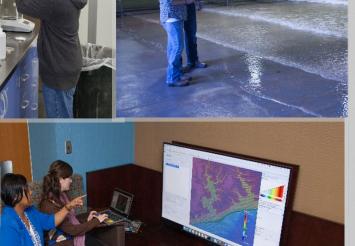


US Army Corps of Engineers

Atmospheric River Forecasts and Post-Wildfire Hydrology Prediction

Ian E. Floyd U.S. Army ERDC, Coastal and Hydraulics Laboratory
06 August 2020











88.373

FL27200

Project Development Team and Partners

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External Partners

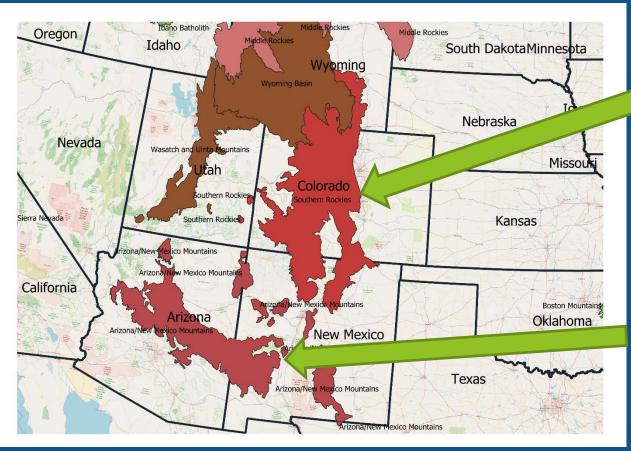
Desert Research Institute USGS and USFS CalFire CalTrans Santa Barbara County Florida International University New Mexico Tech University of New Mexico

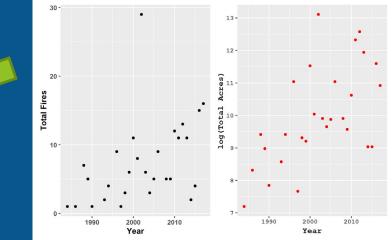
> POST-WILDFIRE FLOOD RISK MANAGEMENT

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Wildfire Trends – Southwest Ecoregions

Southern Rockies

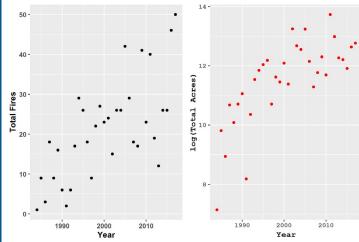




LOOD RISK

MANAGEMENI

Arizona/New Mexico Mountains





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File Name

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.



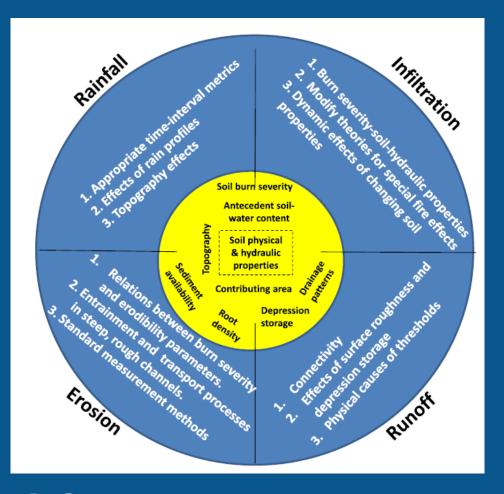


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Post-Wildfire Physical Mechanisms



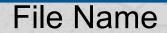
 Physical mechanisms have been investigated for years and have been largely understood qualitatively

> 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.

