United States Environmental Protection Agency

Watershed modeling to assess the sensitivity of streamflow, nutrient and sediment loads to climate change and urban development in 20 U.S. watersheds

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The views expressed in this presentation are those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency

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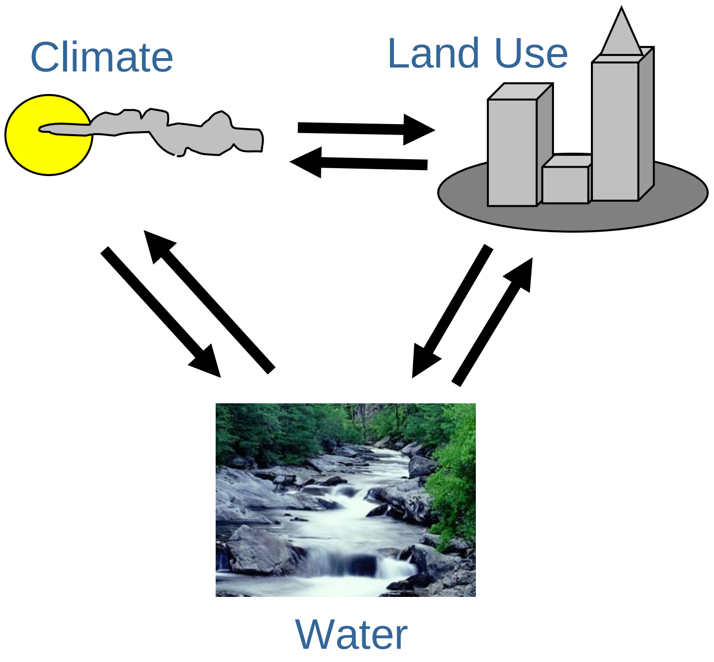
The “20 watershed” modeling project

Goals:

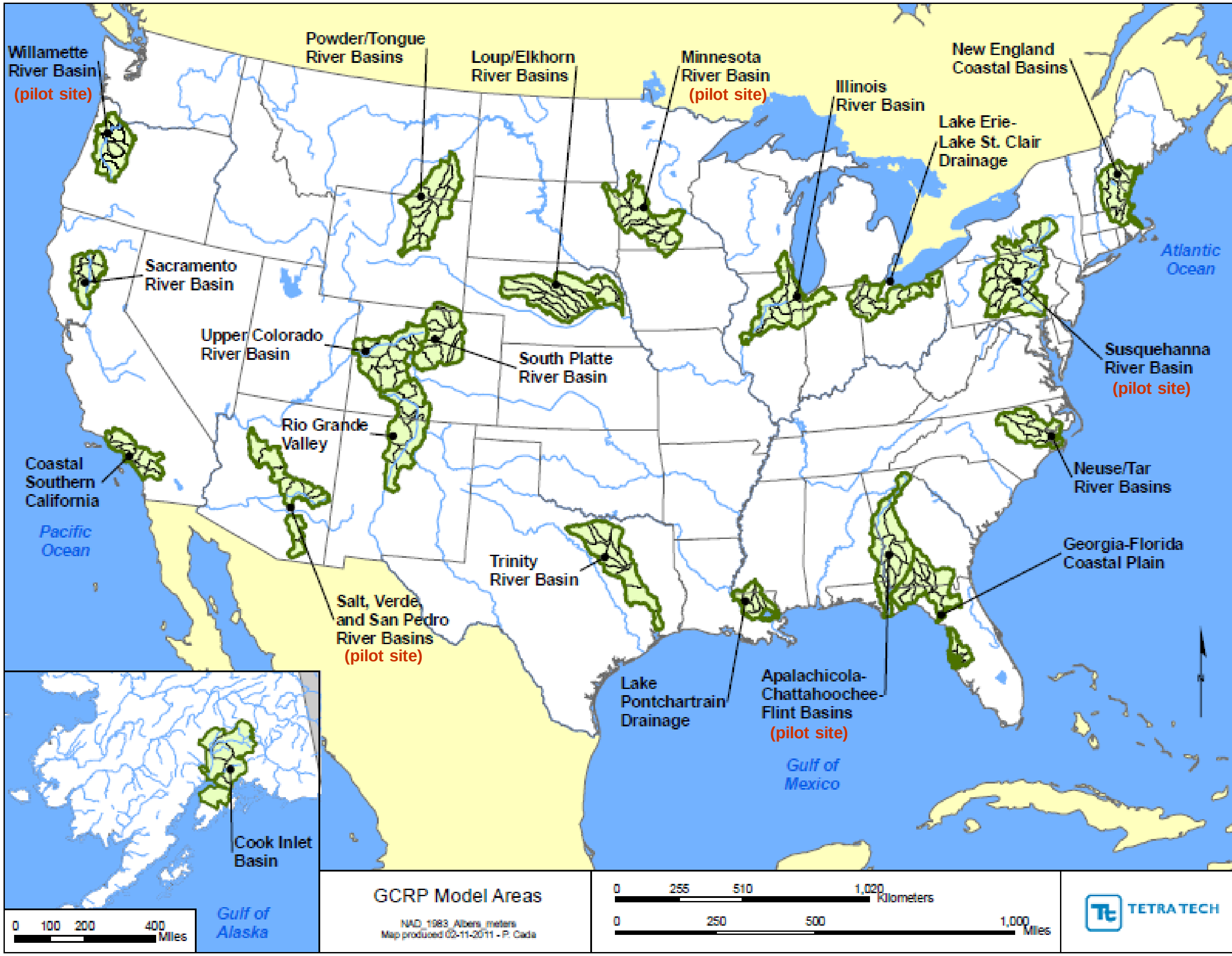
• Assess sensitivity of U.S. streamflow, nutrient (N and P), and sediment loading to climate change across a range of plausible mid-21st Century climate futures

• Assess potential interactions of climate change with increasing urban/residential development in these watersheds

• Assess the implications of different methodological choices for conducting climate change impacts studies (e.g., use of different water models, downscaled climate datasets)



20 Watersheds – Study Sites



Modeling Approach

Continuous (daily) simulations of streamflow, N, P, sediment for current (1971-2000) and mid-21st century (2041-2070)

Watersheds are about HUC4 in size; represented in models at a HUC10 scale
- Simulation output archived at HUC8 scale

In all 20 watersheds:
- Simulations with SWAT (v2005) assessing the individual and combined effects of climate change and urban/residential development scenarios
  - climate = baseline plus 6 dynamically downscaled futures (NARCCAP; A2 emissions)
  - development = baseline plus 1 future (EPA ICLUS; A2)

In subset of 5 "pilot" watersheds:
- 8 additional climate change scenarios
  - 4 based on non-downscaled GCM output
  - 4 based on statistically downscaled GCM output (BCSD; A2 emissions)
- Independent simulations with a second model, HSPF, for all scenarios
- Additional scenarios used to assess variability from use of different water models, methods of downscaling GCM output

Climate Change Scenarios

	GCM			
	CGCM3	**HADCM3**	**GFDL**	**CCSM**
Downscaling Approach or RCM	None	None	None	None
	Statistical (BCSD)	Statistical * (BCSD)	Statistical (BCSD)	Statistical * (BCSD)
	CRCM (NARCCAP)	HRM3 (NARCCAP)	RCM3 (NARCCAP)	WRFP (NARCCAP)
	RCM3 (NARCCAP)		GFDL hires (NARCCAP)	

Total of 14 scenarios based on output from 4 underlying GCMs

* Not same GCM run / from same family

GCM Models
CGCM3: Third Generation Coupled GCM
HADCM3: Hadley Centre Coupled Model, v.3
GFDL: Geophysical Fluid Dynamics Lab GCM
CCSM: Community Climate System Model

RCM Models
CRCM: Canadian Regional Climate Model
RCM3: Regional Climate Model, version 3
HRM3: Hadley Region Model 3
WRFP: Weather Research and Forecasting Mod
GFDL hires: Geophysical Fluid Dynamics Laboratory 50-km global atmospheric timeslice

Sources:
NARCCAP: North American Regional Climate Change Assessment Program (NARCCAP), NCAR (http://www.narccap.ucar.edu/)

BCSD: Bias-corrected and statistically downscaled, Bureau of Reclamation/ Santa Clara/ Lawrence Livermore (http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html)

