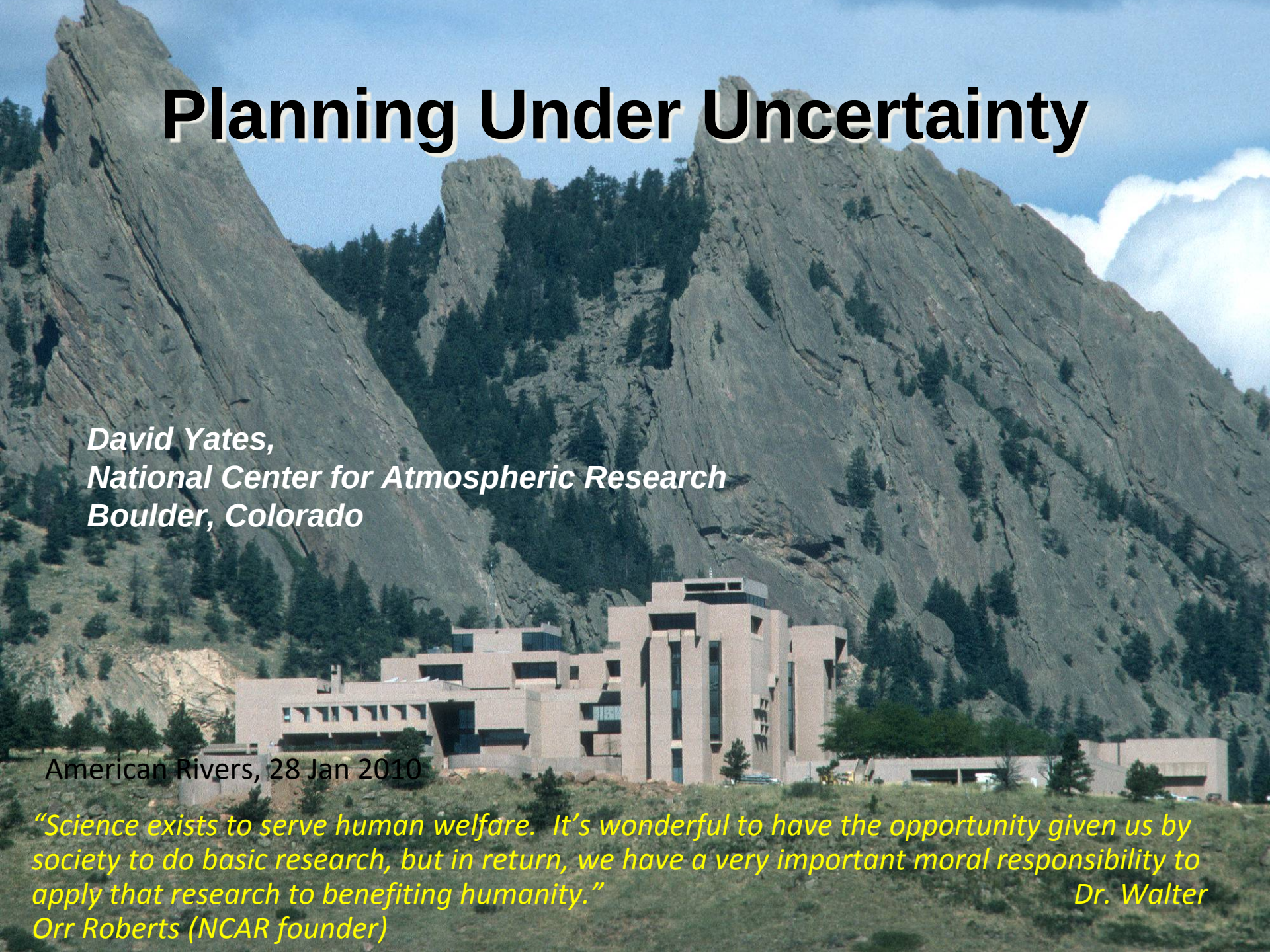
Planning Under Uncertainty



David Yates,
National Center for Atmospheric Research
Boulder, Colorado

American Rivers, 28 Jan 2010

"Science exists to serve human welfare. It's wonderful to have the opportunity given us by society to do basic research, but in return, we have a very important moral responsibility to apply that research to benefiting humanity." Dr. Walter Orr Roberts (NCAR founder)

Planning for Climate Change

- Discard assumption of climate stationarity.
- Integrated water resource management- climate, scenarios, policy, stakeholders.
- Collaborative process – explicit attention to uncertainty & risk management options

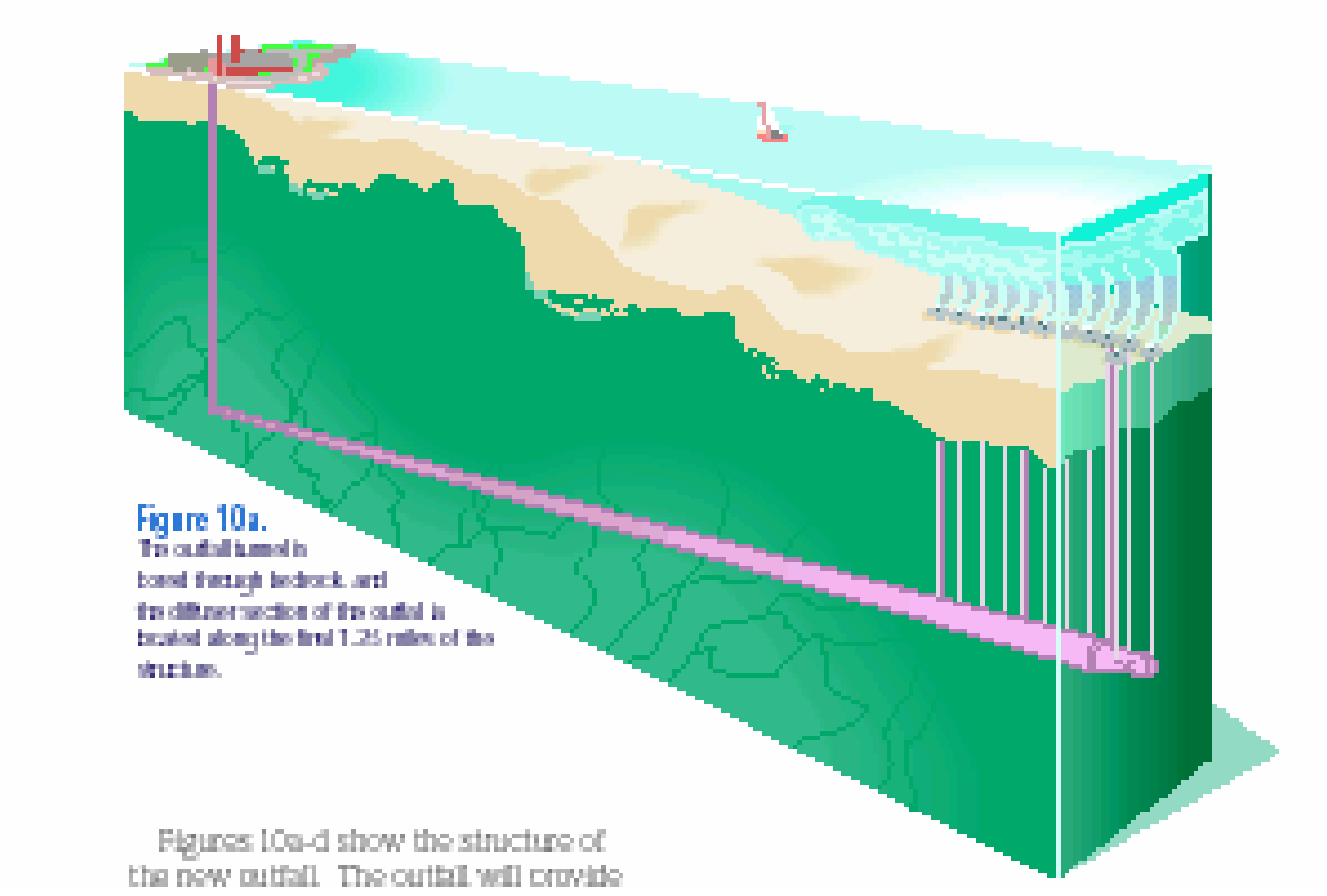
Need “Actionable Information”

David Behar, Water Utility Climate Alliance, “We need actionable
information to make changes or additions to capital investments..”, San Francisco Public Utilities

