A Comparison of GIS-Based Pollutant Loading Models

Watershed Treatment Model (WTM) vs. Generalized Watershed Loading Function (GWLF)

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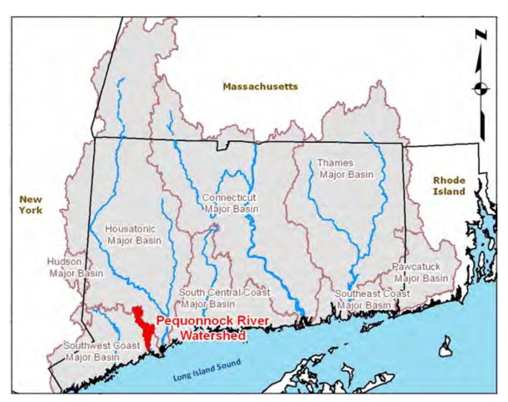
Watershed Management and Pollutant Loading Models

A watershed is the area of land that contributes runoff to a lake, river, stream, wetland, estuary, or bay. A watershed management plan defines and addresses existing or future water quality problems from both point sources and nonpoint sources of pollutants. The watershed plan characterizes existing conditions, identifies and prioritizes problems, defines management objectives, develops protection or remediation strategies, and identifies stakeholders that are responsible for implementing and adapting the objectives of the plan (EPA, 2008).

In support of the watershed plan, a pollutant loading analysis is performed to assess the potential for increases in nonpoint source pollutant loads to compare existing pollutant loads from the watershed to projected future pollutant loads under a watershed buildout scenario. The pollutant loading model is used to identify and rank pollution sources, as well as assist in identifying, prioritizing, and evaluating pollution control strategies.

In this study, results from two commonly used models in watershed planning are compared using land use data from the Pequonnock River Watershed.

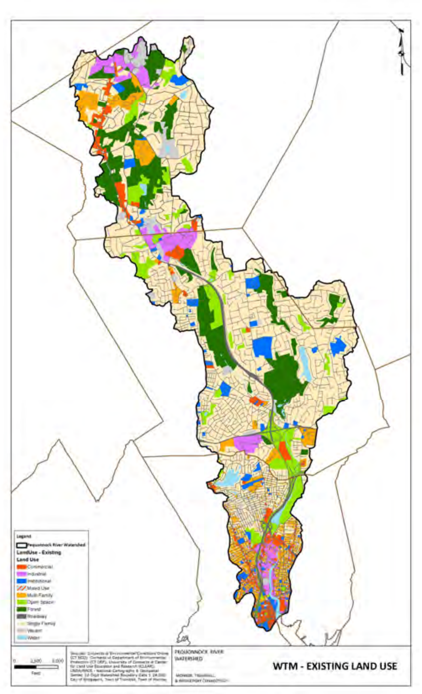
The Pequonnock River Watershed



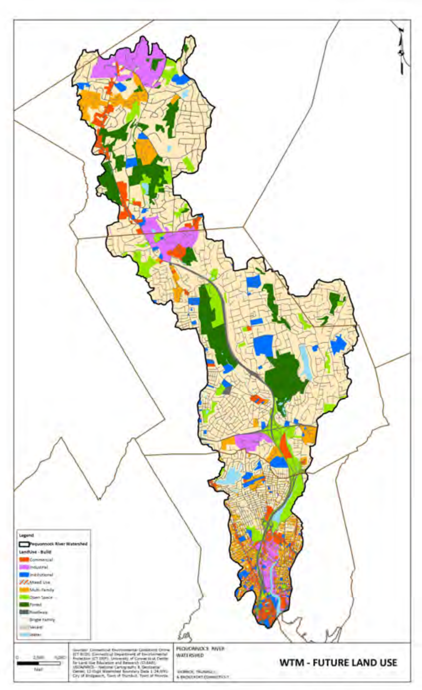
The Pequonnock River is a mixed-use watershed in Bridgeport, Trumbull and Monroe Connecticut consisting of urban, residential, commercial, industrial, agricultural, and open space land uses. A watershed management plan is being prepared for this watershed and is anticipated to be complete in early 2011.

