DC Water Resource Research Institute
&
Agriculture Experiment Station

Modeling Integrated Urban Wastewater System: Model building and Implementation

Tolessa Deksissa and Pradeep Behera

University of District of Columbia

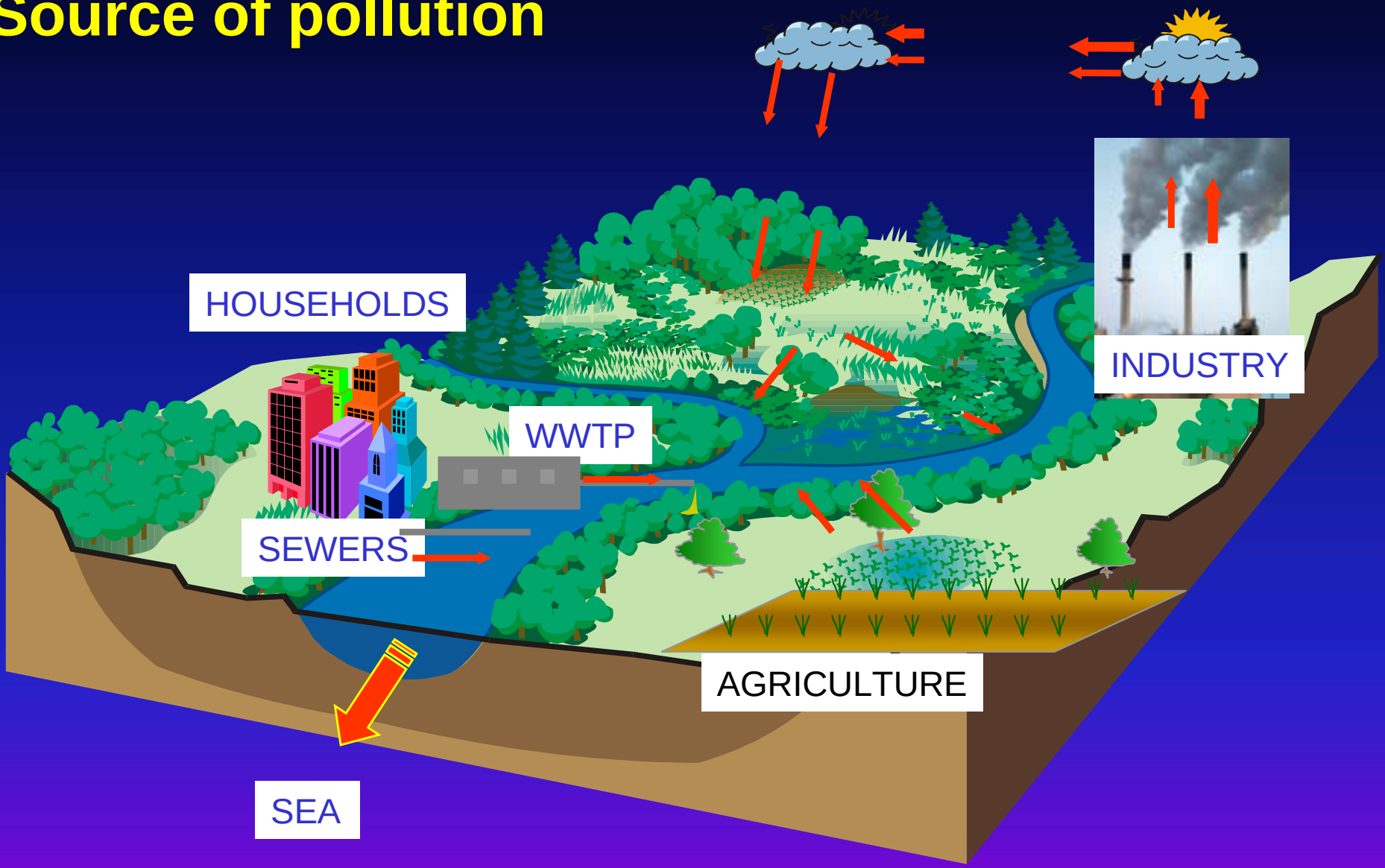
2008 Mid-Atlantic Regional WRRIs Regional Water Conference: the Water Energy Nexus, November 17-19, Shepherdstown, WV

Outline

- Introduction
  - Source pollution and management tools
- Objective
- Methodology
  - Model selection
- Simulation results
- Conclusion

Introduction

- **Source of pollution**



⇒ BOD, Ammonia, N and P, heavy metals, PCBs, PAH, Pesticides …

Effect of Storm Water and CSOs

⇒ Excessive algal blooms, oxygen depletion during night, and mass fish killing

Intro: Pollution Management

- Urban pollution management/legislation approaches
  - Uniform Emission Standards (UES)
    - Focuses on the effluent quality
    - Technology based
    - Applicable for hazardous substances
  - Environmental Quality Objective/Standards (EQO/EQS)
    - Based on the local discharge condition of the receiving water or river
    - Applies for BOD and nutrients

