Example C
Cooperative Ecosystem Study Unit
Cooperative Agreement
Project Framing Document

This framing document is intended to provide the necessary information to Reclamation's Financial Assistance Officers to develop and execute a cooperative agreement with Colorado State University under one of the following existing Cooperative Ecosystem Study Units (CESU) master cooperative agreements:

Colorado Plateau – Agreement Number 9-FG-81-0143
Great Plains- Agreement Number 2-FG-81-0421
Rocky Mountain – Agreement Number 04AG601880

>>>

Project Title

Vulnerability Analysis of Western Water Resources to Climate Variability and Change

Problem

The vulnerability of a given geographic region is not only a function of climatic variables but also of the ecological and socioeconomic systems dependent on the climate of the region, and of how strongly those systems are coupled. The Western U.S. is particularly vulnerable to climate variability and change because climate, vegetation cover, and land-use are strongly coupled there. This coupling or interdependence is strongest in the more arid areas where both natural vegetation and rain-fed crops are water-limited and where most of the precipitation falls during the growing season.

The Intergovernmental Panel on Climate Change has advanced our knowledge of the climate forcings that may be seen through the 21st century— the "supply" side of water resources. For example, most global climate model (GCM) predictions suggest that under a warmer global climate, the Western U.S. may suffer from significantly reduced levels of summer soil moisture. However, both social and environmental demands for water need to be better understood within the context of the changing climate, including interactions with vegetation dynamics and cropping patterns which may be both climatologically and socio-economically driven. This need was identified in USGS Circular 1331, from the Knowledge gaps discussed, C-CAWWG, February 2008: *5.1 Anticipate social responses* and *5.2 Assess water use requirements for different crops under joint climate and atmospheric carbon dioxide changes*.

Uncertainty about the water yield from a basin may exist because the drivers of the water balance in the basin (most particularly climate) are uncertain. An additional, reducible amount of uncertainty arises from our lacking the knowledge or resources to model perfectly the "deterministic" physical and biological processes involved in defining both water supply and demand. These uncertainties imply that predictions of water supply and demand for a given region are random and therefore must be characterized in terms of probability distribution functions. Management and adaptations decisions must therefore be made in a probabilistic framework.

Objective (less than 300 words)

The overarching objective of the proposed work is to develop and implement a probabilistic framework for assessing regional-scale vulnerability of western water resources to climate variability and change that incorporates ecologic and economic factors. In doing so, we will 1) provide a new probabilistic definition of vulnerability; and 2) implement a new statistical-dynamical hydrologic model which incorporates ecological optimality hypothesis governing the long-term and short-term evolution of transpiration efficiency and fractional vegetation cover. Given the importance of uncertainty and variability in scenarios of future climate, as well as our imperfect knowledge of physical and biological processes governing the water balance, the statistical-dynamical hydrologic modeling proposed will allow propagation of uncertainty through to economic modeling and decision-making. Climate uncertainty will be incorporated through a stochastic treatment of precipitation dynamics, while model uncertainty will be explored by defining model sensitivity to the parameters of the physically based water balance model. This will yield a quantitative evaluation of the uncertainty in the modeled hydrology and of its implications for long-term water resource planning and management.

The modeling and analysis framework proposed will allow examination of how these interactions affect water supply and water demand in a probabilistic framework, therefore allowing assessment of the vulnerability of the region’s water resources. Probabilistic statements about vulnerability will allow explicit consideration of the uncertainty in the model predictions when making management decisions affecting the system (i.e., operation and/or adaptation decisions).

Authorities:

Omnibus Appropriations Act, 2009(Public Law 111-8) SEC. 205:

The Secretary of the Interior, acting through the Commissioner of the Bureau of Reclamation, is also authorized to enter into grants or cooperative agreements with universities or nonprofit research institutions to fund water use efficiency research.

Omnibus Public Land Management Act of 2009 (P.L. 111-11), Subtitle F-Secure Water, Sec 9502, 9504, and 9509

Sec 9502
(16) SECRETARY-

(A) IN GENERAL- Except as provided in subparagraph (B), the term `Secretary' means the Secretary of the Interior.
(B) EXCEPTIONS- The term `Secretary' means--in the case of sections 9503, 9504, and 9509, the Secretary of the Interior (acting through the Commissioner)

Sec 9504

(*b) Research Agreements-*

(1) AUTHORITY OF SECRETARY- The Secretary may enter into 1 or more agreements with any university, nonprofit research institution, or organization with water or power delivery authority to fund any research activity that is designed--

(A) to conserve water resources;

(B) to increase the efficiency of the use of water resources; or

(C) to enhance the management of water resources, including increasing the use of renewable energy in the management and delivery of water.

