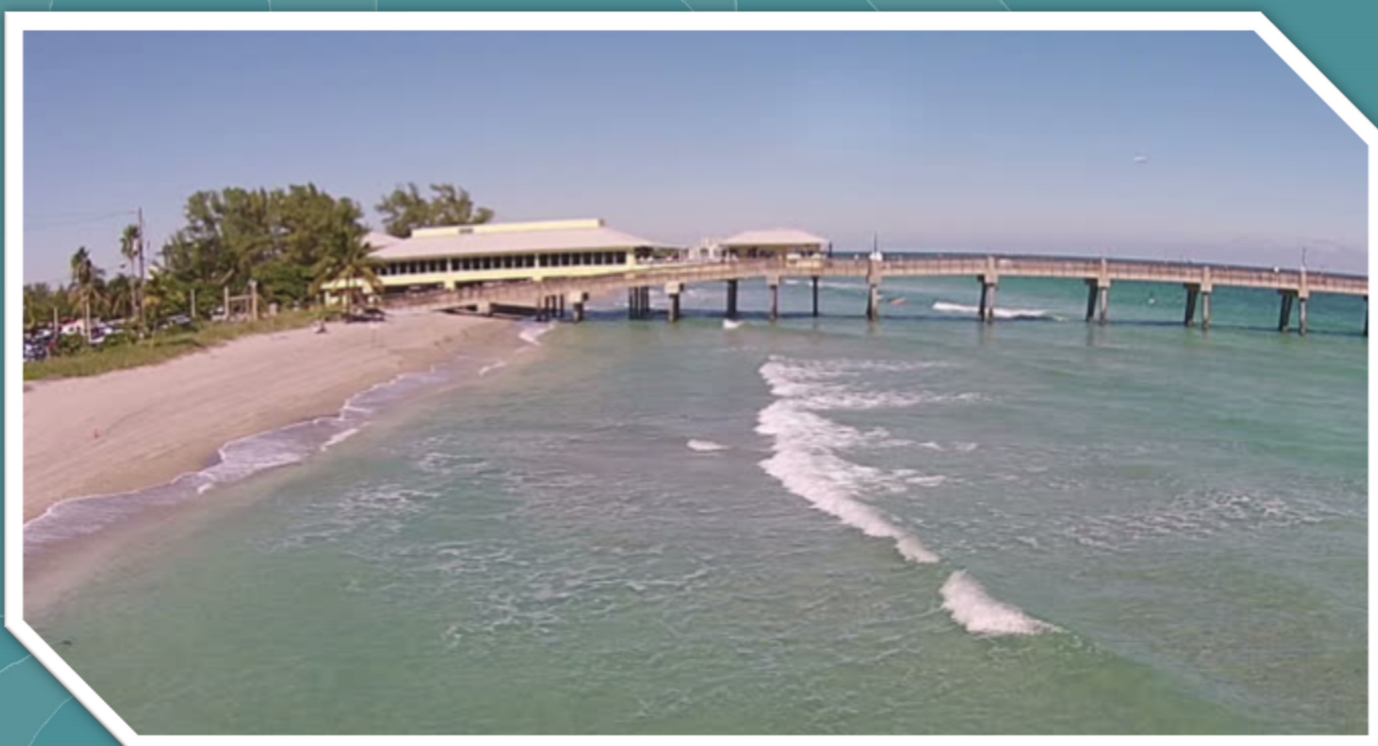
United States Environmental Protection Agency

EPA/600/R-19/066 | July 2019 | www.epa.gov/research

# Community Resilience Planning:
## A Decision-Making Framework for Coastal Communities



Office of Research and Development
National Risk Management Research Laboratory
Land and Materials Management Division

# Community Resilience Planning: A Decision-Making Framework for Coastal Communities

By

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# Notice/Disclaimer

The U.S. Environmental Protection Agency, through its Office of Research and Development, funded and conducted the research described herein under an approved Quality Assurance Project Plan (G-LRPCD-0015776-QP-1-2). It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

This is a contribution to the EPA ORD Sustainable and Healthy Communities Research Program.

This report was partially fulfilled through Contract EP-C-12-022 by Neptune and Company, Inc. under the sponsorship of the United States Environmental Protection Agency.

This document has been reviewed by the U.S. Environmental Protection Agency, Office of Research and Development, and approved for publication.

The citation for this report is:

Dyson, B., Carriger, J., Newcomer-Johnson, T., Moura, R., Richardson, T., Canfield, T. 2019. Community Resilience Planning: A Decision-Making Framework for Coastal Communities. U.S. Environmental Protection Agency, Cincinnati, OH, EPA/600/R-19/066

# Foreword

The U.S. Environmental Protection Agency (US EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, US EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) within the Office of Research and Development (ORD) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

The following report provides information and guidance on the application of tools and decision processes developed by NRMRL and ORD supporting communities faced with making risk-based decisions fostering community health and resilience to environmental challenges.

Alice Gilliland, Director
National Risk Management Research Laboratory

# Abstract

One of the most pervasive challenges facing coastal communities is sea level rise (SLR), both in its geographical extent and potential for adverse social, economic, and environmental impact. Local flooding results in property damage and disruptions to daily life. Likewise, regional problems, such as coastal erosion, saltwater intrusion, reduced ecosystem services and tourism may be exacerbated. As coastal communities continue to face growing risks from SLR and related coastal hazards, additional investments in resilience planning to protect current and future populations will be necessary to address these challenges. This report describes a structured decision-making process with the US EPA webtool DASEES (Decision Analysis for a Sustainable Environment, Economy, and Society) that facilitated developing a shared vision for coastal community resilience planning across three levels of governance/administration in the southeast Florida region. DASEES was used to facilitate two workshops with residents of the coastal community of Dania Beach, FL, environmental planners from Broward County, FL, and the Southeast Florida Regional Climate Change Compact with the aim to identify objectives for coastal decision-making that can inform the development of action plans promoting resilience. It is anticipated that the results obtained from the workshops can be extended to provide a continuing path via DASEES for estimating action consequence assessments, implementation planning and serve as an example process to follow for other communities facing similar challenges. The work described in this report can be used to construct community objectives and find common ground of support with outside agencies and jurisdictions. Available USEPA tools and resources such as DASEES may help support these endeavors in the future.

# Acknowledgements

Acknowledgements and appreciation for the helpful comments and suggestions from reviewers Michael Kolian, EPA/OAR, Climate Change Indicators Program, Tarsha Eason, EPA/ORD, NRMRL Air and Energy Management Division. Planning, workshop support and additional review was provided by Dr. Jennifer Jurado and Dr. Samantha Danchuk of the Broward County, FL Environmental Planning and Community Resilience Division, and Brian Meyers of EPA Region 4. External review provided by Dr. Jessica Whitehead of the North Carolina Office for Recovery and Resiliency. Formatting and contributions to the report from Marilyn ten Brink, EPA/ORD, Claudette Ojo and Alexander Hall, ORISE Fellows.

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# Acronyms and Abbreviations

| | |
|---|---|
| AAA | Adaption Action Area |
| ADCIRC | Advanced Circulation Model |
| AFT | Alternatives-Focused Thinking |
| BN | Bayesian Network |
| CDC | Centers for Disease Control |
| COAST | Coastal Adaptation to Sea Level Rise Tool |
| CT | Consequence Tables |
| BCBCC | Broward County Board of County Commissioners |
| BRACE | Building Resilience Against Climate Effects |
| CCAP | Climate Change Action Plan |
| CERP | Comprehensive Everglades Restoration Plan |
| CRA | Community Redevelopment Agency |
| CRS | Community Rating System |
| CS-HWBI | Community-Scale Human Well-Being Index |
| DASEES | Decision Analysis for a Sustainable Environment, Economy & Society |
| DOE | Department of Energy |
| EPA | Environmental Protection Agency |
| ESML | Ecoservice Models Library |
| FDOT | Florida Department of Transportation |
| FEMA | The Federal Emergency Management Agency |
| FIHI | Florida Institute for Health Innovation |
| GHG | Greenhouse Gas |
| GIS | Geographic Information System |
| GMSL | Global Mean Sea Level |
| HWBI | Human Well-Being Index |
| HUC | Hydrologic Unit Code |
| ICPR | Interconnected Pond Routing |
| ICZM | Integrated Coastal Zone Management |

| | |
|---|---|
| ID | Influence Diagram |
| IPCC | Intergovernmental Panel on Climate Change |
| IWRP | Integrated Water Resources Plan |
| LiDAR | Light Detection and Ranging |
| MIKE SHE | Integrated Hydrological Modeling from the Système Hydrologique Européen |
| MPO/FHWA | Metropolitan Planning Organization/Federal Highway Administration |
| NEP | National Estuary Program |
| NEMAC | National Environmental Modeling and Analysis Center |
| NOAA | National Oceanic and Atmospheric Administration |
| NGO | Non-Governmental Organization |
| NPS | Non-Point Source |
| NRCS | National Resources Conservation Service |
| NRMRL | National Risk Management Research Laboratory |
| OAR | Office of Air and Radiation |
| ORD | Office of Research and Development |
| ORISE | Oak Ridge Institute for Science and Education |
| RCAP | Regional Climate Action Plan |
| RCI | Resort Condominiums International |
| SDM | Structured Decision-Making |
| SFWMD | South Florida Water Management District |
| SHC | Sustainable and Healthy Communities |
| SLAMM | Sea Level Affecting Marshes Model |
| SLOSH | Sea Lake and Overland Surge from Hurricanes |
| SLR | Sea Level Rise |
| TNC | The Nature Conservancy |
| USACE | United States Army Corps of Engineers |
| USDA | United States Department of Agriculture |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| VFT | Values-Focused Thinking |

| | |
|---|---|
| WWS | Water and Wastewater Services |
| WWF | World Wildlife Fund |
| WQ | Water Quality |

# Executive Summary

The following report provides information and guidance on the application of tools and decision processes developed by the National Risk Management Research Laboratory and the Sustainable and Healthy Communities Research Program (SHC) of the U.S. EPA Office of Research and Development (ORD). Research in SHC is involved with supporting communities faced with making risk-based decisions fostering community resilience to health, equity, and environmental challenges.

One of the most pervasive challenges facing coastal communities is sea level rise (SLR), both in its geographical extent and potential for adverse social, economic, and environmental impact. Local flooding results in property damage and disruptions to daily life. Likewise, regional problems, such as coastal erosion, saltwater intrusion, reduced ecosystem services can lead to further stresses on extant socio-economic, health, and equity concerns. As coastal communities continue to face growing risks from SLR and related coastal hazards, additional investments in resilience planning to protect current and future populations will be necessary to address these challenges. This report describes a structured decision-making (SDM) process with the EPA decision support webtool DASEES (Decision Analysis for a Sustainable Environment, Economy, and Society) that facilitates developing a cohesive vision for coastal community resilience planning across three interlocking levels of governance/administration in the southeast Florida region. DASEES was used to facilitate two workshops among residents of the coastal community of Dania Beach, FL, environmental planners in Broward County, FL, and the Southeast Florida Regional Climate Change Compact with the aim to identify common shared objectives and provide guidance for the development of action plans promoting resilience.

The two primary goals of SDM are to 1) develop a common understanding among stakeholders, of a problem requiring decision-making, and 2) identify/develop creative solutions, estimate consequences, evaluate trade-offs, choose an alternative and implement. Consistent with that, two DASEES facilitated workshops were held to aid achieving these SDM goals for Dania Beach and southeast Florida. Workshop 1 was held in Dania Beach and included a broad cross-section of stakeholders encompassing elected city officials, private citizens, business and housing advocates, County environmental planners, and state and federal climate and coastal hydrology experts. The aim of the two-day workshop was to establish a common understanding of the problem or context, from which resilience objectives, performance tracking measures, and preliminary community resilience actions responsive to stated objectives would be developed. The webtool DASEES has a user-friendly interface with features designed to facilitate and capture stakeholder deliberations. All information developed in the workshops was generated and captured within DASEES creating a convenient space for maintaining project data/information for easy retrieval and subsequent quantitative processing in later steps of the DASEES decision process. A crosswalk of the workshop results was performed against previously developed Broward County and Regional Compact resilience goals to find areas of common cause to engender mutual action and leverage limited resources effectively. These

results coupled with a recent EPA urban climate resilience definition, demonstrate a comprehensive multi-dimensional view of resilience with objectives aimed at addressing the environmental, health, equity, and economic resilience concerns of Dania Beach and its County and Regional Compact partners.

Workshop 2 was held a few months later at the Broward County offices of the Environmental Planning and Community Resilience Division. The attendees were primarily technical experts tasked with beginning the formulation of technically feasible/defensible modeling and analysis strategies. These would then be used to address the Workshop 1 objectives by evaluating the effectiveness of proposed actions using stakeholder-driven performance measures. Graphic modeling tools in DASEES were used to characterize these technical approaches, helping to identify the science and data necessary to complete the analyses. Examples of these conceptual and quantifiable modeling methods are demonstrated in the report, showing how stakeholder preferences can be directly used in estimating the effectiveness of resilience implementation actions.

The work described in this report can be used to construct community objectives and find common ground of support with outside agencies and jurisdictions. Available USEPA tools and resources such as DASEES may help support these endeavors in the future. It is anticipated that the results of this exercise can be extended to provide a continuing path via DASEES for estimating action consequence assessments, implementation planning and serve as an example process to follow for other communities facing similar challenges.

# 1. Introduction

The United States coastline has historically been the most densely populated region of the country. According to the 2010 U.S. census, 40 percent of the population of the U.S. is concentrated in coastal regions, comprising less than 10 percent of the land area of the entire country (NOAA Office For Coastal Management, 2018). As urbanization continues, greater investments in infrastructure such as transportation and housing along with protection from coastal hazards will be required. One of the most pervasive challenges facing coastal communities is sea level rise (SLR), both in its geographical extent and potential for social, economic, and environmental impact (NOAA, 2017). Long-term trends show a global mean sea level (GMSL) increase of 8.2 - 9.4 in. since 1880 with projected increases of 1-3 ft higher than the global average for most coastal areas in the continental United States by the year 2100 (NOAA, 2017). Local flooding impacts such as property damage and disruptions to daily life (Wdowinski et al., 2016) are already occurring and expected to persist as SLR increases the intensity of storm surges and decreases the effectiveness of gravity-fed drainage systems to remove stormwater. Likewise, regional problems, such as coastal erosion, saltwater intrusion, and reduced ecosystem services and tourism are also anticipated to be exacerbated (IPCC, 2014). As coastal communities continue to face growing risks from SLR and related coastal hazards, additional investments in resilience-based efforts to protect current and future populations will be necessary to address these challenges (see Appendix A for risk checklists that may be helpful for focusing resilience efforts in communities).

## 1.1 Community Resilience

Maintaining sustainable and healthy coastal communities requires defining and operationalizing resilience. The need for adaptation and mitigation to numerous hazards has spurred the development of frameworks and tools to assess and increase resilience (USEPA, 2017) against the challenges coastal communities are facing.

> **Urban Climate Resilience:** "The ability of a city or urban system, through its risk reduction and response capacity, to reduce exposure to and sensitivity to, and recover and learn from, gradual climatic changes or extreme climate events, in order to retain or improve the integrity of its infrastructure and economic systems; vital environmental services and resources; the health and welfare of its populations and communities; and the flexibility and diversity of its institutional and governance structures" (USEPA, 2017).

Numerous ways of defining and operationalizing resilience exist (e.g., Reid and Courtenay, 2013; Zhou et al., 2010) but usually focus on the capabilities of a system for coping with disruptions to desirable functional processes (Schultz & Smith, 2016). Holling (National Academy of Engineering, 1996) differentiates between engineering and ecological resilience. The former stemming from a physical science and engineering worldview and the latter shape by the biological sciences and have implications for understanding stability and valuing persistence (engineering) or existence (ecological) of ecosystem functions. Community resilience stresses the engineering resilience view. A review of the meanings of resilience (Reid and Courtenay, 2013) reveals that it has varied over the years as the concept has been applied across multiple domains ranging from physics and engineering to public policy. Several descriptions appear useful when considering community resilience to environmental stressors such as SLR. Bruneau et al, (2003) characterize resilient communities as being robust to stressors, having redundant back-up systems, and being capable of rapidly mobilizing human and material resources to contain losses and exploit opportunities. Dovers and Handmer (1992) suggest maintaining a balance between reducing the likelihood of failure in static structures and increasing the rapid recovery aspects of resilience. This balance has been recently defined for climate resilience as strengthening a community's ability to reduce exposure and sensitivity while increasing the ability to recover and learn from gradual stressors such as SLR as well as extreme climate events such as hurricanes (USEPA, 2017). Adopting this definition provides clarity on the meaning of resilience for communities; assisting the deliberative decision-making process of considering which systems (infrastructure, institutional and social) must be further stabilized for sustainability, and which should be re-imagined towards greater adaptability for coastal community resilience redesign.

While the scope of SLR and related impacts could be characterized as a global phenomenon, developing adaptive management plans for resilience is more practically implemented at regional and local scales (Bulla, et al, 2017). This report provides a description of tools, resources and processes for assisting state and county governments in coordinating strategies and pooling resources with coastal communities to address resilience challenges. The report also outlines how DASEES (Decision Analysis for a Sustainable Environment, Economy, and Society), an EPA-developed decision support tool, can aid in resilience planning for the community of Dania Beach, FL, in collaboration with Broward County, FL, and regional environmental, non-governmental organizations. It is anticipated that by demonstrating the potential of decision analysis frameworks and consultations in collaborative processes for coastal resilience, other communities will find these approaches valuable for their respective resilience needs.

## 1.2 Resilience Planning Collaboration: Southeast Florida Region

Southeast Florida is considered one of the most vulnerable areas to SLR due to its peninsular geography and low topography and is expected to experience a SLR of 6 to 10 inches above 1992 mean sea level by 2030 (Compact, 2015). In response, several counties, (Palm Beach, Broward, Miami-Dade, and Monroe) formed the Southeast Florida Regional Climate Change Compact (Compact) (Fig. 1.1) to develop strategies, share information, and assist communities within the southeast Florida region.

As part of the Compact, the counties work cooperatively to formulate adaption activities for climate impacts on a legislative and organizational level, and partner with federal, state, municipal, nonprofit, academic, and private sector entities. The Compact proposes to address climate related impacts by implementing the Compact's Regional Climate Action Plan (RCAP, 2017), which has been formally adopted and includes recommendations for regional action (Appendix B).

### *1.2.1 Coastal Community Application: Dania Beach, Florida*

The City of Dania Beach, FL (Dania Beach) (Fig. 1.2) is a coastal community located just south of Ft. Lauderdale within Broward County and is representative of many communities in the Southeast Florida region facing stressors like SLR and its potential to impact multiple aspects of daily life.

Dania Beach is experiencing increasing threats from SLR (DEP, 2011) along with exacerbating issues such as flooding, salt water intrusion, failing septic systems, and susceptibility to hurricanes. The economy is heavily dependent on tourism (CRA, 2015); making protection of natural areas of paramount importance. Dania Beach is also anticipating up to 40% population growth (Broward Planning Services Division, 2007) over the next two decades because of its proximity to nearby shipping ports and the Ft. Lauderdale International Airport. This projected growth presents an opportunity to redesign the community for resilience but might raise concern that the changes to accommodate growth could cause losses to some of the desirable characteristics of the community (e.g., loss of space in neighborhoods and housing, disruptions to existing social connections across and within neighborhoods) if stakeholder objectives are not considered.

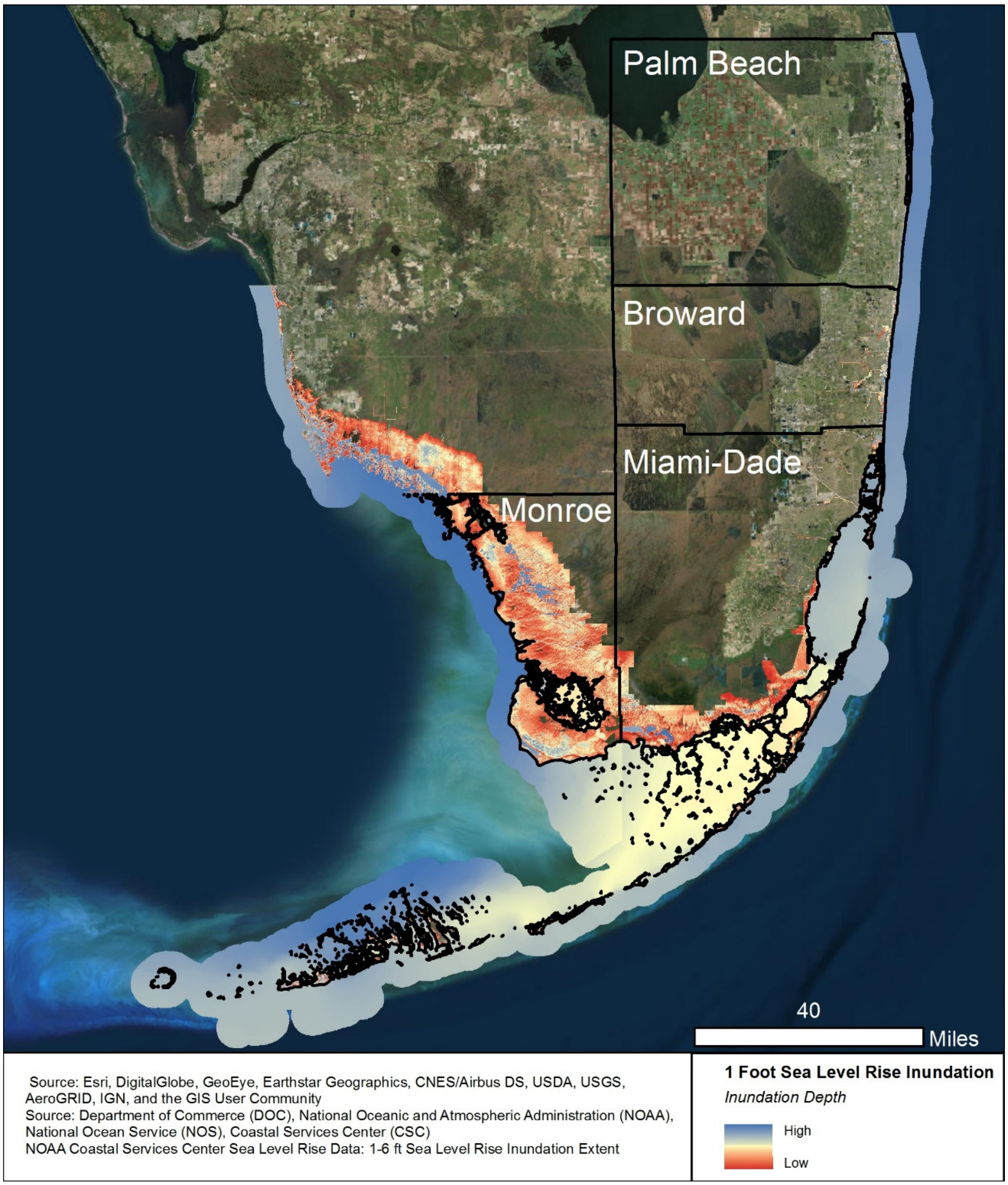


**Figure 1.1** Operational area of the Southeast Florida Region with Counties participating in the Southeast Florida Regional Climate Change Compact (Compact, 2015).

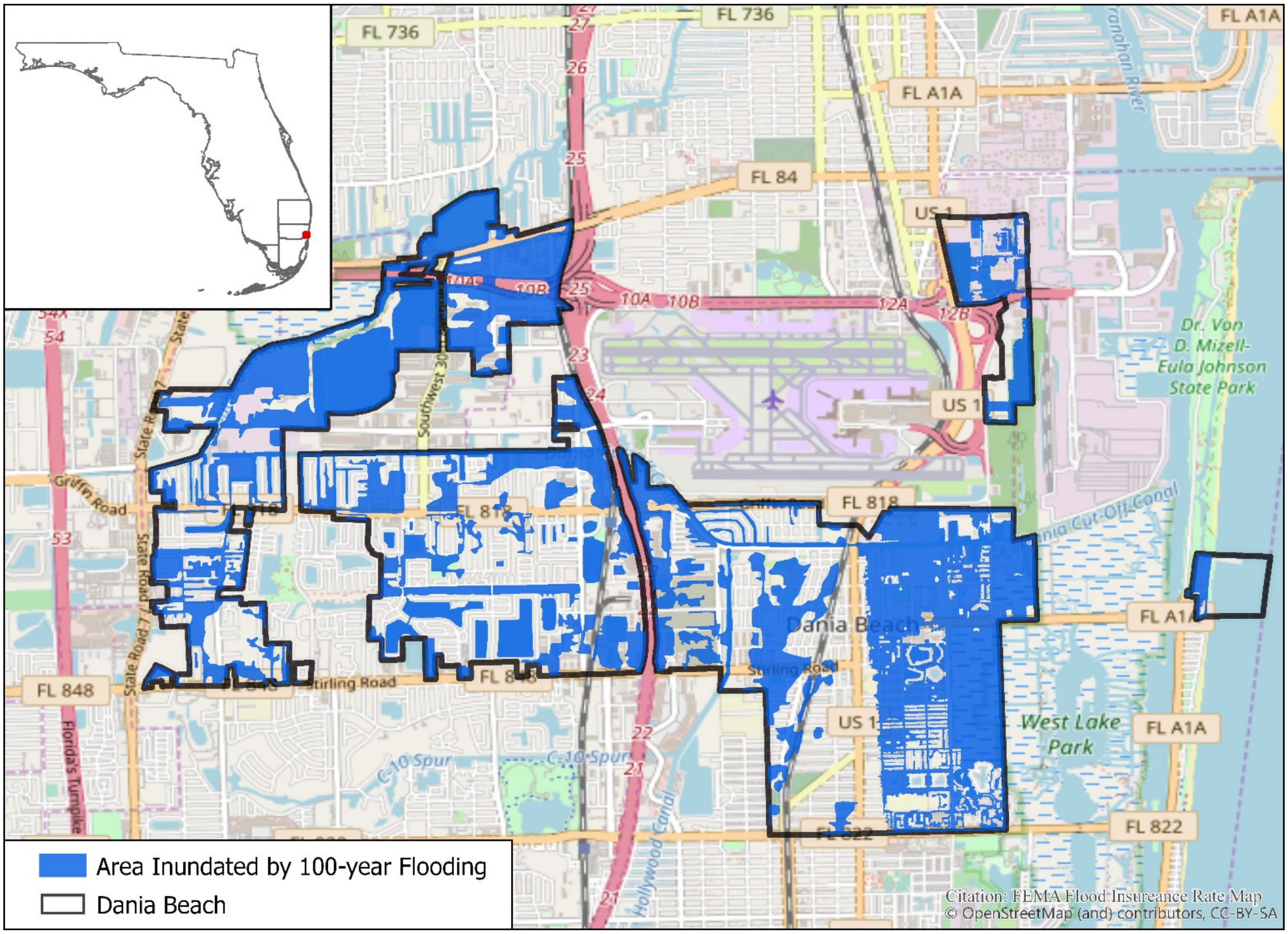


**Figure 1.2** Dania Beach, FL (red dot inset map) in Broward County jurisdiction demonstrating the area inundated by 100-year flooding according to FEMA flood insurance rate map.

In August 2014, Dania Beach participated in the four-day Southeast Florida Resilient Redesign Workshop which was hosted by the Compact (Compact, 2014). The 2019 census listed 32,271 people in Dania beach, 71.6% are white alone, 18.8% are black or African American alone, 28.8% are Hispanic or Latino, 2.2% are Asian alone and 3.1% are two or more races (USCB, 2019). From 2013-7, over a quarter (27.3%) of its population were foreign born persons (USCB, 2019). The economy of Dania Beach The economy includes antique sales (Antique Row), beach and recreational tourism, and marine services (e.g., yacht repair, boat marina, maritime officer training and research, university-level school of ocean engineering) (City of Dania Beach, 2019). The workshop assembled over 50 regional, national and international experts from a diversity of fields, including architecture, engineering, transportation, planning, and water management to collaborate on the identification of climate challenges and resilient redesign opportunities for two representative cities in southeast Florida; Dania Beach and Miami Beach, and the community of Sweetwater in unincorporated Miami-Dade County. Following the development of the workshop redesign concepts, Broward County and Dania Beach administration and technical staff met to discuss strategies and identify opportunities for implementation. While this meeting served to expand the network of decision makers and stakeholders involved in advancing the proposed designs and identify initial opportunities for action, it was decided that further deliberation at a more local level might be needed to evaluate and refine the ideas, cultivate agreement upon a shared vision, and organize the funding and support needed to formalize and implement a plan.

**Dania Beach, Florida**

Incorporated in 1904, it is the first city in Broward County and derives its name from the Danish ancestry of its first citizens. From the south, it abuts the Fort Lauderdale International Airport and Port Everglades, a major port for cruise ship departures (Dania Beach, 2017). The government of Dania Beach serves approximately 30,000 people and uses a Commission-City Manager form of government. The commission candidate with highest vote serves as mayor, with an appointed City Manager to implement policies adopted by the commission. According to the 2010 Census, Dania Beach (area of 8.3 square miles) is the 20$^{th}$ most populous of Broward County's 31 incorporated municipalities (United States Census Bureau 2010). Dania Beach is rapidly growing with a population increase of nearly 50% between 2000 and 2010. To address this population increase, government agencies and initiatives were established to develop and re-develop the community.

As part of its climate and energy initiatives, U.S. EPA Region 4 coordinated a collaboration between the U.S. EPA Office of Research and Development (ORD), in partnership with Dania Beach and Broward County (Fig. 1.3) to utilize expertise and tools developed within ORD's Sustainable and Health Communities Research Program (SHC). The SHC program (SHC Strategic Plan, 2016) has a wide range of research efforts aimed at supporting sustainability goals for U.S. EPA Regions, states, and communities including the development of decision support tools. In particular, DASEES was identified by agencies that serve the community before deployment as a relevant resource to clarify objectives, and measures of success that reflect community values and common areas of interest with the Compact's recommendations and the resilient redesign concepts.

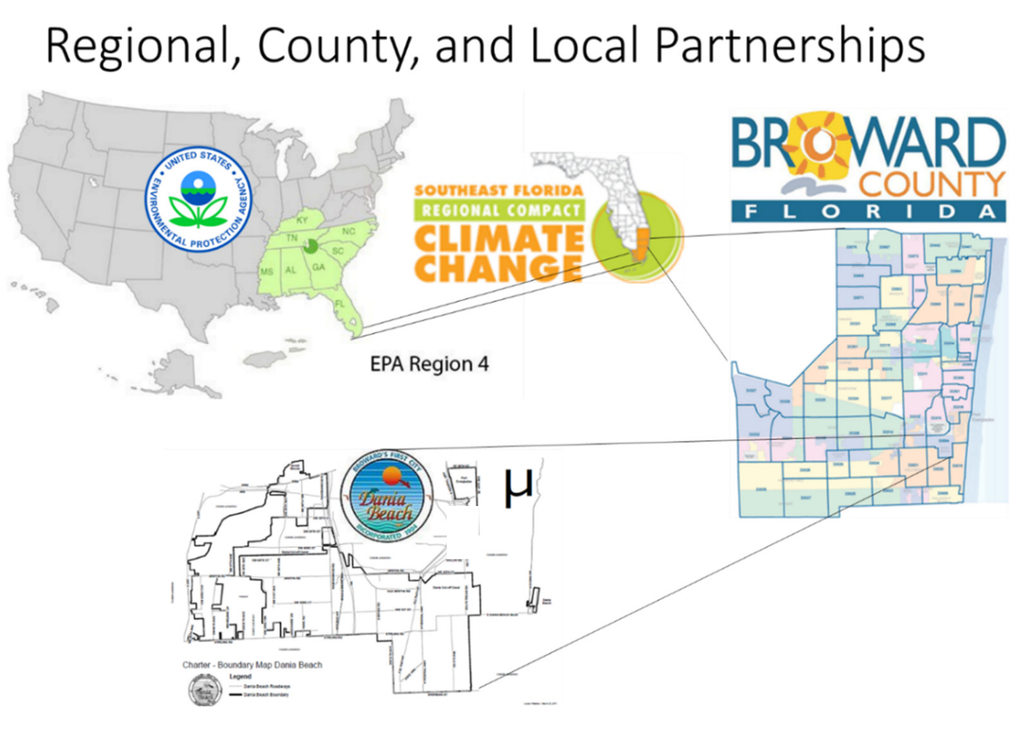


**Figure 1.3** EPA Region, Florida County, and Local Partnerships.

## 1.3 Dania Beach Resilience Planning: Structured Decision-Making with DASEES

From the County and Southeast Florida regional perspective, understanding the concerns and capabilities of local communities enables the counties and Compact to better leverage resources to implement resilience actions effectively across several scales of application e.g. community, county, region. Practical, group-oriented deliberation and analysis methods are needed to facilitate a common understanding, leading to more informed, inclusive decision-making. The decision approach described in this report is called structured decision making (SDM). The approach is applied with the decision support tool DASEES (USEPA, 2012).

### *1.3.1 Structured Decision-Making*

Structured decision-making (SDM) is group decision-making process (Gregory et al., 2012) that has as its aims to: 1) develop common understanding of an issue and 2) create, evaluate, select, and implement innovative solutions. It is a combination of 1) qualitative issue framing through stakeholder engagement and values elicitation, and 2) quantitative alternative consequence analysis for decision-making. The relative amount of the two varies by the problem, the salient point being that common understanding and issue framing comes first.

