

A Decision-Making Framework for Climate Resilience: Community Engagement and Bayesian Network Analysis

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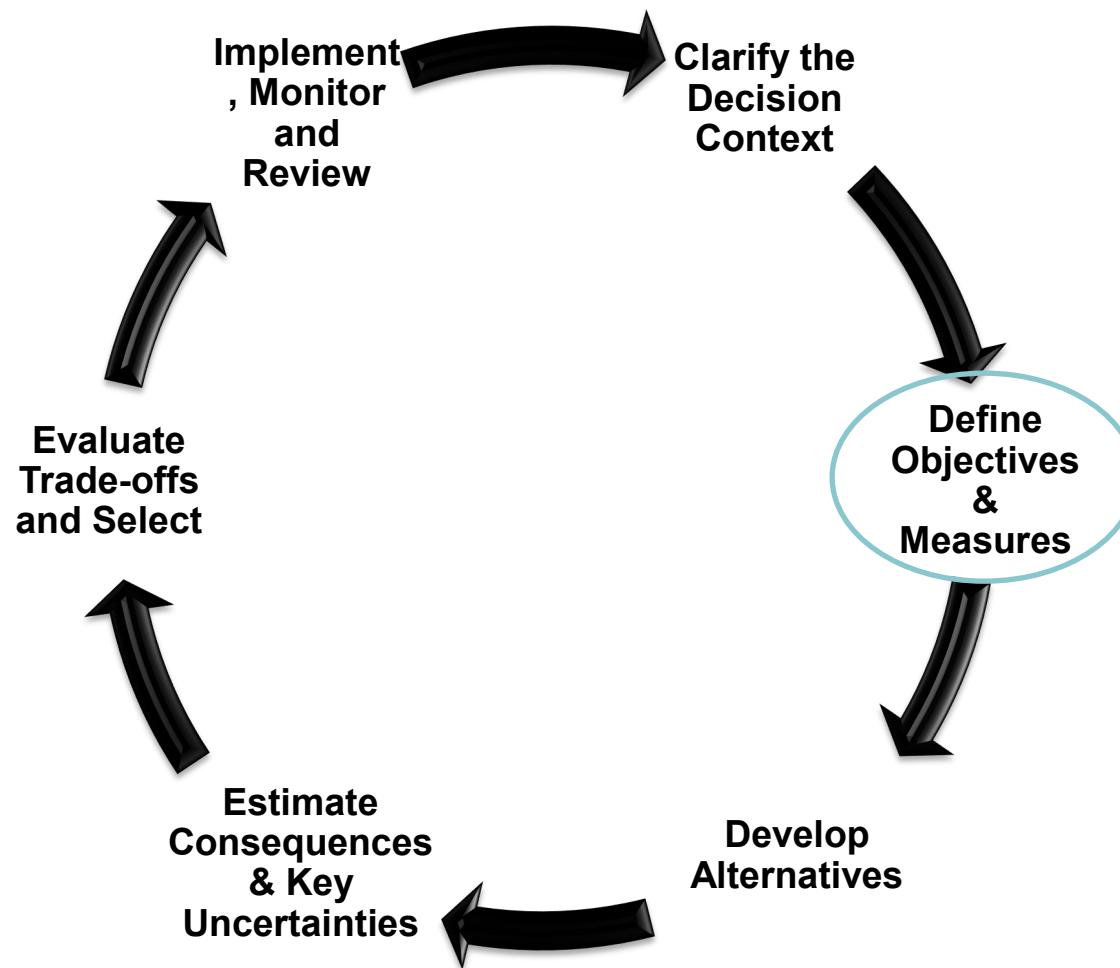
Center for Environmental Solutions and Emergency Response

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Steps in decision analysis

Risk assessment and decision analysis can inform one another at each step of the process

PrOACT/SDM
framework



Objective: something that is sought or valued
Statement of an objective: what is valued, the direction of preference, and a context for alternatives to achieve the objective (Dunning et al. 2000; McDaniels 2000)

Example statement of an objective:

“Increase health by finding a better way to exercise”

Value = *health*

Direction of preference = *increasing*

Context of alternatives = *finding a better way to exercise*

Benefits of specifying objectives

- **Identify what is valued by stakeholders**
- **Reduce double counting**
- **Add transparency to environmental management**
- **Account for unintended consequences**
- **Derive innovative alternatives**
- **Find new opportunities and additional benefits**
- **Focus efforts for modeling and data acquisition**

León OG. 1999. Value-Focused Thinking versus Alternative-Focused Thinking: Effects on Generation of Objectives. *Organizational Behavior and Human Decision Processes* 80(3):213-227.

Merrick JRW. 2010. Defining objectives and criteria for decision problems. In JJ Cochran (ed) *Wiley Encyclopedia of Operations Research and Management Science*. John Wiley & Sons, Inc.

