State of Hawaii
Department of Transportation

US DEPARTMENT OF TRANSPORTATION

Maritime Administration
Port Infrastructure Development Program (PIDP)

Kapalama Container Terminal – Gaining Regenerative and Efficient Energy Needs Project

Appendix H: Climate Resilience Action Plan

Please find supporting documentation at this link:
http://www.kctinfo.com/learn/updates/

HAWAIʻI DEPARTMENT OF TRANSPORTATION
HIGHWAYS DIVISION

HAWAII HIGHWAYS
Climate Adaptation Action Plan
Strategies for a More Resilient Future

May, 2021

A Message from Ed Sniffen,
Deputy Director of the Highways Division

Aloha,

Hawai'i is resilient and self-sufficient. From its very first inhabitants, decisions and actions have been made to accommodate, adapt, and thrive with nature. For thousands of years, environmental conditions in Hawai'i and worldwide have been relatively stable. But such conditions are now changing. Global average temperatures are increasing; sea levels are rising; and in many parts of the world storms are becoming more frequent and intense.

These changing conditions have important implications to Hawai'i – inundated shorelines, coastal erosion, floods from rainfall, a higher water table, more saturated soils and greater risks of landslides, and increased wildfires. Given our understanding of what is changing, we need to make some tough decisions to ensure the long-term viability of the State. It no longer makes sense to continue the same approaches we have been using to maintain and improve the State Highway Network, which assume historic environmental conditions will remain unchanged. The Highways Division of the Hawai'i Department of Transportation (HDOT) needs to be more resilient, adaptive, and engaged in climate change risks to our highway network. It is our responsibility.

This Action Plan is our first step to act comprehensively across the agency in recognizing and considering more fully these changing climatic conditions. The Plan is based on research and studies conducted by other agencies to establish an understanding of how changing environmental conditions will likely impact the State's highway network in the future. It outlines numerous strategies to ensure that today's decisions reflect future long-term environmental risks so that every decision and action we make is one that achieves greater network resilience.

The Action Plan presented in this report identifies the data used by HDOT staff in designing and managing State highways and how this data, combined with the additional climate data shown as required in the plan, can be used to guide future decisions. It focuses on ways to change key procedures and agency capabilities to be better prepared for climate change. The success of the Action Plan requires collaboration with many other agencies and groups that are critical to the State's economy and community. Hawai'i's community fabric is deeply interwoven, and actions taken by HDOT need to be mindful of the critical need for effective transportation options. Such essential collaboration will ensure that future generations will benefit from the actions HDOT takes today.

This Action Plan reflects the input of the professionals who work at HDOT, their thoughts on how to best proceed and change the way they do business to better incorporate resilience into everyday practices. We will work diligently with our partners to ensure the long-term viability of Hawai'i for the generations to come. Thank you for your support.

Mahalo,
Ed Sniffen

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BACKGROUND

Changing climatic conditions are creating challenges for Federal, State, and local government agencies throughout the United States. Hawai'i is experiencing such challenges, which are in many cases unique to the Hawaiian Islands. The Highways Division of the Hawai'i Department of Transportation (HDOT) recognizes its responsibility to better understand how changing climate conditions could impact the State's portion of the National Highway System (NHS). The Hawai'i Highways Climate Adaptation Action Plan (Action Plan) helps HDOT better define the extent and timing of these changing conditions on NHS facilities. Specific actions are identified on how climate change concerns can be considered and acted upon throughout HDOT's programs, ensuring the viability of the highway system for Hawai'is residents, visitors, communities, and businesses.

HDOT is responsible for the condition and performance of approximately 971 (linear) miles of highways on 6 islands within the State. The effective management of these NHS highways is a top priority for HDOT because of their vital contribution toward community access, economic prosperity, national security, and overall mobility. The Action Plan provides a roadmap for HDOT's Highways Division to make the highway system more resilient to climate-related effects. It presents an exposure assessment of climate hazards to the State's highways based on both historical and future climate condition research and data. The Action Plan prioritizes recommendations in a multi-year Implementation Plan that encompasses all aspects of HDOT's core functions and programs—funding, planning, designing, constructing, operating, maintaining, and protecting highway assets. It is considered a living document and will be revised as needed to reflect changes in conditions and implementation status.

The intended audience is primarily HDOT management and staff but also includes Federal, State, and local agencies and government leaders; other county, city, and local governmental agencies; utilities; communities, and businesses. HDOT is committed to working with all stakeholders in addressing the shared climate change challenges.

EXPOSURE ASSESSMENT FINDINGS

The hazards examined in this study are summarized in Table ES-1, Figure ES-2, and fully described in the Exposure Assessment document that was prepared as a companion document to this plan. A map identifying specific areas of concern is presented over the following pages. The State Highway Network was the focus of this study. Of the total mileage, 564 miles (58% of the network) are exposed to potential climate change stresses and lava flows (16% is attributable to lava flows) including 303 bridges (76% of the assessed bridges), 48 culverts (66% of the assessed culverts), and 6 tunnels (100% of the assessed tunnels). Note that lava flows are not climate-related hazards but were considered in a broad approach to increase highway network resilience. The mileage and assets exposed to each stressor, in some cases overlapping with other hazards, are presented below.

Each of these conditions, except for lava flows as noted, is anticipated to be affected by climate change in Hawai'i. It is important to think not only about past experience with such hazards, but also the anticipated changes that could alter the

This document is one of two resources that outlines the potential threats from climate change to Hawai'i Highways. This Plan is a companion to the online mapping platform maintained on HDOT's website to enable the review of climate threats at a level of detail not possible in printed form. That site is located at: https://hidot.hawaii.gov/

Figure ES- 1 *The Basic Framework for Achieving System Resilience*

intensity and character of their impact on Hawai'i. In establishing this baseline understanding of future change, HDOT can take the necessary project development and investment steps to increase the overall resilience of the highway system.

Temperature and precipitation variability and extremes expected from climate change can accelerate damages to pavement, structural support, underground infrastructure, and stormwater conveyance when combined with regular use. The result is more frequent maintenance and repair, as well as reduced lifecycle requiring earlier replacement. The effects of these conditions will be further defined through subsequent work, along with additional hazards such as inland flooding for which data was not currently available.

NEXT STEPS

A key consideration discussed throughout the Action Plan is the need for HDOT to change internal practices to drive more future-oriented decisions and designs to ensure the long-term success of the NHS. For example, most climate adaptation studies in the U.S. use future climate projections rather than relying on historical conditions, which has been the standard in state departments of transportation.

Figure ES-1 above identifies the general approach for achieving highway network resilience—starting with a forward look at possible future risks to the highway network leading to cost-effective investments that lead to a more resilient highway system.

This Action Plan identifies recommendations focused on different functions of the HDOT Highways Division with the end goal of integrating considerations of climate risk and long-term climate change resiliency into agency practices.

Finally, this Action Plan also outlines needed next steps for HDOT in terms of further actions required to provide more definition to the risks to assets. Additional analysis is needed to fully understand asset consequences and impacts from climate and environmental hazards studied. More detailed assessments are needed in some cases to determine the appropriate responses. HDOT will also move forward with the immediate and near-term actions outlined in the Implementation Plan. Implementing these actions will increase HDOT awareness of climate change impacts, encourage internal and external communications regarding data collection, incorporate resilience as a required element of HDOT's internal design and operational procedures, and promote budgets that reflect the reality of climate change impacts.

HDOT has already been working toward creating a resilient highway system to serve the communities and businesses of the Hawaiian Islands, such as integrating potential climate hazards into HDOT's Transportation Asset Management Plan (TAMP), the use of an adaptive design framework in the Waipa and Waikoko bridge repair project on Kaua'i to withstand a tsunami hazard, and the preparation of a Statewide Coastal Highway Program Report in 2019 (Francis et al. 2019). The Action Plan presents additional opportunities for HDOT to better understand the implications of changing climate conditions on agency assets. It is focused on adjusting internal practices within the agency to ensure that all decisions made from this point forward are mindful of expected future climate change conditions. The ultimate result of this Action Plan will be to increase the resilience of the highway system to existing and future risks.

Table ES- 1 Mileage of HDOT Highways Exposed to Climate Hazards (to 3.2 feet Seal Level Rise (SLR)

	Roads		Bridges		Culverts		Tunnels	
Hazard	*Miles*	*%*	*Units*	*%*	*Units*	*%*	*Units*	*%*
Rockfall and landslide	167.6	17%	126	32%	11	15%	6	100%
Sea Level Rise	9.4	1%	92	23%	7	10%	0	0%
Annual high wave flooding	23.9	2%	50	13%	6	8%	0	0%
Coastal erosion	23.7	2%	22	6%	2	3%	0	0%
Storm surge	74.1	8%	120	30%	9	12%	0	0%
Tsunami	178.1	18%	135	34%	15	21%	0	0%
Wildfire	139.2	14%	97	24%	18	25%	0	0%
Lava flow	151.8	16%	18	5%	15	21%	0	0%

3.2 feet used for the summary utilizing values from the Hawaii Sea Level Rise Vulnerability and Adaptation Report (2017)

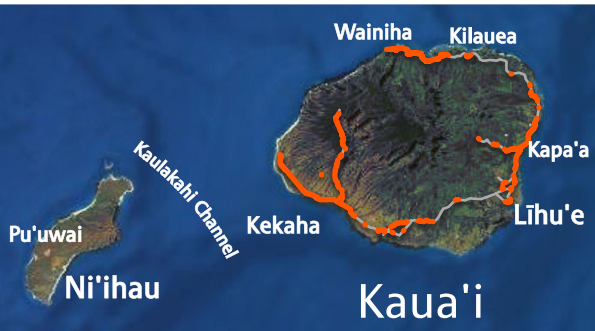


FIGURE ES-1: CLIMATE EXPOSURE SUMMARY BY STRESSOR

CLIMATE STRESSOR	Rockfalls and Landslides
EXPOSURE ASSESSMENT	Segments associated with sites prioritized in HDOT's Rockfall Protection Program and sites determined to have high and very susceptibility according to USGS
ROADS EXPOSED [MILE]	167.6 miles
EXAMPLES OF EXPOSED AREAS	• Kauaʻi District: portions of Kūhiō Highway in Hanalei and near Wainiha; Waimea Canyon Road and Kokeʻe Road • Oʻahu District: portions of Farrington Highway near Mākua Beach and Nānākuli; along Likelike Highway and Pali Highway; along Kalanianaʻole Highway in Waimānalo • Maui District: Hāna Highway in East Maui; portions of Honoapiʻilani Highway in West Maui • Hawaiʻi District: Māmalahoa Highway on Hāmākua Coast

CLIMATE STRESSOR	Sea Level Rise
EXPOSURE ASSESSMENT	Segments exposed to marine flooding and groundwater inundation considering three sea level rise scenarios
ROADS EXPOSED [MILE]	3.2 miles (0.5-ft Sea Level Rise (SLR)), 3.4 mile (1.1-ft SLR), 4.1 mile (2.0-ft SLR), and 9.4 miles (3.2-ft SLR)
EXAMPLES OF EXPOSED AREAS	• Kauaʻi District: portions of North, West, and East Kauaʻi, including Kūhiō Highway between Hanalei and Wainiha; Kaumualiʻi Highway in Kekaha/Waimea; Kūhiō Highway over Wailua River and through Kapaʻa • Oʻahu District: portions of Farrington Highway on the Waiʻanae Coast; Kamehemaha Highway on the North Shore and Windward shore (Kahana to Kahuku), Sand Island and Ala Moana Boulevard; Kalanianaʻole Highway in Hawaiʻi Kai • Maui District: North Kihei Road by Kealia Pond; portions of Kamehameha V Highway on south coast of Molokaʻi

CLIMATE STRESSOR	Annual high wave flooding
EXPOSURE ASSESSMENT	Segments exposed to annual high wave flooding considering three sea level rise scenarios
ROADS EXPOSED [MILE]	2.8 miles (0.5-ft SLR), 4.2 miles (1.1-ft SLR), 9.5 miles (2.0-ft SLR), and 23.9 miles (3.2-ft SLR)
EXAMPLES OF EXPOSED AREAS	• Kauaʻi District: portions of North, West, and East Kauaʻi, including Kūhiō Highway between Hanalei and Wainiha; Kaumualiʻi Highway in Kekaha/Waimea; Kūhiō Highway over Wailua River and through Kapaʻa • Oʻahu District: portions of of Kamehemaha Highway on the North Shore and Windward shore (Kualoa to Laʻie); Ala Moana Boulevard; Kalanianaʻole Highway in Hawaiʻi Kai and Waimānalo • Maui District: portions of Honoapiʻilani Highway in West Maui (Lahaina to Olowalu); North Kihei Road by Kealia Pond

CLIMATE STRESSOR	Coastal erosion
EXPOSURE ASSESSMENT	Segments exposed to coastal erosion considering three sea level rise scenarios
ROADS EXPOSED [MILE]	8.4 miles (0.5-ft SLR), 12.1 miles (1.1-ft SLR), 17.9 miles (2.0-ft SLR), and 23.7 miles (3.2-ft SLR)
EXAMPLES OF EXPOSED AREAS	• Kauaʻi District: portions of North, West, and East Kauaʻi, including Kūhiō Highway between Hanalei and Wainiha; Kaumualiʻi Highway in Kekaha; Kūhiō Highway by Wailua River and Kapaʻa • Oʻahu District: portions of Farrington Highway on the Waiʻanae Coast; Kamehemaha Highway on the North Shore and Windward shore (Kualoa to Laʻie), Kalanianaʻole Highway in Waimānalo • Maui District: portions of Honoapiʻilani Highway in West Maui (Lahaina to Olowalu); North Kihei Road by Kealia Pond

Notes - More detailed information on locations of concern can be found in the on-line map viewer prepared to accompany this document
- Sea Level Rise summarizes infrastructure inundated directly by sea level rise or groundwater rise

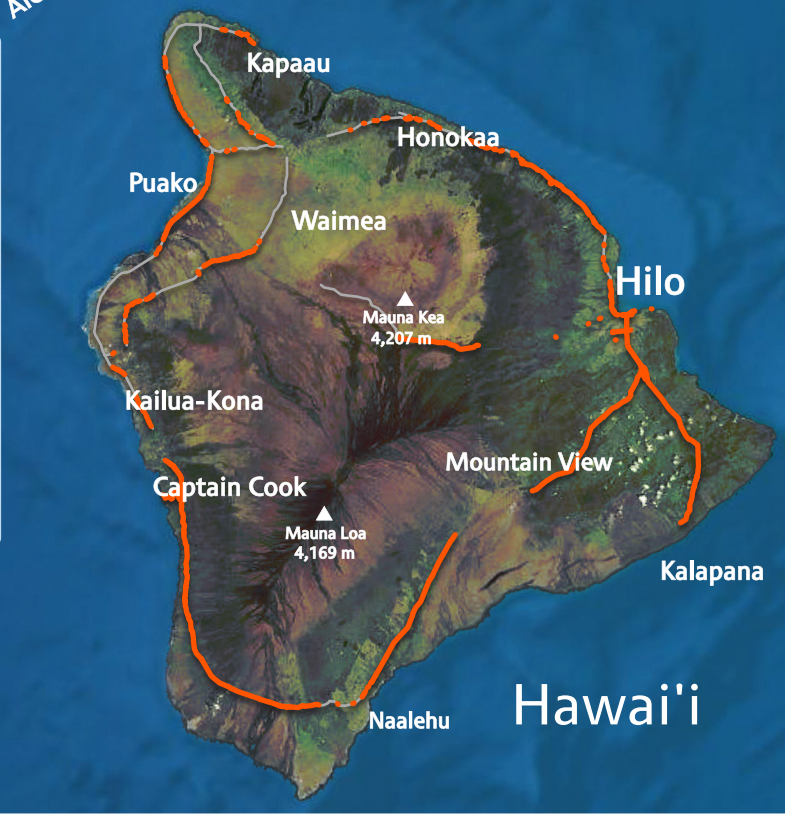
Source: State-Owned Roads: HDOT Highways Division, LRMS; Base maps: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community; World Ocean Reference: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors

CLIMATE STRESSOR	Storm surge
EXPOSURE ASSESSMENT	Segments exposed to storm surge due to hurricanes of Categories 1 through 4
ROADS EXPOSED [MILE]	74.1 miles
EXAMPLES OF EXPOSED AREAS	• Kauaʻi District: portions of North, West, and East Kauaʻi, including Kūhiō Highway between Hanalei and Wainiha; Kaumualiʻi Highway in Kekaha/ Waimea; Kūhiō Highway over Wailua River and through Kapaʻa • Oʻahu District: portions of Farrington Highway on the Waiʻanae Coast, Ewa Beach, areas of Kamehemaha Highway on the North Shore and Windward shore (Kualoa to Laʻie); Sand Island , Nimitz Highway, and Ala Moana Boulevard; Kalanianaʻole Highway through Hawaiʻi Kai • Maui District: portions of Honoapiʻilani Highway in West Maui (Olowalu to Pāpalaua); North Kihei Road by Kealia Pond; roads surrounding Kahului Harbor; portions of Kamehameha V Highway on south coast of Molokaʻi • Hawaiʻi District: roads along Hilo Bay and Kawaihae Harbor

CLIMATE STRESSOR	Tsunami
EXPOSURE ASSESSMENT	Segments exposed to historical (1946, 1952, 1957, 1960, and 1964) and hypothetical tsunamis (two great Aleutian earthquakes with moment magnitudes of 9.3 and 9.6)
ROADS EXPOSED [MILE]	178.1 miles
EXAMPLES OF EXPOSED AREAS	• Kauaʻi District: portions of North, West, and East Kauaʻi, including Kūhiō Highway between Hanalei and Hāʻena; Kaumualiʻi Highway in Kekaha/ Waimea; Kūhiō Highway over Wailua River and through Kapaʻa • Oʻahu District: most coastal roads of Oʻahu, including Kamehameha Highway and Farrington Highway; Sand Island , Nimitz Highway, and Ala Moana Boulevard; Kalanianaʻole Highway through Hawaiʻi Kai and Waimānalo • Maui District: roads in West and Central Maui, including Honoapiʻilani Highway and Hana Highway to Spreckelsville/Paia; Kamehameha V Highway on south coast of Molokaʻi • Hawaiʻi District: roads along Hilo Bay and Kawaihae Harbor

CLIMATE STRESSOR	Lava flow
EXPOSURE ASSESSMENT	Segments associated with lava flow hazard zones 1 through 3 on the Island of Hawaiʻi and zone 1 in the Maui District
ROADS EXPOSED [MILE]	151.8 miles
EXAMPLES OF EXPOSED AREAS	• Hawaiʻi District: portions of Māmalahoa Highway/Hawaiʻi Belt Road through Hilo, Puna, and Volcano area to Kailua-Kona; Queen Kaʻahumanu Highway and Māmalahoa Highway mauka of Waikoloa Village.

CLIMATE STRESSOR	Wildfire
EXPOSURE ASSESSMENT	Segments associated with 1-km2 areas where more than one wildfire ignition occurred between 2000 and 2012
ROADS EXPOSED [MILE]	139.2 miles
EXAMPLES OF EXPOSED AREAS	• Kauaʻi District: portions of Kūhiō Highway including Līhuʻe and Kapaʻa areas • Oʻahu District: Leeward Oʻahu, including Waiʻanae Coast, ʻEwa, Pearl City, urban Honolulu, as well as Wahiawā and Haleʻiwa • Maui District: roads in Kahului, Kīhei, and Lahaina areas • Hawaiʻi District: portions of Queen Kaʻahumanu Highway on the Kona Coast



LEGEND

- Highway Asset Exposed to Climate Hazard
- Highway Asset Not Exposed to Climate Hazard

1 Introduction

VISION

As a steward of the State's investment in the State Highway Network, the Highways Division for the Hawai'i Department of Transportation (HDOT) must plan for, respond to, and recover from disruptions, including those associated with extreme weather events. HDOT's policies, programs, and day-to-day operations must consider increases in the frequency and intensity of such events and, over the long-term, changing climatic conditions such as sea level rise, more frequent floods, increased rockfalls, and wildfires; and impacts to the public. HDOT recognizes this responsibility and will implement the recommendations in this Action Plan to meet climate change challenges. As a member of the State's Climate Commission and its Climate Ready Hawaii Initiative, HDOT will also support the Commission's efforts to develop climate change strategies that are "clean, equitable and resilient."

It should also be noted that HDOT's vision includes initiatives to reduce greenhouse gas emissions from both HDOT and from the public to limit contributions to changing climate conditions. Efforts to encourage the use of active transportation modes, autonomous vehicles, electric vehicle fleets, teleworking, and many others can help to reduce emissions that contribute to climate change.

PURPOSE OF THIS ACTION PLAN

The Hawai'i Highways Climate Adaptation Action Plan (Action Plan) provides a roadmap for HDOT's Highways Division to make the highway system more resilient to climate-related effects. It:

- identifies locations along the state highways that are exposed to natural hazards, and
- outlines strategies to be implemented and actions to be taken to incorporate resilience into its programs and policies.

This Action Plan prioritizes recommended actions that results in a multi-year Implementation Plan that encompasses all aspects of HDOT's core functions—funding, planning, designing, constructing, operating, maintaining, and protecting highway assets.

HDOT's vision is to develop and maintain a viable and resilient highway system for Hawai'i.

HDOT's mission is to provide a safe, efficient, accessible, and sustainable intermodal highway system that ensures the mobility of people and goods and enhances and/or preserves economic prosperity and the quality of life.

Kuhio Highway | Wainiha

Resilience is the ability to adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions. *(HDOT Highways Division Definition 12/20/2019)*

This Action Plan is a living document that will be updated periodically to reflect the following:

- Highways Division progress in incorporating climate adaptation and system resilience concepts and practices throughout the Division, and the corresponding performance of the highway network in response.
- New climate data produced by research institutions such as the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and the University of Hawai'i. HDOT is committed to adopting an adaptive management framework that continuously incorporates new and evolving information. This updated current and future climate information that may be helpful for transportation decisions can be reflected in the exposure assessments via the web map viewer.

WHO SHOULD READ THIS ACTION PLAN?

HDOT management and staff. This is the primary audience for the Action Plan. Importantly, the Action Plan highlights the branches in HDOT with primary responsibility for implementing the recommendations.

Federal, State, and local agencies and government leaders. HDOT relies on collaboration with other agencies and groups that participate in project/strategy development and implementation through such actions as providing funding, issuing permits and project approvals, and influencing public perceptions as part of building and operating critical infrastructure. The active participation of these agencies in implementing the Action Plan will be an important factor in its success. In addition HDOT will work with the Climate Commission to gain active participation of State and local agencies.