Implementation of climate change scenarios in SWAT/HSPF

We used a “change factor” approach:

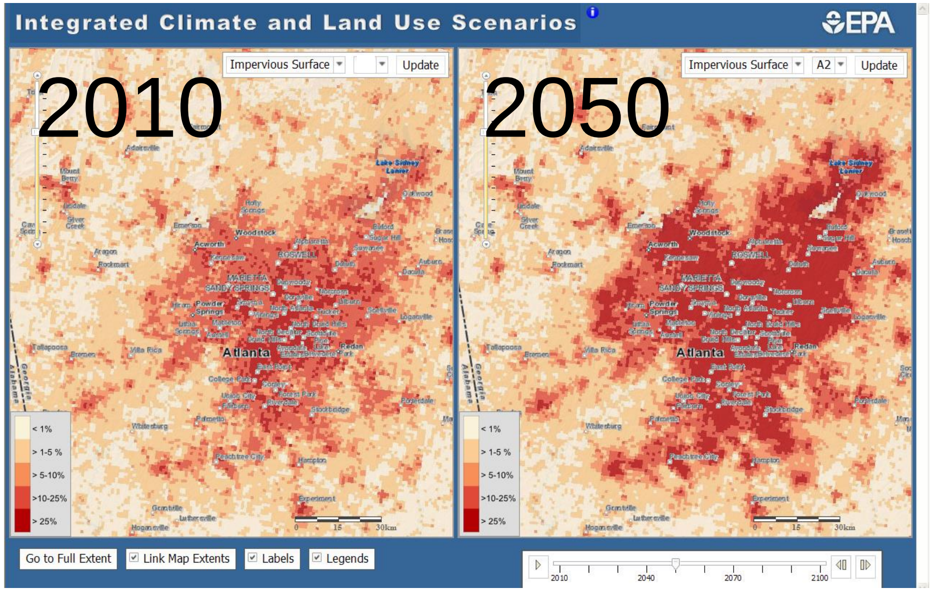
- interpolated climate model output to NCDC weather stations
- calculated mid-21st century changes relative to baseline
- adjusted 30+ years of NCDC weather data (from EPA’s BASINS meteorological database) using change factors

Meteorological variables adjusted:

- temperature
- precipitation (total volume and proportion in large events)
- solar radiation
- relative humidity
- wind speed
- potential evapotranspiration (internal Penman-Monteith for SWAT)

In SWAT runs, also represented projected changes in atmospheric CO_2 (increase from 369 to 533 ppmv CO_2)

Urban/Residential Development Scenario



Source:
ICLUS: Integrated Climate and Land Use Scenarios (ICLUS) dataset (http://www.epa.gov/ncea/global/iclus/)

- provides decadal changes in housing density (100m) consistent with IPCC SRES emissions storylines
- projections are based on population projections, a demographic model and spatial allocation model (SERGoM)

One scenario based on EPA's ICLUS projection for 2050 under the A2 emissions storyline

Modeling approach (continued)

Other things represented in the models:
- major dams and reservoirs (if modify flow >10%)
- major point source discharges (> 1MGD in PCS)

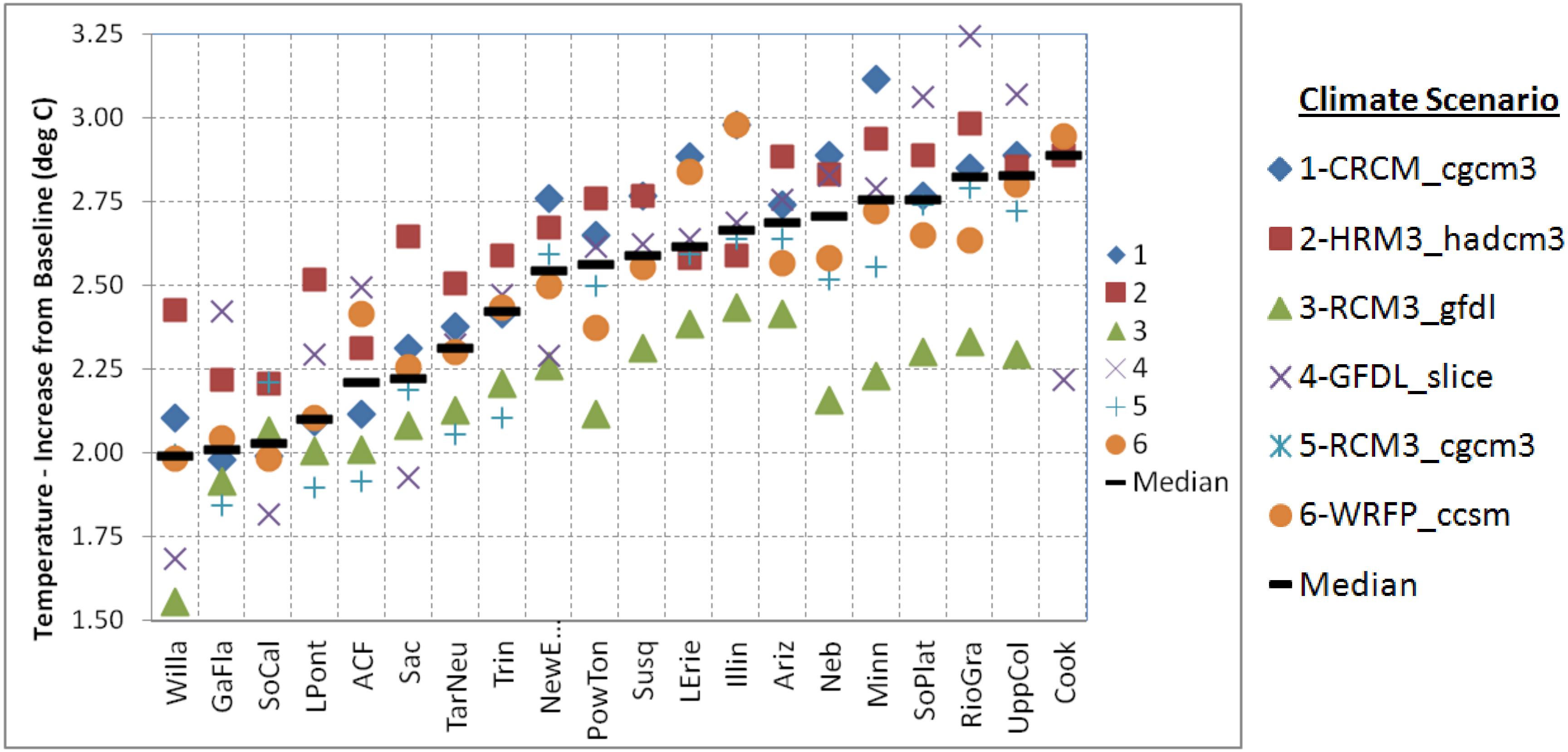
And <u>not</u> represented in models:
- future changes in agriculture
- future changes in water infrastructure management

…more confidence in results expressed as changes relative to current than absolute numbers

