

# Scenario Planning: Overcoming uncertainty and informing action



## Tijuana River National Estuarine Research Reserve



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# Executive Summary

Climate change poses new management challenges for resource managers working to conserve and enhance resilient coastal habitats. Typical vulnerability assessment frameworks are challenging to consistently implement in the complex and uncertain socio-ecological context that resource managers make decisions in.

An alternative approach, **scenario planning**, is emerging as a framework that allows current and future vulnerabilities to be assessed, while overcoming the challenges associated with having to make informed decisions in the short-term while planning for long-term resilience.

**What are scenarios?** Scenarios are not predictions. Each individual scenario is an alternative description of how the future may unfold, outlining a different plausible future state of a system. Three overarching considerations guided the formation of the Tijuana River Valley's scenarios:

- Past: What was the Tijuana River Valley like historically?
- Present: What characterizes the River Valley today?
- Future: How might changes in our climate shape the River Valley in the future?

**Key Variables:** TRNERR used the relationship between two primary variables to frame the development of four separate scenarios:

- **Tidal prism**, and
- **Extreme river flow events**.

**Key Changes:** Each scenario was developed in three stages, through discussions at workshops and in one-on-one interviews with researchers, resource managers, and local agencies:

- **Physical Landscape:** Experts outlined how changes in tidal prism and extreme river flow events may alter how important physical characteristics shape the landscape.
- **Natural Habitats:** Considering the physical scenario characteristics identified in the previous step, the key factors that affect the health of each habitat-type were identified.
- **Built Environment:** The results from the previous two steps were used as a platform to discuss how changes in the physical landscape and natural habitats may impact critical infrastructure and management approaches.

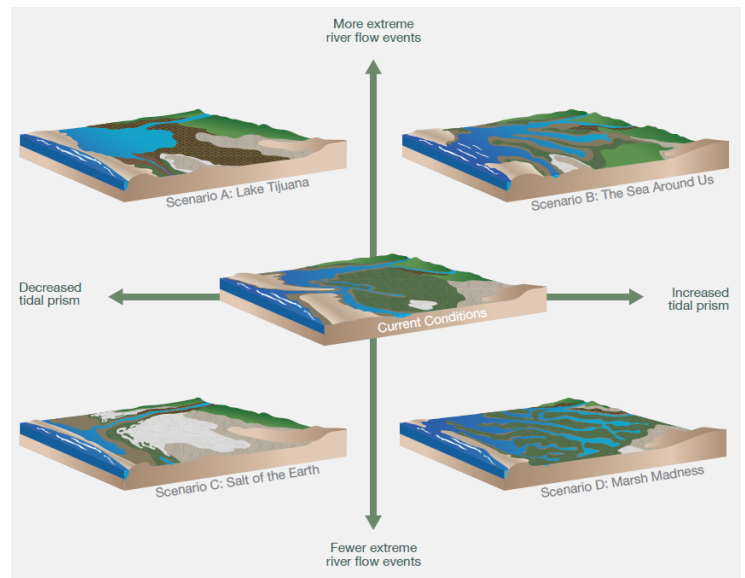


Figure 1: The Tijuana River NERR's four future planning scenarios.

## Linking scenarios to management

These scenarios were developed as part of the Climate Understanding & Resilience in the River Valley (CURRV) project. Through CURRV, the Tijuana River National Estuarine Research Reserve (TRNERR) led a collaborative process to directly inform restoration of coastal habitats and integrate climate adaptation strategies into Reserve management and programs.

# Scenario Planning

## What are scenarios?

A scenario is a plausible, internally consistent description of a possible future state of the world [1]. Scenarios are not forecasts or predictions; rather, each scenario is one alternative representation of how the future may unfold [2].

## Why scenario planning?

Scenario planning:

- ❖ Embraces **uncertainty**, helping decision-makers generate creative approaches by envisioning a range of possible futures [1].
- ❖ Allows planners to consider how **multiple variables** interact, instead of considering climate change impacts in isolation [2].
- ❖ Increases the **applicability** of long-term management plans by taking into account highly uncertain drivers of change and other factors of which managers have no control [1].
- ❖ By exploring the most current information on climate change and uncertainties, managers and planners will be prepared to react to **future challenges** with increased speed and confidence [2].

## Guiding Principles

There are 10 guiding principles, in no particular order, for the scenario planning process as conducted by TRNERR.

### 1. Plausible

Scenarios are not predictions. Each individual scenario is an alternative description of how the future may unfold, outlining a different *plausible* future state of the system.

### 2. Accentuate differences

The benefit of scenarios is to have thought of the widest range of possible changes in response to climate change, meaning that each future scenario should be distinctly different. This allows managers to be prepared to take appropriate action in the event of multiple possible outcomes.

### 3. No time horizons

It is impossible to predict exactly when significant changes in our climate and environment will occur, as there are too many variables interacting on different time scales. The most important aspect of a planning process is to explore potential outcomes and impacts without getting hung-up on exactly when the change may occur. In other words, the primary concern is to be prepared in the event of a change in the system. As management actions are implemented, there may be the need to delve more deeply into specific timeframes by land use managers, but by not identifying a time horizon early on in the process there is more room for flexibility down the road.

### 4. Embrace uncertainty

Two primary variables of uncertainty were chosen to frame the scenario development (e.g., tidal prism and extreme river flow events). These variables were chosen because they are central to the management of the system, and because they encompass not only climate drivers of change but also other environmental and socio-ecological drivers of change in the river valley. This allows managers to think not only about the changes in the system that they can't control (e.g., climatic change) but what parts of the system can be influenced through effective management (e.g., what plants to use in restoration, channelization of the river...).

### 5. Many factors organized into four logically-coherent bins

There are numerous possible scenarios that land use managers may encounter in the future; however, if presented with one hundred different scenarios, it becomes impossible to address each unique

situation, making the scenario planning process more of a thinking exercise than an actionable planning process. This framework focuses on the uncertainties that are central to land use management in the river valley (i.e., tidal prism and extreme river flow events), and organizes a wide variety of potential future conditions and processes into four logically-coherent bins. By limiting the total number of scenarios to four, it allows planners to effectively determine appropriate planning objectives without becoming overwhelmed.

## 6. Qualitative narrative

There is a great deal of quantitative and qualitative future projections available for the river valley. In developing scenarios, it is important to consider all kinds of scientific research and modeling but given that the main purpose of scenario planning is to accept that there is a high level of uncertainty in forecasting the future having a quantitative final result is misleading, as it would provide the illusion of certainty.

## 7. Physical, natural habitat, and built

The scenarios were developed through consideration of changes in the physical landscape, natural habitat vulnerabilities, and the built environment. This creates a holistic understanding of how the complex natural environment interacts with man-made infrastructure and valued non-natural resources (e.g., cultural and historical resources).

## 8. Past, present, and future

The scenarios take into account the historical state of the river valley in conjunction with the current state of the river valley (e.g., monitoring data) and future climate projections. This helps one to better understand the possible changes the river valley has the potential to undergo.

## 9. Informed by experience, expertise, and science

Scientific research is not the only source of information that can be used to help develop the scenarios. It is important to take into consideration all sources of information, such as on-the-ground observations from park rangers, public works staff, and community members. These discussions can help validate the scenarios, ensuring both qualitative and quantitative details are captured throughout the dialogue. This is a valuable step as it increases stakeholder buy-in and helps to ensure all sources of data are integrated into the scenario narratives.

## 10. Begin the dialogue

This process is not about predicting the future. It is about enhancing strong inter-organizational dialogue around climate change. The scenarios are not predicting the future. It is likely that not one of these scenarios will be fully realized in the future but it is highly likely that components within each of the scenarios will be experienced at some time as our climate and environment change. By having moved the conversation forward without getting caught-up in prediction, more organizations, agencies, and individuals can be engaged in a productive conversation and begin to critically assess what changes may need to be made in order to effectively manage the river valley.

# The Process

This guidebook outlines the process taken in developing the scenarios for the Tijuana River Valley and summarizes the results from each step as the scenarios were compiled and developed.

- ❖ Step 1: Scenario Framework
- ❖ Step 2: Physical Characteristics
- ❖ Step 3: Natural Habitat Vulnerability
- ❖ Step 4: Built Environment
- ❖ Step 5: Informing Action
- ❖ Step 6: Linking the Scenarios to the Community

## Step 1: Scenario Framework

A scenario framework, targeting the relationship between two primary variables- (1) the river's connection and interaction with the Pacific Ocean, and (2) riverine water input - was developed to frame the scenario planning process (Figure 2). Tidal prism and extreme river flow events were chosen as the primary uncertainties because of their strong role in shaping the physical landscape and their centrality to effective management of the river valley.

### Primary Uncertainties

#### Tidal prism

Tidal prism is defined as the volume of water that tides bring in and out of the estuary, and is a primary influence on the nature of the connection between the river and the ocean (i.e., open vs. closed river mouth). Increases or decreases in tidal prism will depend in large part on the relationship between local elevations and sea level. For example, over long time scales, tidal prism may decrease if sediment accretion outpaces the rate of sea level rise (i.e., land rises faster than the sea); conversely, tidal prism may increase if sea level rise outpaces this aggradation (i.e., seas rise faster than the land). On a shorter time scale, episodic events can open or close the river mouth and tidal channels, affecting tidal prism. In general, systems with a large tidal prism tend to have a more consistent connection with the ocean (i.e., open river mouth) and estuaries with smaller tidal prisms tend to have a less consistent connection (i.e., closed river mouth). The tidal prism can also be impacted by land management practices, including restoration activities, interventions to keep the river mouth open, or land uses that affect sediment supply.

#### Extreme river flow events

Extreme river events can increase or decrease based on changes in precipitation patterns (e.g., frequency and intensity), water management practices (e.g., dams, channelization of river channels), and / or land use patterns (e.g., increased impervious or denuded surfaces) altering the amount and velocity at which freshwater and sediment enters the system.

Climate change is projected to affect weather

patterns and storms, so considering changes in extreme river flow events is important. From both natural and human perspectives, extreme river flows can change the landscape and produce hazardous flooding. For example, historically, the most dangerous storms in California have been extreme events, particularly wet storms that occur during the winter, producing intense rains over large areas [3].

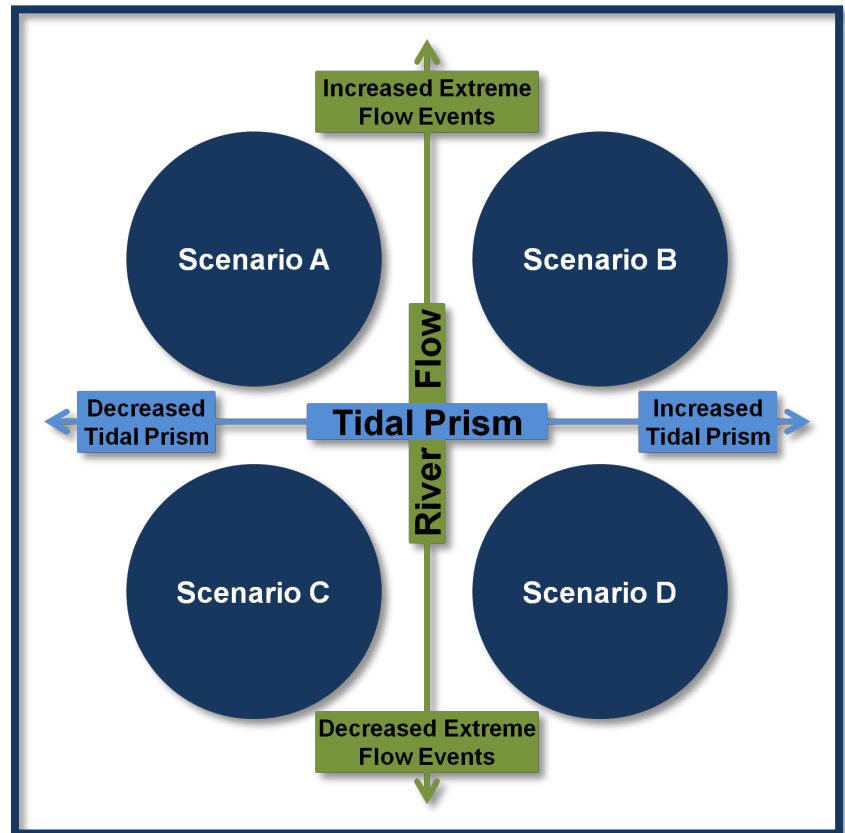


Figure 2: Scenario Framework [1, 2]

### Assumptions

Throughout the development of the scenarios several assumptions were made.

- ❖ **Sea level rise (SLR)** is occurring.
- ❖ A decrease in extreme events means a decrease in the amount of freshwater coming into the system, whereas an increase in extreme events means an increase in the amount of freshwater coming into the system, meaning **typical flows** will remain approximately the same as current conditions. This assumption was made because the river valley is in a Mediterranean climate where most of the freshwater enters the system during extreme events.
- ❖ A **Mediterranean climate** will persist with wet winters and dry summers.