A paramount principle of SDM is the involvement of stakeholders, decision makers, and technical experts to foster the integration of facts and values in decision-making. Factual evidence informs the consequence analysis of decisions, but decisions are also made based on values (i.e., what stakeholders care about). SDM is predicated on the idea of Values-Focused Thinking (VFT) as opposed to Alternative Focused Thinking (AFT) for complex decision problems (Keeney, 1992). When faced with a problem, people often start by identifying actions (alternatives) that could address the problem, such as resilience recommendations or design ideas, without getting clarity on what they are trying to achieve (values) through the alternative's implementation. Keeney (1992) differentiates values, "what we care about in decision-making," from alternatives, "the means for achieving our values." It is incumbent for decision makers to ensure that the selected alternatives are responsive to the values of the stakeholders. For a fuller explanation and example of an SDM application by the U.S. EPA, see Bradley et al., (2016). One of the tools developed by researchers at U.S. EPA/ORD for implementing the SDM process is DASEES.

### 1.3.2 DASEES

DASEES (Decision Analysis for a Sustainable Environment, Economy, and Society) (USEPA, 2012; Bradley et al, 2016; Yee et al, 2017) is a web-based interactive tool (Fig. 1.4) for structured decision-making. It provides an environment where communities can build a shared understanding of complex problems then create and evaluate management alternatives through a multi-objective decision analysis.

**Structured Decision Making**

***A facilitated, collaborative, group decision-making approach for environmental management problems***

1. **Find common understanding and objectives for complex environmental problems**
2. **Create, evaluate, select, and implement innovative solutions.**

***(Gregory et al, 2012)***

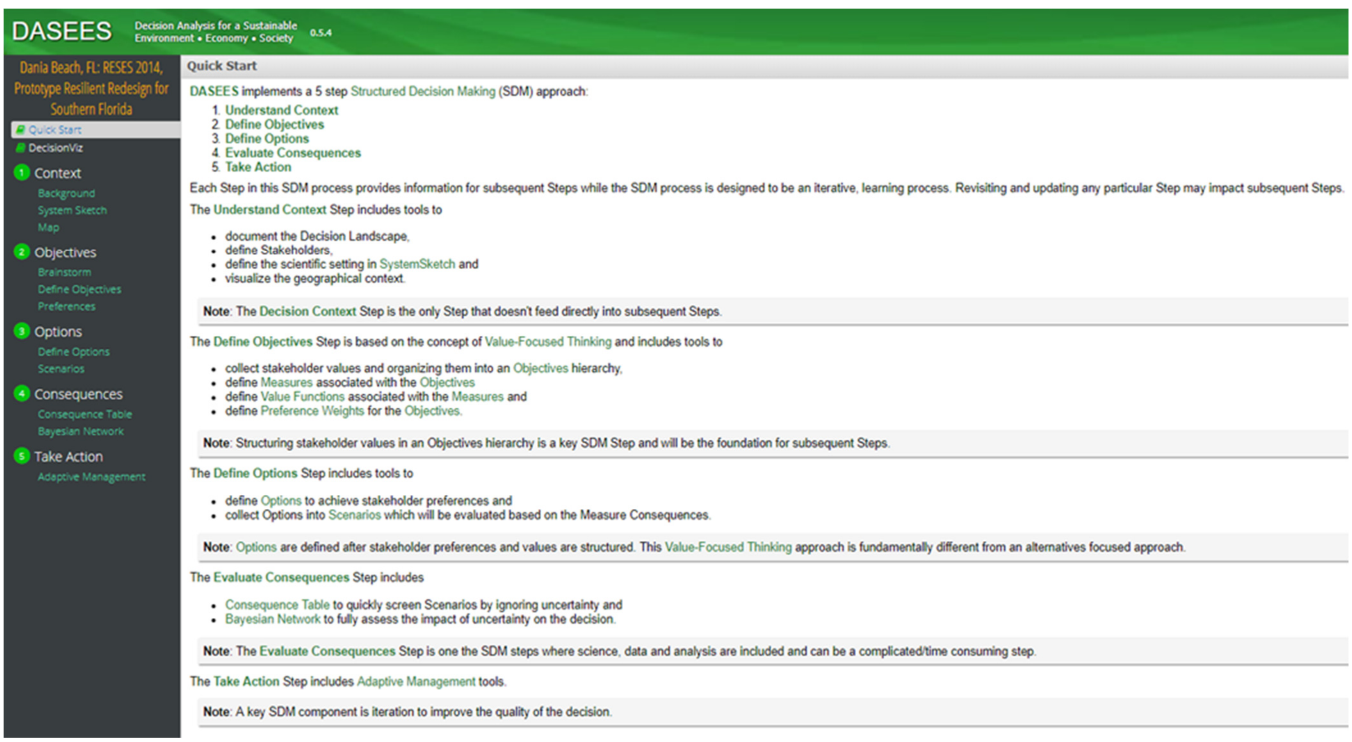


**Figure 1.4** DASEES Start Up screen.

DASEES serves as an integrative framework for the combined assessment of environmental, economic, and social aspects of problems faced by communities such as Dania Beach, FL. ORD and U.S. EPA Region 4, in partnership with Dania Beach and Broward County employed DASEES to establish community stakeholder values and define objectives and key performance measures for informing the development of resilience plans. Such plans assist with prioritizing actions, informing the data and information needs necessary for consequence analysis, and providing a basis for adaptive management. DASEES uses a five-step process (Fig. 1.5) that breaks the decision process into discrete, more easily managed and understood steps. This deliberate segmentation, using formal specific definitions and structuring methods, enforces clarity and understanding for complex problems, making explicit linkages between values and actions, and helps keep track of tradeoffs among alternatives (Gregory et al., 2012). Intuitive decision making, while useful for simple, straightforward decisions, is not always so useful for complex problems with multiple, competing objectives. Thus, it is valuable to have prescriptive tools and approaches to assist decision makers ( French, et al, 2009). This multi-step decision analysis approach is sometimes termed "a formalization of common sense for decision problems which are too complex for informal use of common sense" (Keeney, 1982). Even a minimal amount of effort in the problem formulation stage with decision analysis can have large downstream benefits for the entire decision-making process.

The application of DASEES for SDM guides decision makers and stakeholders in compiling information in an organized, transparent way, providing a platform for better communication and decision-making.

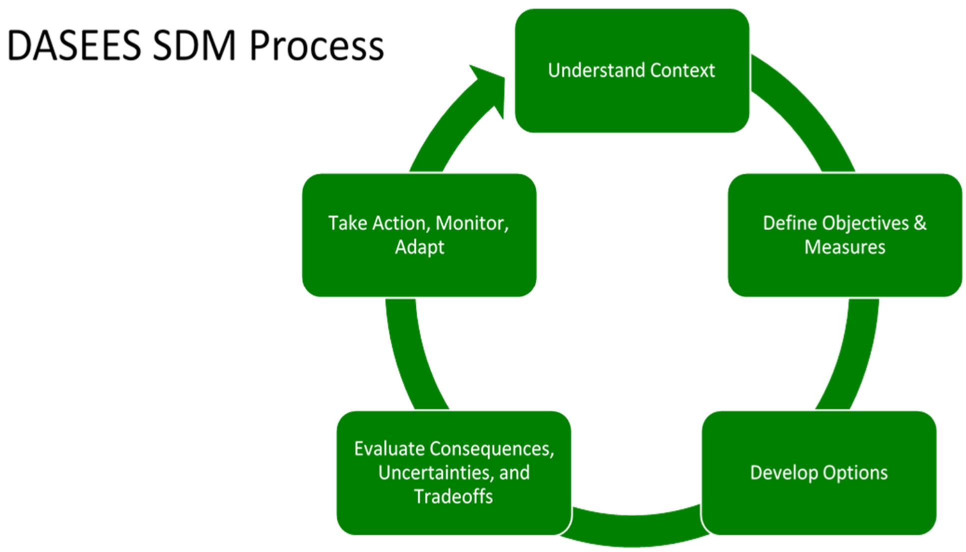


**Figure 1.5** DASEES SDM process.

When applying the DASEES SDM Process, two simple but important ideas should be kept in mind, 1) Complete the steps in order, as much as possible before proceeding, and 2) Iterate as needed.

**Key Concepts for DASEES SDM Process**

- **Complete the steps in order, as much as possible before proceeding**
- **Iterate as needed (iteration is expected)**

Decision structuring and analysis is a process of discovery and is rarely completed in one pass of the 5-step decision cycle. Stakeholders and decision makers often do not have all the needed information for each step at a given time, so iteration of the steps is expected as data and new information is developed. The DASEES process has a qualitative (Steps 1-3) followed by a quantitative (Steps 4-5) phase. All steps are required for a decision, with the level of effort for each phase varying depending on the stakes and complexity of the decision and the available resources. There is no recommended amount of time or resources needed for the use of DASEES across every decision; however, for complex environmental problems, the application of the VFT approach has yielded useful insights for decision makers (Keeney, 1992; Corner et al, 2001). The following is a brief description of the steps in DASEES and how information is structured. Subsequent chapters describe the steps and process as applied to Dania Beach in more detail.

1. Understand Context: The SDM process begins with developing an understanding of the context for the decision that needs to be made, i.e., the political, regulatory, social, institutional, and scientific setting. The context defines the scope of the problem. Sometimes termed the decision landscape (Rehr, 2012), the context encompasses what decisions are relevant for consideration. Clarifying the decision context is the first step in finding common understanding of a problem. A common scope for the decision context is necessary to begin the work of the next step, determining objectives for the context and how to measure their attainment.

2. Define Objectives and Measures: Based on the decision context and problem characterization, stakeholder values are elicited in this step—often directly through use of workshops—but they can also be gleaned through existing management plans and other documentation about the issue. Obtained values are formalized as written objectives and performance measures are identified to track the attainment of objectives. An important activity in this step is the separation of fundamental objectives (ends) and means objectives (Keeney, 1992). Fundamental objectives reflect the values of the stakeholders and are what is important in decision-making. Means objectives are objectives that may be important to attain to achieve the fundamental objectives. For example, a water quality objective might be a means objective for fundamental objectives pertaining to the structure and function of coastal ecosystems.

3. Develop Options: DASEES and SDM support decision-making through the process of identifying or creating decision alternatives that are responsive to the values and fundamental objectives of stakeholders (Gregory et al., 2012). Previously identified means objectives are used to develop or identify specific options that may achieve fundamental or ends objectives. Solutions that otherwise might not be considered are designed for explicitly achieving stakeholder objectives in a transparent manner.

4. Evaluate Consequences, Uncertainties and Tradeoffs: Decision analysis tools are prescriptive (French, 2009) in that they estimate *future consequences* for alternatives evaluation. Evaluation is performed in DASEES with a decision-analytic model; multi-attribute utility theory (Keeney, 1992) that quantitatively assigns stakeholder values and preferences to estimated social, economic, and environmental consequences. This analytic approach can be useful for incorporating quantitative estimates of uncertainties with values-based trade-offs for examining the implications of competing alternatives.

5. Take Action, Monitor and Adapt: Adaptive management defines an iterative process for improving management predicated on the outcomes of monitoring results and evaluation of decisions and policies (Holling, 1978). In DASEES, the iteration of adaptive management is prompted by pre-defined "triggers" of specified performance measure values (DASEES Step 2) anticipated to be achieved. As alternatives are implemented, data on performance measures are collected and compared to these triggers. When a trigger value is met, or an implementation period ends, the decision is re-visited with the new data better informing the next iterative round of structured decision-making where new information is brought to the process.

### *1.3.3 Dania Beach Report Scope*

This report provides a summary of a two-day Coastal Community Resilience Planning and Decision-Making workshop held in Dania Beach, FL on September 21-22, 2015 and a half-day Consequences Modeling Workshop on March 18, 2016 in Ft. Lauderdale, FL.   Dania Beach is representative of many communities along Florida's coast that are facing similar obstacles and likely share parallel objectives. It is anticipated that this approach will be transferable to those communities and be beneficial to the other 109 cities that have signed on to the Southeast Florida Climate Change Compact as well as coastal communities more broadly along the U.S.  coastline.

The overall objective of this report is to initiate a decision process that facilitates developing a shared vision for Dania Beach and Broward County, with common objectives, for assisting in the creation of new and refining existing resilient community design options. It is anticipated that the results of this exercise can be extended to provide a path for options evaluation and implementation planning. Additional analysis of how the decision options under consideration may or may not promote sustainable and resilient outcomes is possible, through consequence assessments that examine potential outcomes from the decisions under consideration.

## 1.4 Quality Assurance and Quality Control

This report does not contain environmental data or use existing data and therefore no discussion of the quality of the data or limitations on the use of the data with respect to their original intended application is included. The development and application of the decision support tool DASEES was done consistent with the requirements outlines in the Quality Assurance Project Plan. Any calculations or results generated with DASEES were for demonstration purposes only.

Peer reviews were completed and discussed for all research described herein. The conclusion of the QA and peer review process is that results presented in this report accurately reflect the course of the research and are scientifically valid and defensible.

# 2 Structuring the Decision Context

Keeney (1982) outlines the stages of a decision analysis as:

1. Structuring the decision problem
2. Assessing the consequences of alternative implementation
3. Constructing decision maker and stakeholder preferences
4. Ranking and evaluating alternatives

As presented in this report, the first three steps in DASEES are focused on Stage 1: structuring the decision problem which includes preliminary work for Stage 2: assessing consequences and a discussion of associated support tools. The emphasis on structuring is deliberate for a careful characterization of the problem, and for generating prescriptive results relevant for alternative assessment and evaluation. The decision analysis structure establishes a formal, non-quantitative representation of the problem including scope, decision makers, stakeholders, values and objectives, candidate performance measures and alternatives (von Winterfeldt et al., 2009).

## 2.1 Understanding and Clarifying the Decision Context

Clarifying the decision context is the first step in structuring a common understanding of the problem and is important as it is a key determinant in the development of objectives and associated performance measures and alternatives. Keeney (1992) describes this process with a financial investment example. Before retirement, investment objectives are focused on capital appreciation and growth. After retirement, the context changes as income is substantially different and investment objectives shift from growth to income generation and preservation of principal. This often results in a change in the investment context, and the resulting alternatives, in order to attain the new objectives.

The decision context usually begins with background information organized into a narrative describing the decision problem. With decision analysis support, the narrative would be jointly developed by the administrative authority with decision-making power (e.g., local or state government agencies) and relevant stakeholders (e.g. communities, civic organizations, regulatory agencies, business groups) (vonWinterfeldt, 2009, Gregory et al, 2012). Important points for consideration in developing the decision context include (Dyson, 2017):

- Who has decision-making authority, and who are the stakeholders
- Relevant statutes and regulatory drivers
- Spatial and temporal scope
- Important socio-economic conditions
- Lines of formal and informal communication
- Relevant documentation, data and information
- Extent of outside and technical expertise to be used
- Sense of expected outcome from the decision (short- and long-term)

Cognitive maps and system-thinking approaches for developing these ideas with key players are beneficial for identifying knowledge gaps and expertise requirements (Yee et al, 2015). The decision landscape (Rehr, 2012) is an organizational approach to better ensure that relevant individuals, organizations, information, and issues are captured systematically. Fig. 2.1 graphically represents the components of a decision landscape. In addition to communicating who and what should be included in a decision context, it describes the overall process leading to a decision and the role each component plays in that process. The central piece in the decision landscape is the authority (green text) with decision-making power. The context within which decision makers can choose a decision option is modified by regulators, standards, stakeholder issues, and costs (black text). How those contextual constraints are systematically and scientifically represented to assist the decision maker is done by decision support providers and tools, such as DASEES (red text). The extent that each facet in a decision landscape will influence an individual decision will vary across decision contexts.

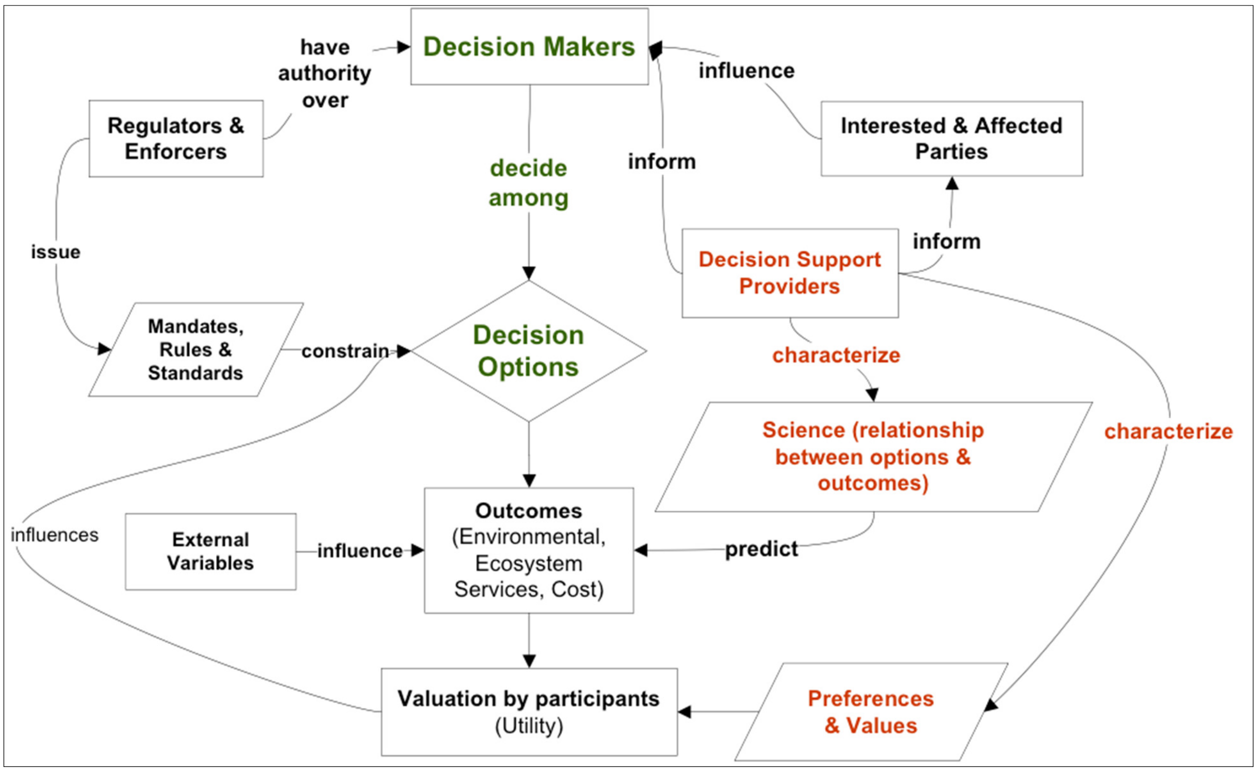


**Figure 2.1** Decision Landscape (Rehr, 2012)

## 2.2 State Region, County, and Local Contexts

Developing and implementing options for coastal resilience integrates scientific understanding, administrative capacity, regulations and cost-sharing requirements across time and geographical scales. Aligning objectives and measures to the greatest extent possible enables more opportunity for collaboration and leveraging of resources. An understanding of the goals, concerns, requirements, and constraints across the three inter-related scales of resilience planning and application will help to find areas of commonality for action, and possible topics of further discussion to understand differences and way to find solutions.

### *2.2.1 Southeast Florida Regional Context*

Southeast Florida currently faces multiple threats from SLR and these threats are expected to increase in the future. Following the first Southeast Florida Regional Climate Leadership Summit in 2009, Broward

County joined Monroe, Miami-Dade, and Palm Beach Counties to ratify the Southeast Florida Regional Climate Change Compact for coordinating mitigation and adaptation actions that would minimize damaging impacts from SLR (Compact, 2015). The Compact has been recognized as a model for regional collaboration and was one of 16 organizations selected by the Department of Energy as Climate Action Champions (DOE, 2014). The member counties work cooperatively to address regional challenges on a legislative and organizational level, and partner with federal, state, municipal, nonprofit, academic, and private sector entities.

One of the Compact's initial actions was to develop a unified SLR projection for the region to aid in understanding potential vulnerabilities and to provide a basis for outlining strategies. First released in 2011, the Unified Southeast Florida Sea Level Rise Projection (Fig. 2.2) was updated in October 2015 (Compact, 2015), projecting the sea level to rise 6 to 10 inches above the 1992 mean sea level by 2030 (2011 projection was 3 to 7 inches), with increasing trends projected out to 2060. Impacts from rising sea levels include increased flooding and drainage problems, destruction of habitats, higher storm surges, increased evacuation areas and evacuation time frames, increased shoreline erosion, saltwater intrusion, and loss of infrastructure and existing development (IPCC, 2014, USEPA, 2017).

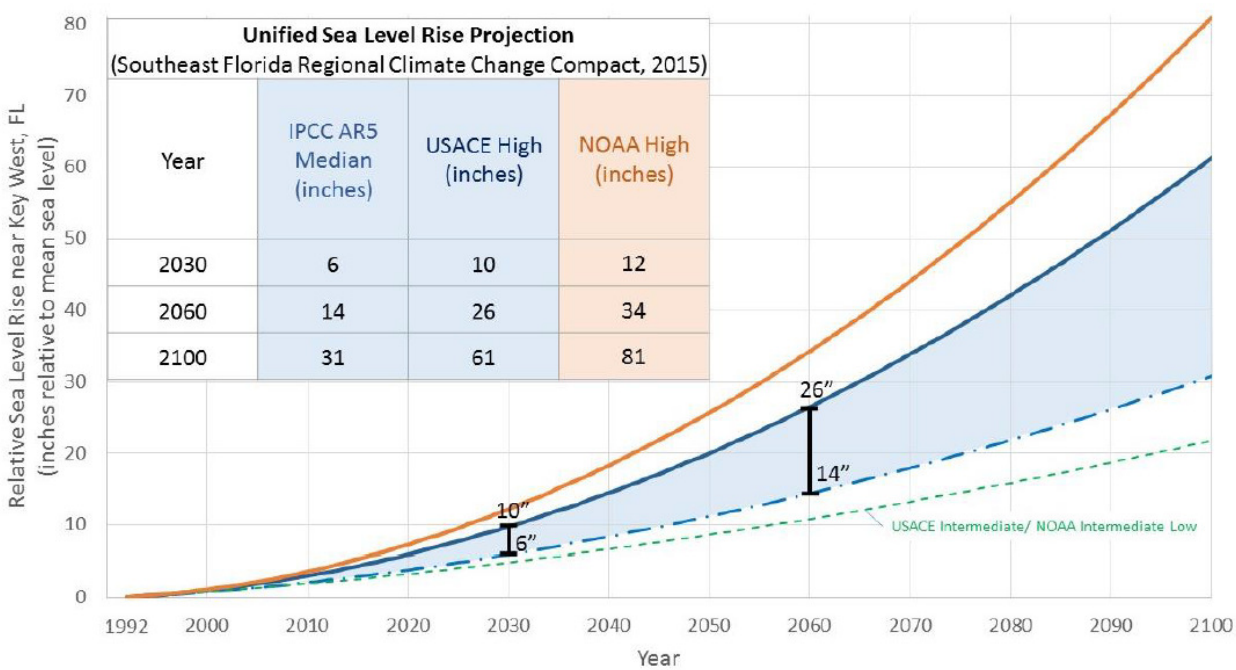


**Figure 2.2** Unified Southeast Florida SLR Projection (Compact, 2015).

In response to these projections, the Compact developed the Regional Climate Action Plan (RCAP, 2017). The Plan created a common vocabulary for outreach and public policy to communicate the steps from risk to resilience with stakeholders including the public, voters, elected officials and decision makers. Regional objectives and action recommendations were identified through a collaborative process involving nearly 100 subject matter experts including representatives from the public and private sectors, area universities, and not-for-profit organizations. The Regional Climate Action Plan (Appendix B) has 12 focus areas and 142 action items (Table 2.1). RCAP serves as a web-based user interface, allowing viewers to explore and create preliminary implementation plans from the action items.

**Table 2.1** Regional Climate Action Plan Focus Areas and Goals (RCAP, 2017).

| RCAP Focus Areas and Goals |
| --- |
| **Agriculture** |
| Goal: Ensure the continued viability of agriculture in Southeast Florida in the face of climate change through policies that encourage sustainable production, remove barriers to production, promote economic incentives, improve water reliability, and promote best management practices |
| **Compact Coordination** |
| Goal: Strengthen coordination and collaboration in Southeast Florida on climate change issues by building the capacity of the Compact to meet evolving regional needs |
| **Energy and Fuel** |
| Goal: Reduce consumption of electricity and fuel and increase renewable energy capacity to increase regional resilience, reduce greenhouse gas emissions, and improve emergency management and disaster recovery adaptation |
| **Natural Systems** |
| Goal: Implement monitoring, management, and conservation programs designed to protect natural systems and the services they provide to society while improving their capacity for climate adaptation |
| **Public Health** |
| Goal: Build capacity to proactively mitigate climate-related public health risks in Southeast Florida |
| **Public Outreach and Engagement** |
| Goal: Build public awareness of the climate-related risks facing Southeast Florida and the opportunities for early, coordinated action to address these risks |
| **Public Policy Advocacy** |
| Goal**:** Guide and influence all levels of government to address climate change in relevant policies, programs, and legislation |
| **Regional Economic Resilience** |
| Goal: Establish a regional resilience strategy involving elected and business leadership, inclusive of funding mechanisms to guide, incentivize, protect, and promote public and private investments and the economic integrity of the region |
| **Risk Reduction and Emergency Management** |
| Goal: Prepare for the inevitable shocks and stresses experienced in Southeast Florida through coordinated and interdisciplinary risk reduction and emergency management planning and investment. |

| RCAP Focus Areas and Goals |
| --- |
| **Social Equity**<br>Goal: Guide and support municipalities and counties in the Compact region to create equitable climate policies, programs, and decision-making processes that consider local socio-economic and racial inequities and ensure all can participate and prosper<br>**Sustainable Communities and Transportation**<br>Goal: Adapt to the impacts of climate change and reduce greenhouse gas emissions by reshaping where and how to build and move from place to place<br>**Water**<br>Goal: Advance the water management strategies and infrastructure improvements needed, in parallel with existing water conservation efforts, to mitigate the potential adverse impacts of climate change and sea level rise on water supplies, water and wastewater infrastructure, and water management systems, inclusive of regional canal networks, pumps, control structures, and operations. |

### *2.2.2 Broward County and Dania Beach Context*

Representatives from the Broward County government ensured that the goals and interests of the county are included in the Compact along with those of the additional counties represented in the southeast Florida region. Within county borders, the 2016-2020 Broward County Commission Strategic Plan (Broward County, 2018), describes a four-point vision emphasizing quality of life through a sense of community, good governance, vibrant economy, and sustainable infrastructure and services. This is further elucidated with eight values (Table 2.2), each with more specific goals (Appendix C).

**Table 2.2** Broward County Values (Broward County, 2018).

| Broward County Values |
| --- |
| A. Ensuring economic opportunities for Broward's diverse population and businesses<br>B. Prominently marketing Broward County as a brand, while increasing public understanding of programs and services<br>C. Approaching human services collaboratively and compassionately, with special emphasis on the most vulnerable<br>D. Cooperatively delivering an efficient and accessible regional intermodal transportation network<br>E. Encouraging investments in renewable energy, sustainable practices and environmental protection<br>F. Cultivating community culture, arts, recreation, and life-long learning<br>G. Offering sustainable, compatible, innovative housing options for all income-levels, including |

| Broward County Values |
|---|
| integrated, permanent supportive housing<br>*H.* Consistently delivering responsive, efficient, quality services to the public and internal customers |

For more than a decade, the Broward County Climate Change Task Force (Task Force, 2018) has conducted vulnerability assessments and taken local steps to analyze municipal level data on infrastructure such as: inundation zones, areas with elevations below mean SLR scenarios, land use, regional indicators, public resource locations and priority planning areas. The county began to play a role in sustainability planning and leadership regionally, nationally and abroad through its participation in the White House Task Force on Climate Preparedness and Resilience (Executive Order 13653) and the Southeast Regional Climate Change Compact.

The Environmental Planning and Community Resilience Division of Broward County has responsibility for 1) Environmental Monitoring, 2) Beach and Marine Resources, 3) Water Resources Policy and Planning, and 4) Climate and Energy Programs. The Director (Dr. Jennifer Jurado) and Assistant Director (Dr. Samantha Danchuk) of the Division were directly involved in the SDM effort with DASEES for Dania Beach and in implementing the Broward Count Climate Change Action Plan (CCAP, 2015). The CCAP contains almost 100 county-wide strategic actions aimed at reducing greenhouse gas emissions and effects of climate change and increasing community resilience. The actions are organized under six plan elements that each have objectives (Table 2.3).

**Table 2.3** Broward County Climate Action Plan (CCAP) Elements and Objectives (CCAP, 2015).

| Broward County CCAP Elements and Objectives |
|---|
| **Policy**<br>• Enact policies and legislation to reduce emissions from transportation and buildings.<br>• Increase community resilience through adaptation. |
| **Natural Systems**<br>• Preserve natural areas and habitats to help protect native species.<br>• Integrate natural systems and green infrastructure throughout the community.<br>• Evaluate current and future impacts of climate change on natural resources and ecosystems |
| **Water Supply**<br>• Ensure existing water resources are protected and remain available through conservation and sustainable management.<br>• Preserve capacity by diversifying source alternatives.<br>• Balance the water needs of public consumers and natural systems |
| **Energy Resources**<br>• Reduce energy intensity of county buildings by at least 20% by 2025 through the Better Buildings Challenge.<br>• Achieve a renewable energy portfolio of 30% by 2030. |

**Broward County CCAP Elements and Objectives**

- Decrease fuel consumption by 10% by 2020.

**Built Environment**

- Assess the impacts of climate change on the built environment.
- Provide tools for climate resilience and support climate-resilient investments.
- Reduce risk through proactive planning for transportation, energy and natural infrastructure.

**Community Outreach**

- Grow community awareness on climate change issues by increasing the number of community partners annually.

Already, Broward County is taking adaptive climate resilience action through the adoption of the state and federal designation of Adaption Action Areas (AAAs) for specific coastal areas in the county. The AAA designation is optional for areas vulnerable to SLR but used to prioritize funding for infrastructure needs (SFRPC, 2013). The Port Everglades Entrance Sand Bypass Project (Broward County, 2014) is a beach nourishment project that can beneficially influence the coastal areas of Dania Beach and was given an AAA designation.

Resilience planning has also been occurring at a city-wide level. One example of this is the Dania Beach Community Redevelopment Agency (CRA) which was founded in 2002 (CRA, 2015) by the city commission. It aims to redevelop Dania Beach through sustainable means and is focused on specific areas of Dania Beach within the CRA boundaries. The CRA area is inclusive of the downtown area, certain neighborhoods and marine and commercial locations. Strategies for redevelopment for specific neighborhoods, transportation, clean energy, and economic development projects are delineated in the Dania Beach CRA Redevelopment Plan (CRA, 2015). Plan goals and scope of the CRA area has expanded in the ensuing years (2009 to present) with the corresponding implementation strategies subject to re-analysis. As delineated in the most recent plan Dania Beach CRA Redevelopment Plan, (CRA, 2015) emphasis is placed on neighborhood revitalization, energy efficiency, sustainability, and adaption planning for resilience to climate impacts. It also groups implementation strategies for the short term (1-5 years) and longer term (>5 years).

> *"The mission of the CRA is to create and implement economically sound redevelopment and revitalization activities in the City of Dania Beach, to improve the unique small-town quality of life, while simultaneously facilitating investment, commercial development, innovation and growth for our diverse population."*
>
> *-Dania Beach CRA Redevelopment Plan (CRA, 2015)*

In parallel, the City Commission passed Resolution No. 2009-026 to establish a Green Advisory Board to assist "City administration in identifying and creating policies and action plans that pertain to energy efficiency and help to mitigate the effects of climate changes." Also, the Dania Beach City Commission passed Resolution No. 2013-011 to provide an endorsement of the Southeast Florida Mayors' Climate Action Pledge; an affirmation of support for the Southeast Florida Regional Climate Change Compact and an agreement that implementing the Southeast Florida Regional Climate Action Plan, in whole or in part, would be appropriate for the city.

One recent project that illustrates the city's approach to re-development is the Dania Beach Oasis Project (Fig. 2.3), a neighborhood redevelopment project led by the City Manager. By design, and implemented incrementally, the Oasis Project was developed to improve individual streets and foster neighborhood pride. It is hoped that it will foster a "ripple effect" that encourages residents to work collectively to improve and beautify their neighborhoods. The City Manager described it as a proactive approach to promoting neighborhood stability, reducing urban blight, preventing crime, and increasing property values.

