LECTURE #2

INTRODUCTION TO HSPF AND THE MODEL APPLICATION PROCESS
HSPF: HYDROLOGIC SIMULATION PROGRAM - FORTRAN

- Continuous simulation model
- Natural and developed watersheds and water systems
- Land surface and subsurface hydrology and quality processes
- Stream/lake hydraulics and water quality processes
- Time series data management and storage
- Time series data statistical analysis and operations
- Core watershed model in EPA BASINS and Army Corps WMS
- Development and maintenance activities sponsored by U.S. EPA and U.S. Geological Survey
CONTINUOUS SIMULATION

Representing hydrologic processes, storages, and pathways (fluxes) for a watershed, continuously for many days to multiple years, with time steps of one day or less, usually in the range of minutes to hours.
RESULTS FROM CONTINUOUS SIMULATION

Daily Flow

Flow Duration/Frequency

Storm Hydrographs
COMPONENTS OF WATER QUALITY PROBLEMS AND POLLUTION
COMPONENTS OF WATERSHED WATER QUALITY MODELS

Nonpoint Loading Simulation
- Runoff quantity - surface and subsurface
- Sediment erosion/solids loading
- Runoff quality
- Atmospheric deposition
- Inputs needed by instream simulation

Instream Simulation
- Hydraulics
- Sediment transport
- Sediment-contaminant interactions
- Water quality constituents and processes
- Point source accommodation
- Lake/reservoir simulation
- Benthal processes and impacts
HSPF APPLICATION & UTILITY MODULES (Version 12, 2001)

APPLICATION MODULES

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>PERLND</th>
<th>IMPLND</th>
<th>RCHRES</th>
<th>BMP</th>
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<tr>
<td>PERLND</td>
<td>PERLND</td>
<td>PERLND</td>
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<tr>
<td>Snow</td>
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<td>Hydraulics</td>
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<td>Conservative</td>
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<tr>
<td>Sediment</td>
<td>Solids</td>
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<td>Temperature</td>
<td>simulated in PERLND,</td>
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<tr>
<td>Quality</td>
<td>Quality</td>
<td>Quality</td>
<td>Sediment</td>
<td>IMPLND or RCHRES</td>
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<tr>
<td>Pesticide</td>
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<td>Nonconservative</td>
<td>BOD/DO</td>
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<tr>
<td>Nitrogen</td>
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<td>Nitrogen</td>
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<tr>
<td>Phosphorus</td>
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<td>Phosphorus</td>
<td>Carbon</td>
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<tr>
<td>Tracer</td>
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<td>Tracer</td>
<td>Tracer</td>
<td>Plankton</td>
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UTILITY MODULES
COPY, MUTSIN, PLTGEN, DURANL, GENER, DISPLY, REPORT
PERLND STRUCTURE CHART

- **PERLND**
  - Simulate a pervious land segment

- **MSTLAY**
  - Estimate solute transport

- **PEST**
  - Simulate pesticides

- **NITR**
  - Simulate nitrogen

- **PHOS**
  - Simulate phosphorus

- **TRACER**
  - Simulate a conservative tracer

- **AGCHEM**

- **ATEMP**
  - Correct air temperature

- **SNOW**
  - Simulate snow and ice

- **PTEMP**
  - Estimate soil temperature(s)

- **PWATER**
  - Simulate water budget

- **SED**
  - Simulate sediment

- **PWTGAS**
  - Estimate water temperature and gas concentrations

- **POUAL**
  - Simulate general quality constituents
IMPLND STRUCTURE CHART

IMPLND

Simulate a segment of impervious land

ATEMP

(see module PERLND)

SNOW

(see module PERLND)

IWATER

Simulate water budget for impervious land segment

SOLIDS

Accumulate and remove solids

IWTGAS

Simulate water temperature and dissolved gas concs.