$\Rightarrow$ Holistic approach = UES + EQO

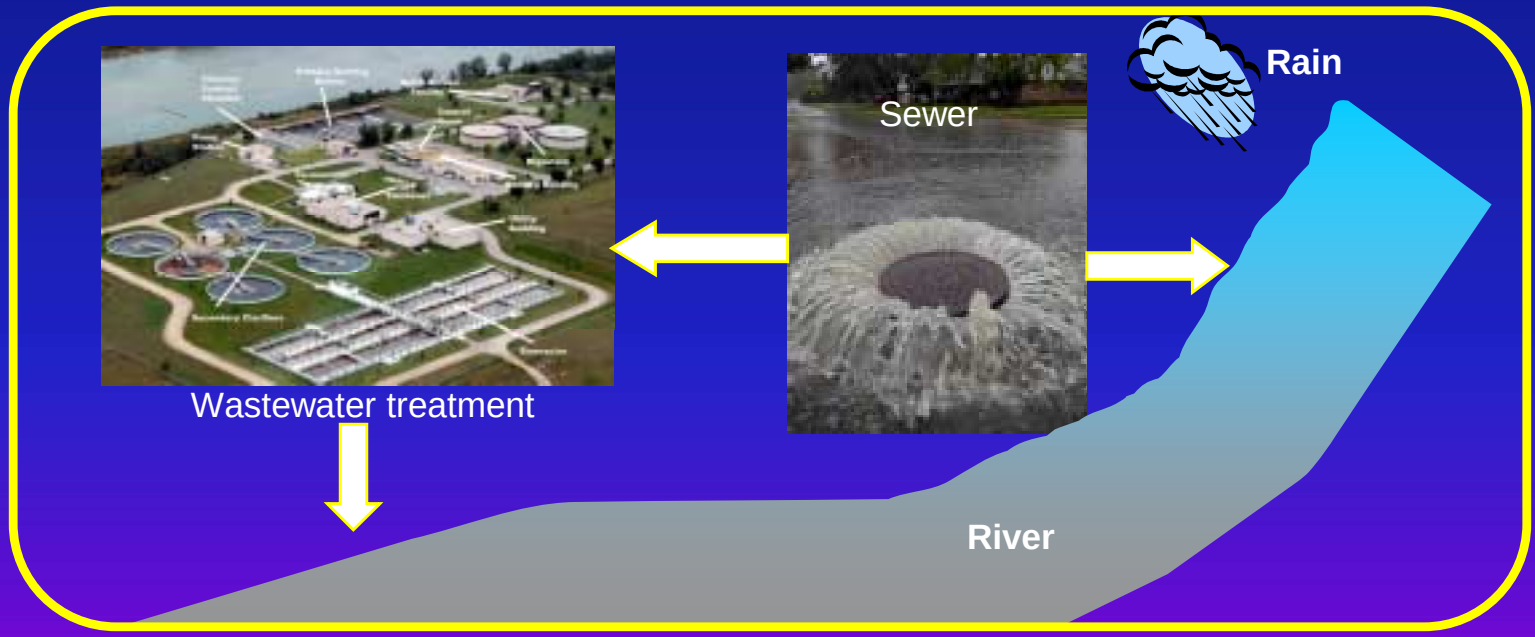
Tools for water resource management: Problem definition

- Monitoring/Real measurement
  - Accurate, but costly

- Mathematical models:
  - Predictive capacity
  - Once developed, it is relatively cheaper

Mathematical models: Problem

- Varies from simple steady state model to complex hydrodynamic model
- PC requirement varies from simple excel sheet to complex simulation package
- Existing models were designed for subsystem: Sewer or Wastewater treatment plant or river



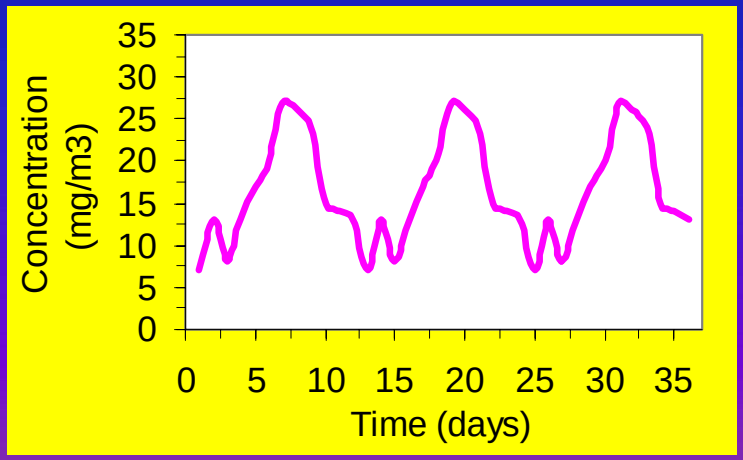
⇒Interaction among subsystems is missing