WTM Categories

Existing Land Use

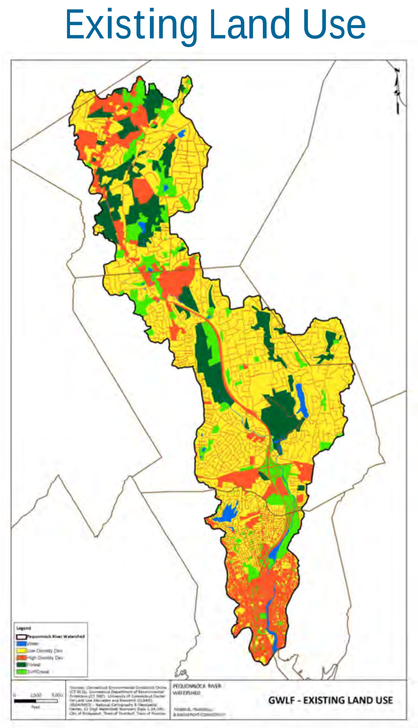


Future Land Use (Full Buildout)

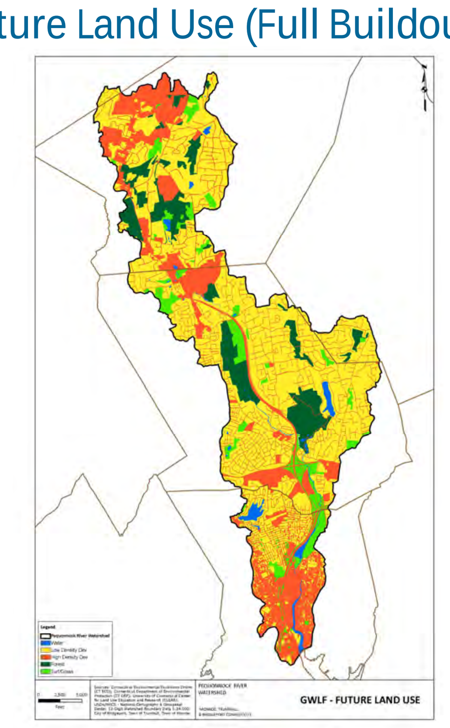


GWLF Categories

Existing Land Use



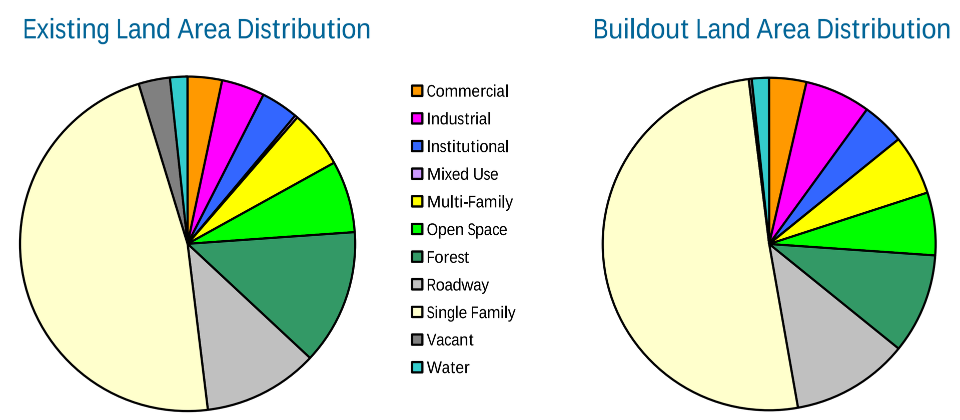
Future Land Use (Full Buildout)