(2) TERMS AND CONDITIONS OF SECRETARY-

(A) IN GENERAL- An agreement entered into between the Secretary and any university, institution, or organization described in paragraph (1) shall be subject to such terms and conditions as the Secretary determines to be appropriate.

(B) AVAILABILITY- The agreements under this subsection shall be available to all Reclamation projects and programs that may benefit from project-specific or programmatic cooperative research and development.

(c) Mutual Benefit- Grants or other agreements made under this section may be for the mutual benefit of the United States and the entity that is provided the grant or enters into the cooperative agreement.

(d) Relationship to Project-Specific Authority- This section shall not supersede any existing project-specific funding authority.

(e) Authorization of Appropriations- There is authorized to be appropriated to carry out this section $200,000,000, to remain available until expended.

Sec 9509 - *The Secretary may enter into contracts, grants, or cooperative agreements, for periods not to exceed 5 years, to carry out research within the Bureau of Reclamation.*

Statement of Work (work plan):

In order to achieve the objectives stated above, three **major tasks** are required: a) estimation of water supply; b) estimation of water demand; and c) evaluation of the probability that future water supply will be less than future water demand. These major tasks are detailed below.

A. Estimation of Water Supply

- A.1: Implement eco-hydrologic model that allows consideration of the interaction of land use, vegetation and climate in the water balance dynamics. This model is based on the Statistical Dynamical Eco-Hydrology Model (SDEM) of Kochendorfer and Ramirez, 2008a; 2008b.
- A.2: Test and calibrate the model based on observations

- A.3: Using data on past weather and vegetation, estimate water supply using the SDEM model
- A.4: Estimate probability density functions of climatic forcing (e.g., precipitation intensity, storm duration, storm depth, storm inter-arrival times, near-surface air temperature, etc.).
- A.5: Predict probability density functions of hydrologic responses to probabilistic climatic forcing.
- A.6: Apply the SDEM model to estimate future water supply under a continuation of past weather and climate
- A.7: Alter the parameters of the model based on GCM predictions of future temperature, precipitation, etc. to estimate future water supply under altered climate

B. Water Demand

- B.1: Collect past estimates of U.S. water withdrawals as a basis for projecting future demand
- B.2: Project water demand using the method of Brown (2000).

C. Vulnerability –. The vulnerability (*V*) of water supply to shortage is defined as the probability that the demand (*D*) exceeds the supply (*Q*), that is, $V = Pr[Q < D]$. Therefore, making use of the probability density functions obtained in major Task A, the following tasks will be perfomed:

- C.1: For current climate conditions, quantify the vulnerability of water supply following the methods of Kochendorfer and Ramirez, (1996).
- C.2: Based on GCM projections, develop scenarios of environmental stressors (e.g., climate, land-use changes, etc.) for future conditions. For example, climate change projections may be based on selected emission scenarios from among those of the Intergovernmental Panel on Climate Change (IPCC).
- C.3: For the above scenarios of climatic and environmental stressors, evaluate vulnerability of future water supply in a probabilistic framework
- C.4: Evaluate implications of model uncertainty for longer-term water resource planning and management. This will use concept of Expected Value of Including Uncertainty (EVIU) which measures the importance of quantifying the uncertainty in model parameters in the decision making process. This analysis will use the hydrologic and water resources design concept of safe yield[1] (e.g., Kochendorfer and Ramirez, 1996) to explore the relevance of the results in planning for drought. This analysis, based on Bayesian decision theory, will examine the decision to invest in some adaptation or mitigation strategy (e.g., to protect against drought.) Then, explore whether, in making mitigation or adaptation decisions (e.g., a decision to protect against drought – augment

[1] The safe yield is a mathematical concept that allows estimating the amount of water that can be withdrawn from a river or reservoir consistently, even under drought conditions. For example, the safe yield can be defined as the amount of water that can be withdrawn from a given reservoir 99% of the days, without water rationing, over the entire period of analysis.

reservoir storage), it might be more important to quantify the uncertainty in climate and economic model parameters than to try to reduce that uncertainty.