## Step 2: Physical Characteristics

In order to explore the physical characteristics of each scenario, TRNERR hosted a workshop where coastal geomorphologists, engineers, oceanographers, land use managers, and ecologists delved into how climate change might alter the physical landscape of the Tijuana River Valley.

During this step, workshop participants worked to describe how changes in tidal prism and extreme river flow events would impact key physical characteristics. Important physical characteristics that shape the landscape, and thus influence management decisions, were used to frame the narratives (Table 1).

**Table 1: Physical Characteristics**

Characteristics	Why are they important?
<b>River-Ocean Connection</b>	<ul style="list-style-type: none"> <li>The status of the river mouth is central to how the valley functions, and will determine how other characteristics manifest themselves.</li> <li>Mouth status does not just impact the estuarine environment, as changes in whether the mouth is open or closed alters how and where the river valley floods.</li> </ul>
<b>Sediment Dynamics</b>	<ul style="list-style-type: none"> <li>Sediment has the capacity to alter topography, which will determine how sea level rise and flooding events impact the valley.</li> <li>Too much sediment can close the river mouth, bury salt marshes, and fill-in the river channels leading to increased flooding extents.</li> <li>Too little sediment can lead to channel reconfiguration and decreased elevations, which are important to maintaining resilient salt marshes in the face of sea level rise.</li> </ul>
<b>Flooding &amp; Inundation</b>	<ul style="list-style-type: none"> <li>Understanding how a system floods, where to expect flooding based on elevations, and what is causing the flooding (e.g., saltwater or freshwater) is crucial to effective management of a system.</li> <li>Flooding is not only an important factor for natural systems, but also for managing built infrastructure (e.g., saltwater corrosion, where evacuation routes are placed, etc.).</li> </ul>
<b>Water Residence Time</b>	<ul style="list-style-type: none"> <li>Long residence times can have widespread consequences, including eutrophication and hypoxia, and can even lead to environmental health concerns with disease vectors and contaminants (e.g., mosquitoes, sewage, trash, chemical runoff, etc.).</li> <li>Residence time may determine the cost of damage experienced by built infrastructure during a flood (e.g., corrosion, how long the facility is out of service, extent of water damage, etc.).</li> </ul>
<b>Surface- and Ground-Water Salinity</b>	<ul style="list-style-type: none"> <li>Determines the distribution of specific habitat types on a landscape.</li> <li>Alters what materials are used in built infrastructure (e.g., corrosion).</li> <li>Impacts availability of irrigation and potable water supplies.</li> <li>Determines the preservation of cultural resources (e.g., through corrosion).</li> </ul>

The results from this step are outlined in Appendix A.

**Experts from the following organizations/ agencies attended the physical characteristic scenario planning workshop:** California Coastal Commission; California Department of Water Resources; California Native Plant Society; California State Coastal Conservancy; California State Parks; California State University, Channel Islands (CSUCI); City of Imperial Beach; Coastal Restoration Consultants; ESA PWA; Goleta Slough Management; Los Peñasquitos Lagoon Foundation; Naval Base Coronado; Oceanographic and Coastal Engineering Service; San Elijo Lagoon Conservancy; San Francisco Estuary Institute (SFEI); Southern California Coastal Water Research Project (SCCWRP); Southwest Wetlands Interpretive Association (SWIA); Thalassa Research and Consulting; University of California, Irvine (UCI); University of California, Los Angeles (UCLA); URS; US Fish & Wildlife Service (USFWS); US Geological Survey (USGS).

## Step 3: Natural Habitat Vulnerabilities

A small group of biologists, ecologists, and land managers, who are intricately familiar with the Tijuana River Valley, were convened to discuss the vulnerability of each habitat type considering the physical scenario characteristics identified in the previous step. **Participatory mapping** was used as a tool to help facilitate conversation, as shifts in habitat were sketched out to reflect participant dialogue (Refer to below photo). Some key components of this process include:

**Key Factors that Affect Habitat Health:** For each of the key habitats in the river valley the key factors affecting habitat health were identified, informing whether the habitats would benefit from the environmental changes identified in the previous step or would be vulnerable to negative impacts. Key factors affecting ecosystem health for each habitat type include:

- ❖ **Beaches & Sand Dunes:** Consistent sediment supply
- ❖ **Tidal Channels & Mudflats:** Open or closed river mouth
- ❖ **Salt Marsh:** Consistent sediment supply; Open or closed river mouth; Saltwater inputs
- ❖ **Salt Flats:** Evaporation; Open or closed river mouth; Saltwater inputs
- ❖ **Wetland-Upland Transition Zone:** Extreme river flow events; Freshwater inputs
- ❖ **Fresh-brackish Marsh:** Freshwater inputs
- ❖ **Riparian:** Freshwater inputs; Open or closed river mouth
- ❖ **Upland:** Open or closed river mouth; Sediment supply

**Vulnerability Compared to Now:** Calculating vulnerability is difficult.

One has to think about the what, when, how and why of a habitat's vulnerability. When scenario planning, does one focus on vulnerability between scenarios (e.g., scenario A has more vulnerability than the other 3 scenarios) or is it better to compare the scenarios to the now (e.g., is vulnerability increased or decreased compared to current vulnerabilities?). For this process, it was determined that since our experience and expertise is grounded in what currently makes a system vulnerable that it would be most logical to determine vulnerability based on changes from current vulnerability (e.g., does vulnerability increase or decrease compared to current conditions?).

- ❖ **Change: Good or Bad?** Some vulnerability assessments consider any change in a habitat to be a negative. For example, some assessments label salt marsh converting to fresh-brackish marsh as bad and hence correlate this transition with system vulnerability. But is all change in a system truly bad? That really depends on what wildlife is being managed for and what habitats society values for aesthetic and recreational purposes. For the purposes of this process, it was decided not to make value judgements about what habitats were more valuable than others and hence what scenario would be the ideal world to live in. Both the good and bad are outlined, and it is for land managers and the community to determine what changes are bad and what changes are actually for the better.
- ❖ **Vulnerability Inversely Correlated with Area:** If the physical conditions in a particular scenario were positive for the habitat type it was assumed the habitat area would increase but if the physical conditions in a particular scenario were negative the habitat area would decrease. Given that science's understanding of what makes a habitat "functional" is extremely complex it was assumed that if a habitat's functionality was impaired it would convert into a new habitat-type (Refer to Table 2).

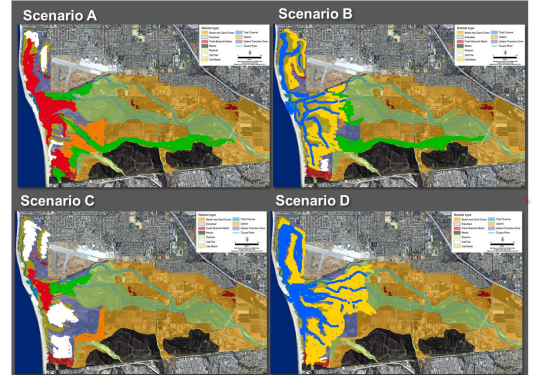












Figure 2: Participatory mapping of potential habitat migration in response to tidal prism, extreme river flow events, and changes to the physical characteristics outlined in the previous step.



**Table 2: Habitat Vulnerabilities & Area**

	Decreased Vulnerability		Neutral (today's vulnerability)	Increased Vulnerability	
Vulnerability	 Large decrease	 Small decrease	 Minimal change	 Small increase	 Large increase
Area	 Large increase	 Small increase	 Minimal change	 Small decrease	 Large decrease
	Increased Area		Neutral (today's vulnerability)	Decreased Area	

- ❖ **Fixed Land Area:** Since the river valley is surrounded on three sides by urban development and by the Pacific Ocean along the western edge, there was a fixed amount of land available for natural habitat shifts. This means that if the area of one habitat-type expands then the area of another habitat-type will decrease. It is a “zero-sum” game.
- ❖ **Experience, Expertise, and Science:** The development of the scenarios was informed by the best available science, including the multiple flood models available for the geographic location of the river valley (e.g., NOAA Sea Level Rise Viewer, Coastal Storm Modeling System (CoSMoS), Marsh Equilibrium Model (MEM), Sea Level Affecting Marshes Model (SLAMM)). However, the process leveraged the vast on-the-ground experience of resource and land managers, capturing the perspectives and expertise of stakeholders that have valuable insight into how the river valley has changed in the past, and the current stressors the river valley faces (e.g., sediment). This leads to scenarios that are grounded in historical and current observation (e.g., 1983 and 2016 river mouth closures) and future climate science projections.
- ❖ **Habitats of the Past, Present, and Future:** The main focus of this exercise was to assess the changes in vulnerability associated with the primary habitats of the river valley but it became apparent that some habitats that are only present in the river valley on a small scale may become dominant habitat types, specifically salt flats. So, it was important to consider this habitat type that currently is only present in a small area of the river valley but historically was more prevalent and may in the future be more prevalent depending on climatic and environmental changes.

The results from this step are outlined in Appendix B.

Experts from the following organizations/ agencies partook in the natural habitat vulnerability workshop and/or provided written feedback: California Sea Grant; California State Parks; Nordby Biological Consulting; San Francisco State University (SFSU); Southwest Wetland Interpretive Association (SWIA); US Fish & Wildlife Service (USFWS); Wetlands Initiative.

## Step 4: Built Environment

Building on the previous steps, one-on-one informational interviews were conducted with the public agencies that own and manage land in the river valley.

**Key Factors that affect the Built Environment:** For each of the primary sectors in the river valley the key factors potentially impacting that sector were identified:

- ❖ **Agriculture:** Flooding, salinity, water quality and availability
- ❖ **Border Security & Infrastructure:** Excess sediment, flooding, riparian habitats
- ❖ **Cultural & Historical Resources:** Erosion, flooding & inundation, higher groundwater levels, sediment accretion
- ❖ **Naval Outlying Landing Field:** Erosion, shifts in bird populations and behavior
- ❖ **Parks, Recreation, & Public Access:** Excess sediment, flooding, presence of habitats valued by public
- ❖ **Transportation:** Erosion, excess sediment, flooding
- ❖ **Stormwater Management & flood control:** Flooding, sea level rise, sediment supply
- ❖ **Wastewater Management:** Extreme events, transportation of sediment and contaminants

**One-on-One Conversations:** Unlike the previous steps, this step was completed through a series of one-on-one informational interviews with local agencies managing assets and infrastructure in the river valley. This occurred because there was such diversity of organizational missions in this category that it would be hard to get to the level of detail that was desired if all the organizations only had a one day workshop to share their perspective. The one-on-one conversation allowed each agency to have a more targeted conversation about climate change and the identified scenarios.

**Confidentiality:** This step also allowed for conversations about assets that are confidential (e.g., archeological sites) to occur within appropriate working groups. Ensuring confidential information is not left out of the broader collaborative dialogue.

**Discussing scenarios in non-scientific terms:** In the previous steps, experts would discuss the scenarios in terms of scenarios (i.e., A, B, C or D). The scenarios were originally described in scientific jargon and primarily only fully understood by scientists and the project team. This step helped the dialogue to transition to a more general audience, focusing on the climatic and environmental changes that are important to each agency's management targets within the river valley. Compare Appendices C & D to see the differences in how the information is presented: specifically referring to the scenarios (Appendix C) vs. highlighting the specific changes that an agency may need to consider (Appendix D).

**Opportunities for Collaboration:** This discussion helped TRNERR to better understand when shared management concerns may arise as adjacent jurisdictions face similar climate impacts, or where the strategies one agency may consider implementing may impact the river valley's resources or impact another agency's ability to meet their mission. This dialogue helps to ensure as different agencies identify adaptation strategies that they are cognizant of opportunities to leverage their actions and can ensure that strategies that are identified are beneficial to multiple agencies.

**The results from this step are outlined in Appendices C & D.**

**Experts from the following organizations/ agencies partook in the natural habitat vulnerability workshop and/or provided written feedback:** Border Patrol, California State Parks, City of Imperial Beach, City of San Diego, County of San Diego, International Boundary & Water Commission, U.S. Fish & Wildlife and U.S. Navy.

## Step 5: Informing Action

### Linking Scenarios to Reserve Management

The Reserve's current management philosophy is built on a foundation that supports and enhances rare habitats and wildlife that are currently present. These habitats need to continuously be managed using strategies that are currently effective in maintaining ecosystem health and function. However, in the future strategies may need to be adjusted as habitats change in response to climatic and environmental conditions. Most of the adaptation strategies in this document will be effective in all four scenarios; however, there are some strategies that will need to be adapted significantly given new science and observations.

