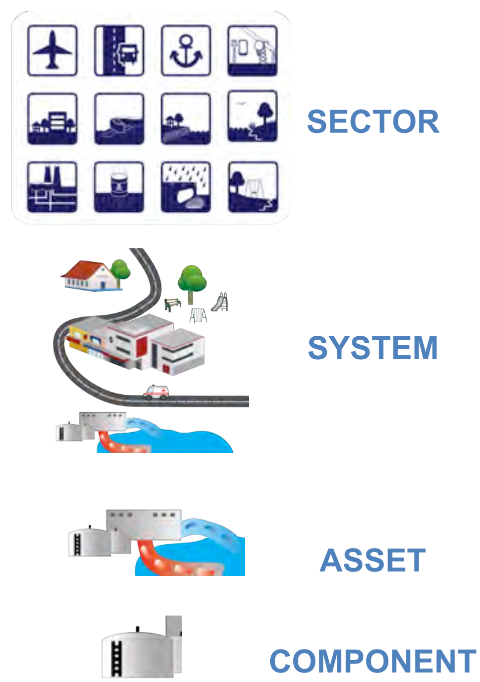
The magnitude of these effects in terms of social equity, the environment, economy, and governance have yet to be sufficiently characterized at a variety of scales, from local to regional to state-wide and even national, in order to understand the trade-offs and benefits among adaptation actions needed to create a resilient Bay Area.

Issues of Scope of Scale in Vulnerability and Risk Assessments

The ART assessment helped answer a number of key process questions. For example, how do the project scope, including the number of assets or geographic scale, affect the assessment and planning outcomes? What is the nature of the analysis that can be completed at different scales? How can issues that cut across different types of assets, or sectors, as well as scales be clearly summarized and communicated?

The ART project was able to investigate these questions because the project scope cut across multiple asset categories and sectors, and because vulnerability and risk were assessed at different geographic scales and levels of specificity within asset categories. At the scale of the project area or subregion that included most of one county's shoreline, each of twelve asset categories was evaluated as a whole. Analyses also addressed specific asset systems, individual assets, and asset components of individual assets (restored tidal marsh). In some cases these more fine-grained assessments looked at a unique sites within the subregion (e.g., a shoreline park, a wastewater treatment plant, or the Port of Oakland Seaport). Where it was impossible to consider all assets in a category, vulnerability of representative assets and asset components was described.

FIGURE 2. Assessment scales used in ART.



The broad scope of the ART assessment showed how relationships among asset categories could lead to secondary vulnerabilities. For example, physical infrastructure at the Port of Oakland Seaport may be relatively resilient to flooding and other storm impacts, but the seaport functions are highly susceptible to disruptions in the regional rail system and the roadways that provide access for goods movement and employees. Unlike the seaport infrastructure, the rail lines that serve the seaport are vulnerable to sea level rise and storm impacts at multiple locations (within, and outside, the ART subregion). This relationship might have been missed with a more limited scope of analysis. The multi-sector approach also yielded insights about consequences that are discussed in the next section.

Broad scale evaluations (e.g., across the entire subregion, an asset category, or a system of assets) highlighted combined and cumulative vulnerabilities. In the assessment of community facilities and services, it became clear that there is insufficient emergency response capacity to deal with widespread flooding which is likely to occur with future sea level rise and storm events. As another example, the analysis of park and recreation areas showed that across the subregion almost all playing fields (e.g., for soccer and baseball) are highly vulnerable to flooding and exposure to salinity. The severity of these issues would not have been apparent if the assessment had only looked at specific sites or individual assets without "scaling" the findings back up to a subregional or category scale.

Analysis of vulnerability and risk at the asset category scale revealed complexities in regulatory and other decision-making processes. For example the Oakland International Airport is regulated by multiple levels of government, from federal to regional to local, and there is little ability to institute changes without a significant amount of oversight. Having this "big picture" context facilitates building effective adaptation responses that identify appropriate and clear implementation responsibilities.

The broad-scope, multi-scale approach used in ART shed light on the benefits and constraints that project scope and different scales of analysis play in adaptation processes and outcomes.

Relying on broad scale – subregional, or sector-level – assessments has some drawbacks. At this scale it is difficult to fully understand asset-specific vulnerabilities that are often caused by particular physical and functional attributes. For example, without scaling down to the site-level it is difficult to identify sensitive components, or specific assets that serve a unique function, or that lack redundancy. Similarly, at the site-level scale is it possible to identify specific management challenges associated with certain assets. This is the case for some shoreline parks in the subregion that are owned by one agency or organization and managed by another.

