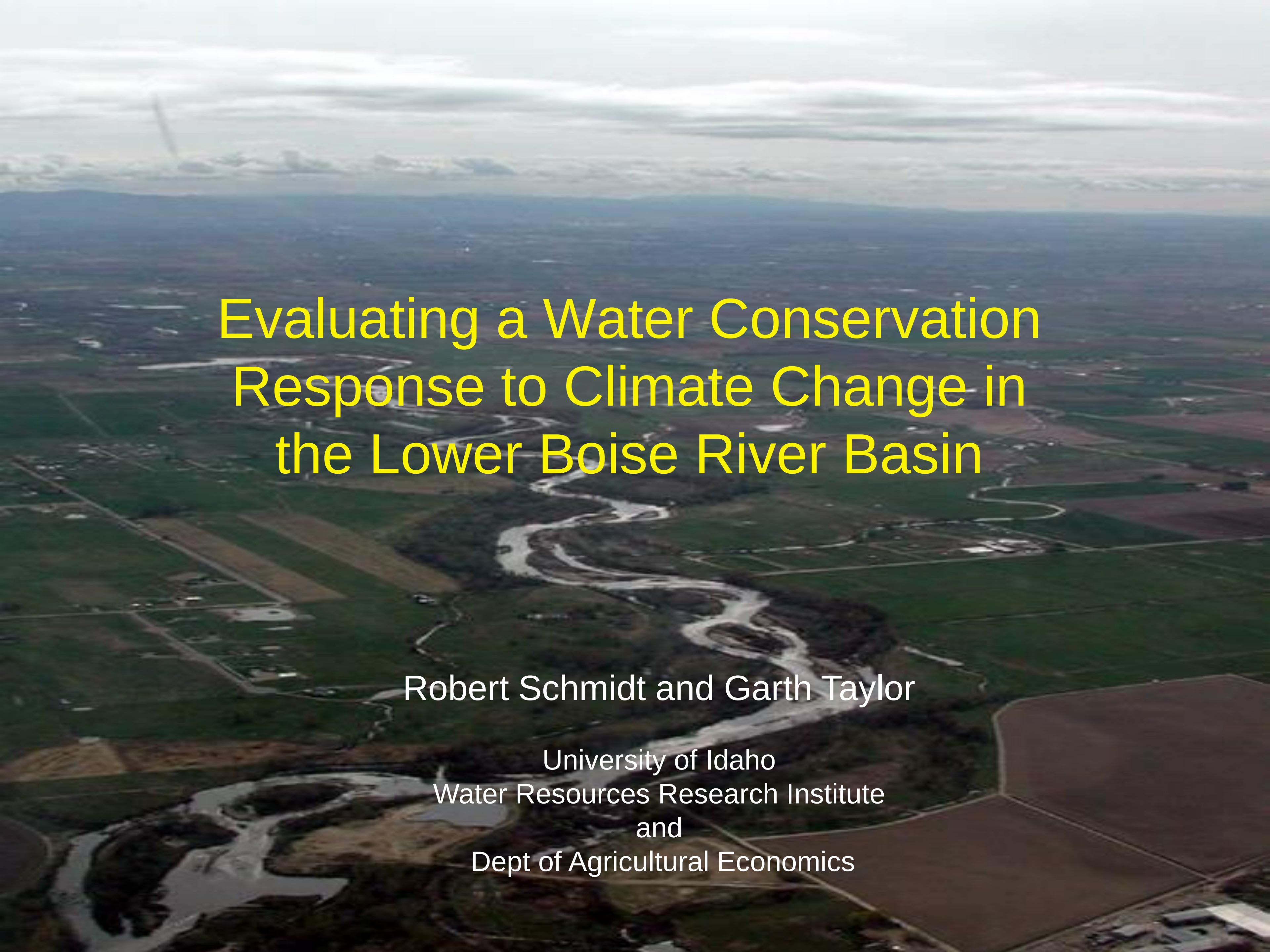
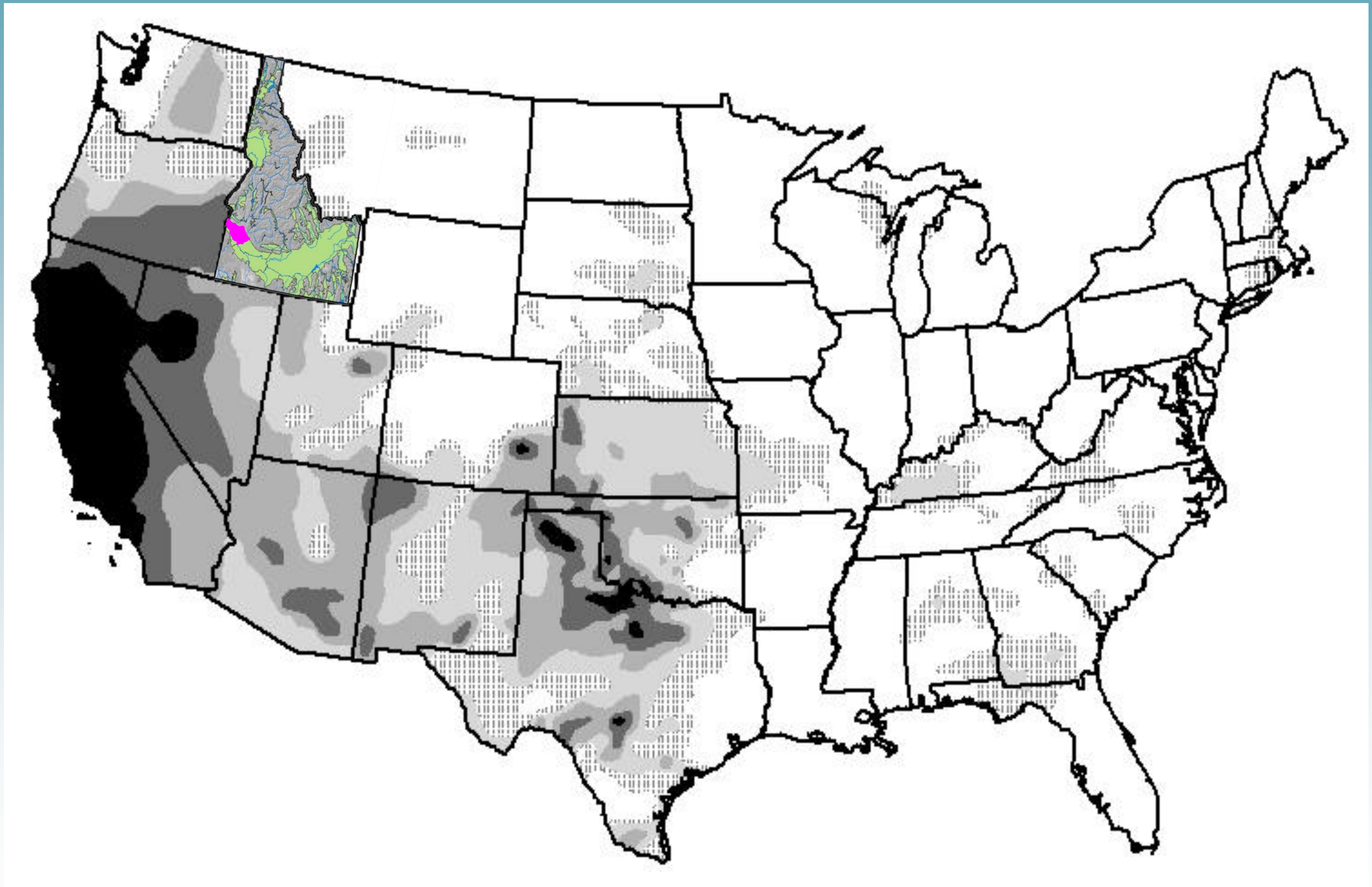


