Hydrologic Modeling with HEC-HMS

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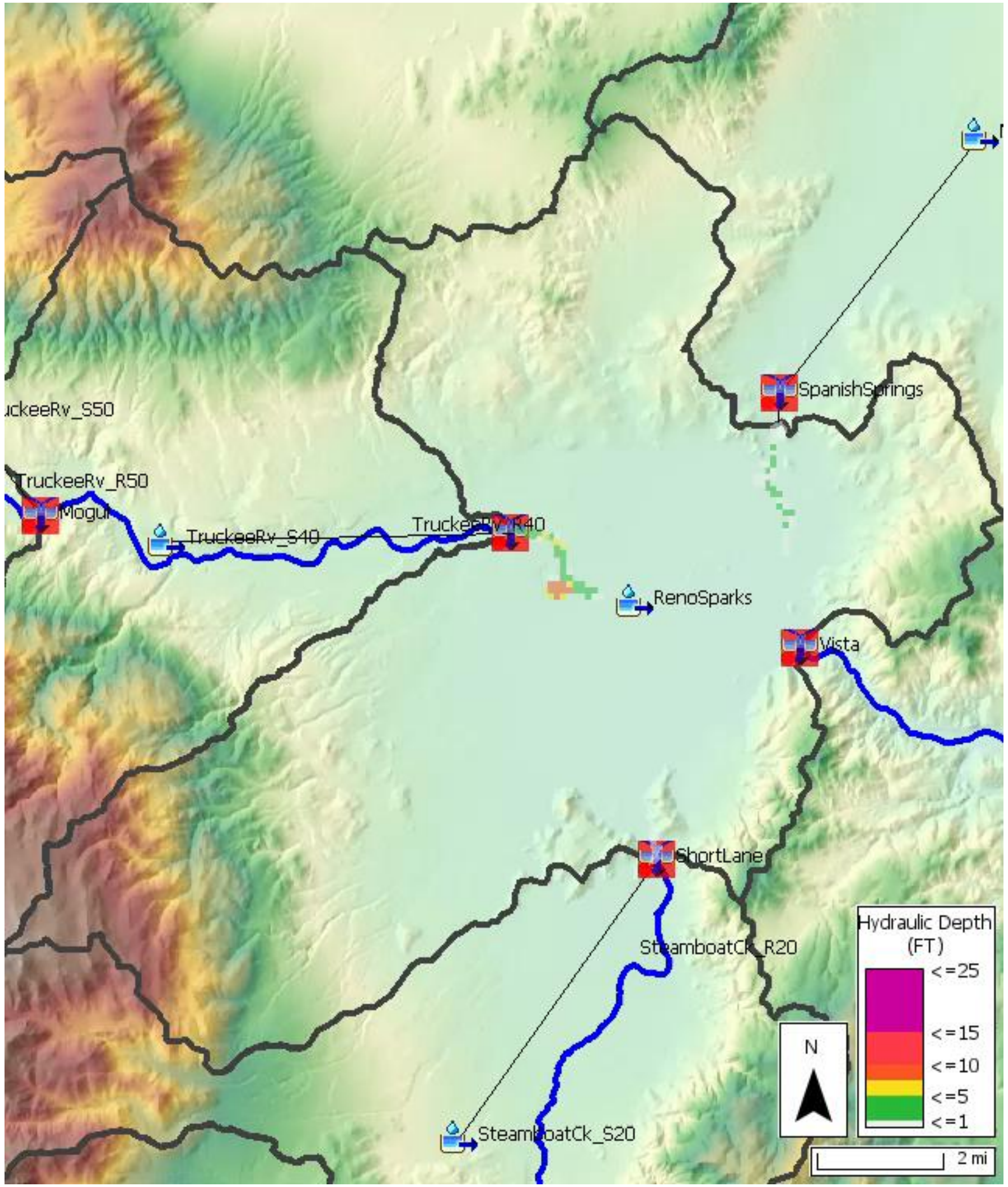
Agenda

- Introductions
- Introduction to HEC-HMS
- Tech Transfer Materials and Documentation
- Purposes of HEC-HMS
- Software Demonstration
    - [Generating a Flow Forecast for Magat River, Philippines]
- Break
- Sediment and Reservoir Siltation
- Upcoming Enhancements
- Q&A



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- University of Florida
  - B.S. (2010)
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- USACE – Galveston District
- USACE – Hydrologic Engineering Center (HEC)
  - HEC-HMS Lead Developer

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Mike Bartles

- Penn State University
  - B.S. (2009)
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- USACE – Hydrologic Engineering Center (HEC)
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- Kyung Hee University, Seoul, Korea
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- USACE – Los Angeles District & Far East District
- USACE – Hydrologic Engineering Center (HEC)
  - Watershed Scale Sediment and Post-Fire Hydrology/Debris Flow Specialist

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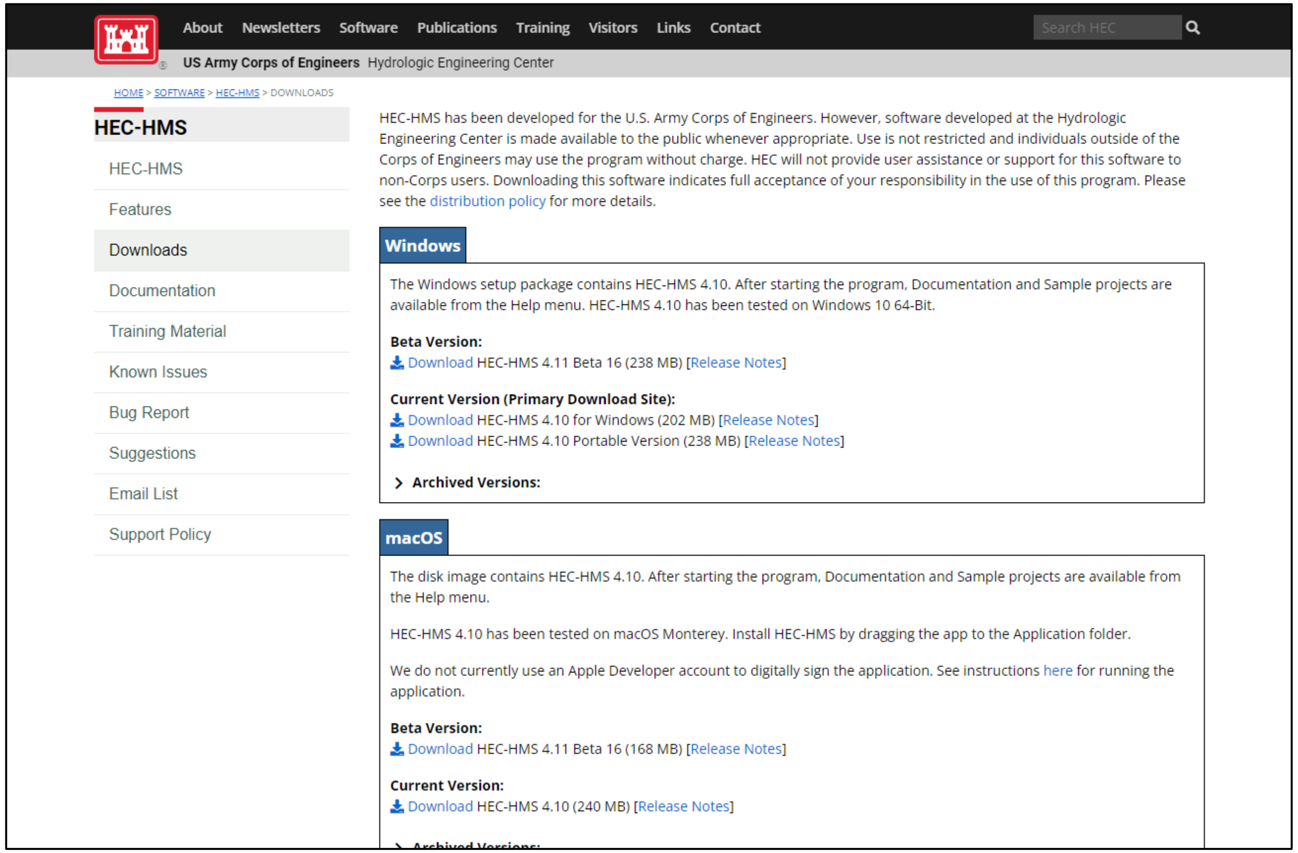
HEC-HMS Overview

- Free!
- ~75,000 downloads per year
- Latest Release
  - Version 4.10
- Beta Release
  - Version 4.11-beta.16
- MacOS and Linux versions available



[Link to Downloads]

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Tech Transfer Materials and Documentation

- Documentation
  - Release Notes
  - User's Manual
  - Technical Reference Manual
  - Applications Guide
  - Validation Guide
- Training Materials
  - Tutorials and Guides
  - Hydrologic Modeling with HEC-HMS
  - Advanced Applications of HEC-HMS
  - Hydrology and Hydraulics for Dam Safety
  - Webinars
  - Conference Materials

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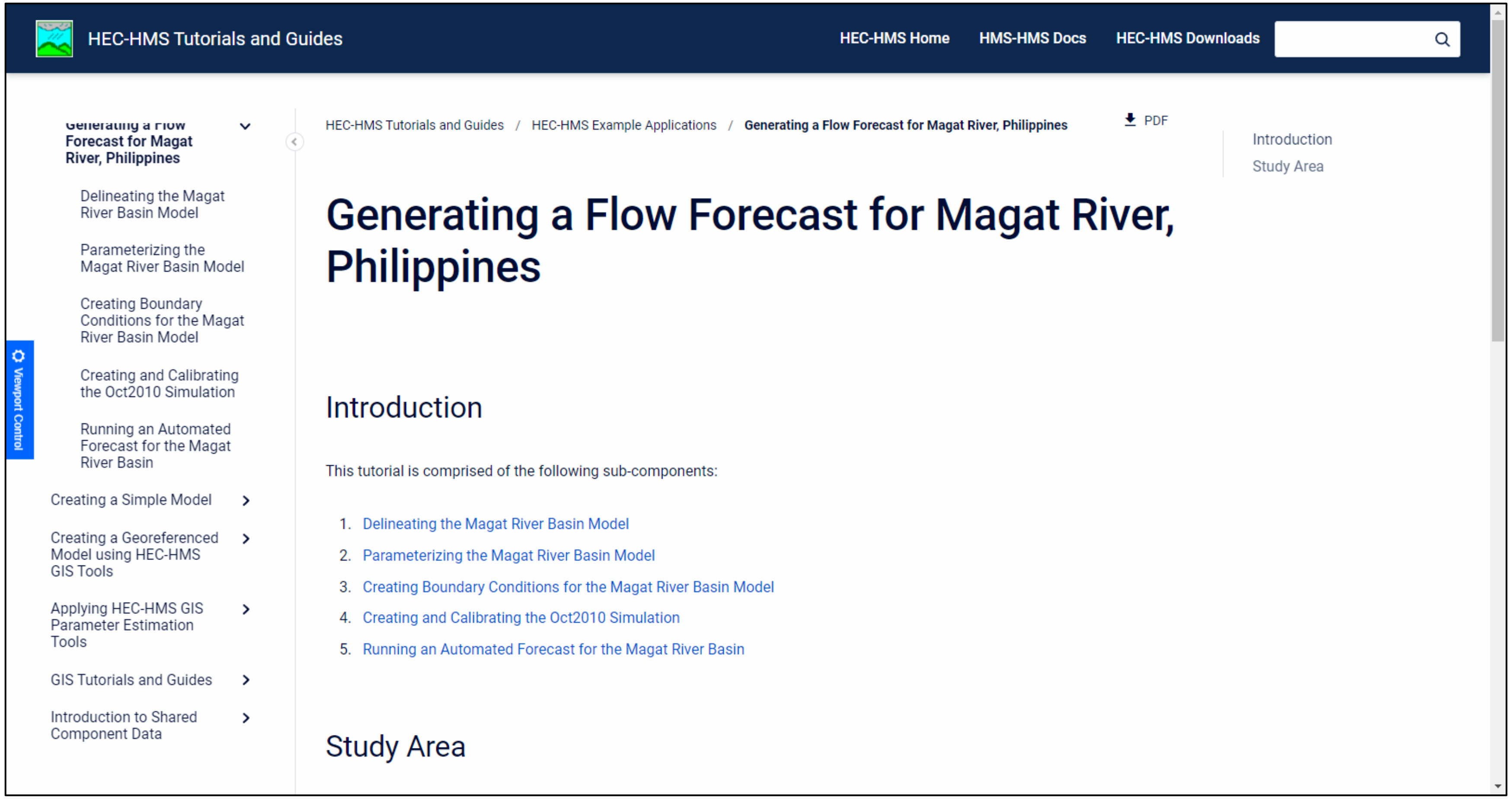
Tech Transfer Materials and Documentation



[Link to Tutorials and Guides](#)

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Tech Transfer Materials and Documentation


HEC-HMS Training

HEC-HMS Home | HEC-HMS Docs | HEC-HMS Downloads

Hydrologic Modeling with HEC-HMS (2022)

Hydrology & Hydraulics for Dam Safety (2022)

Advanced Applications of HEC-HMS (2023)

Post-Wildfire Debris Flow Modeling with HEC-HMS (2023)

HEC-HMS USACE HH&C CoP Webinar Series

Technical Transfer Material

RMC Advanced HMS Workshop 2023

Viewport Control

HEC-HMS Training / **Hydrologic Modeling with HEC-HMS (2022)**

PDF

Hydrologic Modeling with HEC-HMS (2022)

The course provides an introduction to the Hydrologic Modeling System, HEC-HMS, focusing both on using the program and performing watershed studies. The course starts with a summary and overview of the program and the mechanics of constructing watershed models. Then, components of the software are studied in detail. Major modules include GIS tools, data entry, historic precipitation approaches, computing infiltration and excess surface runoff, transforming excess precipitation to runoff, baseflow, and channel routing. Parameter estimation techniques are taught throughout with instruction about model calibration. Instruction material is supported with workshops that illustrate the basic steps of building a model for project applications. A final project is included that ties together topics to create a calibrated model from scratch.

The following table provides links to YouTube videos for all lectures. Links are provided to the workshop pages located in the HEC-HMS Tutorials and Guides space. All workshop files can be downloaded from the workshops pages as well. Finally, all PowerPoint files are included below and can be downloaded for reference. You will need **HEC-HMS version 4.11** or newer to open the workshop files. You can download the software from https://www.hec.usace.army.mil/software/hec-hms/downloads.aspx.

