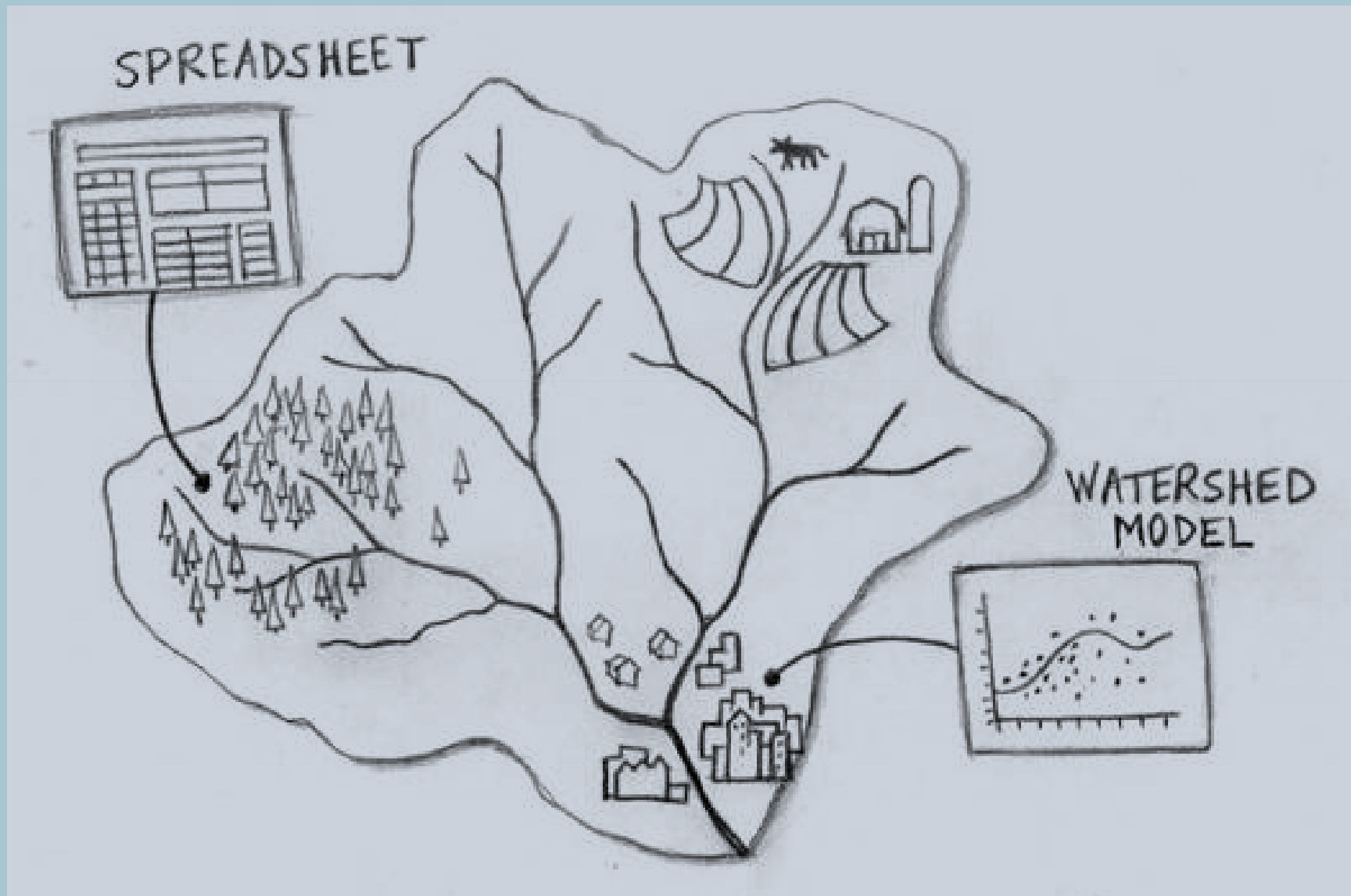


Load Estimation Models



Existing loads come from:

- **Point-source discharges (NPDES facilities)**
 - Info is available on the discharges (DMRs, etc.)
 - Some are steady-flow, others are precip-driven
- **Nonpoint sources**
 - All are (mostly) precipitation-driven
 - Calculating the “wash-off, runoff” load is tough
 - Literature values can be used to estimate
 - Modeling gets you closer do you need it?
- **Air/atmospheric deposition**
 - Can be significant in some locations