> "Disorder in a neighborhood leads to crime. So, we try to create a better area, a safer environment and crime will be reduced. By beautifying a street, the residents see the improvements and start improving their own properties. That's why we call it the Oasis Program because it grows. We plant seeds and the residents react to that by improving their own properties. We really think that this is having such a good effect on Dania Beach."
> ~ Robert Baldwin, City Manager, City of Dania Beach

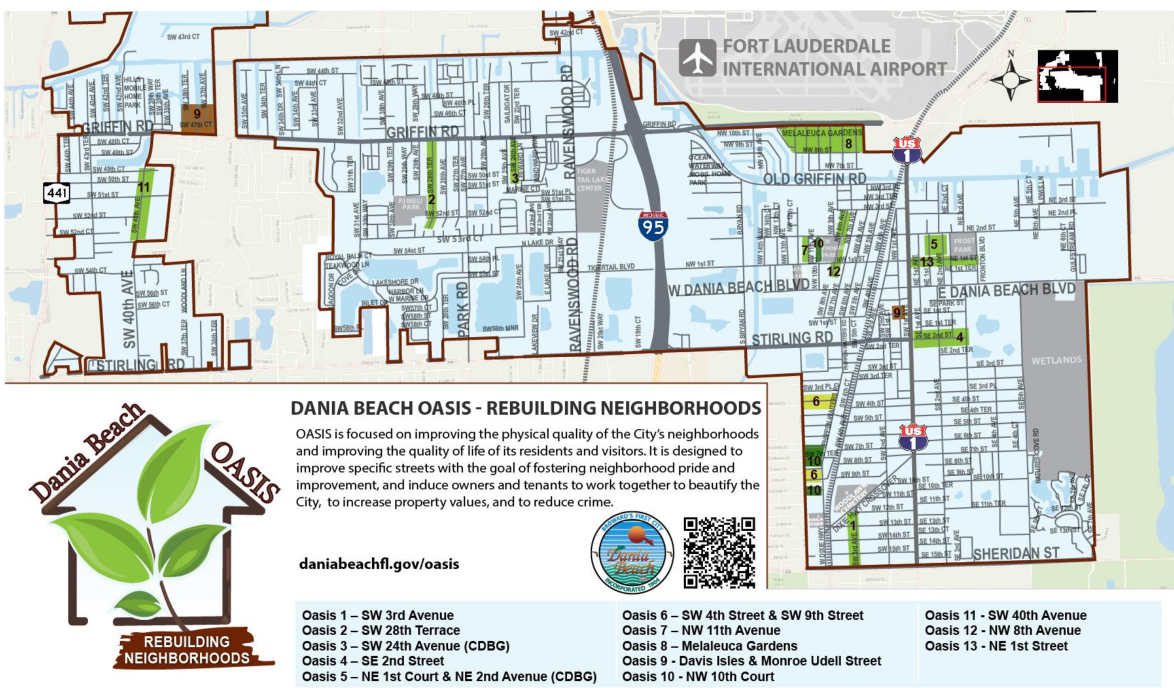


**Figure 2.3** Map of Dania Beach Oasis Projects (http://daniabeachfl.gov/oasis

### 2.2.3 Broward County and Dania Beach Collaboration

In August 2014, the Compact co-hosted the four-day Southeast Florida Resilient Redesign Workshop (Compact, 2014). Over 50 regional, national and international experts from the diverse fields of architecture, engineering, transportation, planning, and water management assembled to collaborate on the identification of challenges and resilient design opportunities for three representative communities in southeast Florida. The Dania Beach in Broward County was included as a representative urban community, along with the City of Miami Beach and the community of Sweetwater in unincorporated

Miami-Dade County which served as respective models for dense-urban (Dania and Miami Beach) and suburban (Sweetwater) landscapes.

Subsequently, the team of experts presented their conceptual designs (Table 2.4) and advice to a body of local stakeholders which led to continued discussions about the possibilities for regional and local collaboration in South Florida. To further build on the aims and products of the Resilient Redesign workshop, Broward County and Dania Beach administration and met to discuss strategies and to identify opportunities for implementing the resilient design concepts. Staff representation from the economic, transportation, housing, planning, and redevelopment agencies facilitated additional discussion about potential alignment with economic development opportunities and planned improvements to infrastructure.
These meetings helped develop a course of action for further protecting residents from the SLR threat while expanding the network of decision makers and stakeholders involved in advancing the proposed resilient design concepts. The introduction of decision-analytic tools and processes can further support the redesign process by helping to evaluate and refine the design concepts, develop a community-wide vision that encompasses the diverse values that might be impacted by these decisions, and organize the funding and support need to formalize and implement a plan. Broward County and the Dania Beach have committed to working together to continue these efforts with the goal of integrating resilient design options into redevelopment strategies and to better engage the community.

### 2.2.4 Structure Decision-Making Workshop Planning

To continue the collaboration on resilient re-design, the U.S. EPA Region 4 was engaged to coordinate support from SHC and DASEES for Broward County and Dania Beach. DASEES facilitates the SDM process, the first step of which (and the scope of this report) is establishing clarity on objectives, performance measures and options to achieve objectives. Identifying stakeholder objectives for Dania Beach is key to informing the prioritization of actions, the development of strategies that are cost-effective, ensuring that diverse stakeholders receive a voice at the table, and helping to shape community and regional goals that are consistent with a community-wide vision for resilience. A more complete understanding of partner perspectives and backgrounds informed the development of the workshops and workshop products described later in this report.

**Table 2.4** Dania Beach Resilient Redesign Summary (Compact, 2014).

| Design Concepts | Recommendations |
|---|---|
| Urban Densification at City Center | • Vertical Expansion<br>• Include Evacuation Shelter<br>• Invest along Coastal Ridge (Higher Elevation) |
| Enhance Natural Infrastructure | • Construct Resilience Center and Wetland Bicycle Path<br>• Mangrove Restoration<br>• Dune Enhancement (Underground Parking)<br>• Reef Enhancement |

| | |
|---|---|
| Flood Control | • Create a Polder (water storage structure)<br>• Raise Perimeter Roads to act as Levees<br>• Add Pumping System<br>• Incorporate Canals |
| Implementation Suggestions | • Use Concepts as Inspiration<br>• Engage the Community<br>• Employ a Decision-Making Process<br>  o Consider Regional Context<br>  o Consider Temporal Scale for Planning<br>  o Develop an Implementation Roadmap |

# 3 Dania Beach Structured Decision-Making Workshops

Making community resilience decisions within a complex, uncertain environment requires a flexible, transparent, and deliberative process, open to a range of values and knowledge that can have a significant impact on the formulation and risk-based analysis of decision options (Failing et al., 2007; Reed, 2008). Fundamental to this is the early and systematic inclusion of relevant stakeholders in the process (Reed, 2008). Engaging appropriate stakeholders in a decision-making process can ensure a broader set of viewpoints and localized understanding of management options, enable learning across the participants and organizers, and increase transparency and perceived credibility of the process and resulting outcomes (French et al. 2009). The general approach to engaging with stakeholders via DASEES can be described as decision sketching (Gregory et al, 2012). Decision sketching is a short (hours to days) high-level review and characterization of the decision problem in order capture the key components of a decision and their relationship to each other. It rapidly covers the first several steps of SDM (DASEES Steps 1-3) to clarify decision context, objectives, performance measures, and options. In DASEES, these decision parts are graphically and causally linked through Bayesian networks (a feature in DASEES Step 4) and discussed more fully in Chapter 4). Bayesian networks (BNs) are a useful visual way to begin conceptual understanding of causal links between proposed resilience actions and expected outcomes.

## 3.1 Pre-Workshop Planning

One key purpose of DASEES is to help better engage stakeholders in the decision-making process. Before the workshop, Dania Beach and Broward County provided a list of the proposed invitees. The list was sorted according to an EPA-developed stakeholder typology framework shown in Table 3.1, which identified stakeholder representation based on affiliation and area of practice. The typology framework lists 16 stakeholder types considered to be most relevant to environmental decision making, along with example organizations of each stakeholder type for clarification. Inviting representatives from all these categories does not ensure a complete or appropriate mix of stakeholders but was used as a check on overlooking potential stakeholders.

The draft invitee list included 14 of 16 categories, with tribal government and tourism stakeholders not yet identified. In an attempt to ensure fuller stakeholder participation a content analysis of documents that captured the attendees of previous environmental management related meetings revealed appropriate representatives for invitation.

For workshops of this type, an essential element is the inclusion of people who are conversant in the ideas of SDM and skilled in elicitation. Expert elicitation (Doria, et al, 2009, Morgan, 2014) employs various methods for drawing out and structuring expert (stakeholder) knowledge both qualitatively and quantitatively, making it useful for decision-making for complex problems often under uncertainty, such as planning for climate adaption. Resources and a fuller description of methods for elicitation are provided in Bradley et al, 2016.

**Table 3.1** Stakeholder Typology for Sorting Dania Workshop Invitees.

| Stakeholder Type | Example Organizations (not specific to Dania Beach) |
|---|---|
| **Local Government (town/city governments)** | City Planning Office, Water Districts, Office of the Mayor |
| **County Government** | County Planning Office, Soil and Water Conservation Districts |
| **State Government** | State Departments of Environmental Management, State Emergency Management, Fish and Wildlife Department |
| **Federal Government** | U.S. EPA, National Oceanic and Atmospheric Administration, U.S. Department of Agriculture |
| **Tribal Governments** | Tribal environmental agencies, planning agencies |
| **Elected Officials** | State representatives, senators, mayors |
| **Environmental NGOs** | The Nature Conservancy, World Wildlife Fund, local watershed groups |
| **Community/Social Welfare NGOs** | National Urban League, Children's Services Council |
| **Industry** | Local manufacturers |
| **Wastewater Treatment Plants** | Public, Private, Municipal, and Industrial plants |
| **Utilities** | Water, Electricity, Gas |
| **University** | Universities, Colleges |
| **Research** | Research institutions (i.e. Woods Hole Oceanographic Institution-MA, Scripps Research Institute-FL) |
| **Tourism** | Bus, Beach, and Gondola Tour Agencies |
| **Land Owners** | Public and Private Land owners |
| **Land Developers** | Commercial and Residential Land Developers |

Experts in environmental decision-making from Neptune and Co., Inc., employed DASEES to elicit stakeholder knowledge, and subsequently process and structure that knowledge in DASEES, making it useful for informing decision makers. DASEES was designed to be user-friendly, and applicable to a wide range of decision problems; its content and tutorials provide examples for developing products for decision support. However, when applying any decision tool or process to complex, uncertain problems such as community resilience planning for climate change involving multiple stakeholders, the inclusion of decision analytic expertise is necessary to ensure the effective application of such tools and processes.

## 3.2 Workshop Implementation

As mentioned in the previous section, two workshops (1 and 2) were conducted. The second was conducted later, once it was understood more time was needed in the first workshop to better formulate the context, objectives, and performance measures. This occurrence highlights the importance of flexibility when conducting stakeholder meetings to provide sufficient opportunity to capture all decision-relevant information. The stakeholder groups in Workshop 1 included local, county and state government officials; social welfare non-governmental organization (NGO) representatives, utility officials, and landowners and developers. Workshop 2 participants were comprised of technical analysts from local and county government. Workshop 1 captured the values and concerns of stakeholders into objectives and used those objectives for developing stakeholder-derived alternatives and Workshop 2 was primarily a technical workshop on potential modeling work that could support the evaluation of results from Workshop 1. Thus, each workshop had a different focus on stakeholders (Workshop 1) and experts (Workshop 2) respectively. The facilitation and analysis of workshop results was designed and implemented by Kelly Black and Dr. Thomas Stockton, Jr. of Neptune and Company, Inc.

These results within and between the two workshops were utilized to build on each other as the activities progressed (Fig. 3.1). Workshop 1 was conducted to construct objectives and identify performance measures with community stakeholders. After an initial hierarchy of fundamental objectives was constructed, performance measures and options to achieve the objectives were proposed by stakeholders. The objectives, measures, and options were then used in an initial discussion to capture stakeholder understanding of causal linkages between options and objectives.

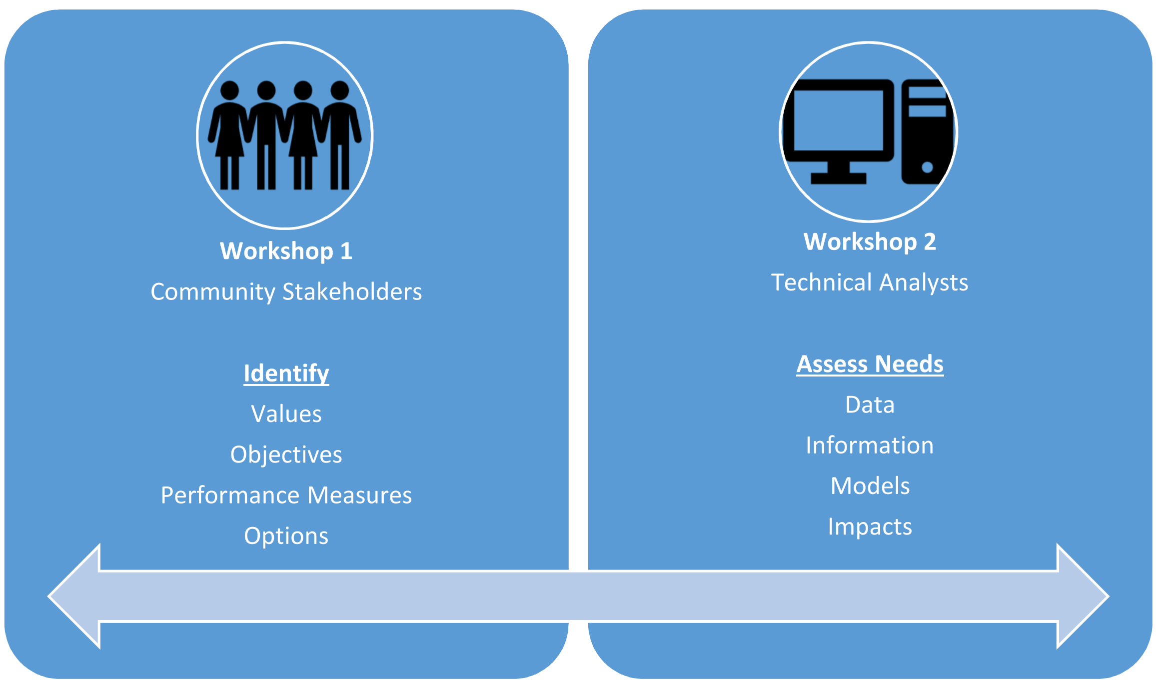


**Figure 3.1** Scope of the two Dania Beach Workshops and their relationship.

Workshop 2 built on the first workshop and delved more into the technical aspects and implications but also included some additional revisions to the measures and alternatives to increase their operability. Workshop 2 was primarily focused on consequence modeling and tools available for predicting the impacts on the objectives from the options identified by stakeholders in Workshop 1.

### 3.2.1 Workshop 1

Workshop 1 (held on Sept. 21-22, 2015) was initiated with contextually-oriented presentations (DASEES Step 1). Rafaela Moura (EPA, Region 4) provided an overview of EPA Region 4's perspectives on the workshops and tools developed by Region 4 that could support community decision making and planning (all slides from the workshop presentations are included in Appendix D). Tammy Newcomer-Johnson (then ORISE/EPA Climate Ready Estuaries) discussed the threats of climate change to coastal communities and tools for climate change assessment, management and planning. Drs. Jennifer Jurado and Samantha Danchuk (Broward County) gave a presentation that updated the stakeholders on Dania Beach's strategies for resilience planning. A review of decision analysis, the importance of understanding objectives for developing and evaluating alternatives and the impetus and goals for the workshop was provided by Brian Dyson (EPA/ORD) before the initiation of workshop activities.

The elicitation process followed the presentations with three sessions that focused on the following questions:
**Session 1:** What are your preferences and concerns? (Objectives) - DASEES Step 1
**Session 2:** How do we measure success? (Performance Measures) – DASEEES Step 2
**Session 3:** How do we achieve success? (Options) – DASEES Step 3
Each session was an hour and a half long and included an elicited discussion with results captured in the DASEES tool.

**Session 1** was a discussion of the objectives for the future of the community (i.e., what the community hopes to achieve or avoid). Workshop elicitors used the structuring capabilities of DASEES (DASEES Step 2) to organize the concerns and values of stakeholders into statements called fundamental objectives. Fundamental objectives specify what is of ultimate importance in a decision problem. They include a clear description of the value and an intent or direction for that value. Examples might be *Maximize ecological integrity* or *Minimize management costs*. This process focused on end values of concern from stakeholders and not technical concerns or means objectives (how to achieve end values) which were captured later. Related objectives were grouped into an *Objective Hierarchy* (Section 3.3) with a higher-level objective containing several sub-objectives. Sub-objectives were later assigned performance measures assigned to track attainment (Section 3.4)

**Session 2** had the community stakeholders form breakout groups to identify candidate performance measures for the fundamental objectives previously identified. Performance measures were chosen that best met the criteria of being "measurable, operational, and understandable." These criteria are used to test the applicability of a proposed measure for the decision at hand (Keeney, 1992). The whole group was reconvened to discuss the measures identified and select a final set of measures. Clarifying measures also helped identify over-lapping objectives (those with similar intent or outcome), which were then removed from the objectives hierarchy (Section 3.3). This is done to avoid "double-counting" when quantifying impacts from proposed management actions

**Session 3** focused on developing means objectives and options (Section 3.5) (DASEES Step 3) for achieving the fundamental objectives with measures organized in DASEES (Section 3.4). This session also used value-focused thinking as the guiding principle by recommending management options that best achieve fundamental (values-driven) objectives; tracked by performance measures. At least one option was developed for achieving each of the objectives.

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An initial "first-cut" approach at graphically modeling (DASEES Step 4) these decision components was conducted with the stakeholders to provide a visual aid (Fig. 3.2) and for the technical analysts to use in Workshop 2.

**Performance Measure Selection Criteria**

**Measurable:** There should be acceptable and verifiable means to assess a condition of interest (environmental, social, economic), track over time, and record data.

**Operational:** There should be the ability to predict or detect changes to the selected measure from implementing proposed actions. Without this ability, it is difficult to determine if fundamental objectives are being achieved. That implies the measure should be relevant to the scale of the problem. For example, attempting to measure global impact from regional actions may be not useful.

**Understandable:** Using technical measures and scientific jargon to report results may be accurate, but not necessarily helpful to a broad reach of stakeholders and decision makers. Translating technical results into more meaningful measures to communities is critical.

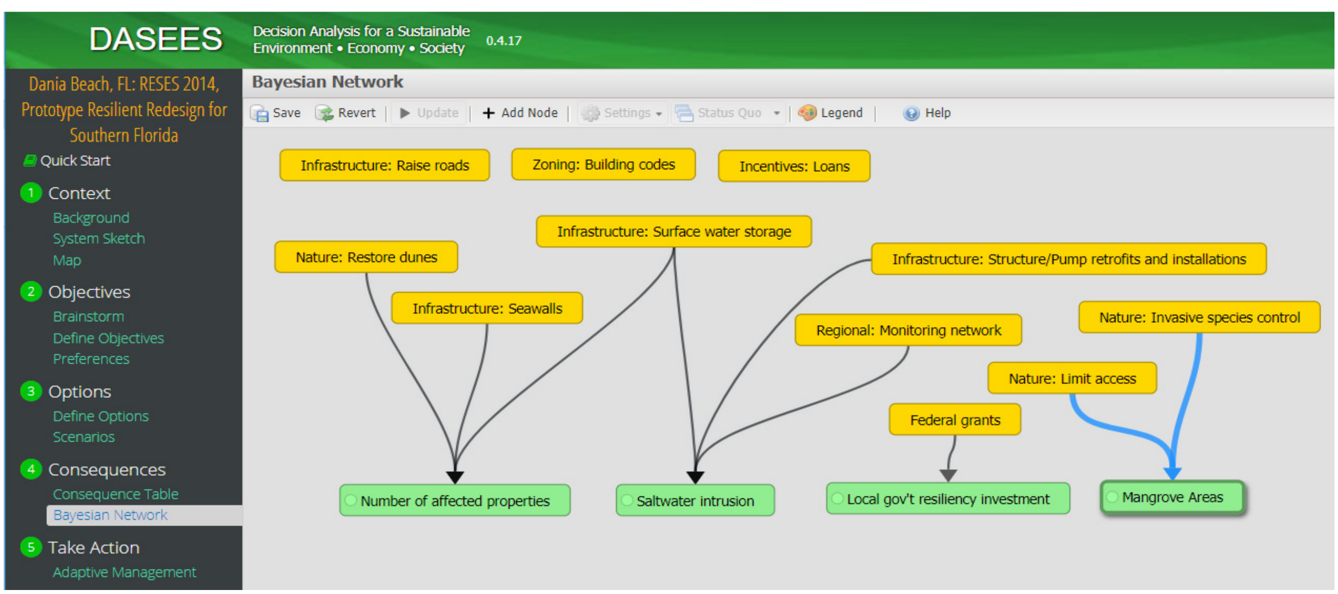



**Figure 3.2** Preliminary stakeholder-driven graphical modeling (influence diagram) linking management options (yellow nodes) to performance measures (green nodes).

### 3.2.2 Workshop 2

A half-day workshop (Workshop 2) was held several months later (March 18, 2016) when the group of technical analysts (Appendix D) could meet. The facilitators provided a presentation on structured decision making to orient the participants to the DASEES decision process and the insights that can be provided by structured decision-making workshops. This was followed by a review of the results from Workshop 1 (Section 3.3). The rest of the workshop was focused on developing an influence diagram (Section 3.6) that specified the modeling tools and data sources that could be used for predicting the impacts of the stakeholder-identified options on the fundamental objectives through the associated measures. Participants were first shown the initial graphical model developed with Workshop 1 stakeholders (Fig. 3.2) with the options connected to each corresponding objective/measure. Then, participants identified how these relationships might best be quantified with numerical models and data sources to further develop the Fig. 3.2 model with relevant economic, hydrologic, and ecological models.

## 3.3 Objectives Hierarchy

Session 1 of Workshop 1 produced an objectives hierarchy covering the concerns and ideas about the future of Dania Beach from the stakeholder group (Fig. 3.3). Seven fundamental objectives were identified by the stakeholders for resilient redesign in Dania Beach. The fundamental objectives covered a range of distinct topics which included maintaining positive aspects of the community, protecting human health, ensuring a good economy, and protecting the ecological integrity of the region. Each fundamental objective had sub-objectives to further define what was meant by the fundamental objective (e.g., Protect community is defined by maintaining small-town feel, preserving historic structures, and five other sub-objectives). The number of sub-objectives identified for each fundamental objective ranged from four to seven and are discussed below.

Equity represents the sharing of burdens and benefits so that the individuals in one group are not disproportionately affected more than another. Fundamental objectives related to equity are often found in decision analysis applications (Merkhofer and Keeney1987). Participants defined equity through sub-objectives covering the distribution of resources, affordable housing, intergenerational impacts from sustainability, and adapting to new generations.

A fundamental objective for community protection was constructed to represent the positive aspects of the community that stakeholders would want to maintain now and in the future. Community protection was defined through multiple distinct elements. Several of the sub-objectives for community protection focused on positive aspects of the history of the community such as preserving historic structures and small-town feel. Similarly, values related to community bonds and ties were expressed through a sub-objective of building community character cohesion. The importance of enhancing the multi-cultural aspects of the community was expressed through a demographic diversification sub-objective. Several additional objectives related to the market-based aspects of the community were also specified through preserving development options, balancing large and small business development, and maintaining the community of small businesses.

The protection of health, lives, and property are key components and source of fundamental objectives in resilience planning. Fundamental objectives were identified for avoiding costs to human safety and flooding along with infrastructure protection and improvements.

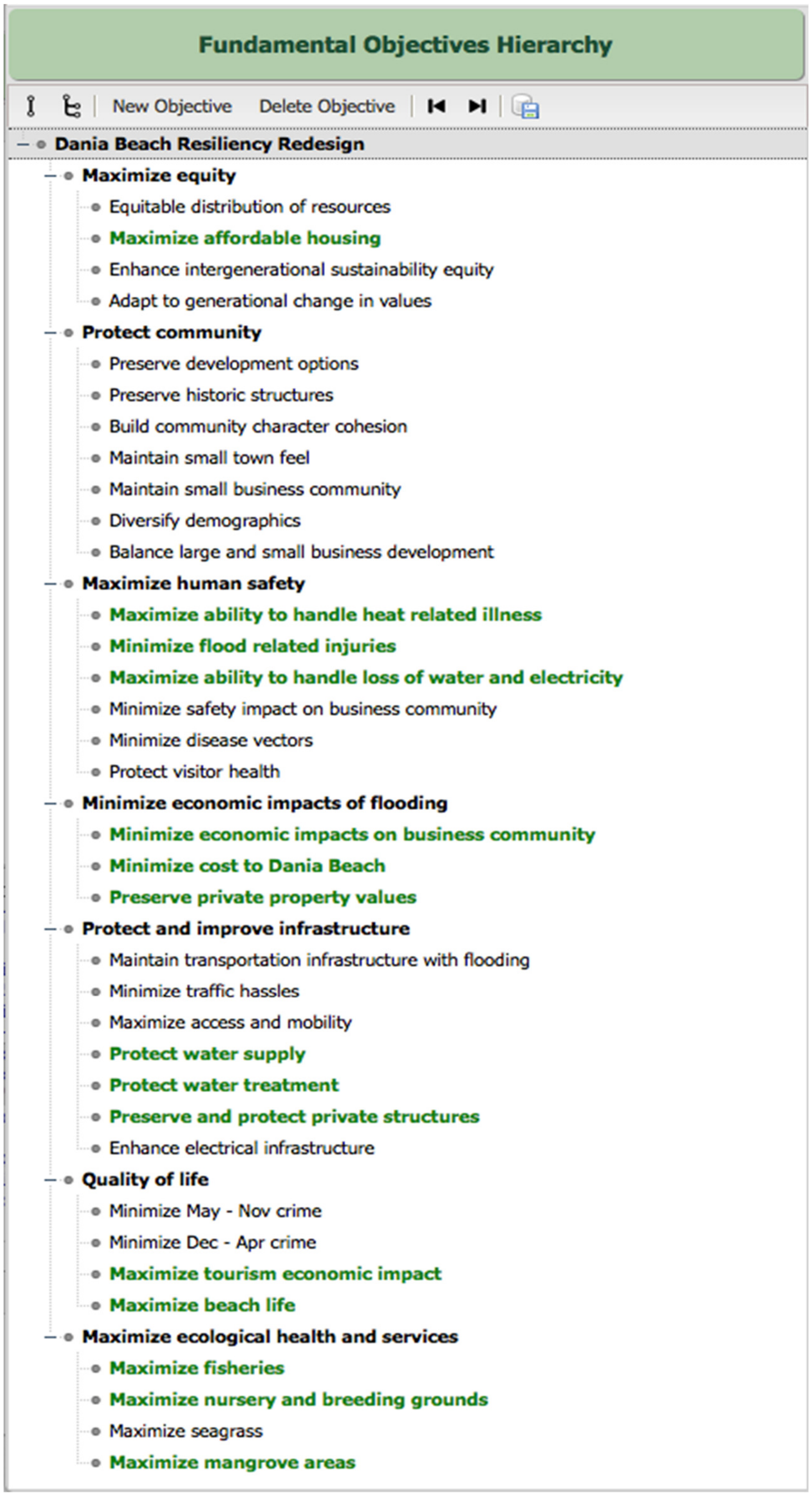



**Figure 3.3** Screenshot of Objectives Hierarchy generated in DASEES Workshop 1. Fundamental objectives are in bold black and sub-objectives are bulleted below. Green sub-objectives were assigned performance measures during Session 2.

The sub-objectives for defining the human safety fundamental objective were diverse and focused on threat types such as injuries from heat, floods, and disease vectors (e.g., mosquito-borne illnesses). One sub-objective focused on stakeholders that should be protected (visitors to the region) and another specified the impacts of safety on the business community. A fundamental objective was also created for infrastructure protection that also touched on a diversity of concerns including impacts to water, electricity, and transportation infrastructure for the public sector and preservation and protection of structures that are privately owned. Two key means objectives (not shown, but captured in DASEES), "*Maximize natural systems water filtering"* and *"Increase surface water storage*," were identified for the sub-objective of protecting water supplies. An analogous fundamental objective examining the economic impacts of flooding was identified. Economic impacts of flooding were further defined as being related to costs to the city government, to the business community and impacts on private property values from flooding events such as from hurricanes.

A quality of life fundamental objective was created that was further specified by crime reductions for different times of the year (possibly to consider differences during tourist- and off-seasons), economic impacts of tourism, and maintaining beach lifestyles through accessibility and availability of the beach now and in the future. A final fundamental objective covered the ecological aspects important to the community. This fundamental objective included sub-objectives for aquatic and semi-aquatic landscapes (seagrass and mangroves) and fisheries abundance along with breeding and nursery grounds for fish.

Several of the objectives were selected to further define and analyze in subsequent steps (bolded in green in Fig. 3.3). For these objectives, performance measures were identified and are described in the next section (3.4). Table 3.2 lists of the objectives that were not included in subsequent steps due to not being unique and operational. These objectives can still provide important considerations for future decisions but were excluded to leave a more focused list of objectives for subsequent workshop activities.

**Table 3.2** Objectives considered as overlapping and excluded from the final list for performance measure identification. Bold text highlights the sub-objectives that were excluded.

| Overlapping Objectives |
|---|
| + Maximize equity |
| **Equitable distribution of resources** |
| **Enhance intergenerational sustainability equity** |
| **Adapt to generational change in values** |
| + Protect community |
| **Preserve development options** |
| **Preserve historic structures** |
| **Build community character cohesion** |
| **Maintain small town feel** |
| **Maintain small business community** |
| **Diversify demographics** |
| **Balance large and small business development** |
| + Maximize human safety |
| **Minimize safety impact on business community** |
| **Minimize disease vectors** |
| **Protect visitor health** |
| + Minimize economic impacts of flooding |
| + Protect and improve infrastructure |

| Overlapping Objectives |
| --- |
| **Maintain transportation infrastructure with flooding** |
| **Minimize traffic hassles** |
| **Maximize access and mobility** |
| **Enhance electrical infrastructure** |
| + Quality of life |
| **Minimize May - November crime** |
| **Minimize Dec - April crime** |
| + Maximize ecological health and services |
| **Maximize seagrass** |

## 3.4 Performance Measures

Performance measures were identified for each sub-objective along with units for each of the measures (Table 3.3). Most of the performance measures had easily identifiable units for measurement, e.g. dollars ($) for cost, or hectares (ha) for area, but several may need specially constructed scales (indices) such as for low income housing and for the health of fish communities. The latter might refer to a diversity index that incorporates measures of fish community health and looks at abundance within and across populations. Several key patterns emerged during the identification of performance measures. Most of the human safety objectives had measures focused on numbers of individuals suffering mortal or morbid injuries related to environmental stressors while most of the economic objectives were measured in dollars with some notable exceptions such as a number of visitors measure for tourism.

Spatial objectives were given an areal measure such as hectares and square miles. Several sub-objectives had multiple measures that could have represented bundled concerns within the objective.
Although the fundamental objectives hierarchy was truncated, many of the objectives identified were more long-range, or strategic, reflecting perspectives on the future of Dania Beach. If applied to specific decision-making contexts, additional information would need to be incorporated in many of the performance measure scales, such as net present value measures for comparisons across time, or further defined to match location-specific needs (e.g., gradations in quality for different species for habitat types). As demonstrated here, coupling the objectives hierarchy and the performance measures provides a clear and focused way of presenting what is important for the future to stakeholders in a community and how might this be operationalized and measured for ensuring the objectives are achieved by the options. Measures can further be refined with subject matter experts and stakeholder input to fully capture the values expressed in the hierarchy and identify more.

**Table 3.3** Objectives Hierarchy with performance measures and units.

| Objective | Performance Measure | Units |
|---|---|---|
| + Maximize equity | | |
| **Maximize affordable housing** | Low income housing | index |
| + Maximize human safety | | |
| **Maximize ability to handle heat related illness** | Health: Heat related hospital visits | number |
| **Minimize flood related injuries** | Health: Flood deaths | number |
| **Maximize ability to handle loss of water and electricity** | User days without water<br>User days without electricity | number<br>number |
| + Minimize economic impacts of flooding | | |
| **Minimize economic impacts on business community** | Cost of insurance | dollars |
| **Minimize cost to Dania Beach** | Cost: Maintenance costs<br>Cost: Dollar capital projects | dollars<br>dollars |
| **Preserve private property values** | Comparative property values | ratio |
| + Protect and improve infrastructure | | |
| **Protect water supply** | Potable Water<br>Reclaimed<br>Saltwater intrusion | million<br>gallons<br>square miles |
| **Protect water treatment** | User days without water | number |
| **Preserve and protect private structures** | Number of affected properties | parcels |
| + Quality of life | | |
| **Maximize tourism economic impact** | Heads in beds | number |
| **Maximize beach life** | Beach Closure (WQ)<br>Beach Closure (Sand) | days<br>days |
| + Maximize ecological health and services | | |
| **Maximize fisheries** | Fish abundance | index |
| **Maximize nursery and breeding grounds** | Mangroves | ha |
| **Maximize mangrove areas** | Mangroves | ha |

## 3.5 Management Actions

Workshop participants identified a set of management actions (options) specifically intended to achieve each of the sub-objectives (Table 3.3). A value-focused brainstorming exercise was used with the stakeholders to generate actions that may be useful to evaluate for effectiveness in achieving the objectives (Gregory et al. 2012). This activity allowed input from stakeholders on potential ways of achieving their objectives and ensured most objectives would have an action that could be evaluated. To ensure understandability when examining effectiveness, actions can be defined by their qualities, location(s), scale, and resource commitments, including implementation time, personnel, information needs, and equipment.

