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Modeling the Hydrologic/Ecologic/Economic/Social Dynamics of Small Scale Community Irrigation Systems

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Sandia National Laboratories

Acequias and the Future of Resilience in Global Perspective *Las Cruces, NM, March 5, 2013*

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Project Team

- Funding
  - National Science Foundation – Program on the Dynamics of Coupled Natural & Human Systems - #1010516
  - NSF NM EPSCoR - #0814449
  - New Mexico Agricultural Experiment Station
- Universities
  - New Mexico State University (Brian Hurd, Sam Fernald, Ken Boykin, Andres Cibils, Steve Guldan, Caiti Steele, Carlos Ochoa)
  - University of New Mexico (Jose Rivera, Sylvia Rodriguez)
  - New Mexico Institute of Mining and Technology (John Wilson)
  - University of Concepcion, Chile (J.L. Arumi)
- Collaborators
  - Sandia National Laboratories (Vince Tidwell)
  - New Mexico Acequia Association (Marquita Ortiz)

Key Questions

- What role do acequias play in:
  - Hydrologic buffering?
  - Community resilience?
  - Ecosystem health?

- How do climate change and urban population growth challenge these functions?

- What strategies are needed to assist in protecting these functions?

Need

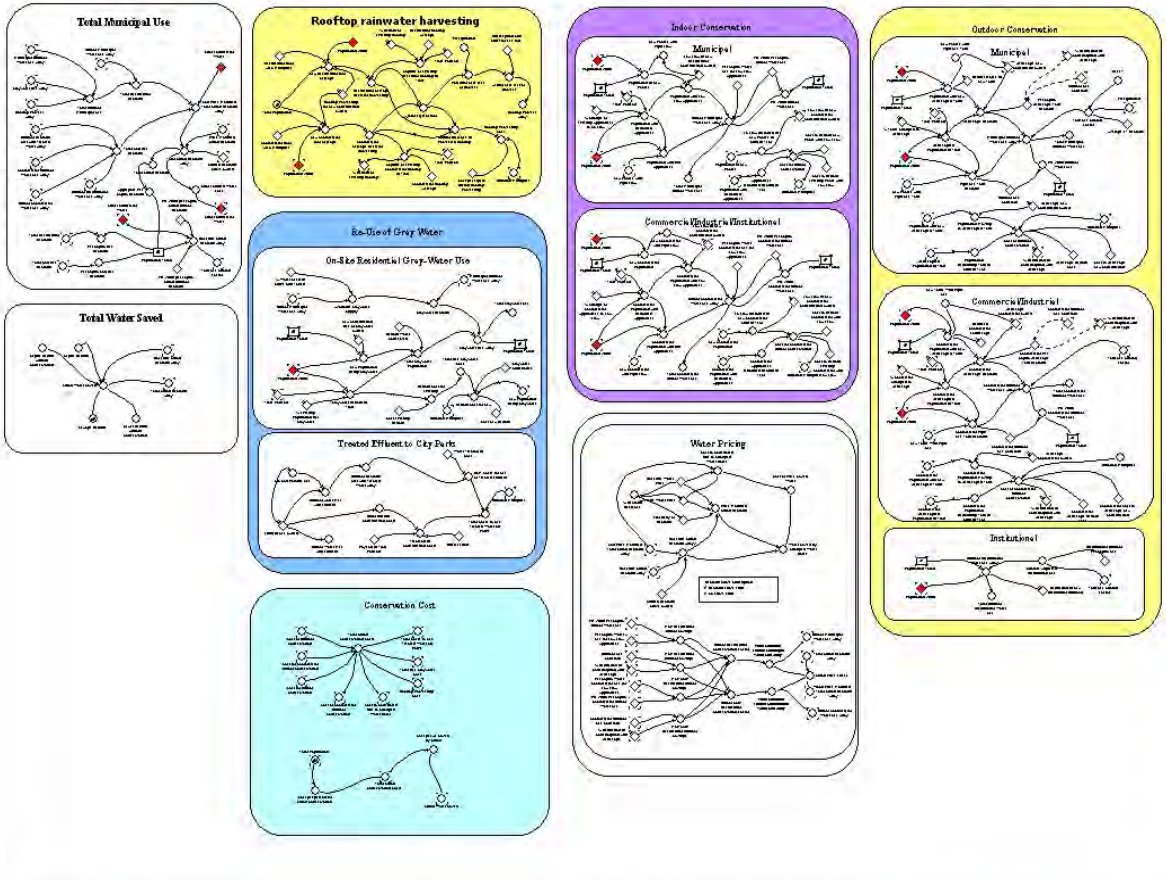
- Tools to integrate knowledge and data developed as part of project
- Tools to evaluate alternative treatments in face of uncertainty.
- Tools that our stakeholders will trust to assist them in long-term planning.

Approach: Collaborative Modeling

- Process of engaging decision-makers and stakeholders in:
  - Model development, and
  - Decision analysis.
- Purpose of broad input includes:
  - Expand knowledge base,
  - Structure group thinking/discussion,
  - Stimulate group learning, and
  - Ultimately lead to improved advocacy.

System Dynamics

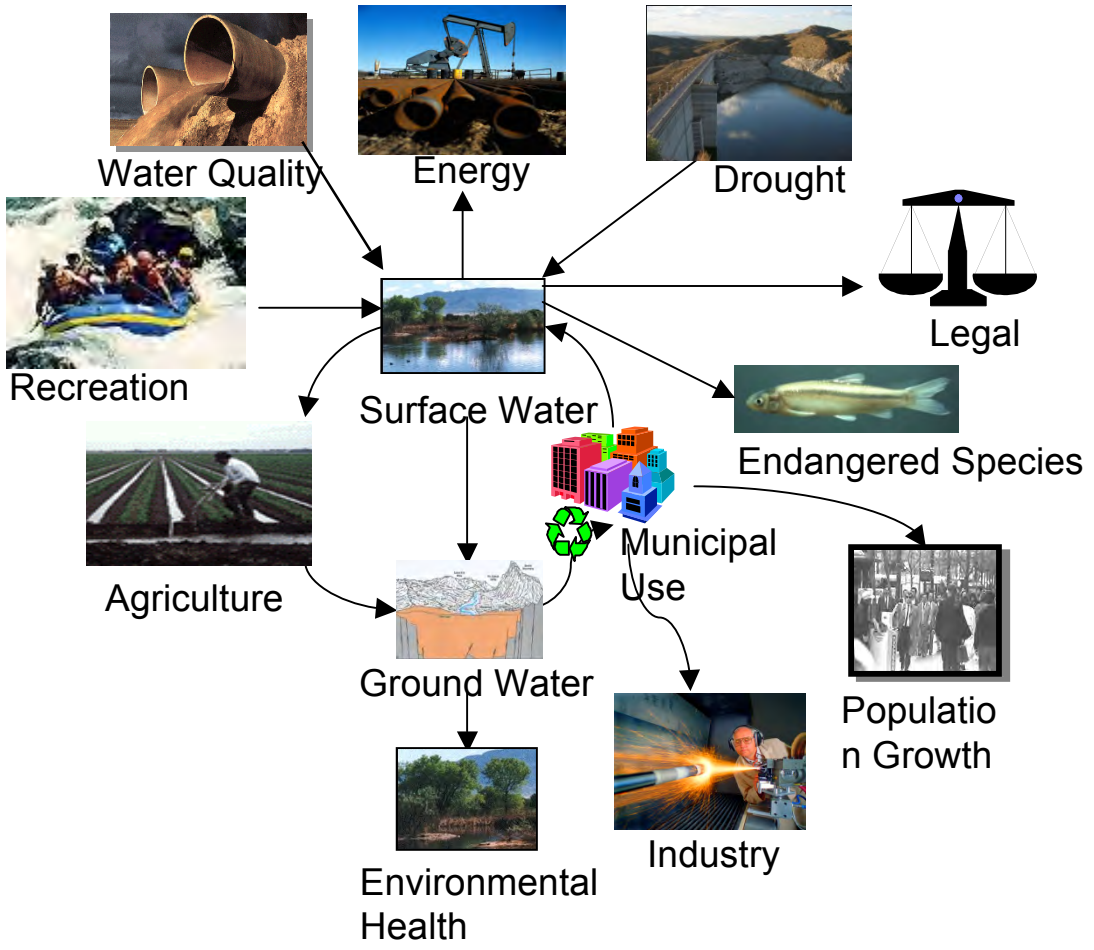
- We employ *System Dynamics*, which provides a formal framework for managing multiple interacting subsystems, each of which vary in time
- With system dynamics we are able to quantify feed-back, time delays, and coupling between subsystem components