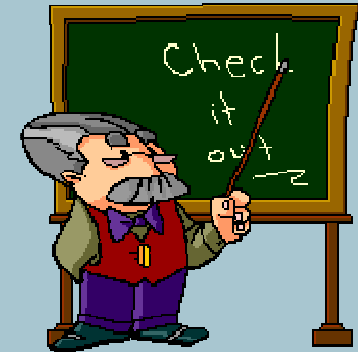
Limitations of Data-driven Approaches

- **Monitoring data**
 - Reflect current/historical conditions (limited use for future predictions)
 - Insight limited by extent of data (usually water quality data)
 - Often not source-specific
 - May reflect a small range of flow conditions
- **Literature**
 - Not reflective of local conditions
 - Wide variation among literature
 - Often a “static” value (e.g., annual)

If a Data-driven Approach Isn't Enough...Models are Available

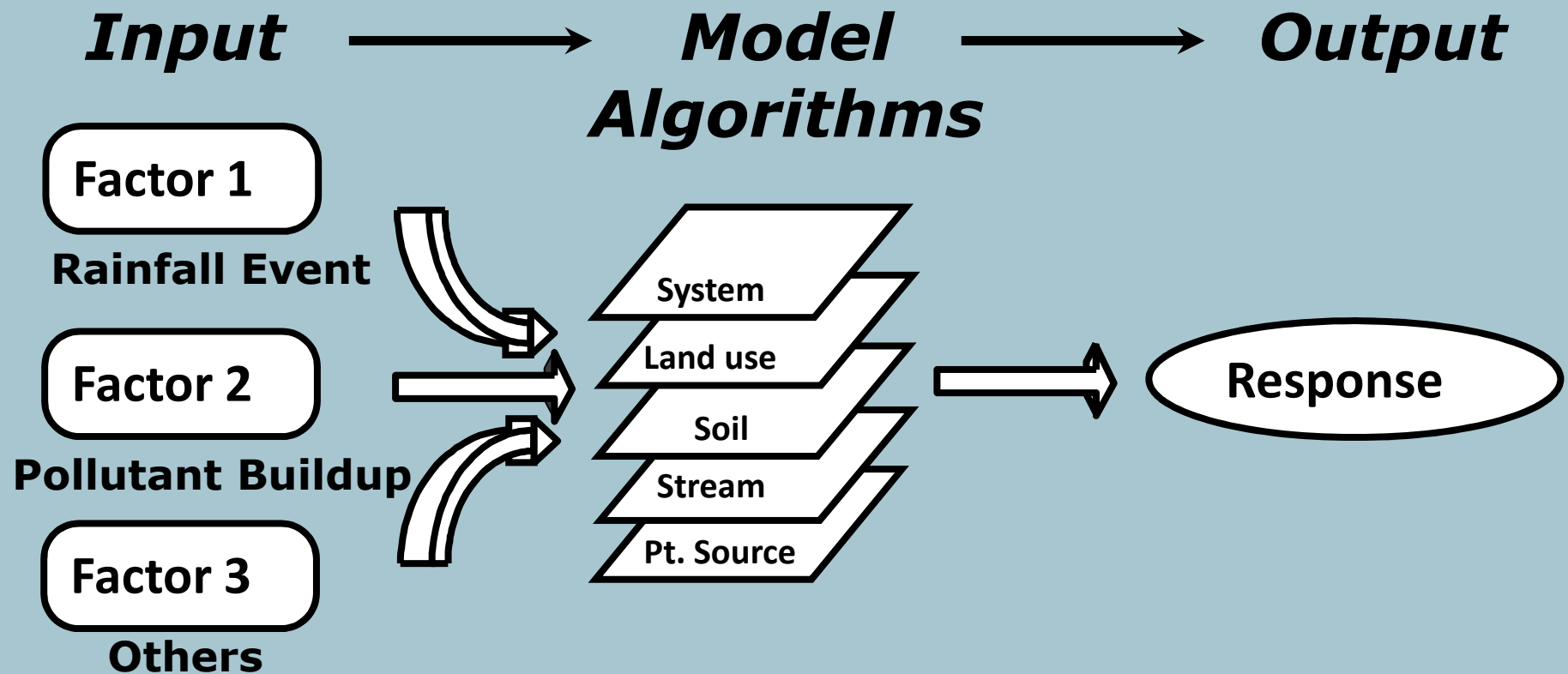
What is a Model?

- A theoretical construct,
- together with assignment of numerical values to model parameters,
- incorporating some prior observations drawn from field and laboratory data,
- and relating external inputs or forcing functions to system variable responses



* Definition from: Thomann and Mueller, 1987

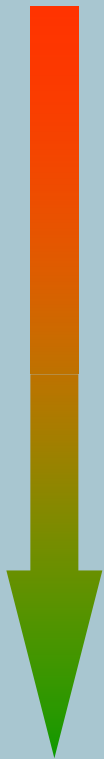
Nuts and Bolts of a Model



Is a Model Necessary?

It depends what you want to know...