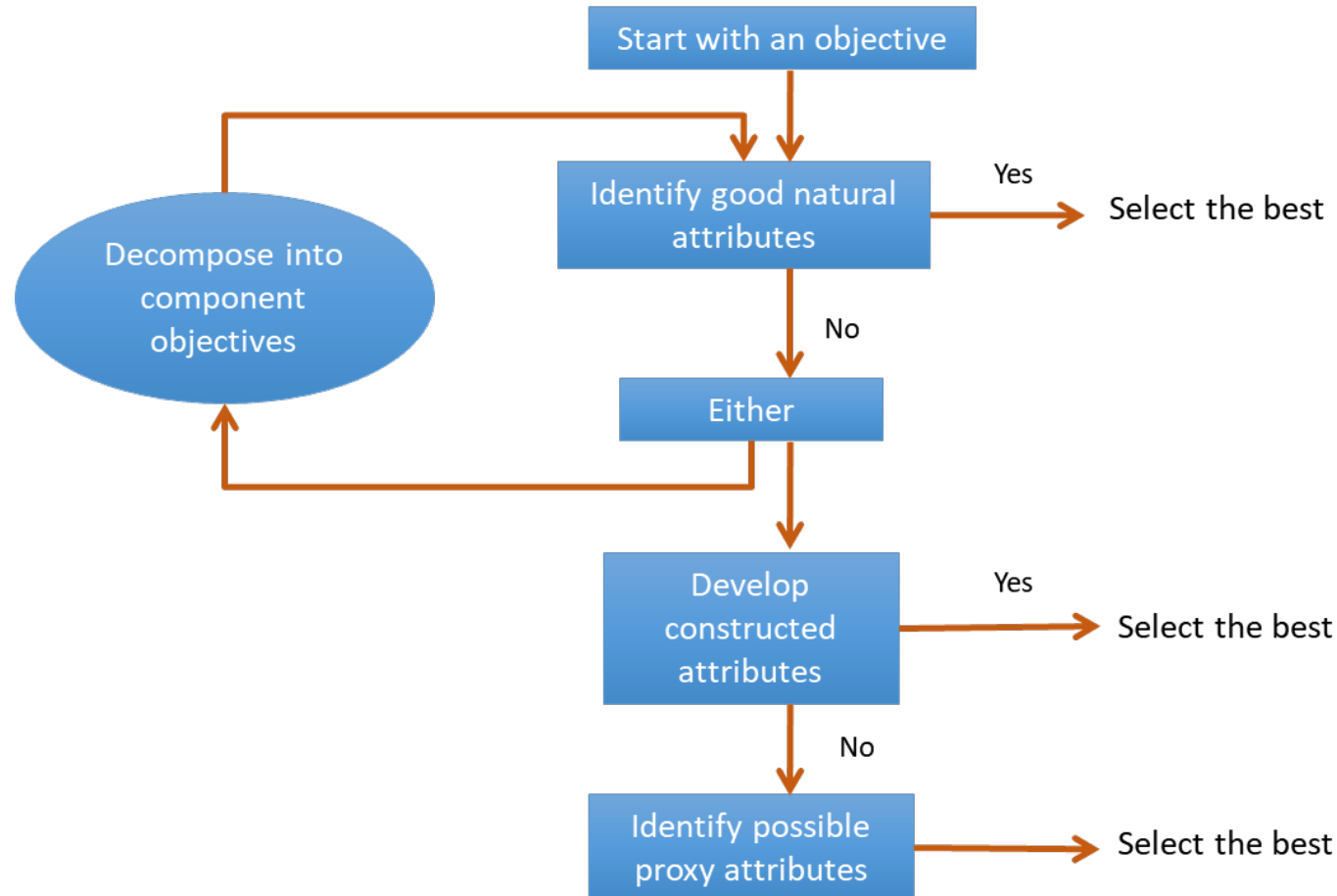
Problem formulation- the foundation

Value statements

- Fundamental objectives

Measures of value

- Attributes/Performance measures

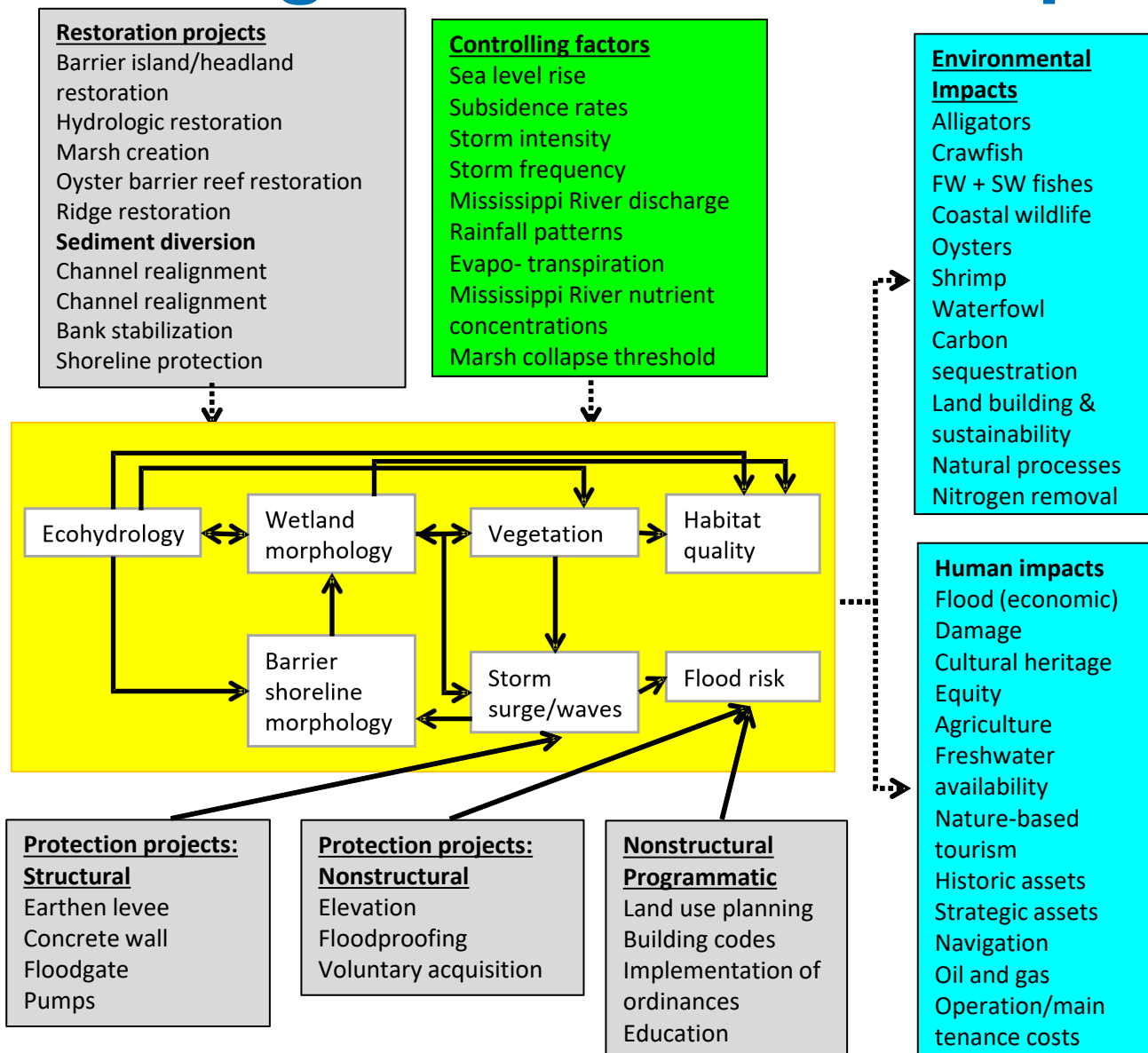


A good attribute is:

- ***Unambiguous***
- ***Comprehensive***
- ***Direct***
- ***Operational***
- ***Understandable***

From: Keeney, R.L. and Gregory, R.S., 2005.
Selecting attributes to measure the achievement of objectives. *Operations Research*, 53(1), pp.1-11.

Problem formulation- Logic models ↔ Conceptual models

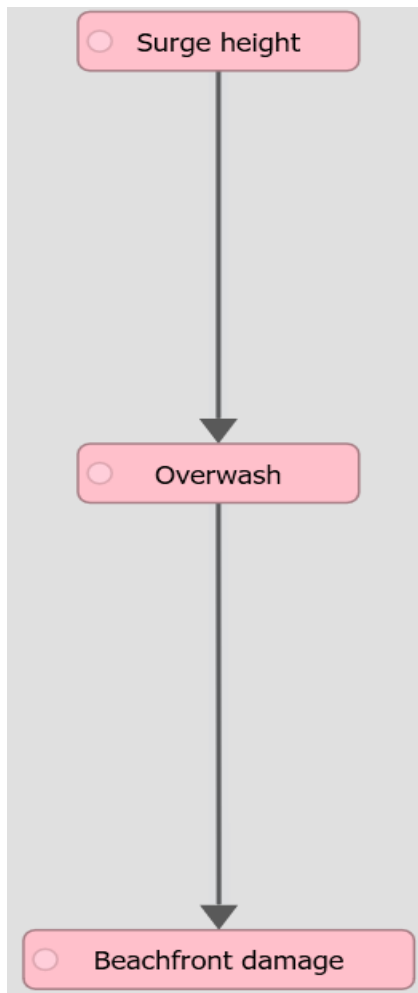


Carriger, J.F., Dyson, B.E. and Benson, W.H., 2018. Representing causal knowledge in environmental policy interventions: Advantages and opportunities for qualitative influence diagram applications. *Integrated environmental assessment and management*, 14(3), pp.381-394.