Other county, city, and local governmental agencies. As the Action Plan was developed, it became apparent that many county, city, and local agencies are interested in how HDOT's actions could affect their activities and how their actions might impact the activities of HDOT. It is therefore critical that active coordination occurs among these agencies as the recommended actions are implemented.

Citizens, businesses, and communities. Finally, given the everyday importance of the highway network to the entire State, the public is an important constituency for the Action Plan. They should be included in the regular communications of the actions that HDOT is undertaking on their behalf.

ACTION PLAN ORGANIZATION

The Action Plan is organized into the following sections:

- Section 2 provides the general context for the needs addressed by the Action Plan.
  - Section 2.2 outlines how decisions will need to be based on an understanding of future conditions.
  - Section 2.3 identifies the need for a proactive approach to managing risks to the system.
  - Section 2.4 includes examples of past natural hazard-related disruptions.
  - Section 2.5 lists the hazards considered in this Action Plan.
  - Section 2.6 recommends a collaborative strategy to achieve a resilient Hawai'i and HDOT's role
  - Section 2.7 discusses the importance of partnerships in achieving the goals of this Action Plan
- Section 3 identifies priority recommendations for implementing the Action Plan by different functional areas and responsibilities in HDOT
  - Section 3.1 Response and recovery
  - Section 3.2 Maintenance programs
  - Section 3.3 Data-driven decisions
  - Section 3.4 Design/mitigation
  - Section 3.5 Planning/programming
  - Section 2.6 HDOT leadership/resources
  - Section 3.7 Training
  - Section 3.8 Partnerships
- Section 4 Next steps
  - Section 4.1 outlines a process by which a scenario-driven risk method can be used to make
  - Section 4.2 describes the need for data specific to resilience decision-making that should become part of HDOT's program
- Appendix A summarizes the recommendations resulting from the Exposure Assessments
- Appendix B provides an overview of State, local, and Federal technical resources and guidance pertaining to climate change in Hawai'i
- Appendix C describes the role and organization of Environmental Offices in other State DOTs
- Appendix D provides more details on desired partnerships towards implementing the Action Plan

2 The Urgency: Why We Must Act and Change Current Practices

THE NEED FOR A RESILIENT HIGHWAY SYSTEM

HDOT is responsible for the condition and performance of approximately 971 (linear) miles of highways on 6 islands within the State. Just over 456 miles of this network is part of the National Highway System (NHS). The effective management of these NHS highways is a top priority for HDOT because of their vital contribution toward community access, economic prosperity, national security, and overall mobility (HDOT 2019a).

The configuration of the State Highway Network reflects the terrain and geography of the State. Belt roadways on low-lying coastal areas typically encircle each island, while steep central mountain ranges a few miles inland limit the number of cross-island routes. These roadways are critical for each island given the limited alternatives for accessing many island communities. Unfortunately, this configuration makes the highway network especially vulnerable to natural hazards. Shoreline change, coastal erosion, and storm surge compromise the State's coastal highways. In addition, the roadways that pass through mountainous terrain are susceptible to natural weathering, erosion, and rockfall where the volcanic rock slopes and cliffs have been excavated to construct the roadways.

Several recent extreme weather events have resulted in significant unanticipated impacts to Hawai'i's highways. The severity and increased frequency of these events are attributed to weather or climate change hazards that are not typically effectively addressed in traditional highway design methods. Applied design standards are based on the analysis of past conditions; however these are proving insufficient, as many states nationally are coping with unanticipated risks to safety and extensive damage to highway infrastructure. Traditional design standards will need to be adjusted to address the effects associated with climate changes and better reflect future risks to the highway system.

HDOT recognizes it is important to increase the resiliency of highway infrastructure by incorporating future climate change considerations into HDOT project design, operations, maintenance, and programming and budgeting. The intended result is improved infrastructure resilience to climate change hazards, reduced operation and maintenance costs, and reduced risk to public safety.

A FUTURE UNLIKE THE PAST

Climate change will result in environmental conditions that are different than those historically considered as a part of transportation project development and decision-making. Transportation planning and design, like most science-based technical disciplines, are dependent on research to develop best practices that often reflect how transportation facilities have responded to historic environmental conditions. Field measurements are made, summaries are created, statistical analyses are completed, and target levels are identified on which to make decisions (e.g. a 50-year storm event, etc.).

Climate change shifts the perspective from past conditions as the only predictor of the future, to forward-looking analyses that consider projections of how the future could be different. Adopting such a forward-looking perspective has proven to be one of the greatest challenges associated with changing standard practice in state transportation agencies.

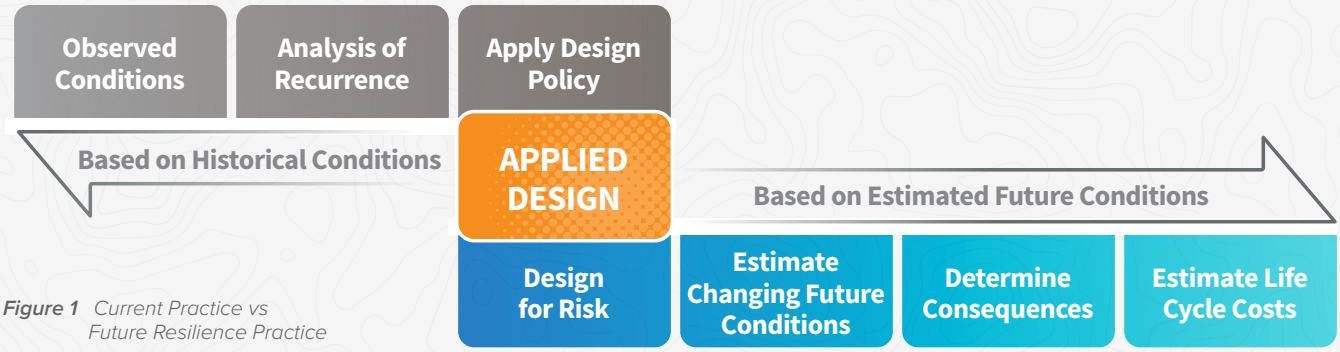


Figure 1 *Current Practice vs Future Resilience Practice*

Values of design input factors such as mean higher high water, precipitation return periods, seismic risks, landslide potential, and similar measures are determined directly from field observations and assessments of existing or past conditions.

Research efforts conducted through agencies such as NOAA, USGS, the Federal Highway Administration (FHWA), the Transportation Research Board, and the American Association of State Highway and Transportation Officials (AASHTO) or by HDOT and the University of Hawai'i contribute to the body of knowledge that supports project decision-making. However, climate change shifts the perspective from past conditions as the only predictor of the future, to forward-looking analyses that consider projections of how the future may be different. Adopting such a forward-looking perspective has proven to be one of the greatest challenges associated with changing standard practice in state transportation agencies. It represents a different approach, and there are many uncertainties associated with the projections of climate variables, and the strategies and designs developed in response need to be more flexible and adaptive to changing environmental conditions. Changing the perspective from one that is based on historic trends and analyses to one that is more oriented to projected changes is an important underlying theme of this Action Plan. The information contained in the Exposure Assessments report of this Action Plan outlines how future conditions are expected to be different from past conditions and thus provide a general basis to make future-oriented decisions.

Figure 1 illustrates the different perspective that is needed to lead to better and more adaptive investment decisions for transportation assets in Hawai'i. The three gray boxes leading into applied design identify how elements of risk are determined through current practices, looking backwards in time. In contrast, the colored boxes identify the steps toward incorporating a future-looking perspective. By addressing inherent uncertainties, such an adaptive approach can facilitate decisions that better consider how future conditions could affect an asset and its users, resulting in better and more resilient investments. The process for how this works at the project level is defined in Next Steps section of this Action Plan. Such a shift in approach is a critical capability, which is an underlying basis for much of this Action Plan.

A PROACTIVE PERSPECTIVE ON MITIGATING RISK

Several recent extreme weather events have resulted in significant impacts to Hawai'i's highway system, and in some cases, the resulting impacts caught HDOT unaware. This is partly because the impacts to highways were much greater than had been expected when the road was designed. It has not been common practice to examine future possible risks to above-normal extreme weather effects. However, providing resilient infrastructure that takes into consideration expected environmental conditions is becoming a greater concern throughout the country. HDOT recognizes that it does not have all the information it needs to adopt such an approach. Efforts undertaken by others and documented in this Action Plan present a positive first step, but more work is needed at a more refined level to identify where adaptation investments are most critical and what it will take to create a highway network that is resilient to the hazards that may affect Hawaii.

In this Action Plan, HDOT has committed to better defining the risks from extreme weather and climate change, develop the information it needs to be more proactive in its assessments, and take action to eliminate or reduce the impacts before they occur (Figure 2). A key element of this effort will be to take a closer look at conditions along the highway network and reduce or eliminate the unknowns and uncertainties associated with expected climate change-related hazards.

Such an effort will require a more extensive program to accurately define specific locations on the highway network that have considerable risk to climate change-related disruptions and that lead to proactive adaptation investment. The identification of some risks is currently being conducted by State partners, including the University of Hawai'i, which is identifying coastal risks at a more refined level, generating data that will be helpful for HDOT in making more fully informed decisions. Other required data could be generated through collaboration with other State and Federal partners. Field reviews and engineering assessments will also provide the necessary information required to assess the immediacy of risks/impacts and the timing for when potential impacts may need to be addressed in investment programs.

EXAMPLES OF PAST EVENTS

Past examples of extreme weather disruptions serve as a good reference to the type of impacts that could occur in the future, especially along the shoreline or in areas of lava flow. A record of past events is presented below as a reference. However, as noted earlier, it should be kept in mind that past events are not fully representative of the events or conditions that may be brought about by changing climate conditions.

COASTAL EROSION AND SHORELINE CHANGE

Coastal erosion and shoreline change are some of the most visible impacts associated with changing climatic conditions in Hawai‘i, especially when coupled with coastal development and shoreline hardening. It is estimated that 70% of the State’s beaches have a trend of chronic erosion (Fletcher et al 2012). Such incidents have been documented for years at multiple locations (Dalton 2020, University of Hawai‘i’ 2016). Sections along the Kamehameha Highway, a vital two-lane highway in Hau‘ula, have been affected by coastal erosion along O‘ahu’s Windward coast. This highway has experienced service disruptions at multiple locations due to erosion, most notably Ka‘a‘awa to the southeast of Hau‘ula (Figure 3) and the Laniākea area farther northwest on the North Shore. In 2015, the governor signed an Emergency Proclamation authorizing emergency repairs of the roadway at Ka‘a‘awa. More recently, HDOT earmarked a project to move the highway farther from the shoreline at Laniākea, and this stretch of highway has been identified as a top-20 priority site (Francis et al. 2019).

STORM SURGE AND HIGH WINDS

Storm surge resulting from tropical storms and hurricanes can exacerbate coastal erosion and cause serious damage to roads. Hurricane Iwa (1982), which passed just north of Ni‘ihau and Kaua‘i as a Category 2 tropical storm, and Hurricane Iniki (1992), which made landfall as a Category 4 storm on the southern shore of Kaua‘i, seriously damaged many parts of the State (Robertson 2015). More recently, Hurricane Iselle (2014), which made landfall as a tropical storm on the southeastern coast of Hawai‘i Island (Big Island), caused power outages and much damage to communities and supporting infrastructure. Category 5 Hurricane Lane (2018) weakened just as it approached the Hawaiian Islands and avoided a direct hit on the State. The Hawaiian Islands will likely experience more frequent tropical storms as ocean temperatures rise and hurricane tracks shift more northerly (Yamaguchi 2019).

Figure 2 *Risk Mitigation Approach*

In addition, the strong winds associated with hurricanes cause portions of buildings, telephone poles and trees/ foliage to fall and block roads. In many recent storm events, emergency crews could not reach damaged areas until the roads were cleared.

INTENSIVE PRECIPITATION, LANDSLIDES, ROCK-FALLS, DEBRIS FLOWS, AND INLAND FLOODING

Precipitation in the mauka and makai areas can cause flooding, landslides, and other geotechnical hazard events such as rockfalls and debris flows. In April 2018, heavy precipitation damaged Kūhiō Highway on Kaua‘i (Figure 4), and traffic was severely restricted for about a year while the roadway was reconstructed and stabilized. Other disruption examples occurred in a nearby area of Kalihiwai in northeast Kaua‘i. In separate occasions, in 2012 and 2018, a Kūhiō Highway stream crossing was re-routed because of high water flow. In February 2019, heavy precipitation caused multiple debris flows along the Pali Highway on O‘ahu. This event caused the closure of one of the entrances to the highway’s four tunnels, temporarily severing roadway

Figure 3 *Kamehameha Highway Repairs at Ka‘a‘awa, O‘ahu*

Figure 4 *2018 Landslides on Kūhiō Highway, North Shore* ***Kauaʻi***

connectivity between the major residential communities on the Windward side of the island and the major employment center in Downtown Honolulu on the other side of the mountain. Traffic operations did not return to normal for several months.

GROUNDWATER INUNDATION

The degradation of a road foundation by rising groundwater seriously impacts roadway integrity that is less visible to the traveling public than other natural hazards, requiring increased maintenance or premature replacement. Rising groundwater also limits the capacity of the land to absorb rainfall, increasing localized flooding. This groundwater inundation effect, sometimes identified first through recurrent high-tide flooding in low-lying areas, is already occurring. The most notable examples on the Island of Oʻahu have occurred in the Māpunapuna neighborhood mauka of the Nimitz Highway in the Honolulu International Airport area and in the Kapiʻolani Boulevard area mauka of Ala Moana Shopping Center. The flooding of the Mapunapuna area caused intrusion/backflow of seawater. At one time, this area had many fishponds, which were later filled in; intruding seawater has reclaimed some of the low areas.

Low-lying coastal highway areas experiencing repeated coastal erosion, such as areas along Kamehameha Highway on Oʻahu, are also susceptible to groundwater inundation or a gradual transition to wetlands that may not be immediately and readily observable (Habel et al 2020).

TSUNAMIS

Tsunamis generated by earthquakes remain a constant, albeit infrequent, threat to Hawaiʻi. Although infrequent, the consequences associated with tsunamis are significant. Two of the most famous and deadly tsunami events occurred in Hilo Bay on the Big Island in 1946 and 1960, completely reshaping the social and economic structure of Hilo, in addition to changing its land use and development patterns (Pacific Tsunami Museum 2020, State of Hawaiʻi 2019). Tsunami wave forces have the capacity to damage bridges and coastal roadways, eliminating access to communities.

WILDFIRES

Climate change is expected to result in some areas experiencing heavier precipitation, while others might become more prone to drier conditions, with each condition resulting in a greater risk of nature- and human-caused wildfires. In areas of heavier precipitation, vegetation growth encouraged by precipitation could act as fuel for future wildfires. In 2018, there were 627 wildfires in Hawaiʻi, which burned 32,386 acres of land (Pacific Fire Exchange. 2019). Fire ignitions tend to occur on the drier leeward side of islands, and they are most associated with population centers and the presence of roads and vehicles, which tend to contribute to the ignition of fires (Trauernicht 2016, Pacific Fire Exchange 2016).

LAVA FLOW

Volcanic eruption and lava flows are an infrequent but potentially devastating hazard in the State. Hawaiʻi Island (Big Island) is most prone to this disruption, with Kīlauea Volcano having erupted 34 times since 1952 (USGS 2020). In the most recent 2018 eruption, which lasted approximately 4 months (USGS 2019a), lava flows disrupted local roadways in the Puna area and cut off access to critical community assets such as schools, local commerce, and the only boat ramp in Puna. No State-owned roads were directly affected by the eruption, but county roads were affected. However, State highways did experience cracks in the pavement due to earthquake-related underground movement of lava and needed repair.

PAST REPAIR SITES

Figure 5 shows the locations of emergency or related HDOT projects from 1997 to January 2019 resulting from natural hazard impacts. These repair projects included both emergency and non-emergency actions needed on roads affected by weather-related events (HDOT 2019b). The repair projects typically resulted from severe storms, landslides, flooding, bridge/drainage, and shoreline erosion. Roughly 60 miles of the total 971 miles of the State's highway network are represented on this list of repair projects during this period. Also mapped are landslides co-located with HDOT highway assets and documented in the USGS National Landslide Inventory (USGS 2019b).

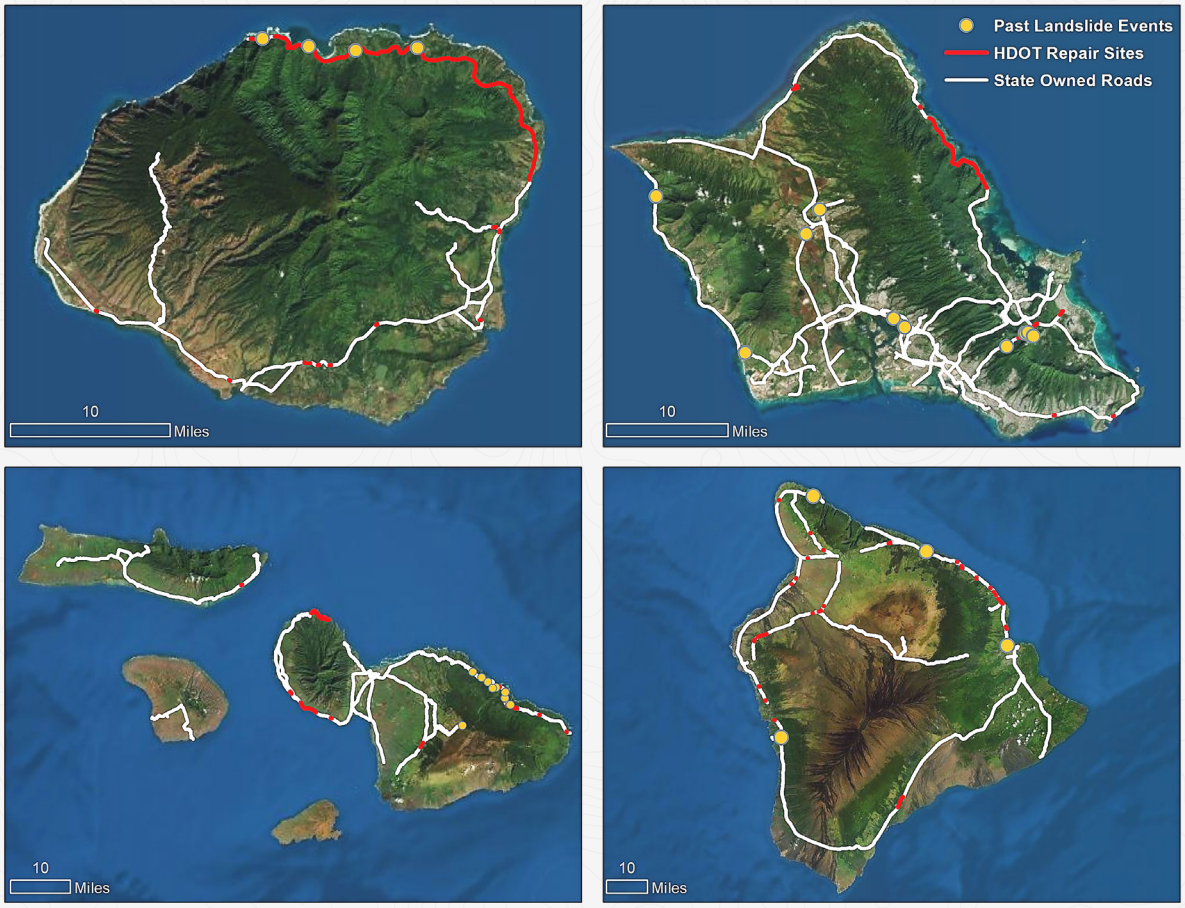


Figure 5 *Selected Repairs Sites on HDOT-Highways Roads Associated with Emergencies Since 1997 (clockwise from top left: Kaua'i County, City and County of Honolulu, Hawai'i County, and Maui County)*

Source: State-Owned Roads: HDOT Highways Division, LRMS; Base maps: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community; World Ocean Reference: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors

HAZARDS EXAMINED IN THIS ACTION PLAN

Understanding and proactively addressing how roads are exposed to climate-related hazards helps inform State agencies and communities about changing environmental conditions that may impact the performance of the highway system. The Exposure Assessment report describes where HDOT roads, bridges, culverts, and tunnels may be exposed to hazard events associated with changing climate conditions. The Exposure Assessment report builds on analyses undertaken to estimate future conditions by international (e.g., the Intergovernmental Panel on Climate Change), national (e.g., NOAA and USGS), and local researchers (e.g., the University of Hawai'i, HDOT). These overviews use the latest scientific data and analytical approaches available for each hazard specific to Hawai'i.

Table 1 shows the exposure assessments in this Action Plan and described in the Exposure Assessments document accompanying this Action Plan.

Each of the exposure assessment technical overviews provides the following:

- Information on previous works and existing data
- The methodology used for determining the exposure of assets to the hazard of interest
- The results of the application of the methodology, along with maps and charts to communicate the degree to which assets may be affected
- Recommendations for the HDOT
- Improvements to existing data and models to support the assessment of risk and resilience related to the State road system

Table 1 Exposure Assessments

Exposure Assessments	Hazards Examined
Climate-related exposure assessments	• Rockfalls and landslides • Sea Level Rise (marine flooding and groundwater inundation) • Annual high wave flooding • Coastal erosion • Storm surges • Tsunamis • Wildfires
Other exposure assessments	• Lava flows

Figure 6 *Assessment Steps Toward Prioritized Action*

MOVING TOWARD PRIORITIZED INVESTMENTS

This Action Plan identifies the primary climate hazards that are of a concern for HDOT assets. The Action Plan also identified an initial set of activities for HDOT to begin to incorporate climate change concerns into the highway work program. A critical element of this Action Plan is recognizing that risk should be the driving decision factor for where and when to invest HDOT dollars to increase the resilience of the highway system. HDOT's Highway's Division Mid-Range Plan (MRP) process is a good example of an opportunity to incorporate climate adaptation data and risk analysis into decision-making (Note that the MRP does not identify the projects themselves). The objectives of the MRP include the following:

- Better connecting the 20-year outlook of priorities and needs established by the long-range plans, the Highways Division programs, and the short-term 4-year outlook of projects identified for implementation by the Statewide Transportation Improvement Program
- Optimizing limited resources and funding in project selection to more efficiently and effectively address needs and priorities
- More effectively incorporating data-driven decision-making into project evaluation and selection

The MRP will evaluate projects against performance criteria established for each goal using a Multi- Objective Decision Analysis (MODA) process. As a tool for decision-making, MODA helps assess the effectiveness of projects across all Highways Division programs in meeting the Division's priorities, needs, and goals. It will help weigh tradeoffs of investment scenarios using a data-driven process and help ensure projects selected for implementation address the highest priorities and needs and make the most effective use of limited resources. The evaluation criteria will focus on the Highways Division goals, including safety, system preservation, modal integration, economic vitality, system efficiency, and resiliency, and will also incorporate considerations for project readiness, equity, and environment.

