A GIS tool to Estimate *E. coli* concentration from failing On-Site Sewage Facilities (OSSFs)

by

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Overall Objective

<u>Develop an automated GIS tool</u>

to estimate spatial *E. coli* concentrations in watersheds resulting from failing Onsite Wastewater Treatment Systems (OWTSs).

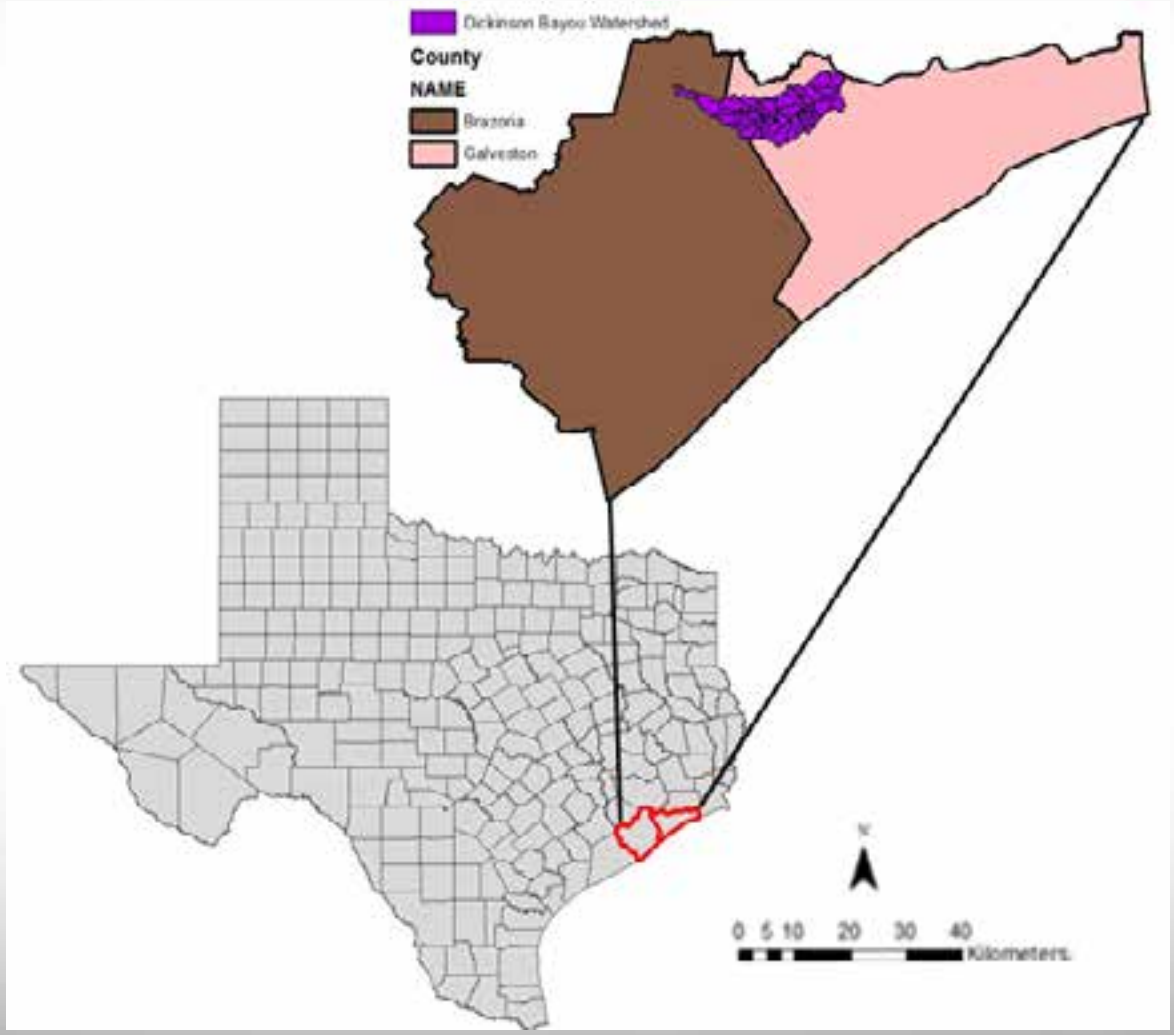
Specific Objectives

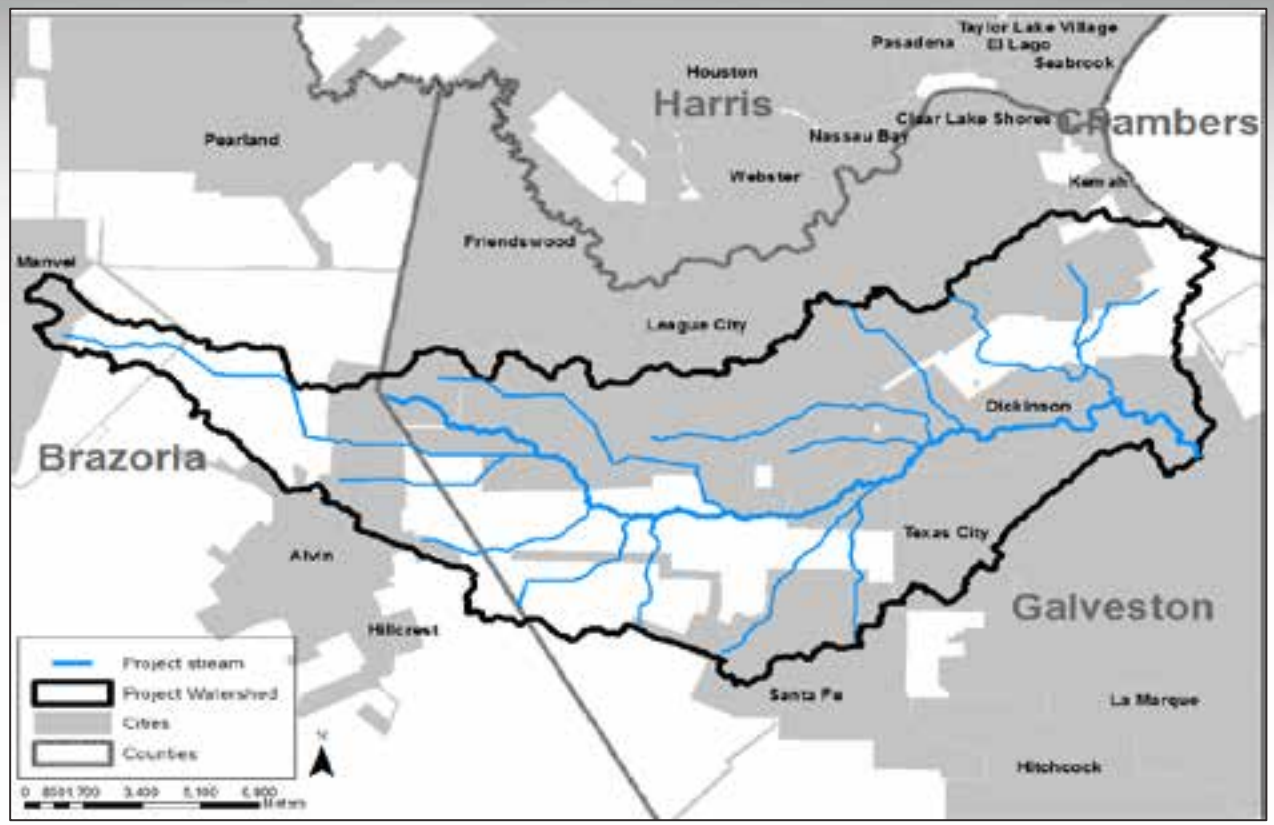
1. Create a rainfall-runoff model using GIS for a watershed based on available data
   - Develop an automated tool in GIS to estimate surface runoff volumes from rainfall
2. Develop a spatial tool in ArcGIS10 to estimate potential accumulated *E. coli* loads
3. Develop a spatial tool in ArcGIS10 to estimate potential accumulated *E. coli* concentrations in the streams