Lectures and Workshops	Videos and Links	PowerPoint Files
Lecture 0: Overview of Hydrologic Modeling for Studies	Overview of Hydrologic Modeling for Studies	L 0 Overview of Hydrologic Modeling For Project Studies.pptx

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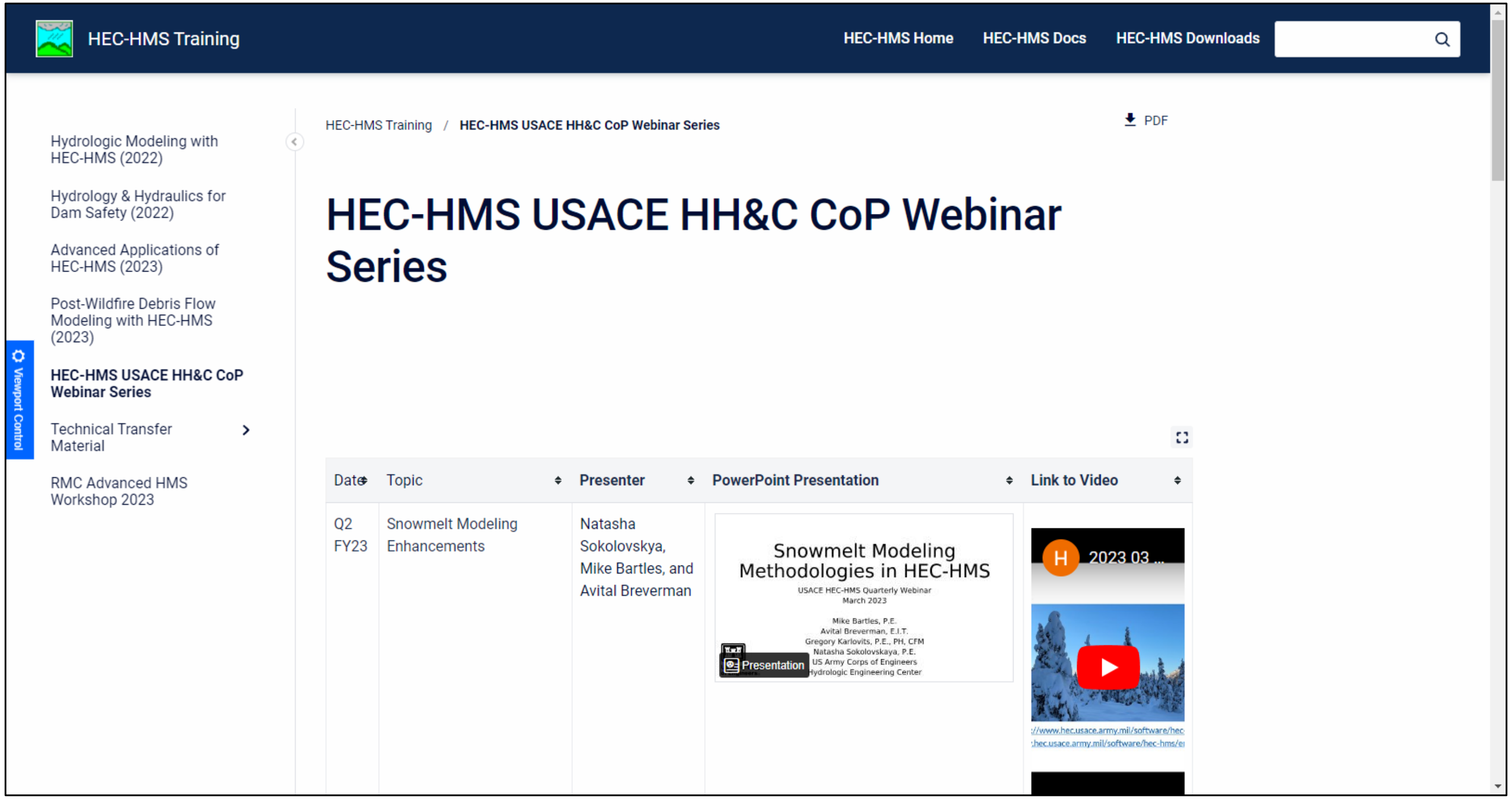
[Basic HEC-HMS Class Materials]

Tech Transfer Materials and Documentation



[HEC-HMS Webinars]

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Purpose of HEC-HMS

- **Simulate the hydrologic processes of dendritic watersheds**
  - Estimate runoff for short (hours to days) and long (months to years) time windows
  - Analyze water availability, urban drainage, flow forecasting, future urbanization impacts, reservoir spillway design, flood damage reduction, floodplain regulation, systems operation, and sediment transport
  - Generate output(s) for use in other applications

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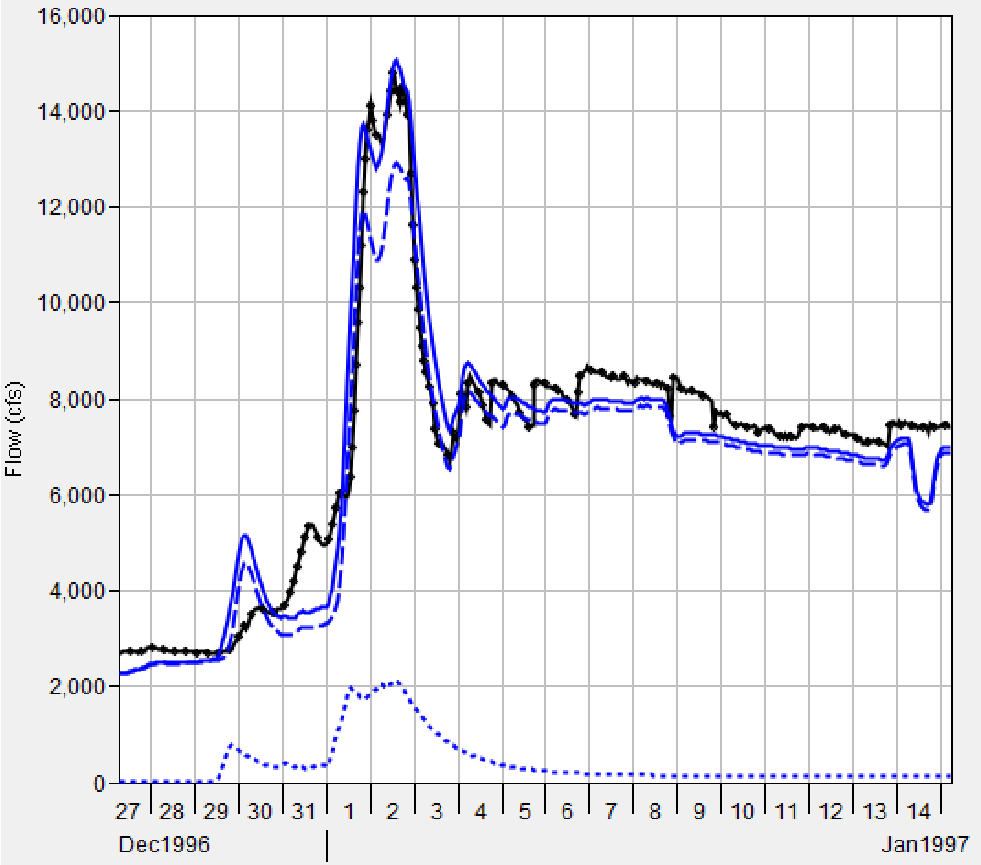
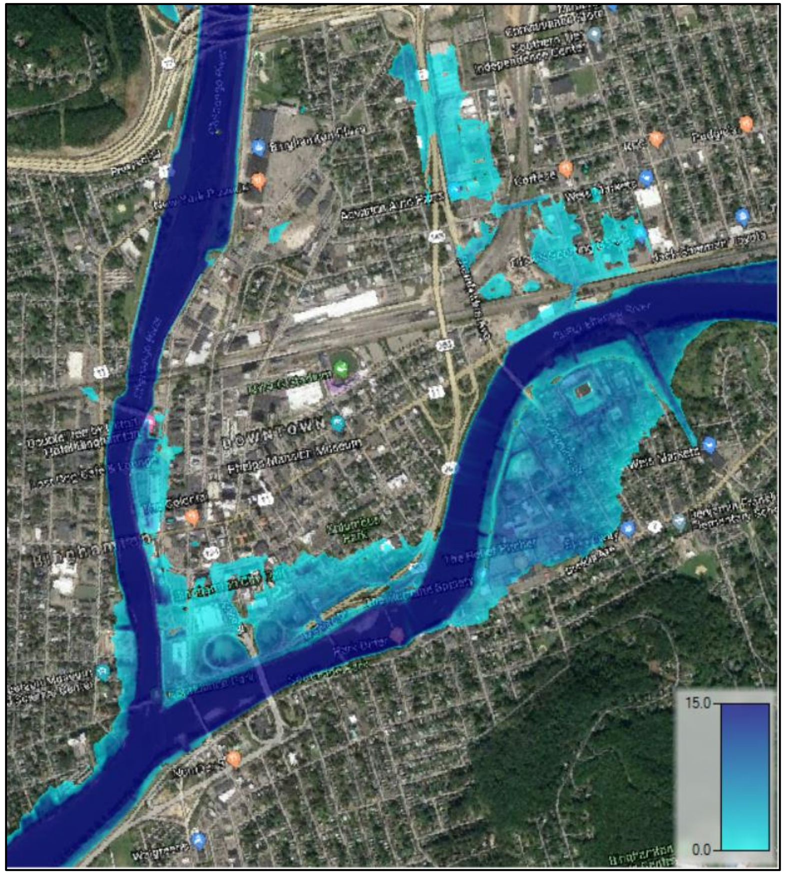
Purpose of HEC-HMS





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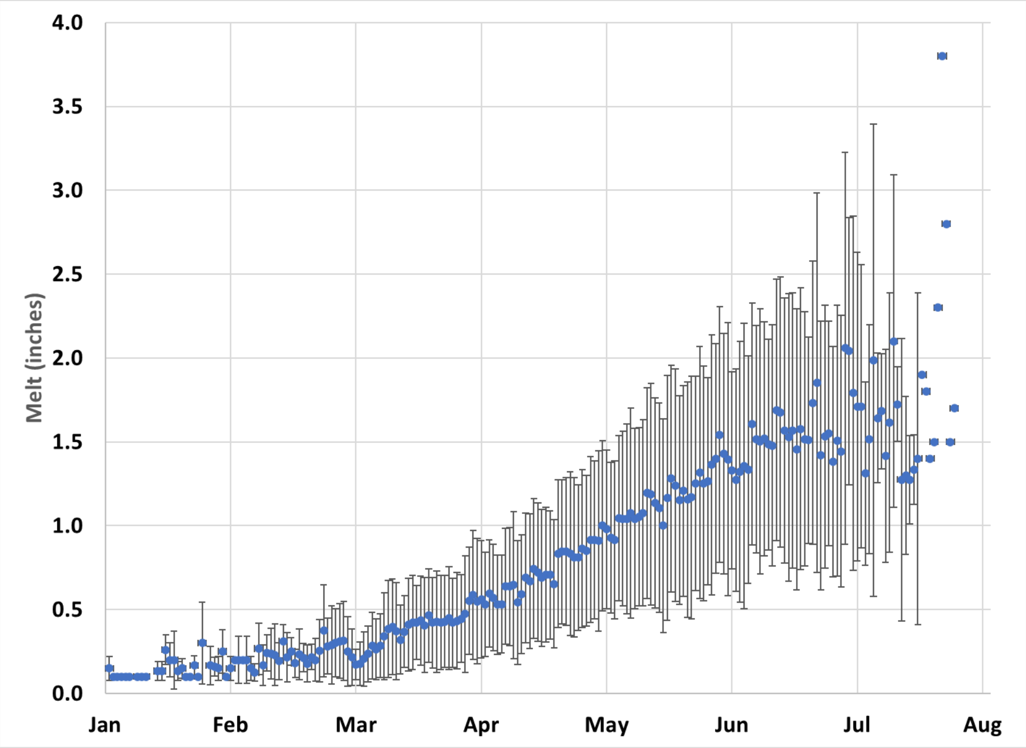
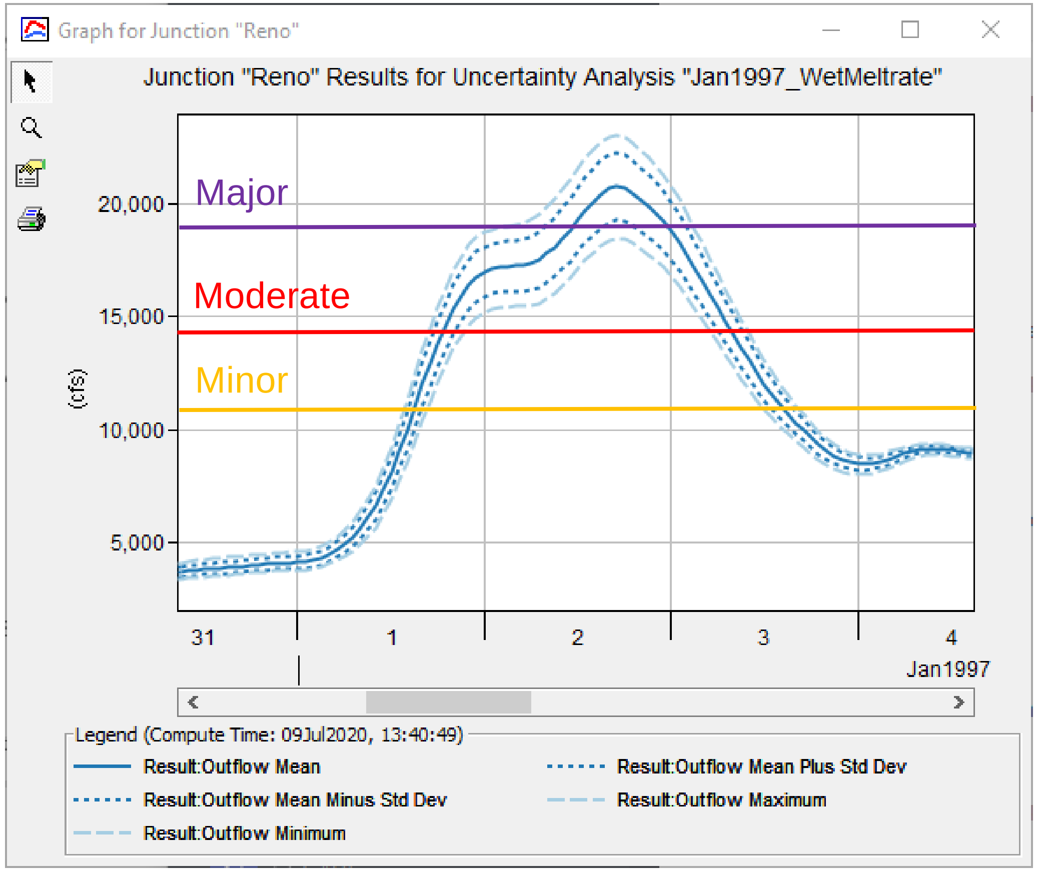
Purpose of HEC-HMS