Combining the evaluation of assets at the broad subregional scale and at the site-specific level provided key insights about vulnerabilities of networked infrastructure. Assets that function as interconnected networks, such as ground transportation, utilities and shoreline protection, are vulnerable because disruption of one segment can have cascading affects on both adjacent and distant system segments. A multi-scale approach to analysis of these types of infrastructure helped pinpoint highly vulnerable assets or segments that are critical to maintain functions of the network.

Other benefits of considering individual assets and their components included insights as to similarities in physical and functional vulnerability among the asset categories. For example, assets with below ground or at-grade electrical and mechanical equipment are highly vulnerable to flooding because these components are sensitive to water and salinity. This physical vulnerability was shared among a number of asset categories, including wastewater, ground transportation, and community land uses. The assessment also highlighted how seemingly dissimilar assets, such as nursing homes, single access roadways, trails used by those with limited mobility, and tidal marshes that are home to threatened or endangered species, all have functional vulnerabilities because of the unique type of service they provide or the population they serve. Findings such as these help simplify future assessments by building a "check list" of conditions that frequently contribute to vulnerability and risk across multiple types of assets.

Lastly, for some asset categories, information challenges that would prevent further necessary assessment and planning only became apparent with a more focused look at the vulnerability of representative, individual assets. For example, in trying to acquire information about specific energy assets it became clear that security concerns restrict access to information. This lack of publicly available data describing the location, age and other important characteristics makes it difficult to understand the vulnerability of energy assets at any scale – whether regional, subregional, or site-specific. In evaluating representative hazardous materials sites it became clear that while data was publically available, and there were many sources, it was not well coordinated among the different agencies, some with overlapping regulatory authority, making it challenging to understand not only the vulnerability of these sites, but the consequences to the surrounding community. Recognizing information challenges that were only fully revealed at the asset scale was critically important to developing adaptation responses because resolving these challenges is almost always an essential precursor to further adaptation efforts.

Scale of the Consequences

The consequences of the identified vulnerabilities were also evaluated across a variety of scales. The assessment of consequences included qualitative considerations of the magnitude of the potential impacts on public health and safety, people where they live, work and recreate, social equity, the economy, and ecosystem services. The geographic scale of these potential consequences depended on the asset category and asset considered. For example, there could be site-specific consequences if a stormwater pump station failed, while disruption of a power substation could likely have neighborhood scale consequences. Many of the asset categories considered could also have significant consequences at multiple scales. For example, there could be neighborhood scale consequences if a specific shoreline park was affected, but larger scale regional consequences if the system of shoreline park and recreation areas was affected. The consequences of disruption for certain assets within the subregion, such as the Oakland International Airport or Port of Oakland Seaport, could easily reach beyond the local or regional scales, with effects on national and international goods and passenger movement.


Photo: Wikimedia Commons

The broad, multi-sector scope of the assessment was also important for developing a comprehensive understanding of the potential consequences of future sea level rise and storm event impacts and responses. Building on the previous example of the disruptions to rail service that, in turn affect cargo movement to and from the Port of Oakland Seaport, a potential outcome is that some cargo movement would be shifted to trucks, exacerbating public health and safety risks to West Oakland neighborhoods. The added traffic could overwhelm capacity of roadways, leading to broader scale impacts on the local and regional economy.

Summary and Conclusions

The ART project demonstrated that each assessment scale has specific benefits as well as constraints. For the ART project, the ultimate outcome was to develop adaptation responses at the subregional scale. To achieve this the assessment was conducted at multiple asset and geographic scales, and the resulting information was eventually used to form a subregional understanding of vulnerability and risk. Before initiating a vulnerability and risk assessment it is important to develop project goals and expected outcomes that can serve as a guide in determining the most practical and efficient scale or scales to be included in the assessment. For example, although the ART project goal is to build regional resilience, it was determined that it was more feasible to conduct an assessment at the subregional scale and then use that information to both scale up and scale down – to support both regional and local adaptation planning.

For the ART project, one of the key benefits of the subregional scale assessment was that it informed an understanding of the functional and cross cutting vulnerabilities that exist between assets and asset categories. These relationships can result in potentially significant or unexpected consequences if not identified and addressed. For example, vulnerabilities due to relationships among assets can cause a cascade of unexpected secondary impacts, leading to additional consequences that can make surrounding communities, land uses, facilities and services even more vulnerable.