Requirements for assessing actions can be further expanded with the stakeholders and technical experts familiar with the place setting and technical areas encompassed by the objectives. Remaining questions about how the suggested actions could achieve an objective might be addressed through the influence diagramming process (previously mentioned graphical maps) to characterize the conditions that must be achieved for beneficial outcomes on the objectives. This is further discussed in later sections.

Some of the actions are currently being undertaken, planned, or considered by Dania Beach or Broward County or external agencies, and some are unique ideas generated at the workshop. Most of the management actions refer to structural projects that would require infrastructure modifications to protect lives, property, social, and economic values (e.g., raise roads, build dunes). The nonstructural options include ones related to education, building codes, and environmental protection. Several of these options were identified to achieve more than one objective. For example, one management action related to zoning was identified to contribute to achieving two objectives: property values and water supply protection.

The fundamental objective pertaining to heat-related illnesses did not have an action identified by the stakeholder group. New actions could be created that might be implementable by the city or the stakeholders within the city and cover the range of heat-related illnesses of concern which could include workplace, domestic, or recreational exposure situations. One or more appropriate experts in heat-related illness prevention or treatment could be consulted for these actions. An appraisal of baseline actions currently in use or expected for future use to address heat-related illnesses would accompany this investigation. Note that the workshop produced the list of management actions in Table 3.4. Greater elaboration on each of these management actions was developed by the EPA after the workshop (Sections 3.5.1 through 3.5.15). It would be ideal to have additional iterations with community stakeholders to ensure their intent has been accurately conveyed. The listed actions may be further refined and expanded with subject matter experts and packaged in coordinated portfolios for further evaluation if helpful for future management decisions.

**Table 3.4** Management actions and measurement units developed to achieve objectives.

| Objective | Management action | Units |
|---|---|---|
| **+ Maximize equity** | | |
| **Maximize affordable housing** | Incentives: Loans | dollars |
| **+ Maximize human safety** | | |
| **Maximize ability to handle heat related illness** | | |
| **Minimize flood related injuries** | Infrastructure: Connect bioswales | number |
| | Infrastructure: Knee walls | meters |
| | Infrastructure: Raise roads | meters |
| | Infrastructure: Seawalls | meters |
| **Maximize ability to handle loss of water and electricity** | Infrastructure: Agile water supply | MGD |
| | Response: Mobile solar power | number |
| **+ Minimize economic impacts of flooding** | | |
| **Minimize economic impacts on business community** | Infrastructure: Connect bioswales | number |
| | Infrastructure: Knee walls | meters |
| | Infrastructure: Raise roads | meters |
| | Infrastructure: Seawalls | meters |
| **Minimize cost to Dania Beach** | Funding: Federal grants | dollars |
| **Preserve private property values** | Infrastructure: Connect bioswales | number |
| | Infrastructure: Knee walls | meters |
| | Infrastructure: Raise roads | meters |
| | Infrastructure: Seawalls | meters |
| | Zoning: Finish floor elevation | |
| | Nature: Re-nourish and build dunes | ha |
| | Education: dunes | number |
| **+ Protect and improve infrastructure** | | |
| **Protect water supply** | Infrastructure: green surface water storage | million gallons |
| | Adaptation Action Areas | number |
| | Infrastructure: Connect bioswales | meters |
| | Zoning: Finish floor elevation | meters |
| **Protect water treatment** | Infrastructure: Connect bioswales | meters |
| **Preserve and protect private structures** | Infrastructure: Knee | meters |

| Objective | Management action | Units |
| --- | --- | --- |
| | walls | |
| | Nature: Re-nourish and build dunes | ha |
| **+ Quality of life** | | |
| **Maximize tourism economic impact** | Infrastructure: Beach nourishment | meters |
| | Infrastructure: Roads | meters |
| | Infrastructure: Connect bioswales | meters |
| | Infrastructure: green surface water storage | million gallons |
| | Infrastructure: Reclaimed water produced | MGD |
| **Maximize beach life** | Infrastructure: Septic Connection | number |
| **+ Maximize ecological health and services** | | |
| **Maximize fisheries** | Nature: Breeding ground protection | ha |
| **Maximize nursery and breeding grounds** | Nature: Breeding ground protection | ha |
| **Maximize mangrove areas** | Nature: Breeding ground protection | ha |

### 3.5.1 Incentives: Loans

To better achieve affordable housing, the suggested action was loans. This might refer to fair and secure loans to low income home purchasers for mortgage purposes. Loans for low-income home buyers might come from private or public (federal, state or local) sources. Characteristics of the loan could be examined for optimally ensuring the availability of affordable housing. Along with generating new loans, the opportunities to apply to existing loans and access to housing support services for disadvantaged individuals and families might be considered with this action. Ensuring affordable housing for residents is part of the Dania Beach Housing Authority's mandate. The authority administers a voucher program for low income residents in the city for rentals and manages public housing units.

### 3.5.2 Infrastructure: Connect Bioswales

Developing connected bioswales was identified as an action that could raise property values, prevent flood-related injuries, benefit tourism, minimize negative economic impacts on the business community, enhance water supply availability, and treat water supplies. Means objectives of minimizing beach pollution and targeting two-foot SLR with bioswale development were discussed at the workshop as important to consider with the design of bioswales. Bioswales can be integrated into urban settings and landscapes as exemplified by Fondy Park in Milwaukee, WI (Fig. 3.4). Bioswales facilitate surface and/or sub-surface transport of water drainage. In areas where rain and surface water accumulate, bioswales might be used to transport the waters away to prevent damage to private or public infrastructure including water supply treatment facilities. Another primary use is for filtering pollutants and solutes through vegetated channels which can assist in treating storm water drainage. Thus, connecting bioswales might be designed for water removal from an area before depth accumulates to dangerous levels while potentially providing or assisting with providing adequate filtration for the ultimate end uses of the transported water. There are currently no bioswales in Dania Beach, so this action could be aligned with community sustainability objectives from the outset of the development stages to implementation.

**Figure 3.4** Aerial view of a bioswale integrated into a neighborhood park and farmers' market (Fondy Park in Milwaukee, WI) (Photo credit: Tim McCollow).

### *3.5.3 Infrastructure: Knee Walls*

Constructing and maintaining knee walls was chosen for protecting property values, preventing flood-related injuries and economic impacts on the business community. A means objective of targeting two-foot SLR with the constructed knee walls was discussed at the workshop. Knee walls refer to outdoor concrete walls that are close to three feet in height, run parallel to the coastline and the beach, and are designed to prevent overtopping and downstream inundation (Fig. 3.5). They would be set up as structure behind the beach to provide additional protection from storm-related surges. They can be out in the open or embedded in sand dunes. Their construction must be optimized and coordinated with other management actions to prevent additional damage to property from large storms and hurricanes. Their presence would provide an additional line of protection from waves and storm surge reaching roads and nearby properties and augment the function of existing dunes in preventing surge and wave damage from storms. Knee walls have already been utilized to address future problems with storms and flooding. State Road A1A in Broward County had a three-foot knee wall added for storm surge protection after severe damage occurred from waves generated by the storm system Sandy (2012). Some additional benefits of "hard infrastructure" such as knee walls and seawalls are that they can be built from simple construction materials and they are easy to fix but they can lead to the loss of intertidal habitats and may not be sustainable for protecting coastal areas in the long term (USEPA 2009).

**Figure 3.5** Knee wall alongside a coastal road in Broward County (Credit: City of Fort Lauderdale)

### 3.5.4 Infrastructure: Raise Roads

Raising road heights would have an indirect impact on property values and prevent negative economic impacts from flooding on the business community. It could also prevent flood-related injuries by keeping roads accessible during evacuations. A means objective of targeting two-foot SLR when raising roads was identified. Although initially a fundamental objective, *Minimizing traffic hassles* related to flooding was decided to be a more useful means objective for the tourism economy. Workshop participants discussed how traffic hassles would be minimized by better road infrastructure. Regions that experience periodic inundations can maintain transportation access and promote greater safety and lead time for automobiles in evacuation situations. Several major roads owned by the city were found to be vulnerable under two-foot sea-level rise scenarios developed by the Unified Southeast Florida Sea Level Rise Projection (Broward County 2011). Road elevation also requires coordination with elevation of buildings to prevent greater inundation (Bloetscher et al. 2016). Along with raising roads, maintaining and developing the road system was identified to benefit the tourism economy. This might also include preventing road blockage from flooding events (Fig. 3.6).

**Figure 3.6** Road flooding in Fort Lauderdale (Credit: Dave/Flickr Creative Commons/CC BY 2.0)

### 3.5.5 Infrastructure: Seawalls

Constructing and maintaining seawalls could have beneficial impacts on property values by preventing temporary or permanent inundation. They could also prevent flood-related injuries and flooding economic impacts on the business community. A means objective of targeting two-foot SLR with the constructed seawalls was discussed at the workshop. Seawall construction and improvements would provide barriers for preventing the inundation of areas of concern along tidally influenced waterways (Fig. 3.7). Seawalls are barriers that prevent the sea from entering dry zones during high tides and/or strong wave activity. Seawalls can be owned by the government or by private interests such as landowners. For the latter, maintaining or building seawalls can affect interests beyond the owners of the property that the seawall is designed to protect. A coordinated plan may be important for alternatives that consider seawalls especially because they can lead to greater erosion in nearby areas without sea walls or in front of the wall itself.

**Figure 3.7** Seawall renovations at Dania Beach Marina (Photo credit: The City of Dania Beach)

### *3.5.6 Infrastructure: Agile Water Supply/ Response: Mobile Solar Power*

The objective related to handling interruptions in water and electricity had several actions constructed to address the need for preventing delays and fostering greater responsiveness. An agile water supply might refer to processes that increase controllability for water distribution, both temporally and spatially. A major portion of water movement management in Broward County is through distribution canals and pumping systems that serve several objectives including flood control and ameliorating and preventing drought impacts via aquifer recharge from canals (Broward County 2009). An Integrated Water Resource Plan was developed by the county to help better manage the interconnected canals and alternate water sources for ensuring water supply availability (Broward County 2009). Likewise, mobile solar power units would deliver energy to pump stations and flood gates that lost connection with the main power grid of the city due to hurricanes or other disaster-related damages. A means objective related to off the grid utilities was identified at the workshop that might be achieved by the development and implementation of a mobile solar power option. Their mobility would target power losses in affected areas until the main source is repaired. Mobile power sources are commercially in use and have been developed for specific public requirements, such as military base camp needs (Fig. 3.8). Candidate options for mobile power sources can be compared as to their capabilities for meeting the needs of the population potentially impacted by different power interruption scenarios.

**Figure 3.8** REDUCE mobile solar panels developed for generating electrical power at forward U.S. Army base camps (Credit: U.S. Army photo)

### 3.5.7 Federal Grants/ Funding

Federal grants such as EPA's Water Infrastructure and Resilience Finance Center https://www.epa.gov/waterfinancecenter might be available to help achieve objectives related to sustainability. An associated means objective of maximizing outside funding sources was identified as something important to consider when developing options for the fundamental objective of minimizing costs to Dania Beach. Receiving these grants will lower cost constraints on developing and implementing new projects and programs including ones related to SLR adaptation and mitigation. The future availability of grants would influence capabilities for covering costs of implementing new actions. State grants would also help with water infrastructure projects. Outside of federal grants, the Florida Department of Environmental Protection distributes hundreds of millions of dollars annually to local governments for water resource protection purposes and additional opportunities might be available from other state and county agencies and programs (BCBCC 2015).

### 3.5.8 Zoning: Finished Floor Elevation

Participants suggested finished floor elevation changes to enhance property values and water supply availability. A means objective of targeting two-foot SLR with finished floor elevations was discussed at the workshop. Protecting private property from flooding would ensure longevity and safety which would raise the value of property. Moreover, flooding insurance rates might be reduced for buildings that are a specified height above base flood elevation (Fig. 3.9). Finished floor elevation changes would raise the habitable height of property and prevent interior flooding of residences, and commercial centers. The action could pertain to both existing structures and structures not yet built. Ranges for different structures and locations might be identified and examined for this action. At the extreme, finished floor elevations could be raised multiple stories above existing levels. Broward County has minimum finished floor elevation requirements for new building construction based on the location of the building and the flooding threat as shown in the 100-year Community Flood Map.

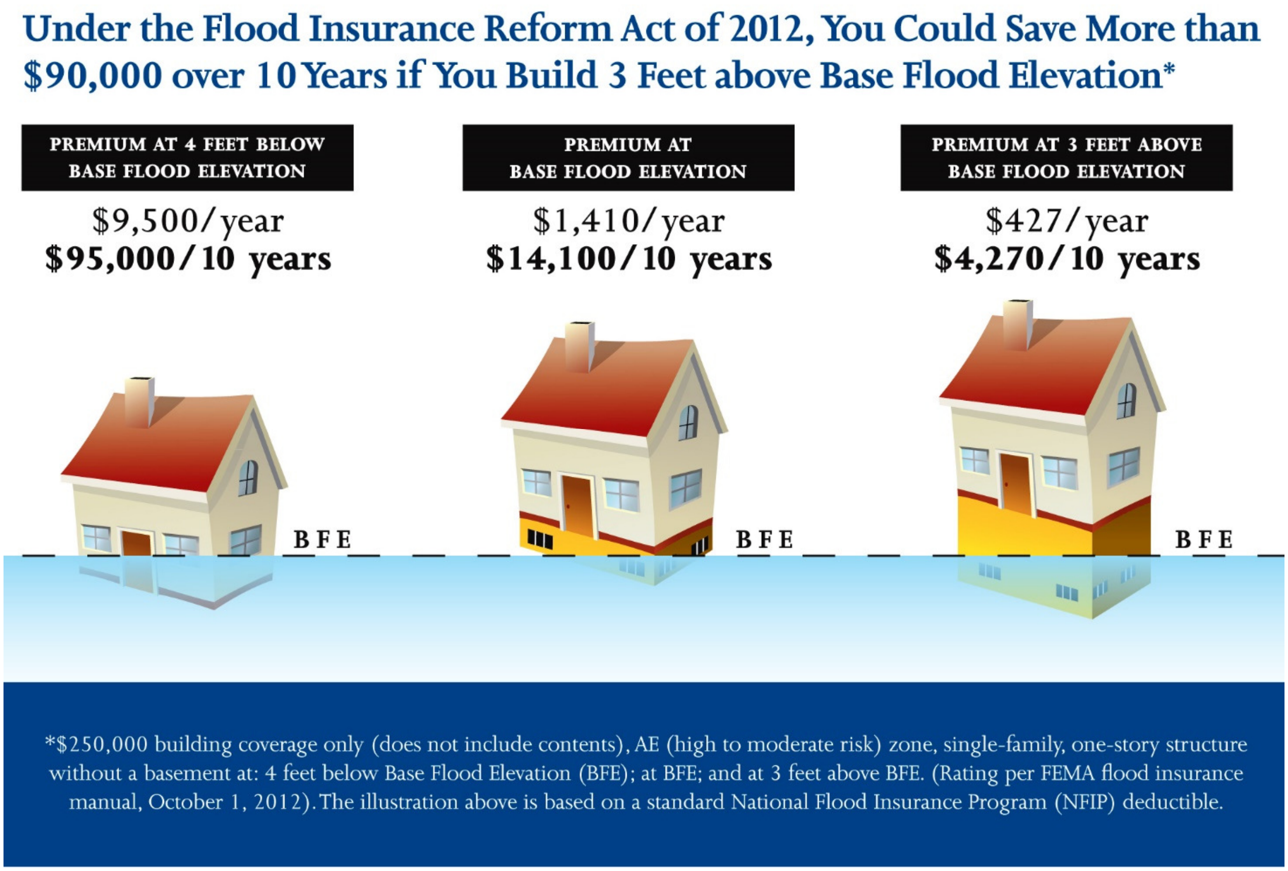



**Figure 3.9** FEMA notification that their flood insurance is reduced for buildings with finished floor elevations higher than the base flood elevation (Courtesy of FEMA).

### 3.5.9 Nature: Re-nourish and Build Dunes/Education: Dunes/ Infrastructure: Beach Nourishment

Enhancing dunes and educating visitors and residents about the importance of protecting dunes could also raise property values and protect properties from flood damage. The means objective of targeting two-foot SLR was attached by workshop participants to options related to dunes. Dunes protect beaches from erosion while helping to decrease the intensity of waves from offshore storms. As a natural line of protection, dunes and dune-related vegetation could assist with other engineered solutions in preventing tidal flooding incidents (Fig. 3.10). The tourism economy might also benefit from beach nourishment to maintain regions that attract visitors. Dunes could help facilitate this by stabilizing the beach substrate as well as providing habitat for valued wildlife on the beach. A means objective related to maximizing beaches was identified at the workshop that was associated with the beach nourishment option and a fundamental objective related to the tourism economy.

**Figure 3.10** Dunes in Blowing Rocks Preserve (Hobe Sound, FL) (Credit: U.S. Geological Survey, Department of the Interior/USGS)

### 3.5.10 Infrastructure: Green Surface Water Storage/ Adaptation Action Areas Funding:

Green surface water storage was identified to enhance the water supply and improve tourism benefits. A means objective of minimizing beach pollution was identified at the workshop as being directly impacted by green surface water storage's filtration capabilities. Green surface water storage could prevent contaminated water from reaching beach zones through natural filtration abilities. One potential way of developing green surface water storage is through the construction of wetlands (Fig. 3.11). During the wet season, surface water storage areas can capture rain and supply water during the dry season. Water is a limiting step in accommodating residential and commercial development and maintenance in an area. Ensuring water availability would be a necessity for growing a tourism economy. Green surface water storage areas can also be constructed in a manner that enhances aesthetics and attract visitors and residents. Examining possible scenarios for green surface water storage in Dania Beach could help with defining actions and the potential identification of new objectives.

**Figure 3.11** Dixie Ranch north of Lake Okeechobee is used for water storage to support the Everglades restoration (Photo credit: South Florida Water Management District)

### 3.5.11 Adaption Action Areas

For protecting water supplies, adaptation action areas (AAAs) were chosen as a management action. The AAA concept was initiated at the state level and Fort Lauderdale (Broward County) was one of the first communities to implement AAAs for addressing SLR (Fig. 3.12) (SFRPC 2013). Fort Lauderdale currently has 16 AAAs and 40 funded AAA projects to address flooding issues (City of Fort Lauderdale 2016). Adaptation in these contexts pertains to developing barriers (protection), improving stormwater and elevation (accommodation), rezoning or moving areas at risk (managed retreat), and constraining future development in high risk areas (avoid). Deciding where these actions could be optimally applied is part of the AAA designation process and AAAs must meet certain criteria for designation and funding prioritization. The AAAs in Fort Lauderdale were chosen with stakeholder and technical input on the vulnerability of present and future assets and the strategies for addressing SLR impacts. Strategies in the AAA toolbox include incentives, building codes, impact fees, conservation easements, real estate disclosures, outreach campaigns, and land trust establishment.

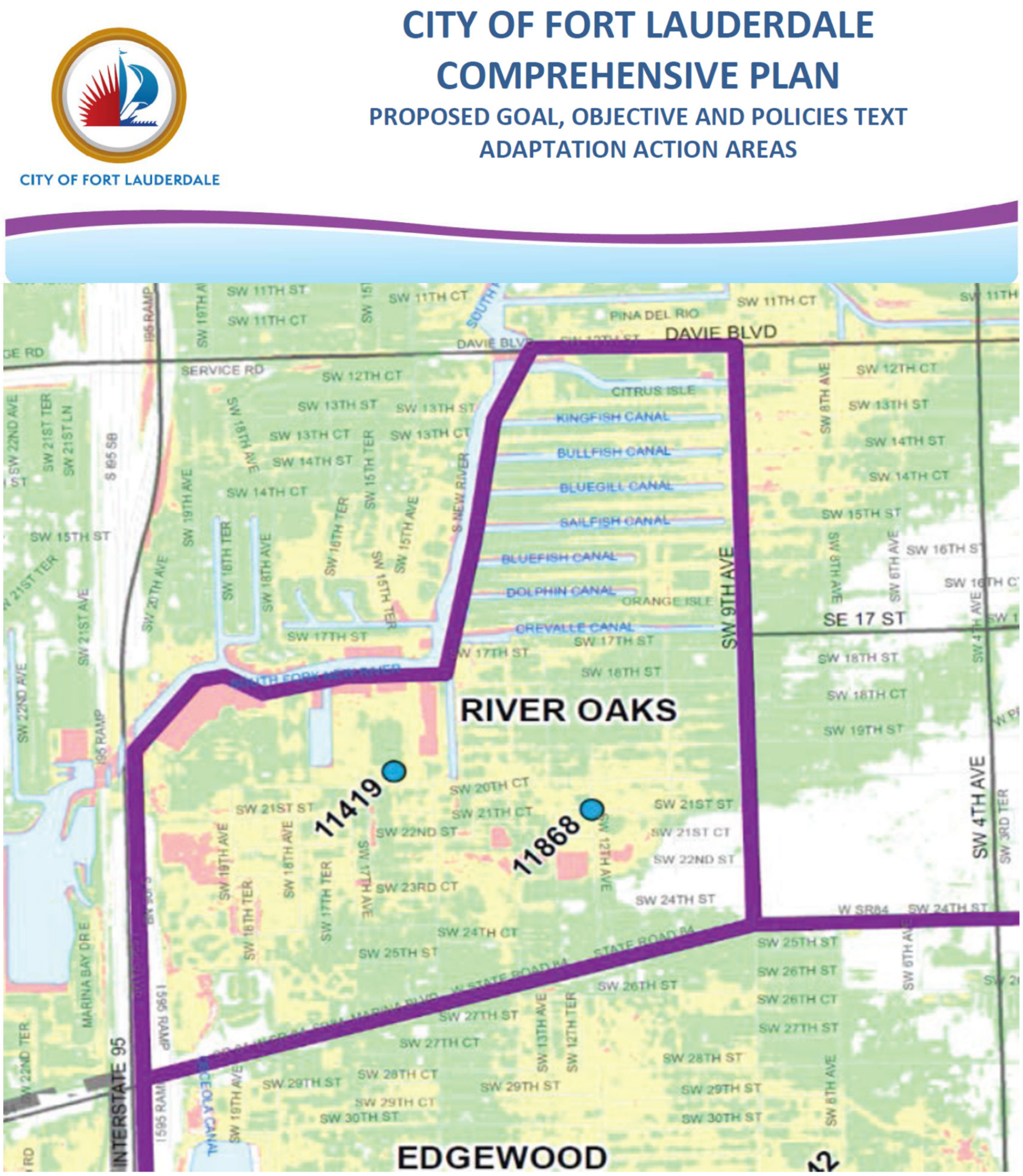



**Figure 3.12** Since 2015, Fort Lauderdale has been using AAA project designations to focus resilience projects that prevent coastal flooding. The map above delineates the River Oaks AAA and two projects within River Oaks (a stormwater park (11419) and a stormwater neighborhood and preserve park (11868)) (Figure from City of Fort Lauderdale, 2016).

### *3.5.12 Infrastructure: Reclaimed Water Produced*

Reclaimed water actions were identified for water supply and tourism economic impacts and have been in consideration by southeast Florida for ensuring the availability of future water supplies (RCAP, 2017). The City of Miramar in Broward has a reclamation facility that uses treated water for irrigating landscapes (e.g., golf courses, public green spaces) (Fig. 3.13). Broward County undertook a feasibility study that examined alternatives for expanding reclaimed water processing and usage for recharge and/or irrigation purposes (Broward County 2009). Dania Beach would currently require partnering with a neighboring community, such as nearby Hollywood, as no reclaimed water facilities exist in the city now although a feasibility study of reclaimed water production options was considered (City of Dania Beach 2014). From workshop discussions, a means objective of minimizing beach pollution was associated with the reclaimed water option and the fundamental objective related to tourism economic impact.


**Figure 3.13** Reclamation facility in Miramar that treats waste water and uses treated water for irrigation (left photo). The entrance fountain to the facility uses reclaimed water (right photo) (Photos' credit: City of Miramar, Florida | www.MiramarFL.gov)

### *3.5.13 Infrastructure: Septic Connection*

Minimizing sewage and excess nutrient runoff could prevent water quality issues from harmful algal blooms and sewage from impacting the desirability of the beach. Connecting septic systems was discussed as important to maintain and enhance beach life and the tourism economy (both fundamental objectives) by minimizing beach pollution (a means objective). This action could refer to connecting to safer and more effective disposal sites or to sanitary sewers. Well-maintained septic systems can be effective, low-impact ways of cleaning household wastewater (Fig. 3.14) (USEPA 2006). Poorly maintained, malfunctioning systems and drainage field failures can release nutrients and pathogens to human drinking/ecological use water systems (USEPA 2006). For example, on site disposal too close to irrigation wells can facilitate the dispersal of contaminated water on lawns and runoff (Rojas 2012). Establishing a wastewater treatment connection might mitigate impacts from septic systems if they are problematic. A recent report from Miami-Dade County found that SLR is threatening existing septic tanks in some areas and this is likely to worsen in the future as groundwater levels rise (Miami-Dade 2018). Dania Beach provides guidance and inspections for septic to sewer conversions. In addition, centralized sewage treatment capabilities have been expanding in Broward County which will provide additional sewer waste disposal conversions in the future (BCBCC 2013). The Florida Department of Health in Broward County oversees permitting for septic systems and inspections (BCBCC 2015). The County grants exemptions for not connecting to sewers such as for homes located where no sewer mains are available, for rural dwellers, or in cases where it would be unjust or unreasonable (Broward County, n.d.).

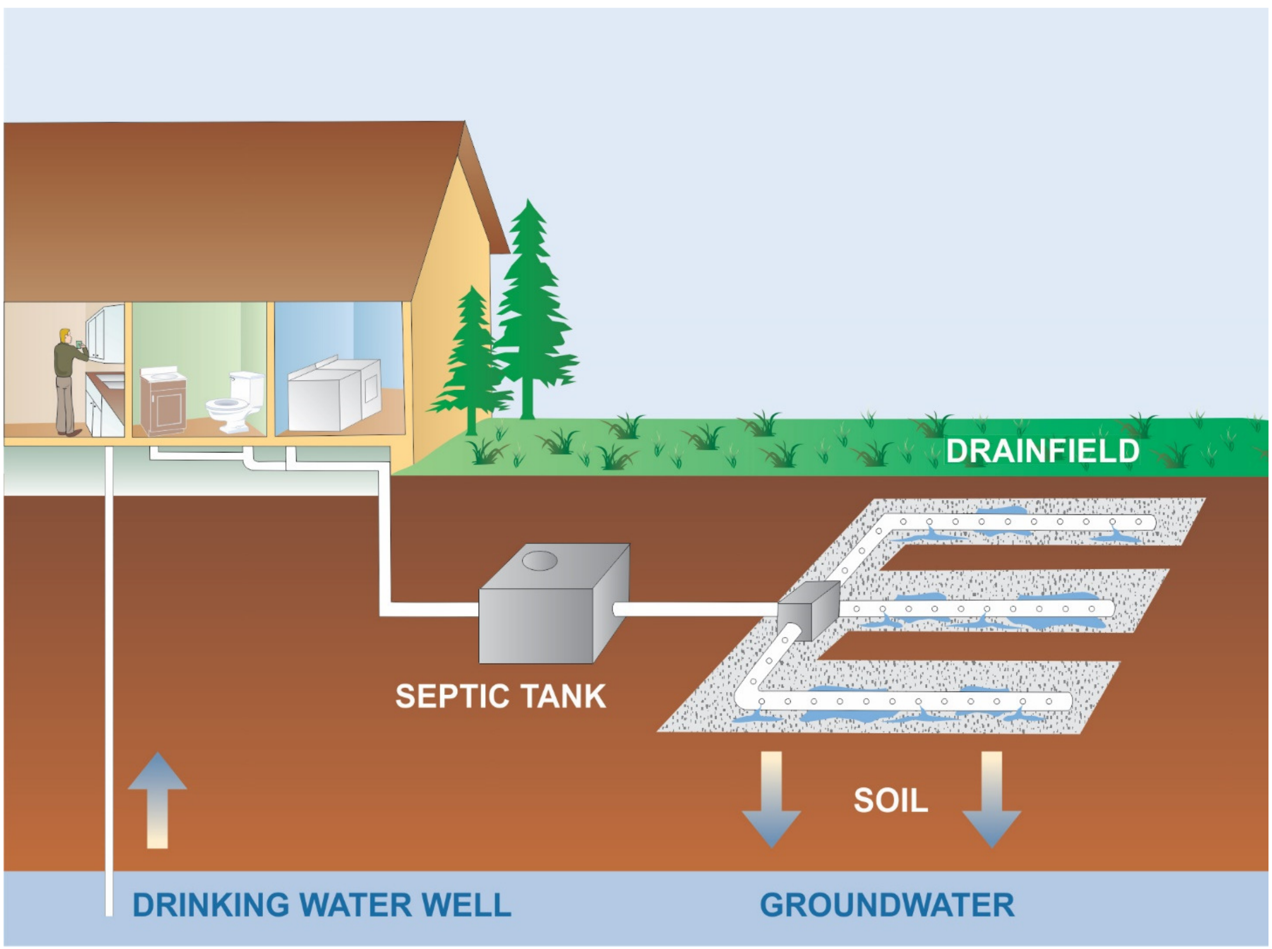



**Figure 3.14** Schematic of a residential septic system (Credit: Snohomish County, WA)

### *3.5.14 Nature: Breeding Ground Protection*

Breeding ground protection was also used for protecting fisheries. Recreational fishing is supported by the City of Dania Beach at locations like the Dania Beach Fishing Pier (Fig. 3.15). Protection of fishes would likely require coordination with state and federal agencies. For example, protecting fishing grounds would be something the fisheries management councils and Florida Department of Environmental Protection could assist with through programs like the essential fish habitat or Florida Aquatic Preserves. For addressing fish population health, the Florida Department of Environmental Protection has authorities for permitting land development that could affect marine fisheries in the state (City of Dania Beach 2009b) and currently is working with Broward County to monitor fish populations (fisheries-independent monitoring) in their Southeast Florida Fisheries-Independent Monitoring Program. Broward County also oversees offshore artificial reef and habitat enhancement programs (BCBCC 2015) and is working to monitor water quality in offshore reef areas (BCBCC 2013).

**Figure 3.15** Fishing from the Dania Beach pier (Credit: The City of Dania Beach)

### 3.5.15 Nature: Mangrove Protection

To improve mangrove communities, the proposed action is focused on protective measures. Protection could also extend to areas where mangroves could potentially move as sea levels change. Mangroves would fall under wetlands which have some federal protections. Permitting for removing or killing mangroves can require approval from county, state, and/or federal agencies. The U.S. Army Corps of Engineers and the Environmental Protection Agency require permitting for coastal development projects that could impact mangroves by excavation or dumping under the 404 program. About 1,500 acres of mangrove ecosystem in West Lake Park are protected by Broward County and include areas shared by Dania Beach and Hollywood (Fig. 3.16) (Broward County n.d.) Cities can also have permit requirements for removing mangroves. In areas with high flooding potential, Dania Beach currently requires a certification from a licensed engineer to implement mangrove alterations and proof that the alterations will not create “potential for flood damage” (Ord. No. 2014-007, §2, 6-24-14). Dania Beach contains mangroves in the eastern region, between the barrier island beach zone and the urban zone, that are currently regarded by the city as stressed but protected by federal, state, and county permitting requirements (City of Dania Beach 2014).

**Figure 3.16** Red mangroves at West Lake Park (Credit: U.S. Geological Survey, Department of the Interior/USGS)

### 3.5.16 Additional Actions

Implementing a value-focused approach to generating alternatives can help identify potentially important actions that might otherwise not be considered and ensure that actions important to experts and stakeholders receive equitable consideration. Along with stakeholder workshops, actions can be identified by speaking with experts and decision makers that faced similar contexts in other regions or time periods. This is exemplified with the Southeast Florida Resilient Redesign workshop process, an allied working group that developed strategies from working groups composed of experts from the Netherlands and the South Florida regions. This workshop was initially convened in 2014 but a second follow-up workshop was scheduled in 2015, and a third in 2016. The study areas that were focused on for strategy development in 2014 were East Dania Beach Boulevard., Alton Road South Beach, and West Dade. The 2014 workshop lead to planning coordination between Dania Beach and Broward County and the workshop that this report describes. Key West, Hollywood and Delray Beach were chosen in 2015 and Lower Matecumbe Key, Shorecrest, and Arch Creek in 2016. These areas are characterized by their potential for flooding and property damage while representing several distinct settings (e.g., urban, suburban) and locations throughout the South Florida region. For Dania Beach, the identified strategies included development of mixed-use green infrastructure such as parking garages within dunes, improving interconnectivity to improve nature, economic benefits and social capabilities, polders for active flood control in low lying regions, and building commercial zones on high elevation areas (coastal ridge). More information can be found in the presentations from Dania Beach case study seminar, available at: [http://rcap.southeastfloridaclimatecompact.org/case-studies/resilient-redesign-dania-beach](http://rcap.southeastfloridaclimatecompact.org/case-studies/resilient-redesign-dania-beach)

## 3.6 Consequence Modeling and Data Sources

Modeling consequences for a decision problem provides quantifiable predictions on the impact of implementing different alternatives (collections of management actions or options). In this section, we discuss the results of a half-day consequence assessment workshop (Workshop 2) that was conducted to understand and deliberate on the utilization of information sources available for quantifying the impacts of Workshop 1 management actions on measures. Consequence modeling tools such as Bayesian networks can accommodate the qualitative and quantitative information needed for both the factual side of decision making and the values side of decision making. The consequence assessment workshop focused on making the link between the qualitative sources of knowledge needed for examining the quantitative impacts of the decisions on the measures (and by extension the objectives).

