COASTAL ADAPTATION VISION FOR NAVAL BASE VENTURA COUNTY POINT MUGU

Prepared for
The Nature Conservancy and
Naval Base Ventura County

September 2020

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Executive Summary

Naval Base Ventura County (NBVC) Point Mugu experiences impacts from coastal erosion and wave run-up, inundation from high tides, and flooding from coastal storm surges and Calleguas Creek. These hazards are increasing in intensity, frequency, and duration and will increase further as sea-levels rise, damaging built infrastructure and natural habitats of the base. Through a partnership between The Nature Conservancy (TNC) and the U.S. Navy, a Vulnerability Assessment and Adaptation Vision was developed to assess risk and guide the adaptation of built assets and habitats on the base to enhance long-term basewide resilience to sea-level rise. This vision works to protect critical assets that must remain in place and identifies opportunities to consolidate other base infrastructure to reduce the current and future vulnerability throughout the base, while also improving natural habitats and the protective services they provide to built assets. By doing so, this Adaptation Vision also meets other base objectives such as reducing operational and maintenance costs over time (personnel transport, road maintenance, utilities, etc.) while preserving overall base function. Other Department of Defense (DoD) installations on the coast face similar climate resilience issues as NBVC. The Adaptation Vision's planning process and approaches to resilience can serve as a model for other installations across the U.S. working to ensure long-term coastal resilience.

The Adaptation Vision was developed collaboratively between TNC, Environmental Science Associates (ESA), a multi-discipline environmental consulting firm, and a multifunctional team at NBVC. These groups have collaborated on an extensive body of base-specific work that was leveraged and culminated in this Adaptation Vision for NBVC Point Mugu. The development process included the following:

- Step 1 – Characterize NBVC Zones by describing analytical zones, and quantifying built and natural asset hazard risk by zone
- Step 2 – Identify opportunities and constraints for NBVC adaptation of assets and habitats
- Step 3 – Develop adaptation strategies to be included in the Adaptation Vision
- Step 4 – Evaluate the benefits of the Vision to built and natural habitats

The overall objective of the Adaptation Vision for NBVC Point Mugu is to develop and analyze a range of adaptation components and actions to remove, relocate, and defend assets in place to improve the overall resilience of built assets and restore natural habitats, while preserving base functionality and supporting the military mission.

Adaptation Vision Components and Actions:

> **Defend:** Protect critical built assets that must be maintained in place (in Area X, Area 2A and Areas 3-4; Executive Summary Figure ES-1) using the following measures, depending on the actual intensity of climate change and sea-level rise. Note that increasing wave run-up with higher sea levels will exacerbate the vulnerability of critical built assets, especially in Areas 3 and 4, and hence realignment and appropriate relocation should be considered through continued planning efforts for all assets on the Pacific shoreline (discussed in Section 3.3.2).

- Beach nourishment / enhancement – place sand to widen beaches seaward and build dunes to provide protection to assets in areas 1, 4 and 5. Consider beneficial reuse of sand dredged from Calleguas Creek and other sources, and consider measures to facilitate the natural deposition and enhancement of sand along the coast.
- Armoring – flooding and or erosion protection such as rock revetments, seawalls, bulkheads, including maintenance of those already constructed.
- Elevation – raise built assets on fill or piles to be above flood levels.

Relocate: Existing assets in base Areas 1, 3, 4, and 5 whose specific location is not critical to their function are relocated to Area 2A, their present site restored, and the following measures are implemented.

- Raise the grades in Area 2A above flood levels to build relocated assets.
- Consider multi-objective beneficial reuse of sediment from Calleguas Creek for fill in Area 2A.
- Consider strategic planning and multiple uses of assets relocated in Area 2A to maximize efficiency and utility while minimizing footprint and expense.
- Some assets in Area 4 were determined to be essential in that location in the near-term, but will need to be relocated as sea levels rise, shorelines erode, and storm impacts increase. These could be sequentially moved back within Area 4 or could be moved back near Area X at a sooner timeframe.

Restore: Assets that are no longer of high or critical use on the base (redundant or obsolete structures, derelict structures, roads, utilities, fill pads, etc.) are removed, and the areas are restored to natural habitats, integrating with other habitat restoration and enhancement plans in Areas 2B, 3, 4 and 5. Note restoration also includes fill areas that support assets that can be relocated.

- Implement Navy Integrated Natural Resource Management Plan (INRMP) (Tetra Tech 2018) and the Restoration Plan for NBVC Point Mugu (Tetra Tech 2104).
- Expand hydraulic conveyance to Area 5 via expanded culvert(s) under the runway (Area X) and roadway crossings in Area 4 to facilitate the maintenance and evolution of marsh systems.
- Expand hydraulic conveyance to existing wetlands in area 3 where constrained by culverts through roadway embankments to enhance marsh health, function, and protective services of base assets in Area 3 and X.
- Remove coastal structures where no longer needed (i.e. structures that protect assets to be removed/relocated), including groins and rock revetments to allow coastal processes to rebuild and enhance the coastal strand, thereby enhancing ecological function, protective services, and resilience.

Implementing the Adaptation Vision would reduce the overall footprint of built assets by approximately 30 percent and thus reduce the vulnerability of the base to hazards with sea-level rise, reduce existing operations and maintenance requirements, and lead to more efficient future adaptation actions compared to the existing distribution of built infrastructure. Further, the reduced footprint is consolidated within an area of the base projected to be the most resilient to all hazards through 2100. By restoring developed areas in the lagoon to wetland and transitional habitats, the Adaptation Vision can increase habitat connectivity and function today while increasing habitat resilience with sea-level rise. This habitat resilience not only meets base ecosystem objectives, but also provides dividends in protective services from flooding and erosion hazards to base assets for decades to come.

The Adaptation Vision is summarized in Figure ES-1. Critical asset areas (red) are maintained in place, assets (blue) in Areas 3, 4, and 5 are relocated to Area 2A or removed altogether, these and the remaining fill area (brown) are restored along with the restoration and or enhancement of adjacent uplands (green). There are assets in Area 5 and east Area 1 that cannot be moved to Area 2A owing to safety regulations and hence their locations may be optimized after specific study.

SOURCE: ESA; TNC Coastal Adaptation

Figure ES-1
Adaptation Vision Opportunities and Constraints at NBVC Point Mugu

Next Steps and Recommendations:

The TNC-ESA, NBVC team identified the following next steps and recommendations to achieve the Adaptation Vision for NBVC Point Mugu:

a. Incorporate the Adaptation Vision into the Installation Development Plan

b. Incorporate the restoration opportunity areas identified in the Adaptation Vision into the next updated Integrated Natural Resource Management Plan (INRMP) and NBVC Restoration Plan.

c. Conduct a refined Vulnerability Assessment that

   i. Quantifies consequences of damages to built assets
   ii. Considers adaptive capacity of base assets
   iii. Evaluates fiscal impacts of flooding/erosion damages to assets

d. Develop NBVC Point Mugu Adaptation Plan

   i. Model geomorphology and habitat evolution to quantify hazard risk reduction provided by natural infrastructure
   ii. Establish adaptation pathways for built and natural assets that identify the timing of adaptation actions
   iii. Determine and refine interim and near-term adaptation actions (beach nourishment, armoring maintenance)
   iv. Examine potential effects of hydrology-altering adaptation actions (e.g. expand tidal connectivity) on existing habitats
   v. Economic assessment of potential adaptation actions and pathways

e. Investigate base housing modifications and options to accommodate infrastructure relocation to Area 2A

Near-term actions that could advance the Vision include:

a. Beach nourishment in Areas 4 and 5. Note that beach nourishment will not confer resilience of built assets on the beach strand but could buy time to plan adaptation of these assets. Continue efforts to evaluate beach nourishment with sand from USACE up-coast dredging related to Hueneme Harbor. Also consider other sources such as windblown sand accreting around critical infrastructure near Ormond.

b. Further study is needed to determine the feasibility of using sediments dredged from upstream portions of Calleguas Creek for fill in Area 2A, beach nourishment and upland enhancement in the base.

c. Execution of the NBVC Restoration Plan (Tetra Tech 2014) would serve the Vision. Opportunity areas from the Adaptation Vision could be added to the restoration plan; specific Restoration Plan components/areas could be integrated with Vision-specific adaptation actions/areas when scoping projects for feasibility.

d. Begin to remove defunct built assets and supporting infrastructure on the base. Removing unused roads, fill areas and associated culverts would improve tidal connectivity to areas that are constricted under current conditions. For example, the L Avenue culvert project will replace pipe culverts with box culvert and make road improvements.

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List of Acronyms

CNRA – California Natural Resources Agency

CRV – Coastal Resilience Ventura

CY – Cubic yard

DoD – Department of Defense

EBA – Engineering Based Adaptation

ESA – Environmental Science Associates

FEMA – Flood Emergency Management Agency

LiDAR – Light Detection and Ranging

MHW – Mean High Water

MHHW – Mean Higher High Water

MLW – Mean Low Water

MLLW – Mean Lower Low Water

MOA – Memorandum of Agreement

NAVD – North American Vertical Datum of 1988

NBA – Nature Based Adaptation

NBVC – Naval Base Ventura County

NOAA – National Ocean and Atmospheric Association

NRC – National Research Council

OPC – Ocean Protection Council

SLAMM – Sea Level Affecting Marshes Model

SLR – Sea-level rise

TNC – The Nature Conservancy

USACE – United States Army Corps of Engineers

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1.Introduction

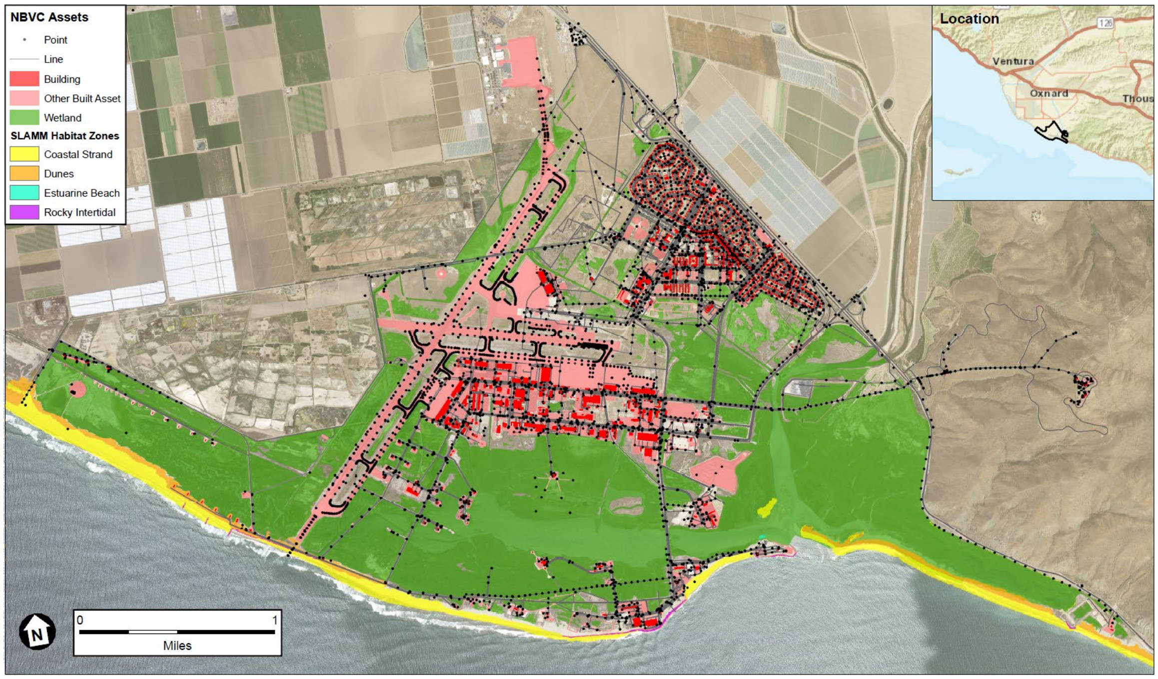
NBVC is a premier naval installation composed of three operating facilities - Point Mugu, Port Hueneme and San Nicolas Island. NBVC Point Mugu is a key element in the Department of Defense (DoD) infrastructure because of its strategic location directly on the coast of Southern California and largely surrounded by open space. The base supports over 80 tenant commands, a base population of 19,000 personnel, which encompasses an extremely diverse set of specialties that support both Fleet and Fighter, including three warfare centers, (Naval Air Warfare Center Weapons Division, Naval Surface Warfare Center Port Hueneme Division and Naval Facilities Engineering and Expeditionary Warfare Center). NBVC is also home to deployable units, including the Pacific Seabees and the West Coast E-2 Hawkeyes (NBVC 2020). The base is also a critical economic driver for the regional economy, with an annual impact of about $2 billion. It is the largest employer in Ventura County and supports a large indirect workforce.

The DoD has defined climate change as a major threat to America’s national security, especially to coastal military installations in the United States and worldwide. In 2019, the Government Accountability Office (GAO) examined DoD’s progress on climate resilience and recommended that DoD assess climate risk and provide guidance for adaptation planning for military installations and facilities (GAO 2019). The DoD is also one of the most important coastal landowners in the United States, controlling over 200,000 acres of coastal land in California alone. In Ventura, Mugu Lagoon is the largest and most intact coastal wetland in southern California and is located within DoD property at NBVC. Lagoons and other natural infrastructure – such as dunes, wetlands, and floodplains – can enhance resilience from sea level rise and coastal storms by buffering the impact of wind and waves and absorbing rising ocean waters.

Mugu Lagoon, within NBVC Point Mugu, is a low coastal marsh fronted by approximately 6 miles of coastline. Base assets are built on uplands, beach strand, and on fill within the lagoon wetland habitats. Given its proximity to the ocean, the base is currently subjected to impacts from coastal erosion and wave run-up, inundation from high tides, and flooding from coastal storm surges and Calleguas Creek. These hazards will increase in intensity, frequency, and duration with climate change, damaging the built infrastructure and natural habitats of the base. Due to the important role NBVC Point Mugu plays, working to ensure base resilience is mission critical. These issues are not unique to NBVC; other DoD installations face similar climate resilience issues, many identified in the 2019 GAO report. The Adaptation Vision’s planning process and approaches to resilience can serve as a model for other installations across the U.S. working to ensure long-term coastal resilience.

The Adaptation Vision for NBVC Point Mugu was developed to promote adaptation actions that improve base resilience to sea-level rise by achieving benefits to both built and natural resources at the base. Figure 1 below shows the distribution of built and natural assets at the base; points represent features such as light poles, utility units, etc., while line features represent utility networks such as gas and electrical lines. This report documents the Adaptation Vision development process, outlines specific actions to be taken, and quantifies benefits to built and natural resources. The Adaptation Vision builds upon prior work by TNC and Environmental

Science Associates (ESA) on Coastal Resilience Ventura (CRV), for which NBVC was an important stakeholder, and prior work by NBVC and others to assess and manage coastal hazards and ecology at the base. The following sections provide context on the development process for the Adaptation Vision, studies that were used to inform the Vision, and sea-level rise scenarios that correspond to the hazard and habitat mapping used in the supporting analysis.



SOURCE: ESA; USDA, NBVC

TNC Coastal Adaptation

Figure 1
Built and Natural Assets at NBVC Point Mugu

1.1. Overall Vision Development Process

In June 2016, the U.S. Navy Region Southwest and TNC entered into a joint Memorandum of Agreement (MOA) focused on coastal resilience planning for natural resources and asset management at Naval Base Ventura County, Point Mugu. This joint MOA was first of its kind, marking the first time DoD partnered with a nongovernmental organization to protect a military installation from sea level rise and other consequences of rising global temperatures. The cooperative agreement is rooted in DoD's authority under the Sikes Act, which governs natural resource management actions on military lands, including enhancing resilience to climate change impacts. The purpose in establishing the MOA is to work in collaboration to demonstrate the use of sea level rise and hydrological models and economic analysis to inform coastal climate change adaptation planning for the long-term protection of critical natural resources and important human infrastructure. The Adaptation Vision presented in this report is the culmination of a multi-year collaborative effort and numerous base-specific studies that examined flooding and erosion hazards and sea-level rise, implications to base vulnerability, potential adaptation strategies, and habitat conditions. The project team includes TNC, ESA, and a multifunctional team at NBVC.

