Use of SWAT for Urban Water Management Projects in Texas

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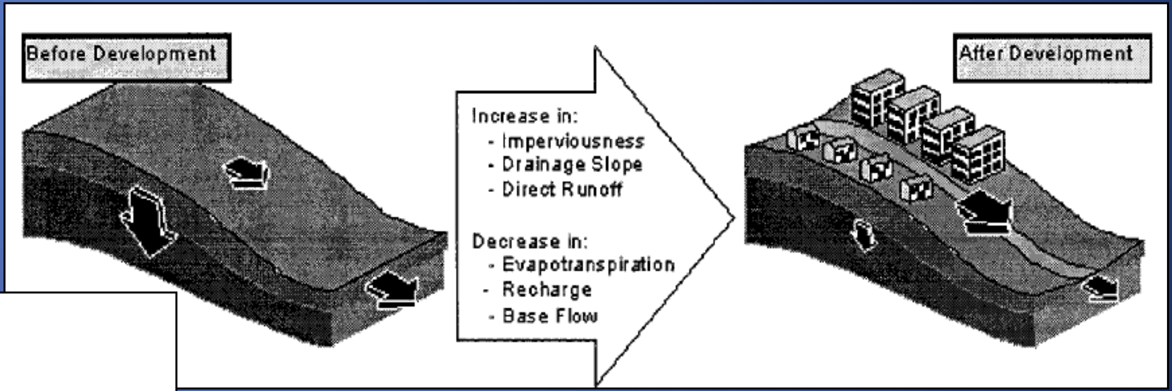
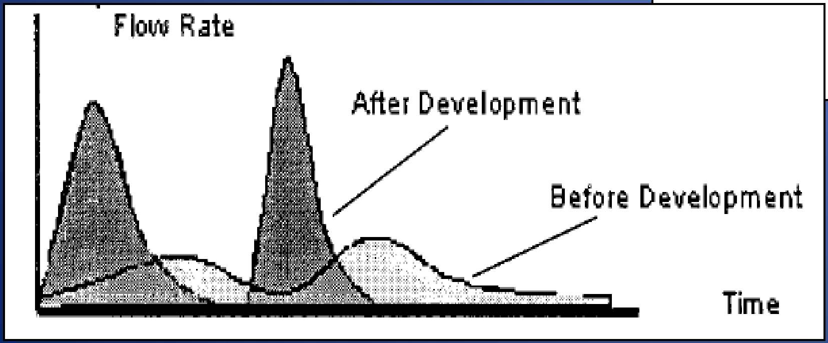
Presentation Outline

- Modeling of Urban Watersheds and Stormwater Best Management Practices (BMPs)
- Trinity River Basin Environmental Restoration Initiative
- The North Central Texas Council of Governments (NCTCOG)
- Cities and Real Estate Developments

Urban Watershed

- Urbanization generally results in increased impervious cover incurring increase in runoff and decrease in baseflow
- Stream flow responses become flashy (shorter duration and higher peaks)
- Urban Non-Point Sources (NPS) pollutants (TSS, nutrients, metals, pathogens, etc)

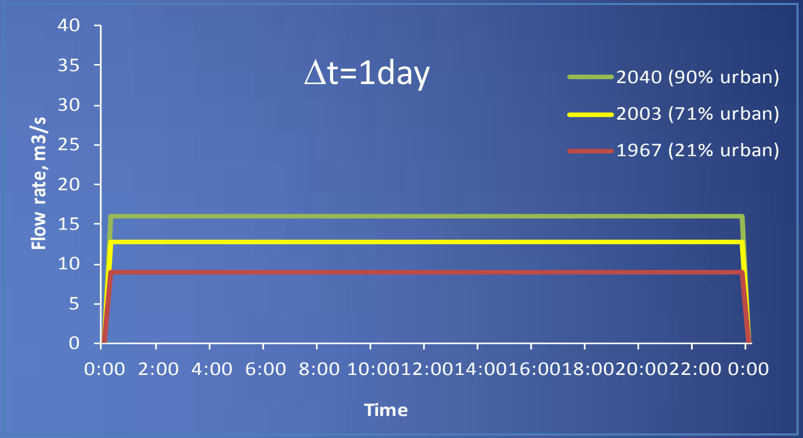


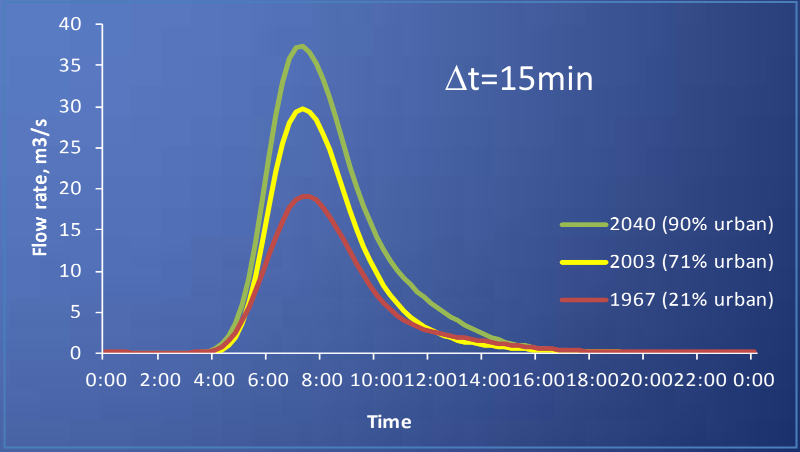


(Roesner et al., 2001)

