Atmospheric River Forecasts and Post-Wildfire Hydrology Prediction

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POST-WILDFIRE FLOOD RISK MANAGEMENT

US Army Corps of Engineers

ERDC ENGINEER RESEARCH & DEVELOPMENT CENTER

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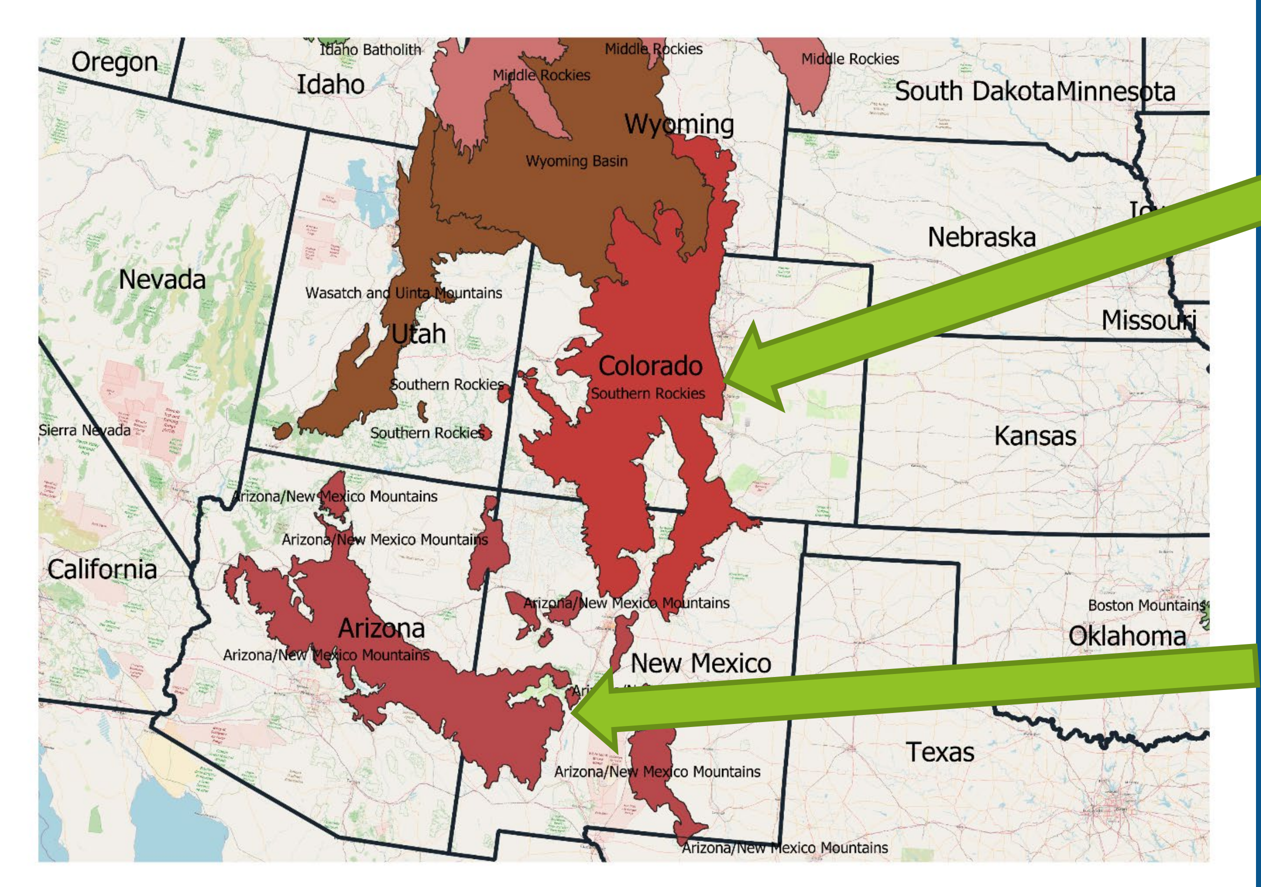
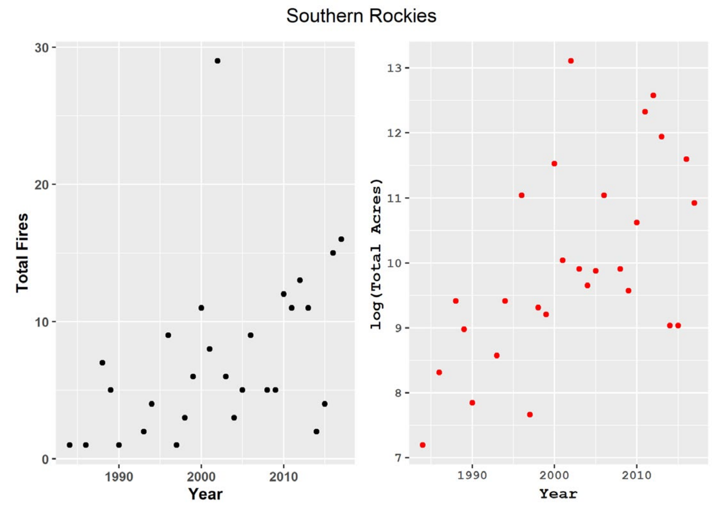
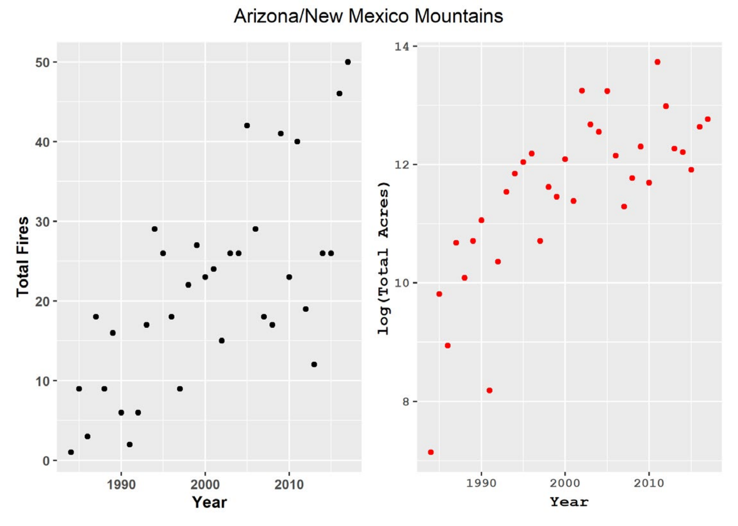
USGS and USFS
CalFire
CalTrans
Santa Barbara County
Florida International University
New Mexico Tech
University of New Mexico

Wildfire Trends – Southwest Ecoregions







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POST-WILDFIRE FLOOD RISK MANAGEMENT

USACE Post-Wildfire Research and Development

Devastating floods following wildfires have been observed in many occasions, especially in Southwestern U.S. Research and Development is focused on improving prediction capabilities for operation H&H numerical modeling.