Coastal Protection and Restoration Authority of Louisiana. 2012. Louisiana's comprehensive master plan for a sustainable coast. Baton Rouge (LA). 190 p

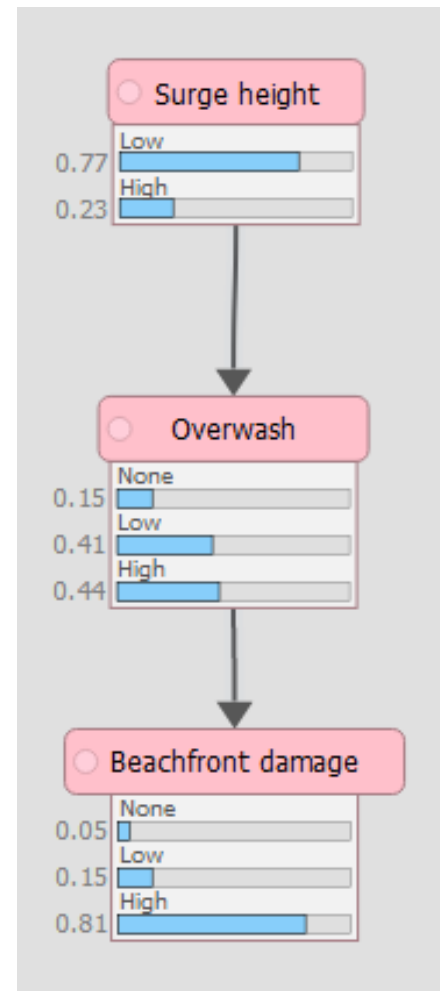
Task Force on Community Preventive Services. 2015. Cardiovascular disease: Interventions engaging community health workers. Oxford (UK): Oxford Univ. [cited 2017 Sep 3]. <https://www.thecommunityguide.org/>

Probabilistic risk assessment



Bayesian Network Modeling

- Probabilistic hypothesis testing



Overwash node conditional probability table

Overwash Settings

Description **Node Probability Table** **Node Evidence**

Choose NPT Input Approach: Direct

Filters

☐ Hide impossible combinations

☒ Filter parents (click on parent conditions to filter):