Objective

- To develop a dynamic integrated model that takes into account:
  - Sewer,
  - Wastewater treatment plant, and
  - River

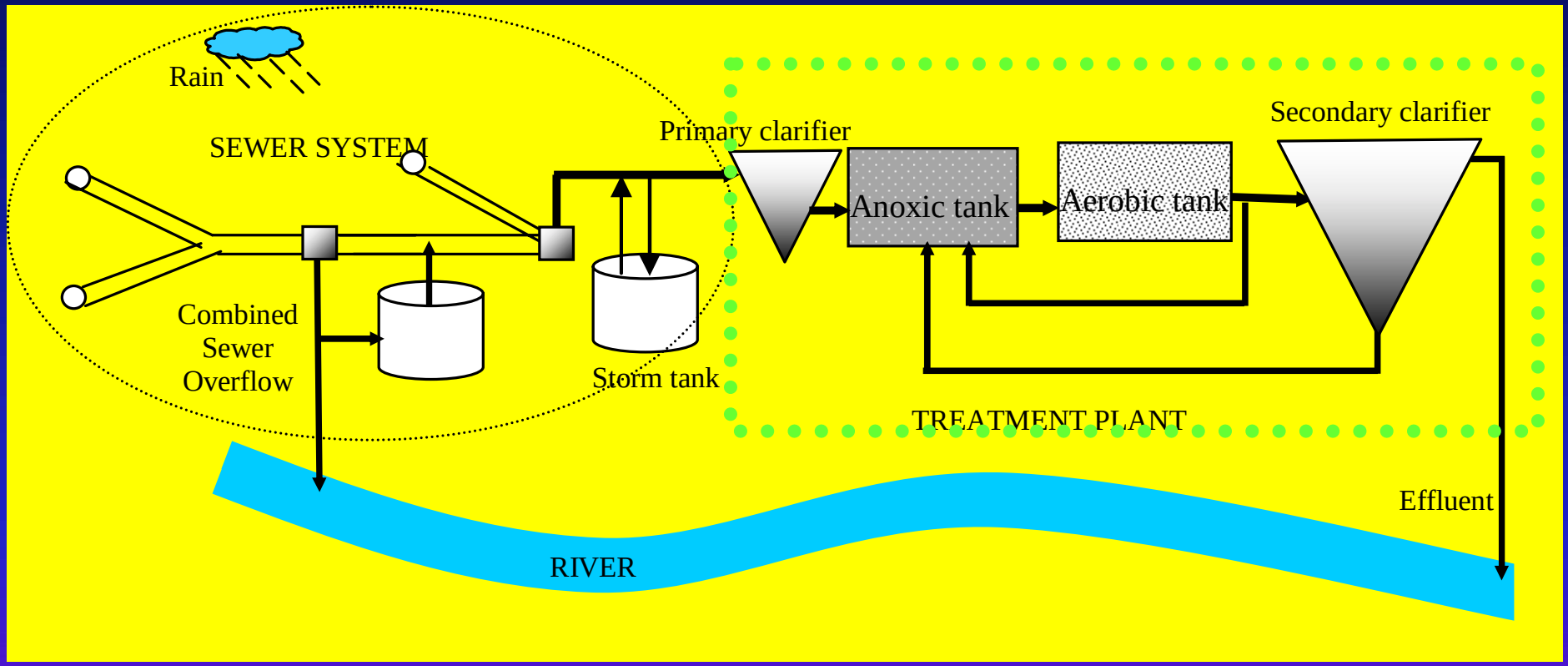
Why Dynamic Integrated Models?

- Dynamic integrated water quality models:
  - Consider inherent temporal fluctuation of water quality variables
  - Describe time of recovery after emission seas
  - Tool for highly variable emission management
  - Holistic approach: allows better understanding of the system as a whole, and mutual interaction between its components
  - Applies to a real time control and evaluation of system performance



Methodology: Scheme of IUWS

- Integrated urban wastewater system (IUWS)



Methodology: Model Selection

- Modeling and simulation tool
  - Closed structure: WASP5, CE-QUAL-ICM, SALMON-Q…
  - Open structure: AQUASIM, WEST …
- Modeling approaches
  - Hydraulics
    - State-of-the art the St. Venant equations
      - Long computation time
      - Not suitable for water quality simulation

