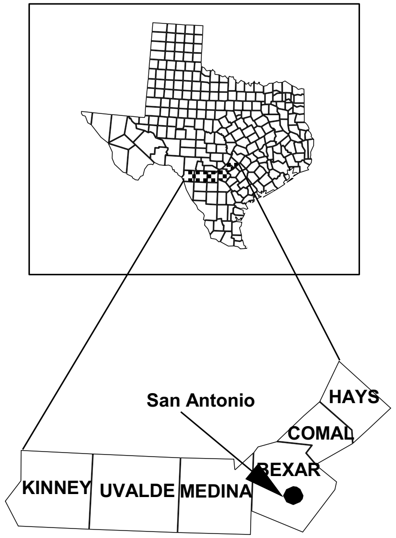
EDSIMR – a regional FEW model



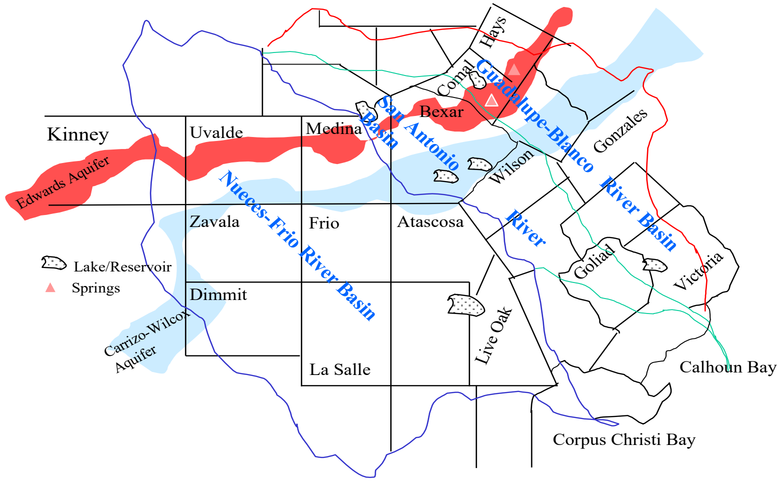
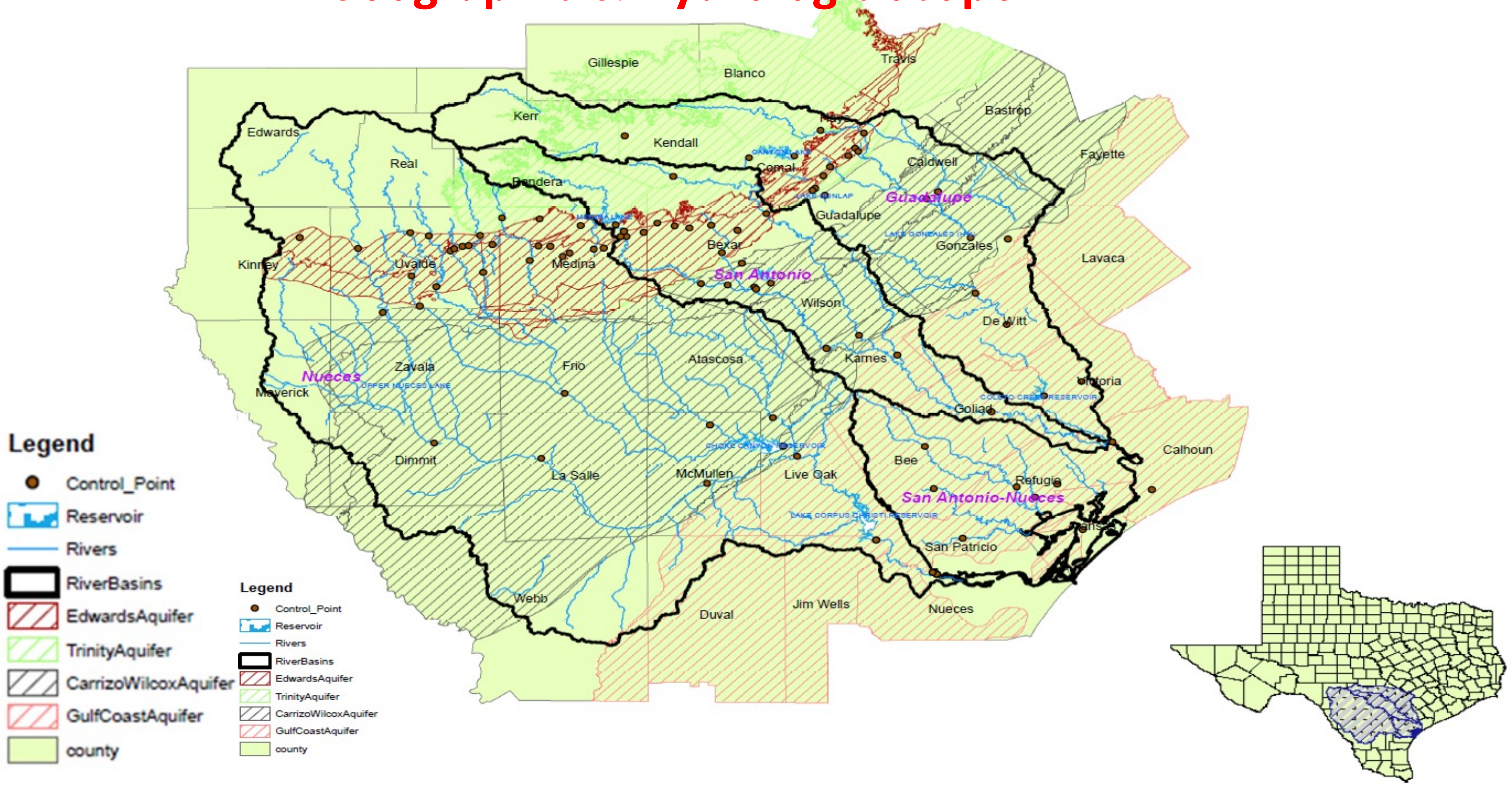


Figure Study Area By Texas Counties

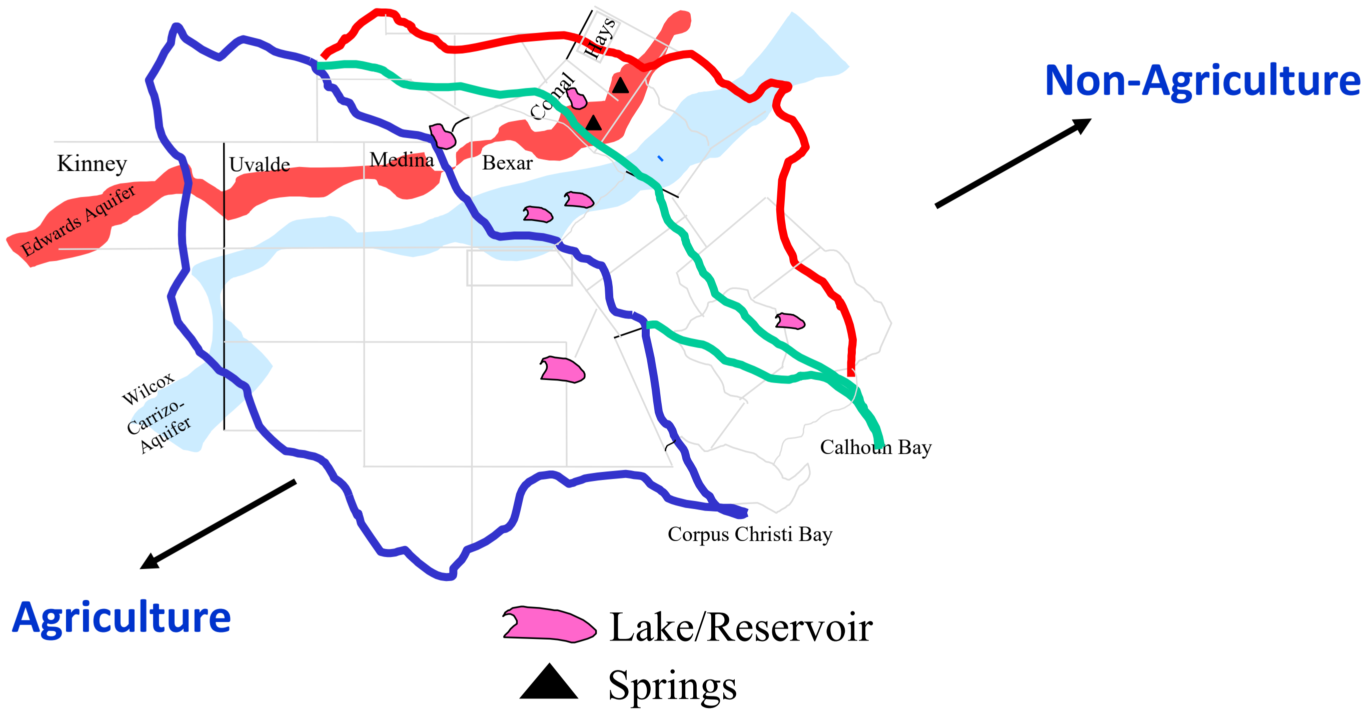
Chen, C.C., D. Gillig, and B.A. McCarl, "Effects of Climatic Change on a Water Dependent Regional Economy: A Study of the Texas Edwards Aquifer," Climatic Change, 49, 397-409, 2001.

Geographic & Hydrologic Scope



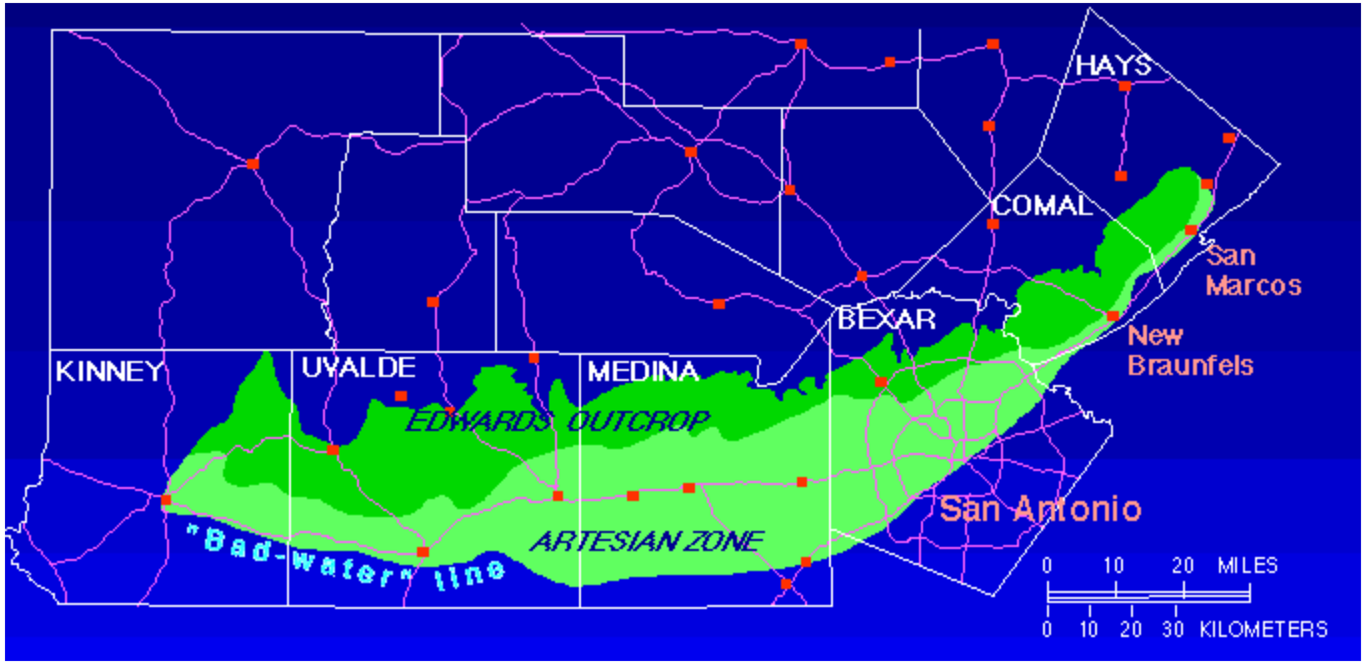
Geographic & Hydrologic Scope

- 4 River Basins + 5 Aquifers + 2 Springs + 6 Lakes/Reservoirs
- EA discharges through springs and wells
  - Comal and San Marcos Springs => habitat for endangered species
  - Well discharge => Agriculture, Municipality, Industries, power, fracking



