GIS-based modeling approach to estimate nitrogen loading and load reduction in lakes/ reservoirs with application to the San Antonio and Guadalupe basins

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Importance of nutrient pollutant

- Organisms require carbon (C), nitrogen (N), phosphorus (P) for critical cellular processes

- During the past century, human activities have been rapidly changing. Most importantly this has led to increases in energy and food production, use of fertilizer and animal manure, atmospheric deposition of nutrients, and wastewater flows

- Non-point source (NPS) pollution from agricultural land is the leading cause of water quality deficiencies in the United States (USEPA, 2007)

Objectives

We use the Texas gulf coast region study to answer the following questions:

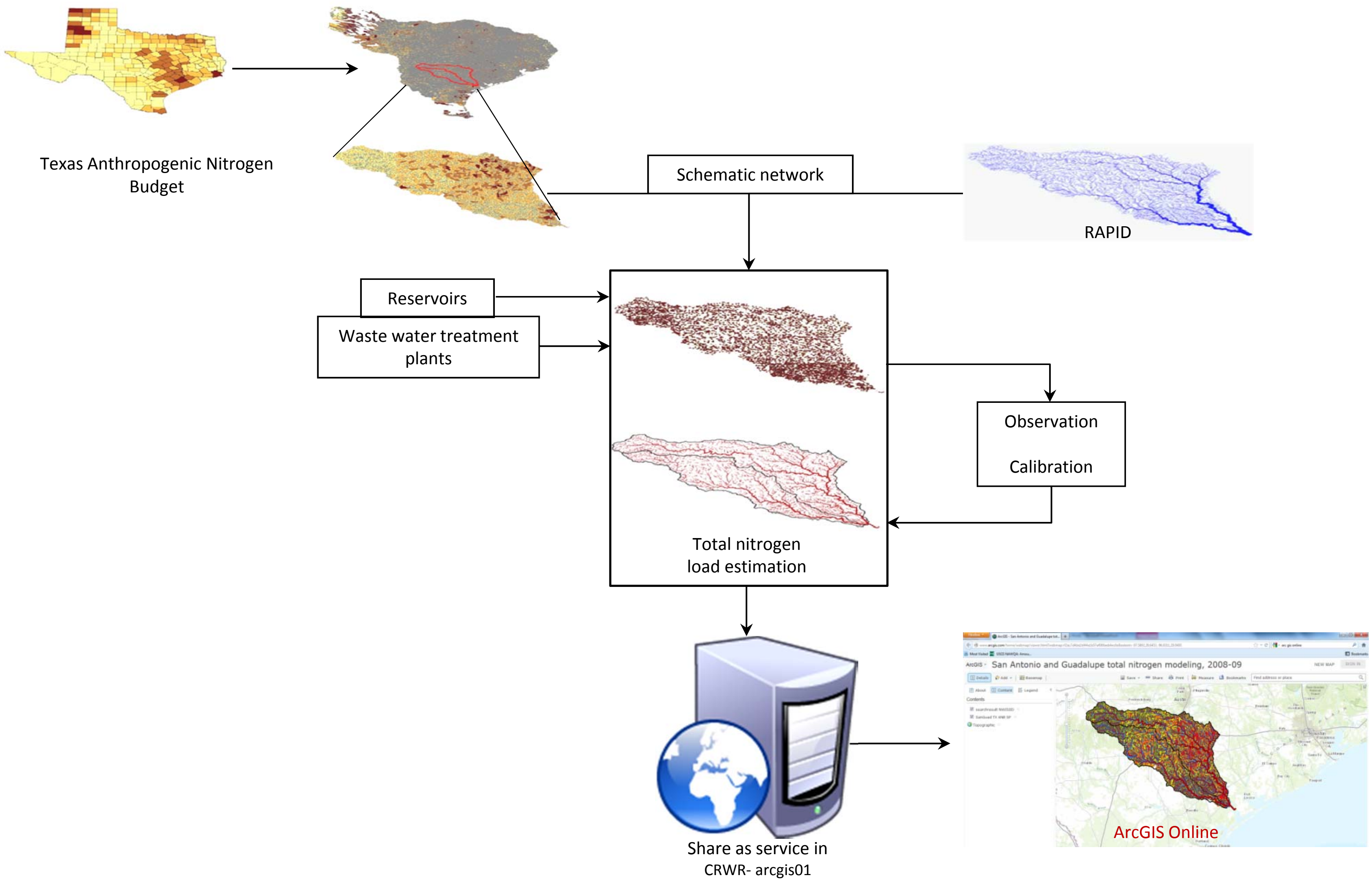
(1) How total nitrogen delivered to streams spatially contribute in San Antonio and Guadalupe basins?

(2) To what extent GIS framework could be applied for nitrogen transport in large scale river network?

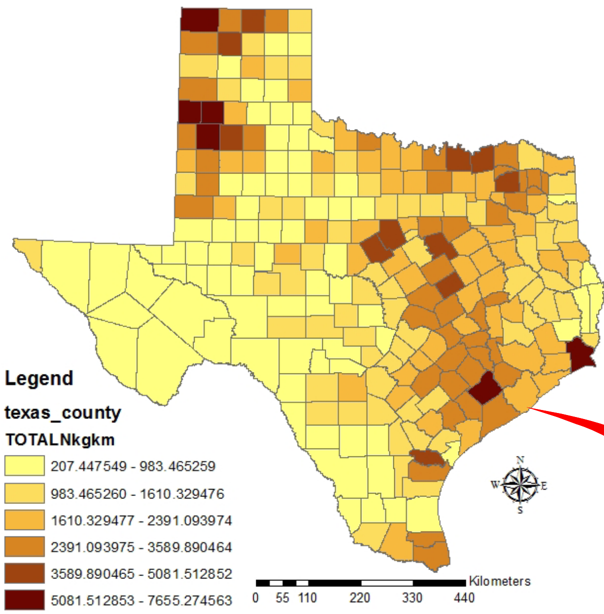
(3) How can we link nitrogen database with river routing model?

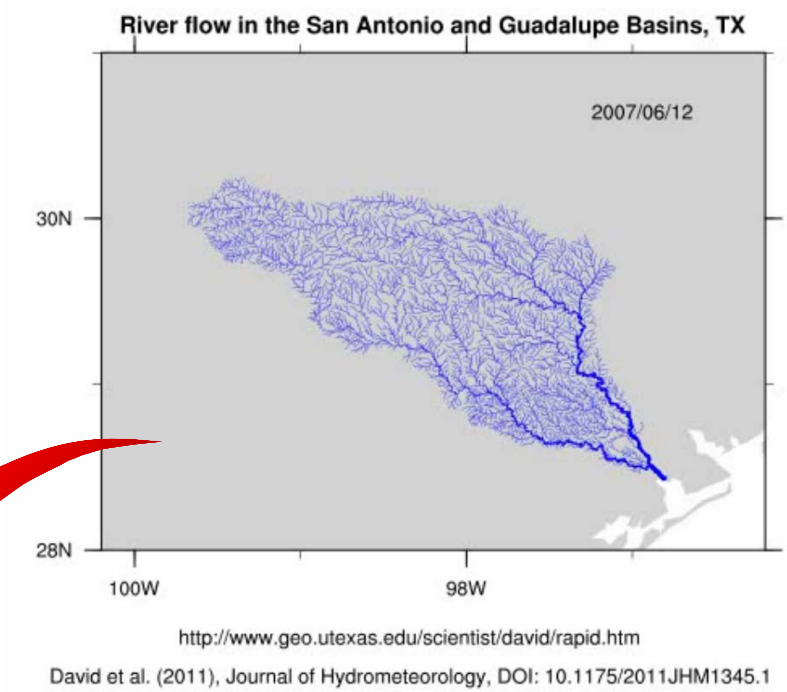
(4) How can we use Schematic Processor for flow and transport modeling in large scale river network?

GIS-based steady-state modeling framework

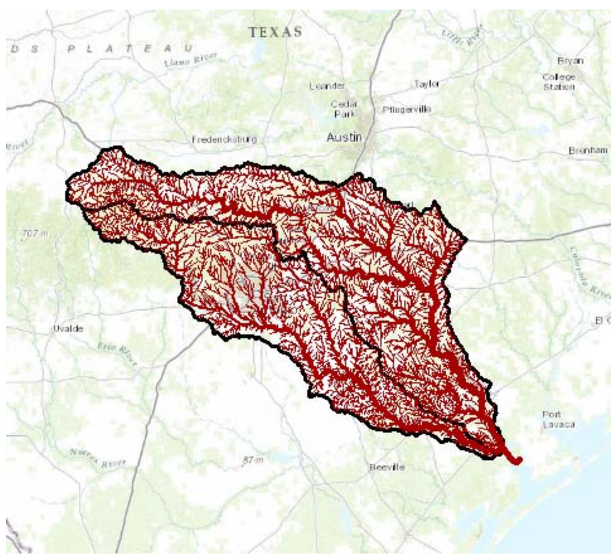


Next step ...