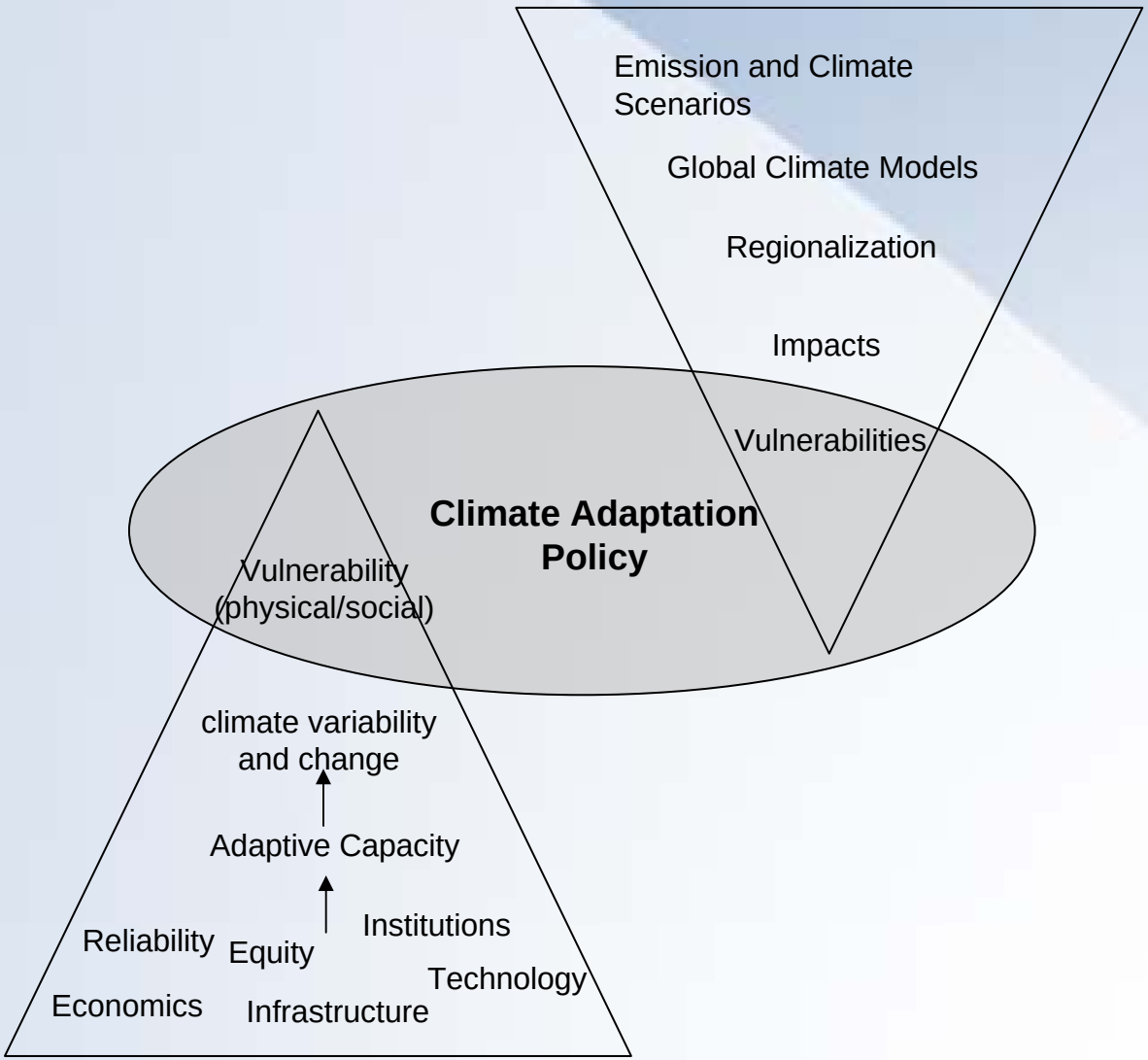
Marc Wagee, Manager of Water Supply, Denver Water,
“Surprisingly, we haven’t dealt well with uncertainty.. Climate change is a wake-up to this fact”

MWRA and the “Boston Harbor Cleanup”,

There are Few Adaptation Examples: Climate Change Considerations in Design of Sewerage Treatment Plant



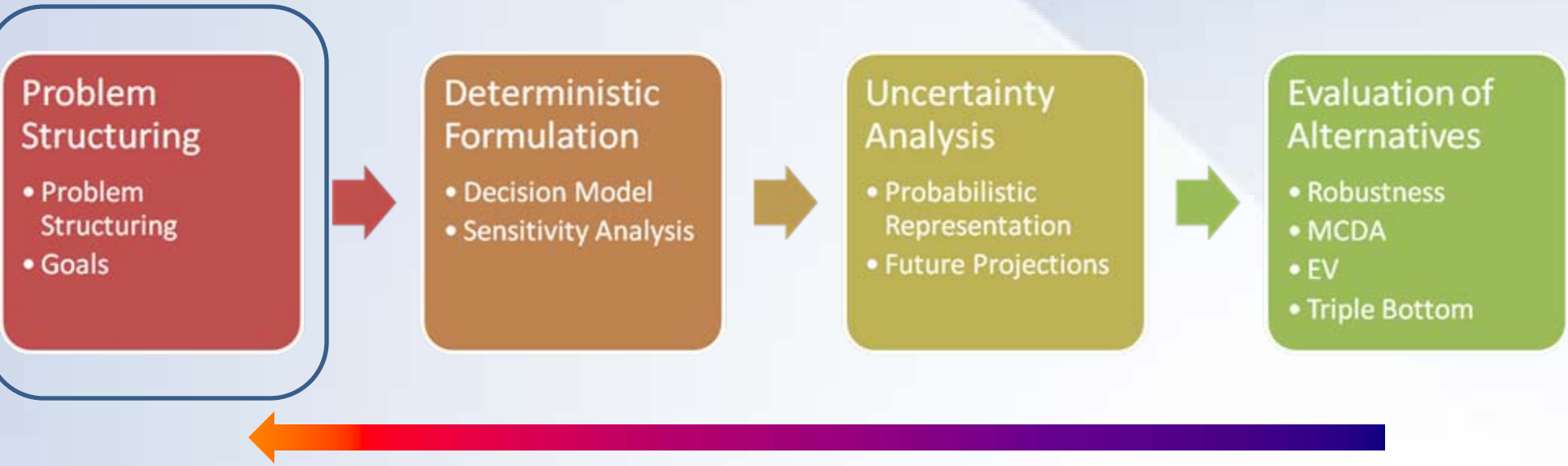
Top Down Vs. Bottom Up



Bottom-up in the Context of Uncertainty

- **Uncertainty:**
  - Specific impacts: type, timing, scale, continuity
  - Cost, effectiveness, lead time of actions
- **Complexity:**
  - Spatial, temporal, feedback loops, local to global scale, breadth and depth of impacts to people, places, and things, institutional, social, political
- **Risk:**
  - Disastrous environmental impacts
  - Disastrous socioeconomic impacts
- **Tradeoffs:**
  - Short-run vs. long-run costs/damages
  - Rural vs. urban; poor vs. rich
  - Act now vs. later

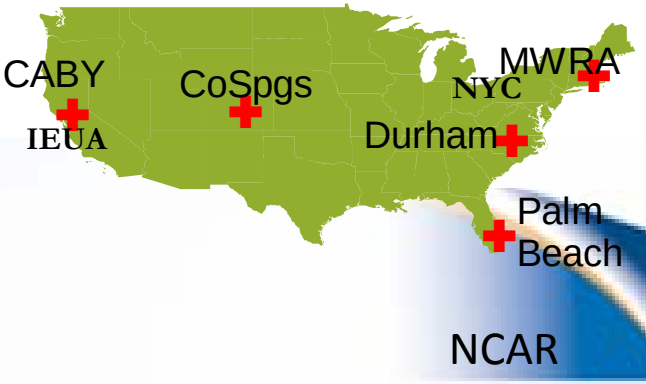
Bottom-Up Approach: Decision Analytic Approach to Climate Change



Municipal Water Planning

- Research-Industry Partnership
- Process to explicitly consider CC into decision making
- Work with partnering utilities