Edwards Aquifer – significance

- Main Source of Water Supply to the City of San Antonio



- Corpus Christi Metro has 452k population and will be 550k in 2050
- Victoria Metro has 100k population and will be 115k in 2050

- City of San Antonio is the sixth largest city in the U.S.
- Population => over 1.5 million in city 2.4 million metro
- ranks third among large U.S. cities in population growth
- 4.3 million population will be in SA metro by 2050

Edwards Aquifer – background

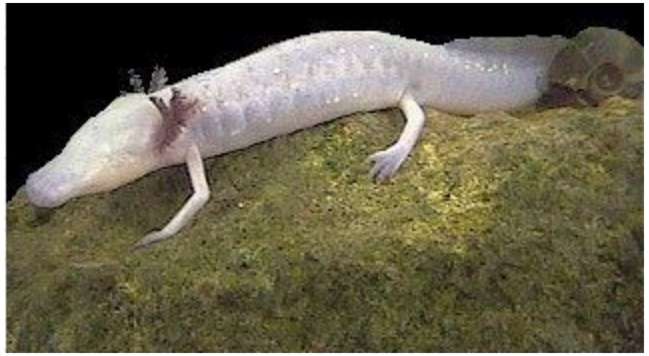
- Use Competition
  - ⇨ farmers
  - ⇨ municipality
  - ⇨ industries
  - ⇨ recreationalists
  - ⇨ environmentalists

Lake Corpus Christi

Source: http://www.tpwd.state.tx.us/park/lakecorp/lakecorp.htm
Source: http://www.edwardsaquifer.net/species.html

Edwards Aquifer – background

- Increase Environmental Awareness
  - ⇨ Endangered species



Texas Blind Salamander

Fountain Darter

San Marcos Gambusia

San Marcos Salamander

Source: http://www.edwardsaquifer.net/species.html

Edwards Aquifer – background

Terrible drought in the 1950s, caused water planning but little progress

Edwards Underground Water District created in 1959 and it was charged with conserving and protecting water in the Aquifer. However, it had no authority to restrict groundwater pumping

Painfully pointed out by fish farm in 1991 using one fourth as much water as San Antonio.

In May 1991, the Sierra Club filed a lawsuit against the U.S. Fish and Wildlife service claiming the Service was not adequately protecting endangered species that depend on the Aquifer.

In January 1993 Federal Judge ruled in favor of the Sierra Club and ordered that springflow must be maintained even during a drought like in the 1950s.

In May 1993 Senate Bill 1477 replaced the Edwards Underground Water District with the Edwards Aquifer Authority authorized to issue permits and regulate groundwater withdrawals

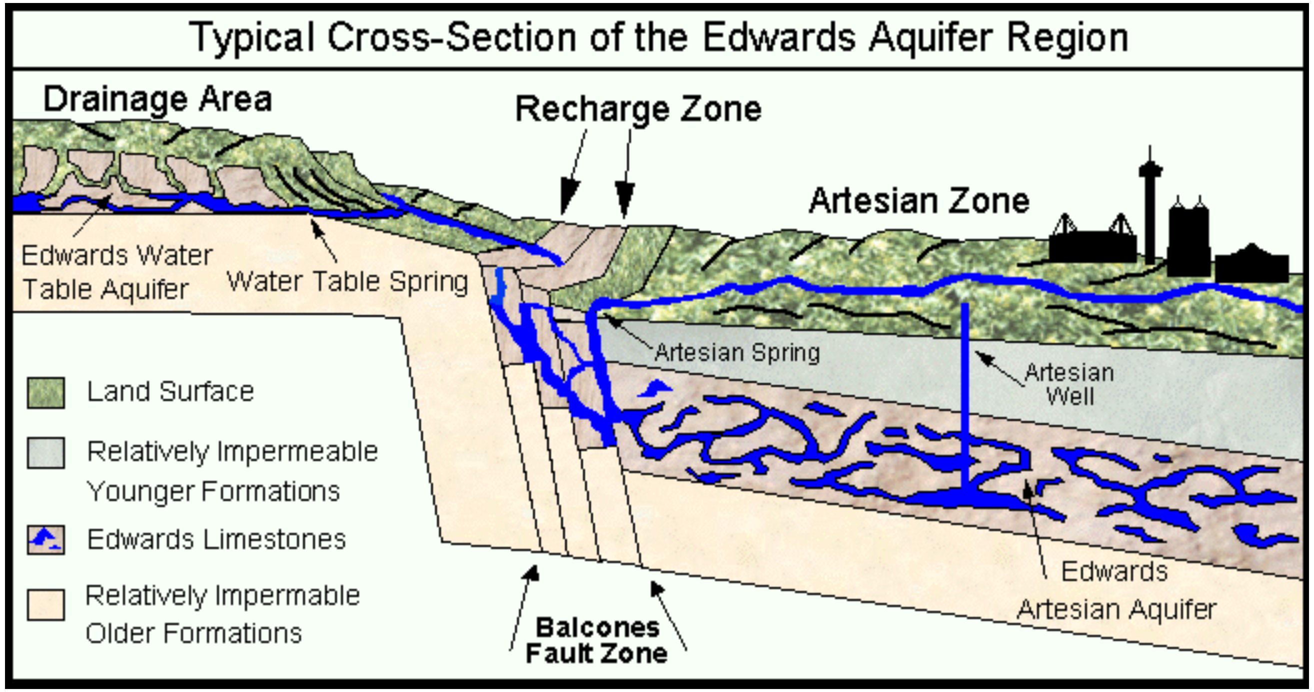
In February 2002 the Texas Supreme Court reaffirmed Authority's powers to regulate pumping.

More Info: http://www.edwardsaquifer.net/pdf/the-little-fish-ssrn.pdf
http://www.edwardsaquifer.net

Edwards Aquifer – background

The Edwards Aquifer is an underground layer of porous, honeycombed, water-bearing rock that is between 300-700 feet thick.

A lot like an under-ground river



Capacity 200 Mil af

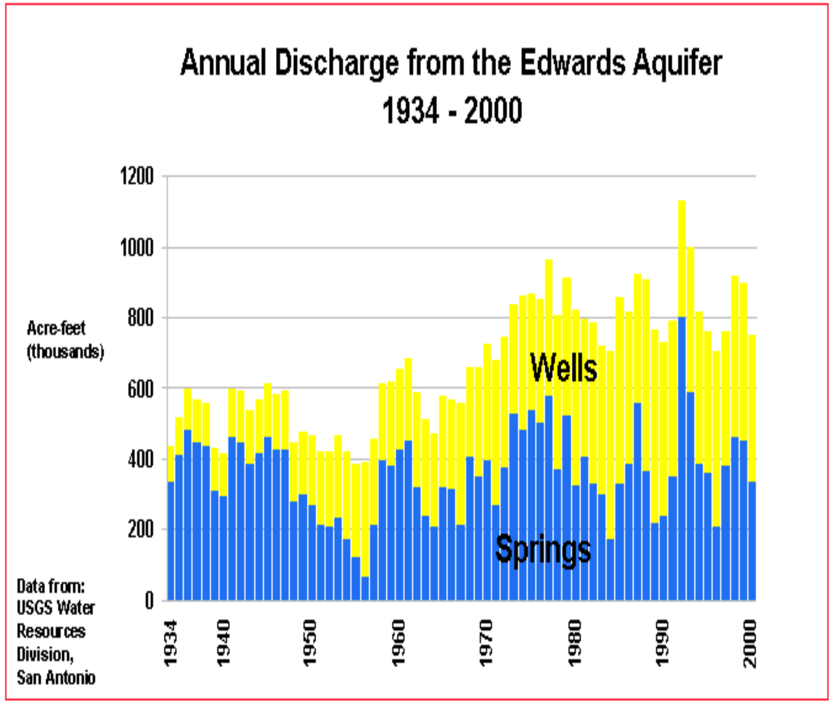
Recharge 674K af

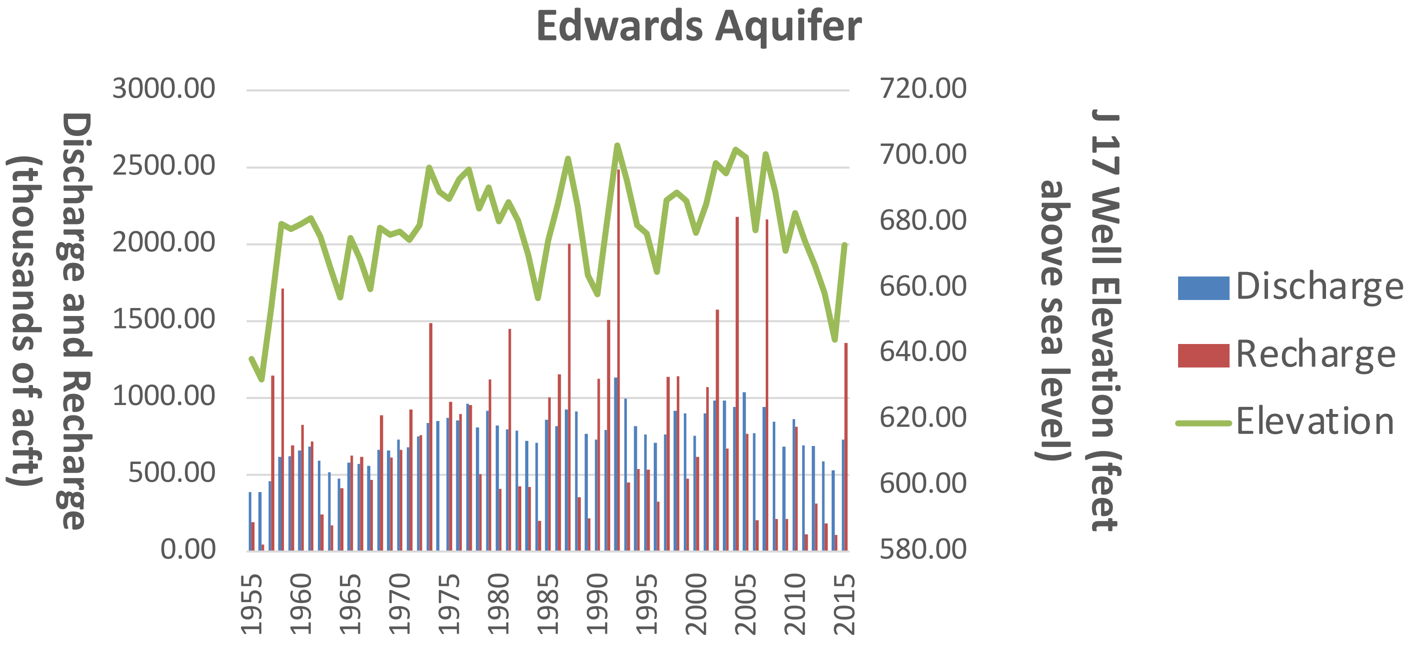
Pumping 450K af

http://www.edwardsaquifer.net/intro.html

Edwards Aquifer – background

- **Water Scarcity**
  - ⇨ **increasing water demand**
  - ⇨ **decreasing water supply**
    (regulation:SB 1477 => 450K to 400K af, or drought)