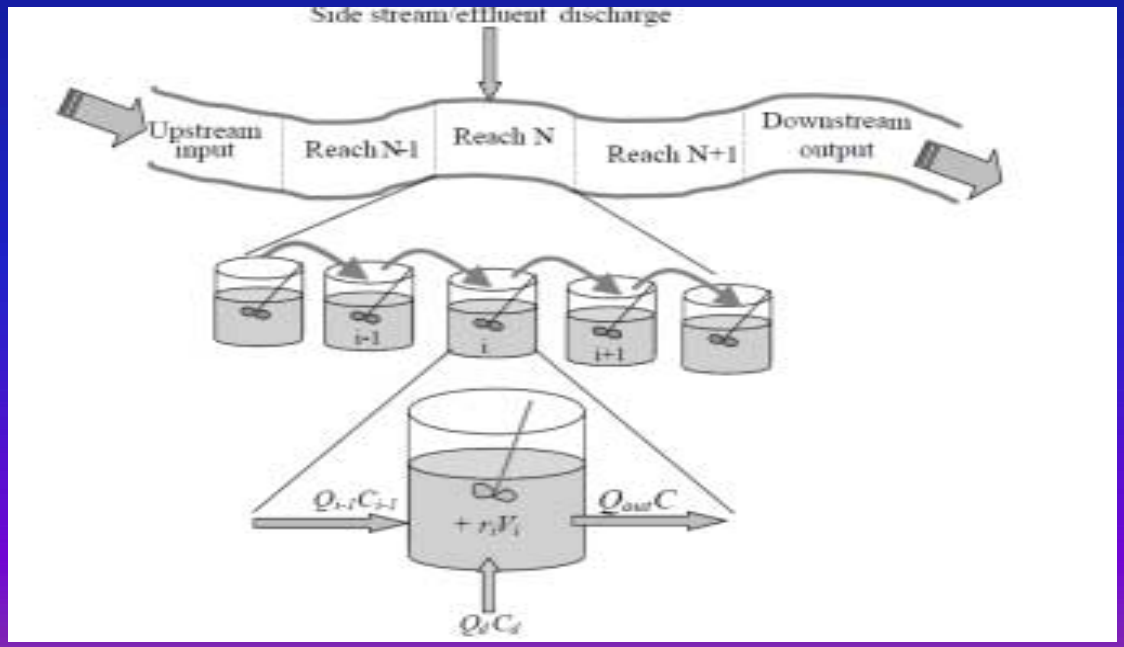
$$\frac{\partial C}{\partial t} = \underbrace{-u_x \frac{\partial C}{\partial x} - u_y \frac{\partial C}{\partial y} - u_z \frac{\partial C}{\partial z}}_{\text{advection}} + \underbrace{E_x \frac{\partial^2 C}{\partial x^2} + E_y \frac{\partial^2 C}{\partial y^2} + E_z \frac{\partial^2 C}{\partial z^2}}_{\text{dispersion}} - \underbrace{R}_{\text{reaction}}$$

⇒ IUWS requires Open Structure and Conceptual mass balance approach

Methodology: Model Selection

- Conceptual, mass balance approach
  - Short computation time.
  - Suitable for water quality simulation

$$\frac{d(VC)}{dt} = Q_{in}C_{in} - Q_{out}C + rV$$



Methodology: Model Selection

- Modeling approaches
  - Biochemical reaction
    - Open mass balance
      - EPA QUAL2
    - Closed mass balance:
      - IWA RWQM1