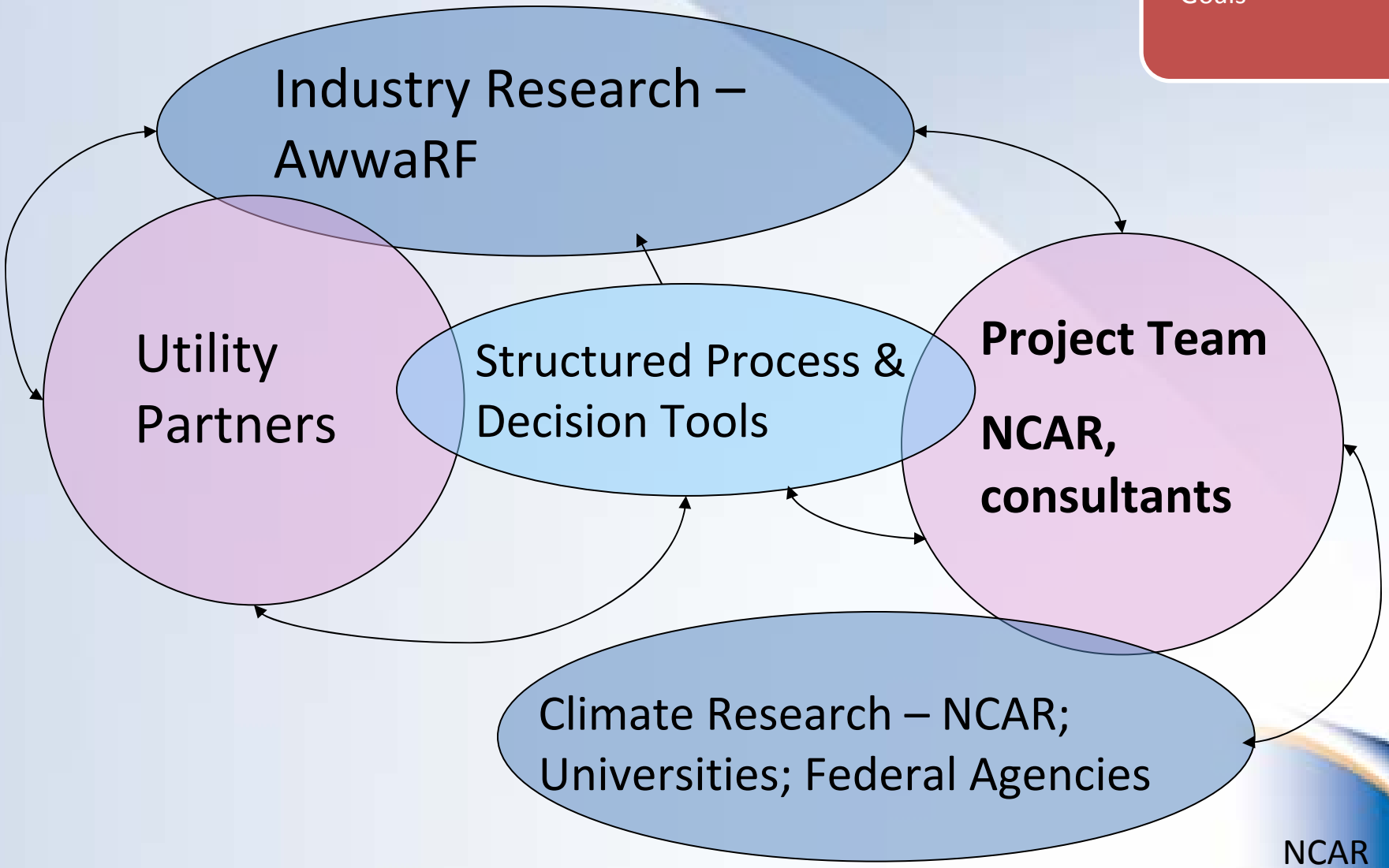
- Inland Empire of Southern California
- El Dorado Irrigation District, CA
- Colorado Springs, CO
- Boston, MA
- Durham, NC
- Palm Beach County, FL
- Portland, OR



Partnership Design and Decision Tools

Problem Structuring

- Problem Structuring
- Goals



Problem Structuring

- Problem Structuring
- Goals

PROBLEM STRUCTURING- GOALS AND OBJECTIVES

Inland Empire Utility Agency

Focus on enhancing local supplies or rely on imports?

Colorado Springs Utilities

Integrated Resource Plan… how to link to current *safe yield analysis*?

MWRA

Safe Yield Analysis- What level of demand meets Quabbin storage targets under climate change

Palm Beach County

IRP in the face of major changes (Lake Okeechobee, future demand, environ interests, sea level rise, climate change, etc.)

Problem Structuring

- Problem Structuring
- Goals

PROBLEM STRUCTURING- GOALS AND OBJECTIVES

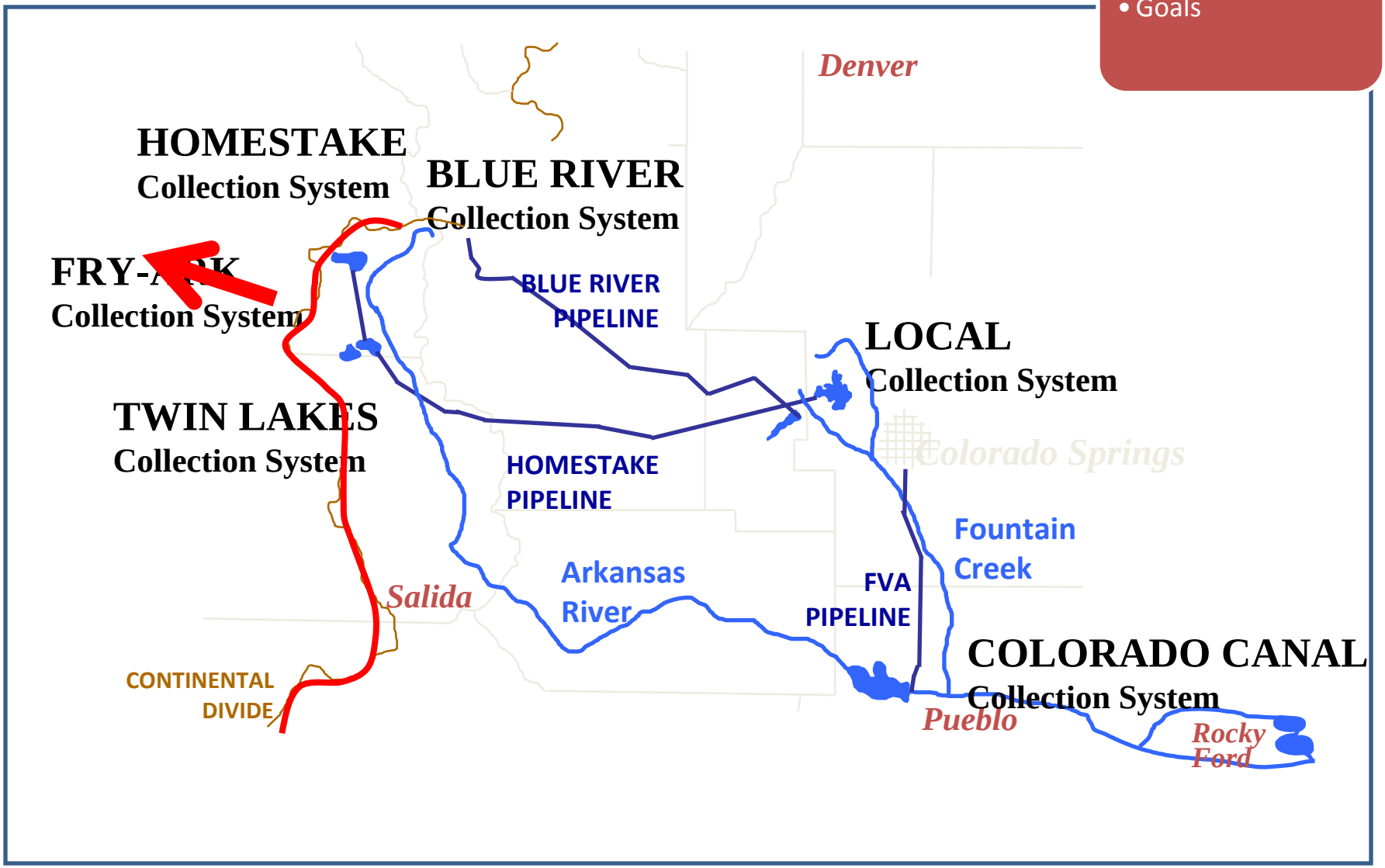
As Problem is Articulated, begin to define scope of Study: *Colorado Springs Utilities, An Example*

- **Enlarge spatial extent,**
- **Consider points of interest to define boundaries (Cameo)**
- **Temporal resolution adequate to reflect operational decisions (Weekly)**