In order to ensure current management strategies are not altered too soon (i.e., forsaking existing, healthy habitats and wildlife) or too late (i.e., climate change impacts lead to mass die-offs), it's important to build in adaptive pathways that can help ensure we are able to successfully manage the river valley. Management approaches will need to adapt in the event of:

- Transitions between scenarios;
- Any component of the four scenarios becoming a reality; and
- A scenario that was not considered or outlined occurring.

The concept of triggers provides the opportunity to better manage in all of these conditions.

### Triggers: Managing for Change

Triggers are events or observations that indicate a critical long-term shift in habitat and wildlife health, potentially meaning the system is shifting into one of our outlined scenarios. The triggers help to ensure management strategies are proactively updated in response to an indicator that a threshold is approaching, and if crossed may lead to a long-term, permanent shift in how the ecosystem functions. Example triggers include:

Category	Trigger
<b>Flooding</b>	Data loggers are indicating an increase in water levels that correlate with flooding at the end of Seacoast Dr.
<b>River mouth</b>	River mouth closes in a non-El Niño year
<b>Sea level rise &amp; sediment</b>	Water level data and the Surface Elevation Tables (SETs) are on a path that indicates sea level rise will soon outpace sedimentation.
<b>Wildlife</b>	Annual bird surveys are indicating a trend of decreasing populations for species of concern.

If one of the events above is observed, a re-evaluation of current adaptation strategies is triggered. For example, if the river mouth closes in a non-El Niño year, all departments commit to re-evaluating their resilience and adaptation strategies to ensure that management strategies are still effective. This will help us to ensure we can effectively manage in:

- ❖ Current habitats,
- ❖ Transitions between scenarios (i.e., moving from scenario A to B),
- ❖ Any of the four scenarios, or
- ❖ A world we have yet to visualize (e.g., Scenario E).

## Linking Scenarios to the Community

The community living in and around the river valley is working to understand the wide range of future scenarios that they may experience as a result of climate change. To ensure that TRNERR's scenarios were not just understood by scientists and experts but by community members, an artist-in-residence brought the scenarios to life through her paintings.

### Art as Science – Science as Art

Each of the four mural scenes highlights the habitats and wildlife that would be characteristic of each of the four scenarios. The paintings are interpretations of the science behind the scenarios, providing a window into the future. This approach helps the community to begin to understand that climate change may lead to different futures but not all change is bad and a community vision of the future can help to encourage positive transformation. The process through which these scenarios were developed brought art and science together in a way that helped to flesh out the final scenario details. The artist brought a fresh perspective to the process and asked tough questions about the underlying reasoning for each of the specific scenario characteristics.



Figure 3: Four mural paintings of each of the four scenarios. In order from left to right: Scenario A- Lake Tijuana; Scenario B- The Sea Around Us; Scenario C- Salt of the Earth; & Scenario D- Marsh Madness. Paintings by Audrey Carver, Idyllwild Art Academy.

## Linking Scenarios to Regional Planning

TRNERR continues to share lessons learned during this process throughout Southern California and the National Estuarine Research Reserve System (NERRS). This process can be adapted for other local planning efforts as it provides the flexibility to ensure local climate science and diverse stakeholder perspectives can be integrated into a single planning process. To learn more about the project and see how it is being utilized to directly inform local action please visit: <http://trnerr.org/currv/>

## Scenario Summary Graphics

Summary figures were developed to identify key drivers, environmental changes (both physical and natural habitat), and potential management challenges in each of the four scenarios:



Decreased tidal prism contributes to sand and sediment building up between the river and the ocean leading to a river mouth that is usually closed, with occasional extreme river flows breaching the built-up sand bar. River water trapped behind the sand bar forms a large freshwater or brackish lake, which displaces many of the more saline habitats in the estuary. This lake also increases flood risk by decreasing the ability of the system to retain additional water produced during a storm. The effect of sea level rise on habitats is limited as increased sedimentation allows the land to rise faster than ocean water levels.

## Changes to the Physical Environment

### River-Ocean Connection & Water Residence Time

The river mouth is usually closed, which traps water in the system for long periods of time. This increases the accumulation of nutrients and contaminants in aquatic habitats.

### Flooding, Inundation, & Sedimentation

Riverine flooding impacts the Valley as water ponds behind the closed river mouth. There is the potential for restructuring of the Valley as storm waters carve new channels and fill others with sediment.

### Surface Water & Groundwater Salinity

Increased freshwater influence is experienced during mouth closure, which may recharge groundwater supplies.

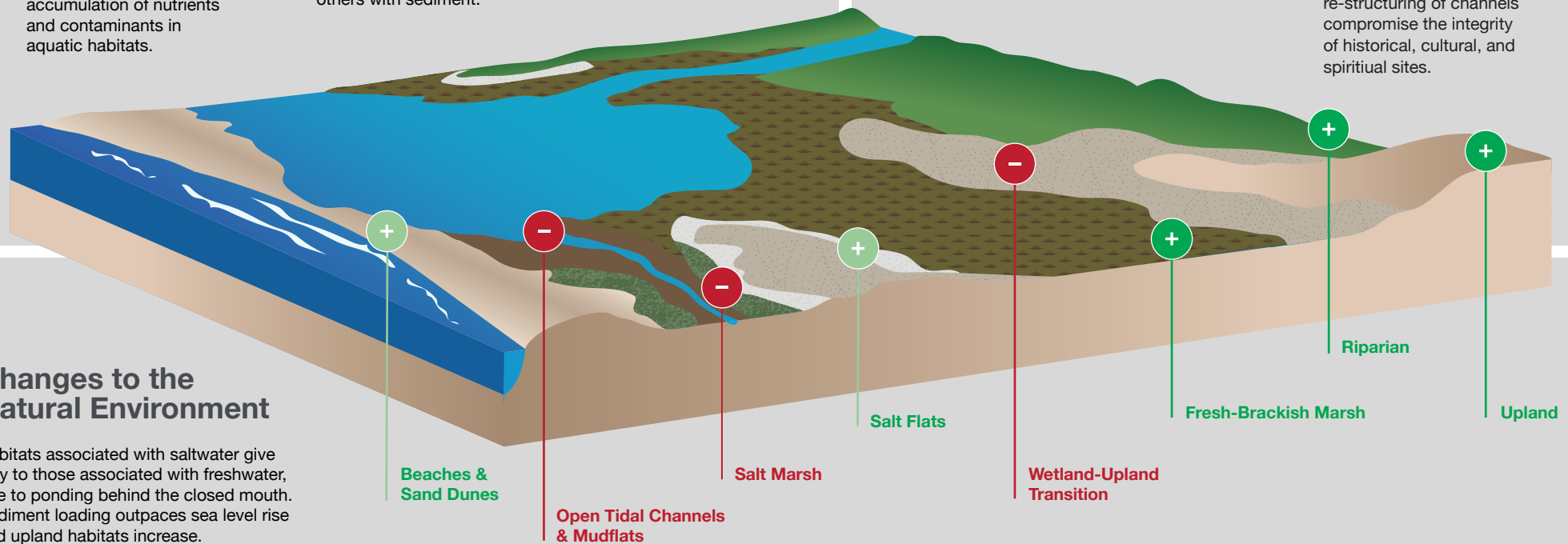
## Potential Management Challenges

### Transportation

Access in the Valley is frequently impaired by sedimentation, standing water, and flooding. This obstructs roads, bridges, trails, and evacuation routes; and leads to a need for increased flood preparedness, especially among emergency responders.

### Cultural & Historical Resources

High rates of erosion and re-structuring of channels compromise the integrity of historical, cultural, and spiritual sites.



## Changes to the Natural Environment

Habitats associated with saltwater give way to those associated with freshwater, due to ponding behind the closed mouth. Sediment loading outpaces sea level rise and upland habitats increase.

Scenarios are not predictions but are alternative representations of how the future may unfold in response to potential climate and environmental changes. For more details visit: <http://www.trnerr.com/currv/>. October 2017

### Change in Habitat Area

- Large Decrease
- + Large Increase
- = No Change
- Slight Decrease
- + Slight Increase

### Habitat Types

- Beaches & Sand Dunes
- Open Tidal Channels & Mudflats
- Salt Marsh
- Salt Flats
- Fresh-Brackish Marsh
- Wetland-Upland Transition
- Riparian
- Upland

# Scenario B: The Sea Around Us

Increased extreme river flow events  
Increased tidal prism

Increased tidal prism, in conjunction with increased extreme river flow events leads to an enhanced connection between the river and the ocean through a consistently open and deep river mouth. This creates a system that is heavily shaped by the ocean both biologically and physically. Ultimately, sea level rise will greatly influence the habitats in the lower valley, and coastal flooding will increase when high sea levels interact with more frequent river flows.

## Changes to the Physical Environment

**River-Ocean Connection & Water Residence Time**  
Water is in the system for short periods of time due to an open river mouth and tidal flushing.

**Flooding, Inundation, & Sedimentation**  
The combination of storms and sea level rise cause extensive flooding throughout the valley. During extreme river flow events, there is increased sediment export from the river to the beaches.

**Surface Water & Groundwater Salinity**  
Saltwater influence in surface water and groundwater reaches further inland.

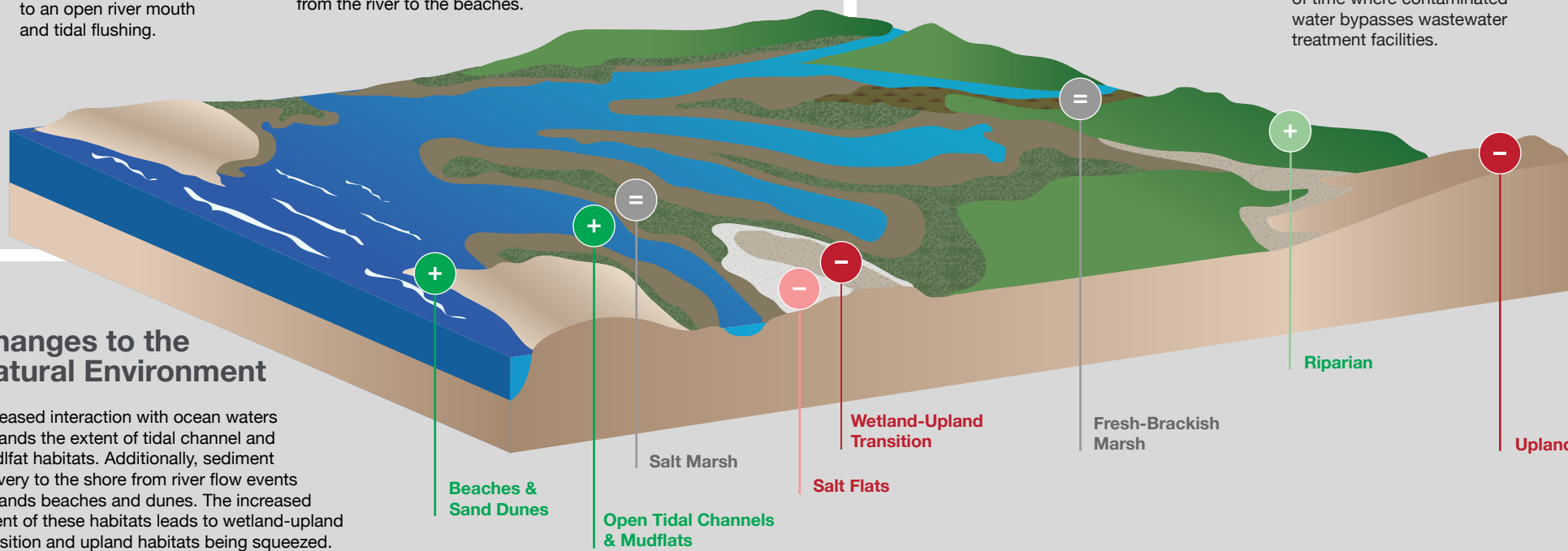
## Potential Management Challenges

**Stormwater Management & Flood Control**  
Critical infrastructure may become ineffective due to rising seas, increased river flows, and the interaction between the two.

**Wastewater Management**  
More frequent extreme river flows increases the amount of time where contaminated water bypasses wastewater treatment facilities.

## Changes to the Natural Environment

Increased interaction with ocean waters expands the extent of tidal channel and mudflat habitats. Additionally, sediment delivery to the shore from river flow events expands beaches and dunes. The increased extent of these habitats leads to wetland-upland transition and upland habitats being squeezed.



Scenarios are not predictions but are alternative representations of how the future may unfold in response to potential climate and environmental changes. For more details visit: <http://www.trner.com/currv/>, October 2017

### Change in Habitat Area

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### Habitat Types

- Beaches & Sand Dunes
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- Salt Marsh
- Salt Flats
- Fresh-Brackish Marsh
- Wetland-Upland Transition
- Riparian
- Upland

# Scenario C: Salt of the Earth

Decreased extreme river flow events  
Decreased tidal prism



Decreased tidal prism, coupled with decreased extreme river flow events, results in the river being cut-off from the ocean as the river mouth closes. Over time, this lack of consistent tidal influence creates a system that is highly variable and is characterized by salt flats that develop as ponded water evaporates. The variability of this system challenges effective management, as long periods of dry conditions are punctuated by extensive flooding associated with the closed mouth.

