WSGS Statewide Groundwater Recharge Study

Wyoming State Geological Survey (WSGS)

Laramie, Wyoming

Karl Taboga, PG

- This project was funded by the Wyoming State Geological Survey consistent with it's mission to:

"Promote the beneficial and environmentally sound use of Wyoming's vast geologic, mineral, and energy resources while helping protect the public from geologic hazards."

Purpose

- Provide preliminary estimates of direct groundwater recharge from precipitation and snowmelt in Wyoming using a data driven model and geospatial analysis

- Inputs should consist of publically available environmental data

- Results were evaluated by comparing estimates from the new model to estimates obtained from other existing models in selected areas of Wyoming.

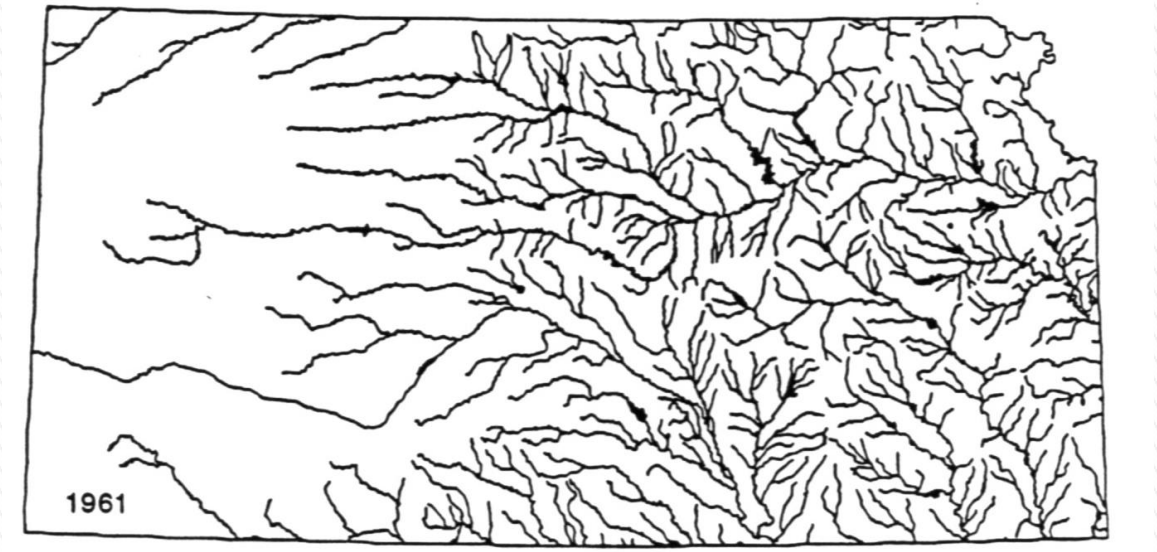
Previous Wyoming Recharge Models

- Statewide: Hamerlinck and Arneson (1998) – a GIS based DRASTIC model (U.S. EPA) that used average annual precipitation rates and U.S. Soil Conservation Service (SCS) soil infiltration rates

- Structural basins:
  - PRB – Long et al, 2014 –Soil Water Balance (SWB) Model
  - Denver Basin – Bartos et al, 2014 – GW fluctuation method; Stanton et al, 2011- SWB and SOWAT models;

Recharge – Baseflow component

- Baseflow – recharge that discharges to surface water bodies such as streams, springs, lakes, and wetlands.
  - Has been interpreted to equal recharge (Green et al., 2012)
  - The link between surface and groundwater, the two components of a single resource system
  - Receiving increased attention from water scientists (Barlow and Leake, 2012) and water law specialists (Platte River Basin decision)



Perennial streams in Kansas

1961 and 1994

(Angelo, 1994)

Baseflow modeling

Precipitation (P) + water inflow (Q_{in}) = evapotranspiration (ET) + water outflows (Q_{out}) + changes in water storage (ΔS)

- Precipitation from the PRISM Climate Group at OSU
- Water inflows - groundwater and surface water inflows
- Evapotranspiration is estimated from a WSGS ET model
- Outflows - streamflows and GW outflows from the basin
  - Streamflow = baseflow + overland flows (Data from USGS stream gaging stations)

