

Coastal Sea-Level Change Societal Challenge Needs Assessment Report

Executive Summary

NOAA has focused its efforts on four climate-related challenges to society, which represent a spectrum of needs for which NOAA can develop and deliver services with information provided to make informed decisions for effective adaptation actions and other climate-sensitive decisions. The four societal challenges, as defined in "A Climate Service in NOAA: Connecting Climate Science to Decision Making, Vision and Strategic Framework," are:

1. Climate Impacts on Water Resources
 - Providing coordinated and authoritative information system to guide water resource managers.
2. Coasts and Climate Resilience
 - Understanding physical processes driving sea-level rise and coastal inundation, and providing best available information to decision-makers on sea-level change impacts and adaptive management strategies.
3. Sustainability of Marine Ecosystems
 - Improving understanding of, and information about, the impacts of climate on ocean physical, chemical and biological properties critical to managing large marine ecosystems.
4. Changes in Extremes of Weather and Climate
 - Developing and delivering information to prepare for and adapt to climate and weather extremes, e.g., droughts, floods, heat waves & cold snaps

This needs assessment will focus on challenge #2 – resilience of coasts to the impacts of sea-level change.

The results of the coastal sea-level change societal challenge needs assessment literature review presented in this document represent a snapshot of data, information and services gaps as captured in fifty-two documents, presentations and publications. This synthesis of findings highlights the needs of coastal decision-makers to assist in making informed decisions about the risks and impacts of sea-level change. This report focuses on a discreet subset of decision-makers who have significant influence in the coastal communities that they manage and where they work. These groups include: 1) tribal, state, and local planners; 2) coastal managers; 3) regional and local professional organizations; 4) port authorities and operators; 5) federal and state natural resource and habitat conservation, restoration, and protection managers; and 6) practitioners and land-acquisition partners. Decisions related to coastal and environmental challenges are made every day and it is a priority of NOAA to ensure that these coastal decision-makers have the data, information, tools and services they require to make the most informed choices about the realities they face.

The results of this report are intended to provide NOAA with current information on the defined needs of coastal decision-makers in order to directly inform the

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development of decision-support tools and applications. This report looks at the specified needs through the lens of NOAA's strategic planning efforts. The gaps identified in the needs assessments reviewed for this report are binned by: category and theme, their relationship to the needs of other societal challenges, and sector. Some of the needs that appear in each of the three sections include:

- **Data, models and information:** Users are interested in a combination of more, better, higher-resolution, local, scalable, integrated and interdisciplinary data, models and information that are validated, comparable and compatible, easily accessible and easy to use. Social science gaps are communal.
- **Tools and Education:** Users need tools that incorporate data, models and information into visualizations, forecasting systems or other products, and training and education to get the most out of the tools.
- **Communication:** Users need to understand their risks and vulnerabilities and the accompanying terminology and concepts in order to make the most informed decisions. A lack of clarity can translate into a reluctance to take action. In addition, users need sufficient understanding to communicate the essential information to their constituents.

The following chapters in this report more fully describe the needs expressed in the fifty-two documents, presentations and publications examined in this process. By reviewing the lengthy list of needs, it is clear that there are extensive gaps in knowledge, understanding, products, and services related to coastal issues, particularly that of sea-level. NOAA's goal is to assess the needs collated here, prioritize them according to those that should and can be addressed first, and develop climate services to assist coastal decision-makers in suitably addressing their everyday needs. As a key societal challenge, adapting to sea-level change requires dedicated communities who will take time to ensure the safety of our growing population living in coastal regions across the globe.

Section 1

Introduction

As documented in the National Oceanic and Atmospheric Administration (NOAA) *Next Generation Strategic Plan*, NOAA envisions an informed society capable of anticipating and responding to climate change and its impacts. This report identifies specific needs associated with an important climate-related challenge to society: sea-level change.

Mission and Goal

To meet NOAA's mission *to understand and predict changes in climate, weather, oceans, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources*, NOAA will continue to enhance the quality, usefulness and accessibility of climate information and services, building on our history of climate science. NOAA's long-term climate goal is to improve understanding and prediction of changes in climate and promote a climate-resilient society by:

- Monitoring climate trends, conducting research, and developing models to strengthen our knowledge of the changing climate and its impacts on our physical, economic, and societal systems,
- Providing authoritative and timely information products and services about climate change, climate variability, and impacts, and
- Informing decision-making and management at the local, state, regional, national, and international levels.

NOAA will deliver climate products and services in collaboration with public, private, and academic partners to maximize social, economic, and environmental benefits.

Societal Challenges

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This needs assessment will focus on challenge #2 – resilience of coasts to the impacts of sea-level change.

Needs Assessment for Coastal Challenge: Sea Level

The goal of the needs assessment process described in this report is to conduct a systematic investigation of decision-maker needs in order to identify information gaps and develop priorities for new climate-related products and services. This process will be ongoing to ensure continued evaluation of existing and emerging stakeholder needs for information, products, and services.