Probably Not



- What are the loads associated with individual sources?
- Where and when does impairment occur?
- Is a particular source or multiple sources generally causing the problem?
- Will management actions result in meeting water quality standards?
- Which combination of management actions will most effectively meet load targets?
- Will future conditions make impairments worse?
- How can future growth be managed to minimize adverse impacts?

Probably

Models are used in many areas...

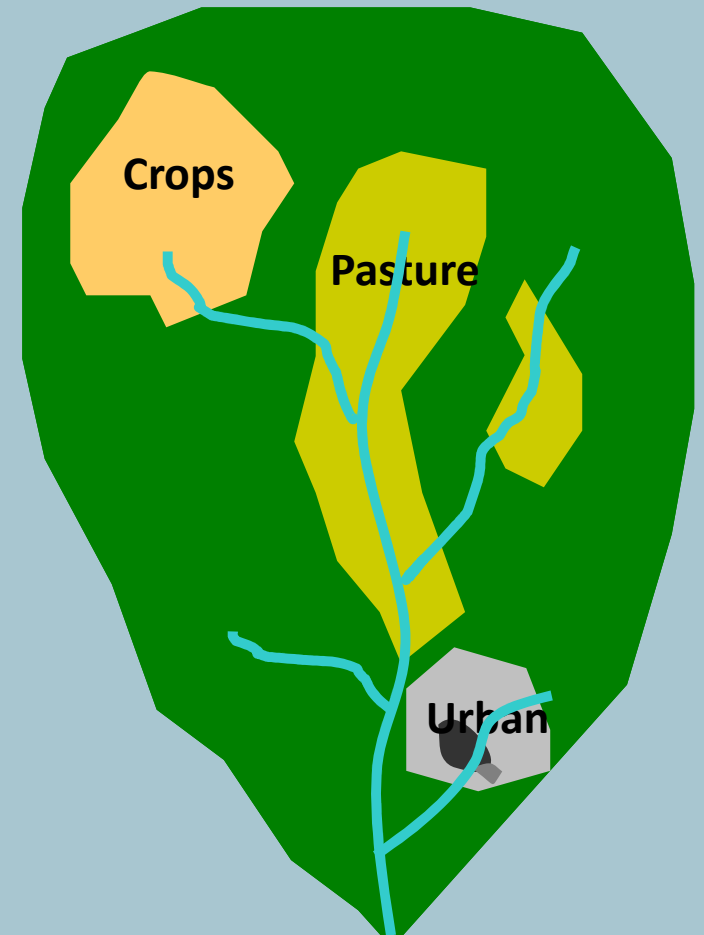
TMDLs, stormwater evaluation and design, permitting, hazardous waste remediation, dredging, coastal planning, watershed management and planning, air studies

Types of Models

- **Landscape models**
 - Runoff of water and materials on and through the land surface
- **Receiving water models**
 - Flow of water through streams and into lakes and estuaries
 - Transport, deposition, and transformation in receiving waters
- **Watershed models**
 - Combination of landscape and receiving water models
- **Site-scale models**
 - Detailed representation of local processes, for example Best Management Practices (BMPs)

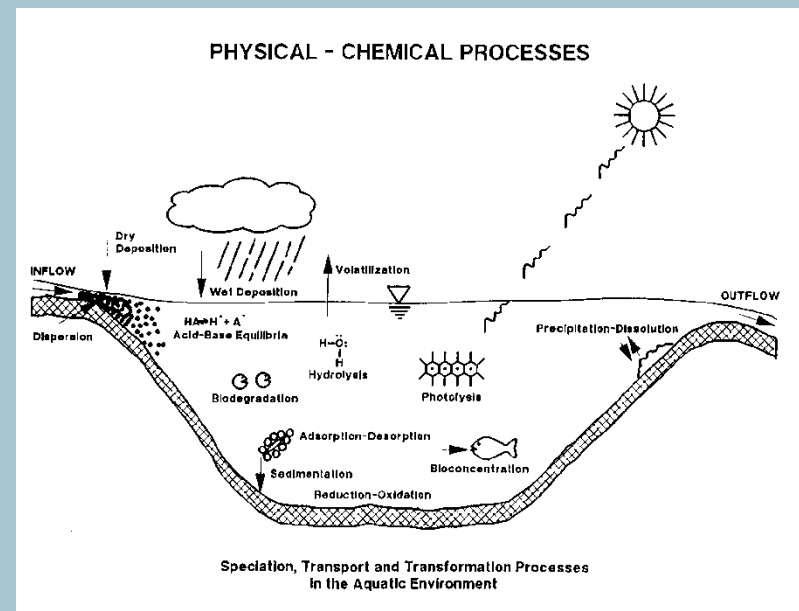
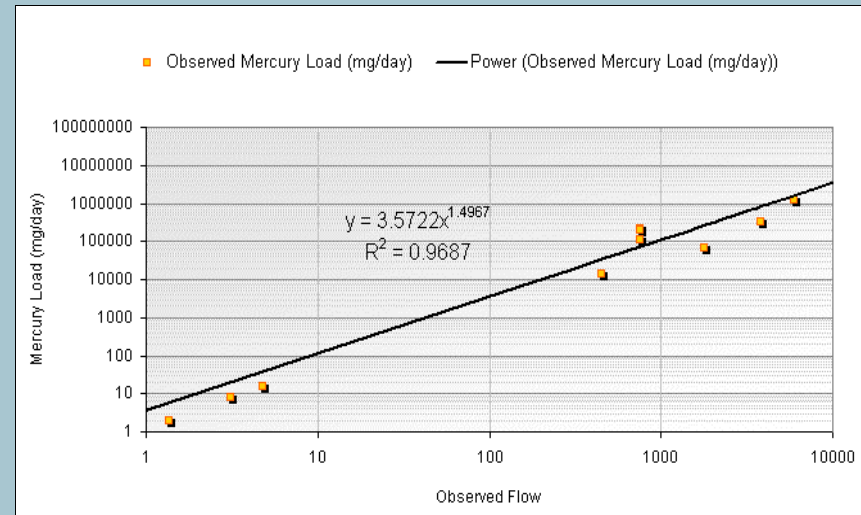
Types of Models