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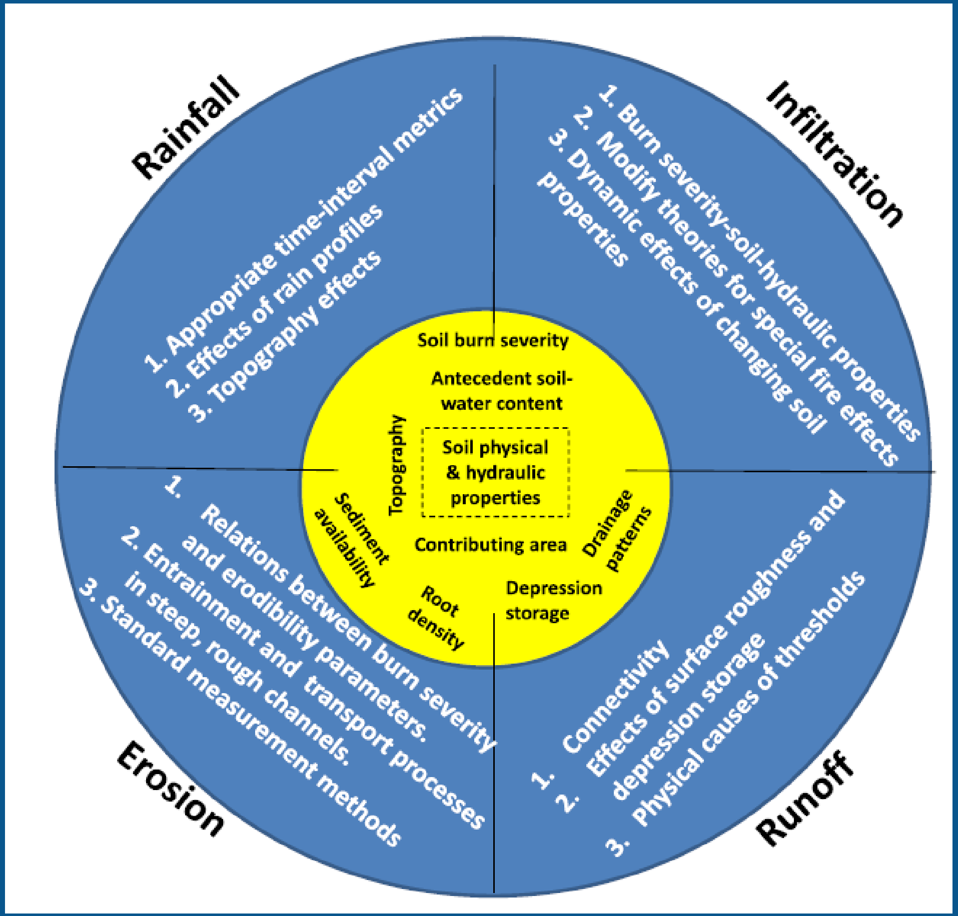
POST-WILDFIRE FLOOD RISK MANAGEMENT

Post-Wildfire Physical Mechanisms



- Physical mechanisms have been investigated for years and have been largely understood qualitatively
  - Wildfire alters vegetation, soil, and microtopography, which can affect the physical processes of infiltration, runoff, erosion during heavy rainfalls.

Moody, J.A., Shakesby, R.A., Robichaud, P.K., Cannon, S.H., Martin, D.A., 2013. Current research issues related to post-wildfire runoff and erosion processes. Earth-Science Reviews 122, p. 10-37.

Wildfire Effect on Vegetation and Hydrology

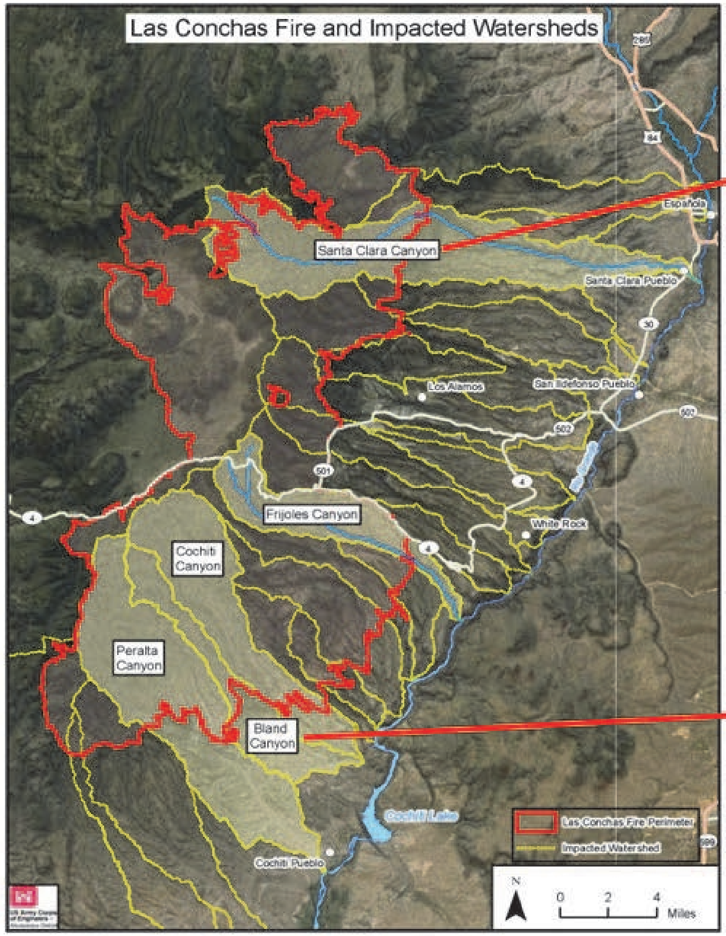
- Less vegetation coverage, less litter and duff layer
- Less rainfall interception
  - More effective rainfall
  - Shorter time to runoff
  - Larger runoff
- Less surface friction (reduced in roughness)
  - Increase surface connectivity
  - Reduce runoff routing time
- Less Evapotranspiration
  - Possibly more soil moisture
  - Higher ground water level

Wildfire Effects on Soil and Sediments

- Soil structure changes
  - Soil aggregates break down and fracturing
  - Surface sealing (layering)
- Reduction in soil permeability
  - Runoff increases (peak flow increases by up to 2-3 orders of magnitude)
  - Difficult to quantify
- Hydrophobic layer (soil water repellency)
  - Formed under appropriate burn conditions
- Generation of Ash layer
- Heterogeneity of land surface

Background – Las Conchas Wildfire and Cochiti Reservoir

- Started: 26 June 2011
- Contained: 03 August 2011
- Burn Area: 631 km^2
- First Day: 162 km^2
- First 2 Days: 243 km^2
- Burn Rate (peak est.): ~4047 m^3/s
- Effected ~16 Major Watersheds that drain into Rio Grande above Cochiti Reservoir




Santa Clara Canyon
July 14, 2011

Bland Canyon
August 7, 2011

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Cochiti Canyon Flood
Dixon's Apple Orchard

August 22, 2011

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Post-Wildfire and USACE Missions