Uncertain Snow Melt



Uncertain Runoff

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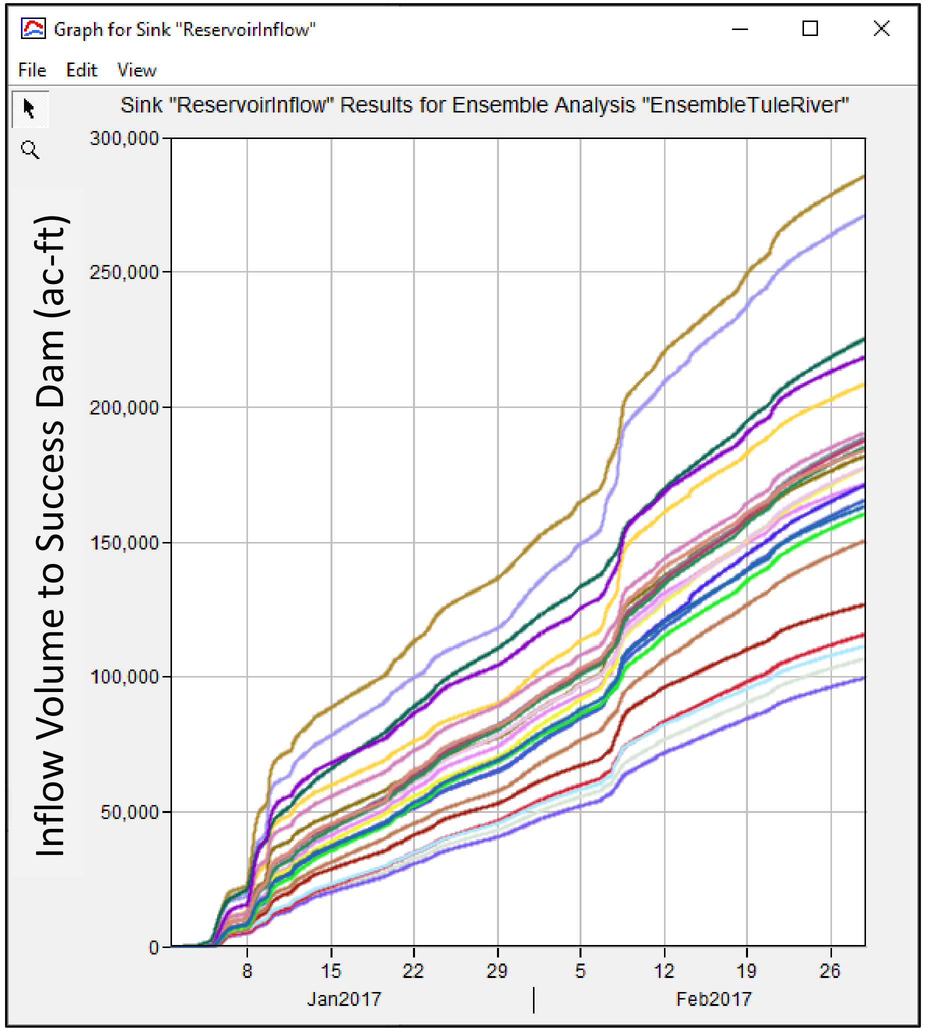
Other Common Use Cases

- Feasibility Studies
- Dam and Levee Safety Risk Assessments
- Flow- and Stage-Frequency Analyses
- Flood Forecasting
- ***Quantitative Climate Change Assessments***



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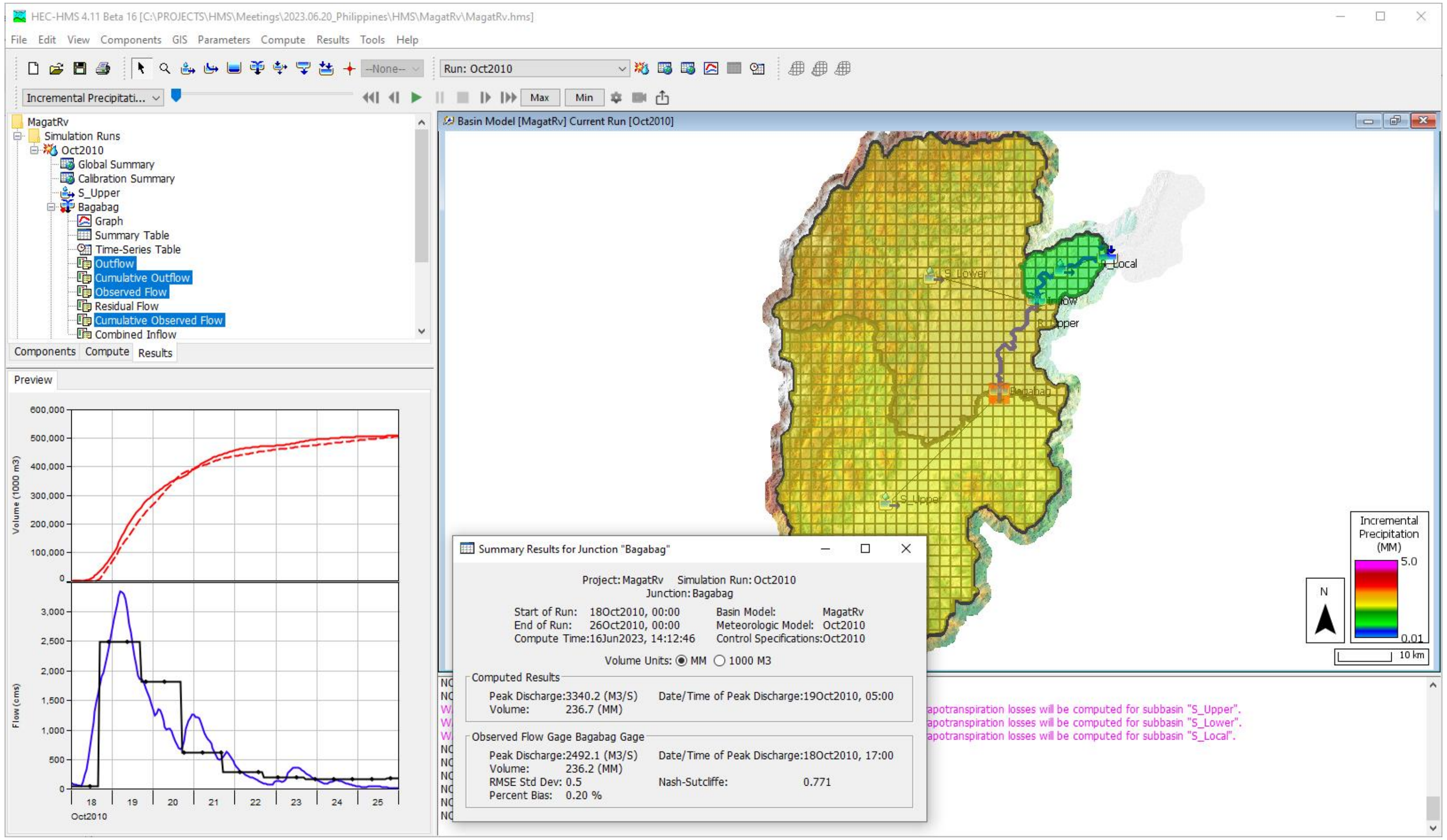
Software Demonstration



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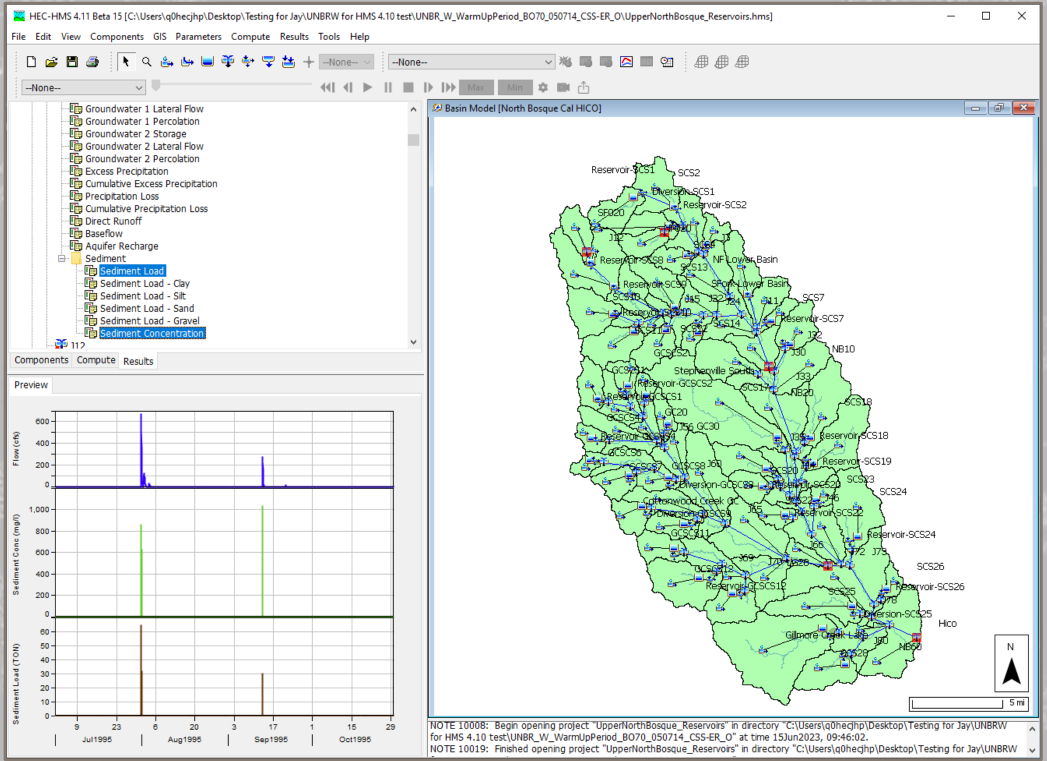
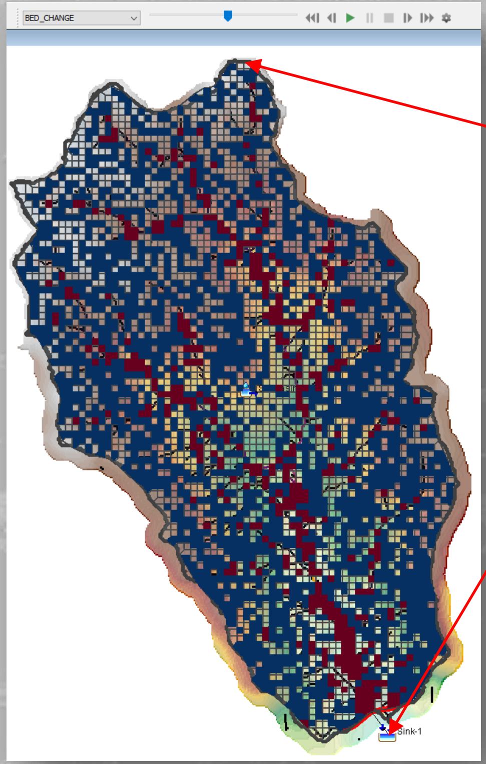
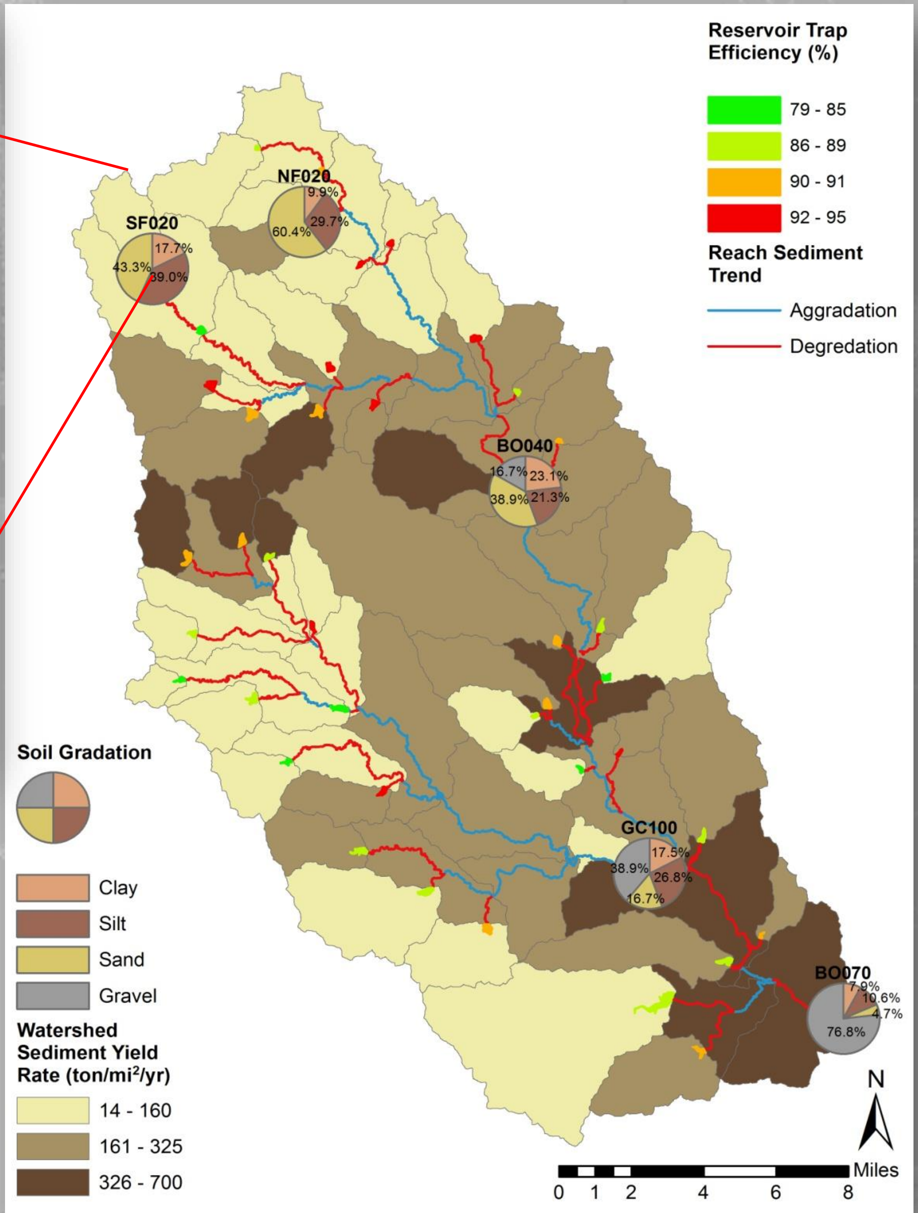
SURFACE EROSION & SEDIMENT TRANSPORT MODELING CAPABILITIES IN HEC-HMS







Jay Pak, Ph.D., P.E.

