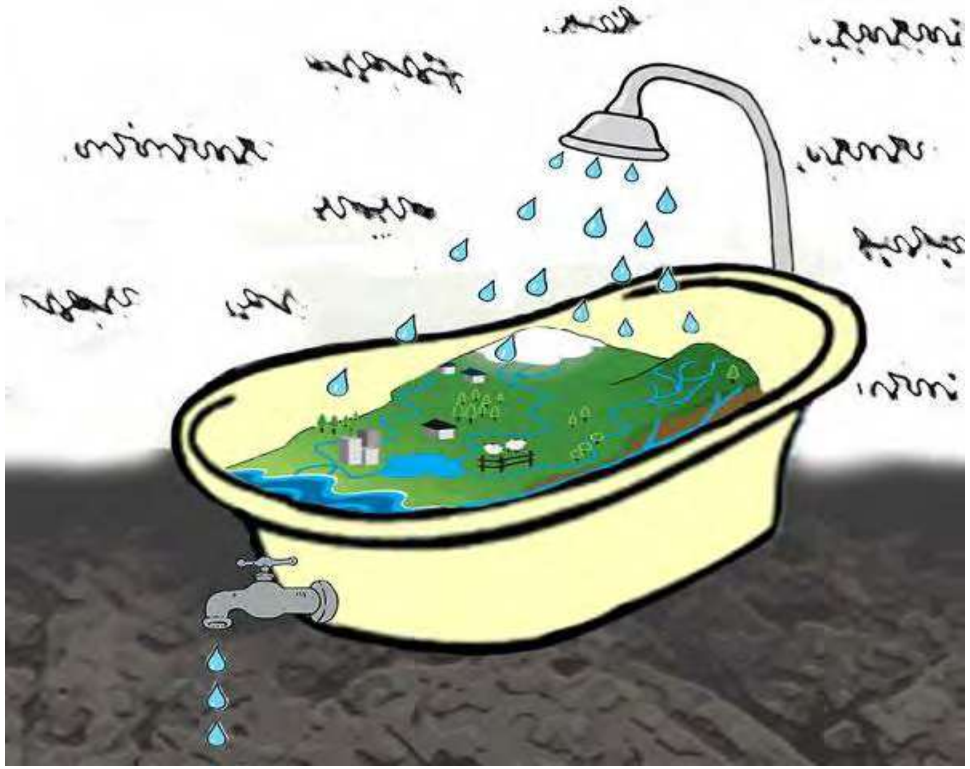
Coordination of built and natural infrastructure to enhance human-natural water system resilience

John Sabo

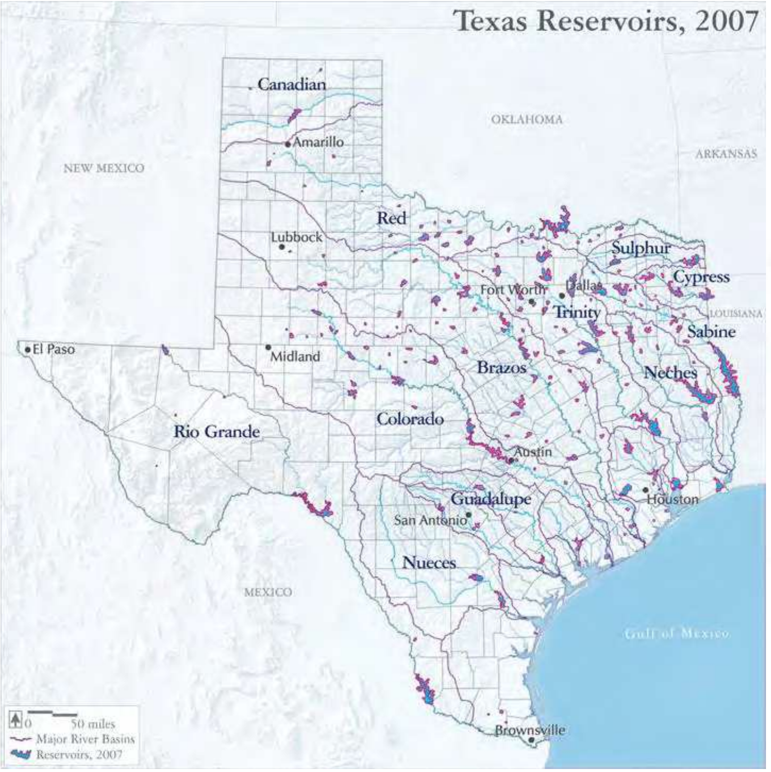
Future H2O

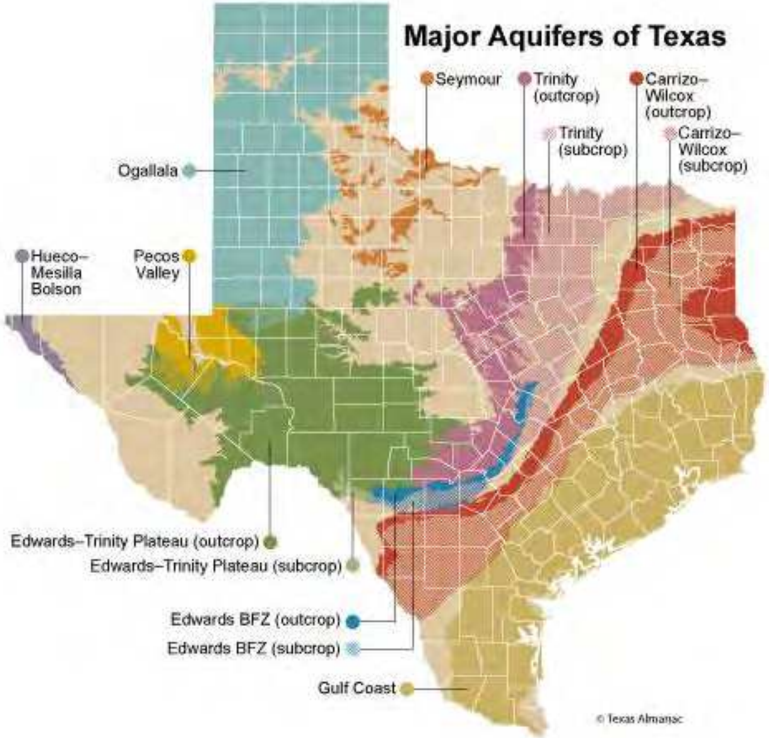
Arizona State University

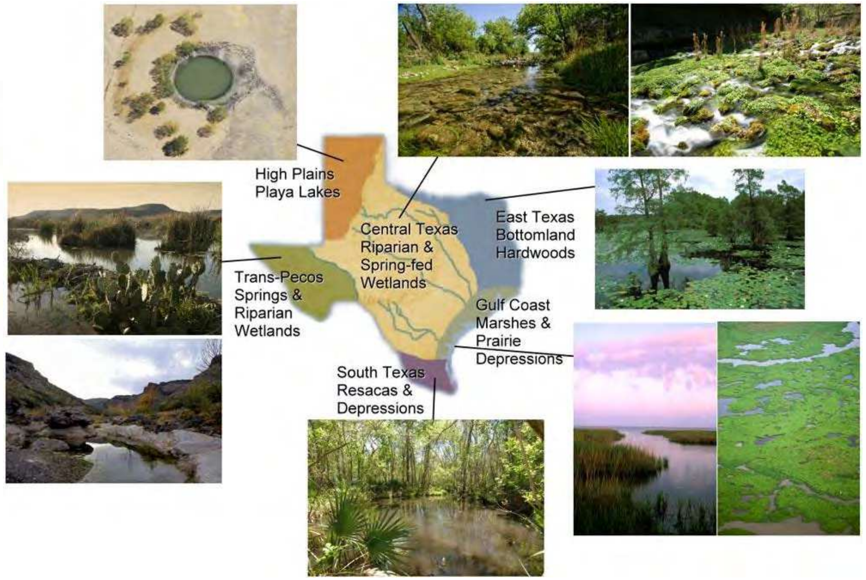
Rethinking natural infrastructure as a highly engineered counterpart to built infrastructure



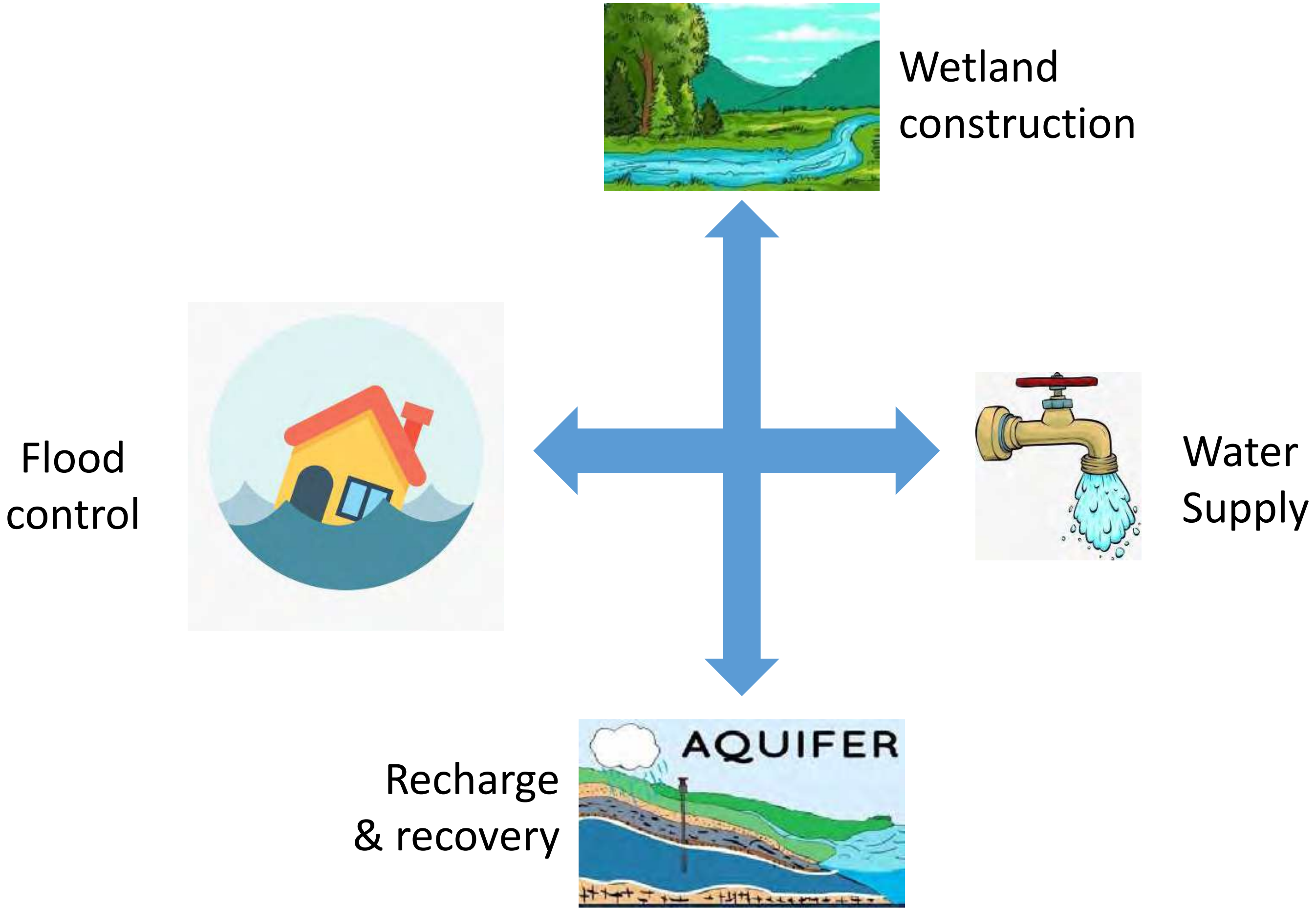
Coordination of built and natural infrastructure to future-proof Texas water supplies







Coordination of built and natural infrastructure to future-proof Texas water supplies



Our mission

"To develop science that quantifies how natural infrastructure can be designed and operated to improve the performance and longevity of built infrastructure in Texas coastal basins"

"To translate science about natural infrastructure into easy-to-use, data-driven decision support tools"

"It's almost as if Mother Nature hasn't figured out who's boss!"