To develop the Vision, an extensive body of base-specific studies were summarized, quantified and presented to the collaborative team to:

1. Evaluate the vulnerability of built assets, habitats, and areas at NBVC.
2. Identify zones of opportunity where actions can be taken to reduce vulnerability and improve resilience of built assets and/or habitats.
3. Review area characterization and high-level opportunity zones with NBVC and discuss adaptation options. Get input from NBVC on additional opportunities and asset constraints (e.g. assets to maintain in place). Agree upon potential adaptation actions and feasibility with NBVC Staff. Map opportunities and constraints to inform adaptation measures for the base.
4. Develop adaptation measures that consider the opportunities and constraints on the base. Map and describe adaptation actions, and quantify resulting changes to built asset and habitat vulnerability and resilience.
5. Recommend next steps to advance the Vision.

1.2. Prior Work Informing NBVC Mugu Hazards and Resilience Utilized to inform the Adaptation Vision

The Adaptation Vision builds upon prior work by TNC and ESA on Coastal Resilience in Ventura County, as well as prior work by NBVC and others to assess and manage coastal hazards and ecology. The following TNC-ESA documents that informed the Adaptation Vision are provided as appendices to this report.

- **Coastal Resilience Ventura – Technical Report for Coastal Hazards Mapping** (ESA PWA 2014a): ESA technical report documenting coastal hazard modeling and mapping with future sea-level rise that were used to determine exposure of NBVC Point Mugu to tidal inundation, coastal storm surge and wave run-up, and coastal erosion. Existing conditions for this CRV study are based on 2010 sea level and topography.
- **Coastal Resilience Ventura – Technical Report for Sea Level Affecting Marshes Model (SLAMM)** (ESA PWA 2014b): Documents the modeling methodology to develop future wetland habitats with sea-level rise in Ventura County. Existing conditions for this CRV study are based on 2010 sea level and topography.
- **Economic Analysis of Nature-Based Adaptation to Climate Change: Ventura County, CA.** (ENVIRON & ESA PWA 2015): The CRV economic study presents a comparison of two SLR adaptation strategies: Nature-Based Adaptation (NBA) and Engineering-Based Adaptation (EBA). The habitat maps produced for this study with SLAMM were used to develop the Adaptation Vision habitat maps for NBVC Point Mugu. Existing conditions for this CRV economic study are based on 2010 sea level and topography.
- **Calleguas Creek Climate Change Impacts to Fluvial and Coastal Flooding** (ESA 2016): The CRV fluvial and coastal flooding study produced floodplain maps showing the projected future 100-year floodplains for Calleguas Creek, based on hydraulic modeling driven by future rainfall run-off projections and increasing ocean water levels. The future run-off projections were derived using downscaled climate models. The hazards were used to determine exposure of NBVC Point Mugu to fluvial flooding. Existing conditions for this CRV fluvial and coastal flooding study are based on 2010 sea level and topography.

- **Initial Sea-Level Rise Vulnerability Assessment and Natural Infrastructure Design Criteria for NBVC Point Mugu** (ESA 2019): This memorandum describes vulnerabilities at the base considering a "do-nothing" scenario that serves as the basis of comparison to illustrate the benefits to built assets and habitats provided by this Adaptation Vision. The hazards from CRV studies listed above were combined to develop hazard exposure risk scores for built assets on the base.

The following reports by others were also considered in the development of the Adaptation Plan.

- **Final Shoreline Protection Study Report** (BradyG2 and Moffat & Nichol, 2012): This study documents coastal processes, sediment transport and budgets, and shoreline protection alternatives analysis for the Pacific coastline of NBVC Point Mugu.
- **Restoration Plan for Naval Base Ventura County Point Mugu, California** (Tetra Tech 2014): This document identifies areas at NBVC suitable for wetland restoration and enhancement and buffer enhancement for the purpose of mitigation banking. Elements of the restoration plan were considered as opportunities for adaptation along with the zone characterization performed by ESA and TNC with the Navy.
- **The Integrated Natural Resources Management Plan (Tetra Tech 2018):** This document is a resource for land use opportunities and constraints and future management activities. Figure 2-3 Point Mugu Opportunities and Constraints shows that Areas 1,3, 4 and 5 have ecological resources including federally listed species nesting habitat area and rare salt marsh bird's beak along the coastal strand, and jurisdictional wetlands which include essential fish habitat. Tidewater goby habitat is identified near the mouth of Calleguas Creek. Areas X and 2A and portions of Area 3 have the least ecological resources. Section 3.2.2.1 Shoreline Sediment indicates that allowing the beach to migrate landward can maintain coastal strand and dune habitat. The installation and maintenance of shoreline protection infrastructure designed to reduce shoreline erosion could degrade the beach habitat at NBVC Point Mugu, and that sand supply for the coastal strand is contingent upon the sand bypass system in the vicinity of Port Hueneme. Section 3.2.2.2 Calleguas Creek Water Sediment indicates historical concerns about high sediment discharge depositing in Mugu Lagoon, which may reduce its depth and volume. The sediment deposition is linked to flood management activities which inhibit sediment deposition in the historical flood plain upstream of Mugu Lagoon and increase sediment discharge into the lagoon. Studies recommend restoration of the flood plain upstream of Mugu to allow sediment deposition, or sediments should be dredged to avoid adverse effects to Mugu. The Coastal Adaptation Vision provides additional management opportunities to maintain natural resources and support the installation mission and base activities for future conditions and should be considered in future INRMPs.

1.3. Sea-level Rise Projections used in this Study and How They Relate to State and Federal Guidance

The Adaptation Vision considers sea-level rise projections, which were selected for the previous studies, and are the sources of hazard and habitat mapping used for this study. The sea-level rise projections for previous studies were selected based on state and federal guidance at the time those studies were completed. This section summarizes the sea-level projections considered in this study and summarizes how they relate to current state and federal guidance.

The sea-level rise projections that inform the Adaptation Vision are based on National Research Council (NRC) 2012 guidance and listed in Table 1 below. The decadal sea-level rise projections start in 2010, which is the baseline for the Coastal Resilience Ventura hazard and habitat studies summarized in Section 1.2. A range is provided for 2060 and 2100 because different studies were relied upon to characterize the applicable hazards (coastal inundation, storm flooding, erosion, wave run-up and fluvial flooding) and habitat mapping (existing and with future adaptation). Hazards were analyzed for existing conditions (current sea level) and with future sea-level rise at 2060 and 2100, shown as bold in Table 1. The sea-level projections emphasize the need to start extensive planning now to achieve the Adaptation Vision.

TABLE 1
SEA LEVEL RISE PROJECTIONS CONSIDERED FOR THE ADAPTATION VISION

	High SLR (NRC 2012)
2010*	**0 feet**
2020	0.6 feet
2030	1.0 feet
2040	1.5 feet
2050	2.0 feet
2060*	**2.1 to 2.6 feet**
2070	3.2 feet
2080	3.9 feet
2090	4.7 feet
2100*	**4.8 to 5.5 feet**

* Coastal Resilience Ventura hazard and habitat projections for 2010 (existing conditions) 2060 and 2100 were used in this Adaptation Vision. Ranges are provided to include each of the CRV studies used. Other decades are provided for context.

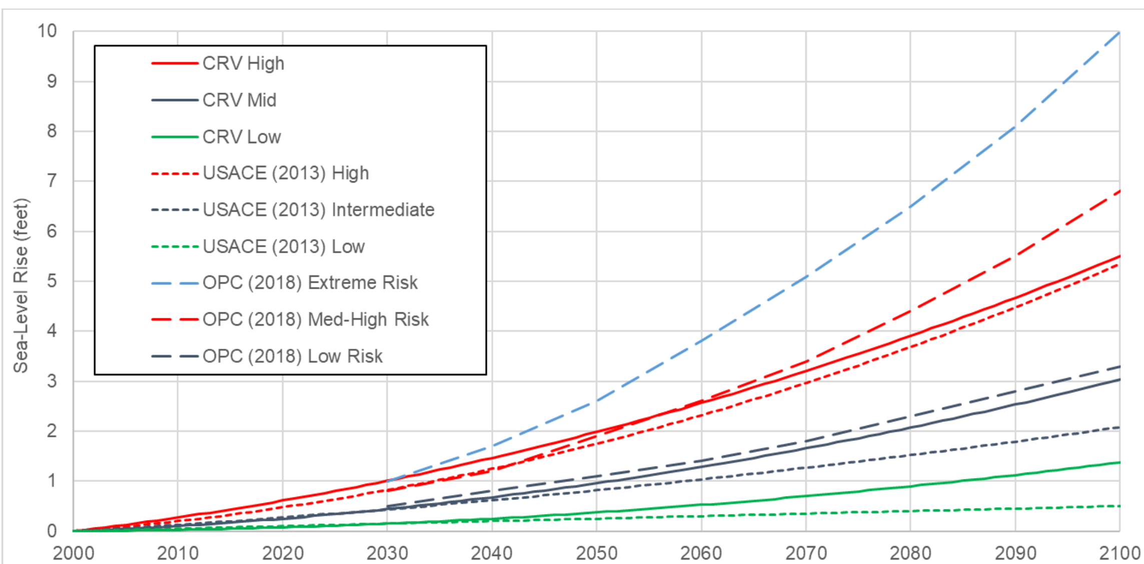
There are various sources for guidance on sea-level rise planning and adaptation, and the science of sea-level rise is constantly improving. The sea-level rise scenarios used for the Adaptation Vision are based on NRC (2012) and the U.S. Army Corps of Engineers (USACE) guidance documents. All sea-level projections include an adjustment for local vertical land motion using the Santa Monica tide station (NOAA #9410840). The USACE last published sea-level rise guidance for civil works programs in 2013 (USACE 2013) with refinements (USACE 2014). Since the data used in this study were developed, new guidance was issued by the State of California (CNRA and OPC 2018). Figure 2 below shows the various sea-level rise projections from these different guidance sources that apply to NBVC Point Mugu to facilitate the comparison of this Adaptation Vision to other efforts. CRV and OPC (2018) values are based on the Santa Monica projections, which is the closest location to Point Mugu (~42 miles).

Federal guidance on sea-level rise has been presented by the U.S Army Corps of Engineers (USACE 2011; 2013) and directs scenario planning, essentially meaning that a range of sea-level rise scenarios are considered without assessing the likelihood of a particular scenario. This guidance describes a low scenario based on projection of historical trends, and refers to NRC

(1987) for medium and high scenarios: The high scenario includes a global (eustatic) rise of 1.5 meters by 2100. The global rates are adjusted for regional conditions, including vertical land motion based on guidance from the National Oceanographic and Atmospheric Administration (NOAA), as described by Zervas et. al. 2013 and historical and tidal datum information as described by Zervas 2009. More recent guidance (USACE 2014) allows higher sea-level rise scenarios to be used, and references Parris et. at., 2012 which includes a 2-meter (by 2100) scenario. Hall et. al. 2016 provide guidance for DoD with a range of five scenarios with the highest amounting to 2 meters by 2100 (global, requires regional adjustment). Hall et al. 2016 acknowledges regional and probabilistic projections consistent with California Guidance (CNRA & OPC 2018).

Since the CRV scenarios for sea-level rise were developed using the best available guidance for California at the time (NRC 2012; OPC 2013), state guidance was updated in 2018 (Griggs et al 2017; CNRA & OPC 2018). As shown in **Figure 2**, the CRV High scenario tracks similarly to the 2018 Medium-High Risk Aversion low emission scenario but diverges from the Medium-High Risk Aversion high emission scenario after 2060, and is 1.3 feet lower than this scenario by 2100. The differences with the H++ scenario are much greater, and the projections diverge sooner.

For DoD natural resources planning context, see Stein and others (2019) Climate Adaptation for DoD Natural Resource Managers: A Guide to Incorporating Climate Considerations into Integrated Natural Resource Management Plans. Stein and others (2019) provide guidance for including adaptation to climate change in Integrated Natural Resource Management Plans (INRMP) and generally to reduce climate-related vulnerabilities or enhance resilience.



SOURCE: ESA; USACE, OPC

TNC Coastal Adaptation

Figure 2
Sea Level Rise Projections from Various Guidance

2. Hazards and Vulnerability of NBVC Built Assets and Natural Habitats

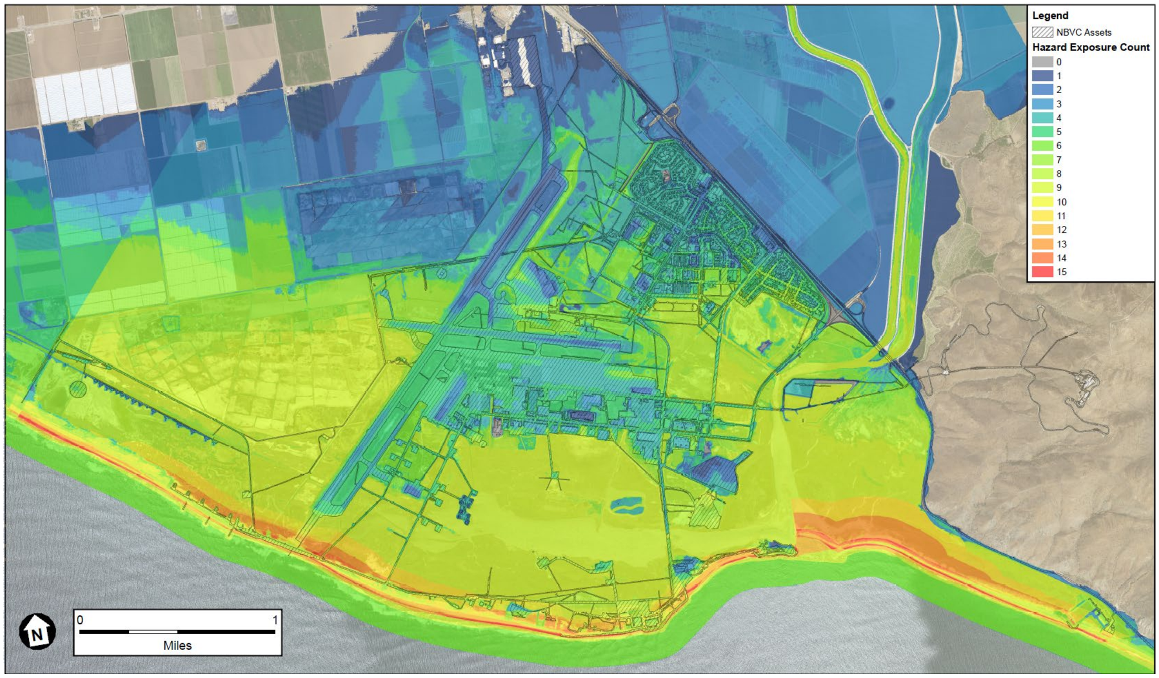
This section summarizes the hazards analyzed for the Adaptation Vision and the corresponding vulnerabilities to built assets and habitats at NBVC Point Mugu. This asset exposure analysis results in lists of natural assets (habitat areas) and built assets (buildings, roads) that are currently subject to flooding and erosion hazards or may become exposed with sea-level rise. For this study, the consequences to the assets were not addressed explicitly, and hence there is not an assessment of economic risk or other functional risk metric, however this is identified as a recommended next step (see Section 5: Next Steps and Recommendations). Under standard vulnerability assessment framework (OPC 2013), an asset risk is dependent on its likelihood and intensity of exposure to hazards as well as the consequences of impacts and adaptive capacity of the asset. See Appendix C for additional discussion of vulnerability.