## Changes to the Physical Environment

### River-Ocean Connection & Water Residence Time

Water will collect behind the closed river mouth, remaining in the system for long periods of time, likely until it evaporates.

### Flooding, Inundation, & Sedimentation

The closed river mouth traps sediment, elevating land and filling in channels. Even though large river flows are rare, those that do occur will lead to extensive flooding as water ponds behind the closed mouth.

### Surface Water & Groundwater Salinity

Conditions are variable, ranging from hypersalinity resulting from the evaporation of trapped seawater to freshwater conditions resulting from ponding of riverine water.

## Potential Management Challenges

### Public Health

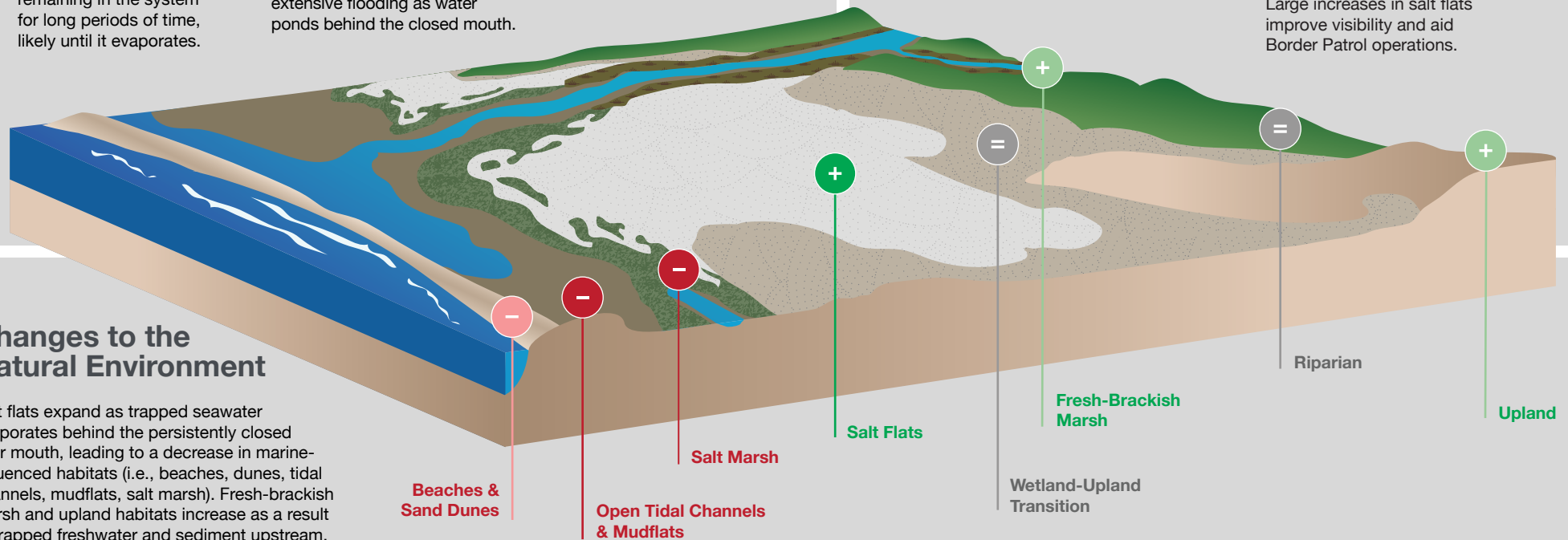
Public health concerns arise as contaminants such as pollutants and trash are trapped within the poorly-flushed system.

### Border Security

Large increases in salt flats improve visibility and aid Border Patrol operations.

## Changes to the Natural Environment

Salt flats expand as trapped seawater evaporates behind the persistently closed river mouth, leading to a decrease in marine-influenced habitats (i.e., beaches, dunes, tidal channels, mudflats, salt marsh). Fresh-brackish marsh and upland habitats increase as a result of trapped freshwater and sediment upstream.



Scenarios are not predictions but are alternative representations of how the future may unfold in response to potential climate and environmental changes. For more details visit: <http://www.trnerr.com/currv/>. October 2017

### Change in Habitat Area

- Large Decrease
- + Large Increase
- = No Change
- Slight Decrease
- + Slight Increase

### Habitat Types

- Beaches & Sand Dunes
- Salt Marsh
- Fresh-Brackish Marsh
- Open Tidal Channels & Mudflats
- Salt Flats
- Wetland-Upland Transition
- Riparian
- Upland

# Scenario D: Marsh Madness

Decreased extreme river flow events  
Increased tidal prism



Increased tidal prism, coupled with decreased extreme flow events results in mouth conditions that are similar to those that occur today – with the inlet typically open to the ocean. Sea level rise, coupled with mouth conditions that allow for some trapping of sediment, expands the area influenced by salt marsh further inland.

## Changes to the Physical Environment

### River-Ocean Connection & Water Residence Time

The river mouth is mostly open and tidal action limits the amount of time water resides in the system.

### Flooding, Inundation, & Sedimentation

The system experiences increased inundation and flooding, especially near the coast, which is left vulnerable to sea level rise effects through the mostly open river mouth.

### Surface Water & Groundwater Salinity

Saltwater influence increases due to higher tidal prism and sea level rise, coupled with decreased riverine inputs.

## Potential Management Challenges

### Agriculture

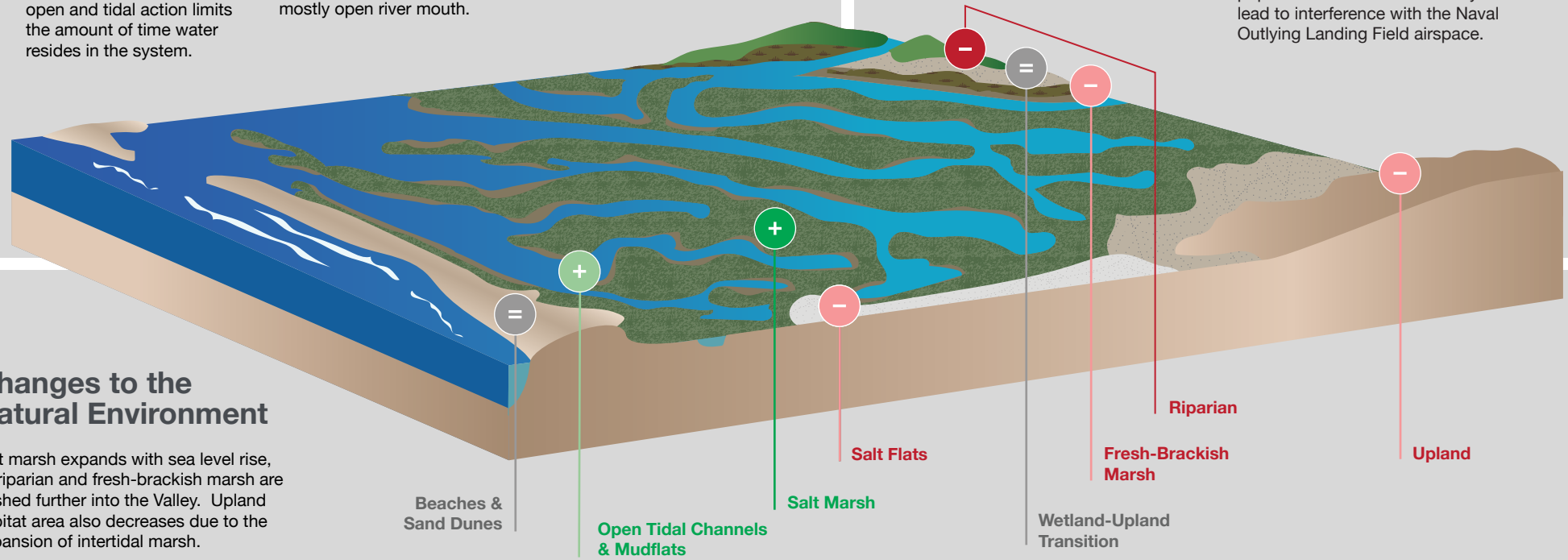
Freshwater becomes less available for crops and other water dependent operations.

### Naval Operations

Potential shifts in local bird populations and behaviors may lead to interference with the Naval Outlying Landing Field airspace.

## Changes to the Natural Environment

Salt marsh expands with sea level rise, as riparian and fresh-brackish marsh are pushed further into the Valley. Upland habitat area also decreases due to the expansion of intertidal marsh.



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### Change in Habitat Area

- Large Decrease
- + Large Increase
- = No Change
- Slight Decrease
- + Slight Increase

### Habitat Types

- Beaches & Sand Dunes
- Salt Marsh
- Fresh-Brackish Marsh
- Riparian
- Open Tidal Channels & Mudflats
- Salt Flats
- Wetland-Upland Transition
- Upland



## Frequently Asked Questions

### Why develop scenarios when flooding models and maps provide a visualization of climate impacts?

Maps and models are one tool in a larger toolbox. They were used to supplement the scenarios. The models used included NOAA Sea Level Rise Viewer, Coastal Storm Modeling System (CoSMoS), Sea Level Affecting Marshes Model (SLAMM), and Marsh Equilibrium Model (MEM). Each of these models provide one piece of the puzzle, providing different insights into how sea level rise may impact the river valley but estuarine areas exist at the interface of land, sea, and rivers, and are very complex and difficult to model. In particular, the river-ocean connection will be a primary driver of the behavior of the entire river valley, and the complexity associated with this extremely dynamic area is not currently incorporated into available models. It should be noted that substantial progress is being made, and new models will be incorporated into future planning as they become available.

### Why not conduct new flood modeling?

There are numerous flood models that are available to the San Diego region through federal agencies (i.e., NOAA Sea Level Rise viewer, CoSMoS), and local universities and research institutions. Given that models are expensive and take a large technological capacity most management agencies don't have the capacity to run models to forecast for each site. Given these considerations, it was a core proponent of TRNERR's process to use the best *available* science and demonstrate how an agency can move forward with adaptation planning without having to secure funding to run a new model.

### Why are extreme riverine event flows important? Why not focus on average flows?

Initially the vertical axis represented average annual river flow, but following group discussions about the physical characteristics and processes that shape estuarine systems in Southern California, stakeholders decided to change the riverine axis from average river flow to extreme river flow events (Figure 2). It was determined that extreme events have historically and could in the future profoundly shape the river valley (e.g., by affecting river mouth status, changing geomorphology, and delivering large volumes of water and sediment). Thus the group decided that having an axis of uncertainty related to extreme events would allow for a fuller exploration of the future physical landscape.

### Why are climate drivers of change not listed on the axes?

Climate drivers, such as precipitation and temperature, are not listed on the axes because the framework was designed to capture uncertainties related to broader socio-ecological drivers of change, as well as emphasize proximate factors important in understanding and managing this system. For instance, extreme river flow events can be influenced by not only climate drivers (e.g., shifts in precipitation patterns altering watershed inputs) but by management decisions (e.g., channelizing the river channel, dams). By labeling the axes in broader terms, it captures potential interconnections between the climate, environment, and social aspects of the whole system.

### Why is sea level rise not listed on the axes?

The axes represent variables with high uncertainty, and not all aspects of climate change carry the same level of uncertainty. For instance, it is virtually certain that sea level rise is occurring and will continue to occur into the future, even if there is uncertainty about how much the seas will rise (i.e., magnitude) and how fast (i.e., rate). This is in contrast to other aspects of climate change, such as weather patterns, that alter river flows, and sediment delivery and accretion, that alters tidal prism, which carry an extremely high level of uncertainty. Sea level rise is therefore treated as an assumption and taken into account in the development of all scenarios.

## **Why was the magnitude or rate of sea level rise not specified?**

Defining meaningful thresholds can be difficult in a multi-agency context, considering “severe” sea level rise would be different for someone working on coastal road infrastructure than someone protecting coastal native plant species [1]. This is why facilitators caution against defining scenarios using drivers whose uncertainty concerns magnitude rather than direction of change [1]. However, throughout the process, maps representing different sea level rise magnitudes were provided to experts and managers to supplement the scenarios provided in this report.

## **Why were management actions not discussed when developing the scenarios?**

The goal of this scenario exercise was to describe the physical, natural, and built setting of potential futures in order to inform the development of climate adaptation and resilience strategies for the Reserve. Explicit consideration of the management actions will be discussed in later phases of the adaptation planning process, as stakeholders begin to develop climate adaptation strategies that identify management practices which will lower vulnerabilities and increase resilience to climate change. Moreover, although the focus is currently on physical processes, management was implicitly considered, as management actions can modify the degree to which the drivers on the axes of uncertainty manifest themselves (e.g., restoration activities increasing tidal prism).