D. Document methodology. Documenting and publishing the results will be a significant component of this research. The results will be published in peer-reviewed literature to ensure broad dissemination and public use of results**.**

In addition to the standard reporting required under Sec???, an annual progress report will also be provided that summarizes:

- Work performed
- Findings
- Updated plan for the upcoming year

The annual progress report will facilitate amending this agreement to fund Year 2 and Year 3 activities.

References

Brown, T. C. 2000. Projecting U.S. freshwater withdrawals. *Water Resources Research* 36(3): 769-780.

Kochendorfer, J. P. and J. A. Ramírez, 1996: Hydrologic/Ecological Modeling for Examining Regional Hydrologic Vulnerability to Climate Variability. *Proceedings, North American Water and Environment Congress '96 - ASCE*, pp 1-9.

Kochendorfer, J. P., & Ramirez, J. A. 2008a. Ecohydrological controls on vegetation density and evapotranspiration partitioning across the climatic gradients of the central United States. *Hydrol. Earth Syst. Sci. Discuss.*, 5, 649–700.

Kochendorfer, J. P., & Ramirez, J. A. 2008b. Modeling the monthly mean soil water balance with a statistical-dynamical ecohydrology model as coupled to a two-component canopy model. *Hydrol. Earth Syst. Sci. Discuss.*, 5, 579–648..

Budget, Tasks, and Schedule

The costs for the activities to be conducted by CSU under this agreement is estimated to be approximately $120,000 beginning in 2009 and ending in 2012 in accordance with the following task-based summary of activities.

The funding for successive years will be provided through an amendment to the agreement, subject to availability of funds.

Year 1: FY 2010 - October 2009 – Sept 2010 ($35,000)
Year 2: FY 2011 – October 2010 – September 2011 ($41,000)
Year 3: FY 2012 - October 2011 – December 2012 ($44,000)

Description of Tasks to be performed by	Start	Complete	FY2010 Cost	FY2011 Cost	FY2012 Cost	Total Cost

CSU						
A) Estimate Water Supply	Oct 2010	Apr 2011				45,000
A.1 - Implement eco-hydrologic model		Jan 2010	5,000			5,000
A.2 - Test and calibrate the model based on observations		Feb 2010	5,000			5,000
A.3 - Using data on past weather and vegetation, estimate water supply using the SDEM model		May2010	10,000			10,000
A.4 - Estimate probability density functions of climatic forcing		Aug 2010	5,000			5,000
A.5 - Predict probability density functions of hydrologic responses to probabilistic climatic forcing		Sep 2010	5,000			5,000
A.6 - Apply the SDEM model to estimate future water supply under a continuation of past weather and climate		Dec 2010	5,000	5,000		10,000
A.7 - Alter the parameters of the model based on GCM predictions of future temperature, precipitation, etc. to estimate future water supply under altered climate		Apr 2011		5,000		5,000
B) Water Demand	Oct 2010	Sep 2011				15,000

Analysis						
B.1 - Collect past estimates of U.S. water withdrawals as a basis for projecting future demand		Apr 2011		10,000		10,000
B.2 - Project water demand using the method of Brown (2000).		Sep 2011		5,000		5,000
C) Vulnerability Analysis	Jan 2011	June 2012				45,000
C.1 - For current climate conditions, quantify the vulnerability of water supply		Oct 2011		4,000	3,000	7,000
C.2 - Based on GCM projections, develop scenarios of environmental stressors				10,000	15,000	15,000
C.3 - evaluate vulnerability of future water supply in a probabilistic framework					6,000	6,000
C.4 - Expected Value of Including Uncertainty analysis					7,000	7,000
D) Documentation	Aug 2011	Sept 2012				15,000
D.1 Research reports				2,000	7,000	
D.2 Publish results					6,000	
Total			35,000	41,000	44,000	120,000

Period of Performance

Date agreement is signed:
End of agreement: December 2012

Participants

<u>Colorado State University</u>
Principal Investigator:

Agreements Administrator

<u>Bureau of Reclamation</u>

Technical Representative

Program Sponsor