Apply the lumped annual nitrogen load for nitrogen modeling



Add nitrogen modeling to river modeling

River routing model, RAPID

RTWDSS v0.1 About

This prototype real-time modeling system downloads Noah-MP Land Surface model data, which forecast runoff, soil moisture, evapotranspiration, and water table levels given land surface features. These results are then used by a river model called RAPID to forecast stream flows. Model forecasts are visualized as a Web application for students and decision makers to understand the impacts of drought and flood conditions on streamflows. Users can adjust model parameters to predict the impacts of alternative curtailment scenarios or weather forecasts.

Setting up Workflow

Input the following parameters to run the workflow

NLDAS Data Period:

From: 2008-01-01

To: 2008-01-01

Visualization Period:

From: 2008-01-01

To: 2008-01-01

Run » Reset

Job Status

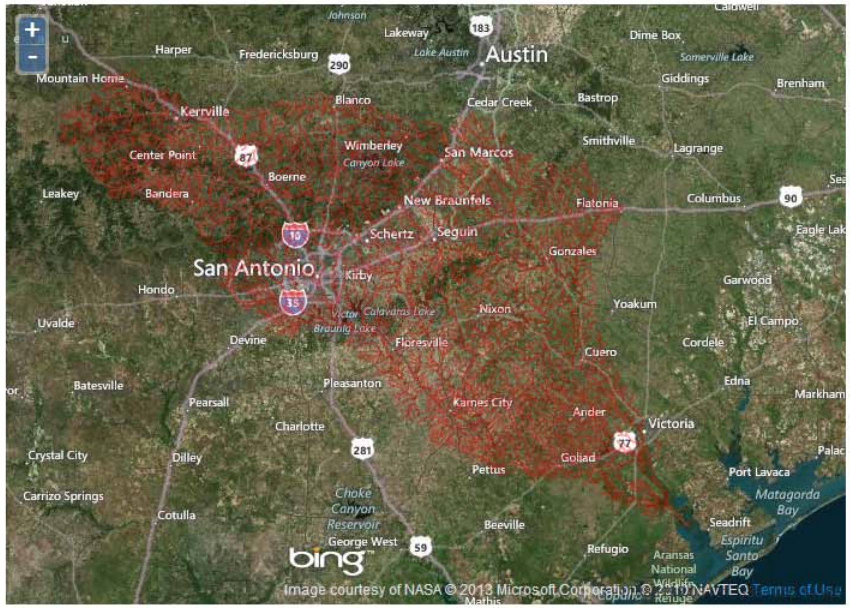
Job Id:

Download NLDAS data:

Execute RAPID:

Generate Viz:

Model Results



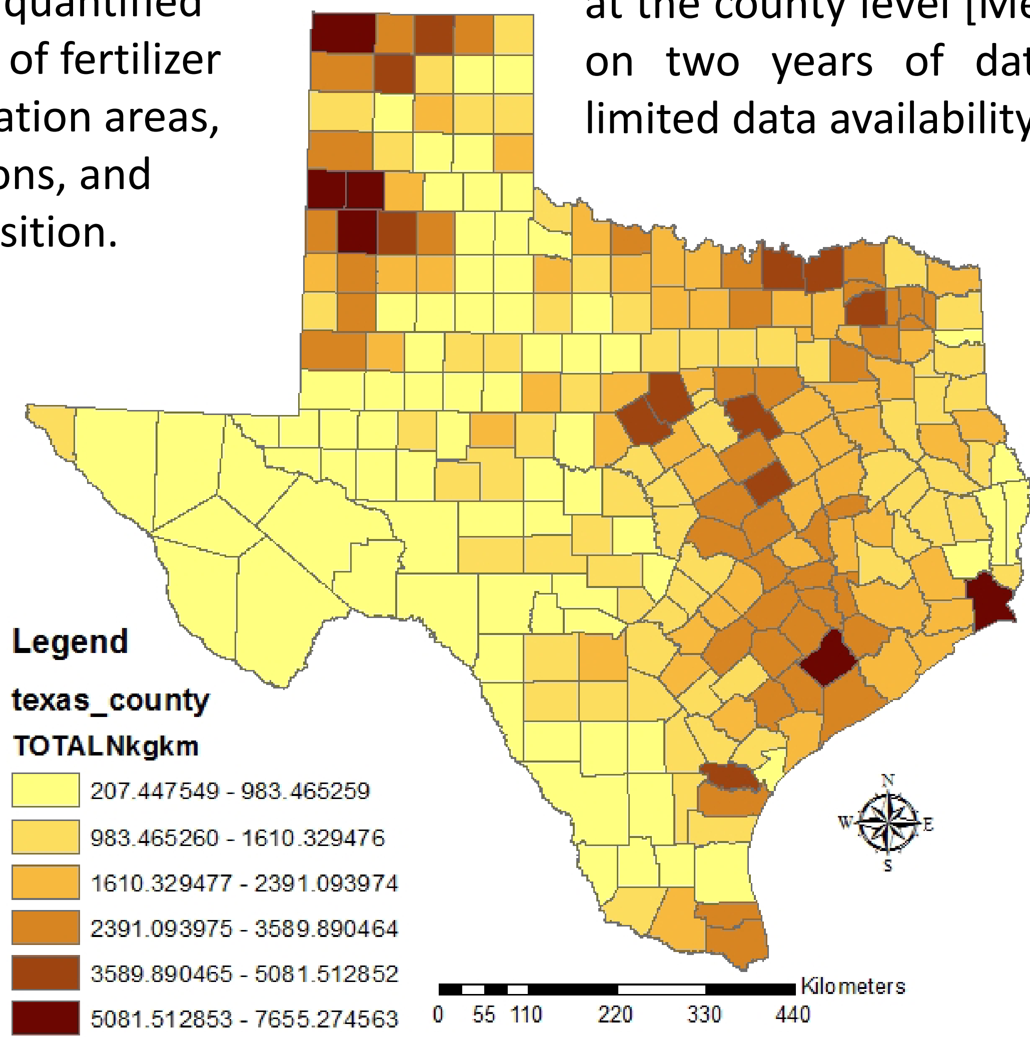
The Noah-MP data are used by a river model called RAPID to forecast stream flows. RAPID uses a matrix-based version of the Muskingum method to compute the flow and volume of water in river networks and is applied to the NHDPlus dataset.

The real time water decision support system is developed in the University of Illinois at Urbana-Champaign

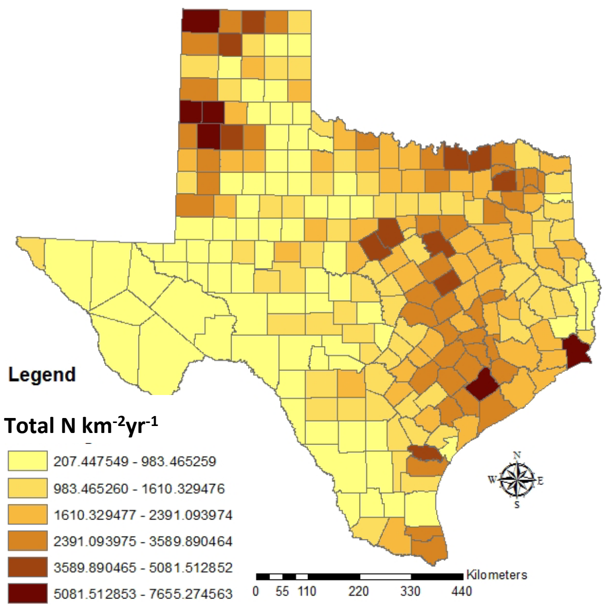
Texas Anthropogenic Nitrogen budget

Sources and inputs of nitrogen within Texas were quantified based on datasets of fertilizer inputs, crop cultivation areas, livestock populations, and atmospheric deposition.

Nitrogen sources in Texas have been quantified at the county level [Meyer, *2012*] and is based on two years of data (2008-2009) due to limited data availability.