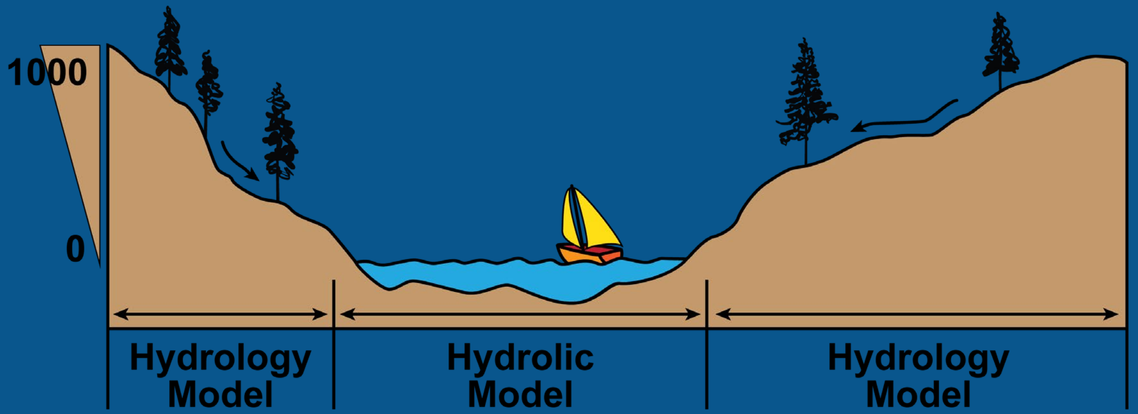
Post Wildfire Effects to USACE Mission

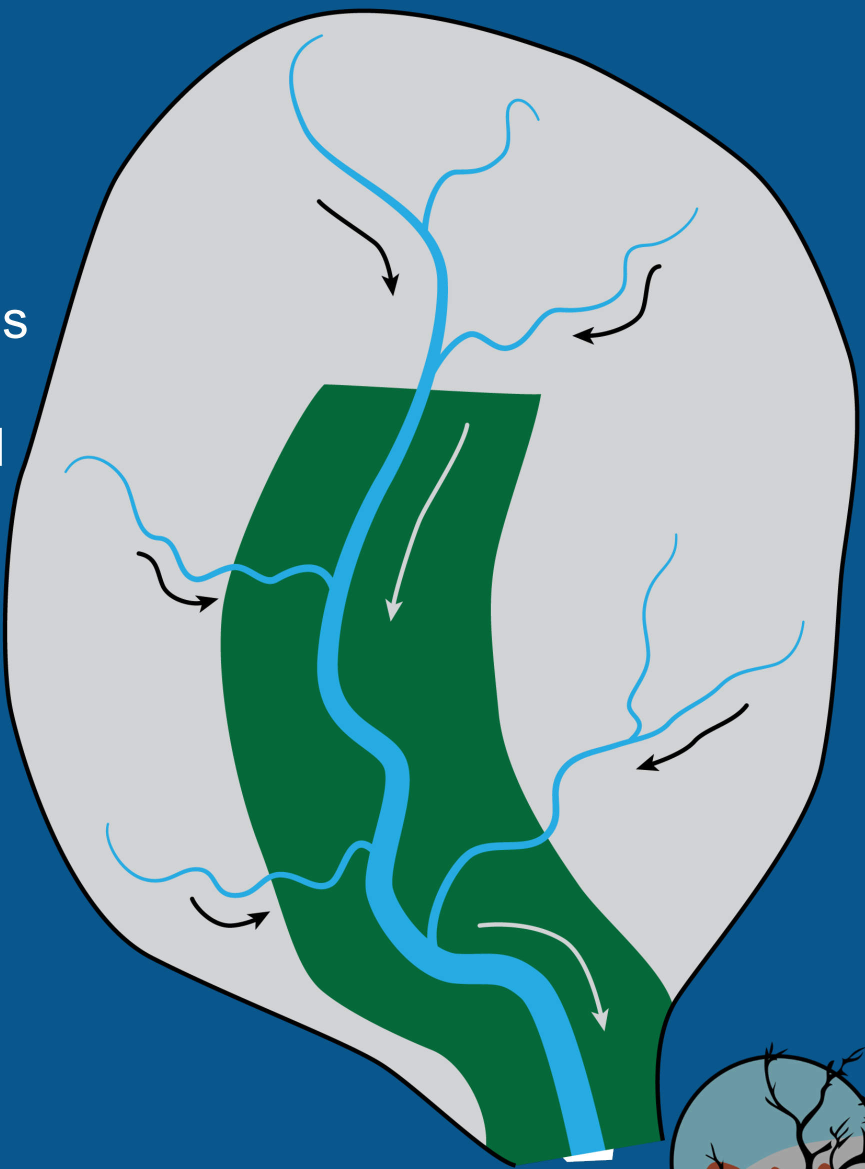
- Significant hazard to life and infrastructure
- Increase wildfire intensity, duration and occurrence across western US
- Peak discharge measured following wildfire have been shown to increase by ~1.5 to 1000 times (plus) over pre-fire rates (Moody and Martin, 2001; Cannon and Gartner, 2005)
- Continuum of post-wildfire flood response (e.g. none, floods, ash flows, mudflow, and debris flows)
- Increased sediment erosion and transport resulting in decreased flood capacity in downstream channels
- Uncertainty in debris-flow frequency-magnitude relationships
- Recovery and climate change uncertainty – Ecotone Shifts
- Significant ecosystem and environmental impacts
- Impacts across multiple business lines and districts

Post-Wildfire Hydrology R&D

USACE Hydrology Model Development

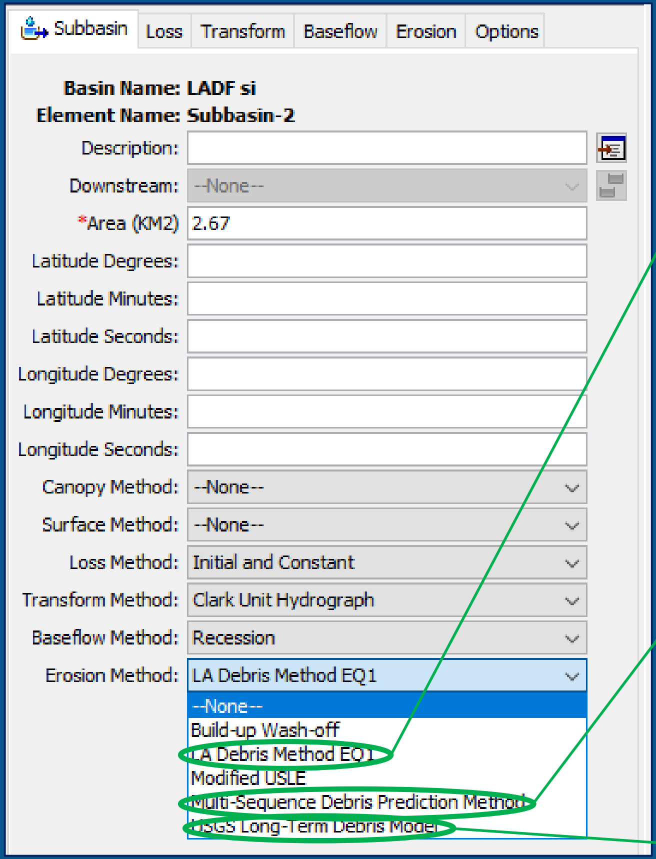
- HEC-HMS
- Gridded Surface and Subsurface Hydrologic Analysis (GSSHA)
- Includes evaluation of non-USACE hydrology-based models (i.e., KINEROS, AGWA, WELP)
- Empirically-derived Sediment Yield Approaches