Who we are

ASU Future H_2O futureh2o.asu.edu

theEARTH GENOME REVEALING THE POSSIBLE

TEXAS A&M UNIVERSITY KINGSVILLE

NSF

DOW®

EWN® Engineering With Nature

THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT TEXAS STATE UNIVERSITY

THE CYNTHIA & GEORGE MITCHELL FOUNDATION

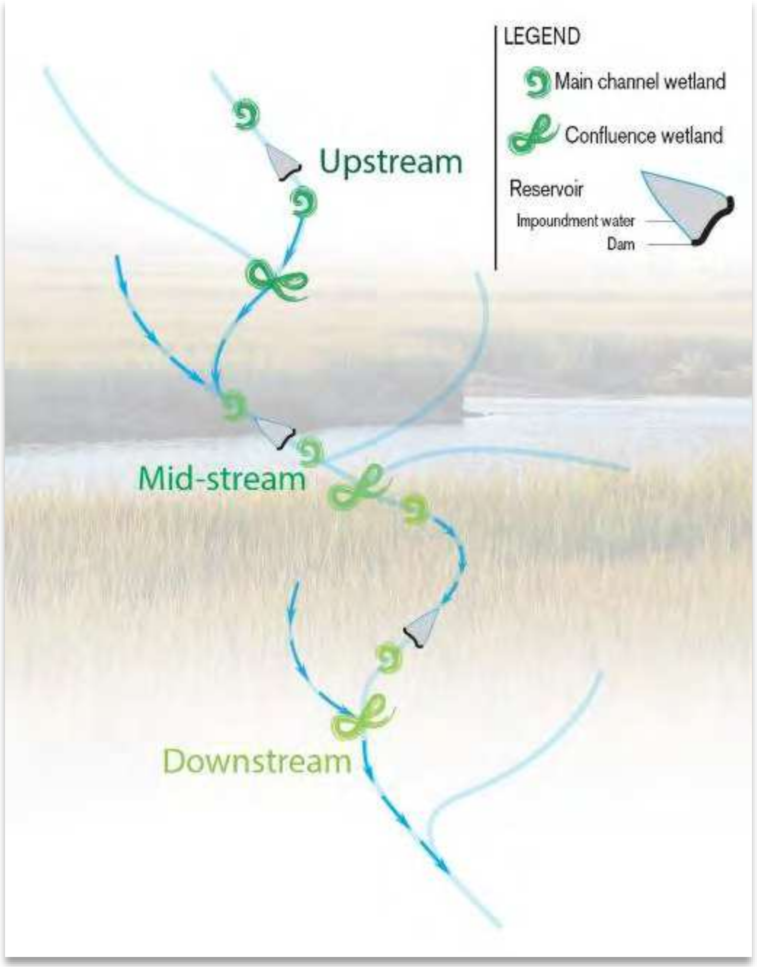
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

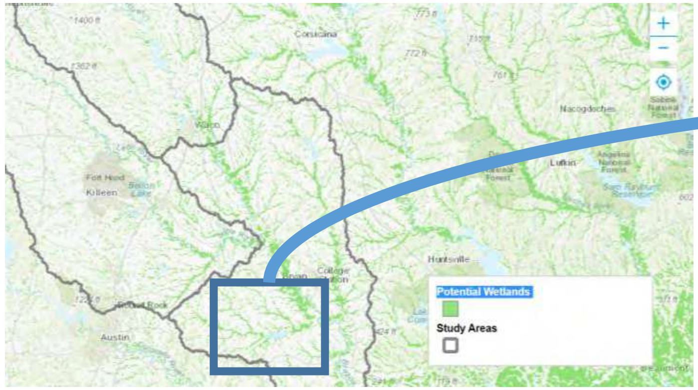
Brazos RIVER AUTHORITY

Texas Water Development Board

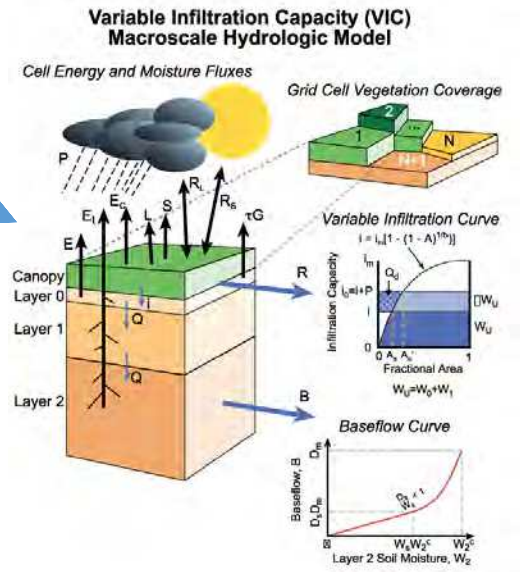
Coordination of built and natural infrastructure to future-proof Texas water supplies

- Surface water system questions
  - Where can wetlands be built?
  - Do they store enough water for the dry season?
  - Do they provide flood protection?
  - Can we coordinate reservoir operations with wetland flood protection?

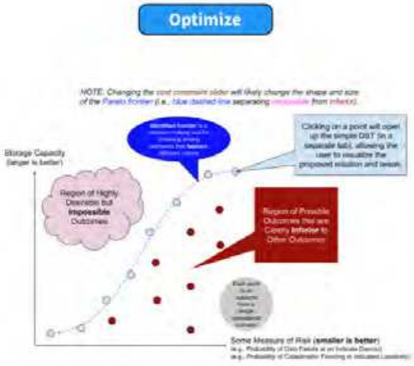




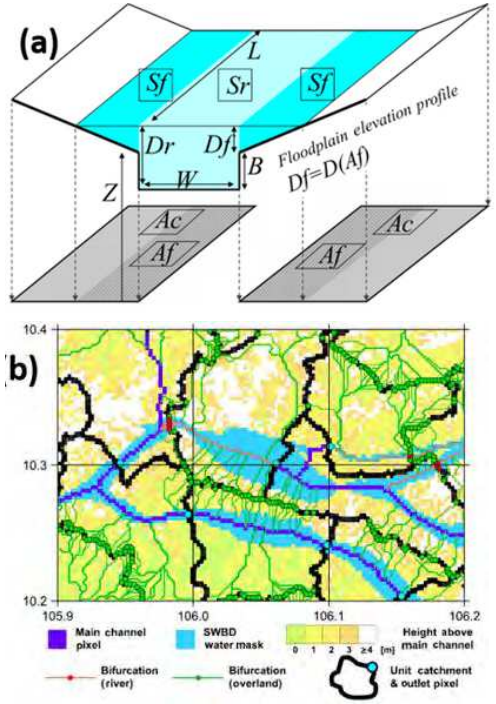
HAND allows us to visualize where wetlands can be built



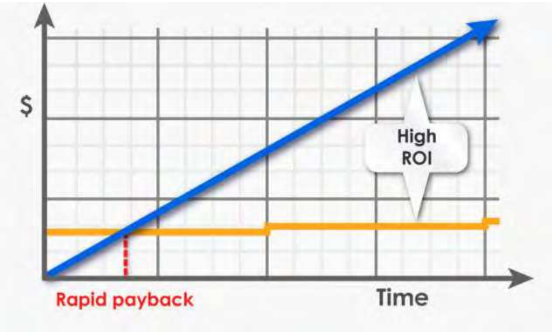
VIC allows us to estimate runoff generation with & without wetlands



Optimization driven by machine learning helps solve cost-safety-storage tradeoffs



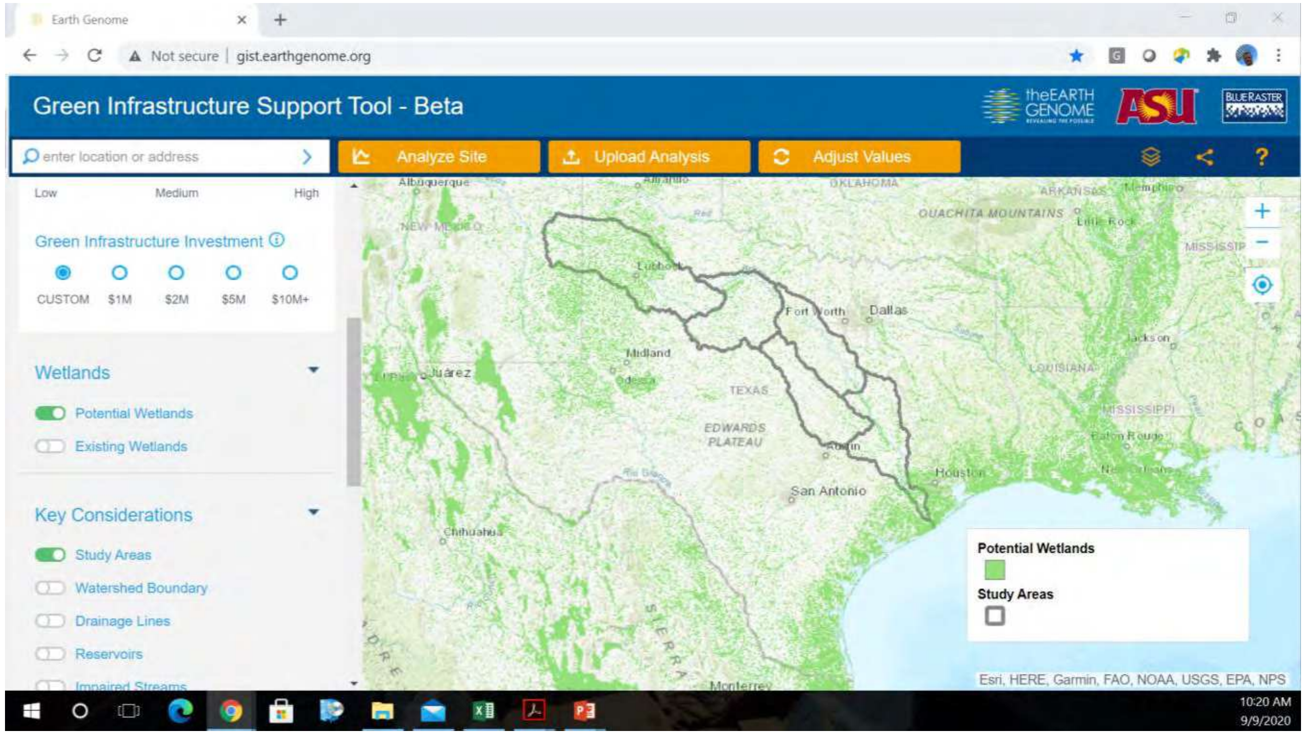
CaMa Flood allows us to route runoff and compare flood peaks with & without wetlands