Surge height

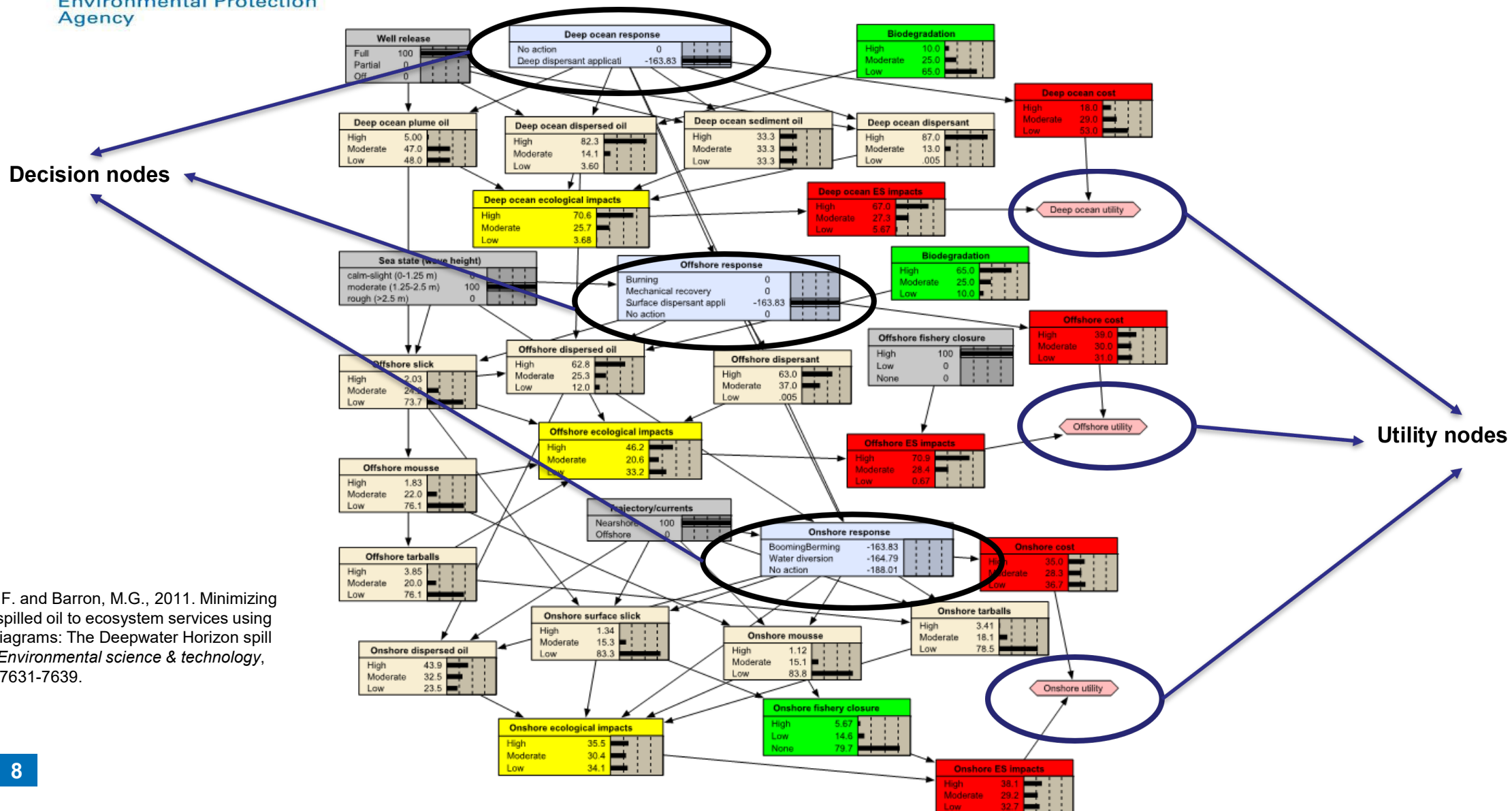
Low High

Conditional Probability Table (click white cells to enter probabilities for each combination)

Surge height	Low	High	
None	0.19	0.02	
Low	0.49	0.14	
High	0.32	0.83	

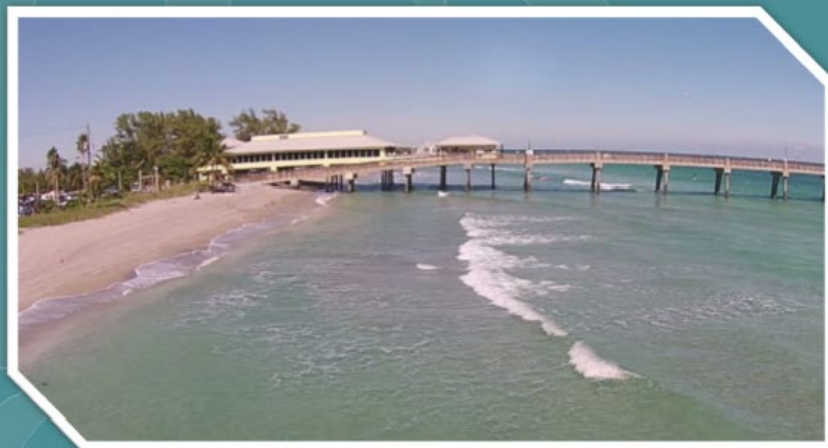
Ok Cancel

Estimate consequences



Carriger, J.F. and Barron, M.G., 2011. Minimizing risks from spilled oil to ecosystem services using influence diagrams: The Deepwater Horizon spill response. *Environmental science & technology*, 45(18), pp.7631-7639.

