Setting the Course for Improved Water Quality: Modeling for TMDL Studies

A TMDL training program for local government leaders and other water managers – Session 11a
Presentation goals

- Define the term **model**
- Identify reasons for using models in TMDL studies
- Discuss the reliability of model outputs
- Describe what is needed to build a model
What is a **watershed model**?

1. An analytical abstraction of the real world

2. A set of mathematical equations that can be used to characterize some of the natural or man-made processes in a watershed system under a variety of conditions.
Why model? Models characterize relative impact of multiple pollution sources to an impaired water load.
Why model?

- **Inform management decisions**
  - Answer questions, such as…
    - What conditions lead to impairment?
    - How extensive is the impairment?
    - What is contributing to the impairment?
    - What changes are needed to attain goals?
      - *Where, when and how much…*
Are models reliable?

In the real world, there are many natural processes

A model may use

one set of equations (simple empirical models)

or

many equations (complex models)
Are models reliable?

No model is perfect.
All models involve uncertainty, especially if not carefully constructed or applied.

- Poor quality data
  - Poor results
How much data do you need?

- Each model has different data input needs.
- The more complicated the model, the more data you need.
- Contiguous data is usually preferred.
- Land use, land management, meteorological, and drainage data are as important as water quality data.
What should you consider when choosing a model?

- Relevance
- Transparency
- Predictive capability
- Scale
- Utility
- Ease of use
Make sure model is relevant to your TMDL project needs – *for example*:

- Models developed for urban or forested rural areas may not be a good choice for an agricultural watershed.
- Lumped parameter models (*like HSPF*) *not* a good choice for field scale simulations.
Seek a model that is transparent. Preferably, use only models which are:

- technically supported
- widely used in public arena
- free – in the public domain
Ease of use

Matches user experience

- New users will likely need training
- Some models are simple spreadsheets
- Some models require complex software packages (e.g. GIS)
Utility

Model should be useful

- Model should be able to predict watershed changes when land use changes
- To select correct model, must know what management practices will likely be used
- How will model be used in the future? As a management tool or to track progress?
Select a model that can be applied at the appropriate scale:

- Select appropriate spatial scale (Minn. River basin vs. small subwatershed)
- Select appropriate temporal scale (hourly vs. seasonal simulations)
Predictive capability

Seek models that can predict changes you need

- Need to predict phosphorus loadings at the watershed outlet after BMPs are implemented?
- Need to determine in-stream dissolved oxygen concentrations during critical conditions?
- Need something else?
Note: Many TMDL studies do not need to use models at all.

Most TMDL studies completed to date have not needed a model.

You can often use simpler tools such as FLUX or duration curves to complete a study.

An exception is where there are excessive nutrients or dissolved oxygen impairments that do require a model.
When needed, these models are used

"Non-models"
- Spreadsheets
- Flow/load duration curves

Simpler Models
- QUAL-2E
- AGNPS
- Etc.

Complex Models
- BASINS:
  - HSPF
  - SWAT
- ECOM-SED/RCA combo

“Non-models” Simpler Models

Complex Models
Modeling overview

- Clarify Objectives / Set Goals
- Collect/Review Available Data
- Design Conceptual Modeling Strategy
- Recommend Collection of Additional Data
- Model Development
  - Framework Revision
  - Calibration
- Model Evaluation
  - Validation with another data set
  - Sensitivity/Uncertainty
- Implementation Planning
  - Analyze Load Scenarios
The modeling process

Phase I
- Identify output requirements
- Collect data
- Prepare input files
- Evaluate parameters

Phase II
- Calibrate (if needed)
- Validate

Phase III
- Analyze scenarios for implementation planning

US EPA, 2005
Build the model

Phase 1

- Identify output requirements: *define exactly what you want the model to predict or do*
- Collect data: *pull together lots of existing data from many sources*
- Prepare input files: *review for quality, completeness; organize into categories*
- Evaluate parameters
Where do we get the data to build a model?

Data sources:
- Met Council
- MPCA
- MDNR
- WDNR
- USGS (LTRMP)
- US Army Corps of Engineers
- U of M
- Others

Minnesota Pollution Control Agency
Calibration and validation

- Calibrate:
  Adjust model parameters so that model outputs resemble available observed data

- Validate:
  Input data from different time periods to evaluate performance & ensure output values are reasonable; model output must match record
More about calibration and validation

**Inputs**
- Actual historical data sets
  - e.g. 1991-1995
  - Physical
  - Water chemistry
  - Climate

**Model**
- Calibrate
  - Refine / tweak parameters to try to approximate reality

**Outputs**
- Predictions based on historical data
  - Streamflow data
  - Water quality data

**Validate**
If predictions satisfactory, test model using a different water quality data set
Implementation planning

- Analyze scenarios:
  Apply model to project future loads under new conditions (after implementing BMPs)

  Use model to evaluate impact of different land use practices (new BMPs, cultivation techniques, etc.) on water quality
What role should local governments play in modeling activities?

- Assist in selecting the appropriate tool – a “non-model” (duration curves, FLUX) or a more complex model
- Coordinate often with MPCA staff and consultants (if used)
- Assist in oversight of consultant work (if applicable)
- Assist in communicating results to stakeholders and the public
Thoughts about communicating modeling results for any project

- Focus presentation on 1-2 model outputs
- Simplify outcomes for general public (3 key points, ~30 words per PowerPoint slide)
- Describe model’s performance (Does it closely simulate reality? Why?)
- Address uncertainty in the outputs
Addressing the skeptics

Messages to the skeptics:

Models, while imperfect, can be an adequate approximation of current and future water quality conditions available.

Models can handle many more data sets than the human mind, making them much more accurate than operating on a hunch.
Be sure to create an official file

Your TMDL project file should include:

- Model **name** and **version**
- Model **assumptions**
- All **calibration data** (if needed) and a detailed explanation of why it was used
- A **validation report** explaining why the model should replicate real-world conditions
- A **scenario report** providing likely water quality outcomes if various BMP solutions are implemented in the watershed
Models are used to integrate many data types (water quality, land use, soils, topography, etc.) to understand pollutant impacts to water quality.

Models allow us to determine water quality impacts under different land management scenarios.

Models are reasonably accurate, given they are applied properly.

Any uncertainties about model outputs should be conveyed to stakeholders.
Summary

- Having good quality and enough data is key to building a reliable model.
- Models should be validated to increase confidence in their outputs.
- Building a model takes time – especially in Phase I, collecting and preparing data.
- Coordinate often with MPCA staff when selecting and using the appropriate analytical tool.
Modeling contacts
“True wisdom consists in not departing from nature and in molding our conduct according to her laws and model.”

—Seneca
ancient Roman writer