While this document is presented as an Action Plan, it is important to note that the Action Plan is not accompanied by the funding necessary to address all the concerns outlined in the assessments. Some actions–such as those to address near-term flooding from sea level rise in areas already experiencing rising water levels–can be implemented without additional analysis while others will require more detailed analysis to reach a conclusion on what risk is present and what adaptation action is most appropriate.

These actions often include data gathering and field surveys to confirm or clarify conditions assumed in this document or to assess the vulnerability of identified assets through a targeted stressor-damage assessment.

Figure 6 lays out a path for HDOT to develop a list of prioritized investments. The major phases can be summarized as follows:

- **EXPOSURE ASSESSMENT** determines which infrastructure assets could be exposed to a probable hazard event or a set of probable hazard events.
- **VULNERABILITY ASSESSMENT** determines how infrastructure assets may be impacted or fail with some probability.
- **RISK ASSESSMENT** estimates the cost of repairs or replacement associated with probable failures and can help prioritize interventions. It estimates the cost and time of the broader impacts associated with probable failures (e.g., societal impacts such as the consequences of lack of access the availability of alternative routes, and the number of people affected by closed roads).
- **RESILIENCE ASSESSMENT** determines the ability of the system to meet critical functions (e.g., (un)acceptable travel time to hospitals, etc. (un)acceptable delays in the delivery of critical supplies).

The type of large-scale geographic analysis conducted for the Exposure phase undertaken in this Action Plan does not provide enough detail to lead to a capital program. The next phases of work for HDOT–Vulnerability and Risk–would need to occur to get to a point that leads to program action. More information is needed to determine the most pressing needs and the most cost-effective design and investment responses. HDOT will need to undertake more detailed site assessments to be able to understand at a finer level of detail whether the findings of this higher-level technical analysis match what is found in the field at those locations.

PARTNERSHIPS IN IMPLEMENTATION

The Action Plan recognizes that preparing and responding effectively to the risks of climate change requires collaboration among a wide range of public and private interests. For example, there is a mutually reinforcing interconnectedness among Federal and State laws and local ordinances that form the basis for a state-level climate adaptation policy. For HDOT to implement this Action Plan,

collaborative and coordinated partnerships will be necessary for creating a resilient Hawai‘i. One way to highlight how changing climate conditions will require effective partnerships is to envision a Hawai‘i with sea levels that are much higher than today. Certainly, many of HDOT’s roads will be impacted, but so too will many other community assets. For example, residential or commercial buildings might need to be elevated or moved to higher ground, and communities might need to find ways to accommodate existing and future community resources within more land constraints.

It should be noted that on September 15, 2020, the Legislature passed HB2486 HD2 SD2, an Act that gives the State Office of Planning the responsibility to coordinate State climate change efforts with attention to sea level rise. To be an effective partner with the Office of Planning, HDOT will need to have the organizational capabilities to understand the implications of climate change on the State’s highway system. The Office of Planning will clearly be an important partner in implementing HDOT’s climate change strategy. In addition, HDOT collaboration with utility companies, the Transportation Environmental Resource Council (TERC), and other State and county partners will be an important factor for success.

The TERC – as an assembled body of county, state and federal agencies in Hawaii that discuss state transportation decisions and environmental considerations – will be a good avenue to work collaboratively towards implementation.

In addition, the State’s Climate Commission has a mandate to provide an overarching and interdepartmental collaboration role among State agencies and local governments. As noted in the Commission’s enabling statute, HRS 225P-3, the Commission “shall establish climate change mitigation and adaptation strategies and goals to help guide planning and implementation statewide using the latest scientific analysis and risk assessment to monitor and forecast climate change related impacts at the regional, state, and local level, including any additional information deemed necessary.” As a member of the Commission, HDOT will work collaboratively on efforts to make sure its efforts and those of others are coordinated and targeted at meeting the goal of a more resilient transportation system and of more resilient communities.

As Hawai‘i grows over the coming decades it seems likely that this growth will have to be accommodated in sustainable and resilient ways. Hundreds, if not thousands, of assets are close to the shoreline that might be impacted by rising sea levels. The public and private agreements that led to much of this development might need to be revisited, and certainly new development decisions should follow a different framework for decision-making–one that recognizes the risks of a very different future.

Some of the questions facing HDOT, just relating to sea level rise alone, include the following:

- Do we continue to maintain roadways near the shoreline where damage continues to occur?
- Do we armor the shoreline to protect roadways, recognizing that this will likely cause loss of adjacent beaches?
- How do we create more resilient infrastructure recognizing that such decisions could expand the footprint of the facilities and increase the impact on sensitive environmental and cultural features?
- In areas where assets are most at risk:
  - Do we relocate them given existing development, natural areas, and sensitive cultural areas that have occurred based on the existence of these assets?
  - Do we continue to maintain, or how long do we maintain, transportation facilities in areas where communities are facing threats from long-term sea level rise?
  - Are there other types of non-highway adaptation strategies that could be considered?
- How should transportation services and highway accessibility be provided in support of development decisions that are made considering long-term climate change impacts?

This list of example concerns is not comprehensive for shoreline concerns nor does it extend to the increasing risks from other climate change threats outlined in this Action Plan. These questions simply highlight the many challenges facing infrastructure agencies throughout Hawai‘i.

HDOT’s vision is to develop and maintain a viable and resilient ground highway system for Hawai‘i. The decisions relating to this vision cannot be made without effective partnerships with many others. Figure 7 shows conceptually how partnerships among various agencies and organizations in Hawai‘i can work to ensure a more resilient future. The figure is not comprehensive nor prescriptive for the institutional relationships that will lead to success. It does suggest, however, that HDOT’s success in climate adaptation depends on such coordination and collaboration. As a steward of the State Highway network, HDOT recognizes this is the way forward and accepts its role. Recommendations relating to partnerships and strengthening institutional relationships are provided in the following Section 3, Implementation Plan.

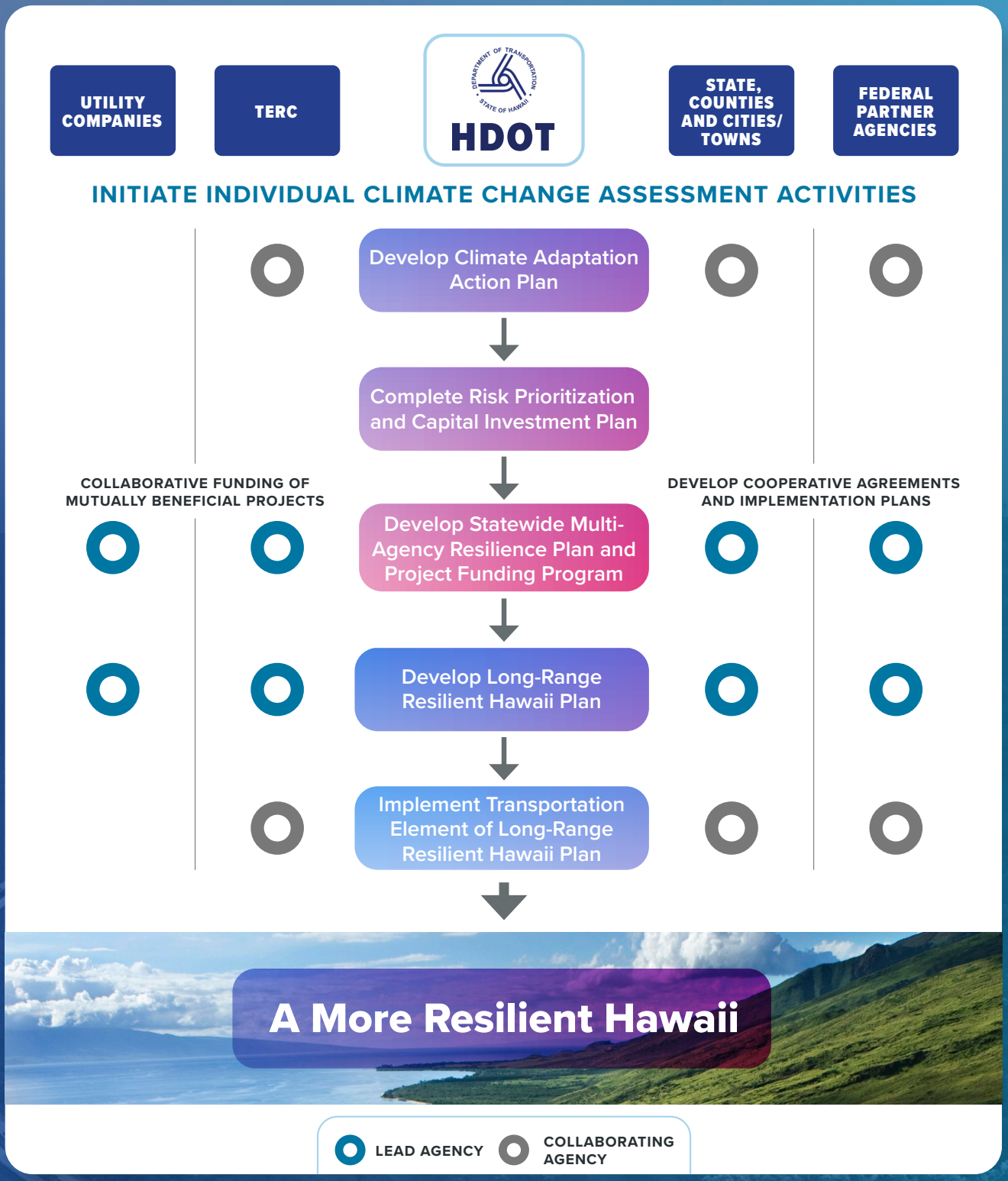


Figure 7 *Conceptual Collaboration Framework for Implementation*

3 Implementation Plan

Climate change imposes a pressing need for change, not only in the types of projects and actions undertaken by state departments of transportation (DOTs), but also in how these agencies conduct their business. The need for change largely reflects the fact that, as noted before, many of the project development decisions today are based on assumptions that historical trends in environmental conditions will remain stable over time. However, the reality of climate change is that many of these conditions may change, and some may be dramatically different than estimated by traditional forecasting methods.

HDOT through this Action Plan has taken the first steps in recognizing this future reality. The actions that follow focus on the important changes HDOT should make to enhance its capacity in developing a more resilient State Highway Network. These recommended changes reflect not only the areas for which HDOT should undertake these changes, but also a recognition that not all changes can or should occur at the same time. Not only do some actions depend on the implementation of earlier steps, but also that successful organizational change often needs to be phased over time in order to build the internal support and external constituencies to support desired change.

The following actions were developed after interviews with HDOT officials responsible for a wide range of functions, limited discussions with representatives of key stakeholder agencies in 2019 and 2020, and a review of existing HDOT plans and guidance documents. Each action below is accompanied by a rating of the level of effort required for implementation—low, medium, and high. These ratings reflect factors such as the need for organizational change, additional budget and/or administrative budget, and the estimated time needed for the change to occur.

RESPONSE AND RECOVERY

ASSESS EMERGENCY RESPONSE CAPABILITIES CONSIDERING CHANGING INSTITUTIONAL RELATIONSHIPS

HDOT has a good reputation for responding to disruptions, despite the often-limited road capacity for diverting traffic around bottleneck points. HDOT has established effective and mutually respected partnerships with emergency management and response agencies, including those at the county and local levels. HDOT will ensure that as counties update their emergency response plans, HDOT will participate as a partner and that its roles and responsibilities are clearly articulated in these plans.

Rating of Implementation Effort: Low.

UPDATE POLICIES AND PROCEDURES FOR HDOT STAFF DURING EMERGENCY SITUATIONS

HDOT will ensure in-house staff are aware of their roles and responsibilities in emergency situations, for example, defining an “emergency worker” more clearly and consistently across the agency. HDOT staff training will include acknowledgment from HDOT leadership that such skills and a knowledge base are essential to the fulfillment of HDOT’s mission. Such an acknowledgment must be reaffirmed when new leadership joins the agency to ensure continuity over time.

Rating of Implementation Effort: Low

ENHANCE EMERGENCY RESPONSE AND RECOVERY DECISION SUPPORT STRUCTURE

HDOT will ensure that the resources necessary for rapid and effective response to disruptions are available and tested for adequacy on each island. This action includes examining the procurement process to address short-term resource needs through contracts and working closely with county and local governments, who also have similar contracts, to improve

emergency response. This action also includes improving the reliability of communications technology during emergencies and incident management coordination tools.
Rating of Implementation Effort: Medium

PROVIDE TECHNICAL CAPABILITY TO CONSIDER BETTERMENT REQUESTS AS PART OF FHWA EMERGENCY RELIEF GRANTS

FHWA has allowed for the use of emergency relief funds to consider climate adaptation and system resilience in projects that are focused on repairing or replacing highway assets that have been damaged by extreme weather. Betterment design strategies have been considered on HDOT grant applications in the past (e.g., the Kaua'i emergency repair project in 2018). To consider betterment requests, FHWA requires a benefit-cost analysis that shows the cost effectiveness of using such designs. HDOT will adopt guidance to provide direction on how such an analysis can be done consistently and credibly for different types of disruptions. This action also relates to the collection of data on costs and actions taken under an emergency declaration for which Federal reimbursement is desired.
Rating of Implementation Effort: Low

MAINTENANCE PROGRAMS

ENSURE THAT MAINTENANCE AND INSPECTION DATABASES ARE STRUCTURED CONSISTENTLY TO FEED INTO FUTURE DECISION-MAKING

Evidence from other states suggests that the standardized collection of maintenance and inspection data is an important step to understand the specifics and costs of past failures, identify highway assets that are at risk of future failures, and value climate adaptation and system resilience measures. This recommendation also includes tying the database established as part of HDOT efforts to the federally required collection of data on facilities repeatedly requiring repair and reconstruction due to emergency events (23 Code of Federal Regulations 667, see Appendix B). In addition to consistently collecting this information, HDOT will use this data to inform future climate-related assessments through development of estimates of future lifecycle costs for all projects. This information should be incorporated into the Asset Management database as a common platform for agency decisions.
Rating of Implementation Effort: Low

DATA-DRIVEN DECISIONS

INVEST IN USER-FRIENDLY, MODERN TECHNOLOGIES FOR DATA COLLECTION AND ANALYSIS

HDOT will continue to explore the application of new technologies to collect and analyze the data necessary to achieve and monitor system resilience. Such use may include drones for monitoring hard-to-access locations, use of real-time monitors for shifting slopes, and use of computer tablets for field inspection and maintenance to collect data more readily on such things as the condition of culverts and the surrounding terrain. Furthermore, the ability to analyze quantitative and qualitative data in electronic format about past events and existing site conditions will support future climate-related assessments.
Rating of Implementation Effort: Medium

PROVIDE DATA- AND EVIDENCE-DRIVEN FOUNDATION FOR HDOT'S DECISION-MAKING PROCESSES

Decisions at HDOT relating to climate adaptation and system resilience will be based on evidence of current problems and projections of future problem areas. The Exposure Assessments document contains a preliminary identification of climate-related hazards to the highway network. These studies provide the foundation for future work focused on determining the socioeconomic impacts of probable climate-related hazard events. Collecting and generating additional data specific to the understanding of probable consequences will be critical activities to effective decision-making.
Rating of Implementation Effort: Medium

DESIGN/MITIGATION

FOLLOW AN ADAPTIVE DESIGN PROCESS FOR PROJECTS EXPOSED TO CLIMATE-RELATED HAZARDS

In addition to developing additional policies, procedures, and standards to integrate seamlessly into design, HDOT's formal design methods and guidelines used in highway project development will be adapted to support the evaluation of climate adaptation and system resilience measures. To that end, the FHWA-supported Adaptation Decision-making Assessment Process (ADAP) (FHWA 2017) and other similar processes will be considered. A good example of a resilience measure is the ongoing replacement of a bridge substructure in Kaua'i to withstand a tsunami and a bridge deck that can be easily and expeditiously replaced if damaged by a tsunami.
Rating of Implementation Effort: Medium

CONSIDER CLIMATE CHANGE IN TECHNICAL AND PROCESS GUIDANCE

The incorporation of climate adaptation and system resilience concepts into HDOT's mission, policies, and plans will be reinforced with proactive guidance from top leadership and unit managers on the importance of such consideration in HDOT's day-to-day actions and the need to update standard operating procedures that guide the agency's technical activities. Guidance processes need to be clear, specific, and tangible to allow for the Design Branch and Districts to implement climate change policies and program goals. For example, project development guidelines need to be clear on points of entry for adding resilience features during project designs for new assets and repairs to existing assets, outlining methods to measure cost effectiveness.
Rating of Implementation Effort: Medium

AMEND INTERNAL MANUALS TO STREAMLINE PROCEDURES RELATED TO DEVELOPING ADAPTIVE PROJECT DESIGNS AND OPERATIONAL STRATEGIES

HDOT's Project Development Manual includes procedures related to project development, including design, advertising, and awarding construction contracts, that require more information to help HDOT managers, planners, engineers, and consultants consider climate change. HDOT will review the manual relative to national design guidance for the types of climate-related hazards facing Hawai'i. Existing guidance includes AASHTO's guide specifications on drainage (AASHTO 2014), coastal bridges (AASHTO 2008), and flooding (FHWA 2016), the anticipated AASHTO guide specifications on tsunamis, and FHWA's Hydraulic Engineering Circular (HEC)-17 (FHWA 2016) on hydraulic design standards and HEC-25 (FHWA 2014) on coastal project design. Several studies have been prepared for the State that also provide important input into design decisions (Tetra Tech 2017). In addition to the project development guidance, HDOT will examine how the Transportation Asset Management Plan (TAMP) can be linked to the changing environmental conditions relating to climate change and thus reflect the need for more adaptive design processes.

Given that HDOT roads are interconnected with county roads, such guidance will also ensure that different agencies design to the same criteria. Such interjurisdictional interaction will require additional interagency coordination. Program guidance and policies will also be established for what types of projects are candidates for climate adaptation considerations.
Rating of Implementation Effort: Medium

Landslide damage | Pali Highway | 2020

CONDUCT A PILOT STUDY ON THE USE OF AN ADAPTIVE DESIGN PROCESS

Several states and the FHWA conduct pilot studies to show how new analysis/design approaches, use of data, and design strategies considered can be integrated into an agency's standard procedures (Colorado DOT 2017). HDOT will identify a project where such a pilot study can be conducted. The pilot study should focus on evolving adaptive design practices such as that represented by ADAP, and the use of design guidance from the FHWA, such as HEC-17 and HEC-25.

The results of the pilot study can then inform the adoption of an adaptive design process for projects that are at risk of climate-related hazards.
Rating of Implementation Effort: Medium

PLANNING/PROGRAMMING

DEVELOP OR AMEND PROGRAMMATIC AGREEMENTS, PARTICULARLY THOSE THAT IMPROVE EFFICIENCY IN ENVIRONMENTAL REVIEW PROCESSES, AS THEY REFLECT CHANGING FUTURE ENVIRONMENTAL CONDITIONS

HDOT will evaluate current programmatic agreements, identify and establish new goals as related to climate change, and revise the current agreements to better address climate change. HDOT activities that can benefit from programmatic agreements range from large-scale corridor planning studies with many unknown variables, to smaller site-specific actions that have elements often repeated in other projects (e.g., bridge replacement and road rehabilitation). Establishing clear programmatic agreements or further streamlining and making the existing review processes consistent for the following permits and approvals will become increasingly important as the agency implements climate adaptation and system resilience projects:

- Clean Water Act permits from the U.S. Army Corps of Engineers and the Hawai'i Department of Health on the use of pre-approved best management practices to protect in-stream water quality
- The environmental impact rules were amended in 2019 to include future SLR projections in the adverse effects assessment. HDOT will comply with the State guidelines and any changes to the National Environmental Policy Act (NEPA) or related regulations.
- Floodplain certifications from the Department of Land and Natural Resources on project impacts involving shoreline changes resulting from sea level rise
- Special management area permits, shoreline setback variances, and shoreline certifications with local county governments
- Historic Properties reviews and consultations with the State Historic Preservation Officer under the National Historic Preservation Act Section 106 and the State Historic Preservation Division under Hawai'i Revised Statutes Chapter 6E
- Protected Species/Endangered Species Act Section 7/ Essential Fish Habitat coordination with the U.S. Fish and Wildlife Service and National Marine Fisheries Service

- Land Use/Conservation District Use coordination with the Department of Land and Natural Resources Office of Conservation and Coastal Lands

Rating of Implementation Effort: Medium

EXPLICITLY RECOGNIZE IN POLICY AND PLANS THAT CLIMATE-RELATED EFFECTS ARE A SIGNIFICANT CHALLENGE

HDOT will incorporate climate adaptation and system resilience explicitly into its mission statement, policies, and transportation plans. HDOT's risk-based TAMP describes the approach HDOT is taking toward considering the probable consequences of hazard events in decision-making. Updates of this Action Plan will include anticipated advancements to address climate change. Other plans that should be targeted for climate change sections when updated include the Statewide Multimodal Transportation Plan, Statewide Surface Transportation Plan, and any corridor/subarea studies sponsored by HDOT.

Rating of Implementation Effort: Medium

HDOT LEAD/RESOURCES

ESTABLISH CLEAR AUTHORITY AND RESPONSIBILITY FOR CLIMATE ADAPTATION AND SYSTEM RESILIENCE WITHIN HDOT

The responsibility for guiding the implementation of the Action Plan and the overall agency climate adaptation and system resilience initiative (policy) will be assigned to an individual manager or to a leadership committee. This responsibility has been similarly assigned in other state DOTs. An assigned responsibility provides direction for actions that must be taken, a location for answering questions on what and how efforts must be taken, and a central accountability for monitoring the progress being made in implementing the Action Plan.