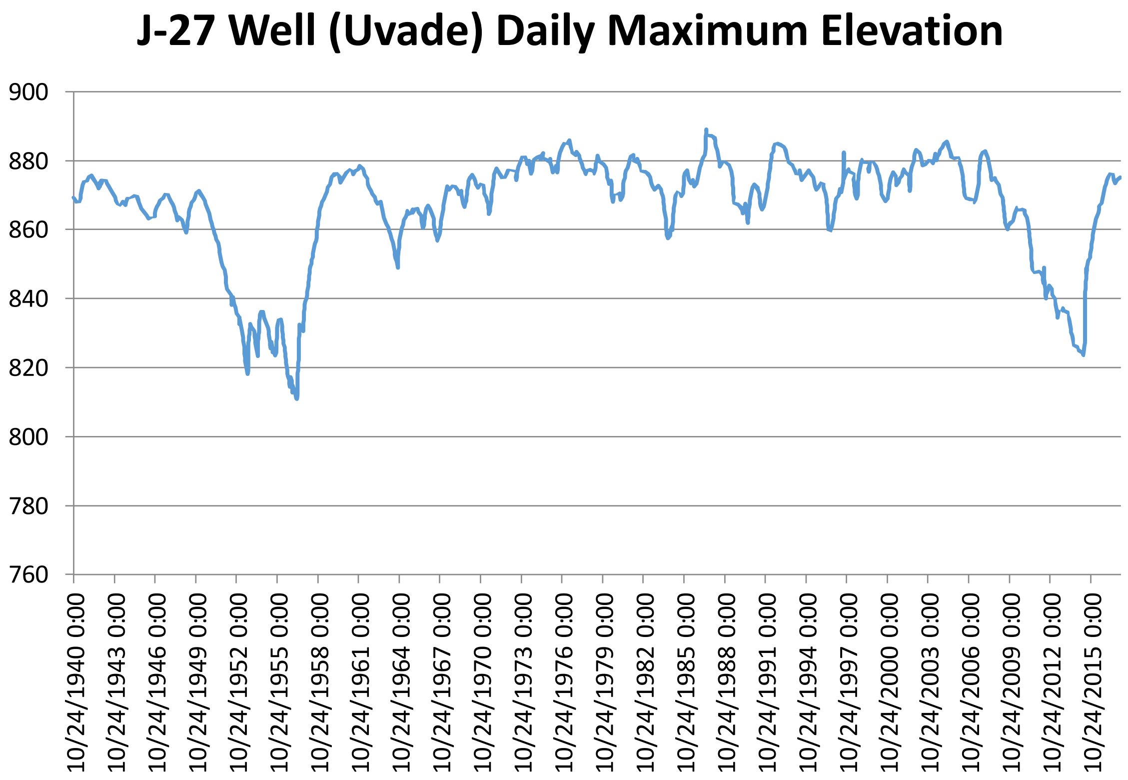
Source http://www.edwardsaquifer.net/charts.html

Does not Hold water

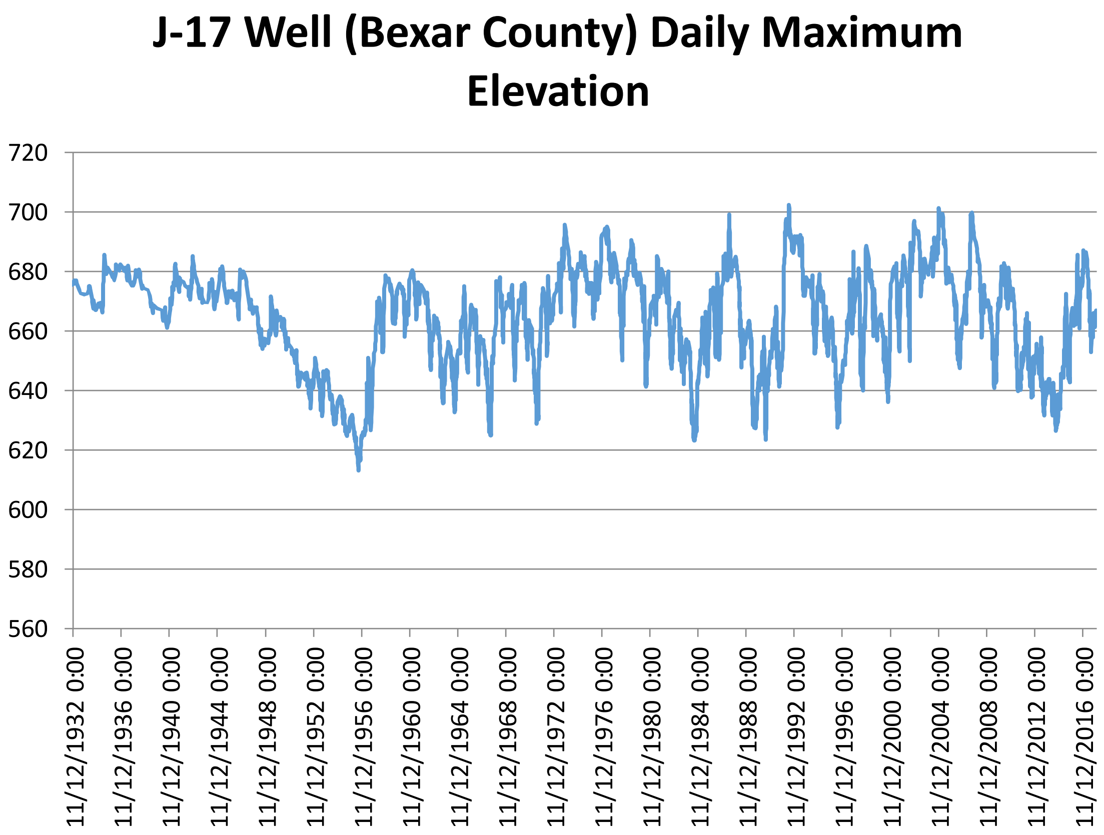
Edwards Aquifer – background

Two Correlated Pools

West



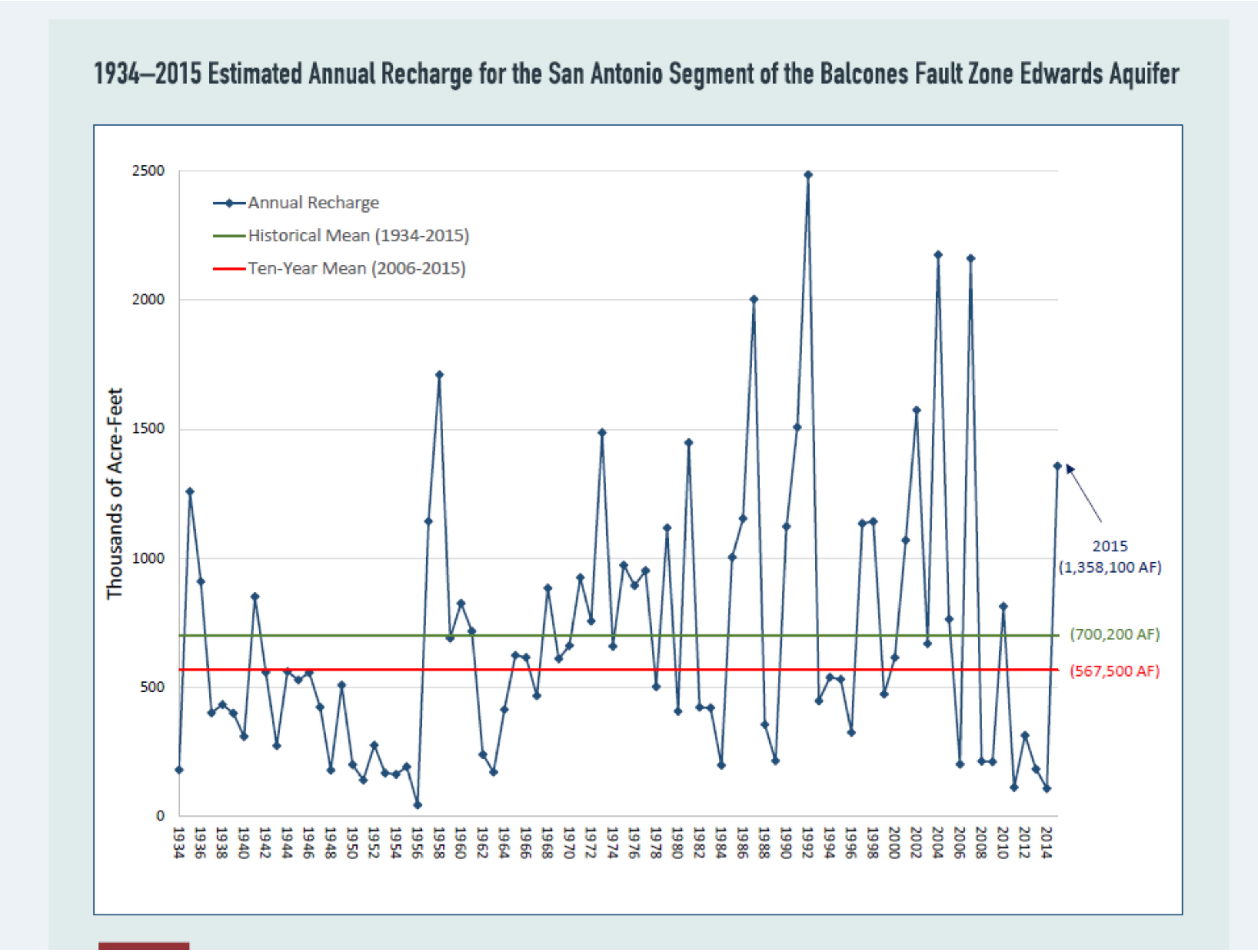
East



Data source: Edwards Aquifer Authority

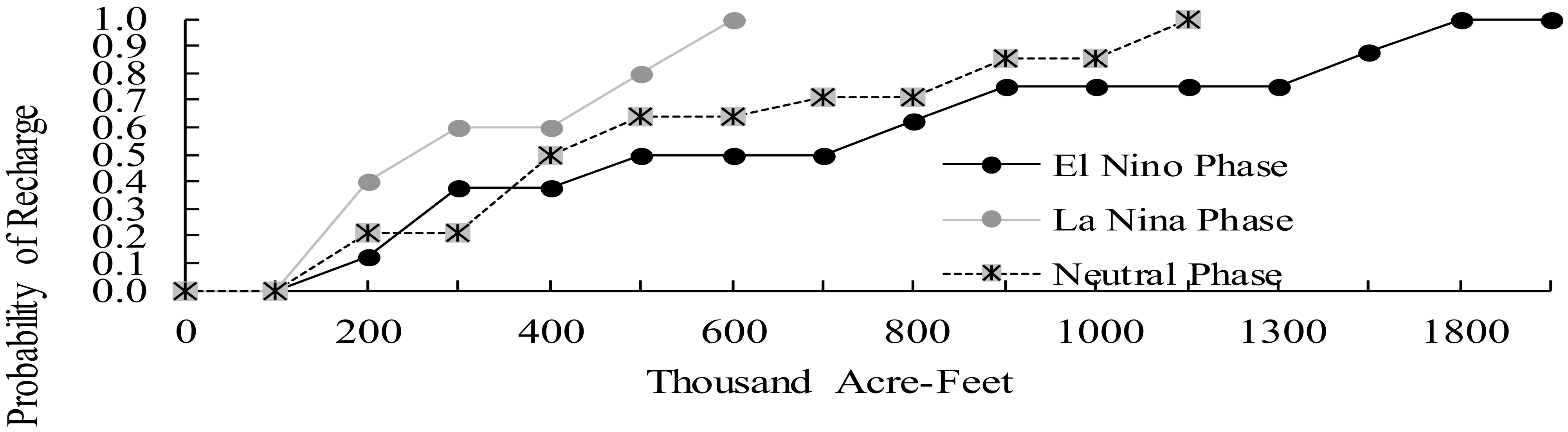
http://www.edwardsaquifer.org/scientific-research-and-data/aquifer-data-and-maps/historical-data/historic-data-downloads

Edwards Aquifer – background



Is recharge dropping?