Focus is on ***Dynamic Complexity*** rather than ***Detail Complexity!***

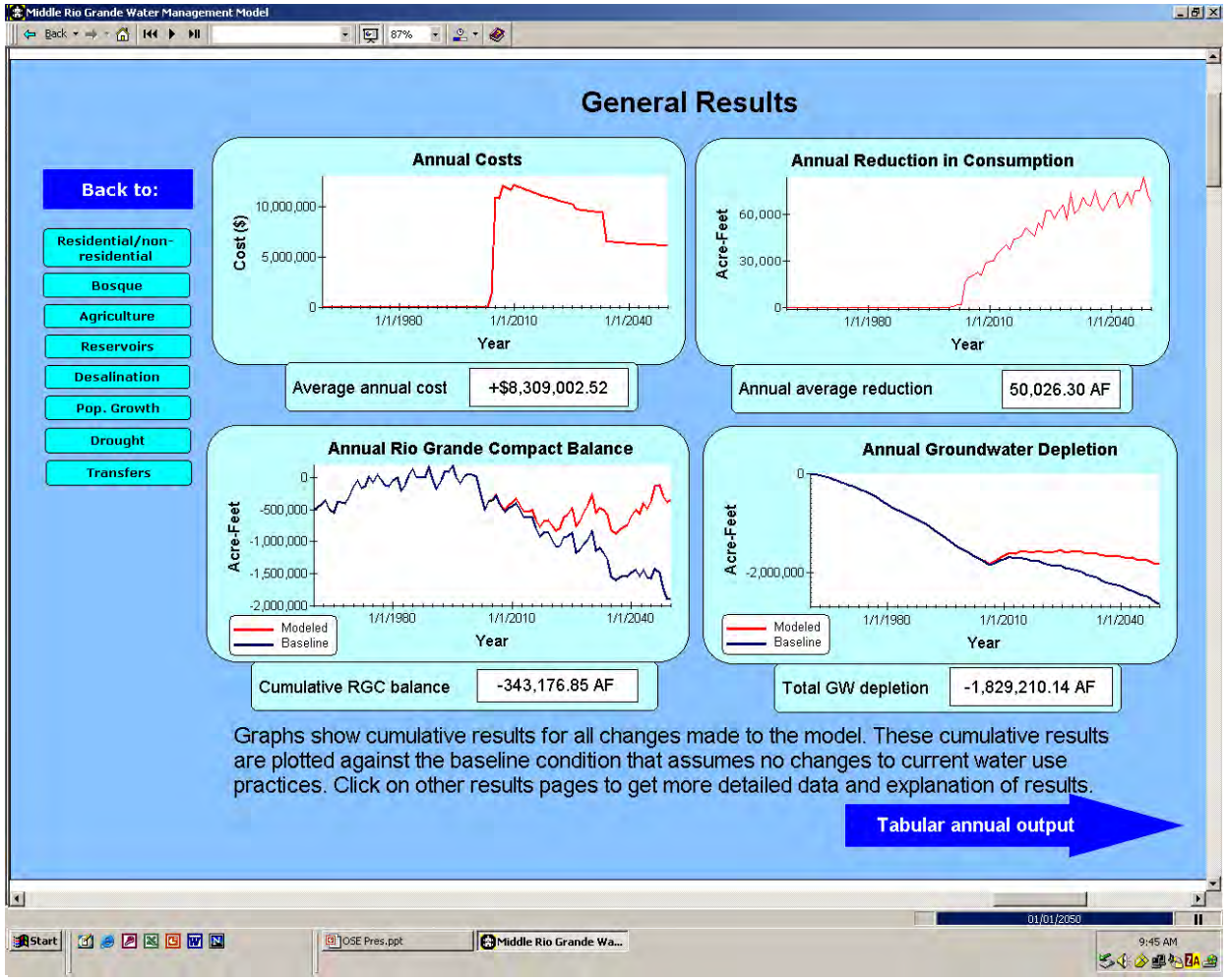
System Dynamics: Integrative Modeling

- Provides a framework for integrating over the broad range of factors influencing resource management