Rating of Implementation Effort: Medium

CREATE AN ENVIRONMENTAL OFFICE, AT THE BRANCH LEVEL OR HIGHER, THAT HAS BROAD RESPONSIBILITY FOR HDOT'S ENVIRONMENTAL, CLIMATE ADAPTATION, AND SYSTEM RESILIENCE EFFORTS

This action can be linked to the previous one in that the new office may be given the responsibility for climate adaptation and system resilience efforts at HDOT. The intent is to create a center of responsibility and capability within HDOT for environmental analysis and interaction with Federal and State environmental resource agencies. Part of this capability is having a new geographic information system (GIS) position in the unit with responsibility for conducting GIS-related analyses. This unit will consolidate the current activities in project-specific environmental reviews and stormwater management and provide guidance on climate adaptation and system resilience in long-term planning projects. Oversight of the climate adaptation program will include administration of climate data for project applications, conduct of climate risk and resilience assessments for projects, and coordination with environmental agencies to obtain approvals on adaptation strategies. See Appendix C for a brief introduction to HDOT's current environmental capabilities and information on how other states structure their environmental analysis responsibility.

Rating of Implementation Effort: High

HIRE STAFF TO LEAD THE AGENCY'S SYSTEM RESILIENCE EFFORT

The implementation of many actions in this Action Plan requires agency staff in leadership and support roles. HDOT will make a business case for the hiring of new staff dedicated to climate adaptation and system resilience by identifying the socioeconomic benefits of a resilient highway system. This effort will require consideration of how to make employment opportunities at HDOT competitive with other options, including working for Federal agencies or the private sector. Making such a case will consider that (1) staff levels in HDOT have been reduced over the past several years; (2) there is a shortage of engineers and planners in Hawai'i ; and (3) government positions, on average, offer lower salaries than those in the Federal government and in the private sector.

Rating of Implementation Effort: Medium

CREATE A HIGHWAY SYSTEM RESILIENCE FUNDING PROGRAM

One of the most important factors supporting an agency's adaptation program is having the funds available to support the planning, design, and construction of project and/or implementation of strategies. The State of Hawai'i and HDOT need to be prepared with funding capacity to implement a climate adaptation program without competing with funds for projects undertaken for other purposes such as safety. Potential sources for this funding include the following:

- State funds made available through new State legislation targeting resilience needs. The State of California has passed similar legislation. HDOT can make the case for such funding legislation based on known needs, including those outlined in this Action Plan.
- Existing Federal competitive grant programs to help states develop the capability of undertaking adaptation efforts, as noted in Appendix B. Funds administered by the FHWA and FEMA's Building Resilient Infrastructure and Communities (BRIC) program are particularly applicable for the highway network.
- Future (potential) Federal transportation funding programs. Draft Federal transportation legislation currently includes funds dedicated to system resilience, particularly climate change adaptation projects. It is also probable that the Federal funds likely to flow through this program will have to be matched with State funds, demonstrating partnerships with other stakeholders and creating a larger potential pool of funding.

The use of funding would be varied and could be applied for projects ranging from those making incremental changes on a broad resilience issue, to others where projects are completed solely to address specific resilience concerns. Efforts could include many of the strategies outlined in this Action Plan, from internal change within the agency, to data collection/generation, to effective project planning, design, and construction. One example of the use of funding would be a project undertaken primarily to replace a bridge deck due to asset condition reasons that could–with the use of the adaptation funds–also investigate and implement improvements to drainage or landscaping features that would protect the bridge from future flooding or wildfires.

Rating of Implementation Effort: High

TRAINING

PROVIDE A COMPREHENSIVE AND CROSS-AGENCY STAFF TRAINING OF THE DIFFERENT COMPONENTS OF HDOT'S CLIMATE ADAPTATION AND SYSTEM RESILIENCE EFFORTS

HDOT will develop training materials on climate adaptation and system resilience to educate its staff on best practices and methods for anticipating and addressing climate-related effects. Topics of such training could include: (1) overall understanding of these climate-related effects and methods for incorporating resilience throughout agency practice; (2) incremental actions and strategies to improve system resilience; (3) job-specific and relevant training on resilience approaches; (4) strategies for better integrating planning and design/engineering in terms of adaptation strategies; and (5) existing and new internal policies and practices that may impact agency actions. The TERC would be a good tool for fostering a common interagency understanding through this training effort, or associated training, due to its cross-disciplinary approach. This training should also be offered to local planning agencies and city/local governments with interest in climate change risks.

Rating of Implementation Effort: Low

PARTNERSHIPS

COLLABORATIVELY DEVELOP IMPLEMENTATION PLANS FOR STATEWIDE CLIMATE ADAPTATION STRATEGIES

This action recognizes HDOT's unique position in State government relating to project development and program management and established ties to State and local leaders. A climate adaptation strategy for the highway system must cover many sectors and encompass a whole-of-government approach to creating the funding and political support for preparing the State for all possible future climate-related effects. This action will include working with other State agencies to assess the capital needs for adapting infrastructure to climate change, including the State's Office of Planning, which is the lead agency for coordinating a statewide response to climate change adaptation and sustainability; and within HDOT among all the units, including with the Office of Statewide Transportation Planning (STP). Because of its large amount of physical assets and experience with infrastructure project implementation, HDOT can be an effective catalyst for establishing the institutional and funding structures to support an Action Plan to implement a statewide climate adaptation strategy.

Rating of Implementation Effort: Medium

REINFORCE CURRENT RELATIONSHIPS WITH KEY AGENCIES AND OTHER PARTNERS THAT ARE CRITICAL IN IMPLEMENTING THIS ACTION PLAN

The participation of other agencies or groups will be required for the successful implementation of this Action Plan. HDOT will prioritize the dialogue concerning this Action Plan and climate considerations with multiple stakeholders, including funding agencies (such as FEMA and FHWA), agencies responsible for land use policy, regulatory agencies, researchers, utility companies, and regulatory agencies. For a description of stakeholders and their relevance to HDOT, please see Appendix D.

Rating of Implementation Effort: Low

ACKNOWLEDGE HDOT'S CRITICAL ROLE IN CLIMATE ADAPTATION

HDOT will continue to play an active role in State efforts to prepare for future climate-related disruptions. Given its mandate to provide and preserve the State's highway network—one of the most important networks to the State that affects the lives of every citizen—HDOT is in a unique position to move the State in a more active and engaged strategy in climate adaptation. HDOT will foster better public awareness of the climate adaptation challenges being faced—economic loss, community disruption, impacts on trade and tourism, and health and safety, among others—and serve as a role model for other agencies. This awareness will be accomplished through public education efforts; leadership in State, county, and local collaborations; formal agreements with partner agencies; and positioning the agency with State legislators and key State officials as a source of information on the climate adaptation challenges facing the State. This role will also include continuing to participate actively in the State's Climate Change Mitigation and Adaptation Commission, other activities of the State's Office of Planning, the City and County of Honolulu's Climate Change Commission, and similar efforts in other counties.

Rating of Implementation Effort: Low

Old Pali Road repair above Pali Highway | Oahu | 2019

Pali Highway Emergency Repairs landslide | Oahu | 2019

4 Next Steps

INVESTING FOR EFFECTIVE DESIGN WHEN CONSIDERING CLIMATE CHANGE

As noted throughout this Action Plan, climate change introduces a few key concepts that need to be considered as a part of effective decision-making, including the following:

- A future that is unlike the past
- A future with conditions that are uncertain
- A need to consider how future conditions may impact a transportation asset
- Considerations of how impacts to a transportation asset may affect system users.

Such considerations as shown in Figure 8 are particularly pressing in Hawai'i as the highway system is limited in extent, and its use continues to grow as the population grows and the number of visitors continues to increase.

HDOT is moving forward as a part of this Action Plan with the implementation of a robust decision-making process on future projects that incorporate future uncertainties to ensure that all investments are effective and well informed. This approach is different than the way decisions were made in the past and presents a more robust framework for decision-making when considering future environmental conditions.

One possible approach is found in the Adaptation Decision-Making Assessment Process (ADAP). ADAP was originally developed by FHWA over the last decade as part of its research into effective decision-making when considering climate change for transportation projects. It introduces key dialogue points critical to effective decision-making, including data uncertainty, asset damage, consequences associated with impacts, and system effects. One key element of the process is that it introduces a broader conversation on risk and risk tolerance than that typically implemented through design criteria methods which apply design criteria without the more in-depth assessment.

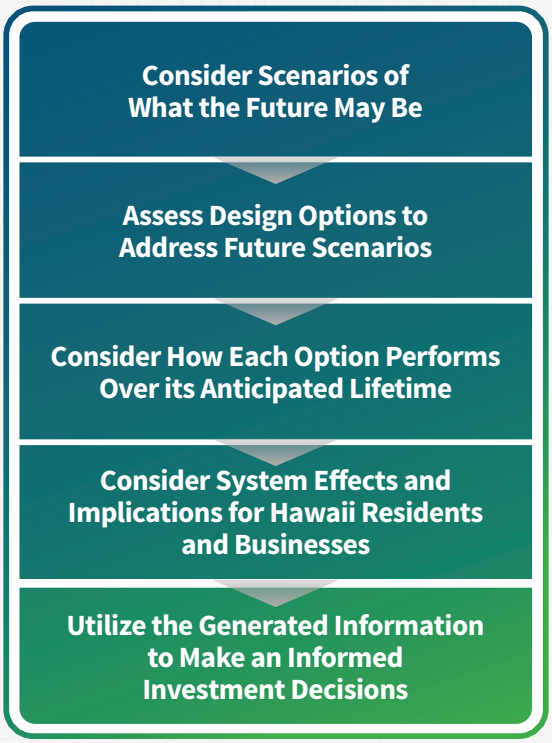


Figure 8 *Resilient Design Process*

Hauula Shoreline Repairs | 2020

This approach is different from what currently occurs and would require training and support to implement widely throughout HDOT. However, the elements that are embedded into the process are familiar to anyone that works in the transportation sector and are therefore considered to be not overly burdensome or costly to implement. The full and robust outputs of this process would ensure that all future projects are built with a consideration of a wide range of critical information that are important for effectively enhancing system resilience.

A DATA-DRIVEN RESILIENCE PROGRAM

Data collection efforts conducted at HDOT today support specific agency activities, some required by Federal regulation. These include condition inventory activities relating to asset management efforts, data on system usage to support traffic management activities, and data on asset condition to support funding needs estimates for future investment. As resilience has grown to be a significant concern nationally, there has been an accompanying interest in gathering or generating the data required for effective transportation decisions while recognizing that much of the data specific to this need does not currently exist and needs to be collected or generated.

Many of the efforts relating to resilience assessment nationally have used available data. However, these measures have had limited effectiveness, are not well correlated to expected future environmental conditions, and can sometimes obfuscate the underlying concerns related to climate change. The basic question of resilience decision-making regarding data can be captured in a few primary concerns, as noted in Figure 9.

Data needs for these three elements include the following:

Hazards:

- What is the extent and timing of changes expected to occur? What levels may be achieved and how do they interact with HDOT assets?

Damage:

- How could the stressor levels identified cause damage to HDOT assets and increase maintenance/repair replacement costs?

User Impacts:

- What could be the impacts to users? How long would the asset be out of service to address repair or replacement needs? Are there alternative routes and does the system have the capacity to handle the additional traffic?

Generating this hazard data at the level of specificity needed will require data-collection efforts to determine potential for impacts (e.g., future rainfall flooding that includes changing precipitation conditions). Potential damage assessments to assets will need data on pavement depth, bridge components or other elements, or a database of estimated hazard-damage functions for assets specific to the HDOT network. User impact assessments can be analyzed in several ways through traffic delay estimates or using tools such as a travel demand forecasting model.

The benefits of a data-driven decision system is that it is directly relatable to practitioners working at HDOT, critical to resilience decision-making and, when combined with economic valuations, enable determinations of no-build or build valuations that can help to make the case for resilience investment in ways that are largely unimpeachable. Such information could be used to make the case for required funding, or as critical information required for FHWA Emergency Relief (ER) processes.

Figure 9 *Concerns to be Addressed Through Data Assembly/Development*

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HAWAII HIGHWAYS
Climate Adaptation Action Plan

HAWAI'I DEPARTMENT OF TRANSPORTATION
HIGHWAYS DIVISION

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HAWAII HIGHWAYS
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APPENDICES

April, 2021

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APPENDIX A. LIST OF RECOMMENDATIONS FROM THE EXPOSURE ASSESSMENTS

The following list of 36 recommendations can be found in the Exposure Assessments document that is included as one of the plan documents. These recommendations are organized by chapter (i.e., Section A.1 in this appendix is Chapter 1 in the Exposure Assessments. Please refer to that document for additional context.

A.1 ASSET INVENTORY

- **Recommendation A.1-1.** Future work should consider improving the asset inventory by integrating other assets such as (1) culverts with span length of less than 20 feet, which may be obtained from stormwater management systems [e.g., HDOT (no date), HDOT (2020)], and (2) county assets in the inventory to assess the overall performance of the road network. The asset inventory may be further improved by including dual carriageways not represented in the Highway Performance Monitoring System (HPMS) dataset used in this study, and spatially capturing the correct location and length along the road of bridges, culverts, and tunnels.
- **Recommendation A.1-2.** Future work should consider the use of the point cloud data accessible through HDOT's Roadview Explorer (Mandli Communications, 2020). These data have the accuracy required to precisely locate the relative position and elevation of assets and asset components (e.g., bridge deck) and determine their geometries. This information can enhance HDOT's capabilities to determine the level of exposure of assets and their vulnerability, including those of specific asset components, to hazard loads.
- **Recommendation A.1-3.** Future work should also be focused on determining a suitable data exchange method to automate the consumption of the results of the exposure assessments by other HDOT information systems, some of which may use these results in posterior analyses.
- **Recommendation A.1-4.** Approximately 40% of the State road network is without 1-meter Digital Elevation Model (DEM) coverage. This part of the network plays a critical role in the connectivity of coastal communities and in the redundancy of the entire road network. Therefore, expanding the coverage of the 1-meter resolution DEM would establish a continuity of statewide elevation data and would improve the elevation characterization of those HDOT assets as well as the assessment of hazards originating inland [e.g., Carswell and Lukas (2018), Lukas and Carswell (2017)]. The USGS 3D Elevation Program (Snyder, 2012) was created to support the generation of high-quality elevation data for the United States, including Hawai'i (Carswell, 2016). Future work should consider collaboration with USGS to identify priority areas in Hawai'i that could benefit from better elevation data.

A.2 PRECIPITATION AND TEMPERATURE PROJECTIONS

- **Recommendation A.2-1.** Precipitation and temperature data at the available temporal scale (i.e., annual, seasonal) cannot be used for the assessment of hazard events. A refined temporal resolution (i.e., daily) is needed. The development of data at this refined resolution is an active area of research. Three research efforts that may contribute to the generation of these data are underway:
    - the dynamical downscaling of climate data using the Weather Research and Forecasting (WRF) model (Wang et al., no date) for additional time horizons and the World Climate Research Programme Coupled Model Intercomparison Project's Global Climate Model (GCM) outputs,

- (2) the role of the Pacific Decadal Oscillation and anthropogenic climate change on determining near-term rainfall and temperature projections (Fandrich, 2020), and
- (3) the development of enhanced statistical methods that also consider precipitation events.

HDOT should engage with these research efforts and monitor the availability of new climate projection data. On the one hand, dynamical downscaling methods using WRF can readily provide daily resolved weather and climate data for precipitation, temperature, and other variables. However, the computational cost and storage of the data are expensive, and thus only a few scenarios and short time intervals have been produced so far. On the other hand, the statistical downscaling is often associated with long development times (data acquisition, processing, tuning of the model parameters, and cross-validation), and hence, may reach limits in applications to data with high temporal resolution. Precipitation and temperature projection data should be obtained by climate simulation (i.e., climate model run under a given future scenario) to ensure that these data represent physically plausible futures. Corresponding statistical descriptors of GCM ensembles are only meant to provide points of reference in the distribution of physically plausible climate projection values.

- **Recommendation A.2-2.** HDOT should assess the impact of diurnal temperature changes in the hottest month of the year and future extreme heat on the quality of pavement. Effects such as pavement buckling would lead to increased repair and maintenance costs. HDOT may seek a partnership with the University of Hawai'i at Mānoa's pavement engineering research group.

A.3 ROCKFALL AND LANDSLIDE

- **Recommendation A.3-1.** HDOT should evaluate the need to prioritize additional rockfall/landslide sites in its Rockfall Protection Program (e.g., sites associated with high or very high susceptibility and areas of increased precipitation), include additional sites, or extend current sites in the program.
- **Recommendation A.3-2.** HDOT should consider the susceptibility values and precipitation estimations used in this assessment in future prioritizations of sites in its Rockfall Protection Program, understanding the limitations of these datasets. Investments in slope-stability mitigation can be prioritized for the following areas, subject to confirmation of localized conditions (e.g., mitigation works may already be in place in several locations):
  - Sites associated with high or very high susceptibility, especially if these sites are associated with areas of increased precipitation
  - Sites of large block size or volume, or of high event frequency, and associated with areas of increased precipitation
- **Recommendation A.3-3.** HDOT should identify and evaluate the performance of culverts in areas that will experience an increase in precipitation to address the adequacy of their drainage capacity. Poorly performing culverts could cause water retention along roadways that leads to slope saturation and potential increases of instability.
- **Recommendation A.3-4.** HDOT should support research efforts focused on detailed precipitation modeling (e.g., short duration-high intensity events) that builds upon the recommendations outlined in Section A.2. These studies would support the evaluation of precipitation intensity-duration distributions and their anticipated changes due to climate change, informing future slope-stability assessments. Special structures

such as bridges, culverts, and tunnels can benefit from improved assessments to determine actual exposure to rockfalls and landslides.

» **Recommendation A.3-5.** In the meantime, HDOT should implement a remote, real-time slope monitoring program for priority sites, especially those sites that are difficult to access, to provide early warning of movement prior to rockfall and landslide events.

A.4 CHRONIC COASTAL FLOODING

» **Recommendation A.4-1.** The protection of transportation assets exposed to sea level rise hazards may not be cost effective in the future. This means that exposed assets, and often adjacent assets, may need to be relocated or elevated. In extreme cases, where communities and their economic activities are relocated, roads may be decommissioned and new roads may be needed. Therefore, HDOT should engage closely with State and local agencies planning and managing the retreat process of communities (e.g., Office of Planning) to inform capital planning and maintenance teams. Please see section B.1 for information on ongoing efforts (i.e., Assessing the Feasibility and Implications of Managed Retreat Strategies for Vulnerable Coastal Areas in Hawai‘i Final Report).

» **Recommendation A.4-2.** The increased presence of groundwater just below the surface also presents an increasing problem for existing assets in low-laying areas. Therefore, a more refined assessment to determine this impact is recommended to ensure that the reliability of transportation assets is not compromised. Such an assessment would include the generation of groundwater inundation data at various distances below surface levels critical to the structural performance of assets.

» **Recommendation A.4-3.** Hazards such as coastal erosion are site-specific and, therefore, require field visits. Such visits would be important in the validation of areas identified in this current work as being exposed to coastal erosion. Some field work has already occurred as part of the work of Francis et al. (2019). In addition to gathering field condition data from HDOT's own highway maintenance team, HDOT should work collaboratively with State and county agencies familiar with local site conditions to share data on field conditions. The State's sea level rise report and sea level rise viewer would also be a good source for erosion projections.

» **Recommendation A.4-4.** HDOT can take a few steps now to understand better the exposure of the statewide asset inventory to sea level rise hazards while new research considers the integration of ice-sheet models to estimate the possible changes of ice sheet and their effects on sea levels. Some of these steps include (1) using sea level rise data generated in Francis et al. (2019) in the development of groundwater inundation estimates, (2) updating annual high wave flooding and coastal erosion estimates for higher sea level rise scenarios consistent with this work, and (3) the generation of new annual high wave flooding and coastal erosion studies for the islands of Moloka‘i and Hawai‘i.

A.5 STORM SURGE

» **Recommendation A.5-1.** Further evaluation of exposed bridges is required to identify bridges of concern given actual superstructure clearances and other site-specific factors affecting the vulnerability of bridges. This evaluation should include the consideration of hydrodynamic loads to determine the reliability of bridges and use the AASHTO guide specification for bridges vulnerable to coastal storms (AASHTO, 2008) and past work [e.g., Hayatdavoodi (2015)].

- **Recommendation A.5-2.** There should be a coordinated effort between HDOT, the Hawai'i State Office of Planning, the Hawai'i Emergency Management Agency and county emergency management offices to update existing evacuation and emergency response planning tools to consider information on additional routes anticipated to be impacted by storm surge. Evaluating the long-term viability of evacuation routes to emergency shelters should be especially considered given potential climate change impacts (refer to Recommendation A.5-4).
- **Recommendation A.5-3.** In the anticipation of a hurricane, an Emergency Operations Center (EOC) may be activated. HDOT should consider further developing and implementing a process to enable direct communication with the EOC, the Hawai'i Emergency Management Agency, and county emergency management offices, the NOAA National Weather Service Central Pacific Hurricane Center, other agencies that are involved in hurricane warning and science, and utility companies to exchange information on the anticipated impact of hurricane events to ensure resources are allocated for the prompt restoration of road services to support the delivery of emergency response services and the recovery of communities in the impacted areas. HDOT's hurricane response responsibility is to make sure the major Highway's (i.e., H-1, H-2 and H-3) are clear within 72 hours.
- **Recommendation A.5-4.** While the frequency of hurricanes is expected to remain the same or increase in Hawai'i over time (Murakami et al., 2013; Li et al., 2010; Widlansky et al., 2019), scientists agree that hurricanes of high intensity (e.g., Category 4) may be observed with higher frequency (Widlansky et al., 2019). Future collaboration with local researchers may need to focus on better understanding the implications of climate change on hurricane events affecting Hawai'i and the impacts of such events to the asset inventory. Some research has been completed in recent years [e.g., Ning et al. (2018), Vitousek et al. (2017), University of Hawai'i Sea Grant College Program (2018)] that may be relevant to future hazard studies.
- **Recommendation A.5-5.** Probabilistic storm surge hazard maps for Hawai'i should be complementary products to the work described in Recommendation A.5-4. Such maps, which would associate inundation depth values to different return periods, can be generated using the hypothetical hurricane events used in Zachry et al. (2015). There is precedence of work performed in this area [e.g., Yang et al. (2019)].

