EPA
United States
Environmental Protection
Agency

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

John Carriger
Brian Dyson
Tim Canfield

Center for Environmental Solutions and Emergency Response

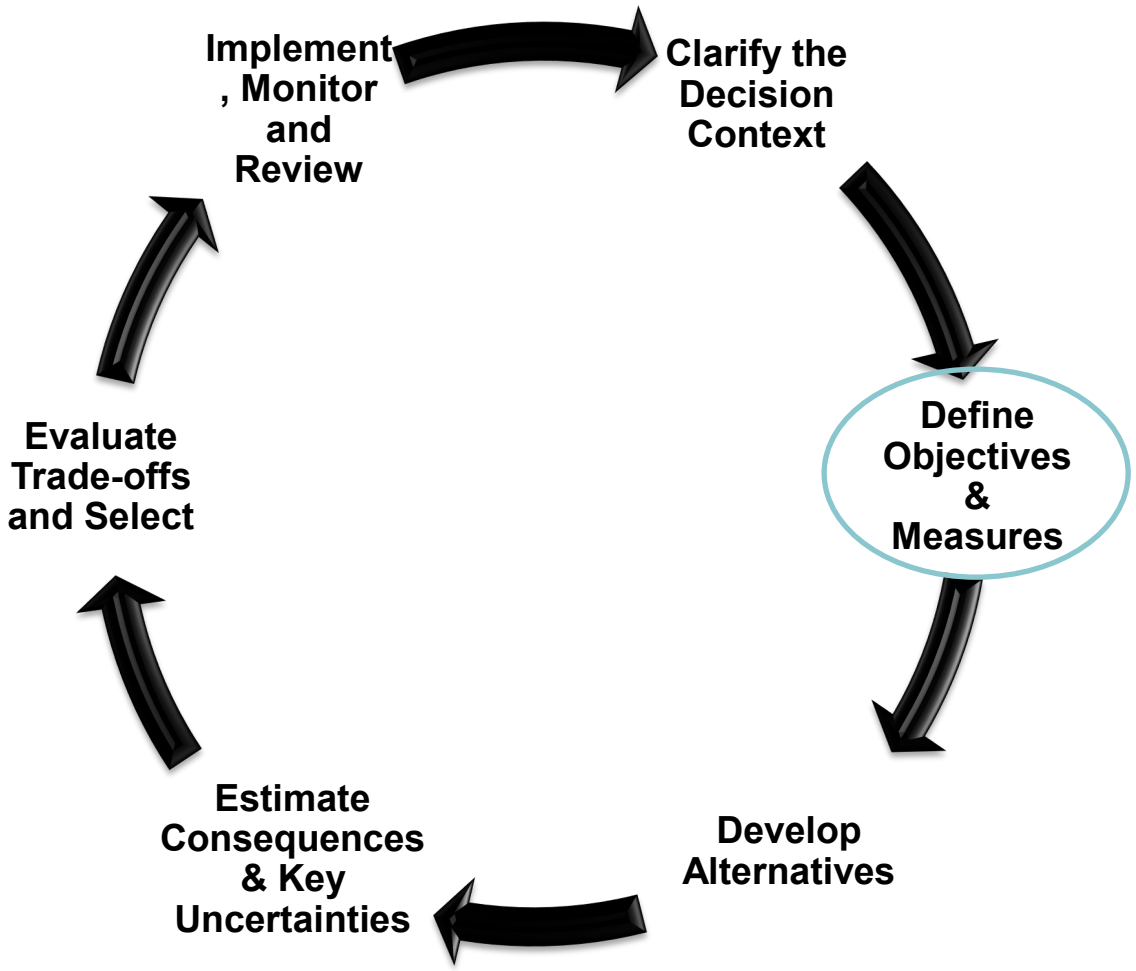
December 4, 2022

The views expressed in this presentation are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

Steps in decision analysis

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

PrOACT/SDM framework



Gregory, R., Failing, L., Harstone, M., Long, G., McDaniels, T. and Ohlson, D., 2012. *Structured decision making: a practical guide to environmental management choices*. John Wiley & Sons.

EPA United States Environmental Protection Agency

***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*

EPA United States Environmental Protection Agency

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.