Colorado Springs

Problem Structuring

- Problem Structuring
- Goals

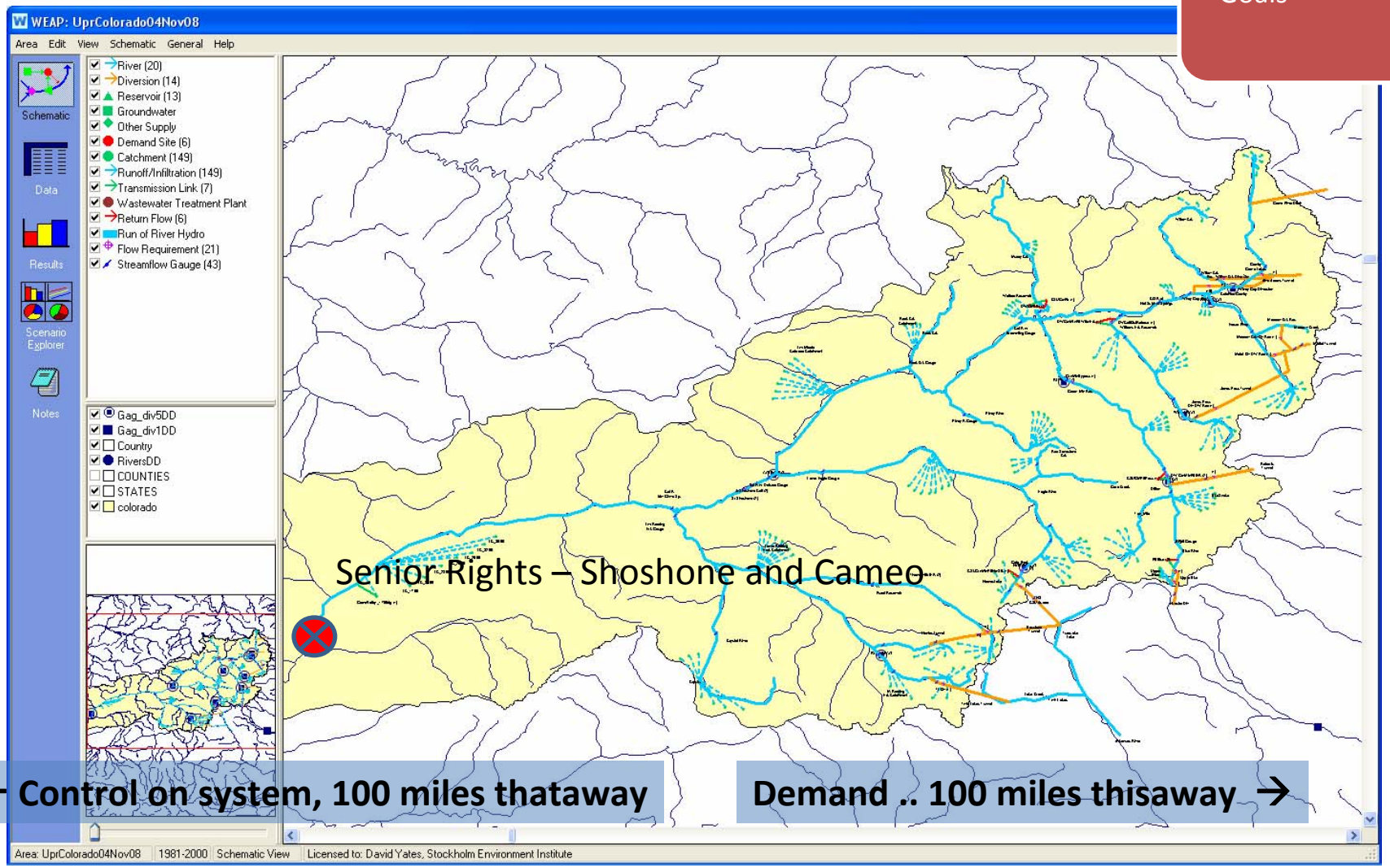


Basin and Infrastructure-

Upper Colorado Watershed

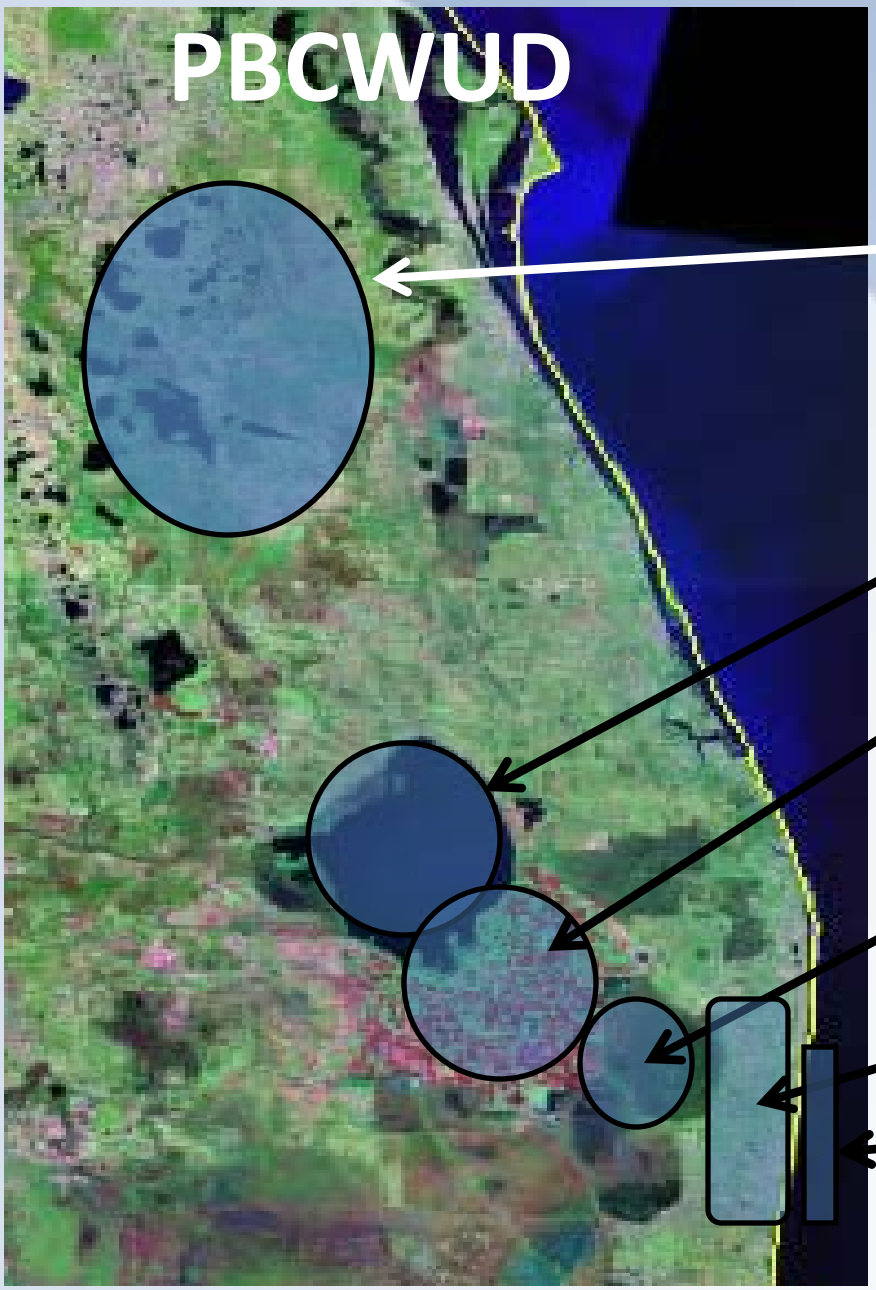
Problem Structuring

- Problem Structuring
- Goals



← Control on system, 100 miles thataway

Demand .. 100 miles thisaway →



Kissimmee Headwaters- Rapid Urbanization

Shallow Freshwater Lake- Reoperated for Flood Control

Largest Sugarcane region in Florida- some interest in 'buying out'

Preservation of Wetland Habitat

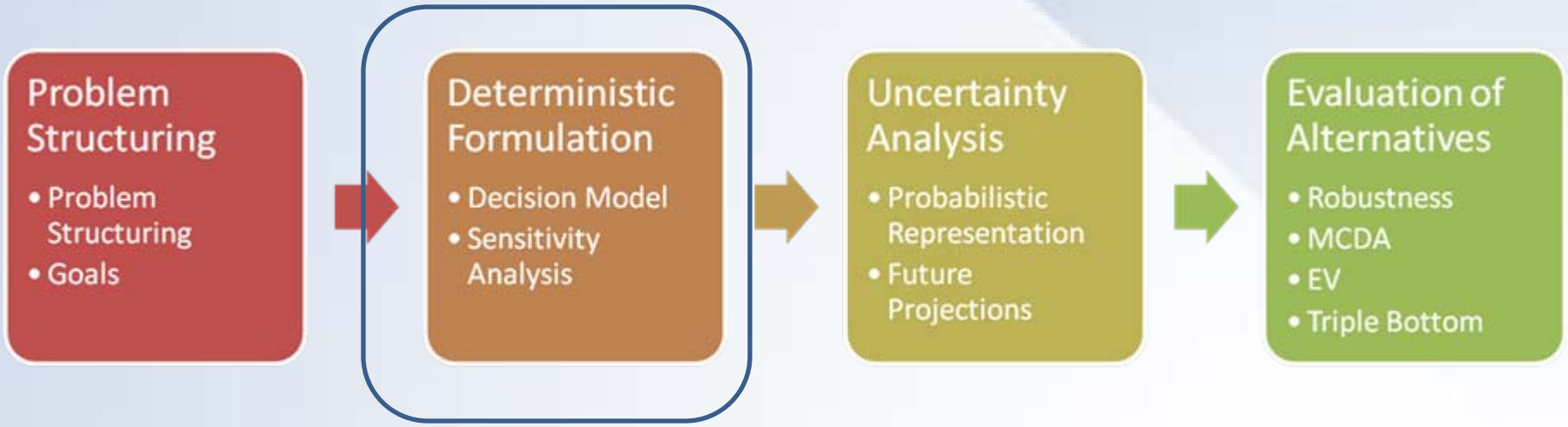
Urbanizing Corridor

Inland Estuary- Freshwater flux to tide

Problem Structuring

- Problem Structuring
- Goals

Bottom-Up Approach: Decision Analytic Approach to Climate Change



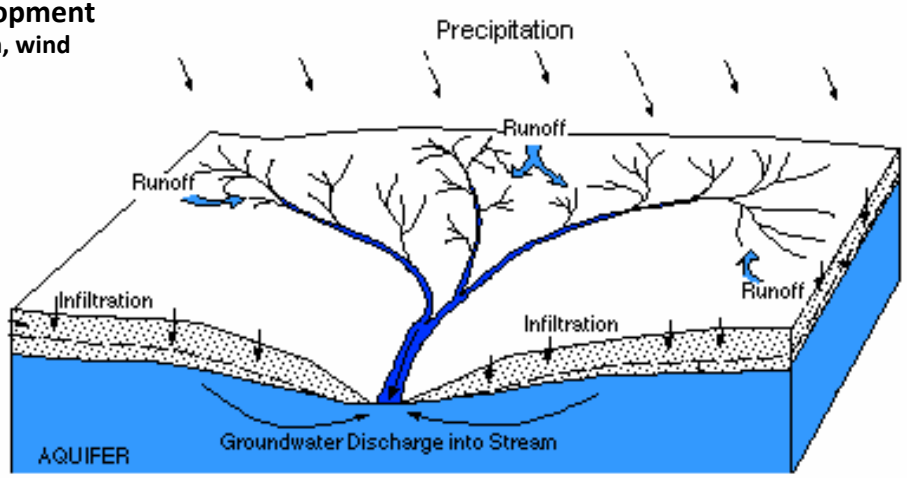
Deterministic Formulation

- **This Approach is Model-based: *"All are wrong, Some are Useful"***
  - **Surprisingly, many water utility models are not "climate-enabled"**
- **Develop approach that can address the questions at hand: "*Keep it simple as possible, and no simpler*" (Einstein)**
- **Begin Climate Change Exploration**