A.6 TSUNAMI

- **Recommendation A.6-1.** Given the significant number of bridges that are exposed to tsunami events (nearly one-third of bridges statewide), HDOT should create a bridge evaluation program/study focused on determining the reliability of bridge structures to anticipated tsunami loads. This program should rely on the upcoming AASHTO guide specification for tsunami design of highway bridges (Transportation Pooled Fund Program, 2020), the inventory of exposed bridges identified in this study, models available at the University of Hawai'i at Mānoa (e.g., Non-hydrostatic Evolution of Ocean Wave model), and similar past work [e.g., Identification of Critical Coastal Bridges in the State of Hawai'i for Coastal Inundation Analysis authored by Leake (2012)]. The tsunami hazard data to be provided with the new AASHTO guide specification (i.e., flow depth and velocity) correspond to an annual exceedance probability of 0.1%, which is consistent with the seismic hazard used for bridge design. These data were generated by considering all identified seismic source zones around the Pacific Ocean.
- **Recommendation A.6-2.** There should be a coordinated effort between HDOT, the Hawai'i State Office of Planning, the Hawai'i Emergency Management Agency and county emergency management offices to

update existing evacuation and emergency response planning tools to consider information on additional routes anticipated to be impacted by tsunami events.

- **Recommendation A.6-3.** At the onset of a tsunami triggering event, an EOC may be activated. HDOT should consider developing and implementing a process to enable direct communication with the EOC, the NOAA Pacific Tsunami Warning Center, the USGS Hawaiian Volcano Observatory (HVO), and other agencies that are involved in tsunami warning and science [refer to Kauahikaua and Tilling (2014) for additional context]. The purpose would be to exchange information on the anticipated impact of such a tsunami event to ensure resources are allocated for the prompt restoration of road services to support the delivery of emergency response services and the recovery of communities in the impacted areas.
- **Recommendation A.6-4.** Future collaboration with the University of Hawai'i at Mānoa may need to focus on better understanding the implications of climate change, specifically sea level rise, on tsunami events affecting Hawai'i. Some research has been completed in recent years [e.g., Johnson et al. (2015), Li et al. (2018), Nagai et al. (2019)] that may be relevant to future studies.
- **Recommendation A.6-5.** An additional area of collaboration with the University of Hawai'i at Mānoa and the team authoring the AASHTO guide specification for tsunami design of highway bridges may be the expansion of the earthquake catalog containing the tsunami triggering events. This expansion would focus on including stochastic events of various return periods that could be used to generate probabilistic tsunami hazard maps for Hawai'i. These scenarios, which may include local earthquake events (Bai et al., 2018), would be used in future risk assessments. Events recorded in the catalog could also be used to support the development of scenario-based emergency response simulations and planning.

A.7 WILDFIRE

- **Recommendation A.7-1.** On-site evaluations are required to determine the exposure of roads to natural or human-caused wildfires (i.e., the conditions that could increase the likelihood of a wildfire). Certain locations will require routinely clearing debris and vegetation along roads to reduce wildfire fuel sources. Other locations may need shoulder areas or larger shoulder areas than what currently exists to increase the distance between road users and roadside vegetation. In selected circumstances, such features could enable emergency response personnel to travel along critical routes during wildfires.
- **Recommendation A.7-2.** HDOT should partner with the Hawai'i Wildfire Management Organization and local authorities, including fire departments, to support wildfire education that specifically covers risks along roadways.
- **Recommendation A.7-3.** Advancements in wildfire predictive technologies and real-time monitoring can support wildfire evacuation and emergency response efforts. HDOT should partner with State and local organizations to secure and improve such capabilities to identify critical parts of the road network to support such operations.
- **Recommendation A.7-4.** Improvements in climate data projections would greatly enhance the opportunity to characterize the wildfire hazard in Hawai'i for the next few decades, especially on the leeward side where climate is anticipated to be drier and temperatures are expected to increase. HDOT should monitor new research taking place at the University of Hawai'i at Mānoa that examines such future conditions that could lead to natural or human caused wildfires.
- **Recommendation A.7-5.** HDOT should determine the effects of past wildfires on the State network, especially in parts of the network with asphalt material, identifying common and recurring impacts as well

as repair and reconstruction interventions, to understand better wildfire events on the network and anticipate probable future consequences, including repair cost estimates. Asphalt material is sensitive to temperatures and can be damaged in a wildfire. Moreover, due to the composition of this material, in very intense temperatures, asphalt can ignite and allow wildfires to spread along and across roads.

A.8 LAVA FLOW

- **Recommendation A.8-1.** When evaluating existing prioritized assets (i.e., those in Zones 1 through 3 in the Hawai'i District and in Zone 1 in the Maui District), HDOT should evaluate the level of network redundancy to allow alternative access to areas served by the network, and improve redundancy if this level is found to be inadequate. Lava flow diversion strategies may be additionally considered. The assessment of network redundancy and lava flow diversion strategies should also be considered when conducting major improvements to existing State highways or constructing new assets in the areas most exposed to lava flow hazards.
- **Recommendation A.8-2.** When an eruption occurs, the USGS HVO estimates the probable paths of lava flow using DEMs representing the topographies of volcanoes, enabling them to identify the steepest descent paths, and broad inundation zones defined by historical lava flow path data. The HVO also estimates lava flow travel times based on the advance rates of active flows and those of earlier flows in the same area (USGS HVO, 2020). During eruptions that require the activation of an EOC, the information generated by the HVO can be accessed by State agencies through the activated EOC. HDOT should consider developing and implementing a process to enable direct communication with the EOC and the HVO to identify assets along the State road network that may be affected by lava flows. This development should review communication during past emergencies, including the eruption of Kīlauea in 2018.
- **Recommendation A.8-3.** HDOT should assess the effects of previous lava flows on the highway network, identifying common and recurring impacts, leading to improving the estimation of probable future consequences.
- **Recommendation A.8-4.** This assessment should also consider seismic hazard events that have occurred in combination with past lava flow events. These combined events can result in significant damage to roadway assets.
- **Recommendation A.8-5.** Underground voids created by lava tubes are hazards associated with active and inactive volcanic zones and lava flows. During the lava flow event of 2018, field crews used ground-penetrating radar to identify the locations of large voids that posed a potential hazard on State highways. These potential hazards were successfully identified in the Puna District of the Big Island, and HDOT subsequently undertook appropriate countermeasures, such as road closures, to protect the traveling public. There is a need to continue collecting field data to identify voids in other locations. This information can be used to complement the results of this exposure assessment and future risk analyses.
- **Recommendation A.8-6.** HDOT should also assess other types of volcano-related hazards, including pyroclastic flows, air-fall tephra, and volcanic gases, along with their potential impacts on highways and personnel.

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APPENDIX B. OVERVIEW OF STATE, LOCAL, AND FEDERAL TECHNICAL RESOURCES AND GUIDANCE PERTAINING TO CLIMATE CHANGE IN HAWAIʻI

The Hawaiʻi Department of Transportation (HDOT) recognizes the efforts of other jurisdictions and agencies to address climate change and their impacts. This Action Plan seeks to complement and support those climate-related policies, rules, and initiatives that guide the overall development of the State, and therefore, are relevant to the State Highway System and HDOT as an organization. In addition, there are several national organizations (such as the American Association of State Highway and Transportation Officials (AASHTO)) and Federal policies, rules, and guidance that are relevant to HDOT's stewardship of the State highway network.

The following is a compilation of existing guidance at the Federal, State, and local levels that require climate change and adaptation planning to be considered for project implementation, regulatory approval, and funding. In addition to the resources listed below, the State of Hawaiʻi's Climate Change Portal also offers a list of State and local documents and tools that addresses resilience and adaptation. It can be found at: http://climate.hawaii.gov/climate-change-reports/.

B.1 STATE GUIDANCE

B.1.1 STATEWIDE DOCUMENTS

- **HB2486 HD2 SD2.** Passed Sept 15, 2020. Accessed October 14, 2020 from: https://www.capitol.hawaii.gov/measure_indiv.aspx?billtype=HB&billnumber=2486&year=2020

  This Act established a statewide sustainability branch within the Office of Planning. The Act updated and reaffirmed the role of the office to coordinate among State agencies regarding climate change adaptation and sustainability. One of the reasons for this action was the fact that sustainability and climate change adaptation priority guidelines had been added to Part III of the Hawaiʻi State Planning Act, chapter 226, Hawaiʻi Revised Statutes. The Act specifically tasks the office with the responsibility for coordinating the management of sea level rise.

- **Executive Order 18-06.** Governor's Executive Order on Climate Action. Office of Governor David Y. Ige. 2018. Accessed July 27, 2020 from: https://governor.hawaii.gov/wp-content/uploads/2019/05/Executive-Order-No.-18-06.pdf

  Governor Ige recognized "Climate Action" as one of several goals to be reached by 2030. This Executive Order recognizes the importance of "… reducing human and economic loss caused by natural disasters…" by "strengthening capacity to climate-related hazards [sic] and natural disasters; integrating climate change into policies and planning; improving information processes regarding climate change and natural disasters."

- **Hawaii Administrative Rules (HAR) 11-200.1.** State of Hawaiʻi Environmental Council, Office of Environmental Quality Control. 2019. Accessed August 24, 2020 from: https://health.hawaii.gov/opppd/files/2019/08/11-200.1.pdf

  Effective July 2019, the State of Hawaiʻi requires all new projects undergoing environmental review under the Hawaiʻi Environmental Policy Act, also known as Hawaiʻi Revised Statutes Chapter 343, to consider

whether a project is likely to have an adverse effect or be exposed to sea level rise using the information documented in the 2017 Hawai'i Sea Level Rise Vulnerability and Adaptation Report (see below).

» ***Hawaii Sea Level Rise Vulnerability and Adaptation Report***. State of Hawai'i Department of Land and Natural Resources. 2017. Prepared by TetraTech. Accessed July 27, 2020 from: https://climateadaptation.hawaii.gov/wp-content/uploads/2017/12/SLR-Report_Dec2017.pdf

The 2017 Hawai'i Sea Level Rise Vulnerability and Adaptation Report, prepared for the State of Hawai'i's Department of Land and Natural Resources, made a critical impact as the first statewide vulnerability assessment for sea level rise in Hawai'i, identifying areas that would be inundated by sea level rise under different future scenarios. The associated Hawai'i Sea Level Rise Viewer identified the 3.2 feet sea level rise exposure area projected to occur in the State by the end of the century as one of the primary planning criteria for existing and future development (Pacific Islands Ocean Observing System 2020).

» ***Assessing the Feasibility and Implications of Managed Retreat Strategies for Vulnerable Coastal Areas in Hawai'i, Final Report***. Office of Planning. 2019. Accessed July 27, 2020 from: https://files.hawaii.gov/dbedt/op/czm/ormp/assessing_the_feasibility_and_implications_of_managed_retreat_strategies_for_vulnerable_coastal_areas_in_hawaii.pdf

In February 2019, the Office of State Planning released a study examining the feasibility of "managed retreat" from coastlines to explore one possible solution for loss of coastal land. This report summarized the complexities of reshaping developed areas abutting shorelines, including the difficulties of relocating, demolishing, or restricting access to development in affected coastal areas. The report also articulated land use, planning, legal, financial, and community disruption issues that would need to be weighed carefully before managed retreat could be undertaken. The report provided examples of where managed retreat has been undertaken in Hawai'i and other states, most notably the town of Hilo on the Big Island, which was reshaped after the devastating 1960 tsunami. One redevelopment requirement in that historical case was the creation of "open space" along Hilo Bay, where residential uses were banned.

» ***State of Hawai'i 2018 Hazard Mitigation Plan***. August 6, 2018. Accessed July 27, 2020 from: https://dod.hawaii.gov/hiema/files/2018/11/State-of-Hawaii-2018-Mitigation-Plan.pdf

The 2018 update of the State of Hawai'i Hazard Mitigation Plan (HMP Update) prepared for the Hawai'i Emergency Management Agency is a document that evaluates known risks from various potential emergency events in Hawai'i. The hazard types addressed in the 2018 HMP Update overlap to a great degree with the hazards evaluated in this Action Plan for Highways, including but not limited to, events such as sea level rise, flooding, and landslides.

B.2 HDOT STUDIES AND PROGRAMS

» ***State of Hawai'i Statewide Coastal Highway Program Report.*** 2019. Prepared for HDOT Highways Division by Oceana Francis, Horst Brandes, Guohui Zhang, and David Ma. Project Number HWY-06-16. https://hidot.hawaii.gov/highways/files/2019/09/State-of-Hawaii-Statewide-Coastal-Highway-Program-Report_Final_2019.pdf

This report provided adaptation recommendations for coastal roads by considering their exposure to multiple coastal hazards. The report first presents a ranking methodology to the susceptibility of State of Hawai'i coastal roads to erosion and structural degradation due to ocean hazards such as waves, currents, tides, and sea level rise, using an indicator-based methodology. The second part of the project examined

traffic patterns and related factors to present a traffic priority index to address coastal erosion. The third part of the report documented the exposure of roads to ocean hazards, including sea level rise, tsunamis, and storm surge.

» ***Statewide Federal-Aid Highways 2035 Transportation Plan.*** 2014. Prepared for HDOT Highways Division by CH2MHill. https://hidot.hawaii.gov/highways/files/2014/09/Statewide-Federal-Aid-Highways-2035-Transportation-Plan_Yong.pdf

  This comprehensive long-range planning document identifies HDOT goals for land transportation systems statewide. Two of the statewide needs identified in the Implementation section of this long-term policy document include "preserve and maintain highway operations" and "provide emergency access and improve resiliency." The range of potential solutions presented to address these needs ranges from critical day-to-day maintenance functions, such as "perform regular maintenance on roads and bridges" and "improve drainage facilities" to more complex solutions including "constructing alternate routes and bypass roads" and "relocate roads away from shoreline," which will require a multi-stakeholder approach for success.

» ***Transportation Asset Management Plan (TAMP).*** June 30, 2019. Prepared by HDOT. https://hidot.hawaii.gov/highways/files/2019/06/HDOT_TAMP_Final_June2019.pdf

  This risk-based TAMP fulfills the requirements described in the Federal section of this appendix. It not only inventories HDOT assets, but it also provides a discussion of Hawaii's unique challenges and vulnerabilities relating to climate change and other natural factors that affect system operation and maintenance, emphasizes the need for life-cycle planning, and presents a financial plan and investment strategies. The report contains a summary list of HDOT facilities repeatedly requiring repair and reconstruction due to emergency events.

» Rockfall Protection Study at Various Locations, Statewide. 2014. Prepared for HDOT by AECOM.

  This study investigated and evaluated the then existing conditions of potential rockfall hazard locations along 96 highways and roadways under the jurisdiction of the HDOT Highways Division, and developed a systematic rockfall hazard management database. Potential rockfall sites statewide were grouped into three classes: A, B, and C in accordance with the Federal Highway Administration's (FHWA) Rockfall Hazard Rating System. "A" means the potential of rock falling and reaching the roadway was moderate to high; a "B" means the potential of rock falling and reaching the roadway was low to moderate; and a "C" means the potential of a rock falling and reaching the roadway was nonexistent to low.

» ***Practical Solutions Action Plan***. 2017. With Smart Growth America.

  According to this report, "practical solutions" is an outcome-focused approach to decision making for transportation project development and delivery. The goal is to precisely identify a transportation problem and then finely tune the scope of the solution to address it. This report is a guide for HDOT on how to identify and implement practical solutions and provides references for best practice examples of such solutions.

B.3 LOCAL GUIDANCE

B.3.1 CITY AND COUNTY OF HONOLULU'S MAYOR'S DIRECTIVE

In 2018, the Mayor of the City and County of Honolulu issued *Directive No. 18-02* requiring county projects and programs to "help protect and prepare the infrastructure, assets, and citizens of the City for the physical and

economic impacts of climate change," including following the Honolulu Climate Change Commission's *Sea Level Rise Guidance* to assume a 3.2 feet sea level rise by mid-century and a 6-foot rise by the end of the century as planning benchmarks. The sea level guidance, as well as a guidance for revisions to the shoreline setback rules, are located at the following links:

- City and County of Honolulu, Office of the Mayor. 2018. Directive No. 18-2: City and County of Honolulu Actions to Address Climate Change and Sea Level Rise. Accessed July 27, 2020 from: https://static1.squarespace.com/static/5e3885654a153a6ef84e6c9c/t/5ef3b2774954db49fc136b20/1593029239884/Mayor%27s%2BDirective%2B18-02.pdf
- City and County of Honolulu Climate Change Commission. 2019. Guidance on Revision to the Revised Ordinance of Honolulu Chapter 23, Regarding Shoreline Setbacks. https://static1.squarespace.com/static/59af5d3cd7bdce7aa5c3e11f/t/5e54414b18df847f4c6610e3/1582580063308/ROH+23+Shoreline+Setback+Guidance.pdf

B.3.2 ESTABLISHMENT OF NO BUILD ZONES BY COUNTY GOVERNMENTS

Most counties in Hawai'i, which are responsible for shoreline setbacks, Special Management Areas (SMAs), and building permits, are moving toward defining "no build" zones to prevent future improvements in areas exposed to sea level rise and coastal erosion. Both Maui and Kaua'i Counties have already instituted shoreline setback rules, which use multiple criteria to determine appropriate setback distances. The City and County of Honolulu is also likely to start modifying its uniform 40-foot shoreline setback and its SMA to include parts of the 3.2-feet sea level rise exposure area projected to occur in the State by the end of the century that are not currently in the SMA. Such changes will affect future land use decisions and coastal highway development.

County of Maui: https://www.mauicounty.gov/697/Shoreline-Setback-Area-Limitations

County of Kaua'i: https://www.kauai.gov/Government/Departments-Agencies/Planning-Department/Shoreline-Setback

B.3.3 COUNTY HAZARD MITIGATION AND RESILIENCE PLANS

As with State government, county governments also prepare their own Hazard Mitigation Plans (HMP), focusing on local vulnerability to natural events such as sea level rise, flooding, and landslides. In addition, county governments are increasingly incorporating climate planning in their planning documents. Examples at the local level include the following:

- ***Ola, the O'ahu Resilience Strategy.*** Prepared by the City and County of Honolulu. 2019. Accessed July 27, 2020 from: https://www.resilientoahu.org/resilience-strategy
- ***West Kaua'i Community Vulnerability Assessment.*** University of Hawai'i Sea Grant College Program. 2020. Accessed July 27, 2020 from: http://seagrant.soest.hawaii.edu/coastal-and-climate-science-and-resilience/ccs-projects/west-kauai-community-vulnerability-assessment/
- ***West Maui Community Plan Update.*** County of Maui, Department of Planning. 2019. Prepared for West Maui Community Plan Advisory Committee. Accessed July 27, 2020 from: https://wearemaui.konveio.com/draft-west-maui-community-plan
- ***County of Hawai'i's Climate Change Action Report***. County of Hawaii Research and Development Management Department. 2020. Accessed July 27, 2020 from: https://www.rd.hawaiicounty.gov/economic-development/climate-change-action.

B.4 FEDERAL/NATIONAL GUIDANCE

B.4.1 AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

» **Resilient and Sustainable Transportation Systems Technical Assistance Program.** Accessed July 27, 2020 from: https://environment.transportation.org/center/rsts/products_programs.aspx

This website serves as a portal for state departments of transportation (DOT) to exchange information on resilience and climate change, including the findings of workshops and symposia on extreme weather impacts on the transportation system.

» ***Validation of Tsunami Design Guidelines for Coastal Bridges.*** Transportation Pooled Fund Program, Lead State: Oregon DOT. 2020. Accessed July 27, 2020 from: https://www.pooledfund.org/Details/Study/556

Tsunami design guidelines have been proposed by many transportation agencies; however, the reliability of the numerical results is unknown due to a lack of experimental data needed for verification and validation. This project conducted experiments to provide data to verify and validate the numerical results to assess the accuracy of the load prediction equations. Draft guidelines have been developed.

» ***AASHTO Guide Specifications for Bridges Vulnerable to Coastal Storms.*** 2010. ISBN Number: 1-56051-429-9. Accessed July 27, 2020 from: http://aashto-specifications.blogspot.com/2011/07/aashto-guide-specifications-for-bridges.html

Examines limit states, load combinations, and design forces against bridges in coastal areas and provides comprehensive specifications for the design of bridges vulnerable to coastal storms.

B.4.2 FEDERAL HIGHWAY ADMINISTRATION (FHWA)

» ***Integration of Resilient Infrastructure in the Emergency Relief Program.*** Memorandum from Hari Kalla, Associate Administrator for Infrastructure, and Gloria Shepherd, Associate Administrator for Planning, Environment, and Realty to Associate Administrators, Division Administrators, and Directors of Field Services, October 11, 2019. Washington, D.C. Accessed July 27, 2020 from: https://www.fhwa.dot.gov/specialfunding/er/191011.cfm

Memorandum to clarity on how states can incorporate resilience into their Emergency Relief (ER) program funded projects. ER program funds that are provided following a disaster may be used for repairs that improve the long-term resilience of the Federal-aid highways if, 1) they are consistent with current standards, or 2) the state DOT demonstrates that the resilience feature is economically justified to prevent future recurring damage. For this latter case, if rebuilding to current standards does not reduce risks to acceptable levels, facilities being repaired under the FHWA ER program may use ER funds for betterments (added protective features) if the state DOT can demonstrate that that the feature is economically justified to prevent future recurring damage.

» Using an LCP (Life Cycle Planning) Process to Support Transportation Asset Management: A Handbook on Putting Federal Guidance into Practice. 2019. Report FHWA-HIF-19-006. Accessed July 27, 2020 from: https://www.fhwa.dot.gov/asset/guidance/hif19006.pdf

LCP is an essential aspect of transportation asset management and a required component of risk-based TAMPs under Federal regulation (23 Code of Federal Regulations [CFR] 515.5). This regulation defines LCP as "a process to estimate the cost of managing an asset class, or asset sub-group over its whole life with

consideration for minimizing cost while preserving or improving the condition." This handbook examines the use of pavement and bridge management systems to perform LCP analysis in support of risk-based TAMPs. Several aspects of TAMPs and transportation performance management, such as performance model development, target setting, and performance gap analysis, provide input to LCP and are impacted by LCP results.