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Wildfire Effect on Vegetation and Hydrology

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CHL COASTAL & HYDRAULICS LABORATOR

- 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



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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

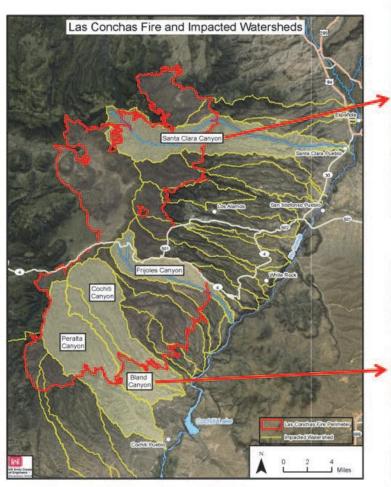


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File Name

Background – Las Conchas Wildfire and Cochiti Reservoir

- Started: 26 June 2011
- Contained: 03 August 2011
- Burn Area: 631 km²
- First Day: 162 km²
- First 2 Days: 243 km²
- Burn Rate (peak est.): ~4047 m³/s
- Effected ~16 Major Watersheds that drain into Rio Grande above Cochiti Reservoir





Santa Clara Canyon July 14, 2011



Bland Canyon August 7, 2011





File Name

Cochiti Canyon Flood Dixon's Apple Orchard

August 22, 2011





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File Name

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





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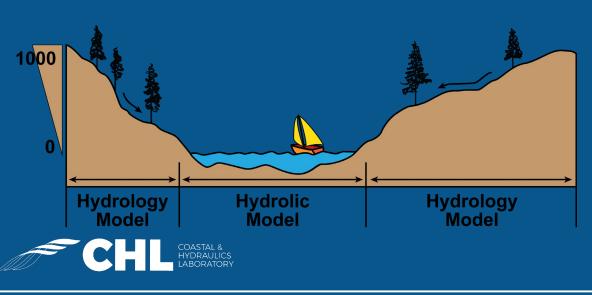


File Name

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



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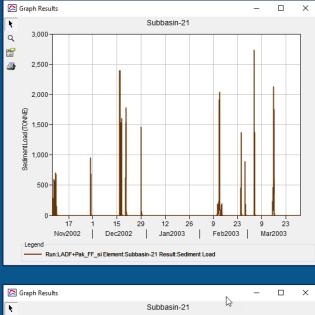
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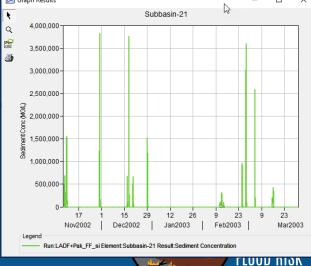
Post-Wildfire Hydrology R&D HEC-HMS 4.5 Beta: GUI for Three Debris Yield Prediction Methods

🚑 Subbasin	Loss	Transform	Baseflow	Erosion	Options				
Basin Na Element Na									
Descrip	otion:								
Downstr	eam:	None V							
*Area (KM2)	2.67							
Latitude Deg	rees:								
Latitude Min	utes:								
Latitude Seco	onds:								
Longitude Deg	rees:						/		
Longitude Min	utes:					_/			
Longitude Seco	onds:								
Canopy Met	thod:	None ~							
Surface Met	thod:	None ~							
Loss Met	thod:	Initial and Constant 🗸 🗸 🗸							
Transform Met	thod:	Clark Unit Hydrograph 🗸 🗸 🗸							
Baseflow Met	thod:	Recession V							
Erosion Met	thod:	LA Debris Me	ethod EQ1			~			
		None Build-up Was	h off						
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		Modified USL		rediction	Method				
		usid Sequer			ne u lou				
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		HYDRAULICS							