During the consequence assessment workshop, conceptual models were built that connect the identified management actions to the performance measures (Fig. 3.2). These connections were mediated by the mathematical models or data that were recommended for predicting the impact of management actions on the performance measures (Fig. 3.17). The models for quantifying the functional relationships were recommended based on the knowledge and expertise of the workshop participants. Several models were identified that connected multiple actions to multiple measures. Some of the models were general quantitative concepts (e.g., hydrodynamic model, inundation model, erosion model) where more specific models could be identified or developed to meet assumptions for the management scenarios. Other models were specific modeling tools that included government curated and commercial model products. In practice, a model of this complexity would not be used for calculation. Specific sub-models would be developed and run for a select group of measures with the results linked to the larger model for further integrated analysis as necessary. The benefit of this exercise is to create pathway to use all the data, modeling, and technical resources necessary to answer stakeholder concerns, and to communicate to stakeholders how much is feasible given time and funding resources.

Most connections between management actions and measures were discussed in the workshop and at least one useful model or potential data source was identified for predicting the relationship. For these cases, the relationships between actions and measures were causally linked by nodes specifying the data and model needs. However, some of the relationships between the actions and measures did not have an identified data source or model for characterizing the relationship. For these relationships, a direct arc tied the management action and the measures. This was the case for septic connection and beach closures due to water quality violations, road development and hotel occupancy ("heads in beds"), funding and management costs (project costs and maintenance costs), loans and low-income housing, mobile solar power and user days without water or electricity. As mentioned in the management actions section of the report, the performance measure for heat-related hospital visits did not have an attached action. Also, the land use planning action was not attached to any of the measures. Future workshops can cover these data gaps if needed for research or management decision making purposes.

Existing models, data, and results available for use at the time of the workshop (Table 3.5) were considered for inclusion and several were captured in the DASEES consequence network (Fig. 3.17) and are briefly discussed below. The graphical approach (influence diagram) layout helped capture multiple sources of information and expertise for consequence estimation. Additional steps might examine how some of the chosen options could influence the non-targeted objectives/measures (i.e., unintended consequences) and new objectives that might be important to consider from action implementation.

### 3.6.1 Variable Density Model

A variable density model was suggested for predicting impacts on potable water availability and saltwater intrusion from agile water supply and reclaimed water production actions. The variable density model would also be used to process SLR output and monitoring data on well pumping and precipitation for assessing impacts on saltwater intrusion and water availability. A variable density model is used as changes in salinity affect the density and resulting behavior of ground and surface water or cause it to vary. This type of model was endorsed for analyzing risks to water supplies and infrastructure by the Regional Climate Action Plan group (RCAP, 2017). Variable density model results have been obtained for groundwater stage and saltwater intrusion across Broward County. A phased process was used for examining saltwater intrusion scenarios at different coastal regions of Broward County (northeastern, central, and south) and results were incorporated into an integrated water model for the entire county (Broward County 2009). Changes in salinity levels at 16% of the water supply and 41% of the wells in the county were found to have the potential to occur due to future SLR. The variable density model was recently run to test several infrastructure mitigation action scenarios (establishing recharge wells, moving established structures) (Hughes et al. 2016). Results from the model predicted the potential risks for westward increase in groundwater salinity levels as sea levels rise. Mitigation benefits were estimated to be spatially confined to adjacent regions to the action areas (Hughes et al. 2016). Uncertainties and knowledge gaps were also identified for future iterations (Hughes et al. 2016).

### 3.6.2 IWRP Groundwater Regional Monitoring Network

A monitoring network was suggested to gather information on saltwater intrusion and indirectly on potable water availability (through the variable density model). The USGS and partners in the state and county maintain groundwater monitoring wells throughout South Florida with decades of historical data for some sites (Bloetscher et al. 2016). Since the 1980s, Broward County's Water Resources Assessment Program has been tracking chloride levels in groundwater to assess saltwater encroachment on freshwater supplies (BCBCC 2015). The influence of groundwater fluctuations, tides and precipitation on changes in salinity has been analyzed and tracked for regions with useful data (Broward County 2009). Broward County, along with Miami, was recognized by Prinos (2016) for having one of the more advanced and useful saltwater intrusion monitoring systems.

**Table 3.5** Summary of Modeling Scenario Results and Data collected by Broward County available for use to assess and evaluate stakeholder identified management actions for Dania Beach (2016).

| Type of Model/ Dataset | Output | Findings | Spatial Extent | Temporal Scale | Study Name |
|---|---|---|---|---|---|
| Groundwater | Groundwater Level Elevations; salinity as sea level rises and rainfall patterns change | Moving control structure inland has only local impact on saltwater intrusion. SLR increases rate of intrusion. 41% of coastal wells will be contaminated or 16% of total County supply. | Countywide (two model grids) | historic- 2100 | Variable Density Models |
| Groundwater Monitoring | Water level; salinity | Position of saltwater interface (<6.6 miles inland from coast) | Region-wide | 1980-2016 | IWRP- Groundwater Regional Monitoring |
| Groundwater | Water availability as population increases; effects of offset strategies | 10-year Water Supply Plan, Water Reuse Master Plan | Countywide | 2015- 2025 | IWRP- Water Mgmt Master Plan |
| Aquifer geology | substrate by depth | Porosity varies. | Countywide | 2012- 2015 | IWRP- Floridan Aquifer Geotec |
| Surface Water | Flood elevations, canal elevations under storm and SLR scenarios | Groundwater rises at same rate as sea level in coastal areas. Pump stations will have to run more frequently. | 2 neighborhoods in Fort Lauderdale | 2015, 2030, 2060 | Stormwater/ Climate Inundation Study |
| Surface Water | Volume of C-51 reservoir | Productive adaptation scenario for surface water storage. | 2200 acres in Palm Beach County | Not constructed | Regional Reservoir Feasibility |
| Surface Water | 3D rendering of flooding in neighborhoods | Inland communities will require evacuation/ emergency response assistance; homes flood under certain storm scenarios | 2 neighborhoods in Fort Lauderdale | 2015, 2030, 2060 | NEMAC Flood Visualization |

| Type of Model/ Dataset | Output | Findings | Spatial Extent | Temporal Scale | Study Name |
|---|---|---|---|---|---|
| Infrastructure-Transportation | Elevations of existing county roads/ bridges; rankings of vulnerable road segments under storm, surge and SLR scenarios | Highlighted vulnerable evacuation routes | Broward, Miami-Dade, Palm Beach | 2015- 2080 | MPO/ FHWA Climate Study |
| Infrastructure-Flood Control | Elevations of seawalls and coastal structures; vulnerable seawall segments; water levels under storm surge, SLR and tidal scenarios | Regional resilience standard recommendation of top elevation of 5 feet NAVD | Intracoastal and Nearshore | Storm period | USACE Flood Risk Study |
| Rainfall | Rainfall Scenarios | 10% increase; 2-20% decrease; seasonal change | Region-wide | 2000-2100 | Downscaled Global Climate Model Data |
| Surface Water | Base flood elevations | | County-wide | 2015 | FEMA flood maps |
| Infrastructure-Buildings | Damage costs of SLR, tidal flooding, and storm surge scenarios | Benefit-cost ratio of elevating and flood-proofing is between 11 and 31; BC of relocation is <0.6 | Coastal Areas of Dania Beach, Hollywood, and Fort Lauderdale | 2015-2065 | Metropole Coast Model |
| Infrastructure-Natural systems | Density of urban canopy, habitat, food deserts, dune vegetation, parks and green space by City | Dania Beach: Food Deserts 30-51%; >85% within ½ mile of park; <10 habitats per square mile; Sea turtle lighting intensity <-8 GiZ; Tree Canopy: 20-39%; Dune Vegetation >80%; Water Reuse <9% | County-wide | 2015 | Green Infrastructure Maps |
| Infrastructure-Transportation | Limits of surge by hurricane category; vulnerable evacuation routes | Dania Beach Blvd and Sheridan St are vulnerable. East of Federal Hwy is vulnerable to surge flooding. | Region-wide | Storm period | SLOSH modeling, hazard areas and Evacuation Maps |
| Infrastructure-Natural systems | Environmental indicators | Climate and population pressures are increasing. Air, water and marine environments are healthy. | County-wide | 1990-2014 | Environmental Benchmarks |

| Type of Model/ Dataset | Output | Findings | Spatial Extent | Temporal Scale | Study Name |
|---|---|---|---|---|---|
| Infrastructure-Natural systems | Beach widths, erosion rates | Critical erosion areas need nourishment. | County-wide | 2015 | Beach Management Plan |

*This table was provided at the 2nd workshop by Samantha Danchuk, Ph.D., P.E., Assistant Director for Broward County's Environmental Protection and Growth Management Department.

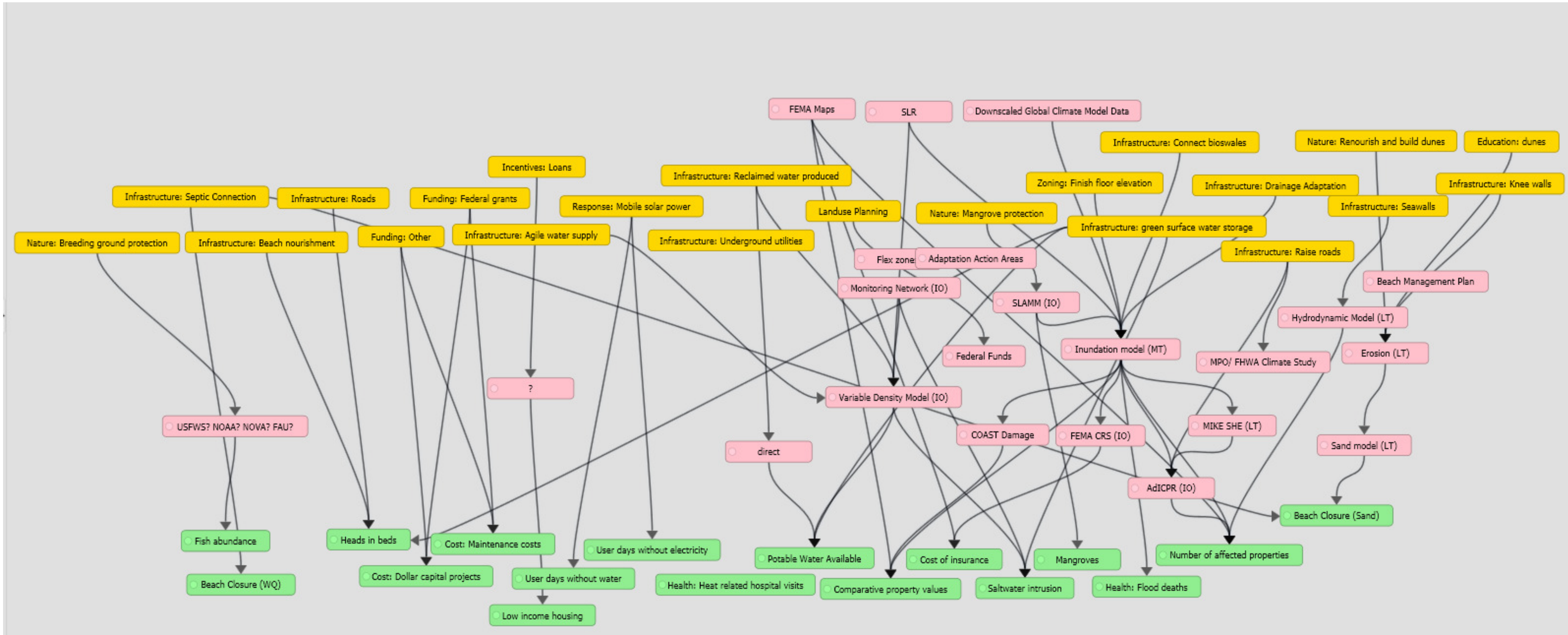



**Figure 3.17** Influence diagram constructed at the consequences workshop. Yellow nodes are management actions. Green nodes are performance measures for the fundamental objectives. Pink nodes are recommended models, data sources, or intermediate variables that connect the management actions to the performance measures.

### 3.6.3 Sand Model/ Erosion Model

A sand model was suggested for examining beach closure incidences. The sand model would process the output of an erosion model to examine scenarios that improve beach features through education and remediation. A sand model has currently not been developed for use by the county. For Santa Rosa island, the Sea Level Affecting Marshes Model (SLAMM) model was modified by Chu et al. (2014) to consider extreme storm event impacts on beach elevation with and without the availability of sand nourishment activities. Efforts such as sand bypassing at Port Everglades are currently being undertaken as the importance of reliable sources of sand gain in importance (Broward County 2013). An erosion model was also suggested for indirectly examining beach closures (through the sand model) from nourishing and building dunes, educating the public about the dunes, and building knee walls. Like the sand model, beach erosion is currently not being examined by the county in their modeling efforts though it has been identified as an important issue in Dania Beach. Recent storm events have indicated that visible erosion occurs when beaches lack resilient characteristics such as the presence of healthy dune systems (RCAP, 2017) Thus, it would be important to consider long term changes to the beach profile and event-based changes to the integrity of the beach from storms. An erosion model can couple these scenarios with management and nourishment actions to examine impacts on the integrity of the beach. The Beach and Marine Resources Section of Broward County oversees programs for the assessment and amelioration of erosion issues on beaches as well as assessing the impacts of erosion (Broward County 2015).

### 3.6.4 Inundation Model

An inundation model was suggested for predicting impacts on flood deaths, affected properties, cost of insurance (with FEMA CRS models), comparative property values (with the COAST damage model), and on number of affected properties (with the ICPR model). SLR and downscaled global climate model data would provide needed input data to the inundation model. Actions that would be used for scenarios in the inundation model would be finish floor elevation changes, bioswale development, and drainage adaptation. SLAMM output and mangrove protection scenarios would also be used by the inundation model. The U.S. Army Corps of Engineers is currently partnered with Broward County to examine the impacts of seawalls and other structures on flooding prevention in coastal regions. The USGS and Broward County also work together to develop inundation models for water supply impacts and flooding maps (Broward County 2015).

### 3.6.5 Hydrodynamic Model

A hydrodynamic model was suggested for predicting impacts on affected properties from seawall development and enhancement. The current applications of hydrodynamic modeling are focused on assessing the prevention of seawater inundation for at risk properties. Multiple surface water models have been used by the county including ones to assess flooding and storm and SLR impacts, surface water storage capabilities (C-51 reservoir), and household flooding under storm scenarios. Several federal agencies are currently developing hydrodynamic models for assessing flooding in South Florida. One example would be ADCIRC from FEMA which has been applied to predict tidal flooding or flooding from storm surge. A USACE flood modeling effort examined water levels given coastal structure elevations. NOAA also generated tidal field estimations for South Florida that are used to examine vulnerability for SLR (RCAP 2017).

### 3.6.6 SLAMM

The Sea Level Affecting Marshes Model (SLAMM) model was suggested for predicting mangrove impacts along with comparative property values, flood deaths, and affected properties. Though SLAMM is currently not in use for Broward County, it is a popular model for examining impacts of SLR on wetlands and mangroves that has found worldwide application. SLAMM has recently been used to examine SLR impacts on marshes, shoreline modifications and multiple natural land cover feature changes in New York State (Clough et al. 2016). For Dania Beach, the SLAMM model could be combined with estimates for SLR changes for predicting future erosion of mangroves. One benefit of using SLAMM is the capability it has for representing uncertainties in the parameters of the model and how the uncertainties can influence mangrove coverage predictions over time. This capability could allow useful transfer of the output from the SLAMM model to a Bayesian network that would combine the management predictions for mangroves with the output of predictive modeling for the other objectives for a comprehensive trade-off analysis.

### 3.6.7 COAST Damage

The COAST Damage model (Coastal Adaptation to Sea Level Rise Tool) was suggested for assessing comparative property values. Output from the inundation model would be fed to the COAST Damage model for expected real estate value loss predictions. Additional modeling may be necessary to translate this to estimates of property value changes for some properties such as ones in regions with uncertainties about inundation in future projections. The COAST model was used by Broward to examine storm surge plus SLR instigated property damages and estimated land losses from SLR. Output from the model provided map-based capabilities for viewing projected flood levels and economic damages and adaptation cost/benefit analyses. Scenarios run with COAST looked at elevation and flood proofing, relocation (voluntary) with and without buyouts for assessing potential and avoided damages and comparisons with status quo scenarios.

### 3.6.8 ICPR

The Interconnected Channel & Pond Routing model (ICPR) was suggested for indirectly assessing the number of affected properties from raising roads. A two-dimensional hydrologic framework is utilized in ICPR for both surface and groundwater coupling to allow assessments of SLR interactions with freshwater input, stormwater and irrigation management scenarios and groundwater in a region of concern. Output from the inundation model and MIKE SHE would be input to ICPR for these predictions. ICPR is in use by Broward County for surface water management purposes and was being adapted to include Dania Beach stormwater infrastructure inputs at the time of this workshop. The model has been adapted to previous infrastructure and road protection problems with flooding issues. The State of Florida Department of Transportation (FDOT) recommends applying ICPR for drainage assessments of Florida roadways (FDOT 2017).

### 3.6.9 MIKE SHE

MIKE SHE is a coupled surface and groundwater model that includes 1D, 2D, and 3D flow modeling functions. MIKE SHE was suggested for indirectly assessing the number of affected properties. Output from the inundation model would be used in MIKE SHE for predicting flooding on properties. MIKE SHE is in use by Broward County along with the SFWMD for examining hydrologic issues as part of the central, southern, and northern aquifer drainage assessments (Broward County 2009). In the Central Aquifer Drainage Assessment, several scenarios have been examined for comparison with baseline conditions using MIKE SHE including canal and lake water diversions for aquifer recharge purposes, ecological impacts of canal diversions, storage and recovery options for dry season water resource uses, and flooding prevention management (Broward County 2009). Hughes et al. (2016) discuss their use of MIKE SHE results from Broward County's applications for water management assessments and model building.

### 3.6.10 MPO/FHWA Climate Study

The MPO/FHWA Climate Study did not have a connection to the objectives but was discussed during the workshop as important for assessing the vulnerability of existing roads. The county uses output from this study to assess how road raising might assist in keeping open evacuation routes and protecting transportation infrastructure from flooding. The MPO is the Broward Metropolitan Planning Organization that examines transportation issues, including rush hour traffic and transportation efficiency, across the county of which Dania Beach is a participating member. The MPO collects data, develops and implements transportation plans for cities, and receives and distributes federal funding (USEPA 2015). The FHWA is the Federal Highway Administration that oversees transportation plans developed by the MPOs. The FHWA planning policy provisions for MPOs and state DOTs may help facilitate climate change considerations in transportation plans (FHWA 2008).

### 3.6.11 FEMA National Flood Insurance Program Community Rating System

The FEMA Community Rating System (CRS) was suggested for assessing cost of insurance. Output from the inundation model would also be fed to the FEMA CRS. Dania Beach currently participates in the CRS system, but its rating status has not changed since its entry in 1993 (class level 9). Participation requires applying to FEMA and annual recertification based on flood prevention implementation. Exceeding National Flood Insurance Program requirements provides additional insurance policy premium reductions through FEMA. The FEMA CRS provides these discounts to flood insurance based on a community's rating (1 to 9) which can be approved through compliance and implementing extra flood protection activities in the community. The Fort Lauderdale adaptation action area strategic plan (discussed in Section 3.5) has an objective of reducing flooding and adapting to SLR. By identifying and implementing adaptation action areas, a target was set to reduce (improve) the CRS rating two levels. The County itself also participates for communities in unincorporated areas and has achieved premium reductions in flood insurance for these regions (Broward County 2016). County residents have saved over a million dollars from maintaining the CRS and National Flood Insurance Program standing (BCBCC 2015).

### 3.6.12 FEMA Maps

The FEMA maps were suggested as useful inputs for comparative property values, cost of insurance, and number of affected properties. The FEMA flood hazard maps identify high, low, and moderate hazard areas based on the location in, near or outside of the Special Flood Hazard Area (i.e., 1% annual chance flood event, 100-year flood). These maps might be used as baseline current flooding conditions for comparison to future flooding scenarios with sea level and storm projections as well as improvements to infrastructure. They do not include future scenarios such as SLR impacts to coastal zone regions and land use changes. Properties that are subject to inundation based on different flood occurrences (e.g., 100-year, 500 year) can be examined with the usage of FEMA maps. The Dania Beach area has a high hazard of coastal flooding according to FEMA maps (City of Dania Beach 2009a). Earlier work across the county estimated that 73.4% of residents live in flood hazard zones and over 100,000 in areas at risk from storm surges (FDOCA 2006). FEMA maps can support seawall codes in a manner that reduces property damage from flooding by setting the maximum height lower than the finished floor elevation for residential structures (SAB 2016). The South Florida Regional Council implemented a critical facilities vulnerability analysis with FEMA Flood Maps and the Critical Facility Inventory maintained by the Florida Division of Emergency Management (SFRC 2010, 2016). They combined this with storm surge modeling (SLOSH model) to provide useful information on potential storm surge impacts that can be used by government agencies to design future options that prevent damage to facilities or evacuation issues (SFRC 2010, 2016).

### *3.6.13 Downscaled Global Climate Model Data*

A downscaled global climate model data set was suggested for indirectly assessing comparative property values, flood deaths, affected properties, and cost of insurance. Downscaling refines global scale data for application in regional decision making. These data are used for establishing rainfall scenarios including chances of increases or decreases in precipitation. Broward County is currently developing an Urban Runoff Package to model storm and tidal impacts on flooding with downscaled climate data and SLR projections (BCBCC 2015).

### *3.6.14 Sea Level Rise*

SLR predictions were suggested for inputs to the inundation model and the variable density model. SLR projections are utilized with groundwater, flood and canal elevations to determine impacts on roads, infrastructure, and public and private property. The Florida Department of Health has been working on SLR projections (using a bathtub model) for the BRACE project with the CDC. A modified bathtub method is also used by the Florida Institute for Health Innovation (FIHI) with LiDAR in their assessments of health impacts from climate change (FIHI 2016). The modified bathtub method takes into account groundwater levels along with elevation for assessing flooding due to SLR. Soil storage capacity is a major factor considered and higher groundwater levels lead to greater inundation.

# 4 Overview of Dania Beach Coastal Resilience Consequence Modeling Approaches

The focus of the work described thus far pertains mostly to the qualitative, problem structuring phases of SDM (DASEES Steps 1-3 establishing the linkages among context, objectives, measures, and options, i.e. decision sketching, with some preliminary planning for the more quantitative consequence assessment and evaluation work (DASEES Step 4)). The first steps of consequence modeling were started in Workshop 2 where technical experts began identifying data and modeling needed to more systematically develop the causal and conceptual linkages between actions and results initially developed by the stakeholders in Workshop 1 (Figs. 3.2 and 3.17). This chapter gives a brief overview of SDM consequence assessment tools in DASEES and their potential benefits for evaluating coastal community resilience and management decisions. The problem formulation phases of objective elicitation, performance measure identification, and defining options are necessary for ensuring that subsequent analytical work is applicable for the decision context. The tools that will be briefly reviewed here for assessing consequences with qualitative and quantitative output are the consequence table, influence diagram, and Bayesian network tools found in DASEES.

## 4.1 Consequence Tables in DASEES

Consequence tables (CTs) are an easily understandable way to communicate the potential outcomes of decisions and their impact on objectives to decision makers and stakeholders. In most contexts where uncertainty or environmental variability are important, CTs can still present results from the analyses and serve as a screening tool to eliminate dominated alternatives and objectives that do not differentiate among the alternatives, ensuring that limited time and other resources are used for more detailed analysis of better-quality solutions. In contexts where uncertainty is less important, output from deterministic models or straightforward measurement can be directly entered into the CT in DASEES.

The CT in DASEES can accept information for categorical as well as continuous variables. These inputs are translated from their initial measured value and units into a normalized score using a *value function* (Fig. 4.1) ranging from zero to one reflecting the relative preference for different levels of the actual measure which can be elicited from the stakeholders and decision makers. The shape of the value function reflects decision-maker risk tolerance and other constraints such as regulatory compliance. Working with the stakeholders to define that shape, provides opportunity to get group input on what it should be. This calculation is repeated for all measures associated with objectives. This normalization allows for all the results to be combined in DASEES for an overall multi-measure assessment of the alternatives as well as giving a common measure to compare alternatives against each other.

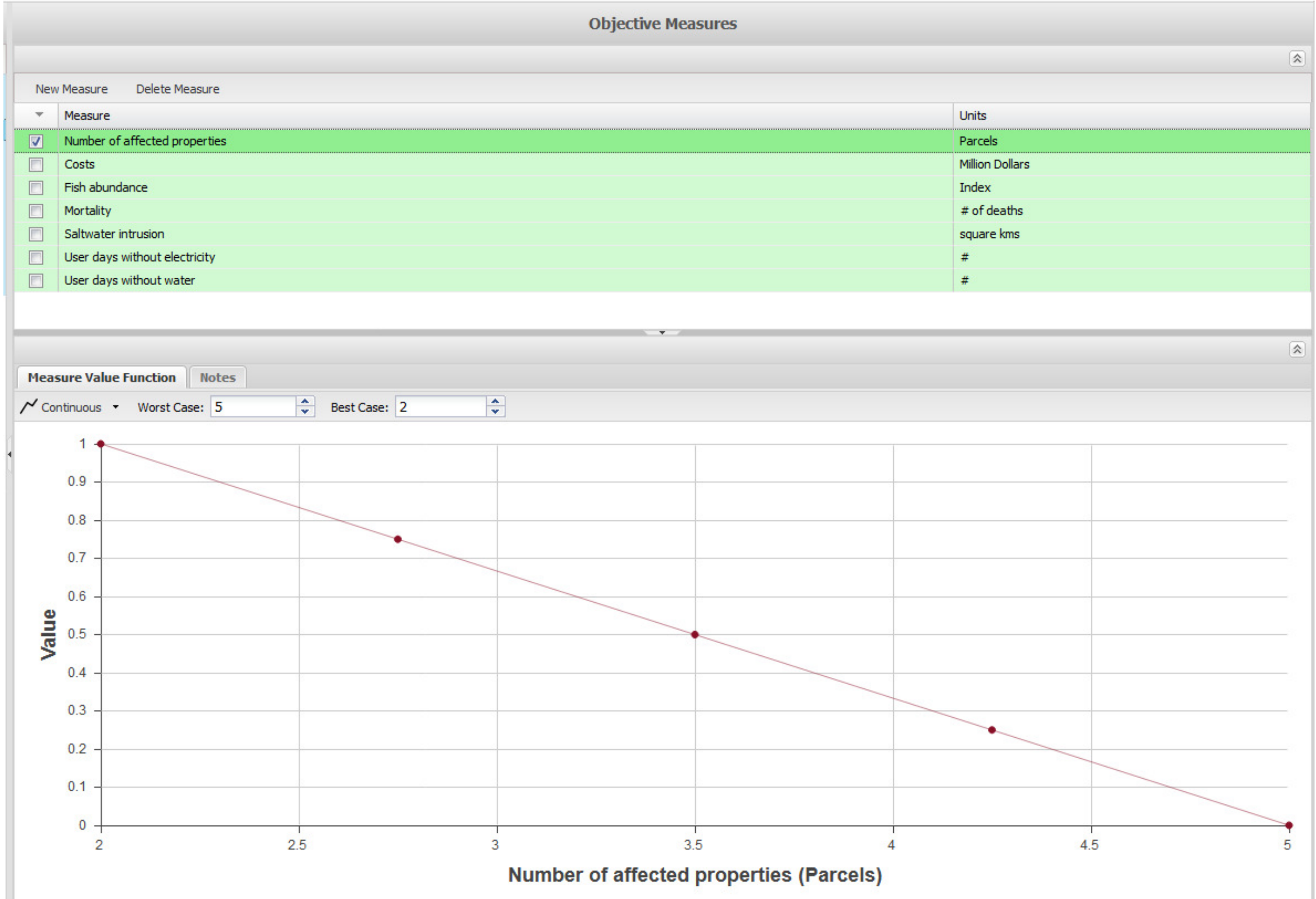



**Figure 4.1** Value function tool in DASEES Step 2 (lower right). For a given context, a possible best and worst case is defined, and value ascribed across that range. Stakeholder (hypothetical) preference indicates a normalized value of 1 (best case) for two affected property parcels and a value of 0 for the opposite extreme. The path between the two extremes is adjustable per stakeholder preference.

An example CT was constructed (Fig. 4.2) demonstrating the integration of facts (science, data) and values (stakeholder appraisal of science) for decision maker review. These illustrative example scenarios represent suites of actions to achieve coastal resilience via natural infrastructure (mangroves) or by coastal engineering (armor) approaches. For each of the measures and scenarios (combinations of implemented options) information was input in the CT. The measures were then transformed using the individual measure's value function and combined to give an overall bar length in the value graph that extends horizontally at the top of the screen. The highest value scenario is the *Status Quo* strategy. Thus, the *Status Quo* scenario's bar graph is the longest of the three. Likewise, the scenario with the lowest expected value is *Blended* (referring to a judicious blend of green and hard infrastructure options). *Status Quo* outperformed the other scenarios on costs and preventing electrical service interruptions but performed worse on fisheries than the *Natural* strategy or the same for all others in at least one of the other strategies. As demonstrated here, the CT in DASEES allows users to input each measure's estimated consequence and combine this with the valuation information to differentiate the decisions by their expected outcomes.

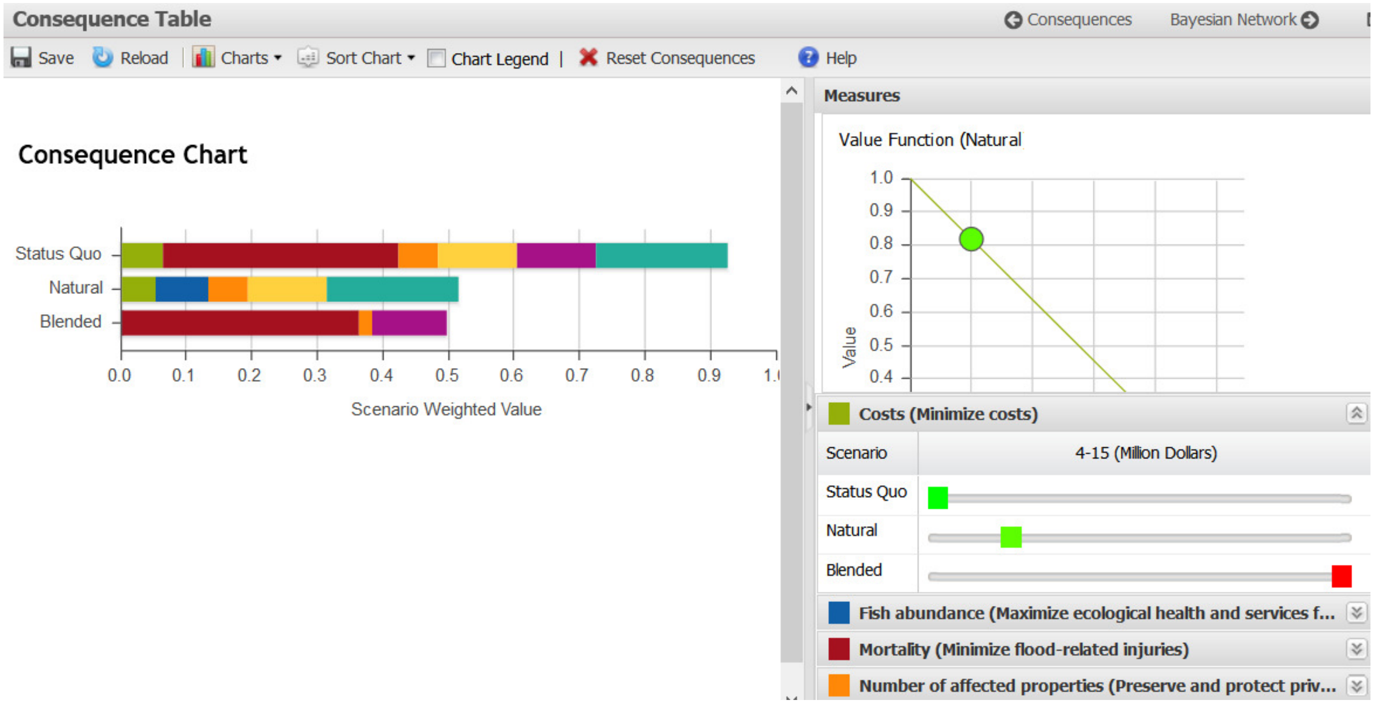



**Figure 4.2** Example (hypothetical) consequence table showing weighted values stacked for each of the scenarios (horizontal bar chart) for the Consequence Chart and information input for the measure mangrove areas for each scenario. The value function shows the graphed function for costs (in million dollars) and the green circle indicates a normalized value of 0.82 resulting from an estimated value of 6 million dollars for the Natural scenario.