- **Landscape/Site-scale models**
- **Receiving water models**
- **Watershed models**



Model Basis

- Empirical formulations
 - mathematical relationship based on observed data rather than theoretical relationships
- Deterministic models
 - mathematical models designed to produce system responses or outputs to temporal and spatial inputs (process-based)



Review of Commonly Used Models

- **Landscape and Watershed models**
 - **Simple models**
 - **Mid-range models**
 - **Comprehensive watershed models**
 - **Field-scale models**

Simple Models

- Minimal data preparation
 - Landuse, soil, slope, etc.
- Good for long averaging periods
 - Annual or seasonal budgets
- No calibration
- Some testing/validation is preferable
 - Comparison of relative magnitude



Loading Rate



Simple Method



USLE / MUSLE



USGS Regression



PLOAD



STEPL

Limitations:

- Limited to waterbodies where loadings can be aggregated over longer averaging periods
- **Limited to gross loadings**

Mid-range Models

- More detailed data preparation
 - Meteorological data
- Good for seasonal/event issues
- Minimal or no calibration
- Testing and validation preferable
 - Application objectives
 - Storm events, daily loads
- *Limitations:*
 - Limited pollutants simulated
 - Limited in-stream simulation & comparison w/standards
 - **Daily/monthly load summaries**



AGNPS



GWLF



P8



SWAT (+ receiving water)

Comprehensive Watershed Models

- Accommodate more detailed data input
- Short time steps and finer configuration
 - Complex algorithms need state/kinetic variables
 - Ability to evaluate various averaging periods and frequencies
- Calibration is required
- Addresses a wide range of water and water quality problems
- Include both landscape and receiving water simulation
- *Limitations:*
 - More training and experience needed
 - Time-consuming (need GIS help, output analysis tools, etc.)



Source of Additional Information on Model Selection

- **EPA 1997, *Compendium of Models for TMDL Development and Watershed Assessment*. EPA841-B-97-007**
 - Review of loading and receiving water models
 - Ecological assessment techniques and models
 - Model selection

Key Considerations When Selecting a Model

- **Relevance**
 - Representation of key land uses and processes
 - Pollutants of concern
- **Credibility**
 - Peer-reviewed
 - Public domain and source code is available on request
- **Usability**
 - Availability of documentation, training, and support
 - Availability and accessibility of data to run model
 - Model and user interface is reliable and tested
- **Utility**
 - Able to predict range of management options considered