This coastal needs assessment report focuses on sea-level change and will help identify gaps in the science, understanding, and services required by coastal decision-makers in order to make the most informed management decisions. The document is a synthesis of climate-related needs of coastal decision-makers gathered from an array of relevant sources (see Appendix I for bibliography). It is a snapshot of sea level-related information gaps identified in these sources. Coastal decision-maker needs and broader needs are categorized in the following sections after a review of the methodology used to obtain the needs assessment information. Next steps are offered in the concluding section.

The results of this needs assessment will additionally serve as one input to help frame National and International Climate Science Assessments. This effort will help NOAA understand the nation's vulnerability to climate variability and change, and to inform climate adaptation and mitigation strategies at all levels.

Section 2

Needs Assessment Methodology

A systematic, well-planned needs assessment is critical for informed product and service development, and a powerful force for guiding agency decision-making. The proceeding narrative identifies the systematic sequence used to conduct the needs assessment for the Coasts and Climate Resilience Societal Challenge. In addition to a rigorous, systematic approach, this methodology takes great care to fit within the realities of current time and budget constraints.

As a precursory activity to the needs assessment process, it was necessary to clearly articulate the issue and target audience of interest. To reiterate, the question addressed in this needs assessment is “what are the management needs surrounding the issue of local sea-level rise and inundation that affect coastal regions and communities?” This question served as a reference point to frame subsequent steps of the needs assessment. The initial audience, broadly stated for the assessment was coastal managers. This would be further expanded and then prioritized during the assessment process.

As a second, preliminary step, a planning team was formed in January, 2011 and included representatives from diverse NOAA line offices and programs positioned to assist with solutions to the needs identified in this report. The committee includes representatives from the National Ocean Service, the National Environmental Satellite, Data and Information Service, the National Marine Fisheries Service, and the Climate Program Office. See Appendix II for a complete list of planning team members.

Following the initial activities described above, the planning team collectively engaged in a formal needs assessment process outlined in Figure 1. The first step was to conduct an audience analysis to further identify audiences of interest, as well as the discreet interests and concerns of each group. This step revealed three primary audience types or groupings. These were generally referred to as 1) state-level managers, 2) county- and local-level managers, and 3) other influencers. The first two categories focused predominantly on a geographic scale as opposed to jurisdictional. For example, federal agencies were dispersed across these categories based on the focus of their work in relation to the needs assessment question. The third category did not possess a clearly defined geography, but had considerable influence on decision-making and associated outcomes. Such audience subgroups in the “other influencers” category included the media, educators, and the insurance industry. Upon reviewing the extensive list of sub-audiences within each category, a collective decision was made by the group to focus exclusively on the state-level category in this effort to effectively account for the working group’s time and budget realities. This prioritized audience includes state, local and tribal planners and managers with foci on the coast, floodplains, infrastructure, utilities, emergency management, natural resources and conservation, etc., land acquisition partners, state/regional/local professional organizations, and port authorities. The general sentiment was that all NOAA line offices had current initiatives and high interest in

this audience segment which allowed for all offices to effectively engage from the start. It is the understanding of the planning team that later needs assessment processes will examine the needs of other audiences.