Risk is characterized for built assets (Section 2.1) by counting the number of scenarios by which flooding or erosion hazards extents intersect the location of each asset (called “Hazard Exposure Count”), and a plan-view metric (area, length, number) of an exposed asset class (building, tidal wetland). Conceptually, exposure to a higher number of potentially damaging scenarios indicates increased exposure and increased, but not quantified, risk. We call this risk metric “Exposure Risk Score” which ranges from 0 (low risk of damage) to 15 (high risk of damage). For natural assets (Section 2.2), the risk was quantified by a change in the area of each habitat category (e.g. salt marsh, beach) based on the Sea Level Affecting Marshes Model (SLAMM).

Sea-level rise hazards and vulnerability of NBVC assets are detailed in ESA’s **Sea-Level Rise Vulnerability Assessment** (ESA 2019). ESA characterized built asset vulnerability to sea-level rise using the aggregated hazard exposure levels on the base under current and future sea-levels. Hazards include:

- Tidal inundation (extreme monthly high water)
- Coastal storm flooding storm surge
- Coastal storm flooding wave run-up
- Coastal erosion (long term and storm event) and
- Fluvial flooding (100-year recurrence interval discharge)

The hazard zones for each of these sources were overlaid to produce the aggregated exposure of assets within the base, as shown in Figure 3 below. The aggregated hazard exposure level is numerical based on the number of hazards affecting a location at a given time (5 hazards * 3 time horizons), with scores ranging from 0 to 15. The aggregated hazard exposure map was “intersected” with the NBVC GIS asset data layers to develop aggregated hazard exposure levels for each asset, summarized in the following section. The following tables and figures summarize the hazard exposure of built assets at NBVC Point Mugu corresponding to a do-nothing baseline approach. The results show the assets most at risk to hazard impacts under current and future sea-levels; the relocation of high-risk assets provides the most benefit in terms of base resilience. Hazard maps for the four individual sources listed above are provided in Appendix C.



SOURCE: ESA; NBVC

TNC Coastal Adaptation

Figure 3
Aggregated Hazard Exposure at NBVC Point Mugu through 2100 with built assets shown for reference

2.1. Built Assets Vulnerability at NBVC Point Mugu

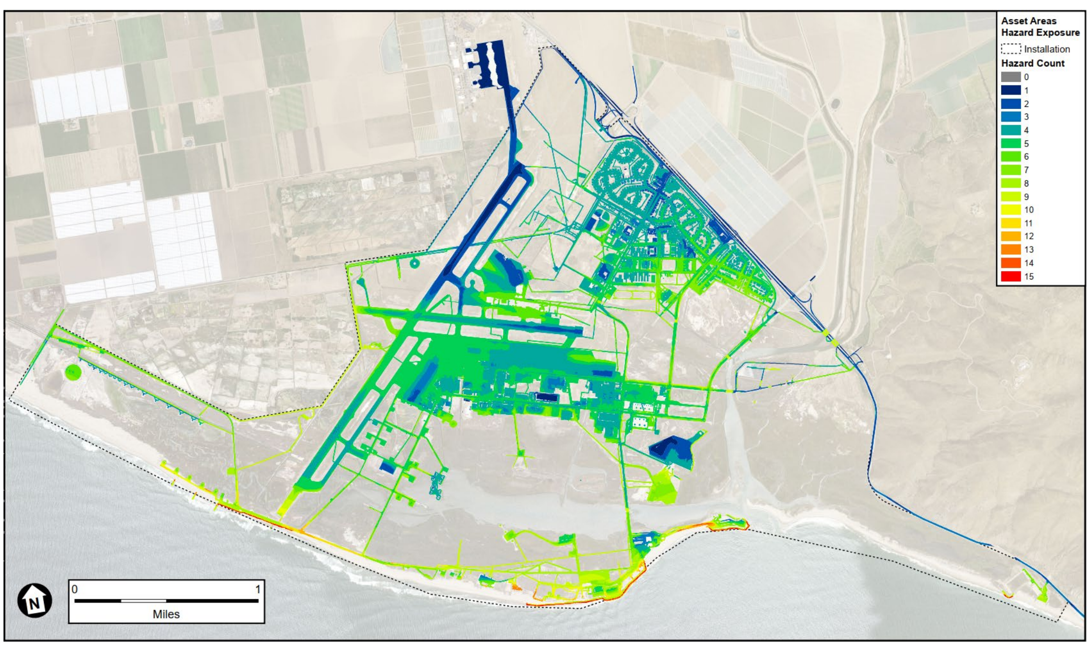
Sea-level rise vulnerability of built assets at NBVC Point Mugu was previously assessed by ESA (2019; Appendix C) using GIS data provided by the Navy and hazard mapping discussed above. The range of hazard exposure levels for each asset type are summarized in Table 2 and shown on Figure 4. Table 2 lists assets (Group, Asset) and the sum (Total) of each asset type on the entire base by linear foot or square foot (Unit) in the first four columns. The central columns depict the distribution of the corresponding Exposure Risk Scores that were developed by weighting (by length or area) the aggregated hazard exposure level for each feature included in the asset data layers.

Another source of exposure to the NBVC shoreline is the migration of the Mugu Submarine Canyon. It is currently within 100 feet of the shoreline at Family Beach and migrating landward at a rate of 1-2 feet per year (BradyG2 M&N 2012). At this rate, the canyon could jeopardize the east end of the Central Revetment in 50-100 years, and further narrow Family Beach and expose the East Revetment. The canyon is a major sediment sink that captures much of the sand that flows from NW-SE onto down coast beaches. The current configuration of armoring on the beach strand may influence this process, as discussed in Section 3.3.2 below.

TABLE 2
AGGREGATED HAZARD EXPOSURE RISK SCORES FOR NBVC POINT MUGU ASSETS

Group	Asset	Total	Unit	Exposure Risk Score
Common	Airfield Section	13,660,149	SF	**3.9**
	Bank Armoring	461,840	SF	**9.9**
	Bridge	81,639	SF	**6.3**
	Building	4,466,112	SF	**3.9**
	Playground	90,808	SF	**4.1**
	Recreation Site	848,828	SF	**5.2**
	Road Centerline	296,404	LF	**4.6**
	Road Section	17,786,646	SF	**4.8**
	StorageTank	12,227	SF	**4.3**
	Structure	412,530	SF	**5.9**
Electrical	Electrical Facility	18,303	SF	**3.5**
	Pri OH Line	133,137	LF	**5.6**
	Pri UG Line	450,659	LF	**5.1**
Gas	Main Line	131,471	LF	**5.0**
	Service Line	32,914	LF	**4.8**
Sanitary	Force Main	14,172	LF	**4.2**
	Gravity Main	191,298	LF	**5.0**
	Pump Station	60,134	SF	**2.5**
Water	Main Line	340,152	LF	**5.2**
	Service Line	1,606	LF	**4.8**
	UG Enclosure	1,704	SF	**7.7**

Note: The Exposure Risk Score is calculated as the average Hazard Exposure Count for each asset category on the base. Hazard Exposure Count is based on five hazard types over three timeframes, fifteen total possible. The higher the Exposure Risk Score, the greater the exposure to potentially damaging flooding and erosion through year 2100.



SOURCE: ESA;

TNC Coastal Adaptation

Figure 4
Aggregated Hazard Exposure for Assets at NBVC Point Mugu to 2100

2.2. Natural Habitat Vulnerability at NBVC Point Mugu

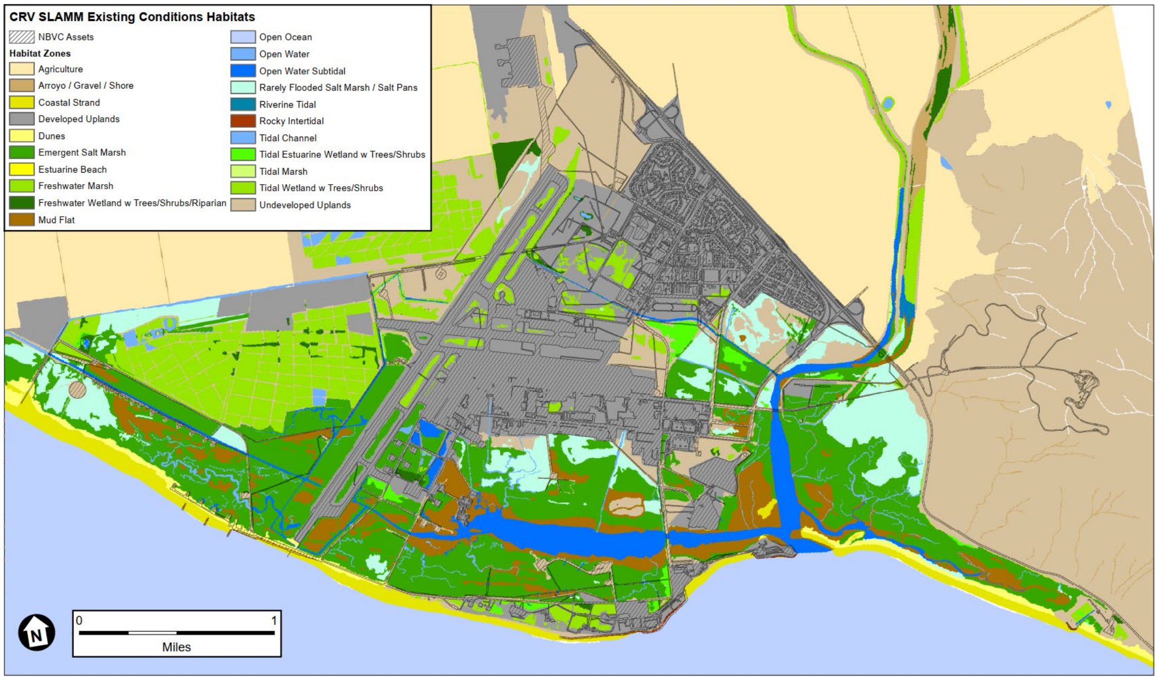
Natural habitat vulnerability at NBVC Point Mugu was developed from CRV habitat projections previously developed by ENVIRON & ESA PWA (2015). In addition to existing conditions, future habitats were mapped for two management scenarios that represent engineering-based or nature-based approaches to adaptation on the base. The habitat maps from these two scenarios provide an indication of the Adaptation Vision benefits to NBVC habitats. Table 3 below summarizes the current habitat acreages at NBVC Point Mugu and future projections at 2060 and 2100 for Nature-based Adaptation (NBA) and Engineering-based Adaptation (EBA). The NBA measures include restoration of wetlands, dunes and natural processes as well as asset realignment (i.e. managed retreat), new levee around the interior base, and elevation of certain areas. The EBA measures include reinforcement of existing and construction of new seawalls and revetments along the entire Point Mugu shoreline, tidal barrier for the west arm of Mugu Lagoon, and raised/new levees around the interior base components. See ENVIRON & ESA PWA 2015, provided in Appendix C to this report, for figures showing the various measures for each adaptation scenario and detailed descriptions.

The results indicate that wetland habitats are vulnerable to sea-level rise especially if built assets are defended in place, whereas using nature-based solutions can improve habitats' resilience. Specifically, the natural areas need space to migrate inland and accrete vertically as sea-levels rise – the armoring of built assets prevents this habitat migration and interrupts natural processes (e.g. water flow, sediment delivery, and species movement) necessary for them to be maintained in place and overall resilience. The results in Table 3 and Figures 5,6 and 7 show larger reductions in salt marsh and freshwater marsh associated with engineering-based adaptation compared to a nature-based approach. Figure 5 below shows the distribution of existing habitats at Point Mugu based on the SLAMM habitat classifications, while Figure 6 and Figure 7 show the future habitat evolution (for 2060 and 2100, respectively) considering the EBA alternative. Together these figures show that salt marsh converts to mudflat and open water with higher sea-levels when marsh accretion cannot keep pace with accelerating sea-level rise and maintaining the current built asset distribution throughout the base will exacerbate this trend. For comparison, NBA alternative habitat evolution is shown in Appendix C, figures A11 (2060) and A12 (2100) which was useful in developing this Vision. Note that SLAMM does not model coastal erosion and hence losses of beach and dune areas will likely exceed the SLAMM projections.

TABLE 3
HABITATS AT NBVC POINT MUGU FOR NATURE AND ENGINEERING BASED ADAPTATION

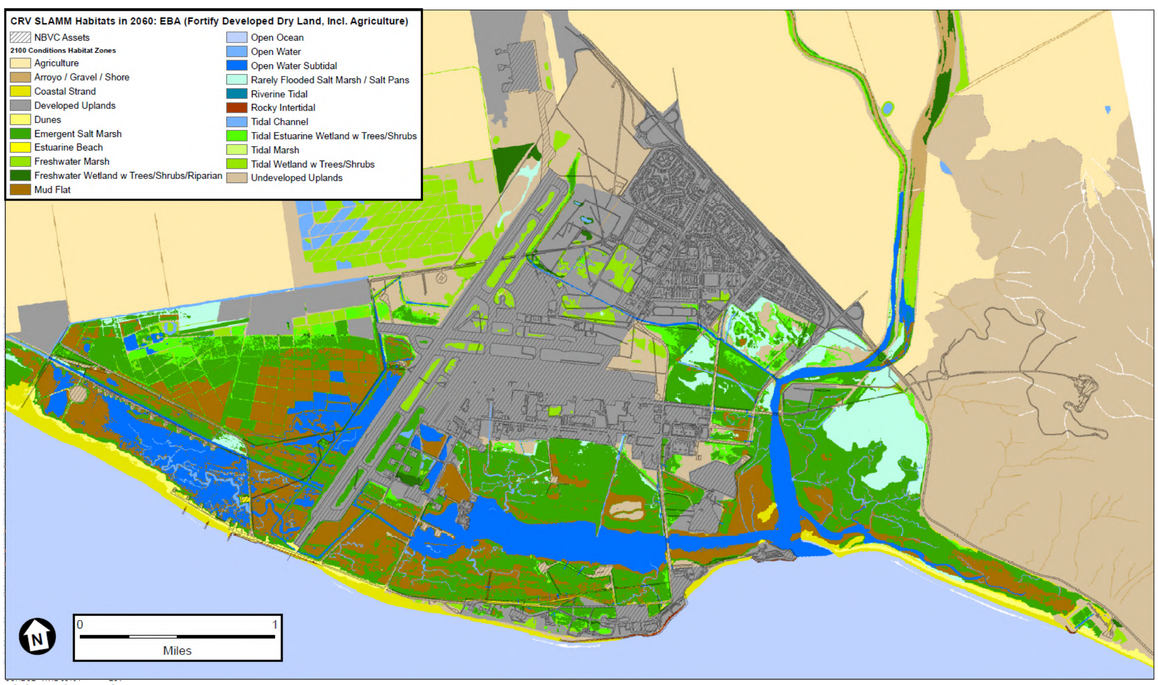
Habitat Type	Existing and Future Acreages with Adaptation					Percent Change with Adaptation			
	2010	2060		2100		2060		2100	
	Existing	NBA	EBA	NBA	EBA	NBA	EBA	NBA	EBA
Developed Uplands	1410.2	1333.1	1410.2	595.3	1410.2	-5%	0%	-58%	0%
Undeveloped Uplands	583.3	485.2	485.2	236.5	236.5	-17%	-17%	-59%	-59%
Freshwater Wetland with Trees/Shrubs/Riparian	13.9	10.8	10.8	1.4	1.4	-22%	-22%	-90%	-90%
Freshwater Marsh	153.3	107.7	107.7	21.9	21.9	-30%	-30%	-86%	-86%
Tidal Estuarine Wetland with Trees/Shrubs	40.8	99.8	78.4	441.5	97.6	145%	92%	983%	140%
Emergent Salt Marsh	1039.0	873.5	859.2	713.5	371.2	-16%	-17%	-31%	-64%
Estuarine Beach	0.8	5.5	2.7	13.5	8.3	628%	261%	1690%	1000%
Mud Flat	319.3	487.1	485.8	645.1	599.2	53%	52%	102%	88%
Coastal Strand	149.6	155.6	121.6	190.0	124.3	4%	-19%	27%	-17%
Rocky Intertidal	3.2	3.0	3.0	2.7	2.7	-7%	-7%	-18%	-18%
Open Water	4.6	4.0	4.0	0.4	0.5	-13%	-12%	-92%	-90%
Riverine Tidal	0.8	0.0	0.1	0.0	0.1	-100%	-86%	-100%	-86%
Open Water Subtidal	231.5	466.9	463.6	1299.4	1287.6	102%	100%	461%	456%
Tidal Channel	55.1	55.1	55.1	55.1	55.1	0%	0%	0%	0%
Open Ocean	81.6	132.6	132.4	177.1	176.7	62%	62%	117%	116%
Rarely Flooded Salt Marsh / Salt Pans	314.1	192.1	192.1	41.9	41.9	-39%	-39%	-87%	-87%
Arroyo / Gravel / Shore	2.4	2.1	2.1	0.8	0.8	-12%	-12%	-68%	-68%
Tidal Wetland with Trees/Shrubs	4.2	3.2	3.2	1.4	1.4	-22%	-22%	-65%	-65%
Dunes	62.4	52.6	52.6	32.6	32.6	-16%	-16%	-48%	-48%
Agriculture	0.2	0.2	0.2	0.2	0.2	0%	0%	0%	0%
Total	**4470.4**	**4470.4**	**4470.4**	**4470.4**	**4470.4**	**Risk:**	**Low** (<50% loss)	**Medium** (50-75% loss)	**High** (>75% loss)

Note: Green acreage bars on left side of table indicate relative distribution of existing habitat categories for each timeframe and growth/reduction of habitats for nature and engineering-based adaptation. Percent change with adaptation on right side of table compares future habitats to existing acreages, gains are shown in green, losses are shown in red. Changes are color coded by risk based on percent change as indicated by bottom row on right side of table.