Need for An Integrating Model Framework

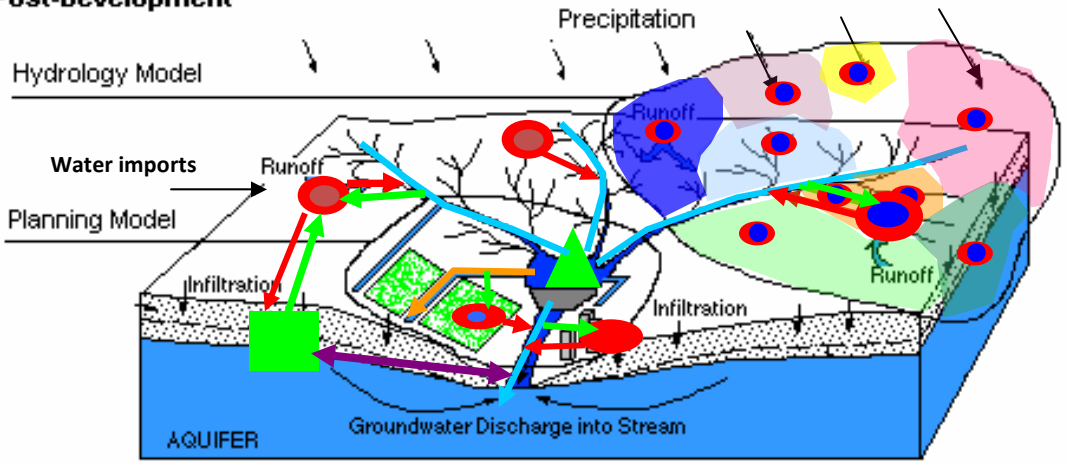
Deterministic Formulation
- Decision Model
- Sensitivity Analysis

Pre-development
Temp, rh, wind

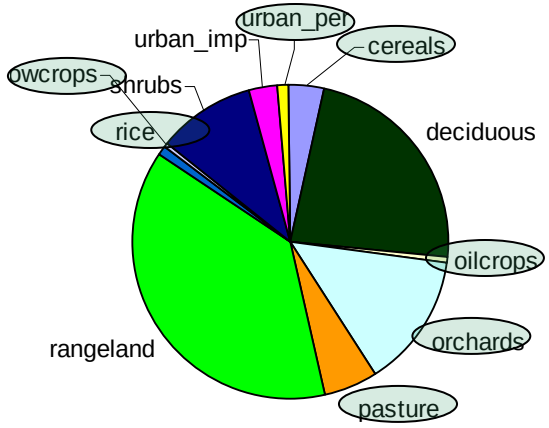


Natural Watershed

Post-Development



Developed Watershed

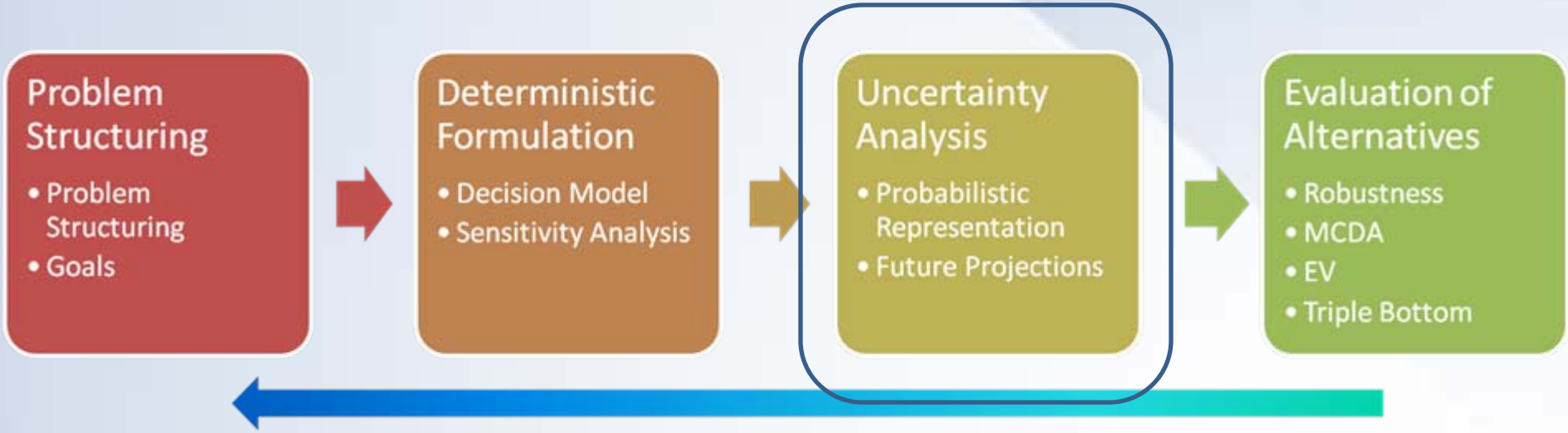


Climate Change Scenarios: A menu of Choices

Deterministic Formulation
- Decision Model
- Sensitivity Analysis

1. **Simple Sensitivity Experiments, Guided by Results from Global Climate Models ($)**
2. Statistical Downscaling ($$)
3. Hybrid Methods (Analogs, K-nn, etc.) ($$)
4. Regional Climate Simulations ($$$)
5. Dynamical Modeling with Statistical Downscaling ($$$$)

Bottom-Up Approach: Decision Analytic Approach to Climate Change

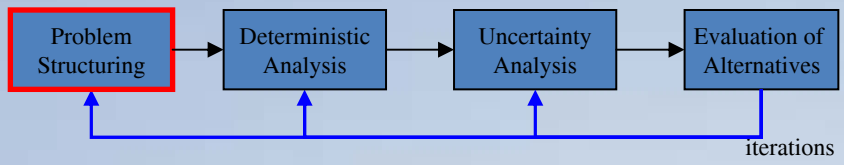


UNCERTAINTY ANALYSIS

Uncertainty Analysis

- Probabilistic Representation
- Future Projections

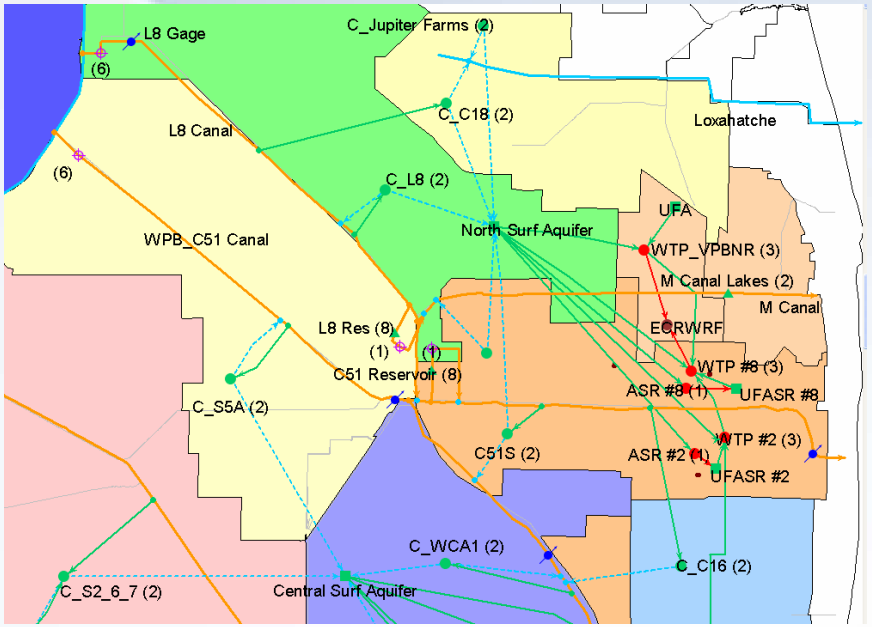
1) Need to evaluate decision performance under alternative future climates
2) Climate isn't the only uncertain variable
3) Decisions have multiple effects – how should they be weighted?