Some summary results



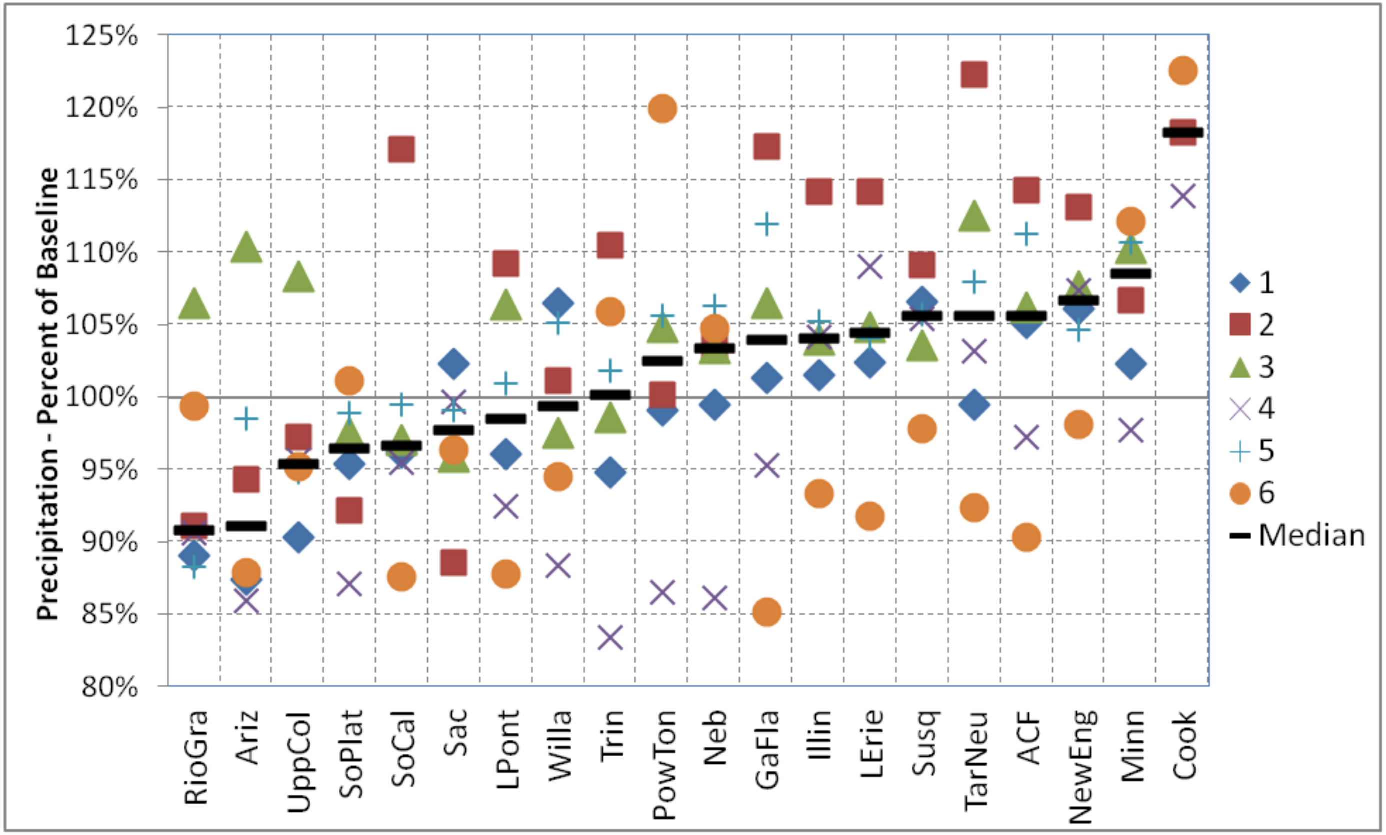
Projected temperature changes range from about 1.5 – 3.2 ºC (6 NARCCAP, mid-21st century)



Projected precipitation changes range from about –15 to +20% (6 NARCCAP, mid-21st century)