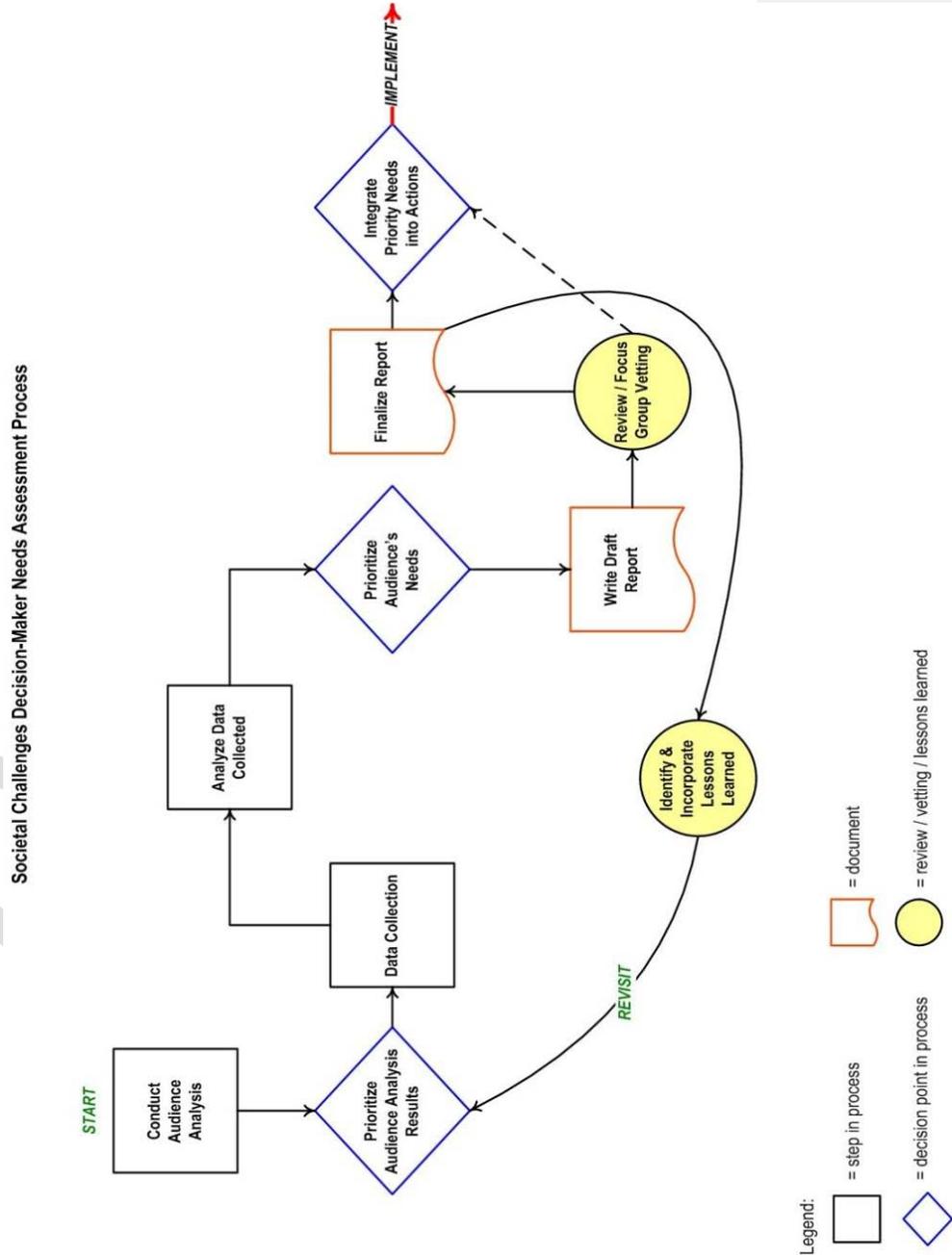
Following the results and decisions made regarding the audience analysis and prioritization, the data collection phase was initiated. There are a number of considerations that go into selecting the most appropriate data collection method(s) for a needs assessment, including the method that would be most receptive to the target population, cost implications, and legal requirements. The decision was made to employ a literature review as a primary approach. Analysis of an array of reports, management documents, and similar resources revealed an array of expressed needs and challenges within the community of interest. These needs were compiled, documented, and subsequently prioritized (based on expressed need reported by the audience) by the planning team. These findings were summarized into a draft report.

Once the draft report was completed, as a secondary data collection approach, findings were ground-truthed by vetting the report through an assemblage of key informants in the audience of interest. These comments were noted, addressed or incorporated to provide verification or correction to the findings of the literature review. Information received through the interviewing process was integrated into this final report.

It should be noted in the figure below that needs assessment is a continual process. Once findings have been determined, reported, and integrated over time, lessons will be learned and new challenges will surface. This necessitates that the investigator revisit both the audience of interest, as well as the needs assessment question and determine if these elements are in need of refinement.

Comment [ncc1]: Note to Veters: the “vetting the report through an assemblage of key informants” reflects the current stage in the process. It is the intent of the team to review every comment received. Thank you for your efforts, they are useful and appreciated.

Figure 1



Section 3 Coastal Decision-Makers' Needs for Sea-Level Changes

Needs Across the Spectrum

The need for information for decision-making in coastal areas has been increasingly focused on sea-level changes and has been well documented based on feedback from state and regional partners, as well as partner organizations. For example, when asked about their highest climate impacts of concern in a 2008 survey, three-quarters of Washington state shoreline planners and coastal managers who responded prioritized sea-level rise. At a regional perspective, the Gulf of Mexico Alliance held a 2010 Special Session on management strategies for sea-level change in the Gulf region, identifying not just data and modeling gaps, but the need to engage local coastal managers so they understand, accept and use the data and information for managing resources and risks. In addition, coastal decision-makers identified several sectors where there were specific needs for information on the impact of SLR on coastal communities, including trade, infrastructure, finance, economic development and transportation.

Sea-level change impacts will affect the entire spectrum of decision-makers in coastal areas, from state and local to sectoral, and efforts have been underway to determine their needs. This section of the literature review will categorize the commonalities and define the broad themes that have emerged from the data.

Categorized Needs

From the literature examined, the needs expressed by coastal decision-makers were grouped into five general categories:

1. Improved ability to predict sea-level change
2. Assessment and predictions of sea-level impacts to coastal communities (trade, tourism, infrastructure, etc.)
3. Science-based assessment and predictions of sea-level change impacts to coastal ecosystems
4. Adaptation and mitigation strategies for coastal decision-makers
5. Education and outreach to stakeholders on sea-level change science and adaptation strategies

Improved Ability to Predict Sea-Level Change

Many coastal decision-makers have expressed a need for an improved ability to predict sea-level change. Improving predictions and projections of local sea-level change requires several information types, including bathymetric, elevation and tide gauge data, and down-scaled sea-level change models. Coastal decision-makers are aware that a means to analyze, interpret and apply scientific research to land use decisions is needed that incorporate multiple fields of data, such as shorelines, geomorphology, socioeconomic data and model projections to develop realistic scenarios for planning purposes. These specific needs are covered in the three following subsections, where appropriate.