SWAT limitations in modeling urban watersheds

- Daily simulation may not be sufficient to capture the impact of flashy storms
- Hourly runoff/streamflow simulation is available but is limited in application
- Sub-hourly time interval is ideal for simulating first flush of urban runoff
- Urban BMPs that have various inlet/outlet controls are not available (e.g., sand filter, wet pond, retention-irrigation, detention pond)





Predicted stream flow based on pre-development, current, and projected land uses for the Walnut Creek Watershed in Austin, Texas

SWAT algorithms for urban modeling

Flow models

- ✓ Reconstruct SWAT routines for anytime interval simulation
- ✓ Add a gamma distribution Unit hydrograph method
- ✓ Overland flow, stream flow, ponds, reservoirs, and point sources routed at any time interval
- ➢ SWAT interface development

Erosion models

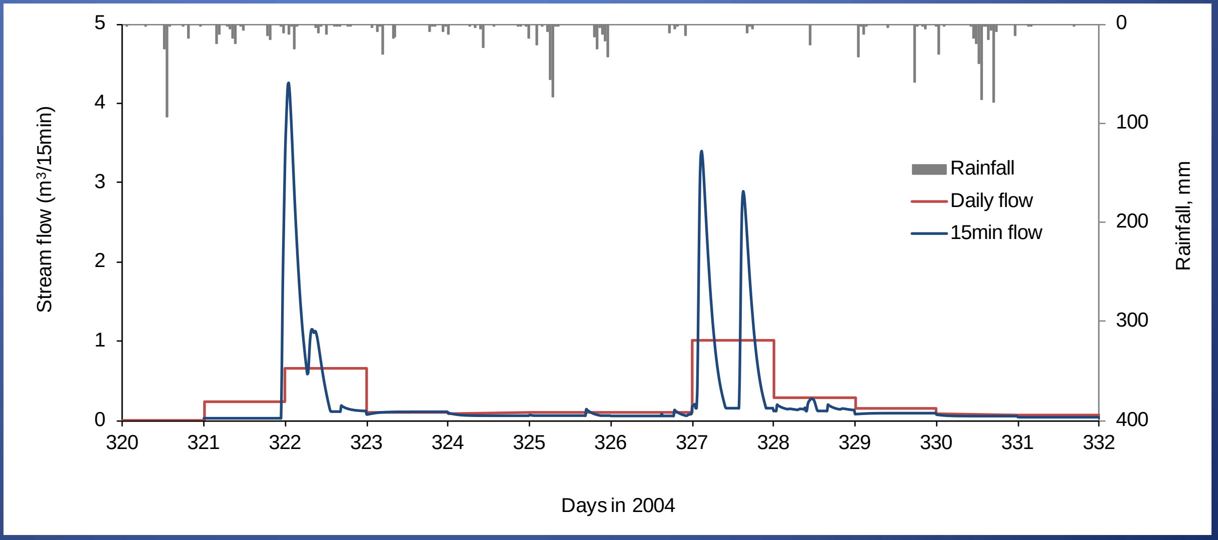
- ✓ Splash erosion model adapted from EUROSEM
- ✓ Overland flow erosion adapted from ANSWERS model
- ✓ Yang model and Brownlie model for instream erosion
- ✓ Test and validation
- ➢ SWAT interface development

BMP models

- ➢ Algorithms for urban BMPs are being developed
- ✓ Sedimentation-filtration
- ✓ Retention irrigation
- ✓ Detention ponds
- ➢ Wet ponds
- ➢ SWAT interface development

Development of sub-hourly flow models in SWAT

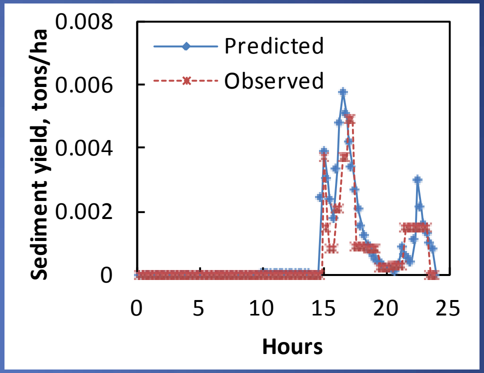
- Sub-hourly flow model
  - Surface runoff is estimated every time step
    - The Green & Ampt equation
    - A triangular shape Unit Hydrograph (UH) method or a Gamma distribution UH method
    - Urban runoff from impervious cover is routed separately from non-urban runoff
  - Stream flow, ponds, reservoirs, and point sources are also simulated at any subdaily time interval
  - Baseflow and evapotranspiration are estimated daily, then distributed to each time step