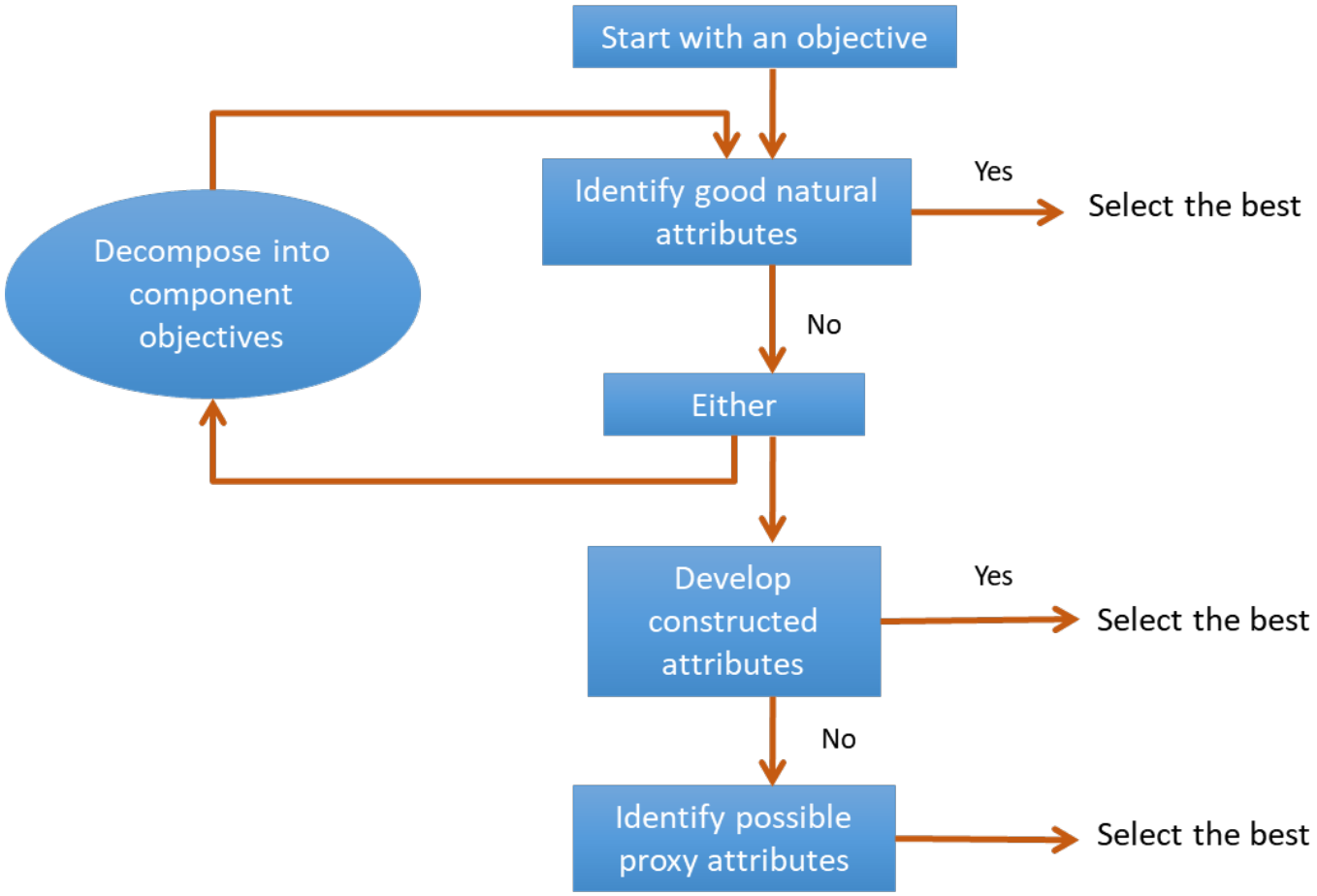
Problem formulation- the foundation

Value statements

- Fundamental objectives

Measures of value

- Attributes/Performance measures

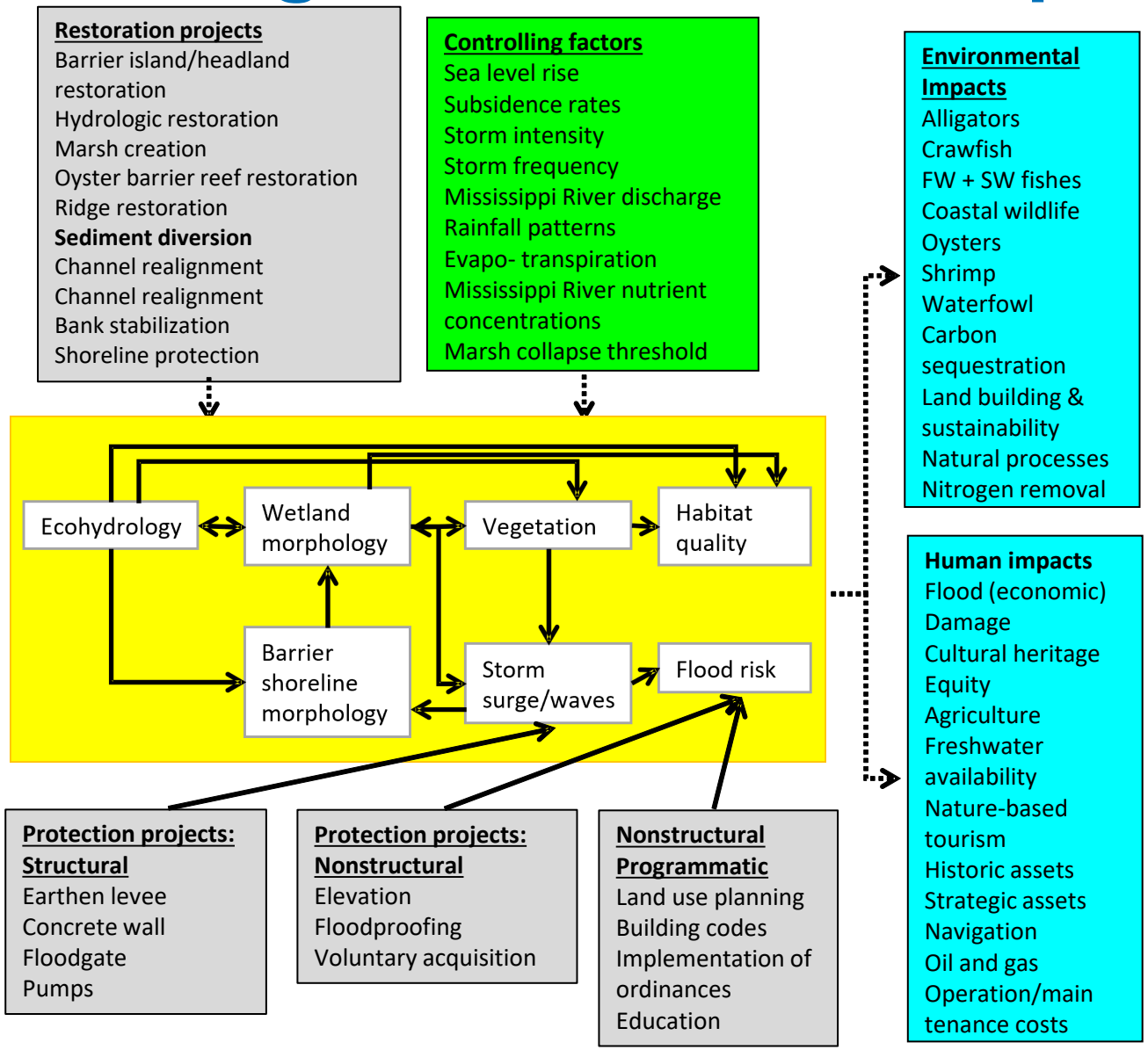


A good attribute is:

- ***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

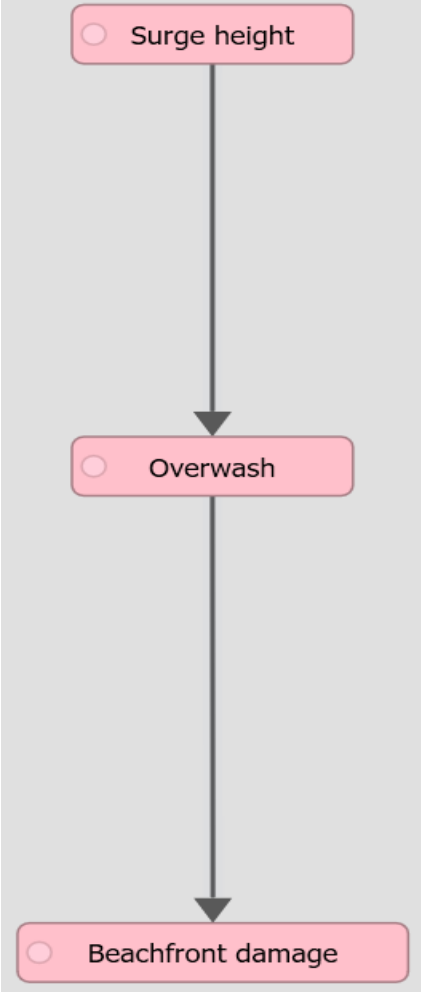


Carriger, J.F., Dyson, B.E. and Benson, W.H., 2018. Representing causal knowledge in environmental policy interventions: Advantages and opportunities for qualitative influence diagram applications. *Integrated environmental assessment and management*, *14*(3), pp.381-394.