Edwards Aquifer – background



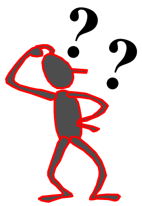
Edwards is vulnerable note much less recharge under La Nina

EDSIMR – the concept

Unify

- **Detailed aquifer hydrologic model**
- **Regionalized economic Model**
- **Surface water flow model**
- **Hydrology embedded in regional economic model via regression (Keith Keplinger dissertation)**

- Keith O. Keplinger. "An investigation of Dry Year Options for the Edwards Aquifer. " Ph.D. Thesis, TAMU, 1996.
- File Number 598 - Keplinger, K.O., and B.A. McCarl, "Regression Based Investigation of Pumping Limits and Springflow Within the Edwards Aquifer", Texas A and M University, 1995.
- File Number 829 - Gillig, D., B.A. McCarl, and F.O. Boadu, "An Economic, Hydrologic, and Environmental Assessment of Water Management Alternative Plans for the South-Central Texas Region", Journal of Agricultural and Applied Economics, 33, 1 (April), 59-78, 2001.



EDSIMR – Components

Edwards Aquifer Groundwater and River System Simulation Model

What is contained in EDSIMR ?

AKA RIVERSIM

- **Simulation Model (GAM)**
  springflow, beginning/ending aquifer elevations, pumping

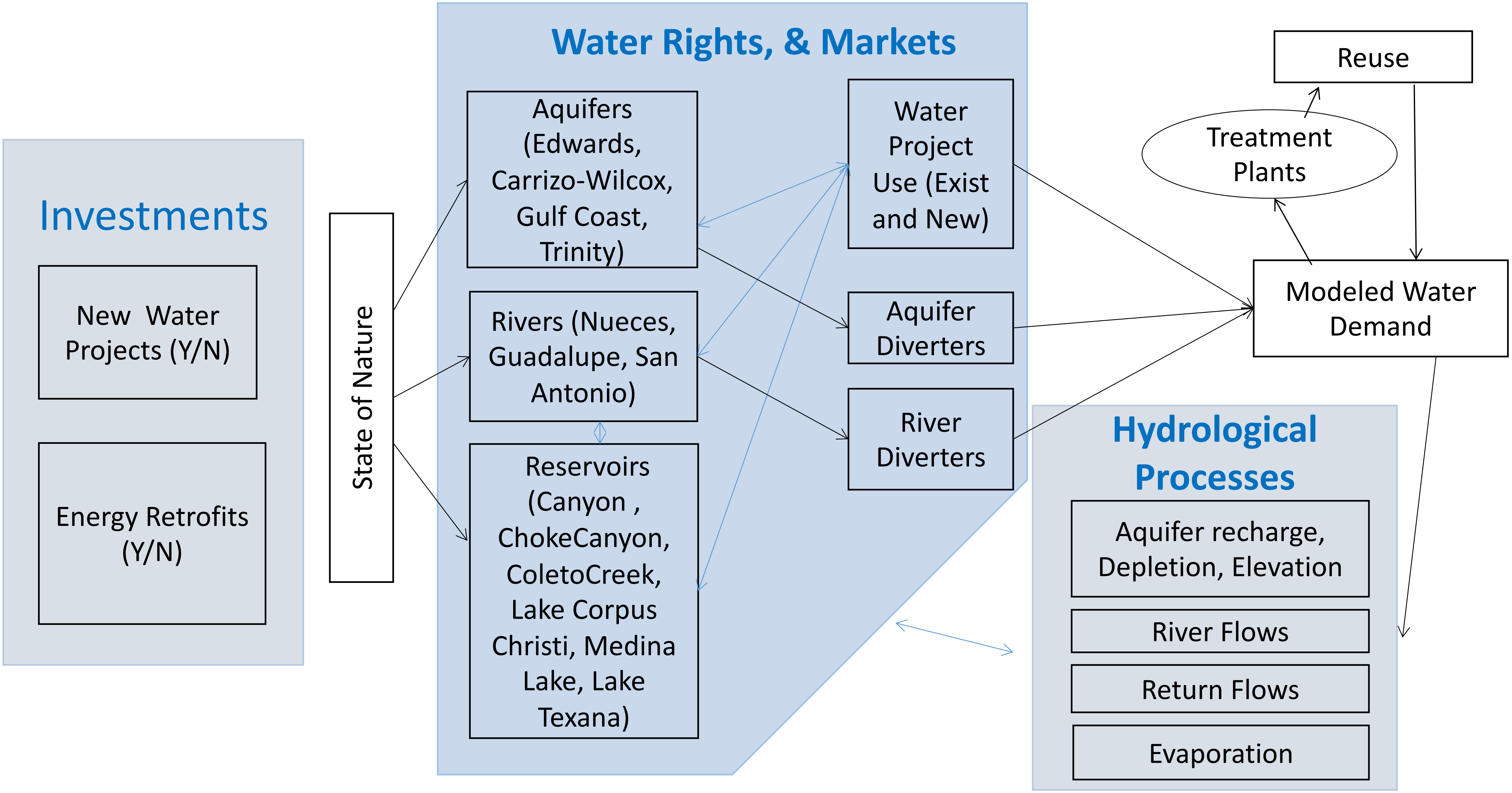
- **Econometric Model**
  springflow/ending = f (beginning, recharge, pumping)

- **Mathematical Linear Programming**
  - **Components** : objective function
    : ag, M&I power and fracking decision variable
    : constraints
    : Surface water Network flow
    : ground water characteristics
  - **Linkage** : Ground Water + Surface Water

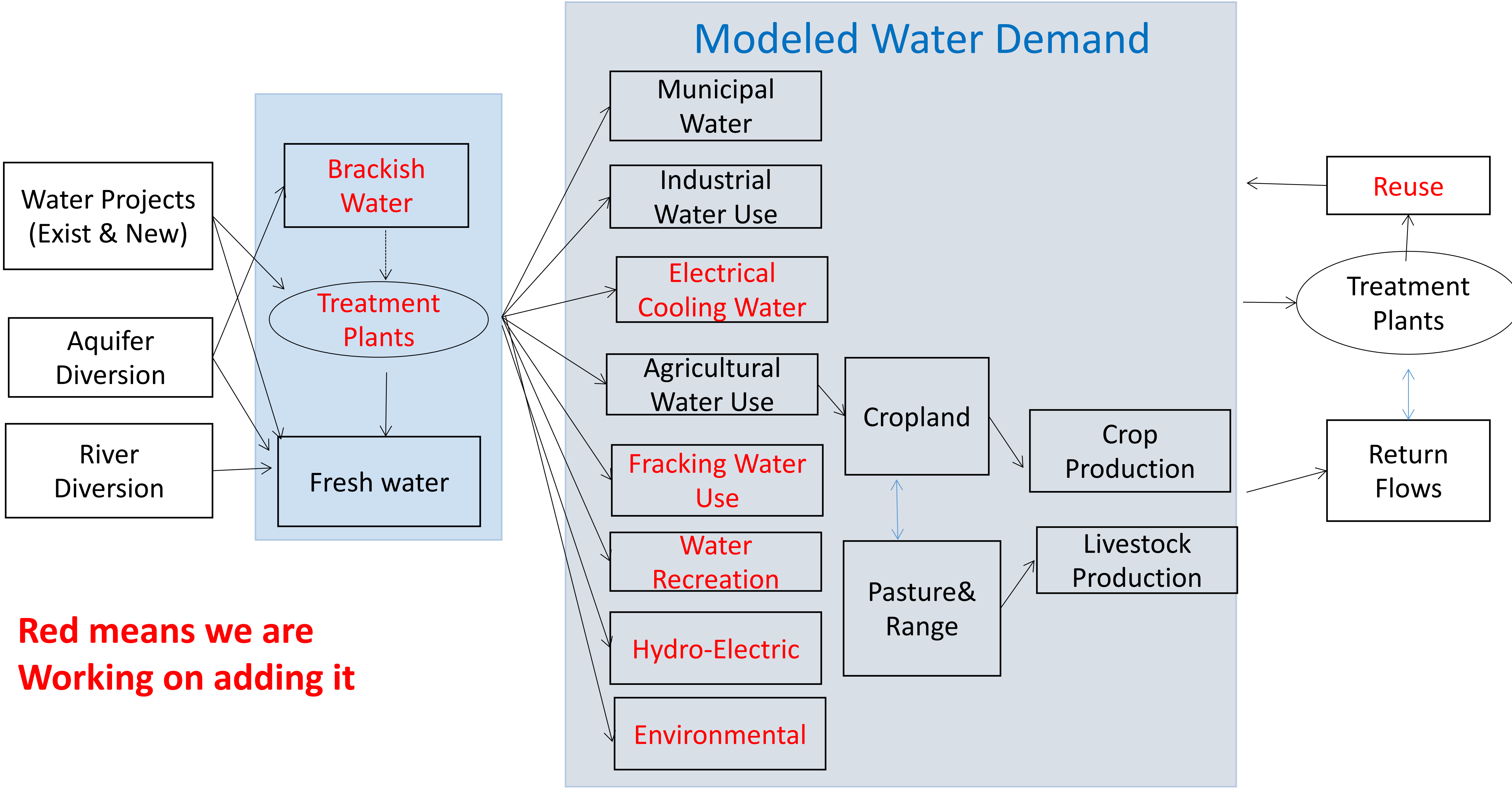
EDSIMR – Example Analysis Objectives

- Evaluate the economic and environmental consequences of a set of water management and energy project plans
- Determine the "*best*" mix of water and energy retrofit options for a given demand and environmental constraints
- Undertake a comparative assessment of the model "*best*" set of water management and energy project plans.