## **Why do some habitats seem to benefit in certain scenarios?**

A habitat’s health is tied to a specific set of environmental conditions, and as the climate changes there will be some habitat-types that are “winners” and others will be “losers”. Some habitats will thrive and expand their range, and others will begin to disappear. What changes are viewed as “bad” or “good” will be a direct reflection of what habitats the community values and wishes to conserve. This process is not intended to make value judgements but is simply to provide insight into the possible changes that may occur.

## **Why wasn’t the traditional vulnerability assessment framework used?**

The original project design was outlined using the common climate vulnerability assessment (VA) framework but as stakeholders tried to implement the VA framework it became apparent that it didn’t work well in an area where uncertainty is high, and the socio-ecological system is complex. The components of a vulnerability assessment- exposure, sensitivity, and adaptive capacity- are theoretically well defined but are hard to apply to on-the-ground management. Stakeholders began to get caught up in defining the terminology, stalling the process and ultimately preventing the dialogue from moving forward. Transitioning to scenario planning provided the process with a framework that not only embraced uncertainty but also allowed stakeholder to implicitly consider exposure, sensitivity, and adaptive capacity without being sidetracked by defining the terms.

## Appendix A: Physical Characteristics

Scenario A Increased extreme river flow events & Decreased tidal prism	Scenario B Increased extreme river flow events & Increased tidal prism
<b>River-Ocean Connection</b>	
<b>Mostly Closed</b>	<b>Open</b>
<ul style="list-style-type: none"> <li>Marine processes and a decreased tidal prism keep the river mouth closed for prolonged periods of time.</li> <li>Because riverine flood events that tend to reinforce an open mouth are relatively frequent, the system will periodically open.</li> </ul>	<ul style="list-style-type: none"> <li>Riverine and marine processes keep the river mouth primarily open.</li> <li>Relatively brief durations of closure are possible.</li> </ul>
<b>Sediment Dynamics</b>	
<b>Moderate Sediment Export &amp; Riverine Sedimentation</b>	<b>Increased Sediment Export &amp; Beach Sedimentation</b>
<ul style="list-style-type: none"> <li>Aggradation outpaces SLR in the lower valley, due largely to riverine sedimentation.</li> <li>Estuary / ocean exchange of sediment and other materials is decreased.</li> <li>Frequent riverine sediment inputs increase sedimentation, but localized scour and deposition have the potential to dramatically restructure the system (e.g., changing channel configurations).</li> <li>Increased inputs of riverine sediment get trapped in a largely closed system, but export to the beaches occurs during the large river flow events that open the river mouth.</li> </ul>	<ul style="list-style-type: none"> <li>SLR outpaces aggradation in the lower valley, as the increased tidal prism and open river mouth will increase marine influences.</li> <li>Estuary / ocean exchange of sediment and other materials is increased.</li> <li>Increased extreme river flow events, and increased marine influence due to open river mouth, have the potential to both deliver sediment and restructure the upper and lower valley.</li> <li>Increased inputs of riverine sediment will interact with ocean processes and provide sediment to the beaches.</li> </ul>
<b>Flooding &amp; Inundation</b>	
<b>Severe Riverine Flooding</b>	<b>Riverine Flooding &amp; Coastal Flooding / Inundation</b>
<ul style="list-style-type: none"> <li>Increased riverine flooding, due to increased extreme events and a mostly closed river mouth, could lead to ponding, which decreases the system's ability to store extra water during flow events (i.e., if the bathtub is full, any extra water will cause a flood).</li> <li>Transient mouth opening associated with extreme riverine flows may mitigate some flooding, but it also increases the chance that riverine flooding will interact with coastal flooding (e.g., high tides or storm surge).</li> <li>Flooding of beachfront areas will occur with SLR, and may be exacerbated by more frequent riverine flooding of the estuary.</li> </ul>	<ul style="list-style-type: none"> <li>Increased riverine and coastal flooding, due to increased extreme events, SLR, and an open river mouth.</li> <li>The highest likelihood of riverine and coastal flooding reinforcing one another.</li> <li>Although increased export of sediment from the estuary will enhance beach-building, flooding of beachfront areas still occurs with SLR and may be exacerbated by more frequent riverine flooding.</li> </ul>
<b>Water Residence Time</b>	
<b>Long Residence Time</b>	<b>Shortest Residence Time</b>
<ul style="list-style-type: none"> <li>Residence times are relatively long due to poor estuary / ocean exchange.</li> <li>The system occasionally has decreased residence times when the river mouth is breached during an extreme river event.</li> </ul>	<ul style="list-style-type: none"> <li>Residence times are short due to the open river mouth and increased river events.</li> </ul>
<b>Surface- and Ground-Water Salinity</b>	
<b>Increased Freshwater Influence with Variability</b>	<b>Saltwater Influence with Freshwater Pulses</b>
<ul style="list-style-type: none"> <li>Increased freshwater influence due to frequent riverine flooding, coupled with decreased tidal exchange.</li> <li>Periodic mouth openings allow some marine influence, but openings are counter-balanced with inputs of freshwater from riverine flooding.</li> <li>Variable conditions due to the largely closed river mouth, ranging from hypersalinity (e.g., evaporation of trapped seawater) to low salinities (e.g., freshwater inputs) in the lower valley are experienced.</li> <li>Saltwater intrusion into groundwater is reduced.</li> </ul>	<ul style="list-style-type: none"> <li>Tidal influence reaches further inland due to daily tidal exchange and SLR.</li> <li>Freshwater zones will tend to be compressed, since more frequent exposure to freshwater only occurs transiently during extreme riverine events.</li> <li>Less salinity extremes due to an open river mouth and increased tidal mixing are experienced.</li> <li>Saltwater intrusion into groundwater is increased.</li> </ul>

## Appendix A: Physical Characteristics

<b>Scenario C</b> <b>Decreased</b> extreme river flow events & <b>Decreased</b> tidal prism	<b>Scenario D</b> <b>Decreased</b> extreme river flow events & <b>Increased</b> tidal prism
<b>River-Ocean Connection</b>	
<b>Closed</b>	<b>Mostly Open</b>
<ul style="list-style-type: none"> <li>Riverine and marine processes keep the river mouth primarily closed.</li> <li>Rare riverine flood events transiently open the mouth, but not enough to keep it persistently open.</li> </ul>	<ul style="list-style-type: none"> <li>Marine processes and an increased tidal prism keep the river mouth open for prolonged periods of time.</li> <li>Because riverine flood events that tend to reinforce an open mouth are relatively rare, the system will periodically close.</li> </ul>
<b>Sediment Dynamics</b>	
<b>Decreased Sediment Export &amp; Riverine Sedimentation</b>	<b>Moderate Sediment Export &amp; Beach Sedimentation</b>
<ul style="list-style-type: none"> <li>Aggradation outpaces SLR in the lower valley despite decreased riverine sediment inputs, as the closed river mouth will trap sediment and increase sedimentation rates throughout the valley.</li> <li>Estuary / ocean exchange of sediment and other materials is dramatically decreased.</li> <li>Decreased amount of riverine sediment reaching the beaches, due to the closed river mouth and decreased riverine inputs.</li> </ul>	<ul style="list-style-type: none"> <li>SLR outpaces aggradation in the lower valley, due largely to a decrease in riverine sediment inputs.</li> <li>Estuary / ocean exchange of sediment and other materials is increased.</li> <li>Marine processes have the potential to restructure the lower valley.</li> <li>Less riverine sediment enters the system, but increased tidal exchange allows some material to be exported to the beach.</li> </ul>
<b>Flooding &amp; Inundation</b>	
<b>Riverine Flooding</b>	<b>Coastal Flooding / Inundation</b>
<ul style="list-style-type: none"> <li>Even relatively low river event flows may lead to flooding because a closed river mouth will lead to ponding, which decreases the system's ability to store extra water in the event of flows (i.e., if the bathtub is full, any extra water will cause a flood).</li> <li>The areal extent of flooding will increase due to filling of the channels and river mouth with sediment, leading to greater flooding and inundation of areas in the upper valley.</li> <li>Flooding of beachfront areas will occur with SLR, and could be exacerbated by decreased export of sediment from the estuary onto the beach.</li> </ul>	<ul style="list-style-type: none"> <li>Increased coastal flooding, due to SLR and a mostly open river mouth.</li> <li>Flooding will be mostly dependent on coastal processes, including tides, wave run-up, and storm surge.</li> <li>Flooding of beachfront areas will occur with SLR.</li> </ul>
<b>Water Residence Time</b>	
<b>Longest Residence Time</b>	<b>Short Residence Time</b>
<ul style="list-style-type: none"> <li>Residence times are long due to the closed river mouth and decreased extreme river events.</li> </ul>	<ul style="list-style-type: none"> <li>Residence times are short due to the mostly open mouth.</li> <li>The system occasionally has increased residence times when the river mouth is closed.</li> </ul>
<b>Surface- and Ground- Water Salinity</b>	
<b>Variability with Increased Freshwater Influence</b>	<b>Greatest Saltwater Influence</b>
<ul style="list-style-type: none"> <li>Increased freshwater influence due to very limited tidal exchange and prolonged mouth closures.</li> <li>Variable conditions due to the closed river mouth, ranging from hypersalinity (e.g., evaporation of trapped seawater) to freshwater conditions (e.g., freshwater ponding) to in the lower valley are experienced.</li> <li>Saltwater intrusion into groundwater is reduced.</li> </ul>	<ul style="list-style-type: none"> <li>Increased tidal influence farther inland due to decreased extreme riverine events and SLR.</li> <li>Salinity gradients are relatively consistent, with lower valley areas dominated by marine conditions.</li> <li>Less salinity extremes due to an open river mouth and reduced extreme river flow events are experienced.</li> <li>Saltwater intrusion into groundwater is markedly increased.</li> </ul>

Decreased Vulnerability		Neutral	Increased Vulnerability	
Large Decrease in Vulnerability to Identified Environmental Changes	Small Decrease in Vulnerability to Identified Environmental Changes	Minimal Increase/ Decrease in Vulnerability to Identified Environmental Changes	Small Increase in Vulnerability to Identified Environmental Changes	Large Increase in Vulnerability to Identified Environmental Changes

## Appendix B: Natural Habitat Vulnerabilities

Scenario A Increased extreme river flow events & Decreased tidal prism		Scenario B Increased extreme river flow events & Increased tidal prism	
<b>Beaches &amp; Sand Dunes</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Consistent sediment supply			
Increased extreme events deliver high sediment yields to beaches and dunes, increasing overall habitat area. However, a mostly closed river mouth will limit the total amount of sediment reaching the beaches and dunes, keeping the increase in habitat area small.		Increased extreme events deliver high sediment yields to beaches and dunes, increasing overall habitat area. In addition, an open river mouth will allow the majority of sediment to reach the beaches and dunes, making the increase in habitat area large.	
<b>Open Tidal Channels &amp; Mudflats</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Open or closed river mouth			
Mostly closed river mouth limits marine influence, decreasing habitat area. In addition, an increase in sediment aggradation, due to the closed mouth, will elevate the land, limiting how far tidal influence reaches inland, making the decrease in habitat area large.		Open river mouth and increased tidal prism increase marine influence, leading to an increase in habitat area. However, the increased extreme events lead to increased freshwater in the system, keeping the increase in habitat area small.	
<b>Salt Marsh</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Open river mouth, saltwater inputs, consistent sediment supply			
Mostly closed river mouth and decreased tidal prism will limit the amount of saltwater influence, decreasing habitat area. In addition, increased extreme events will increase freshwater inputs, making the decrease in habitat area large.		Open river mouth and increased tidal prism will increase the saltwater influence. However, increased extreme events will increase the amount of freshwater inputs, meaning the habitat area will remain about the same.	
<b>Salt Flats</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Open or closed river mouth, saltwater inputs, evaporation			
Mostly closed river mouth will lead to high salinity as water trapped behind the river mouth evaporates, increasing habitat area. Additionally, extreme events will increase sediment aggradation, as sediment is trapped behind the closed river mouth, helping to increase habitat area. However, increased extreme events will occasionally open the river mouth altering salinity and aggradation of sediment, keeping the increase in habitat area small.		Open river mouth and increased tidal prism, coupled with increased extreme events will lead to a small decrease in habitat area, due to increased freshwater inputs, increased coastal flooding and inundation (SLR outpaces aggradation in the lower valley).	
<b>Wetland-Upland Transition Zone</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Extreme river flow events, freshwater inputs			
Increased extreme events and freshwater inputs will expand riparian and fresh brackish habitats, causing a large decrease in habitat.		Increased extreme events and increased tidal prism increase the intertidal and riparian habitats squeezing the upland habitat, leading to large habitat decrease.	
<b>Fresh-brackish Marsh</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Freshwater inputs			
Mostly closed river mouth coupled with increased extreme events will pond water and increase freshwater inputs, leading to a large increase in habitat.		An increase in marine and fresh water inputs due to increased riverine extreme events and increase tidal prism, will keep the habitat current habitat area extent.	
<b>Riparian</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Open or closed river mouth, freshwater inputs			
Increased extreme river events deliver more freshwater into the system, leading to an increase of habitat area in both the lower and upper river valley.		Increased extreme events deliver more freshwater into the system, leading to an increase in habitat area in the upper river valley. Increased tidal prism will limit the habitat increase in the lower part of the river valley.	
<b>Upland</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Open or closed river mouth, sediment supply			
Closed river mouth with high sediment yields due to extreme river flow events will mean sediment aggradation will outpace SLR in the lower valley		Increased extreme events and increased tidal prism increase the intertidal and riparian habitats squeezing the upland habitat, leading to large habitat decrease.	