Map Source: Fuss & O'Neill, Inc., 2010

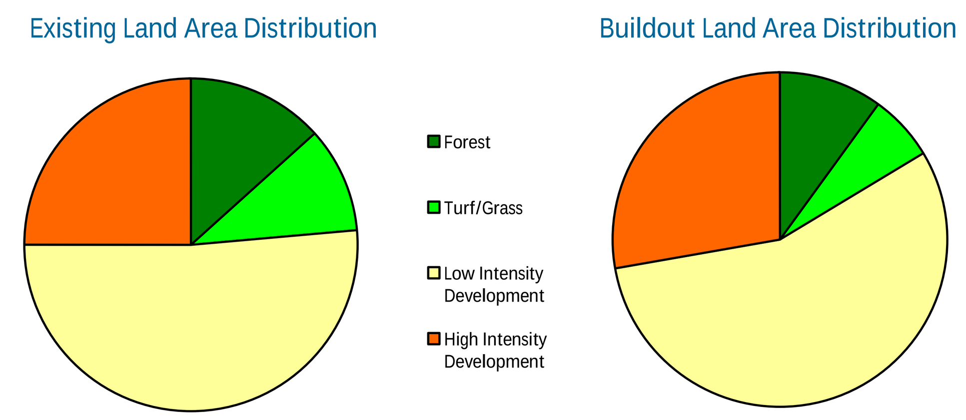
Model Input

Watershed Treatment Model (WTM)



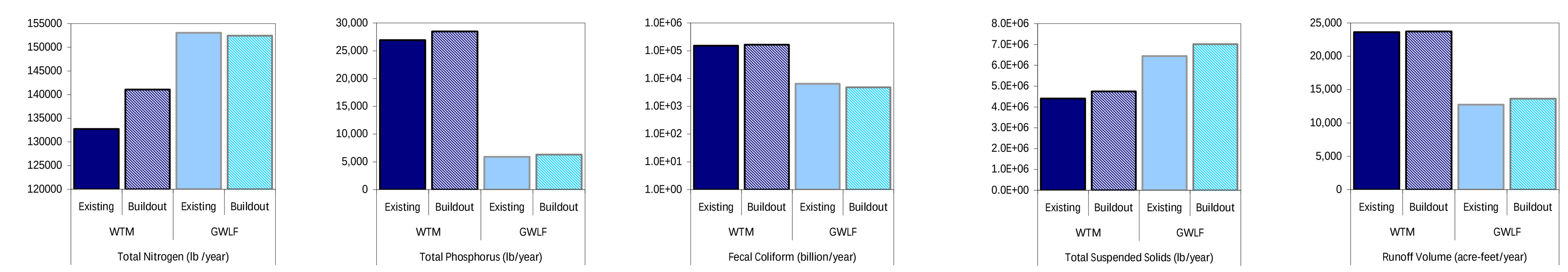
- Single family land use comprises 47% of the total existing land area in the Pequonnock River watershed.
- Vacant land area decreases by 95% in the buildout scenario, while industrial ;and use has the largest percent increase (52%) since there are large areas of undeveloped industrially-zoned areas in Monroe.

Generalized Watershed Loading Function (GWLF)



- GWLF has fewer land use categories than WTM, and low intensity development comprises the greatest existing land area (51%).
- Turf/grass and Forest area decrease by a combined 30% in the buildout scenario.