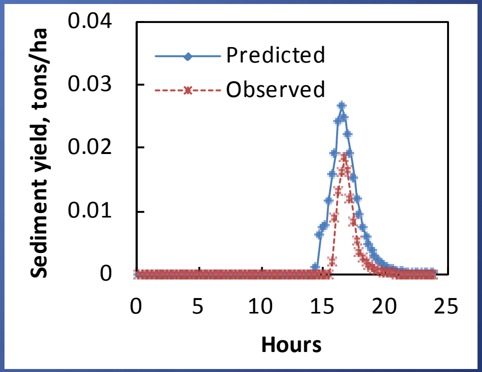
Predicted 15min flow vs. daily flow at the LGA watershed in Austin, Texas

Development of sub-hourly erosion and sediment transport models

- The Modified USLE equation in SWAT was replaced by a set of physically based erosion models for subdaily upland erosion and sediment transport
- The new models include:
  - Splash erosion based on the kinetic energy in rain drops
  - Overland flow erosion with consideration of rill and interill processes
  - Addition of Yang model and Brownlie model for instream sediment routing



October 21, 2002 (NSE=0.58, R^2=0.72)



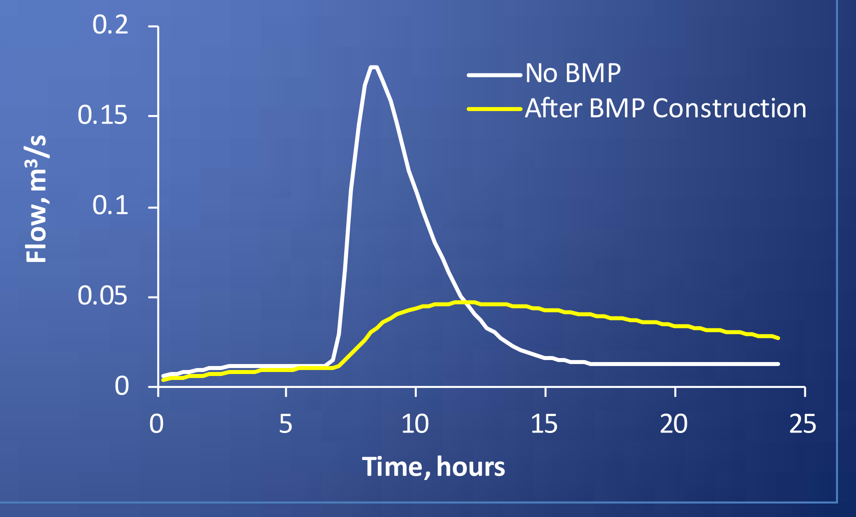
March 8, 2001 (NSE=0.08, R^2=0.85)

15min sediment at the Riesel Y2 Watershed

Models for urban BMPs

- Urban structural BMPs with innovative technology are widely used in urban areas of the United States; however the performance of BMPs as a system of stormwater management has been rarely evaluated at the watershed scale
- Process-based algorithms for urban BMPs were developed modeling in SWAT which will be used as a performance evaluation tool for existing BMPs and also a decision supporting tool for policy makers and watershed managers

- Distributed BMPs:
  - Sedimentation-filtration basin
  - Retention-irrigation basin
- In-line BMPs:
  - Detention pond
  - Wet pond