Evaluating a Water Conservation Response to Climate Change in the Lower Boise River Basin

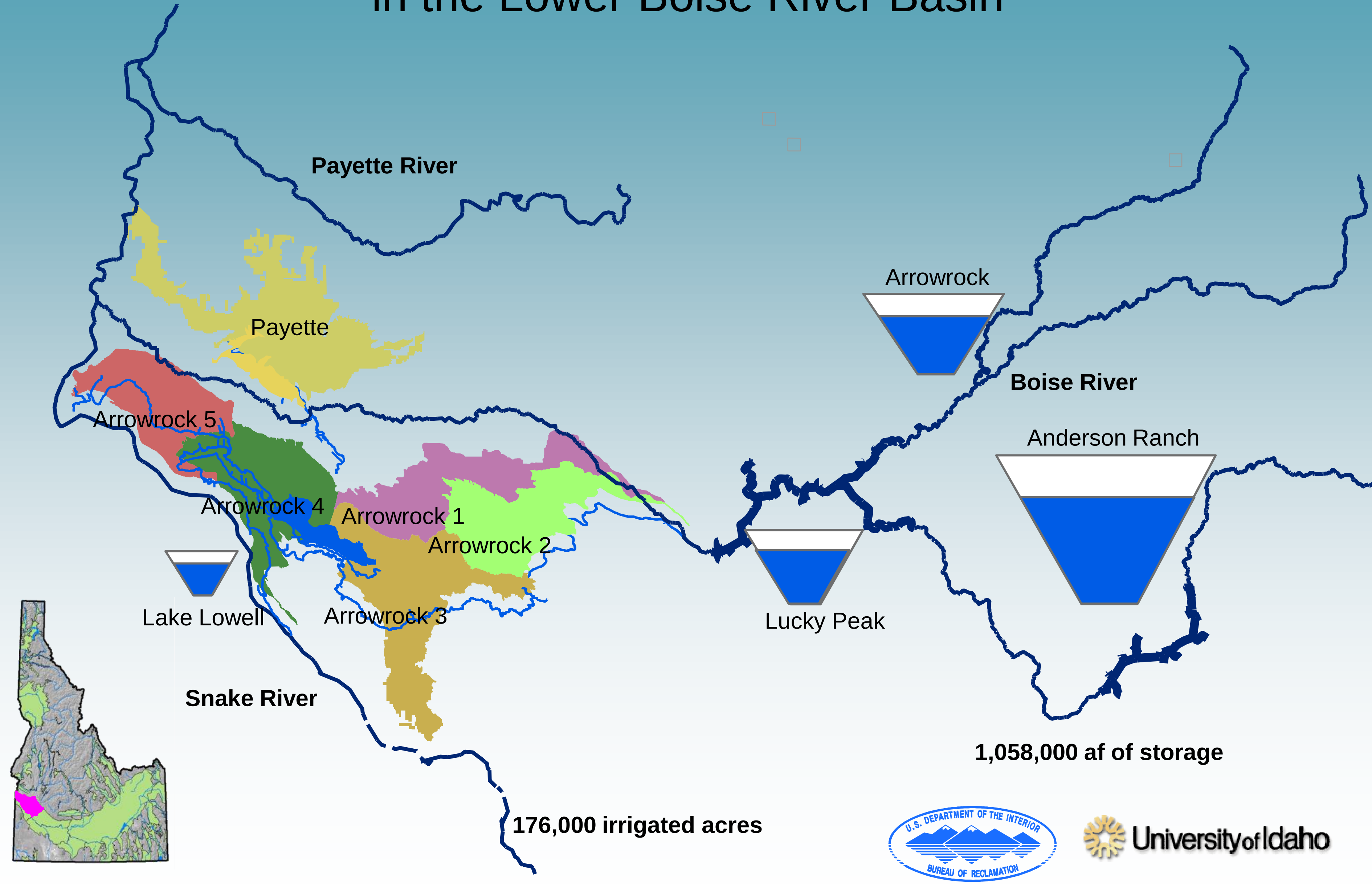
Robert Schmidt and Garth Taylor

University of Idaho
Water Resources Research Institute
and
Dept of Agricultural Economics

Lower Boise River Basin in southwestern Idaho

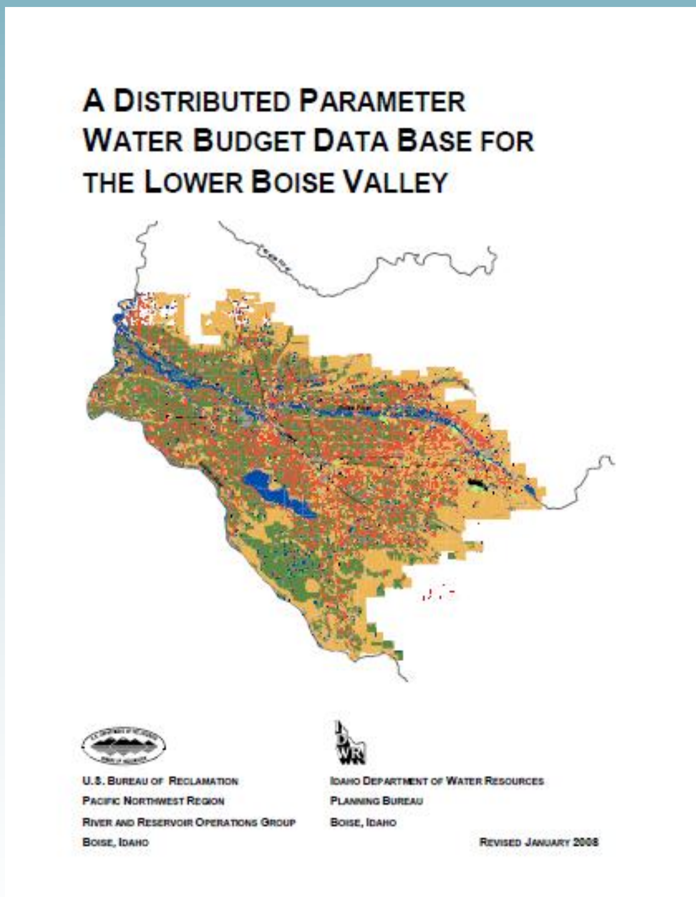


Bureau of Reclamation Boise Project in the Lower Boise River Basin



A Recent Lower Boise River Basin Water Budget

(USBR, 2008)