EDSIMR – the scope

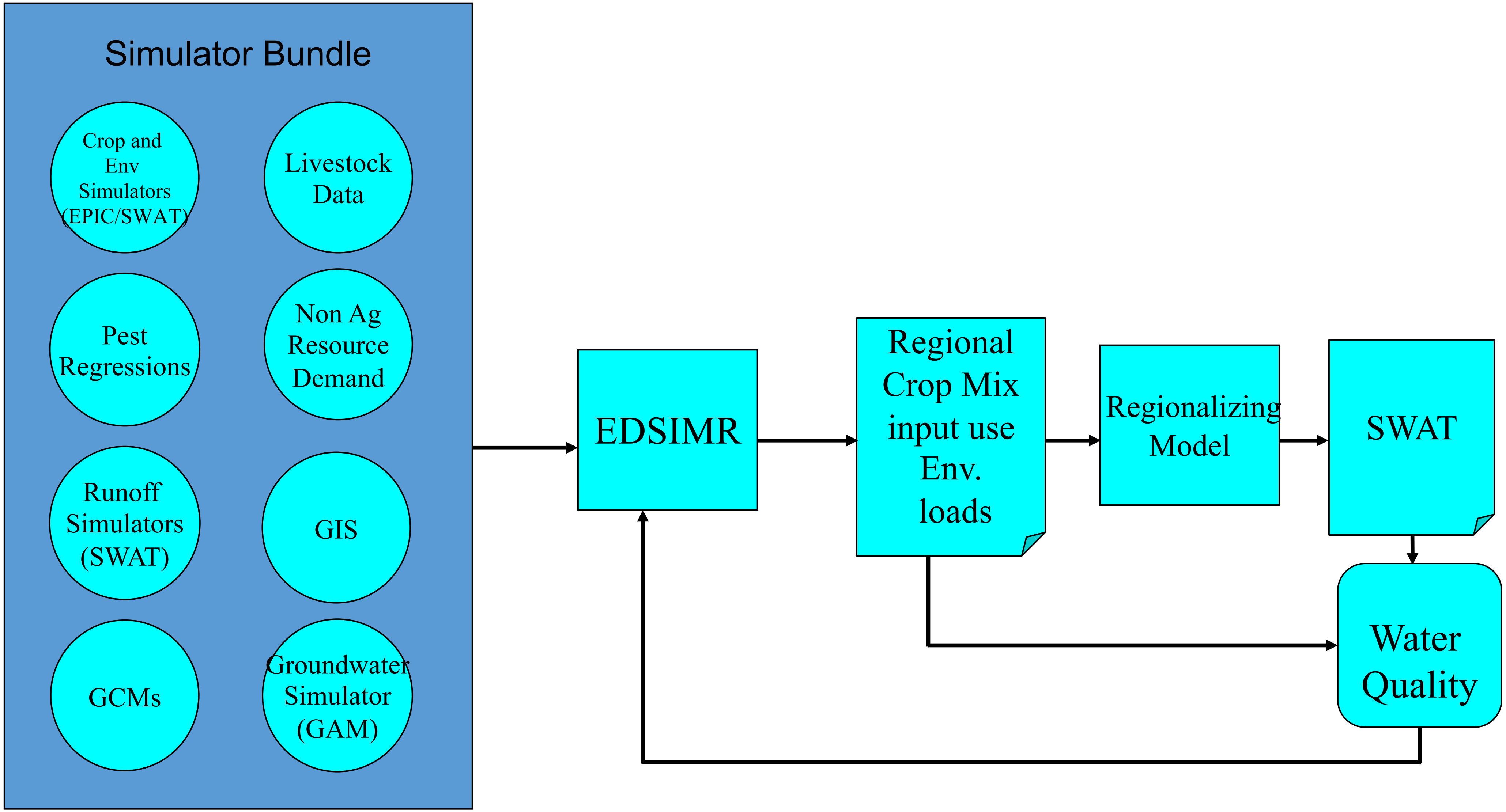


EDSIMR – demand scope

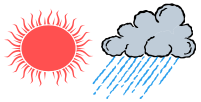


Red means we are Working on adding it

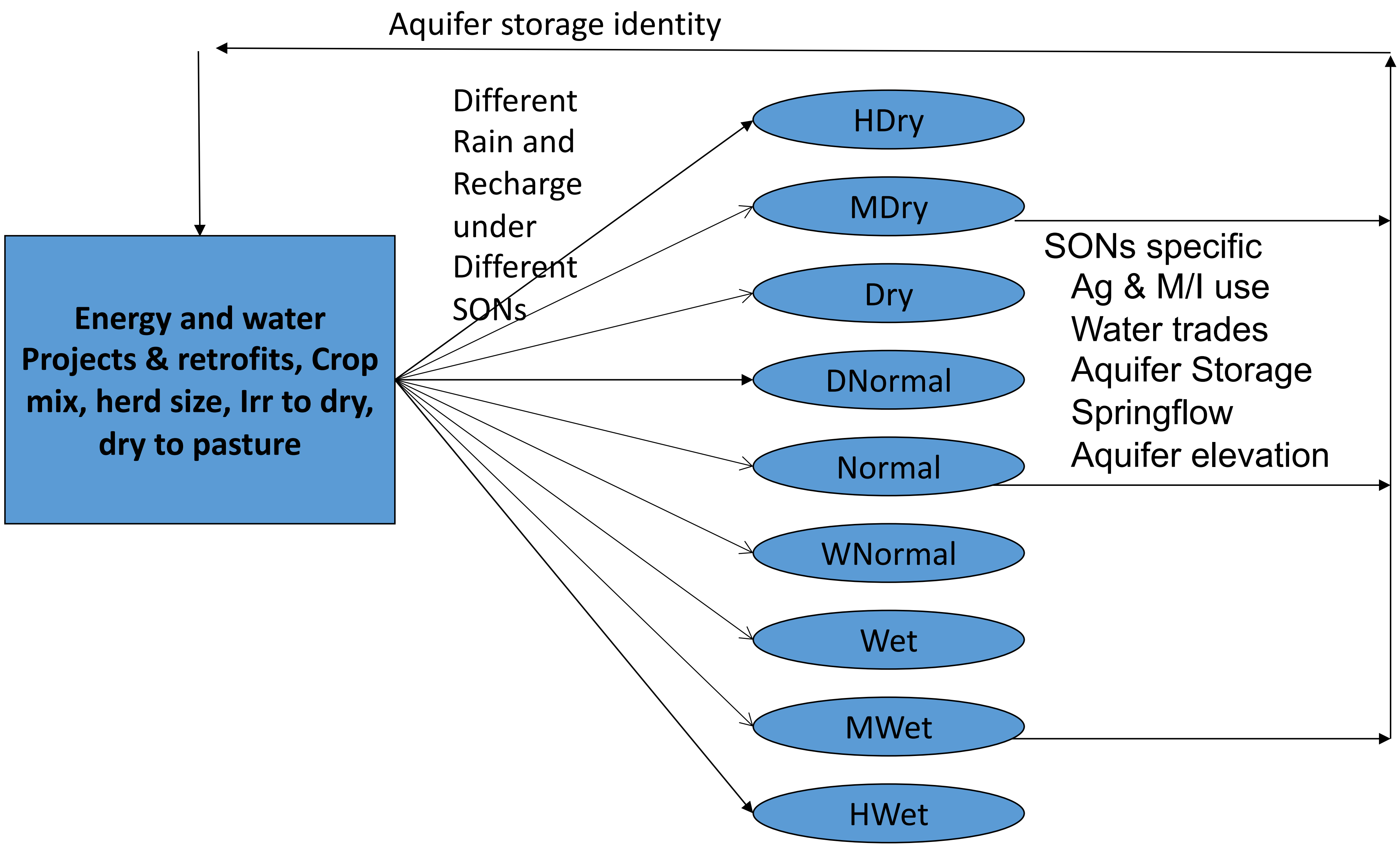
EDSIMR "System" (and friends/ancestors)



EDSIMR – Basics of Stochastics

- Discrete Stochastic Model :9 weather states 
- 2 Stage Decision
- Stage 1
  - Water and energy projects
  - Crop mix
  - Livestock numbers
  - Initial levels of aquifers and reservoirs
- Stage 2
  - Crop water use strategy
  - Recharge and surface inflows
  - Pumping/diversion
  - Water flows

EDSIMR – stochastics



State of Nature Allocation

State of Nature	Years
Hdry	1951,1956,2011,2014
Mdry	1934,1948,1954,1963,2013
Dry	1950,1955,1989,2006,2008,2009
Dnormal	1940,1952,1962
Normal	1937,1938,1939,1947,1949,1964,1967,1980,1982,1983,1993,1996,1999,2012
Wnormal	1942,1944,1945,1946,1959,1965,1966,1969,1970,1972,1974,1994,2000,2003,2005
Wet	1936,1941,1957,1968,1971,1975,1976,1977,1979,1985,1986,1990,1997,2001,2010
Mwet	1935,1958,1973,1991,2002,2015
Hwet	1987,1992,2007

EDSIMR – Basics of Stochastics

- Stochastics
  - Temp and precip
  - Crop Yields and Water Requirements and pest costs
  - Livestock stocking rate
  - Livestock performance
  - M&I demand
  - Cooling requirements
  - Water available

EDSIMR – Big Picture Stochastics

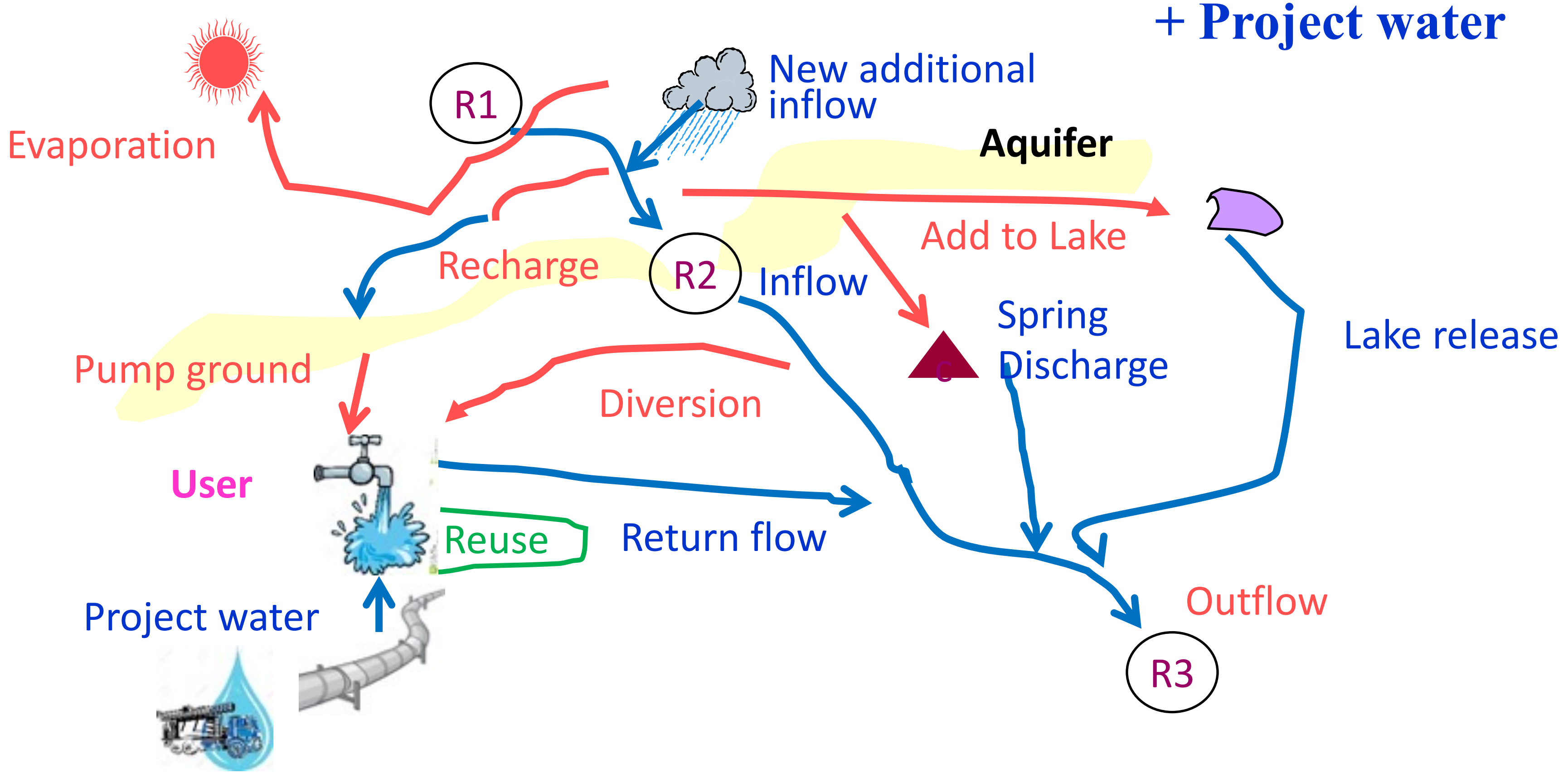
	Build Project	Irr to Dry Land	Crop /Animal Mix	SON1 Ag	SON1 Lease Agwat	SON1 NonAg	SON2 Ag	SON2 Lease Agwat	SON2 Non Ag	RHS
Obj	-fix Cost	-convert cost	-plant/ buy cost	+Prob1* sales	-prob1* Mkt cost	+prob1* nonag val	+Prob2* sales	-prob2* Mkt Cost	+prob2 * nonag val	Max
DryLand		-	+							< +
Irr Land		+	+							< 0
Son1 Crops/animals			-	+						< 0
Son1 Ag wat				+	+					< +
Son1 Non Ag	-CAP				-	+				< +
Son1 Hydrol				+		+				> 0
Son2 Crops			-				+			< 0
Son2 Ag wat							+	+		< +
Son2 Non Ag	-CAP							-	+	< +
Son2 Hydrol							+		+	> 0

EDSIMR – River flow detail

Diversion
+ Aquifer recharge
+ Evaporation
+ Lake addition
+ Downstream/bay outflow

=

Upstream inflow
+ New Additional inflow
+ Return flow
+ Spring discharge
+ Lake release
+ Treated reuse
+ Project water



EDSIMR – Demand Summary

Agriculture:

- 23 crops and 5 animal types are covered
- Fixed price are used for all commodities.

Municipal water demand:

- Demand function with constant elasticity present for each county and 4 major cities (San Antonio, Victoria, Corpus Christi, and Gonzales) in the region.