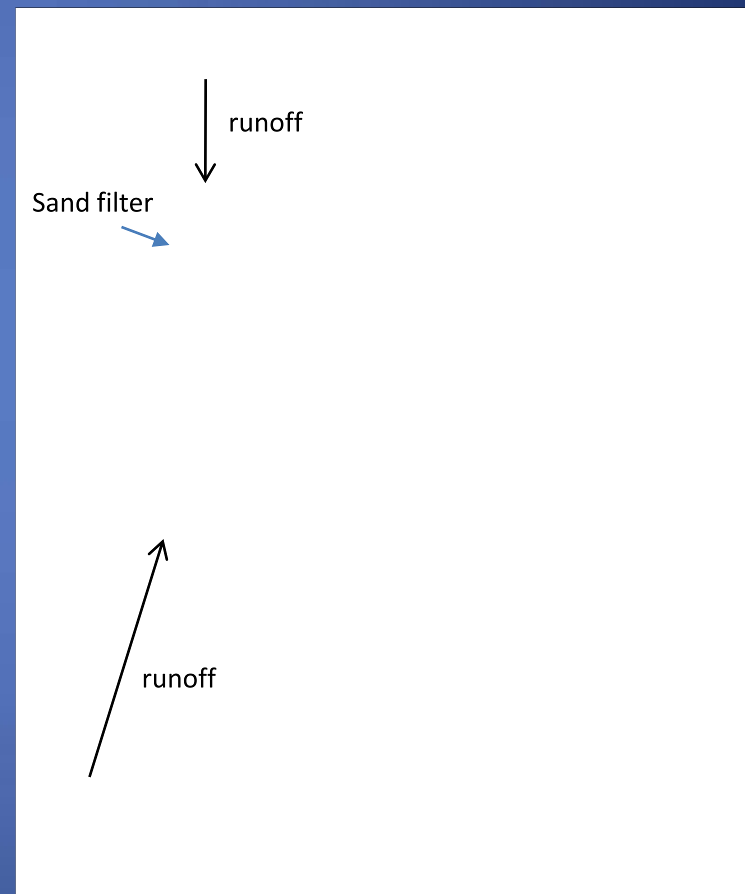
BMP model details

- Distributed BMPs:
  - Located at upland areas (not on the stream network)
  - Multiple BMPs may be modeled in a subbasin
  - A fraction of urban runoff generated in the subbasin drains to each BMP
- In-line BMPs
  - Located within the stream network
  - A combined in-line BMPs can be defined in a subbasin
  - The design size of a BMP can be estimated by the model based on the COA design guideline
- Process based algorithms were developed for simulating BMP processes
- The size of a BMP structure can be estimated by the model based on the watershed geometry and the COA design guideline for a design purpose

Case study: Jollyville Sand Filter

- Located in downtown Austin, Texas
- Filter area: 250 m^2
- Drainage area: 2.8ha
  - 90% impervious cover
  - 84% roads and 11% commercial
- Filter flow is estimated with a modified Green & Ampt equation and the Darcy's Law
- TSS removal is calculated by a Single Isolated Collector model

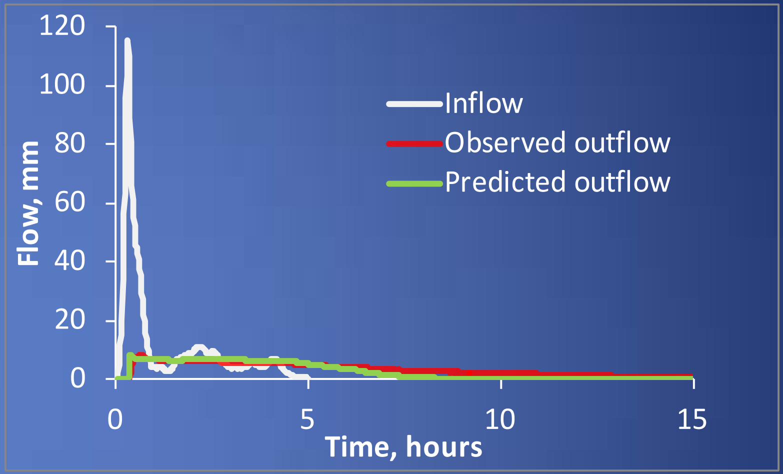
LU Code	Description	Fraction Drainage Area (%)	FCIMP[1] (%)	Curb Density (kg/ha)	Wash-off Coeff (mm^{-1})	Maximum Dirt amount (kg/curb km)
UCOM	Commercial	11	64	0.28	53.67	200
UINS	Office	5	47	0.4	41.29	360
UTRN	Road	84	95	40.28	27.53	340

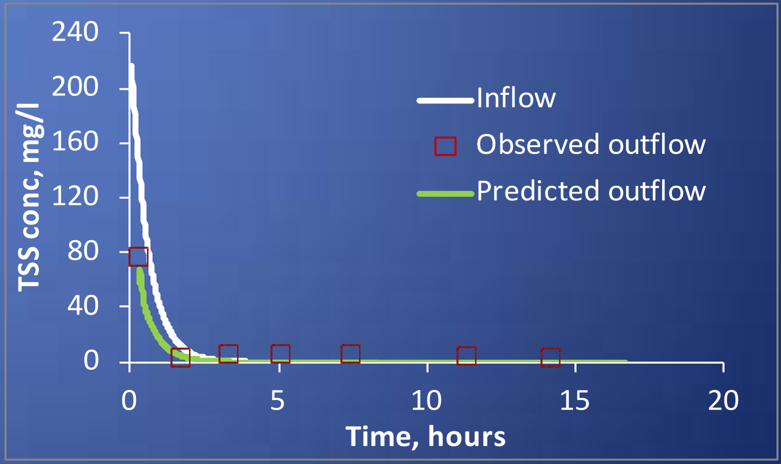


(The Jollyville Sand Filter in Austin, Texas)

Case study (cont.)