IQUAL

Simulate quality constituents using simple relationships with solids and/or water yield
Simulate hydraulic behavior

Estimate advective behavior of constituents

Simulate conservative constituents

Simulate heat exchange and water temperature

Simulate inorganic sediment

Simulate generalized quality constituents

Simulate constituents involved in biochemical transformations

Simulate a reach or mixed reservoir
SEGMENTATION OF COMPLEX WATERSHEDS FOR MODELING

INPUTS:
Meteorological:
Precipitation, Temperature, Etc.

Physical:
Soil Properties, Channel Properties, Land Use, Etc.

OUTPUTS:
Stream Flows, Concentration, Etc.

II Land Segment Number
--- Land Segment Boundary
↑ Stream Reach
② Stream Reach Number
SOIL PROFILE REPRESENTATION
BY THE AGCHEM MODULE

Outflow to Stream With:

- Sediment, Surface Runoff
- Interflow

Layer:

- Surface
- Upper
- Lower
- Ground Water
HSPF - STRENGTHS

- Comprehensive representation of watershed land and stream processes
- Comprehensive representation of watershed pollutant sources, including nonpoint sources (by multiple land uses), point sources, atmospheric, etc.
- Flexibility and adaptability to a wide range of watershed conditions
- Well-designed code modularity and structure
- Companion database and support programs to assist model users (e.g., WDMUtil, WinHSPF, GenScn, HSPEXP)
- Ongoing development and support by U.S. EPA and U.S.G.S.
- Continuing code enhancements funded by numerous groups
- Strict code version control through joint agreement of U.S. EPA & U.S.G.S.
HSPF - IDENTIFIED/PERCEIVED LIMITATIONS AND WEAKNESSES

- Extensive data requirements (e.g., hourly rainfall) – BASINS helps
- User training normally required – BASINS helps
- No comprehensive parameter guidance available – BASINS helps
- Limited spatial definition (i.e., lumped parameter approach)
- Hydraulics limited to non-tidal freshwater systems and unidirectional flow
- Simplified representation of urban drainage systems (e.g., culverts, pipes, CSOs)
- Limited representation of algal species - phytoplankton, zooplankton, benthic algae – 3 types of BA in V 12
HSPF - RECENT ENHANCEMENTS AND DEVELOPMENTS

- Wetlands and shallow water-table hydrologic capabilities (funded by SFWMD)
- Implementation of water quality linkage between land segments for modeling buffer strips, riparian zones, grass waterways, etc. (funded by MPCA)
- Irrigation capabilities added to define application methods and sources (funded by SFWMD)
- Simplified snow algorithms (degree-day method) added to minimize meteorologic data needs (funded by EPA OW/OST for use within BASINS)
- Online interactive HSPF HELP available (complete HSPF Manual, V.11 in Windows) (funded by USGS)
- Development of Scenario Analysis (GENSCN) GUI software for generation, display, and evaluation of watershed model scenarios (funded by USGS & EPA)
- BMP and REPORT modules developed (funded by TMDL studies in Georgia)
- Multiple benthic algae species incorporated (Version 13, funded by NV group)
THE BASINS/HSPF APPLICATION PROCESS
THE MODELING PROCESS

Phase I
- Data collection
- Model input preparation
- Parameter evaluation

Phase II
- Calibration
- Validation
- (Post-audit)

Phase III
- Analysis of alternatives
HSPF APPLICATION PROCESS

• Study definition
• Development of modeling strategy
• Learn operational aspects of HSPF
• Input/management of time series data
• Parameter development
• Calibration/validation
• Analysis of alternate scenarios
STUDY DEFINITION

- Problems/questions for analysis, study goals
- Data availability
- Project resource availability (time, money, expertise)
MODELING STRATEGY

- Processes, constituents, and sources to be modeled
- Watershed segmentation (spatial and temporal detail)
- Channel segmentation and tributary areas
- Data to support modeling effort
- Human impacts, alternatives to be analyzed
- Develop simulation plan
CONSTITUENT SOURCES IN HSPF

- Initial storages
- Nonpoint loadings
- Point loadings
- Atmospheric deposition
- Chemical transformations
- Releases from the channel bottom
- Atmospheric gas invasion
MODEL VERSUS NATURAL SYSTEM: INPUTS, OUTPUTS, AND ERRORS