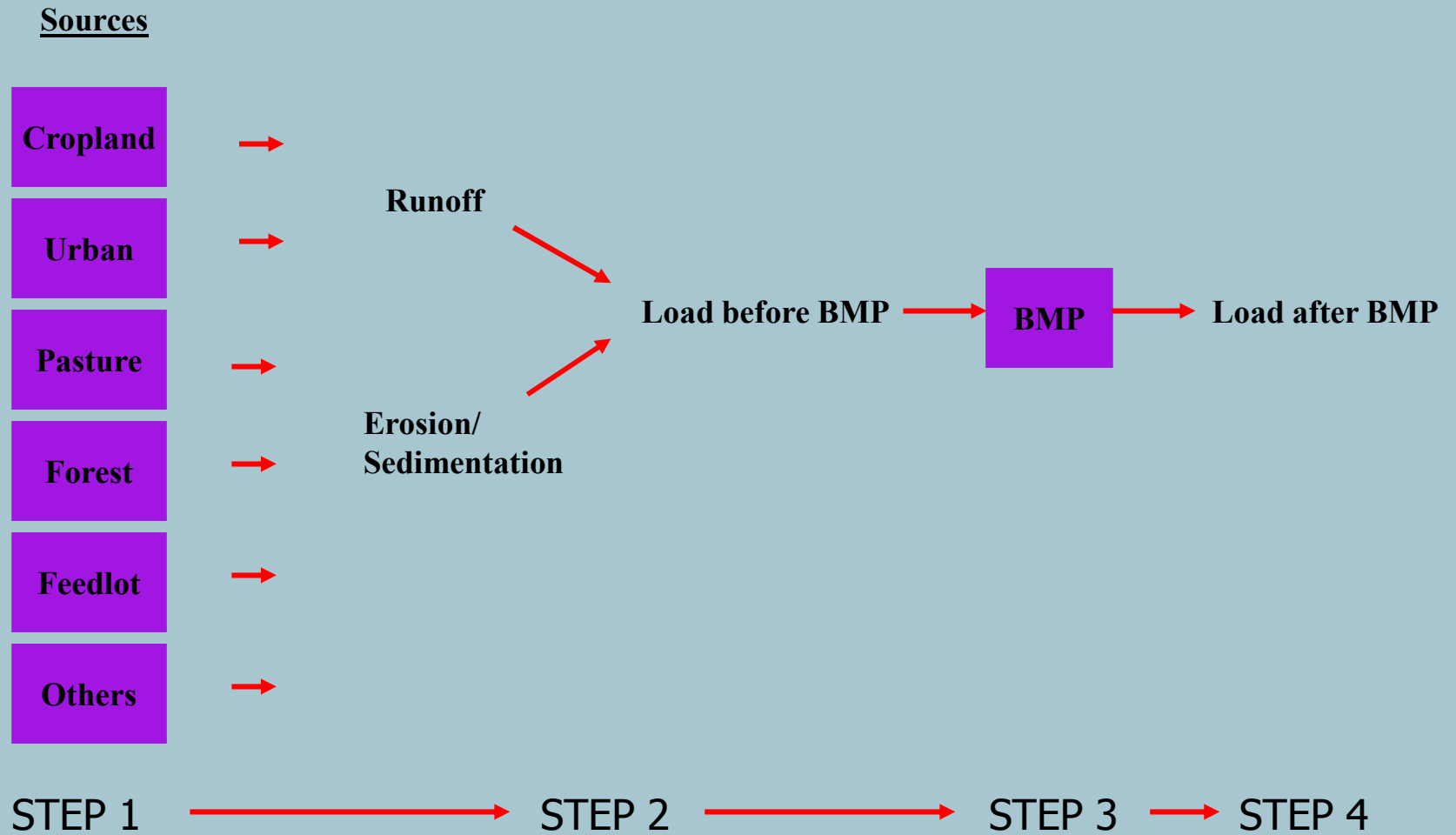
Example of Simple Model Application

- **Spreadsheet Tool for Estimating Pollutant Load (STEPL)**
 - **Employs simple algorithms to calculate nutrient and sediment loads from different land uses**
 - **Also includes estimates of load reductions that would result from the implementation of various BMPs**
 - **Data driven and highly empirical**
 - **A customized MS Excel spreadsheet model**
 - **Simple and easy to use**

STEPL Users?

- **Basic understanding of hydrology, erosion, and pollutant loading processes**
- **Knowledge (use and limitation) of environmental data (e.g., land use, agricultural statistics, and BMP efficiencies)**
- **Familiarity with MS Excel and Excel Formulas**

Process



STEPL Web Site

Link to on-line Data server →

Link to download setup program to install STEPL program and documents →

U.S. Environmental Protection Agency

STEPL - Spreadsheet Tool for Estimating Pollutant Load

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[EPA Home](#) - [STEPL](#)

Welcome to STEPL and Region 5 model



Spreadsheet Tool for Estimating Pollutant Load (STEPL) employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that would result from the implementation of various best management practices (BMPs). STEPL provides a user-friendly Visual Basic (VB) interface to create a customized spreadsheet-based model in Microsoft (MS) Excel. It computes watershed surface runoff, nutrient loads, including nitrogen, phosphorus, and 5-day biological oxygen demand (BOD5), and sediment delivery based on various land uses and management practices. For each watershed, the annual nutrient loading is calculated based on the runoff volume and the pollutant concentrations in the runoff water as influenced by factors such as the land use distribution and management practices. The annual sediment load (sheet and oil erosion only) is calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. The sediment and pollutant load reductions that result from the implementation of BMPs are computed using the known BMP efficiencies.