- Overall, the model performance is acceptable considering the complexity of flow dynamics caused by overflow weir, sedimentation chamber, and filter
- Calibrated hydraulic conductivity:
  - K_{sat}=200mm/hr for 1995
  - K_{sat}=80mm/hr for 1997
- The result suggests modeling of clogging effects.
- A probabilistic or statistical approach may yield a better result than the deterministic model to predict TSS as observed TSS profile shows no strong correlation with other physical processes





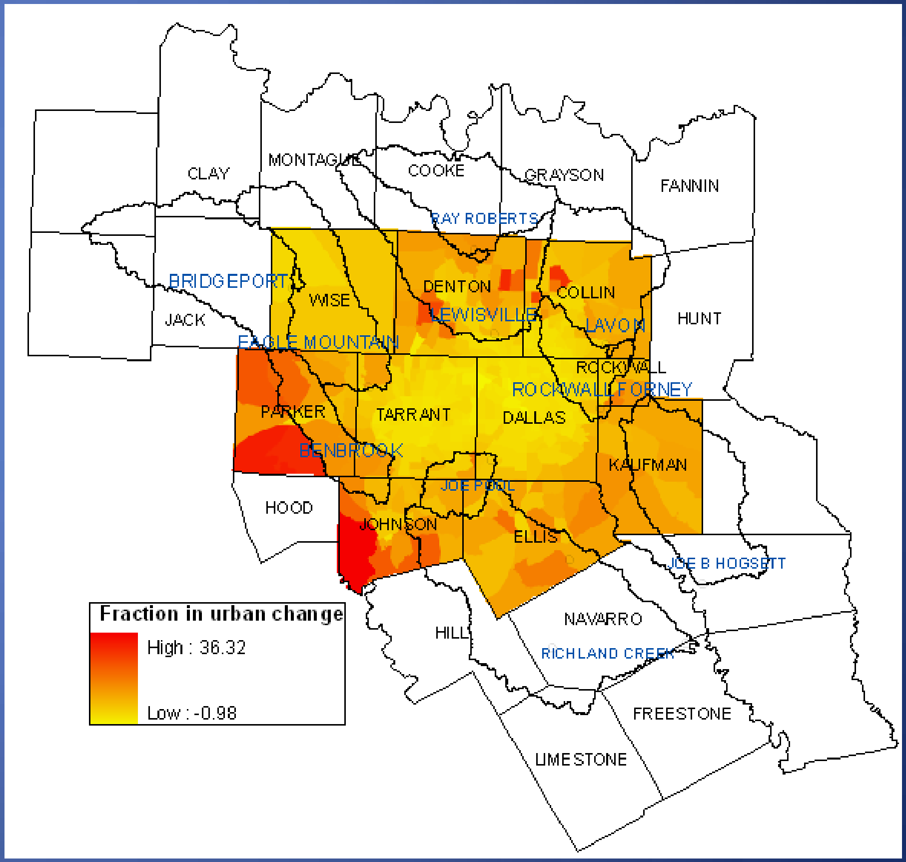
(Filter flow and TSS removal during a storm event on June 11, 1995)

Summary on urban BMPs modelling

- Physical processes such as first flush, bypass flow, and through flow can be explicitly simulated with the sub-hourly urban swat model
- The new SWAT algorithms developed for modelling urban processes will be used as a decision supporting tool by the City of Austin and other cities in Texas