$$\frac{d(VC)}{dt} = Q_{in}C_{in} - Q_{out}C + rV$$

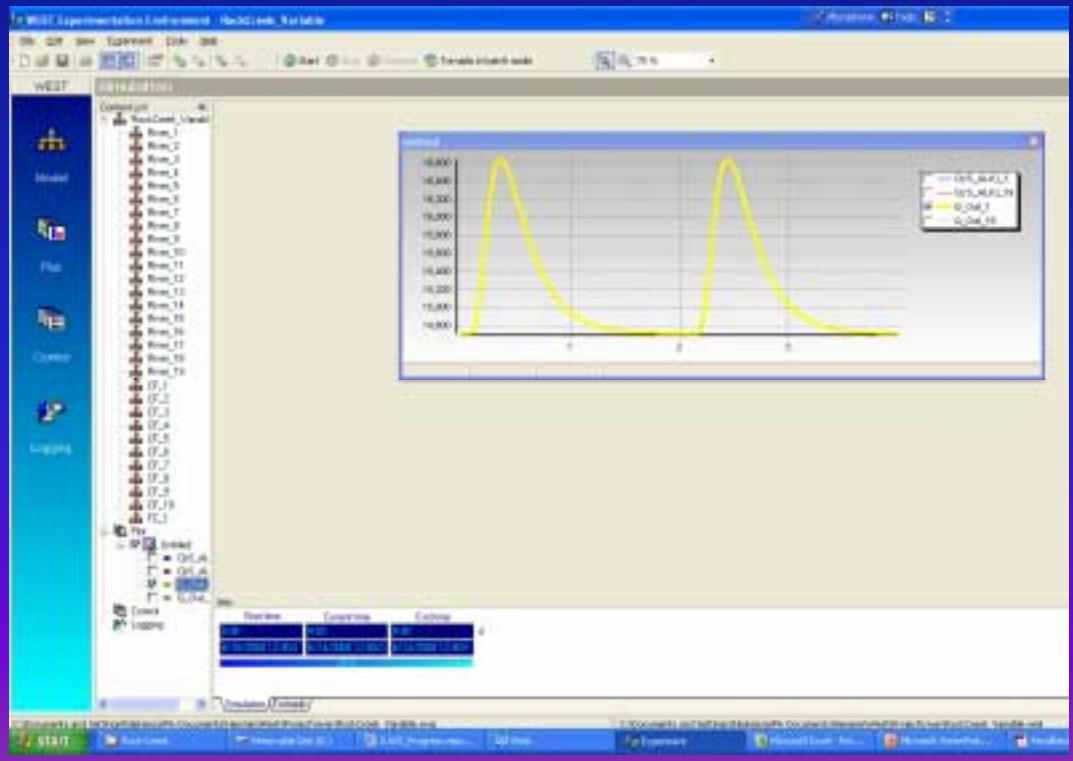
Methodology: Model Selection

- Simulation approach
  - SYNOPSIS simulator:
    - Uses different existing models in different software packages
  - Simultaneous parallel simulation
    - Uses one integrated model in one software packages

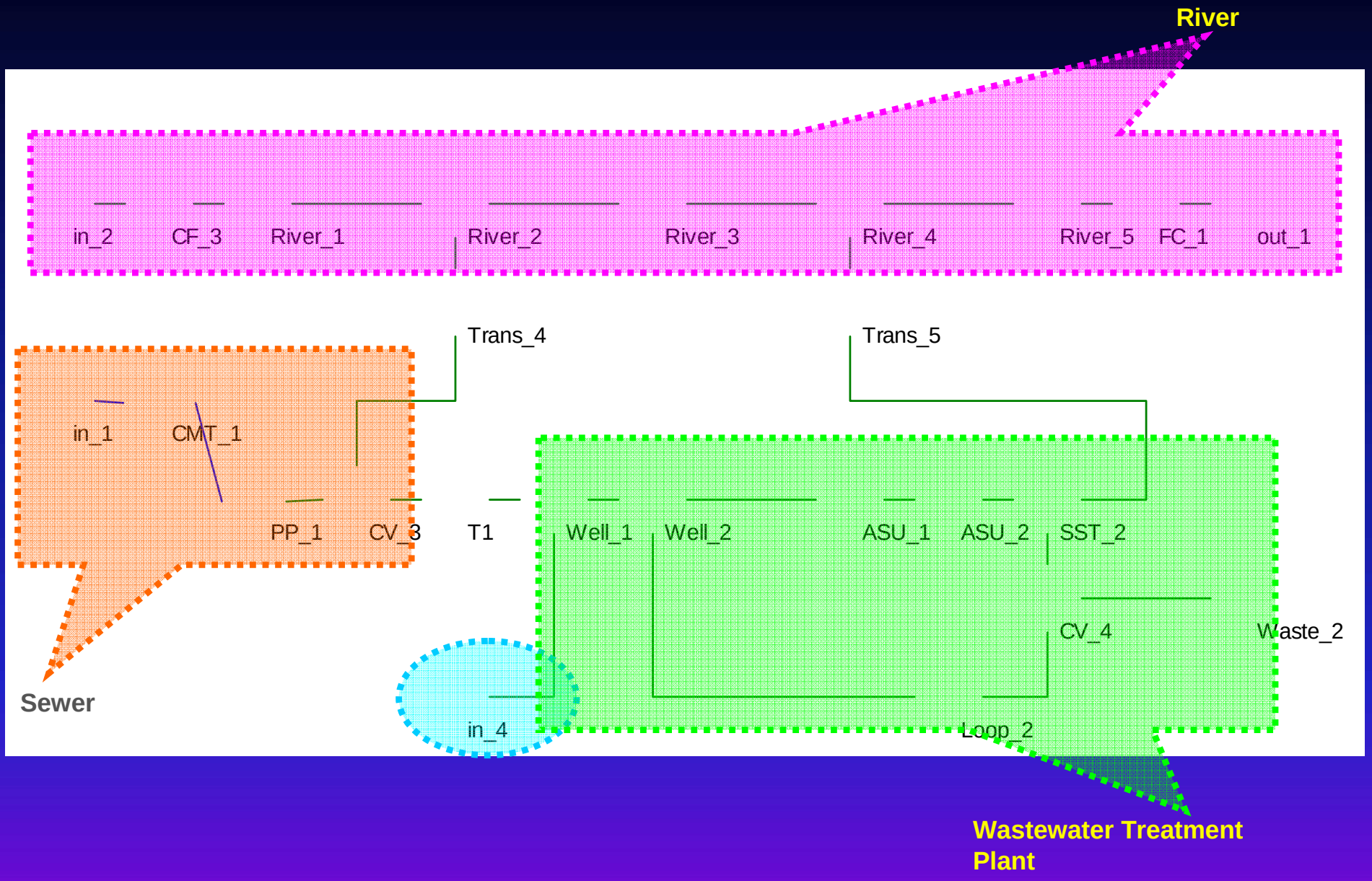
⇒ IUWS requires Open Structure and Conceptual mass balance approach