🚑 Subbasin	Loss	Transform	Basef	low	Erosion	Options			
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		Subbasin	_						
*A-T	Factor:	1.0	0						
*Relief Ratio:	(M/KM)	280							
		Pak & Lee Fire Factor 🗸 🗸 🗸							
*Date(DDMMM	IYYYY):	User-Speci	User-Specified Fire Factor						
*P	ercent:	Pak & Lee Fire Factor							
*Exp	onent:	1							
Gradation	Curve:	Debris Flow	v Mixtu	re		~			
🔐 Subbasin	Less	Transform	Paget	1	Erosion	Options			
Subbasin	LOSS	mansioni	Dasei	IOW	LIUSION	Opuons			
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	elief Ratio: ((M/KM)							
*Max. 1-HR R			• •				4		
*Total I		nfall Amoun							
	re Factor M	ethod:	Pak	& Lee Fin	e Factor 🗸 🗸 🗸				
	*Da	ate(DDMMM	IMMYYYY): 09Sep2002						
	*Pe	rcent:							
			onent:						
		Gradation (Curve:	Deb	oris Flow N	1ixture 🗸			
🚑 Subbasin	Loss	Transform	Base	flow	Erosion	Options			
Basin	Name	: USGS si							
		Subbasin	-4						
*Rel	ief: (M)	2096			т		٦		
*Date(DDMMN	(YYYY):	09Sep200	09Sep2002						
*Burn Area	: (KM2)	2.403	2.403						
*Exp	ponent:	1	1						
Gradation	Curve:	Debris Flo	Debris Flow Mixture 🗸						

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MANAGEMENT

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POST-WILDFIRE

<u>FLOOD RISK</u> MANAGEMENT

Post-Wildfire Hydrology R&D – Case Studies

Debris Basin	Area (ha)/(mi²)	Burn Area (%)	Relief Ratio (m/km)	Measured Sediment Yield (m3)	MSDP M (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	267/1.0 3	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%

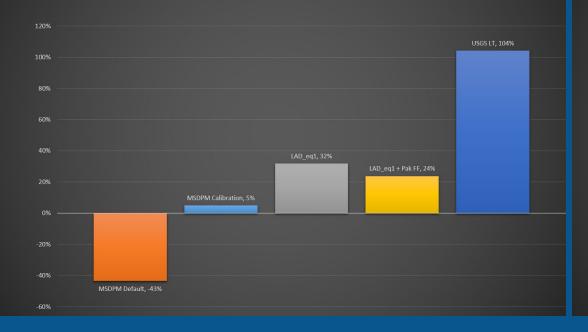


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Post-Wildfire Hydrology R&D – Case Study

Brand Debris Basin with Mountain Fire (20 Sep 2002) Simulation Period: 8 Nov 2002 - 2 April 2003, 90% Burn



25% USGS LT, 203% 15% 10% 5% 5% MSDPM Calibration, 3% LAD_eq1, 26% LAD_eq1, 26% LAD_eq1, 26% LAD_eq1, 40%

Childs Debris Basin with Mountain Fire (20 Sep 2002)

Simulation Period: 8 Nov 2002 - 2 April 2003





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Post-Wildfire Hydraulics and Sediment Transport R&D

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

RAS

Adaptive Hydraulics 2D Finite Area C++ Code

ADH

DebrisLib



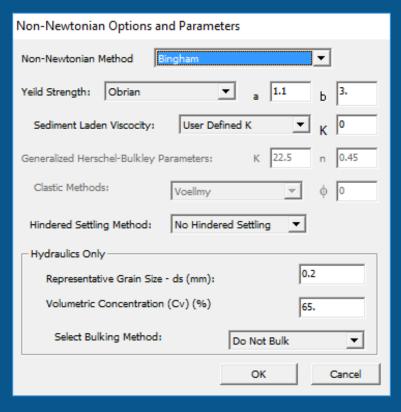
POST-WILDFIRE FLOOD RISK MANAGEMENT



File Name

Selecting a Non-Newtonian Method in HEC-RAS Non-Newtonian Parameters are Unsteady Flow Variables