» ***Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide.*** August 2019. Report FHWA-HEP-19-042. Accessed July 27, 2020 from: https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/implementation_guide/

This Implementation Guide helps practitioners understand how and where nature-based and hybrid solutions can be used to improve the resilience of coastal roads and bridges. It summarizes the potential flood-reduction benefits and co-benefits of these strategies. The guide follows the steps in the project delivery process, providing guidance on how to consider nature-based solutions in the planning process, how to conduct a site assessment to determine whether nature-based solutions are appropriate, key engineering and ecological design considerations, permitting approaches, construction considerations, and monitoring and maintenance strategies. The guide also includes appendices with site characterization tools, decision support for selecting nature-based solutions, suggested performance metrics, and links to additional tools and resources. Note: the FHWA website on nature-based solutions also includes results of pilot projects. Additional information is available at: https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/

» ***Asset Management, Extreme Weather, and Proxy Indicators Pilot Program*** (2017-2019). 2019. Accessed July 27, 2020 from: https://www.fhwa.dot.gov/asset/resources/pilot.pdf

This FHWA pilot program illustrates how state DOTs can incorporate information on resilience into asset management programs and their TAMPs, including assessment of risks and LCP. Five of the six pilots participating in the pilot program examined the vulnerability of highways to extreme weather events. Pilot study reports are available from:

Arizona DOT: https://azdot.gov/sites/default/files/2019/07/Asset-Mgmt-Extreme-Weather-and-Proxy-Indicators-Pilot-Project.pdf

Kentucky Transportation Cabinet: https://www.fhwa.dot.gov/asset/pilot/ky.pdf

Maryland: https://www.fhwa.dot.gov/asset/pilot/md.pdf

Texas DOT: https://www.fhwa.dot.gov/asset/pilot/tx.pdf

» ***23 United States Code (U.S.C.) 119 and 23 CFR Part 515 Pertaining to Asset Management.*** 2016. Accessed August 24, 2020 from: https://www.govinfo.gov/app/details/USCODE-2011-title23/USCODE-2011-title23-chap1-sec119

23 CFR § 515.7 — Process for establishing the asset management plan

This section requires a state DOT to develop a risk-based asset management plan focusing on assets on the National Highway System (NHS). It relates the asset management plan to performance measures and state DOT performance and condition targets. It also adopts a life-cycle costing perspective on considering asset risks. A process for developing the asset management plan includes the identification of risks and the use of a prioritization process for selecting those assets in most need of risk mitigation.

23 CFR § 515.9 — Asset management plan requirements

This section outlines the minimum components of the state DOT asset management plan. These components include a description of the risk management analysis for NHS pavements and bridges, a summary of the periodic evaluations undertaken as part of Section 667, which requires state reporting for those sections of the NHS that have continual and repeated emergency maintenance requirements, and the identification of investment strategies.

» ***Asset Management Plans.*** Rule by the FHWA on October 24, 2016**.** Accessed July 27, 2020 from: https://www.federalregister.gov/documents/2016/10/24/2016-25117/asset-management-plans-and-periodic-evaluations-of-facilities-repeatedly-requiring-repair-and

This rule responds to requirements in the Moving Ahead for Progress in the 21st Century Act (MAP-21). First, as part of the National Highway Performance Program (NHPP), MAP-21 adopted a requirement for states to develop and implement risk-based asset management plans for the NHS to improve or preserve the condition of the assets and the performance of the system. Second, for the purpose of carrying out the NHPP, MAP-21 requires FHWA to establish minimum standards for states to use in developing and operating bridge and pavement management systems. Third, to conserve Federal resources and protect public safety, MAP-21 mandates periodic evaluations to determine if reasonable alternatives exist to roads, highways, or bridges that repeatedly require repair and reconstruction activities. Investment strategies are encouraged that collectively make or support progress toward: (1) achieving and sustaining a desired state of good repair over the life cycle of the assets; (2) improving or preserving the condition of the assets and the performance of the NHS relating to physical assets; (3) achieving the state DOT targets for asset condition and performance of the NHS in accordance with 23 U.S.C. 150(d); and (4) achieving the national goals identified in 23 U.S.C. 150(b).

» ***23 CFR 667 Periodic Evaluations of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events.***

Each state is required to conduct evaluation statewide to determine "if there are reasonable alternatives to NHS roads, highways, and bridges that have required repair and construction activities on two or more occasions due to emergency events." State DOTs must update the list of such facilities after every emergency event if such facilities are affected, as well as at least every four years. The results of these evaluations are to be considered by state DOTs and Metropolitan Planning Organizations (MPOs) when developing the State Transportation Improvement Programs (STIPs) and Transportation Improvement Programs (TIPs), respectively.

» ***Statewide Planning.*** 2016. Final Rule. Accessed August 24, 2020 from: https://www.federalregister.gov/documents/2016/05/27/2016-11964/statewide-and-nonmetropolitan-transportation-planning-metropolitan-transportation-planning

§ 450.206 — Scope of the statewide and nonmetropolitan transportation planning process

This section requires state DOTs to have a "continuing, cooperative, and comprehensive" statewide transportation planning process that examines a range of goals. Over the legislative history of this section, national goals have been added over time as critical national concerns have come to the attention of Congress. The latest Federal legislation added the following two factors:

1. Emphasize the preservation of the existing transportation system

2. Improve the resiliency and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation

§ 450.216 — Development and content of the long-range statewide transportation plan

This section requires the long-range statewide transportation plan to include by reference or by inclusion several planning or policy studies. The latest Federal legislation added emergency relief and disaster preparedness plans to the list of references plans.

» ***Metropolitan Transportation Planning.*** Final Rule, with Federal Transit Administration. Accessed September 14, 2020 from: https://www.federalregister.gov/documents/2016/05/27/2016-11964/statewide-and-nonmetropolitan-transportation-planning-metropolitan-transportation-planning

§ 450.306 — Scope of the metropolitan planning process

Similar to the above planning requirements for states, this section requires MPOs to develop a long-range transportation plan and TIPs that are "performance-driven and outcome-based." The section lists national factors that the planning process shall consider. Recent Federal legislation includes the following two factors as part of the requirement:

» Emphasize the preservation of the existing transportation system

» Improve the resiliency and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation

§ 450.316(b) — Interested parties, participation, and consultation

In developing metropolitan transportation plans and TIPs, the MPO should consult with agencies and officials responsible for other planning activities within the Metropolitan Planning Area that are affected by transportation (including State and local planned growth, economic development, tourism, natural disaster risk reduction, environmental protection, airport operations, or freight movements) or coordinate its planning process (to the maximum extent practicable) with such planning activities.

§ 450.324(f)(7) — Development and content of the metropolitan transportation plan

This section requires metropolitan transportation plans to include consideration of a range of concerns and issues. Recent Federal legislation added ***actions to reduce the vulnerability of the existing transportation infrastructure to natural disasters*** to this list.

» ***2013-2015 Climate Resilience Pilot Program: Outcomes, Lessons Learned, and Recommendations.*** Report FHWA-HEP-16-079. 2016. Accessed August 27, 2020 from: https://www.fhwa.dot.gov/environment/sustainability/resilience/pilots/

Results from pilot studies on incorporating resilience concepts into transportation decision-making processes include the following examples:

Hillsborough MPO, Florida:

https://web.archive.org/web/20170113175350/_http://www.fhwa.dot.gov/environment/sustainability/resilie nce/pilots/2013-2015_pilots/florida/final_report/index.cfm

Interesting and important consideration of risks associated with sea level risk, storm surge, and inland flooding. The Plan developed a prioritized list of highly vulnerable locations on the transportation system.

Maryland State Highway Administration:
https://web.archive.org/web/20170113175350/http://www.fhwa.dot.gov/environment/sustainability/resilience/pilots/2013-2015_pilots/maryland/final_report/index.cfm

Systematic examination of potential sea level rise impacts on the state highway network. The process has been institutionalized in the agency's decision-making processes.

Massachusetts DOT:
https://web.archive.org/web/20170113175350/http://www.fhwa.dot.gov/environment/sustainability/resilience/pilots/2013-2015_pilots/massdot/index.cfm

Systematic examination of sea level rise and storm surge impacts on coastal Massachusetts with special emphasis on downtown Boston and impacts on depressed freeway.

Minnesota DOT:
https://web.archive.org/web/20170113175350/http://www.fhwa.dot.gov/environment/sustainability/resilience/pilots/2013-2015_pilots/minnesota/final_report/index.cfm

Innovative use of risk factors and a systematic process for identifying the vulnerability of state DOT assets to inland flooding. Focus was on two DOT districts. The approach used the latest methods for predicting future flood levels.

South Florida:
https://web.archive.org/web/20170113175350/http://www.fhwa.dot.gov/environment/sustainability/resilience/pilots/2013-2015_pilots/south_florida/final_report/index.cfm

Three MPOs and one county study on potential impacts of sea level rise and storm surge on state highway and fixed rail assets. Plan development was based on then state-of-practice methods for identifying vulnerable assets. Plan also recommended changes to planning and decision-making processes.

- ***2017-2019 Pilot Program: Asset Management, Extreme Weather, and Proxy Indicators.*** Accessed September 14, 2020 from: https://www.fhwa.dot.gov/asset/pilot/
  The purpose of this pilot program was to develop information on how asset management practice could be better linked to extreme weather stresses and incorporated into asset decision making. Six states participated in the pilot study and prepared reports on their results: Arizona, Kentucky, Maryland, Massachusetts, New Jersey, and Texas. A description of each pilot study and a list of asset management-related resources can be found at: https://www.fhwa.dot.gov/asset/resources/pilot.pdf
- ***2016-2017 Pilot Program: Nature-based Resilience for Coastal Highways.*** Accessed September 14, 2020 from:
  https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/
  Five states and the U.S. Army Corps of Engineers participated in a pilot program to examine the potential for natural infrastructure to protect coastal roads and bridges: Delaware, Maine/New Hampshire (in one pilot), Mississippi, and Oregon. The pilots ranged from assessing different types of vegetated berms to developing conceptual designs for protecting coastal roads.
- ***Transportation Engineering Approaches to Climate Resiliency (TEACR) Study*.** 2016. Accessed July 27, 2020 from:
  https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/teacr/

Synthesizes lessons learned and innovations from a variety of recent FHWA studies and pilots to help transportation agencies address changing climate conditions and extreme weather events at the asset level. Provides information on why, where, and how to integrate climate considerations into the project development process. Practical information in related disciplines is provided such as climate science and economics and lessons learned from project-level studies of engineering adaptation options. Climate change stresses examined included: sea level rise and storm surge impacts on a coastal bridge, barrier island roadway over washing from sea level rise and storm surge, living shoreline along coastal roadways exposed to sea level rise, temperature and precipitation impacts on cold region pavement, temperature and precipitation impacts to pavements on expansive soils, precipitation and temperature impacts on rock and soil slope stability, and addressing environmental conditions in the design of roadways built on permafrost.

- ***Incorporating Risk Management into Transportation Asset Management Plans.*** November 2017. Office of Asset Management. Accessed July 27, 2020 from: https://www.fhwa.dot.gov/asset/pubs/incorporating_rm.pdf

  Guidance amending 23 U.S.C. 119 as per MAP-21 to develop risk-based TAMPs. The required risk-based TAMP takes risk-performance factors into account, provides guidance on the risk element of the TAMP, defines risk, and provides guidance on how the risk element can be applied to meet risk-based TAMP requirements. A risk-based TAMP is one that identifies, assesses, and prioritizes the uncertainties, variability, and threats that could impede its objectives. A risk-based plan also may make trade-offs based on risks. Limited resources may be prioritized to high-risk assets or to make the transportation network more resilient to the greatest threats.

- ***Highways in the River Environment — Floodplains, Extreme Events, Risk, and Resilience, 2nd Edition.*** June 2016. Highway Engineering Circular No. 17, 2nd edition. Report HIF-16-018. Accessed July 27, 2020 from: https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=16&id=162

  This manual provides technical guidance and methods for assessing the nexus of riverine and transportation as it relates to floods, floodplain policies, extreme events, climate change, risks, and resilience. An important focus is quantifying exposure to extreme flood events considering climate change and other sources of nonstationarity. Describes and discusses: 1) FHWA and other floodplain policies and guidance, 2) uncertainty associated with hydrologic models, 3) nonstationarity and two drivers: climate change and land use/land cover changes, 4) several tools for identifying and adjusting for trends in the historical record, 5) techniques for projecting floods, 6) global/regional climate models, downscaling techniques, and emissions scenarios, and 7) risk and resilience and the probabilistic nature of flood events.

- ***Highways in the Coastal Environment: Assessing Extreme Events***: 2014. Volume 2, 1st edition. FHWA Publication Number: NHI-14-006. Hydraulic Engineering Circular No. 25, Volume 2. Accessed July 27, 2020 from: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/nhi14006/nhi14006.pdf

  The purpose of this manual is to provide technical guidance and methods for assessing the vulnerability of coastal transportation facilities to extreme events and climate change. The focus is on quantifying exposure to sea level rise, storm surge, and wave action. This manual focuses only on extreme events along the coast such as storm surge and waves found in hurricanes, nor'easters, fronts, and El Niño-related coastal storms on the west coast. Tsunamis are also discussed as extreme events. Examples of damage to coastal infrastructure resulting from storm surge and waves that are addressed by the methods in this manual include: 1) damage to coastal bridge superstructures in Hurricanes Ivan and Katrina due to waves on storm surge, 2) damage to highway embankments and pavements due to waves and flowing water in storm surges

from numerous coastal storms, including Hurricanes Sandy, Katrina, Ivan, Floyd, and Ike, 3) damage to roadways on coastal bluffs due to waves and wave runup in the El Niño-related coastal storms of the Pacific in 1992 and in the Great Lakes throughout the past several decades, and 4) damage resulting from flooding of highways and tunnels in Hurricane Sandy.

» ***Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events.*** FHWA Order 5520. December 15, 2014. Accessed July 27, 2020 from: https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm

Established FHWA policy on preparedness and resilience to climate change and extreme weather events. The Order states that it is FHWA's policy to strive to identify the risks of climate change and extreme weather events to current and planned transportation systems. The FHWA will work to integrate consideration of these risks into its planning, operations, policies, and programs in order to promote preparedness and resilience; safeguard Federal investments; and ensure the safety, reliability, and sustainability of the nation's transportation systems. FHWA managers and staff shall ensure that FHWA programs, policies, and activities for which they are responsible integrate consideration of climate change and extreme weather event impacts and adaptation into its planning, operations, policies, and programs in order to promote climate change and extreme weather event preparedness and resilience. Proactive management involves developing engineering solutions, operations and maintenance strategies, asset management plans, and transportation programs that address risk and promote resilience at both the project and systems levels.

B.4.3 U.S. ARMY OF CORPS OF ENGINEERS (USACE)

The USACE has developed numerous technical guidance documents relating to coastal resilience and mitigation of weather-related stresses. An excellent overview is available at: https://www.usace.army.mil/corpsclimate/Climate_Preparedness_and_Resilience/Coastal-Risk-and-Reduction-and-Resilience/ (accessed September 14, 2020). Particularly relevant documents for HDOT include the following:

» ***Implementation of Resilience Principles in the Engineering & Construction Community of Practice.*** Engineering and Construction Bulletin 2020-6. May 29, 2020. Accessed July 27, 2020 from: https://www.wbdg.org/FFC/ARMYCOE/COEECB/ecb_2020_6.pdf

Policy and guidance for applying the USACE principles of resilience. Resilience evaluations should be completed as needed based on engineering judgment and reflective of project complexity and assessed risk. Analyses and outcomes should be formally documented. Where appropriate, interconnections between project components and systems and their individual and cumulative effect on project performance and resilience should be considered.

» ***Incorporating Sea Level Change in Civil Works Programs, Engineer Regulation No. 1100-2-8162.*** June 15, 2019. Accessed July 27, 2020 from: https://www.publications.usace.army.mil/Portals/76/Users/182/86/2486/ER_1100-2-8162.pdf?ver=2019-07-02-124841-933

Guidance for incorporating the direct and indirect physical effects of projected future sea level change across the project life cycle in managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of projects. Potential relative sea level change must be considered in every USACE coastal activity as far inland as the extent of estimated tidal influence.

- ***EP 1100-2-1, Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation.*** June 30, 2019. Accessed July 27, 2020 from: https://www.publications.usace.army.mil/Portals/76/Users/182/86/2486/EP-1100-2-1.pdf?ver=2019-09-13-141310-707

  Instructional and procedural guidance to analyze and adapt to the direct and indirect physical and ecological effects of future projected future sea level rise. Integrates the recommended planning and engineering to understand and adapt to impacts of projected sea level change through a hierarchy of decisions and review points that identify the level of analysis required as a function of project type, planning horizon, and potential consequences.

- ***Engineer Regulation (ER) 1105-2-101, Risk Assessment for Flood Risk Management Studies***. July 15, 2019. Accessed July 27, 2020 from: https://www.publications.usace.army.mil/Portals/76/Users/182/86/2486/ER%201105-2-101_Clean.pdf?ver=2019-10-17-144237-503

  Guidance on risk assessment requirements for flood management studies including, but not limited to, feasibility studies, post-authorization changes, general reevaluation studies, dam and levee safety studies, and major rehabilitation studies. A risk framework is recommended that comprises three tasks: risk assessment, risk communication, and risk management.

- ***Engineering and Construction Bulletin (ECB) 2019-8, Managed Overtopping of Levee Systems.*** April 24, 2019. Engineering and Construction Bulletin 2019-8. Accessed July 27, 2020 from: https://www.wbdg.org/FFC/ARMYCOE/COEECB/ecb_2019_8.pdf

  Engineering guidance on setting top of levee profile, determining overtopping reach length and depth, and considering resiliency measures in the overtopping reach. Provides a methodology for configuring the engineered capacity exceedance related to flood overtopping at a specific location or locations along the levee system.

- ***Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects.*** September 10**,** 2018.Accessed July 27, 2020 from: https://www.wbdg.org/FFC/ARMYCOE/COEECB/ecb_2018_14.pdf

  Applies to all hydrologic analyses supporting planning and engineering decisions having an extended decision time frame (i.e., not for short-term water management decisions). Requires consideration of climate change in all current and future studies to reduce vulnerabilities and enhance the resilience of communities.

- ***Use of Natural and Nature-Based Features (NNBF) for Coastal Resilience.*** 2015. Report SR-15-1. U.S. Army Engineer Research and Development Center, Environmental Laboratory, Coastal and Hydraulics Laboratory. Accessed July 27, 2020 from: https://cdm16021.contentdm.oclc.org/digital/collection/p266001coll1/id/3442

  This report describes the use of NNBF to improve coastal resilience and was designed to support post-Hurricane Sandy recovery efforts under the North Atlantic Coast Comprehensive Study. An integrative framework is offered that focuses on classifying NNBF, characterizing vulnerability, developing performance metrics, incorporating regional sediment management, monitoring and adaptively managing from a systems perspective, and addressing key policy challenges.

» ***Engineering and Design, Risk-Based Analysis for Flood Damage Reduction Studies***. Manual No. 1110-2-1619. August 1, 1996. Accessed July 27, 2020 from: https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1619.pdf

Describes and provides procedures for risk and uncertainty for USACE flood damage reduction studies. Estimation of expected benefits of proposed flood damage reduction plans using risk and uncertainty analysis. Includes quantitative and qualitative methods of representing the likelihood and consequences of exceedance of the capacity of selected measures.

B.4.4 NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

» ***US Climate Resilience Toolkit***.

Provides compiled resources, including data sources, resource agency contacts, tools and case studies to enable effective climate resilience efforts for agencies nationally. Information for Hawaii can be found in the section on the Pacific Region.

B.4.5 FEDERAL EMERGENCY MANAGEMENT AGENCY

» ***Building Resilient Infrastructure and Communities (BRIC).*** Accessed August 24, 2020 from: https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities

This program "supports states, local communities, tribes and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards." It provides grant funding prior to disasters to undertake efforts to reduce the risks associated with disasters by encouraging innovative mitigation strategies and partnerships among agencies and groups involved with planning for and responding to disasters. The program website links to a useful Hazard Mitigation Portfolio that presents examples of different strategies used by states and communities for a wide range of hazards (see https://www.fema.gov/sites/default/files/2020-08/fema_mitigation-action-portfolio-support-document_08-01-2020_0.pdf).

» ***Building Community Resilience with Nature-Based Solutions: A Guide for Local Communities. 2020.*** Accessed August 24, 2020 from: https://www.fema.gov/sites/default/files/2020-08/fema_riskmap_nature-based-solutions-guide_2020.pdf

This guide is an excellent resource for understanding the need for and the characteristics of nature-based solutions relating to community resilience. Importantly, the guide presents information on how to make the business case for resilience-related investments and focuses on the upfront planning and policy elements of an overall resilience strategy.

B.5 APPENDIX B REFERENCES

Pacific Islands Ocean Observing System. 2020. Hawaii Sea Level Rise Viewer. Accessed April 1, 2020 from: https://www.pacioos.hawaii.edu/shoreline/slr-hawaii/.

APPENDIX C. ENVIRONMENTAL OFFICES IN STATE DOTS

C.1 INTRODUCTION

The role of oversight nationwide for climate adaptation and for adaptation studies is typically found in environmental/transportation planning offices within state departments of transportation (DOTs). This organizational responsibility aligns with early consideration of climate adaptation, which occurs early (compared to other DOT efforts) in the plan and project development phase and includes the following activities:

- Studying the changing future environmental conditions associated with climate change
- Outlining methods to assess uncertainties and create scenarios of future conditions to help guide decisions
- Coordinating with engineers to determine the failure mechanisms of assets
- Determining system/community effects that should be considered as a part of facility decisions
- Assessing economic impacts that should also be considered as part of facility planning
- Conducting a cost-effectiveness assessment that incorporates these considerations to draw conclusions on the best design option

Most of these are typically the purview of planning and/or environmental staff. The consideration of climate adaptation in the context of the Hawai‘i Department of Transportation (HDOT) project decisions would normally occur in an environmental division; currently, such an office does not exist in HDOT.

This Overview presents background information on creating an environmental office within HDOT and is organized into four sections: 1) the current environmental organizational structure in HDOT, 2) the rationale and roles for creating an environmental office, 3) a description of the changing policy and technology environment for state transportation agencies, and 4) examples of how other state DOTs have structured their environmental analysis capability within their organization.

Every state DOT is different, and thus there are many ways environmental analysis can be integrated into an organizational structure. This is especially true given the many different and often unique challenges HDOT is facing that reflect the unique environmental circumstances of the State.

C.2 HDOT'S CURRENT ENVIRONMENTAL ORGANIZATIONAL STRUCTURE

Currently, HDOT has several sections within the Highways Division with some environmental function: HWY-D, HWY-CE, HWY-P, and HWY-L. Highways District offices also require support on environmental reviews and implement stormwater and maintenance programs. As part of this study, HDOT staff recommended that a more definitive leadership effort on each of these areas would provide a more comprehensive and effective approach to environmental and climate action initiatives.

- HWY-D, the Design Branch, is responsible for taking highway projects through the environmental review and project design process. HWY-DE is the Design Branch's Environmental section that reviews the environmental documentation and provides guidance on various highway projects to ensure its consistency with design policy and procedures.