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

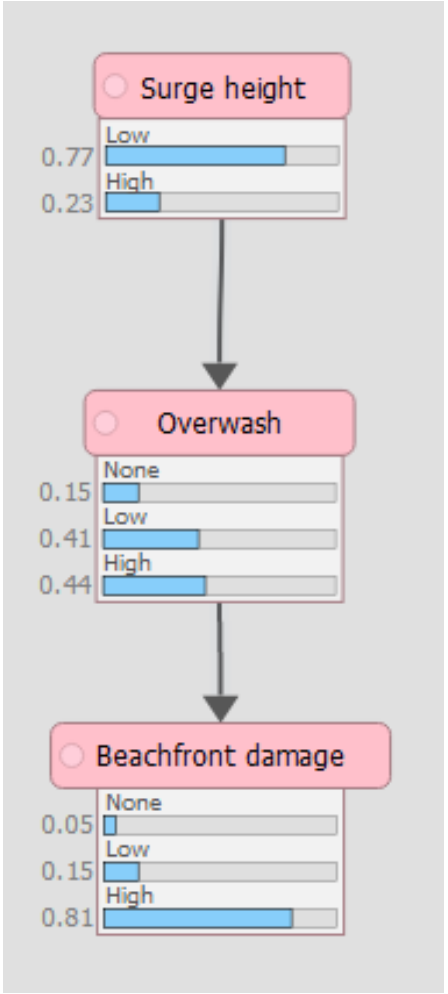
Task Force on Community Preventive Services. 2015. Cardiovascular disease: Interventions engaging community health workers. Oxford (UK): Oxford Univ. [cited 2017 Sep 3]. https://www.thecommunityguide.org/