A DISTRIBUTED PARAMETER WATER BUDGET DATA BASE FOR THE LOWER BOISE VALLEY

U.S. BUREAU OF RECLAMATION
PACIFIC NORTHWEST REGION
RIVER AND RESERVOIR OPERATIONS GROUP
BOISE, IDAHO

IDAHO DEPARTMENT OF WATER RESOURCES
PLANNING BUREAU
BOISE, IDAHO

REVISED JANUARY 2008

898,000 AF Boise Project average annual diversion

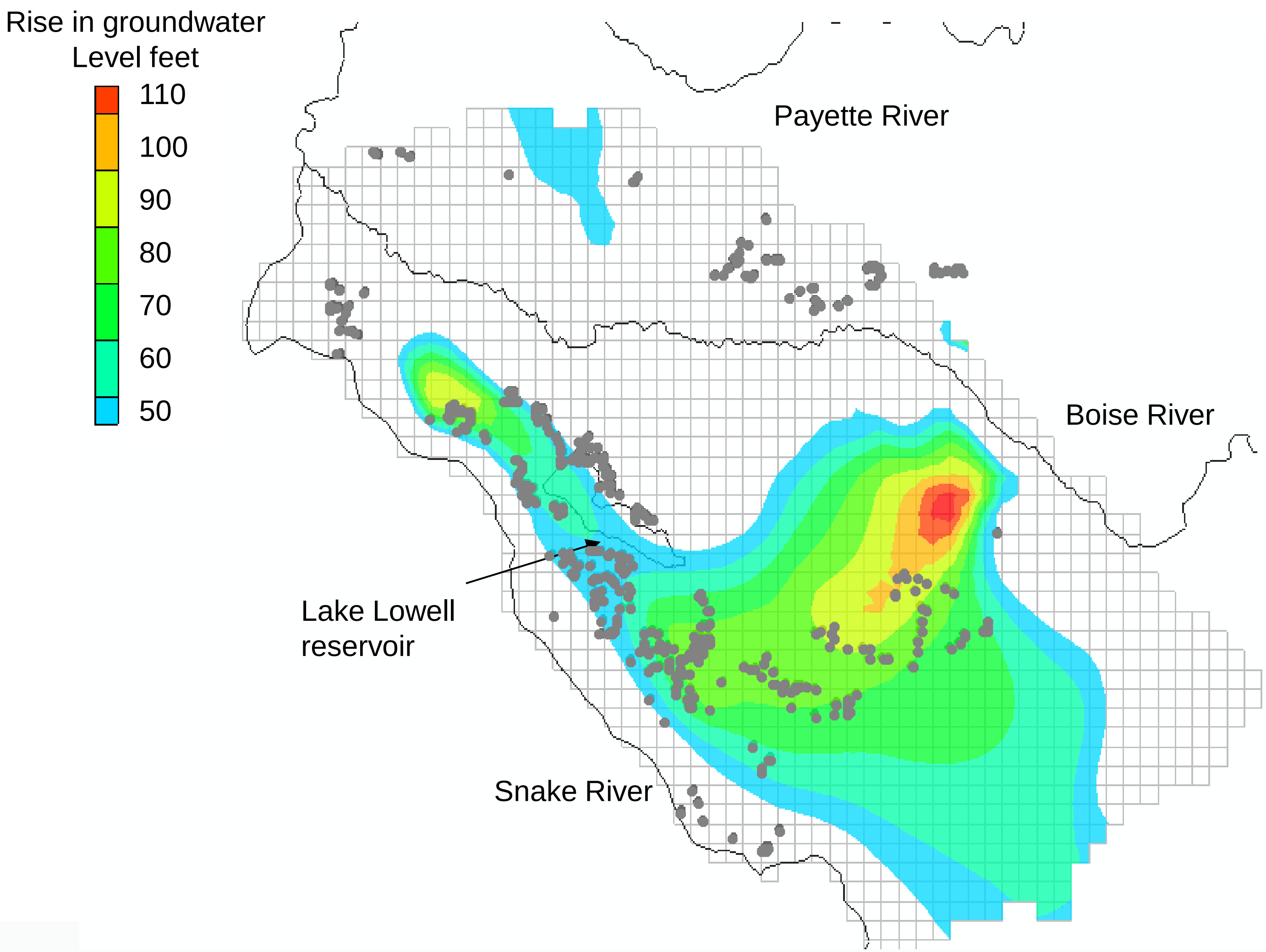
41% of diversions consumptively used by Project canal irrigators.

27% of diversions seep from Project canals and laterals into shallow aquifer.

52% of diversions return to drains. (surface and subsurface)

Boise Project Groundwater Response Zone

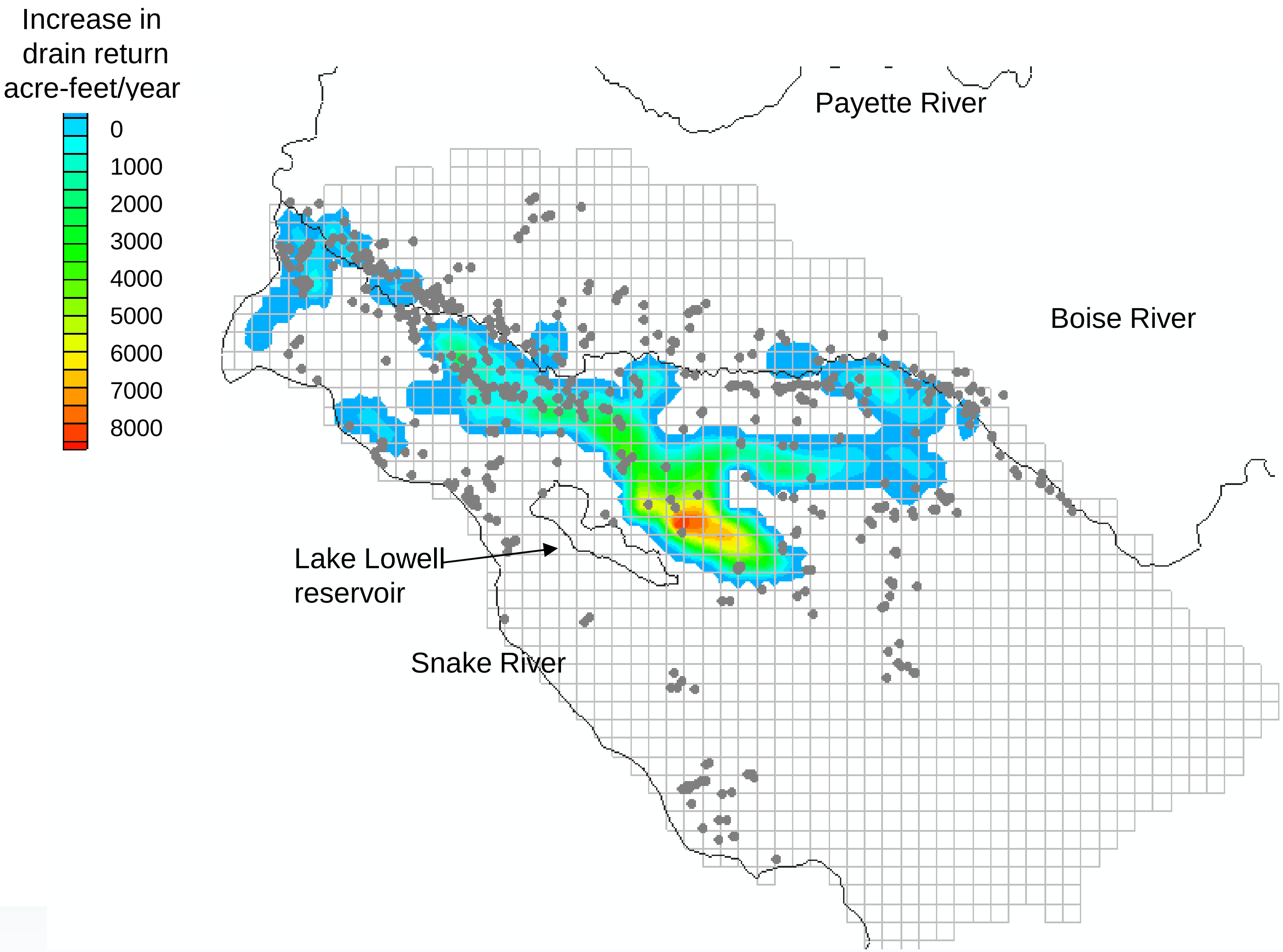
and groundwater points of diversion



Boise Basin hydrologic model (IWRRI, 2012)