Model implementation in WEST®

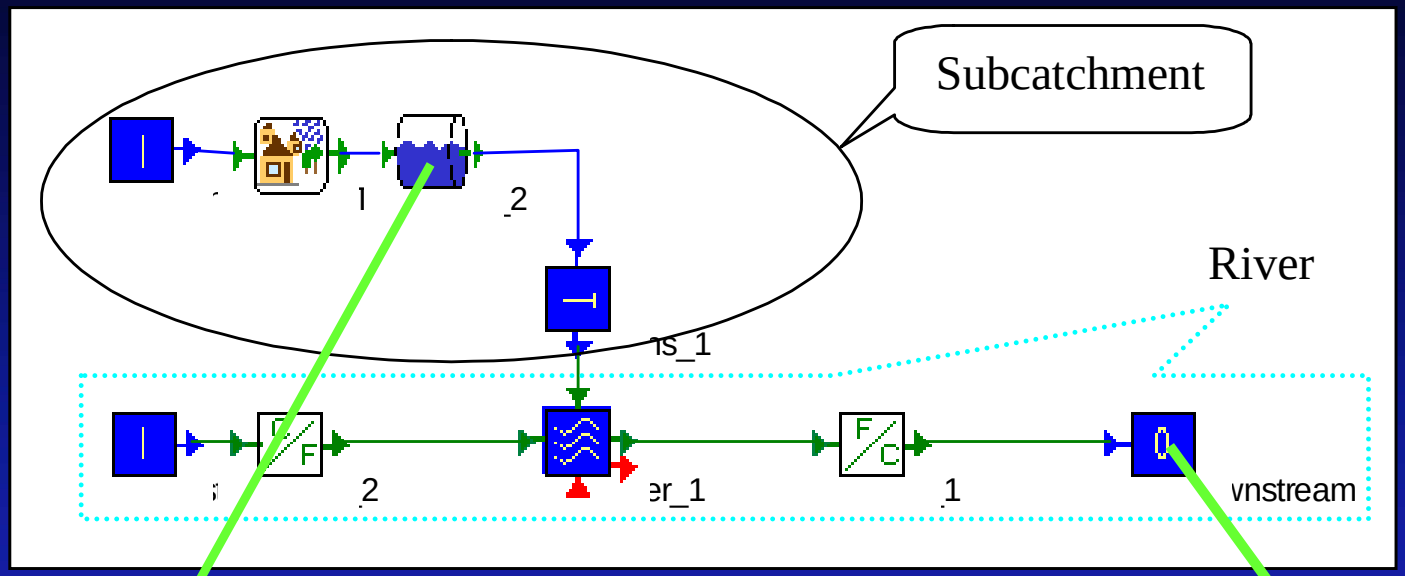
- Why WEST?
  - Open structure
  - Allows parallel/simultaneous simulation
  - Reuse of model bases