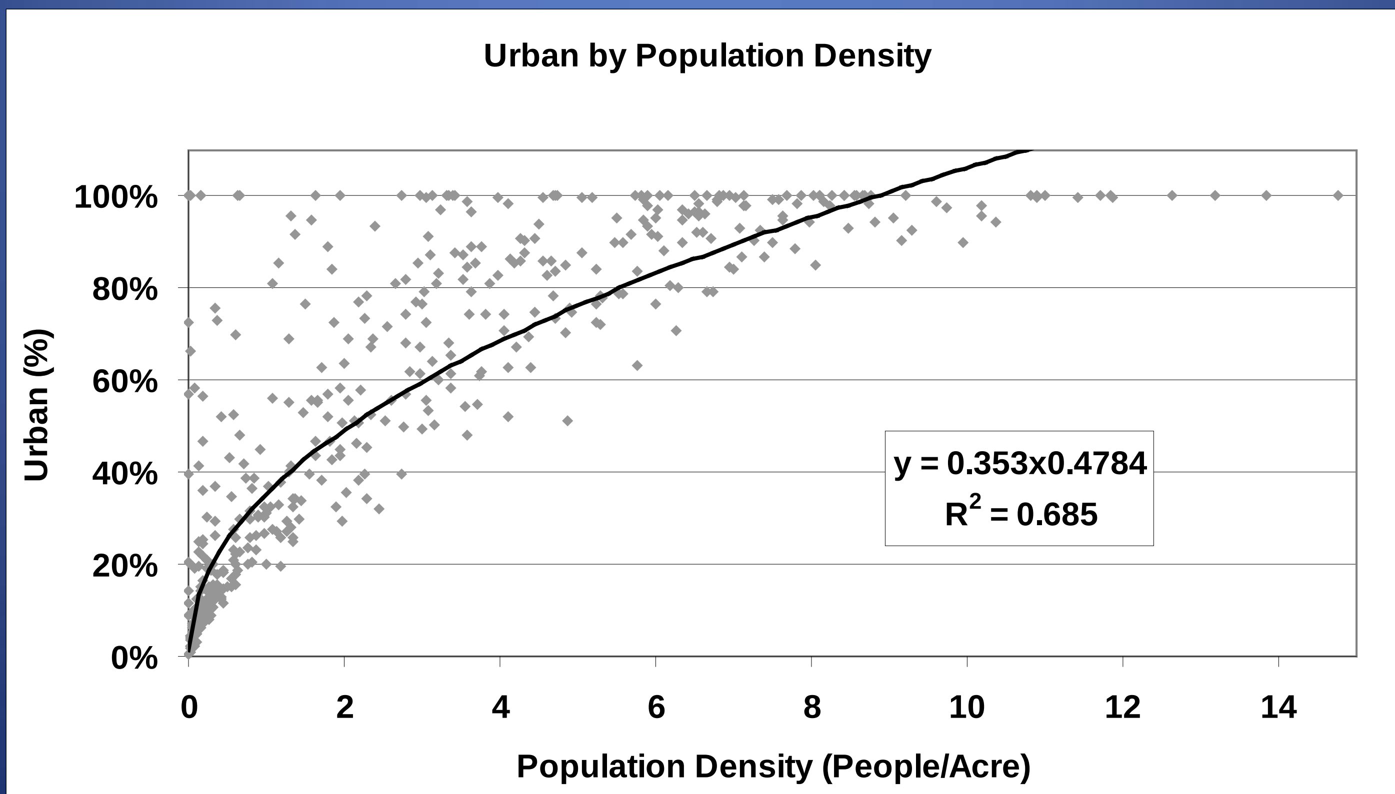
Trinity River Basin Environmental Restoration Initiative

- The most populated river basin in Texas
- There are twelve major reservoirs in the Trinity River Basin study area, which drain a total area of about 29,500 km^2 including seven 8-digit watersheds
- Impact of urbanization was accessed based on a population projections for 2000 and 2030
- Other “what if” scenarios
  - Ponds, point sources, grazing



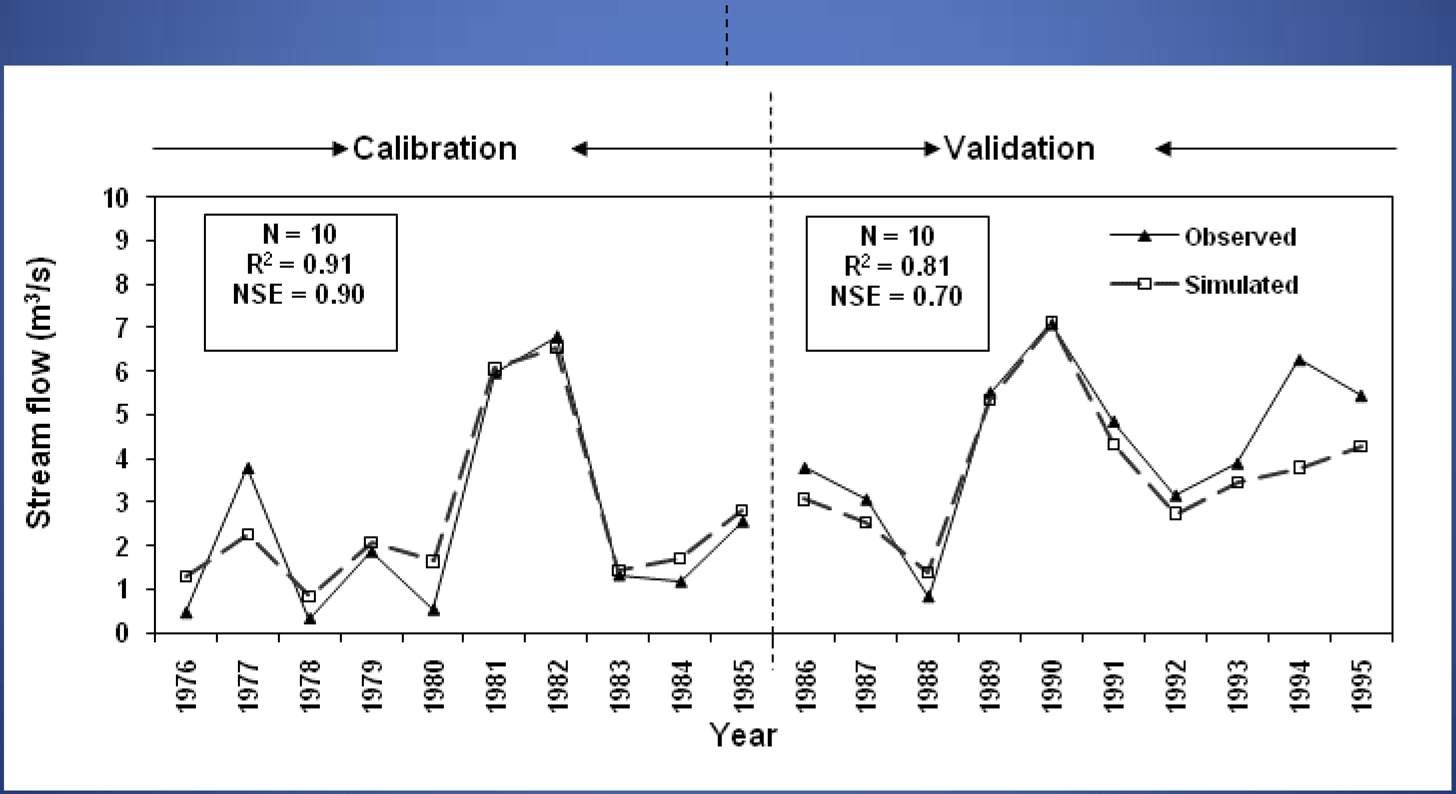
Trinity River Basin Environmental Restoration Initiative