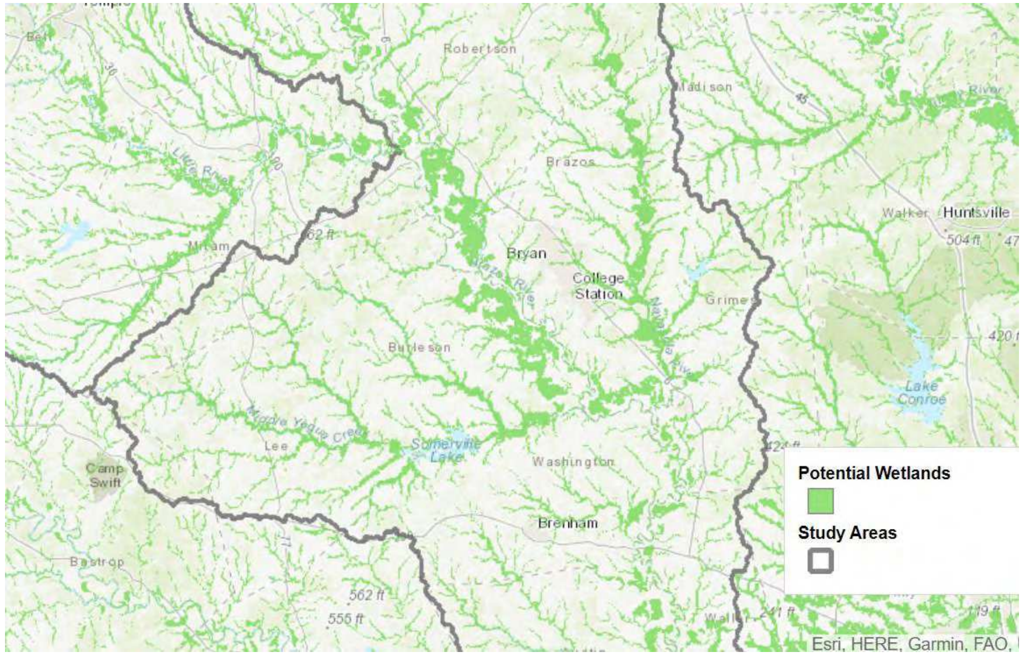


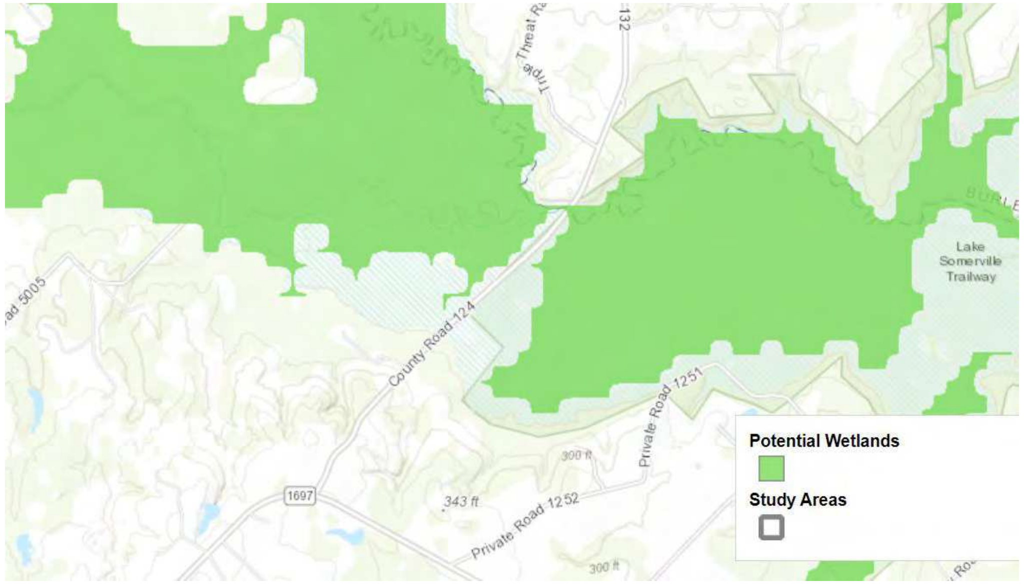
Financials allow us to compare price points and returns on projects

Where wetlands can be built:

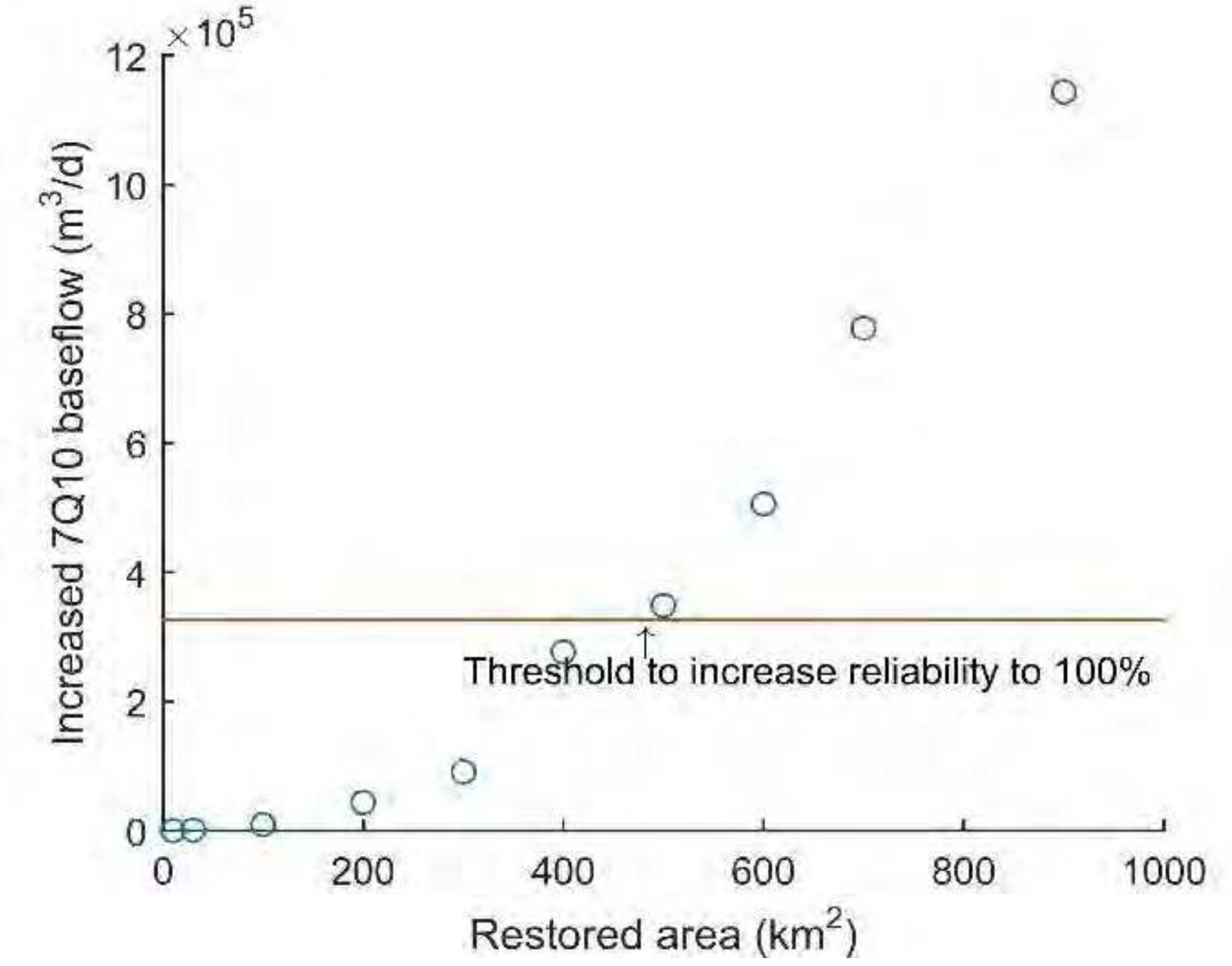
GIST—HAND map at 30m resolution for North America

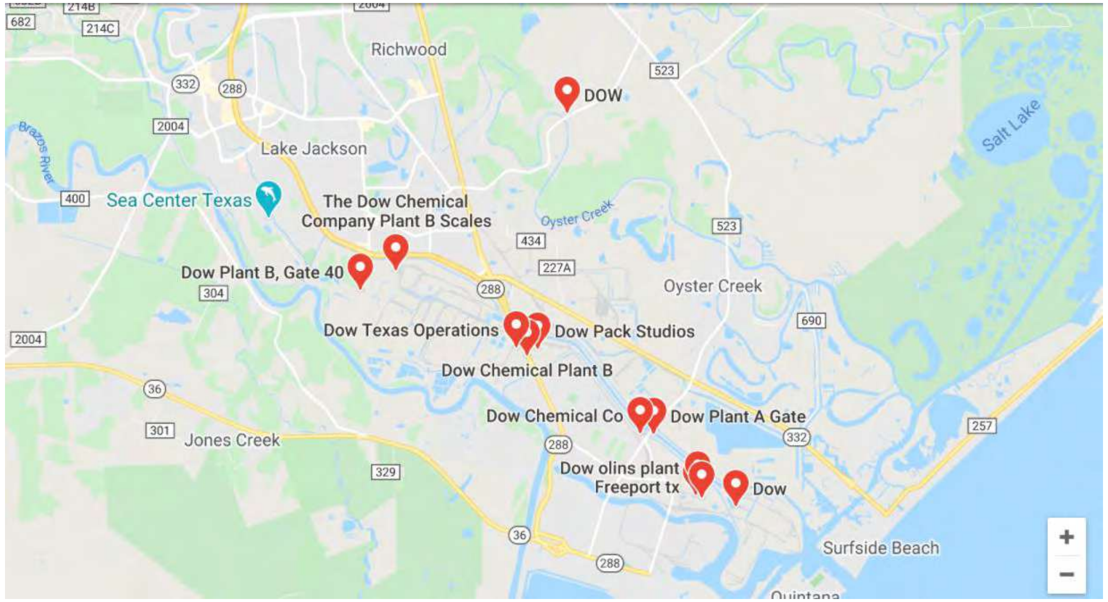




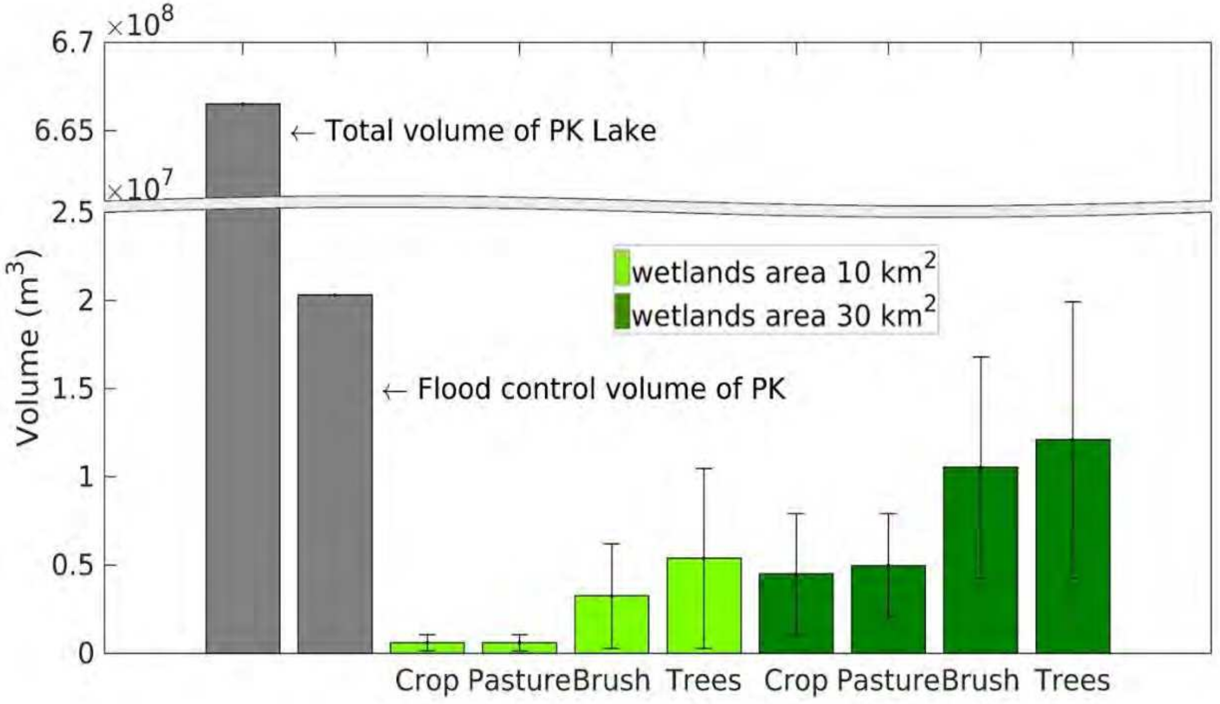


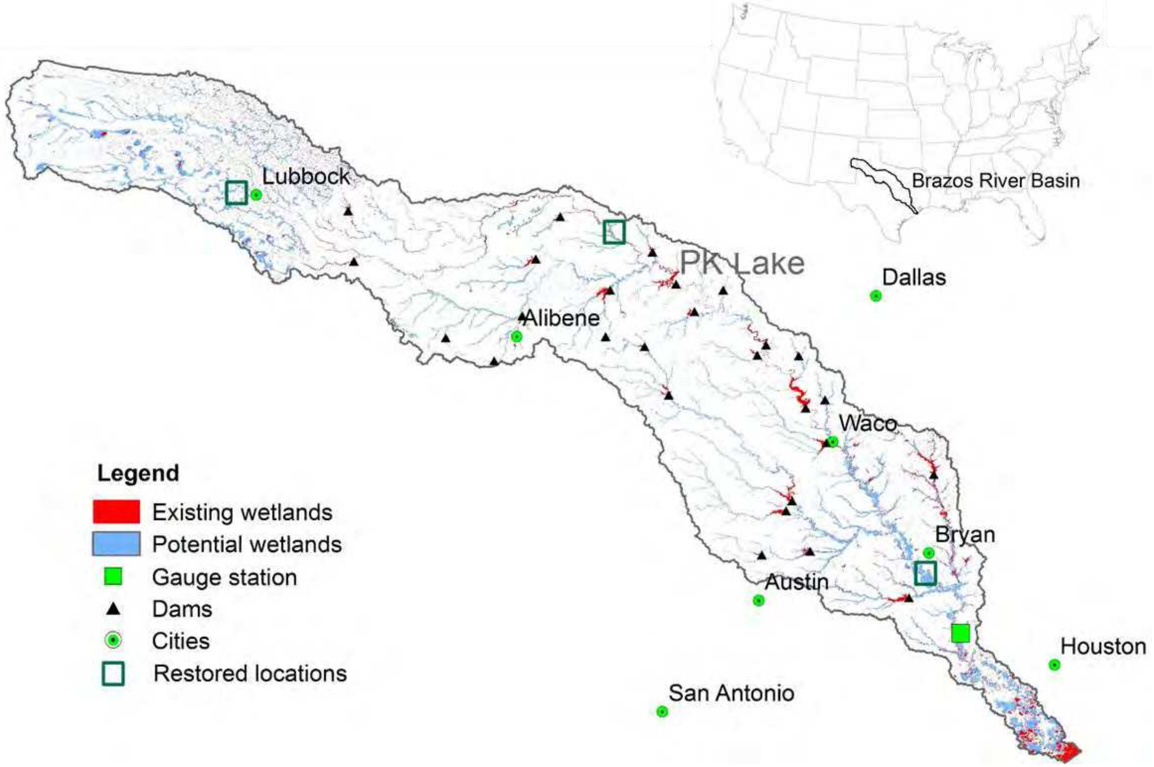
Do constructed wetlands store enough water?: VIC-CaMaFlood