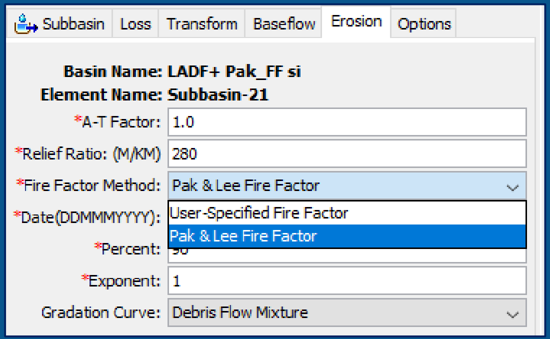


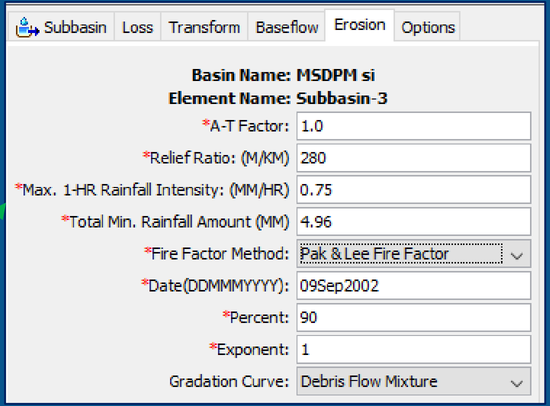


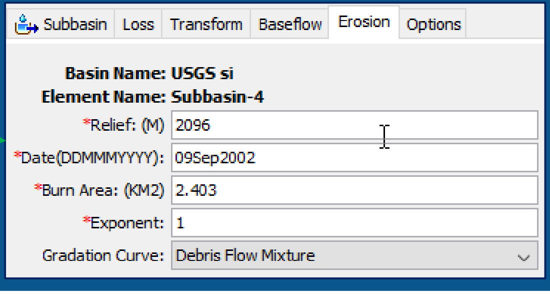
Post-Wildfire Hydrology R&D

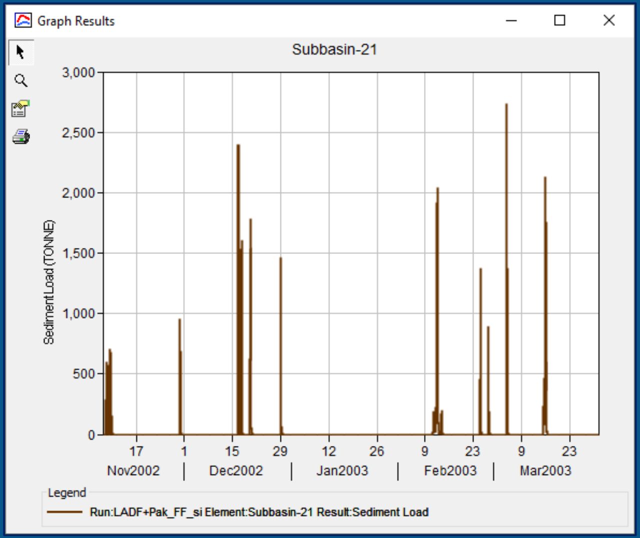
HEC-HMS 4.5 Beta: GUI for Three Debris Yield Prediction Methods

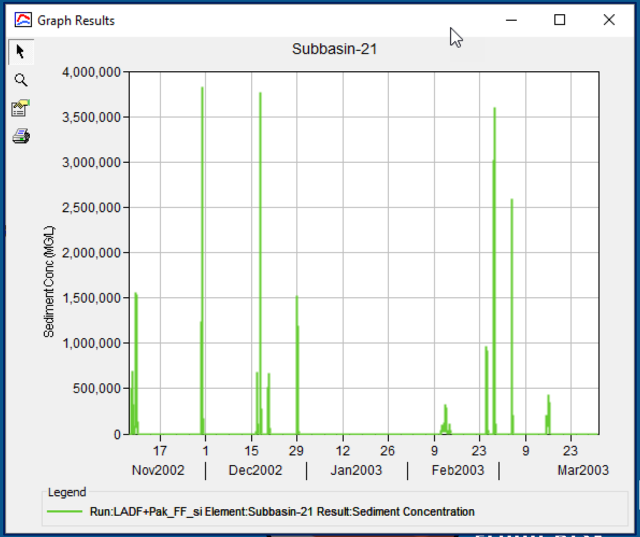












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FLOOD RISK MANAGEMENT

Post-Wildfire Hydrology R&D – Case Studies

Debris Basin	Area (ha)/(mi^2)	Burn Area (%)	Relief Ratio (m/km)	Measured Sediment Yield (m3)	MSDPM (m3)	MSDPM Diff. (%)	LAD EQ. 1	LAD EQ. 1 Diff. (%)	LAD EQ.1 + Pak FF (m3)	LAD EQ.1 + Pak FF Diff. (%)	USGS LT (m3)	USGS LT Diff. (%)
Brand	267/1.03	90	280	81385	85422	5%	107184	32%	100697	24%	166109	104%
Childs	81/0.31	80	314	22249	22956	3%	28083	26%	23879	7%	67434	203%