Results summarily communicated in a CT such as in Fig. 4.2 are often based on a more causal understanding of how actions are expected to result in a desired outcome. A useful graphical way to represent that understanding is through influence diagrams.

## 4.2 Influence Diagrams

Influence diagrams are a type of conceptual model used to graphically represent causal relationships important to decisions and desired outputs and are useful for linking economic, environmental, and social aspects of a system (Gregory et al., 2012). Figure 3.17 (Section 3.6) shows an example of a preliminary influence diagram for Dania Beach. A hypothetical and more tractable influence diagram (Fig. 4.3) was created to highlight some of the potential cause and effect pathways from a subset of the stakeholder-generated options and performance measures.

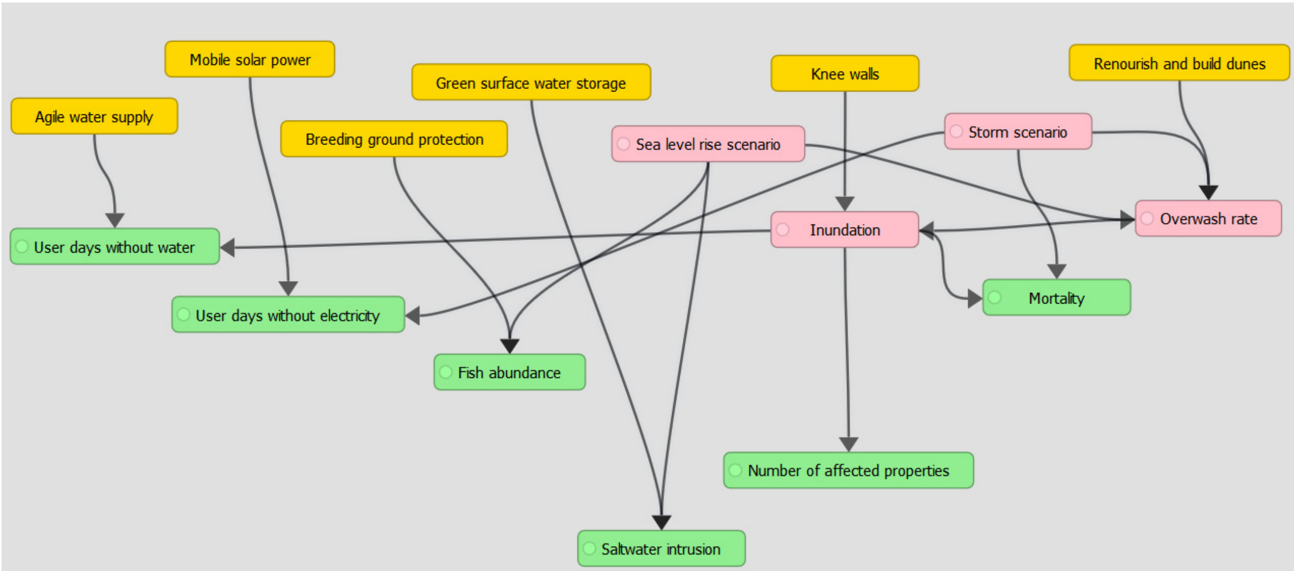



**Figure 4.3** Example of a coastal resilience influence diagram in DASEES. The diagram causally connects options (yellow node), performance measures (green nodes), and other system level components identified as necessary (pink nodes) to link the other two.

Deterministic modeling may be used to quantify these relationships and calculate potential consequences on the performance measures from proposed actions. This can impart a deeper understanding of the effect on system components from different options and can augment the communication process for how and why decisions were made. However, in problems where uncertainties are significant, deterministic modeling results may be insufficient for evaluating and communicating decisions.

Another analytical option available in DASEES which allows for the inclusion of variable data is the Bayesian network feature (Step 4). Structuring probabilistic models to represent the causal influence of decisions provides required depth for estimating the impacts of decisions on objectives. Causal influences can be represented by ensuring that cause to effect directionality is maintained when connecting arcs (arrows) between variables in the decision model. Thus, any parent node would be a hypothesized causal factor for a child node which would represent a hypothesized effect of the parent. DASEES initializes the structure of the network with cause-effect relationships between parent and child nodes (Fig. 4.4). The parent nodes are the options and the child nodes are the affected measures.

## 4.3 Bayesian Networks in DASEES

For predictive environmental assessments, uncertainties are often important to weigh and consider in a decision models (Pearl, 1988). Bayesian networks are an important tool for analyzing the uncertainty in decision models. For the environmental field, several useful examples of BNs can be found in the risk assessment work for polar bear populations (Armstrup et al. 2008), predicting water quality issues in coastal regions (Fernandes et al. 2012), fisheries recruitment (Shenton et al. 2011), effluents from wastewater treatment plants (Li et al. 2013), and nanoparticle risk predictions (Money et al. 2012).

Bayesian networks are probabilistic graphical models that include the key pieces of a problem and their relationship in the format of a directional graph. The influence diagram (Fig. 4.3) represents the graphical (qualitative) portion of the Bayesian network. The basic components of BNs are the variables themselves (called nodes when graphically represented), their connections (depicted as a directed arrow called an arc), and the probabilistic conditional and unconditional functions that underlie the relationships in a BN. The probabilistic relationship between nodes can be estimated via modeling output (e.g. deterministic), laboratory studies, literature results and/or field data collection. For data-poor scenarios, expert opinion can be utilized as the best available input to characterize the uncertainties of the relationships between the nodes.

In Step 4, DASEES creates a default influence diagram  from the information input in previous steps (Options- Step 3 and Measures -Step 2). An example diagram in DASEES is shown in Fig. 4.4. which was derived from a subset of options and performance measures elicited in the Dania Beach workshops.

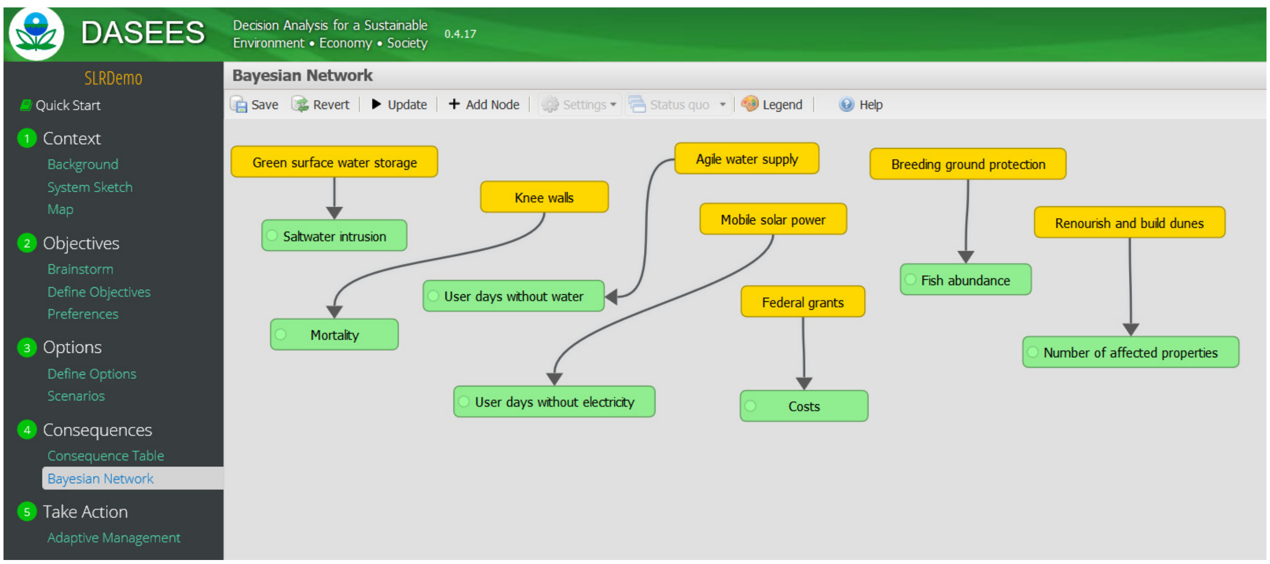



**Figure 4.4** Initial Bayesian network constructed in the DASEES tool with options (yellow nodes) attached to performance measures (green nodes). The connections and component nodes are provided based on the information input in previous steps of DASEES.

For complex environmental contexts with uncertainty, technical experts and analysts will then need to include additional nodes and arcs that elucidate the causal relationships between the options and performance measures. For example, the storm surge height could have detrimental effects on beachfront properties but estimating these effects requires knowledge of a key intermediary such as the overwash of the surge beyond the beach dunes.  By representing the overwash as a key uncertainty in the network, the impacts on beachfront properties can be more easily estimated from the known relationship with the amount of overwash that leaves the beach area. This leads to a simple serial connection (Fig. 4.5a) which is a useful start to developing a coherent causal network. Establishing the probabilities among the nodes (from modeling, data, or expert knowledge) for surge height creates a network with prior probabilities (Fig. 4.5b). Changing the probabilities in one node will update the probabilities for all the nodes in the network that are affected to display the posterior probabilities given these changes. This network says that the occurrence of high storm surge height is three times less likely than low storm surge height. This storm will be likely to still lead to low or high overwash and high beachfront property damage. As demonstrated here, the Bayesian network can display a lot of the information available about the causal relationships and the probabilities of future occurrences for scenarios of concern.

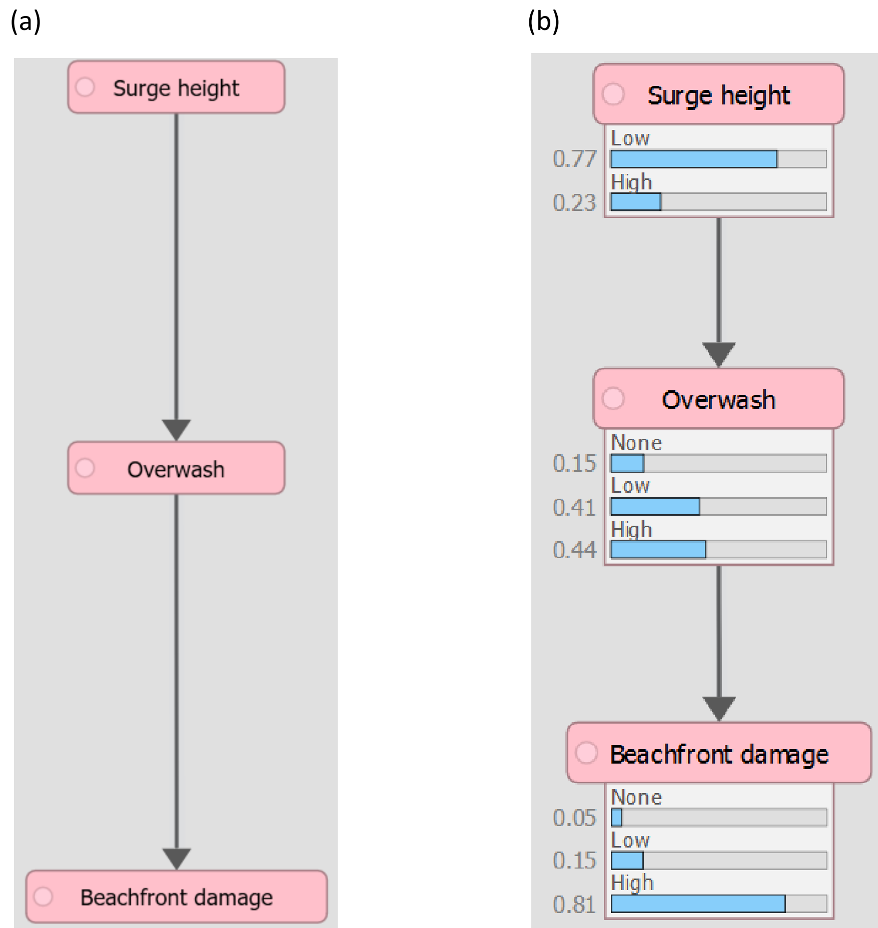



**Figure 4.5** Example of a Bayesian network in DASEES. (a) qualitative structure, (b) network with numerical prior probabilities for the occurrences of each of the states of each variable listed next to proportional probability bars in blue.

DASEES combines the pre-set Options-Measures linkages in a causal direction in the initial structure (Fig. 4.6). In DASEES, all node types have the same shape, but default colors are used for differentiating node types. The chance/causal pathway nodes are pink (e.g., storm scenario), decision nodes (options) are gold (e.g., agile water supply), and performance measures are green (e.g., saltwater intrusion).

Entering the probabilities for each nodal relationship and running the model yields results reported in a fashion like the CT (Fig. 4.6). The probabilities can be developed from past data, simulation models such as Monte Carlo analysis, and/or expert opinion. The difference being explicit consideration of likely causal mechanisms and the related probability of occurrence. In this case, the inclusion of more information indicates that the *Blended* scenario would bring about the highest overall expected value. This is a change from the CT's recommendation (shown in Fig. 4.2). The sum of the individual expected values in the weighted bar chart provides some information on the differences based on the expected values for individual objectives. Probability distributions for each scenario can also be examined for causal factors and performance measures. Only one example is shown in Fig. 4.6, but more can be seen by selecting the scenarios in DASEES.

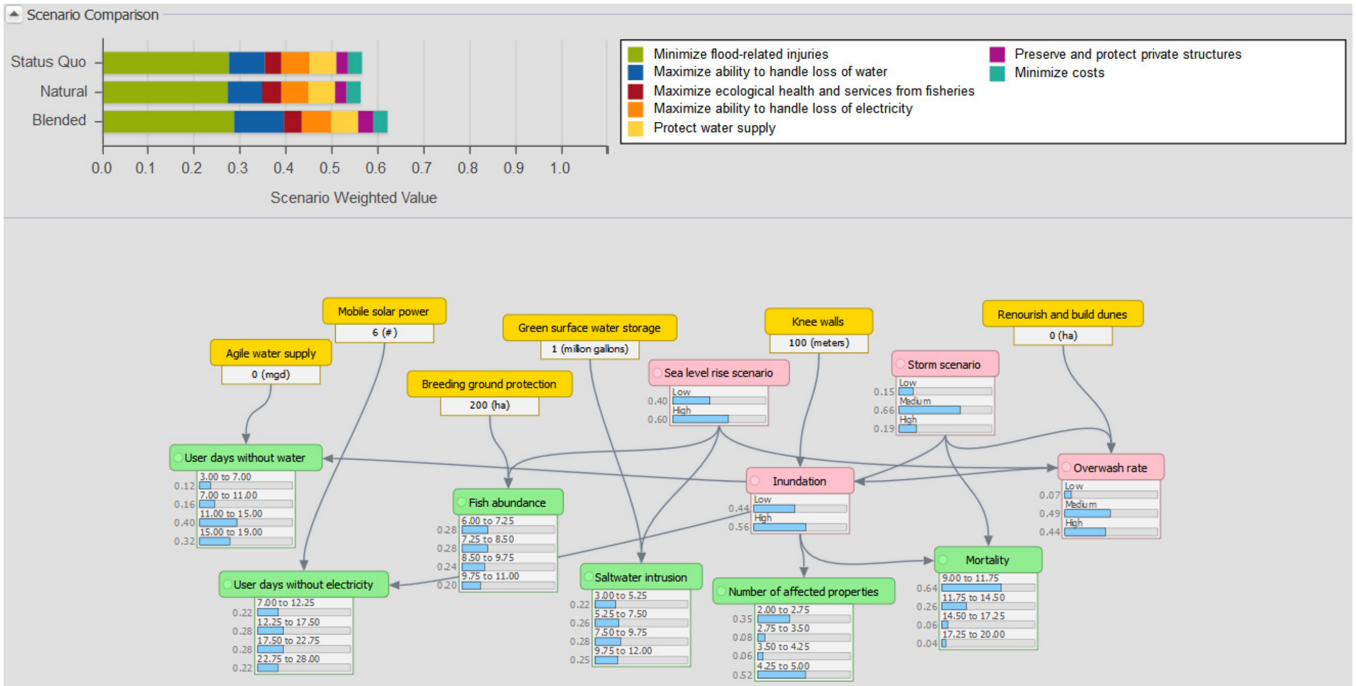



**Figure 4.6** Expected results for each decision scenario calculated by the network and value functions input in previous steps in DASEES. The bar length represents the overall expected value for a scenario and colored bars represent the expected value for individual objectives.

## 4.4 Developing consequence models in DASEES

Consequence tables are useful in cases where only point estimates for values are available or required, and where uncertainty can be reasonably ignored. The values for CTs should come from the best available expertise as discussed in the workshops, or the output of model simulations. The output can also be elicited from experts if models or data are not available. Gregory and Keeney (2017) describe a process for developing a CT when there are uncertainties, but individual, representative numbers are required. In the Gregory and Keeney (2017) approach, the CTs would be developed with individual stakeholders or with groups of aligned stakeholders and the implications of the individual CTs would be discussed across the group. Trade-off analysis would be done after the CT development if dominant alternatives are not identified.

A Bayesian network in DASEES will show a range of probabilities for consequences with appreciable uncertainty. Like CTs, influence diagrams and Bayesian networks can be developed throughout the phases of the SDM process. These models are developed through first eliciting the structure through causal mapping with experts and then populating them with data and probabilistic functions. The breadth and the depth of the models are often developed based on elicitations that take the form of expert workshops and cognitive mapping. Alternatively, one-on-one elicitations with domain experts for the variables involved may be implemented with analysts building the decision model and incorporating feedback. A combination of these two methods might also be used with one-on-one elicitations and feedback from a group or expert panel on the initial structure. The use of influence diagrams and

Bayesian networks can follow the application of consequence tables first. The use of consequence tables can be used to help decide if influence diagrams/Bayesian networks are necessary based on the difficulty of the trade-offs and the information loss from assuming individual (expected) value.

# 5 Resilience Planning Across Scales of Implementation

Chapters 1 and 2 describe the impetus and ongoing efforts for resilience planning in Southeast Florida across several geographical and administrative scales. Working independently, each stakeholder group (Compact, County, and City) has already demonstrated success in planning and implementing actions aimed at resilience that is meaningful at that scale. Chapter 3 describes the application of a decision process and tools for clarifying and linking objectives, performance measures and actions for Dania Beach. The aim being to better enable the creation of implementation strategies that are more responsive to objectives and acceptable to stakeholders at the city scale and to find connections to objectives at the County and regional scales. The workshop results are direct responses from community members, informed by attending regional Compact, County, City, and technical experts. This chapter compares the Dania Beach workshop results both across regional Compact and County, and within City scales and to find identified areas of overlapping interests. Finding areas of common interest and capacity across scales of implementation will enable leveraging resources and expertise while strengthening cooperation. Finding areas that are not in common is instructive as well. As Miles' Law observes, "Where you stand on an issue depends on where you sit" (Britannica, 2018); being cognizant of stakeholder constraints, duties, and the resultant objective preferences can avoid unnecessary misunderstandings among collaborators and perhaps help develop new mutually beneficial objectives and management actions.

## 5.1 Objectives and Actions across implementation Scales

The comparison of Dania Beach workshop identified objectives and action is not intended to be an exhaustive review among the three implementation scales, but rather an example of what areas of concordance can be found through a cursory review of regional Compact, County, and City resilience planning resources and an understanding of how alignment changes with scope. The results of which provide a jumping off point for more in-depth discussion with potential collaborators. The comparison intent is two-fold: 1) to demonstrate how communities like Dania Beach can follow a similar process to identify and clarify community resilience objectives, measures, and actions, and use that information to find areas of common objectives with nearby communities, county governments, and larger regional resilience-focused organizations, and 2) highlight EPA resources that communities can avail themselves of for such endeavors.

### *5.1.1 Southeast Florida Regional Climate Change Compact scale comparison*

The Dania Beach objective hierarchy (Tables 3.2 and 3.3) developed in the workshop (Chapter 3), has six broad categories of emphasis (higher level objectives) with 15 sub-objectives for assigning performance measures and resilience actions for implementation. The Southeast Florida Regional Climate Change Compact (Compact) provides the Regional Climate Action Plan (RCAP, 2017), covering 12 focus areas and 142 action items (Appendix B; Table 2.1) developed by experts, and aimed at broad public policy outreach for climate resilience. The RCAP has a web-based user interface, (Fig. 5.1) allowing viewers to explore and create preliminary implementation plans from the focus area organized action items. The Compact surveyed southeast Florida communities and asked them to self-report which RCAP actions were completed. Dania Beach reported completing 28 actions across seven focus areas.

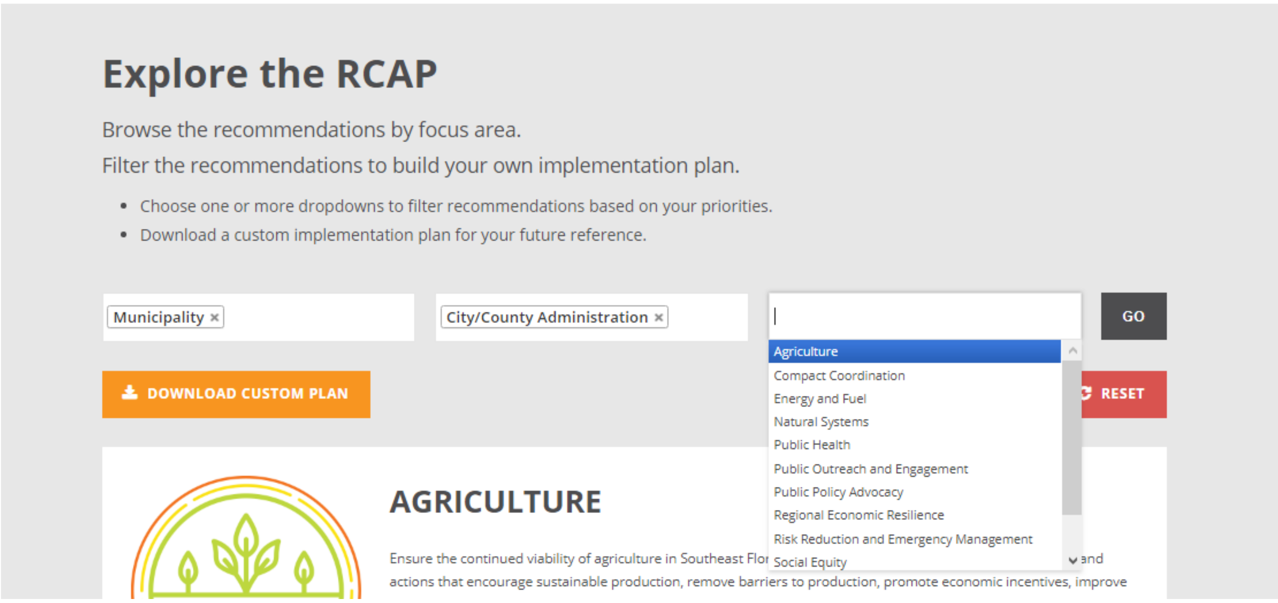



**Figure 5.1** The RCAP 2.0 interface allows users to search management actions by scale of implementation, type of stakeholder, and by Focus Area. This example assumes someone from Dania Beach city administration is searching for action suggestions.
http://www.southeastfloridaclimatecompact.org/regional-climate-action-plan/

Table 5.1 provides a crosswalk of the objectives and action identified by Dania Beach and (where applicable) corresponding focus area and action item from the regional Compact scale. Action in bold are reported as complete by Dania Beach. In general, the description and scope of action implementation at the city scale (Dania Beach) appears more oriented towards construction and developmental changes leading to more immediate community level changes. The suggested actions from the Compact are focused more on developing plans and policies leading to increased capacity for resilience across many sectors, e.g. social equity, natural systems, economic resilience. Understanding actions and objectives at different scales helps in finding common ground for united action. Linked Dania-Compact actions that are not in bold are at this stage preliminary and serve as a point for further discussion.

### *5.1.2 Broward County scale comparison*

Broward County is one of the signatories of the Compact and has its own county-level Climate Change Action Plan (CCAP, 2015) covering six plan elements (Table 2.3) and nearly 100 actions to achieve the elements.

**Table 5.1** Comparison of Dania Beach DASEES workshop and Compact Resilience Objectives and Possible Actions. Compact Actions in bold are self-reported as complete by Dania Beach.

| **Dania Beach Objectives:** Possible Actions | **Compact Focus Areas:** Possible Actions |
|---|---|
| Maximize affordable housing:<br>Loans | Sustainable Communities and Transportation:<br>ST-11 Modify local land use plans and ordinances to support compact development patterns, creating more walkable and affordable communities.<br>ST-14 Adopt social equity policies that support equitable economic growth and increase affordable housing opportunities near critical infrastructure. |
| Minimize flood related injuries:<br>Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls | Social Equity:<br>EQ-3 Support public infrastructure that enables economic mobility, health, and safety for all community members.<br>EQ-4 Address the needs of socially vulnerable populations by engaging existing community leaders and representative organizations in decision-making processes, particularly for critical public infrastructure.<br><br>Water:<br>WS-7 Modernize infrastructure development standards in the region.<br>**WS-10 Integrate combined surface and groundwater impacts into the evaluation of at-risk infrastructure and the prioritization of adaptation improvements.**<br>WS-11 Encourage green infrastructure and alternative strategies.<br>**WS-17 Advance capital projects to achieve resilience in water infrastructure.** |
| Maximize ability to handle loss of water and electricity:<br>Agile water supply<br>Mobile solar power | Energy and Fuel:<br>EF-4 Increase accessibility to distributed renewable energy technology.<br>EF-5 Utilize renewable and distributed energy technologies for emergency management and disaster recovery.<br>EF-8 Build the capacity for distributed renewable energy and energy storage technologies in future building stock.<br><br>Water:<br>**WS-13 Practice integrated water management and planning.**<br>**WS-17 Advance capital projects to achieve resilience in water infrastructure** |
| Minimize economic impacts on business community: | Regional Economic Resilience:<br>ER-2 Advance regional resilience infrastructure standards. |

| **Dania Beach Objectives:** Possible Actions | **Compact Focus Areas:** Possible Actions |
|---|---|
| Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls | ER-7 Engage in the National Flood Insurance Program (NFIP) process. |
| Minimize cost to Dania Beach:<br>Federal grants | Regional Economic Resilience:<br>ER-5 Integrate resilience and economic development at the regional level.<br>ER-6 Establish funding strategies to provide for equitable investment.<br>ER-9 Strive for economic equity in adaptation planning. |
| Preserve private property values:<br>Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls<br>Finish floor elevation<br>Re-nourish and build dunes<br>Dunes Education | Natural Systems:<br>**NS-1 Foster public awareness of the impacts of climate change on the region's natural systems and ecosystem services.**<br>NS-7 Promote the protection and restoration of coastal natural systems and the creation of living shorelines at the regional scale.<br><br>Sustainable Communities and Transportation:<br>**ST-7 Incorporate strategies to reduce risk and economic losses associated with sea level rise and flooding into local comprehensive plans, post-disaster redevelopment plans, building codes, and land development regulations.**<br><br>Water:<br>WS-11 Encourage green infrastructure and alternative strategies. |
| Protect water supply:<br>Green surface water storage<br>Adaption Action Areas<br>Connect bioswales<br>Finish floor elevation | Sustainable Communities and Transportation:<br>**ST-4 Designate adaptation action areas, restoration areas, and growth areas as a priority setting tool for vulnerable areas, and as a means to maximize benefits to natural systems while guiding people and commerce to less vulnerable places in the region.**<br><br>Water:<br>**WS-1 Foster innovation, development, and exchange of ideas for managing water.**<br>**WS-4 Coordinate saltwater intrusion mapping across Southeast Florida.**<br>WS-11 Encourage green infrastructure and alternative strategies.<br>**WS-13 Practice integrated water management and planning.**<br>WS-21 Expand regional surface water storage. |
| Protect water treatment:<br>Connect bioswales | Water:<br>**WS-1 Foster innovation, development, and exchange of ideas for managing water.**<br>WS-11 Encourage green infrastructure and alternative strategies. |

| **Dania Beach Objectives:** Possible Actions | **Compact Focus Areas:** Possible Actions |
|---|---|
| Preserve and protect private structures:<br>Knee walls<br>Re-nourish and build dunes | Natural Systems:<br>**NS-1 Foster public awareness of the impacts of climate change on the region's natural systems and ecosystem services.**<br>NS-7 Promote the protection and restoration of coastal natural systems and the creation of living shorelines at the regional scale.<br><br>Sustainable Communities and Transportation:<br>**ST-7 Incorporate strategies to reduce risk and economic losses associated with sea level rise and flooding into local comprehensive plans, post-disaster redevelopment plans, building codes, and land development regulations.**<br><br>Risk Reduction and Emergency Management<br>RR-11 Promote and leverage existing policies and programs designed to reduce flood risks and economic losses. |
| Minimize tourism economic impact:<br>Beach nourishment<br>Roads<br>Connect bioswales<br>Green surface water storage<br>Reclaimed water produced | Natural Systems:<br>NS-7 Promote the protection and restoration of coastal natural systems and the creation of living shorelines at the regional scale.<br><br>Sustainable Communities and Transportation:<br>**ST-1 Incorporate unified sea level rise projections, by reference, into all city, county, and regional agency comprehensive plans, transportation and other infrastructure plans, and capital improvement plans.**<br><br>Water:<br>**WS-13 Practice integrated water management and planning.**<br>WS-21 Expand regional surface water storage. |
| Maximize beach life:<br>Septic connections | Sustainable Communities and Transportation:<br>ST-16 Phase out septic systems where necessary to protect public health and water quality. |
| Maximize fisheries:<br>Breeding ground protection | Natural Systems:<br>NS-11 Identify the effects of climate change on fish populations, the sustainability of key fisheries, and the fishing industry, then develop adaptation plans as needed. |
| Maximize nursery and breeding grounds:<br>Breeding ground protection | Natural Systems:<br>NS-11 Identify the effects of climate change on fish populations, the sustainability of key fisheries, and the fishing industry, then develop adaptation plans as needed. |
| Maximize mangrove areas:<br>Breeding ground protection | Natural Systems:<br>NS-11 Identify the effects of climate change on fish populations, the sustainability of key fisheries, and the fishing industry, then develop adaptation plans as needed. |

Like the Compact RCAP, Broward County's Climate Change Action Plan (CCAP, 2015) includes ~100 actions to achieve the six plan elements. Broward County has already prioritized two objectives:

> Overarching Goals of Broward County Climate Change Action Plan
>
> 1. Mitigate the effects of climate change by reducing greenhouse gas emissions by 2% per year by 2020 (leading to an 80% reduction by 2050)
> 2. Increase the resilience of our community to the effects of climate change.

Initially, to achieve these goals, the CCAP identified 20 High Priority Actions across the six plan elements (Table 5.2). Similar to Table 5.1, Dania Beach objectives and actions are cross-walked against the Elements and Prioritized Actions. The Dania Beach objectives do not include any objectives or actions specifically aimed at reducing greenhouse gas emissions. The comparison in Table 5.2 will focus on where Dania Beach and Broward might find common objectives for the second Broward objective of increased community resilience. The prioritized Policy element action: *Contribute to local, regional, and state climate planning efforts* was not specifically linked to a Dania Beach objective as it was and is being achieved through actions like hosting and participating in the Dania Beach workshop and the Resilient Redesign Charette described in Chapter 2.

From Table 5.2 there appears to be concordance between Dania Beach and Broward County for goals that increase resilience to climate effects on water supply, quality, and water resources i.e. flood management, including actions related to the Broward Elements of the Built Environment, Energy Resources, and Natural Systems. Several of these actions link to regional Compact water resource management goals as well, suggesting connections across levels of administration and avenues of greater co-operation.

### 5.1.3 Dania Beach scale comparison

Within the scale of Dania Beach administration there are three sets of objectives and actions each developed by a different set of stakeholders and organizational context. There are the 1) objectives from the DASEES workshop representing a comprehensive cross-section of stakeholder interests, listed, discussed, and compared in this report, the 2) the more economic and infrastructure re-vitalization driven Dania Beach Community Redevelopment Agency (CRA, 2015) redevelopment goals and implementation strategies and 3) the proposed climate effects driven resilient redesign concepts and recommendations (objectives and actions) from the Resilient Redesign Charrette (Chap. 2; Compact, 2014).

The Dania Beach CRA Redevelopment Plan has five goals with associated short and long-term actions.

1. Redevelopment Goal 1: To Enhance and Reinforce CRA sub Areas.
2. Redevelopment Goal 2: Affordable Housing
3. Redevelopment Goal 3: Energy Efficiency and Sustainability
4. Redevelopment Goal 4: Business Attraction and Attention
5. Redevelopment Goal 5: Community Redevelopment Programs

CRA sub Areas are sections of the larger municipal Dania Beach area divided and organized by land use and zoning. The goals are tailored to the specific sub-area. Table 5.3 identifies the long and short-term actions that are applicable across sub-areas and correlate with DASEES workshop objectives and actions. The comparison found links to Goals 1-3 but not for Goals 4-5. These last two goals are focused on enhancing the attractiveness of Dania Beach for local business development (Goal 4) and funding mechanisms to do that (Goal 5). The first three goals in the CRA plan, the DASEES workshop goals, Broward County, and Compact goals were more focused on funding and grants from State and Federal sources for water infrastructure, housing, and other quality of life investments. Aside from the Goal 1 focus on the Marine sub-Area and Goal 4 on increasing coastal and shipping business, the CRA does not emphasize protection or enhancement of natural systems for resilience.