Boise Project Drain Return Response Zone

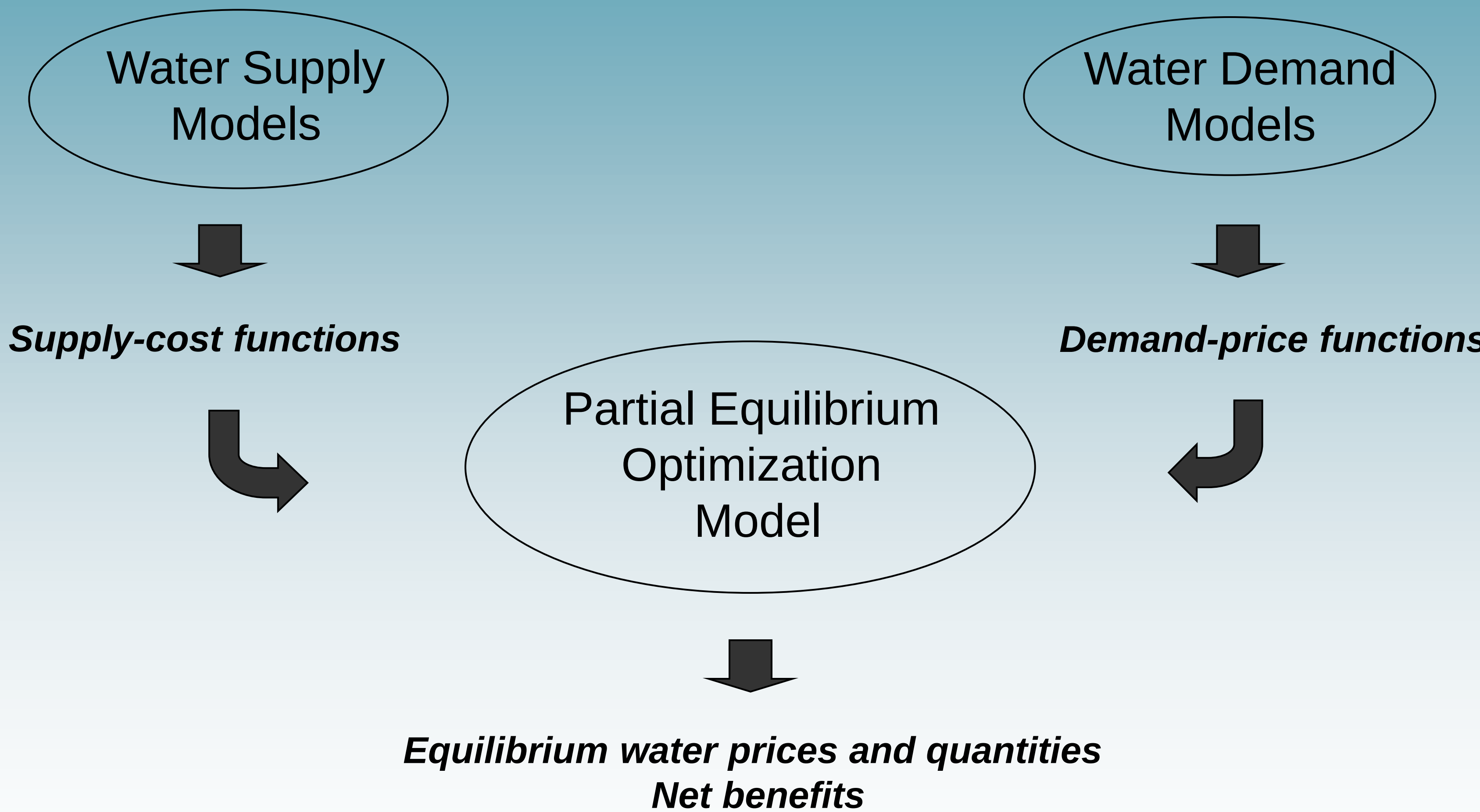
and drain water points of diversion



Boise Basin hydrologic model (IWRRI, 2012)

Un-priced Boise Project canal seepage is a positive externality for non-Project groundwater and drain water irrigators

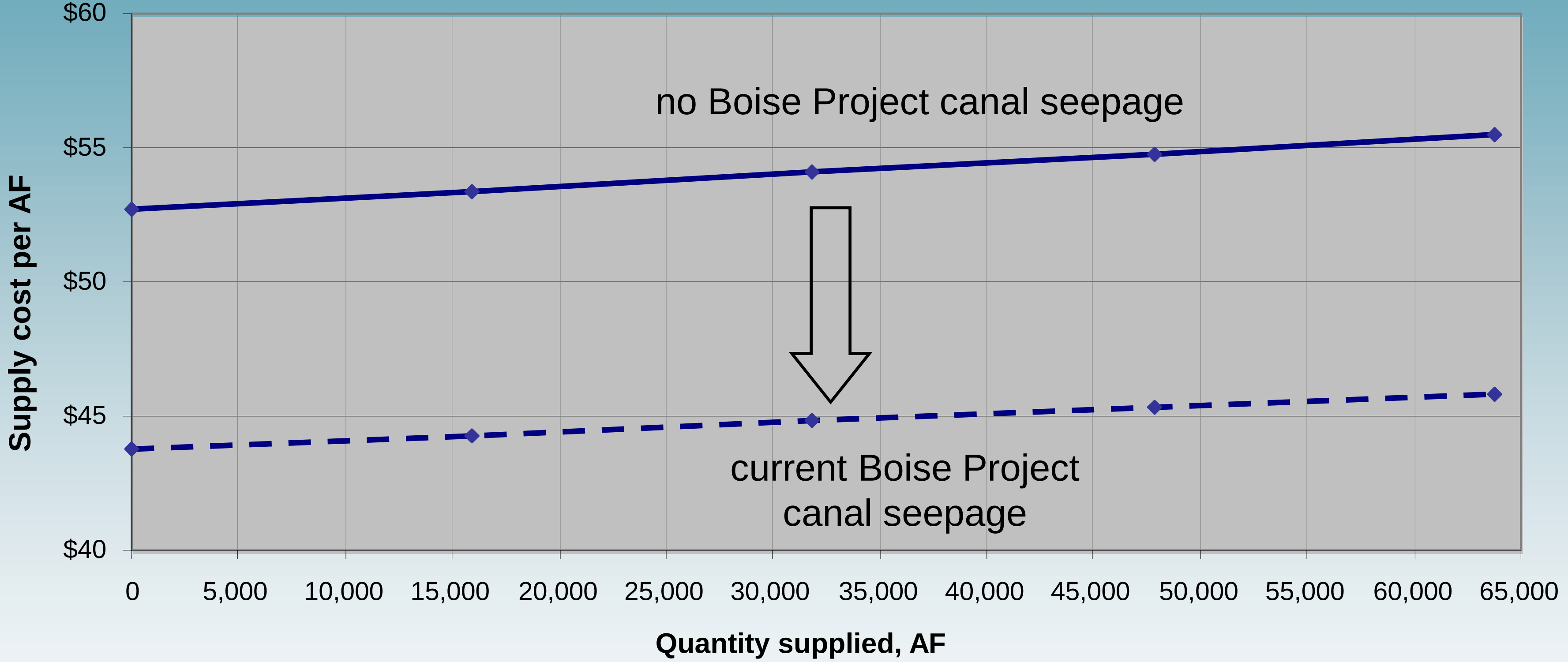
A Modular Approach to Hydro-Economic Modeling