Coastal decision-makers have a very clear idea of what they need in terms of data. Over a third of the needs assessments reviewed provided specific detailed needs such as:

- High-resolution topography and bathymetry at consistent temporal and spatial coverage
- Inundation and tidal elevation maps
- Land cover maps(physical coverage of the earth's surface – examples include trees, grass, asphalt, water, etc)
- Additional surface elevation tables and water-level stations to track relative sea-level rise and subsidence
- Paleoclimatological data
- Wave heights, precipitation and wind data

They are also knowledgeable about their needs for modeling. In addition to an overarching request for high-resolution, downscaled models that are easy to use, they need:

- Shoreline change modeling
- Socio-economic models such as economic valuation models, ecosystem change models, comparative evaluation of models, public health models, social and environmental justice models, hazard response models, and population forecasting
- Combined models of inundation and shoreline erosion that also incorporate changes in coastal geomorphology, hydrological conditions, and human alterations and response (seawalls, sand replenishment, etc.) to assess social, environmental, and economic vulnerabilities
- Local and regional scale modeling and projections of specific ecosystems

Coastal decision-makers also need to understand the costs of obtaining this data and information.

Assessment and Predictions of Sea-Level Rise Impacts to Coastal Communities

The societal challenge of coastal resilience to climate change was the leading issue identified in the needs assessments reviewed. Of the sectors identified as having specific needs for information on the impact of SLR on coastal communities, coastal decision-makers most frequently cited infrastructure, followed by economic development and transportation. Specific needs include:

- The ability to devise adaptation practices, standards and strategies, and adjust them in the future as forecasts and predictions improve or are refined
- Standardized information on key indicators of social and economic vitality
- Understand more about how people perceive and respond to risk
- Gaps in regional and local planning response systems
- Tools for decision-makers to easily see potential risk to people and development due to sea-level rise, flooding, and related hazards such as sea-level rise visualizations

- Ability to demonstrate importance of weather, climate, and ocean information in business models
- Predictive models showing the socioeconomic impacts of sea-level change

Science-based Assessment and Predictions of Sea-Level Change Impacts to Coastal Ecosystems

Valuable coastal habitats, including salt marshes, oyster reefs, mangroves and coral reefs may be adversely affected by sea-level change over the coming year and decades. Two-thirds of the needs assessments examined identified 'natural resources' as one of the areas of concern. Coastal decision-makers identified the need for science and information to inform decisions on the conservation and restoration of coastal wetlands, and to guide permitting and other land-use policies, including:

- Understanding of marine resources and ocean dynamics and targeted studies of biological and physiological tolerances to changes anticipated from sea-level change
- Issues and information related to nearshore water circulation, shoreline stability and erosion, coastal hazards, and ocean acidification
- Understanding the human connection and our dependence on healthy ecosystems
- How to design and prioritize restoration projects given sea-level and climate change predictions
- Better understanding of natural erosion and deposition cycles in tidal marshes and sediment trapping/accretion
- Landscape response to sea-level and salinity changes
- Natural resource mapping and identification of high-priority areas and the impacts of sea-level rise
- Models that predict migration and/or vertical accretion of coastal wetlands and beaches
- Data and tools to predict impacts on habitats

Adaptation and Mitigation Strategies for Coastal Decision-Makers

In order to prepare coastal communities for projected sea-level change, the literature review clearly indicates a need for adaptation and mitigation strategies by coastal decision-makers. Collectively, these strategies represent the actions coastal decision-makers can take to respond to threats to local communities and habitats from sea-level change. Coastal decision-makers need:

- Specific determination of likely changes to human communities or local ecosystems
- To develop local capacity to assess community status and barriers to achieving sustainable and vibrant communities, and develop strategies to move towards sustainability and vibrancy
- Risk assessment and planning and vulnerability assessments
- Adaptive management planning

- Strategies for incorporation of the outputs of sea-level rise research and modeling into planning, policies and regulations
- Catalog of best management practices for climate adaptation strategies
- Dialogue to determine practical strategies

Adaptation strategies were linked to short-term risks, and mitigation strategies to longer-term risk. In addition to the adaptation strategies themselves, a need for an economic assessment of adaptation strategies was expressed.