Study Area

Dickinson Bayou Watershed

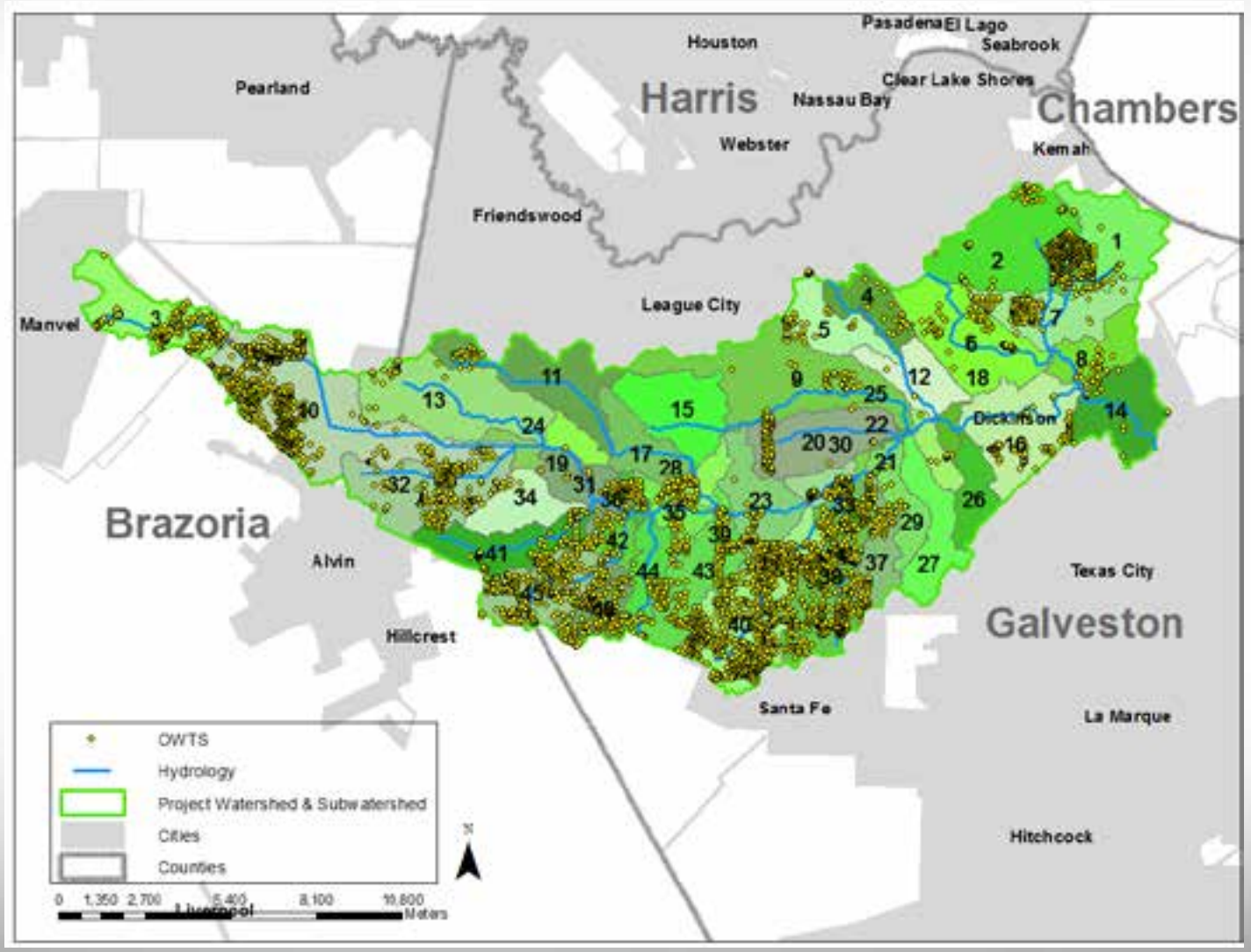
Dickinson Bayou watershed





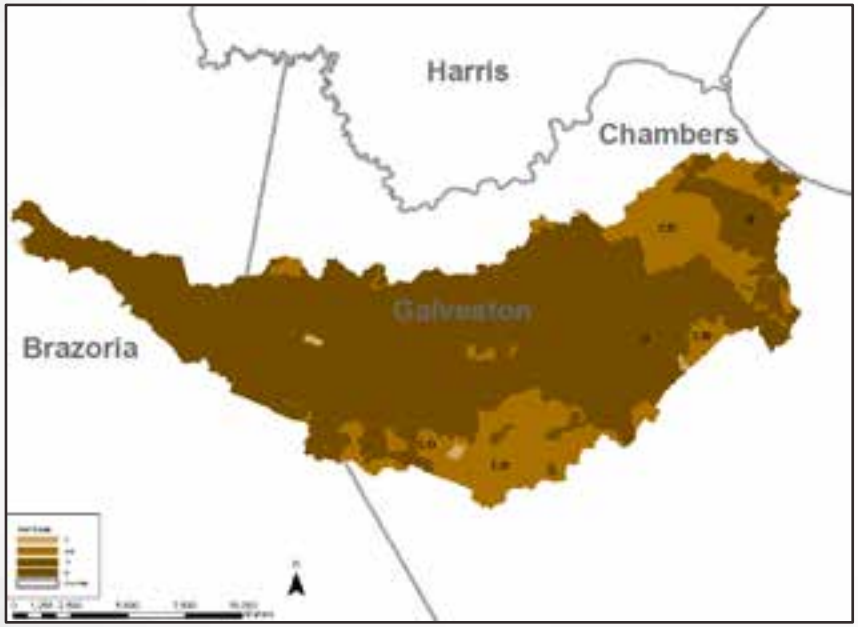
- Listed as impaired, due to bacteria
- Poorly designed OWTS, inappropriate site characterizations
- Length: 38.6 km
- Width: 11.3 km
- Drainage area: 258.2 km^2
- OWTS: 4,565 (3,243 gravity fed and 1,322 ATU)

OWTS locations



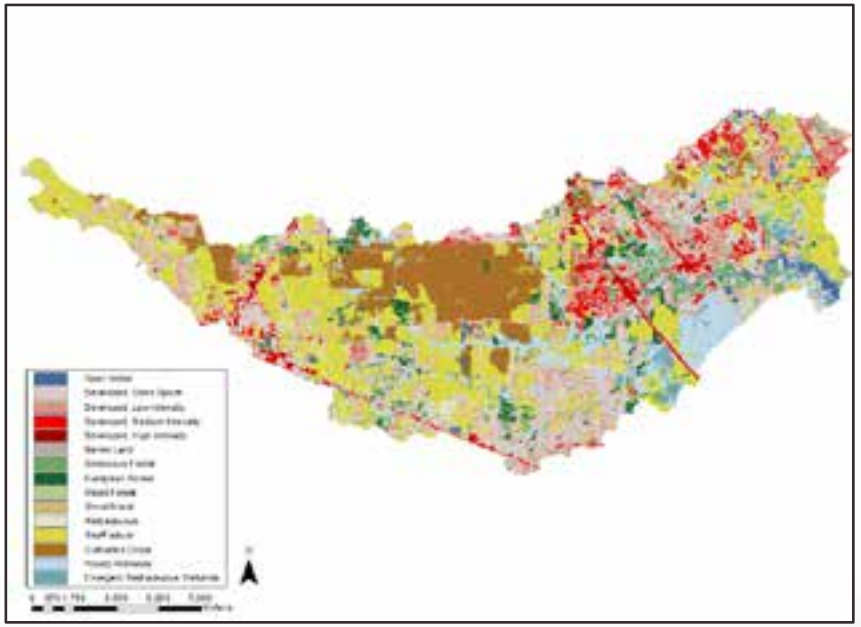
Dickinson Bayou watershed

Hydrological Soil Group



Hydrological Soil Group for Dickinson Bayou watershed (SSURGO, 2013)

Land use



Land use Data for Dickinson Bayou watershed (NLCD, 2006)

Spatially Explicit Methodology

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$$C = \frac{Y}{a * R * A}$$ *(McElroy et. al, 1976)*

- *C* = *E. coli* concentration (CFU/mL)
- *Y* = *E. coli* Load (CFU)
- *R* = Daily Runoff (mm)
- *a* = Conversion factor (1 x10^6)
  - § Convert from m^3 to mL
- *A* = Grid Cell Area (m^2)
  - § 900 m^2