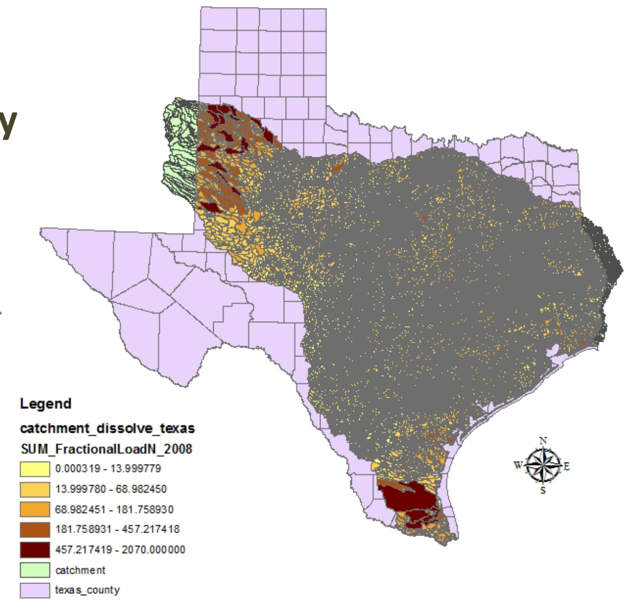


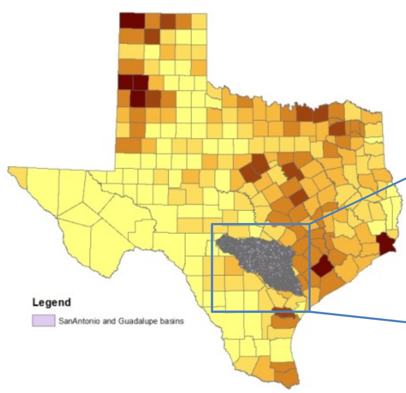
Nitrogen load for every catchment



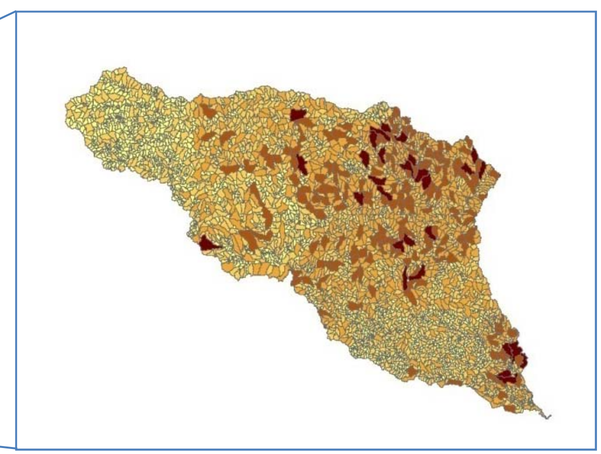
Create catchment resolution from county resolution

66,477 catchments





San Antonio and Guadalupe basins 5,195 catchments

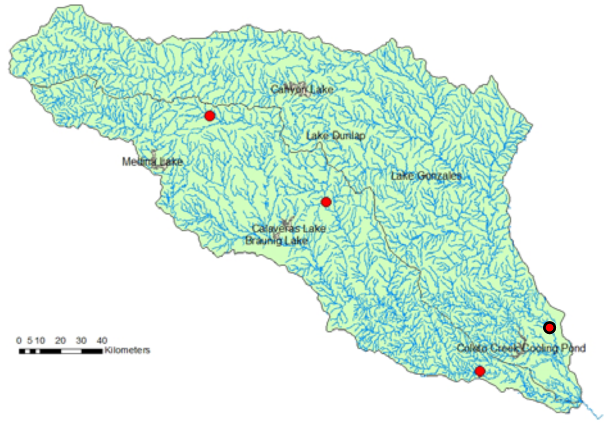


Data Acquisition and Processing

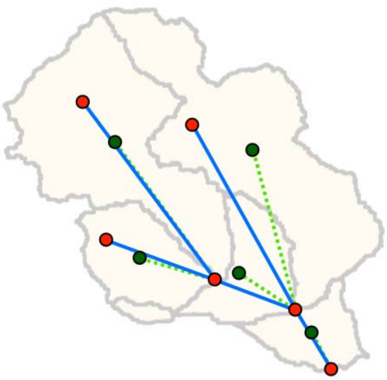
The vector-based river network and reservoir data from the enhanced version of the National Hydrography Dataset (NHDPlus)
http://www.horizon-systems.com/nhdplus/

Point source from EPA:
Discharge Monitoring Report (DMR) Pollutant Loading Tool
http://cfpub.epa.gov/dmr/

Monitored water quality N data:
Texas Commission on Environmental Quality
and Marine Science Institute UT
http://www.tceq.texas.gov/waterquality/clean-rivers/data/samplequery.html



Schematic processor



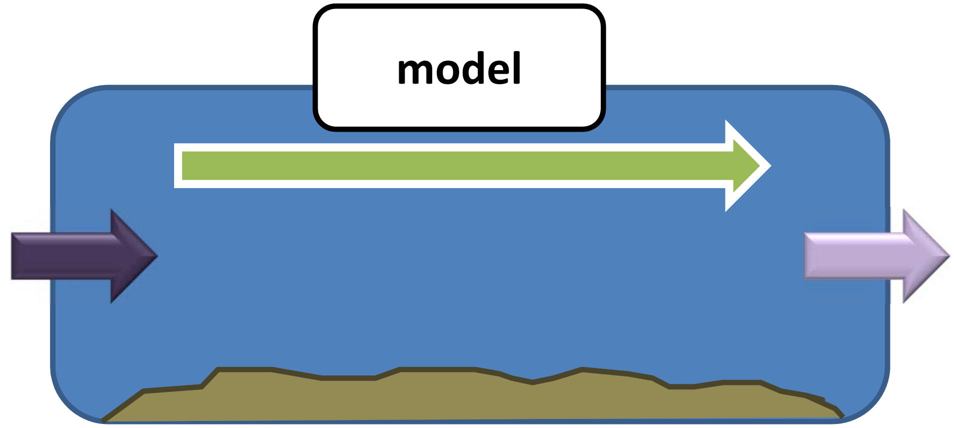
Schematic network

+

$$C_x = C_0 e^{-\lambda t}$$

Equations to simulate hydrologic processes

=

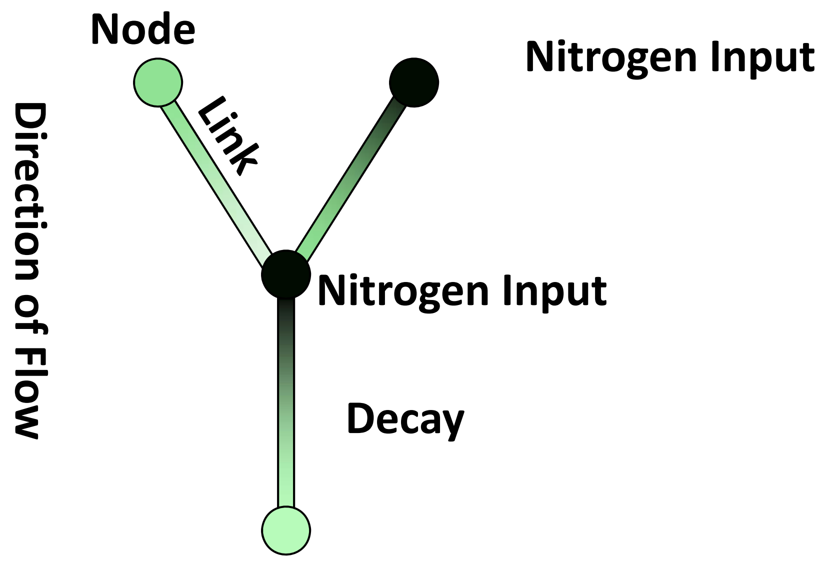


The schematic network represents the hydrologic features as a network of links and nodes. SchemaNodes show hydrologic features, such as catchments or stream junctions. SchemaLinks describe the connections between nodes.