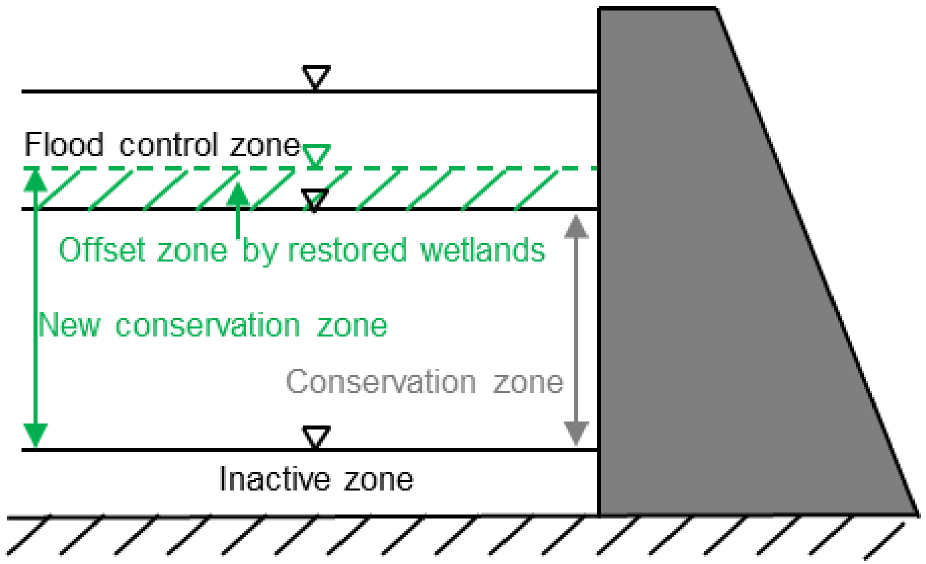
Do constructed wetlands reduce flood peak?: VIC-CaMaFlood

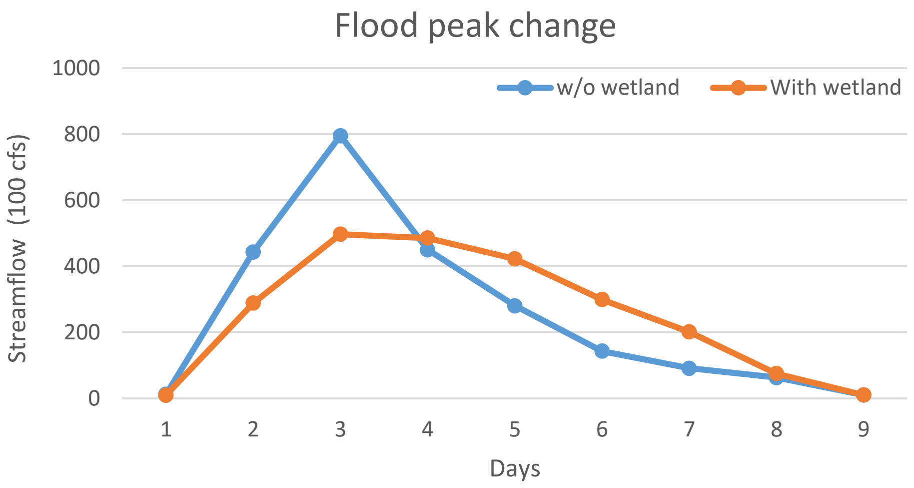




Peak flow reduction 219-10,593 AF

Investing in flood storage to secure conservation storage





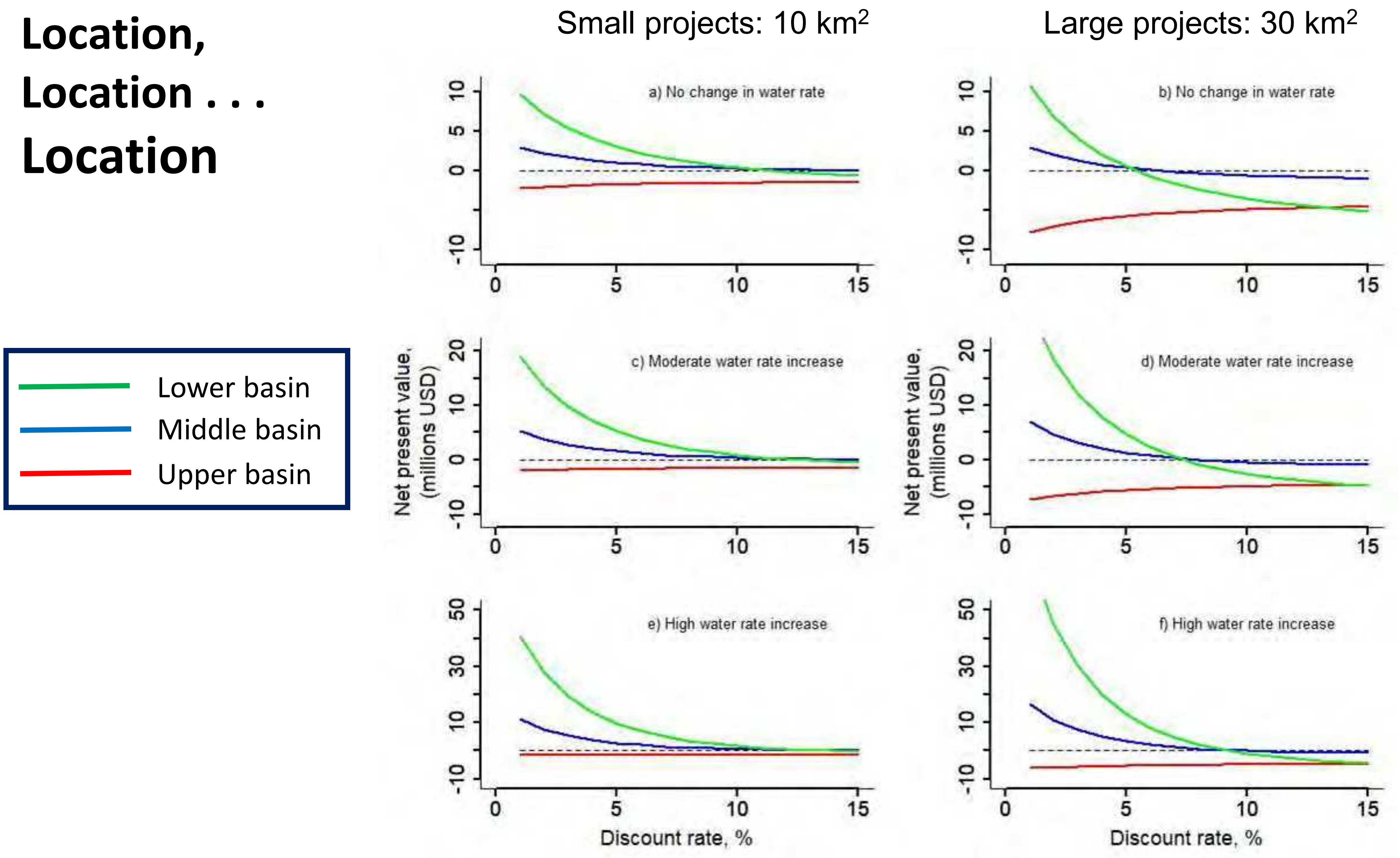
Premise: Flood pool offset from natural infrastructure can increase flood control flexibility and conservation storage

Does wetland construction pencil out?

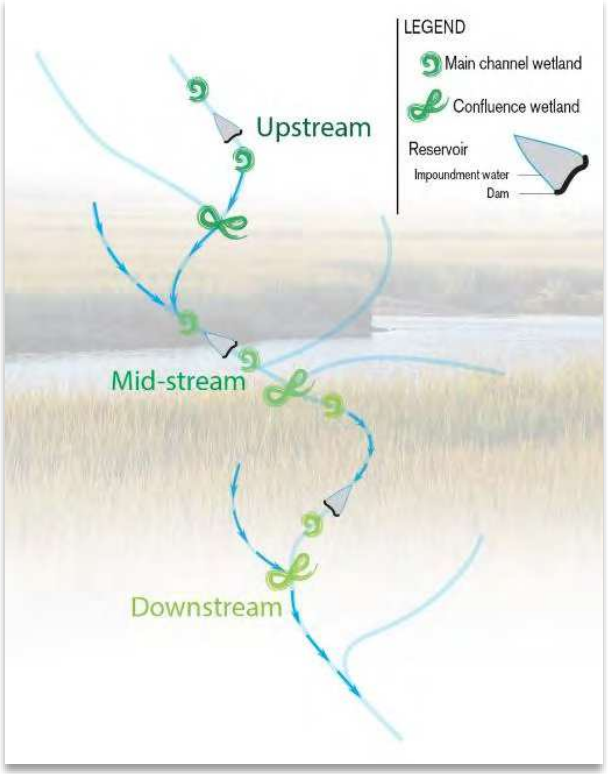
$$NPV = \sum_{i=1}^{n} \frac{Cash\ Flow_i}{(1+r)^i} - Initial\ Investment$$

- Cash flow = Water revenue - Wetland maintenance costs
- Initial investment is cost to purchase land
- Land prices (Cap-Ex) and maintenance (Op-Ex) data from USDA
- And r is the discount rate