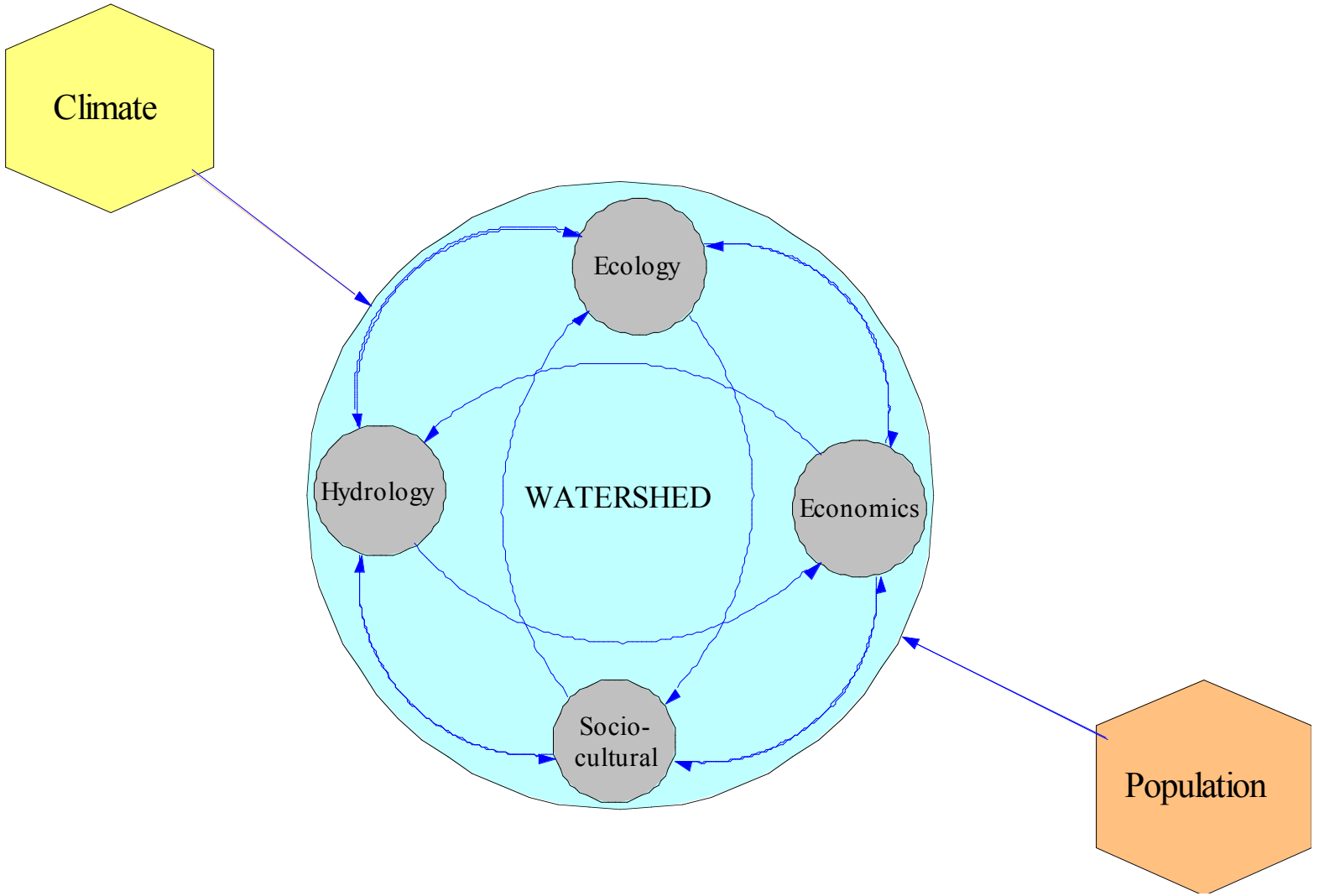


System Dynamics: Interactive Modeling

- Broadly accessible
  - PC based
  - User friendly interfaces
  - Computations in seconds to minutes
- Provides interactive environment for scenario testing



Integration Across Disciplines



Downstream Integration

Resources

Climate

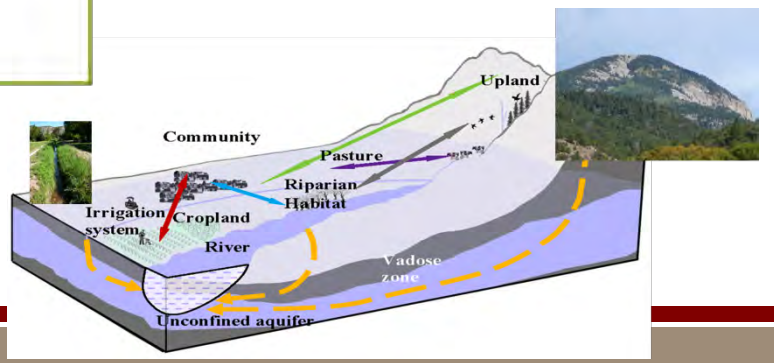
Watershed
- Hydrology
  - Precipitation/runoff
  - Groundwater recharge
- Landscape evolution
  - Climate
  - Land use
  - Fire
- Land use decisions
  - Grazing
  - Hunting
  - Thinning
  - Ignore

Irrigated Valley
- Hydrology
  - Water use
  - Hydrograph modification
- Landscape evolution
  - Climate
  - Land use
- Land use decisions
  - Farming
  - Tourism
  - Selling out
- Economics
  - Locally derived income
  - Externally derived income
- Community
  - Immigration
  - Participation

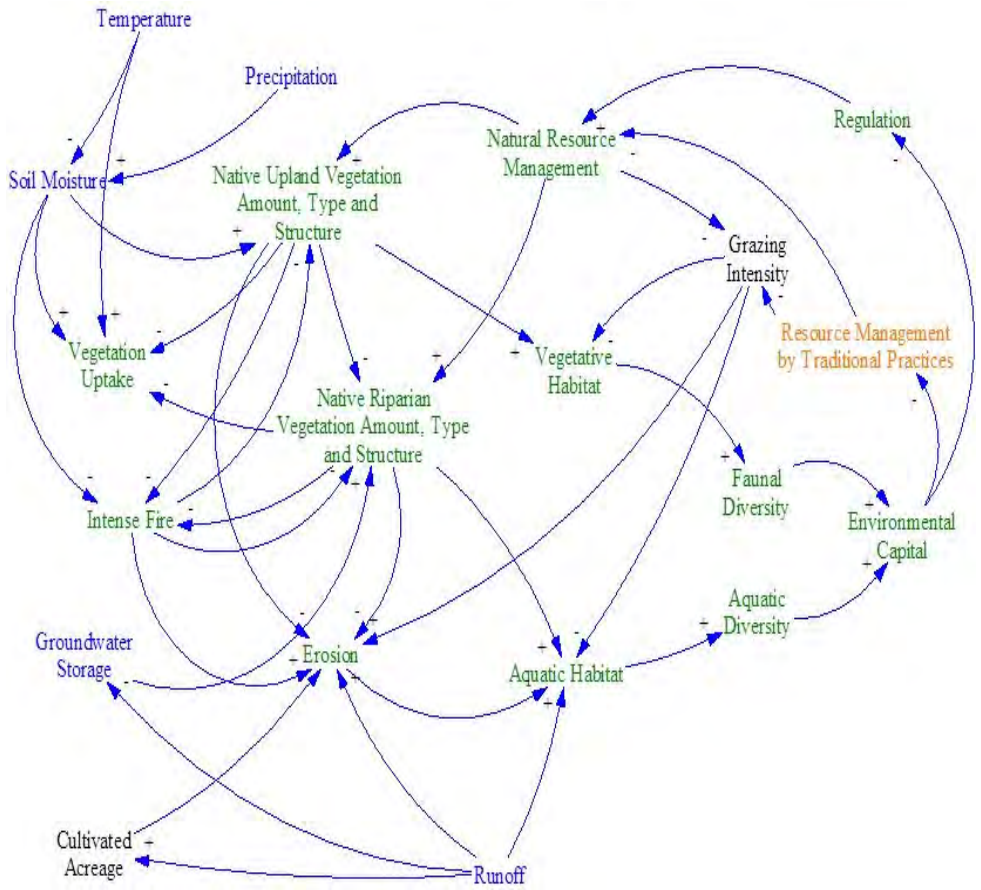
Urban Zone
- Economics
  - Demand for water
  - Other demands
- Opportunities
  - Jobs
  - Demand for land
  - Demand for water