Watershed Scale Sediment and Post-Fire Hydrology/Debris Flow Analysis Specialist, USACE IWR-HEC

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OVERVIEW

1. Surface Erosion and Sediment Transport Process
2. Surface Erosion Method (Watershed/Subbasin)
3. Transport Potential Functions (Channel/Reach)
4. Dynamic Volume Reduction/Siltation Method (Reservoir)
5. Case Studies:
   - Large Reservoir Volume Reduction Studies (Long-Term Simulation)
   - Sediment Analysis Study with Upper North Bosque River Watershed (UNBRW), TX

SURFACE EROSION AND SEDIMENT/DEBRIS TRANSPORT PROCESS

Watershed →
- None
- MUSLE
- BUWO
- LADM EQ 1
- MSDPM
- USGS-LT
- USGS-EA
- LADM EQs 2-5

Watershed Outlet →
- Power Function
- Enrichment Ratio

Fall Velocities: →
1. Rubey
2. Van Rijn
3. Toffaleti
4. Report 12
5. Richardson & Zaki
6. Kumbhakar

In-Channel →
- None
- 7- Transport Function (Non-Cohesive)
- Krone & Parthenadies (Cohesive)
- SDR (Debris Flow)

↕
- None
- Deposition Limiter
- Erosion Limiter

↕
- 2-Layer Conceptual Sediment Reservoir

Channel Outlet →
- None
- Uniform Equilibrium
- Volume Ratio
- Linear Reservoir
- Fischer's Dispersion EQ.
- Muskingum

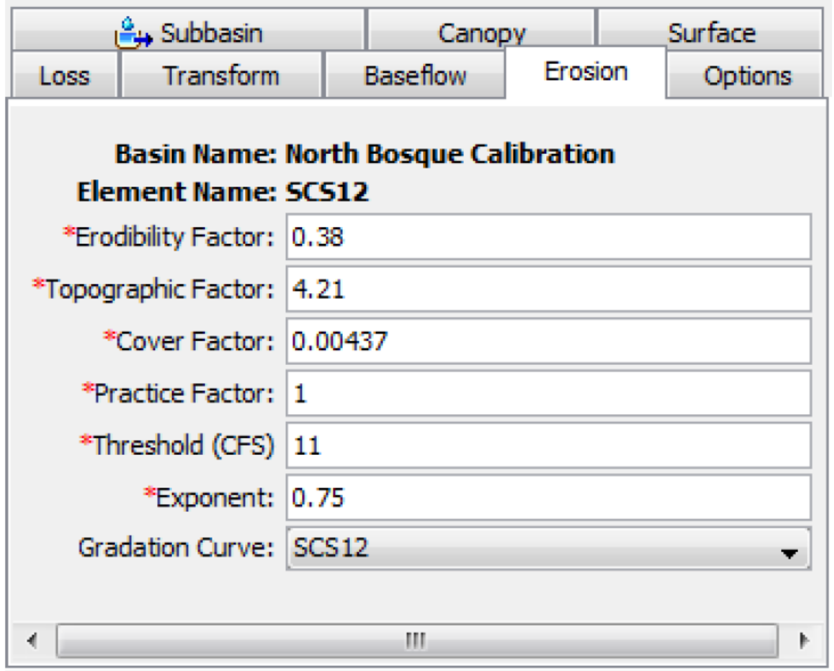
Reservoir
- Volume Reduction
- Chen & Brune Trap Efficiency Methods

↓
- Dynamic Reservoir Bottom Layer

SUBBASIN: MUSLE EQUATION

- Modified Universal Soil Loss Equation (MUSLE).
  - Developed by Williams, 1975.
  - Rainfall energy factor replaced by *Runoff factor*
  - Incorporates detachment and transport
  - Applicable to individual storms

$$Sed = 11.8(Q_{surf} \times q_{peak})^{0.56} \times K \times LS \times C \times P$$



- – Sed = Sediment Yield per Event (metric tons)
- – Q_{surf} = Surface Runoff Volume (m^3)
- – q_{peak} = Peak Runoff Rate (m^3/s)
- – K = Soil Erodibility Factor
- – LS = Topographic Factor
- – C = Cover and Management Factor
- – P = Support Practice Factor

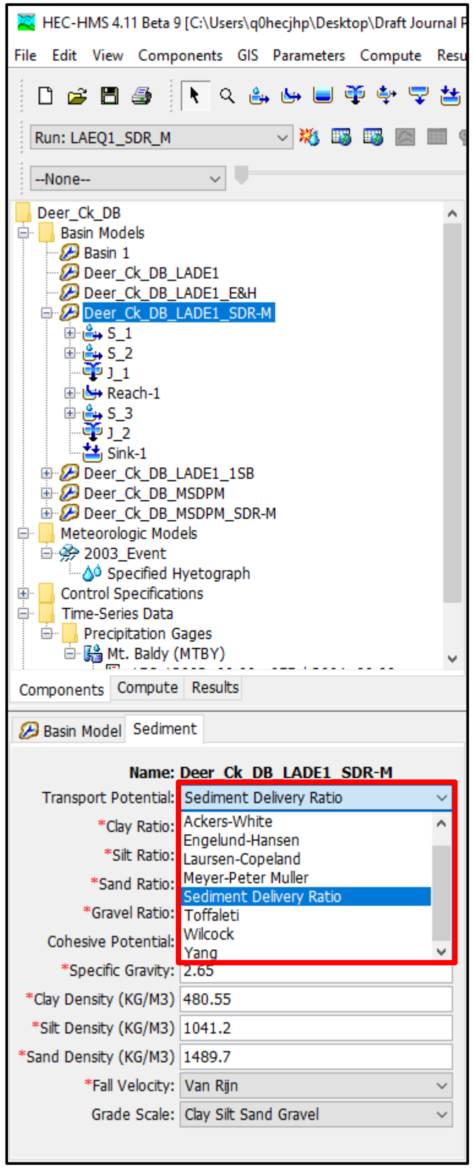
REACH: TRANSPORT POTENTIAL FUNCTIONS

- Ackers-White (1973)
- Englund-Hansen (1967)
- Laursen (1968)-Copeland (1989)
- Myer-Peter-Müller (1948)
- Toffaleti (1968)
- Yang (1973/1984)
- Wilcock (2001)
- Sediment Delivery Ratio (SDR)

A little guide to how Stanford thinks about transport functions

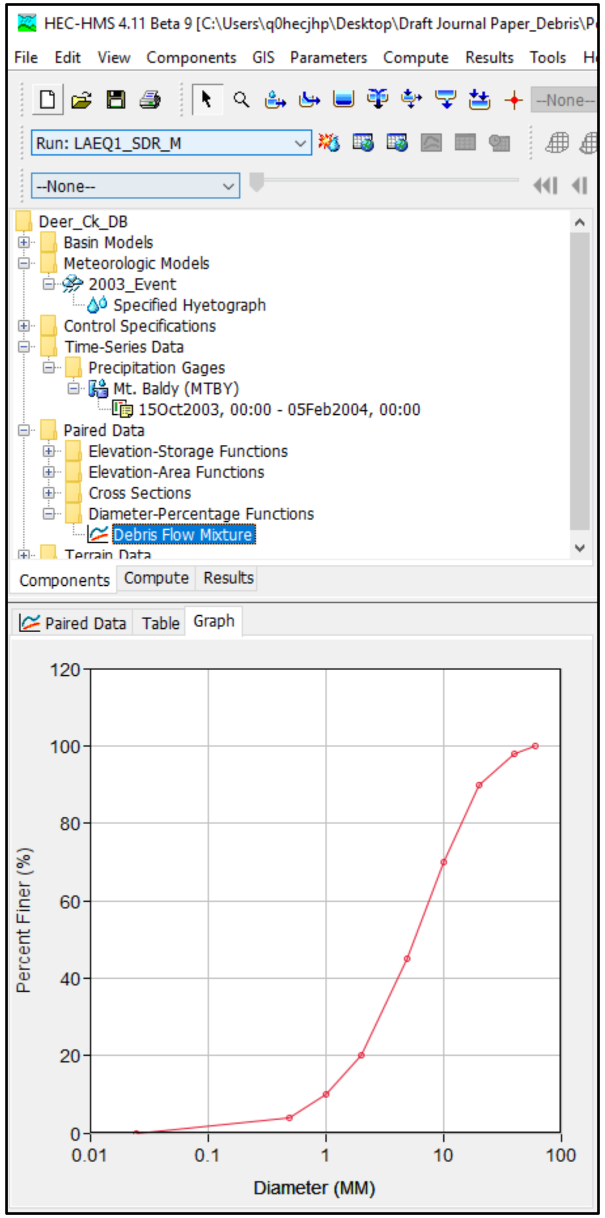
What is the Sediment Type?	What Functions are 'In Play'?	Additional Considerations?
Clay	Krone-Parthinades	
Silt	Laursen-Copeland Krone-Parthinades	-If mixed with clay – need additional data
Sand	Ackers-White Englund-Hansen Toffaletti Yang Laursen-Copeland	-Primarily for 'large rivers' – not good for coarse material
Gravel+	MPM[1] Wilcock[1] Yang Larsen-Copeland	-Recommend Wong-Parker correction -Mainly for 'bimodal' beds (gravel or cobble beds with 25-40% sand) – must use surface gradation and 'Active Layer' mixing method -Separate gravel function -Separate gravel function

Excess Shear Stress	Stream Power
Meyer-Peter Muller	Ackers-White (*tV*)
Laursen-Copeland	Englund-Hansen (*tV*)*
Wilcock and Crowe	Yang (*VS*)



Sources: HEC-RAS 1D Sediment Transport User's Manual (https://www.hec.usace.army.mil/confluence/rasdocs/rassed1d/1d-sediment-transport-technical-reference-manual/computing-transport-capacity)

REACH: TRANSPORT CAPACITY



Bed Material and Inflowing Load divided into separate grain classes (up to 20)

Transport Potential is calculated for each grain size

Transport Capacity (Existing 7-transport Potential Functions) = (Transport Potential for each grain size) X (fraction of that material in active layer of bed)

$$T_c = \sum_{j=1}^{n} \beta_j T_j$$

Where:

T_c = Total transport capacity

N = number of grain size classes

β_j = % of active layer composed of material in grain size class "j"

T_j = Transport potential computed for 100% of the material grain class "j"

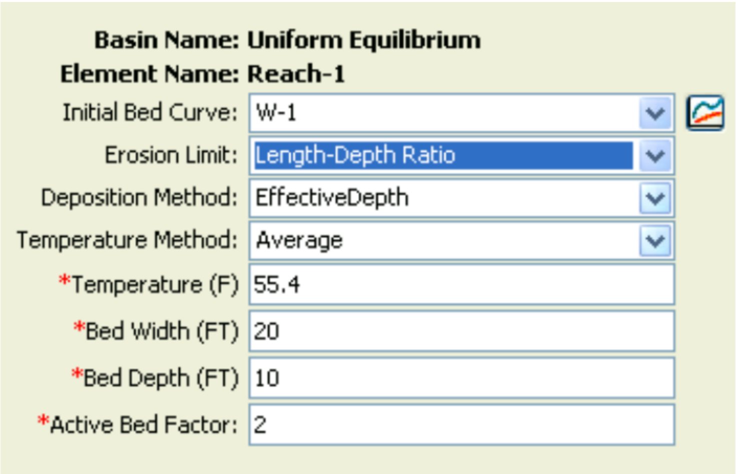
SDR is not function of fraction of each grain size material in active layer of bed)

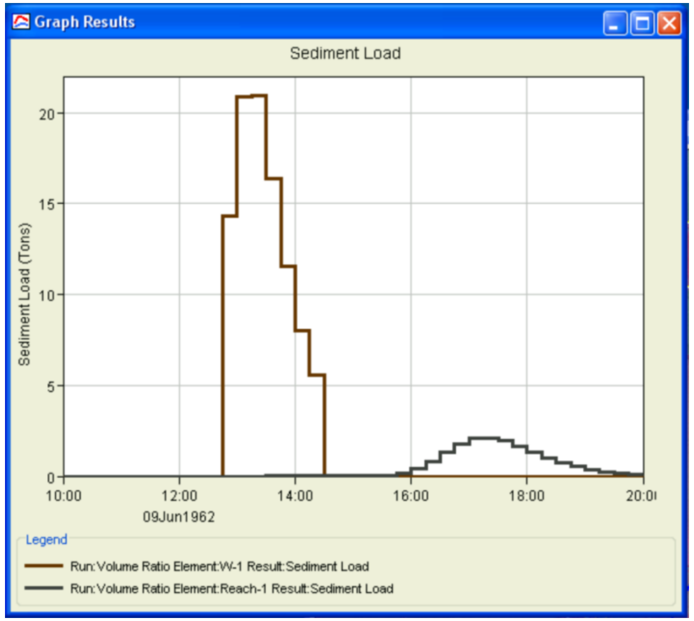
Transport Potential = Transport Capacity

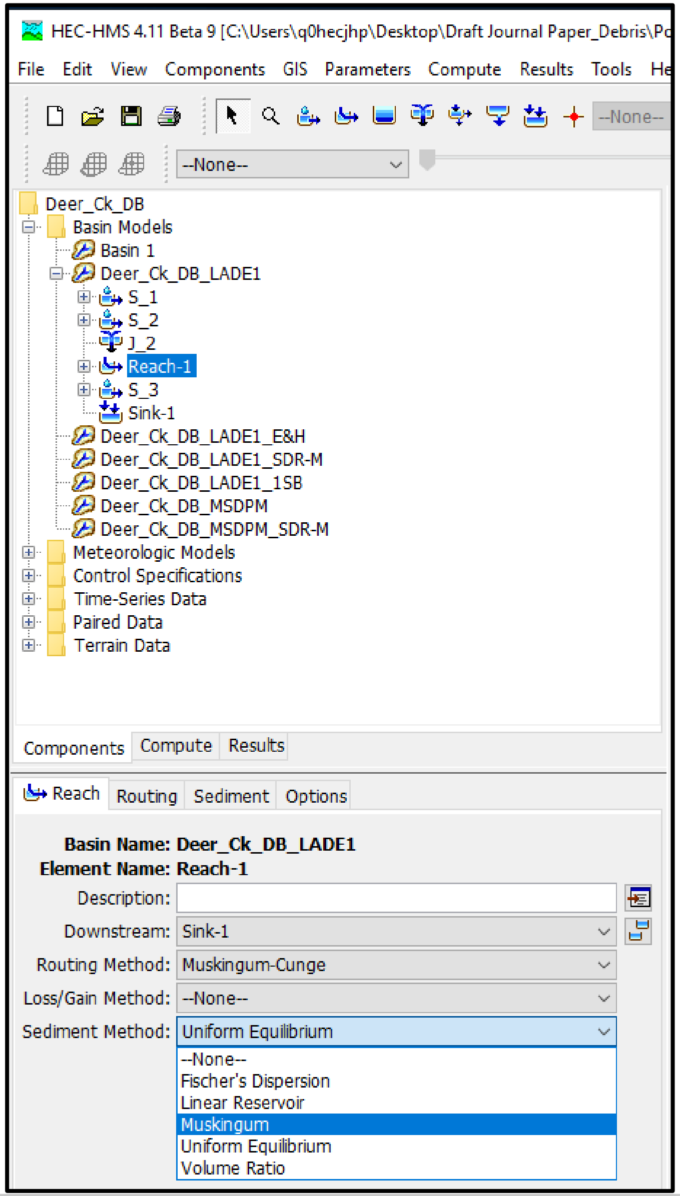
REACH: SEDIMENT CHANNEL ROUTING

- Fisher's
- Linear Reservoir
- Uniform Equilibrium
- **Volume Ratio**
- Muskingum

$$Sed_{out} = \frac{Volume_{out}}{Volume_{channel}} Sed_{channel}$$







RESERVOIR: CHEN'S SEDIMENT TRAP EFFICIENCY METHOD (CHEN 1975)

- Critical settling velocity

$$v_c = \frac{h}{T} = \frac{Q}{A} = overflow\ rate$$

- Trapping Efficiency
  - Stratified (quiescent) reservoir (upper bound)

$$TE = 100\frac{v_s}{v_c} = 100\frac{A}{Q}v_s$$

  - Mixed (turbulent) reservoir (lower bound)

$$TE = 100\left[1 - e^{-\frac{v_s}{v_c}}\right]$$

Fall Velocities (v_s):

1. Rubey
2. Van Rijn
3. Toffaleti
4. Report 12

- The settling velocity is computed using the method selected for the Basin Model.
- The critical settling velocity is computed as the discharge rate (Q) from the reservoir divided by the surface area (A). The computations are performed separately for each grain size class or subclass.