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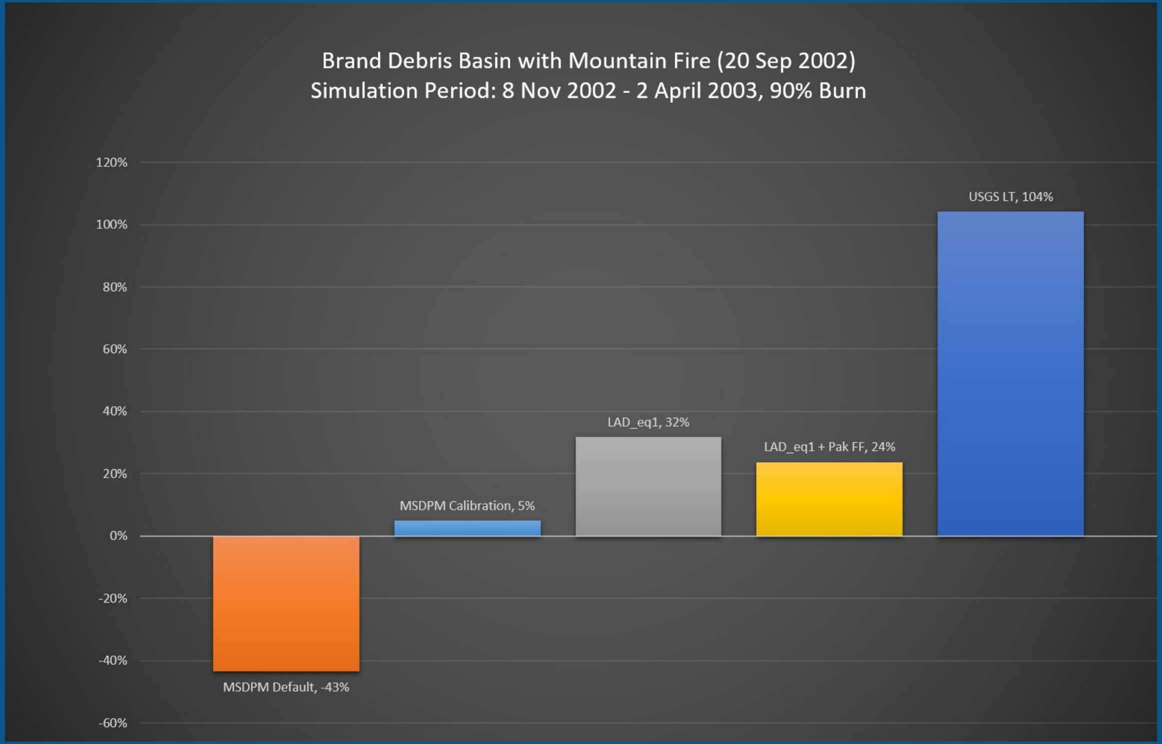
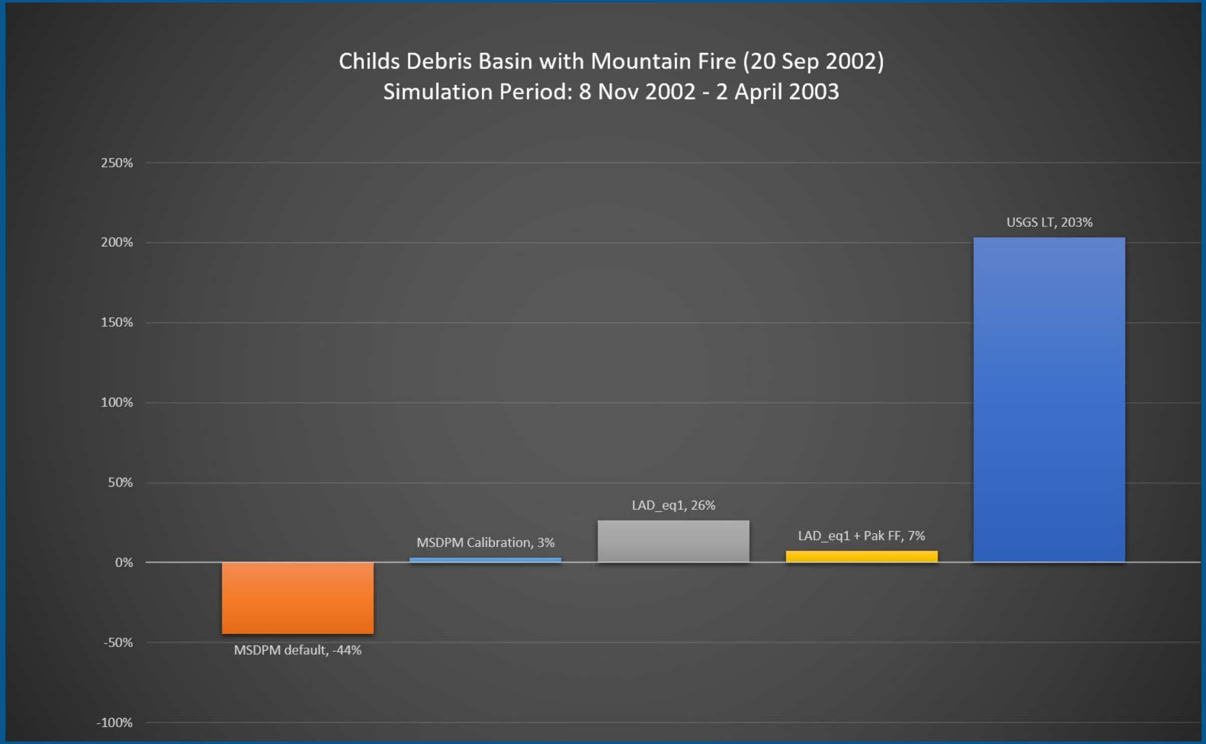
POST-WILDFIRE FLOOD RISK MANAGEMENT

Post-Wildfire Hydrology R&D – Case Study





Post-Wildfire Hydraulics and Sediment Transport R&D

HEC-RAS
1D Finite Difference
2D Finite Volume
Fortran Code

Adaptive Hydraulics
2D Finite Area
C++ Code

RAS

ADH

DebrisLib

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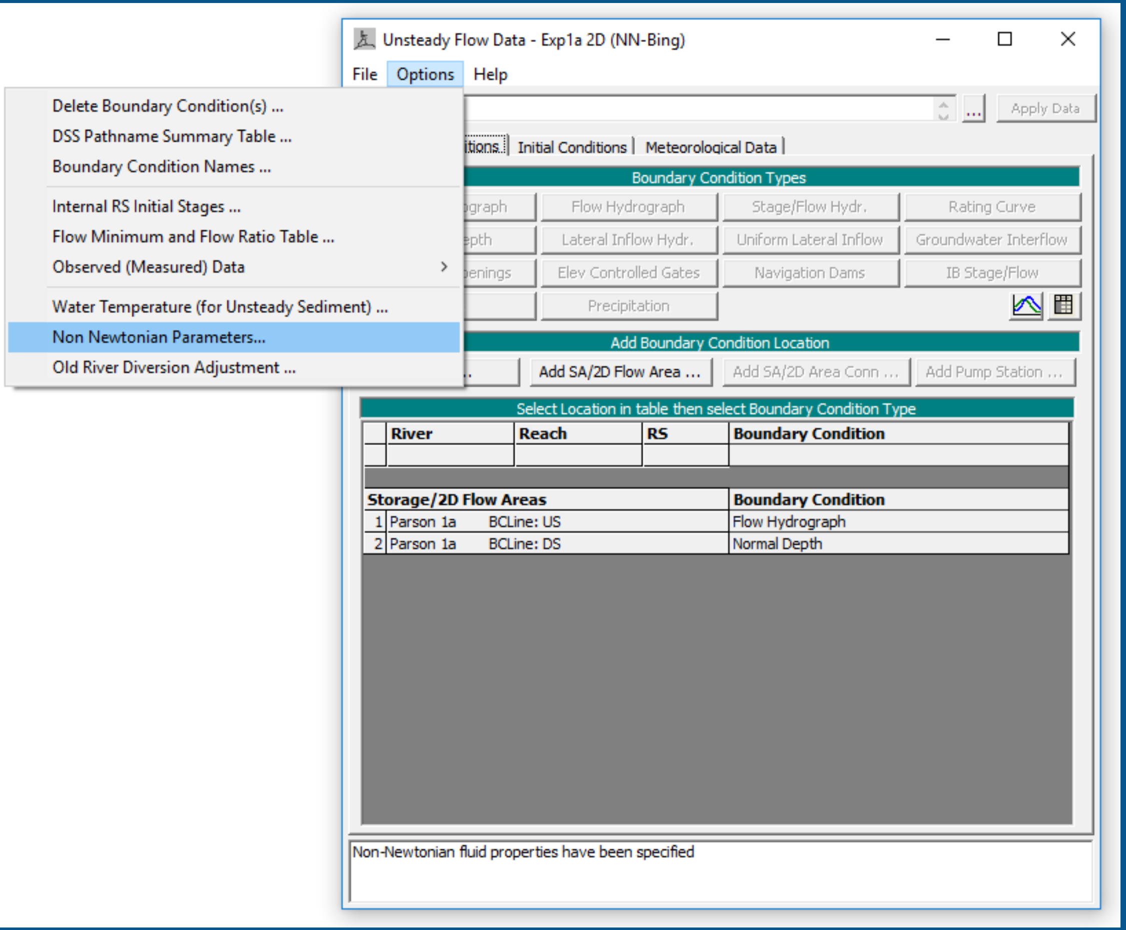
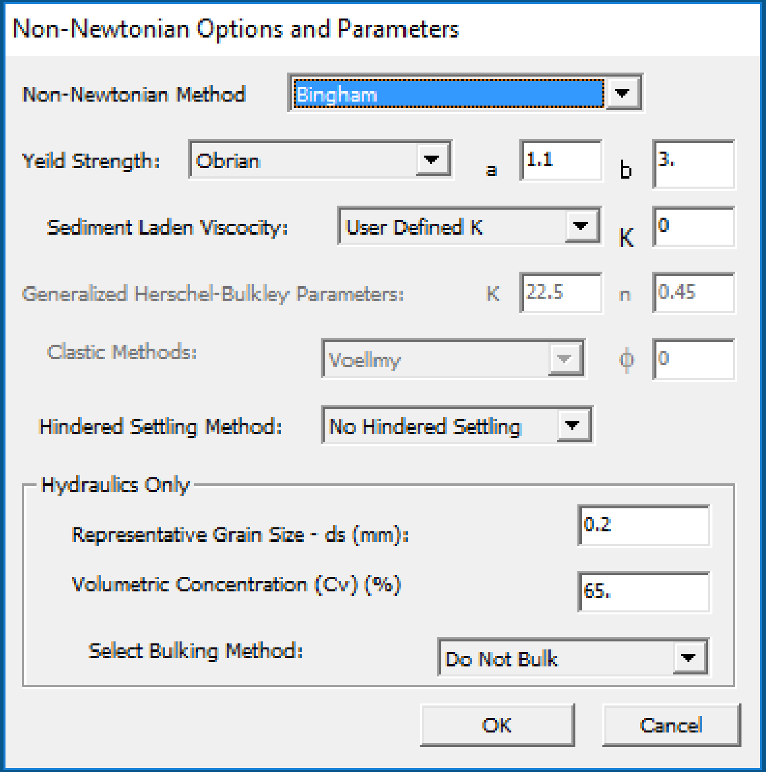
POST-WILDFIRE FLOOD RISK MANAGEMENT