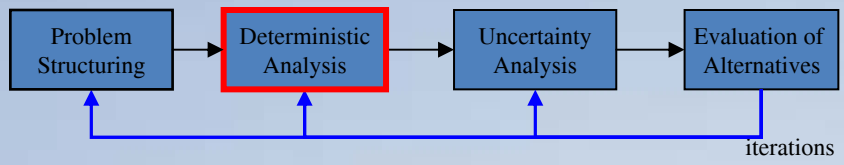
Goal or Question:
Is there a "Robust" Capital Improvement Plan?

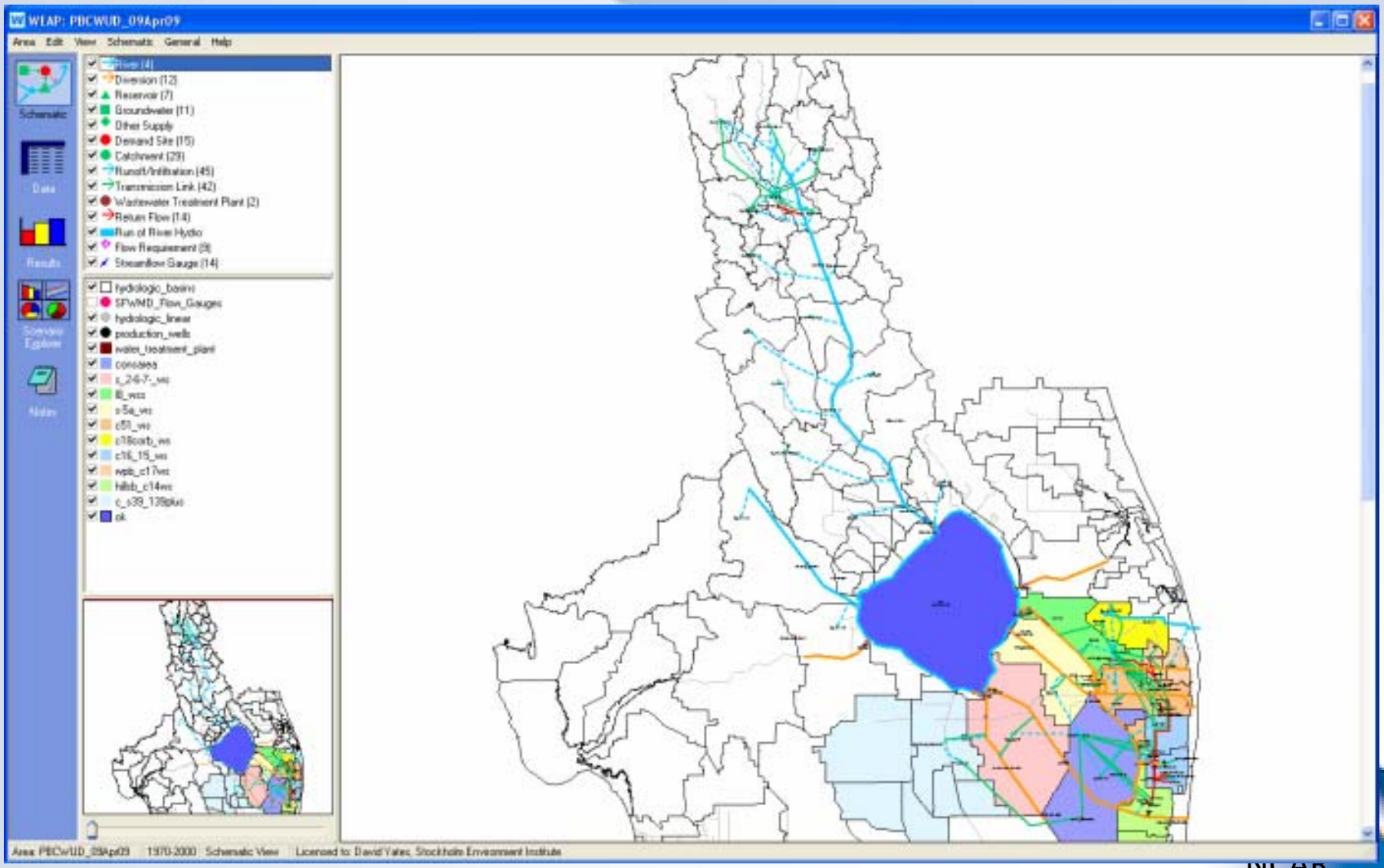
20-Year CIP Projects:

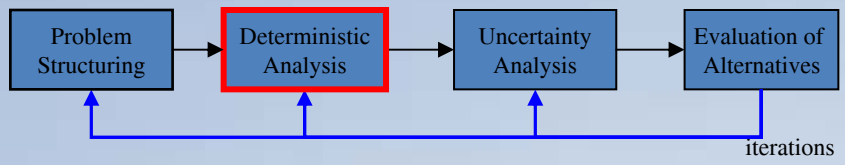
- ASR wells
- Surface Storage
- Water and WWTP Expansions
- New RO Treatment Facility
- Wellfield Expansions
- New Deep Injection Wells