Whiteaker et al., 2006

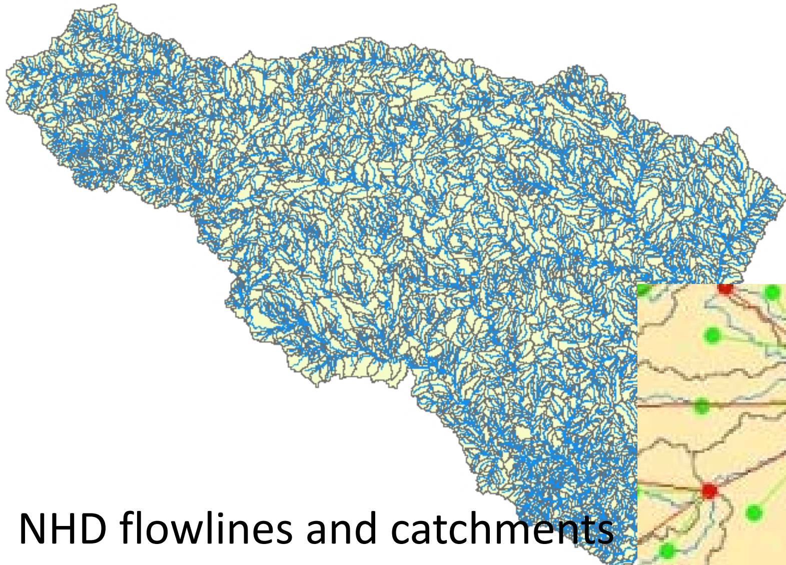
Schematic processor

What if we could move things through the network based on the NHDPlus river network …

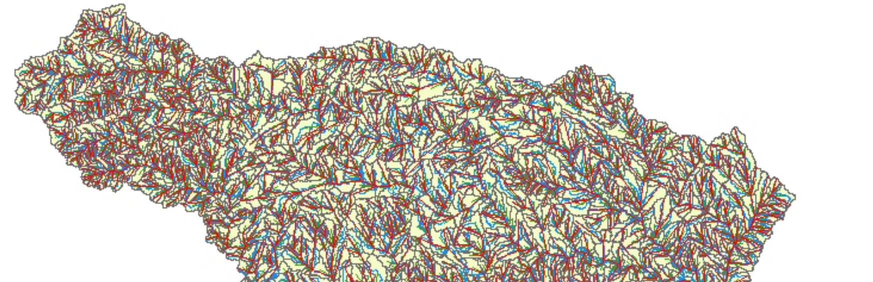


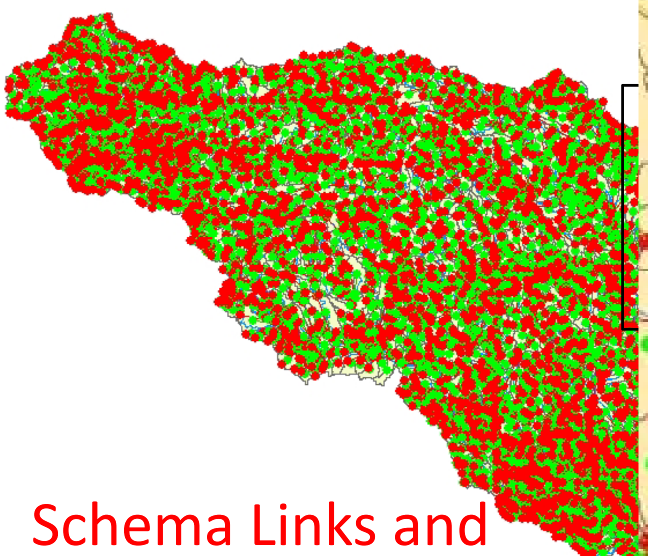
…simulating processes along the way

Schematic network

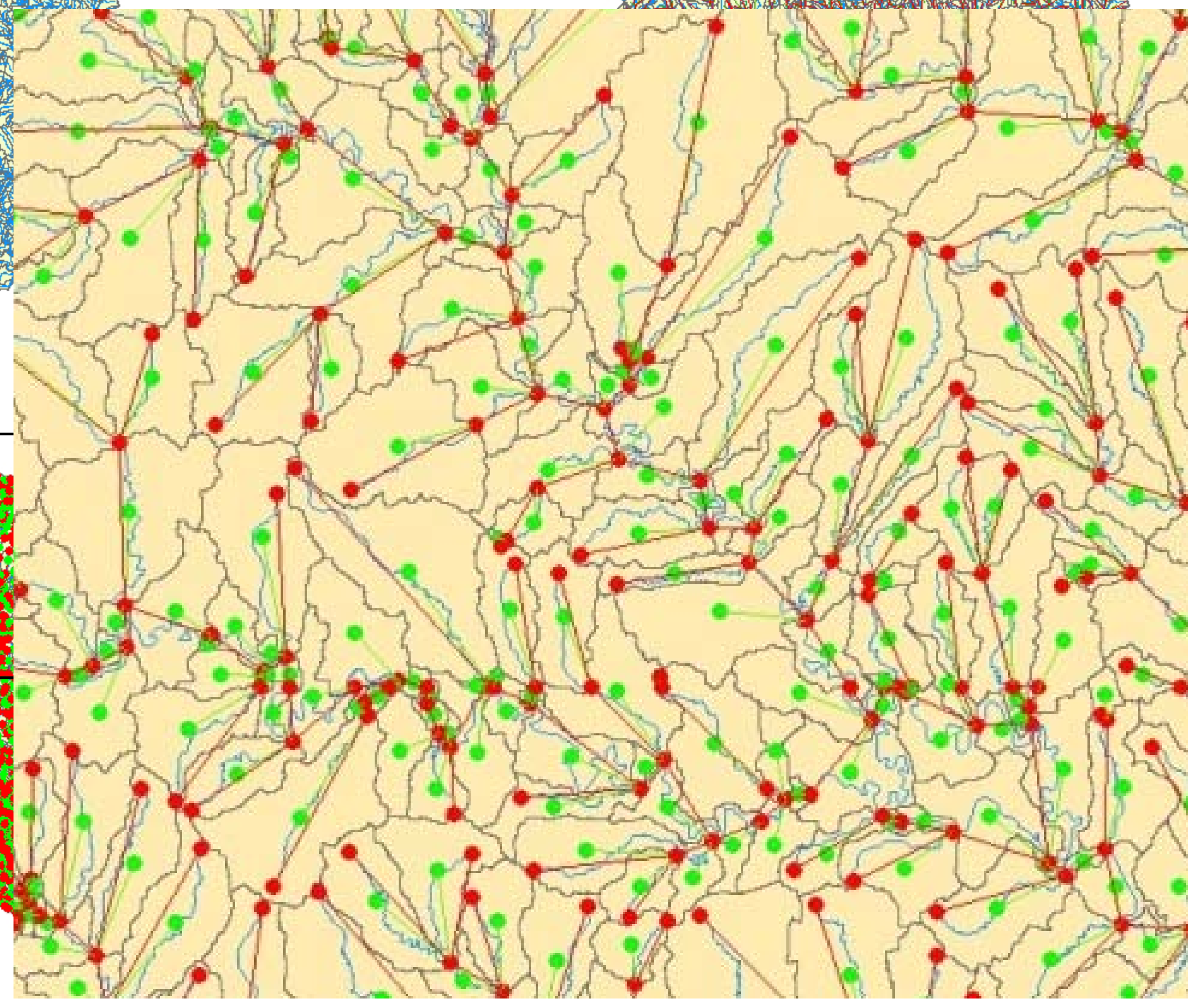


NHD flowlines and catchments





Schema Links and Nodes



First order decay rate

$$C_x = C_0 e^{-\lambda t}$$

C_x= nitrogen load (kg/yr) , C_0= initial load (kg/yr), λ= decay rate (s^{-1})

t= residence time (s)

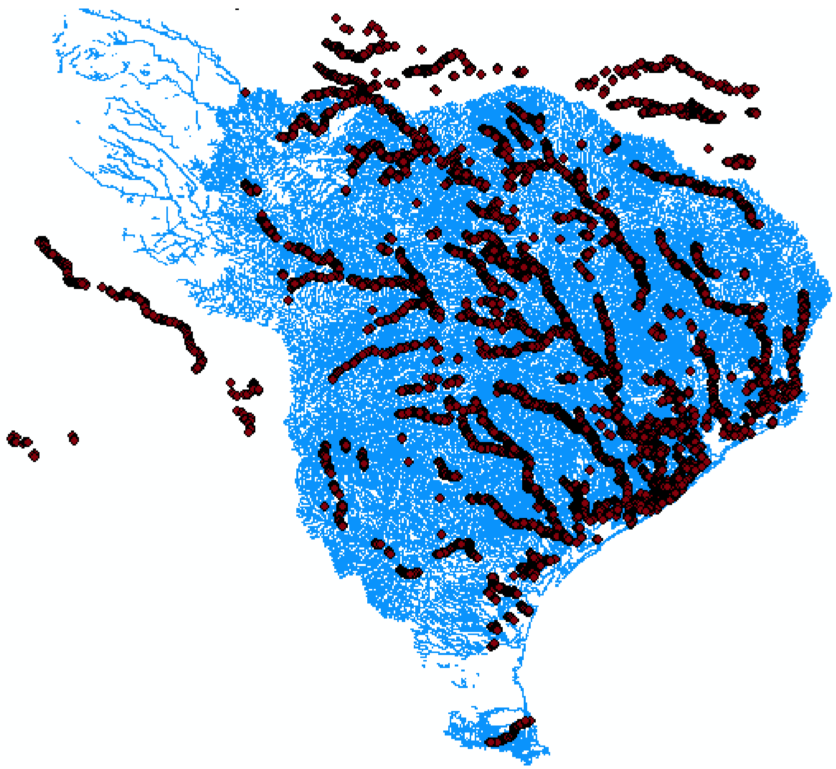
<u>How to calculate the residence time?</u>