Selecting a Non-Newtonian Method in HEC-RAS

Non-Newtonian Parameters are Unsteady Flow Variables





1D, Unsteady, FD (Working)
2D, Unsteady, FV (Working)
1D, Unsteady, FV (coming soon)
1D/2D Mobile Bed (coming later)
-Not in Steady or Quasi-Unsteady

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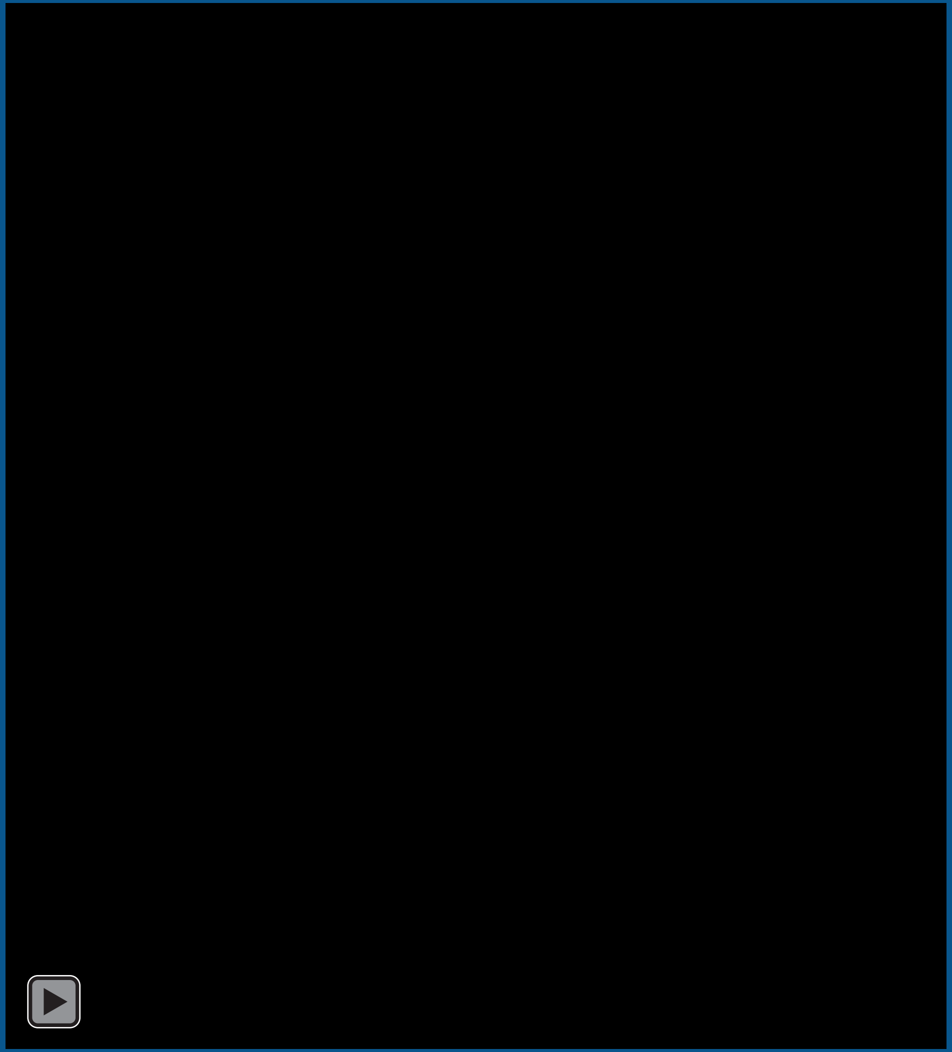
Santa Barbara Mud-and-Debris Flow



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POST-WILDFIRE FLOOD RISK MANAGEMENT