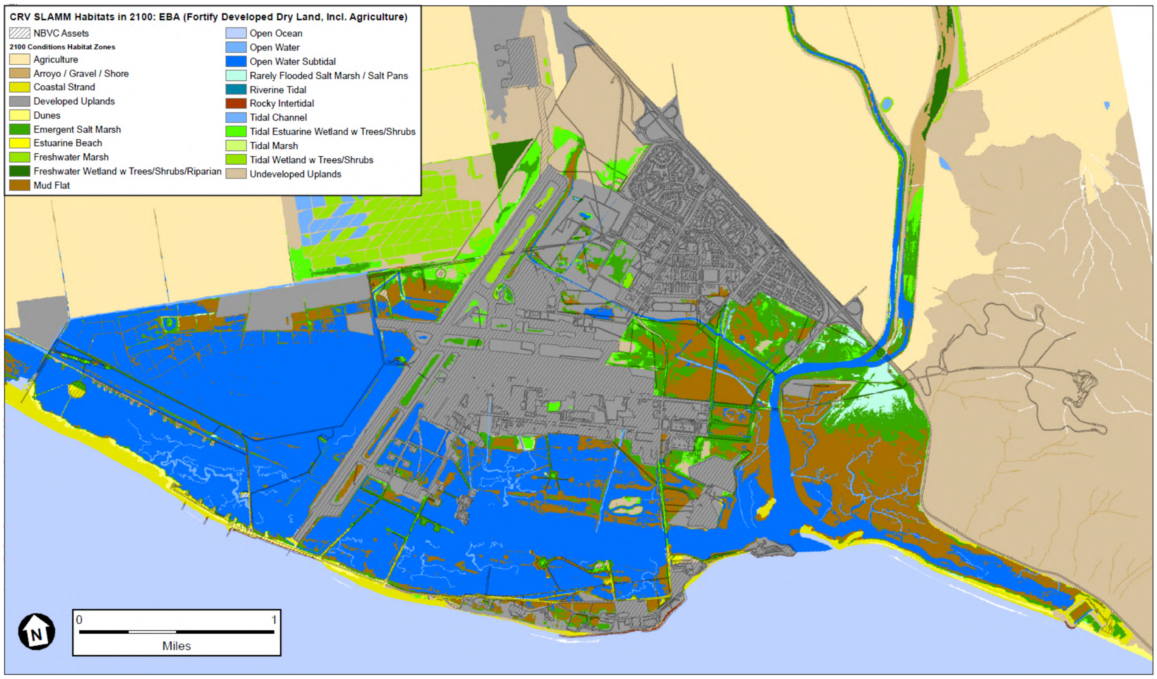
SOURCE: ESA; TNC Coastal Adaptation

Figure 5
Existing Conditions Habitats at NBVC Point Mugu



SOURCE: ESA; TNC Coastal Adaptation

Figure 6
2060 Habitats at NBVC Point Mugu with Engineering-based Adaptation



SOURCE: ESA; TNC Coastal Adaptation

Figure 7
2100 Habitats at NBVC Point Mugu with Engineering-based Adaptation

3. Adaptation Vision for NBVC Point Mugu

The following sections describe the goals of the Adaptation Vision, the development process, and key adaptation actions to be taken on the base to achieve the Vision.

3.1. Goal of the Adaptation Vision

Natural and built assets are presently exposed to coastal erosion and flooding and river flooding from Calleguas Creek, all of which will be exacerbated by climate change and sea-level rise. The goal of the Adaptation Vision is to improve the resilience of both built and natural assets through the strategic realignment of built assets and the restoration of natural habitats with protective services. The Vision is intended to:

(i) Enhance built asset and basewide resilience through realignment where feasible, natural infrastructure services, and hard infrastructure where necessary,

(ii) Enhance the area, health, and function of natural habitats to prevent or reduce restrictions to military training, testing, and operational missions; and,

(iii) Expand natural infrastructure services.

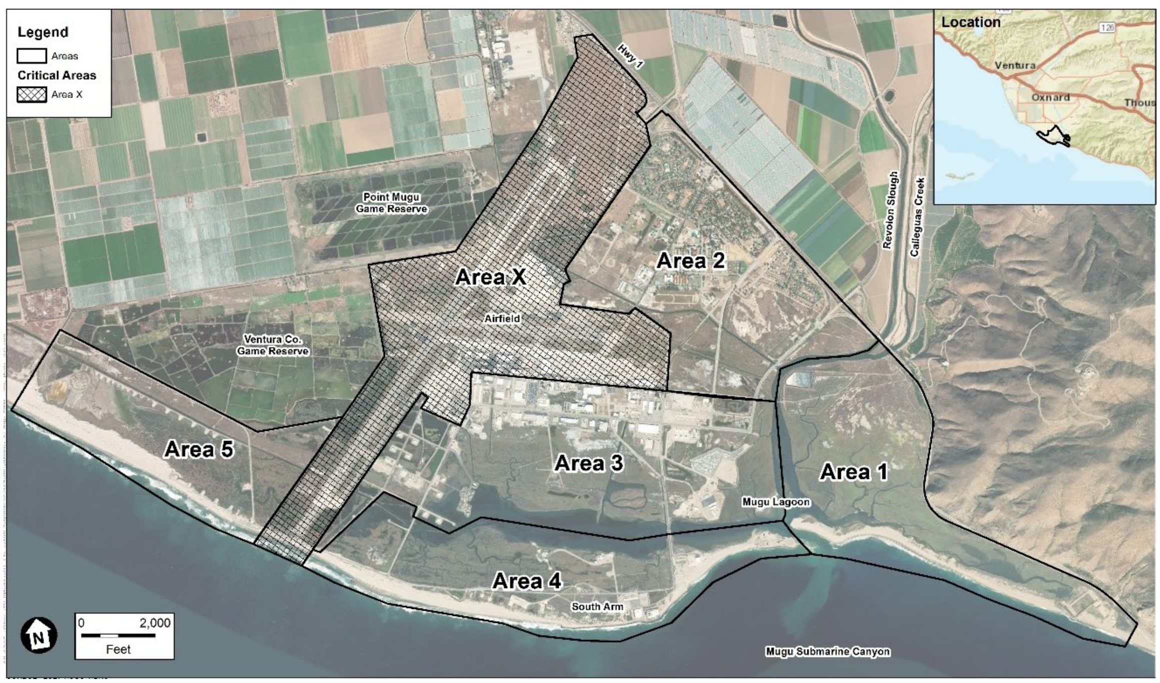
We believe this Adaptation Vision will also meet some of the base's other objectives, such as consolidating infrastructure, and increasing base efficiencies (travel, utilities, maintenance, etc.). The following subsections summarize the key actions to be taken under the Adaptation Vision.

3.2. Development of the Adaptation Vision

The development of the adaptation vision was a collaborative process between NBVC staff and the TNC/ESA team. The following subsections describe the key steps taken by the project team to develop the Adaptation Vision. The team first characterized analysis areas, addressed the resilience and vulnerability of NBVC assets and habitats, and identified opportunities and constraints for adaptation on the base. These first steps then enabled the TNC-ESA team to develop adaptation measures that consider the opportunities and constraints on the base and subsequently map and describe adaptation actions and related changes to built asset and habitat vulnerability and resilience.

3.2.1. Characterization of NBVC Point Mugu Base Areas

ESA worked with TNC and NBVC staff to delineate analysis areas on the base that were used to organize the Adaptation Vision. The Analysis Areas are shown in Figure 8. Area X was designated to encompass mission critical assets that shall be maintained in place to ensure the continuity of the military mission within the context of the Vision.



SOURCE: ESA; USDA

TNC Coastal Adaptation

Figure 8
Analysis Areas at NBVC Point Mugu

3.2.2. Resilience and Vulnerability of NBVC Assets and Habitats

Building upon the asset vulnerability assessments (Section 2 of this report), "opportunity zones" were identified where adaptation actions could improve built asset and habitat resilience to existing conditions and given future SLR. In order to identify these opportunity zones, the following area categories were defined based on hazard and habitat projections to 2100:

a. Resilient asset areas – Asset areas that are not at risk to flooding and/or erosion hazards.
b. Resilient upland areas – Current undeveloped upland area that are not at risk to flooding and/or erosion hazards and will not become wetland by 2060 and 2100.
c. Vulnerable built asset areas – Asset areas that are vulnerable to flooding and/or erosion.
d. Vulnerable habitat areas – Habitat areas (defined from CRV SLAMM outputs for current and future habitat distributions) that are vulnerable to SLR.
e. Resilient habitat areas – Habitat areas not vulnerable that have space for transgression (migration inland) and accretion (elevation gain) with sea-level rise and changing hydraulics and vegetation.

Figure 9 and Figure 10 show the resilient (purple) and vulnerable (red) assets in 2060 and 2100 respectively as well as resilient uplands (green) that could support realigned assets. Adaptation opportunity zones were identified based on the presence and vulnerability of natural (habitat) and built assets in the base as indicated by the above area types. These high-level opportunity zones enabled the identification of actions to achieve the Adaptation Vision. Note that detailed vulnerability could not be determined because asset functions and potential consequences information was not available to the team under the scope of this project, but is identified as an important next step (See Section 5: Next Steps and Recommendations). Hazards are based on 2013 CA Topobathy Merge Project (NOAA 2013) and may over represent the ground elevations for some buildings.

3.2.3. Opportunities and Constraints for Nature-based Adaptation at NBVC Point Mugu

ESA and TNC met with NBVC staff to review the resilience and vulnerability characterization of base assets and uplands and vet potential adaptation actions for the Vision. The meeting included NBVC input on opportunities and constraints to inform what adaptation actions are possible and prudent to improve asset resilience to SLR. Asset and habitat opportunities and constraints are detailed below.

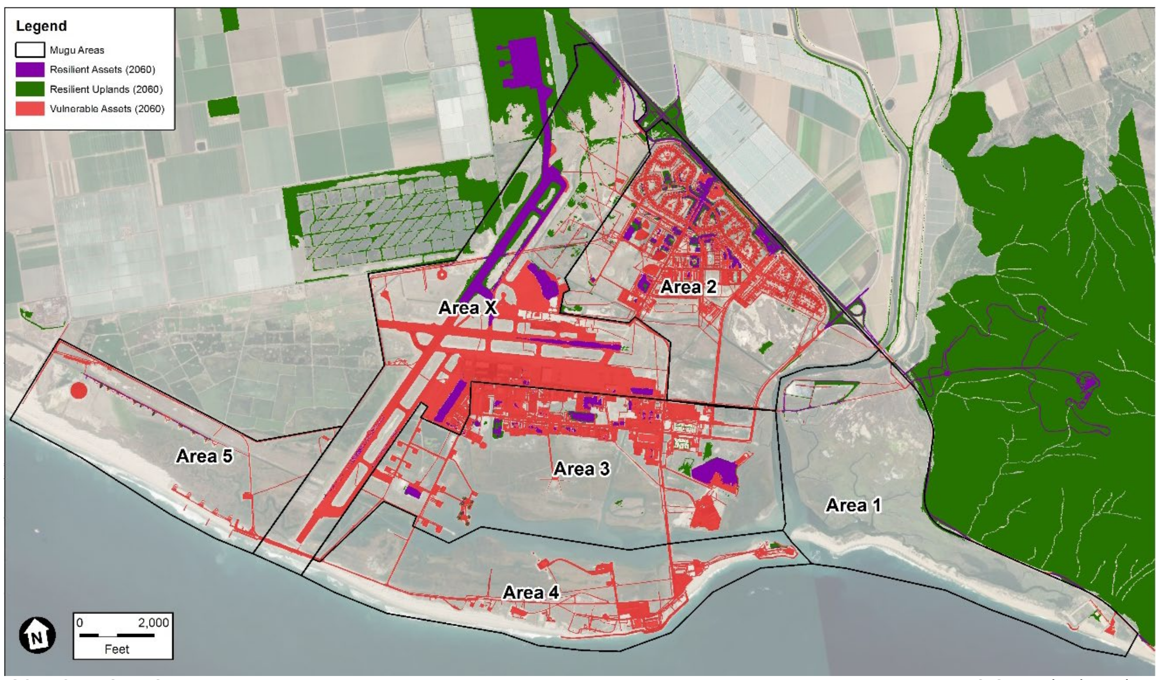
- **Asset constraints and opportunities** were refined via discussions with NBVC about what assets can be: removed and not rebuilt; removed and rebuilt elsewhere (i.e. relocatable); or need to be maintained in place to support base function/mission.
- **Habitat constraints and opportunities** are based on the SLAMM projections from CRV and the habitat proximity to transgression space and built assets. Proximity to built assets that could not be moved forms a constraint to habitat areas. Proximity to undeveloped uplands where the habitat could migrate with higher sea-levels provides the highest opportunity.

Mixed cases where assets exist but could be relocated, or where habitat restoration could be accomplished, were considered potential opportunities. Protective services of habitat enhancement to built assets were also considered.

Areas of opportunities and constraints resulting from the collaborative process by the TNC, ESA, NBVC team are mapped on Figure 11.