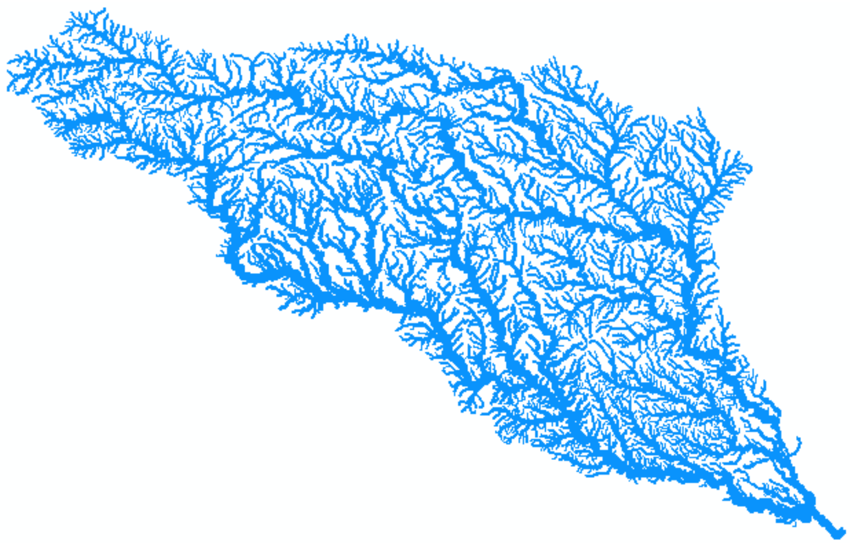
$t = \frac{l}{v}$

l: river length; v: velocity

We can use NHDPlus MAV but it wont consider residence time changes from wet year to dry year!

Measured channel with





Spatial variation of channel width in San Antonio and Guadalupe basins

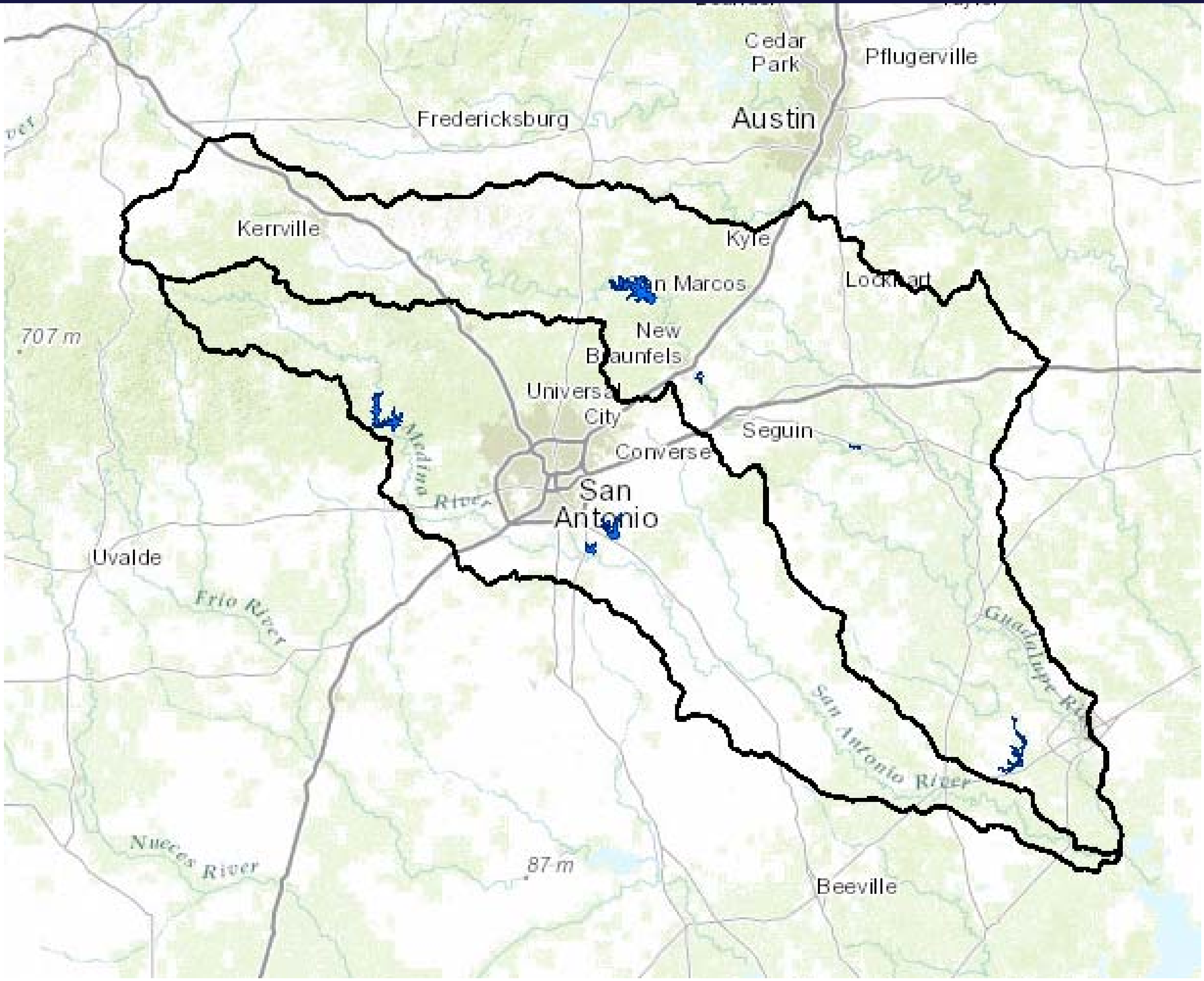
To model nitrogen transport we need hydraulic parameters: width, velocity, travel time. Estimate width of river reaches for San Antonio and Guadalupe basins based on measured values by **Brian Kiel**.

Leopold law

Width = a * (Drainage Area)^b

Total drainage area is available from NHDPlus v.2

Reservoirs and lakes in San Antonio and Guadalupe



Load reduction on lakes and reservoirs

N_{rem}=R x N_{in}

N_{in} is an estimate of N input to lake and reservoir surface waters

R is an estimate of the fraction of N retained within lakes and reservoirs

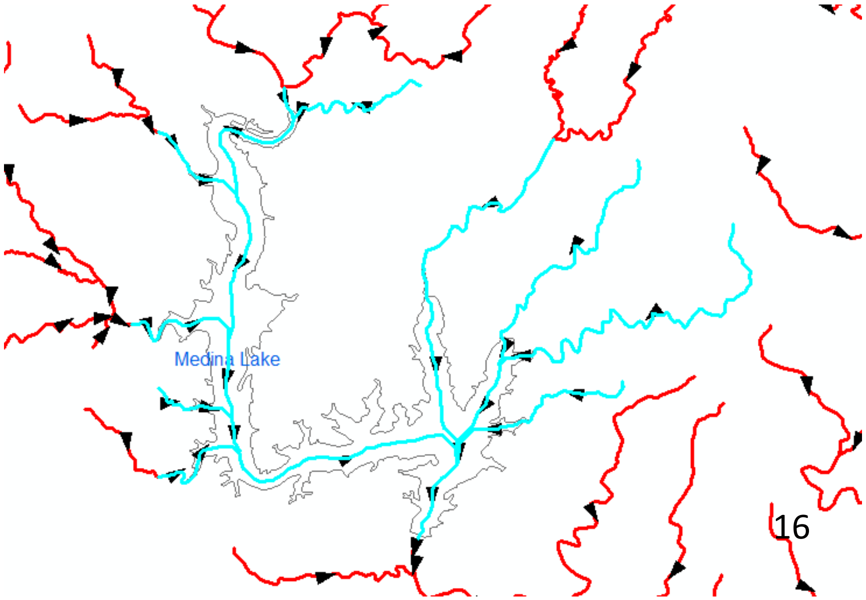
$$R = 1 - \exp\frac{-V_f}{H_l}$$

V_f= is the apparent settling velocity for N (m $year^{-1}$) by lake or reservoir sediments; H_l is the hydraulic load (m year-1) for a given lake, reservoir