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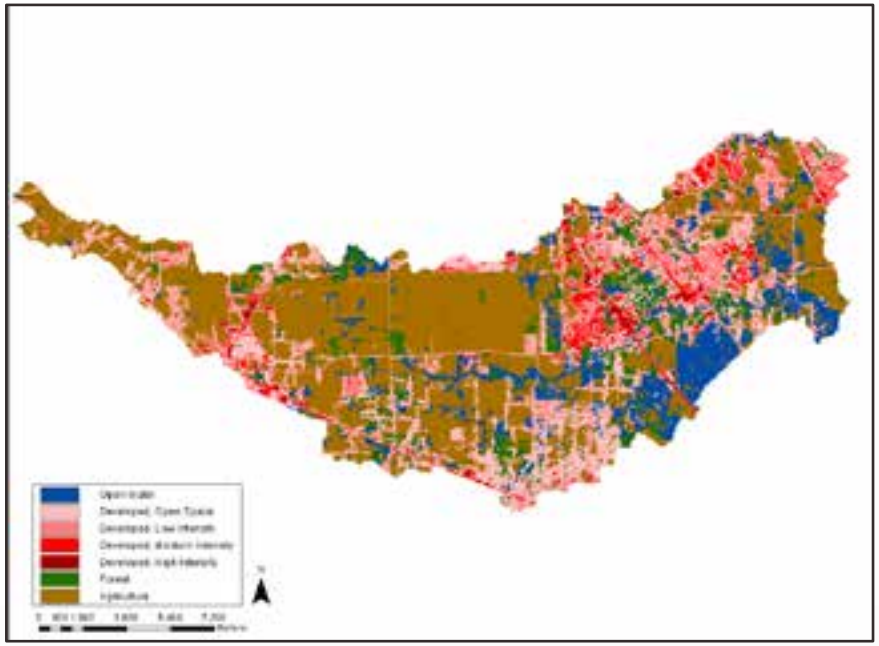
Rainfall-runoff model

- Rainfall-Runoff Grid
  - 30 x 30 meter grid
  - Curve Number – HEC-GeoHMS, ArcHydro
  - Soil Data- SURRGO
  - Land use (re-classified) NLCD 2006
  - Accumulated to the stream

- # Rainfall-Runoff Grid

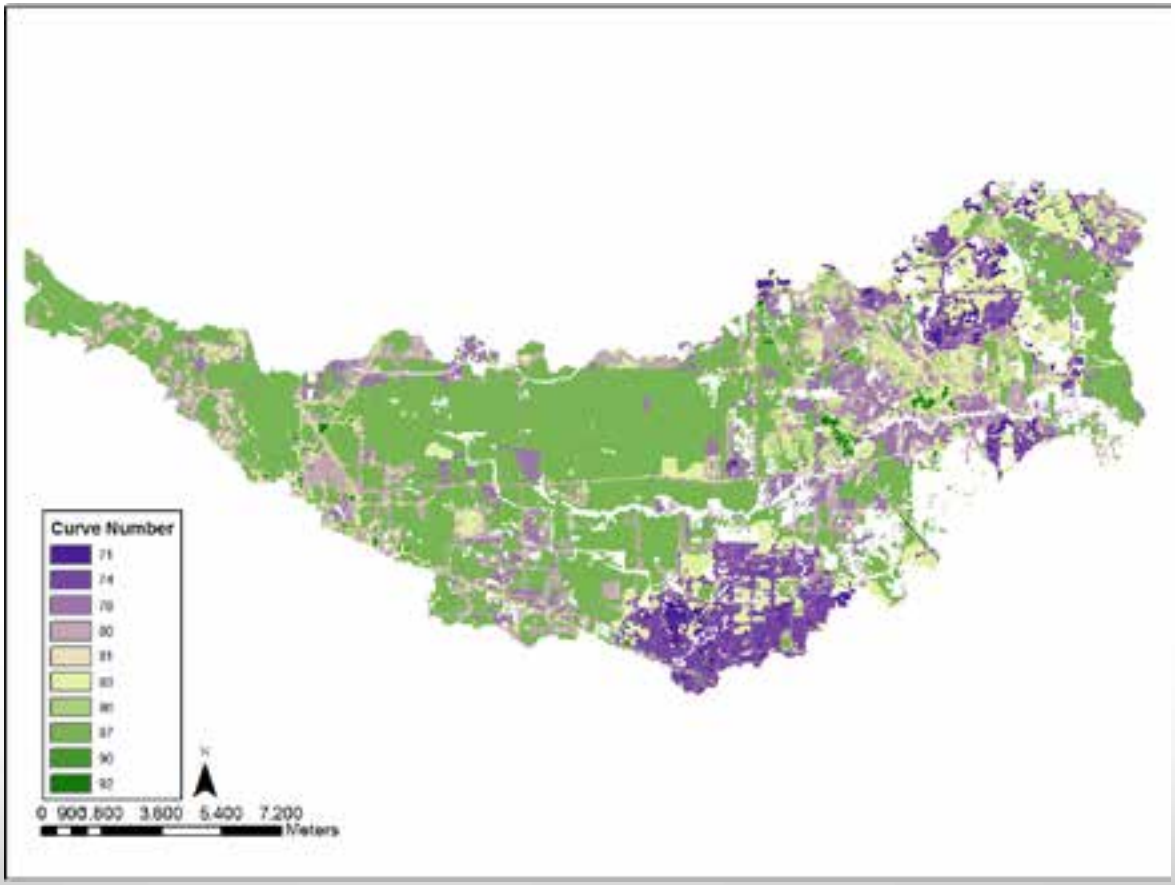
Land Use Type	Hydrologic Soil Group	Curve Number
Open Water	A	0
	B	0
	C	0
	D	0
Developed, Open Space	A	39
	B	61
	C	74
	D	80
Developed, Low Intensity	A	48
	B	66
	C	78
	D	83
Developed, Medium Intensity	A	57
	B	72
	C	81
	D	86
Developed, High Intensity	A	77
	B	85
	C	90
	D	92
Forest	A	30
	B	58
	C	71
	D	78
Agriculture	A	67
	B	77
	C	83
	D	87

Curve Number Lookup Table (AMC II)



Re-classified Land use for Dickinson Bayou

- Rainfall-Runoff Grid
  - Curve Number Grid



Curve Number grid for the Dickinson Bayou watershed

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- *E. coli* load

(Borel et. al, 2012)

- Unit: CFU/day
- Aggregated to subwatershed level

- *E. coli* Concentration
- *E. coli loads was combined with hydrological modeling* to predict concentrations that will be transported to the stream by runoff
- *Unit: CFU/100 mL*
- *Accumulated to the stream*