Economics

Management

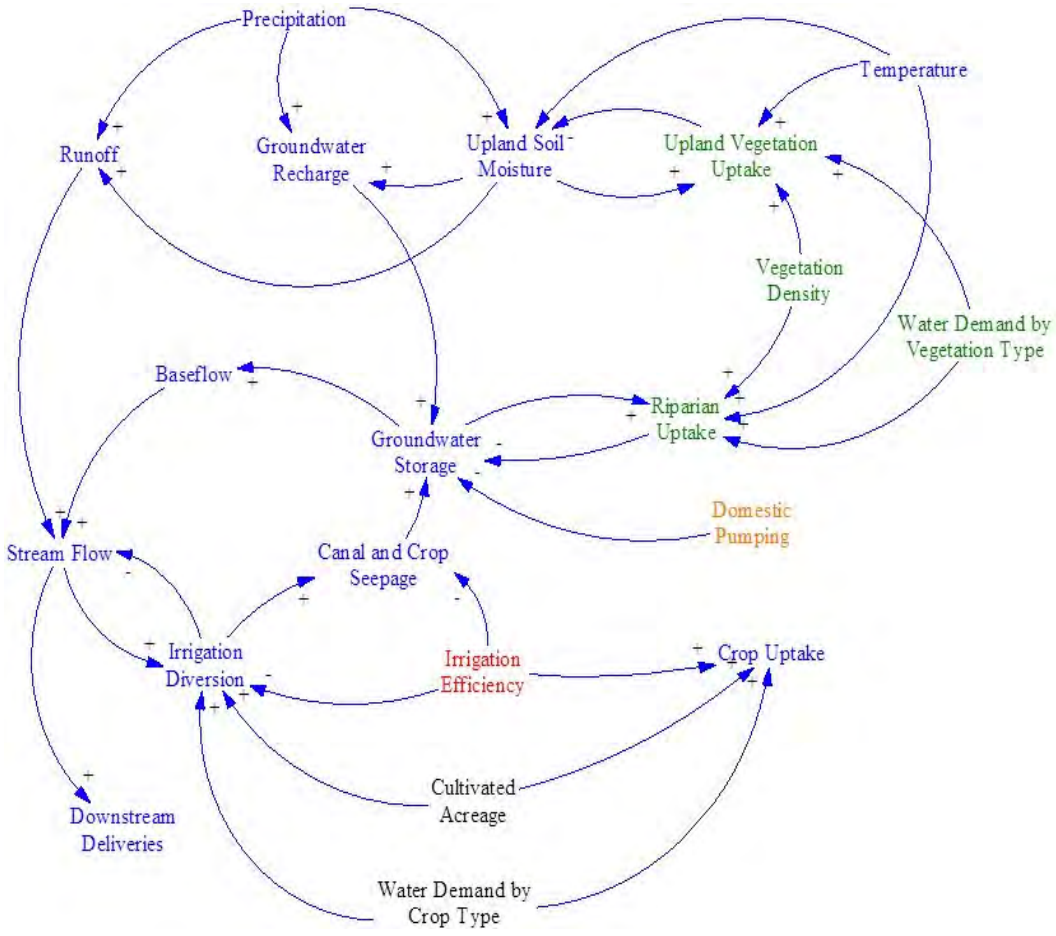


Ecologic Dynamics



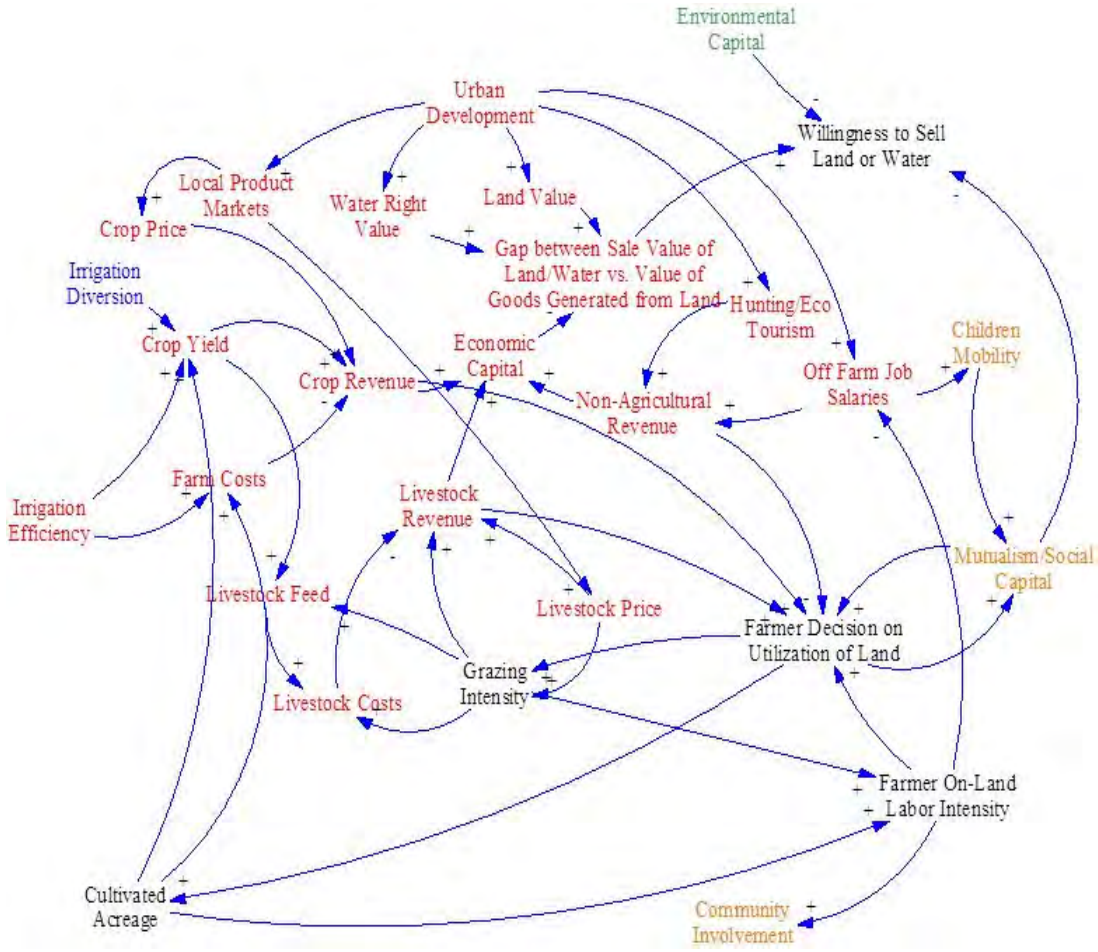
- How will climate impact:
  - Vegetation type and density,
  - Wildfire frequency,
  - Species diversity,
- How is ecology influenced by:
  - Grazing,
  - Hunting,
  - Fuels/wildlife management,
- How do climate and watershed management influence:
  - Stream flows,
  - Groundwater recharge,