Post-Wildfire Hydraulics and Sediment Transport R&D

RAS

HEC-RAS

1&2D Hydraulic and
Morphdynamic Software

100,000 Downloads/Year
in 200 countries

Newtonian Assumptions

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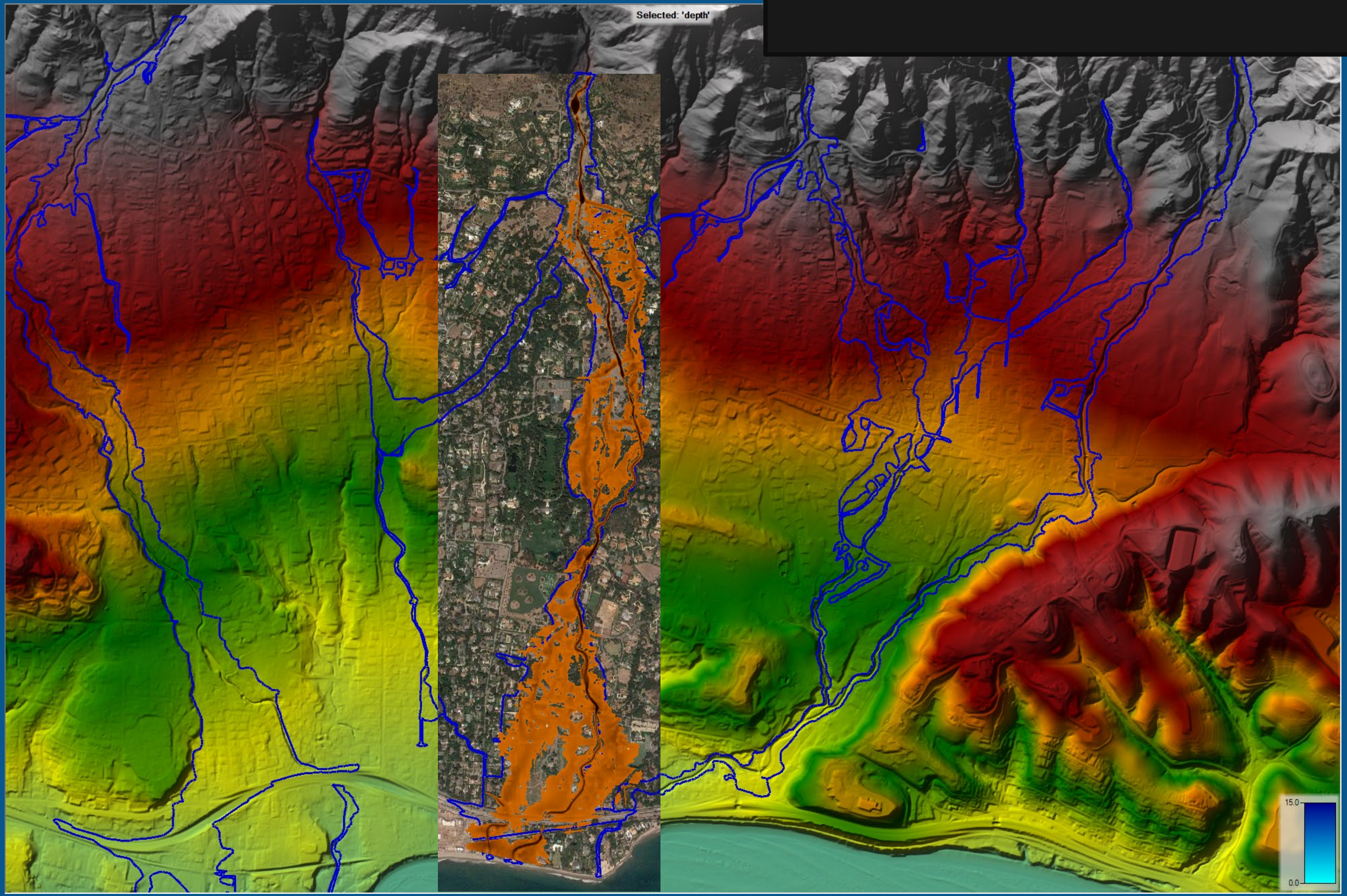
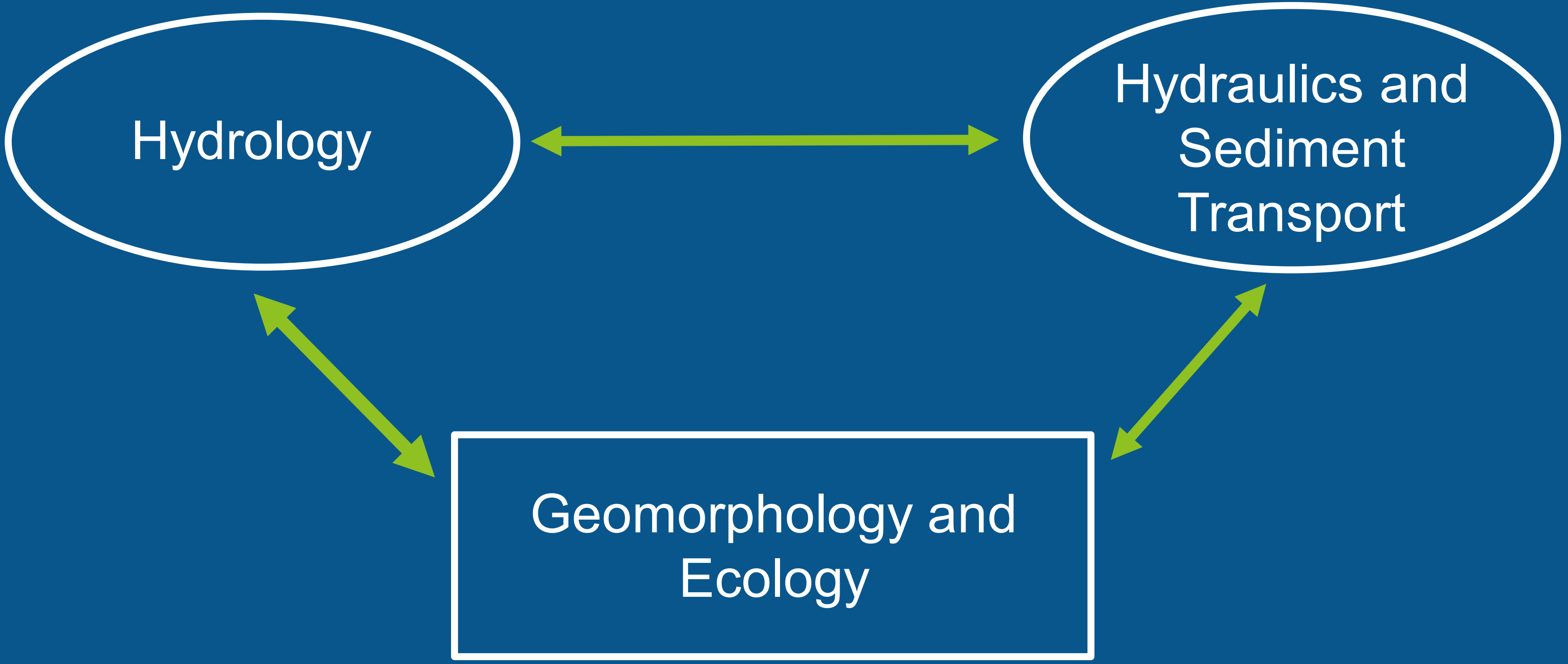


Post-Wildfire Model Library



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POST-WILDFIRE FLOOD RISK MANAGEMENT

Post-Wildfire Model Library

- Hydrology
  - Rainfall/Precipitation
  - Infiltration and Evapotransporation
  - Soil Moisture/Initial Conditions
  - Overland Erosion and Runoff
  - Sediment and Debris Yield

- Hydraulics and Sediment Transport
  - Open Channel Flow Conditions
  - In channel Sediment Transport
  - Hazard Magnitude and Intensity
  - Fluid-Structure Interaction (Bridges, Culverts, etc.)