The following constraints were highlighted in discussions with NBVC staff:

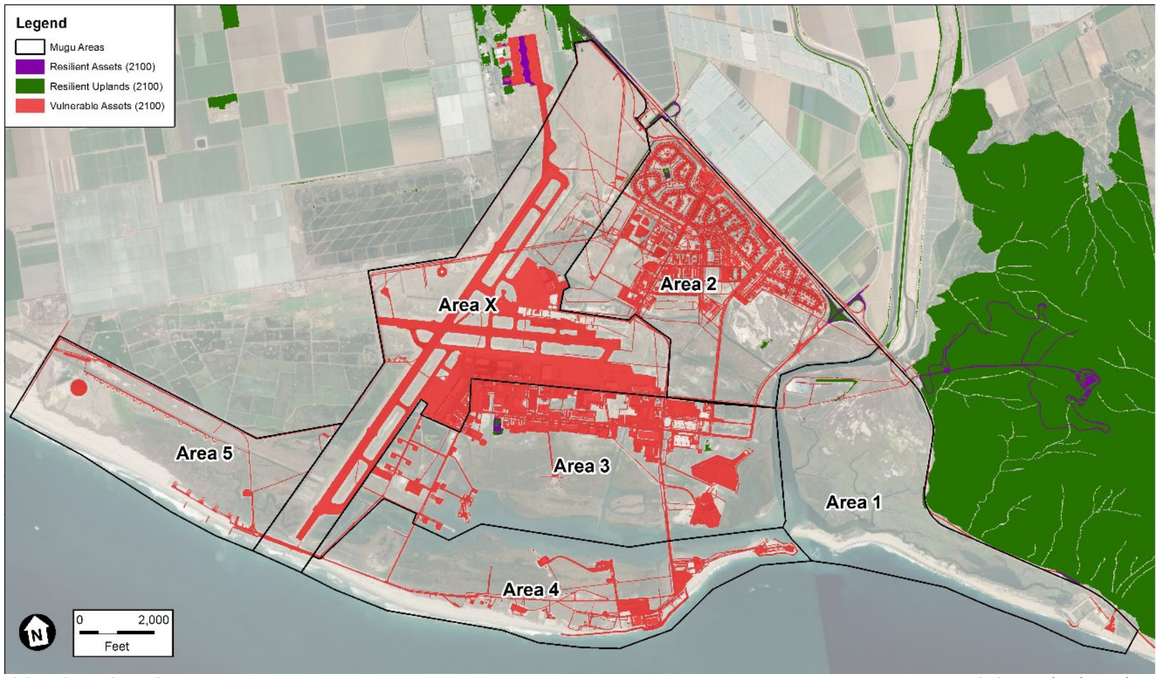
- Area X encompasses the airfield and supporting infrastructure that must be protected in place.
- Several critical assets were identified seaward of Area X on the lagoon and beach strand which must be protected in place (shown in red on Figure 11).
- Several assets were determined critical that must remain in Area 2A (shown in red on Figure 11).



SOURCE: ESA; USDA

TNC Coastal Adaptation

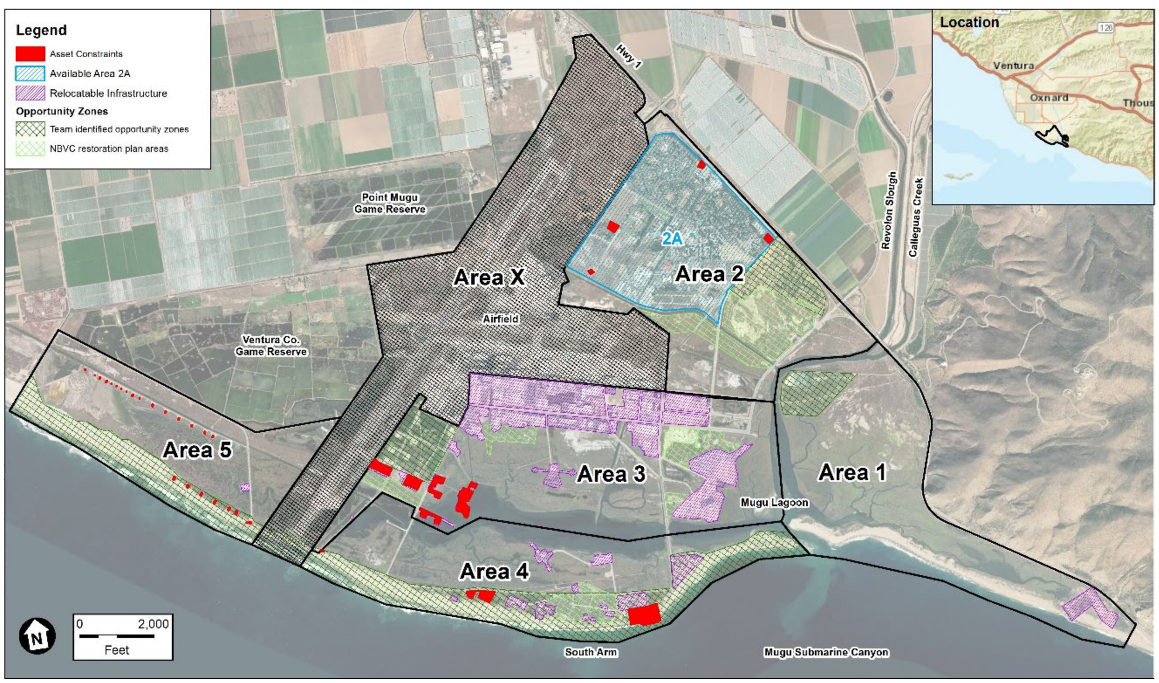
Figure 9
Resilient and Vulnerable Built Assets at NBVC Point Mugu in 2060



SOURCE: ESA; USDA

TNC Coastal Adaptation

Figure 10
Resilient and Vulnerable Built Assets at NBVC Point Mugu in 2100



SOURCE: ESA;

TNC Coastal Adaptation

Figure 11
Review of Opportunities and Constraints at NBVC Point Mugu

The following opportunities were identified through discussions with NBVC staff:

- Area 2A was identified a potential area for redevelopment as it contains some of the highest ground in the base. It has a few critical infrastructure elements but primarily consists of base housing or other support assets. Investigating base housing modifications and options to accommodate infrastructure relocation to Area 2A is identified as next step (See Section 5: Next Steps and Recommendations). Thus, Area 2A was designated by NBVC staff as a location to accept relocated assets from elsewhere on the base. ESA assessed the available space in Area 2A and found it sufficient to accommodate assets of Areas 3 and 4 that need realignment. Assets that can be realigned (purple in Figure 11) total 87 acres (within Areas 1, 3, 4, 5), while the available undeveloped space in Area 2A is 90 acres. The shooting range in Area 1 and ammunition storage in Area 5 were identified as able to be realigned, but a suitable location would need to be identified.
- Restoration areas were added to the map from the base restoration plan (Tetra Tech 2014) (light green in Figure 11).
- TNC and ESA identified opportunity areas (dark green in Figure 11) by reviewing the resilience and vulnerability areas shown in Figure 9 and Figure 10.
- Area 5 has assets that are strategically located away from other built assets for safety and hence are also highlighted red. The assets on the back of the beach, west of the airfield, can be relocated but need a buffer around them and a receiving area has not yet been determined.

Opportunities and constraints mapping was updated and refined to include access roads and utilities that serve the critical assets outside of Area X and 2A. Figure 12 shows the various constraints and opportunities on the base. Critical assets shown in red include the airfield and supporting infrastructure (Area X) and other facilities in Areas 2, 3, 4, and 5, as well as entrance access to the base. Area 2A (light blue hatch) could receive the relocated/realigned assets from elsewhere on the base and be protected over time. Opportunities are represented by assets throughout the base that are removable/relocatable and associated developed uplands and undeveloped uplands. Undeveloped uplands (green) include filled areas within the lagoon that could be restored to wetlands or used as other natural infrastructure features. Note there are assets in Area 5 and east Area 1 that cannot be moved to Area 2A owing to safety issues and hence their locations may be optimized after specific study.

Adaptation actions were then identified to address the vulnerability of built and natural assets while considering the opportunities and constraints at the base. These adaptation actions are discussed within the context of the Adaptation Vision in Section 3.3.

SOURCE: ESA; TNC Coastal Adaptation

Figure 12
Adaptation Opportunities and Constraints at NBVC Point Mugu

3.3. Key Components to the Adaptation Vision

The Adaptation Vision for NBVC Point Mugu utilizes a range of adaptation components and actions to defend in place, relocate, and remove assets to improve the overall resilience of built assets, and restore natural resources while preserving base functionality.

Defend critical built assets that must be maintained in place (in Area X, Area 2A and Areas 3-4) using the following measures, depending on the actual intensity of climate change and sea-level rise. Note that increasing wave run-up with higher sea levels will exacerbate the vulnerability of critical built assets in Areas 3 and 4, and hence realignment and appropriate relocation should be considered through continued planning efforts for all assets on the Pacific shoreline. (discussed in Section 3.3.2).

- Beach nourishment – place sand to widen beaches seaward and build dunes to provide protection to assets in areas 1, 4 and 5. Consider beneficial reuse of sand dredged from Calleguas Creek and other sources, and consider measures to facilitate the natural deposition and enhancement of sand along the coast.
- Armoring – flooding and or erosion protection such as rock revetments, seawalls, bulkheads, including maintenance of those already constructed.
- Elevation – raise built assets on fill or piles to be above flood levels.

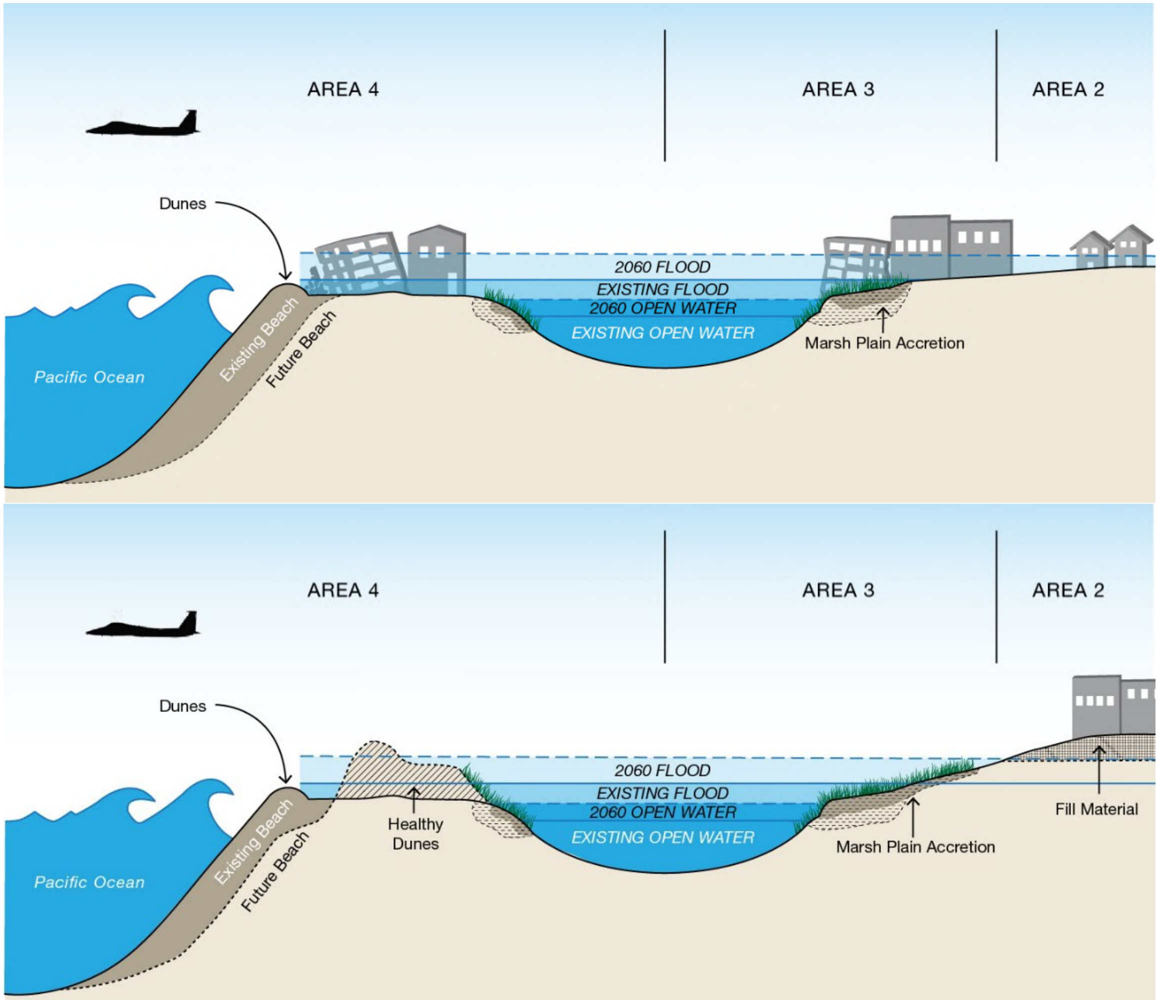
Relocate assets in base Areas 1, 3, 4, and 5 whose function is not critical to their specific location are relocated to Area 2A, their present site restored, and the following measures are implemented.

- Raise the grades in Area 2A above flood levels to build relocated assets
- Consider multi-objective beneficial reuse of sediment from Calleguas Creek for fill in Area 2A
- Consider strategic planning and multiple uses of assets relocated in Area 2A to maximize efficiency and utility while minimizing footprint and expense.
- Some assets in Area 4 were determined to be essential in that location in the near-term, but will need to be relocated as sea levels rise, shorelines erode, and storm impacts increase. These could be sequentially moved back within Area 4 or if no other assets were on Area 4 could be moved back near Area X at a sooner timeframe.

Restore: assets that are no longer of high or critical use on the base (redundant or obsolete structures, derelict structures, roads, utilities, fill pads, etc.) are removed, and the areas are restored to natural habitats, integrating with other habitat restoration and enhancement plans in Areas 2B, 3, 4 and 5. Note restoration also includes fill areas that support assets that can be relocated.

- Implement NBVC Integrated Natural Resource Management Plan (INRMP) (Tetra Tech 2018) and the Restoration Plan for NBVC Point Mugu (Tetra Tech 2104).
- Expand hydraulic conveyance to Area 5 via expanded culvert(s) under the runway (Area X) and roadway crossings in Area 4 to facilitate the maintenance and evolution of marsh systems.
- Expand hydraulic conveyance to existing wetlands in area 3 where constrained by culverts through roadway embankments to enhance marsh health, function, and protective services of base assets in Area 3 and X.
- Remove coastal structures where no longer needed (i.e. structures that protect assets to be removed/relocated), including groins and rock revetments to allow coastal processes to rebuild and enhance the coastal strand, thereby enhancing ecological function, protective services, and resilience.

The conceptual diagram in Figure 13 illustrates the baseline hazard impacts (top) and implemented Adaptation Vision (bottom) at 2060. The diagrams show a theoretical cross section extending from the ocean, across the beach strand in Area 4, through vulnerable assets in Area 3 and up to higher ground in Area 2A. Solid water surface lines represent the existing tidal (open water) and flooding elevations while 2060 conditions are represented by dashed water surface lines. Future sea-level rise will impact assets along the beach strand and within the lagoon, as shown in the top frame. By relocating exposed assets instead of armoring and maintaining them in place, the restored natural habitat can flourish while providing protective services. Adaptation Vision benefits to built and natural assets are depicted in the lower frame. Dunes that are allowed to migrate landward and upward with sea-level rise can limit ocean wave overwash along the beach strand. Similarly, restored/enhanced salt marsh in the lagoon and/or wetland transition slopes can attenuate wind-waves in the lagoon and limit flooding impacts to upland built assets.



SOURCE: ESA; TNC Coastal Adaptation

Figure 13
Conceptual Schematic of No Action Baseline (top) and Adaptation Vision (bottom) for NBVC Point Mugu

3.3.1. Adaptation in Area 2A

Area 2A is identified as an opportunity zone to accept relocated built infrastructure that presently exists in Areas 1, 3, 4, and 5. Area 2A is currently higher in elevation than other areas and is removed from wave-induced erosion and flooding and existing habitat areas. With potential future climate-driven increased precipitation intensity and higher sea-levels, Area 2A is exposed to flooding from Calleguas Creek. However, adding elevation with fill throughout Area 2A will increase resilience to flooding for assets relocated into Area 2A as discussed below.

There are four critical assets currently within Area 2A: Police Station, Recruit Processing Building, communication building and radio transmitters, and water treatment and pumping stations. In discussion with NBVC, Area 2A is identified as a potential location to accept assets removed and restored from Areas 1, 3, 4, and 5. An important next step is to investigate base housing modifications and options to accommodate infrastructure relocation to Area 2A.

There are approximately 90 acres within Area 2A available to receive relocated assets, and the assets in Areas 1, 3, 4 and 5 that will be relocated totals 87 acres as currently built. Strategic planning of the rebuilding of these structures in Area 2A, optimizing multi-use and efficient footprint could allow an open “feel” to Area 2A with open space and upland habitat between structures. Assets relocated into and those original to Area 2A will need to adapt over time to maintain flood resilience. Structural elevation and flood-proofing are asset-specific measures that could be used to improve coastal storm surge and fluvial flood resilience. Area-wide adaptation measures could include perimeter levees and/or floodwalls, or raising grades on fill.