- Relationship between the fraction of urban area and population density, derived from North Central Texas Council of Governments (NCTCOG) population data for 2000 and National Land Cover Data (NLCD) for 2001



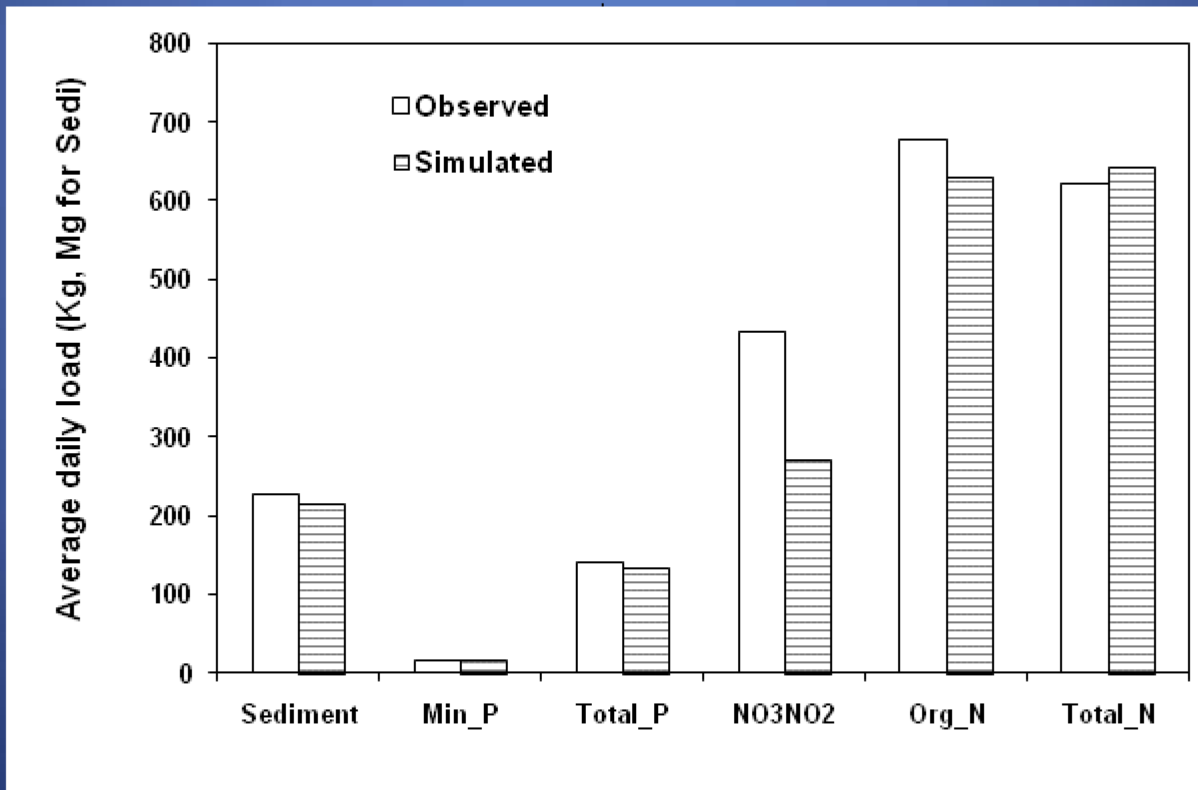
Trinity River Basin Environmental Restoration Initiative