Education and Outreach to Stakeholders on Sea-Level Change Science and Adaptation Strategies

In order for coastal decision-makers to implement strategies to build resilience to climate impacts such as sea-level change, it is important to be able to explain, advocate and get support for the implementation of adaptation strategies. Across the nation, coastal decision-makers have identified the need for help in educating stakeholders on the science supporting sea-level change predictions, the impacts of sea-level change on coastal communities and habitats, and why and how adaptation strategies will work. According to the literature reviewed, tools that support coastal decision-makers' education of and outreach to the public regarding sea-level change will enable stakeholders to:

- 1) better understand SLR impacts, as well as risk and uncertainty;
- 2) make informed personal and collective decisions (behavior change); and
- 3) inspire engagement in decision-making and planning processes.

Many coastal decision-makers specified that education and outreach tools should be focused at the local level, in order to most effectively inform the public on their climate risks and initiate action. It was noted that current climate science needs to be articulated in a way that is "not only understood, but accepted by, the audience targeted." The literature review identified a suite of potential tools that could help translate climate change science into localized impacts, and facilitate education and outreach regarding SLR impacts. These included:

- Products and tools with user-friendly interfaces, e.g. interactive maps such as data layers that are available via Google Earth, preferably at a local scale
- Models that are more intuitive to laymen
- Public relations information that might include brochures, DVDs, and traveling exhibits
- K-12 education materials

Two documents also noted the need for coastal decision-makers to better understand the factors that support or prevent resilient behavior and decision-making, so that outreach and education at the local level can be tailored to "foster resilient behaviors and support local champions of resilience who can make a significant impact in their communities." These different tools and information would allow coastal decision-makers to engage a variety of stakeholders in the process of understanding, anticipating, and responding to sea-level change.

Thematic Needs

Throughout all of these categories run five overarching themes that point to the bigger picture of climate needs:

1. Defining and understanding uncertainty
2. The need for standards, protocols and access for everything from data collection to infrastructure design
3. The need for a centralized database and resource list
4. The need for interdisciplinary, integrated information, data, models, tools and strategies, to incorporate biological, physical, ecological, economic and social information to better inform all decision-making
5. The need to take general information to the local actionable level, whether the information is sea-level change rates, adaptation strategies, or threats to infrastructure.

Defining and Understanding Uncertainty

Coastal decision-makers find that communicating uncertainty is difficult and must be done in a meaningful way and in some cases, require assistance in doing so. Data gaps also lead to uncertainty. Some of the specific uncertainties are in:

- Impacts of sea temperature, acidification, and sea-level rise on the marine environment.
- Ranges for climate change impact projections to indicate scientific confidence.
- Well-founded distinctions between more and less likely impacts (e.g., at-least vs. maybe as much as)
- Clearly presented assumptions of sea-level rise models: Disagreement leads to indifference.

Standards, Protocols and Access

Establishing standards, methodologies and protocols for data collection, storage and analysis as well as processes such as infrastructure design and projects such as mapping allows for data and information to be accessible to a wider audience and user group. A common ground provides a platform for others to build upon what is already known and "better integrate science into decision making." A publically accessible format allows for broader use.

Centralized Database and Resource List

Coastal decision-makers need data and information to help them make decisions. They are also asking for the climate data and information to be housed in a single location for easier access and better understanding of what else may be available. Some sector-based or regional users of climate data and information are looking for more specifically categorized information. Coastal decision-makers are also looking for a venue to share information.

Interdisciplinary and Integrated Decision-Making

Decision-makers understand they are facing increasingly complex issues that require multifaceted solutions. Their requests for data, tools and services are punctuated with their clear need for the information to integrate biological, physical, ecological, economic and social information. Several representative examples include:

- Information that can be used in socio-economic, physical, biological and physiological models
- Cross-disciplinary coordination and collaboration across government agencies and with the private sector
- Interdisciplinary training and research, bridging the gap between climate research and other disciplines such as ecology, fisheries, socioeconomics, etc.
- Integrated natural and social science approaches to identify the attributes of populations, ecosystems, and natural and human communities that promote resilience
- Stronger tools that include economic, social and institutional factors

Local, Actionable Information

Coastal decision-makers also need information or services at a level and scope where they can use that information to make policy, planning or emergency decisions and take action at their individual level of authority or influence. Some of these include:

- Downscaled global sea-level rise models to a finer resolution to adequately represent regional or local effects
- Localized climate science
- Sea-level change data at the local level to better incorporate socio-economic data for local impacts
- Local planning capacity
- Development of local-level tools and technical assistance
- Tools for sea-level rise that are local and specific, show a range of scenarios, highlight loss of tax money from lost infrastructure, clearly present assumptions, indicate landmarks as examples to make relevant, and give concrete ideas of how this information can be incorporated into decision-making processes, including examples

Section 4 Relationships and Needs of Decision-Makers Associated With Other Societal Challenges

The Societal Challenges

NOAA's draft Vision and Strategic Framework for Connecting Climate Science to Decision Making identifies four specific societal challenge areas where a dedicated focus of NOAA's climate capabilities will provide the information and services necessary to make informed decisions for effective adaptation actions and other climate-sensitive decisions: Climate Impacts on Water Resources; Coasts and Climate Resilience (the main focus of this needs assessment report); Sustainability of Marine Ecosystems; and Changes in the Extremes of Weather and Climate. These societal challenges areas are driven by NOAA's mission responsibilities and will provide initial focus and integration in NOAA's efforts to deliver climate services, linking NOAA's world-class climate science and research to the urgent and growing needs of NOAA's customers. This section will identify the trends in the relationship between sea-level change and the needs of coastal decision-makers as they apply to Climate Impacts for Water Resource, Sustainability of Marine Ecosystems and Changes in the Extremes of Water and Climate societal challenge areas.