Hydrologic Dynamics



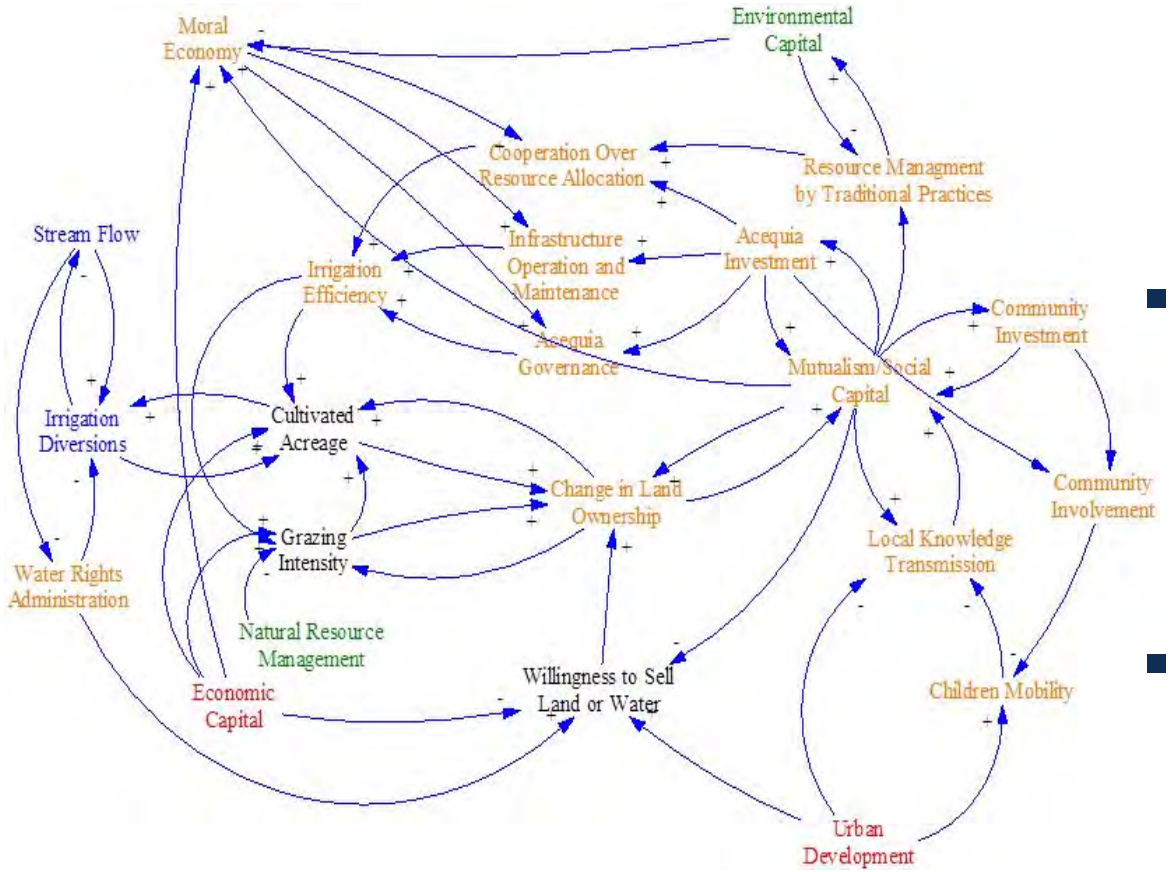
- How does water availability influence:
  - Irrigation practices,
  - Upland grazing decisions,
- How do irrigation practices influence the ecology:
  - Riparian habitat,
  - Hydrograph modification,
  - Water quality
- What steps can be taken to improve water availability:
  - Conservation,
  - Cooperative management,

Economic Dynamics



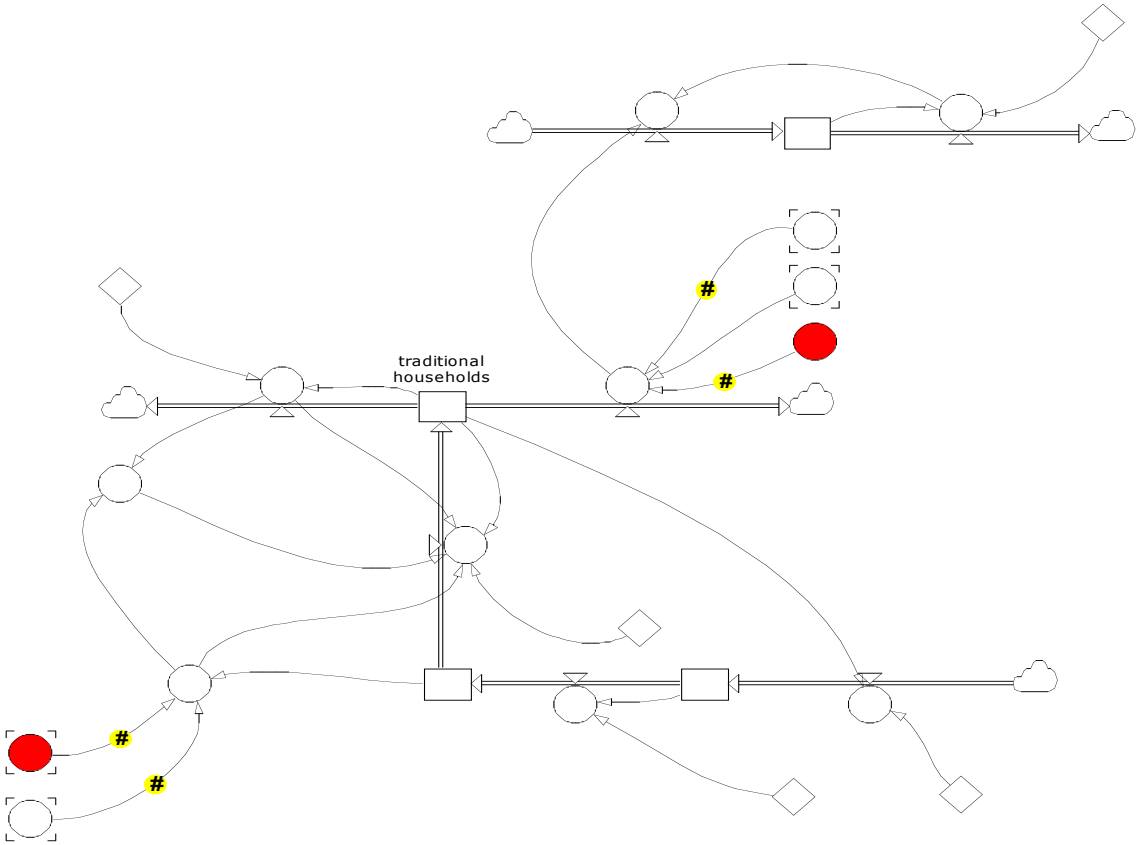
- What influences landowner decisions:
  - Drought,
  - Neighbors,
  - Crop value,
- How are landowners influenced by downstream urbanization:
  - Land and water values,
  - Job opportunities,
  - Basic services,
- What are adaptive mechanisms
  - Outside jobs,
  - Cooperation,
  - Conservation,