Note: values expressed as percent of baseline

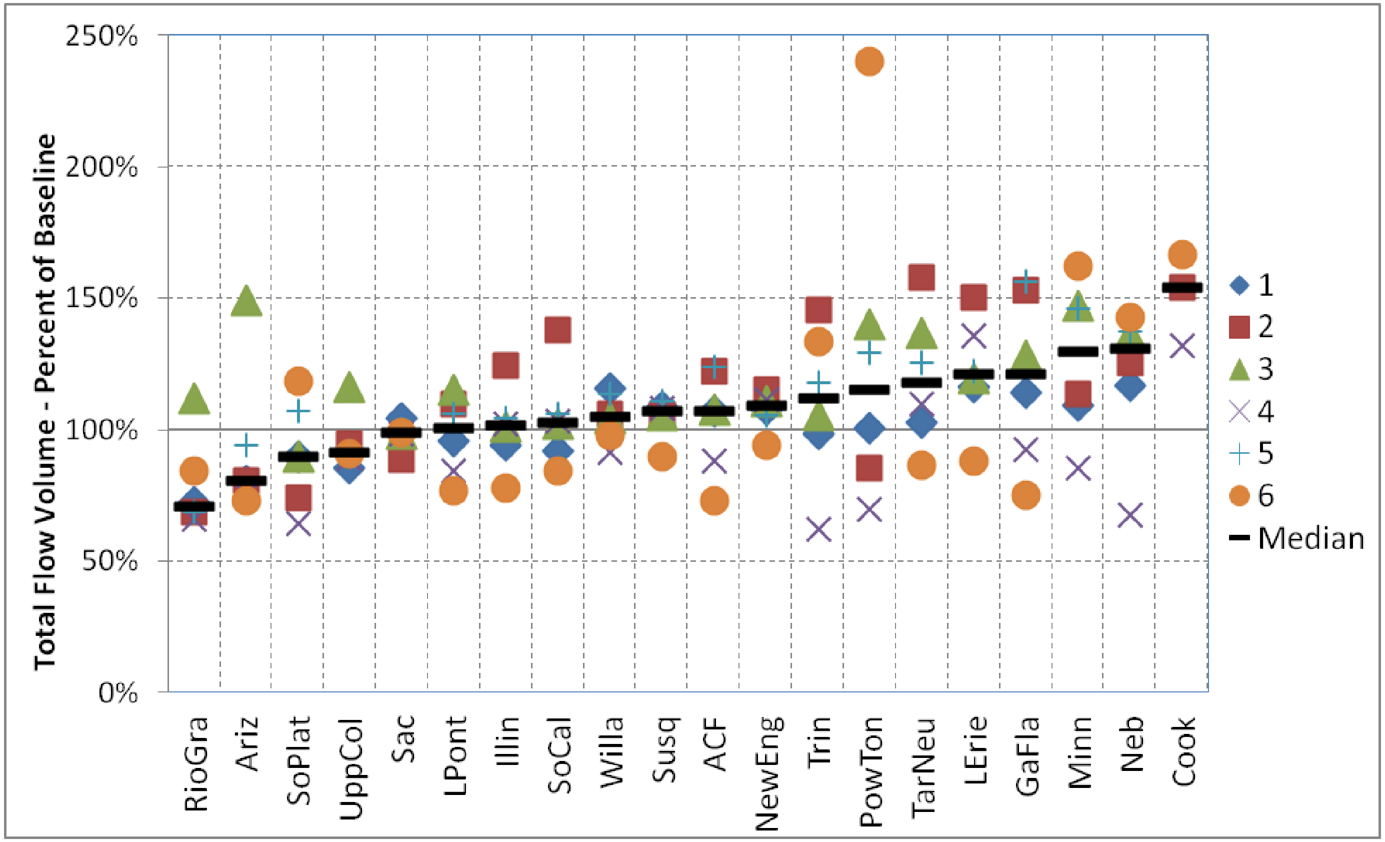
100% = baseline →



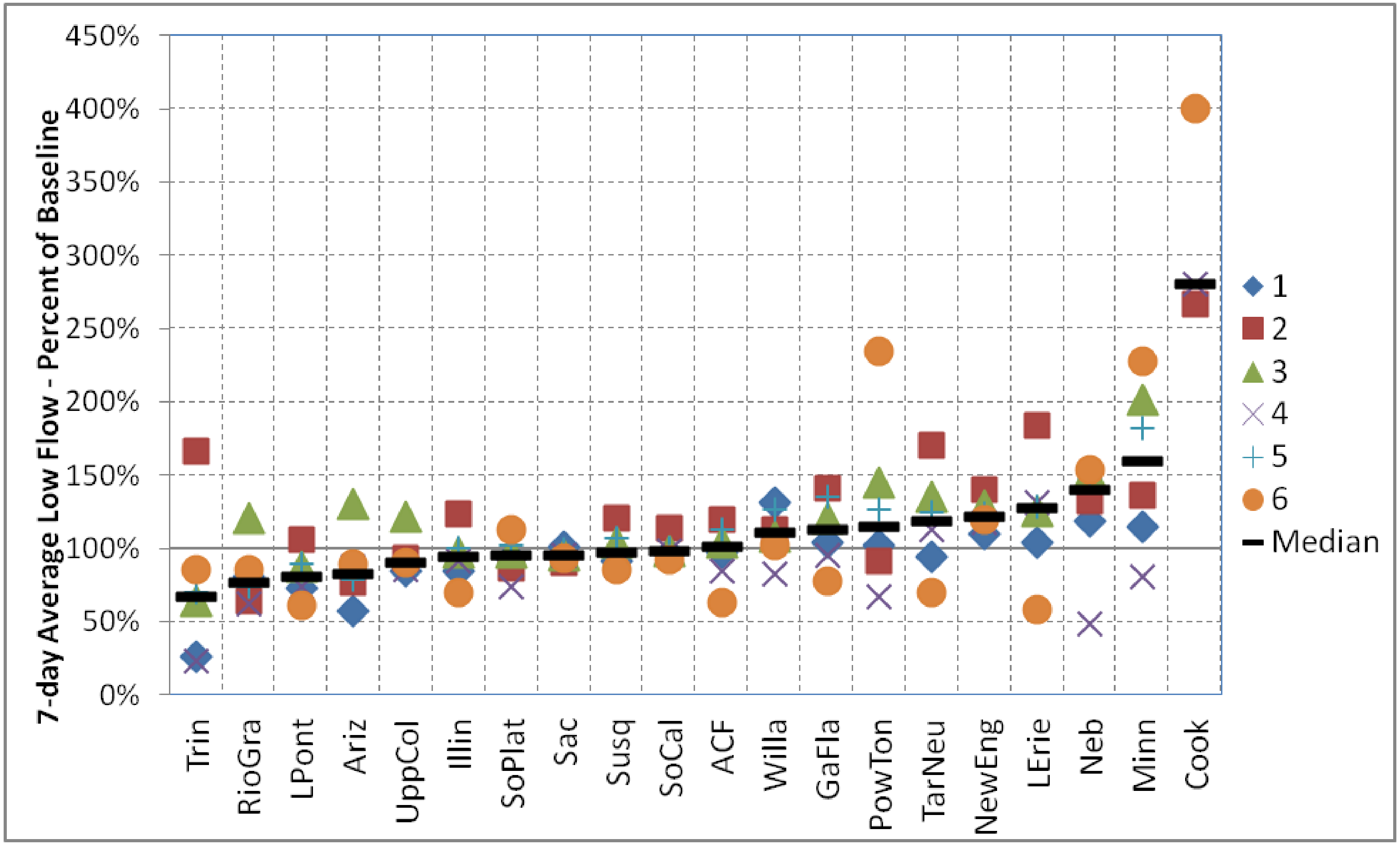
Total streamflow response to climate change: SWAT simulations for the 6 NARCCAP scenarios

Key to Site Names

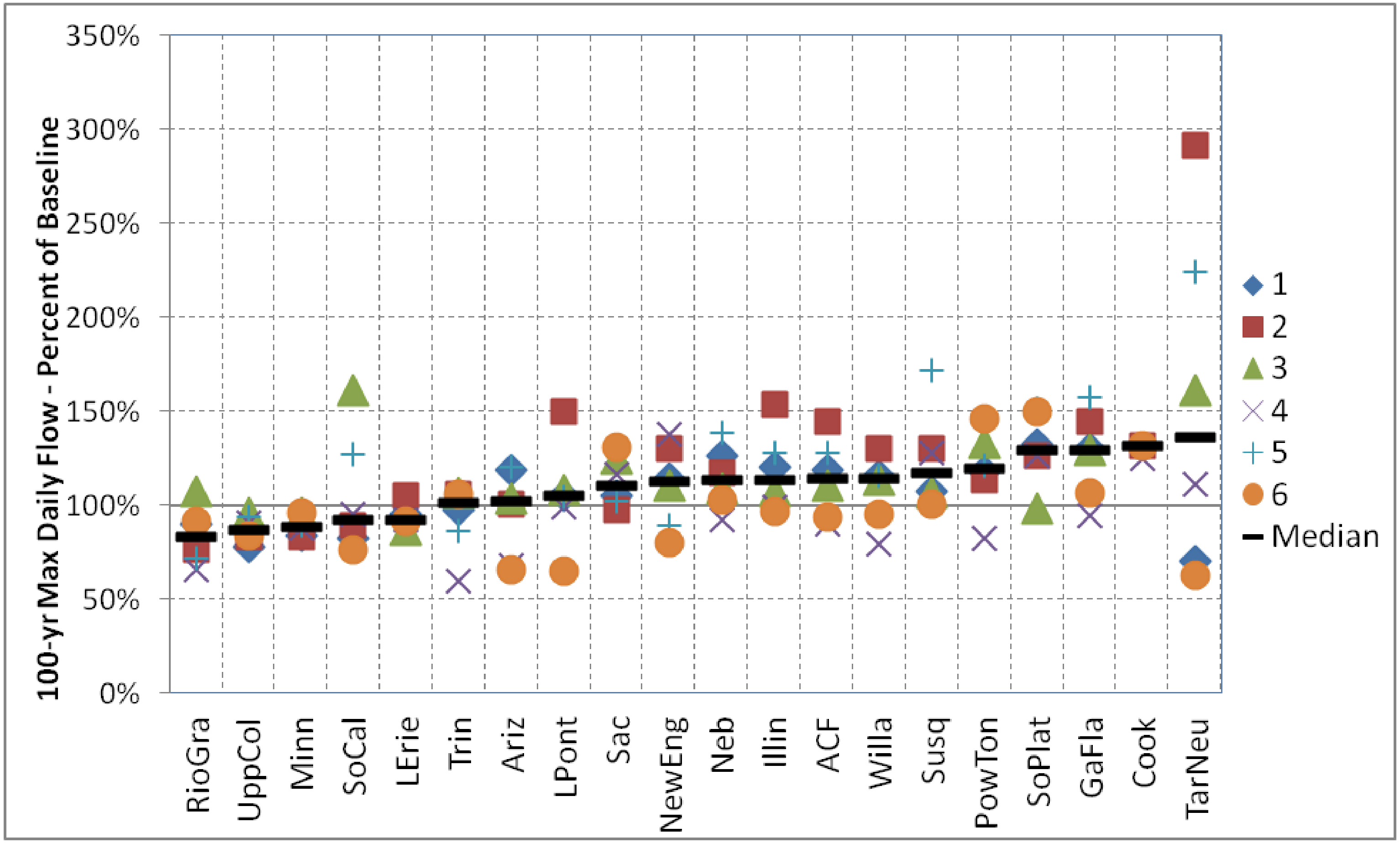
Study Area	Downstream Station
ACF	Apalachicola River at mouth
Ariz	Salt River near Roosevelt
Cook	Kenai River at mouth
GaFla	Suwanee River at mouth
Illin	Illinois River at Beardstown
LErie	Maumee River at mouth
LPont	Amite River at mouth
Neb	Elkhorn River at mouth
NewEng	Merrimack River at mouth
PowTon	Tongue River at mouth
RioGra	Rio Grande at Albuquerque
Sac	Sacramento River at mouth
SoCal	Los Angeles River at mouth
SoPlat	S. Platte River at Henderson
Susq	Susquehanna River at mouth
TarNeu	Neuse River at mouth
Trin	Trinity River at mouth
UppCol	Colorado River at state line
Willa	Willamette River at mouth



7-day average low flow response to climate change: SWAT simulations for the 6 NARCCAP scenarios



100-year max daily streamflow response to climate change: SWAT simulations for the 6 NARCCAP scenarios