The subregional scale was also a practical and efficient scale at which to assess vulnerability and risk because it quickly led to the identification of similarities between asset categories, and resulted in the development of adaptation responses that were applicable to a broad range of assets. A challenge of the subregional scale assessment was the large number of assets included in the assessment due to the size of the project area. The sheer number of assets even within one category (e.g., hazardous materials sites and contaminated lands) limits the ability to understand asset-specific vulnerabilities and risks. In order to bring a finer level of detail into the subregional scale assessment the ART project conducted site-specific scale assessments on representative individual assets. This combined approach resulted in a fairly rigorous understanding of vulnerability and risk, and is a process that can be repeated by others in the region and beyond.

Ultimately, vulnerability and risk assessments will be necessary at a variety of scales. Site-specific or individual asset assessments will be needed by managers to understand the vulnerabilities and risks they face. Neighborhood scale assessments will be needed to uncover relationships between individual assets that could cause secondary vulnerabilities or cascading consequences on the communities that rely on them. And both local and regional assessments will be necessary to address regionally important issues such as identifying relationships among assets and understanding the vulnerabilities and consequences of networked infrastructure. In selecting the scale of the assessment it is important to remember that each assessment scale is best suited to answer certain questions. For example, regional or larger scale assessments will be most suited for analyzing broad questions about regional assets and systems and identify the key issues, geographic areas and assets that need further analysis. This will lead to further, more detailed analysis to be conducted at a neighborhood, asset specific or site-level scale.

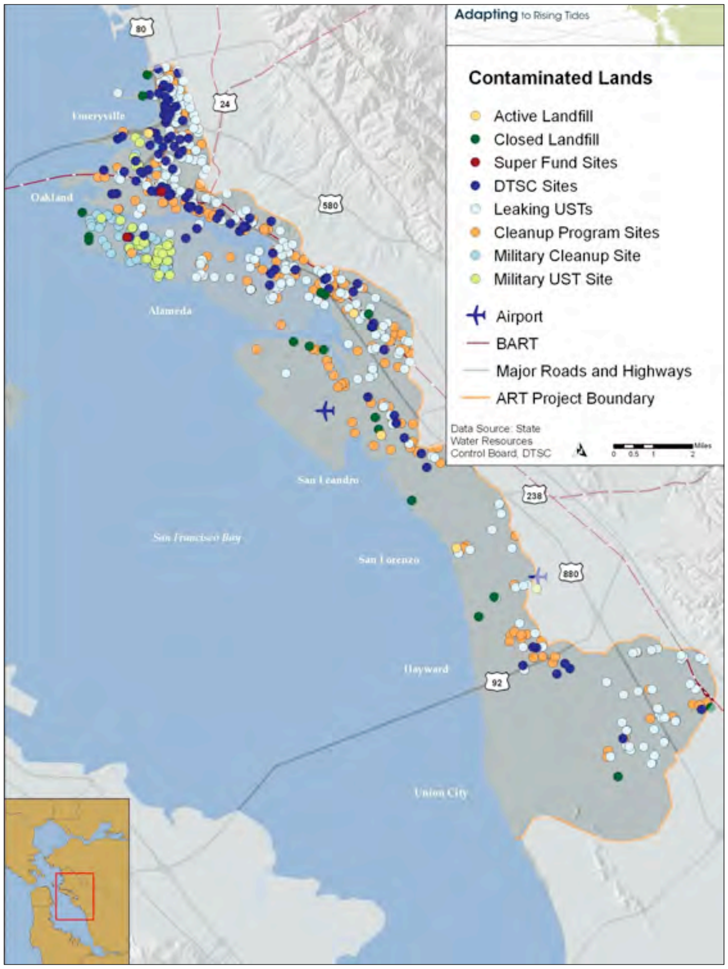


FIGURE 2. Contaminated lands in the ART subregion.

The large number of contaminated lands in the project area precluded assessments of individual sites. In order to develop a more refined understanding of vulnerability and risk for this and other categories with numerous, similar assets, the ART project conducted site-specific scale assessments on representative individual assets. Combined with the broader assessment for the entire asset category, this resulted in a comprehensive understanding of vulnerability and risk and supported the development of specific adaptation actions.

Conducting assessments at differing scales simultaneously in a coordinated manner can be an efficient and practical approach to achieving robust outcomes. Alternatively, assessments conducted independently at different scales can be connected in a sequential manner. For example, site or neighborhood scale planning efforts can use the findings of a local scale assessment, such as the ART subregional efforts, as starting point, which will result in a more comprehensive analysis. Assessments at the regional or statewide scale will need to be grounded in information gathered at the site, neighborhood and local scales if they are to lead to tangible outcomes. In addition, assessments at the broader regional or state-wide scale need to be advanced through strong partnerships and active participation of the communities, cities, counties and agencies that operate at the site, sector, neighborhood and local scales in the assessment area, which will be more fruitful if local partners start with a strong understanding of their own vulnerability and risk.