$$H_l = \frac{1000 \times Q}{A}$$

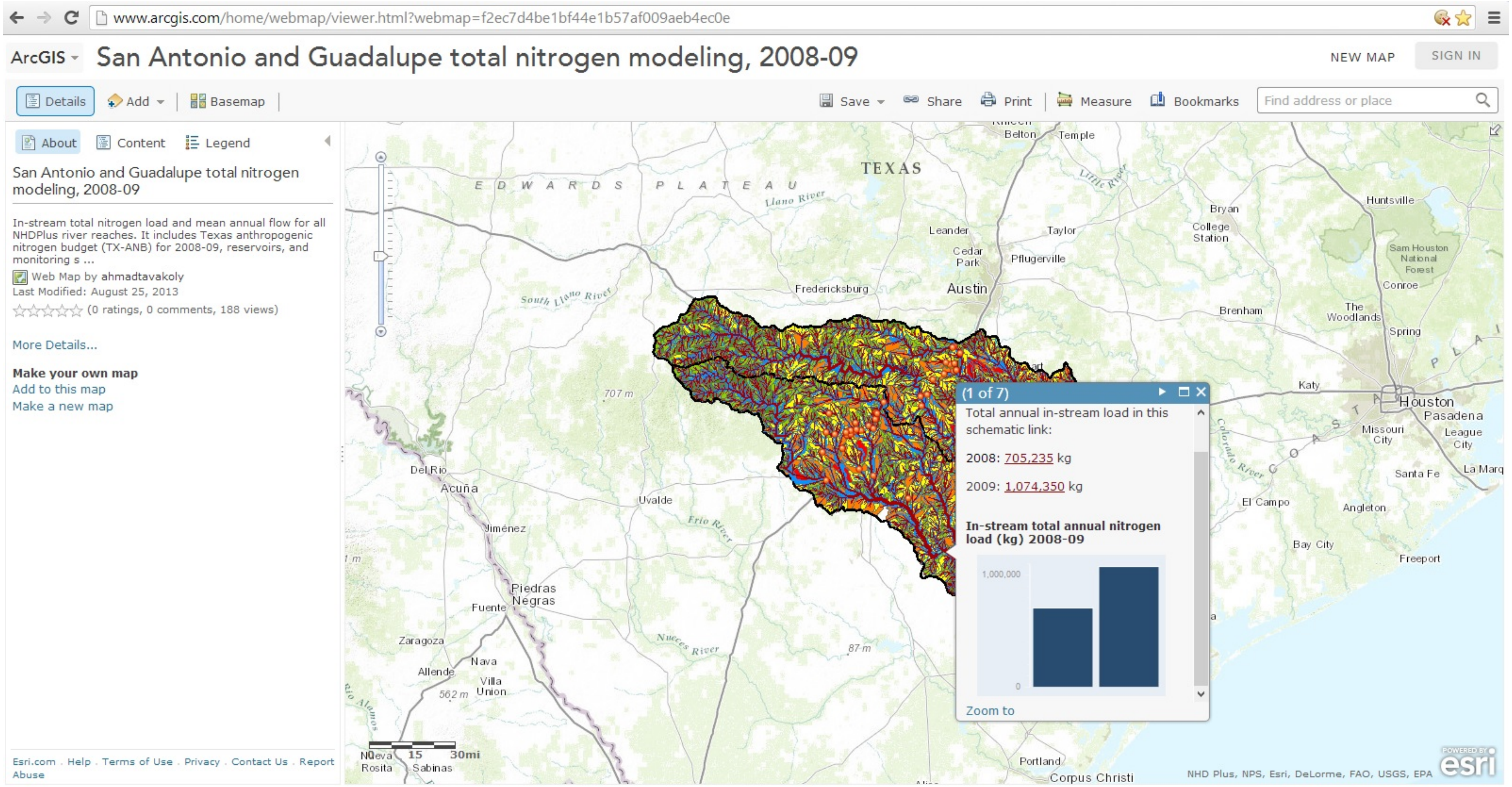
Q is water input to lakes and reservoirs (km^3 $year^{-1}$) and A (km^2) is surface area of individual lakes.

Average V_f: 8.91 (m/yr)



Ref.: Alexander et al. (2002) Harrison et al., (2009)

Results


www.arcgis.com/home/webmap/viewer.html?webmap=f2ec7d4be1bf44e1b57af009aeb4ec0e
ArcGIS
San Antonio and Guadalupe total nitrogen modeling, 2008-09
NEW MAP
SIGN IN
Details
Add
Basemap
Save
Share
Print
Measure
Bookmarks
Find address or place
About
Content
Legend
San Antonio and Guadalupe total nitrogen modeling, 2008-09
In-stream total nitrogen load and mean annual flow for all NHDPlus river reaches. It includes Texas anthropogenic nitrogen budget (TX-ANB) for 2008-09, reservoirs, and monitoring s ...
Web Map by ahmadtavakoly
Last Modified: August 25, 2013
(0 ratings, 0 comments, 188 views)
More Details...
Make your own map
Add to this map
Make a new map
Esri.com . Help . Terms of Use . Privacy . Contact Us . Report Abuse
(1 of 7)
Total annual in-stream load in this schematic link:
2008: 705,235 kg
2009: 1,074,350 kg
In-stream total annual nitrogen load (kg) 2008-09
1,000,000
0
Zoom to
TEXAS
EDWARDS PLATEAU
Austin
Houston
Pasadena
Corpus Christi
Fredericksburg
Uvalde
Del Rio
Acuña
Piedras Negras
NHD Plus, NPS, Esri, DeLorme, FAO, USGS, EPA
esri

Thank you for your attention!!

Question??