WEAP Supply-Demand Model Rigorous Representation

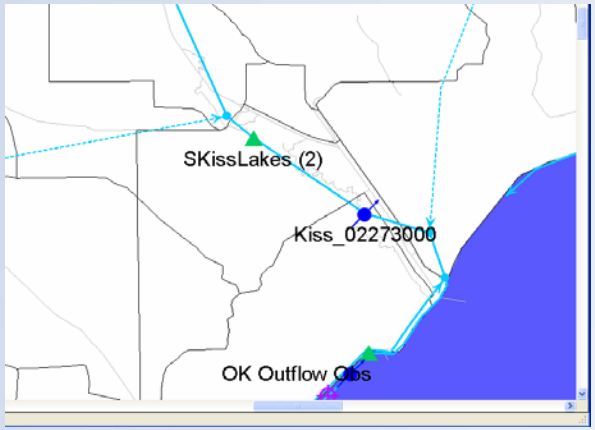




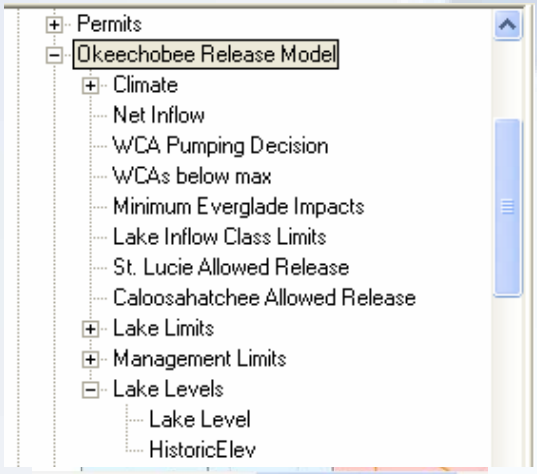


WEAP Model- Model of Supplies

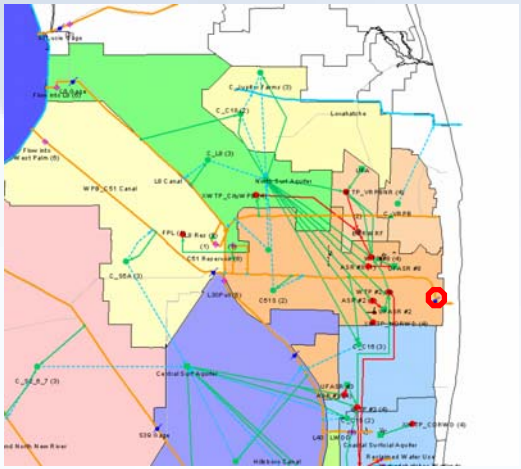
Kissimmee Inflows

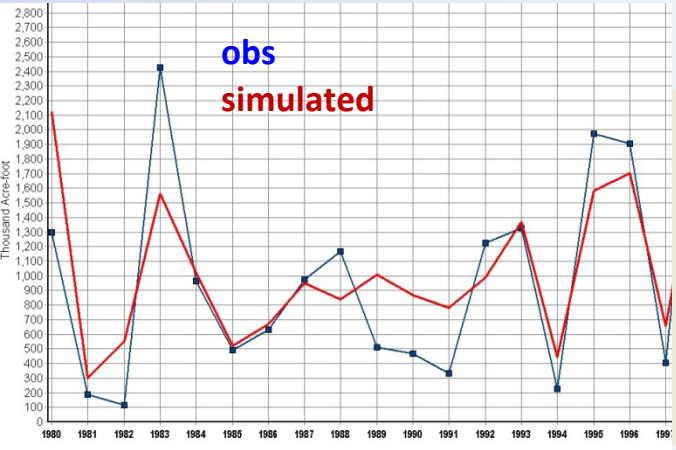


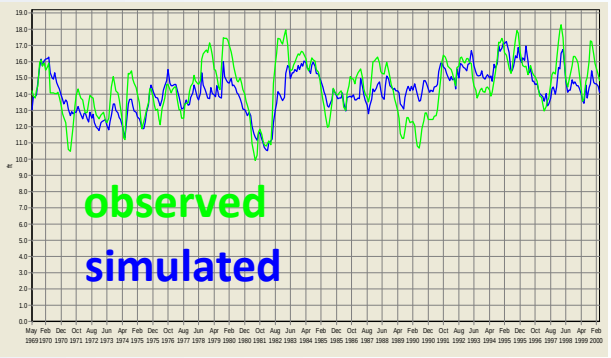
Lake Okeechobee Storage

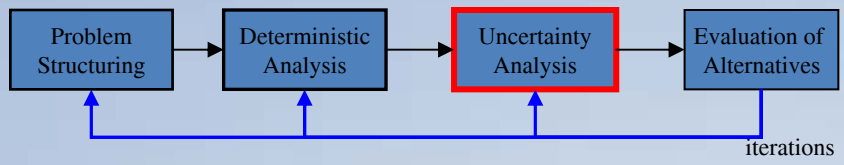


C-51 Outflow

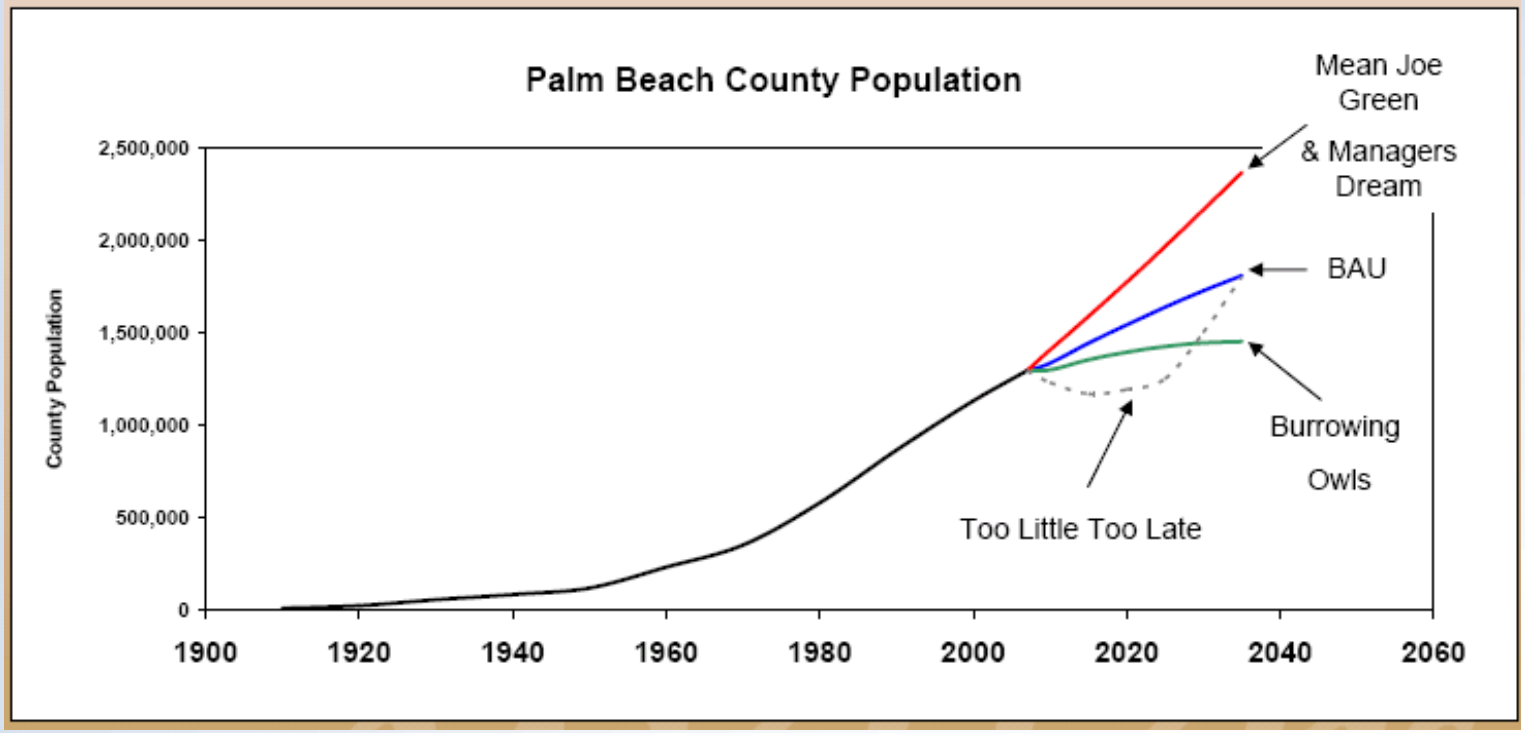






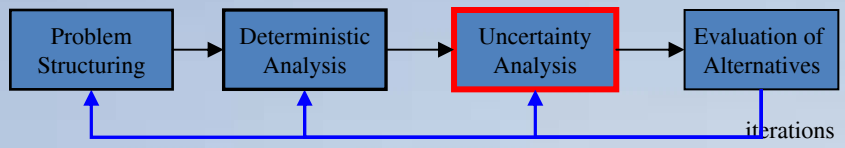


Population: An Uncertain Future in South Florida?



PBCWUD Total Demand in 2008 - ~80 MGD

Regional Demand in 2008 - ~ 225 MGD



Climate Scenarios- Spatial-Statistical Downscale

Statistically Downscaled WCRP CMIP3 Climate Projections - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html

JAN 07 climate water epa

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Santa Clara University

RECLAMATION

Statistically Downscaled WCRP CMIP3 Climate Projections

This site has been optimized for Internet Explorer (IE) 6., IE 7.*, and Firefox 2.*.*
Requires JavaScript to be enabled.

Welcome | About | Limitations | Tutorials | Data: Subset Request | Data: Complete Archives | Feedback | Links

Oct 31, 2008: Due to an unusually heavy demand in custom data requests over the last few days, requests may take several days to process. We are looking into adding an email notification feature to inform users of potential wait times.

Announcements (updated January 8, 2008)

Summary

This archive contains fine-resolution translations of 112 contemporary climate projections over the contiguous United States. The original projections are from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset, which was referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report. The "About" section on this website contains development information on these downscaled projection datasets (i.e. background, data attributes, and methodology).

Purpose

The archive was developed to provide planning analysts access to climate projections "downscaled" to a finer spatial resolution. Such access permits development of decision-support information and associated regional and local adaptive strategies under potential climate change. Several types of analyses are supported by this archive, including:

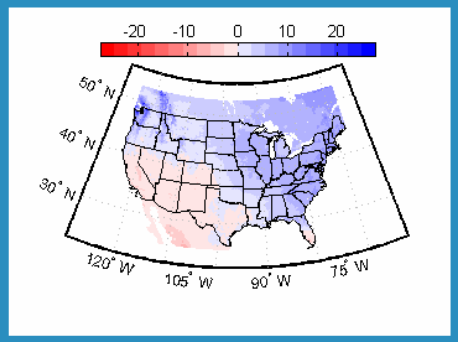
- regionally distributed assessments of projection frequency (Figure 1).
- location-specific assessments of projection frequency (Figure 2).
- climate change impacts assessments for social and natural systems.
- risk-based exploration of planning and policy responses.

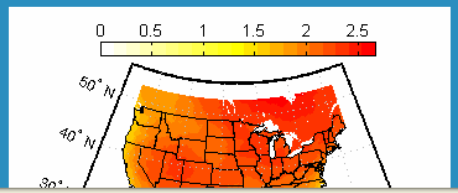
Terms of Use

These data are being distributed to interested users for consideration in research and planning applications. Such applications may include any project carried out by an individual or organized by a university, a scientific institute, public agency, or private sector entity for research or planning purposes. Any decision to use these data is at the interested user's discretion and subject to the Disclaimer provided below.