Decreased Vulnerability		Neutral	Increased Vulnerability	
Large Decrease in Vulnerability to Identified Environmental Changes	Small Decrease in Vulnerability to Identified Environmental Changes	Minimal Increase/ Decrease in Vulnerability to Identified Environmental Changes	Small Increase in Vulnerability to Identified Environmental Changes	Large Increase in Vulnerability to Identified Environmental Changes

## Appendix B: Natural Habitat Vulnerabilities

Scenario C Decreased extreme river flow events & Decreased tidal prism		Scenario D Decreased extreme river flow events & Increased tidal prism	
<b>Beaches &amp; Sand Dunes</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Consistent sediment supply			
Decreased extreme events and a closed river mouth will decrease the amount of sediment delivered to beaches and dunes, decreasing the overall habitat area. However, there would be space to retreat meaning there would only be a small decrease in habitat area.		Decreased extreme events will decrease the overall amount of sediment delivered to beaches and dunes. However, an open river mouth will allow the majority of sediment within the system to be delivered to the beaches and dunes, meaning the habitat area will remain about the same.	
<b>Open Tidal Channels &amp; Mudflats</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Open river mouth			
Closed river mouth limits marine influence, causing large decrease in habitat area.		Mostly open river mouth and increased tidal prism increase marine influence, leading to an increase in habitat area. In addition, the decreased extreme events lead to decreased freshwater in the system, making the increase in habitat area large.	
<b>Salt Marsh</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Open river mouth, saltwater inputs, consistent sediment supply			
Closed river mouth and decreased tidal prism will limit the amount of saltwater and marine influence, leading to a large decrease in habitat area.		Mostly open river mouth and increased tidal prism will maintain a consistent saltwater influence, increasing overall habitat area. However, decreased extreme events will decrease the freshwater inputs, making the increase in habitat area large.	
<b>Salt Flats</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> River mouth status, saltwater inputs, evaporation			
Closed river mouth will lead to high salinity as water trapped behind the river mouth evaporates, increasing habitat area. Additionally, extreme events will increase sediment aggradation in the lower valley, as sediment is trapped behind the closed river mouth, making the increase in habitat area large.		Mostly open river mouth and increased tidal prism will lead to a large decrease in habitat area, due to the increased of intertidal and saltmarsh habitats, and SLR outpacing aggradation in the lower valley.	
<b>Wetland-Upland Transition Zone</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Extreme river events, freshwater inputs			
With decreases in extreme river events and tidal prism the Wetland – Upland Transition Zone habitat maintains its existing area.		With decreased extreme riverine events and increased tidal prism the Wetland-Upland Transition Zone will maintain the same area but move inland.	
<b>Fresh-brackish Marsh</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Freshwater inputs			
Closed river mouth will pond water, leading to a small increase in habitat area. However, infrequent extreme river flow events limits the amount of water ponded behind the closed river mouth		Mostly open river mouth and increased tidal prism will increase marine influence on the system, while less extreme riverine events will decrease freshwater inputs, leading to a decrease in habitat area. However, fresh-brackish habitats in the river valley tend to be far away from the river mouth, meaning some advancement of intertidal areas may not impact them too heavily, keeping the loss in habitat area small.	
<b>Riparian</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Freshwater inputs, river mouth			
Less freshwater and saltwater inputs due to decreased extreme river events coupled with a decreased tidal prism will maintain the current habitat area.		Decrease freshwater input will lead to a decrease in habitat area. In addition, an increased tidal prism will exacerbate the habitat area loss, leading to a large decrease in habitat area.	
<b>Upland</b>			
<b>Key Factors affecting Habitat Type Vulnerability:</b> Sediment supply, river mouth status			
A close river mouth will make aggradation to outpace SLR, leading to a small habitat increase in the lower river valley.		Increased tidal prism and intertidal habitats encroach on upland habitat, leading to a decrease in habitat area. However, the impact by decreased river flow events will be minimal; meaning the loss in habitat area is small.	

## Appendix C: Built Environment

### Agriculture

**Key Factors affecting Sector Vulnerability:** Flooding, Water quality, Salinity

Scenario A <b>Increased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario B <b>Increased</b> extreme river flow events & <b>Increased</b> tidal prism	Scenario C <b>Decreased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario D <b>Decreased</b> extreme river flow events & <b>Increased</b> tidal prism
<ul style="list-style-type: none"> <li>Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, drowning crops and bringing unwanted contaminants (e.g. trash, sewage, pollutants) to local farms and ranches.</li> <li>Potential for crops to be buried under excess sediment accompanying extreme river flow events.</li> <li>Public access roads/ trails are frequently impaired during extreme events by excess sediment and flooding, obstructing emergency evacuation routes, ability to bring agricultural goods to market, and horse trails.</li> </ul>	<ul style="list-style-type: none"> <li>Potential for crops to be buried under excess sediment accompanying extreme river flow events.</li> <li>Public access roads/ trails are frequently impaired during extreme events by excess sediment and flooding, obstructing evacuation routes, impacting ability to bring agricultural goods to market, and accessibility to horse trails.</li> <li>Due to sea level rise, potential for increased saltwater intrusion into freshwater supplies.</li> </ul>	<ul style="list-style-type: none"> <li>Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, drowning crops and bringing unwanted contaminants (e.g. trash, sewage, pollutants) to local farms and ranches.</li> <li>Decreased availability of freshwater with decreased extreme river flow events.</li> </ul>	<ul style="list-style-type: none"> <li>Decreased availability of freshwater with decreased extreme river flow events.</li> <li>Due to sea level rise, high potential for increased saltwater intrusion into freshwater supplies.</li> </ul>



# Agriculture

## Existing Conditions

- One of the primary economic activities that takes place in the river valley, containing numerous equestrian and ranch facilities, including the U.S. Border Patrol's horse patrol facility.
- Additionally, both organic and sod farming are present throughout the river valley.

## Key Factors affecting Sector Vulnerability

- Flooding
- Salinity
- Water quality

## Key Vulnerabilities in Scenarios

### Sea Level Rise & Increased Tidal Prism

- Potential for increased saltwater intrusion into freshwater supplies.

### Closed Tijuana River Mouth

- Floods throughout the valley will last longer and cover a greater aerial extent, drowning crops and bringing unwanted contaminants (e.g. trash, sewage, pollutants) to local farms and ranches.

### Increased Extreme River Flow Events

- Potential for crops to be buried under excess sediment accompanying extreme river flow events.
- Public access roads/ trails are frequently impaired by excess sediment and flooding, obstructing emergency evacuation routes, ability to bring agricultural goods to market, and horse trails.

### Decreased Extreme River Flow Events

- Decreased availability of freshwater.



## Appendix C: Built Environment

### Border Security & Infrastructure

**Key Factors affecting Sector Vulnerability:** Flooding, Excess sediment, Riparian habitats

<b>Scenario A</b> Increased extreme river flow events & Decreased tidal prism	<b>Scenario B</b> Increased extreme river flow events & Increased tidal prism	<b>Scenario C</b> Decreased extreme river flow events & Decreased tidal prism	<b>Scenario D</b> Decreased extreme river flow events & Increased tidal prism
<ul style="list-style-type: none"> <li>• Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, making it difficult to patrol the valley, and limiting access to field locations and border station.</li> <li>• Access roads/ trails in the upper valley are frequently impaired during extreme events by excess sediment and flooding.</li> <li>• Maintaining trails and roads in the upper valley becomes difficult as river channel configurations are altered more frequently.</li> <li>• Frequent flooding of the culverts leads to erosion and may compromise the structural integrity of the border fence and border road.</li> <li>• Increased extreme events may lead to more resources needed for emergency rescue operations.</li> <li>• Mostly closed river mouth leading to polluted water (e.g. sewage) remaining in the system for prolonged periods of time, becoming a primary public health concern for agents in the field.</li> <li>• Expanded beaches will make access to the beach by vehicle more consistent, making patrolling the shoreline easier.</li> <li>• Due to a large increase in fresh-brackish marsh, mosquito control may become a primary public health concern for agents in the field.</li> <li>• Additionally, expanded fresh-brackish marsh will limit vehicle access to the upper marsh, due to an increase in muddy habitats.</li> <li>• Expanded riparian habitat limits access and impairs visibility in the upper valley, due to increased canopy cover, making patrols difficult.</li> </ul>	<ul style="list-style-type: none"> <li>• Access roads/ trails, field locations, infrastructure (e.g., the portion of the border fence that extends into the ocean) in the lower valley severely impacted by sea level rise, with some areas becoming permanently inundated.</li> <li>• Access roads/ trails in the upper valley are frequently impaired during extreme events by excess sediment and floods, making it difficult to patrol the valley and limiting access to field locations and border station.</li> <li>• Frequent flooding of the culverts leads to erosion and may compromise the structural integrity of the border fence and access road.</li> <li>• Increased extreme events may lead to more resources needed for emergency rescue operations.</li> </ul>	<ul style="list-style-type: none"> <li>• Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, making it difficult to patrol the valley and limiting access to field locations and border station.</li> <li>• Mostly closed river mouth leading to polluted water (e.g. sewage) remaining in the system for prolonged periods of time, becoming a primary public health concern for agents in the field.</li> <li>• Decrease in area of beaches will make access to the beach by vehicle more inconsistent, making patrolling the shoreline difficult.</li> <li>• Potential benefit of having an increase in salt flat habitat, increasing visibility and ability to patrol in the lower valley.</li> <li>• Due to a large increase in fresh-brackish marsh, mosquito control may become a primary public health concern for agents in the field.</li> </ul>	<ul style="list-style-type: none"> <li>• Access roads/ trails, field locations, infrastructure (e.g., the portion of the border fence that extends into the ocean) in the lower valley severely impacted by sea level rise, with some areas becoming permanently inundated.</li> <li>• Decreased flooding and sedimentation in the upper valley makes maintenance of trails easier.</li> <li>• Expanded fresh-brackish marsh will limit vehicle access to the upper marsh, due to an increase in muddy habitats.</li> <li>• Decreased riparian habitat improves access and visibility in the upper valley, due to decreased canopy cover, making patrols easier.</li> </ul>



# Border Security & Infrastructure

## Existing Conditions

- U.S. Border Patrol is active throughout the valley with important security facilities including, the border fence (e.g., secondary fence, tertiary fence), border lighting, camera towers, and border fence gates.
- The Imperial Beach Border Patrol Station, including BP's horse patrol facility are located in the TRV off Saturn Blvd.

## Key Factors affecting Sector Vulnerability

- Excess sediment
- Flooding
- Riparian habitats

## Key Vulnerabilities in Scenarios

### Sea Level Rise & Increased Tidal Prism

- Access roads/ trails, field locations, infrastructure (e.g., the portion of the border fence that extends into the ocean) in the lower valley are severely impacted by sea level rise, with some areas becoming permanently inundated.

### Closed Tijuana River Mouth

- Several public health concerns for agents in the field may arise including polluted water (e.g. sewage) remaining in the system for prolonged periods of time, and an increase in fresh-brackish marsh may lead to increased mosquito populations.

### Increased Extreme River Flow Events

- Access roads/ trails in the upper valley are frequently impaired during extreme events by excess sediment and flooding making it difficult to patrol the valley and may lead to more resources needed for emergency rescue operations.
- Frequent flooding of the culverts leads to erosion and may compromise the structural integrity of the border fence and border road.
- Expanded riparian habitat may limit access and impair visibility in the upper valley, due to increased canopy cover, making patrols difficult.