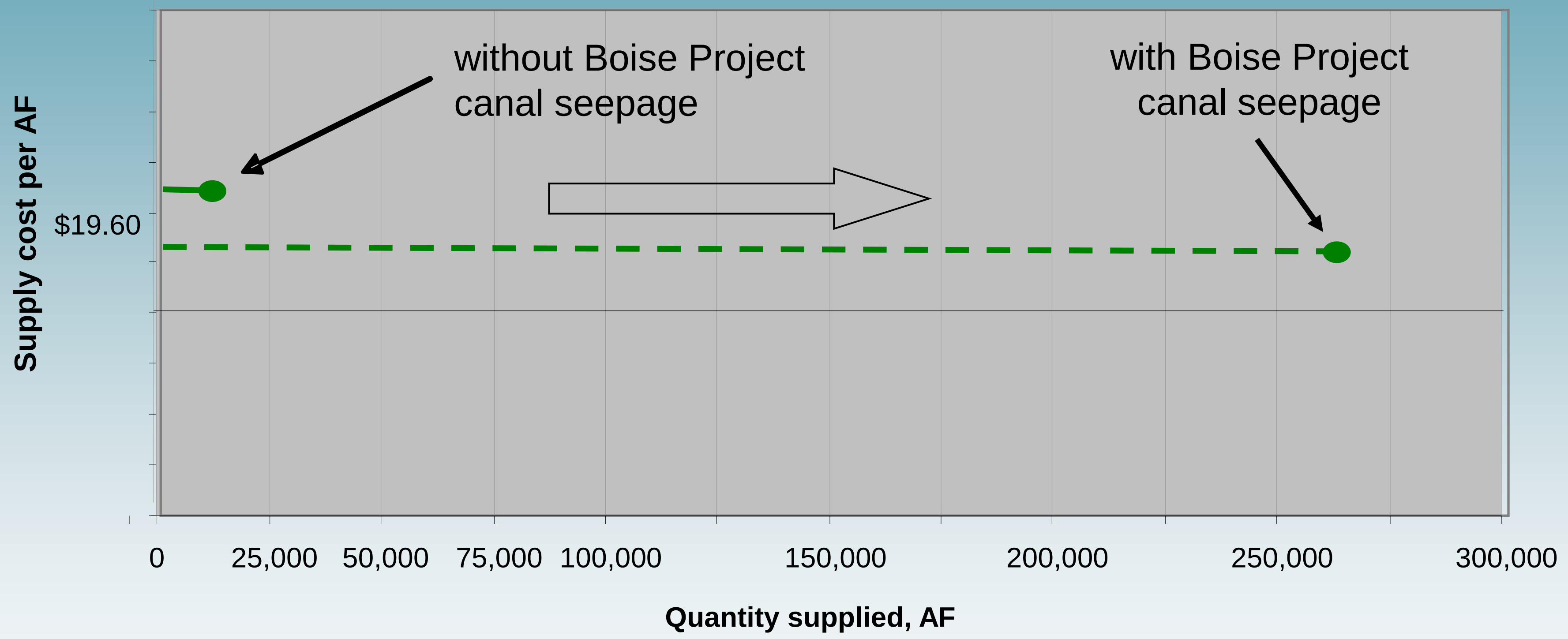
Irrigator Supply-Cost Functions

- Supply-cost functions are developed for canal, groundwater and drain water irrigators
- Supply-cost functions include a canal seepage hydrologic response term that shifts supply-costs of groundwater and drain water irrigators
- Illustrations…

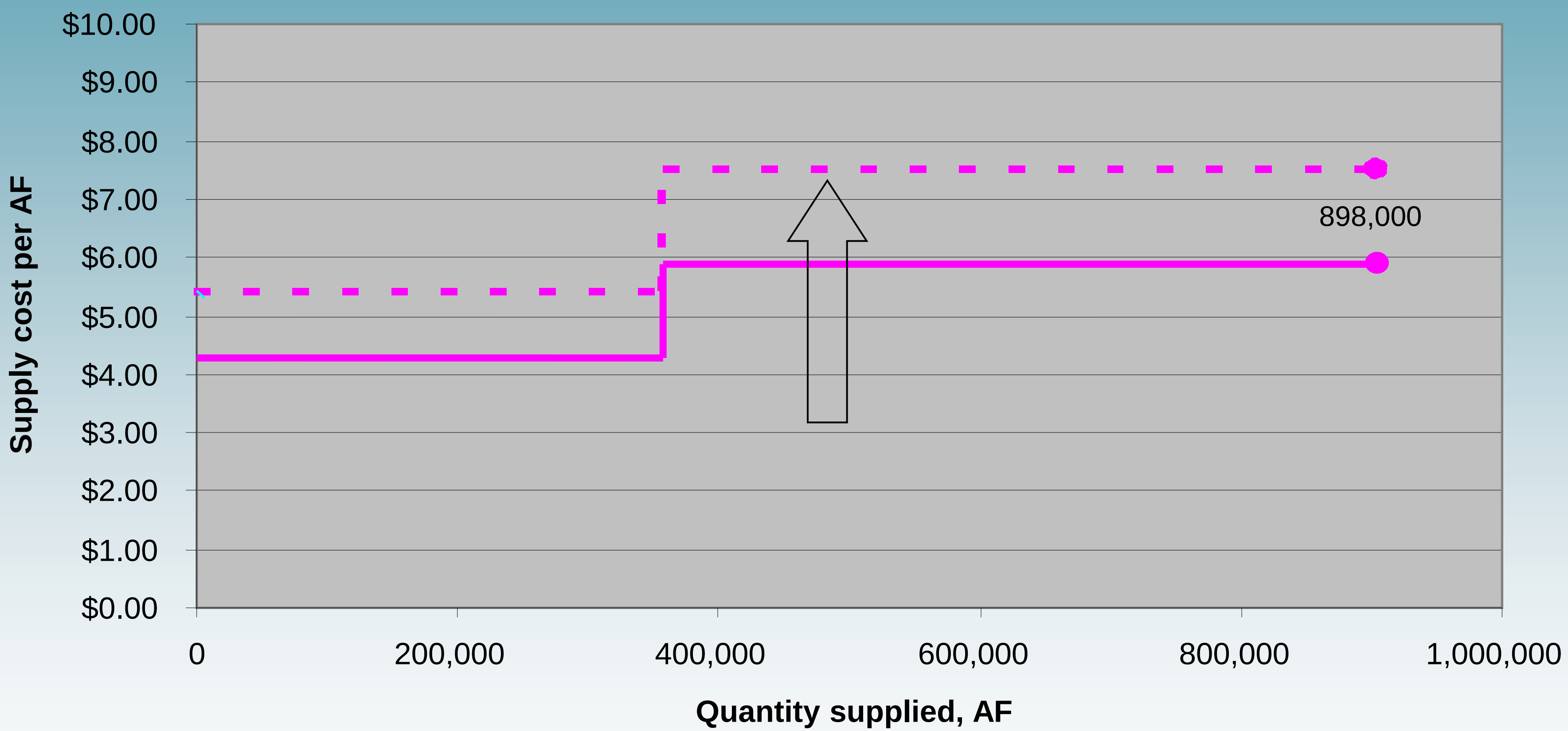
An aquifer response function shifts groundwater supply (pumping) costs downward