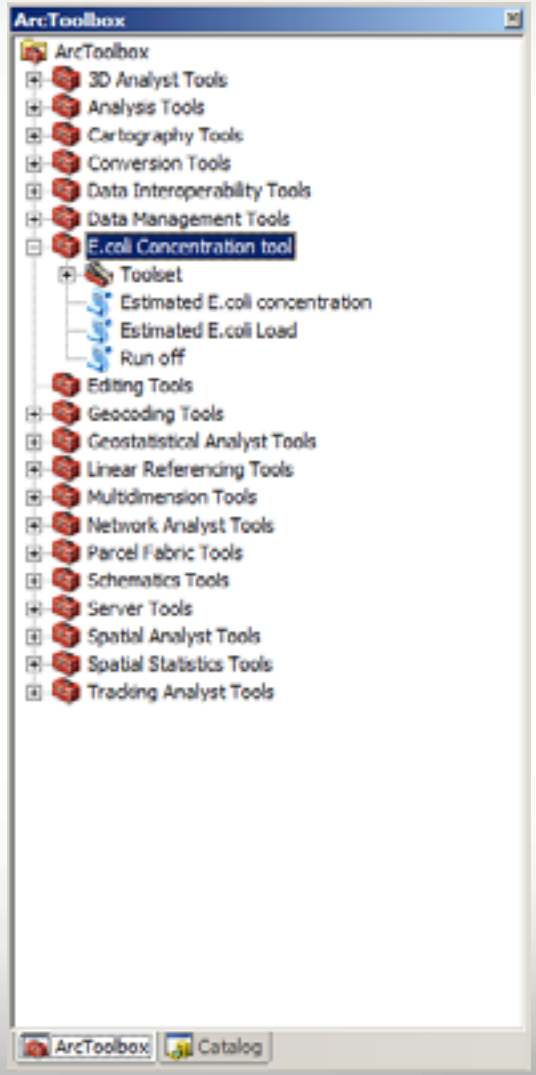
- Simulation Scenarios

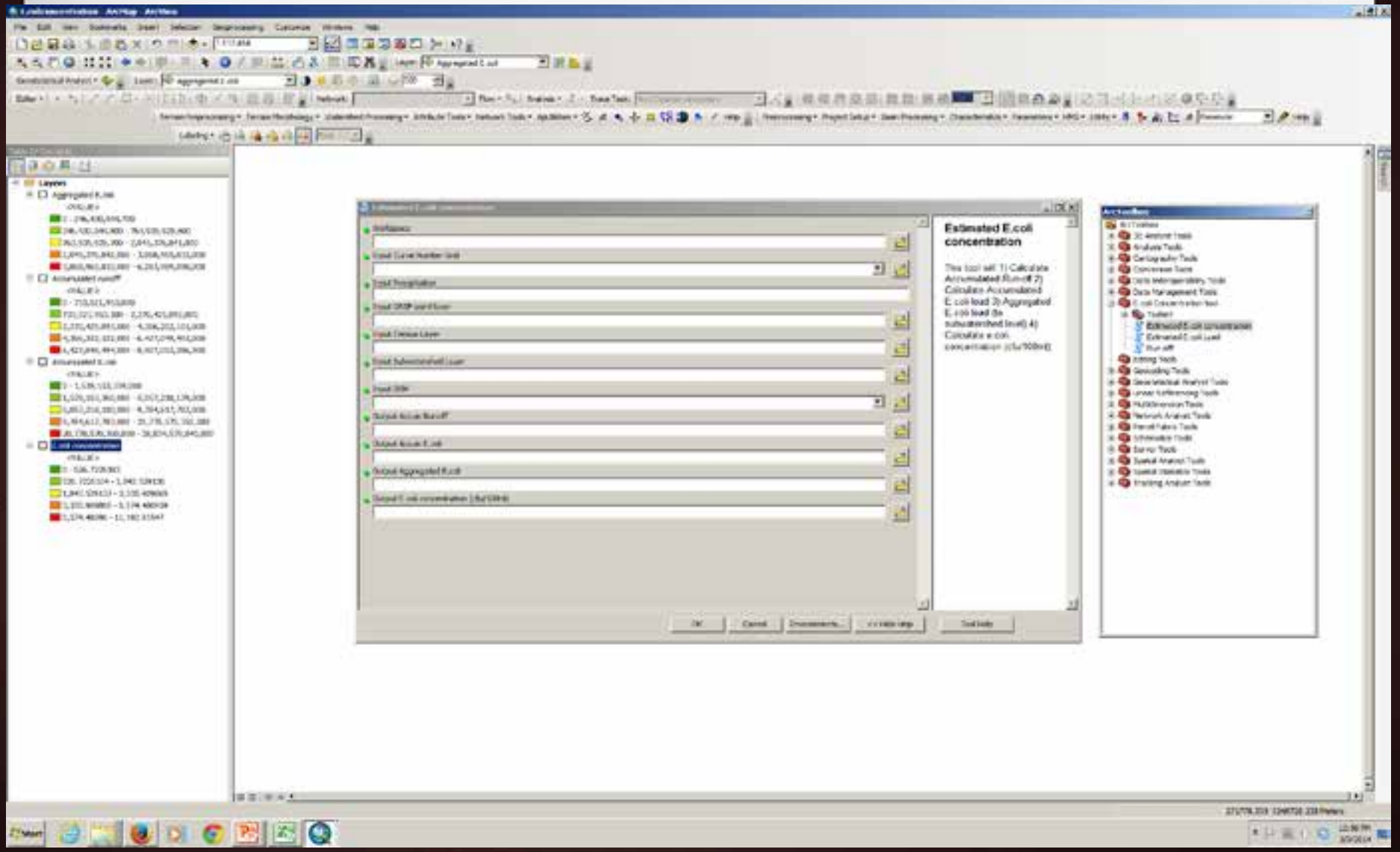
1. Rainfall conditions
   - Two-year, 24-hr rainfall
   - Five-year, 24-hr rainfall
   - Ten-year, 24-hr rainfall
   - Twenty-five-year, 24-hr rainfall
   - Fifty-year, 24-hr rainfall
   - Hundred-year, 24-hr rainfall

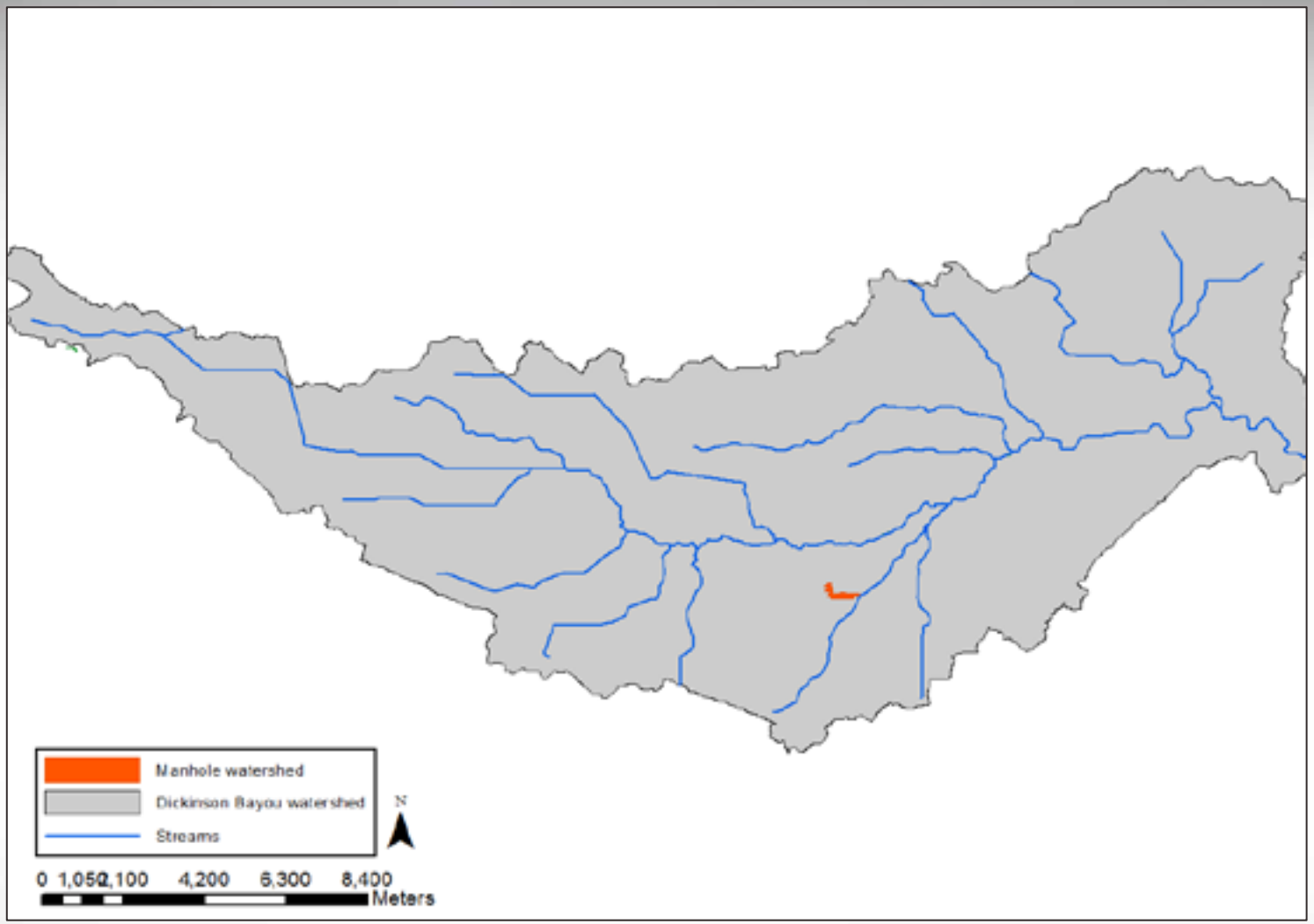
2. Age of the System
   - More then 30 years failing (35% gravity fed)