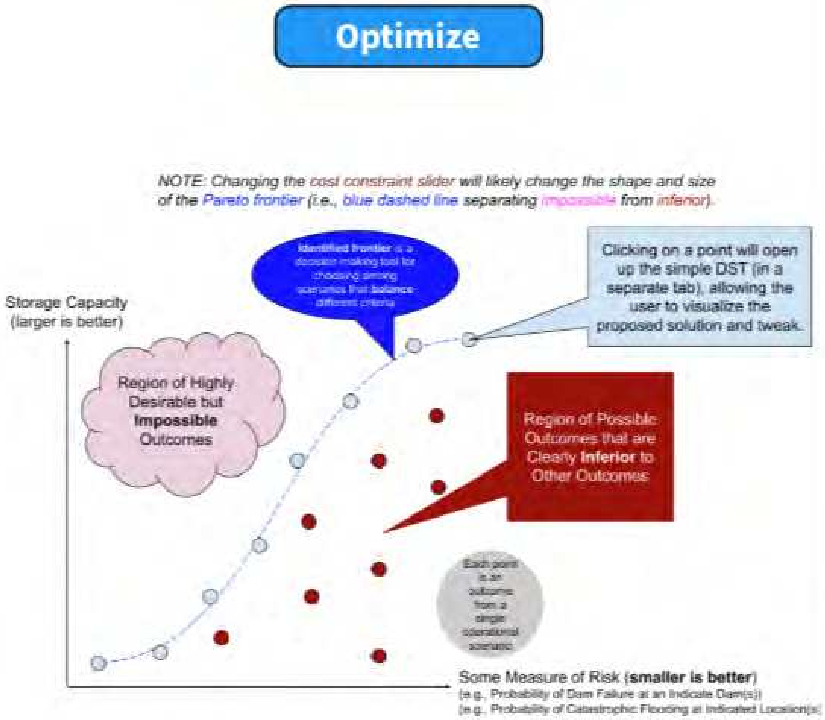
Location, Location . . . Location



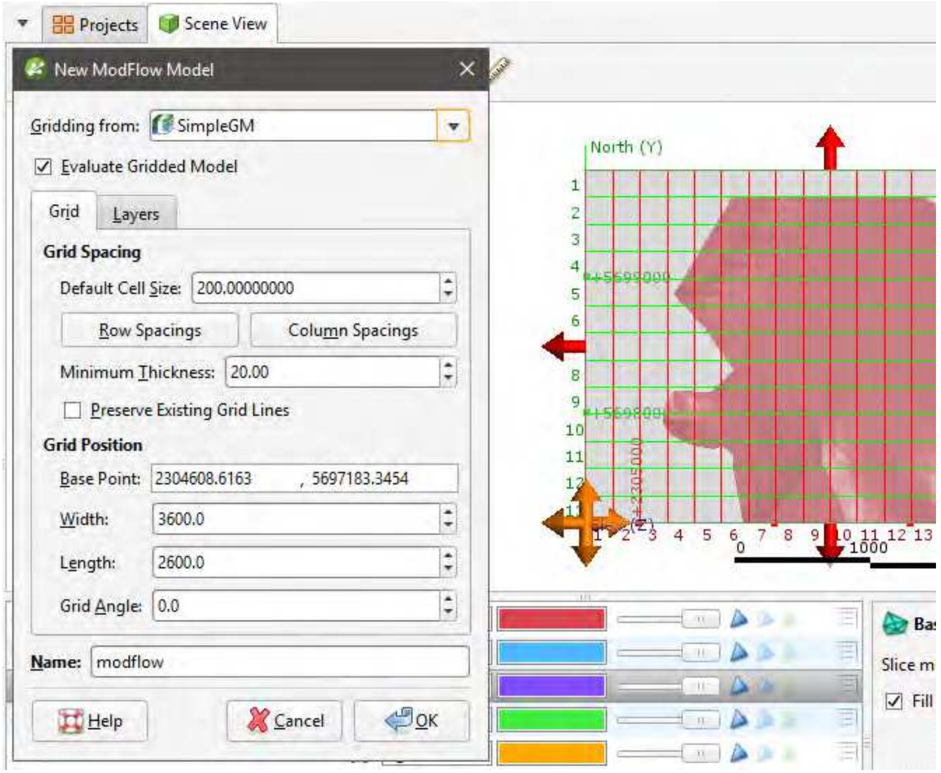
What’s next (science)



Basin-wide analysis:
Where, how many,
how big



Optimize supply cost efficacy with constraint of safety

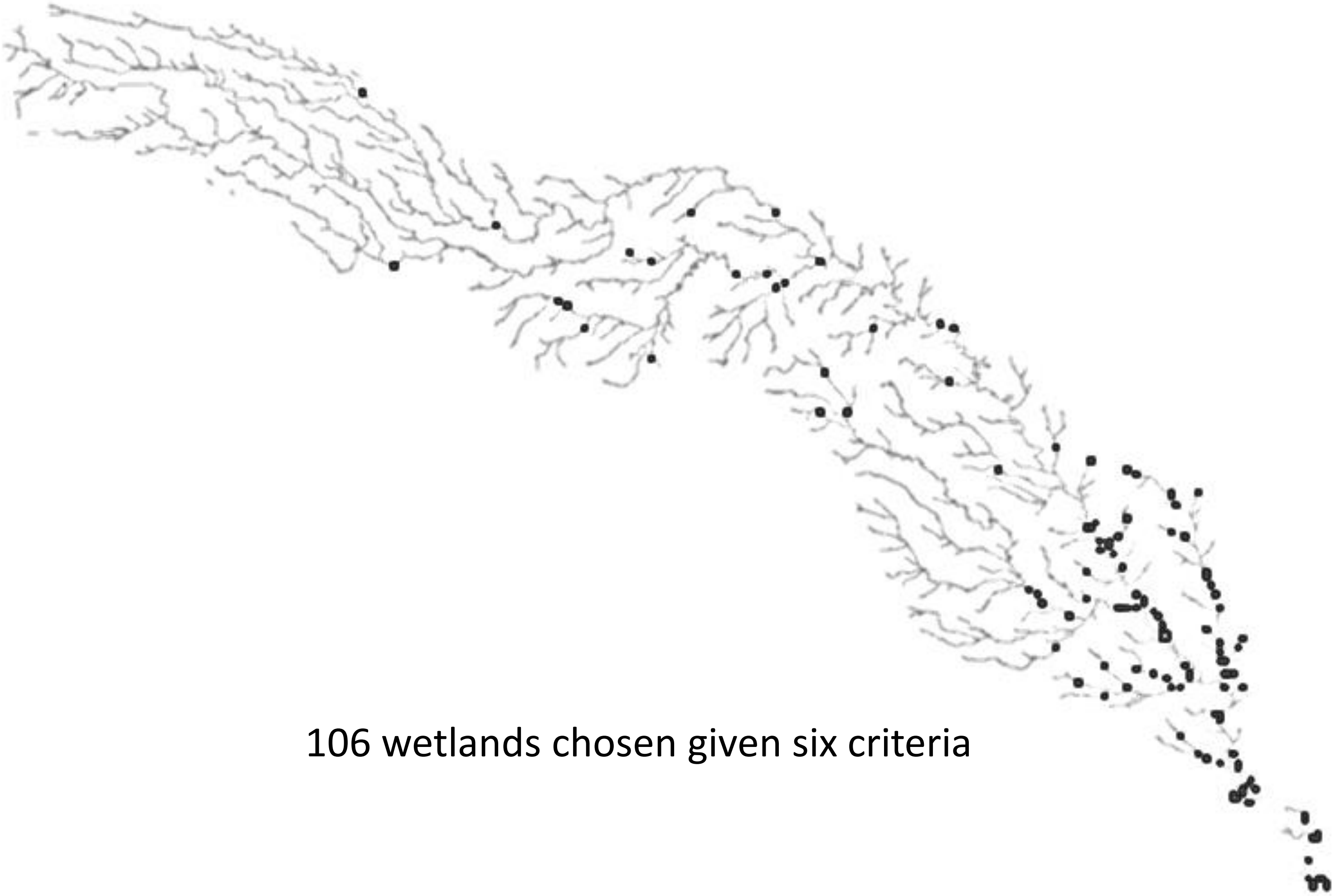


Groundwater:
Local storage
benefits through ASR

Wetland selection criteria

S. No.	Criteria		GIS Layers
1	Wetland Size	Area = 10, 30, and 50 sq. km	1/16 and 1/8 grids area
2	Land Use	Crops, Pasture/Hay, Shrubs, Grasslands, Barren, Forest	NLCD 2011, NASS Crop Layer
3	Topography (HAND Map)	HAND map from GIST (used 90 m DEM to create it)	DEM 90 m x 90 m
4	Water Table Depth (D)	D < 1 == 3; 1 < D < 5 == 2; 5 < D < 10 == 1, D > 10 m == 0	GW Wells data
5	PET map	<20 perc == 2; 20 per < PET < 80 per == 1; >80 per == 0	percentiles: 20/80
6	Soil Properties	Potential wetland soil landscape	RasClip1kmBR