Industry water demand

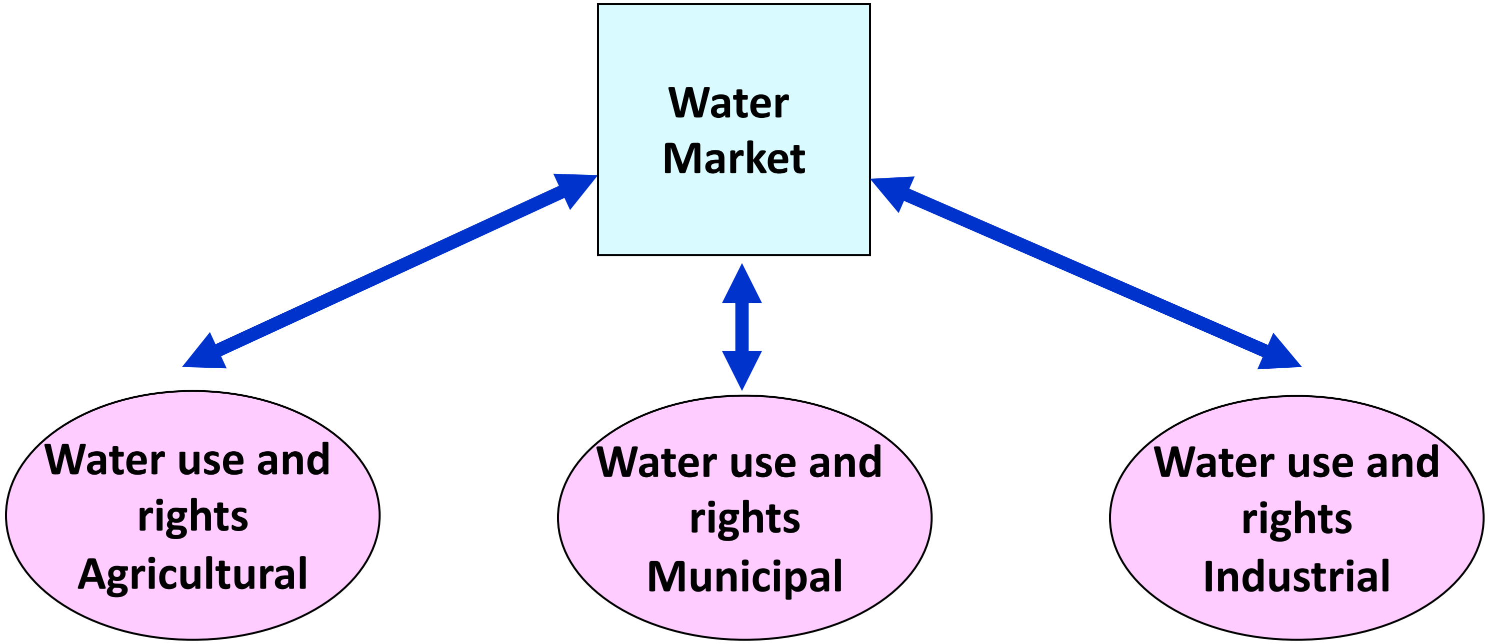
- Demand function with constant elasticity are present in the model for each county.

- Electricity KWH demand
    - Fixed price??
    - Model can choose water demand depending on technology and retrofit plus new
- Fracking activity–
    - Fixed amount
    - Model can choose water demand depending on technology and retrofit plus new
- Water for Recreation, instream flows, escape to bay and estuary
    - Fixed price
- For Now one homogeneous water later may allow substitution of alternative qualities for some uses or some part of uses

EDSIMR – Water Supply Summary

- Surface Water
  - Divert water from river or stream directly
  - Limited by water permits capacity for all rivers in Texas
- Aquifers
  - Pumping water from Major Aquifers
  - May limited by water permits and other regulation
  - Some aquifer contains brackish water (high treatment cost)
- Water Projects (from region L and later others)
  - Get water from other regions by pipelines
  - Water reuse
  - Build new reservoirs
  - Desalinate brackish water or seawater
  - Aquifer Injection

EDSIMR – Incorporating Water Markets



Includes friction in mkt ($50 in Edwards)

EDSIMR – Incorporating Projects and Retrofits

- **Water management options (e.g. dams, reallocations, artificial recharge, etc.)**
- **Power and fracking retrofits**
- **New power**
- **Capacities**
- **Amortized fixed costs**
- **Joint constraints between the water development alternatives**
    - Interdependencies between management options
    - Mutual exclusivity between some options
- **Tradeoff between water supply benefits and investment fixed costs**

EDSIMR – Possible Projects and Retrofits

Ag	Irrigation methods and practices	Alternative crops
	Land to dryland or grazing	Removing minimum limits
	Degraded water use	Crop mix
	Dry year option	
Water	Use of more distant aquifers	Injection &recovery
	Reservoirs	Saline sources
	Enhanced recharge	Conservation
	Reuse	Broader markets and leasing
Energy	Alternative cooling	Coal to Natural Gas
	Renewables wind solar Geotherm	Import more
	Fracking water reuse	Fracking technology

EDSIMR – Conceptual Results

- **Projects built**
- **Water Use Pattern and Trading**
- **Economic Effect by party**
  - regional ag farm income + non-ag net surplus
  - regional water prices and costs
- **Hydrologic Effect**
  - EA elevation at the J-17 well index and river flows
- **Environmental Effect**
  - spring flows, river flows, and the Estuary bay flows
- **Social Effect**

EDSIMR

Now we go technical

EDSIMR – Objective function terms

- Municipal Elasticity
- Industrial Elasticity
- Climate demand shifts
- Max Expected Regional Net Benefit
  - agricultural sector => revenues – production cost
  - non-agricultural sector => areas under demand – supply curves
  - Power – operations cost and rev from fixed price
  - Fracking – operations cost and fixed demand
  - Env sector – to be determined
  - Project cost and retrofit cost (water, power, fracking)

EDSIMR Objective Expected Net Benefits Maximization

The objective function is a probabilistically weighted across the states of nature to reflect stochastic weather

MAXIMIZE

$$
\begin{aligned}
\sum_r prob_r * \langle & \sum_{pc} \left(irrprofit_{cr} * IRRCROPPROD_{pcr} \right) \\
& + \sum_{pc} \left(dryprofit_{cr} * DRYCROPPROD_{pcr} \right) \\
& + \sum_{ac} \left(liveprofit_{ar} * LIVESTOCK_{acr} \right) \\
& + \sum_{pm} \left(\int gmundem_{pmr}(GMUN_{pmr})\, dGMUN_{pmr} + \int ginddem_{pmr}(GIND_{pmr})\, dGIND_{pmr} \right) \\
& + \sum_{n} \left(\int smundem_{nmr}(SMUN_{nmr})\, dSMUN_{nmr} + \int sinddem_{nmr}(SIND_{nmr})\, dSIND_{nmr} \right) \\
& - \sum_{pm} groundagpumpcost_{pr} * GAGWATER_{pmr} \\
& - \sum_{nm} surfaceagpunpcost_{nr} * SAGWATER_{nmr} \\
& - \sum_{pm} groundmunindpumpcost_{pr} * \left(GMUN_{pmr} + GIND_{pmr} \right) \\
& - \sum_{nm} surfmunindpumpcost_{nr} * \left(SMUN_{nmr} + SIND_{nmr} \right) \\
& + \mathrm{EnvBenefit} * (\mathrm{Instream} + \mathrm{reserviorrec} + \mathrm{bayestuaryinflow}) \\
& - \sum_{p} \left(transaction * TRANSFERS_{pr} \right) \rangle
\end{aligned}
$$

Net Ag income from Irr and dry Crop and animalproduction

areas under M&I demand curves

Ag

M&I

pumping delivery costs

Water Mkt Transaction costs

Less SON independent costs

$$- \sum_{dm} annualcost_d * NEWPROJECTS_{dmr}$$

- Planting cost
- Animal herd cost
- Land transfer cost

Annual project dev costs - Integer

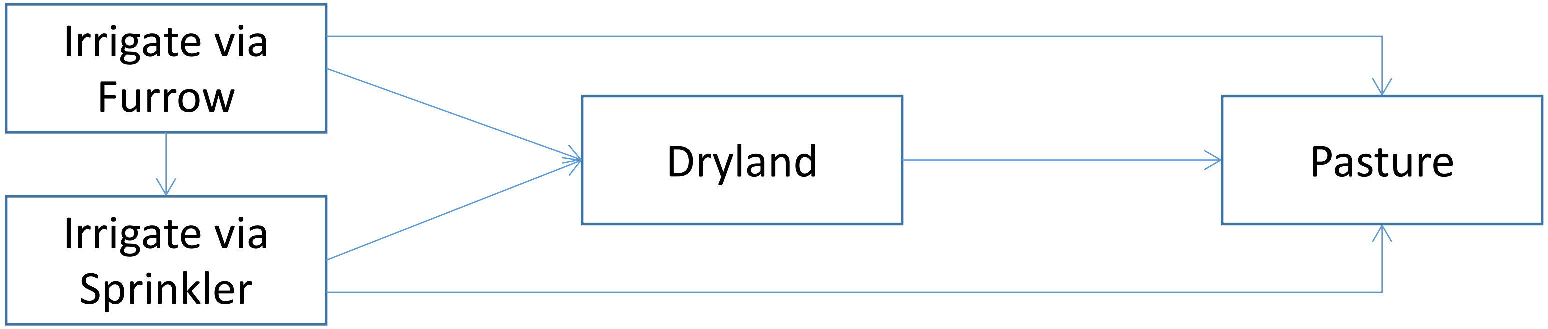
Crop plant cost

Animal acquisition annual cost

Cost of irr to dry or dry to past

EDSIMR – Agriculture Sector
Land Modeling

- Land Balance:
  Cropland + Pasture <= Total available land
- Land Transfer



- Land use decisions are made in Stage 1 of the model (CROPACRES and LIVEPROD)

EDSIMR – Agriculture Sector
Crop Mix Modeling

- Crop Mix Balance
  - Crop mix should be a convex combination of historical crop land allocation
  - Dryland and Irrigated crops mixes are counted separately

$$\sum_{zones} CROPACRE_{county,zones,crops,irrigstatus} \leq \sum_{mixesa} [CROPMIX_{county,irrigstatus,mixesa} * cropmixdata_{county,crops,irrigstatus,mixesa}] \quad \forall county, crops, irrigstatus$$

EDSIMR – Agriculture Sector
Crop Production Modeling

- Crop Strategy Balance
  - Sum_strategy of StratAcres(stateofnature, strategy)<= CropAcres

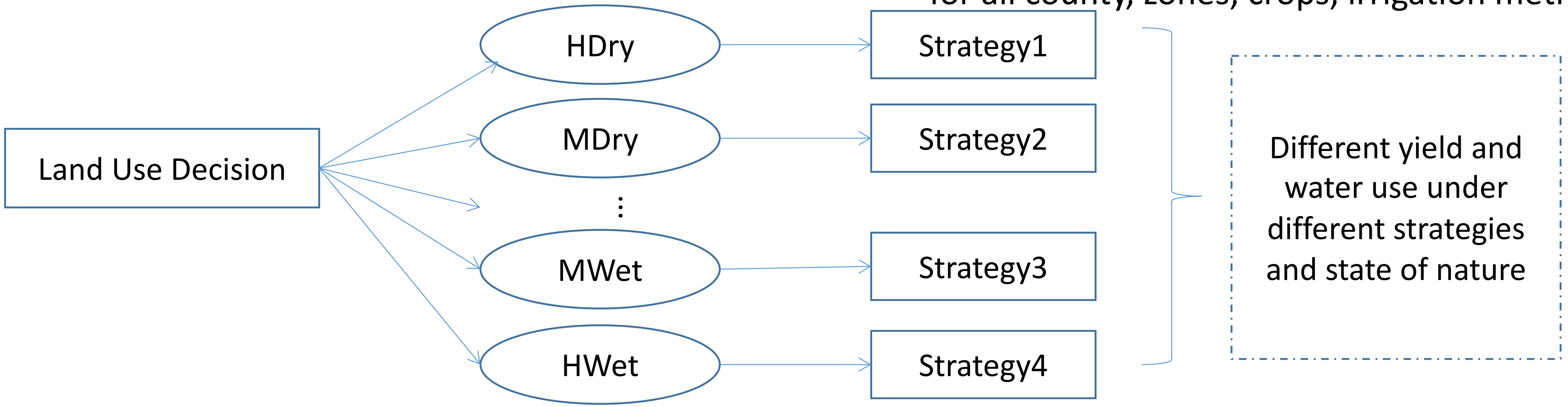
    for all county, zones, crops, irrigstatus

- Crop Production Balance

  Crop Production (stateofnature)<=

  sum_strategy [Yield_(stateofnature, strategy)*StratAcres_(stateofnature, strategy)]

  for all county, zones, crops, irrigation method



EDSIMR – Agriculture Sector
Crop water and livestock Modeling

- Crop Water Use Balance

  Crop water use (stateofnature)= sum_strategy [CropWaterUse_(stateofnature, strategy)*StratAcres_(stateofnature, strategy)] for all county, zones, crops, irrigation method and month

- Livestock (Similar to Crops)
  - Herd size set in phase 1
  - Constrained by livestock mix
  - Constrained by land use in AUMS
  - Feeding decisions are made in stage 2
  - Possible sell off in stage 2???