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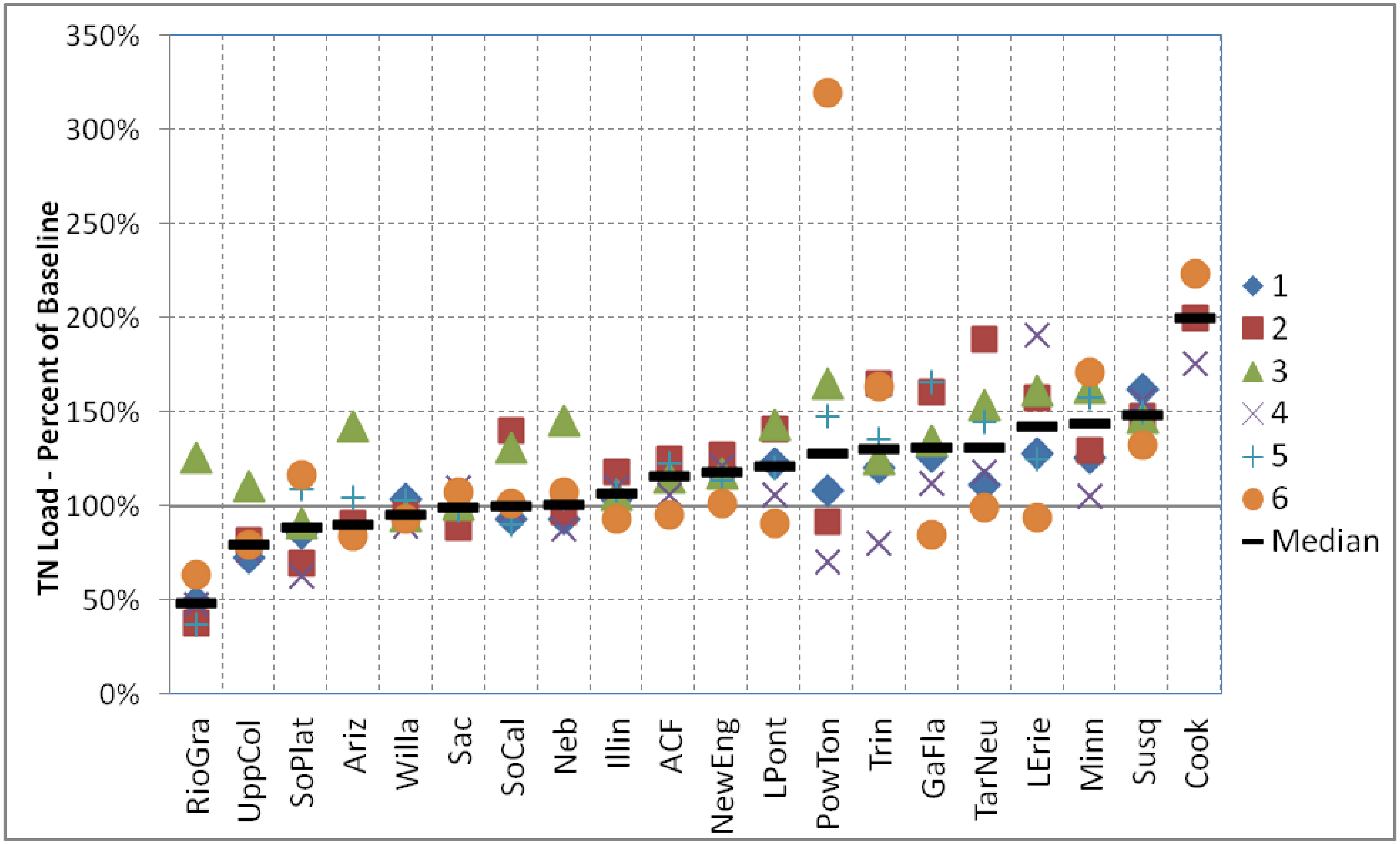
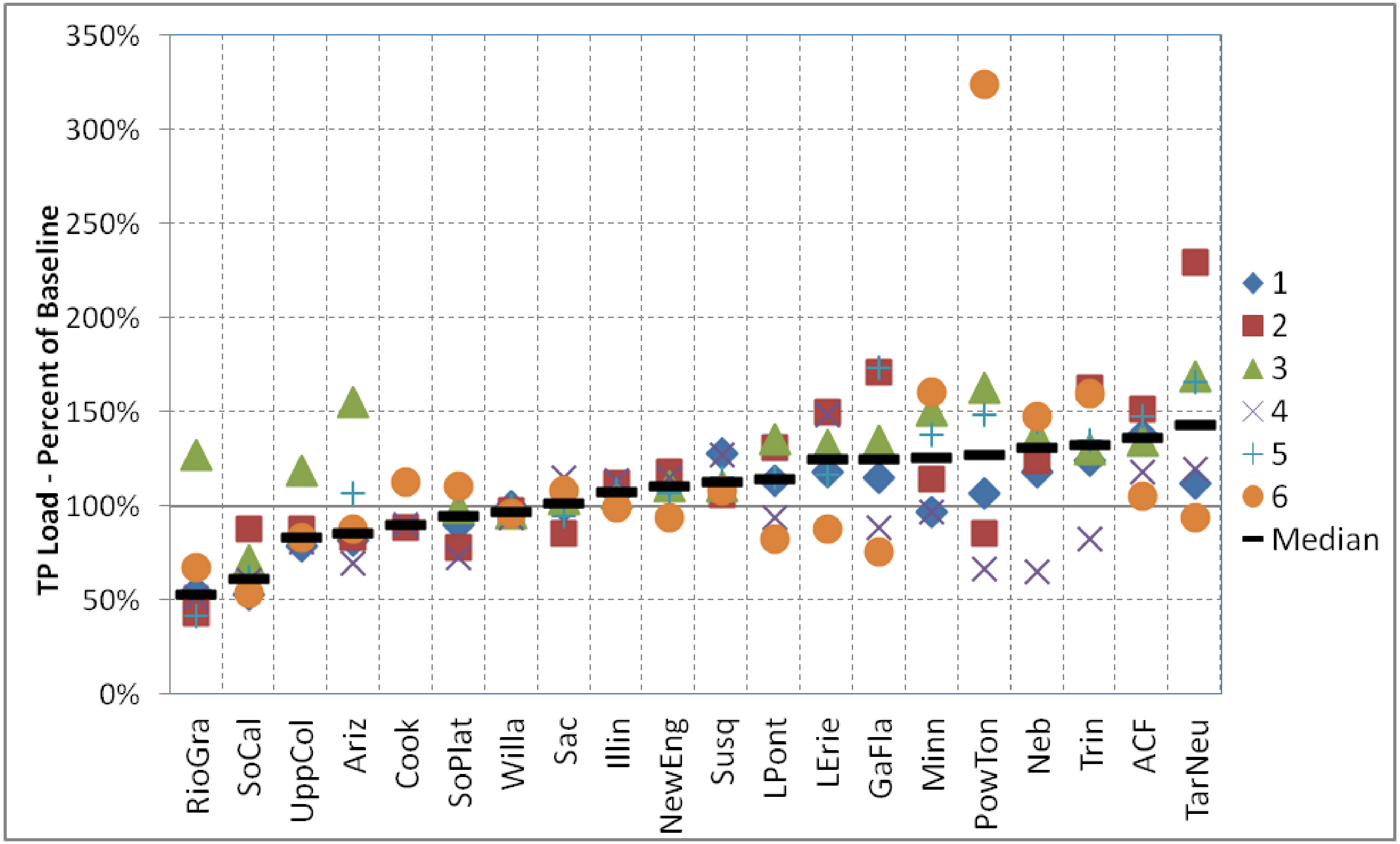
Total nitrogen response to climate change: SWAT simulations for the 6 NARCCAP scenarios



Total phosphorus response to climate change: SWAT simulations for the 6 NARCCAP scenarios