Disclaimer

Figure 1a-b: Median projected change in average-annual precipitation (above, cm/year) and temperature (below, °C), 2041-70 versus 1971-2000





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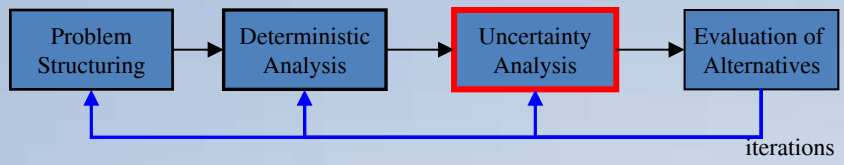
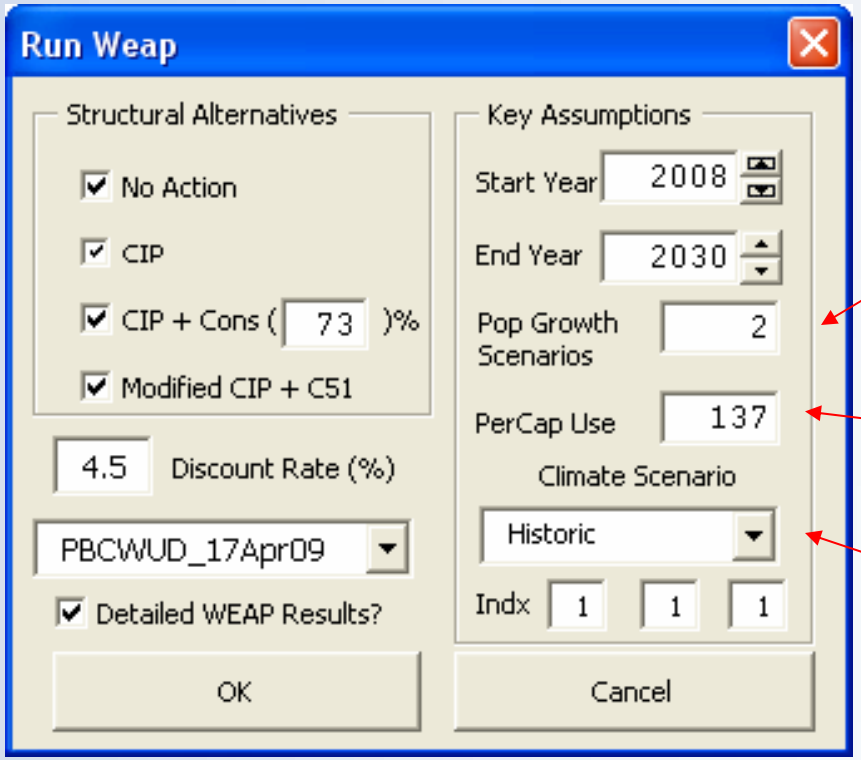


Microsoft Excel, MCDA Dashboard- *Explore Uncertainties*

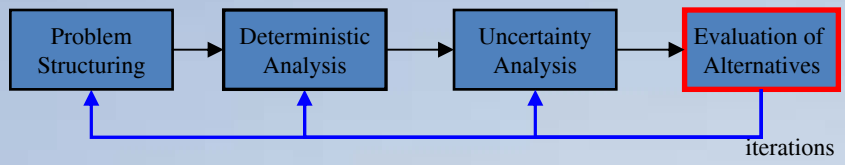


MCDA (Excel) used to set parameters

WEAP

- Population Growth Scenario
- Water Use Rate (gpcpd)
- Climate (Historic or Model)
- Regulation

MCDA



Stakeholder Weights Assigned to Each Criteria

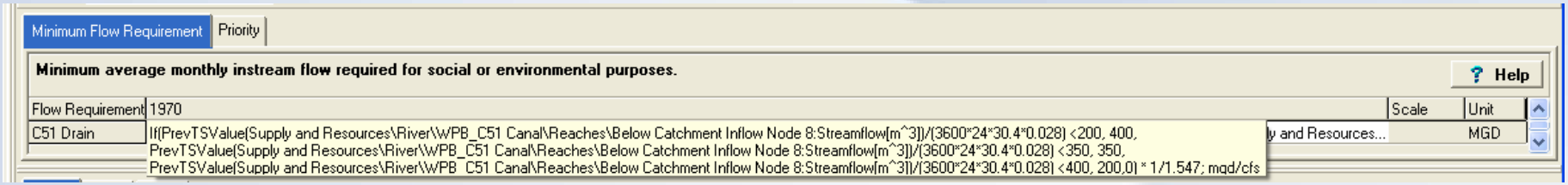
MCDA Matrix

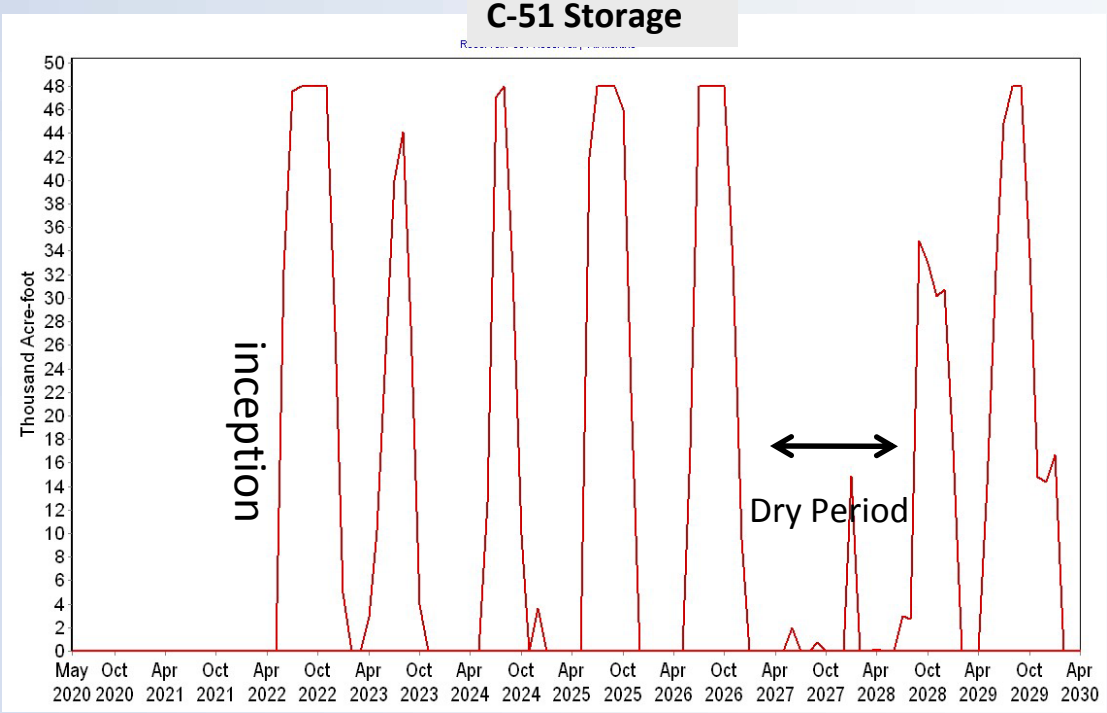
Alternative		Criteria								
		C1	C2	C3	C4	C5	C6	C7	C8	C9
		Water available net demand (excess cap)	Regional System Offsets	New Storage (Res and ASR)	Deep Injection	Regional solution-Flexible & Future	Long-term capital & permit risks	Project Cost-Capital Investm	Wet Season Flow to tide	Energy needs and use
		VEAP	VEAP	VEAP	VEAP	Project Description	Project Description	VEAP	VEAP	Relative Estimate
		Max	Max	Max	Min	Max	Min	Min	Min	Min
		mgd	mgd	T ac-ft/yr	mgd	L,M,H	L,M,H	$M NPV	mgd	L,M,H
	Active	Yes	Yes	Yes	Yes			Yes	Yes	
1	CIP	Yes	13.04	4.58	0.2	4.22	Low / Moderate	Low / Moderate	$158	303.2	Low / Moderate
2	CIP + Conservation	Yes	20.2	4.98	0.2	2.75	Low / Moderate	Low / Moderate	$87	305.4	Low / Moderate
3	Mod CIP + C51 Res	Yes	4.34	18.56	8.7	4.41	Moderate / High	Moderate / High	$142	332.9	Moderate / High
4	No Action	Yes	0.0	3.02	0.0	2.34	Low / Moderate	Low / Moderate	$0	249.7	Low / Moderate
							Moderate / High	Low / Moderate			Low / Moderate

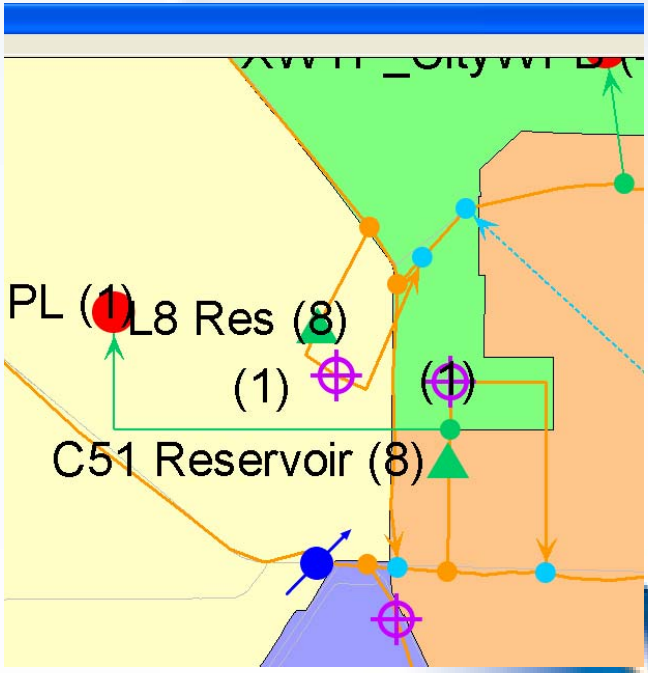
Each Criteria is Evaluated for Each Alternative

HOW? Then Use Model to Evaluate Alternatives

Focusing in on an Alternative: *Modified CIP + C51*
WEAP Mathematical "Expression Builder" is used to mimic the operations of C-51, e.g. Fill during high flows, release during low flows







NCAR

Example Results – C-51 Reservoir

Monthly Mean Discharge, 2023-2030 (Historic climate 'repeats')