EDSIMR – User Water use balance

- For each sector and county,

  Water used <=

  + Water diverted from Rivers (if this county has diverters for the specific sector)
  + Water pumped from Aquifers (if this county seat on the aquifer)
  + water from water projects (if the county is project destination and the sector is the target sector)
  + reuse

EDSIMR –Water rights, and Markets

- Diversion Constraint:

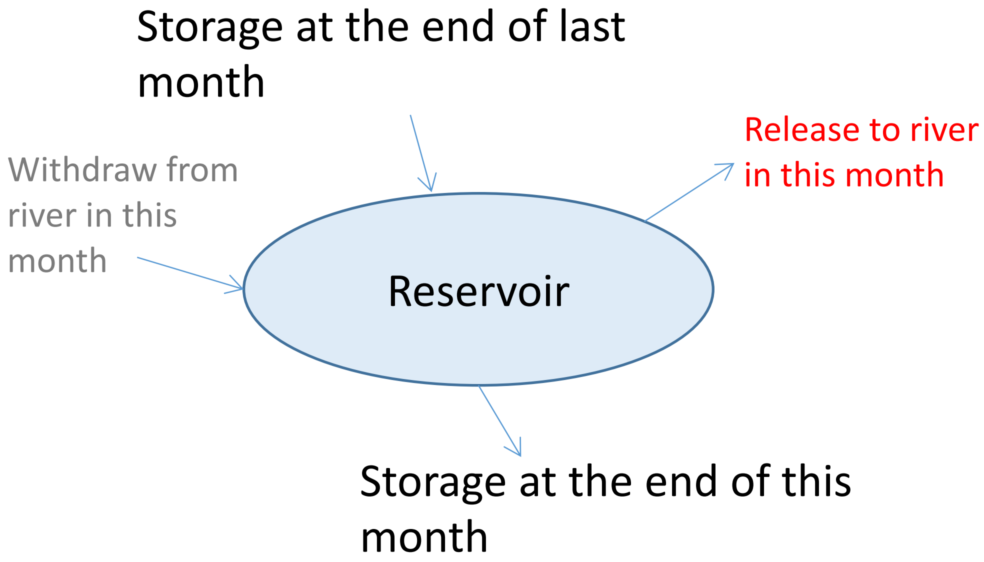
  Amount of water diverted from river by one permit

  +Sold to others — not in current version

  -Buy from others — not in current version

  <= Permitted Capacity

EDSIMR – Reservoirs



- Reservoir Balance

  Reservoir storage in current month <=

  Reservoir storage in last month

  + Withdraw from River

  – Release to River

- Reservoir Storage Balance
  - Reservoir initial storage level is the weighted average of December ending storage level under all states of nature.

  Reservoir Initial Storage (Storage level on Jan 1st)

  <= sum_stateofnature (prob_stateofnature * DecStorage_stateofnature)

- Reservoir Capacity

  Reservoir storage <= Reservoir Capacity

EDSIMR – Aquifers

- Aquifer Initial Elevation Balance
  - Aquifer Initial Elevation is the weighted average of Aquifer December ending Elevation in different state of nature.
- Aquifer Elevation
  - Aquifer Elevation is estimated by econometric model using the simulated result of GAM

  EndLift=f(BeginLift, Recharge, Pumping, Drainage, Endlift in related Region, etc)
- Spring Discharge
  - Spring Discharge is estimated by the same method of Aquifer Elevation
  - SpringDischarge=f(BeginLift, Recharge, Pumping, Endlift in related Region, etc)

EDSIMR – Projects
Water, Power, Fracking

- Integer variables in most cases
- Capacity Constraint
  - Water from projects <= { the project capacity if the project is built.
    0, otherwise
- Project capacity may be stochastic
- Operating cost per acre foot
- Fixed amortzed construction costs per project
- State of nature (stage 2) operation
- Injection Balance
  - Water could only be recovered in the Hdry state
  - Water recovered in the Injection projects in Hdry state <= water injected into aquifer in other state of nature

EDSIMR – Constant Elasticity Demand Function

- The Constant elasticity demand function

$$P = P(Q) = FQ^{\frac{1}{e}}$$

where F is a constant and E is the elasticity

- $(\hat{P}, \hat{Q})$is the price and quantity point that the curve will pass through
- Solve for the unknown value of F getting $F = \hat{P}\hat{Q}^{1/E}$
- We then could get $P = \hat{P}\left(\frac{Q}{\hat{Q}}\right)^{\frac{1}{e}}$

$$\int_a^{Q^*} P(Q)dQ = \frac{\hat{P}\hat{Q}}{1+\frac{1}{e}}\left(\frac{Q^*}{\hat{Q}}\right)^{1+\frac{1}{e}} - \frac{\hat{P}\hat{Q}}{1+\frac{1}{e}}\left(\frac{a}{\hat{Q}}\right)^{1+\frac{1}{e}} + a$$

- Set $X = \frac{Q^*}{\hat{Q}}$, the integration becomes a function of X

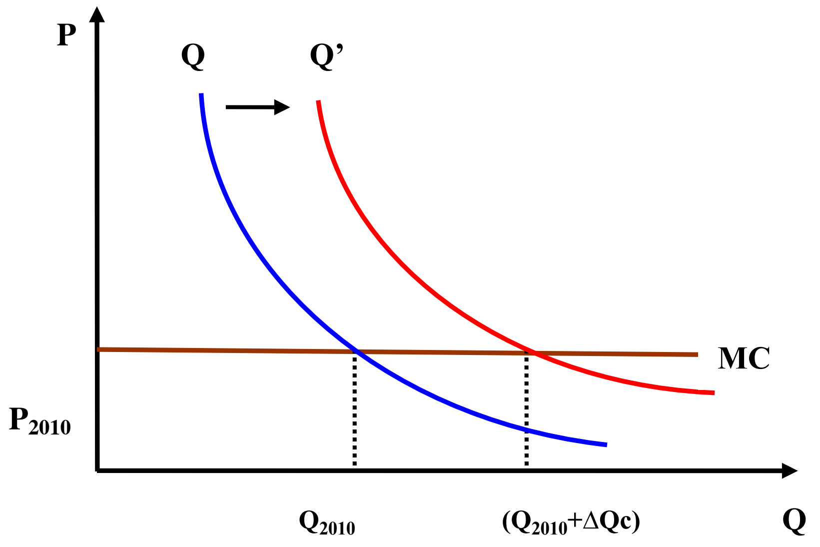


Figure 5: **Mun-city Water Demand Curve & its Climate Shift Factor**

EDSIMR – Separable programing

- $f(X) \cong f(\hat{X}_k) + \frac{f(\hat{X}_{k+1}) - f(\hat{X}_k)}{\hat{X}_{k+1} - \hat{X}_k}(X - \hat{X}_k) = \mathrm{F(X)}$
- Suppose we write X as convex combination of $\hat{X}_k$ and $\hat{X}_{k+1}$ using some new variable λ,

$$\begin{aligned} X &= \lambda_k \hat{X}_k + \lambda_{k+1} \hat{X}_{k+1} \\ &\quad \lambda_k + \lambda_{k+1} = 1 \\ &\quad \lambda_k \ , \ \lambda_{k+1} \geq 0 \end{aligned}$$

- We then get $F(X) \cong \lambda_k f(\hat{X}_k) + \lambda_{k+1} f(\hat{X}_{k+1})$
- Do steps on $\left(\frac{Q}{\hat{Q}}\right)$

- See McCarl and Spreen or 1212 on web

EDSIMR – Data Requirements

- **Water Demand by non ag users**
- **Power and fracking data**
- **Hydrological data**
- **Aquifer recharge and discharge distribution**
- **Weather - temperature, precipitation**
- **Agricultural production budgets**
- **Development alternatives**
  - water development costs
  - agricultural and non-agricultural pumping/diversion costs
  - water supply seasonally by recharge SON
  - Power and fracking retrofits, fixed and operating costs

EDSIMR – Sample Analysis Results

Adoption of the new management regime comes at the expense of regional water users, in particular, non-agricultural users.

Agricultural users marginally gain not because of agricultural operations but rather because of additional income generated by water sales.

Ag sells a lot of water due to lower use value.

Continuing the traditional rule of capture regime until 2012 would result in zero Comal spring flow under many states of nature.

When pumping limits are imposed, Comal spring flow does not cease. Clearly some form of pumping restrictions are needed to avoid having the endangered species habitat compromised in the face of anticipated water demand growth.

Water market improves water allocation efficiency transferring from lower to higher valued users

Agricultural sector is better off due to additional income from water market sales

EDSIMR – Sample Analysis Results

There is a distinct tradeoff in the EA region between the economic well being of pumping users and regional environmental attributes.

Leaving behind the *rule of capture* to take on the highest of the HCP motivated pumping limits reduces regional pumping user related welfare by $246 million per year. The most extreme limit examined (175,000 acft) under the emerging HCP raises the welfare loss to $633 million per year.

The emergence of the EA water market improves regional welfare to pumping users but worsens environmental attributes unless the East-West pools could somehow be factored into its design.

Water development from alternative sources will be stimulated greatly by HCP related EA use restrictions.

The EA region will have to develop an expanded set of water development alternatives if the severe Habitat Conservation Plan based restrictions are imposed.