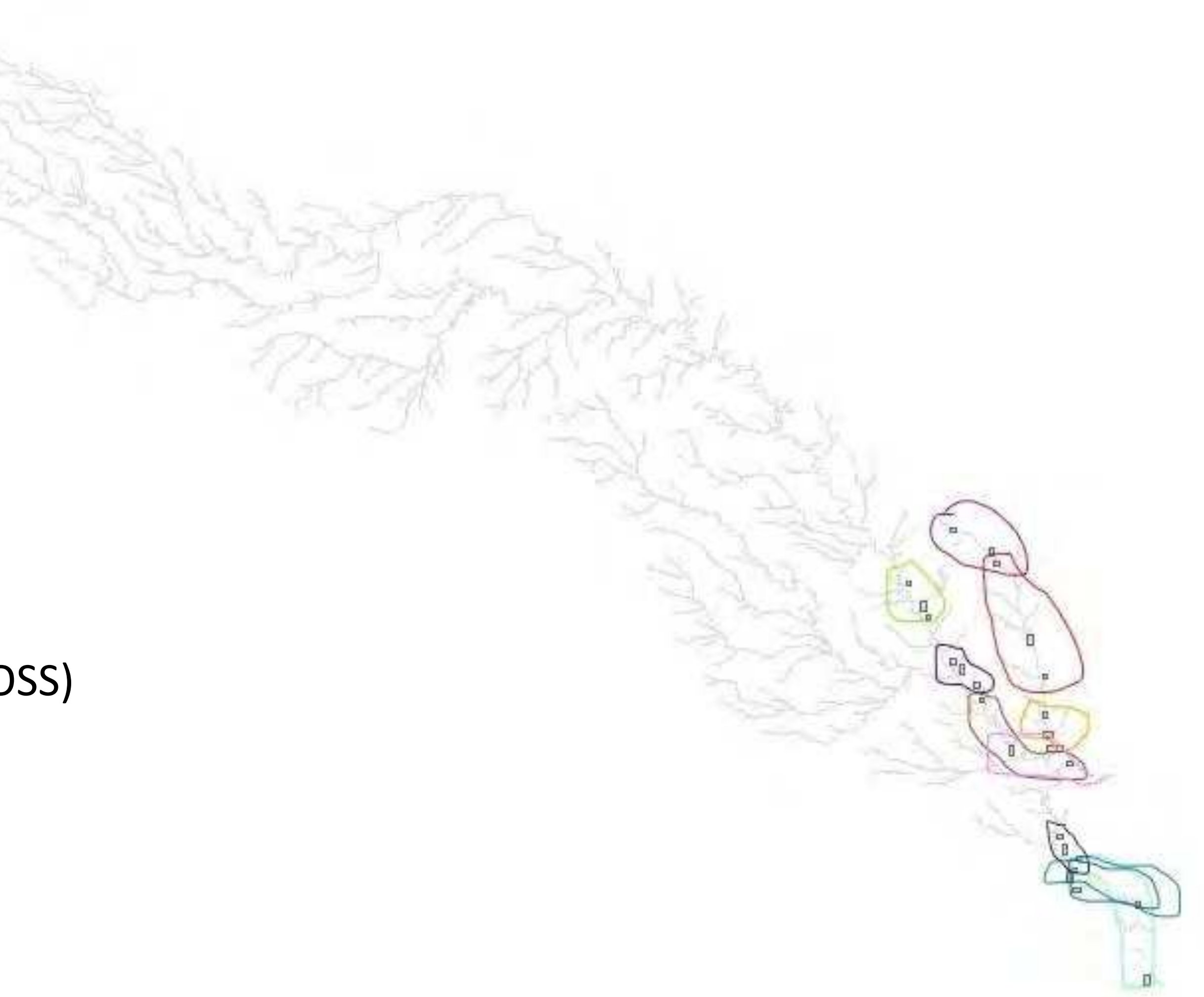
Basin scale assessment underway



106 wetlands chosen given six criteria

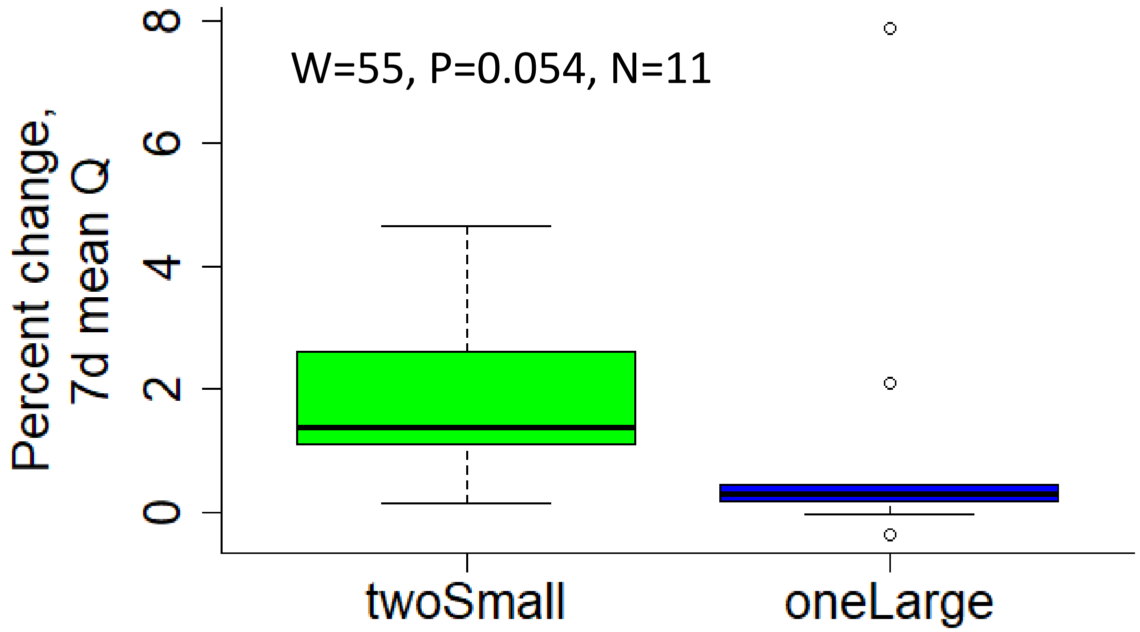
Thought experiment

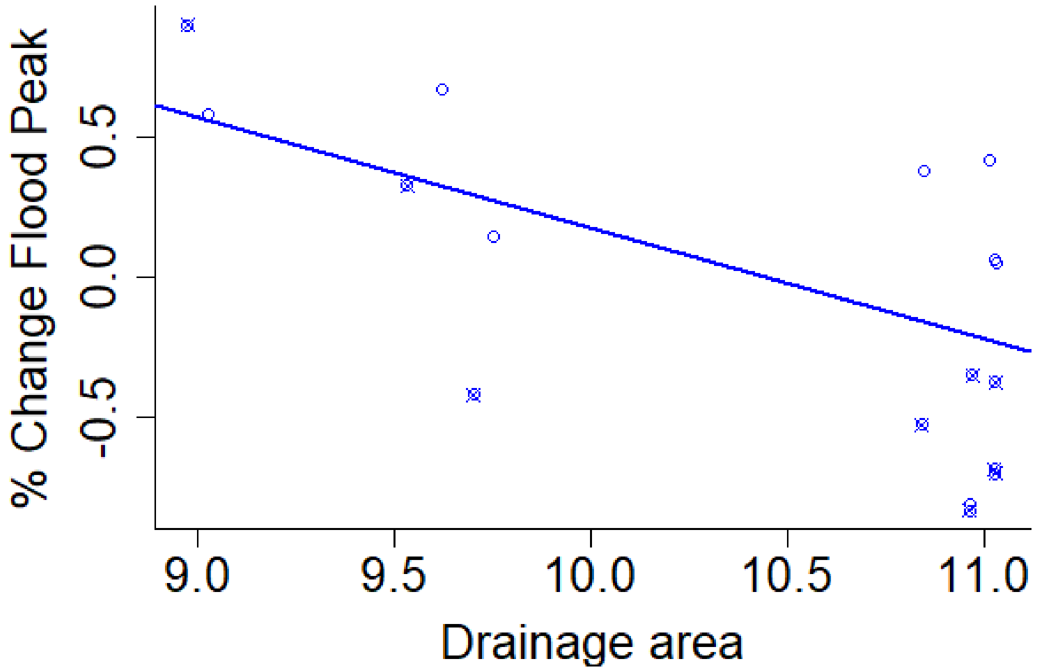
Single large or several small (SLOSS)



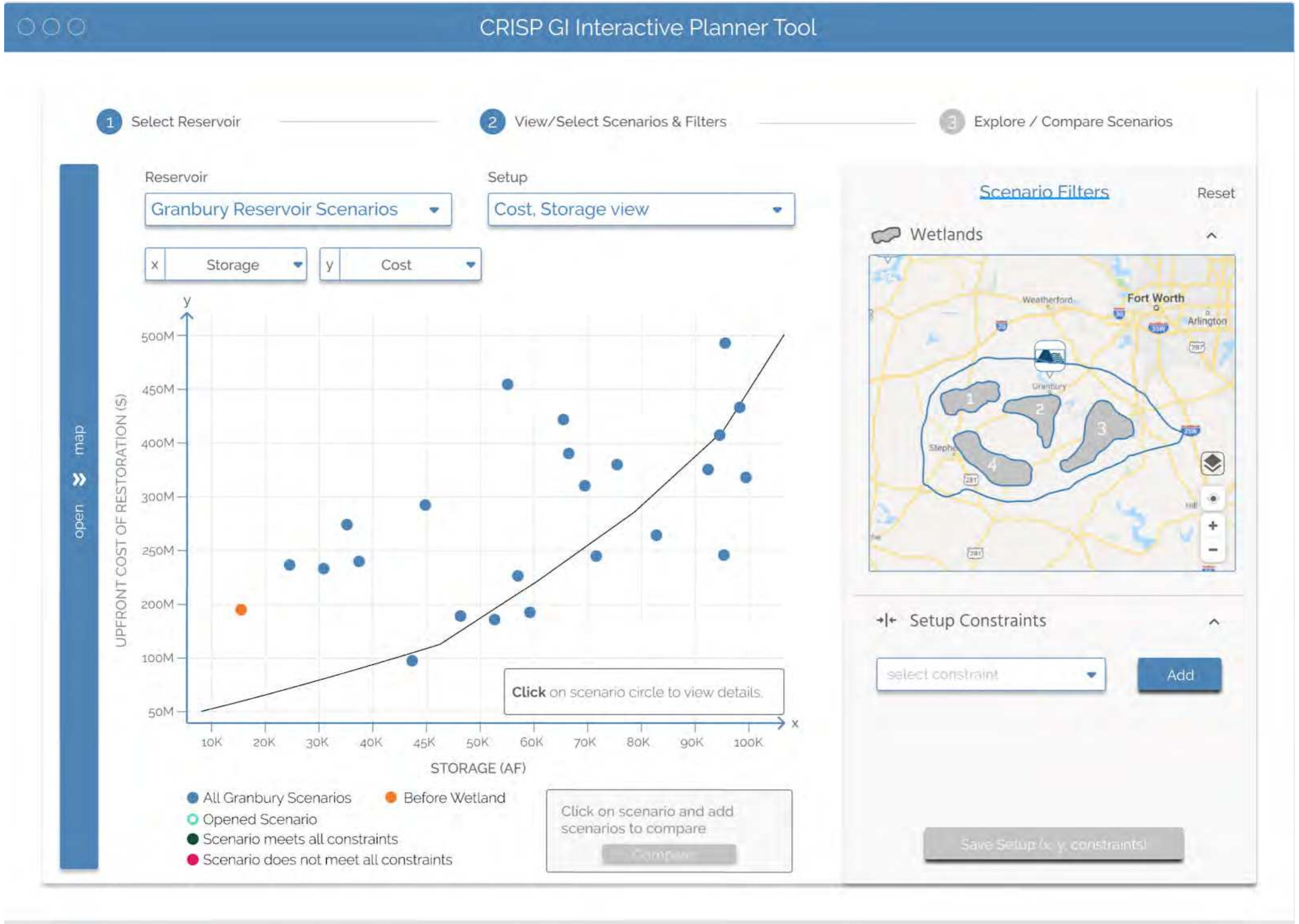
Thought experiment 1

Factor	df	SS	MS	F	P	Sig
log10(WA)	1	1.67256	1.67256	14.4554	0.001566	**
Area	1	1.39369	1.39369	12.0452	0.003153	**
log10(WA):Area	1	0.30051	0.30051	2.5972	0.126599	
Residuals	16	1.85128	0.1157			



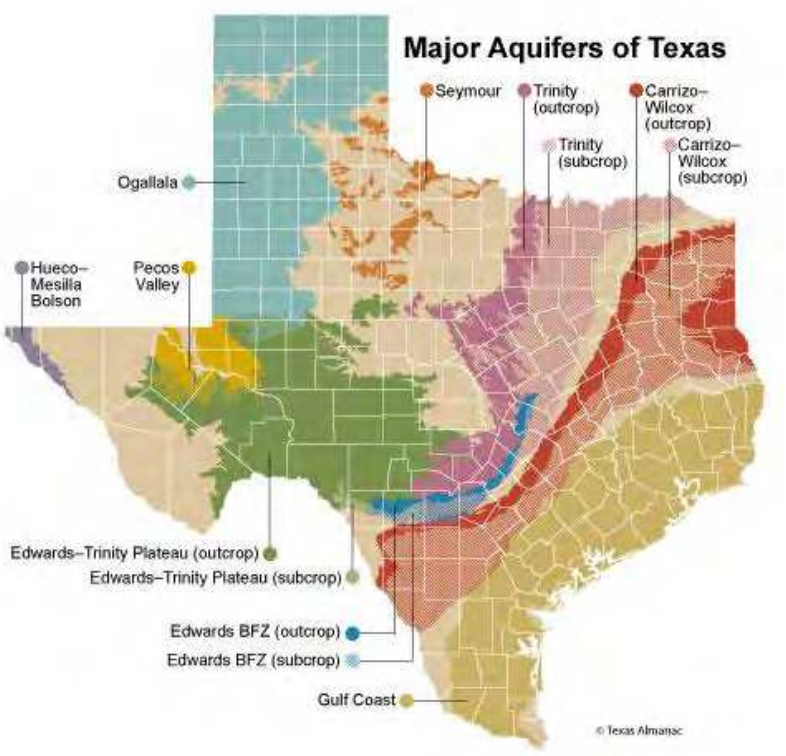


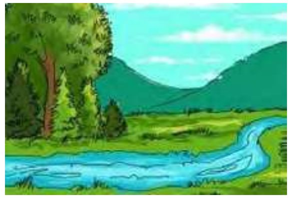
What's next: Decision support tool development



Goal: To visualize tradeoffs between flood protection and storage in terms of costs when operating natural and built infrastructure