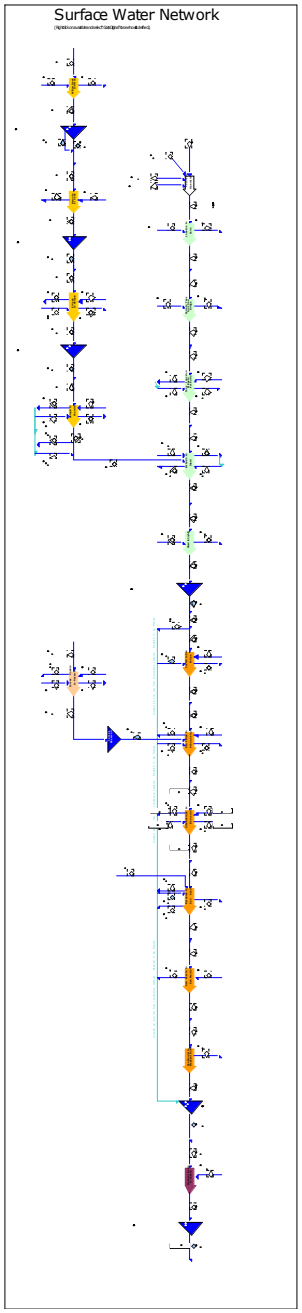
Socio-Cultural Dynamics



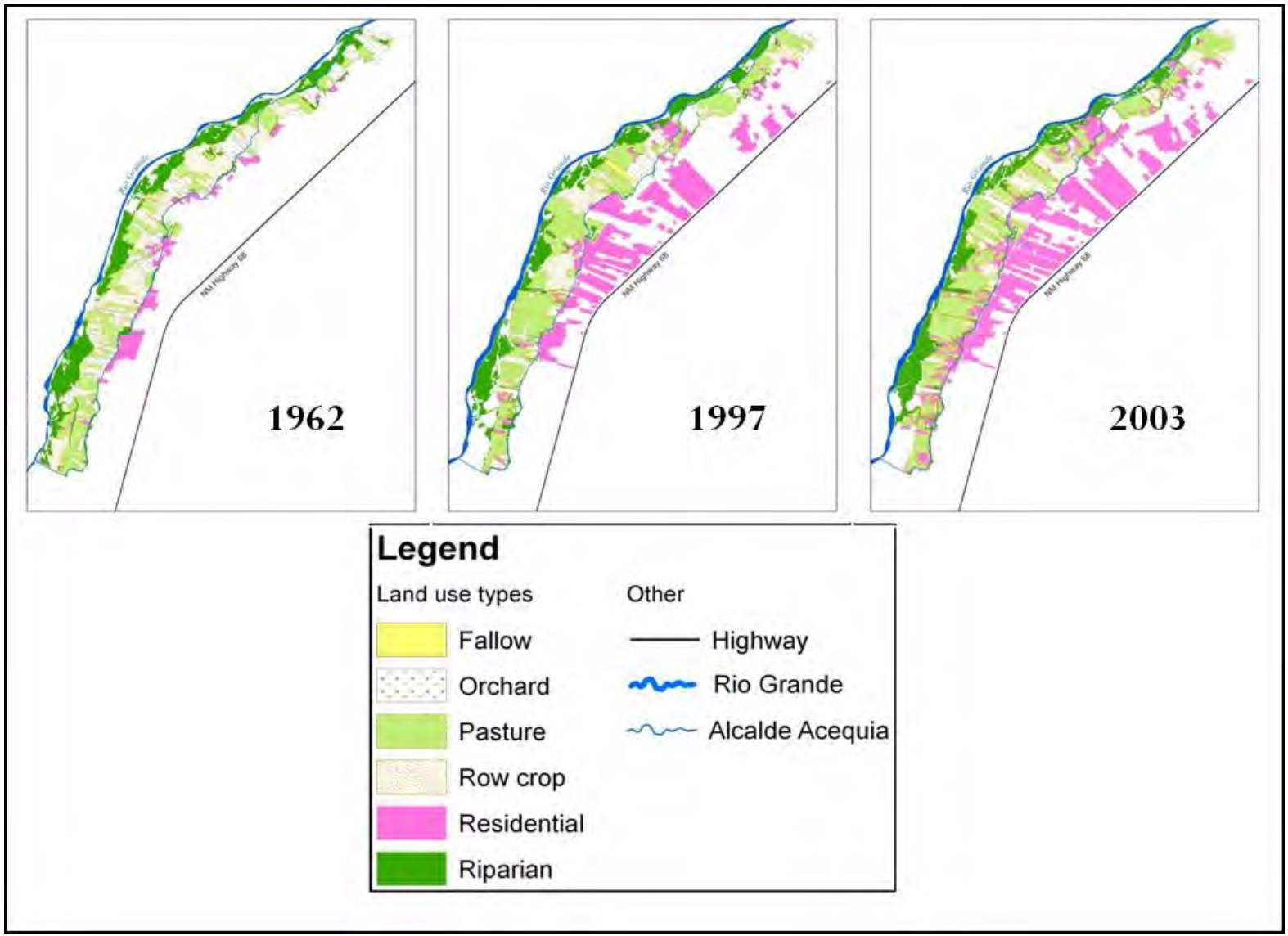
- What holds people to the land:
  - Family,
  - Sense of community,
  - Traditional practices,
- What ties the community together:
  - Acequia ,
  - Community participation,
  - Shared labor,
- How does urbanization threaten community:
  - Loosing children off land,
  - Changing demographics,
  - Loss of water,