RESERVOIR: BRUNE'S SEDIMENT TRAP EFFICIENCY METHOD (BRUNE 1953)

- Capacity/Annual Inflow Ratio

$$V_* = \frac{V_{res}}{V_{inflow}}$$

  - V_{res} = *Reservoir Capacity*
  - V_{inflow} = *Annual Inflow (A user specified initial value is required)*

- Trapping Efficiency

$$TE = a\left[1 - 2e^{-bV_*^{0.35}}\right]$$

  - *a* = *Coefficient (Low=95, Medium=97, High=100)*
  - *b* = *Coefficient (Low=5.37, 6.42, High=7.71)*

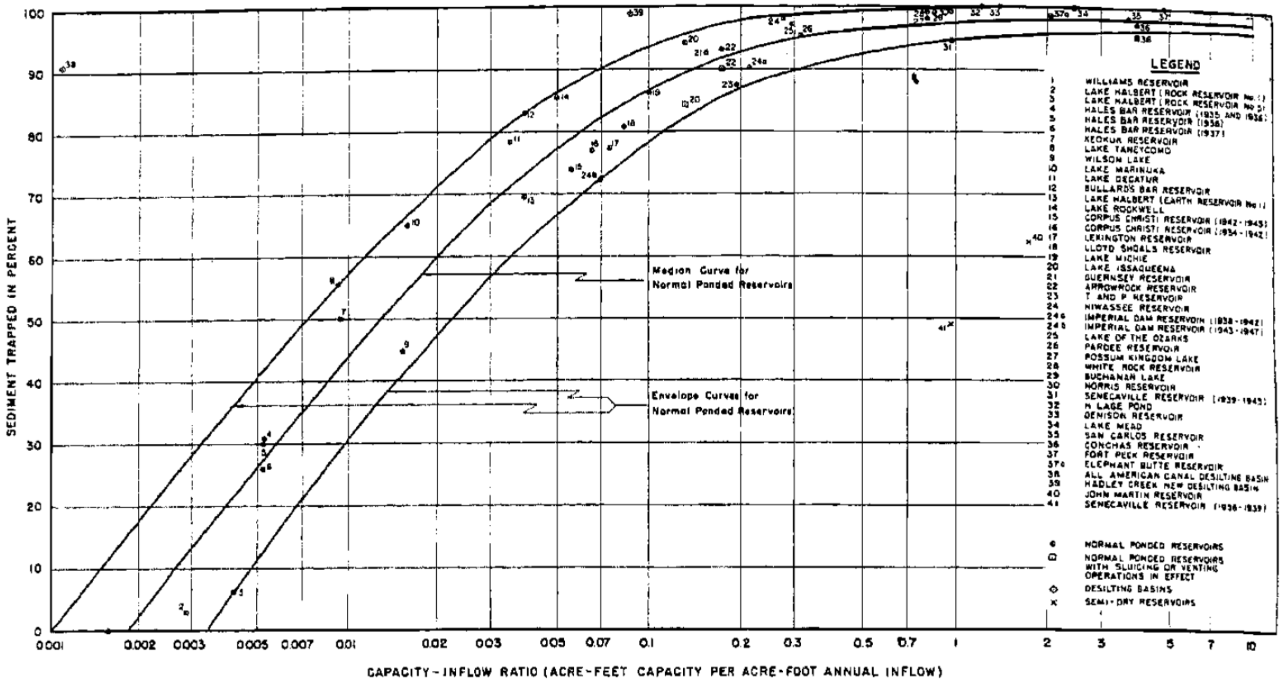


Fig. 6--Trap efficiency as related to capacity-inflow ratio, type of reservoir, and method of operation

RESERVOIR: SEDIMENT ROUTING METHODOLOGY

- Sediment deposition

$$D_b = Q_{sed}^{In} \times \frac{TE}{100}$$

- Suspended sediment

$$S_R = Q_{sed}^{In} - D_b$$

- Outflow sediment

$$Q_{sed}^{Out} = S_R \frac{V_{Out}}{V_R}$$

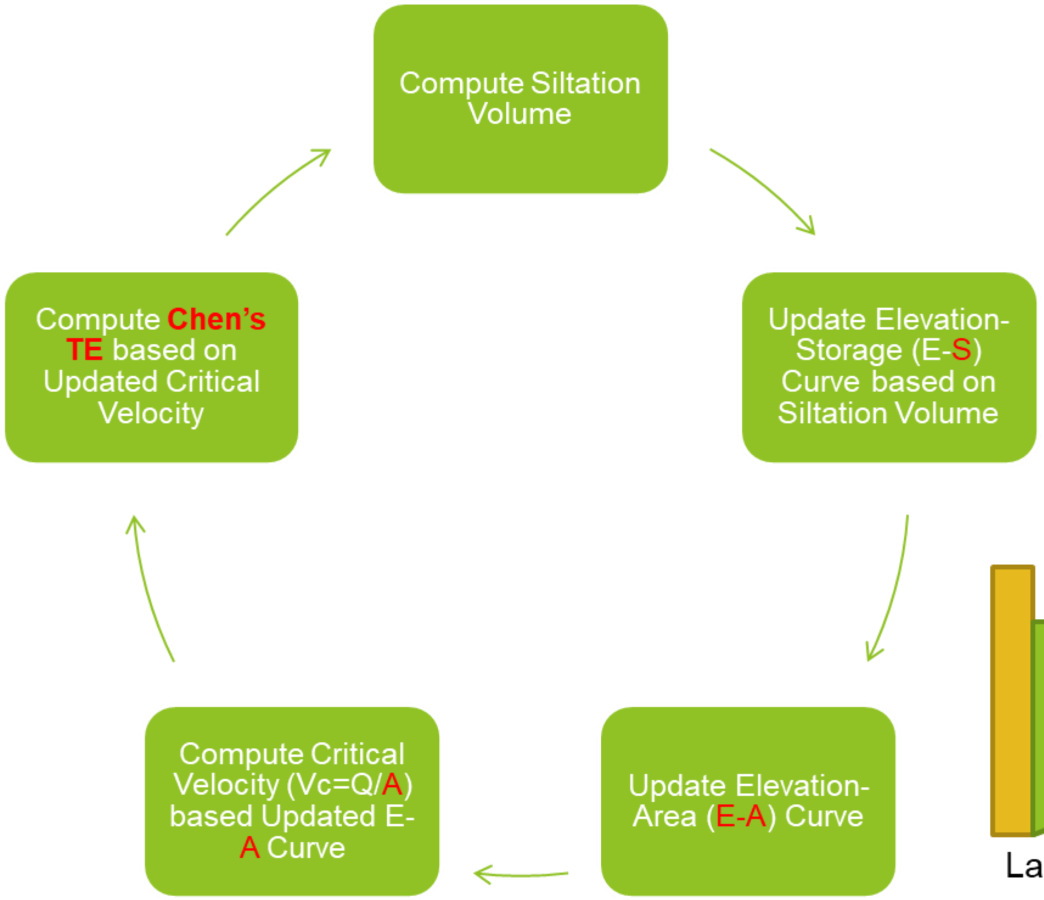
Q_{sed}^{In} = Total Inflow Sediments

Q_{sed}^{Out} = Total Outflow Sediments

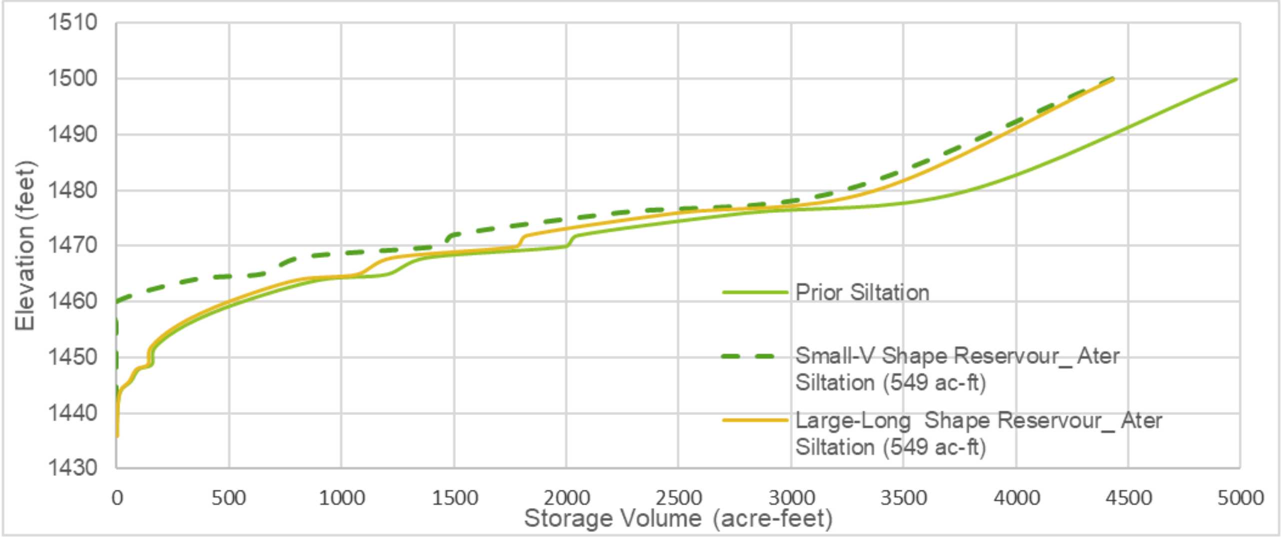
V_{Out} = Outflow volume

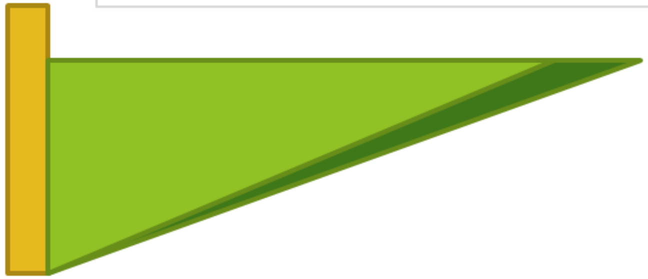
V_R = Reservoir volume

RESERVOIR: VOLUME REDUCTION PROCESS

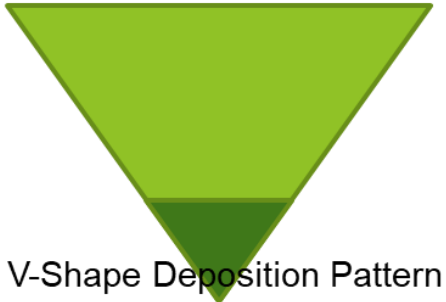


Update Elevation-Storage-Area-Discharge Curves Each Time Step based on siltation volume





Large & Long-Shape Deposition Pattern for granular materials such as **Sand & Gravel**

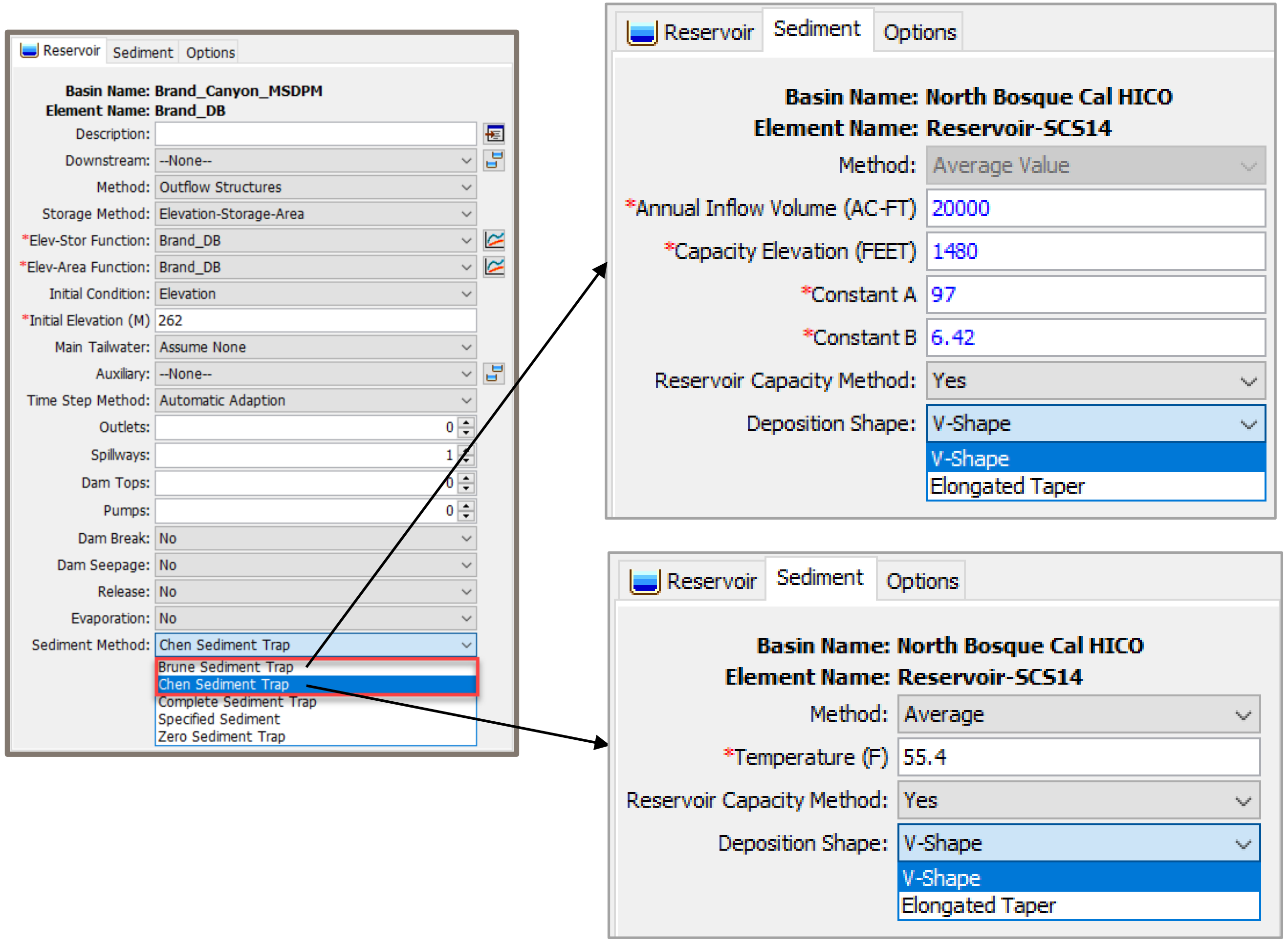


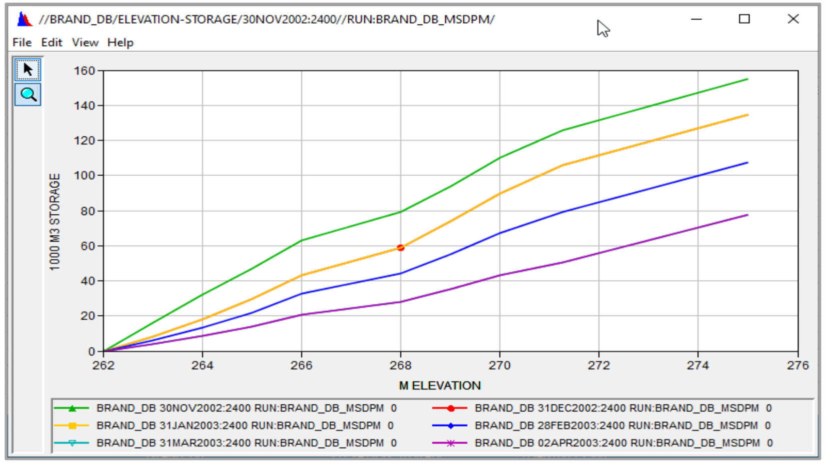
Small & V-Shape Deposition Pattern for fine particles such as **Clay & Silt**