SYSTEM INPUTS

- Observed Values
  - + ERROR

MODEL (System Representation)
- Parameter Estimation
  - + ERROR

- ± ERROR

MODEL TESTING
- Calibration/Validation
  - + ERROR

NATURAL SYSTEM
- Observed Values
  - + ERROR

- System Outputs

Model Outputs
- Calibration/Parameter Adjustment
  - + ERROR
ANALYSIS OF ALTERNATIVES

• Definition of alternatives

• Selection of constituents and numeric/statistical measures

• Representation of alternatives
  – input changes
  – system configuration
  – parameter changes
## RELATIVE EFFORT FOR HSPF APPLICATION STEPS (through calibration/validation)

<table>
<thead>
<tr>
<th>TASK</th>
<th>% EFFORT</th>
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<tbody>
<tr>
<td>Problem definition</td>
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<tr>
<td>Modeling strategy</td>
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<tr>
<td>Learn operational aspects</td>
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<tr>
<td>Development and input of time series</td>
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<tr>
<td>Parameter development</td>
<td>15</td>
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<tr>
<td>Calibration and validation</td>
<td>30</td>
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</table>
# REPRESENTATIVE HSPF PROJECT SCHEDULE

<table>
<thead>
<tr>
<th>TASK</th>
<th>TIME (weeks or months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem definition</td>
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<tr>
<td>Modeling strategy</td>
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<tr>
<td>Operational aspects</td>
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<tr>
<td>Time series data development</td>
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<tr>
<td>Parameter development</td>
<td></td>
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<tr>
<td>Calibration/verification</td>
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<tr>
<td>Analyze alternatives</td>
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BASINS Provides
- Tools for Watershed Delineation and Segmentation; GIS Data Layers
- WDM Meteorologic Data, BASINS Data, WDMUtil Software
- GIS Data Layers / Tools, HSPFParm and WinHSPF Software
- WinHSPF/GenScn Functionality and Post-Processing
- WinHSPF/GenScn Functionality and Post-Processing
- WinHSPF/GenScn To Facilitate Analysis

Application Steps
- Study Definition Modeling Strategy (Simulation Plan)
- Input/Management of Time Series Data
- Parameter Development Model Setup
- Hydrology Calibration/Validation
- Water Quality Calibration/Validation
- Scenario Analysis

Other Inputs / Issues
- Stakeholders, TMDL Needs, Watershed Assessment, Water Resources Issues, Local Data Availability
- USGS, National Weather Service, Local Sources
- Soils, Landuse, Land Practices, Other Local Data; External GIS Capabilities
- Stakeholder and Advisory Group Reviews, Calibration and Validation Targets, Acceptable Uncertainty
- Stakeholder and Advisory Group Reviews, Calibration and Validation Targets, Acceptable Uncertainty
- Local Stakeholder Needs, Regulatory Requirements, Public Health Issues

Related Workshop Exercises
- 1, 2, 5
- 3
- 4, 15
- 6, 7, 8
- 9, 10, 11, 12, 13
- 14
CASE STUDY
INTRODUCTION
PATUXENT STUDY

• Initiated in 1985 by the U.S. Geological Survey and the Maryland Department of the Environment

• Nonpoint source nutrient loadings

• Representative of other subbasins of the Chesapeake Bay
MAJOR ISSUES

• Substantial commercial, residential, and industrial development

• Investigate effects of future growth on water quality

• Planning growth to minimize potential adverse effects
WESTERN BRANCH

• Discharges directly to the Patuxent estuary

• Land use 45% Forest/Wetland, 25% Agriculture, 25% Urban

• Gage at Upper Marlboro, drainage area about 90 square miles
WATER QUALITY CONSTITUENTS SIMULATED

- Water Temperature
- Sediment
- Dissolved Oxygen, BOD
- Nitrogen – NH$_3$, NO$_2$/NO$_3$, Org N
- Phosphorus – PO$_4$, Org P
- Plankton – Phytoplankton, Benthic Algae (as Chl a)