## Appendix C: Built Environment Cultural & Historical Resources

**Key Factors affecting Sector Vulnerability:** Flooding & Inundation, Sediment Accretion, Erosion, Higher Groundwater Levels

Scenario A <b>Increased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario B <b>Increased</b> extreme river flow events & <b>Increased</b> tidal prism	Scenario C <b>Decreased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario D <b>Decreased</b> extreme river flow events & <b>Increased</b> tidal prism
<ul style="list-style-type: none"> <li>• Water ponding and riverine sedimentation in a system with a mostly closed river mouth restricts ability to locate new sites and access previously recorded sites for research and spiritual purposes.</li> <li>• Extreme river events lead to localized scouring, erosion, and cliff failure, with the potential for dramatic restructuring of the system, disturbing, damaging, and destroying once buried paleontological and archaeological sites throughout the river valley.</li> <li>• Long water residence times lead to highly polluted waters contaminating sites of research and spiritual significance, restricting access and potentially damaging sites in the lower valley.</li> <li>• Higher groundwater levels caused by sea level rise permanently restricts ability to locate new sites and access previously recorded sites for research and spiritual purposes.</li> <li>• Additionally, increased groundwater levels may inundate and degrade historic structures and structural remains, and may potentially lead to cliff erosion and failure resulting in potential destruction of archeological sites.</li> </ul>	<ul style="list-style-type: none"> <li>• Increased tidal prism and sea level rise leads to permanent inundation in low lying areas, permanently restricting ability to locate new sites and access previously recorded sites for research and spiritual purposes in the lower valley.</li> <li>• Extreme river events lead to localized scouring, erosion, and cliff failure, with the potential for restructuring of the system, disturbing, damaging, and destroying once buried paleontological and archaeological sites throughout the river valley.</li> <li>• Higher groundwater levels caused by sea level rise permanently restricts ability to locate new sites and access previously recorded sites for research and spiritual purposes.</li> <li>• Additionally, increased groundwater levels may inundate and degrade historic structures and structural remains, and may potentially lead to cliff erosion and failure resulting in potential destruction of archeological sites...</li> </ul>	<ul style="list-style-type: none"> <li>• Water ponding and riverine sedimentation in a system with a closed river mouth restricts ability to locate new sites and access previously recorded sites for research and spiritual purposes.</li> <li>• Long water residence times lead to highly polluted waters contaminating sites of research and spiritual significance, restricting access and potentially damaging sites in the lower valley.</li> <li>• Higher groundwater levels caused by sea level rise permanently restricts ability to locate new sites and access previously recorded sites for research and spiritual purposes.</li> <li>• Additionally, increased groundwater levels may inundate and degrade historic structures and structural remains, and may potentially lead to cliff erosion and failure resulting in potential destruction of archeological sites.</li> </ul>	<ul style="list-style-type: none"> <li>• Increased tidal prism and sea level rise leads to permanent inundation in low lying areas, permanently restricting ability to locate new sites and access previously recorded sites for research and spiritual purposes in the lower valley.</li> <li>• Higher groundwater levels caused by sea level rise permanently restricts ability to locate new sites and access previously recorded sites for research and spiritual purposes.</li> <li>• Additionally, increased groundwater levels may inundate and degrade historic structures and structural remains, and may potentially lead to cliff erosion and failure resulting in potential destruction of archeological sites...</li> </ul>



# Cultural & Historical Resources

## Existing Conditions

- Prehistoric sites and artifacts, with sites dating in the Paleoindian, Early Archaic, and Late Prehistoric periods. Site primarily include shellfish and lithics, with habitation sites being uncommon but including the ethnographically documented Kumeyaay village of Millejo.
- Several recorded paleontological resources associated with the San Diego formation and unnamed Pleistocene terrace deposits . These sites are significant as they contain highly preserved fossils, and have a high potential for yielding important remains of fossil marine vertebrates, especially rare marine mammal fossils.

## Key Factors affecting Sector Vulnerability

- Flooding and inundation
- Sediment accretion
- Erosion
- Higher groundwater levels

## Key Vulnerabilities in Scenarios

### Sea Level Rise & Increased Tidal Prism

- Higher groundwater may permanently restrict ability to locate new sites and access previously recorded sites
- Increased groundwater levels may inundate and degrade historic structures and structural remains, and may potentially lead to cliff erosion and failure resulting in potential destruction of archeological sites.

### Closed Tijuana River Mouth

- Water ponding and riverine sedimentation may restrict ability to locate new sites and access previously recorded sites.
- Long water residence times lead to highly polluted waters contaminating sites of research and spiritual significance, restricting access and potentially damaging sites in the lower valley.

### Increased Extreme River Flow Events

- Localized scouring, erosion, and cliff failure, with the potential for dramatic restructuring of the system, may disturb, damage, and destroy once buried paleontological and archaeological sites throughout the river valley.

## Appendix C: Built Environment

### Naval Outlying Landing Field

**Key Factors affecting Sector Vulnerability: Erosion, Shifts in Bird Populations and Behavior**

<b>Scenario A</b> <b>Increased</b> extreme river flow events & <b>Decreased</b> tidal prism	<b>Scenario B</b> <b>Increased</b> extreme river flow events & <b>Increased</b> tidal prism	<b>Scenario C</b> <b>Decreased</b> extreme river flow events & <b>Decreased</b> tidal prism	<b>Scenario D</b> <b>Decreased</b> extreme river flow events & <b>Increased</b> tidal prism
<ul style="list-style-type: none"> <li>Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, causing frequent flooding at NOLF.</li> <li>Increased extreme events lead to increased erosion along the southern edge of the airfield, with the potential for erosion to be mitigated by changes in channel configuration directing large flows away from the base.</li> <li>Large decrease in open tidal channels &amp; mudflats and salt marsh, in addition to a large increase in freshwater habitats, possibly leading to changes in local bird populations and behavior leading to conflicts, around airspace usage.</li> </ul>	<ul style="list-style-type: none"> <li>Access roads/ trails and infrastructure in the lower valley severely impacted by sea level rise, with some areas of the base being flooded when riverine storms interact with rising seas.</li> <li>Access roads/ trails frequently impaired during extreme events by excess sediment and floods, making it difficult for personnel to access NOLF.</li> <li>Increased extreme events lead to increased erosion along the southern edge of the airfield.</li> </ul>	<ul style="list-style-type: none"> <li>Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, causing frequent flooding at NOLF.</li> <li>Decreased extreme events lead to a potential decrease in erosion along the southern edge of the airfield.</li> <li>Large decrease in open tidal channels &amp; mudflats and salt marsh, in addition to a small increase in freshwater habitats, possibly leading to changes in local bird populations and behavior, leading to conflicts around airspace usage.</li> </ul>	<ul style="list-style-type: none"> <li>Access roads/ trails and infrastructure in the lower valley severely impacted by sea level rise, with some areas of the base being flooded when riverine storms interact with rising seas.</li> <li>Decreased extreme events lead to a potential decrease in erosion along the southern edge of the airfield.</li> </ul>



# Naval Outlying Landing Field

## Scenario Vulnerabilities

### Existing Conditions

- One of the largest Naval helicopter training facilities on the West coast of the United States, a branch of the Naval Air Station North Island (located on Coronado Island).
- Portions of Naval land are leased as agricultural lands or managed as critical habitat for endangered species by US Fish & Wildlife Service.

### Key Factors affecting Sector Vulnerability

- Erosion
- Shifts in bird populations and behavior

### Key Vulnerabilities in Scenarios

#### Sea Level Rise & Increased Tidal Prism

- Access roads/ trails and infrastructure in the lower valley severely impacted by sea level rise, with some areas of the base being flooded when riverine storms interact with rising seas.

#### Decreased Tidal Prism

- Decreases in open tidal channels and salt marsh, in addition to a small increase in freshwater habitats, possibly leading to changes in local bird populations and behavior, leading to conflicts around airspace usage.

#### Closed Tijuana River Mouth

- Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, causing frequent flooding.

#### Increased Extreme River Flow Events

- May lead to increased erosion along the southern edge of the airfield, with the potential for erosion to be mitigated by resulting changes in channel configuration directing large flows away from the base.
- Access roads/ trails frequently impaired during extreme events by excess sediment and floods, making it difficult for personnel to access NOLF.

## Appendix C: Built Environment

### Parks, Recreation, & Public Access

**Key Factors affecting Sector Vulnerability:** Flooding, Excess sediment, Presence of habitats valued by public

Scenario A <b>Increased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario B <b>Increased</b> extreme river flow events & <b>Increased</b> tidal prism	Scenario C <b>Decreased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario D <b>Decreased</b> extreme river flow events & <b>Increased</b> tidal prism
<ul style="list-style-type: none"> <li>Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, making access to all park lands in the river valley less reliable.</li> <li>Access roads/ trails are frequently impaired during extreme events by excess sediment and floods, making access to park lands less reliable.</li> <li>Maintaining trails and roads in the upper valley becomes difficult as river channel configurations are altered more frequently, making certain North-South crossings dangerous.</li> <li>Large decrease of habitats that are highly valued by lower valley park visitors and the general public (e.g., open tidal channels and salt marsh).</li> <li>Large piles of trash and impaired water quality that may come along with increased extreme riverine events may restrict access and recreation due to both physical barriers and for public health reasons. Additionally, it may adversely impact visitor's experiences (e.g., aesthetics, undesirable odors) throughout the river valley.</li> <li>Due to a large increase in fresh-brackish marsh, mosquito control may become a primary public health concern.</li> </ul>	<ul style="list-style-type: none"> <li>Access roads/ trails (e.g., Monument Road, access to Monument Mesa, North-South Crossings, Oneonta Slough berm trail, Clapper Rail trail and observational pier) and infrastructure in the lower valley, severely impacted by sea level rise, with some areas becoming permanently inundated.</li> <li>Sea level rise, coupled with storms, leads to increased erosion along Monument Mesa, making cultural resources and State Parks day-use facility vulnerable.</li> <li>Access roads/ trails are frequently impaired during extreme events by excess sediment and floods, making access to park lands less reliable.</li> <li>Large piles of trash and impaired water quality that may come along with increased extreme riverine events may restrict access and recreation due to both physical barriers and for public health reasons. Additionally, it may adversely impact visitor's experiences (e.g., aesthetics, undesirable odors) throughout the river valley.</li> <li>Increased presence of beach-dune habitat, supporting endangered species nesting and publically valued recreation (e.g., horseback riding on the beach).</li> </ul>	<ul style="list-style-type: none"> <li>Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, making access to all parks in the river valley less reliable.</li> <li>Large decrease of habitats that are highly valued by lower valley park visitors and the general public (e.g., open tidal channels and salt marsh).</li> <li>Due to a large increase in fresh-brackish marsh, mosquito control may become a primary public health concern.</li> </ul>	<ul style="list-style-type: none"> <li>Access roads/ trails and infrastructure in the lower valley, severely impacted by sea level rise (e.g., Monument Road, access to Monument Mesa, North-South Crossings, Oneonta Slough berm trail, Clapper Rail trail and observational pier), with some areas becoming permanently inundated.</li> <li>Sea level rise, coupled with storms, leads to increased erosion along Monument Mesa, making cultural resources and State Parks day-use facility vulnerable.</li> <li>Increase in habitats that are highly valued by lower valley park visitors and the general public (e.g., open tidal channels and salt marsh).</li> </ul>



# Parks, Recreation, & Public Access

## Existing Conditions

- An extensive network of hiking trails that are popular among avid bird watchers; a public beach north and south of the Tijuana River Mouth; and equestrian trails, remaining one of the last places where horseback riding is allowed on a beach in Southern California.
- The protected areas preserved for public access include NOAA's Tijuana River National Estuarine Research Reserve- which includes Tijuana Slough National Wildlife Refuge (USFWS), Border Field State Park (CA State Parks), the Tijuana River Valley Regional Park (County of SD), and Friendship Park (U.S. Border Patrol).

## Key Factors affecting Sector Vulnerability

- Excess sediment
- Flooding
- Presence of habitats valued by public

## Key Vulnerabilities in Scenarios

### Sea Level Rise & Increased Tidal Prism

- Access roads/ trails (e.g., Monument Road, access to Monument Mesa, North-South Crossings, Oneonta Slough berm trail, Clapper Rail trail and observational pier) and infrastructure (e.g., State Parks day-use facility) in the lower valley severely impacted, with some areas becoming permanently inundated.

### Closed Tijuana River Mouth

- Floods throughout the valley will last longer and cover a greater aerial extent, making access to all parks in the river valley less reliable.
- A large decrease in habitats that are highly valued by lower valley park visitors (e.g., open tidal channels and salt marsh).
- Large increase in fresh-brackish marsh, mosquito control may become a primary public health concern.

### Increased Extreme River Flow Events

- Access roads/ trails are frequently impaired by excess sediment and floods, making access to park lands less reliable and certain North-South crossings dangerous.
- Large piles of trash and impaired water quality that may restrict access and recreation due to both physical barriers and for public health reasons.