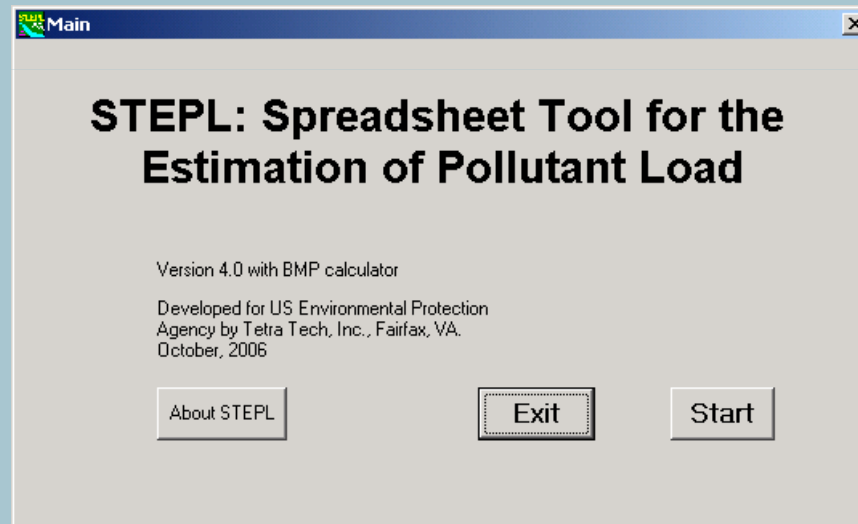
Region 5 model is an Excel workbook that provides a gross estimate of sediment and nutrient load reductions from the implementation of agricultural and urban BMPs. The algorithms for non-urban BMPs are based on the "Pollutants controlled: Calculation and documentation for Section 319 watersheds training manual" (Michigan Department of Environmental Quality, June 1999). The algorithms for urban BMPs are based on the data and calculations developed by Illinois EPA. Region 5 model does not estimate pollutant load reductions for dissolved constituents.

Questions? Please contact:
[STEPL support](#)
Department for P.D.S. Office of Water

Temporary URL: <http://it.tetrattech-ffx.com/step/> until moved to EPA server

STEPL Main Program

- Run STEPL executable program to create and customize spreadsheet dynamically
- Go to demonstration



STEPL Data Input

- **11 input tables**
- **4 tables require you to change initial input values**
 - Land use (acres of urban, cropland, pasture, forest, user defined, feedlots), % feedlot paved
 - Average rain, rain days, average rain/event
 - Number of agricultural animals (beef, dairy, swine, sheep, horse, chicken, turkey, duck)
 - Number of months manure applied
 - Number of septic systems, population per septic system, septic failure rate (%)
 - Number of people who discharge wastewater directly to streams, % reduction of people discharging directly to streams
 - USLE parameters (R, K, LS, C, P, R, K) for cropland, pasture, forest, and user-defined land use

STEPL Data Input

- **7 tables contain default values that you may choose to change:**
 - **BMPs and efficiencies for N, P, BOD, and sediment on cropland, pasture, forest, user-defined land use, urban, and feedlots**
 - **% of land use area to which each BMP is applied**
 - **Combined watershed BMP efficiencies from the BMP calculator if interactions of BMPs are considered (optional)**

STEPL Data Input

- **Optional greater detail:**
 - Average soil hydrologic group
 - Soil N, P, and BOD concentrations (%)
 - N, P, and BOD concentrations in runoff and shallow ground water from each land use
 - Reference runoff curve numbers (A, B, C, D) for each land use and subcategories of urban land use
 - Acreage of urban subcategories (e.g., commercial, multi-family, vacant)
- **Cropland irrigation (acres, inches pre- and post-BMPs, times/year)**