Automated tool: User Interface

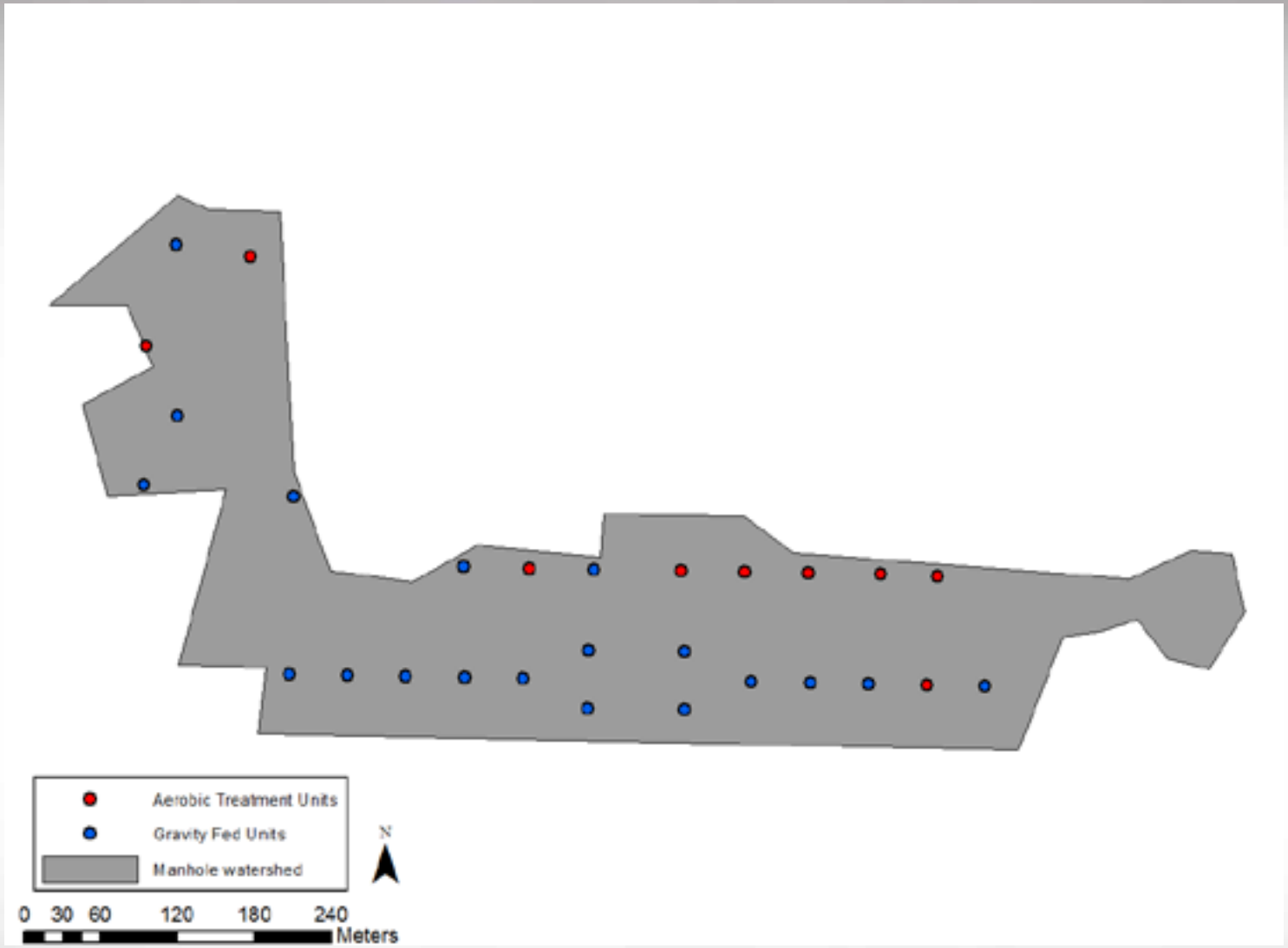
User Interface




EsEmated E.coli concentration

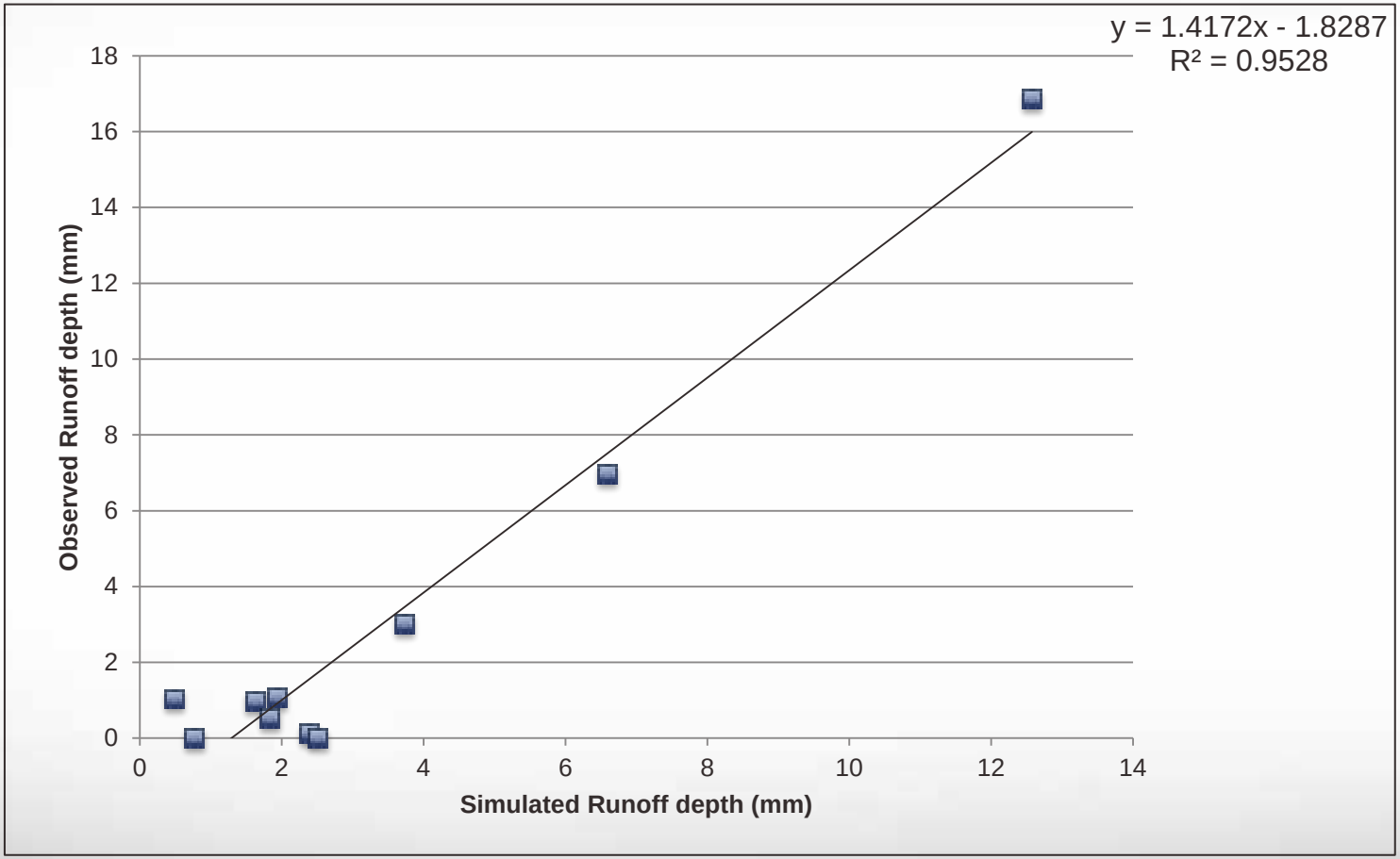


Spatial location of the manhole watershed within the Dickinson Bayou watershed where the data was monitored.