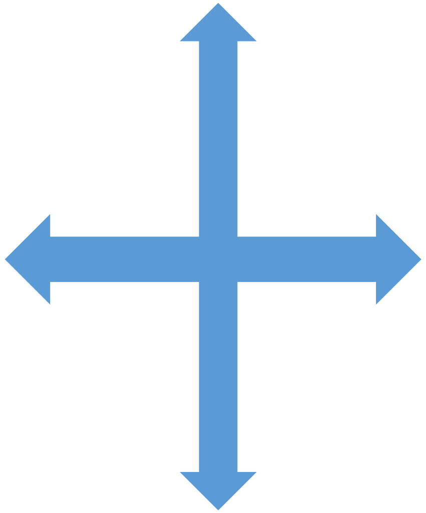
Groundwater in Texas can be wheeled





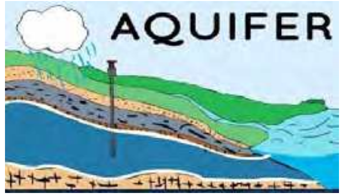
Wetland construction

Flood control



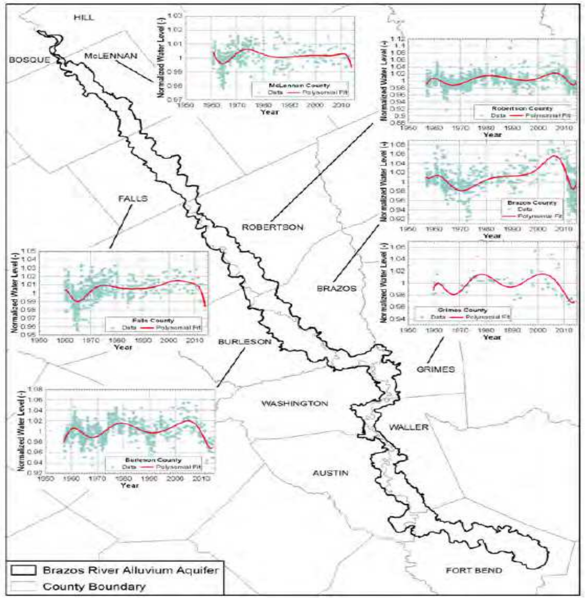
Water Supply

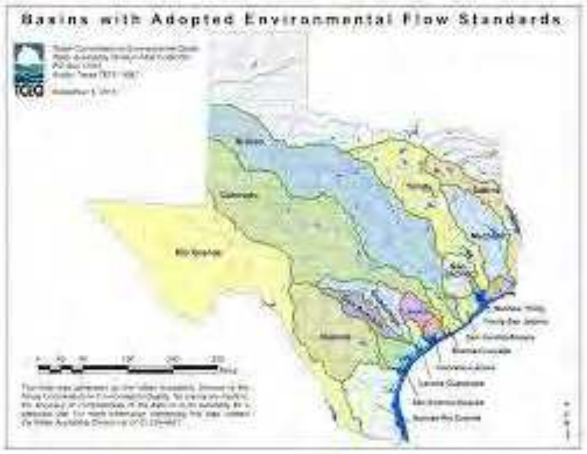
Recharge & recovery

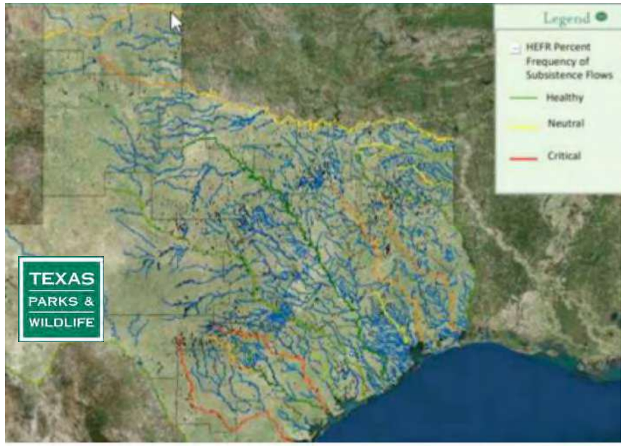


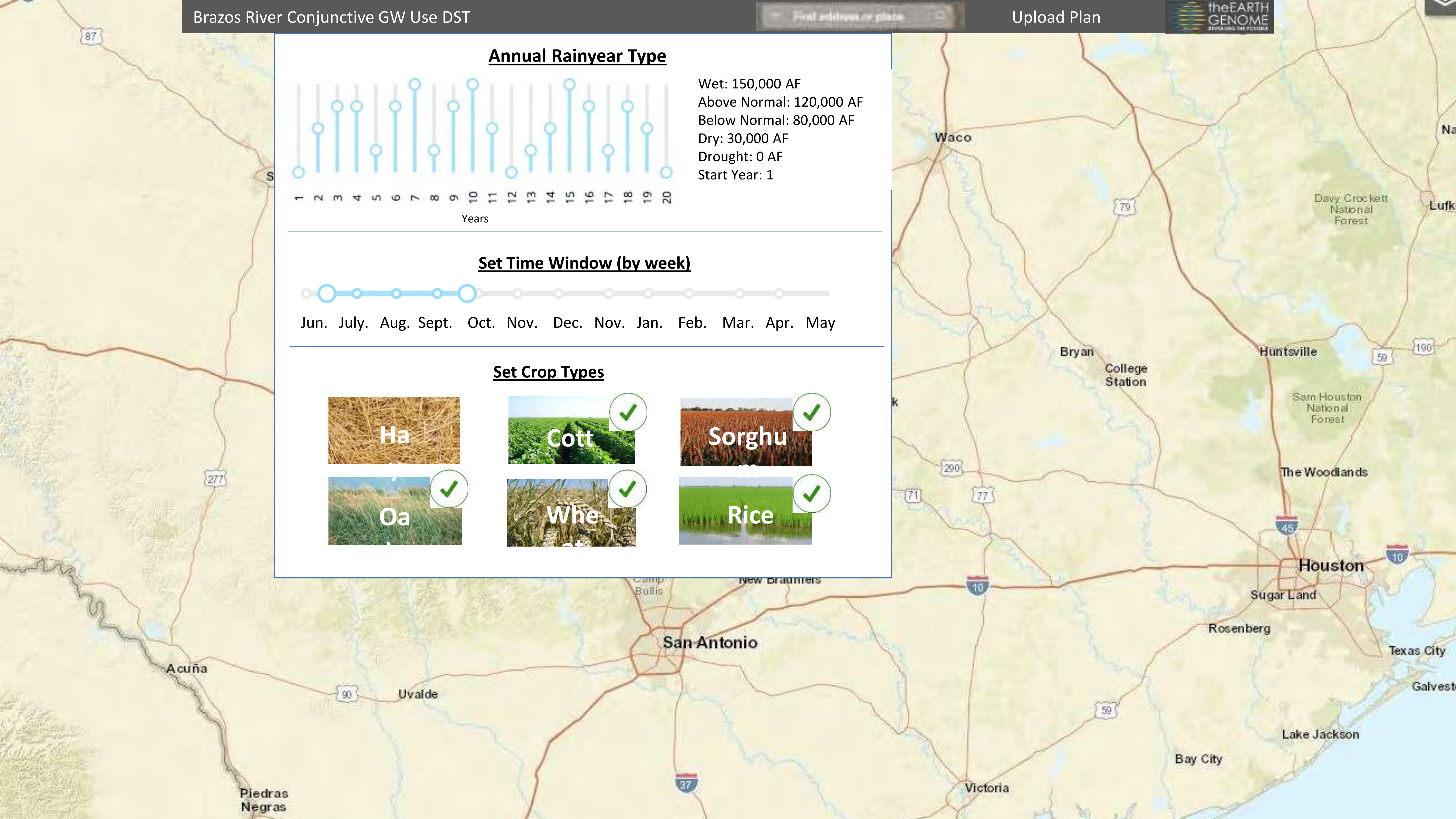
Groundwater leasing has the potential to create a Win-Win for farmers, downstream manufacuturing and other water users while improving instream flows

- Find new opportunities to create **win-win-win options** for all players, in spirit of better overall watershed management
- Develop reliable supply for downstream users
- Advance science and understanding
- Overcome barrier to growth
- Maintain baseflow in dry conditions
- Enable innovative voluntary market approach



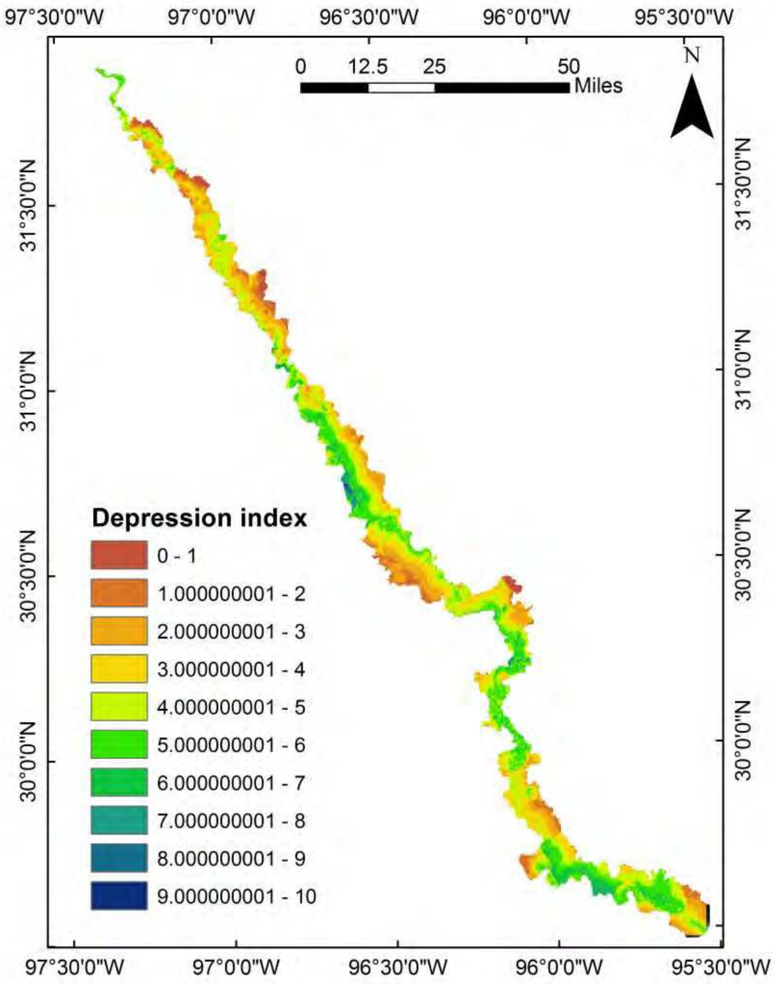




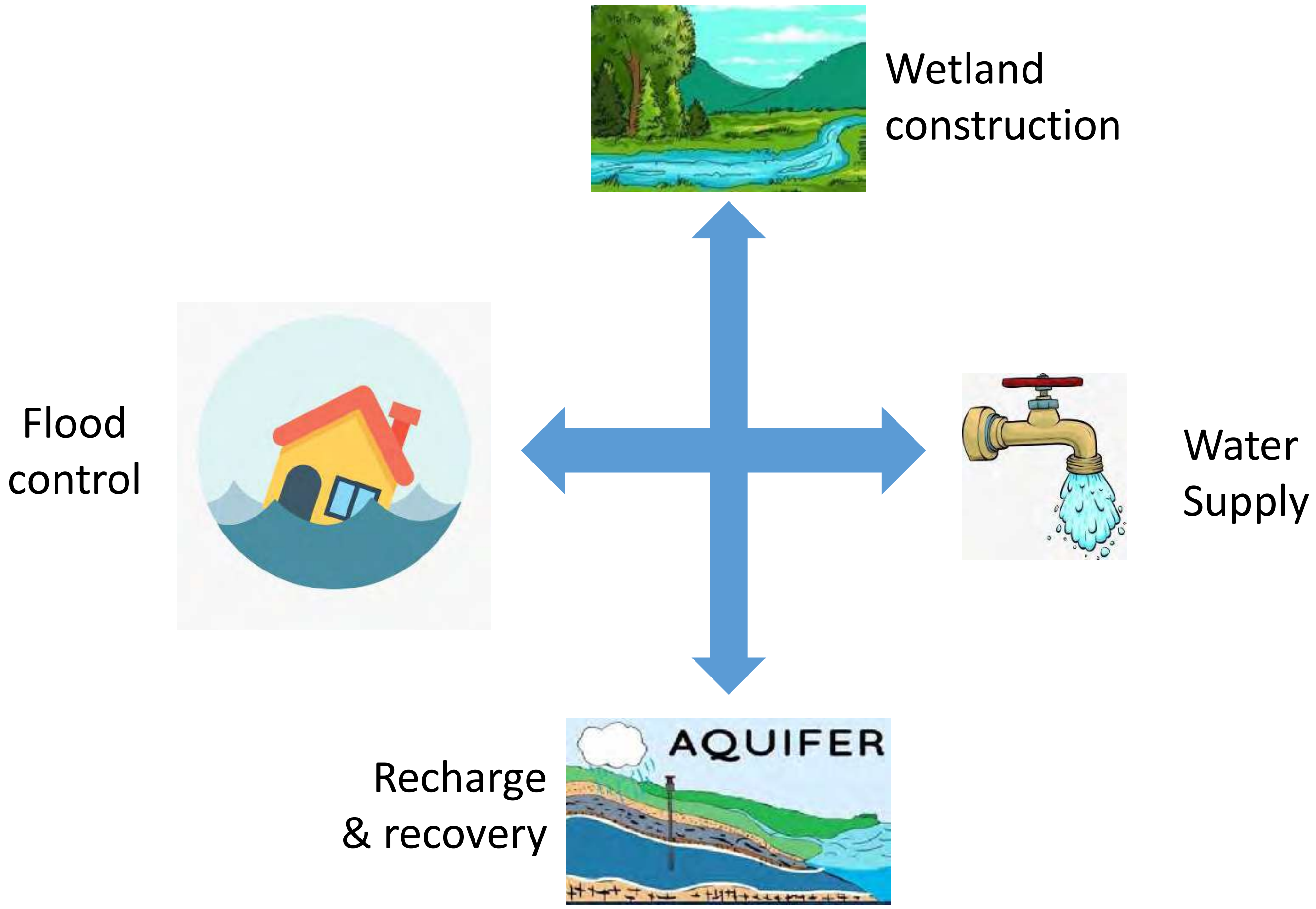

Brazos River Conjunctive GW Use DST
Upload Plan
theEARTH GENOME
Annual Rainyear Type
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Years
Wet: 150,000 AF
Above Normal: 120,000 AF
Below Normal: 80,000 AF
Dry: 30,000 AF
Drought: 0 AF
Start Year: 1
Set Time Window (by week)
Jun. July. Aug. Sept. Oct. Nov. Dec. Nov. Jan. Feb. Mar. Apr. May
Set Crop Types
Ha
Cott
Sorghu
Oa
Whe
Rice
Waco
Bryan
College Station
Huntsville
Davy Crockett National Forest
Sam Houston National Forest
The Woodlands
Houston
Sugar Land
Rosenberg
Texas City
Lake Jackson
Bay City
Victoria
San Antonio
Camp Bullis
New Braunfels
Uvalde
Acuña
Piedras Negras

Question: Can upstream aquifer storage provide downstream surface water resilience without robbing Peter to pay Paul?

And can it enhance progress towards SB3 E-flow targets?