An analysis of existing grades was performed to characterize the effort required to raise grades in Area 2A using imported fill. Table 4 below lists the amount of neat fill volume needed to raise grades to elevations spanning 7 feet to 16 feet NAVD in 0.5-foot increments. The total area of Area 2A is approximately 1,770,000 square yards (SY). Existing mean ground elevation in Area 2A is 10 feet NAVD while existing maximum ground elevation is approximately 13 feet NAVD. Approximately 880,000 cubic yards is needed to elevate the entire Area 2A by 1 foot. The analysis is based on topographic LiDAR flown in 2010 (from the NOAA CA Topobathy Merge Project 2013). The simplified volumes below provided for reference and do not include elements such as daylight slopes along the area boundary.

TABLE 4
VOLUME-BY-ELEVATION TO RAISE GRADES IN NBVC AREA 2A

Elevation NAVD	Area[1] Below Elevation (SY)	Volume[1] Needed to Raise Grades to Elevation (CY)
7	38,100	9,700
7.5	88,800	41,400
8	137,000	97,500
8.5	213,600	182,700
9	340,400	318,200
9.5	559,900	539,600
10	835,600	886,500
10.5	1,152,400	1,383,100
11	1,438,700	2,035,100
11.5	1,605,100	2,802,000
12	1,691,500	3,627,300
12.5	1,736,100	4,486,100
13	1,747,600	5,357,800
13.5	1,750,500	6,232,600
14	1,752,100	7,108,200
14.5	1,754,100	7,984,700
15	1,758,100	8,862,800
15.5	1,760,000	9,742,500
16	1,760,700	10,622,900
+1 foot	*1,760,700*	*+880,000*

1. Area and Volume (cumulative) are based on 2010 topographic LiDAR.
Last row shows volume needed to raise entire Area 2A by 1 foot.

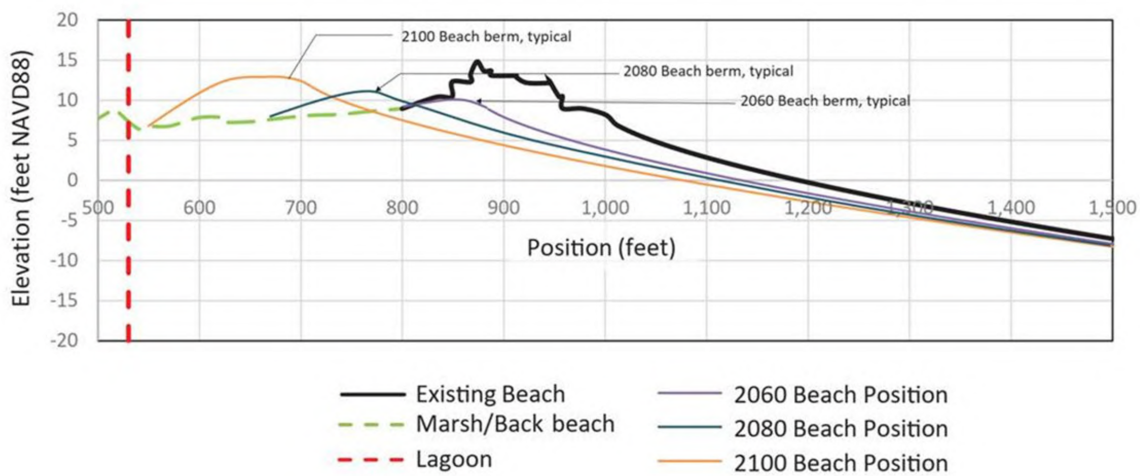
The dominant flood hazard for Area 2A is Calleguas Creek. The 100-year flood level from Calleguas Creek in Area 2 is approximately elevation 9.2 feet NAVD (ESA 2016). Approximately 500,000 cubic yards of compacted fill would be required to raise all of Area 2A to elevation 9.5 (Table 2), and about 880,000 cubic yards to raise the entire Area 2A by one foot. Future flood elevations from Calleguas Creek at Area 2 are approximately 13.4 feet NAVD in 2060 and 14.5 feet in 2100 (ESA 2016). Approximately eight million cubic yards of compacted fill would be required to raise all of Area 2A to elevation 14.5 (Table 2). However, the mean elevation in Area 2A is 10 feet, about 70% of the area is above +9.5' so fill placement could be targeted to raise the higher areas for development and maximize the utility of fill volumes. Approximately 500,000 cubic yards of fill would be required to raise higher areas (above 10 feet NAVD) per additional foot. For example, 3 feet of fill in higher areas alone would require approximately 1.5 Million cubic yards (vs 2.6 Million cubic yards to raise all of Area 2A 3 feet).

One source of sediment is Calleguas Creek, which has the third highest sediment yield of all rivers in California (USGS 2009). We estimate that about 100,000 cubic yards of sand is deposited in the Calleguas Creek channel on an average-annual basis, based on an estimated 200,000 tons of bed load deposition per year (Ventura County 2004). Sediment deposition in the channel causes the bed of the creek to aggrade, thereby increasing flood risk to adjacent lands. Consequently, removing sediment from the channel may have multiple benefits, including flood risk reduction in the Calleguas Creek flood plain as well, as providing fill for Area 2A, sand for beach nourishment, and material to create transition slope areas to accommodate wetland migration with sea-level rise. Furthermore, removing tidal constrictions and removing assets from Areas 1, 3, 4, and 5 would increase the tidal flows into these sections of the lagoon, thus increasing transport and deposition of Calleguas Creek sediment loads on marsh habitats throughout NBVC Mugu. Restoring these connections will ultimately facilitate salt marsh accretion to maintain elevation and resilience as sea-level rises. Further evaluation of Calleguas Creek management actions as a potential sediment source is required to assess the feasibility of opportunistic reuse of the sediments for each of the above applications.

3.3.2. Adaptation in Coastal Strand Areas 1, 4 and 5.

The Pacific shore (Areas 1, 4 and 5) consists of a sandy beach and dune, linear form called a coastal strand. Historically, sand discharged by rivers built the Oxnard Plain, and waves transported sand along the shore, primarily from northwest to southeast. The seaward progression of the shore is controlled by the Hueneme and Mugu submarine canyons, locally framing Mugu Lagoon. Since the mid-1900s, sand supply from the north has been affected by harbor construction and mechanical sand bypassing of Channel Islands and Hueneme harbors. Also, it appears that the head (landward end) of Mugu Submarine Canyon has migrated toward shore, inducing migration of the coastal strand, thereby eroding the beach in front of base assets (BradyG2 and MN 2012). In response, coastal erosion control structures have been constructed to protect base assets. However, these protective works are likely to be overwhelmed in the future and hence all base assets on the littoral strand are at risk of erosion, flooding and high-velocity wave action that can overload typical structures with high momentum forces and scour of foundations. Therefore, the Adaptation Vision calls for built assets on the coastal strand to be relocated landward (to Area 2A or elsewhere), or setback horizontally and raised vertically to accommodate the projected increase in exposure. For those built assets not relocated, significant damage will likely be incurred as sea level rises, potentially accruing significant costs to protect these structures and functions in their current location.

The Adaptation Vision calls for built assets to be removed from the strand, thereby allowing the shore to migrate landward but maintain its high beach and dunes which provide protective services to the Mugu Lagoon and built base assets in Areas X and 2A. Figure 14 provides a projection of shore migration just north of NBVC Point Mugu at southern Ormond Beach, near Arnold Road (ESA 2019). This figure shows the transgression (landward and upward migration with sea-level rise) induced by waves building the beach and wind building the dunes.

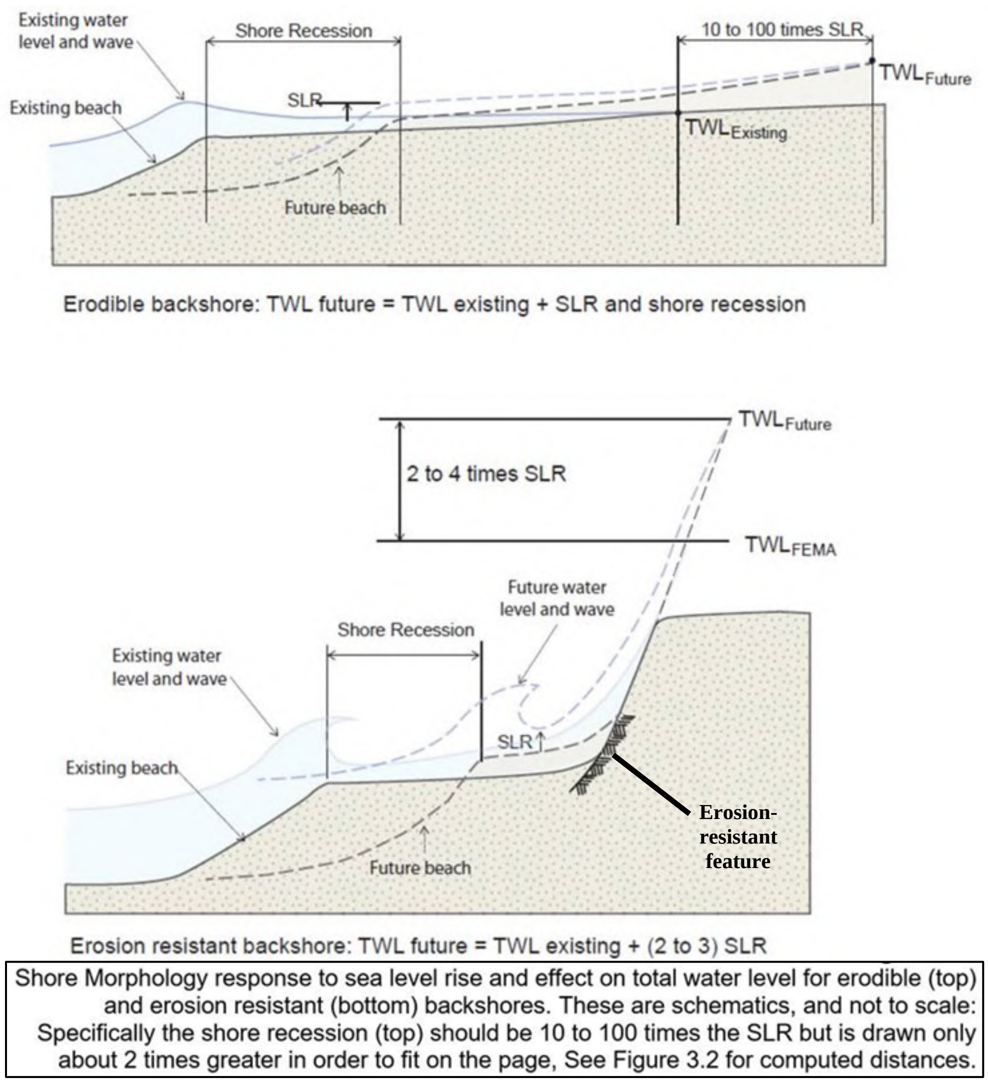


SOURCE: ESA 2019;

TNC Coastal Adaptation

Figure 14
Conceptual Schematic of Future Shore Migration at Ormond Beach, vicinity of Arnold Road, upcoast from NBVC Point Mugu

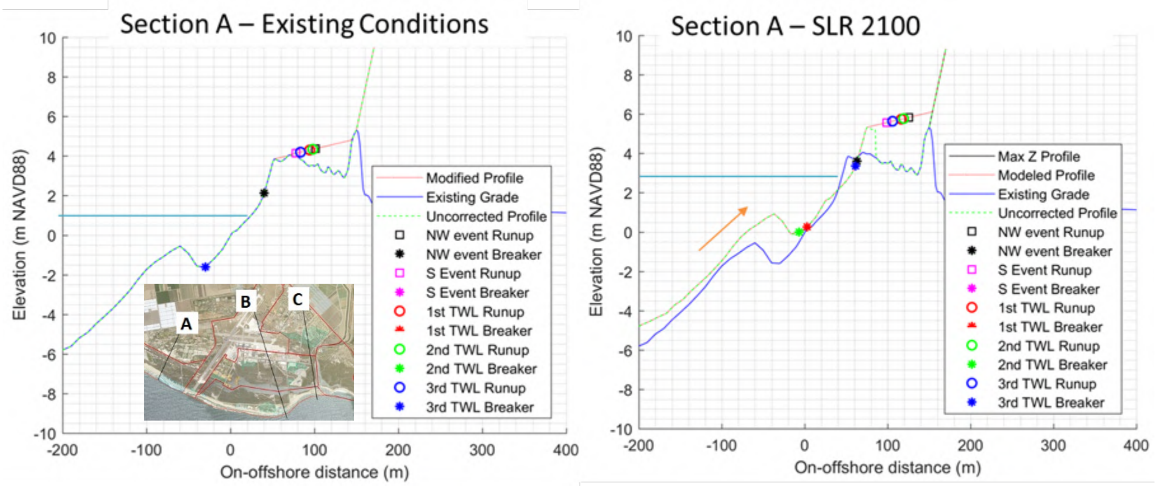
Shore protection on a migrating shore results in a loss of beach and a deepening and steepening of the foreshore, resulting in larger depth-limited breaking waves and a non-linear amplification of wave run-up and overtopping at the shore protection barrier. Recent research indicates that run-up can be amplified at shore protection 2 to 4 times the amount of sea-level rise whereas there is no amplification if the shore can adjust by transgression (Vandever and others 2017; Battalio and others 2016). Figure 15 shows that, for an unarmored shore, the wave run-up increases with sea-level rise primarily in the inland direction whereas for an armored shore the run-up increases in a more vertical direction, with increasing hydraulic loading in the vicinity of the shore protection, including the “protected” assets (Battalio and others 2016).



SOURCE: Battalio et al 2016 [Reproduced] TNC Coastal Adaptation

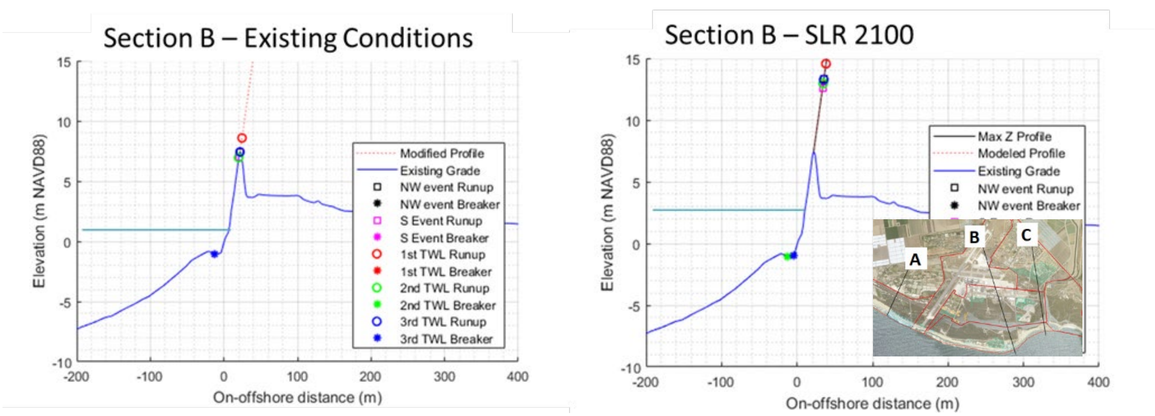
Figure 15
Amplification of wave run-up at an un-armored, transgressing shore (top) and with an erosion resistant (armored) shore (bottom)

ESA analyzed wave run-up at NBVC, building upon prior work (ESA PWA 2014; ESA 2019). As shown in Figure 16 and Figure 17. In each figure, the horizontal light blue line represents MHW elevation. The beach profile is shown as black and dashed green while the red line shows a monotonic slope projection defined for run-up computations. Five wave events were simulated as shown in the legend, squares and circles represent the landward limit of run-up while the corresponding wave breaking point is shown on the profile with an asterisk. Descriptions for each figure are provided in the next paragraph.