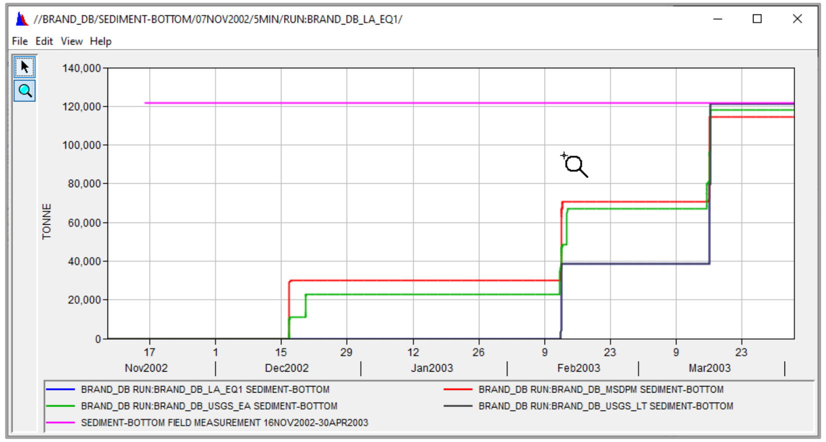
Clay & Slit: Only 1-Option (V-Shape)

Sand & Gravel: 2-Optopn (V-Shape or Elongated Taper)

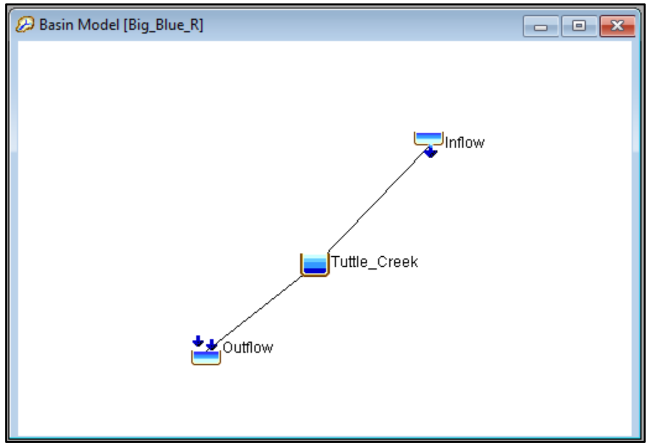
RESERVOIR: HEC-HMS GUI FOR TWO SEDIMENT TRAP EFFICIENCY METHODS

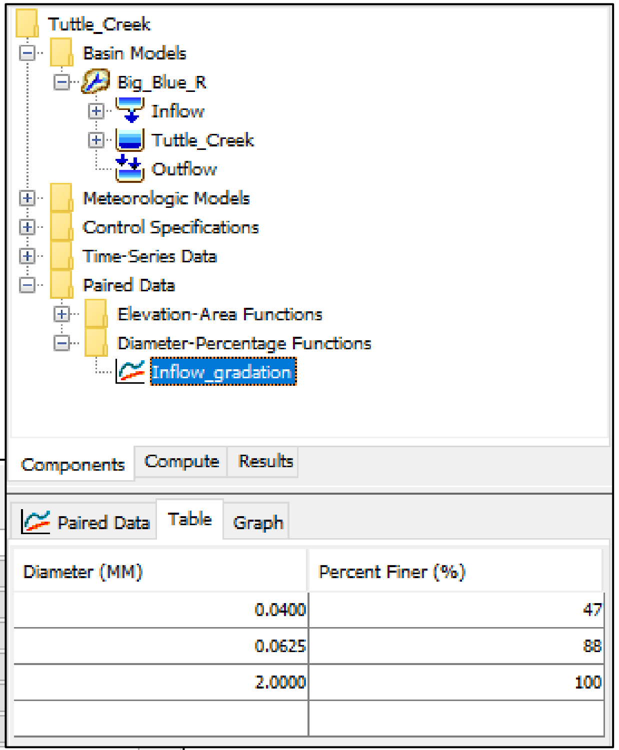


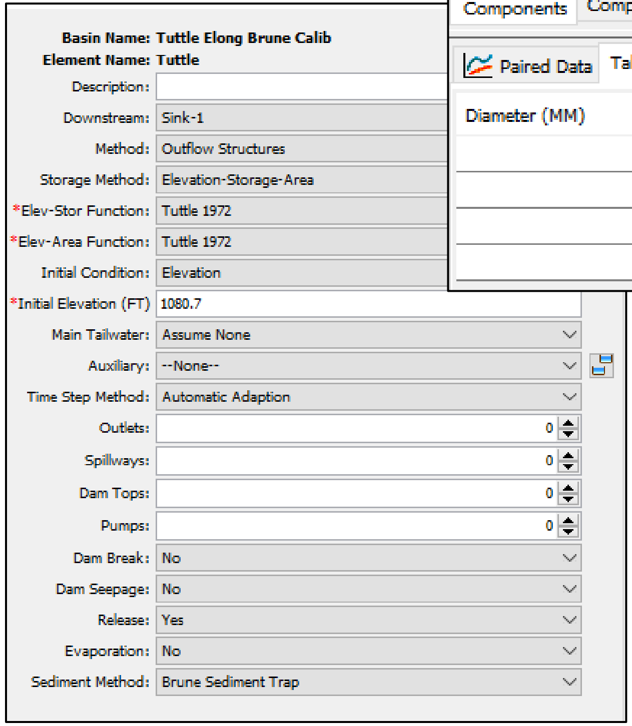




CASE STUDIES: LARGE RESERVOIR VOLUME REDUCTION







Basin Model

- Inflow element
- Reservoir element
- Outflow element

Inflow Element

- Daily sediment loads taken from the Kansas Watershed Study
- Incoming gradation from USGS measurements

Reservoir Element

- Initial elevation-storage and elevation-area tables
- Trapping Efficiency: both the Brune and Chen methods tested
- Deposition Shape: both the V-shape and Elongated tested
- Outflow: specified release

Control Specifications

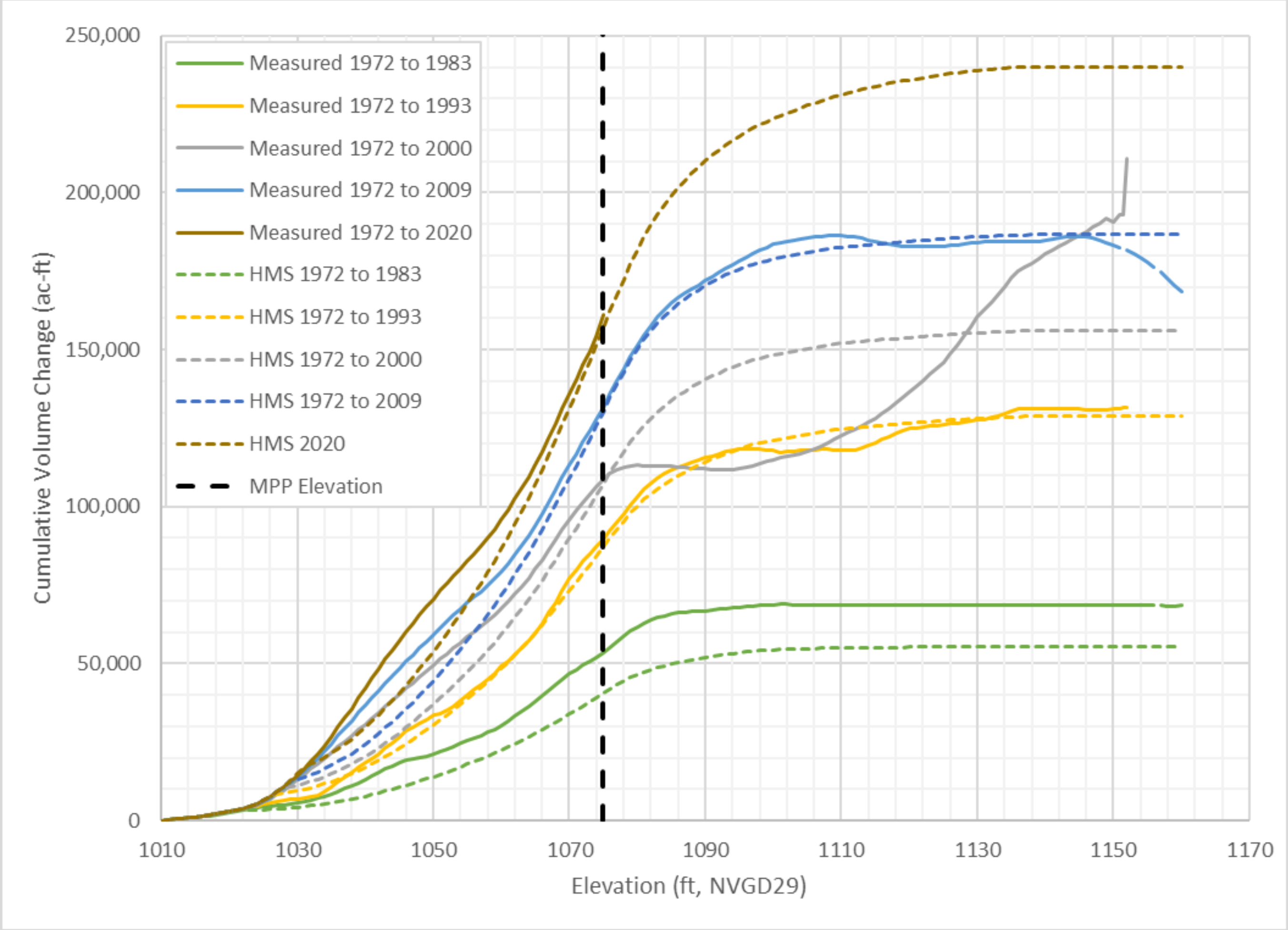
- Timestep: 12 hours
- Simulation period
  - Tuttle Creek: 1972-2020
  - Kanopolis: 1960-2017
  - Perry: 1979-2009

TUTTLE CREEK RESULTS

Calibration Method

- Shifted majority of fine and silt fraction to sand
- Maintained volume balance by lowering sand and clay specific weights
- Final gradation was 5% clay and 95% sand
- Models further calibrated by adjusting sand specific weight
- Measured data may have errors

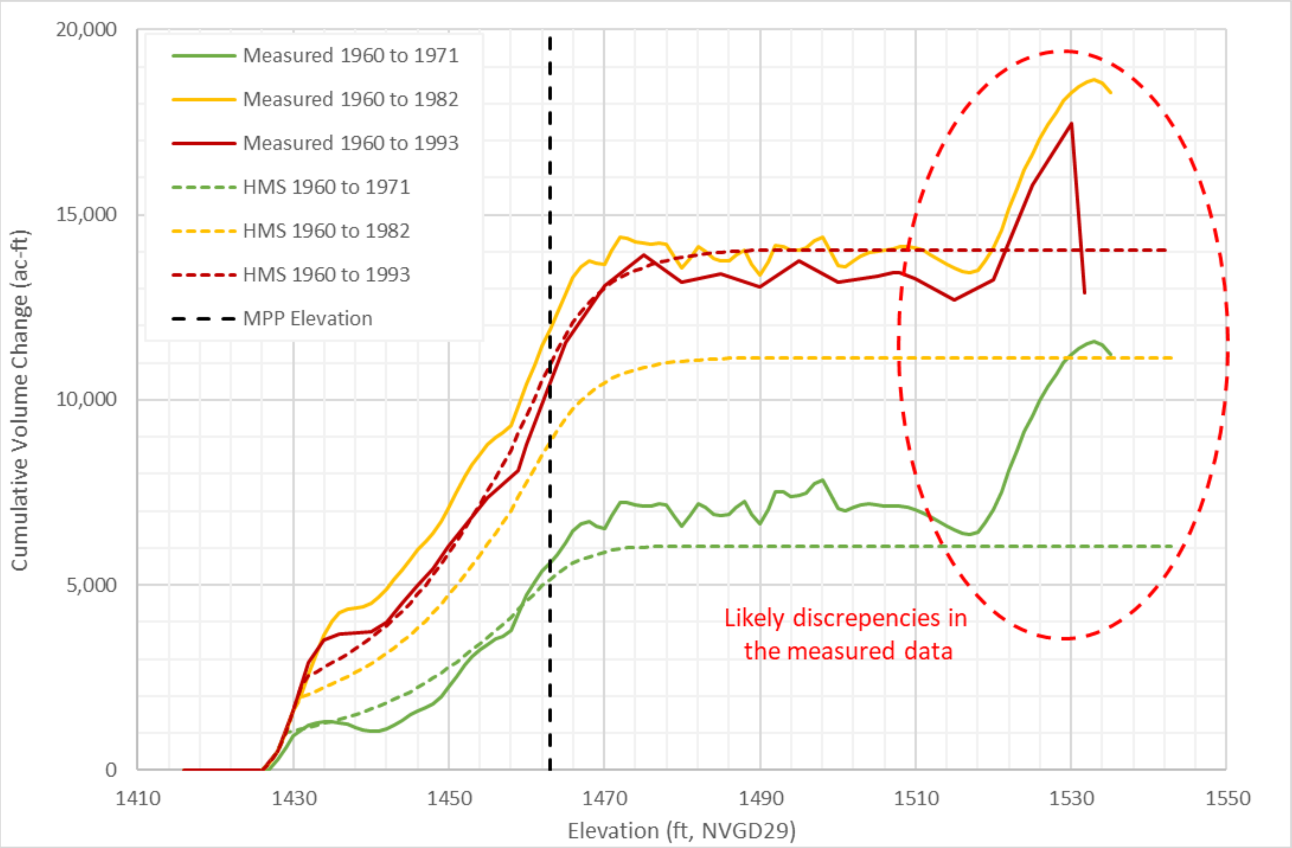
Name:	Tuttle Elong Brune Calib
Transport Potential:	--None--
Cohesive Potential:	--None--
*Specific Gravity:	2.65
*Clay Specific Weight (LB/FT3)	23.2
*Silt Specific Weight (LB/FT3)	65
*Sand Specific Weight (LB/FT3)	49.57
*Fall Velocity:	Rubey
Grade Scale:	Clay Silt Sand Gravel