Probabilistic risk assessment

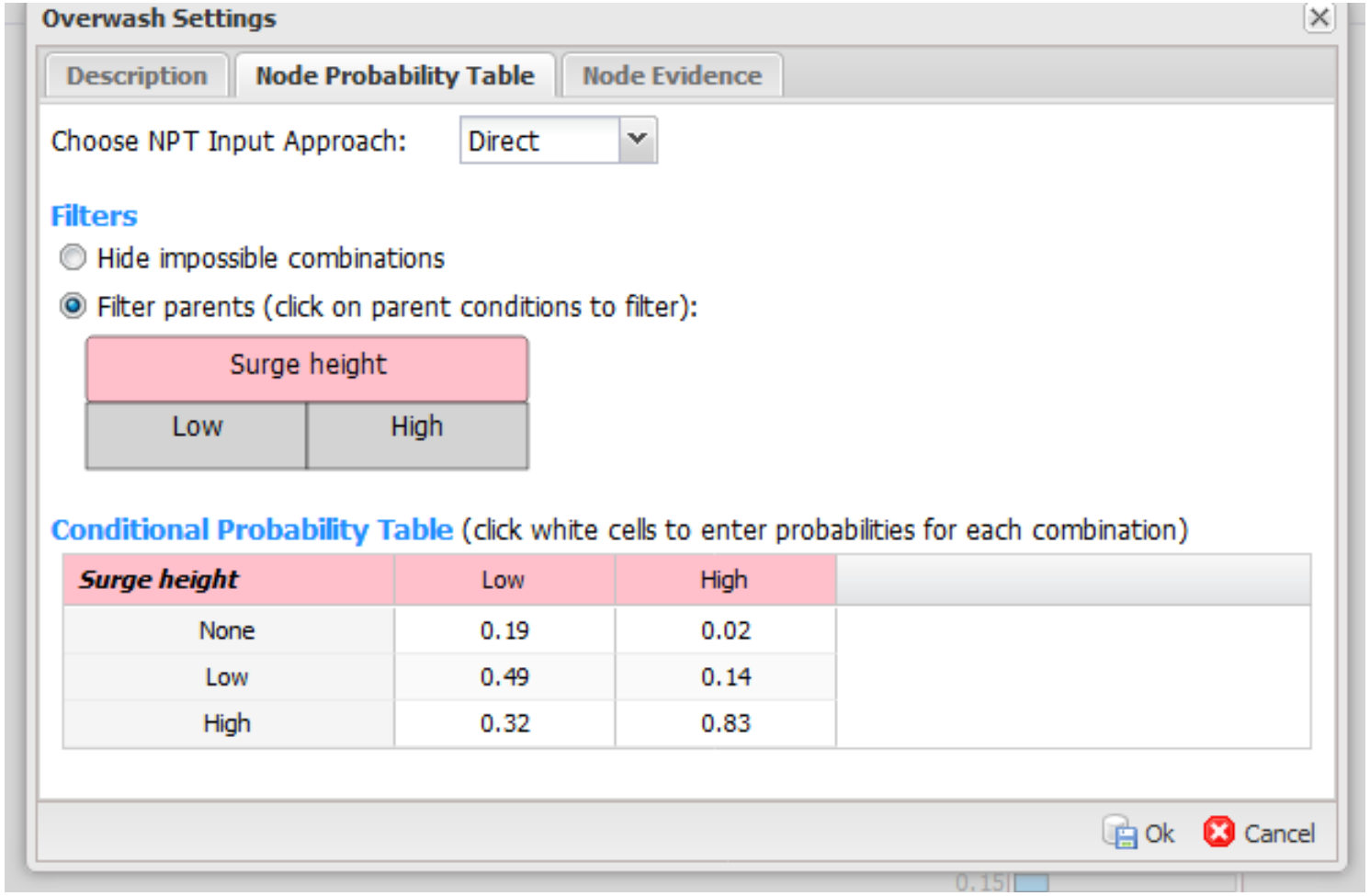


Bayesian Network Modeling

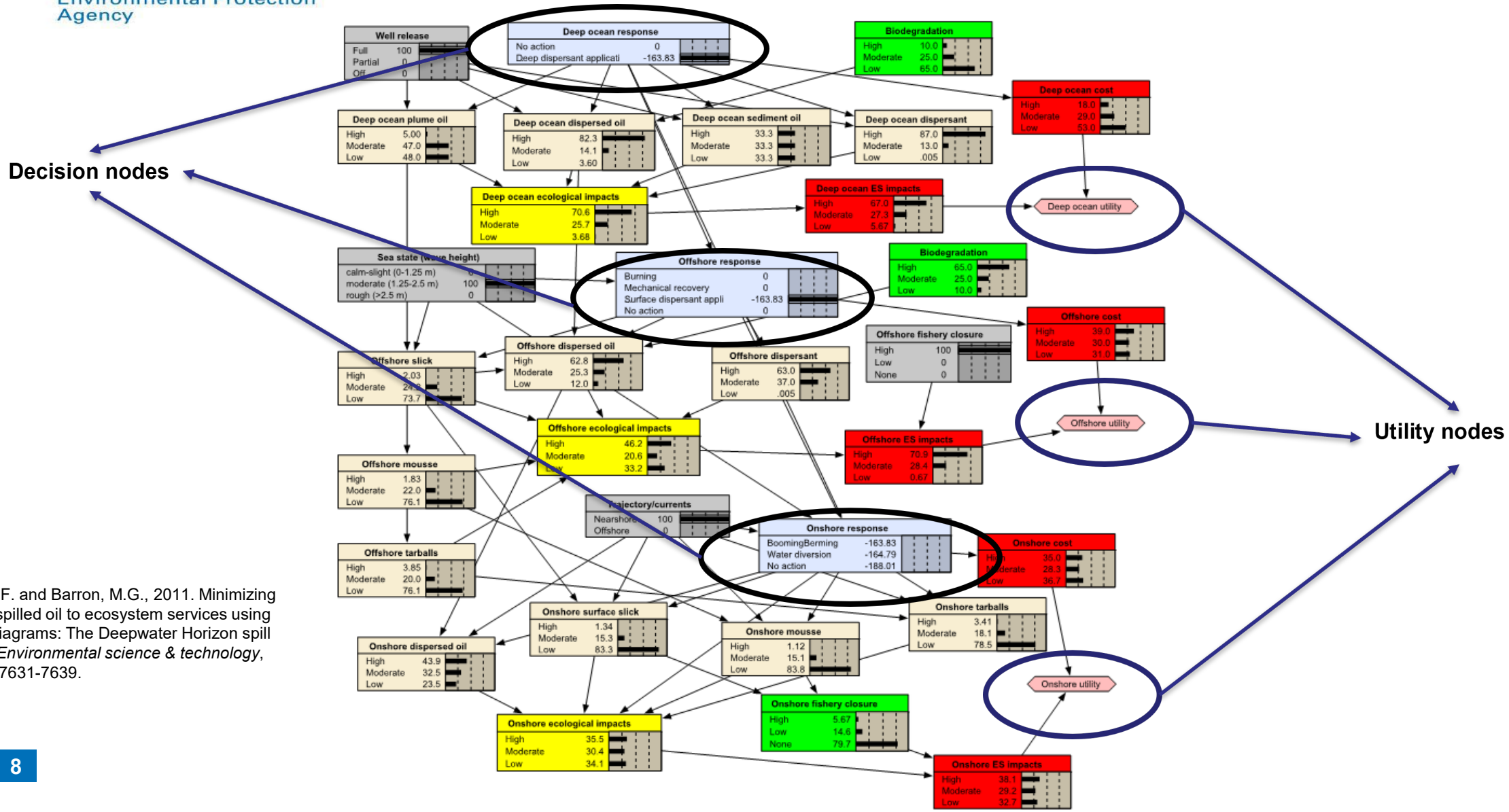
- **Probabilistic hypothesis testing**



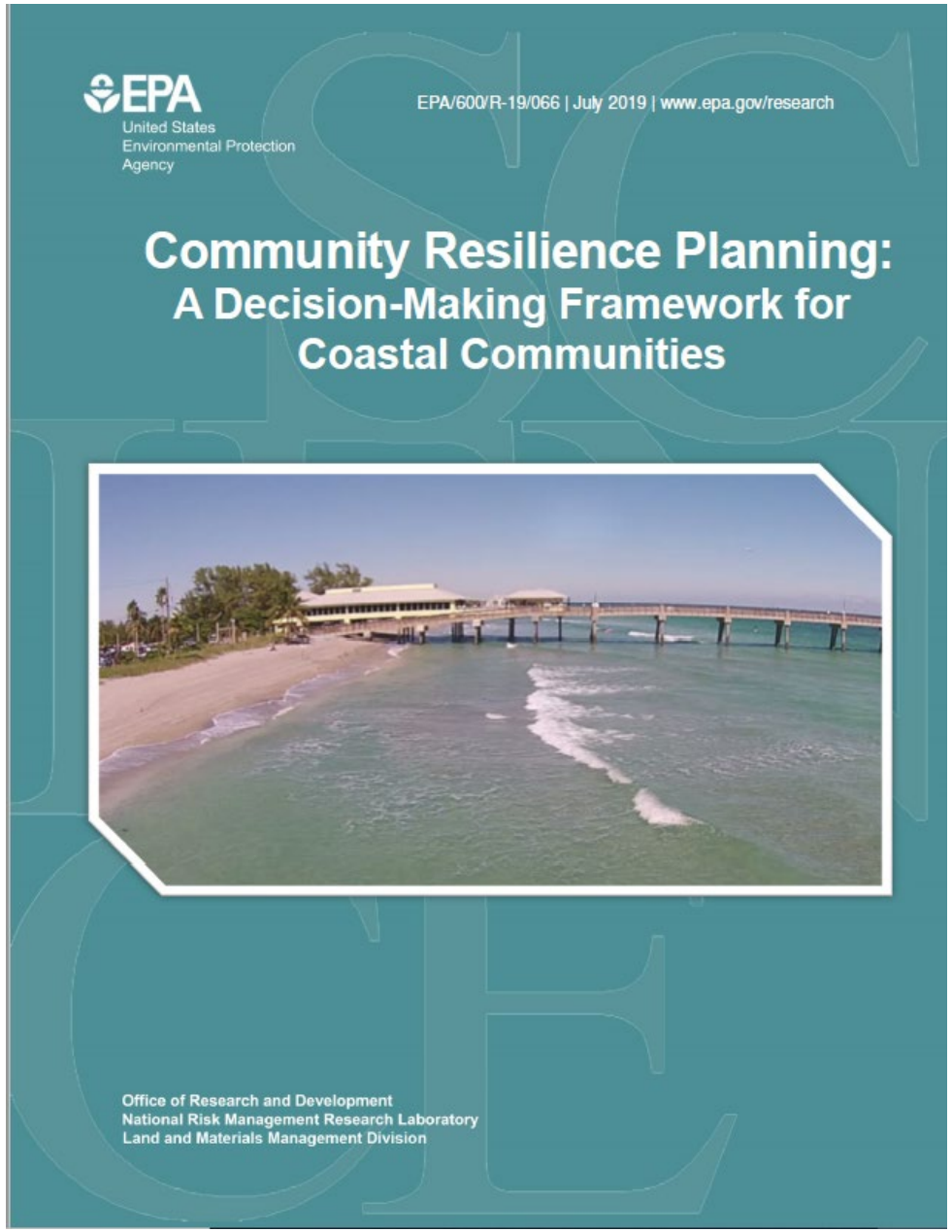
Overwash node conditional probability table