Frontier: Connecting natural infrastructure above and below ground to game extremes



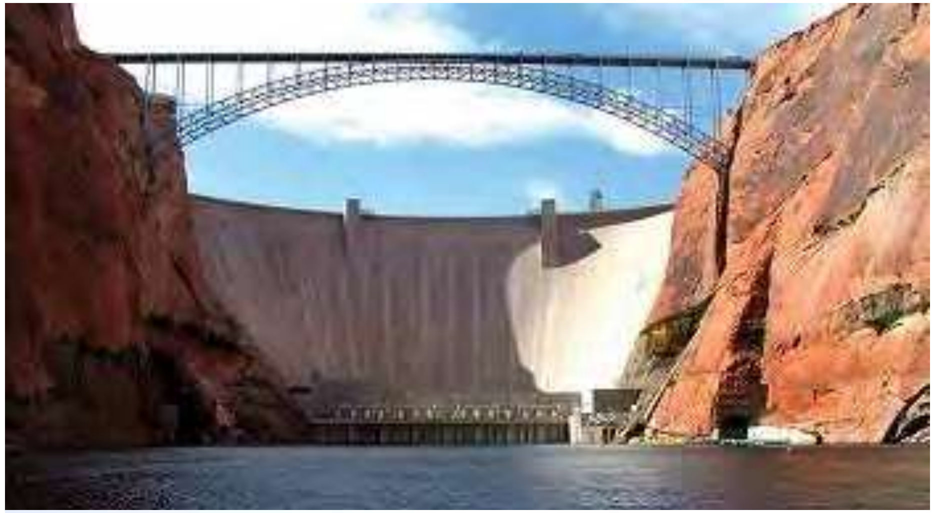
Co-operation of built and natural infrastructure in Texas

- Army Corps manages floods and surface water
- Groundwater and surface water storage managed by State agencies
- Wetlands have been converted to agriculture
- Intervention: Wetland construction at reasonable scale to bolster flood protection in wet years and create credits for conservation storage in dry years
- Private sector investment is key
- Rules of thumb: Several small wetlands lower in the basin, but upstream of reservoirs
- Next step: Explore aquifer recharge in constructed wetlands to extend benefits of flood control and storage in combined intervention

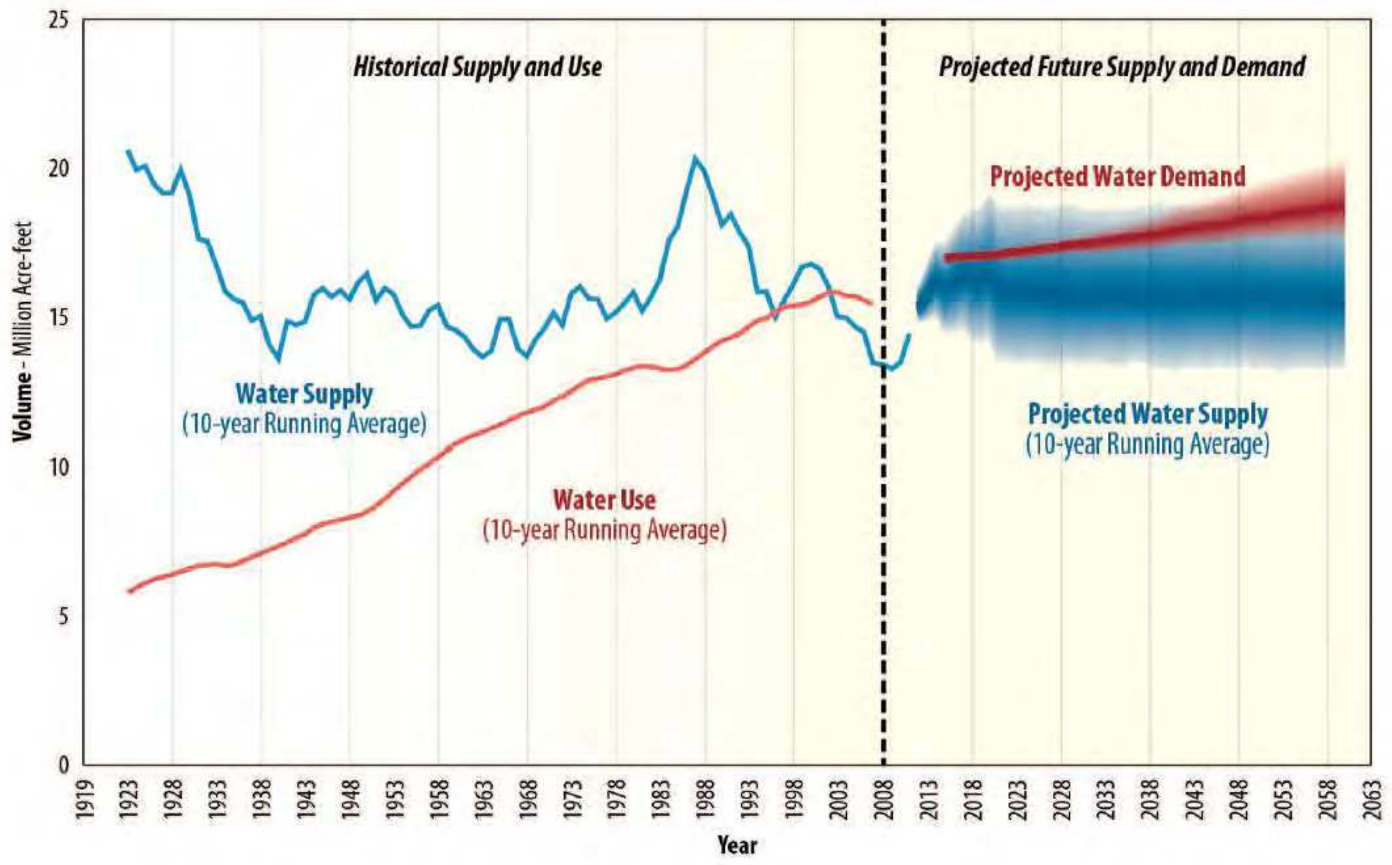
Vision for application

- The notion of operating natural infrastructure as a viable flood control tool and water supply source is embraced in state water planning
- Communication of the natural infrastructure concept is broadened to include aquifers, and hence a three dimensional storage profile
- The flood peak offset and local storage benefits of wetlands are deployed state wide as a water right
- Pilot projects financed by the state and private sector and co-managed with reservoir operations by the Army Corps of Engineers

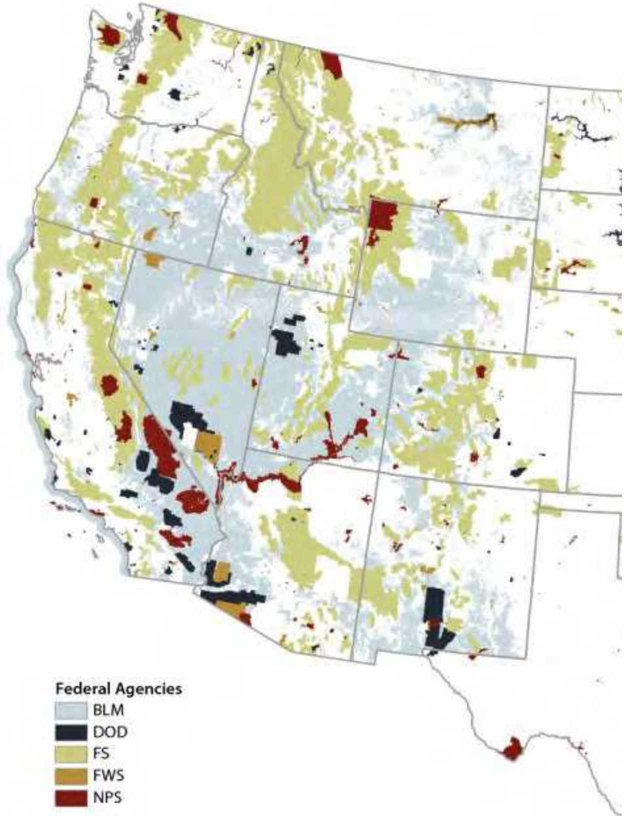
Segue to Colorado River basin



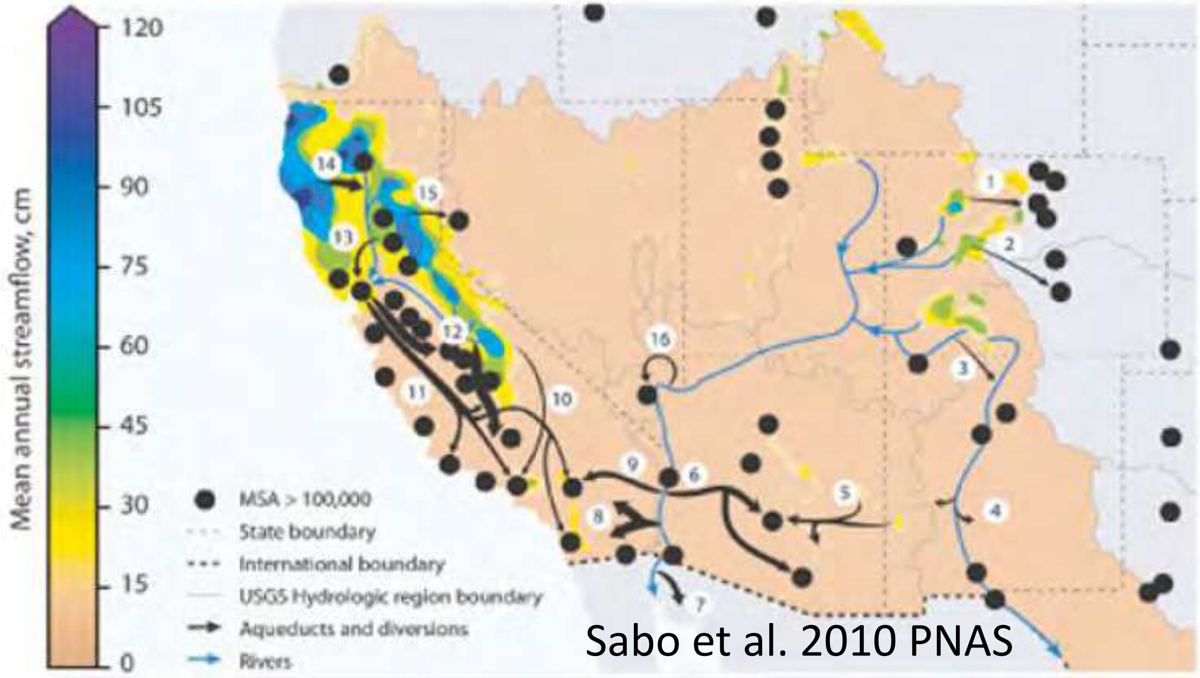

Water resources in the Colorado River Basin



Western water infrastructure in the greater Colorado River Basin



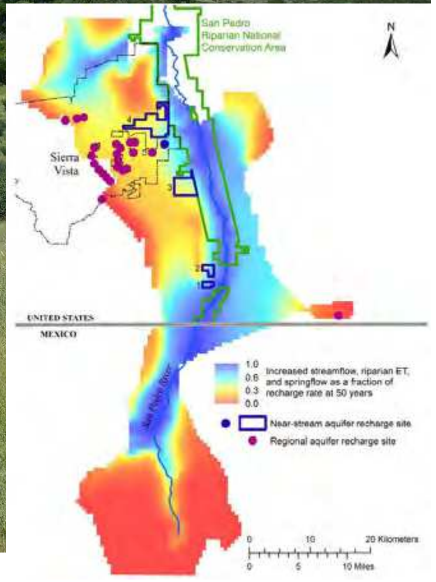
More than two-thirds of DoD lands are & operated by the Corps



Sabo et al. 2010 PNAS

The built infrastructure system is vast, redistributing water from areas of plenty to areas of scarcity. Operated by the Corps and the Bureau

Natural infrastructure can sustain storage in built infrastructure and provide significant natural storage



Upshot: Coordination and prioritization could enhance storage but **research** is needed

- Fire management reduces erosion and sediment infilling in reservoirs
  - More science is needed to prioritize intervention
- Healthy forests slow down overland flow, promote infiltration to aquifers
  - More science is needed to understand balance between ET and infiltration
- Coordination of recharge and reservoir management could extend supplies
  - More science is needed to predict recovery:recharge ratio and optimize this
- Setting priorities requires research and interagency coordination
  - Intersection between basic and applied appropriate for university-ERDC collaboration
  - Natural infrastructure holdings: USACE, USDA and NPS
  - Built infrastructure holdings USBR & USACE
  - Local water and power agencies and utilities—guide siting and funding
  - Private sector companies—catalyst and seed funder for strategic projects