SOURCE: ESA; TNC Coastal Adaptation

Figure 16
Wave run-up at Section A (Area 5) for existing (left) and future (right) conditions



SOURCE: ESA; TNC Coastal Adaptation

Figure 17
Wave run-up at Section B, Area 4 for existing (left) and future (right) conditions

Figure 16 shows the wave run-up computed for Area 5 (labeled Section A), presuming the shore can migrate, for existing and future sea level at 2100. The wave run-up elevation increases about the same as the amount of sea-level rise while the entire shore profile migrates landward and up. Note that the model did not include dune building by wind (which is probable), and hence the backshore beyond the beach was not modified for future conditions. Figure 17 shows the wave run-up computed for Area 3 where massive shore protection has been installed. Note that the predicted future run-up increases more than 4 times the amount of sea-level rise, indicating a non-linear increase in wave overtopping and hydraulic loadings on armoring structures. The run-up analysis was accomplished using methods consistent with Guidelines for Pacific Coast Flood Studies (FEMA 2005) and the Coastal Engineering Manual (USACE 2003).

Another adaptation strategy that can be employed on the coastal strands is to place sand to widen the beaches (Brady G2 and MN 2012). The amount of sand needed to widen a beach can be approximately calculated using the height of the shore face. For example, a shore face that is 54 feet high (measured vertically from the top of dunes or beach elevation to the offshore closure depth where the active shore profile ends) would require 54 cubic feet of sand to widen the beach one square foot: Dividing by 27 cubic feet / per cubic yards would yield 2 cy/sf of beach. The portion of the shore subject to active sand transport due to wave action (the shore face) extends from the outer surf zone (closure depth), across the beach and includes the dunes. At Ormond Beach and Mugu coastal strands, the height of the shore face is approximately 80 feet (from -30 feet to +30 feet) to 40 feet (from -25 feet to +15 feet), with the smaller value representing the Family Beach area where waves are small due to wave refraction. Therefore, approximately 1.5 to 3 cubic yards (cy) of sand are required to widen the beach one foot for every foot of beach length, that is 1.5 to 3 cy sand per square foot of beach. This compares closely with previous estimate of 1.44 cy/sf beach for a shore face extending from -24 feet to +15 feet MLLW (Brady G2 and MN 2012). For the approximate 24,000-foot long strand of Areas 4 and 5, widening the beach 50 feet would require about 7.2 to 3.6 million cubic yards. Taking the slope of the shore face as about 1:50, this amount of sand would be needed to counter each one-foot increment of sea-level rise. Since the US Army Corps of Engineers bypasses sand from Channel Islands Harbor to the shore at the town of Port Hueneme at a rate of about 1.5 to 2 Million cubic yards every two years, it may be feasible to place sand directly at NBVC Point Mugu for a marginal increase in cost per cubic yard. It is our opinion that the effectiveness of sand placement, as measured by the persistence of a wider beach, will be enhanced by allowing the shore to migrate landward. Regardless, beach nourishment is one adaptation strategy, or measure, that is potentially feasible and effective in the near term before sea-level rise accelerates, and prior to further migration of the Mugu submarine canyon. It is worth noting that while beach nourishment enhances physical beach area, it has been shown to degrade ecological aspects of healthy beaches including impacts to the amount and diversity of invertebrate infauna (Defeo et al. 2009, Schlacher et al. 2012, Peterson et al. 2014). Given the importance of the beaches on the base as feeding grounds to migratory birds and nearshore fish communities, further studies are merited to explore the potential impacts to be weighed against the potential benefits of beach nourishment. Further study is needed to determine feasibility of beach nourishment at NBVC Mugu, including sediment transport calculations, assessment of source sediments, and hazard modeling. Beach nourishment is not likely a sustainable way to protect assets on the coastal strand in the long term, as required sand volumes will increase with sea-level rise.

It should be noted that the existing shore protection structures may be contributing to the reduction of beach width by forcing sand to migrate along shore in deeper water, and diverting sand into the submarine canyon before migrating around the shore bend in area 4, toward Family Beach and the Mugu Lagoon mouth. Further, it is possible that the armoring approach will result in the coastal strand being segmented and breached, thereby "breaching" the protective services to inland areas such as Area 3 wetlands and built assets and Area X. In short, maintaining the coastal strand intact with a beach and dune barrier that provides protective services to the natural and built assets at NBCV Point Mugu is strategically important. Maintaining the beach strand by allowing shore migration and natural constructive processes is an important component of the Adaptation Vision.

The dredging of Hueneme and Channel Islands Harbors and down coast nourishment at Hueneme Beach may be affecting beach widths at NBVC Point Mugu for decades. Since the construction of the Hueneme Harbor in 1938 and subsequently Channel Islands Harbor in 1960, over 58 million cubic yards of sand has been placed at Hueneme Beach from maintenance dredging of the two harbors and bypassing from the Channel Islands sand trap (BradyG2 and M&N 2012). Aside from the large sand placements associated with harbor construction, scheduled sand bypassing and placement at Hueneme Beach has occurred since 1963 on a 2 to 3-year interval averaging about 1,000,000 CY per year from 1963 to 2011 (range of 10,000 CY to 3,500,000 CY per placement). These bypassing events maintain the sediment flow around the two harbors and is the single largest sediment source for the NBVC coastline (BradyG2 M&N 2012).

3.3.3. Adaptation in Developed Marsh Areas 1, 3, 4, and 5.

Areas 1, 3, 4, and 5 include built assets intermingled with emergent tidal marsh. These areas are subject to increased inundation due to sea-level rise, threatening both natural and built assets. Moreover, the loss of emergent marsh and the protective services it provides will exacerbate risks to built assets throughout the base. Therefore, the Adaptation Vision for Areas 1, 3, 4, and 5 is to remove built assets and relocate these assets into area 2A (or other upland areas), restore filled and otherwise disturbed areas to wetlands and transitional slopes that provide space for wetland migration with sea-level rise. The removal of built assets dispersed throughout marsh habitats of Areas 1, 3, 4, and 5 will greatly enhance the ecological function of these estuarine habitats and protective services they provide to base assets.

Increasing hydraulic connectivity in Areas 3, 4, and 5 will increase the transport capacity of sediments and nutrients to these areas, thereby enhancing marsh function and providing sediments necessary for marsh habitats to accrete vertically to keep pace with rising seas. By removing and restoring built assets out of these areas, natural flooding and sediment loads from Calleguas Creek could be allowed to flush and flow throughout Areas 1, 3, 4, and 5 and enable these marshes to accrete and keep pace with sea level rise. Having Areas 3, 4, and 5 more hydraulically and physically connected will also allow the transport of propagules and individuals of plants and animals, facilitating the shifting of plants and animals and adaptation as sea levels and local conditions change.

If natural processes are allowed and facilitated throughout natural areas of the base (e.g. flooding and sediment deposition from Calleguas Creek and wind born sand building dunes blowing into the lagoon) marsh habitats will reconnect with historic sediment sources and processes that maintained them for thousands of years throughout the Oxnard Plain, thereby increasing their ecological function and resilience to climate change and sea-level rise. For example, increasing the hydrological connection (tides) to wetlands will allow them to hold more water during high tides, storm surges and creek flooding events. Removing assets and roads that interrupt these natural processes will enhance these eco-physical processes as well as create larger expanses of continuous healthy self-maintaining coastal habitats. This will ease and facilitate the management, maintenance, and enhancement of imperiled species protected under state and federal endangered species acts. Allowing these areas to hold more flood waters as well as accrete vertically to minimize wave energy will increase the protective services they provide to assets and enhance overall base resilience.

4. Adaptation Vision Benefits to Infrastructure and Habitats

Based on identified adaptation actions that consider the opportunities and constraints for assets and habitats in NBVC Point Mugu, ESA assessed the resulting change in risk/vulnerability of assets and habitats for each base area. Changes were determined by modifying maps and habitat projections to account for actions taken at the opportunity zones. Changes are quantified in terms of asset exposure risk scores and habitat areas for existing conditions and with sea level rise, compared with the no-action scenario.

4.1. Reduced Hazard Exposure to Built Assets

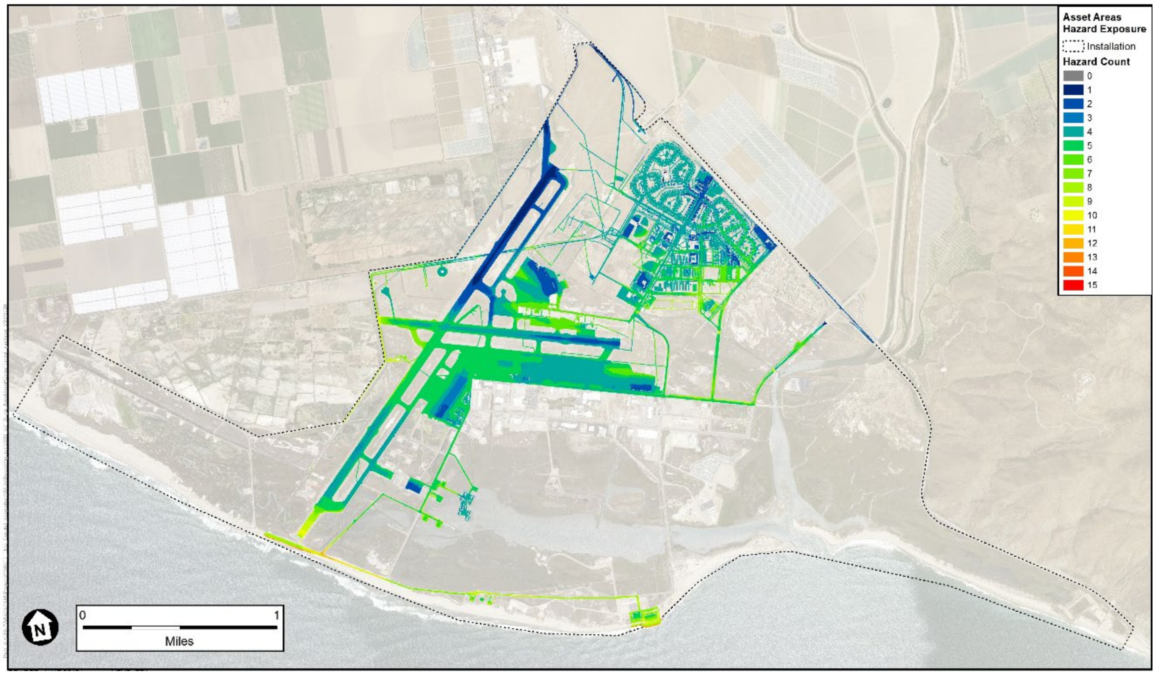
There is a significant increase in NBVC resilience to erosion and flooding hazards accounted for in this study by relocating NBVC assets into Area 2A. Table 5 below shows the hazard exposure risk scores that result from the consolidation of assets into 2A for the Adaptation Vision through 2100 considering the existing grades and assets on the base. Note that these scores would be reduced further through the implementation of measures to protect critical assets on the base and raising grades in Area 2A to maintain resiliency of realigned assets. These reduced exposure results were developed to illustrate the lower extent of protection that is needed on the base compared to maintaining base assets as currently distributed within the base. Ultimately, the goal of the Adaptation Vision is to maintain long-term resilience of the base assets to flooding and erosion hazards by reducing asset exposure to a minimum.

The scores were calculated for each asset group as the area- or length-weighted average hazard exposure count for all features in the group. The hazard exposure risk score is calculated from 5 distinct hazard types (tidal inundation, coastal erosion and wave run-up, coastal storm surge, and fluvial flooding) at each time horizon (existing conditions, 2060 and 2100). The hazard exposure count ranges from a score of zero (not exposed to any of the five hazards analyzed through 2100) to 15 (exposed to all five hazards under all three time horizons). Figure 18 summarizes these results in plan view, depicting the hazard exposure count for asset areas which may contain more than one asset. See Figure 4 for a comparison to the full extent of exposed assets under the no-adaptation baseline. Detailed tables numerating hazard exposures to assets under the no-adaptation baseline and with the Adaptation Vision are provided as Appendix B. See Figure 19 and Figure 20 for a comparison of discrete hazard exposure counts at 2060 and 2100 respectively. These figures show baseline (top) and reduced asset exposure counts the Adaptation Vision (bottom) that total 5 maximum (tidal inundation, coastal erosion and wave run-up, coastal storm surge, and fluvial flooding) at each time horizon (2060 or 2100). Each figure is reviewed further in the following paragraphs.

TABLE 5
ADAPTATION VISION BENEFITS TO NBVC BUILT ASSETS: ADAPTATION VISION HAZARD EXPOSURE RISK SCORES COMPARED TO BASELINE

Group	Asset	Total	Unit	Hazard Exposure Risk Score		
				Baseline	Adaptation Vision	Percent Change
Common	Airfield Section	13,660,149	SF	**3.9**	**3.8**	**-2%**
	Bank Armoring	461,840	SF	**9.9**	**3.2**	**-68%**
	Bridge	81,639	SF	**6.3**	**1.3**	**-80%**
	Building	4,466,112	SF	**3.9**	**2.1**	**-46%**
	Playground	90,808	SF	**4.1**	**3.0**	**-27%**
	Recreation Site	848,828	SF	**5.2**	**2.7**	**-48%**
	Road Centerline	296,404	LF	**4.6**	**2.2**	**-51%**
	Road Section	17,786,646	SF	**4.8**	**2.0**	**-59%**
	StorageTank	12,227	SF	**4.3**	**0.3**	**-93%**
	Structure	412,530	SF	**5.9**	**1.0**	**-83%**
Electrical	Electrical Facility	18,303	SF	**3.5**	**1.6**	**-55%**
	Pri OH Line	133,137	LF	**5.6**	**1.9**	**-67%**
	Pri UG Line	450,659	LF	**5.1**	**0.9**	**-82%**
Gas	Main Line	131,471	LF	**5.0**	**2.7**	**-45%**
	Service Line	32,914	LF	**4.8**	**2.3**	**-53%**
Sanitary	Force Main	14,172	LF	**4.2**	**3.0**	**-30%**
	Gravity Main	191,298	LF	**5.0**	**2.4**	**-52%**
	Pump Station	60,134	SF	**2.5**	**1.9**	**-23%**
Water	Main Line	340,152	LF	**5.2**	**3.1**	**-40%**
	Service Line	1,606	LF	**4.8**	**3.5**	**-26%**
	UG Enclosure	1,704	SF	**7.7**	**3.5**	**-55%**

NOTE: Hazard Exposure Risk Score is the average hazard exposure count of all assets at NBVC Point Mugu (asset exposure count ranges from 0 to 15). Percent change is Adaptation Vision relative to Baseline (no adaptation) score. A lower Risk Score means lower exposure.