Other Features of STEPL

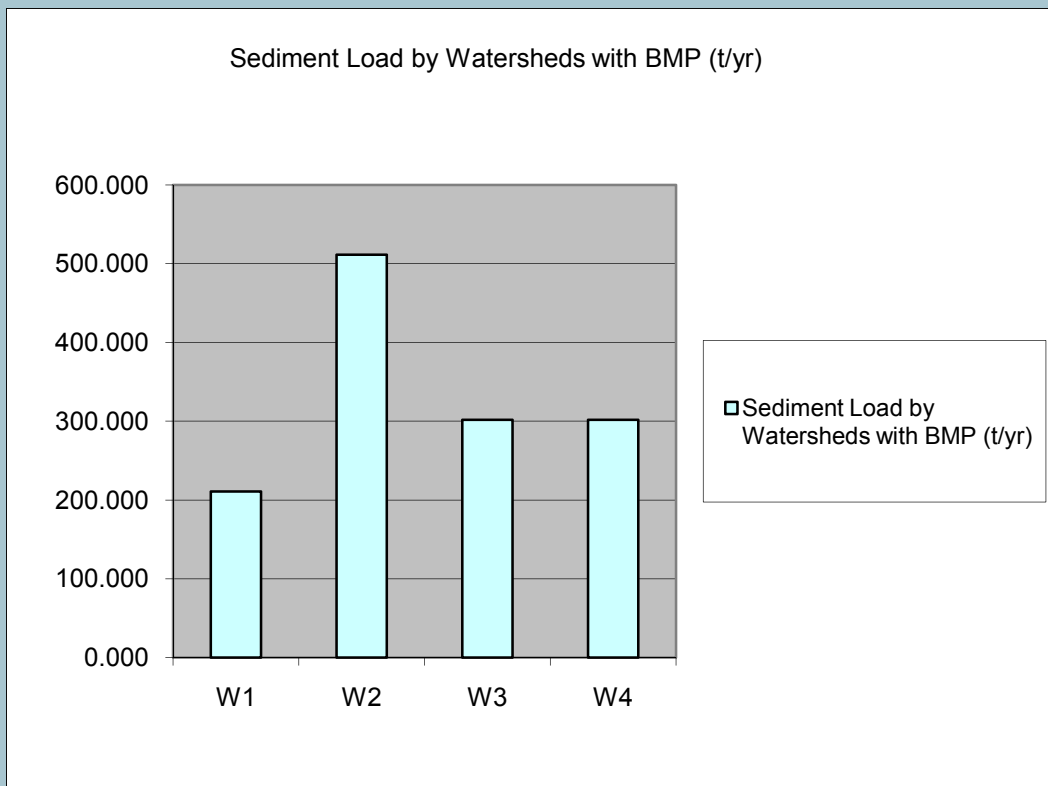
- **Lots of default values/options:**
 - **Rainfall and USLE parameters based on location and nearby weather station**
- **BMPs can be added and efficiencies can be edited**
- **Urban BMP Tool for BMPs or LIDs for urban land uses**

Other Features of STEPL

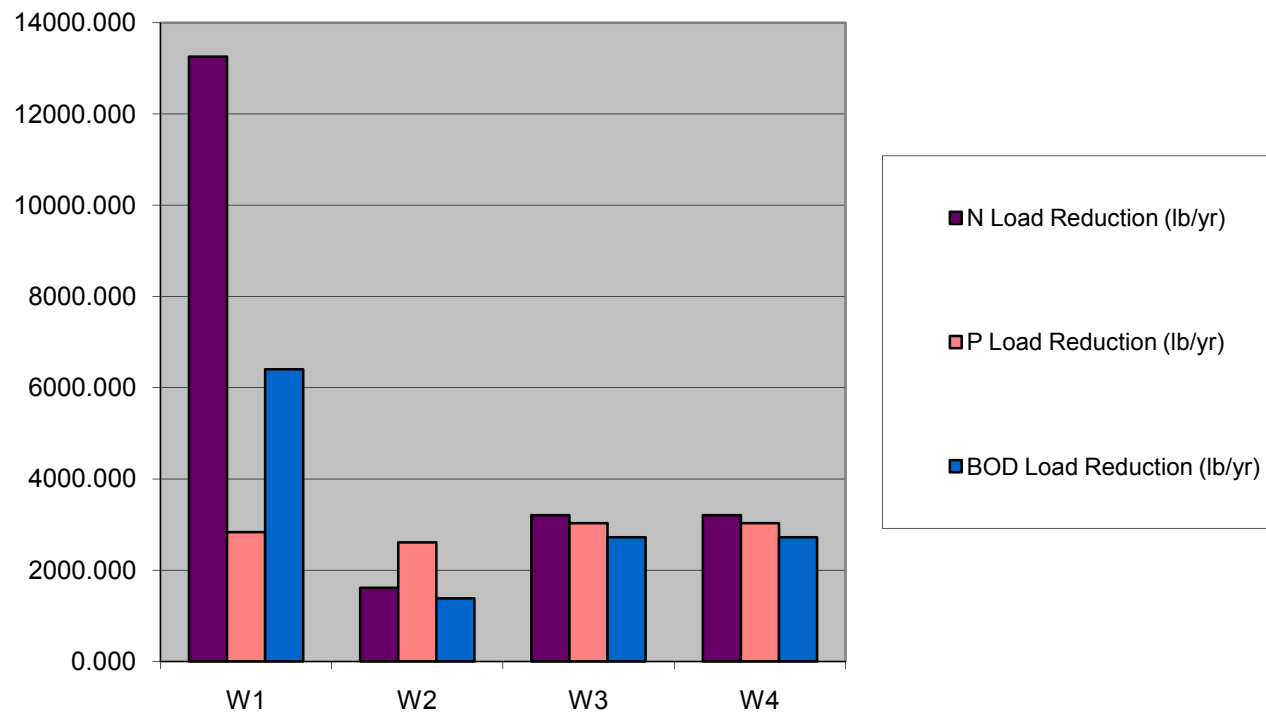
- **Gully and Streambank Erosion Tool input parameters**
 - **Gully dimensions**
 - **Number of years gully has taken to form the current size**
 - **Gully stabilization (BMP) efficiency (0-1) and the gully soil textural class**
 - **Streambank dimensions**
 - **Lateral recession rate (ft/yr) of the eroding streambank**
 - **Streambank stabilization (BMP) efficiency (0-1) and streambank soil textural class**