The Importance of Sea-Level Change

In the 2010 Coastal Management Customer Survey Report, 68.5% of respondents considered sea-level rise to be a high priority management topic, particularly in the Mid-Atlantic, Southeast and Alaskan regions. Subsidence is compounding the issue of sea-level change in the Gulf of Mexico and in other select locales around the nation. Climate change impacts overall were the highest priority for almost all of the U.S. regions, and these impacts stretch across the societal challenge areas, resulting in similar needs for basic data and information. Spatial data, for example, has been identified as key information used by coastal decision-makers and corresponding needs have been identified. For example, the needs identified in this assessment clearly show spatial data needs related to sea-level change including storm surge, sea-level rise, economics, and climate change impacts.

While there are some distinct requirements within the societal challenge areas, there is some overlap of specific data needs. For example, coastal decision-makers in various fields are using LiDAR and land elevation data for a variety of purposes, risk and vulnerability assessments unique to their missions, and social and economic indicators, data and information to better inform how to weight and make decisions affecting coastal communities and ecosystems. They also want multidisciplinary information presented in a comprehensible manner in order to make better decisions across their increasingly complex scope of responsibilities.

Needs Across the Societal Challenge Areas

Across the societal challenge areas, the most prevalent trend is the need for data. While the specific needs for data are sometimes unique, common needs that are shared with sea-level change were identified with respect to data accessibility,

utility, interoperability, and reliability. Each societal challenge area is facing the need for more data that are:

- Covering broader specific geographic regions, and/or more parameters
- Higher resolution (especially topography and bathymetry);
- Scalable or already scaled to be appropriate for a particular use;
- Validated, provided by a reputable source, and clearly articulating assumptions and uncertainties, where applicable;
- Comparable to and compatible with other data being collected (i.e., using common formats); and
- Easily accessible and provided in an easy-to-use format.

Correspondingly, there is a need for the data to be translated for use in decision-making into user-friendly tools, including visualizations and prediction and forecasting systems. For example, the literature documents a pressing need for sea-level rise planning tools that allow decision-makers to visualize impacts to people and development under a range of potential sea-level rise scenarios. However, to ensure utility for decision-making, the models and predictions applied should be accompanied by a clear articulation of the underlying assumptions and level of uncertainty, as disagreement among the data and model outputs can lead to skepticism and/or indifference within coastal communities.

Climate Impacts on Water Resources Needs

Addressing the Climate Impacts on Water Resources societal challenge area will help NOAA improve the nation's capacity to manage its water resource, and contribute to NOAA's abilities to anticipate, prepare for, and adapt to drought and flooding events on climate time scales. Intersecting with sea-level change, the needs for this societal challenge area are:

- Aquifer problems, including groundwater sustainability and recovery rates
- Salt water intrusion
- Changes in water quality
- Inundation mapping with GIS overlay
- Risk & vulnerability analysis for water management infrastructure, including floodmaps
- Seasonal climate forecasts

Sustainability of Marine Ecosystems Needs

Addressing the Sustainability of Marine Ecosystems societal challenge area will enhance resource managers' access to and application of the best available information to manage marine ecosystems in a changing climate. Within this societal challenge area, there is a range of needs for information, research, and guidance on environmental/habitat changes associated with sea-level change, including:

- Ecosystem/species migration and the spread of invasive species
- Geospatial information on climate and ocean processes
- Tools that forecast ecosystem and habitat changes

- Coastal wetlands/habitat loss and other natural resource mapping to facilitate risk assessments
- Data inventories and monitoring systems for an adequate baseline understanding of local species and ecologic indicators
- Data and models that address water & air temperature, salinity, precipitation, ocean acidification
- Survey standardization
- Coordinated monitoring

A number of needs were identified for tools and models that incorporate the above research and information toward a particular management question. For example, users require tools that can inform prioritization of restoration and conservation efforts based on a given sea-level rise and/or climate change prediction. This information can guide project design and provide critical information relative to the anticipated impact on the longevity of the project. Improved models are also needed to characterize the ecological migration of habitats and species and potential impediments to that migration.

Social science needs were identified relative to the economic cost of accelerated sea-level rise impacts, such as migration and/or vertical accretion of coastal wetlands and beaches and/or the consequences of taking no action. More robust socioeconomic analysis of ecological values is needed in order to fully understand and characterize local impacts.