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

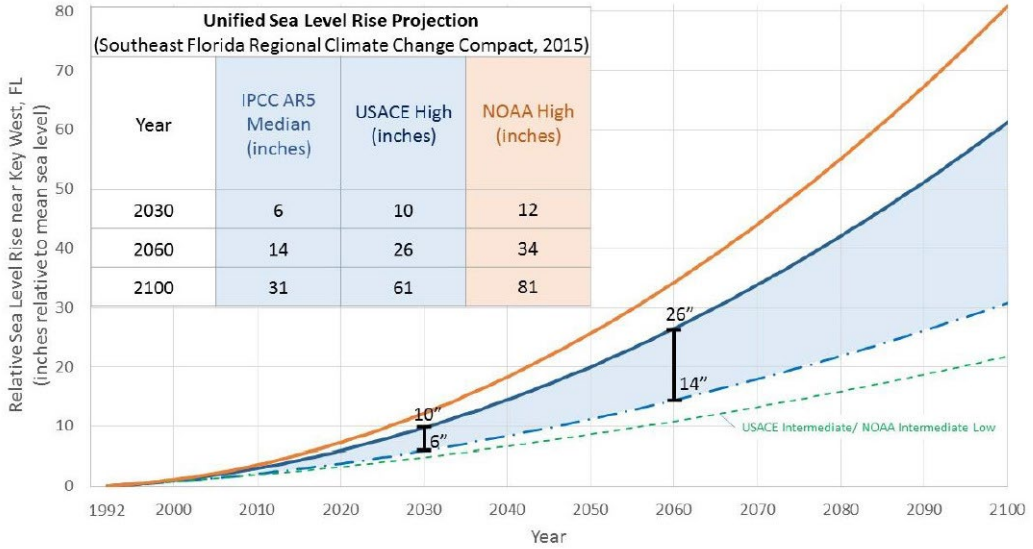
Dyson, B., Carriger, J., Newcomer-Johnson, T., Moura, R., Richardson, T., Canfield, T. 2019. Community Resilience Planning: A Decision-Making Framework for Coastal Communities. U.S. Environmental Protection Agency, Cincinnati, OH, EPA/600/R-19/066

United States Environmental Protection Agency

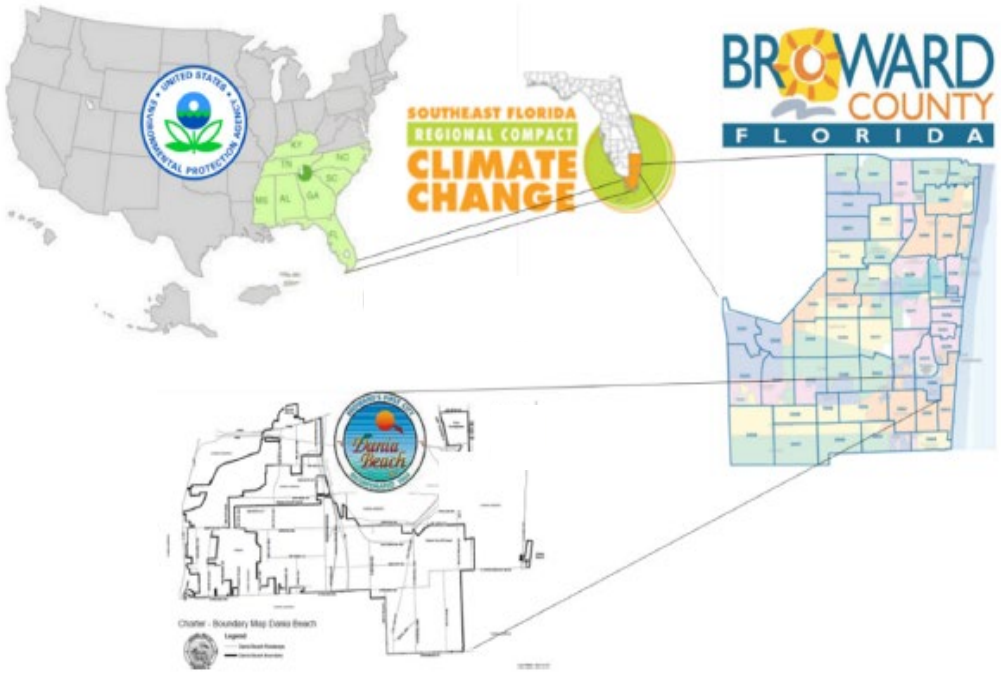
Projected Sea Level Rise in Southeast Florida

Unified Sea Level Rise Projection
(Southeast Florida Regional Climate Change Compact, 2015)