A drain return response function shifts the drain water supply constraint outward

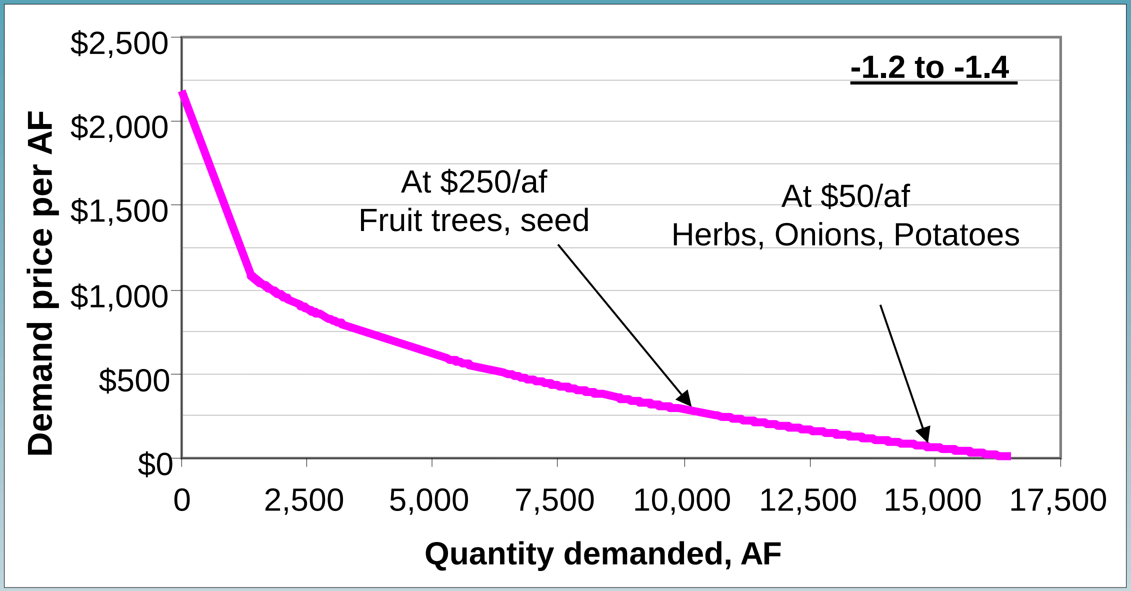


A canal seepage conveyance cost function shifts the “effective” supply cost of Project canal water upward

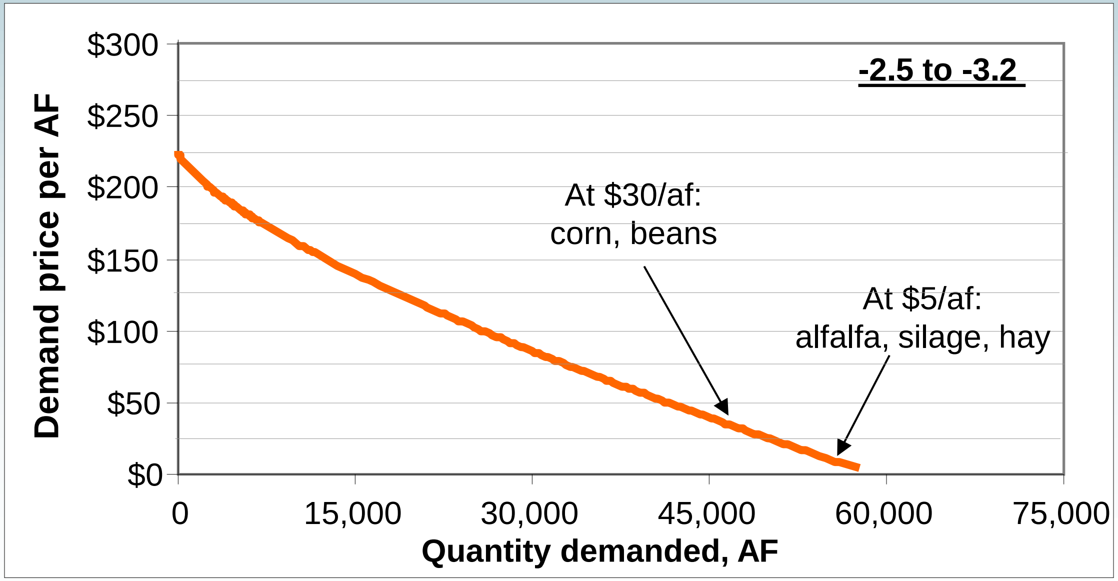


Irrigator Demand-Price Functions

High value (cash) crops
- Fruit trees
- Seed
- Onions
- Potatoes
- Herbs



Low value (field) crops
- Alfalfa
- Corn
- Dry Beans
- Silage
- Hay



Irrigation Water Demand from ET Production Functions (Contor, 2010)

Modifications made to the Constrained Optimization Model of Takayama and Judge (1971)

- Three new exogenous functions are introduced:
  - Aquifer response function
  - Drain response function
  - Canal conveyance cost function
- Two new endogenous variables are introduced:
  - The quantity of seepage externality accruing to groundwater irrigators.
  - The quantity of seepage externality accruing to drain water irrigators.

Partial Equilibrium Conditions with Externalities

1. $\mathbf{p}_i - \boldsymbol{\rho}_i \leq 0$ and $\mathbf{q}_i(\mathbf{p}_i - \boldsymbol{\rho}_i) = 0$ for $\mathbf{q}_i \geq 0$

Demand price = Equilibrium demand price

2. $\boldsymbol{\rho}^i - \mathbf{p}^i \leq 0$ and $\mathbf{q}^i(\boldsymbol{\rho}^i - \mathbf{p}^i) = 0$ for $\mathbf{q}^i \geq 0$

Supply price = Equilibrium supply price

3. $\sum_j \mathbf{x}_{ji} + \sum_k \sum_j \mathbf{EX}_{kji} - \mathbf{q}_i \geq 0$ and $\boldsymbol{\rho}_i(\sum_j \mathbf{x}_{ji} + \sum_k \sum_j \mathbf{EX}_{kji} - \mathbf{q}_i) = 0$ for $\boldsymbol{\rho}_i \geq 0$

No excess demand. Quantity transported + Quantity of externality produced = Total quantity demanded.