Manhole watershed with the spatial location of Aerobic Treatment Units (ATU) and Gravity Fed Units in the watershed.

Regression line



Regression line can be considered as an acceptable estimation of the true relationship between the observed and predicted.

Statistical Tests

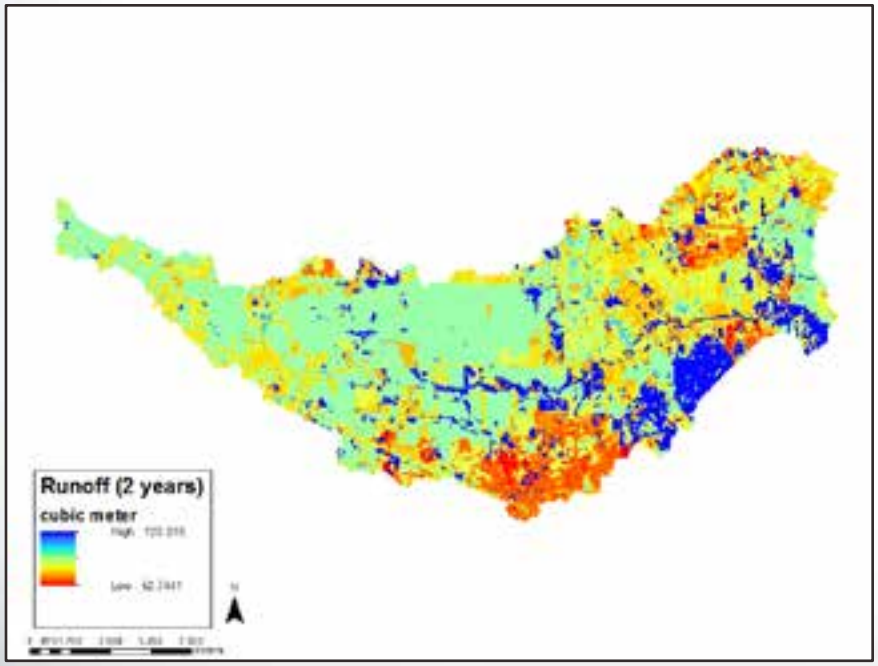
The model's accuracy was evaluated using the:

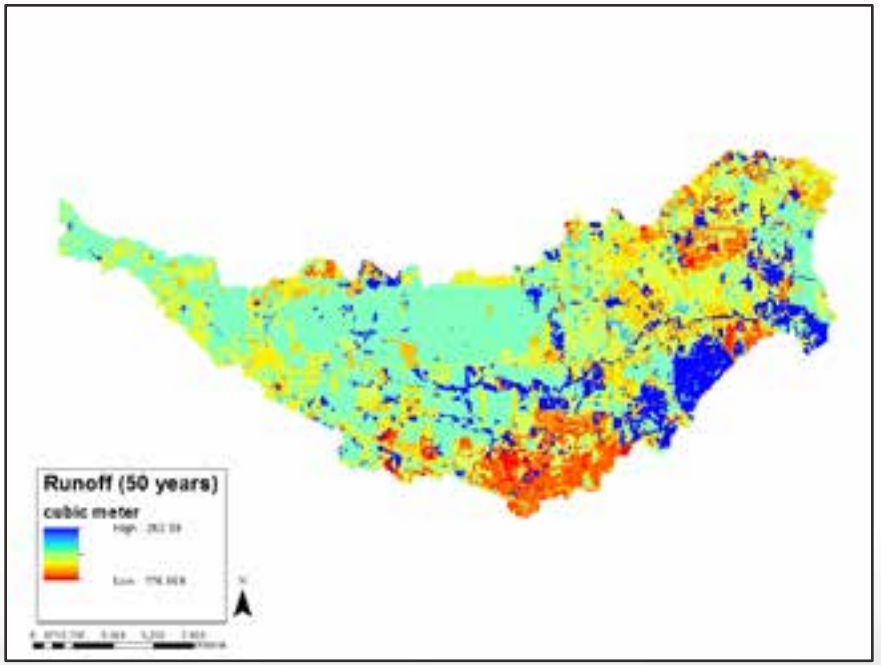
1. Nash-Sutcliffe Efficiency (E)
   - $E = 1 - [\sum_{i=1}^{n}(O_i - P_i)^2 / \sum_{i=1}^{n}(O_i - \bar{O})^2]$
2. Root mean square error (RMSE)
   - $RMSE = \sqrt{\sum_{i=1}^{n}(O_i - P_i)^2 / n}$
3. RMSE-observations standard deviation ratio (RSR)
   - $RSR = \left[\sqrt{\sum_{i=1}^{n}(O_i - P_i)^2}\right] / \left[\sqrt{\sum_{i=1}^{n}(O_i - \bar{O})^2}\right]$

E, RSR, & RMSE

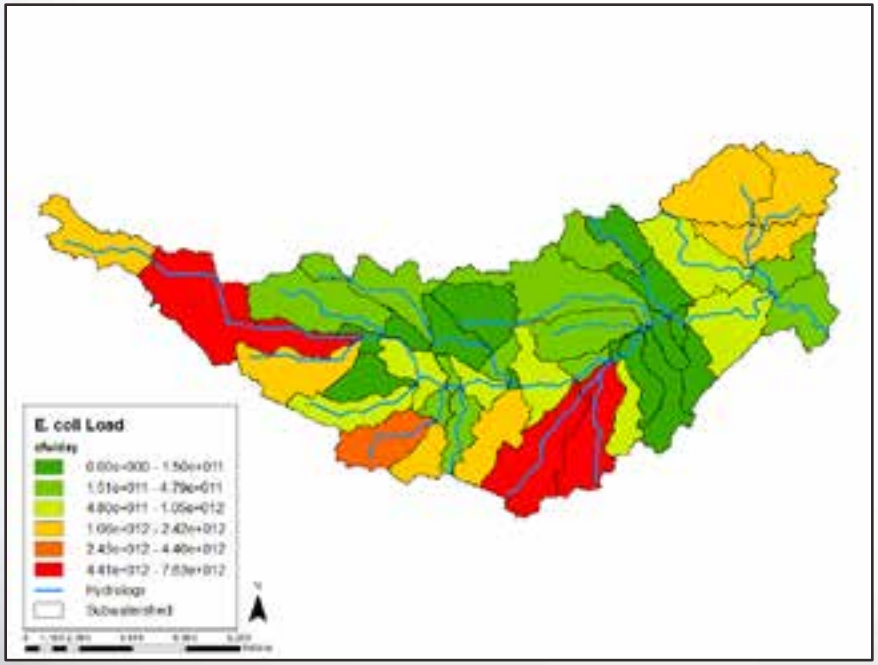
Runoff Calculation	Statistic	Observed
Model simulated	E	0.73 (good agreement)
	RSR	0.51 (good agreement)
	RMSE	1.79 (good agreement)
	Observed Average	3.44
	Observed Standard Deviation	3.64