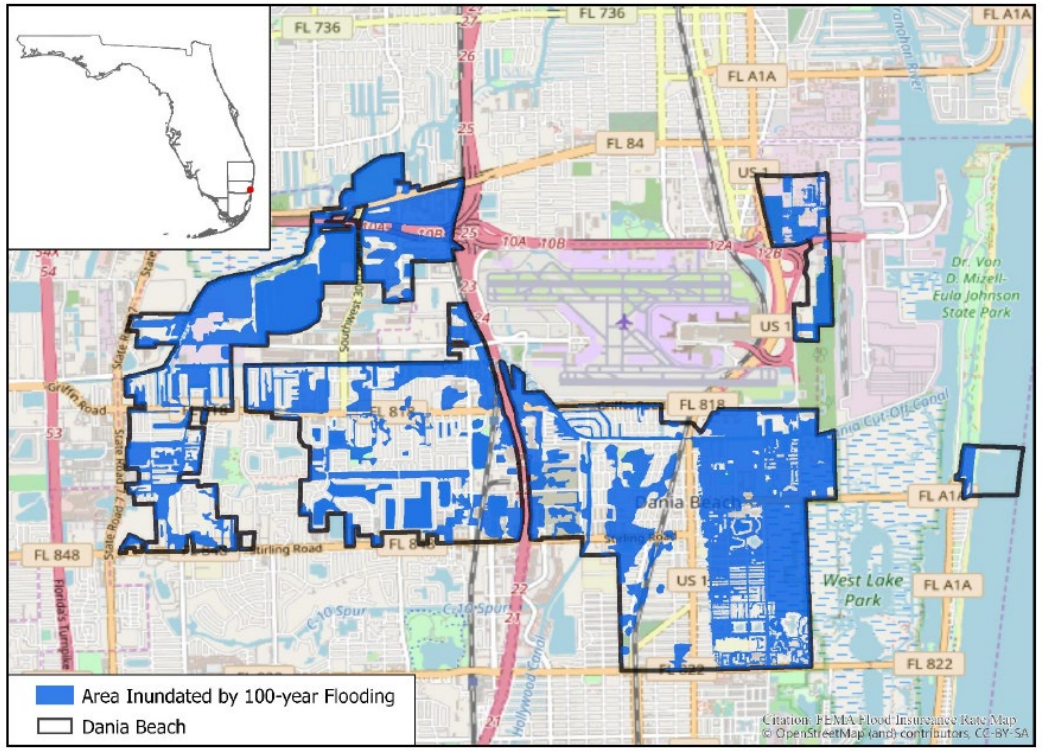
Year	IPCC AR5 Median (inches)	USACE High (inches)	NOAA High (inches)
2030	6	10	12
2060	14	26	34
2100	31	61	81



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

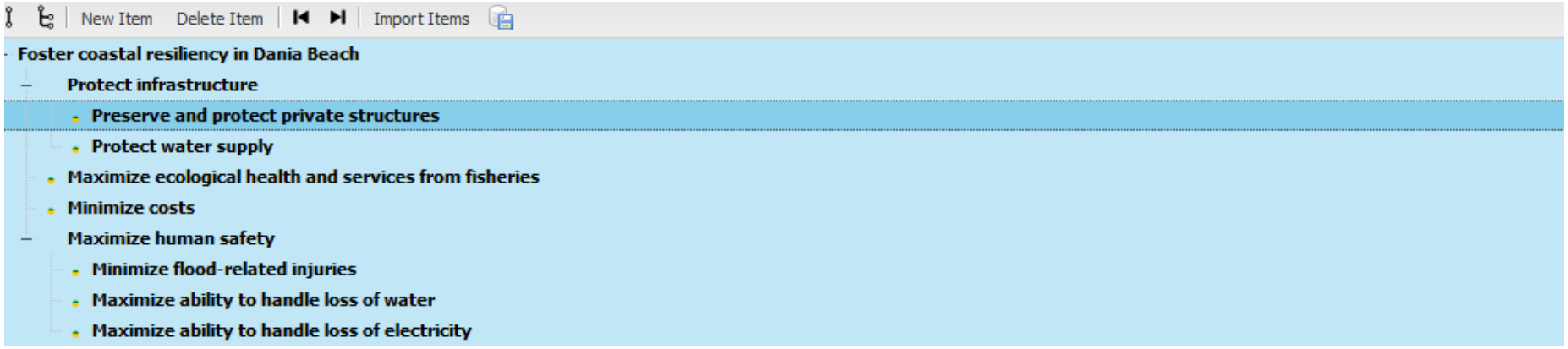
Data

Information

Models

Impacts

Structured Decision Making
Objectives, Measures, and Options Workshop 1 Stakeholders



New Measure Delete Measure

	Measure	Units
☑	Number of affected properties	Parcels
☐	Costs	Million Dollars
☐	Fish abundance	Index
☐	Mortality	# of deaths
☐	Saltwater intrusion	square kms
☐	User days without electricity	#
☐	User days without water	#