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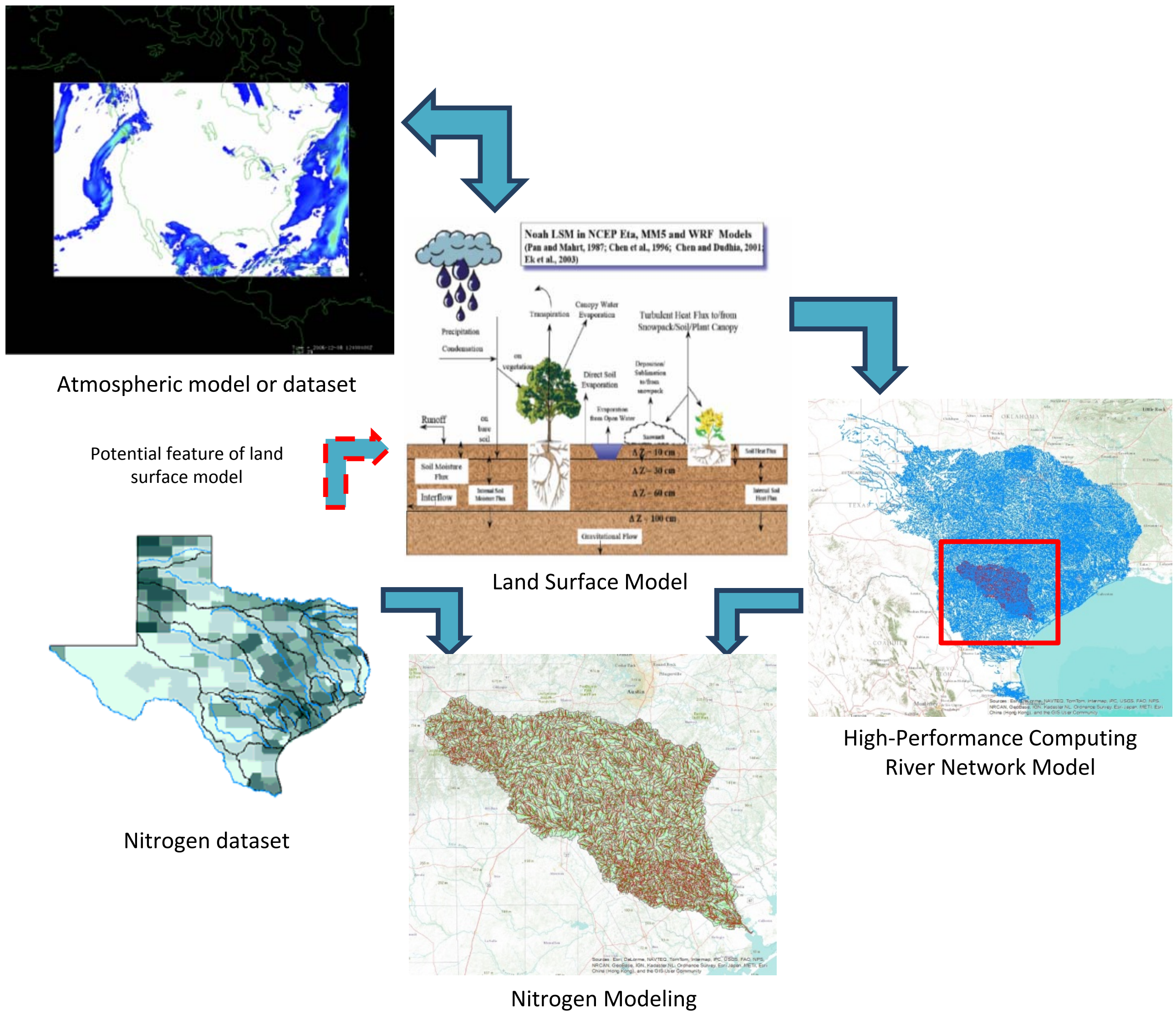
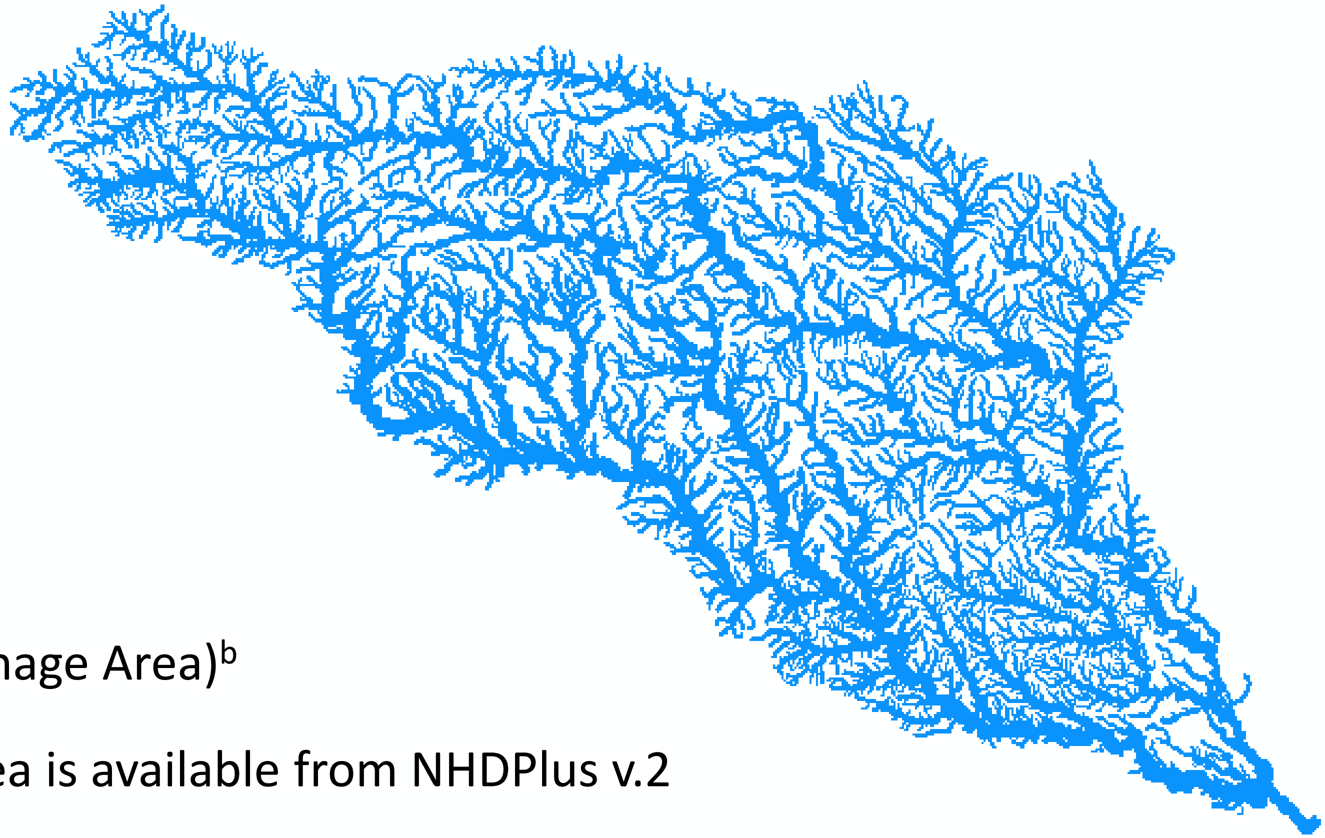
URL: https://sites.google.com/a/utexas.edu/atavakoly/