EDSIMR – Sample Analysis Results

Table 2. Economic and Hydrologic Effects of Water Management Plans

	2050 Base[a]	Optimal 400	Optimal 200	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
		---------------------------- change from the 2050 Base ----------------------------						
Average Welfare Measures (Mil.$):								
Agricultural Income	19.1	**-31.5%**	**-9.8%**	-12.7%	-41.2%	-10.0%	-16.9%	-72.3%
Non-agricultural Surplus	878.0	**2.2%**	**0.9%**	**-5.7%**	-7.2%	-12.1%	-8.2%	2.0%
Other Regional Agricultural Income	59.1	0.02%	0.02%	-2.1%	-2.1%	-2.1%	0.02%	-2.3%
Other Regional Non-Agricultural Surplus	216.5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total Regional Welfare	1232.8	1.1%	0.5%	-4.2%	-5.9%	-8.8%	-6.1%	0.2%
Agricultural Activity Measures (10^3 acres):								
Edwards Aquifer Irrigated Acres Harvested	74.5	-35.7	-21.6	-21.9	-45.4	-21.8	-25.1	-64.4
Edwards Aquifer Dry Land	17.2	-5.9	-6.6	-8.1	-1.6	-6.9	-7.6	-5.8
Purchased Edwards Aquifer Irrigated Land	N/A	40.4	27.9	28.4	45.1	28.2	31.1	59.2
Leased Edwards Aquifer Irrigated Land	N/A	1.9	0.4	1.5	1.5	0.3	1.5	8.6
Average Hydrologic Measures:								
Comal Spring Flow (cfs/year)	196.0	-46.0	**125.6**	-8.7	71.9	128.7	-16.9	-44.5
Corpus Bay Inflow (10^3 acft)	1025.7	-4.7	-1.6	5.5	7.6	0.4	-38.1	-9.2

- **The EA ag sector is worse off.**
- **The economic gain accrues to the EA non-agricultural sector, but is basically offset by the water development costs.**

EDSIMR – Sample Analysis Results

Table 1. Water Management Options Used in the Alternative Plans

Water Option	Optimal 400	Optimal 200	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
Surface Water Diversion/Transfer							
Lower Guadalupe River diversion	x	x	x	x			
Colorado River in Colorado County					x		
Colorado River in Bastrop				x			
Joint development of water supply with CCC/LCC system						x	
Medina Lake							
Canyon Reservoir			x	x	x	x	x
Wimberley & Woodcreek Reservoirs			x	x	x	x	x
Cibolo Reservoir			x				
Lockhart Reservoir			x				x
Purchase/lease surface water irrigation rights	x	x					
Groundwater Pumping/Recharge/Recovery							
EA irrigation transfers	x	x	x	x	x	x	x
EA recharge Type 2	x		x	x	x	x	x
Guadalupe River diversion near Comfort							x
Springflow recirculation		x		x	x		x
Medina Lake irrigation reduction and recharge enhancement				x	x		x
Carrizo Aquifers pumping and/or recharge enhancement	x	x	x	x	x	x	x
Gulf Coast Aquifers pumping and/or recharge enhancement	x	x				x	
Simsboro Aquifers pumping and/or recharge enhancement			x	x		x	
Trinity Aquifers pumping and/or recharge enhancement		x	x				x

EDSIMR – Files

aa_Part1-Dataset.gms aa_Part2-ModelEquations.gms aa_Part3-solvestatement.gms aa_Part4-ClimateChange.gms	Model part: Part 1 merges all of the data - parameters and sets, Part 2 sets up the model, Part 3 is solve and Part 4 runs the scenarios (in this case for climate).
calc_climatedata.gms calc_setup_tuples.gms	Calculation of data
data_aa_allsets.gms data_ag_budget.gms data_ag_crop_AlterStrategy.gms data_ag_land.gms data_ag_mix.gms	Agriculture data (set elements, crops and livestock budget and mixes, crop water alternative strategies, and Available land
data_climate_precip_data.gms data_climate_sens.gms data_climate_temperature_data.gms	Climate data, including precipitation, temperature, and climate sensitivity data (e.g crop yield change under different climate scenarios)

EDSIMR – Files

- data_projection_industrial.gms
- data_projection_populationpercentage.g...

Projected population and Industrial water use increase rate

- data_water_aquifer_grounddata.gms
- data_water_aquifer_GroundReg.gms
- data_water_aquifer_part.gms

Aquifer information, historical data (this part will be updated soon)

- data_water_demand_mun_ind.gms
- data_water_demand_projected.gms

Current municipal and Industrial water price, quantity and monthly consumption share

- data_water_diverter.gms
- data_water_diverter_maptocounty.gms
- data_water_diverter_type.gms
- data_water_diverter_upperlimit.gms
- data_water_diverter_use.gms

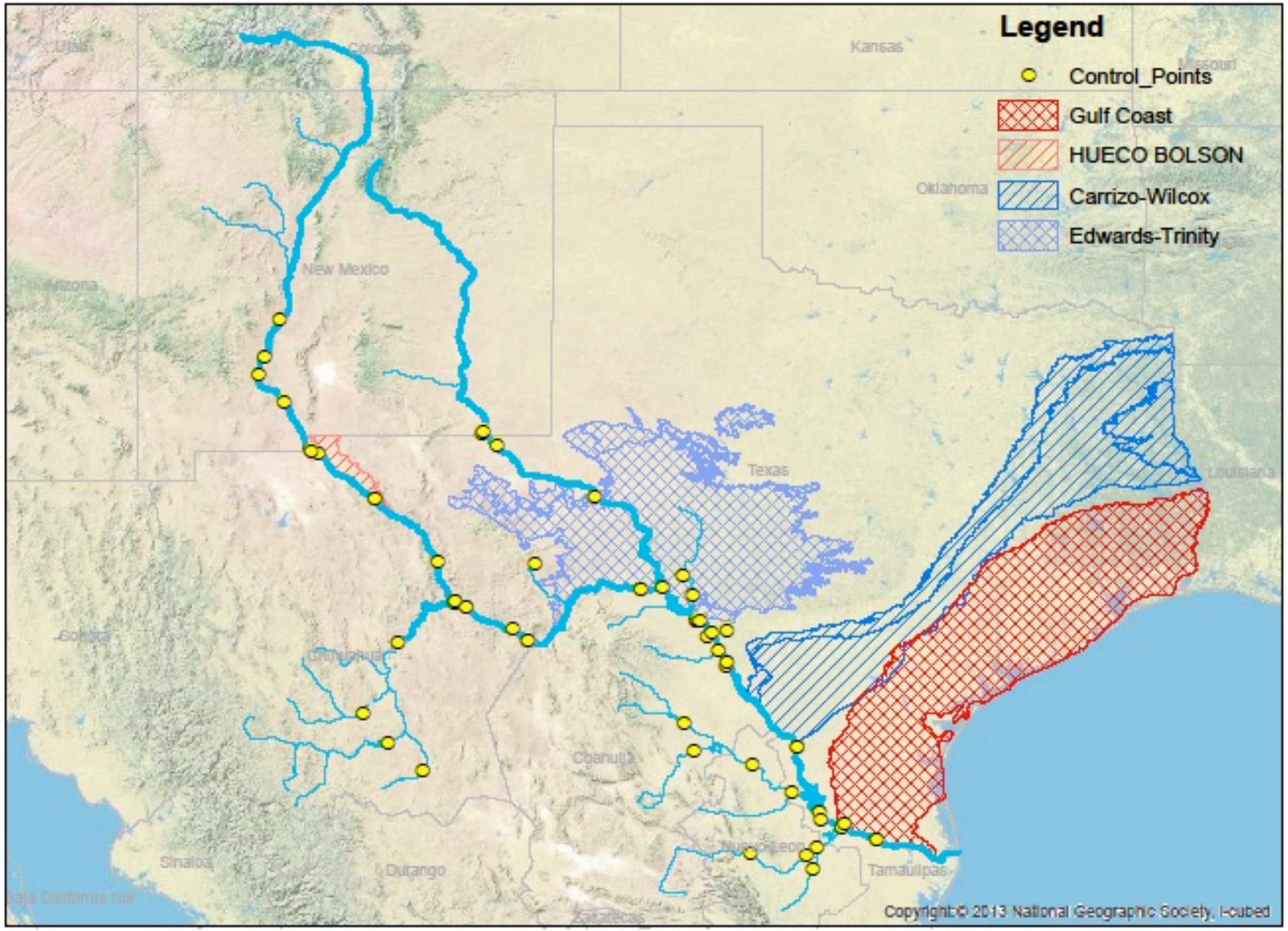
River Diverter information, including diverter name, location (county), sector and capacity

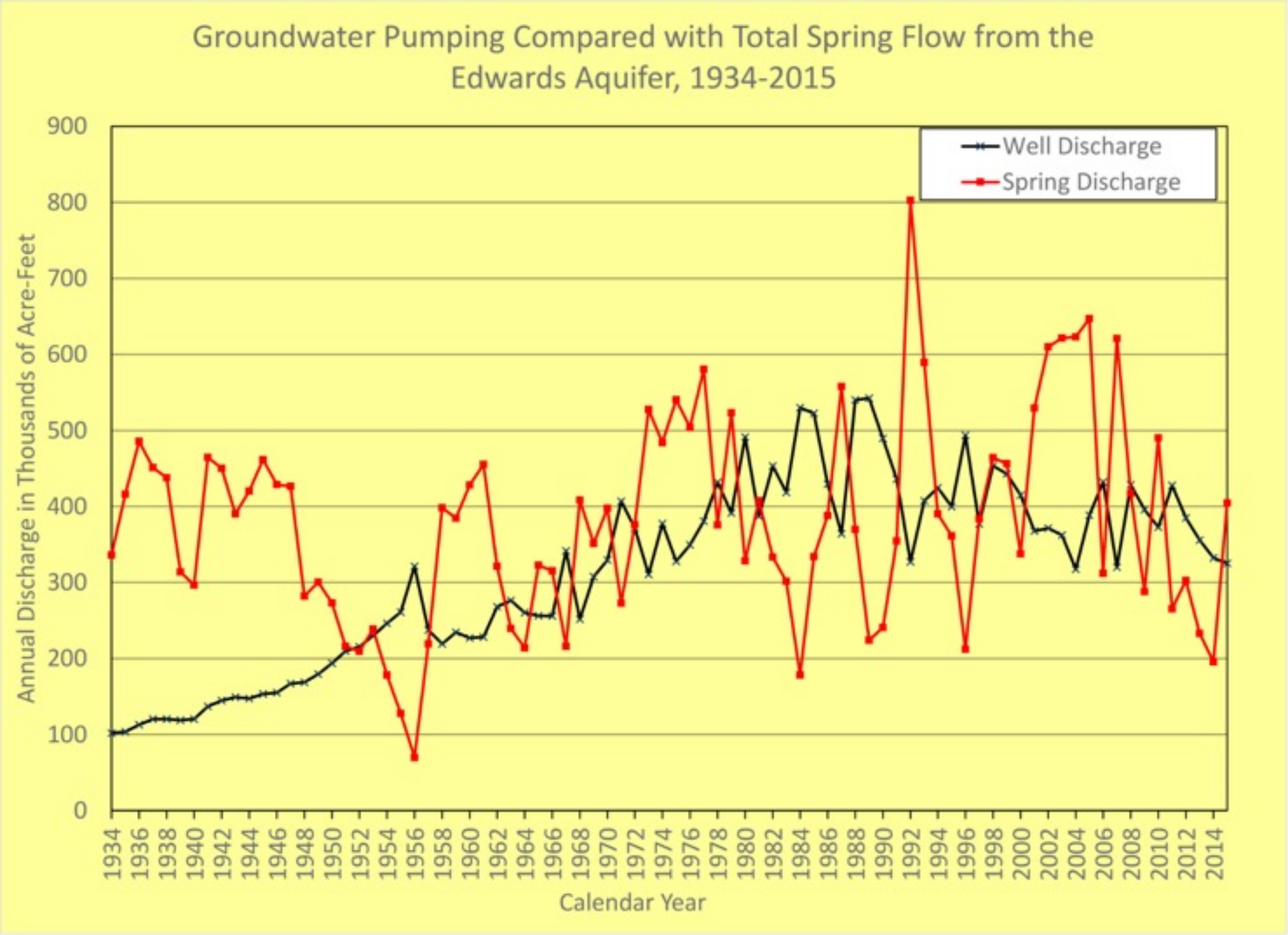
- data_water_project_investment.gms

Water project information, including fixed and operating cost, capacity, etc

- data_water_reservior_capacity.gms
- data_water_reservior_evaporation_loss.gms
- data_water_river_naturalized_inflow.gms
- data_water_river_reachmember.gms
- data_water_riverplace.gms
- data_water_spring_flows.gms

Surface water information:
1) reservoir capacity and evaporation loss
2) River naturalized inflow,
3)mapping between water diverter
And diversion location - riverplace
4) Mapping among riverplace and
5) spring flow observation


Legend
Control_Points
Gulf Coast
HUECO BOLSON
Carrizo-Wilcox
Edwards-Trinity
Colorado
Kansas
Oklahoma
New Mexico
Arizona
Texas
Louisiana
Sonora
Chihuahua
Coahuila
Nuevo Leon
Tamaulipas
Sinaloa
Durango
Zacatecas
Copyright:© 2013 National Geographic Society, i-cubed



Pumping has dropped since Endangered species finding - 1990

Acknowledgement

This material is based upon work partially supported by the National Science Foundation under Grant Addressing Decision Support for Water Stressed FEW Nexus Decisions Numbered 1739977