The results of the Resilient Redesign Charrette were developed as concepts reflecting an underlying objective of redesign for resilience to flooding and may not naturally correlate to an objectives-action structure (Table 5.4). Nonetheless, there are some readily identifiable connections with the DASEES workshop goals, the breadth of which seem to act as a complement to the CRA goals. Taken together, it appears reasonable to interpret the CRA and Redesign objectives as meshing well with the DASEES workshop goals as well as helping to provide greater specificity to the some of the DASEES-SDM derived actions.

Part of the Redesign Charrette results includes implementation suggestions such as engaging the community and using a decision-making process and making an implementation roadmap. This report and its results demonstrate a way to do the first two recommendations via DASEES and SDM and provide a starting point for the third recommendation. Through this crosswalk, discussions of objectives and actions common across scales can be identified for further implementation feasibility and decision consequence analyses. The measures associated with the identified objectives and actions provide direction for prioritizing resources towards appropriate data collection, modeling, and analyses (Chapter 3), and subsequent evaluation of assessed or predicted results for tradeoff and uncertainty analysis (Chapter 4) facilitating more informed decision-making promoting community resilience.

While many sources of information have been and continue to be identified and generated by the Compact and Broward County for communities to use, other federal resources are also available in addition to DASEES. The next chapter is an overview of such resources that the EPA provides to help communities address their resilience challenges.

**Table 5.2** Comparison of Dania Beach DASEES workshop and Broward County Prioritized Actions for resilience from the Climate Change Action Plan (CCAP. 2015).

| **Dania Beach Objectives:** Actions | **Broward CCAP Elements:** Prioritized Actions |
|---|---|
| Maximize affordable housing:<br>Loans | Built Environment<br>71 Develop adaptive management strategies<br>#72 Apply models to develop resilient design standards |
| Minimize flood related injuries:<br>Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls | Built Environment:<br># 61 Encourage FEMA to consider sea level rise in flood map updates<br>#70 Analyze sea level rise, drainage and hurricane impacts<br>#71 Develop adaptive management strategies<br>#72 Apply models to develop resilient design standards |
| Maximize ability to handle loss of water and electricity:<br>Agile water supply<br>Mobile solar power | Energy Resources:<br>#50 Support third party retail power purchase agreements<br>#51 Increase rooftop solar on county facilities |
| Minimize economic impacts on business community:<br>Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls | Built Environment:<br># 61 Encourage FEMA to consider sea level rise in flood map updates<br>#70 Analyze sea level rise, drainage and hurricane impacts<br>#71 Develop adaptive management strategies<br>#72 Apply models to develop resilient design standards |
| Minimize cost to Dania Beach:<br>Federal grants | Built Environment<br>#72 Apply models to develop resilient design standards |
| Preserve private property values:<br>Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls<br>Finish floor elevation<br>Re-nourish and build dunes<br>Dunes Education | Natural Systems:<br>#19 Increase number of miles of living shorelines and dunes<br><br>Built Environment:<br># 61 Encourage FEMA to consider sea level rise in flood map updates<br>#70 Analyze sea level rise, drainage and hurricane impacts<br>#71 Develop adaptive management strategies<br>#72 Apply models to develop resilient design standards |
| Protect water supply: | Natural Systems: |

| **Dania Beach Objectives:** Actions | **Broward CCAP Elements:** Prioritized Actions |
|---|---|
| Green surface water storage<br>Adaption Action Areas<br>Connect bioswales<br>Finish floor elevation | #16 Lessen cumulative impacts to natural systems<br><br>Water Supply:<br>#26 Continue local water conservation programs<br>#29 Monitor and protect wellfields<br>#30 Develop alternative water supply strategies |
| Protect water treatment:<br>Connect bioswales | Water Supply:<br>#29 Monitor and protect wellfields<br>#30 Develop alternative water supply strategies |
| Preserve and protect private structures:<br>Knee walls<br>Re-nourish and build dunes | Natural Systems:<br>#19 Increase number of miles of living shorelines and dunes<br><br>Built Environment:<br># 61 Encourage FEMA to consider sea level rise in flood map updates<br>#70 Analyze sea level rise, drainage and hurricane impacts<br>#71 Develop adaptive management strategies<br>#72 Apply models to develop resilient design standard |
| Minimize tourism economic impact:<br>Beach nourishment<br>Roads<br>Connect bioswales<br>Green surface water storage<br>Reclaimed water produced | Water Supply:<br>#26 Continue local water conservation programs<br>#29 Monitor and protect wellfields<br>#30 Develop alternative water supply strategies |
| Maximize beach life:<br>Septic connections | Natural Systems:<br>#16 Lessen cumulative impacts to natural systems<br><br>Water Supply:<br>#29 Monitor and protect wellfields |
| Maximize fisheries:<br>Breeding ground protection | Natural Systems:<br>#18 Develop habitat buffer zones |
| Maximize nursery and breeding grounds:<br>Breeding ground protection | Natural Systems:<br>#18 Develop habitat buffer zones |
| Maximize mangrove areas; | Natural Systems: |

| **Dania Beach Objectives:** Actions | **Broward CCAP Elements:** Prioritized Actions |
|---|---|
| Breeding ground protection | #18 Develop habitat buffer zones |

**Table 5.3** Comparison of Dania Beach DASEES workshop and Dania Beach CRA Redevelopment Plan short and long-term goals.

| **Dania Beach Objectives:** Actions | **Dania Beach CRA Redevelopment Goals:** Short and Long-term Actions |
|---|---|
| Maximize affordable housing:<br>Loans | CRA Redevelopment Goal 2 Affordable Housing:<br>Short-term:<br>• Identify funding and implement a neighborhood vacant lot acquisition program for replacement and infill housing<br>• Create a Housing Rehabilitation Program for owner occupied and rental properties<br>• Create an affordable housing trust fund that is tied to the mixed-use zoning districts that would allow development of pay "in lieu" of providing affordable housing and that can be used to purchase vacant residential lots or properties for infill housing and/or existing housing stock within the CRA neighborhoods. |
| Minimize flood related injuries:<br>Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls | CRA Redevelopment Goal 3 Redevelop the CRA in a manner that is Energy Efficient and Sustainable<br>Long-term:<br>• Implement mitigation strategies in terms of infrastructure upgrades based on AAA priority |
| Maximize ability to handle loss of water and electricity:<br>Agile water supply<br>Mobile solar power | CRA Redevelopment Goal 1 Enhance and Reinforce CRA prioritized redevelopment areas<br>Short-term:<br>• Install solar lighting<br>Long-term:<br>• Install landscape, curb, and gutter drainage improvements<br><br>CRA Redevelopment Goal 3 Redevelop the CRA in a manner that is Energy Efficient and Sustainable<br>Short-Term:<br>• Coordinate with FPL to encourage installation of solar or other alternate energy source infrastructure within its existing transmission line easement |
| Minimize economic impacts on business community:<br>Connect bioswales | CRA Redevelopment Goal 3 Redevelop the CRA in a manner that is Energy Efficient and Sustainable<br>Long-term:<br>• Implement mitigation strategies in terms of infrastructure upgrades based on AAA priority |

| **Dania Beach Objectives:** Actions | **Dania Beach CRA Redevelopment Goals:** Short and Long-term Actions |
|---|---|
| Knee walls<br>Raise roads<br>Seawalls | |
| Minimize cost to Dania Beach:<br>Federal grants | CRA Redevelopment Goal 1 Enhance and Reinforce CRA prioritized redevelopment areas<br>Long-term:<br>• Pursue opportunities to engage in public-private partnerships to achieve redevelopment goals |
| Preserve private property values:<br>Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls<br>Finish floor elevation<br>Re-nourish and build dunes<br>Dunes Education | CRA Redevelopment Goal 3 Redevelop the CRA in a manner that is Energy Efficient and Sustainable<br>Long-term:<br>• Implement mitigation strategies in terms of infrastructure upgrades based on AAA priority |
| Protect water supply:<br>Green surface water storage<br>Adaption Action Areas<br>Connect bioswales<br>Finish floor elevation | CRA Redevelopment Goal 3 Redevelop the CRA in a manner that is Energy Efficient and Sustainable<br>Short-Term:<br>• Promote water reuse and recycling in all public and private developments and conduct community water reuse and rain barrel workshops for residents.<br>Long-term:<br>• Identify areas in priority order as Adaption Action Areas (AAA) based on 1, 3, and 5foot sea level rise<br>• Implement mitigation strategies in terms of infrastructure upgrades based on AAA priority |
| Protect water treatment:<br>Connect bioswales | CRA Redevelopment Goal 3 Redevelop the CRA in a manner that is Energy Efficient and Sustainable<br>Long-term:<br>• Implement mitigation strategies in terms of infrastructure upgrades based on AAA priority |
| Preserve and protect private structures:<br>Knee walls<br>Re-nourish and build dunes | CRA Redevelopment Goal 3 Redevelop the CRA in a manner that is Energy Efficient and Sustainable<br>Long-term:<br>• Implement mitigation strategies in terms of infrastructure upgrades based on AAA priority |
| Minimize tourism economic impact:<br>Beach nourishment<br>Roads | CRA Redevelopment Goal 3 Redevelop the CRA in a manner that is Energy Efficient and Sustainable<br>Long-term:<br>• Implement mitigation strategies in terms of infrastructure upgrades based on AAA priority |

| **Dania Beach Objectives:** Actions | **Dania Beach CRA Redevelopment Goals:** Short and Long-term Actions |
|---|---|
| Connect bioswales<br>Green surface water storage<br>Reclaimed water produced | |
| Maximize beach life:<br>Septic connections | CRA Redevelopment Goal 2 Affordable Housing:<br>Short-term:<br>• Create sewer hook-up funding and or financing program for residential properties |
| Maximize fisheries:<br>Breeding ground protection | |
| Maximize nursery and breeding grounds:<br>Breeding ground protection | |
| Maximize mangrove areas:<br>Breeding ground protection | |

**Table 5.4** Comparison of Dania Beach DASEES workshop and Resilient Re-design Charette Concepts and Recommendations (Compact, 2014).

| **Dania Beach Objectives:** Actions | **Dania Beach Resilient Redesign Concepts:** Recommendations |
|---|---|
| Maximize affordable housing:<br>Loans | |
| Minimize flood related injuries:<br>Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls | Urban Densification:<br>Include Evacuation shelter<br><br>Flood Control:<br>Raise perimeter roads to act as levees |
| Maximize ability to handle loss of | |

| **Dania Beach Objectives:** Actions | **Dania Beach Resilient Redesign Concepts:** Recommendations |
|---|---|
| water and electricity:<br>Agile water supply<br>Mobile solar power | |
| Minimize economic impacts on business community:<br>Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls | |
| Minimize cost to Dania Beach:<br>Federal grant | |
| Preserve private property values:<br>Connect bioswales<br>Knee walls<br>Raise roads<br>Seawalls<br>Finish floor elevation<br>Re-nourish and build dunes<br>Dunes Education | Urban Densification at City Center:<br>Vertical Expansion<br>Invest along coastal ridge (higher elevation)<br><br>Flood Control:<br>Raise Perimeter Roads to act as levees |
| Protect water supply:<br>Green surface water storage<br>Adaption Action Areas<br>Connect bioswales<br>Finish floor elevation | Flood Control:<br>Create a Polder (water storage structure)<br><br>Enhance Natural Infrastructure:<br>Mangrove Restoration |
| Protect water treatment:<br>Connect bioswales | Flood Control:<br>Incorporate Canals<br>Add Pumping Station |
| Preserve and protect private structures:<br>Knee walls | Enhance Natural Infrastructure:<br>Dune Enhancement (Underground Parking) |

| **Dania Beach Objectives:** Actions | **Dania Beach Resilient Redesign Concepts:** Recommendations |
|---|---|
| Re-nourish and build dunes | |
| Minimize tourism economic impact:<br>Beach nourishment<br>Roads<br>Connect bioswales<br>Green surface water storage<br>Reclaimed water produced | Enhance Natural Infrastructure:<br>Dune Enhancement (Underground Parking)<br>Mangrove Restoration<br><br>Flood Control:<br>Create a Polder (water storage structure)<br>Raise Perimeter Roads to act as levees<br>Incorporate Canals |
| Maximize beach life:<br>Septic connections | |
| Maximize fisheries:<br>Breeding ground protection | Enhance Natural Infrastructure:<br>Mangrove Restoration<br>Reef Enhancement |
| Maximize nursery and breeding grounds:<br>Breeding ground protection | Enhance Natural Infrastructure:<br>Mangrove Restoration<br>Reef Enhancement |
| Maximize mangrove areas:<br>Breeding ground protection | Enhance Natural Infrastructure:<br>Mangrove Restoration<br>Reef Enhancement |

# 6 Resilience Planning: Integration, Implementation, and Decision-making Resources

The initial impetus for coastal community resilience planning in southeast Florida is the confluence of the trends of increasing coastal population and SLR. The administrative bodies in the region (Compact, County, and Community) also recognize the need to work co-operatively across scales, on a broad range of resilience initiatives including SLR, greenhouse gas (GHG) reduction, alternative energy options, human health, and socio-economic equity. The southeast Florida results are congruent with the EPA urban climate resilience framework (USEPA, 2017) pointing to promising future collaborations between States and EPA on similar projects.

The example of other communities or regions facing similar problems is instructive and may provide analogous models to consider. The most recognizable being the historic success of the Netherlands in holding back the sea and reclaiming land with a massive system of dams, dikes, polders, pumps and barriers (Government of the Netherlands, 2018), providing a strong defense against seaside flooding and protection of inland freshwater resources. Dutch experts have been providing advice to coastal South Florida decision makers (charrette results in Chapters 2 and 5).

The Netherlands example, is an ongoing, evolving enterprise in adaptability, moving from historic reactive barriers to creating current multi-use spaces for satisfying human needs and floodwater occupancy (New York Times, 2015) and is driven as much by cultural context as by practical concerns. Similarly, the construction and implementation of resilience strategies by Dania Beach, other coastal communities in Florida or elsewhere in the U.S. will necessarily require expanded consideration of issues beyond flood management including health, safety, economic, energy, transportation, and other quality of life concerns.

## 6.1 Community Resilience Planning Integration and Implementation Assessment

For this stage in Dania Beach resilience, the primary benefit of using DASEES was in fostering the first step in SDM; finding common understanding of a complex problem. Coming to an accord on the need to view Dania Beach resilience within its own and larger contexts, facilitates the identification of cross-scale objectives and measures, promoting the development of innovative actions for integrated resilience planning. As described in Chapter 1, understanding context is the first step in the SDM process, from which community specific resilience objectives including flood control, and other economic, social, and cultural concerns are derived, driving options development, technical assessment, trade-off evaluation, and prioritization needs. The three levels of administration (Chapter 2), regional (Compact), county (Broward), and community (Dania Beach), provide comprehensive planning documents characterizing the environmental, social, and economic trends and issues with concomitant goals, ongoing and proposed actions, and performance measures for their respective scale of implementation.

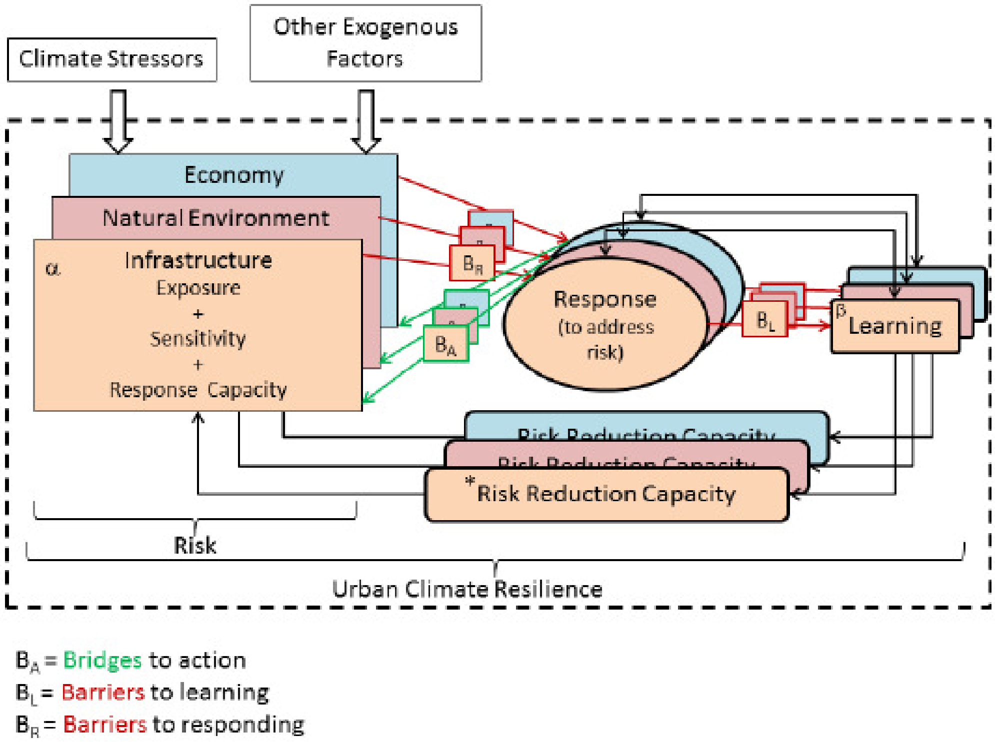
Following the first workshop, the resultant Dania Beach objective hierarchy served as a basis for the cross-scale analysis of objectives (Chapter 5), and investigation of resilience actions (Chapter 3), providing impetus to identify a starting place of common objectives and candidate resilience actions to implement for objective attainment; leading to the second main step in SDM - create and evaluate solutions. Implementing resilience actions can require significant commitment of resources and should not be initiated before a prescriptive assessment of decision consequences is assessed and evaluated. Broward County has and continues to conduct hydraulic, hydrologic, and oceanographic modeling studies (Chapter 3) to provide the necessary scientific knowledge to assess the effectiveness of water and shoreline management actions. Preliminary conceptual modeling with DASEES (Chapter 3) captures the linkage of these actions to performance assessment measures. Examples of specific action consequence modeling is demonstrated using the Consequence Table and Influence Diagram tools of DASEES (Chapter 4). Important to note is that inclusion of needed economic assessment models and studies for understanding the impact of actions on property values, flood insurance rates, and tourism. Other socio-economic concerns captured in objectives may not be adequately represented in the current conceptual modeling and should be re-visited.

## 6.2 Decision-Making Resources

The SDM process facilitated via tools like DASEES provide the organizational structure for more clarified thinking about complex problems and the practical quantitative methods for integrating multiple assessments and uncertainty, weighting priorities, and ranking alternatives. The relative ease of use and methodological flexibility of the SDM process and DASEES features allow broad applicability to a wide range of decision problems, with the caveat that the users must bring or develop needed specific data, background information, and assessment results to DASEES for decision-focused processing. This chapter presents previously referenced and new information sources useful for coastal community resilience problems that may be applied by DASEES for subsequent decision-making for Dania Beach and beyond by other communities facing similar issues.

### *6.2.1 Evaluating Urban Resilience to Climate Change: A Multisector approach*

In Chapter 1, an EPA report was referenced (USEPA, 2017) which provides working definitions for climate related resilience planning, a conceptual framework for problem and solution formulation, and indicators/indices for assessing the community/urban resilience to climate stressors such as increased flooding (Fig. 6.1). The information within the report would be useful for establishing context, common understanding of the problem leading to creative solutions, and potentially applicable performance measures.




α = These three elements—exposure, sensitivity, and response capacity—compose urban vulnerability.
β = Learning outcomes are on three levels: reacting, reframing, and transforming (see Figure 1-3, IPCC, 2012). Examples: reacting = increase a levee height; reframing = realizing the need to assess new storm duration frequency distributions; transforming = assessing societal constructs and migrating to a more robust and comprehensive risk management strategy.
*Risk reduction capacity is the ability to reduce exposure, reduce sensitivity, and/or increase the system's inherent recovery potential in anticipation of harmful climatic changes/events.

**Figure 6.1** Urban climate resilience framework (Adapted from US EPA, 2017).

### *6.2.2 Climate Change Indicators in the United States 2016, 4th edition.*

The Climate Change Indicators report (US EPA, 2016) is in its fourth edition since 2010, providing continuous updates on 37 indicators (Fig. 6.2) across six areas related to climate and its effects. Each indicator is selected based on usefulness for decision-making, data quality, and relevance to climate change. Detailed information for each indicator, including downloadable data, data sources, collection and analysis methods are available at http://www.epa.gov/climate-indicators.

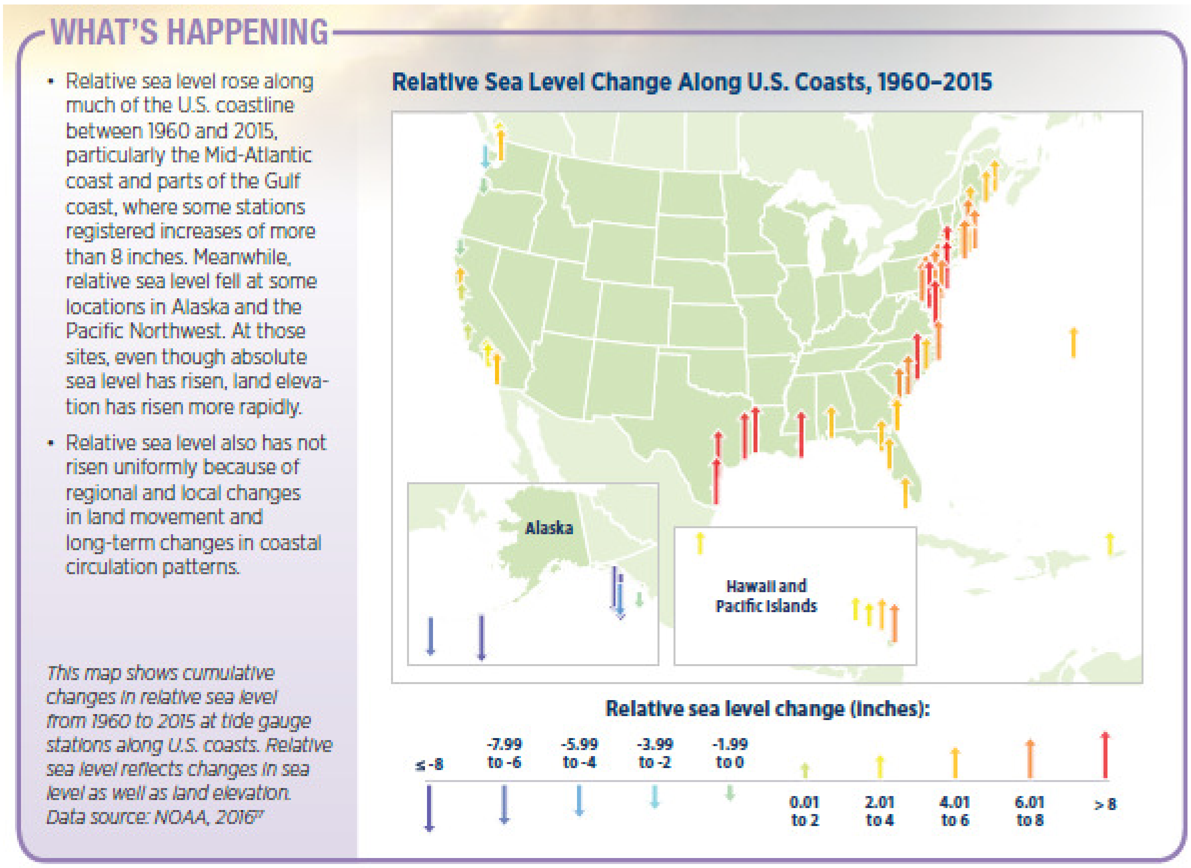



**Figure 6.2** Indicator for relative sea level change along U.S. coasts 1960-2015 (US EPA, 2016).

### 6.2.3 Climate Ready Estuaries Program

The EPA Climate Ready Estuaries program supports the coastal management community and the National Estuary Program in addressing climate change and its impacts to watersheds and coastal areas. The resource provides tools, case studies, information, and assistance for coastal communities seeking to assess climate vulnerability and develop adaptation plans. Additional information on these resources can be found at: https://www.epa.gov/cre This report's Appendices contain a Dania Beach relevant crosswalk to risk checklists from "Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans" (Appendix A; US EPA 2014) and adaptation options from a "Synthesis of Adaptation Options for Coastal Areas" (US EPA 2009).

### 6.2.4 Climate Change Adaptation Resource Center (ARC-X)

The EPA's Adaptation Resource Center (ARC-X) https://www.epa.gov/arc-x is an online, interactive resource for communities enabling them to find resources and develop adaption plans specific to their region and needs.

### 6.2.5 Climate Resilience Evaluation and Awareness Toolkit (CREAT)

CREAT is a web-based tool that provides utilities with tools to explore consider how SLR, and other climate related changes may impact their operation. https://toolkit.climate.gov/tool/climate-resilience-evaluation-awareness-tool-creat

### 6.2.6 EPA Research Program Methods, Models, Tools, and Databases

EPA maintains a clearing house for highlighting methods, models, tools, databases and other resources supporting environmental resilience assessment and planning needs. These resources cover support decision-making across air, climate change, ecosystems, health, homeland security, human health risk assessment, land and waste management, safer chemical, and water domains. https://www.epa.gov/research/methods-models-tools-and-databases

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# Appendix A. Checklists of Potential Climate Change Risks

This Appendix is a reprinting of material from the EPA publication Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans (EPA 842-K-14-002, August 2014). The full workbook is available through the Climate Ready Estuaries website, www.epa.gov/cre.

**Appendix A Table 1. Potential climate change risks for pollution control**

| Clean Water Act goals | Warmer summers | Warmer winters | Warmer water | Increasing drought | Increasing storminess | Sea level rise | Ocean acidification |
|---|---|---|---|---|---|---|---|
| Controlling point sources of pollution and cleaning up pollution | | ☐ Loss of melting winter snows may reduce spring or summer flow volume, and raise pollutant concentration in receiving waters | ☐ Temperature criteria for discharges may be exceeded (thermal pollution)<br>☐ Warmer temperatures may increase toxicity of pollutants | ☐ Critical-low-flow criteria for discharging may not be met<br>☐ Pollutant concentrations may increase if sources stay the same and flow diminishes | ☐ Combined sewer overflows may increase<br>☐ Treatment plants may go offline during intense floods | ☐ Treatment plants may not be able to discharge via gravity at higher water levels<br>☐ Treatment infrastructure may be susceptible to flooding<br>☐ Sewage may mix with seawater in combined sewer systems<br>☐ Contaminated sites may flood or have shoreline erosion<br>☐ Sewer pipes may have more inflow (floods) or infiltration (higher water table) | |
| Controlling nonpoint sources of pollution | ☐ Wildfires may lead to soil erosion | ☐ Longer growing season can lead to more lawn maintenance with fertilizers and pesticides | ☐ Higher solubility may lead to higher concentration of pollutants<br>☐ Water may hold less dissolved oxygen<br>☐ Higher surface temperatures may lead to stratification<br>☐ Greater algae growth may occur<br>☐ Parasites, bacteria may have greater survival or transmission | ☐ Pollution sources may build up on land, followed by high-intensity flushes | ☐ Streams may see greater erosion and scour<br>☐ Urban areas may be subject to more floods<br>☐ Flood control facilities (e.g., detention basins, manure management) may be inadequate<br>☐ High rainfall may cause septic systems to fail | ☐ Tidal flooding may extend to new areas, leading to additional sources of pollution | ☐ Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters |

**Appendix A Table 2. Potential climate change risks for habitat**

| Clean Water Act goals | Warmer summers | Warmer winters | Warmer water | Increasing drought | Increasing storminess | Sea level rise | Ocean acidification |
|---|---|---|---|---|---|---|---|
| Restoring and protecting physical and hydrologic features | ☐ Higher temperatures may lead to greater evaporation and lower groundwater tables<br><br>☐ Switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies<br><br>☐ Greater electricity demand may affect operation decisions at hydropower dams | ☐ Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change<br><br>☐ A spring runoff pulse may disappear along with the snow<br><br>☐ Rivers may no longer freeze; a spring thaw would be obsolete<br><br>☐ Marshes and beaches may erode from loss of protecting ice | ☐ Warmer water may lead to greater likelihood of stratification | ☐ Groundwater tables may drop<br><br>☐ Base flow in streams may decrease<br><br>☐ Stream water may become warmer<br><br>☐ Increased human use of groundwater during drought may reduce stream baseflow<br><br>☐ New water supply reservoirs may affect the integrity of freshwater streams | ☐ The number of storms reaching an intensity that causes problems may increase<br><br>☐ Stronger storms may cause more intense flooding and runoff<br><br>☐ Coastal overwash or island breaching may occur<br><br>☐ Turbidity of surface waters may increase<br><br>☐ Increased intensity of precipitation may yield less infiltration | ☐ Shoreline erosion may lead to loss of beaches, wetlands and salt marshes<br><br>☐ Saline water may move farther upstream and freshwater habitat may become brackish<br><br>☐ Tidal influence may move farther upstream<br><br>☐ Bulkheads, sea walls and revetments may become more widespread | |
| Constructing reefs to promote fish and shellfish | | | ☐ Desired fish may no longer be present<br><br>☐ Warmer water may promote invasive species or disease | | ☐ Stream erosion may lead to high turbidity and greater sedimentation<br><br>☐ Lower pH from NPS pollution may affect target species | ☐ Light may not penetrate through deeper water<br><br>☐ Higher salinity may kill targeted species | ☐ Long-term shellfish sustainability may be an open question<br><br>☐ Fish may be adversely affected during development stages |

**Appendix A Table 3. Potential climate change risks for fish, wildlife and plants**

| Clean Water Act goals | Warmer summers | Warmer winters | Warmer water | Increasing drought | Increasing storminess | Sea level rise | Ocean acidification |
|---|---|---|---|---|---|---|---|
| Protecting and propagating fish, shellfish and wildlife<br><br>Controlling nonnative and invasive species<br><br>Maintaining biological integrity and reintroducing native species | ☐ Species that won't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems<br><br>☐ Species may be weakened by heat and become out-competed<br><br>☐ Essential food sources may die off or disappear, affecting the food web<br><br>☐ Species may need to consume more water as temperature rises | ☐ Species that used to migrate away may stay all winter<br><br>☐ Species that once migrated through may stop and stay<br><br>☐ Pests may survive winters that used to kill them<br><br>☐ Invasive species may move into places that used to be too cold<br><br>☐ Some plants may need a "setting" cold temperature<br><br>☐ A longer growing season may lead to an extra reproductive cycle<br><br>☐ Food supplies and bird migrations may be mis-timed | ☐ Newly invasive species may appear<br><br>☐ Habitat may become unsuitably warm, for a species or its food<br><br>☐ Heat may stress immobile biota<br><br>☐ Dissolved oxygen capacity of water may drop<br><br>☐ Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature<br><br>☐ Coral bleaching episodes may increase<br><br>☐ Parasites and diseases are enhanced by warmer water | ☐ Species may not tolerate a new drought regime<br><br>☐ Native habitat may be affected if freshwater flow in streams is diminished or eliminated<br><br>☐ Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat) | ☐ Greater soil erosion may increase turbidity and decrease water clarity<br><br>☐ Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species | ☐ Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat)<br><br>☐ Light may not penetrate through the full depth of deeper water<br><br>☐ Greater coastal wetland losses may occur | ☐ Corrosive waters may impact shellfish development<br><br>☐ Shellfish predators may not survive the disappearance of shellfish<br><br>☐ Fish may be adversely affected during development stages by changes to water chemistry<br><br>☐ The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain |

**Appendix A Table 4. Potential climate change risks for recreation and public water supplies**

| Clean Water Act resource goals | Warmer summers | Warmer winters | Warmer water | Increasing drought | Increasing storminess | Sea level rise | Ocean acidification |
|---|---|---|---|---|---|---|---|
| Restoring and maintaining recreational activities, in and on the water | ☐ More people using water for recreation may raise the potential for pathogen exposure | | ☐ Harmful algal blooms may be more likely<br>☐ Jellyfish may be more common<br>☐ Fishing seasons and fish may become misaligned<br>☐ Desired recreational fish may no longer be present<br>☐ Invasive plants may clog creeks and waterways | ☐ Freshwater flows in streams may not support recreational uses<br>☐ Increased estuary salinity may drive away targeted recreational fish | ☐ More frequent or more intense storms may decrease recreational opportunities<br>☐ Greater NPS pollution may impair recreation | ☐ Beaches or public access sites may be lost to coastal erosion or inundation<br>☐ Clearance under bridges may decrease | ☐ Eco-tourism resources or attractions (e.g., birding, diving, fishing) may be degraded<br>☐ Recreational shellfish harvesting may be lost |
| Protecting public water supplies | ☐ Warmer temperatures may drive greater water demand<br>☐ Evaporation losses from reservoirs and groundwater may increase | ☐ Summer water supplies that depend on winter snow pack may disappear<br>☐ Cold places may see more freeze/thaw cycles that can affect infrastructure | ☐ Changes in treatment processes may be required<br>☐ Increased growth of algae and microbes may affect drinking water quality | ☐ Lower freshwater flows may not keep saltwater downstream of intakes<br>☐ Groundwater tables may drop<br>☐ Coastal aquifers may be salinized from insufficient freshwater input<br>☐ Coastal aquifers may be salinized from higher demand on groundwater<br>☐ Maintaining passing flows at diversions may be difficult | ☐ Water infrastructure may be vulnerable to flooding<br>☐ Flood waters may raise downstream turbidity and affect water quality | ☐ Sea level may push salt fronts upstream past water diversions<br>☐ Water infrastructure may be vulnerable to inundation or erosion<br>☐ Saltwater intrusion into groundwater may be more likely | |

# Appendix B. Southeast Florida Regional Climate Change Compact's 142 Action Items

These 142 action items are from "A Region Responds to a Changing Climate; Southeast Florida Regional Climate Change Compact Counties Regional Climate Action Plan 2; October 2017." These action items are sorted into the plan's twelve goal areas: 1) Agriculture, 2) Compact Coordination, 3) Energy and Fuel, 4) Natural Systems, 5) Public Health, 6) Public Outreach and Engagement, and 7) Public Policy Advocacy, 8) Regional Economic Resilience, 9) Risk Reduction and Emergency Management, 10) Social Equity, 11) Sustainable Communities and Transportation, and 12) Water. More information can be found at: http://www.southeastfloridaclimatecompact.org/

## Agriculture

***GOAL: Ensure the continued viability of agriculture in Southeast Florida in the face of climate change through policies and actions that encourage sustainable production, remove barriers to production, promote economic incentives, improve water reliability, and promote best management practices.***

AG-1 Promote policies that preserve the economic viability of agriculture.