- HWY-CE, the Environmental Statewide Construction Section, manages the Statewide Solid Waste Management Program and conducts periodic audits of each of the District's base yards.
- HWY-P, the Planning Branch, and HWY-PA (Planning Branch's Advanced Planning Section), conducts transportation studies using planning procedures and environmental evaluations. This Action Plan was developed in HWY-PA. HWY-PS (the Planning Branch's Systems Planning Section) reviews and coordinates departmental evaluations of environmental review documents and land use applications.
- HWY-L, the Lab Materials Testing and Research Branch, is responsible for both the Shoreline and Rockfall Programs. These programs conduct studies to identify and prioritize areas based on likely highway disruptions and propose engineering treatments.
- Both the Oʻahu and Maui Districts have dedicated Environmental Management Sections and staff that manage, implement, and report on the Municipal Separate Storm Sewer System (MS4) stormwater programs.

A 2015 Federal Highway Administration (FHWA) review of HDOTs environmental program found HDOT to be generally in compliance with Federal regulations, although several areas of concern were noted (FHWA 2015):

- Several important HDOT manuals, guides, and letters were unclear and incomplete and had not been updated in years.
- Staffing at the FHWA Hawai'i Division and HDOT is minimally enough to administer successfully the Federal-aid Highway Program.
- Environmental resource agency coordination needs improvement.

C.3 ROLES FOR A STATE DOT ENVIRONMENTAL UNIT

Almost all state DOTs in the nation have very well defined organizational units with environmental responsibilities. However, every state DOT is different in how it organizes the environmental unit. Based on nationwide best practice examples and a review of the available literature, the benefits of having a separate environmental unit in a state DOT include the following:

- Providing support on environmental requirements (e.g., reviews, documentation, and permits) for project delivery
- Providing a central point of contact and communication with external agencies/groups for environmental issues and initiatives
- Sending a message to the rest of the agency that environmental factors and concerns are critical aspects of the DOT's business and in the project development process
- Providing a point of advocacy for environmental considerations in the agency
- Enhancing the DOT's image among key environmental constituency and public groups
- Working with other agencies (e.g.., CZM, DLNR, EPA) to align vision and share resources regarding environmental concerns and climate change-related impacts.
- Elevating environmental concerns and issues higher in the decision-making hierarchy if the unit director is at a level commensurate with the responsibility and accountability given the unit
- Acting as a centralized point of responsibility, authority, and accountability for environmental initiatives (e.g., implementing a climate adaptation action plan)

- Allowing those having similar interests in environmental issues and concerns to work collaboratively among themselves and with others in the DOT as a unitary identity
- Depending on the responsibilities given the unit, linking environmental policies and goals with implementation responsibilities; for example, two of the state DOT examples below have placed operating authority for certain programs in the environmental unit (e.g., roadside vegetation/landscape and erosion control/stormwater management)
- (Potentially) establishing an environmental staff career path for those interested in environmental issues and concerns, assuming such a career path is developed as part of the creation of the unit

As indicated above, the advantages of establishing a separate environmental unit in a DOT will depend on the roles given to this unit. Experiences from other DOTs, however, show that the success of an environmental unit will largely depend on how it links to, and is integrated with, other project development processes in the agency. What needs to be avoided is the perception (or reality) of a separate environmental unit being viewed by others in the Department as an obstacle to achieving departmental goals.

C.4 CHANGING CONTEXTS FOR TRANSPORTATION AND ENVIRONMENTAL ANALYSIS

An increasing policy concern for environmental issues goes beyond the usual state DOT environmental function of making sure environmental impact documents meet Federal and, where appropriate, state laws and regulations. Environmental offices provide a range of capabilities to state DOTs and many have been given the lead role for climate adaptation studies. This range of interests is well illustrated by a recent survey of state DOT planning directors. A 2020 survey of the directors for a National Cooperative Highway Research Program (NCHRP) project focused on future staff needs for transportation planners to identify the policy and technical analysis trends they anticipated for state DOTs over the next five years. The intent of the survey was to link these trends to needed staff capabilities for today's state DOT transportation planning units. The key question with respect to these trends asked planning directors to rate expected changes in terms of how important they are for defining what transportation planners will need to know five years from now.

The results of this survey question (shown in Table C-1) are quite telling in terms of the likely future issues that will face state DOTs. Two of the top three issues identified by transportation planning directors related to environmental and livability factors:

1. Increasing public/policy focus on transportation as related to livability and community quality (e.g., increasing the importance of Active Transportation, including pedestrianization, bicycle and scooter accommodation, and micro transit
2. Increasing concern for changing environmental conditions and impacts, including climate change

This latter issue, "Increasing concern for changing environmental conditions and impacts" also received the second-most "important or very important" number of votes, while "changes in transportation technologies (e.g., vehicle types, networks, communications, automated/ connected, etc." received the most votes.

State DOT planning directors clearly view the environmental and community context for transportation decision making as being some of the most important issues transportation officials are likely to face soon.

Table C-1: Survey Ranking of Important Factors Influencing Transportation in the Future, State DOTs, 2019

Factor	Rank1	# of Most Important or Important Votes
Increasing public/policy focus on transportation as related to livability and community quality (e.g., increasing importance of Active Transportation, including pedestrianization, bicycle and scooter accommodation, and micro transit)	4.4	31
Changes in transportation technologies (e.g., vehicle types, networks, communications, automated/connected, etc.)	4.3	34
Increasing concern for changing environmental conditions and impacts, including climate change	4.2	32
Mobility needs of those underserved by effective transportation	4.2	31
Evolving socioeconomic trends and development/land use patterns and their impact on travel	4.1	30
Changing demographic characteristics/lifestyles of the population	4.0	27
Changes in personal communication technologies (e.g., internet-based interpersonal communications, mobile phone technologies, etc.). Changes in data collection/analysis technologies	3.9	29
New forms of financing/funding transportation systems	3.8	24
Increasing focus on economic development/new economic entities	3.7	24
Changing roles of public agencies and private firms (e.g., public/private partnerships) and increasing policy emphasis on performance and cost effectiveness	3.4	17
Security/system disruption risks	3.4	17
Global economic competition as related to transportation costs and economic development	3.3	13
Total of 37 responses		

[1] (least important) to 5 (most important)

Source: Survey conducted for NCHRP Project 8-125, Attracting, Retaining, and Developing the Transportation Workforce: Transportation Planners

C.5 ILLUSTRATIVE STATE DOT STRUCTURES FOR ENVIRONMENTAL UNITS

The case examples below highlight how environmental offices provide a range of capabilities to state DOTs. In some cases, a state DOT has placed the lead role for climate adaptation studies in an environmental unit, while others have put the monitoring of environmental permit compliance in the unit as well. The specific responsibilities will depend on how an environmental unit fits into the overall policy and technical practices of an agency. However, as noted earlier, the success of an environmental unit in the larger departmental context will largely depend on how it links to, and is integrated with, other project development processes in the agency.

The four states highlighted below were selected based on two criteria that were considered best suited for the HDOT context: 1) national reputation for being a leader in the consideration of environmental factors in decision

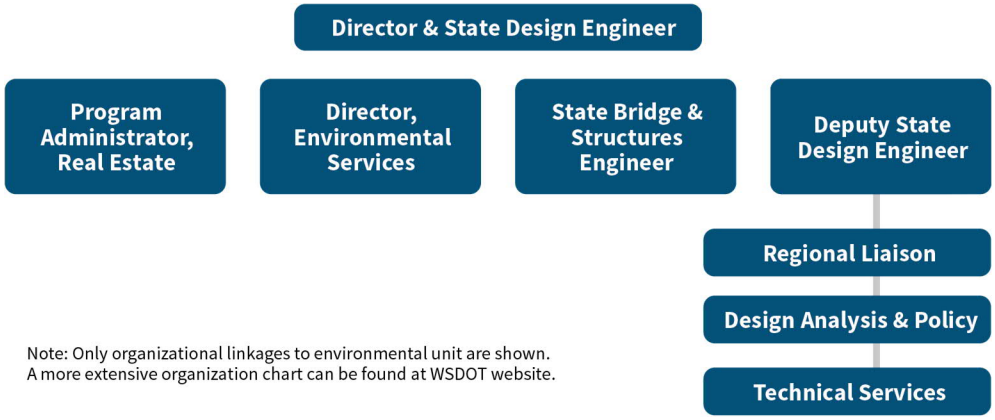
making and/or 2) existence of sensitive, nationally significant environmental areas or issues that must be addressed in policy and project development.

Washington State DOT and Minnesota DOT are viewed as some of the most advanced states in the nation with respect to linking environmental considerations to transportation project development decisions. Maryland DOT with the Chesapeake Bay coastal environment and facing significant sea level rise and storm surge issues was considered a good peer example. In addition, Florida DOT, with the Everglades, sensitive coastal environs and inland groundwater issues, is facing similar environmental sensitivities as HDOT.

Other states were considered but were not included for various reasons. For example, the California DOT (Caltrans) is also viewed as a national leader in environmental considerations, but the sheer size of the state and the very large staffs assigned to both planning and environmental analyses suggests it would not be the best example for HDOT.

C.5.1 WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT)

Up to the 2000s, WSDOT had an environmental office that was typical of many DOTs at that time. The focus was primarily in producing environmental documents in compliance with Federal and State laws, and in satisfying the requirements for obtaining permits from environmental resource agencies. A new Secretary of Transportation in the early 2000s created a more robust environmental services division, which among other things became more visible on the overall organization chart. The intent of this restructuring was to enhance the visibility of the Department's environmental services to external audiences as well as to send a message to the rest of the agency on the importance of environmental factors in Department decision making. The environmental services area grew from approximately 10 positions to the current 90 positions (see Figure C-1). As noted by Paula Hammond, former Secretary of Transportation for WSDOT in a personal communication, "it is not hard to recognize that over these 20 years, the evolution of all the disciplines has become more robust and integrated in everything the Department does these days."



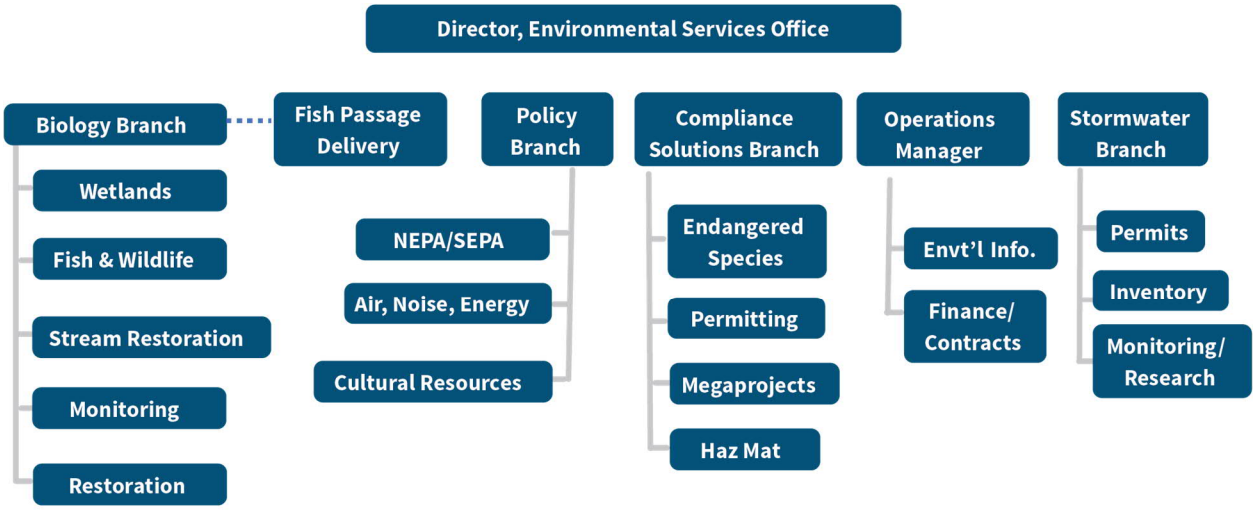
Source: WSDOT. 2019. "Organization Chart." Accessed April 15, 2020 from: https://www.wsdot.wa.gov/sites/default/files/2018/10/16/wsdot-organizational-chart.pdf

Figure C-1. WSDOT's Environmental Services Office within Multimodal Development and Delivery Development Division

The Environmental Services Office has been very aggressive in providing public material on the many efforts at WSDOT to enhance the environment in addition to providing regulatory compliance reviews. For example, videos, webpages, information centers, and publications are found in the following areas (WSDOT 2020):

- History, archaeology, and culture
- Improving fish passage
- Litter on state highways
- Maintaining vegetation along our highways
- Protecting pollinators
- Sustainable transportation
- Managing stormwater from state highways
- Improving wildlife habitat connectivity
- Reducing the risk of wildlife collisions
- Road noise and noise walls

One of the most recent initiatives in the Environmental Services Office is enhancing the recognition of the climate change and resilience role the office plays. The Deputy Secretary has established a cross-functional resilience task force, which to date has not formalized its focus in the organizational structure shown in Figure C-2.



Note: Only organizational linkages to environmental unit are shown.
A more extensive organization chart can be found at WSDOT website.

Source: WSDOT. 2019. "Agency Organization Charts." Accessed April 15, 2020 from: https://www.wsdot.wa.gov/sites/default/files/2016/09/14/2016_Tab_A_2017_19BudgetRequest.pdf

Figure C-2. Organization of WSDOT's Environmental Services Office

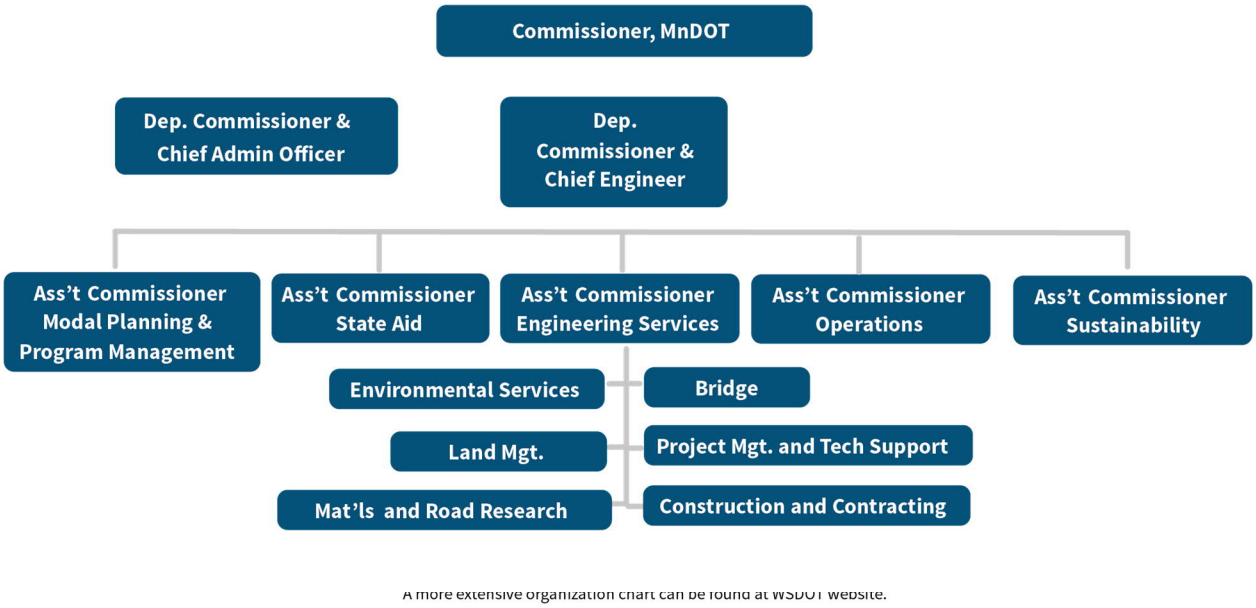
C.5.2 MINNESOTA DEPARTMENT OF TRANSPORTATION (MNDOT)

MnDOT has long held a national reputation for one of the more advanced DOTs in how environmental considerations are included in transportation decision making.

MnDOT created an Assistant Commissioner and Chief Sustainability Officer position within the Department, which does not overlap with the Office of Environmental Services. The purpose of this position is to act as a central focus for MnDOT's sustainability efforts. In 2016, MnDOT created a Sustainable Transportation Committee to identify sustainability goals and incorporate sustainability into agency decision making and business practices. The Assistant Commissioner acts as the main support for the committee. In response to state legislation, the major focus of this office is on strategies to reduce carbon emissions from transportation sources. Although not directed by the office, MnDOT has also included under its sustainability umbrella its climate change resilience efforts.

For example, MnDOT's sustainability website describes the Statewide Extreme Flood Vulnerability Analysis that has been conducted by the agency, which followed a pilot study of this issue in 2014-2015. The intent of this analysis is to develop a process for evaluating future flood risk to MnDOT bridges, large culverts, and pipes.

The MnDOT Office of Environmental Services is located in the Engineering Services division (Figure C-3).



Source: Minnesota DOT. 2019. "Organization Chart." Accessed April 15, 2020 at https://www.dot.state.mn.us/information/orgchart/chart.pdf

Figure C-3. Office of Environmental Services, MnDOT

MnDOT is organized into the following units: (MnDOT 2020):

Cultural Resources Unit: Reviews FHWA undertakings for potential impacts to historic properties pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended. FHWA undertakings are defined as anything funded and approved by FHWA, including Interstate Access Requests. In addition to Federal reviews, the unit reviews state-funded MnDOT projects pursuant to applicable state statutes.

Environmental Assessment: Provides technical support for MnDOT Districts and other stakeholders in the areas of aquatic resources, wetland mitigation, stormwater requirements, and wildlife, including federally threatened and endangered species. Also reviews and approves environmental documents (environmental impact statements, environmental assessments, and categorical exclusions) and provides guidance on the interpretation of the National Environmental Policy Act (NEPA) and Minnesota Environmental Protect Act regulations.

Environmental Modeling and Testing: Provides technical expertise in the areas of transportation-related air, noise, soil, and water quality.

Environmental Planning and Design: Provides technical and design support for all aspects of project development from project scoping to maintenance activities of MnDOT right-of-way corridors and district landscape and planning projects.

Roadside Vegetation: Works to create safer traveling conditions, improved water quality, and aesthetically pleasing landscapes for the highway user.

Erosion Control and Stormwater Management: Works with design, construction, and maintenance project managers to develop plans and procedures that promote cleaner project sites and to protect the waters of the state during construction and maintenance activities.

Scenic Byways: A cooperative effort between MnDOT and local community groups to preserve, promote, and enhance some of the most scenic and historic state highway corridors.

C.5.3 MARYLAND DEPARTMENT OF TRANSPORTATION (MDOT)

Given its location on Chesapeake Bay and with many other environmentally sensitive areas throughout the state, the State of Maryland has established numerous legal and regulatory processes that require state agencies such as MDOT to conduct extensive environmental studies when projects affect vulnerable areas. For many years, MDOT has been a national leader in various environmental areas, most recently in climate change adaptation (especially as it affects coastal areas).

Of interest to HDOT in the context of the current Action Plan, MDOT has developed vulnerability assessment data and resiliency plans for current and future impacts of climate change. Data from the vulnerability assessment have been made available to the Maryland State Highway Administration (SHA) planning, programming, and design as input into the types of project designs that might be necessary in areas of high risk to changing climatic conditions. The SHA has developed a Vulnerability Viewer that can be used to see this data. Sea level change and coastal precipitation were modeled and mapped for 2015, 2050, and 2100 for the 10, 25, 50, 100, and 500-year return interval storms.

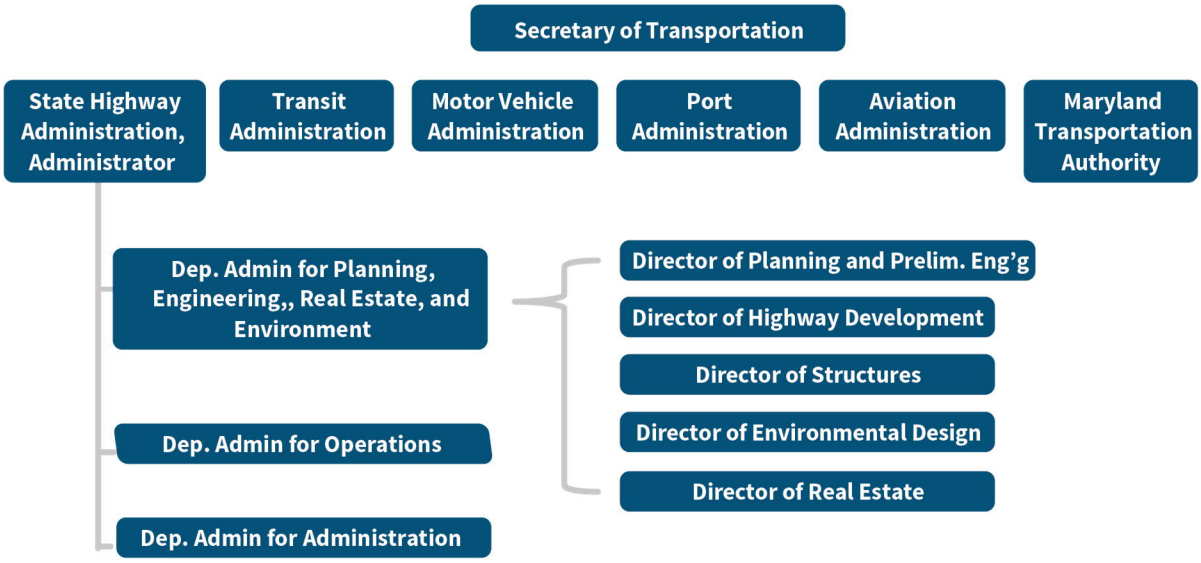
MDOT consists of five business units (modal agencies) and one Authority, a structure somewhat like HDOT. The Secretary's Office provides overall policy and budgetary direction. Five administrations focus on specific modal networks: Maryland SHA, Maryland Transit Administration, Maryland Motor Vehicle Administration, Maryland Port Administration, and the Maryland Aviation Administration. A Maryland Transportation Authority focuses on toll roads in the state.

MDOT has adopted “Environmental Stewardship” as one of the state transportation policy goals, defined as:

> *“Ensure the delivery of the State’s transportation infrastructure program conserves and enhances Maryland’s natural, historic and cultural resources”*

The website for MDOTs environmental program lists major initiatives in air quality, climate change, energy, solar program, land and water resources, and environmental compliance. MDOT is a member of the Maryland Commission on Climate Change and collaborates with the Maryland Department of the Environment, other state agencies, local governments, nongovernmental entities, and communities in planning and implementing a climate resiliency plan.