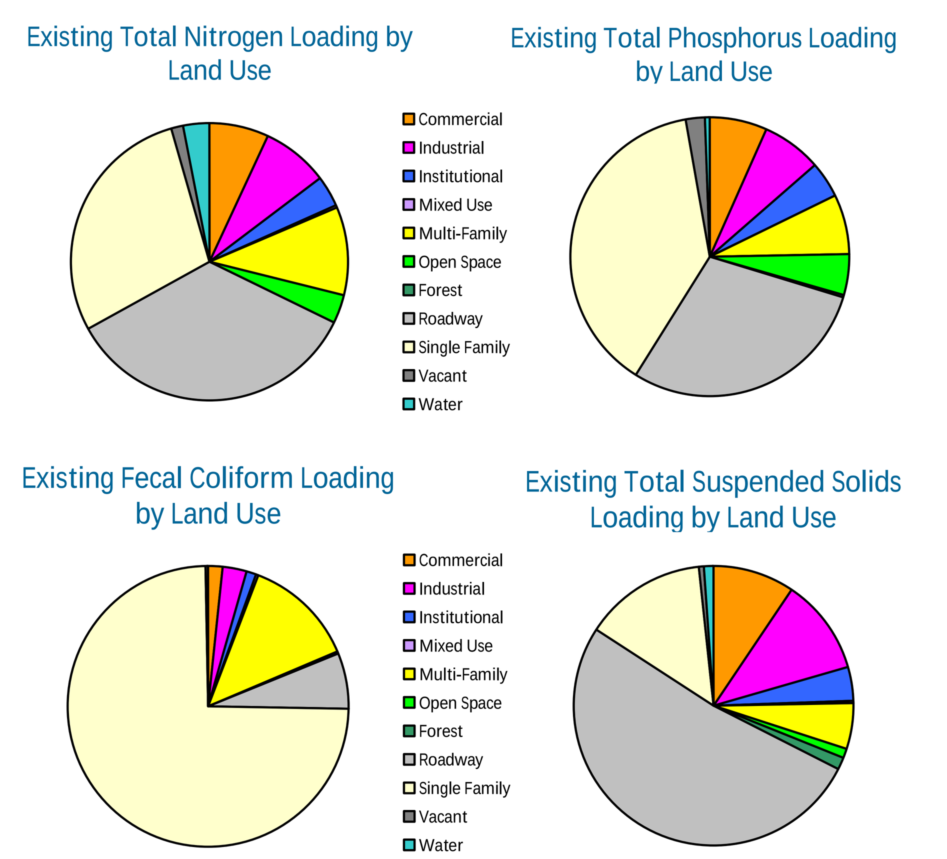
Model Comparison by Pollutant

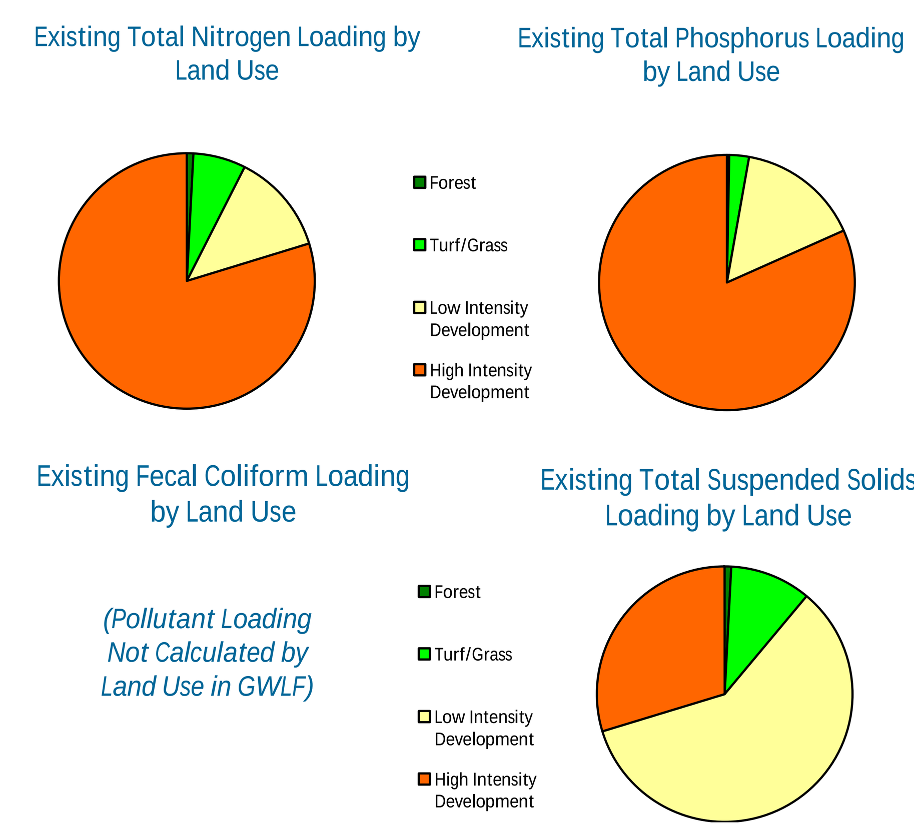


Percent Increase from Existing Pollutant Loading to Buildout Scenario

	WTM	GWLF
Total Nitrogen (lb /year)	6.3%	-0.4%
Total Phosphorus (lb/year)	5.8%	7.2%
Total Suspended Solids (lb/year)	7.8%	8.9%
Fecal Coliform (billion/year)	8.2%	-25.8%
Runoff Volume (acre-feet/year)	0.5%	7.1%

Pollutant Loading Results by Land Use





WTM vs. GWLF

Model	WTM	GWLF
Model Methodology	Simple Method w/ runoff coefficients and mean concentrations of pollutants from various land uses.	Combined distributed/lumped parameter watershed model. Surface runoff is modeled using the Curve Number approach and erosion and pollutant loading are calculated based on monthly runoff and watershed transport capacity.
Time scale	Annual	Calculated daily, reported monthly
Pollutants	Nutrients, Sediment, Pathogens	Nutrients, sediment, pathogens
Data Requirements	Land use, Event Mean Concentrations (EMCs)	Daily weather, basins, streams, soils, elevation, loading rates
Evaluation of Management Practices	Structural and Non-structural best management practices (BMPs), Low Impact Development (LID) practices	Only land use change scenarios
Comments	Recommended model; good screening level analysis because of moderate data requirements and annual time scale	Models pathogens; requires daily data; limited ability to model urban BMPs (stronger for agricultural BMPs)

Discussion

- In WTM, pollutant loading for all parameters increased from the existing to the buildout scenarios. The increases range from 5.8% for total phosphorus to 7.8% for TSS. The increase in pollutant loading rates is expected due to a conversion from undeveloped forest and open space land uses to developed land uses such as residential and commercial.
- In GWLF, total phosphorus and TSS increased at levels similar to rates calculated in WTM. Unexpectedly, total nitrogen and fecal coliform loading decreased in the buildout scenario.