- Monthly stream flow calibrated at the Lake Lavon



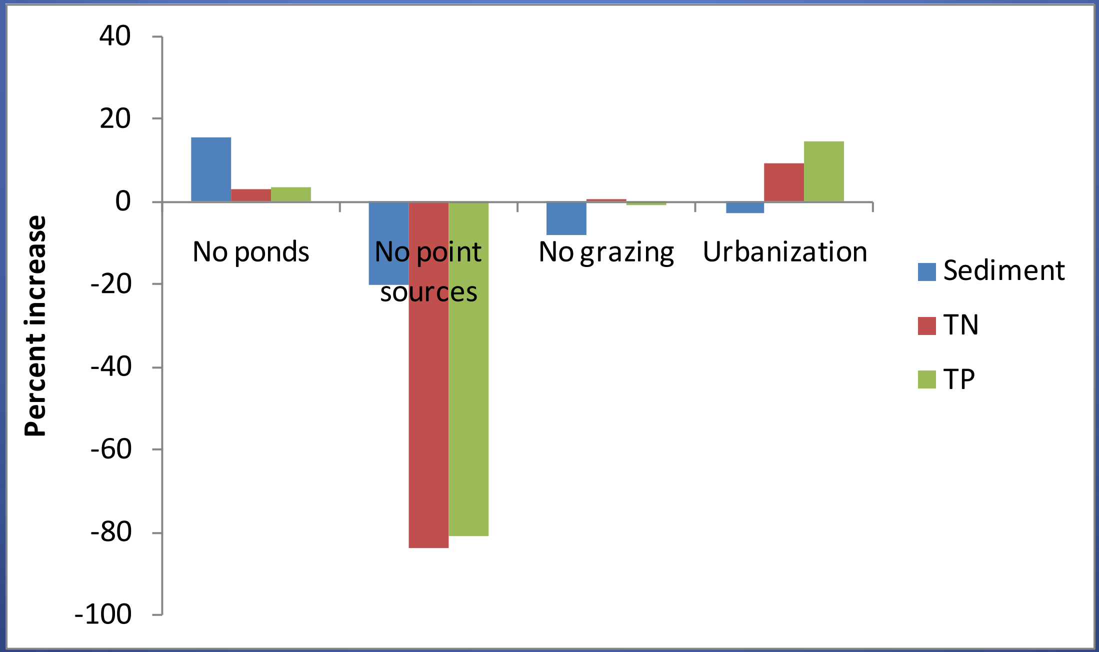
Trinity River Basin Environmental Restoration Initiative

- Average daily loads for sediment, nitrogen, and phosphorus at the Lavon Reservoir watershed (1981-1995)



Trinity River Basin Environmental Restoration Initiative

- Different scenarios yield different level of impact to sediment and nutrients
- Point sources have the greatest impact among other scenarios in the case of the Lavon Reservoir watershed



(Lavon Reservoir watershed)

Trinity River Basin Environmental Restoration Initiative

	Percentage reduction from baseline scenario									
	Lavon	**Ray Hubbard**	**Ray Roberts**	**Lewisville**	**Joe Pool**	**Bridgeport**	**Benbrook**	**Eagle Mountain**	**Cedar Creek**	**Richland-Chambers**
Sediment										
No ponds	15.70	2.90	19.40	48.30	9.90	9.60	13.10	8.20	16.00	7.50
No range grazing	-7.90	-5.20	-2.90	-37.20	-7.70	-7.60	-16.70	-4.80	-0.30	-1.00
Urban	-2.90	-10.30	1.00	-2.5	-3.60	-1.70	-0.03	31.60	3.40	3.80
No Point Sources	-20.20	-16.70	-0.10	-0.20	-4.40	0.00	0.00	-1.90	-0.20	-0.35
Total Phosphorus										
No ponds	3.70	0.70	6.40	10.00	5.80	8.60	5.80	7.90	6.50	5.80
No range grazing	-0.70	-2.70	-5.00	-9.10	-2.80	-9.70	-3.10	-7.80	-0.02	-5.70
Urban	14.40	3.20	16.60	23.50	37.40	30.70	111	3.30	6.30	-1.05
No Point Sources	-81.00	-90.70	-6.00	-14.40	-1.00	-2.90	-9.30	-1.20	-6.00	-0.25

The North Central Texas Council of Governments (NCTCOG)

- The NCTCOG developed the integrated Storm Water Management (iSWM^{TM}) design ***manual***
- The "Conservation Practices Modeling Guide for SWAT and APEX" has been developed to facilitate simulation of iSWM

Cities and Real Estate Developments

- Projects have recently begun to use SWAT in the design of several “new urbanism” and “low-impact” developments, as well as to assist municipalities in improving stormwater management in their extraterritorial jurisdictions