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

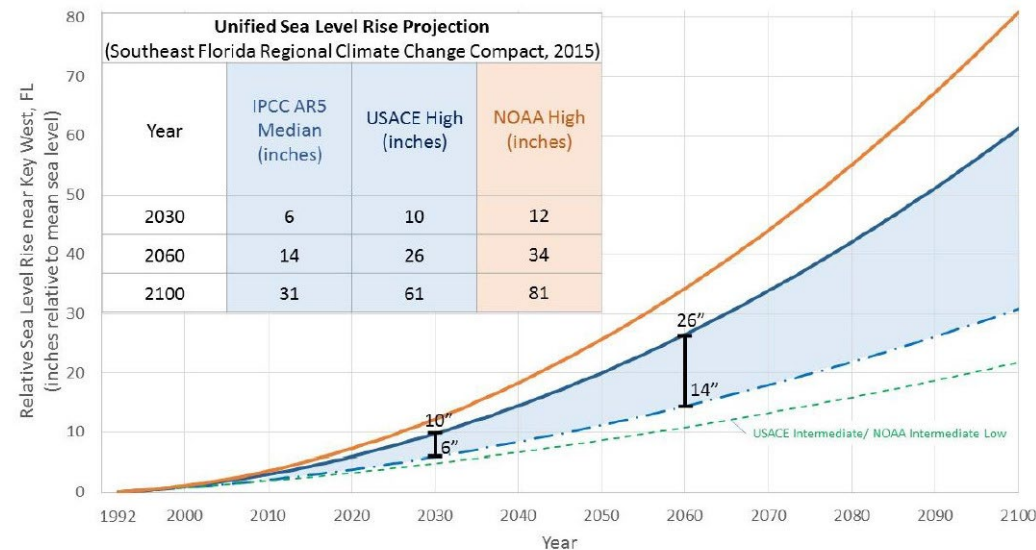


Office of Research and Development
National Risk Management Research Laboratory
Land and Materials Management Division

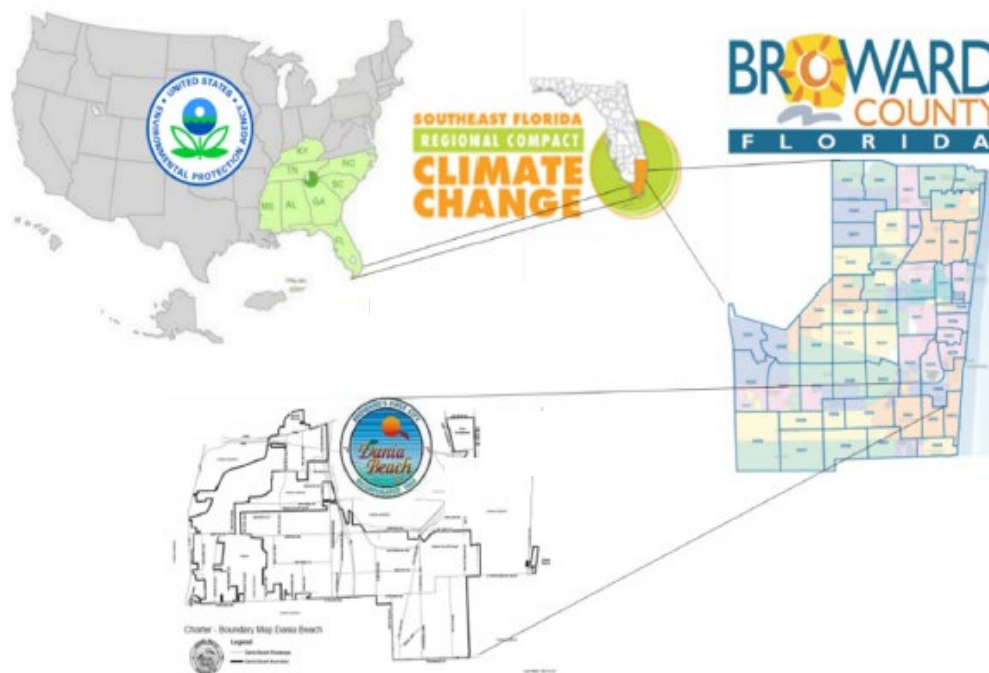
Community Resilience Planning: A Decision-Making Framework for Coastal Communities

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

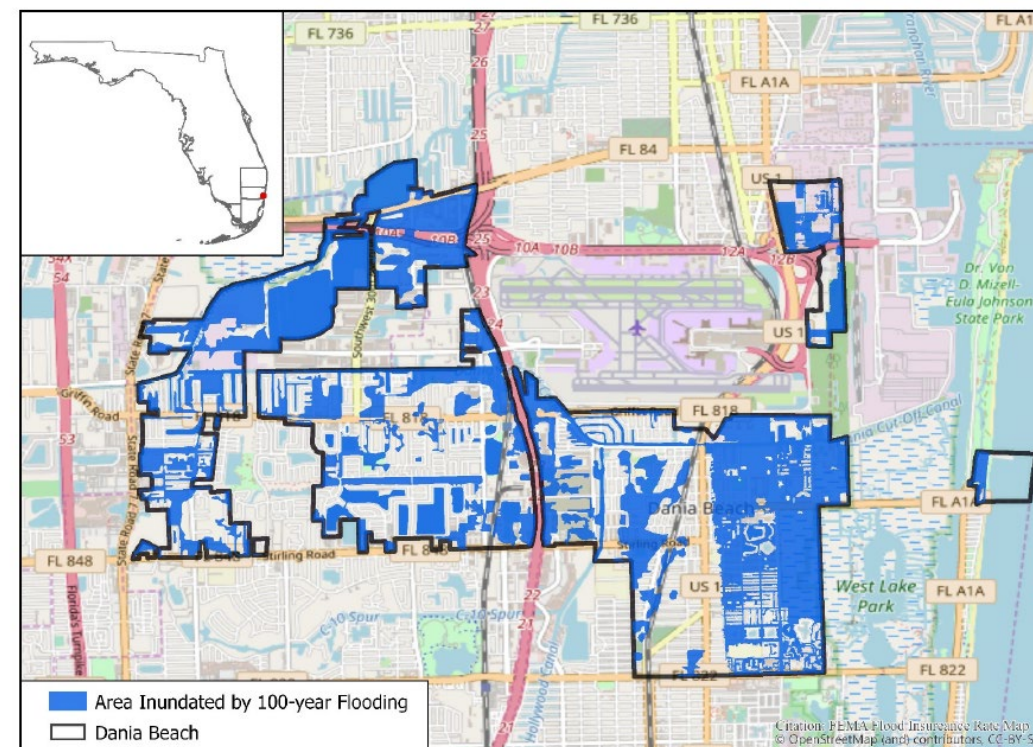
Projected Sea Level Rise in Southeast Florida