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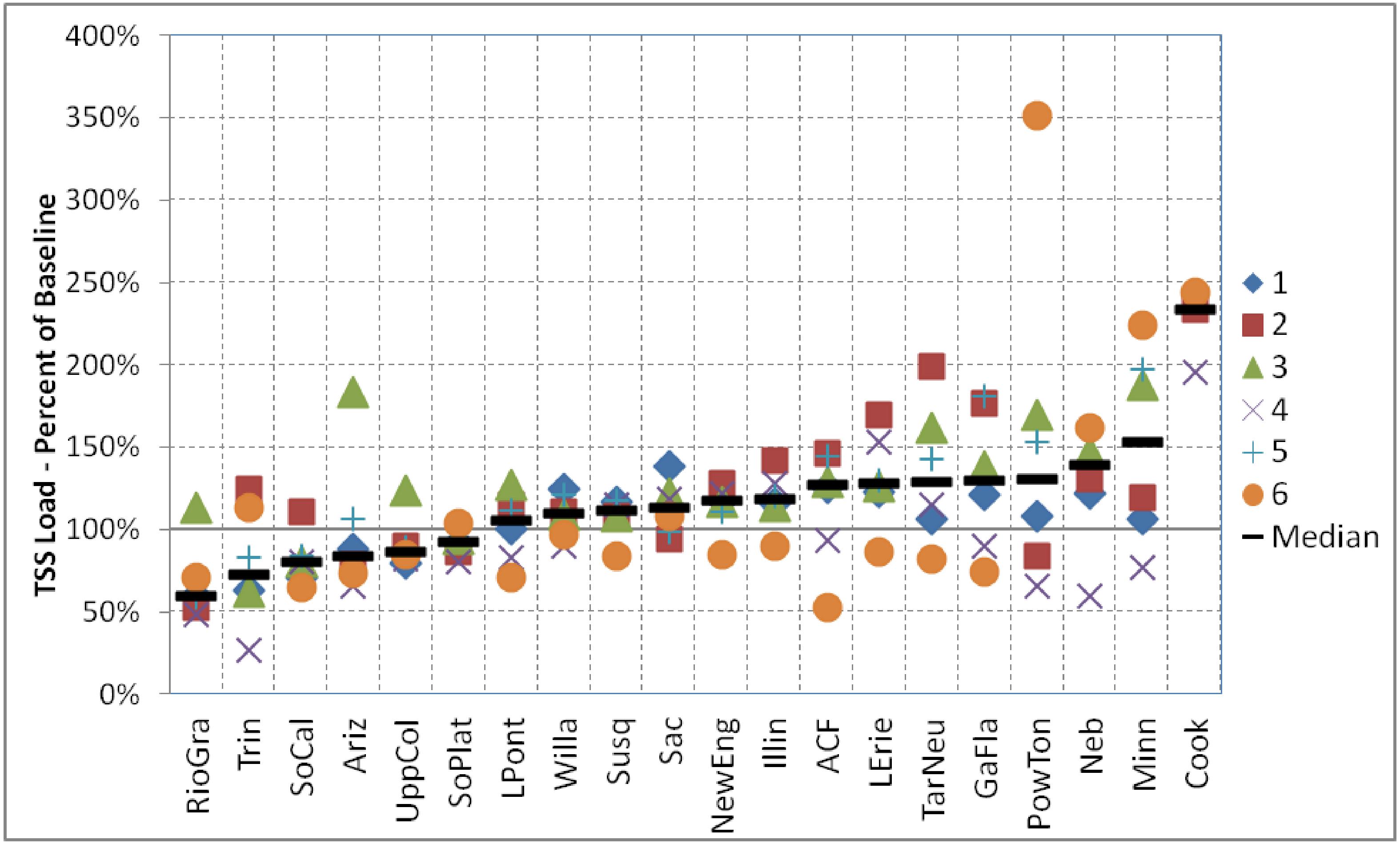
Total suspended solids response to climate change: SWAT simulations for the 6 NARCCAP scenarios



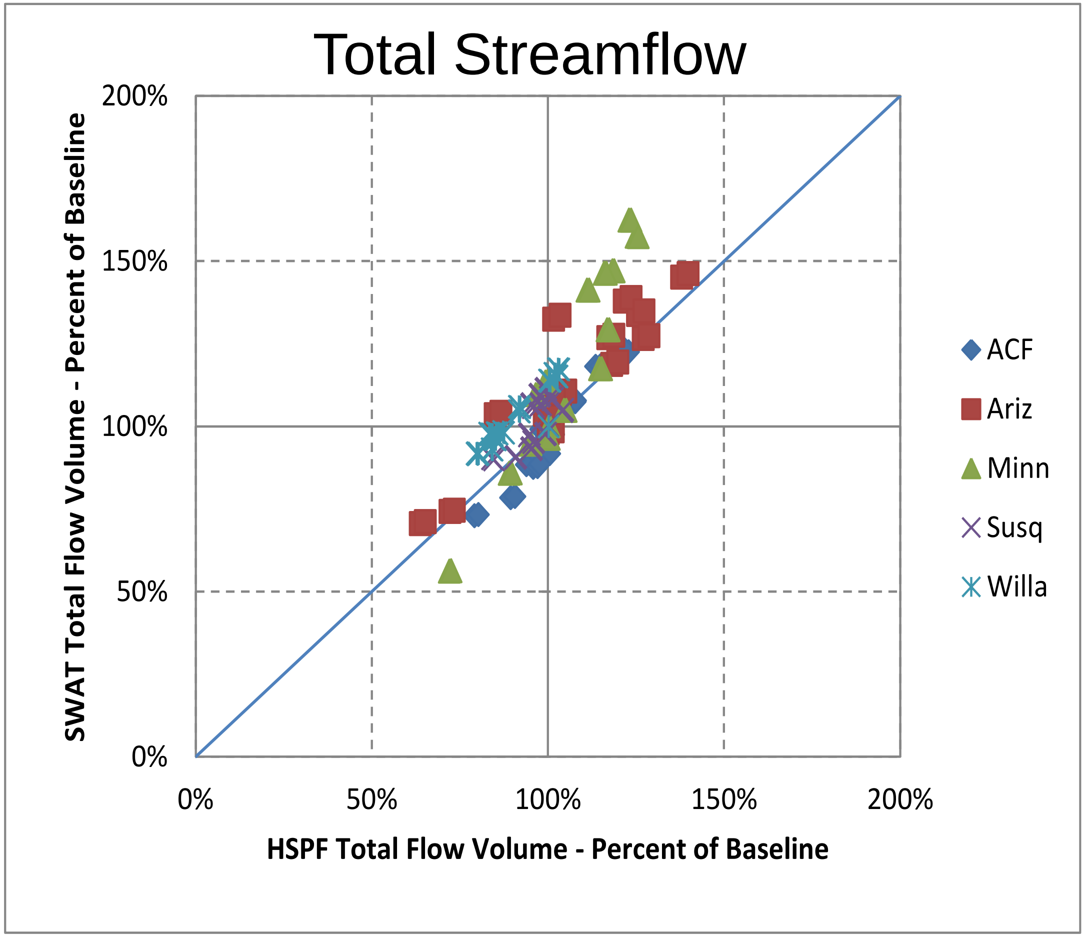
Mean streamflow response to urban/res development: range of changes in SWAT simulations for HUC8 subbasins within each study area

Projected changes in development are small at the HUC8 and larger scale; streamflow response also small. Larger responses likely at smaller spatial scales where development is concentrated

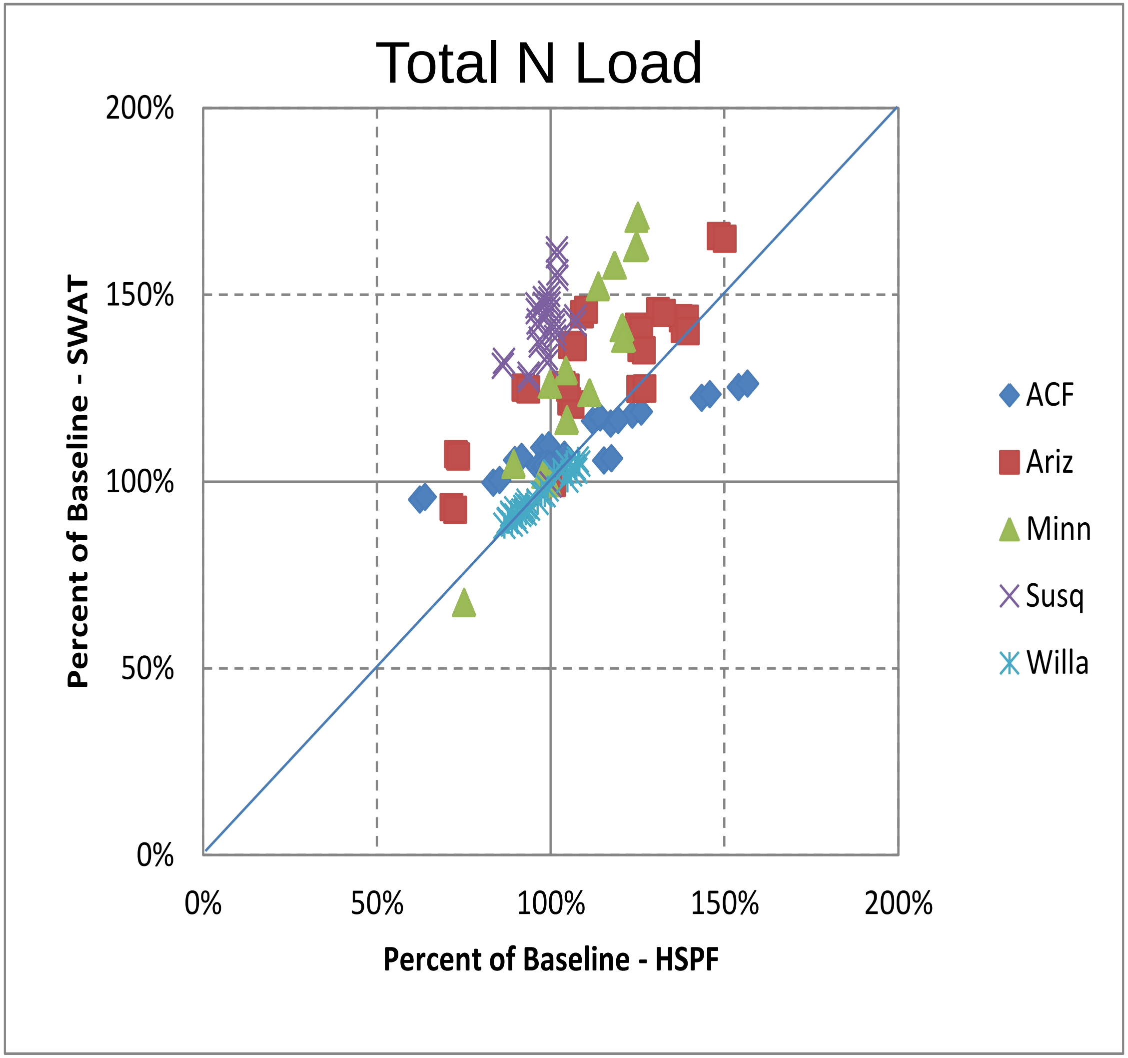
	Climate Change Response		Urban/Res Response		Projected change in impervious cover	
	Minimum (%)	Maximum (%)	Minimum (%)	Maximum (%)	Minimum (%)	Maximum (%)
ACF	-46	25	0	1	0	5
Ariz	-35	153	0	1	0	0
GaFla	-40	70	0	7	0	8
Illin	-22	34	0	12	0	8
LErie	-23	72	0	2	0	2
LPont	-25	22	0	1	0	4
Minn	-23	85	0	0	0	2
Neb	-79	73	0	0	-1	0
NewEng	-13	20	0	1	0	2
PowTon	-42	206	0	0	0	0
RioGra	-45	20	0	0	0	2
Sac	-21	10	0	0	0	2
SoCal	-27	62	-4	6	3	13
SoPlat	-53	59	-1	3	0	5
Susq	-24	26	0	0	0	1
TarNeu	-14	62	0	4	0	3
Trin	-61	126	7	35	0	12
UppCol	-20	23	0	0	0	1
Willa	-18	23	-1	0	0	4