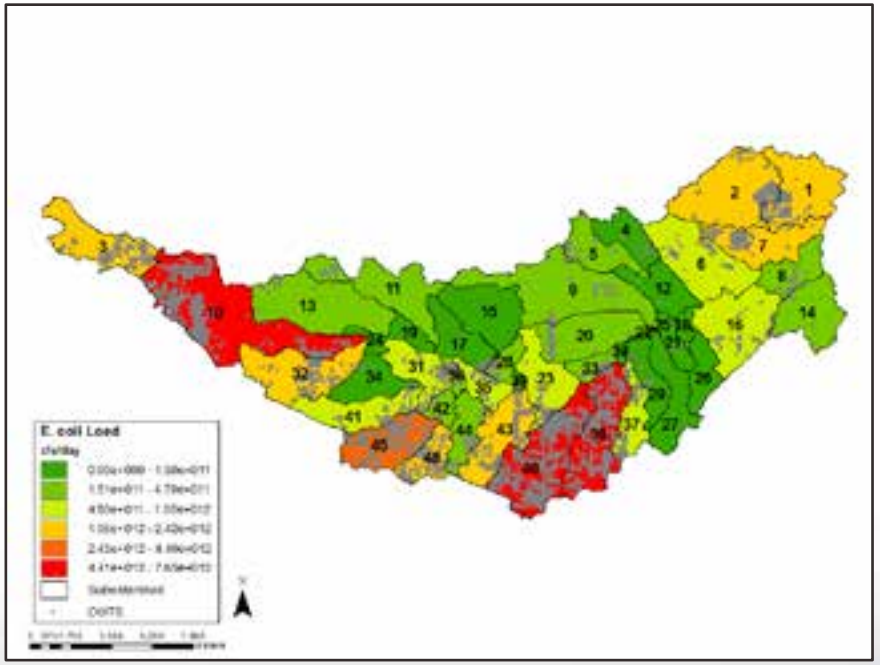
- Rainfall-Runoff Grid





- Total daily potential *E. coli load*





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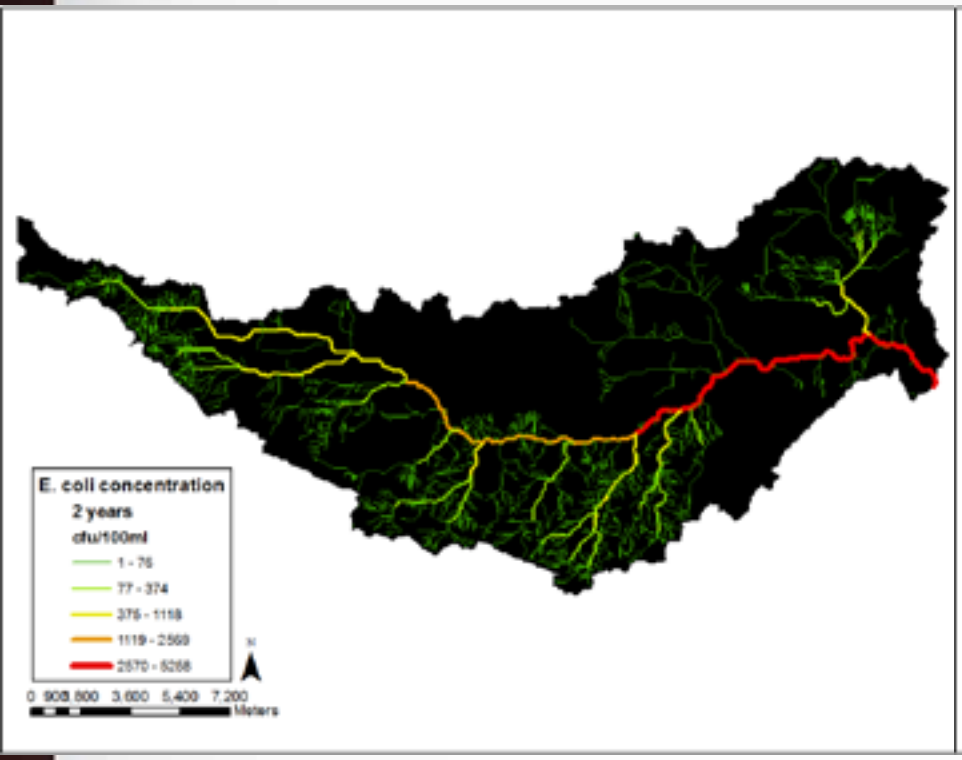
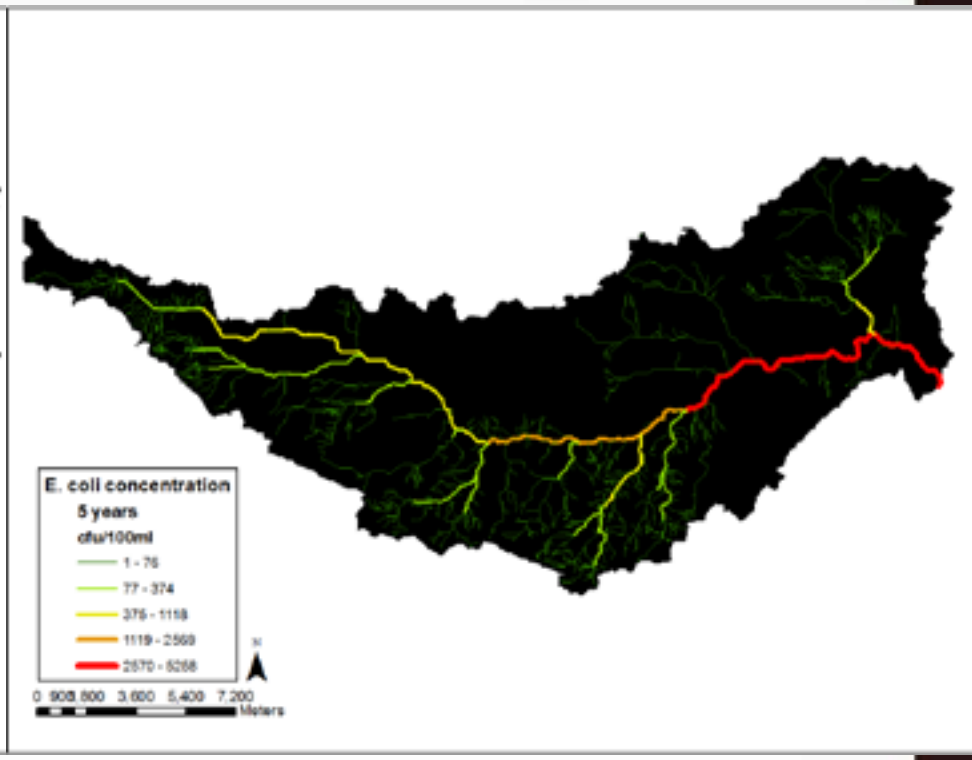
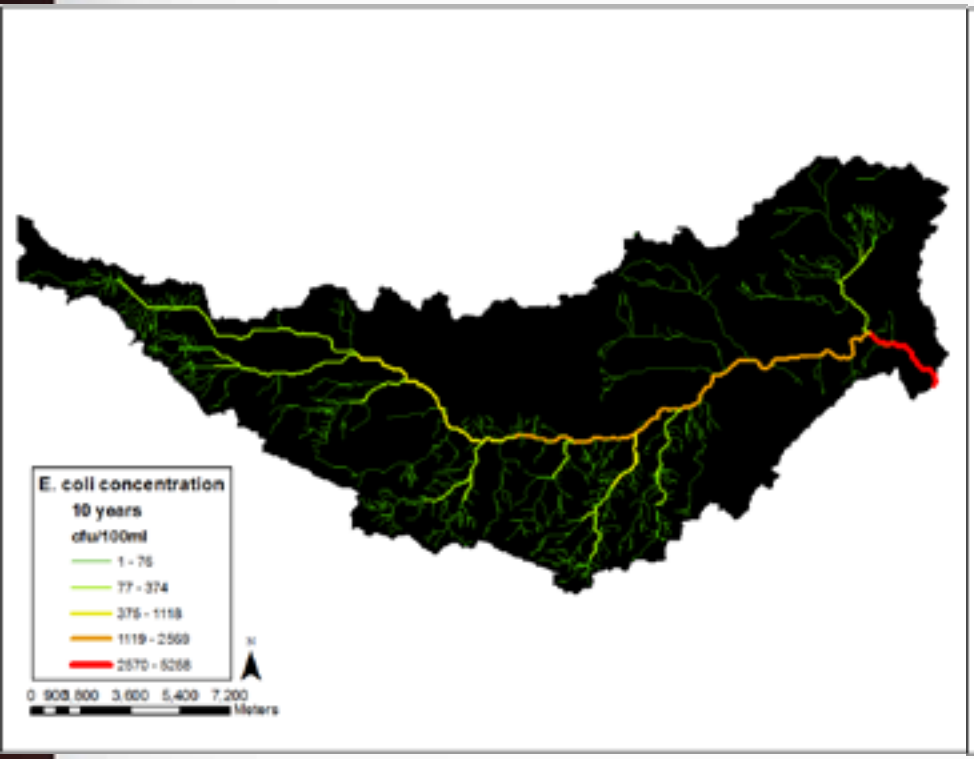
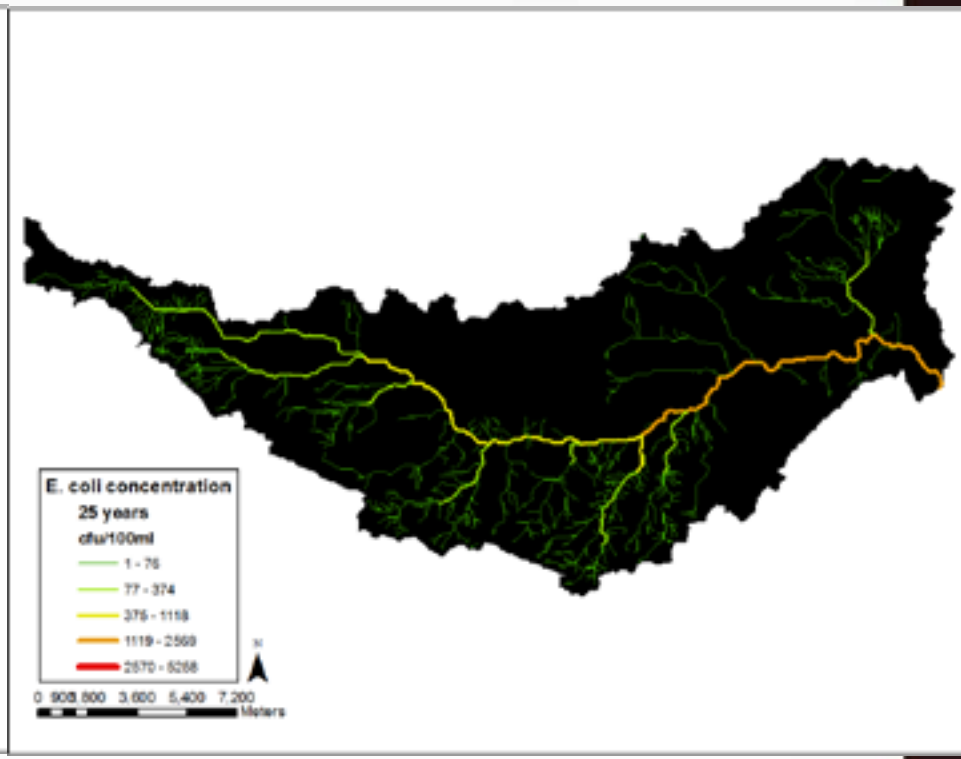
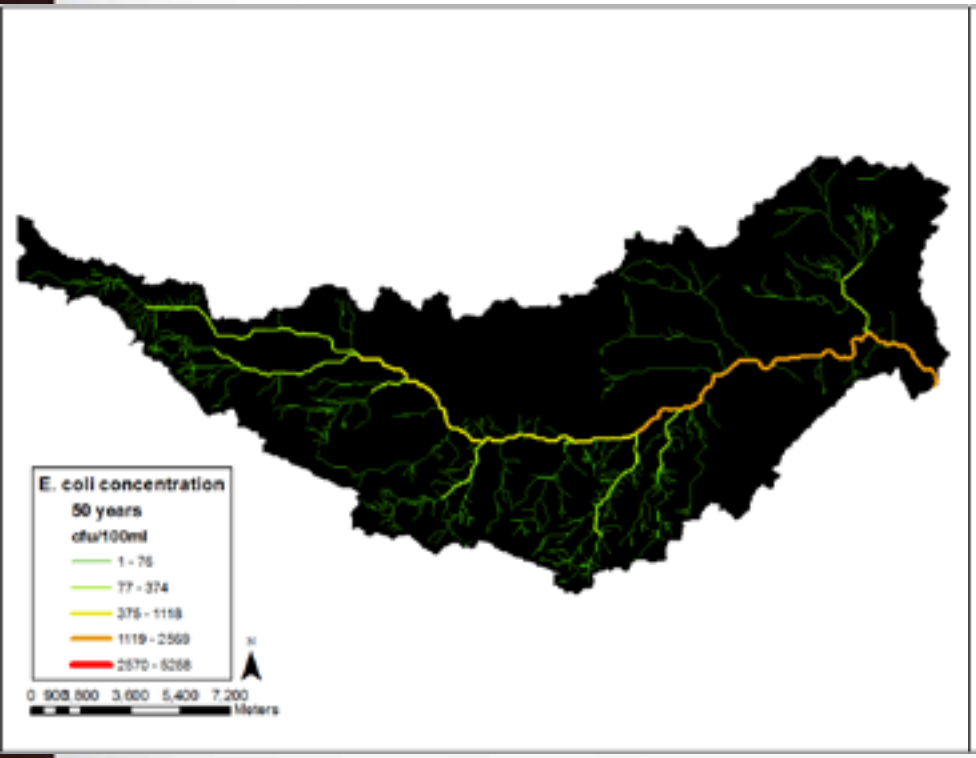
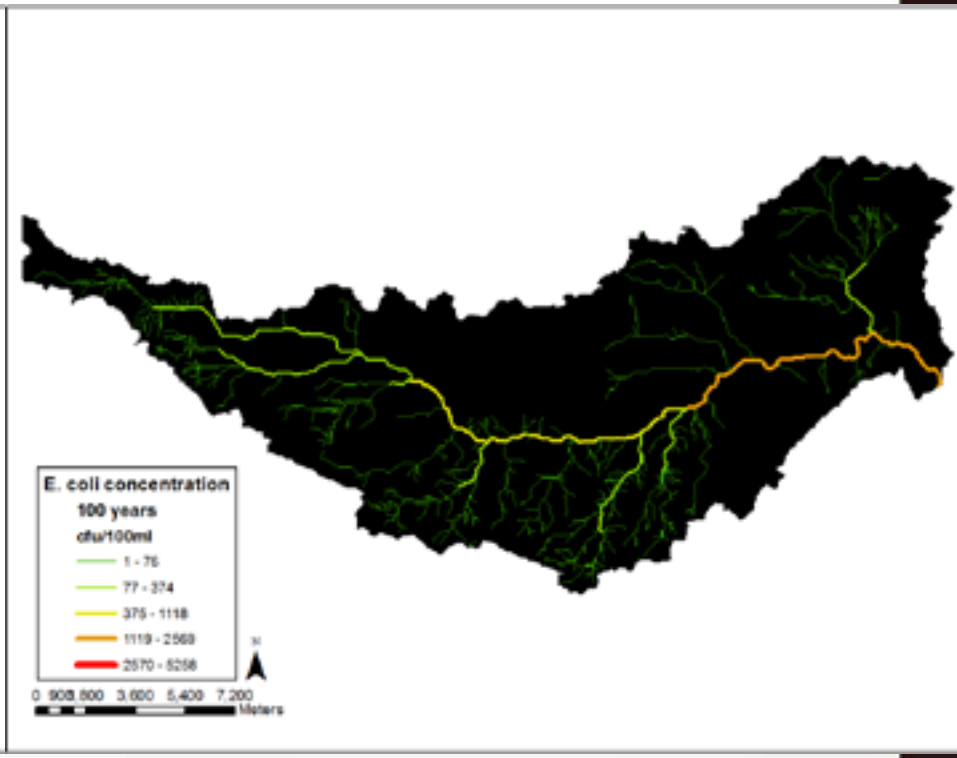





E. coli concentration
10 years
cfu/100ml
1 - 76
77 - 374
375 - 1118
1119 - 2569
2570 - 6268
N
0 900 1,800 3,600 5,400 7,200
Meters


E. coli concentration
25 years
cfu/100ml
1 - 76
77 - 374
375 - 1118
1119 - 2569
2570 - 6268
N
0 900 1,800 3,600 5,400 7,200
Meters


E. coli concentration
50 years
cfu/100ml
1 - 76
77 - 374
375 - 1118
1119 - 2569
2570 - 5268
N
0 900 1,800 3,600 5,400 7,200
Meters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Conclusions

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- Hydrological model was created in GIS
- An automated tool was developed in ArcGIS10 to simulate runoff volumes from rainfall, and validated with observed data.
- An automated tool was developed ArcGIS 10 to estimate *E. coli* concentrations in Dickinson Bayou watershed

Thank you!
Questions?

Subtitle

TEXAS A&M UNIVERSITY