Local, Regional, and Federal Collaboration



Flood Prone Areas in Dania Beach, FL





Workshop 1
Community Stakeholders

Identify

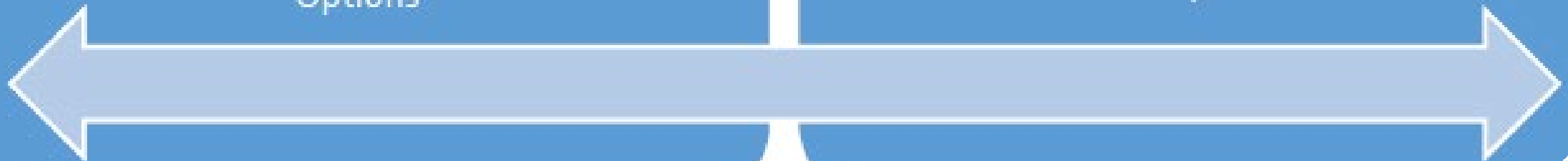
Values
Objectives
Performance Measures
Options



Workshop 2
Technical Analysts






Assess Needs

Data
Information
Models
Impacts



Structured Decision Making

Objectives, Measures, and Options Workshop 1 Stakeholders



New Item
Delete Item


Import Items


Foster coastal resiliency in Dania Beach








- Protect infrastructure**
 - Preserve and protect private structures
 - Protect water supply
 - Maximize ecological health and services from fisheries
 - Minimize costs
- Maximize human safety**
 - Minimize flood-related injuries
 - Maximize ability to handle loss of water
 - Maximize ability to handle loss of electricity

New MeasureDelete Measure

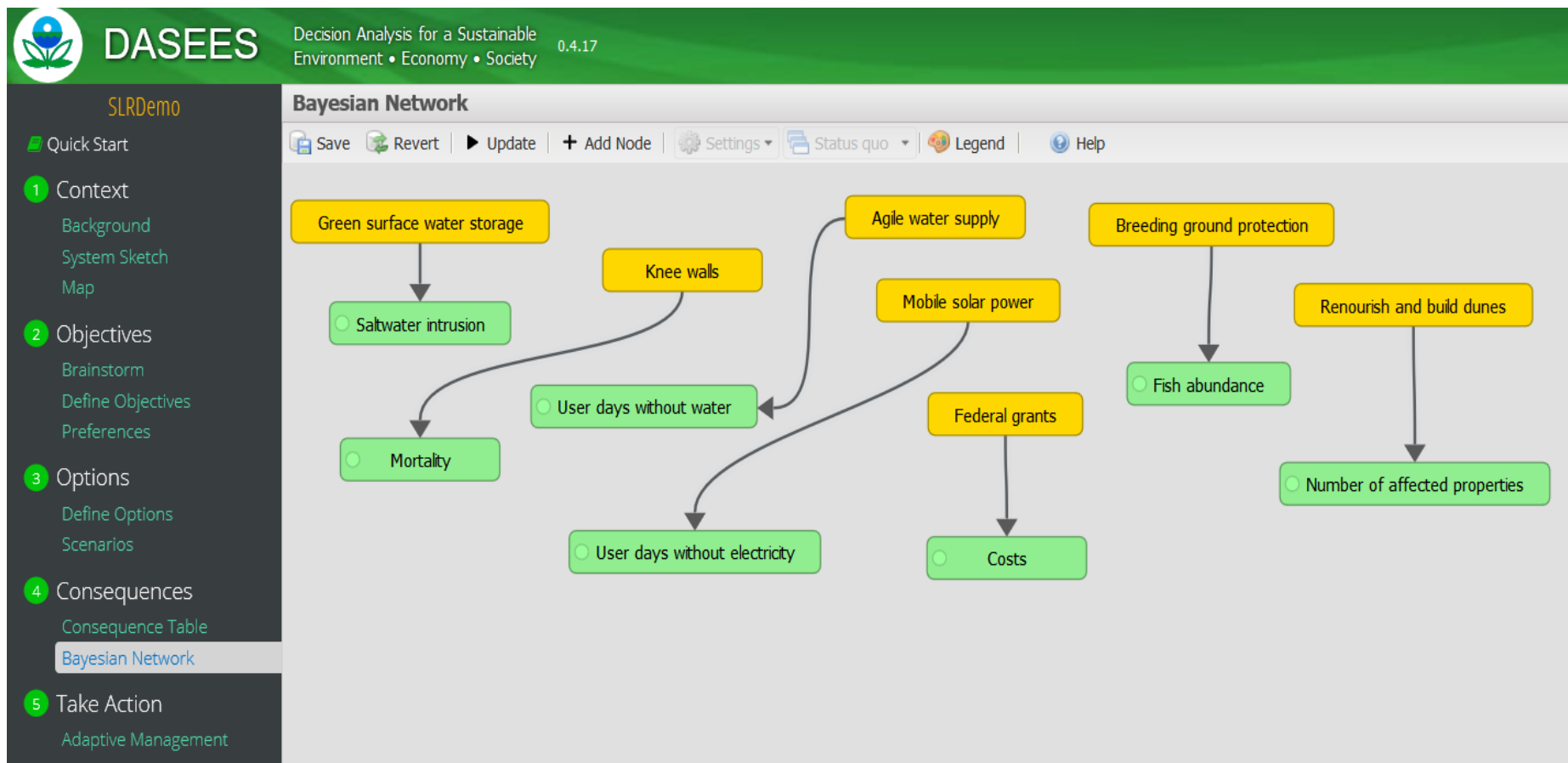
Measure	Units
<input checked="" type="checkbox"/> Number of affected properties	Parcels
<input type="checkbox"/> Costs	Million Dollars
<input type="checkbox"/> Fish abundance	Index
<input type="checkbox"/> Mortality	# of deaths
<input type="checkbox"/> Saltwater intrusion	square kms
<input type="checkbox"/> User days without electricity	#
<input type="checkbox"/> User days without water	#