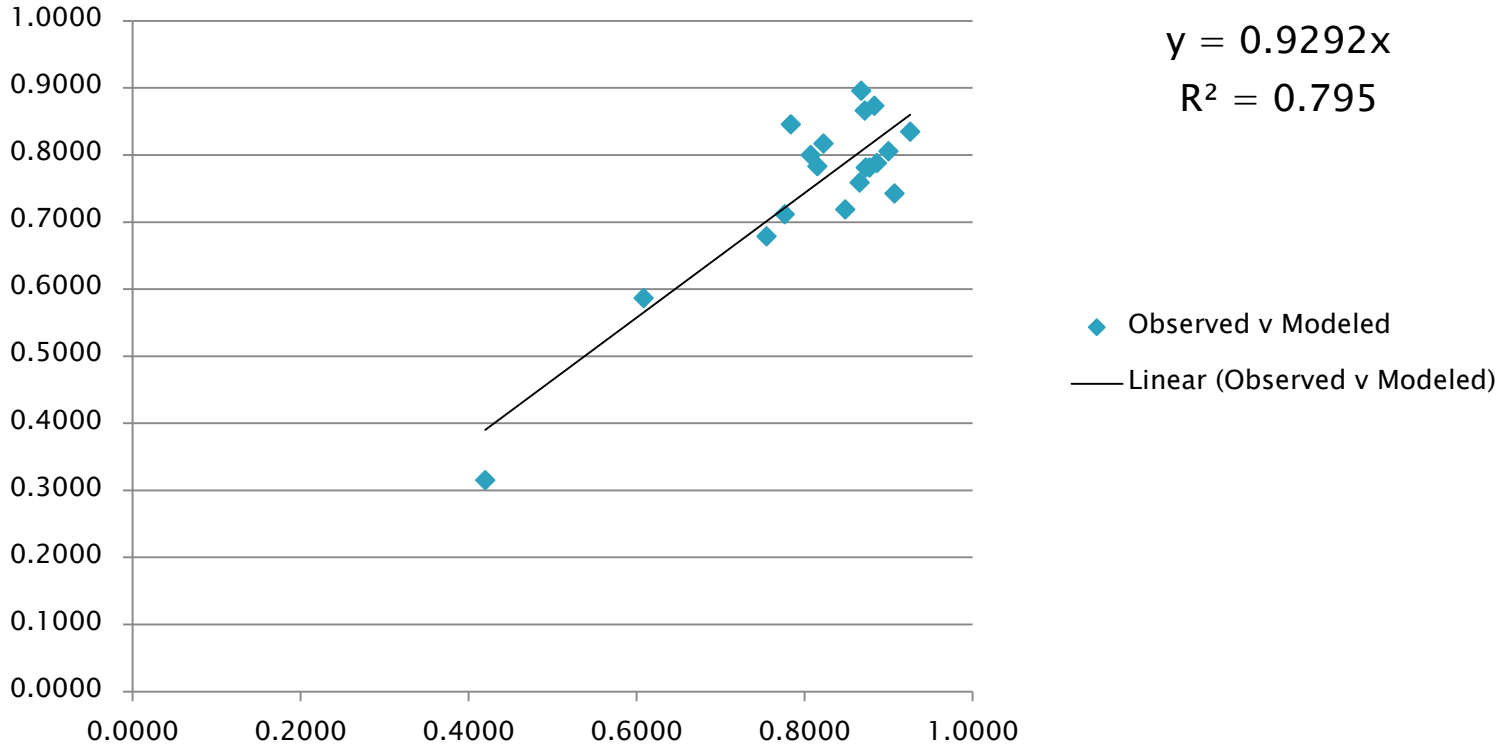
- Precipitation (P) = ET + streamflows (baseflow + overland flows)