Results are sensitive to use of different watershed models with different structures and representation of processes (SWAT, HSPF)

Comparison of SWAT and HSPF total streamflow projections in the 5 pilot study areas (expressed as percent of current conditions)



Comparison of SWAT and HSPF Total N projections in the 5 pilot study areas (expressed as percent of current conditions)



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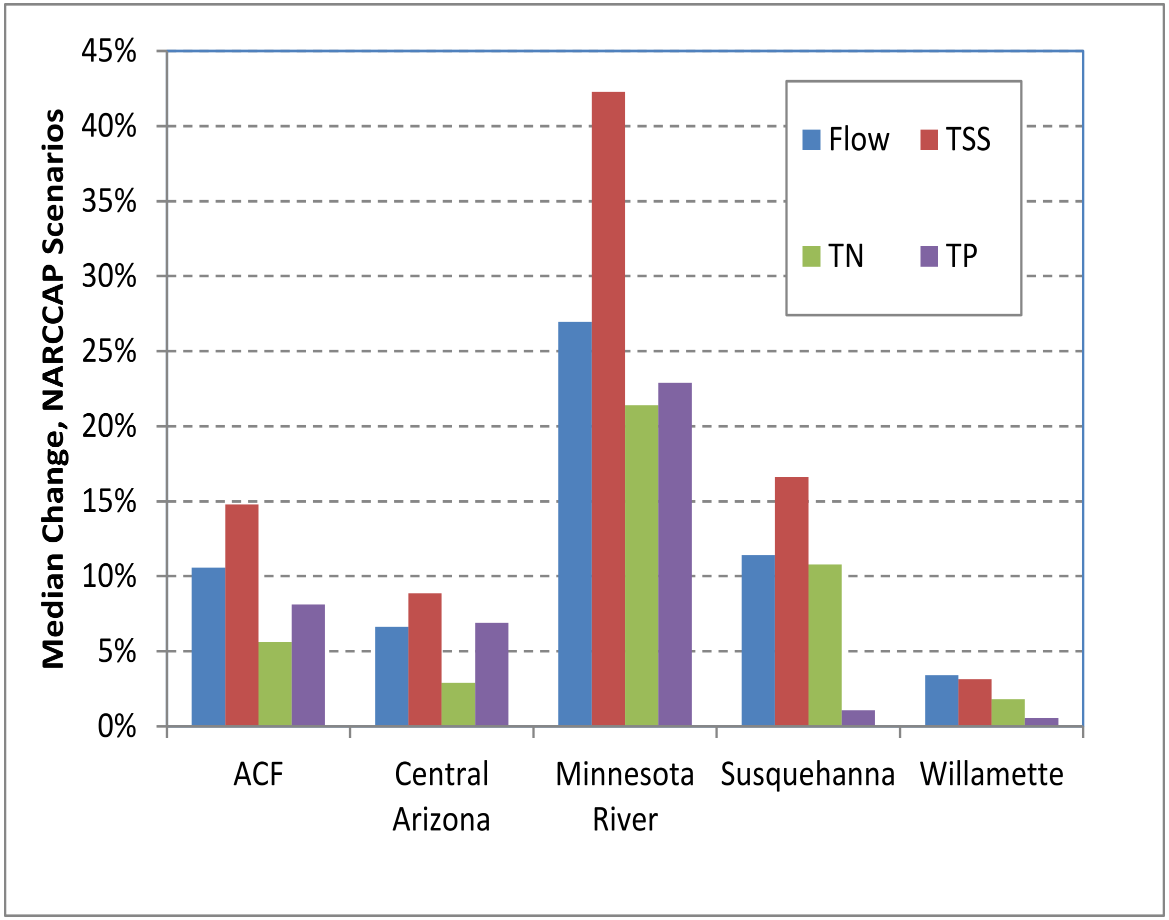
Representation in SWAT of future changes in atmospheric CO_2 resulted in increased streamflow and pollutant loads

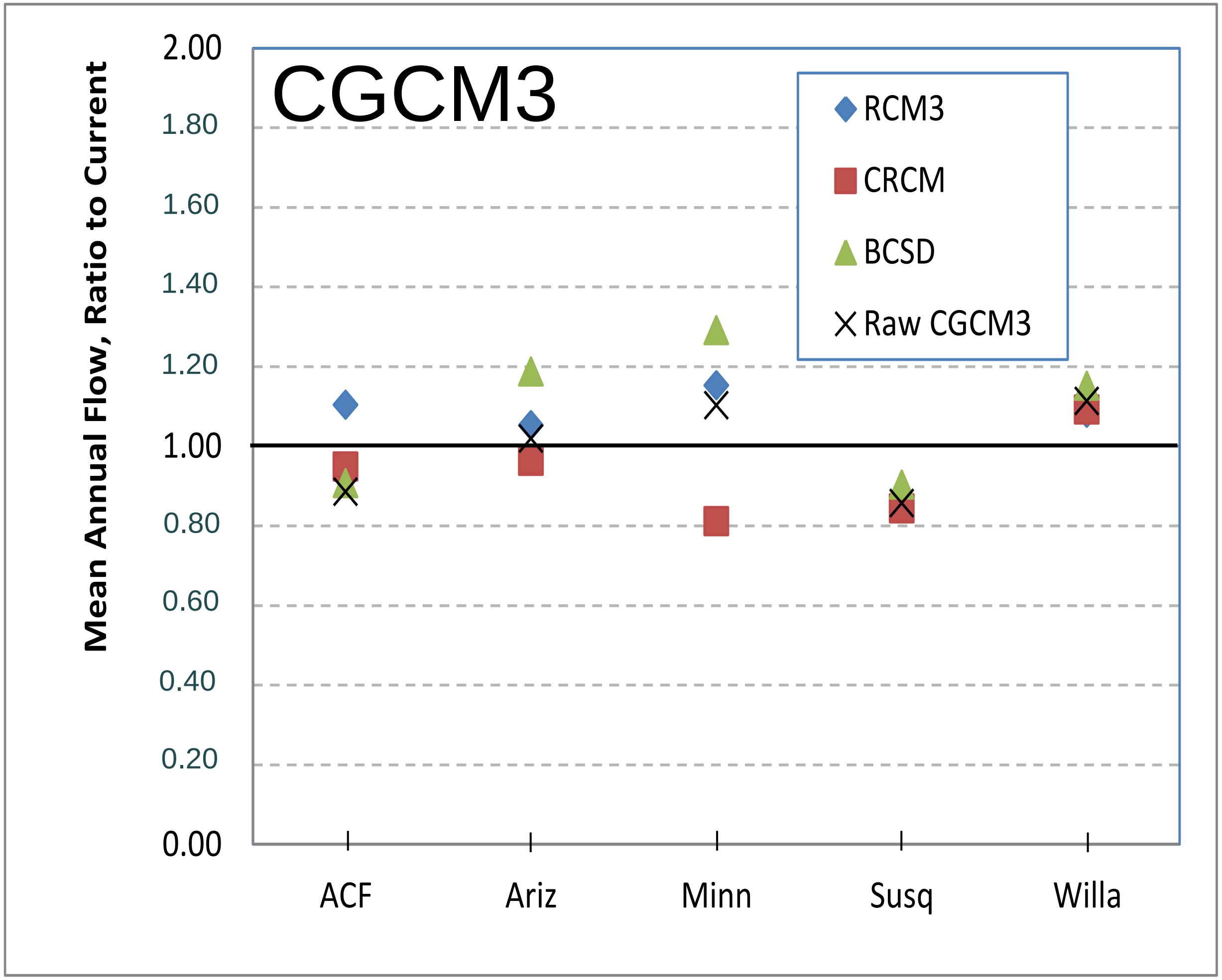
Differences in SWAT streamflow and water quality projections (median across six NARCCAP scenarios) with and without representation of increased atmospheric CO_2 (increase from 369 to 533 ppmv CO_2)