Changes in Extremes of Weather and Climate Needs

Addressing the Changes in Extremes of Weather and Climate societal challenge area will enhance the ability of resource managers, policy-makers and the public to apply the best information to anticipate, prepare for, and adapt to ongoing changes in climate extremes and their impacts. The sea-level change-related needs for this societal challenge area are:

- Data, information and better understanding of environmental drivers such as tides, water levels, waves, precipitation and temperature
- Spatial data and visualization tools to inform risk assessments, such as population density and other demographic information, coastal infrastructure, flood zones, and high hazard zones
- Detailed models and mapping and visualizations of future sea-level change including extreme states, variability, frequency, magnitude of inundation events
- Combined models of inundation and shoreline erosion that incorporate changes in coastal geomorphology, hydrological conditions, and shoreline protective structures
- Risk assessment model that considers the additive impact sea-level rise on other hazards, such as erosion, wetlands loss, storm surge increase, and increased intensity and/or frequency of storms.

- Better understanding of the linkage between climate change, sea-level rise and wave climatology
- Climate monitoring stations
- Dynamic models
- Inundation models, including Digital Elevation Models

A variety of social science data and analyses are needed to articulate the long-term costs of sea-level change. For example, there is a need to assess the social, legal, and economic issues related to sea-level change and the various adaptation strategies a community might employ, including “retreat,” armoring, renourishment, and “no action” alternatives across developed and urbanized coastlines.

Sharing Needs Across Societal Challenge Areas

The literature also illuminated where the societal challenge areas shared the same needs with each other, as well as coastal decision-makers addressing sea-level change.

Cross-Cutting Needs Shared By Societal Challenges	Sea-level Change	Water Resources	Marine Ecosystems	Extremes
Understand how sea-level change & storm surge will change nutrient dynamics	X	X	X	X
Predictions of impacts from storms on estuaries	X		X	X
Downscaled climate models to help deal with increased impacts from storms	X	X		X
Information on marine over wash	X	X		X
Data and information to monitor and mitigate impacts linked to ecological changes, i.e., wetlands migration	X		X	X
Information related to pollution loads, potential runoff and temperature and salinity data for water flowing into the coastal and estuarine areas	X		X	X
Information on ecosystem services at risk due to inundation and saltwater intrusion	X	X	X	

Section 5 Broad Needs That Cross Sectors

The Sectors

NOAA's draft Vision and Strategic Framework for Connecting Climate Science to Decision Making identifies core capabilities which will support basic services in a variety of sectors. In looking across a wide variety of climate literature produced over the past decade, we note common areas of requirements that are repeatedly mentioned, regardless of whether the needs are addressing the structural sectors of Transportation, Energy, and Infrastructure; the economic sectors such as Finance, Trade and Economic Development or the well-being sectors of Health and vital Natural Resources. Across each of these sectors there is a recognized need to understand and improve social and ecological resilience in the context of a shifting climate, and changes in sea level by:

- Integrating locally relevant data in a more holistic and geospatial approach to planning that includes vulnerabilities from climate and hazards impacts that cross natural habitats; to transportation, health and safety infrastructure; and socioeconomic factors
- Improving understanding by users of the terminology and concepts of sea-level rise, its uncertainty, and probabilistic risk
- Investing in research and improving science answers

Integrating Locally Relevant Data to Ensure Structural and Systems Integrity

Increasingly, decision-makers are seeing the need to take a systems approach to planning for resilience in the face of sea-level change, and they are asking for the data and tools to enable this methodology. Even if a planner is from the highway transportation sector, for example, there is an inherent understanding that both multi-modal transportation vulnerabilities (airports, highways, ports, rails) and the socio-economic factors that determine how and who will use these systems need to be considered. The vulnerability of support systems such as waste treatment and power plants are also key examples. Communities are looking to assess which locations and facilities will remain usable under different sea-level change scenarios, and which portions may need to "yield to the sea." The specific local data, information and knowledge should incorporate region-specific climate change forecasts and scenarios, and should include:

- Geospatial techniques to better analyze the spatial relationships among topography, development, infrastructure, habitats and climate.
- Geospatial tools and approaches to help coastal and habitat managers assess habitat resiliency and adaptation under different climate change and management scenarios
- Tools and protocols that incorporate high-resolution data on habitat distribution and condition with projected decadal climate conditions and other factors (e.g., socio-economic conditions) to target priority areas for habitat restoration and protection.
- Comprehensively documented infrastructure elevations

- Preferred setbacks from high water line
- Migration of frequently flooding areas
- Priorities for the state's coast and shoreline and factoring these into any new proposals for coastal development
- Requirements for enhanced communication technologies to access data and to deal with episodic response emergencies
- Describing and mapping the environmental characteristics in districts, including current conditions (soil type, etc), and natural buffers and habitats
- Mapping wetland and habitat types
- Development of risk analysis methods and tools is needed to enable planners and managers to assess the range of potential climate impacts, the vulnerability of infrastructure segments, and the relative risk of components of the transportation network.
- Increased modeling capability and ease of use
- High resolution, high quality topographic data consistently available for a region
- Observations and monitoring to more clearly understand the key threats in the region, measure and monitor local sea level (includes both water level and subsidence rates)
- Monitoring capabilities that more directly provide advanced warning of impending infrastructure failures due to repeated weather hazards or climate
- Improved data management and accessibility (e.g., establish a data clearinghouse across agencies)
- Socioeconomic data, including census data, tax data, demographic data, infrastructural data, land use data, economic data, and legal frameworks