WSGS Recharge/Baseflow Model

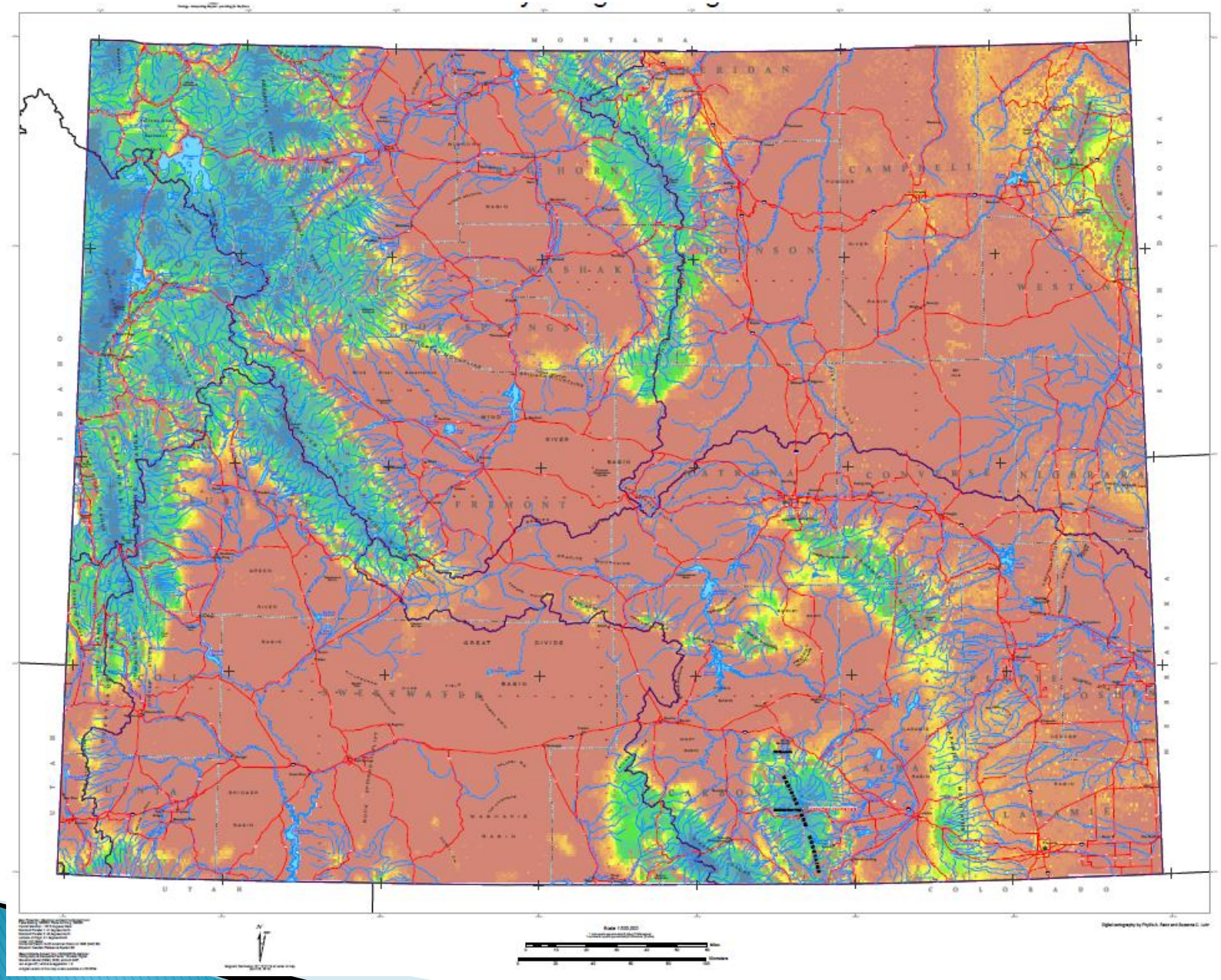
$$P = ET + runoff$$

- WSGS developed a formula to estimate baseflows in 19 unregulated Wyoming drainage basins using runoff, land surface slope and soil permeability data
- The coefficients in the model formula were determined with an optimization algorithm
- Results were evaluated by comparing modeled baseflows in the 19 watersheds to baseflows calculated from the USGS groundwater toolbox http://water.usgs.gov/ogw/gwtoolbox/

Observed v Modeled Baseflow



$$Baseflow/Runoff = 0.485\ (RO^{4.069}\ (M^{2.751} + 0.013)\ P^{0.01})^{0.0253}$$


MONTANA
WYOMING
IDAHO
UTAH
COLORADO
SOUTH DAKOTA
NEBRASKA
SHERIDAN
CAMPBELL
JOHNSON
WESTON
WASHAKIE
HOT SPRINGS
WIND RIVER BASIN
BIG HORN BASIN
FREMONT
CONVERSE
NIOBRARA
GREAT DIVIDE BASIN
GREEN RIVER BASIN
WASATCH
UINTA
LARAMIE
PLATTE

How does the WSGS model compare?

- To streamflows from Wyoming's major river basins and Hamerlinck and Arneson (1998)?

Basin Name	Outflows[1]	Inflows[1]	Streamflow Depletions[2]	Net Annual Outflows[3]	WSGS Recharge	H&A Recharge[4]
Bear	348,604	185,241	101,370	264,733	254,257	201,880
Green/Great Divide/Little Snake	1,841,836	442,131	636,348	2,036,054	1,907,840	2,129,986
North Platte/South Platte	1,428,394	509,649	829,564	1,748,309	1,554,486	1,735,521
Powder/Tongue/NE Basins	851,299	3,332	312,233	1,160,200	851,360	1,271,844
Snake/ Salt/ Falls Rivers/ Teton Creek	5,216,626	43,901	202,965	5,375,690	4,505,935	2,942,359
Wind/Bighorn/Yellowstone/ Missouri Headwaters	6,369,781	408,154	1,365,402	7,327,029	5,867,476	5,661,326

[1] Stafford, and others (2009)

[2] WWC (2007); Meyers (1962)

[3] Outflows minus inflows and streamflow depletions

[4] Hamerlinck and Arneson (1998)

To USGS recharge models in Wyoming?

- Powder River Structural Basin

  USGS SWB model: 0.18 in/yr (Long, 2014)

  WSGS model: 0.20 in/yr

- High Plains Aquifer in Wyoming

  USGS SWB: 0.53 in/yr (Stanton, 2011);

  SOWAT 6.5 in/yr.

  WSGS model: 0.31 in/yr.

SWB / SOWAT - Soil Water Balance models

Conclusion

- The WSGS empirical recharge model appears to provide reasonable estimates of baseflow/recharge for the State of Wyoming.
- As expected recharge rates are highest in areas receiving the most precipitation.

Thank you

Other groundwater studies at:
http://www.wsgs.wyo.gov/water/groundwater

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WSGS Groundwater Atlas

- Available online:

http://www.wsgs.wyo.gov/water/groundwater

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