Although the Secretary's Office has overall authority and responsibility for environmental policy for the Department, much of the actual environmental effort is found in the modal administrations. For example, the Office of Environmental Design in the SHA reports to the SHA Deputy Administrator for Planning, Engineering, Real Estate, and Environment (Figure C-3) (SHA 2020). Note that this structure is similar to the recommendation for HDOT found in the Action Plan.



Source: Maryland SHA. 2019. "Organization Chart." Accessed April 15, 2020 from: https://www.roads.maryland.gov/OC/MDOTSHA_Org_Chart.pdf

Figure C-4. Office of Environmental Design in Maryland SHA

The office consists of the following six divisions:

Environmental Compliance Division: Responsible for SHA compliance with Federal, State, and local environmental laws, regulations, and permits. The Division has developed an Environmental Management System for highway and facility operations.

Environmental Programs Division: Responsible for environmentally sensitive highway, bridge, and maintenance projects in order to minimize impacts to sensitive natural resources. In addition, the Division tracks environmental permit applications; prepares the plans, specifications, and estimates for all MDOT SHA's compensatory wetland mitigation, stream mitigation, reforestation, and critical area projects; identifies, evaluates, and delivers successful environmental stewardship projects to improve water quality to the Chesapeake Bay and its tributaries; and includes responsibilities for wetland delineation and functional assessment services, water quality monitoring, wetland mitigation and stream restoration monitoring, and environmental monitoring of construction projects.

Landscape Programs Division: Responsible for managing integrated vegetation of roadsides providing innovative, context-sensitive landscape architectural design solutions and technical support for highway projects and roadsides; developing landscape planting and hardscape plans, specifications, and estimates for highway construction projects; and enforcing vegetation management and landscape design standards, guidelines, and construction specifications.

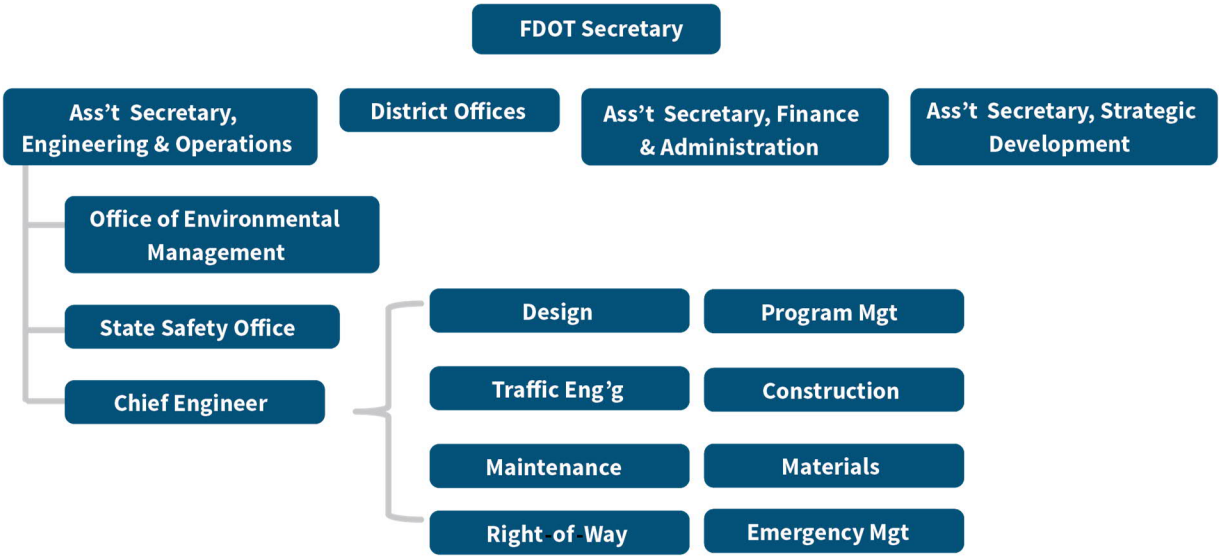
Program Support Division: Responsible for procurement and contract management activities for the Office of Environmental Design; prepares and manages contracts; provides information technology support for staff at headquarters and satellite locations throughout the State; conducts contract closeout of office-administered capital construction and operations-maintenance projects.

Quality Assurance Division: Responsible for ensuring all SHA construction and maintenance activities requiring compliance with the stormwater and sediment control laws of Maryland and the United States Clean Water Act obtain review and approval; develops comprehensive policies, procedures, interpretations, guidance, and training related to erosion and sediment control and storm water management requirements; and communicates with Maryland Department of the Environment and other regulatory agencies.

Water Programs Division: Responsible for compliance with state water quality standards and the Federal Clean Water Act by administering National Pollutant Discharge Elimination System (NPDES) MS4 permits, and Chesapeake Bay and local waterway requirements. The Division supports the implementation of best management practices throughout the state.

C.5.4 FLORIDA DEPARTMENT OF TRANSPORTATION (FDOT)

FDOT has been one of the nation's leaders in integrating environmental considerations into transportation decision making. The focus of the Department's efforts has centered in the Office of Environmental Management (OEM) whose director reports to the Assistant Secretary for Engineering and Operations (Figure C-5).



Source: Florida DOT. "Organization Chart." Accessed April 15, 2020 from: https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/humanresources/documents/fdotorganizationchart.pdf?sfvrsn=9004b8c6_51

Figure C-5. FDOTs Office of Environmental Management

The following vision, mission, and role statements describe the functions of the office.

VISION

"The Office of Environmental Management leads in planning, developing and implementing environmental programs for transportation projects and facilities in support of the Department's mission that promote and preserve Florida's environmental quality, community values, and economic prosperity" (FDOT 2020a).

MISSION

"The mission of the Office of Environmental Management is to establish consistent, predictable and repeatable environmental policies, procedures and programs that promote and preserve Florida's environmental quality, community values, and economic prosperity in support of implementing Department's programs and projects" (FDOT 2020a).

ROLE

"The role of the FDOT Office of Environmental Management (OEM) is to develop and ensure the implementation of quality environmental policies, procedures and practices in the development of transportation improvements through each of the Department's core processes plan, produce, deliver and maintain. Establish policy and procedures to ensure implementation of environmental programs and initiatives of the Department. Coordinate with Federal and State environmental resource and regulatory agencies in the development and implementation of environmental processes and procedures consistent with environmental laws and regulations to assist the Department in achieving its mission" (FDOT 2020b).

OEM is divided into three sections (FDOT 2020c):

Engineering Review and Analysis Section: This section develops and maintains environmental policy, procedures, manuals, and guidelines consistent with state and Department policy. Statewide technical and engineering expertise is provided for all physical environmental considerations in all phases of project development, planning through maintenance. This section also manages and/or coordinates other FDOT statewide environmental program areas, including Transportation Enhancements, Scenic Highways, and Landscape Architecture. This section ensures quality processes are developed and implemented for environmental analyses by performing quality assurance reviews, providing training and direction, as well as coordinating with other State and Federal agencies, FDOT Districts, and others.

Environmental Review and Analysis Section: This section develops and maintains environmental policy, procedures, manuals, and guidelines consistent with project delivery processes, as well as statewide planning initiatives. This section is largely responsible for the maintenance of the Project Development & Environment (PD&E) Manual, which outlines procedures for adherence to NEPA and its implementing regulations in addition to applicable state environmental laws. Natural and community considerations and program areas include wildlife and habitat, wetlands and mitigation, historic, archaeological, tribal, sociocultural, and public involvement.

Quality Assurance and Performance Section: This section is responsible for the administrative and technology-based functions of the Efficient Transportation Decision Making (ETDM) program, a decision support system described further below. This section ensures quality processes are developed and implemented by performing quality assurance reviews, providing training and direction, as well as coordinating with other State and Federal agencies, FDOT Districts, and others.

ETDM was one of the transportation decision-making innovations developed by FDOT in the late 1990s. ETDM allows FDOT and other stakeholder review of environmental impacts of transportation projects in the planning phase. Stakeholders involved in the ETDM process generally include Metropolitan Planning Organizations/Transportation Planning Organizations, county and municipal governments, Federal and State agencies, Native American tribes, and the public. This process provides stakeholders with the opportunity for early input, involvement, and coordination. The intent is to inform the development of scopes for projects advancing to the PD&E phase (Figure C-6) (FDOT 2020d).

Coordination with external resource agency representatives occurs through an Environmental Screening Tool (EST), an Internet-accessible interactive database and mapping application. The EST provides quick, standardized Geographic Information System analyses, identifying potential natural, physical, cultural, and community resources present in the project area.

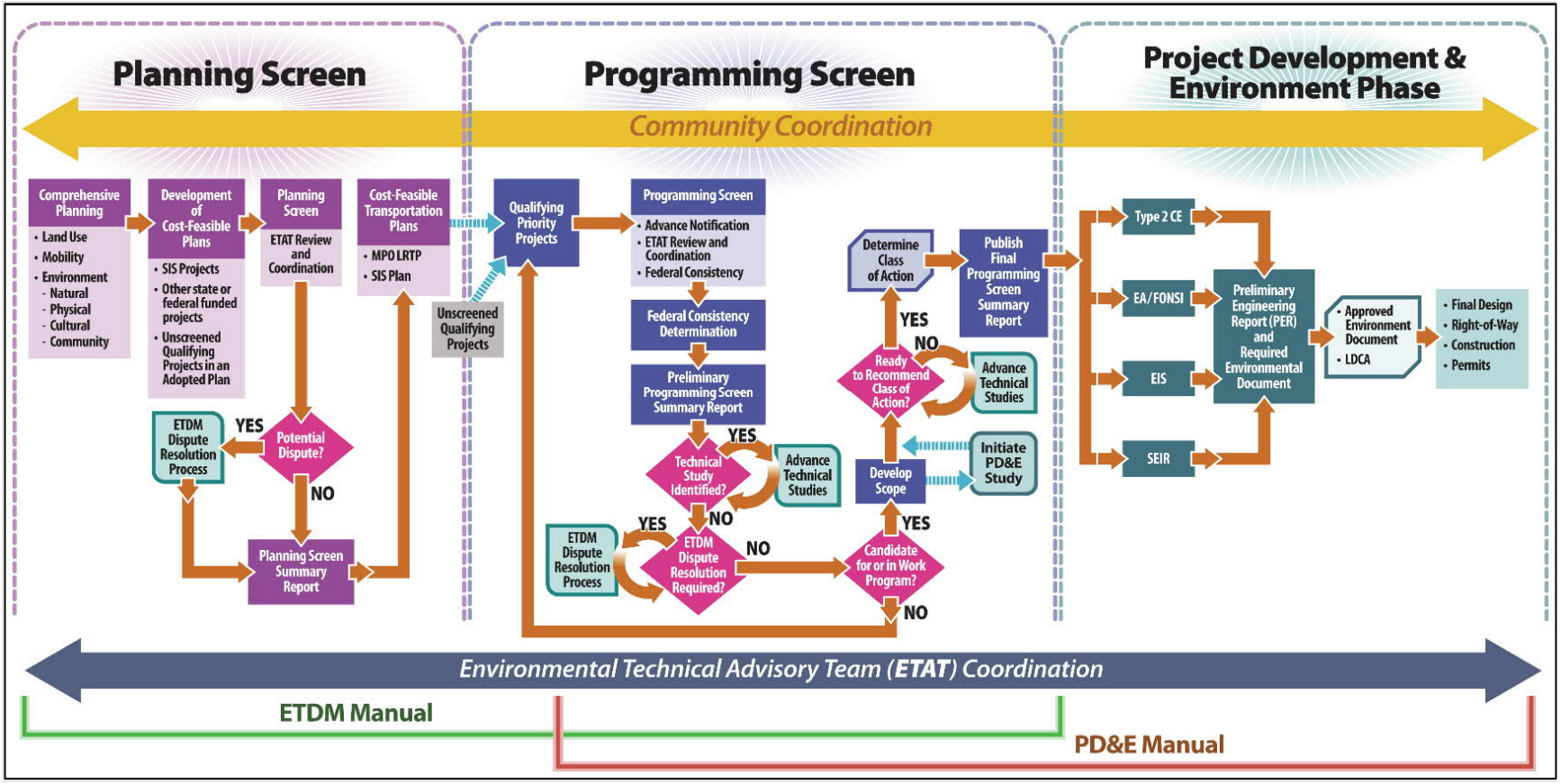


Figure C-6. FDOTs ETDM and PD&D Program Diagram

The types of issues and efforts undertaken by OEM is represented by the long list of publications and resources available on its website, which include the following:

- PD&E Manual
- Alternatives Corridor Evaluation Report Template
- Cultural Resource Management Handbook
- Cumulative Effects Evaluation Handbook
- Cumulative Effects Evaluation Quick Guide
- Environmental Policy
- Environmental Review and Final Approval of Interchange Access Requests
- Essential Fish Habitat
- Endangered Species Act Lead Agency Consultation Correspondence
- Environmental Screening Tool Handbook
- ETDM Dispute Resolution Brochure
- ETDM Funded Position Reference Handbook
- ETDM Manual
- ETDM Programmatic Agreements
- FDOT Environmental Review Guidance for Emergency Relief Projects
- FDOT NPDES MS4 Statewide Stormwater Management Plan
- FDOT Quick Guide: Transforming our State Pre-Construction Process
- FDOT-FDEP Memorandum of Understanding – Addressing Discharges of Petroleum Pollutants
- FDOT/FHWA Planning Consistency Information
- FDOT Designated by National Marine Fisheries Service to Complete Informal Consultation under Section 7 of Endangered Species Act (ESA)
- FDOT Designated by U.S. Fish and Wildlife Service to complete Informal Consultation under Section 7 of ESA
- FDOT Permit Handbook
- Legislatively designated Scenic Highways
- Mitigation Payment Handbook
- Memorandum of Agreement between FDOT and State Historic Preservation Officer Template
- MSAT Quantitative Analysis and ERLT
- NEPA Assignment Quality Assurance and Quality Control Plan (PDF)
- OEM EDMS Quality Assurance/Quality Control Process (PDF) (PPT)
- OEM Bulletins and Memorandums
- Preliminary Engineering Report Outline and Guidance
- Public Involvement Handbook
- Programmatic Agreement for Categorical Exclusions under 23 CFR 771.117 between FHWA and FDOT (superseded by NEPA Assignment Memorandum of Understanding December 14, 2016)
- PSM Codes and Environmental Document Schedule Templates
- Quality Control Plan Template and Checklists for PD&E Studies
- Quality Environmental Documents
- Safety Analysis Guidebook for PD&E Studies
- Section 106 Programmatic Agreement
- Section 106 PA NEPA Assignment Amendment
- Sociocultural Effects Evaluation Handbook
- Standard Scopes of Services
- Statewide Acceleration Transformation
- Transportation Improvement Program/ State Transportation Improvement Program/Long-Range Transportation Plan/NEPA Consistency Info
- U.S. Coast Guard and FDOT Coordination Guidance

- FDOT Use of Programmatic Effect Determination Keys
- Final Natural Resources Evaluation Guidance
- Freshwater Mussel Programmatic Approach
- Gopher Tortoise Guidance
- Historic Highway Bridges of Florida
- FDOT Procedure for Section 4(f) *de minimis* Approvals
- Wildlife Crossing Guidelines – March 2018
- 2019 – Application for Federal Assistance
- A Method to Determine Reasonableness and Feasibility of Noise Abatement at Special Use Locations
- Special Use Locations Worksheet – Users Guide (Word doc)
- Special Use Locations Worksheet (Excel spreadsheet)
- Traffic Noise Modeling and Analysis Practitioners Handbook (PDF)

C.5.5 SUMMARY

This technical overview provided examples of how some other state DOTs structure their environmental analysis and policy capabilities in their organization. Every state DOT is different in how this is done. However, almost all state DOTs in the nation have very well defined and identified organizational units with environmental responsibilities.

The increasing policy concern for environmental issues goes beyond the usual state DOT environmental function of making sure environmental impact documents meet Federal and, where appropriate, state laws and regulations. As was seen in the case examples, the highlighted environmental offices provide a range of capabilities to state DOTs. In some cases, a state DOT has placed the lead role for climate adaptation studies in an environmental unit, while others have put the monitoring of environmental permit compliance in the unit as well. The specific responsibilities will depend on how an environmental unit fits into the overall policy and technical practices of an agency. However, as noted earlier, the success of an environmental unit in the larger departmental context will largely depend on how it links to, and is integrated with, other project development processes in the agency.

C.6 APPENDIX C REFERENCES

Federal Highway Administration (FHWA). 2015. *Hawaii Environmental Program Review*. January.

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APPENDIX D. PARTNERSHIPS TOWARD IMPLEMENTATION

PARTNERSHIPS TOWARD IMPLEMENTATION

Planning for and effectively responding to disruptions often requires alignment among Federal, State, and county agencies, as well as interaction with the communities they serve. As one of the most effective government agencies in project delivery, the Hawai'i Department of Transportation (HDOT) already collaborates regularly with many such groups. These existing and additional partnerships must remain strong to ensure that the transformative changes required to adapt to climate change occur proactively and routinely during project planning and development in a way that also respects local community values and priorities. Examples of these partnerships are provided below.

Partnerships can lead to:

- Collaborative assessment of probable climate-related effects on Hawai'i
- Development and implementation of statewide climate adaptation strategies
- Mutual and collaborative investment to reduce climate-related effects across shared systems
- Institutionalization of climate adaptation and system resilience into standard operating procedures
- Education of other stakeholders and the public on the need for, and challenges of, climate adaptation and system resilience strategies

D.1 FUNDING AGENCIES

As the primary Federal funding agency for highway projects, the Federal Highway Administration (FHWA) remains a critical partner to HDOT. In addition to making regular highway funds available through Federal-aid programs, the U.S. Department of Transportation annually offers the Better Utilizing Infrastructure to Leverage Development (BUILD) grant program (formerly Transportation Investment Generating Economic Recovery, or TIGER, grants). This program supports road, rail, transit, ports, and multimodal projects that promise to achieve national objectives to build and repair freight and passenger transportation networks. These Federal funds can be used for climate adaptation and system resilience.

The Federal Emergency Management Agency is another critical partner to HDOT in taking proactive action. Its new Building Resilient Infrastructure and Communities (BRIC) program, established by the Disaster Recovery Reform Act of 2018, is one of its pre-disaster hazard mitigation programs designed to incentivize innovative infrastructure projects with the potential of promoting adaptation and resilience prior to a major disaster (see Appendix B 4.4). BRIC aims to shift Federal spending from a reactive, post-disaster approach toward proactive, pre-disaster investments, which presents an opportunity for HDOT and other state partners.

D.2 BOND-RATING AGENCIES

Climate-related effects and adaptation will play an increasing role in bond ratings, affecting the ability of governments to borrow and invest funds in capital improvements. Governments at higher risk of climate effects will be asked by bond-rating agencies to explain how they are prepared to reduce these probable effects. This

Action Plan can be used as an instrument to communicate HDOT's efforts on climate adaptation and system resilience.

D.3 LEGISLATORS

State legislators are important enablers of state DOT actions in that they often establish the legal and institutional relationships between and among state agencies and provide the funding that will be used to plan, build, operate, and maintain state highways. It is important therefore that they are aware of HDOT's initiatives and efforts relating to a more resilient highway network. HDOT has worked closely with the State Legislature for many years and thus the process for such an outreach is well established.

D.4 REGULATORY AGENCIES

HDOT is legally required to obtain reviews and approvals for roadway projects from several regulatory agencies. Some agencies currently participate in the Transportation Environmental Resource Council (TERC), which allows information sharing and collaboration among relevant agencies to streamline project development. Regulatory agency reviews for minor HDOT actions have been streamlined by existing programmatic agreements such as the National Environmental Policy Act Categorical Exclusions with the FHWA, Endangered Species Act Section 7 consultations with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, and Hawai'i Revised Statutes Chapter 6E review for historic properties with the State Historic Preservation Division. Continuing to foster cooperation among all agencies, including developing programmatic agreements to streamline both high-priority projects and minor actions needed for climate change adaptation, will allow critical projects to be reviewed more quickly and implemented sooner.

D.5 STATE AND COUNTY AGENCIES

Non-regulatory state agencies and county governments, especially those responsible for land use policy, also are leading the way in identifying and implementing climate adaptation and system resilience measures. County-specific general plans and community plans, shoreline setbacks, as well as state land use and coastal zone management policies drive existing and future land uses that affect where and how roadways are designed and maintained. They also govern what transportation projects can be permitted. (see Appendix B). Decisions on land use can impact the performance of transportation assets during the occurrence of climate-related events and, therefore, close coordination on land use decisions is needed. Furthermore, HDOT's state-owned roads are also interconnected with county roads, and in some cases with federal and private roads. Therefore, collaboration to design facilities under the same set of design criteria is critical to create a cohesive and resilient transportation system in the State.

D.6 LARGE LANDOWNERS

Large landowners, including the public and private sectors, are also potential partners with HDOT and with all agencies that seek to develop alternatives to existing roadways. Owners or stewards of properties near or immediately adjacent to existing roadways or properties mauka of coastlines may be considered for needed highway realignments to increase system resilience. Laniākea Beach on the North Shore of O'ahu and Honoapi'ilani Highway in West Maui are prime examples of such collaborative efforts.

D.7 RESEARCHERS IN LOCAL, NATIONAL, AND INTERNATIONAL INSTITUTIONS

HDOT should continue to work with those entities that monitor climate change trends and those that contribute to the understanding of potential future climate-related effects on highway assets. This group includes universities and science-based agencies such as the University of Hawai‘i, the United States Geologic Survey, and the National Oceanic and Atmospheric Administration.

D.8 UTILITY COMPANIES

In project design and implementation, routine maintenance, and emergency response, HDOT must partner with public utilities such as the local power, communications, and water/sewer companies, which often share the same rights-of-way. From a safety standpoint, the local electric company is one of the most critical utilities for such collaboration to ensure effective operation of the HDOT system. HDOT should continue to build and strengthen relationships with public utilities to reduce shared risks and deliver services to businesses and residents.

D.9 GENERAL PUBLIC AND PUBLIC AWARENESS

HDOT should foster a better public understanding of the challenges that climate change could pose to the State and to the State's highway network—economic loss, community disruption, impacts on trade and tourism, and health and safety, among others. In addition, HDOT should explain the Action Plan in ways that the public can understand, and in a manner that places HDOT in State leadership for considering climate change risks in investment decision making. HDOT can be a role model in State and local coordination and a resource on climate adaptation options for key elected officials and other senior government leaders. HDOT's representatives should also remain engaged in the State Climate Change Commission, other state planning activities, and similar efforts at the county level.