4. $\mathbf{q}^i - \sum_j \mathbf{x}_{ij} - \sum_j \sum_k \mathbf{EX}_{ijk} \geq 0$ and $\boldsymbol{\rho}^i(\mathbf{q}^i - \sum_j \mathbf{x}_{ij} - \sum_j \sum_k \mathbf{EX}_{ijk}) = 0$ for $\boldsymbol{\rho}^i \geq 0$

Excess supply. Quantity transported + Quantity of externality produced = Quantity supplied + Excess supply

5. $\boldsymbol{\rho}_j - \boldsymbol{\rho}^i - t_{ij} + \sum_k c_{ijk} \frac{\partial F_{ijk}(x_{ij})}{\partial x_{ij}} \leq 0$ and $\mathbf{x}_{ij}(\boldsymbol{\rho}_j - \boldsymbol{\rho}^i - t_{ij} + \sum_k c_{ijk} \frac{\partial F_{ijk}(x_{ij})}{\partial x_{ij}}) = 0$ for $\mathbf{x}_{ij} \geq 0$

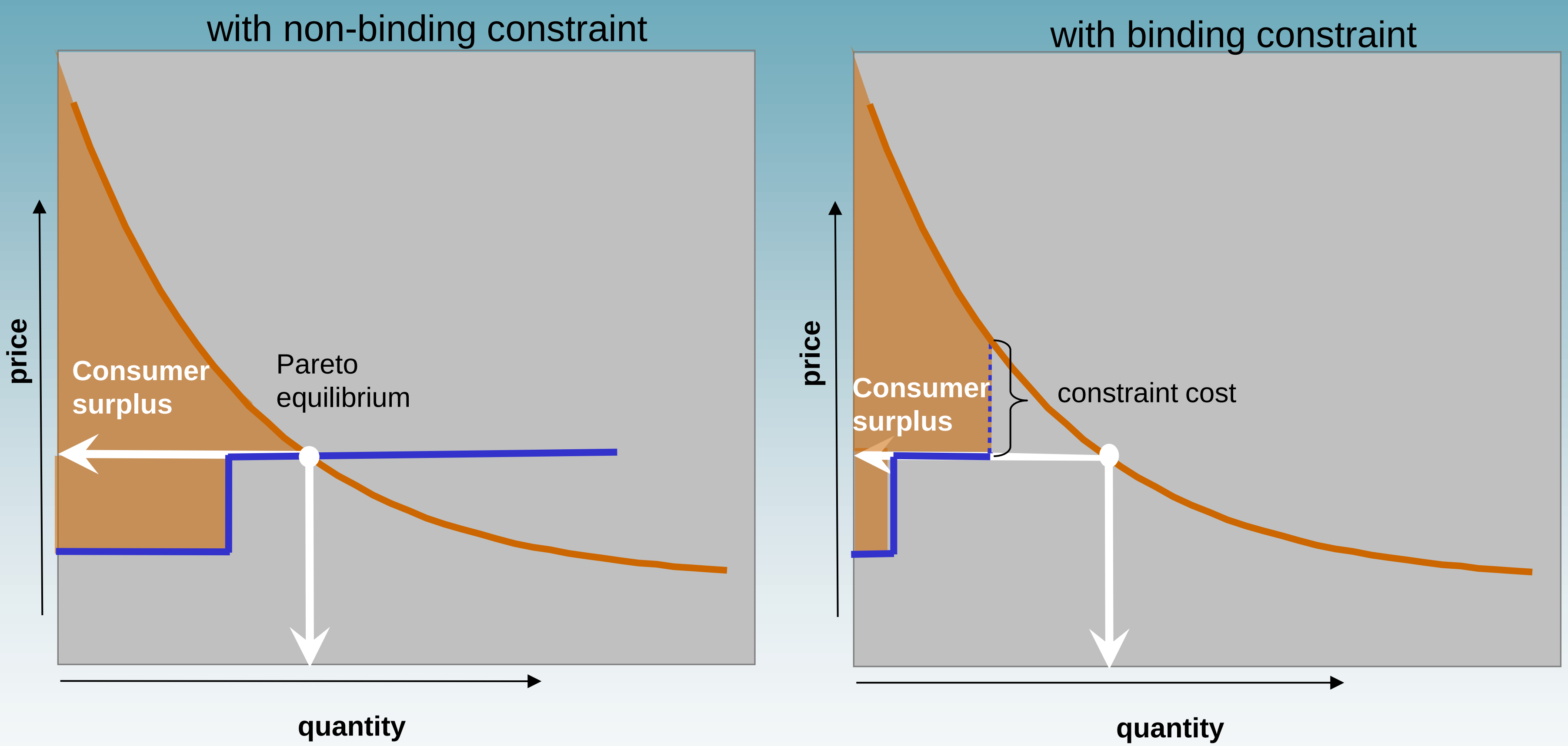
Price linkage equation. Equilibrium demand price - Equilibrium supply price = Externality conveyance cost

6. $\mathbf{F}_{ijk}(\mathbf{x}_{ij}) - \mathbf{EX}_{ijk} = 0$

Quantity of externality produced = Quantity of externality transported

- PE conditions do not correspond to KKT, no (benefit) objective function to maximize.
- PE conditions are solved for equilibrium quantities and prices using MCP (GAMS, PATH).

Net-benefits are obtained using equilibrium prices and quantities as limits of integration



Impact of Climate Change on Lower Boise Basin Water Supply

(WCRP and USBR, 2012)

- Altered timing of snow melt and natural flow

⇩

- Increased uncertainty in runoff forecasting
- Reduced supplies for Boise Project irrigation

World Climate Research Program, 2012

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Six Projections of Boise Project Water Shortages

(USBR, 2012)

	WCRP Climate models	30 year average diversion (AF)	Supply Shortage (AF)	Percent shortage
	base-case	898,000	0	0
1	ccsm	898,000	204,661	23 %
2	cgcm	898,000	44,132	5 %
3	echam	898,000	90,427	10 %
4	echo	898,000	246,762	27 %
5	hadcm	898,000	95,958	11 %
6	pcm	898,000	156,364	17 %

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Net-Benefit Results of Three PE Model Scenarios

- Base case scenario: Boise Project 30 year average water availability
- Shortage scenario: Boise Project water supply constrained by projected shortages.
- Shortage + Conservation scenario: Boise Project water supply constrained by shortages with new canal lining conservation measures.