Communication of Sea-Level Change Concepts

Across all sectors, decision-makers noted that addressing sea-level change requires both improved information but also improved understanding of the key concepts by those who need to act on this information. The concepts and terminology of uncertainty, vulnerability, impacts and risk, as well as subsidence, local and global sea-level change, are frequently intermingled and not always clear and distinctly articulated. This lack of clarity can translate into a reluctance to take action. Even when decision-makers have been trained and feel comfortable with the predictions and tools used by sea level change practitioners, they are not always equipped to convey this information on to their constituents. Coastal decision-makers need:

- Improved methods to convey sea-level change concepts to the public, and particularly to local and state governments
- Training efforts clarifying how adaptation strategies, model and tool applications can be applied to the decision making process
- Ways to stay informed and current on the best scientific information available, as the science of sea-level change advances and is refined

Communities are also looking for feedback on plans that are developed at the local level, and for policy changes which will support identifying and enforcing measures to mitigate the identified vulnerabilities.

Improving Science Answers

Coastal decision-makers are also cognizant of the science on which tools and services are built. In addition to communicating risk and uncertainty, coastal decision-makers also need to have the uncertainty lowered, in order to better understand their risks. Research priorities include:

- General support for more research led by the federal sector
- Interdisciplinary climate impact research to include mapping, modeling, and risk analysis
- Research to improve the accuracy and specificity of forecasts
- Information on past, current and future habitat responses to climate change including ecological tipping points.
- Including ecological changes and impacts in inundation models

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- **Section 6: Next Steps for Translating Needs Into Actions**

This sea-level change needs assessment literature review has provided NOAA with a wealth of information regarding the science, tools, and services requested by coastal decision-makers to address the management challenges associated with sea-level change. Coastal decision-makers make risk-base, uncertain decisions everyday with the best available science they can find. They generally know what their needs are, ranging from data and models to predict sea-level change and better understand impacts to coastal communities and ecosystems, to tools that inform the development of adaptation strategies and public outreach and education materials. This assessment illustrated that climate information is needed to guide decisions made across a variety of sectors that are considered in coastal management, including: transportation, energy, economic development, and natural resources. In addition, general themes regarding the relevancy of and access to science and services emerged, such as: local-scale information, publically accessible data and models, inter-disciplinary and integrated tools and strategies, and translation of information that includes direct and personal contact.

In accordance with its mission “to improve understanding and prediction of changes in climate and promote a climate-resilient society”, NOAA is already working to develop and provide these types of climate products for coastal decision-makers. Making the best available science easier to find is a vital service, as is effectively communicating this data and information to those who have already asked for it. NOAA will be better consolidating and making available the science that is available already. However, successful development and delivery of the breadth of climate information and products articulated in this report depends on NOAA’s collaboration with its public, private, and academic partners. Providing relevant and accessible climate science, service, and tools to support decisions for a variety of sectors needs to happen through partnerships across:

- government in the development of standard protocols and integration of social, economic and behavioral information;
- the private sector through publically accessible data via widely available sources such as Google Earth,;
- academia regarding model standards and scaling; and,
- non-governmental and professional organizations to help translate information.

Prioritizing how we address these needs will also occur in a variety of collaborative ways, including at the intra- and inter- agency levels, through partnerships with the private sector and academia, and through relationships with non-governmental and professional organizations. For example, at the interagency level, both the US Global Change Research Program and the National Ocean Council are working on strategic plans that articulate current climate science and service gaps, and identify how the Federal government can work to address them in the short to mid-term. Bi- and tri-lateral interagency agreements are also in place to enhance cooperation in meeting

the needs of a wide variety of users. Within NOAA, addressing the priority needs identified through this and other needs assessments will be approached through the Annual Operating Plans, beginning in Fiscal Year 2012. NOAA is also collaborating with the private sector and academia through the Climate Working Group, a sanctioned body of NOAA's Science Advisory Board. Linkages with coastal management professionals and organizations are also made through conferences and workshops, where informal needs assessments occur and collaborations are developed to leverage resources in response.

Needs assessments such as this are critical to guiding the development and delivery of NOAA's climate services. Through continued communication and collaboration with both its customers and partners, NOAA will be able to better understand the nation's vulnerability to climate variability and change, to address science and service needs and help inform climate adaptation decision-making, and to help build a more resilient society.

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Coastal Sea-Level Change Societal Challenge Needs Assessment Report

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Coastal Sea-Level Change Societal Challenge Needs Assessment Report

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