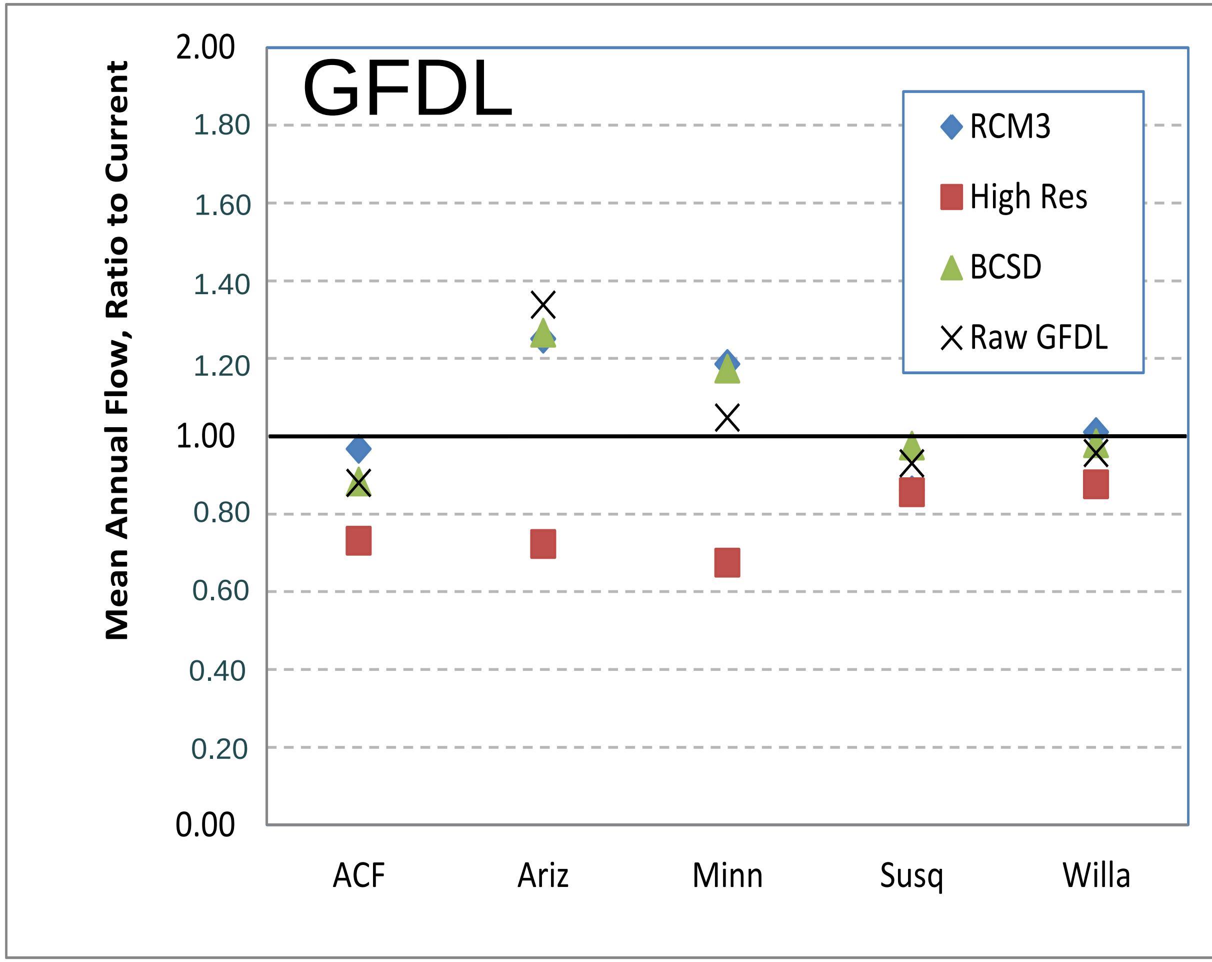
Results are sensitive to use of scenarios based on different approaches for downscaling GCM outputs

Comparison of SWAT streamflow projections for the 5 pilot study areas using climate scenarios based on the CGCM3 GCM model and:

- no downscaling (Raw),
- statistically downscaled (BCSD)
- dynamically downscaled (RCM3, CRCM)



Comparison of SWAT streamflow projections in the 5 pilot study areas for climate scenarios based on the GFDL GCM model



Closing comments

- Results suggest that in many locations future conditions could be different from past experience

- Results provide a plausible envelope on the range of likely responses, and in some locations a direction of change

- Projected mid-21st century changes in urban development small at the spatial scale of this study; simulated hydrologic responses also small. Larger responses likely where development is concentrated

- Simulations can be sensitive to methodological choices such as use of different watershed models and approaches for downscaling GCMs

- Many complex questions requiring further study; science/models can and will improve, but there will always be uncertainty, important to also think about how we can use models to support decision making

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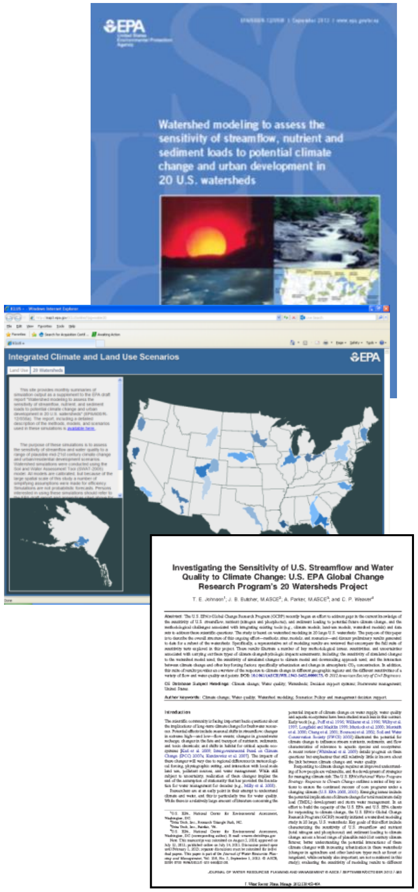
For more information

EPA Report:
- Available at ORD NCEA Web Page
http://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=256912

Journal Papers
- Sensitivity studies in pilot sites (JWRPM, 2012)
- Representing CO2 effects in SWAT v. HSPF (accepted; J. Hydrol)
- Others in prep

Simulation Datasets
- SWAT results at HUC8 scale available at ICLUS Web Page
http://map3.epa.gov/ICLUSonline/?pg=water20



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Thanks!