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Watershed Model Development Within The US Army Corps of Engineers

Pat Deliman
ACOE/ERDC, USA

Bill Scharffenberg
HEC, USA

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Watershed Model Development Within The US Army Corps of Engineers

Pat Deliman, Ph.D.
Bill Scharffenberg, Ph.D.
Watershed Modeling System (WMS)

- Developed by Engineering Modeling Research Laboratory (EMRL) at BYU (1990s)
- HEC-1, HEC-RAS, HEC-HMS, TR-20, TR-55, NFF, Rational, MODRAT, HSPF, CE-QUAL-W2, and GSSHA
- Current distribution through Aquaveo LLC
- Complete program for developing watershed computer simulations
  - GIS Tools
  - Web-based data acquisition tools
  - Terrain data import and editing tools
  - Automated watershed delineation & hydrologic modeling
  - Export WMS animations to Google™ Earth
SWWRP Program Rationale

Program Development

- Recognized need for system-wide and watershed based approach to water resource management
- Recognized need for suite of tools for planning and assessing at various scales
- Included field input from multiple listening sessions and interagency workshops
- Recognized need for partnering

Program Features

- Supports goals of ecosystem restoration and environmental sustainability
- Provides technology for meeting mission requirements over broad temporal and spatial scales
- Designed to maximize interactions within the Corps and with its partners
# Program Structure

## USACE/National Water Resource Needs

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## Unifying Technologies

- Integrating Frameworks
- Data Management
- Geospatial Applications Development
- Regional Measurement and Monitoring
- Model Integration
- Decision Support and Knowledge Management
SWWRP Watershed Assessment – Capabilities and Applications

- Watershed Notebook – Online Users
- MAWI:
  - Russian River, CA
  - Camp Pendleton, CA
  - Beale AFB & Miramar NAS, CA
- TASTR:
  - Piney Run Reservoir, MD
  - Smithville Lake, MO
  - Eau Galle, WI
  - Cullman Reservoir
  - Beaver Lake, AR
- EDYS:
  - Cibola & Honey Creek Watersheds, TX
- HMS:
  - Dam Break Analysis
  - Wetland Restoration
- GSSHA:
  - Kishwaukee Watershed, IL
  - Rio Grande River, NM
  - Eau Galle River, WI
  - Upper Auglaize, OH
  - San Jacinto Watershed, CA
- ADH:
  - South Florida/Everglades
  - Biscayne Bay
- Subsurface Toolkit
  - New Orleans, LA

Watershed Notebook
- Online Reference

HMS – Pseudo-Distributed Hydrology

WASH123D – 1, 2, and 3 Dimensional Hydrologic Model

GSSHA – Distributed Hydrology

MAWI – Geospatial And Index Models

TASTR – TMDL Assessments And Reservoir Loadings

EDYS – Vegetation And Hydrologic Models

Subsurface Toolkit – Integrated Seepage & Slope Stability
Nutrient Sub-Model (NSM)

**NSM Model Components**

- Overland/Soils Module
  - NH4, NO3, Organic Nitrogen (Dissolved and Adsorbed)
  - PO4 and Organic Phosphorus (Dissolved and Adsorbed)

- Channel Module
  - NH4, NO3, Organic Nitrogen (Dissolved and Adsorbed)
  - PO4 and Organic Phosphorus (Dissolved and Adsorbed)
  - Dissolved Oxygen
  - Algae Groups
    - Phytoplankton (Floating Algae)
    - Benthic or Periphyton (Submerged Attached Algae)

- Plant Module (Terrestrial)
  - EPIC formulations based upon the Heat Index Method
  - EDYSLite (developed put not integrated within NSM yet)

*Developed for Integration with USACE H&H Modeling Systems*
Contaminant Transport Transformation and Fate Sub-Module for Military Installations (CTT&F)

Capabilities:

• Assess soil, sediment and surface water environments contaminated with explosives and energetics for military installations.
• Study the environmental impacts of other contaminants entering in watershed systems such as toxic chemicals, acid mine drainage, metals from mining areas, and the deposition of solid compounds from the atmosphere to the land surface.
• Implement for installation compliance with water quality regulations as well as long-term watershed planning and management.
• Provide exposure assessment and risk management for sustained and future sustainable mission capacity for military installations.

Developed for Integration with USACE H&H Modeling Systems
CTT&F

Features:
- Multi-species
- Multi-phase partitioning (dissolved, DOC bound, sediment sorbed, solid particles)
- 2D land surface contaminant transport via. runoff and sediment
- 1D channel contaminant transport via. flow and sediment
- Water column interaction with upper sediment/soil layer
- Eight transformation processes - Biodegradation
  - Hydrolysis
  - Oxidation
  - Photolysis (Photodegradation)
  - Volatilization
  - Dissolution of solid phase
  - User-defined extra reaction
  - Transformations and daughter products.
Training Range Environmental Evaluation and Characterization System (TREECS)

Training Range Environmental Evaluation and Characterization System (TREECS) is a client-based system that provides forecasts of Munitions Constituents (MC) fate on and off range based on munitions use on range. Provides multiple tier modeling capability to meet user’s needs.

**Development Approach:**
Formulate and couple screening level MC fate/transport-transformation-sequestration models in an integrated framework for fast assessments with a minimal amount of user input.