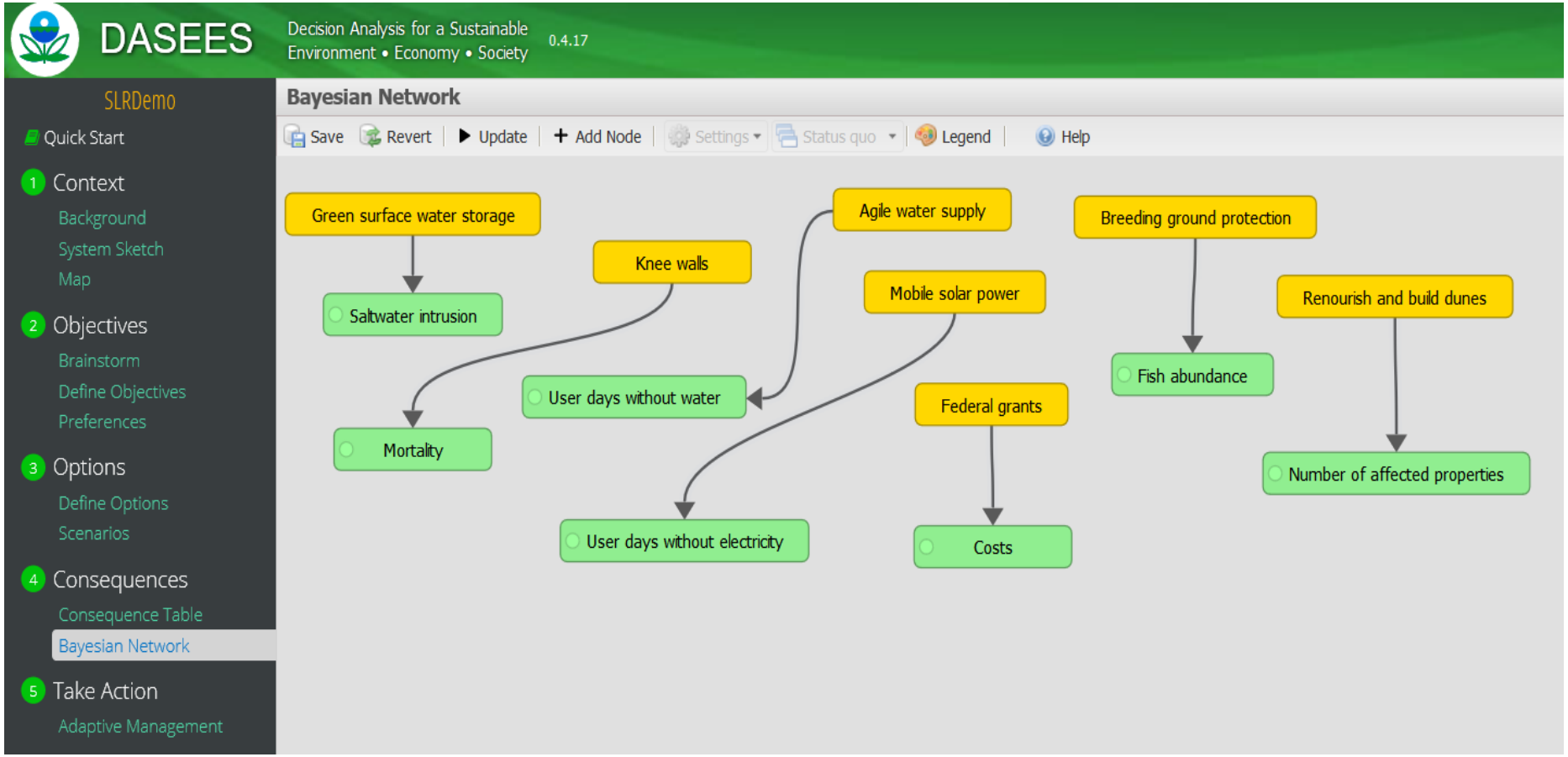
Management Options

New Option Delete 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

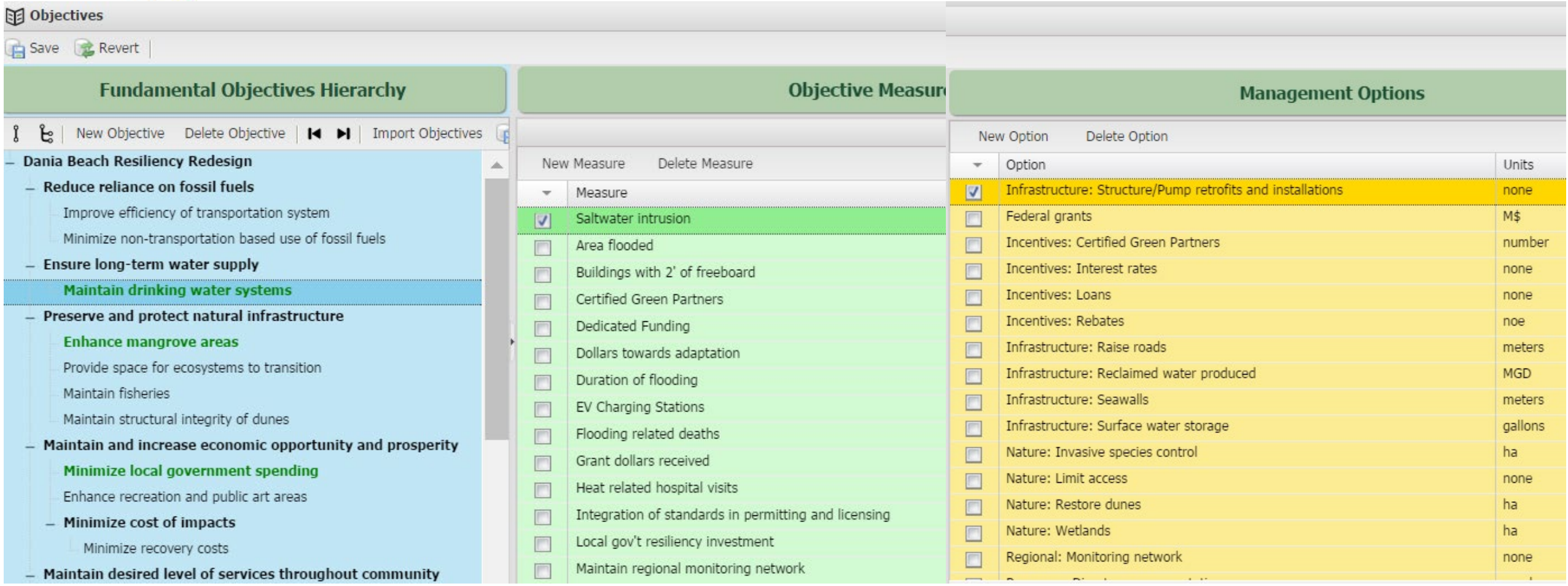
EPA United States Environmental Protection Agency