Management Options

New OptionDelete Option

Objective Linked	Option Name ^	Type	Units
	Agile water supply	Continuous	 mgd
	Breeding ground protection	Continuous	 ha
	Federal grants	Continuous	 \$ (x100,000)
	Green surface water storage	Continuous	 million gallons
	Knee walls	Continuous	 meters
	Mobile solar power	Continuous	 #
	Renourish and build dunes	Continuous	 ha

SDM informed Initial Bayesian Network



SDM Derived Objectives, Measures, and Options

Workshop 2 Technical Iteration

Objectives

Save Revert

Fundamental Objectives Hierarchy

- Dania Beach Resiliency Redesign**
 - Reduce reliance on fossil fuels**
 - Improve efficiency of transportation system
 - Minimize non-transportation based use of fossil fuels
 - Ensure long-term water supply**
 - Maintain drinking water systems**
 - Preserve and protect natural infrastructure**
 - Enhance mangrove areas**
 - Provide space for ecosystems to transition
 - Maintain fisheries
 - Maintain structural integrity of dunes
 - Maintain and increase economic opportunity and prosperity**
 - Minimize local government spending**
 - Enhance recreation and public art areas
 - Minimize cost of impacts**
 - Minimize recovery costs
 - Maintain desired level of services throughout community**

Objective Measure

New Measure Delete Measure

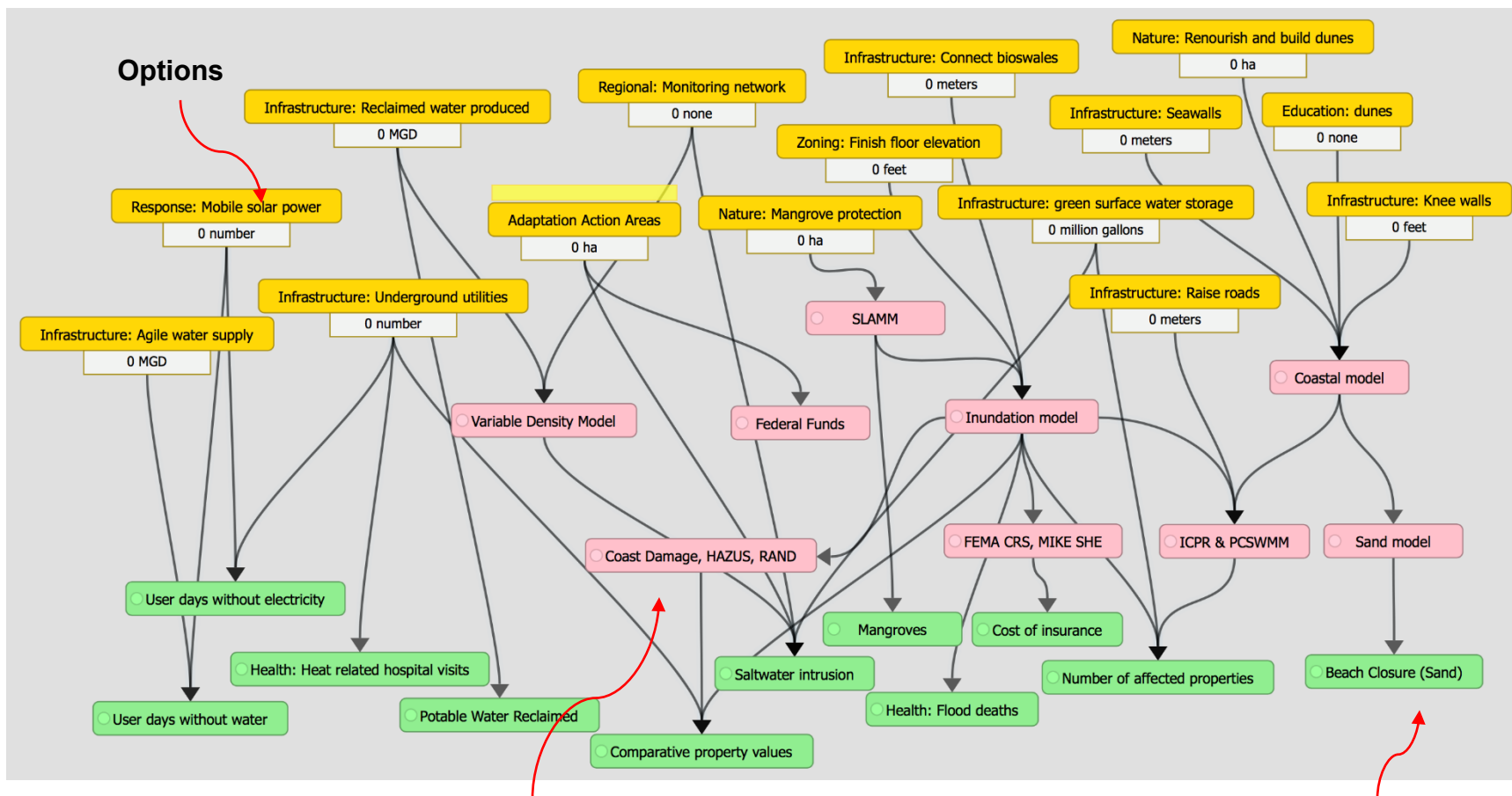
Measure
<input checked="" type="checkbox"/> Saltwater intrusion
<input type="checkbox"/> Area flooded
<input type="checkbox"/> Buildings with 2' of freeboard
<input type="checkbox"/> Certified Green Partners
<input type="checkbox"/> Dedicated Funding
<input type="checkbox"/> Dollars towards adaptation
<input type="checkbox"/> Duration of flooding
<input type="checkbox"/> EV Charging Stations
<input type="checkbox"/> Flooding related deaths
<input type="checkbox"/> Grant dollars received
<input type="checkbox"/> Heat related hospital visits
<input type="checkbox"/> Integration of standards in permitting and licensing
<input type="checkbox"/> Local gov't resiliency investment
<input type="checkbox"/> Maintain regional monitoring network