KANOPOLIS RESULTS (OLDER SURVEYS)

Calibration

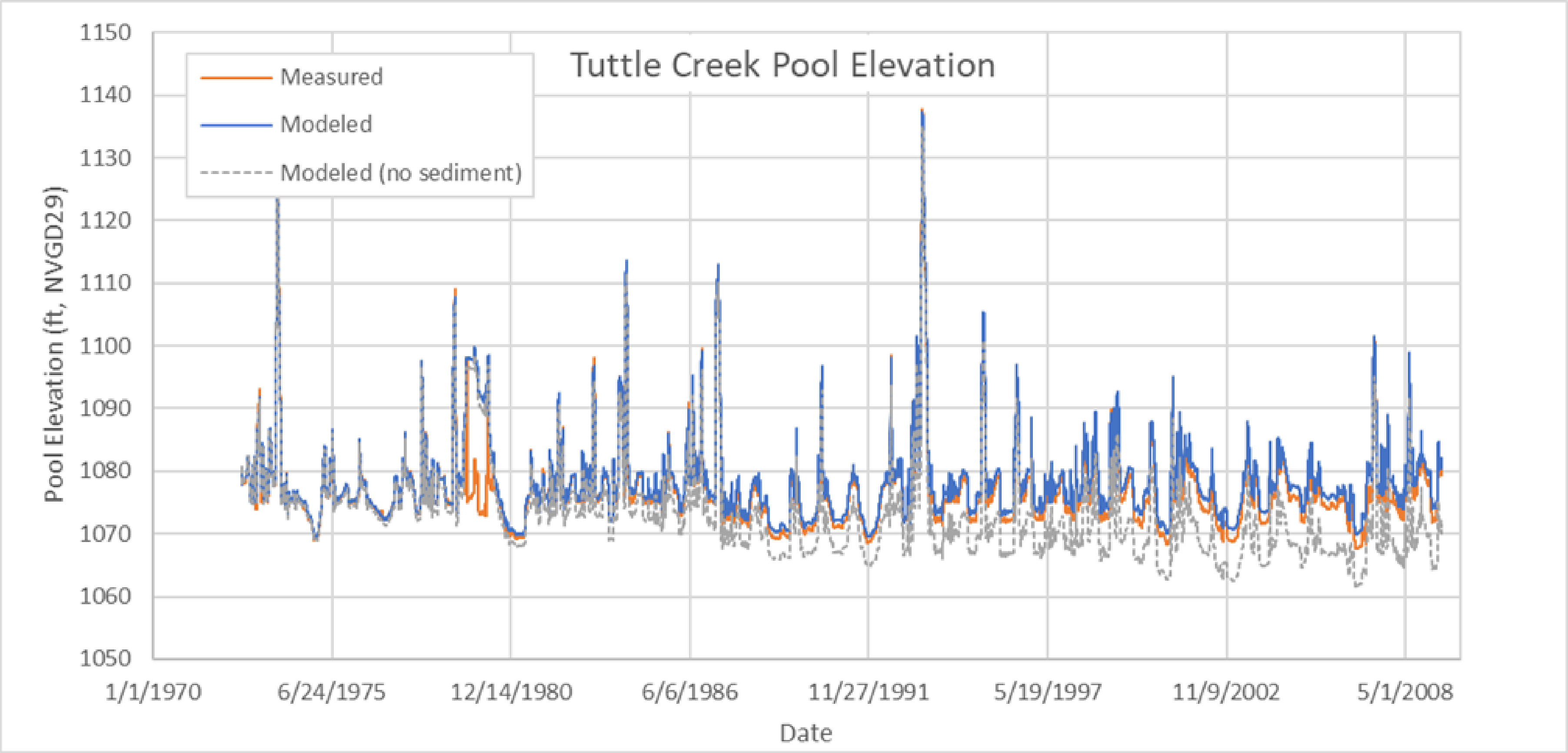
- Applied same methodology as for Tuttle Creek
- Kanopolis showed more deposition at lower elevations
- Final gradation was 10% clay and 90% sand.
- Errors in the observed data.



POOL ELEVATION

Modeled pool elevation matched well with observed

Without sediment, the model underpredicts stage by as much as 9 feet



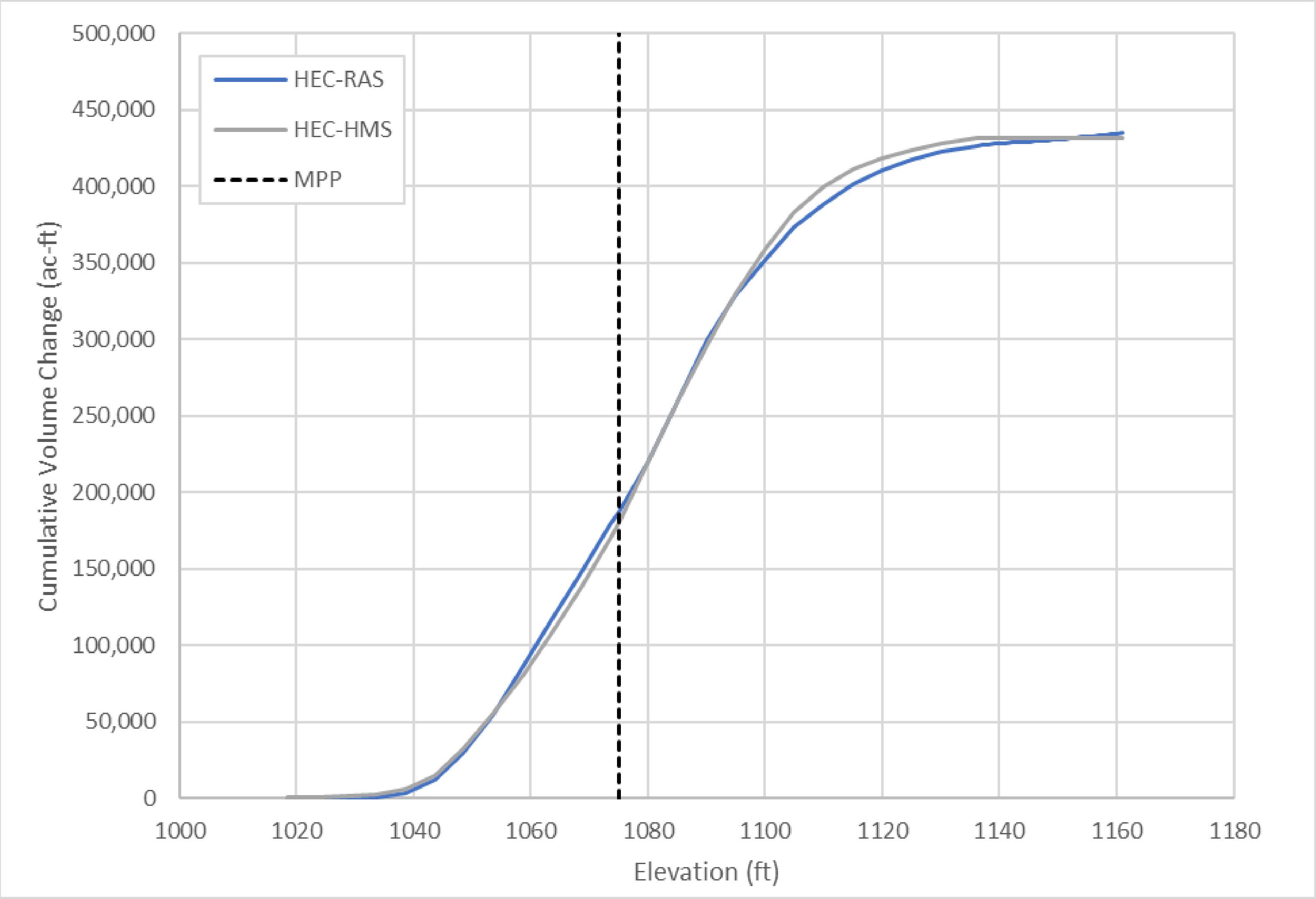
HEC-RAS COMPARISON

HEC-RAS Model

- 1D quasi-unsteady sediment
- Same inputs for incoming sediment load
- Calibrated to the 2009-2020 period

Comparison

- Both model agreed relatively well
- HEC-RAS deposits more sediment at higher elevations



CASE STUDY: UNBRW

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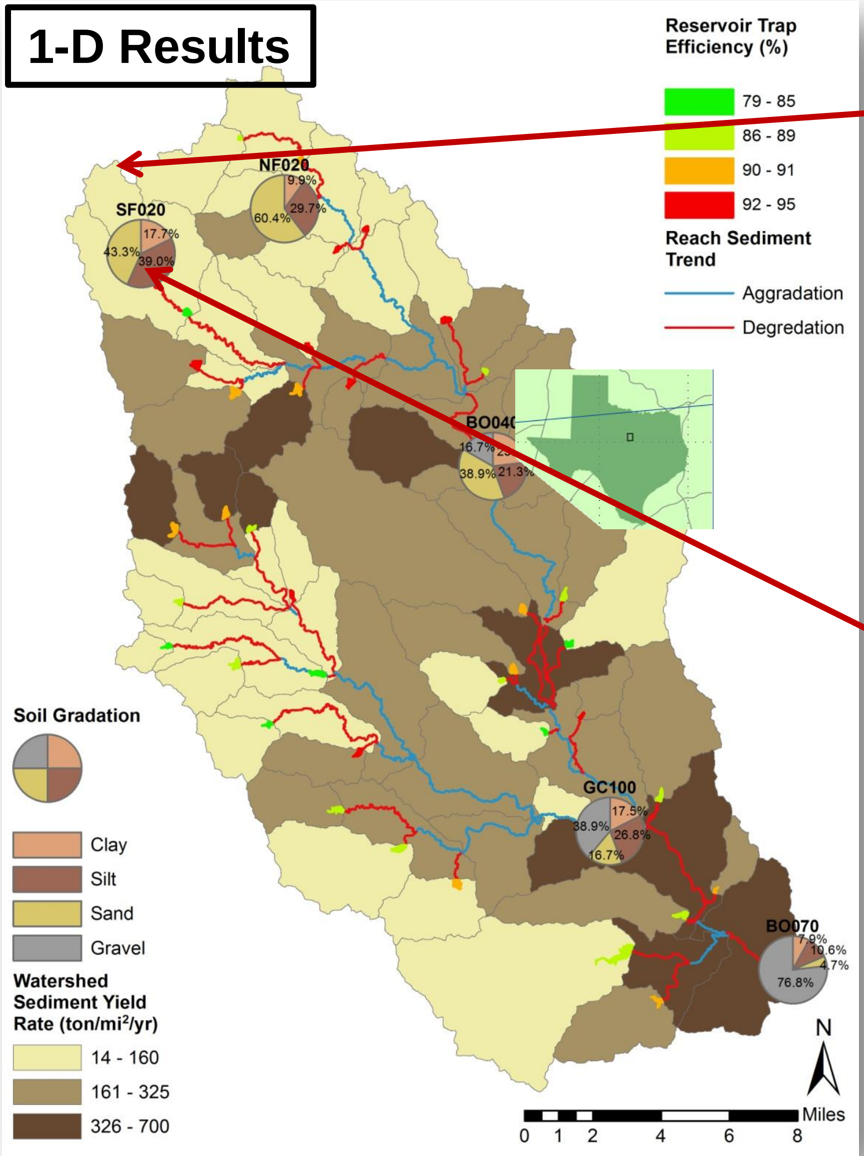
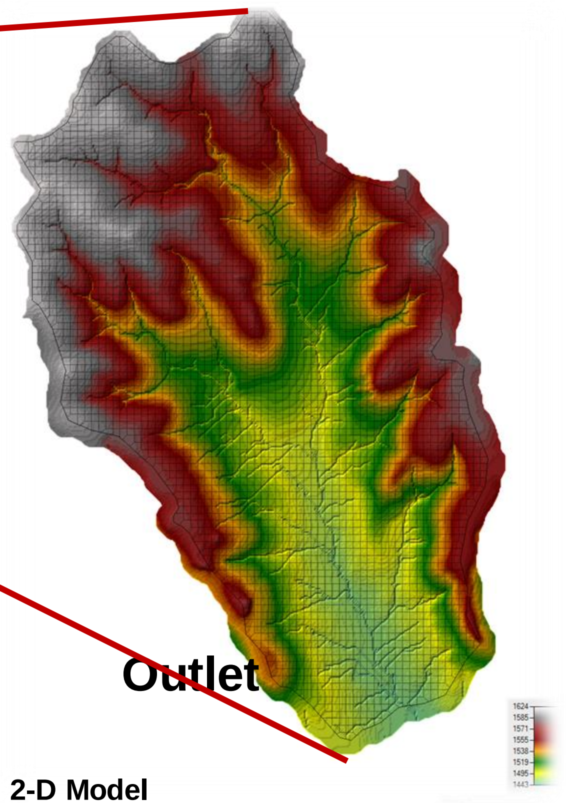
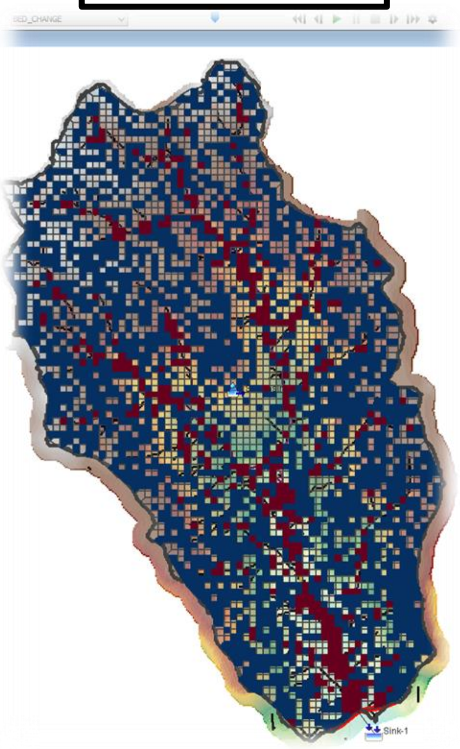
1-D Model
- Precipitation: 750 mm/year
- Soil Type: fine sandy loams
- 1D Area: 355.6 mi^2 (921 km^2)
- Elevation: 299 m - 495 m
- Subbasin: 68
- Reservoir: 40