SDM informed Initial Bayesian Network

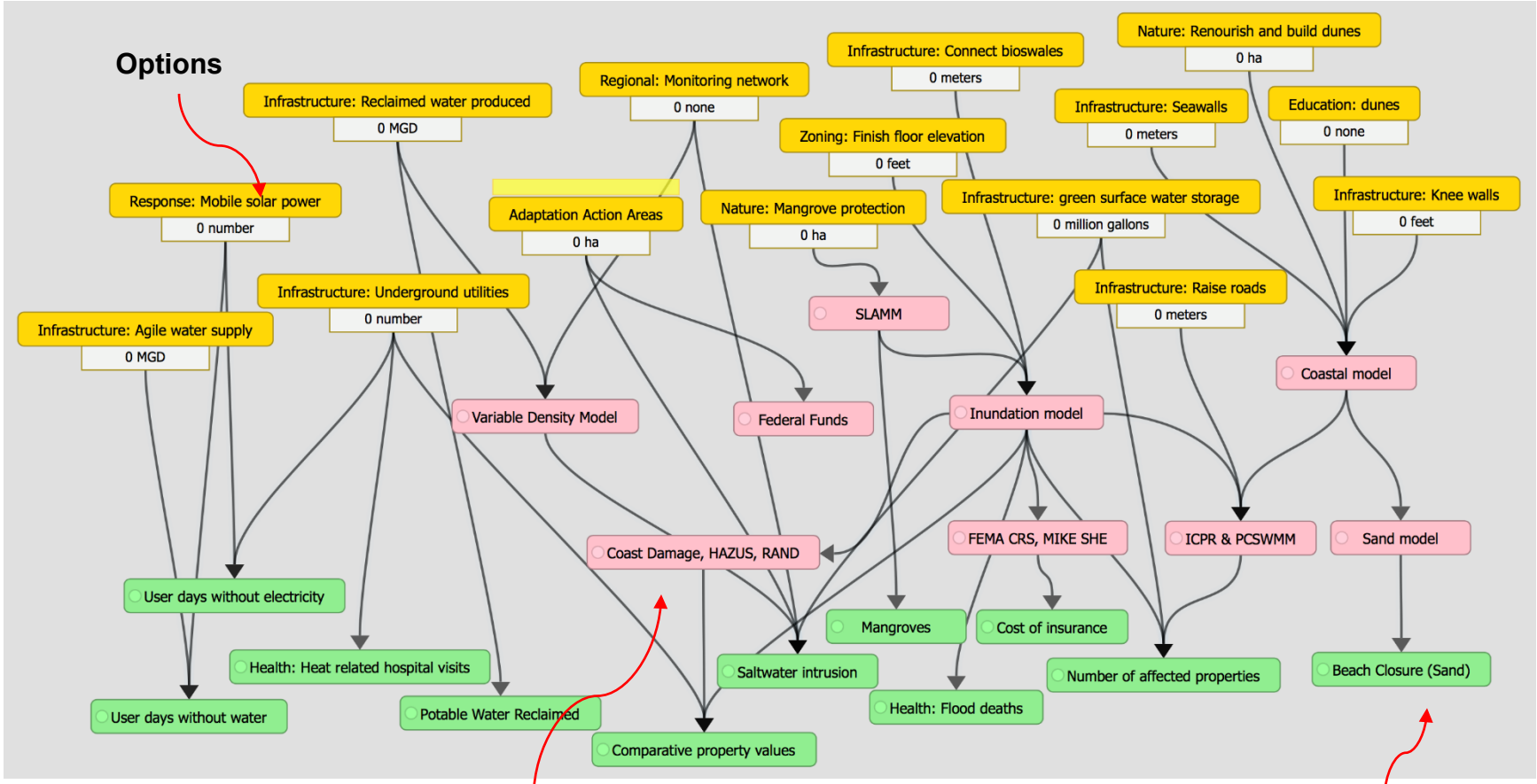


SDM Derived Objectives, Measures, and Options

Workshop 2 Technical Iteration



Expanded Bayesian Network Structure



Technical Experts: EPA, USACE, FEMA

Measures and Fundamental Objectives

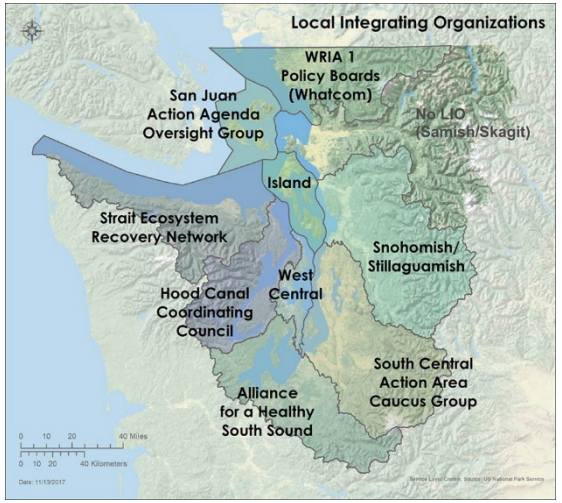
EPA United States Environmental Protection Agency

Workshop results

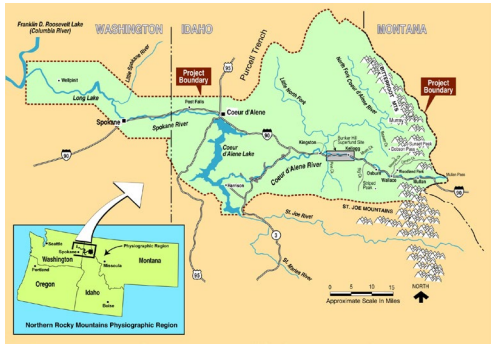
- Provide recommendations on how to analyze the effectiveness of alternatives
- Demonstrated to Dania Beach and Broward County how graphical tools can be used to structure decision problems
- Provided valuable information for future coastal resiliency modeling efforts for Dania Beach and Southeast Florida

- 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

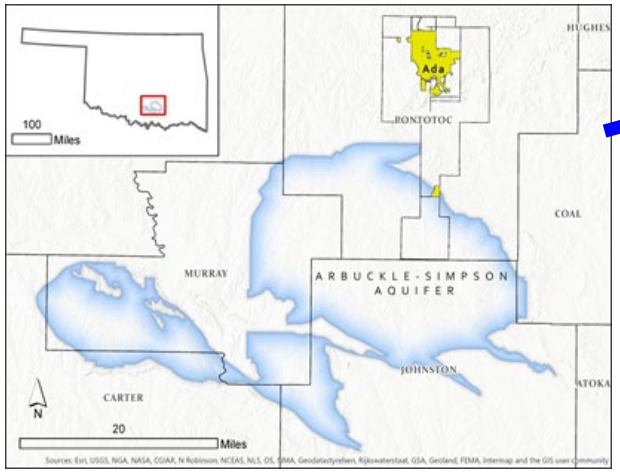


Restoration Planning Puget Sound

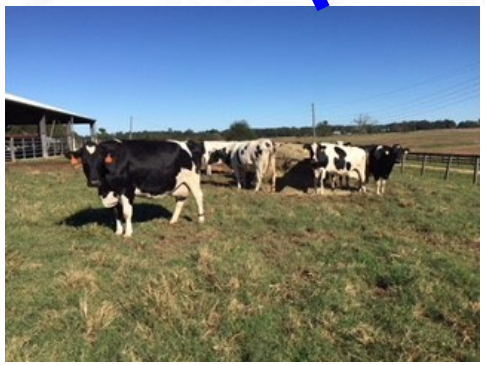


Contaminated Wetland Cleanup Coeur d'Alene, ID

Community Flood Resilience Planning
Southeast Region, FL



Aquifer Management
Southern Plains, OK



Dairy Farm Lagoon Managment
Tangipahoa Parish, LA

Watershed/Estuary Managment
Guanica Bay, Puerto Rico

EPA

EPA
United States
Environmental Protection
Agency

Thank you!

- **Questions?**