	上し	Jnsteady F	low Da	ta - Exp1a 2D (– 🗆 🗙					
	File	Options	Help							
Delete Boundary Condition(s)							👶 Apply Data			
				tions. Initial Conditions Meteorological Data						
Boundary Condition Names		Boundary Condition Types								
Internal RS Initial Stages			graph Flow Hydrograph		Stage/Flow Hydr.	Rating Curve				
Flow Minimum and Flow Ratio Table	ıd Flow Ratio Table			epth Lateral Inflow Hydr		Uniform Lateral Inflow	Groundwater Interflow			
Observed (Measured) Data		>	enings Elev Controlled Gates		Navigation Dams	IB Stage/Flow				
Water Temperature (for Unsteady Sediment)				Prei	cipitation]				
Non Newtonian Parameters					Add Boundary C	Condition Location				
Old River Diversion Adjustment			. Add SA/2D Flow Area		Flow Area	Add SA/2D Area Conn Add Pump Station				
			elect Boundary Condition Ty	/pe						
		River		Reach	RS	Boundary Condition				
]]					
			Flow Areas			Boundary Condition				
	1 Parson 1a 2 Parson 1a			.ine: US .ine: DS		Flow Hydrograph Normal Depth				
	Non-I	Newtonian f	iuid pro	perties have be	een specified					



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

OST-WILDFIRE

FLOOD RISK MANAGEMENT

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Santa Barbara Mud-and-Debris Flow





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Post-Wildfire Hydraulics and Sediment Transport R&D