SOURCE: ESA; TNC Coastal Adaptation

Figure 18
Adaptation Vision Benefits: Reduced Hazard Exposure Levels for NBVC Point Mugu Built Assets through 2100

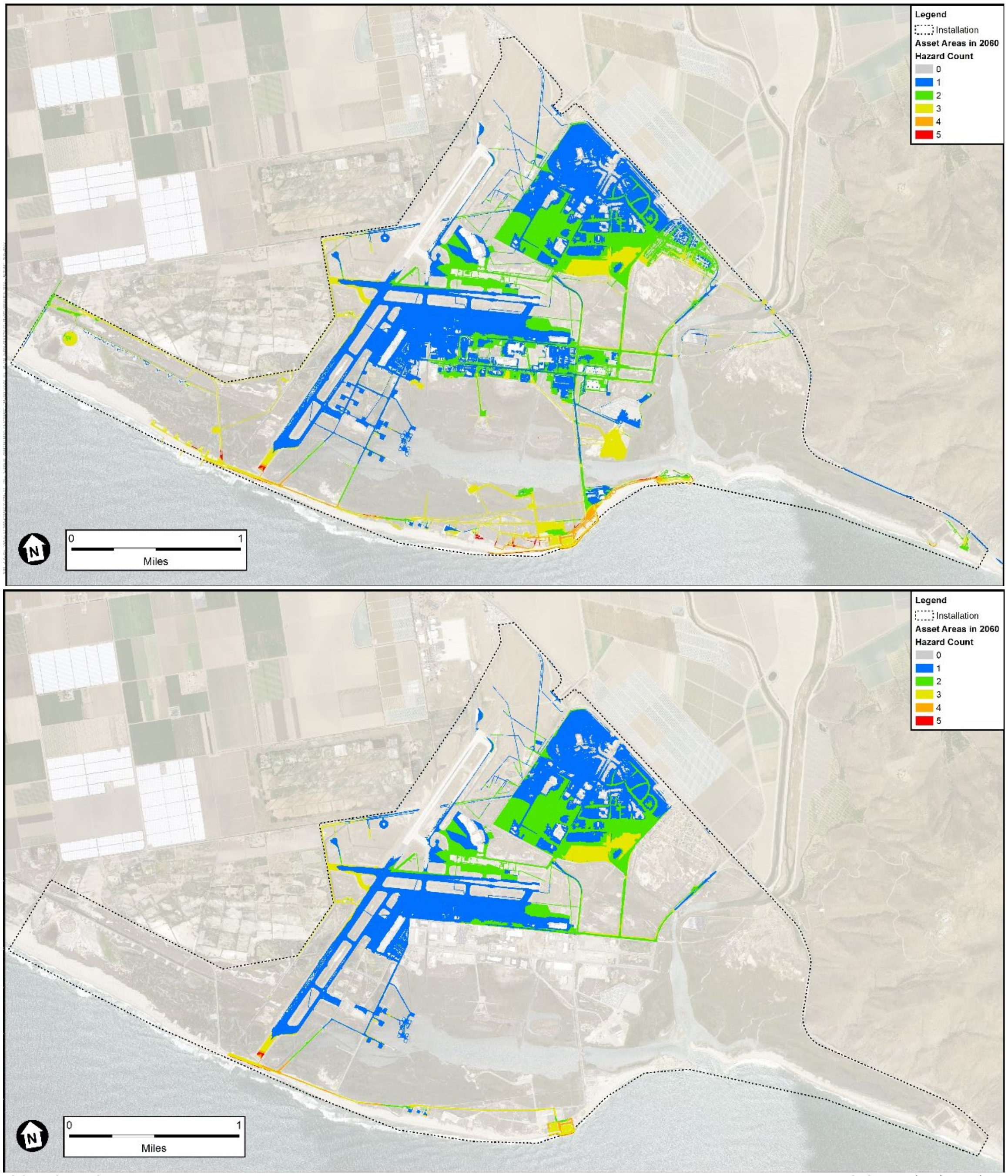
Figure 18 shows the cumulative hazard exposure count from existing conditions through 2100 (up to 15; 5 hazards at 3 time horizons). To facilitate comparisons at individual times of 2060 and 2100, aggregated hazard exposure was developed for assets for each future time horizon.

Figure 18, Figure 19 and Figure 20 show the elimination of hazards resulting from realignment of built assets to Area 2A and removal of other assets no longer of use. Exposure to the remaining assets is based on existing conditions and does not account for further risk reduction benefits to remaining assets gained from restored habitats and the protective services they provide. Thus, these figures convey the minimum risk reduction that could result from the Adaptation Vision.

Additional benefits of the Adaptation Vision could be quantified based on modeling hazards and habitat evolution for adapted conditions. These adapted conditions would accrue additional risk-reduction benefits over and above those shown in Figure 18, Figure 19 and Figure 20. These additional hazard reduction benefits would include:

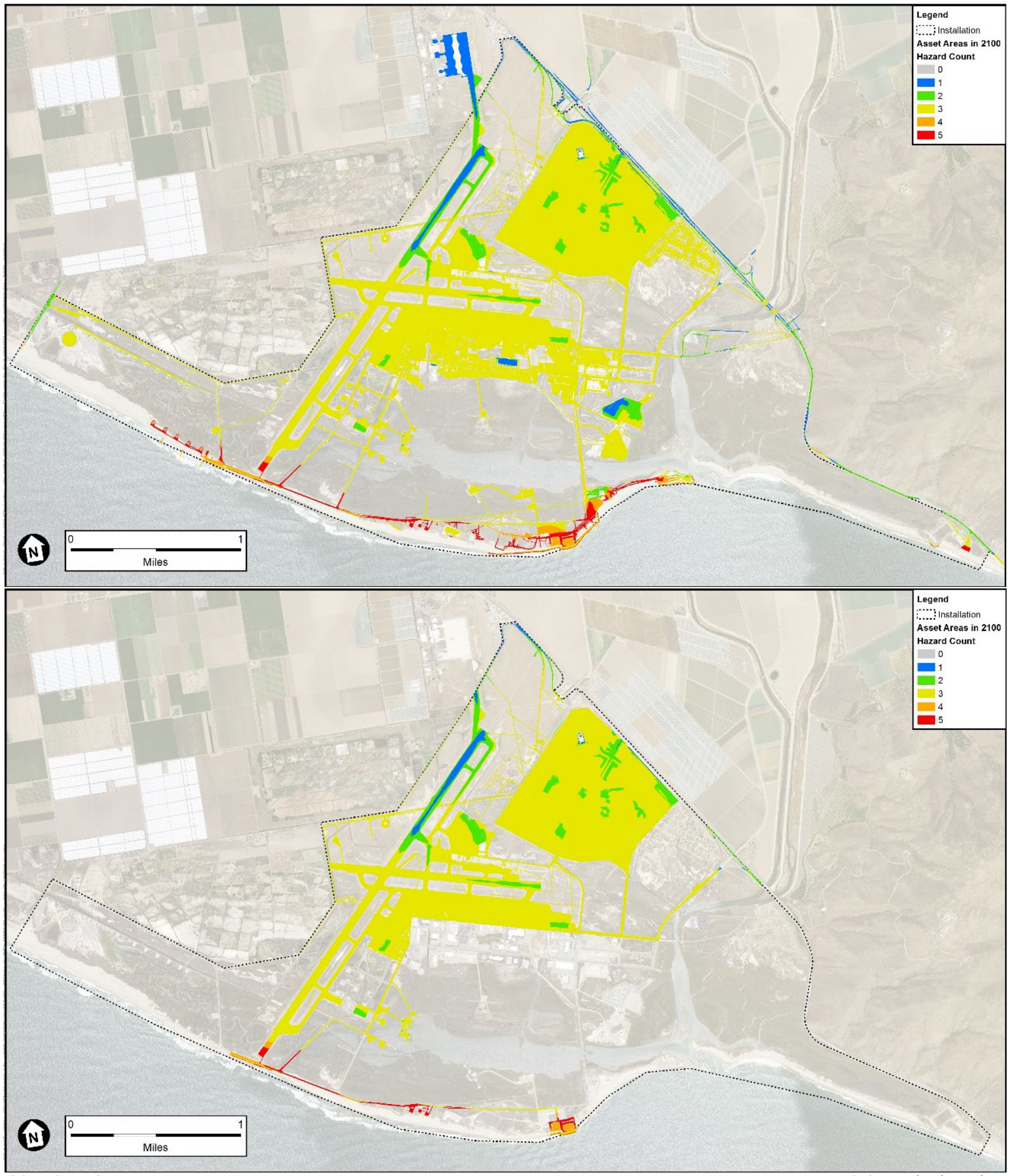
- Assets in Area 2A would be on raised ground and hence not flooded until sea-level rise exceeded the new grades (to be determined)
- Assets in Areas X and 3 would have reduced erosion and/or flooding vulnerability due to the protective services of restored marsh and shore strand in areas 3, 4 and 5. A healthy beach and dune strand and healthy marshes of Areas 3, 4, and 5 provide buffers against SLR, flooding, and wave run-up impacts.

- Reduced protection would be needed for assets surrounded by natural infrastructure due to flooding and erosion protective services they provide (e.g. smaller armoring structures, lower floodwalls in Areas X and 2A). Similarly, restoring/maintaining natural infrastructure would delay the need for new protection or other actions to reduce vulnerability as sea-levels rise.



SOURCE: ESA; TNC Coastal Adaptation

Figure 19
Adaptation Vision Benefits: Baseline (top) and Reduced (bottom) Hazard Exposure Levels for NBVC Point Mugu Built Assets at 2060



SOURCE: ESA; TNC Coastal Adaptation

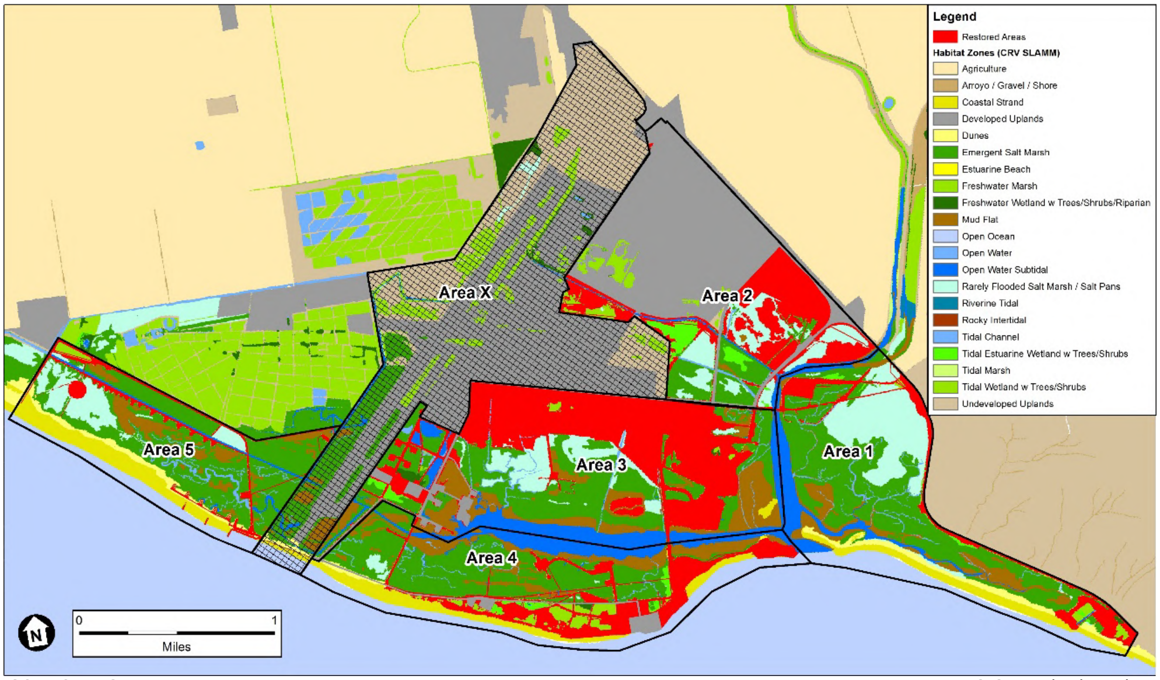
Figure 20
Adaptation Vision Benefits: Baseline (top) and Reduced (bottom) Hazard Exposure Levels for NBVC Point Mugu Built Assets at 2100

4.2. Improved Habitat Connectivity and Resilience

Removing all or most of the assets out of Areas 1, 3, 4, and 5 and restoring the remaining natural areas provides several key benefits beyond enhancing resilience to built assets throughout the base. Firstly, the removal of assets and supporting fill areas out of Areas 1, 3, 4, and 5 frees up 378 acres of space to be restored and managed as habitat. Note that this asset area is much greater than the space needed to place relocated built assets in Area 2A (see Section 3.2.3 for discussion). Over 730 acres of potential habitat restoration is possible at Mugu including developed and undeveloped uplands at Mugu (see red areas in Figure 21). This total does not include existing habitat areas within Area X and Area 2A that could be enhanced and managed. Local conditions including elevation, soil conditions, and hydrology will determine the appropriate habitat type to be restored in and around areas where built assets are removed. However, a larger planning process may be taken to restore a composition of species that represents historical ecology, functions in current conditions, and is resilient to projected changes. Such a process is taking place at the neighboring Ormond Beach Restoration site.

Secondly, the Adaptation Vision also restores Mugu lagoon with more contiguous habitat area throughout Areas 1, 3, 4, and 5. Pulling built assets out of and restoring Areas 1, 3, 4, and 5 to larger areas of contiguous habitat will allow for natural ecosystem processes throughout Mugu lagoon such as marine and riverine flooding, each depositing sediments and nutrients to maintain and enhance coastal habitats as sea levels rise. Greater areas of contiguous habitat uninterrupted by built environment will allow the slow shifting of location for plants and animals as conditions change making populations more resilient to climate change and sea level rise. Increased contiguous area of habitat is more healthy, functional, and resilient and is also easier to maintain to meet habitat and species management obligations. Increased contiguous habitat area also provides much more resilience benefits to built assets than when it is fragmented or interrupted by built assets.

Thirdly, it is worth noting that the Adaptation Vision allows for and facilitates habitat changes that will occur with a changing climate and rising seas. Without changes outlined in the Adaptation Vision it will become increasingly difficult to maintain a specific habitat and the imperiled species it holds in place as micro-climates shift, sea levels rise, and as periodic storm disturbances cause dramatic shifts. Conditions will change such that a habitat may be lost in one area, however, simultaneously other areas of the base may change or could be restored to favor this same habitat type with more area. Thus, it is recommended to consider a basewide planning approach for the maintenance of habitat types and area. By increasing contiguous habitat area and connectivity, habitats will be more able to naturally adjust vertically and/or laterally to environmental changes and less prone to being transformed to open water.



SOURCE: ESA; TNC Coastal Adaptation

Figure 21
Adaptation Vision Restoration Areas shown with Existing SLAMM Habitat Categories

5.Next Steps and Recommendations

The TNC-ESA, NBVC team identified the following next steps and recommendations to achieve the Adaptation Vision for NBVC Point Mugu:

a. Incorporate Adaptation Vision into the Installation Development Plan

b. Incorporate Adaptation Vision opportunities into the next updated Integrated Natural Resource Management Plan (INRMP) and NBVC Restoration Plan.

c. Conduct a refined Vulnerability Assessment that

    iv. Quantify consequences of damages to built assets
    v. Consider adaptive capacity of base assets
    vi. Evaluate fiscal impacts of flooding/erosion damages to assets

d. Develop NBVC Point Mugu Adaptation Plan

    vi. Model geomorphology and habitat evolution to quantify hazard risk reduction provided by natural infrastructure
    vii. Establish adaptation pathways for built and natural assets that identifies the timing of adaptation actions
    viii. Determine and refine interim and near-term adaptation actions (beach nourishment, armoring maintenance)
    ix. Examine potential effects of hydrology-altering adaptation actions (e.g. expand tidal connectivity) on existing habitats.
    x. Economic assessment of potential adaptation actions and pathways

e. Investigate base housing modifications and options to accommodate infrastructure relocation to Area 2A

Near-term actions that could serve the Vision include:

a. Beach nourishment in Areas 4 and 5. Note that beach nourishment will not confer long-term resilience of built assets on the beach strand but could buy time to plan adaptation of these assets. Continue efforts to evaluate beach nourishment with sand from USACE up-coast dredging related to Hueneme Harbor. Also consider other sources such as windblown sand accreting around critical infrastructure near Ormond.

b. Further study is needed to determine the feasibility of using sediments dredged from upstream portions of Calleguas Creek for fill in Area 2A, beach nourishment and upland enhancement in the base.

c. Execution of the INRMP (Tetra Tech 2018) and the NBVC Restoration Plan (Tetra Tech 2014) would serve the Vision. Opportunity areas from the Adaptation Vision could be added to these plans; specific Restoration Plan components/areas could be integrated with Vision-specific adaptation actions/areas when scoping projects for feasibility.

d. Begin to remove defunct built assets and supporting infrastructure on the base. Removing unused roads, fill areas and associated culverts would improve tidal connectivity to areas that are constricted under current conditions. For example, the L Avenue culvert project will replace pipe culverts with box culvert and make road improvements.

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