  - The fecal coliform levels decreased because a large percentage of fecal coliform is generated from wildlife and is calculated using the forested area; As the forested land use decreases in the buildout scenario, the fecal coliform decreases.
  - The total nitrogen is believed to decrease due to a reduction in the turf/grass land use category for which fertilizers were applied.
- The differences in pollutant loading between the two models is primarily due to different calculation methods. WTM uses empirically-based impervious values and Event Mean Concentrations (EMCs) for pollutant loading based on land use. GWLF models the sediment and runoff volume using the Universal Soil Loss Equation algorithm.
- The greatest variability between WTM and GWLF was the fecal coliform loading estimate, which is 22 times greater in WTM than in GWLF. The WTM calculates fecal coliform loading based on mean concentrations in runoff from various land uses without considering die-off rates. GWLF uses an estimate of 75% die-off rate from the land source to the watershed outlet.

Conclusions

1. WTM is an easily-implemented empirical model and GWLF is a physically-based model and requires more parameters, assumption, and input data than WTM. Watershed managers should choose a pollutant loading model that matches model complexity with data availability.
2. The objective of this study was to reveal discrepancies between different pollutant loading models. The accuracy of either model can not be assessed without water quality sampling for model calibration. Further research could assess model accuracy using water quality samples collected from the Pequonnock River and its tributaries.
3. Pollutant loading results for existing conditions:
   - WTM predicts 3.5x greater Total Phosphorus loading, 22x greater Fecal Coliform loading, and 85% greater runoff volume than GWLF.
   - GWLF predicts a 15% greater Total Nitrogen load, 46% greater TSS load than WTM.

References

U.S. Environmental Protection Agency. (2008). *Handbook for Developing Watershed Plans to Restore and Protect Our Waters.* EPA 841-B-08-002, March 2008.

Fuss & O'Neill, Inc. (2010). *Baseline Watershed Assessment: Pequonnock River Watershed, DRAFT.* September, 2010.