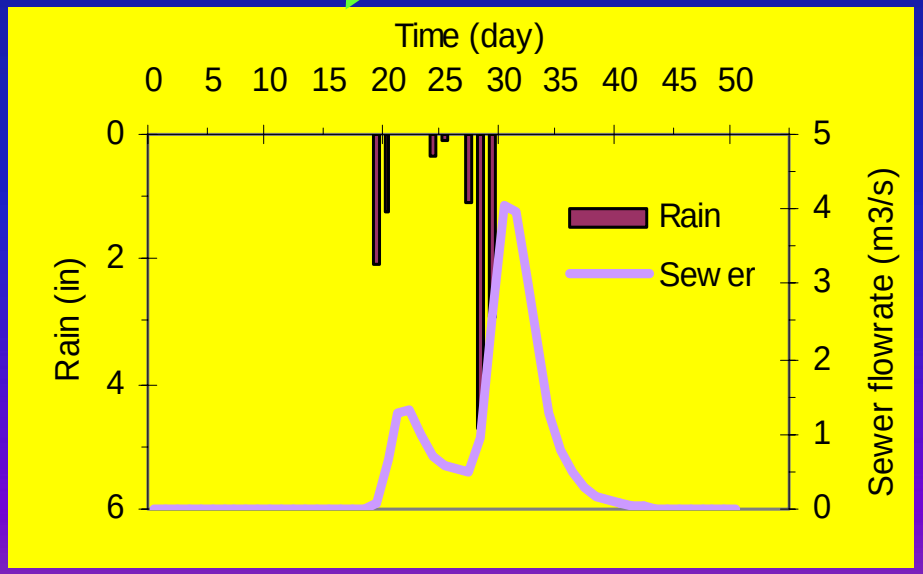


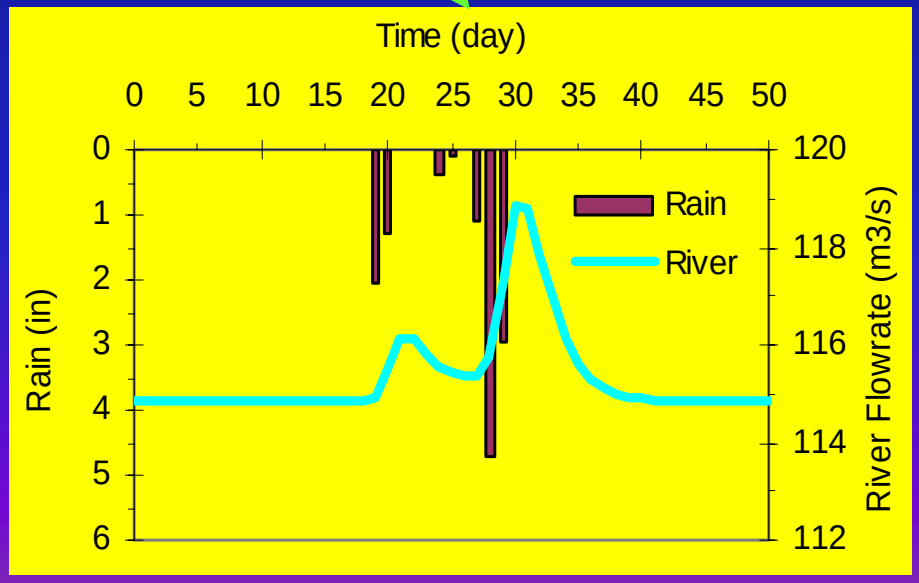
IUWS Model Configuration in WEST®



Model Evaluation: Storm water

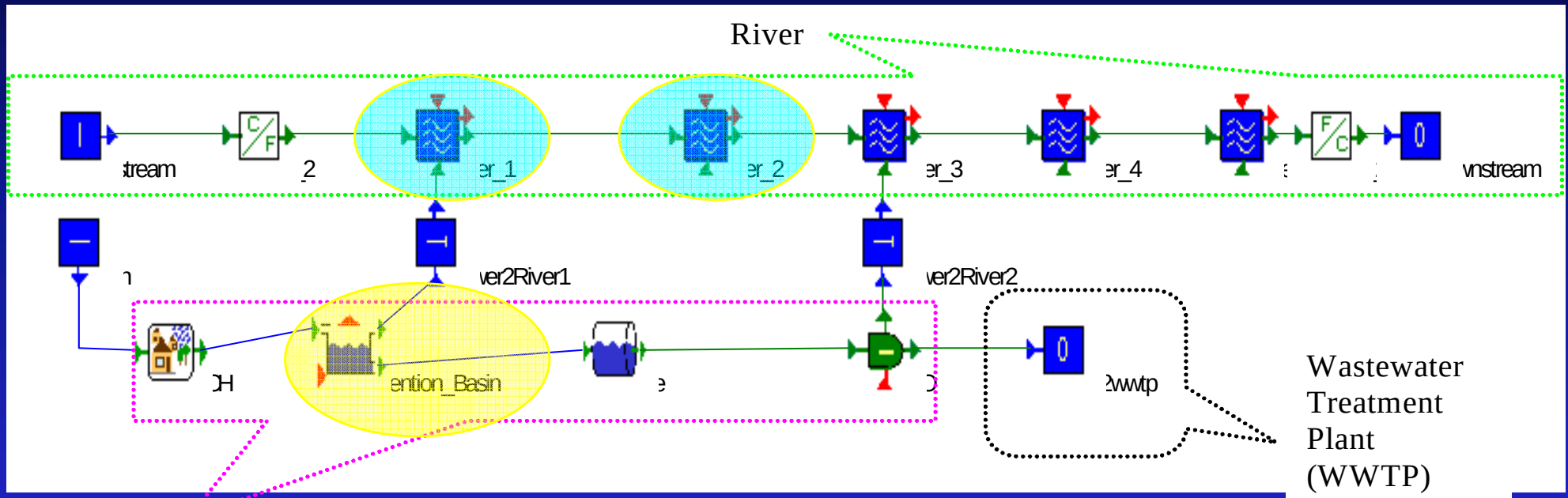






Model Evaluation: Retention Basin

Rainfall Runoff and River

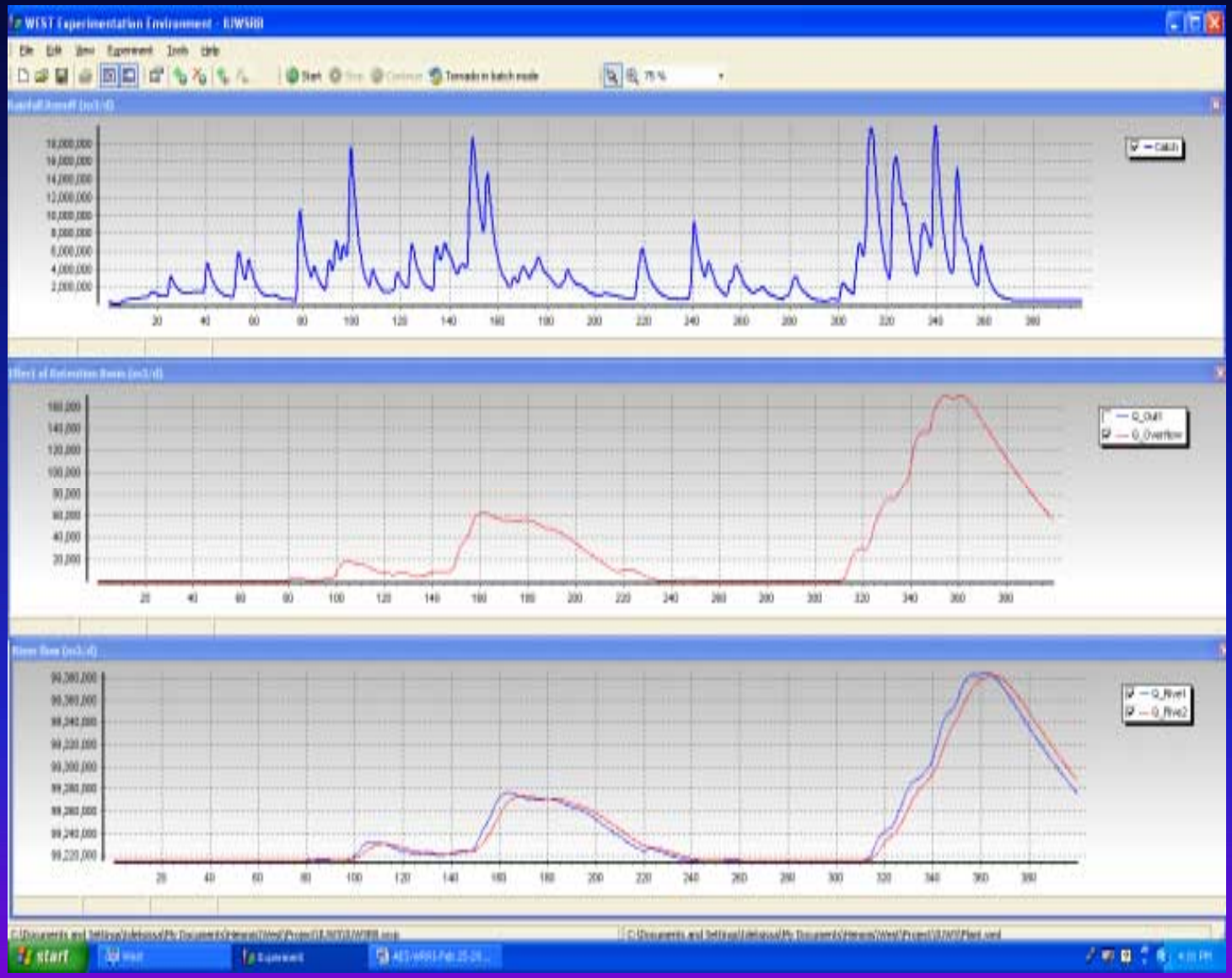


Effect of retention basin on CSOs

Runoff/Sewer

River 1

River 1 and 2



⇒Retention basin reduces frequency of river contamination by CSO

Conclusion

- IUWS model is can be a useful tool for system performance analysis and real control analysis
- Useful for scenario analysis.

Farther research

- Model calibration
- Model verification
- More scenario or “what if” analysis