Integrated river modeling



Calculate channel width using Leopold law



Leopold law

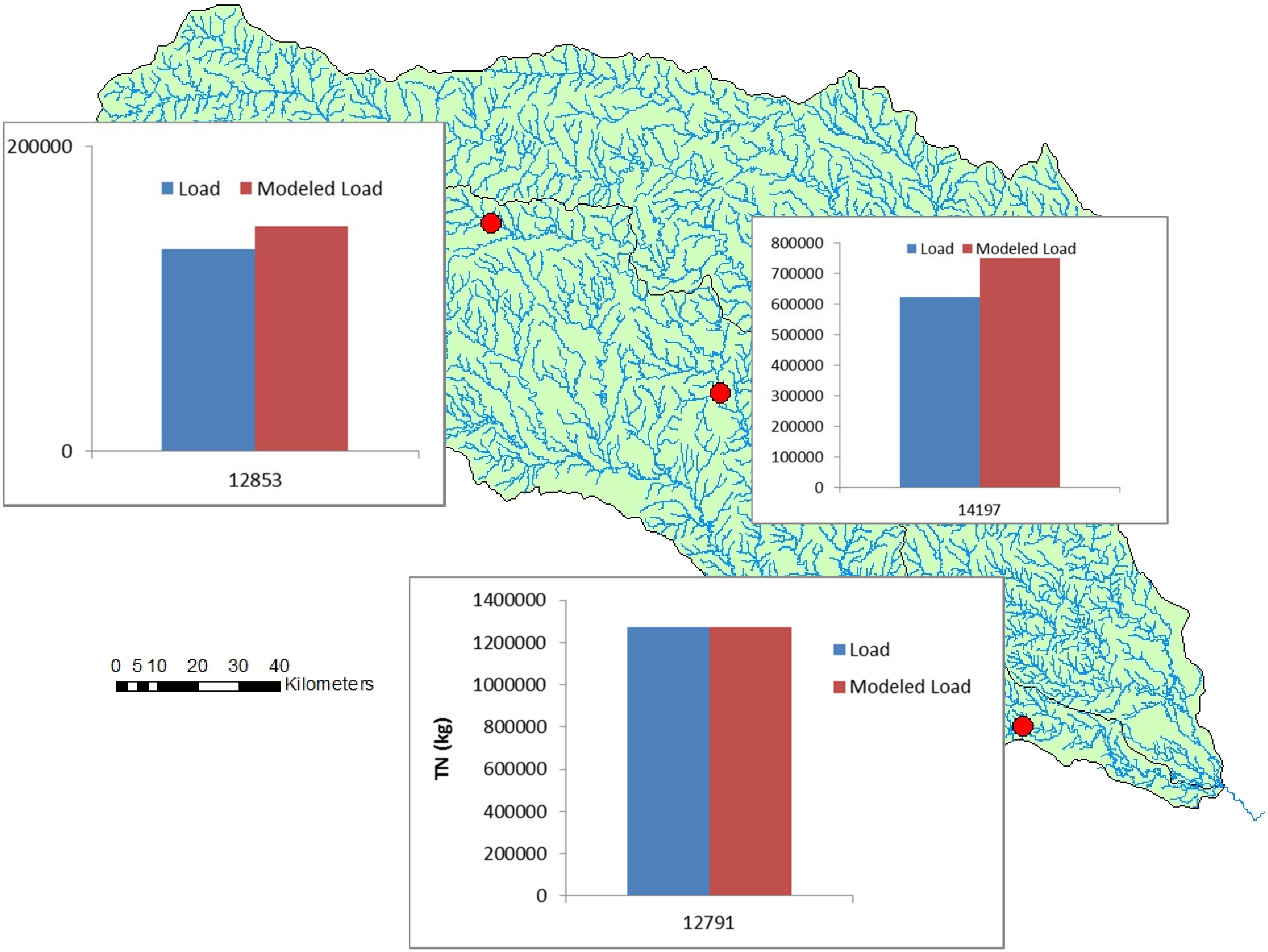
Width = a * (Drainage Area)^{b}

Total drainage area is available from NHDPlus v.2

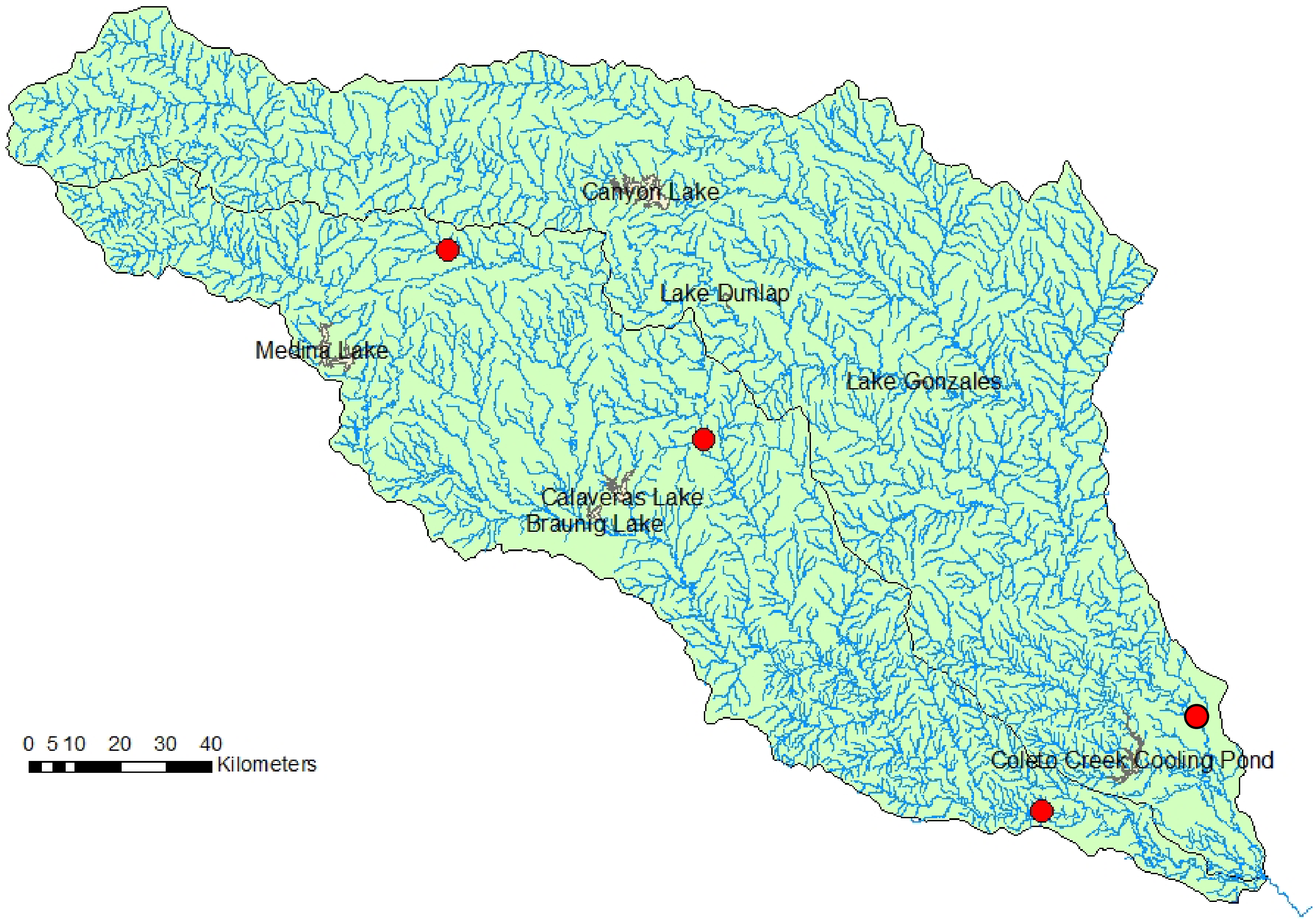
Width = 14.2 * (Drainage Area)$^{0.1}$

Once we have channel width we can calculate velocity using manning equation

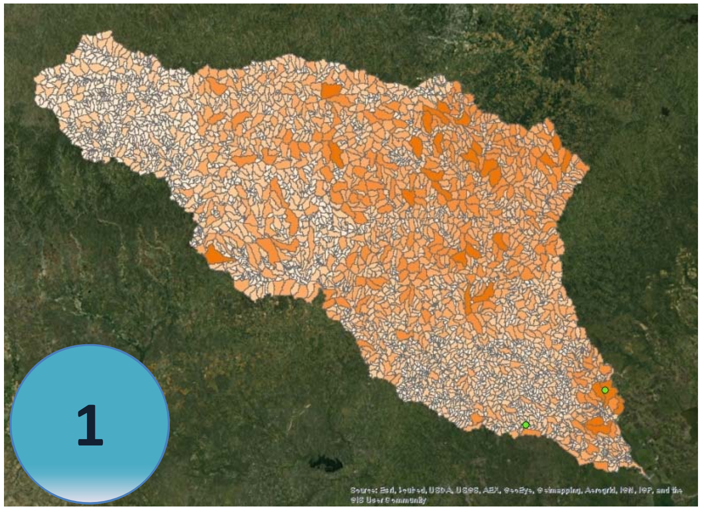
Calibration results



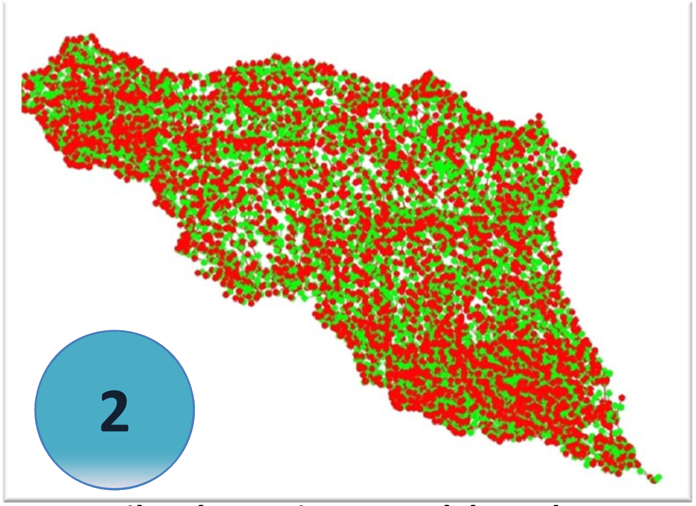
Stations


Canyon Lake
Lake Dunlap
Medina Lake
Lake Gonzales
Calaveras Lake
Braunig Lake
Coleto Creek Cooling Pond
0 5 10 20 30 40
Kilometers

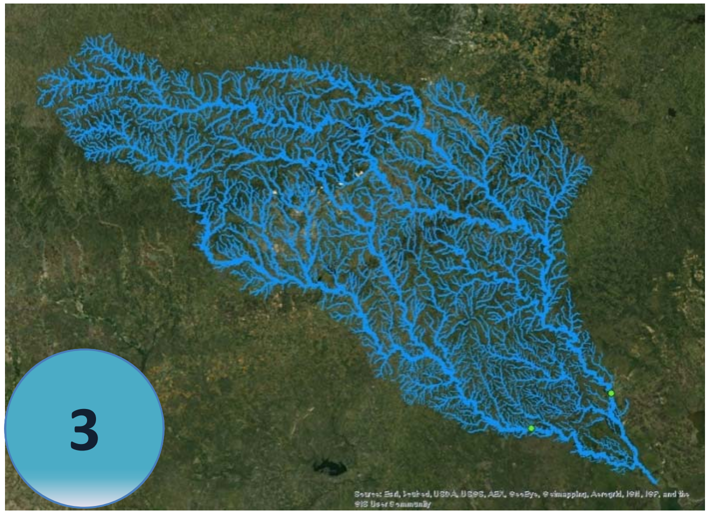
GIS modeling framework



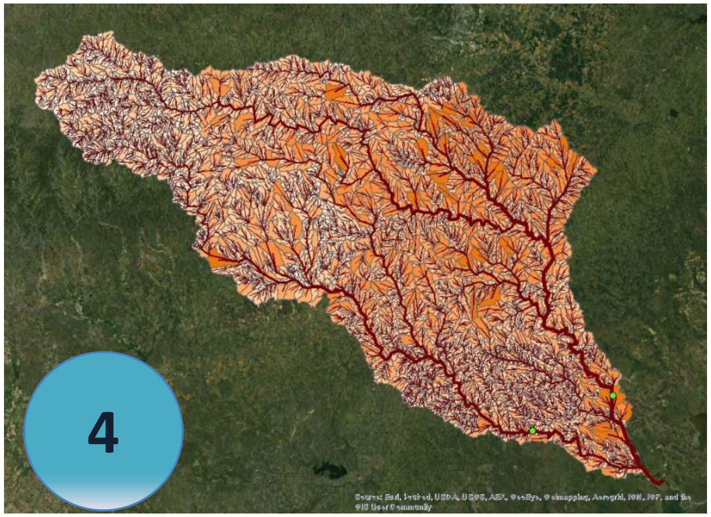
Created GIS database in
catchment scale



Built schematic network based on
the NHDPlus dataset



RAPID mean annual velocity



TN modeling using Schematic Processor

Tavakoly et al., AGU Fall meeting 2012