Training Range Environmental Evaluation and Characterization System (TREEECS) – Tier 2 Analysis

Note: Tier 1 does not include those processes in Red
Watershed Hydrology Simulation Ongoing R&D

- HMS
  - Sediment Transport
- GSSHA
  - Constituent transport (kinetics using GSSHA 1st Order Decay, NSM and CTT&F) – NSM and CTT&F integration not finalized
  - Coupling with EDYS and CEQUAL-W2
  - Terrestrial/aquatic nutrient and sediment transport
- ADH
  - Groundwater, Surface Water, GW/SW interactions
  - Preliminary Nutrient Fate and Transport using ICM and NSM
- Subsurface Toolkit
  - User interface improvements
  - 2D Flow under dams & levees
  - Non-circular failure
- Uncertainty Analysis
  - Parameter estimation modules for multi-D models
- Surface Water/Groundwater Algorithms
  - Parameter Estimation Routines for multi-D models
    (1D parameterization covered in FCSDR)
  - Wetting/Drying and Infiltration Algorithms
Need for Integrated Watershed Analysis

- The United States faces large and growing water resources challenges:
  - Population growth and migration.
  - Changes in land use.
  - Changes in national priorities and societal values.
  - Aging infrastructure (dams and levees).
  - Protection against climate extremes (floods and droughts).

- Availability of water will be a significant factor in our economic prosperity and quality of life.
Need for Risk Informed Decision Making

- Corps guidance and direction has stressed conducting water resource studies in an integrated, collaborative environment. Also, that a risk-based assessment be included.

- Therefore the Corps is shifting from attempting to control floods to employing flood risk management that identifies and assesses risks and uncertainty in key factors that are related to flood events (runoff, levee performance, reservoir reliability, etc).

- A risk-based assessment of a river system acknowledges the uncertainty and variability that is present in watershed systems. This assessment seeks to apply the best available knowledge, tools, and techniques to analyze, assess, and communicate the risks.

- The Corps currently has several notable studies under way that are employing risk-based analysis techniques.
Introduction to HEC-WAT
Watershed Analysis Tool

- To meet the needs of performing water resources studies in an integrated, collaborative, systems-based approach, HEC has developed the Watershed Analysis Tool (HEC-WAT).

- Will be a tool for reconnaissance and feasibility studies; incorporates social and environmental consequences.

- Improves the capability to facilitate, convene, advise, and work collaboratively across a study team and with stakeholders.

- Provides an effective way to communicate risk within the study team and to external partners and the public.
Introduction to HEC-WAT

An overarching interface that allows the PDT to perform water resources studies in a comprehensive, systems based approach by building, editing and running models commonly applied by multi-disciplinary teams and save and display data and results in a coordinated fashion.
HEC-WAT Framework

- Coordinate a watershed study, while the individual pieces of software provide the analytical computations.
- Load GIS-based files including ARC shapefiles, digital elevation models, etc.
- Develop a spatially correct representation of the study watershed.
- Develop and organize system alternatives.
- Import existing models or develop new models.
- Match models to system alternatives.
- Edit model data.
- Run the modeling software and manage data transfer between models.
- View results and compare results between system alternatives.
HEC-WAT Plug-In Concept

- The "plug-in" concept allows the framework to utilize existing modeling tools instead of creating new tools.
- The "plug-in" is special software that connects the framework to a model, and allows the transfer of commands and data. The framework does not require specific "knowledge" of the model.
- The framework does not change in order to add a new model. The model implements the "plug-in" and can then be integrated.
- There are two implementation levels of the "plug-in" concept:
  - Level 1 – The "plug-in" computes an existing model simulation.
  - Level 2 – The "plug-in" provides for use of the model's native parameter editors and results visualization, in addition to model simulation.
HEC-WAT Basic Structure

**HEC-WAT Framework**

- HEC-HMS Plug-In
- HEC-ResSim Plug-In
- HEC-RAS Plug-In
- HEC-FIA Plug-In

**Model Results (simulation.dss)**

HEC-WAT Simulation With Default Program Order
HEC-WAT Model Integration

- Integrate models and tools used during the analytical process:
  - Hydrology - *HEC-HMS, GeoHMS*.
  - Reservoir Operations - *HEC-ResSim*.
  - Hydraulics - *HEC-RAS, GeoRAS*
  - Economics - *HEC-FIA*
  - Environmental - *HEC-EFM*
  - Statistical - *HEC-SSP*
  - Other software - *GSSHA, FLO-2D, ADH, RiverWare*

- Share data across models.
- Involve modelers early in the study process and encourage a team approach.
HEC-WAT Application
Sacramento River Bank Protection Project (SRBPP)

- SRBPP is a continuing construction project authorized by the Flood Control Act of 1960 and jointly sponsored by the Corps Sacramento District and the State of California.

- The SRBPP includes multiple components:
  - Protection of the existing levee system and flood control projects.
  - Long-term erosion control program.
  - Levee inspection with identification and ranking of erosion problems, leading to remedial repairs.

- Under Phase II of the project, a requirement for system-wide benefit analysis was added.

- Under Phase III of the project, requirements for flood risk management and ecosystem restoration activities were added.
SRBPP Study
Hamilton City to Rio Vista

- Large system comprised of levees, weirs, and bypasses:
  - 1,300 miles of levees.
  - Protects 800,000 acres.
  - Protects thousands of structures.
  - Protects a population numbered in hundreds of thousands.

- Significant upstream storage volume.
- Downstream channel capacity must be maintained.
SRBPP Study
Natomas Basin Consequence Area