Boise Project net benefits (consumer surpluses) with climate change and canal lining conservation. (in millions $)

Base-case scenario	WCRP Climate model	**Boise Project shortage scenarios**		WCRP Climate model	**Boise Project shortage with canal lining scenarios**	
Net benefit		Net benefit	percent difference		Net benefit	percent difference
$90.45	ccsm	$74.50	**-17.2%**	ccsm	$91.40	**1.6%**
$90.45	cgcm	$88.60	**-1.6%**	cgcm	$91.50	**1.7%**
$90.45	echam	$85.60	**-4.9%**	echam	$90.80	**0.9%**
$90.45	echo	$70.70	**-21.4%**	echo	$91.60	**1.8%**
$90.45	hadcm	$85.10	**-5.4%**	hadcm	$90.90	**1.0%**
$90.45	pcm	$79.00	**-12.2%**	pcm	$91.20	**1.3%**

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Groundwater response zone net benefits (consumer surpluses) with climate change and canal lining conservation.
(in millions $)

Base-case scenario	WCRP Climate model	**Boise Project shortage scenarios**		WCRP Climate model	**Boise Project shortage with canal lining scenarios**	
Net benefit		Net benefit	percent difference		Net benefit	percent difference
$10.00	ccsm	$9.90	**-1.0%**	ccsm	$9.80	**-2.0%**
$10.00	cgcm	$10.00	**0.0%**	cgcm	$9.70	**-3.0%**
$10.00	echam	$10.00	**0.0%**	echam	$9.90	**-1.0%**
$10.00	echo	$9.90	**-1.0%**	echo	$9.60	**-4.0%**
$10.00	hadcm	$10.00	**0.0%**	hadcm	$9.90	**-1.0%**
$10.00	pcm	$9.90	**-1.0%**	pcm	$9.80	**-2.0%**

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Drain return response zone net benefits (consumer surpluses) with climate change and canal lining conservation.
(in millions $)

Base-case scenario	WCRP Climate model	Boise Project shortage scenarios		WCRP Climate model	Boise Project shortage with canal lining scenarios	
Net benefit		Net benefit	percent difference		Net benefit	percent difference
$22.20	ccsm	$19.20	**-13.5%**	ccsm	$6.60	**-70.3%**
$22.20	cgcm	$21.80	**-1.8%**	cgcm	$3.80	**-82.9%**
$22.20	echam	$21.20	**-4.5%**	echam	$17.50	**-21.2%**
$22.20	echo	$18.50	**-16.7%**	echo	$0.06	**-99.7%**
$22.20	hadcm	$21.10	**-5.0%**	hadcm	$17.20	**-22.5%**
$22.20	pcm	$20.00	**-9.9%**	pcm	$13.60	**-38.7%**

Basin-wide net benefits (consumer surpluses) with climate change and canal lining conservation. (in millions $)

Base-case scenario	WCRP Climate model	Boise Project shortage scenarios		WCRP Climate model	Boise Project shortage with canal lining scenarios	
Net benefit		Net benefit	percent difference		Net benefit	percent difference
$122.37	ccsm	$103.6	**-15.3%**	ccsm	$107.8	**-11.9%**
$122.37	cgcm	$120.4	**-1.6%**	cgcm	$105.0	**-14.2%**
$122.37	echam	$116.7	**-4.6%**	echam	$118.1	**-3.4%**
$122.37	echo	$99.1	**-19.0%**	echo	$101.3	**-17.2%**
$122.37	hadcm	$116.1	**-5.1%**	hadcm	$117.9	**-3.6%**
$122.37	pcm	$109.0	**-10.9%**	pcm	$114.6	**-6.3%**

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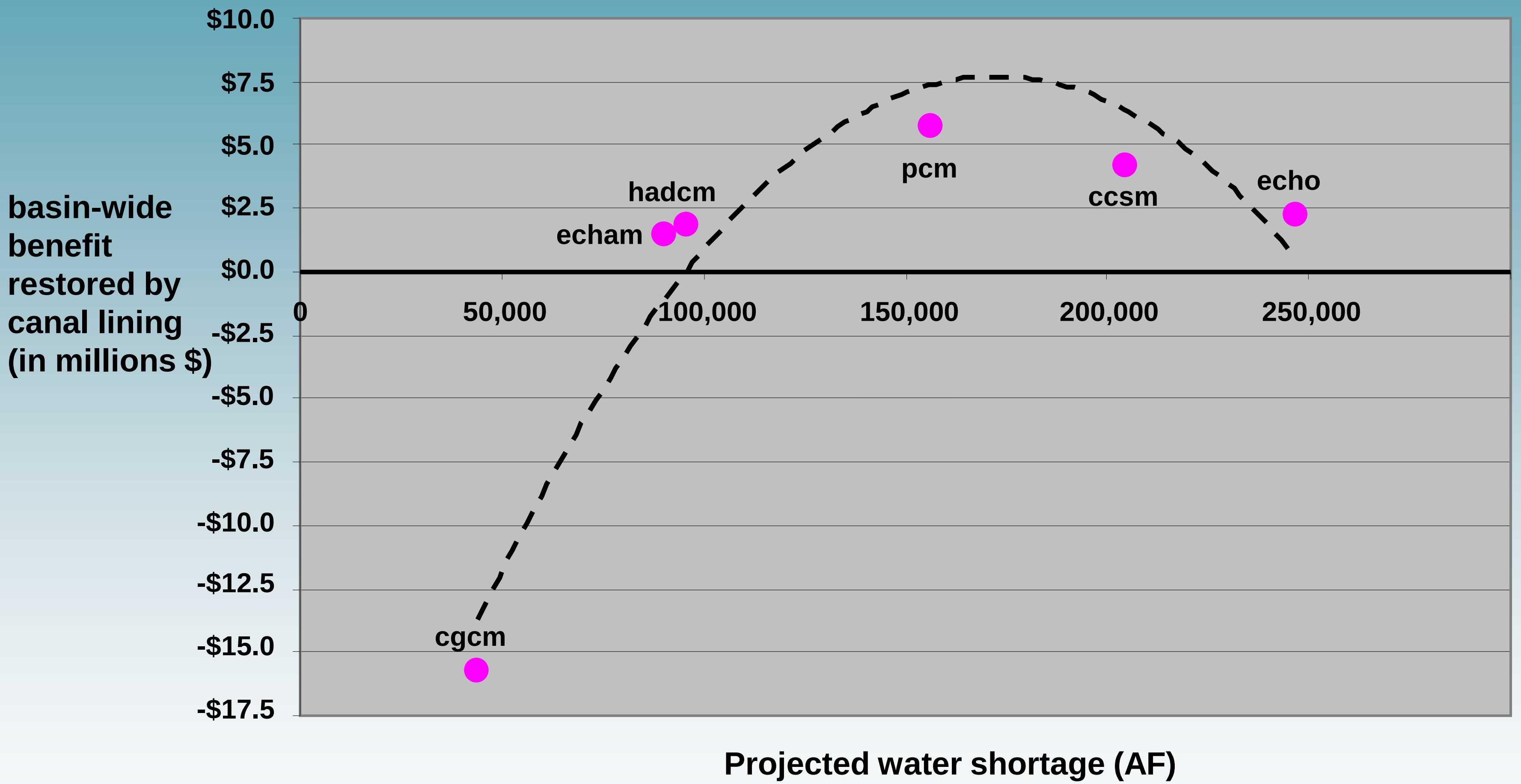
Potential Benefit and Forgone Benefit of new Water Conservation Measures



Conclusions

- Hydrologic externalities resulting from conjunctive surface and groundwater irrigation are common in the West.
- Hydro-economic modeling is an important tool for <u>managing</u> externalities (there are alternatives to eliminating them).
- Ignoring externalities can lead to an incorrect assessment of basin-wide benefits and foregone benefits of water conservation projects.

Revised 2009 principles and guidelines for
Federal Water Resource Planning

End

- Edits slide 7, slide 9, slide 15