Model Development

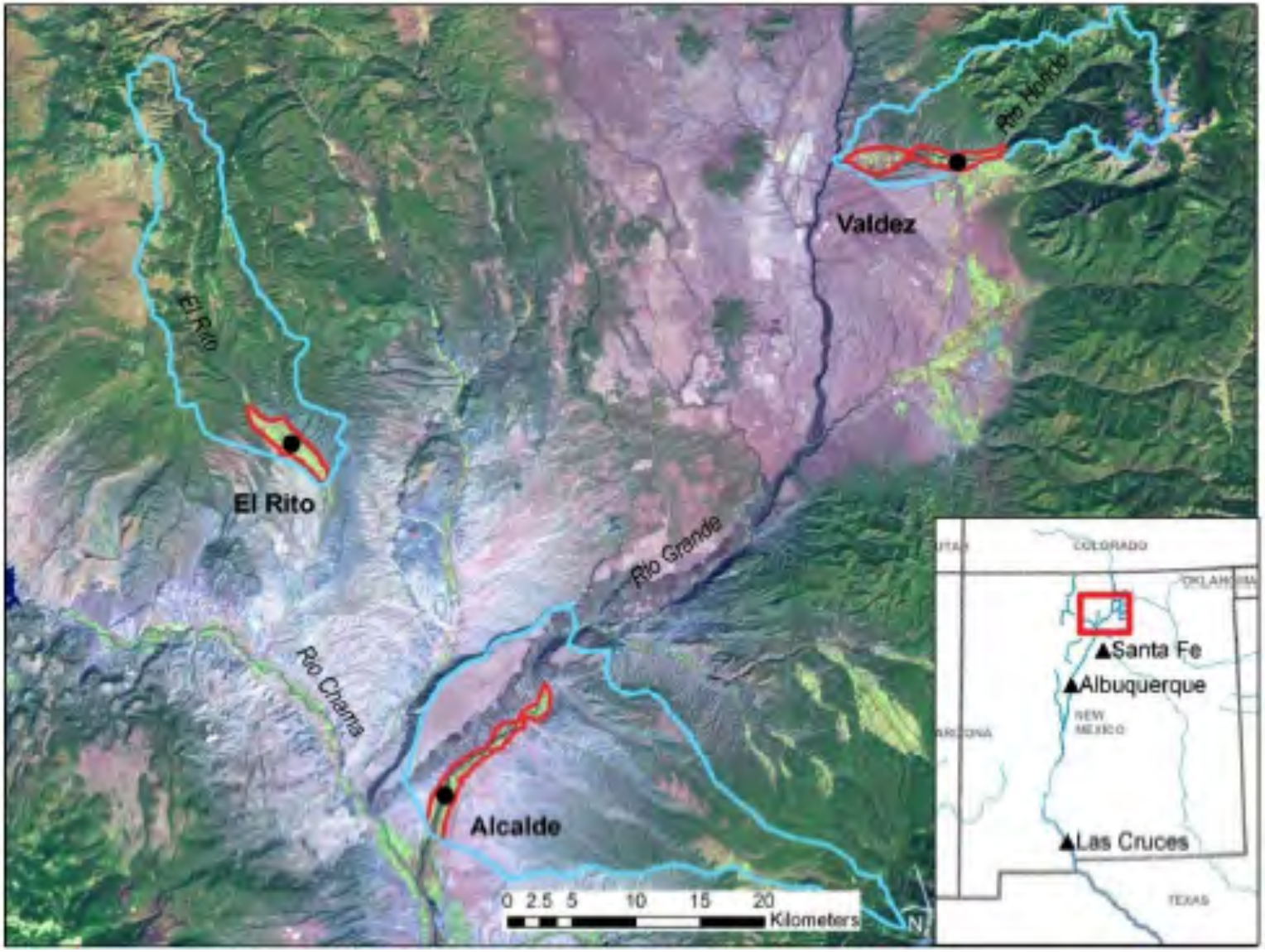




Calibration



Extending Results Downstream



Middle Rio Grande

Data availability:

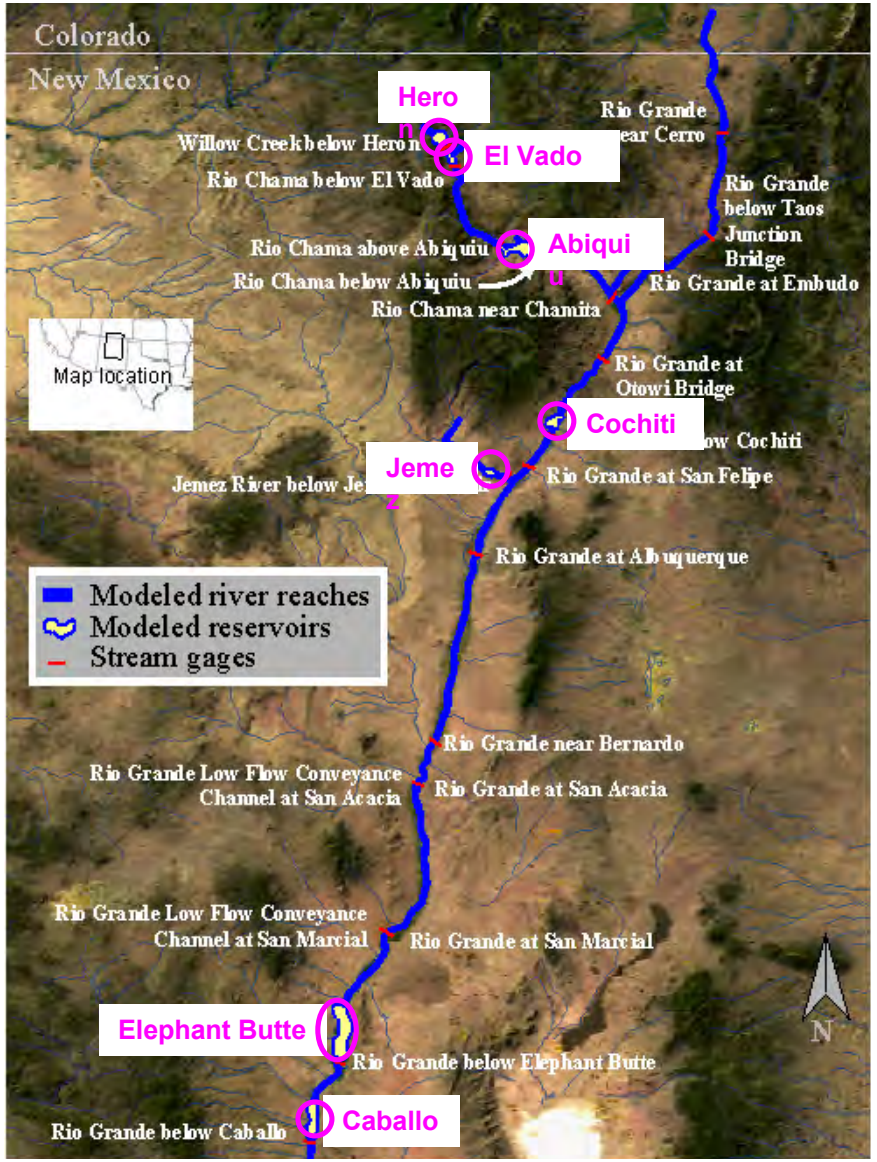
- Dominant historical data set is from USGS stream flow gages:

"River reach": gage location based spatial unit of mass balance.

17 river reaches

- 12 Rio Grande
- 4 Rio Chama
- 1 Jemez River

In addition to river reaches, there are 7 spatial mass balance units representing major reservoirs