1-D Results



2-D Results





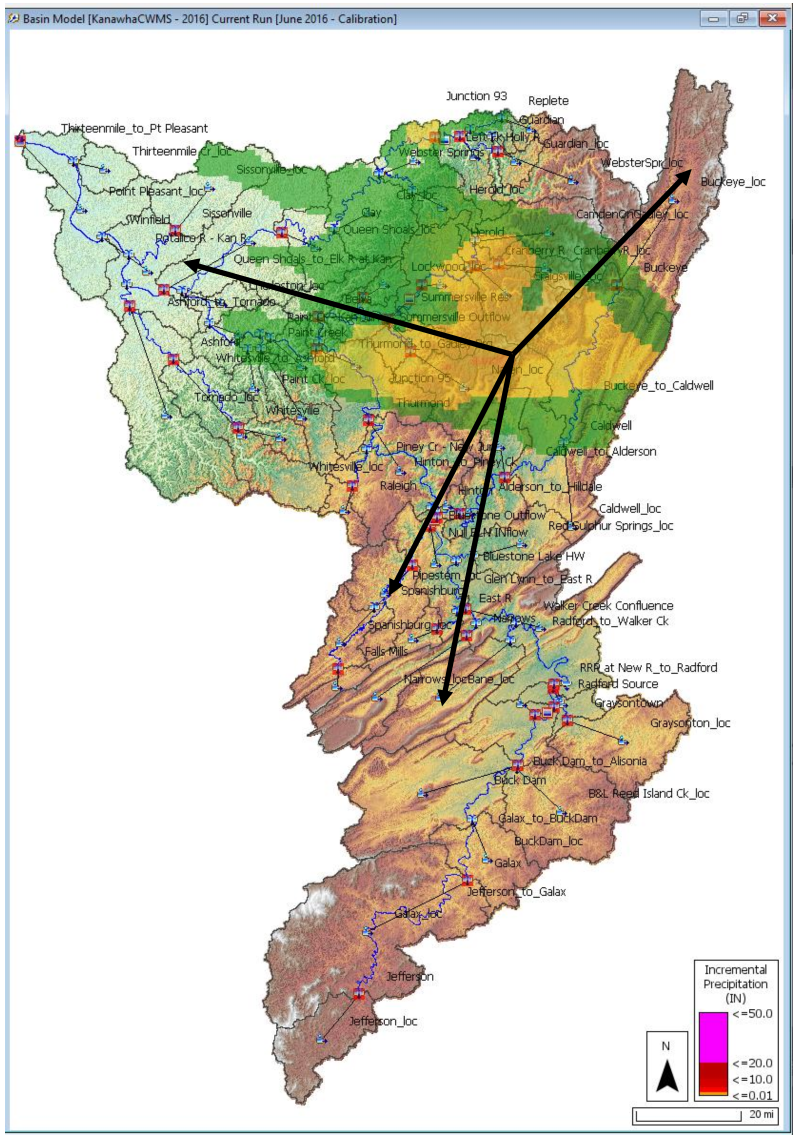
2-D Model
- 2D Area: 3.3 mi^2 (8.5 km^2)
- Elevation: 1457 ft – 1624 ft (444 m – 495 m)
- Terrain Model: 10 m DEM
- Grid Cell Number: 4035
- Grid Cell Size: 150 ft X 150 ft

2-D STM Results
- Water Depth
- Flow Velocity
- Concentration
- Bed Change

Source: https://ascelibrary.org/doi/full/10.1061/%28ASCE%29HE.1943-5584.0001205

Upcoming Enhancements

- Ensemble analysis enhancements
- Time-varying parameters
- Temporal disaggregation of daily gridded inputs
- Gridded data modeling enhancements
- ***Stochastic Storm Transposition***
- Sediment transport and debris flow enhancements



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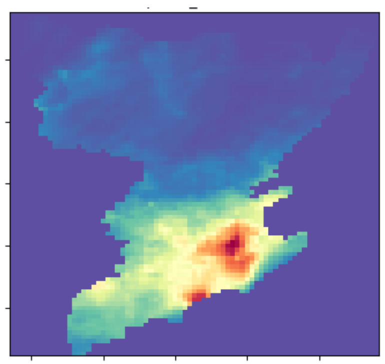
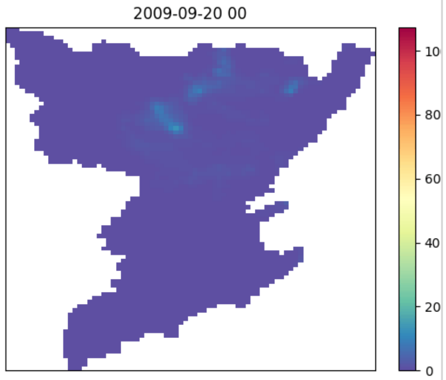
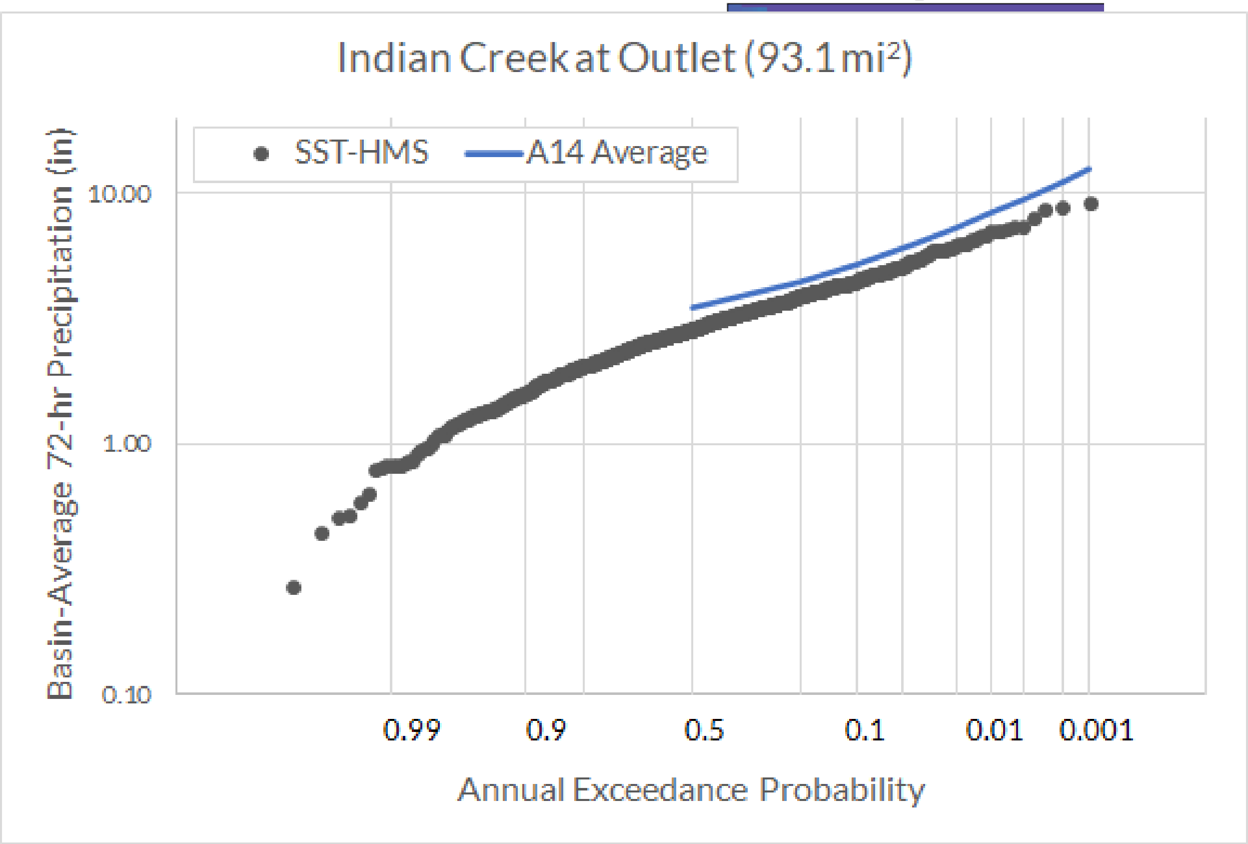
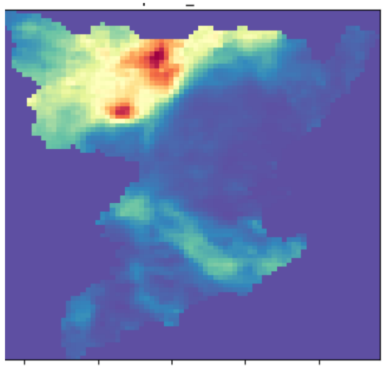
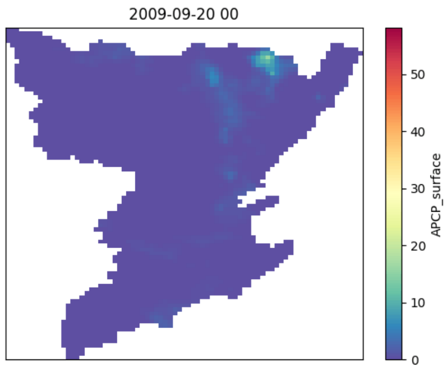
Stochastic Storm Transposition











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Interface Translation

- HEC-HMS was designed to operate independent of regional and language settings on a user's computer
- 95+ language, countries, and/or locales are supported

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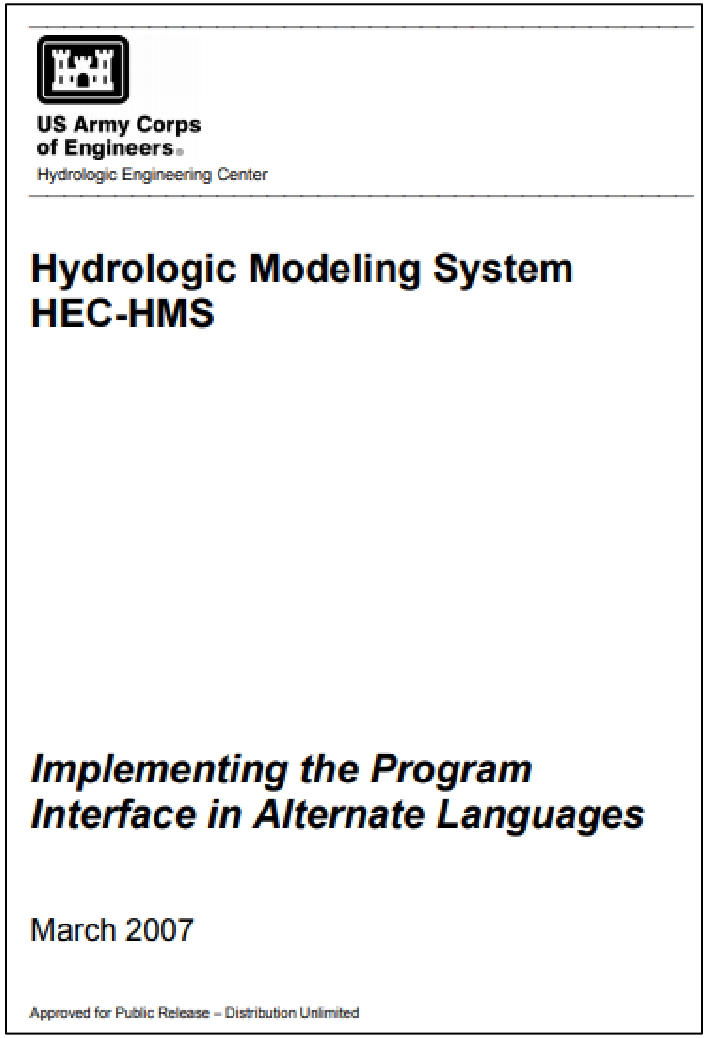
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Hydrologic Engineering Center

Hydrologic Modeling System
HEC-HMS

Implementing the Program Interface in Alternate Languages

March 2007

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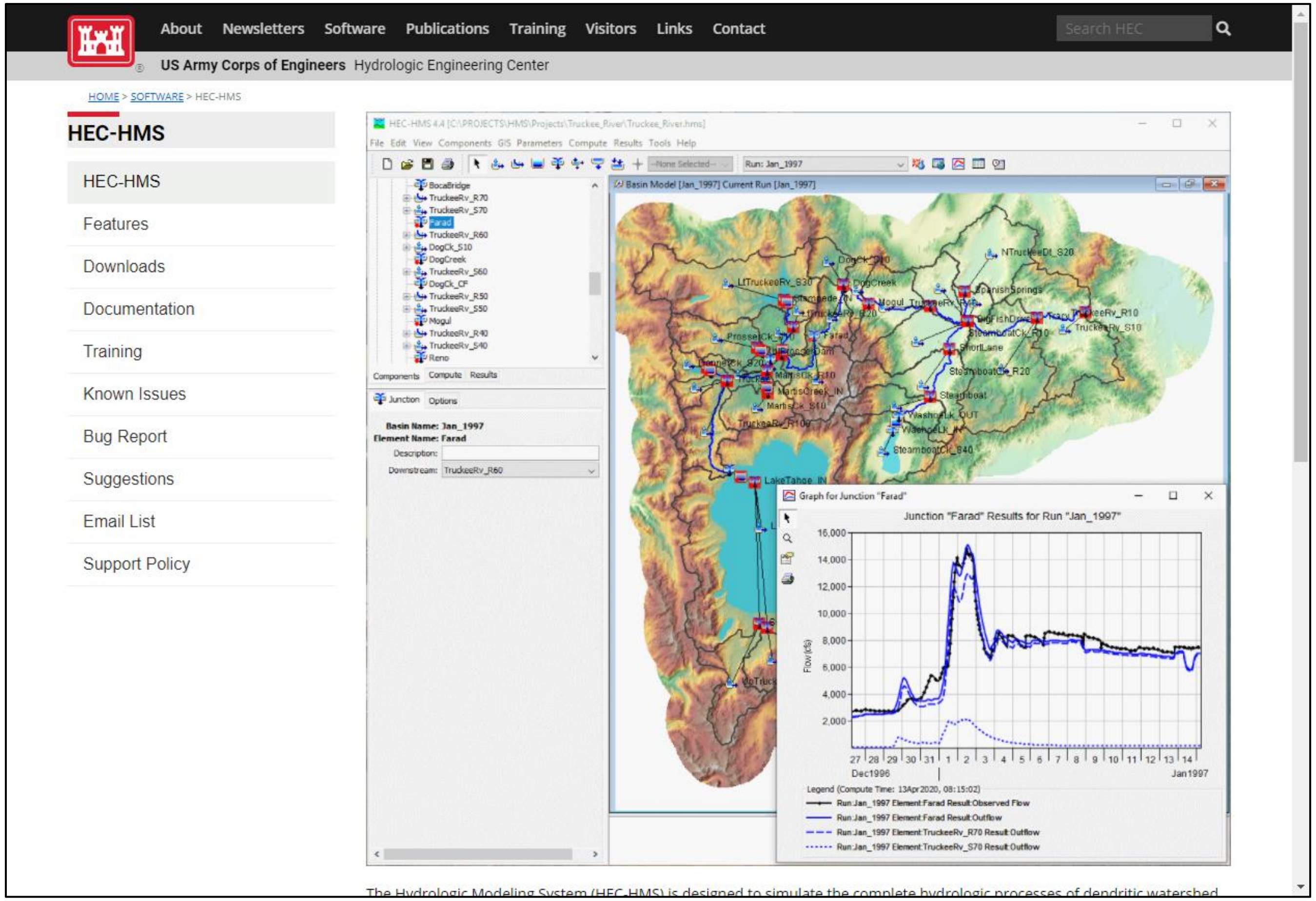
Thank You!



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https://www.hec.usace.army.mil/software/hec-hms/