Management Options

New Option Delete Option

Option	Units
<input checked="" type="checkbox"/> Infrastructure: Structure/Pump retrofits and installations	none
<input type="checkbox"/> Federal grants	M\$
<input type="checkbox"/> Incentives: Certified Green Partners	number
<input type="checkbox"/> Incentives: Interest rates	none
<input type="checkbox"/> Incentives: Loans	none
<input type="checkbox"/> Incentives: Rebates	noe
<input type="checkbox"/> Infrastructure: Raise roads	meters
<input type="checkbox"/> Infrastructure: Reclaimed water produced	MGD
<input type="checkbox"/> Infrastructure: Seawalls	meters
<input type="checkbox"/> Infrastructure: Surface water storage	gallons
<input type="checkbox"/> Nature: Invasive species control	ha
<input type="checkbox"/> Nature: Limit access	none
<input type="checkbox"/> Nature: Restore dunes	ha
<input type="checkbox"/> Nature: Wetlands	ha
<input type="checkbox"/> Regional: Monitoring network	none

Expanded Bayesian Network Structure



Technical Experts: EPA, USACE, FEMA

Measures and Fundamental Objectives

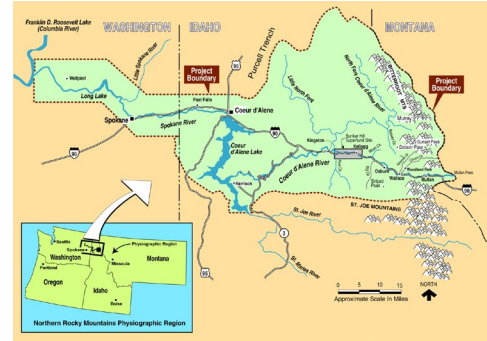
Workshop results

- **Provide recommendations on how to analyze the effectiveness of alternatives**
- **Demonstrated to Dania Beach and Broward County how graphical tools can be used to structure decision problems**
- **Provided valuable information for future coastal resiliency modeling efforts for Dania Beach and Southeast Florida**

- Decision Analysis for a Sustainable Environment, Economy, and Society (DASEES) will help:
 - Find common understanding of complex problem
 - Create, analyze, select, and implement solutions
 - Manage the overall decision-making process
 - Organize decision-relevant information
 - Useful for complex decision problems with uncertainty
- Adaptable data/information needs
 - Expert judgment
 - Varied data sources, e.g. local, government, NGOs, etc.



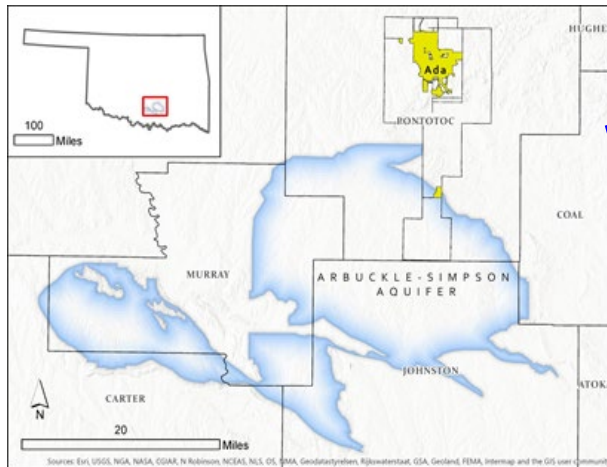
Broad Applicability of DASEES



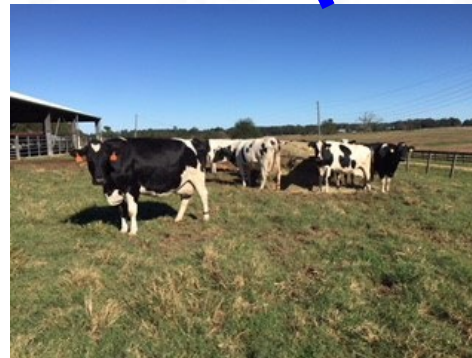
Contaminated Wetland Cleanup Coeur d'Alene, ID



Community Flood Resilience Planning Southeast Region, FL



Aquifer Management Southern Plains, OK



Dairy Farm Lagoon Managment Tangipahoa Parish, LA



Watershed/Estuary Management 18
Guanica Bay, Puerto Rico



Thank you!

- **Questions?**