- Geomorphology and Ecology
  - Blend of qualitative and quantitative
  - Critical for Improving Long Term Modeling
  - Understanding recovery for Better Management

Wildfire Effects on Hydrology

- Less vegetation coverage, less litter and duff layer
- Less rainfall interception
  - More effective rainfall
  - Shorter time to runoff
  - Larger runoff
- Less surface friction
  - Increase surface connectivity
  - Reduce runoff routing time
- Less ET
  - Possibly more soil moisture
  - Higher ground water level
- Soil structure changes
  - Aggregates break down
  - Surface sealing (layering)
- Reduction in soil permeability
  - Runoff increases (peak flow increases by up to 2-3 orders of magnitude)
  - Hard to quantify
- Hydrophobic layer (soil water repellency)
- Production of Ash layer
- Heterogeneity of land surface

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Post-Wildfire Hydrology R&D – Wildfire Recovery

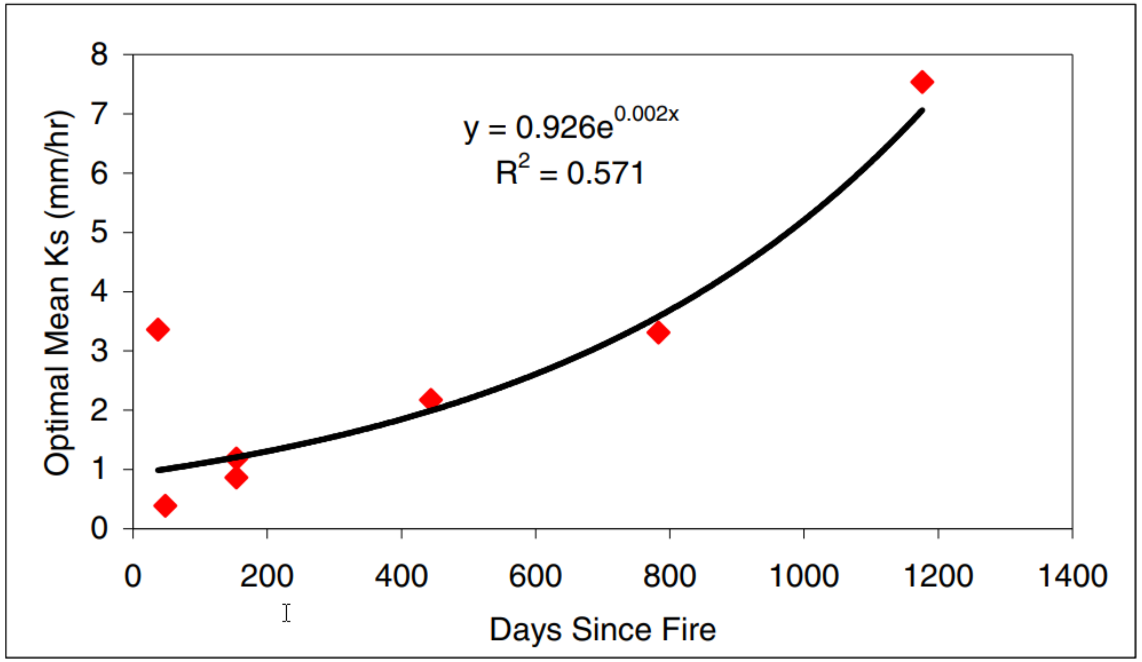

Figure 5 – Optimal Hillslope Hydraulic Conductivity Following the Cerro Grande Fire at Starmer Canyon Plotted vs. Time

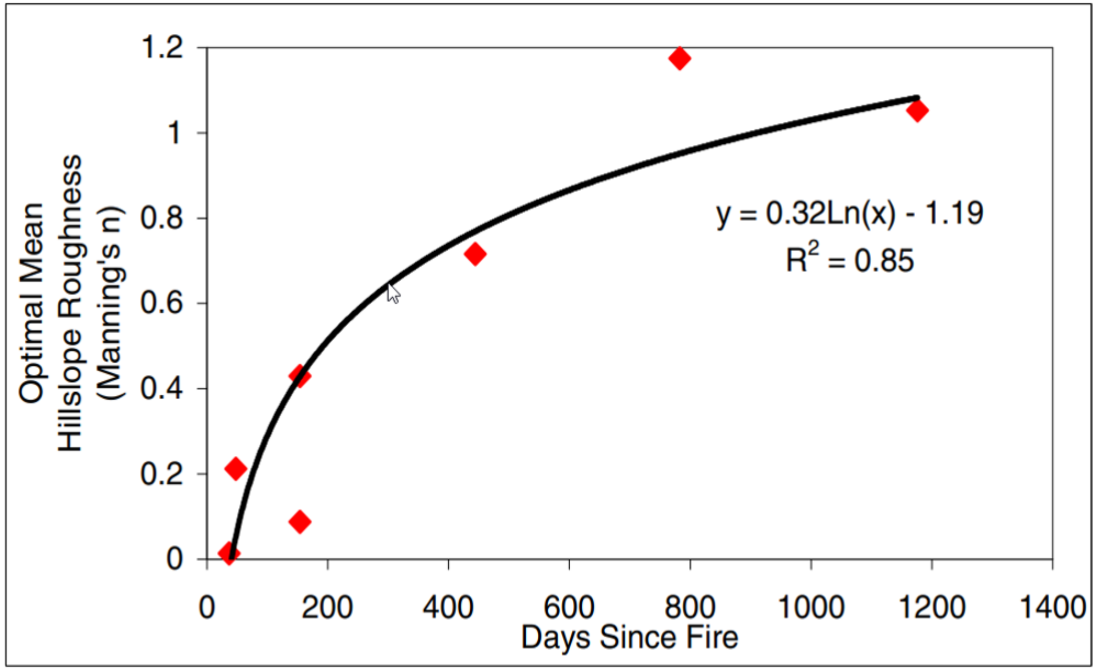

Figure 4 – Optimal Hillslope Roughness for Events that Occurred after the Cerro Grande Fire at Starmer Canyon Plotted vs Time

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Source: Selection of Parameters Values to Model Post-fire Runoff and Sediment Transport at the Watershed Scale in Southwestern Forests (Canfield, Goodrich, and Burns, 2005)

POST-WILDFIRE FLOOD RISK MANAGEMENT

Recap and Next Steps

Post Wildfire Flood Risk Management and Uncertainty

Initial applications will focus on *improving predictions of flood risk and uncertainty* for:

- Inundation from debris flows and other non-Newtonian phenomena
- *Management of risks to infrastructure and military installations*
- Updated debris basin design and mitigation methods
- Understanding of long-term evolution of post-wildfire recovery

Future Goals and Gains

Our five (5) year goal:

- Experience gained from model applications and additional field verification will allow us to address progressively challenging flood risk management problems including *development of near real-time models for emergency management*
- R&D is being conducted in partnership with USACE districts for continuous knowledge transfer and training
- Collaboration between researchers and practitioners of post-wildfire knowledge and technologies within a *USACE district-level Center of Expertise*

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