AG-2 Continue to meet the water needs of agriculture.

AG-3 Promote locally produced foods and goods.

AG-4 Align research and extension with climate-related needs of agriculture.

AG-5 Maintain or create agriculture purchase of development rights programs.

AG-6 Assess opportunities for growers and agricultural landowners to manage land to lessen the impacts of climate change and incentivize those actions.

AG-7 Seek a national designation for Southeast Florida as a critical source of domestic agricultural products.

AG-8 Identify and reduce obstacles for enabling urban agriculture, gardening, and other backyard agricultural practices.

AG-9 Increase resources for the study and implementation of invasive, non-native pest and pathogen prevention; early detection; and rapid response.

AG-10 Promote sustainable aquaculture, perennial crops, diversified farming systems, precision agriculture, and re-contouring field elevations.

AG-11 Assess and address public health risks of more frequent and intense high-heat days to agriculture and farm workers.

## Compact Coordination

***GOAL: Strengthen coordination and collaboration in Southeast Florida on climate change issues by building the capacity of the Compact to meet evolving regional needs.***

CC-1 Establish and implement a regional communications strategy among business, government, and community leadership.

CC-2 Update regional unified sea level rise projections.

CC-3 Explore opportunities to better coordinate cross-agency and cross-jurisdiction reviews of major infrastructure projects.

CC-4 Continue to provide high-quality implementation support resources for jurisdictions seeking to implement the Regional Climate Action Plan and other sustainability and resilience measures.

CC-5 Develop and track regional indicators of climate change impacts, emissions reduction, and adaptation action.

CC-6 Create a Compact advisory group composed of organizations that represent the region's climate work, equitable community development, and vulnerable populations in order to track and share best practices on equitable climate action with the region.

## Energy and Fuel

***GOAL: Reduce consumption of electricity and fuel and increase renewable energy capacity to increase regional resilience, reduce greenhouse gas emissions, and improve emergency management and disaster recovery***

EF-1 Promote renewable energy through policies and technological development in order to reduce greenhouse gas (GHG) emissions.

EF-2 Advance energy efficiency and conservation through technological solutions, behavioral strategies, and policies in order to reduce greenhouse gas (GHG) emissions.

EF-3 Increase accessibility to energy efficiency solutions for limited-income families.

EF-4 Increase accessibility to distributed renewable energy technology.

EF-5 Utilize renewable and distributed energy technologies for emergency management and disaster recovery.

EF-6 Streamline permitting and administrative processes to reduce the soft costs associated with renewable energy technologies.

EF-7 Establish financing mechanisms for current homeowners to invest in renewable energy and energy efficiency.

EF-8 Build the capacity for distributed renewable energy and energy storage technologies in future building stock.

EF-9 Enable grid-independent energy and waste-to-energy systems.

EF-10 Enable a fuel-efficient public vehicle fleet.

EF-11 Establish a fuel-efficient municipal vehicle fleet.

EF-12 Promote community use of electric vehicles (EV).

## Natural Systems

***GOAL: Implement monitoring, management, and conservation programs designed to protect natural systems and the services they provide to society while improving their capacity for climate adaptation.***

NS-1 Foster public awareness of the impacts of climate change on the region's natural systems and ecosystem services.

NS-2 Promote collaborative federal, state, and local government conservation land acquisition and easement programs.

NS-3 Support regional wildland fire management coordination efforts.

NS-4 Develop sustainable financing for the monitoring, protection, restoration, and management of natural areas and ecosystem services.

NS-5 Identify or create a regional group to coordinate a plan to create adaptation corridors, living collections, and other approaches to species dispersal and conservation.

NS-6 Conduct a predictive assessment of current and potential invasive species ranges and impacts.

NS-7 Promote the protection and restoration of coastal natural systems and the creation of living shorelines at the regional scale.

NS-8 Support coral reef protection, restoration, and sustainable-use initiatives to help Florida's sensitive reefs adapt to the changing climate and ocean acidification.

NS-9 Advocate for federal and state funding for applied monitoring and climate-related science, conducted in partnership with the Florida Climate Institute.

NS-10 Examine and propose revisions to environmental regulations to account for the effects of climate change.

NS-11 Identify the effects of climate change on fish populations, the sustainability of key fisheries, and the fishing industry, then develop adaptation plans as needed.

NS-12 Promote the protection, restoration, and creation of freshwater wetlands, open space buffer areas, and connectivity between freshwater and estuarine waters.

NS-13 Develop and implement long-term, sustainable, regional solutions to beach erosion and sediment supply.

NS-14 Maintain, create, and/or restore urban tree canopy.

NS-15 Support and advocate for continued implementation and funding on the state and federal levels for the Comprehensive Everglades Restoration Plan.

## Public Health

***GOAL: Build capacity to proactively mitigate climate-related public health risks in Southeast Florida.***

PH-1 Understand and communicate public health risks associated with climate change.

PH-2 Adopt and update all Florida Department of Health plans to reflect climate and sea level rise impacts on public health.

PH-3 Adapt federal and state public health resources to support specific community needs.

PH-4 Reduce extreme heat exposure to promote public health.

PH-5 Advocate for policy changes and funding for local health departments to collect data more frequently to influence public health plans.

PH-6 Increase reporting of health data monitoring systems to evaluate emerging diseases related to climate change.

PH-7 Develop tools to assess the impacts of climate change and sea level rise on existing chronic conditions and to report trends or concerns for action.

## Public Outreach and Engagement

***GOAL: Build public awareness of the climate-related risks facing Southeast Florida and the opportunities for early, coordinated action to address these risks.***

PO-1 Assess community needs to guide local government communications.

PO-2 Promote public awareness and understanding of climate impacts, as well as the personal actions and public policy options available to respond to climate change.

PO-3 Inspire community action to address the causes and impacts of climate change.

PO-4 Create open data platforms and digital tools.

PO-5 Create culturally- and linguistically-appropriate information gathering tools and strategies to help inform decision-makers of the priorities and concerns in communities.

## Public Policy Advocacy

**GOAL: *Guide and influence all levels of government to address climate change in relevant policies, programs, and legislation.***

PP-1 Support—at all levels of government—policy, legislation, and funding to reduce greenhouse gas emissions in all sectors, use less energy and water, deploy renewable energy and low-carbon transportation, prepare for and adapt to climate impacts, build community resilience, and study climate and earth science.

PP-2 Develop common positions on climate, energy, and resilience issues, and advocate jointly as the Compact for those positions before state and federal legislatures, regulatory bodies, and the executive and judicial branches of government.

PP-3 Urge federal, state, regional, and local partners to prioritize climate change considerations in the planning, construction, and operation of the regional water management and flood control system.

PP-4 Participate in coalitions of public-, private-, nonprofit-, and/or academic-sector actors dedicated to climate, energy, and resilience issues.

PP-5 Coordinate climate, energy, and resilience policies among counties, municipalities, school districts, and other units of government in the region.

PP-6 Prioritize climate policies that advance social and economic equity for high vulnerability populations and limited-income residents

PP-7 Consider the direct and indirect impacts of projects, policies, and investments on relevant stakeholders.

PP-8 Encourage the general public to engage in civic discourse regarding climate, energy, and resilience issues.

## Regional Economic Resilience

***GOAL: Establish a regional resilience strategy involving elected and business leadership, inclusive of funding mechanisms to guide, incentivize, protect, and promote public and private investments and the economic integrity of the region.***

ER-1 Establish a regional economic resilience communications strategy.

ER-2 Advance regional resilience infrastructure standards.

ER-3 Seek federal and state engagement to develop a resilience strategy.

ER-4 Pursue the development of regional water models.

ER-5 Integrate resilience and economic development at the regional level.

ER-6 Establish funding strategies to provide for equitable investment.

ER-7 Engage in the National Flood Insurance Program (NFIP) process.

ER-8 Serve as a model for regional resilience.

ER-9 Strive for economic equity in adaptation planning.

## Risk Reduction and Emergency Management

***GOAL: Prepare for the inevitable shocks and stresses experienced in Southeast Florida through coordinated and interdisciplinary risk reduction and emergency management planning and investment.***

RR-1 Identify and quantify infrastructure and populations at risk to sea level rise and storm surge.

RR-2 Integrate climate scenarios into emergency planning, evacuation training, and exercises.

RR-3 Integrate climate vulnerability analysis data, as well as climate adaptation planning and funding, into existing emergency planning and funding documents.

RR-4 Create and invest in strategic pre-disaster plans for post-disaster recovery.

RR-5 Identify the most advanced insurance coverage models to reduce exposure in the face of climate-related risks.

RR-6 Prioritize adaptation investments to reduce the impact of flooding and sea level rise on transportation infrastructure, particularly on evacuation routes.

RR-7 Ensure local comprehensive plans align with the state Coastal Construction Control Line.

RR-8 Continue to adopt and update consistent plans at all levels of government in the region that address and integrate mitigation, sea level rise, and climate change adaptation.

RR-9 Review the Florida Building Code through the lens of climate vulnerability.

RR-10 Understand and communicate risk information to all residents.

RR-11 Promote and leverage existing policies and programs designed to reduce flood risks and economic losses.

RR-12 Increase long-term community resilience and disaster recovery through distributed renewable energy and battery storage systems.

RR-13 Use effective social media for emergency messaging, public health updates, and tidal flooding updates.

RR-14 Encourage individual small business recovery plans and personal home adaptation plans.

RR-15 Support disaster planning and preparedness training for city and county staff.

RR-16 Connect with members from highly vulnerable populations to build trust and inform emergency management planning.

RR-17 Ensure the emergency management definition of "communities at risk" includes economically vulnerable people.

RR-18 Align and integrate emergency management staff and responsibilities with chief resilience officer roles to bolster long-term plans

## Social Equity

***GOAL: Guide and support municipalities and counties in the Compact region to create equitable climate policies, programs, and decision-making processes that consider local socio-economic and racial inequities and ensure all can participate and prosper.***

EQ-1 Encourage dialogue between elected officials, staff, and socially vulnerable populations about local climate impacts and community priorities to inform leaders of community needs.

EQ-2 Integrate social vulnerability data into all local government processes.

EQ-3 Support public infrastructure that enables economic mobility, health, and safety for all community members.

EQ-4 Address the needs of socially vulnerable populations by engaging existing community leaders and representative organizations in decision-making processes, particularly for critical public infrastructure.

EQ-5 Build the capacity of existing and future leaders of socially vulnerable populations to ask, analyze, and communicate about their community's climate resilience.

EQ-6 Partner with intermediary organizations that have deep community ties with socially vulnerable populations to co-create engagement and outreach strategies.

EQ-7 Provide equity and social justice training for local government staff.

## Sustainable Communities and Transportation

***GOAL: Adapt to the impacts of climate change and reduce greenhouse gas emissions by reshaping where and how to build and move from place to place.***

ST-1 Incorporate unified sea level rise projections, by reference, into all city, county, and regional agency comprehensive plans, transportation and other infrastructure plans, and capital improvement plans.

ST-2 Ensure locally produced maps for planning and project documents include the latest storm surge and sea level rise projections.

ST-3 Use vulnerability and risk assessment analyses and tools to identify priorities for resilience investments.

ST-4 Designate adaptation action areas, restoration areas, and growth areas as a priority setting tool for vulnerable areas, and as a means to maximize benefits to natural systems while guiding people and commerce to less vulnerable places in the region.

ST-5 Ensure beneficial social equity outcomes in considering the impacts of land use policy, public infrastructure, and public service decisions on high-vulnerability populations.

ST-6 Develop localized adaptation strategies for areas of greatest climate-related vulnerability in collaboration with appropriate agencies and jurisdictions to foster multi-jurisdictional solutions and maximize co-benefits.

ST-7 Incorporate strategies to reduce risk and economic losses associated with sea level rise and flooding into local comprehensive plans, post-disaster redevelopment plans, building codes, and land development regulations.

ST-8 Consider the adoption of green building standards to guide decision-making and development and to provide an incentive for better location, design, and construction of residential, commercial, and mixed-use developments and redevelopment.

ST-9 Implement best practices for the identification, evaluation, and prioritization of threatened resources to preserve historic and archaeological resources and increase resource resilience.

ST-10 Employ transit-oriented developments and other planning approaches to promote higher-density development capable of supporting more robust transit.

ST-11 Modify local land use plans and ordinances to support compact development patterns, creating more walkable and affordable communities.

ST-12 Develop and implement policies and design standards that recognize the transportation system's most vulnerable users and incorporate sustainable elements.

ST-13 Conduct an assessment of unused or underutilized properties and develop an approach for utilizing such properties that enhances overall resilience goals.

ST-14 Adopt social equity policies that support equitable economic growth and increase affordable housing opportunities near critical infrastructure.

ST-15 Develop policies to enhance the urban tree canopy to protect pedestrians and bicyclists from heat and pollution exposure.

ST-16 Phase out septic systems where necessary to protect public health and water quality.

ST-17 Ensure investments reduce greenhouse gas (GHG) emissions and increase the resilience of the transportation system to extreme weather and climate impacts.

ST-18 Increase the use of transit as a transportation mode for the movement of people in the region.

ST-19 Expand, connect, and complete networks of bicycle and pedestrian facilities, including those supporting access to transit.

ST-20 Expand the use of transportation demand management strategies to reduce peak period and single-occupant vehicle travel.

ST-21 Address resilience, maximize efficiency, and increase the use of low-carbon transportation modes for the movement of freight in the region.

ST-22 Implement transportation system management and operations strategies to maximize the efficiency of the existing transportation system in a coordinated manner across local governments and agencies in the region.

ST-23 Use evidence-based planning and decision-making for transportation system investments and management.

## Water

***GOAL: Advance the water management strategies and infrastructure improvements needed, in parallel with existing water conservation efforts, to mitigate the potential adverse impacts of climate change and sea level rise on water supplies, water and wastewater infrastructure, and water management systems, inclusive of regional canal networks, pumps, control structures, and operations.***

WS-1 Foster innovation, development, and exchange of ideas for managing water.

WS-2 Ensure consistency in water resource scenarios used for planning.

WS-3 Plan for future water supply conditions.

WS-4 Coordinate saltwater intrusion mapping across Southeast Florida.

WS-5 Maintain regional inventories of water and wastewater infrastructure.

WS-6 Develop a spatial database of resilience projects for water infrastructure.

WS-7 Modernize infrastructure development standards in the region.

WS-8 Address the resilience of the regional flood control system.

WS-9 Update the regional stormwater rule.

WS-10 Integrate combined surface and groundwater impacts into the evaluation of at-risk infrastructure and the prioritization of adaptation improvements.

WS-11 Encourage green infrastructure and alternative strategies.

WS-12 Integrate hydrologic and hydraulic models.

WS-13 Practice integrated water management and planning.

WS-14 Advance comprehensive improvements to regional and local stormwater management practices.

WS-15 Foster scientific research for improved water resource management.

WS-16 Expand partnerships and resources to further innovation in water resource management.

WS-17 Advance capital projects to achieve resilience in water infrastructure.

WS-18 Coordinate innovation and regional funding.

WS-19 Recognize adaptable infrastructure.

WS-20 Support the Comprehensive Everglades Restoration Plan (CERP).

WS-21 Expand regional surface water storage.

# Appendix C. Broward County FY2016-2020 Strategic Plan

## The Broward County Board of County Commissioners envisions:

- From our *Sawgrass to our Seagrass*, a home for everyone seeking a sense of community and an exceptional quality of life, and a destination for visitors from every corner of the globe.
- A model County, governed in an open and ethical manner, where innovative ideas are encouraged, and public and private sectors work collaboratively to achieve shared goals.
- A vibrant economy with a diverse, skilled workforce, in a County offering unique advantages that attract all types of businesses to create equitable, countywide prosperity.
- A sustainable system of world-class intermodal transportation, infrastructure, quality human services, public safety, affordable housing, recreation, arts and culture, complementing and balancing our natural resources and environment.

### *A. VALUE: Ensuring economic opportunities for Broward's diverse population and businesses*

***Goals:***

1. Attract and retain all types of business, especially high-wage industries that offer employee benefits, through partnerships with the Alliance, chambers of commerce, colleges and universities, CareerSource, and any other available avenues.
2. Increase the economic strength and impact of revenue-generating County enterprises balancing economic, environmental, and community needs.
3. Diversify the local economy, attract industries offering high-wage jobs with benefits while balancing economic, educational, environmental, and community needs.
4. Utilize policies and strategies to create employment opportunities and supports for economically disadvantaged members of the community (e.g., Workforce Investment Program, quality and affordable child care, trainee and internship opportunities tied to Skills Gap Assessment by Alliance, better collaboration with colleges and universities, and construction projects using small and certified businesses).

### *B. VALUE: Prominently marketing Broward County as a brand, while increasing public understanding of programs and services*

***Goals:***

1. Consistently and effectively market and brand Broward County programs and services, locally and globally, through effective collaboration
2. Promote to the public, through effective diversification of mediums and messages, the County's positive works and efforts to improve the quality of life for all residents.

### *C. VALUE: Approaching human services collaboratively and compassionately, with special emphasis on the most vulnerable*

### *Goals:*

1. Effectively advocate for and acquire municipal, state and federal financial support to equitably address health and human services needs of the entire community, through a truly coordinated system of care.

2. Deliver evidence-based services to the public, and connect customers and their family members, to sustainable support, with special emphasis on financial supports

3. Collaborate with public and private partners to find creative, equitable, and responsible solutions to systemic community problems, especially permanent, supportive housing for persons experiencing, or at risk of, homelessness.

### *D. VALUE: Cooperatively delivering an efficient and accessible regional intermodal transportation network*

### *Goals:*

1. Actively seek through an effective marketing plan, a full penny transportation surtax in 2018 to support a world-class intermodal transportation system including: a robust and reliable transit level of service, rail, intersection reconfiguration, adaptive signalization, and congestion relief.

2. Seek local, state, federal funding and public support for transportation projects that connect to existing transportation corridors, balancing ridership with community redevelopment demands.

3. Support the development, design and construction of sustainable, multi-modal transportation facilities throughout the County, to meet the demands of residents, travelers, and businesses.

### *E. VALUE: Encouraging investments in renewable energy, sustainable practices and environmental protection*

### *Goals:*

1. Seek funding for, implement policies and pursue projects promoting, the use of alternative energies and sustainable practices.

2. Proactively lead in the planning, design and construction of projects supporting resilience and climate adaptation, including coordination with other entities to foster resilient design as part of local and regional projects, especially shore protection efforts.

3. Increase water quality protection efforts and lead creative approaches to water storage and aquifer recharge, as well as diversification of water supplies, regionally.

4. Educate the public about the fragile South Florida ecosystems, impacts of severe weather, sea level rise, and climate change, with special emphasis on the coral reef ecosystem.

5. Support and seek local, state, and federal funds for coastal management of coral reefs through collaboration with other governmental jurisdictions.

### *F. VALUE: Cultivating community culture, arts, recreation and life-long learning*

***Goals:***

1. Provide diverse artistic, cultural, educational, and historical amenities and programs that contribute to a vibrant, multi-cultural and economically-viable community, including an annual signature event.
2. Improve access to business development, educational, cultural, and recreational opportunities and amenities to the economically disadvantaged.
3. In coordination with our community partners, market and deliver world-class recreational opportunities.
4. Enhance funding for Library programs and various life-long-learning opportunities for our residents and visitors.

### *G. VALUE: Offering sustainable, compatible, innovative housing options for all income-levels, including integrated, permanent supportive housing*

***Goals:***

1. Facilitate a regional approach to growth and redevelopment through coordination and collaboration at the federal, state, and local levels.
2. Increase the availability of affordable housing of all types, countywide, in every community using effective, uniform criteria, policies and strategies.
3. Identify affordable workforce housing funding, to include a local, dedicated source of revenue.
4. Develop, through municipal collaboration, neighborhoods and communities connecting affordable housing to reliable, accessible modes of transportation.
5. Promote housing and community redevelopment that integrates energy efficiency, community resilience, and other livability standards and initiatives.

### *H. VALUE: Consistently delivering responsive, efficient, quality services to the public and internal customers*

***Goals:***

1. Create a system of expectation and accountability across the institution that assures effective communication, continuous performance review and improvement.
2. Offer effective mandatory and optional coursework, addressing the lines of business and needs of the entire organization.
3. Grounded in the intrinsic value of quality Public Service, respond to every customer, internal or external, expeditiously, thoroughly and professionally.

4. Build into every process and service effective checks and balances that do not cause inefficiency, but rather ensure consistency, continuity, and quality.

# Appendix D. DASEES Workshop Materials

## Workshop Participants

### *September 21, 2015, City Hall, Dania Beach, FL*

| Name | Affiliation | Category |
|---|---|---|
| Sandy- Michael McDonald | Broward County | Economic Development/ Small Business |
| Samantha Danchuk | Broward County | Engineering |
| Lenny Vialpando | Broward County | Environmental Licensing & Permitting |
| Carol Morgenstern | Broward County | Parks |
| Jill Horwitz | Broward County | Planning |
| Maribel Feliciano | Broward County | Planning |
| Jason Liechty | Broward County | Public Policy |
| Kristen Carter | Broward County | Public Policy- County Commissioner's Aide |
| Jennifer Jurado | Broward County | Water Resources |
| John Kraus/ Susan Bodman | Broward County Utilities/ WWS | Engineering- Water Supply/ Wastewater |
| Buffy Sanders | Broward MPO | Transportation |
| Greg Stuart | Broward MPO | Transportation |
| James Cromar | Broward MPO | Transportation |
| Peter Gies | Broward MPO | Transportation |
| Sue Gallagher | Children's Services Council | Social Issues/ Education |
| Mark Laferrier | City of Dania Beach | Community Development |
| Rachel Bach | City of Dania Beach | Community Redevelopment |
| Dan Murphy | City of Dania Beach | Economic Development |
| Eleanor Norena | City of Dania Beach | Engineering- Floodplain Management |
| Fred Bloetscher | City of Dania Beach | Engineering- Stormwater |
| Ronnie Navarro | City of Dania Beach | Engineering/ Public Services |
| Anna Christine Carrie | City of Dania Beach | Planning |

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|---|---|---|
| Corinne Lajoie | City of Dania Beach | Planning |
| Mariluz Maldonado | City of Dania Beach | Planning |
| | City of Dania Beach | Planning & Zoning Board |
| Mayor Marco Salvino, Sr. | City of Dania Beach | Public Policy- City Mayor |
| Colin Donnely | City of Dania Beach (Assistant City Manager) | Public Administration |
| Bob Shapiro | Developer | Stakeholder- Developer |
| Brian Dyson | EPA/ORD | Structured Decision Making |
| Tammy Newcomer-Johnson | EPA/OW | Water Resources |
| Lois Bush | FDOT | Transportation |
| | Green Advisory Board | Stakeholder- Sustainability |
| | Marine Advisory Council | Stakeholder- Marine Economy |
| Kelly Black | Neptune | Structured Decision Making |
| Richard Grosso | Nova University Law School | Public Policy- Land Use |
| Peter Flynt | Owner | Stakeholder- Land Owner |
| Anne Castro | Planning Council (former City Commissioner) | Public Policy |
| Courtney Biscardi | Urban League | Social Programs |

### *September 22, 2015, City Hall, Dania Beach, FL*

| Name | Affiliation | Category |
|---|---|---|
| Samantha Danchuk | Broward County | Engineering |
| Jennifer Jurado | Broward County | Water Resources |
| Mike Zygnerski | Broward County | Water Resources |
| Buffy Sanders | Broward MPO | Transportation |
| Eleanor Norena | City of Dania Beach | Engineering- Floodplain Management |
| Fred Bloetscher | City of Dania Beach | Engineering- Stormwater |

| | | |
|---|---|---|
| Ronnie Navarro | City of Dania Beach | Engineering/ Public Services |
| Corinne Lajoie | City of Dania Beach | Planning |
| Mark Laferrier | City of Dania Beach | Community Development |
| Brian Dyson | EPA/ORD | Structured Decision Making |
| Tammy Newcomer-Johnson | EPA/OW | Water Resources |
| Kelly Black | Neptune | Structured Decision Making |

### *March 18, 2016, Broward County Government Offices, Fort Lauderdale, FL*

| Name | Affiliation | Expertise |
|---|---|---|
| Samantha Danchuk | Broward County | Engineering |
| Jennifer Jurado | Broward County | Water Resources |
| Mike Zygnerski | Broward County | Water Resources |
| Lenny Vialpando | Broward County | Water Resources |
| Albert Lee | Broward County | Planning/Sustainability |
| Buffy Sanders | Broward MPO | Transportation |
| Anne-Christine Carrie | City of Dania Beach | Zoning |
| Kelly Ray | City of Dania Beach | Planning |
| Leslie Kerr | City of Dania Beach | Planning |
| Brian Dyson | EPA/ORD | Structured Decision Making |
| Tammy Newcomer-Johnson | EPA/OW | Water Resources |
| Kelly Black | Neptune | Structured Decision Making |
| Dorothy Sifuentes | USGS | Hydrologic Modeling |

## Workshop Agenda – September 21-22, 2015

# Dania Beach Resiliency Planning Workshop

**September 21-22, 2015**
**City Hall,**
**Dania Beach, FL**

### Stakeholder Preference Workshop Agenda

08:30 – 08:40 Welcome (J Jurado)
08:40 – 08:50 EPA Region 4 Overview (R Moura)
08:50 – 09:00 Preparing for Climate Change (T Newcomer-Johnson)
09:00 – 09:15 Workshop goals (B Dyson)
09:15 – 09:45 Introductions (K Black)
09:45 – 10:15 Dania Beach Resiliency background (J Jurado, S Danchuk)
10:15 – 10:30 Break
10:30 – 12:00 What are your preferences and concerns? (K Black, T Stockton)
12:00 – 01:00 Lunch
01:00 – 02:30 How do we measure success? (T Stockton, K Black)
02:30 – 02:45 Break
02:45 – 04:15 How do we achieve success? (T Stockton, K Black)
04:15 – 04:30 Wrap up (B Dyson)

### Consequences Workshop Agenda

08:30 – 08:45 Welcome & Introductions (S Danchuk)
08:45 – 09:15 Structuring decisions (B Dyson)
09:15 – 09:45 Stakeholder objectives hierarchy, performance measures and alternatives – outcomes of Day 1 (B Dyson)
09:45 – 10:30 Influence Diagram Development (T Stockton, K Black)
10:30 – 10:45 Break
10:45 – 12:00 Model Structuring (T Stockton, K Black)
12:00 – 01:00 Lunch
01:00 – 02:00 Model Structuring (T Stockton, K Black)
02:00 – 02:15 Break
02:15 – 03:00 Identification of Resources (T Stockton, K Black)
03:00 – 04:00 Identification of Technical Gaps (T Stockton, K Black)
04:00 – 04:30 Wrap up (B Dyson, J Jurado)

## Workshop Description – September 21-22, 2015

# Dania Beach Resilience Planning Workshop

**Purpose:**

*This two-day meeting will bring stakeholders together to develop common objectives and solutions for the resilience challenges facing Dania Beach and identify the technical needs to evaluate those solutions.*

**Workshop Objectives**

- Bring stakeholders together to develop a shared understanding of the inter-related economic, social, and environmental challenges facing Dania Beach.
- Identify resilience goals for the region, including health & safety, community well-being, ecological integrity, and economic competitiveness.
- Devise management actions responsive to identified goals
- Develop conceptual models to evaluate proposed resilience management actions, and identify scientific, technical, and socio-economic data/information needs.

**Day 1***:* The aims of Day 1 are to help stakeholders develop clear, comprehensive, objectives and performance measures, and identify practical solutions that help achieve objectives.

**Day 2:** The activities of Day 2 include applying the tools of systems thinking and structured decision-making in a participatory modeling process. It will focus on the technical/scientific needs to assess how well proposed actions identified in Day 1 meet objectives. This in turn, will allow subsequent development of an implementation plan for the resilient redesign of Dania Beach.

## Speaker Biographies – September 21-22, 2015

**Ms. Kelly Black** is an environmental statistician and decision analyst with over two decades experience supporting the U.S. EPA in data quality and usability issues. Kelly works to integrate stakeholder opinions into optimal solutions for complex problems. *President, Neptune and Company, Inc., kblack@neptuneinc.org, 720-746-1803, ext. 1005.*

**Dr. Samantha Danchuk, P.E.,** is responsible for implementation of the County's priority actions pertaining to energy, climate action and resilience, sustainability, and urban lands enhancement. Since joining Broward County in 2014, Samantha has overseen the update of the County's Climate Action Plan, the installation of the County's first Community Solar Demonstration Project, the launch of Plan It Green, the County's event-based local carbon offset program, and provided support for the Compact's Resilient Redesign Workshops and Sea Level Rise Working Group, the Climate Change Task Force and Government Operation Climate Change Working Group. *Environmental Planning & Community Resilience Division, Broward County, SDANCHUK@broward.org, (954) 519-1295.*

**Dr. Brian Dyson** is a researcher in the U.S. EPA's Office of Research and Development, and is the Lead for the Decision Science and Support Tools Project in the Sustainable and Healthy Communities Research Program. *Operations Research Analyst National Risk Management Research Laboratory, U.S. Environmental Protection Agency, Office of Research and Development, dyson.brian@epa.gov, (513) 569-7789.*

**Dr. Jennifer Jurado** is responsible for county wide water resource policy and planning; implementation of the County's regional climate initiatives; administration of beach, marine and land stewardship programs; and environmental monitoring. Since joining Broward County in 2002, Jurado has overseen development of Broward's county wide integrated water resources plan, the convening of regional water and climate change task forces, and advancement of multi-jurisdictional initiatives focused on water conservation, alternative water supply planning, and climate adaptation. *Director, Environmental Planning & Community Resilience Division, Broward County, JJURADO@broward.org, (954) 519-1295.*

**Ms. Rafaela Moura** is the Energy and Climate Change Coordinator for EPA Region 4 (http://www.epa.gov/climatechange/impacts-adaptation/southeast.html) with over 15 years of sustainable community development experience. She has extensive experience in pollution and mitigation control projects. Rafaela has been involved in a plethora of community and stakeholder outreach consultations focused on addressing community needs and strengthening community participation. *Environmental Protection Specialist, Region IV Energy and Climate Change Coordinator, Office of the Regional Administrator, U.S. Environmental Protection Agency, moura.rafaela@epa.gov, (404) 562-9607.*

**Dr. Tammy Newcomer Johnson** supports the Climate Ready Estuaries (CRE) Program (http://www2.epa.gov/cre) in EPA's Oceans and Coastal Protection Division. CRE works with the National Estuary Programs and the coastal management community to: (1) assess climate change vulnerabilities, (2) develop and implement adaptation strategies, and (3) engage and educate stakeholders. *Postdoc ORISE Participant, Oceans and Coastal Protection Division, Office of Wetlands, Oceans, and Watersheds, U.S. Environmental Protection Agency, Office of Water, Newcomer-Johnson. Tammy@epa.gov, (202) 566-1653.*

**Dr. Tom Stockton** is an environmental statistician, decision analyst, and modeler with Neptune and Company. Tom's work focuses on facilitating environmental decision-making by integrating environmental spatial and temporal statistical modeling, process modeling, and economics under a common structured decision-making framework. *Principal Scientist, Neptune and Company, Inc., Stockton@neptuneinc.org, (505) 662-0707, ext.* 17.

**YOU!** This workshop depends on the active involvement of all participants. Please be sure to speak up and share your opinions. We won't be successful without your input, so both to increase your enjoyment and to make our planning more robust, please express your opinions freely and constructively. *Various City, County, and*

*Community representatives, Dania Beach Stakeholders, (555) 555-5555, stakeholders@imaginarydaniabeachURL.*