STEPL Outputs

- Pollutant loads and reductions will be calculated and graphed

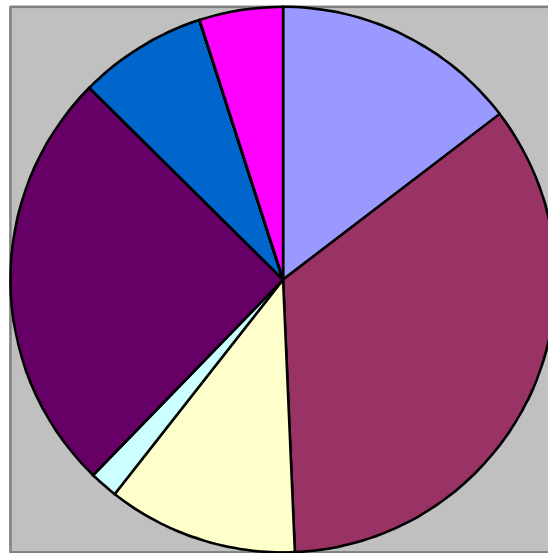


STEPL Outputs



STEPL Outputs

Total P Load by Land Uses (with BMP) (lb/yr)



Urban

Cropland

Pastureland

Forest

Feedlots

User Defined

Septic

Gully

Streambank

Groundwater

STEPL Output as Function of Input Data Accuracy

Minor tinkering with several parameters resulted in the following ranges for P Load

Output Parameter	Base Value	High Value	Low Value
Pre-BMP P Load	4797.8 lb/year	5273.9 lb/year	4338.6 lb/year
Post-BMP P Load	1964.3 lb/year	2478.5 lb/year	1781.0 lb/year
P Load Reduction	59.1%	60.0%	48.3%

STEPL Outputs

- **BMP Efficiencies are MAJOR driving force for load reductions and are quite insensitive to changes in other parameters (e.g., rainfall)**
- **Need to have a very good sense of the true efficiencies in each situation (i.e., starting point is key)**
- **Rainfall data must be accurate or loads can vary considerably (but % reduction won't change much!)**

Region 5 Load Reduction Model

- Spreadsheet to estimate loads and load reductions
- Gullies, bank stabilization, and agriculture fields and filter strips:
 - Sediment, P, and N
- Feedlots:
 - BOD, P, and N
- Urban:
 - BOD, COD, TSS, Pb, Cu, Zn, TDS, TKN, TN, DP, TP, and Cd

AVGWLF (www.avgwlf.psu.edu)

- **Facilitates use of GWLF (Generalized Watershed Loading Function) with ArcView interface**
- **Used on TMDL projects in Pennsylvania**
- **GWLF (Haith and Shoemaker, 1987)**
 - **Continuous simulation model**
 - **Simulates runoff, sediment, N, and P watershed loadings given variable-size source areas (e.g., agriculture, forest, and developed)**
 - **Has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data**
 - **Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values**

AVGWLF General Approach

- 1. Derive input data for GWLF for use in an “impaired” watershed**
- 2. Simulate N, P, & sediment loads in impaired watershed**
- 3. Compare simulated loads in impaired watershed vs. loads simulated for a nearby “reference” watershed (unimpaired but with similar landscape, development and agricultural patterns)**
- 4. Evaluate potential mitigation strategies for impaired watershed to achieve pollutant loads (average annual nutrient and sediment loads) similar to those calculated for the reference watershed**

Conclusions

- Many tools are available to quantify pollutant loads
- Approach depends on intended use of predictions
- Simplest approaches are data-driven
- Watershed modeling is more complex and time-consuming
 - provides more insight into spatial and temporal characteristics
 - useful for future predictions and evaluation of management options
- One size does NOT fit all!

References

Haith, D.A. and L.L. Shoemaker, 1987. *Generalized Watershed Loading Functions for Stream Flow Nutrients*. *Water Resources Bulletin*, 23(3), pp. 471-478.

Michigan DEQ. 1999. *Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual*, Michigan Department of Environmental Quality, Surface Water Quality Division, Nonpoint Source Unit, Lansing, Michigan. <http://www.deq.state.mi.us>

Thomann, R.V. and J.A. Mueller, 1987. *Principles of Surface Water Quality Modeling and Control*, Harper and Row, NY.