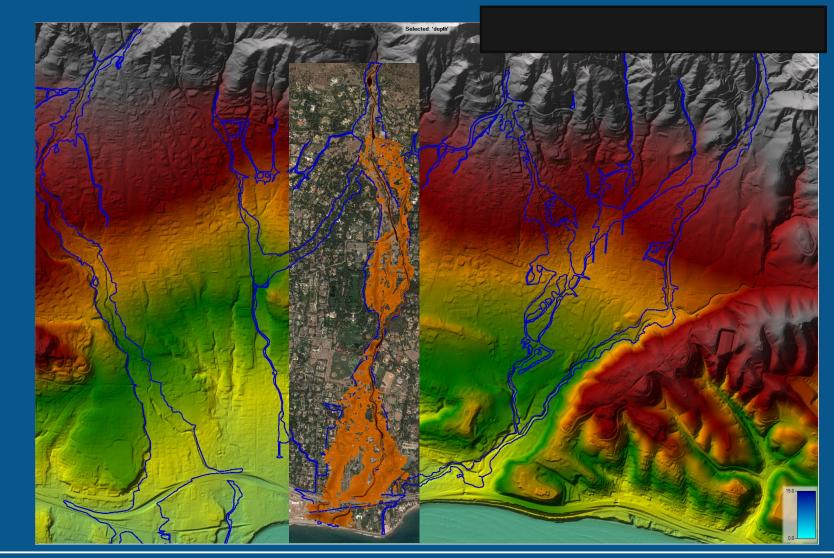


HEC-RAS 1&2D Hydraulic and Morphdynamic Software

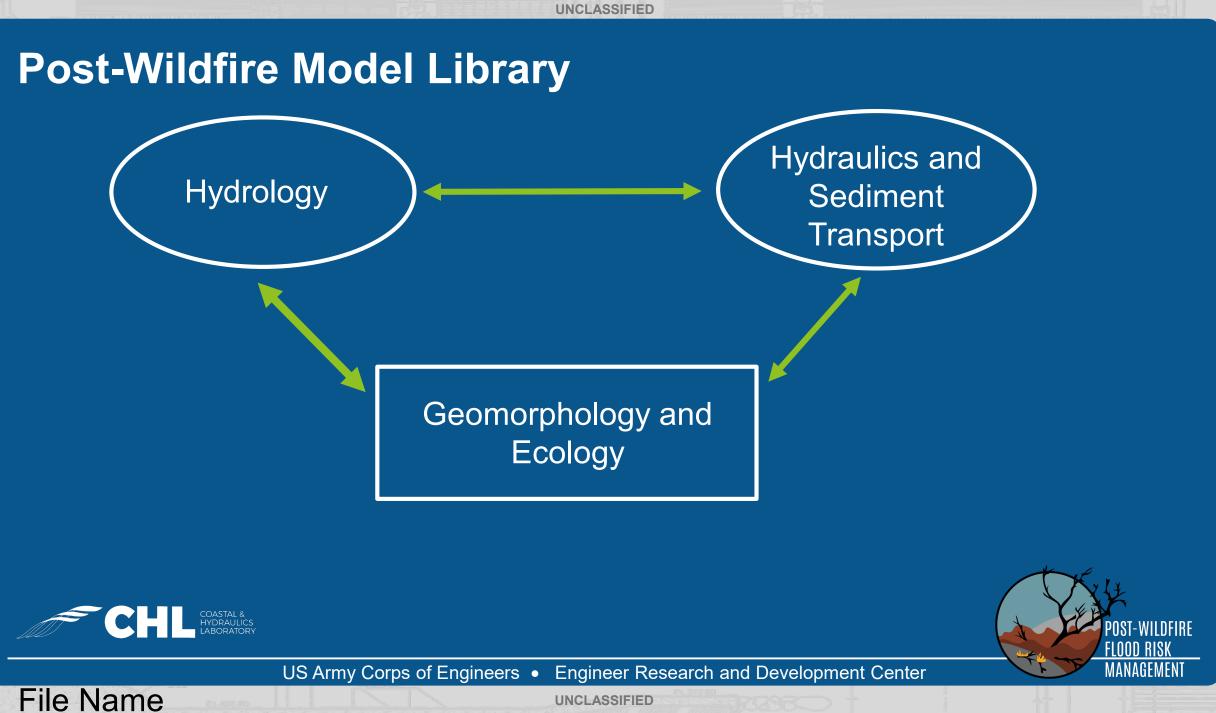
100,000 Downloads/Year in 200 countries

Newtonian Assumptions





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Post-Wildfire Model Library

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

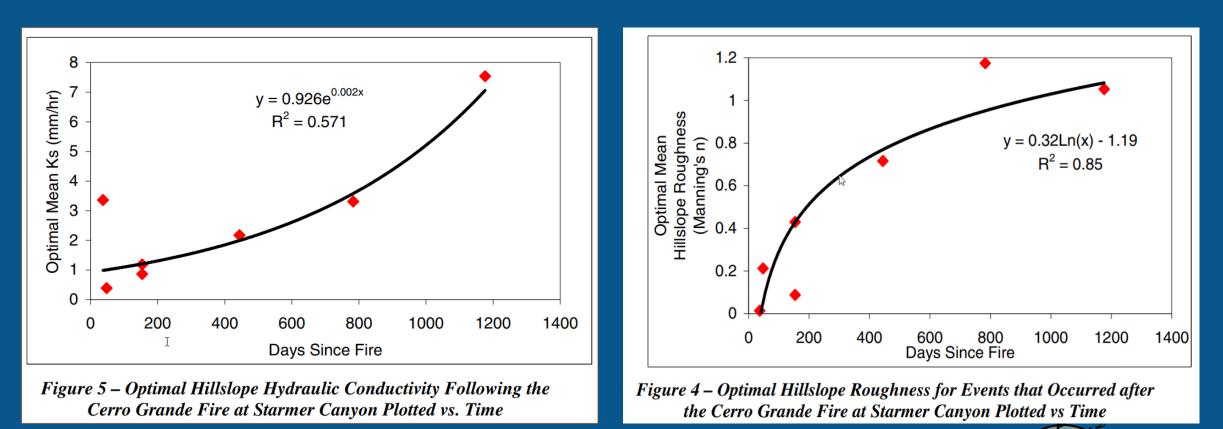




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Post-Wildfire Hydrology R&D – Wildfire Recovery



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)

File Name

POST-WILDFIRE FLOOD RISK MANAGEMENT

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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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File Name

Contact Information

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