Middle Rio Grande

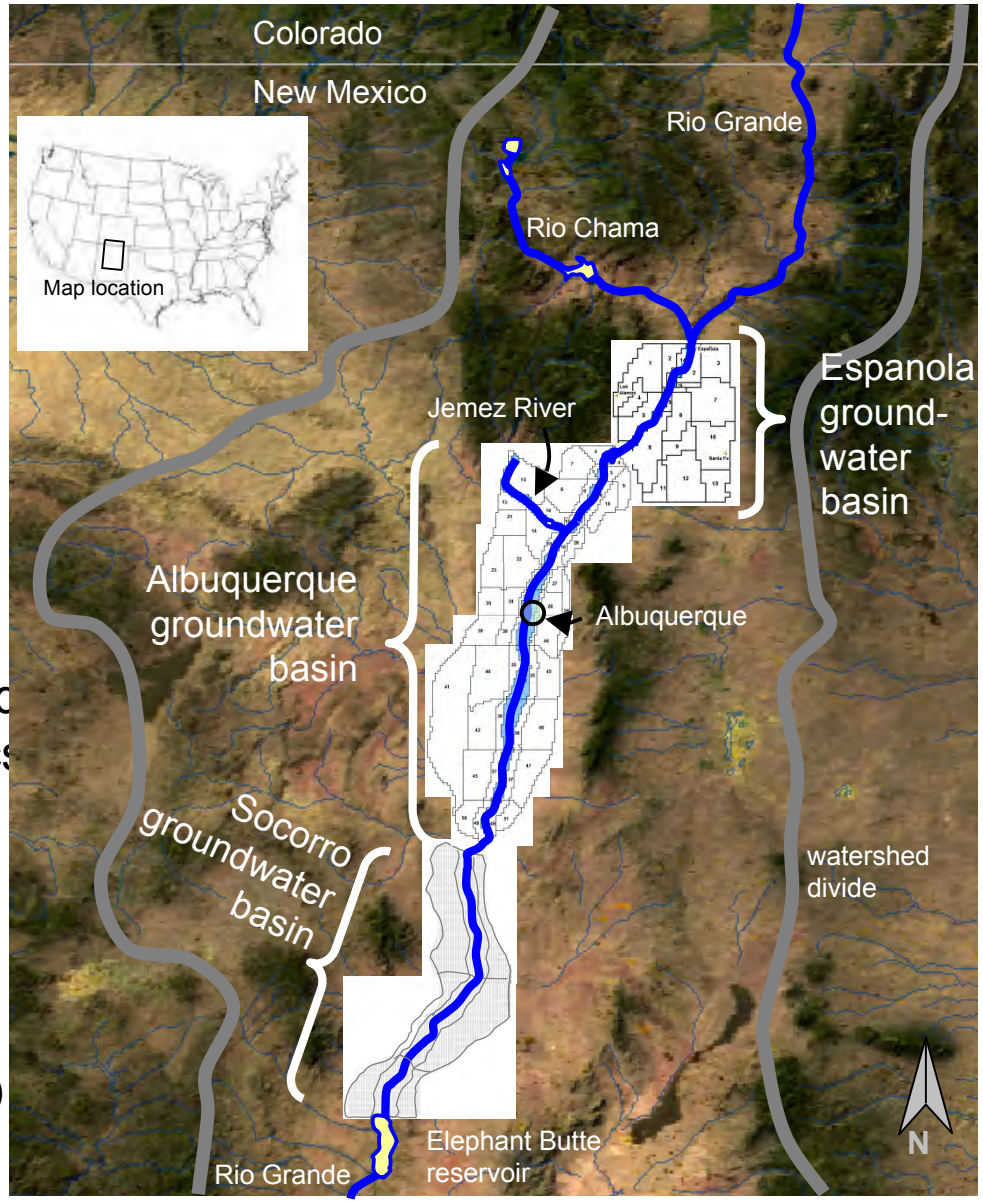
Goal:

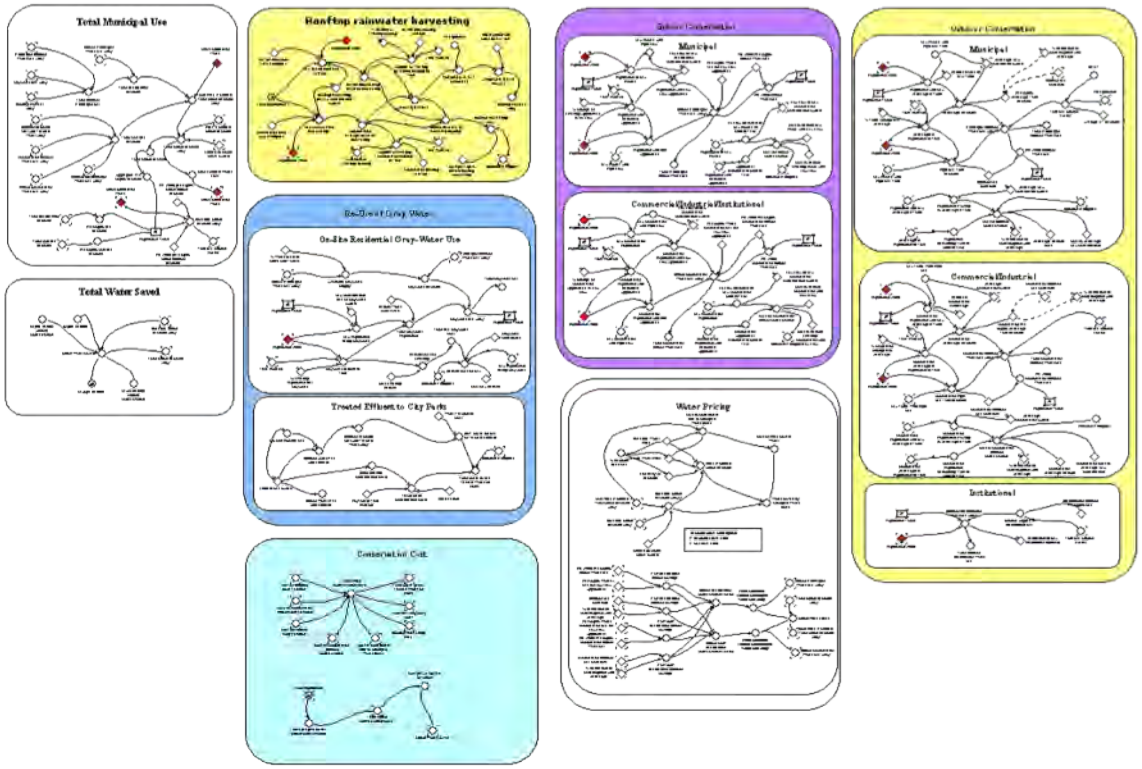
- A rapid and physically based, dynamic representation of sw-gw interactions in Rio Grande river system coupled directly to dynamic surface water model.

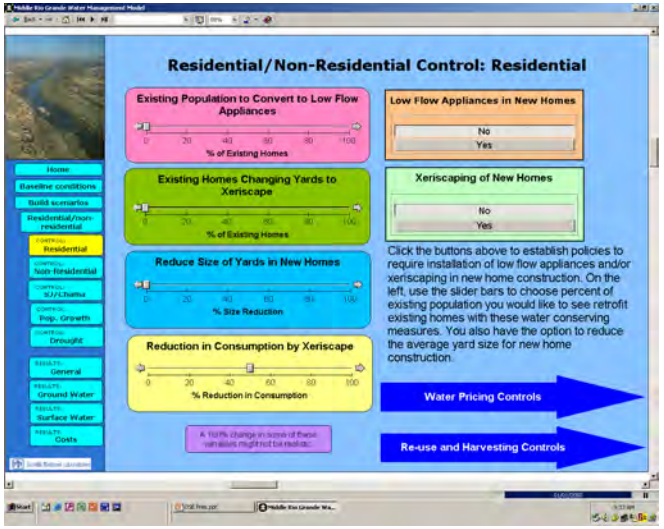
Strategy:

- Use spatially explicit groundwater models to calibrate spatially aggregated versions in Powersim (system dynamics software).

- Three spatially explicit models of interest:
  - Espanola Basin (Frenzel 1995)
  - Albuquerque Basin (McAda et al 2002)
  - Socorro Basin (Shafike 2005)







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