## Appendix C: Built Environment

### Stormwater Management & Flood Control

Key Factors affecting Sector Vulnerability: Flooding, Sediment supply, Sea level rise

Scenario A <b>Increased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario B <b>Increased</b> extreme river flow events & <b>Increased</b> tidal prism	Scenario C <b>Decreased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario D <b>Decreased</b> extreme river flow events & <b>Increased</b> tidal prism
<ul style="list-style-type: none"> <li>Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, making stormwater management and flood control more difficult.</li> <li>Large amount of sediment transport during extreme river flow events possibly overwhelming current sediment management BMPs (e.g., overtop sediment basin, berms).</li> <li>Infrastructure frequently impaired during extreme events by excess sediment, trash, and flooding.</li> <li>Decreased habitat types (e.g. open tidal channels and salt marsh) that can absorb large amounts of water during a flood, make flooding more likely and complex.</li> </ul>	<ul style="list-style-type: none"> <li>Stormwater management infrastructure near the beach and coastal properties may become ineffective due to rising seas, with coastal areas possibly experiencing regular flooding during high tides.</li> <li>Large amount of sediment transport during extreme river flow events possibly overwhelming current sediment management BMPs (e.g., overtop sediment basin, berms).</li> <li>Infrastructure frequently impaired during extreme events by excess sediment and flooding.</li> </ul>	<ul style="list-style-type: none"> <li>Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, making stormwater management and flood control more difficult.</li> <li>Decreased habitat types (e.g. open tidal channels and salt marsh) that can absorb large amounts of water during a flood, exacerbating the impacts of flooding.</li> </ul>	<ul style="list-style-type: none"> <li>Stormwater management infrastructure near the beach and coastal properties may become ineffective due to rising seas, with coastal areas possibly experiencing regular flooding during high tides.</li> <li>Increased habitat types (e.g. open tidal channels and salt marsh) that can absorb large amounts of water during a flood, helping to mitigate the impacts of flooding.</li> </ul>



# Stormwater Management & Flood Control

## Existing Conditions

- There are several miles of storm drain pipes and channels, and numerous storm drain inlets, cleanouts, catch basins, and headwalls throughout the TRV.
- Critical facilities include: Goat Canyon sediment basin (CA State Parks); North and South Levees, Tijuana River Flood Control Project (IBWC); Goat Canyon Border Culvert, Smuggler's Gulch Border Culvert, W-8 Culvert, and Stewart's Culvert (U.S. Border Patrol); and Pilot Channel (City of San Diego).

## Key Factors affecting Sector Vulnerability

- Flooding
- Sea level rise
- Sediment supply

## Key Vulnerabilities in Scenarios

### Sea Level Rise & Increased Tidal Prism

- Stormwater management infrastructure near the beach and coastal properties, may become ineffective due to rising seas, with coastal areas possibly experiencing regular flooding during high tides.

### Closed Tijuana River Mouth

- Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, making stormwater management and flood control more difficult.

### Increased Extreme River Flow Events

- Large amount of sediment transport during extreme river flow events possibly overwhelming current sediment management BMPs (e.g., overtop sediment basin, berms).
- Stormwater management infrastructure frequently impaired during extreme events by excess sediment, trash, and flooding.

# Appendix C: Built Environment Transportation

**Key Factors affecting Sector Vulnerability: Flooding, Excess sediment, Erosion**

Scenario A <b>Increased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario B <b>Increased</b> extreme river flow events & <b>Increased</b> tidal prism	Scenario C <b>Decreased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario D <b>Decreased</b> extreme river flow events & <b>Increased</b> tidal prism
<ul style="list-style-type: none"> <li>Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, making roads inaccessible and more difficult to maintain.</li> <li>Roads (e.g., Monument Road, Hollister St.) and bridges (e.g., Hollister St. bridge) frequently impaired during extreme events by excess sediment, flooding, and erosion, obstructing emergency evacuation routes.</li> <li>Increased extreme riverine events may lead to roads being more frequently undermined resulting in the infrastructure under the roads (e.g., sewer, water pipes, electricity) becoming less reliable and requiring more frequent maintenance.</li> <li>Maintaining roads in the upper valley become difficult as river channel configurations are altered more frequently.</li> </ul>	<ul style="list-style-type: none"> <li>Roads in the lower valley, severely impacted by sea level rise, with some areas becoming permanently inundated, and coastal storms causing more frequent damage by depositing large sediment loads on coastal streets (e.g., Sea Coast Dr.).</li> <li>Roads (e.g., Monument Road, Hollister Street) and bridges (e.g., Hollister street bridge) frequently impaired during extreme events by excess sediment, flooding, and erosion, obstructing emergency evacuation routes</li> <li>Increased extreme riverine events may lead to roads being more frequently undermined resulting in the infrastructure under the roads (e.g., sewer, water pipes, electricity) becoming less reliable and requiring more frequent maintenance.</li> </ul>	<ul style="list-style-type: none"> <li>Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, making roads inaccessible and more difficult to maintain.</li> <li>Decreased extreme events lead to a potential decrease in erosion in localized areas.</li> </ul>	<ul style="list-style-type: none"> <li>Roads in the lower valley, severely impacted by sea level rise, with some areas becoming permanently inundated, and coastal storms causing more frequent damage by depositing large sediment loads on coastal streets (e.g., Sea Coast Dr.).</li> <li>Decreased extreme events lead to a potential decrease in erosion in localized areas.</li> </ul>

## Existing Conditions

- The primary roads that are important to maintain for emergency vehicles, community evacuations, border security, and public access include: Dairy Mart Road; Hollister Street; Monument Road; Seacoast Drive; Roads on North and South Levees, Tijuana River Flood Control Project (IBWC); Access to Imperial Beach Border Patrol Station from Saturn Blvd (U.S. Border Patrol); Border Road running from the Ocean to the Levy (U.S. Border Patrol); Smuggler's Gulch access road ;and dirt roads throughout TRNERR.

## Key Factors affecting Sector Vulnerability

- Flooding
- Erosion
- Excess sediment

## Key Vulnerabilities in Scenarios

### Sea Level Rise & Increased Tidal Prism

- Roads in the lower valley, severely impacted by sea level rise, with some areas becoming permanently inundated, and coastal storms causing more frequent damage by depositing large sediment loads on coastal streets (e.g., Sea Coast Dr.).

### Closed Tijuana River Mouth

- Floods throughout the valley will last longer and cover a greater aerial extent due to a mostly closed river mouth, making roads inaccessible and more difficult to maintain.

### Increased Extreme River Flow Events

- Roads (e.g., Monument Road, Hollister St.) and bridges (e.g., Hollister St. bridge) will be more frequently impaired during extreme events by excess sediment, flooding, and erosion, obstructing emergency evacuation routes.
- Increased extreme riverine events may lead to roads being more frequently undermined resulting in the infrastructure under the roads (e.g., sewer, water pipes, electricity) becoming less reliable and requiring more frequent maintenance.

# Appendix C: Built Environment

## Wastewater Management

**Key Factors affecting Sector Vulnerability:** Extreme Events, Transportation of Sediment and Contaminants

Scenario A <b>Increased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario B <b>Increased</b> extreme river flow events & <b>Increased</b> tidal prism	Scenario C <b>Decreased</b> extreme river flow events & <b>Decreased</b> tidal prism	Scenario D <b>Decreased</b> extreme river flow events & <b>Increased</b> tidal prism
<ul style="list-style-type: none"> <li>• Increased extreme events lead to increased sediment loads and trash, potentially plugging/ damaging infrastructure; however, a large increase in riparian habitat may help to filter out some sediment and trash before infrastructure is damaged.</li> <li>• Localized scour may affect electrical lines and potable water supplies for treatment plants during an extreme riverine event, additionally pipelines may become exposed causing an alignment problem which may ultimately lead to a break in a line.</li> <li>• Increased extreme events may lead to decreased capacity of some pump stations (e.g., Goat Canyon pump station) to treat sewage as surface water seeps into the pump, meaning some of the pumping capacity is used to pump stormwater instead of sewage.</li> <li>• Untreated water will remain in the system for longer periods of time due to the ponding of the water around the mostly closed river mouth, creating public health concerns.</li> </ul>	<ul style="list-style-type: none"> <li>• Sea water encroaches further into the South Bay outfall pipeline due to rising sea levels, requiring regular maintenance to keep clear.</li> <li>• Increased extreme events lead to increased sediment loads and trash, potentially plugging/ damaging infrastructure; however, a large increase in riparian habitat may help to filter out some sediment and trash before infrastructure is damaged.</li> <li>• Increased extreme events may lead to decreased capacity of some pump stations (e.g., Goat Canyon pump station) to treat sewage as surface water seeps into the pump, meaning some of the pumping capacity is used to pump stormwater instead of sewage.</li> </ul>	<ul style="list-style-type: none"> <li>• Decreased extreme events lead to decreased sediment loads and trash, leading to a decrease in the plugging/ damaging of infrastructure.</li> <li>• Untreated water will remain in the system for longer periods of time due to the ponding of the water around the closed river mouth, creating public health concerns.</li> </ul>	<ul style="list-style-type: none"> <li>• Sea water encroaches further into the South Bay outfall pipeline due to rising sea levels, requiring regular maintenance to keep clear.</li> <li>• Decreased extreme events lead to decreased sediment loads and trash, leading to a decrease in the plugging/ damaging of infrastructure.</li> <li>• Large decrease in riparian habitat may mean less of an opportunity for sediment and trash to be filtered out before infrastructure is damaged during extreme riverine events.</li> </ul>



# Wastewater Management

## Existing Conditions

- There are several pump stations, miles of sewer mains, diversion facilities and pipelines, and land and ocean outfalls located throughout the TRV.
- Critical facilities include: South Bay International Wastewater Treatment Plant (IBWC); South Bay Water Reclamation Plant (City of San Diego); South Bay Land and Ocean Outfalls (IBWC, City of San Diego).

## Key Factors affecting Sector Vulnerability

- Extreme events
- Transportation of sediment and contaminants

## Key Vulnerabilities in Scenarios

### Sea Level Rise & Increased Tidal Prism

- Sea water may encroach further into the South Bay outfall pipeline due to rising sea levels, requiring regular maintenance to keep clear.
- Resulting decrease in riparian habitat may mean less of an opportunity for sediment and debris to be filtered out of flood waters before infrastructure is damaged.

### Increased Extreme River Flow Events

- May result in increased sediment loads and trash potentially plugging and/ or damaging wastewater infrastructure.
- May lead to a decreased capacity of some pump stations (e.g., Goat Canyon pump station) to treat sewage as surface water seeps into the pump, meaning some of the pumping capacity is used to pump stormwater instead of sewage.
- Localized scour may expose pipelines causing an alignment problem which may ultimately lead to a break in a line.

# Glossary

**Aggradation:** The raising of the bed of a watercourse (e.g., river channels, salt marshes) caused by the accumulation/ deposition of sediment [4]. (Synonym: sedimentation)

**Alluvial fan:** A landscape feature whose surface is shaped like an open fan or a segment of a cone, and is formed by the accumulation of sediment and organic material deposited by flowing water [4].

**Eutrophication:** An increase of nutrient inputs into a system that increases the growth of algae, produces declines in the health of fish and shellfish, and depletes dissolved oxygen in the water (i.e., hypoxia) [4].

**Flood:** Temporary submergence of land from river water flows (i.e., riverine flooding) or the ocean (i.e., coastal flooding).

**Geomorphology:** The study of physical landscapes (i.e., landforms), and the processes that create and mold them [4].

**Hypoxia:** A condition where there is not enough oxygen in the water, suffocating plant and animal life, typically a result of excess nutrients (i.e., eutrophication) [4].

**Inundation:** Permanent submergence of land. If a section of land is regularly submerged (i.e., during a tidal cycle), it is considered inundated.

**Resilience:** “Amount of change a system can undergo (i.e., its capacity to absorb disturbance) and retain essentially the same functions, structures, and feedbacks [5].”

**Lower valley:** The portion of the Tijuana River Valley that is currently tidally-influenced (i.e., downstream estuarine portion of the valley).

**Ponding:** The creation of a lake/ lagoon around the river mouth, typically caused by a closed mouth.

**Scour:** The weathering of river banks, caused by the clearing and digging action of flowing water, especially the downward erosion by stream water during flood events [4].

**Sediment export:** Sediment delivered from the upper river valley out to the sea.

**Sedimentation:** The raising of the bed of a watercourse (e.g., river channels, salt marshes) caused by the accumulation/ deposition of sediment [4]. (Synonym: aggradation)

**Storm surge:** Water that is pushed toward the shore by the force of wind associated with a storm, as well as elevated due to low atmospheric pressure. [6].

**Upper valley:** The portion of the Tijuana River Valley that is not currently tidally-influenced (i.e. the upstream riparian & upland portions of the valley).

**Water residence time:** The average amount of time that water remains in system (e.g., how long freshwater remains in the estuary before heading out to sea, how long flooding waters remain before dissipating)

**Wave run-up:** The upper levels reached by a wave on a beach or coastal structure [4].

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