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Utah Department of Transportation - Research Division
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Report No. UT-25.13

PROACTIVE PLANNING TOOL TO REDUCE WILDFIRE SEDIMENTATION RISKS

Prepared For:

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DISCLAIMER

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16. Abstract

The geospatial modeling framework includes Direct Geohazard Impact Tools, which estimate debris flow triggering rainfall intensities and sediment erosion along transportation corridors based on predicted wildfire burn severity scenarios, and Downstream Impact Tools, which assess sediment delivery from hillslope erosion and debris flows to river networks. The outputs from these analyses are structured for seamless integration with watershed-scale sediment transport models, such as the Network Sediment Transporter (NST), to further evaluate downstream infrastructure risks. To demonstrate the utility of this approach, it was applied to five high-risk transportation corridors across Utah. These case studies illustrate how proactive assessments can inform infrastructure planning by identifying locations most vulnerable to post-fire sedimentation impacts. The proactive planning framework outlined in this report provides transportation agencies with a scientifically robust and user-friendly method for mitigating future wildfire-induced sediment hazards, enhancing infrastructure resilience, and supporting data-driven decision-making.

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UNIT CONVERSION FACTORS

SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. (Adapted from FHWA report template, Revised March 2003)

LIST OF ACRONYMS

DEM	Digital Elevation Model
dNBR	Differenced Normalized Burn Ratio
RUSLE	Revised Universal Soil Loss Equation
SBS	Soil Burn Severity
UDOT	Utah Department of Transportation
AOI	Area of Interest
BAER	Burned Area Emergency Response
CBI	Composite Burn Index
DEM	Digital Elevation Model
EPA	Environmental Protection Agency
ERC	Energy Release Component
GIS	Geographic Information System
IM-WEST	Infrastructure Modified Watershed Erosion and Sediment Toolkit
IM-USUAL	Infrastructure Modified Utah State University Applied Watershed Toolkit
MTBS	Monitoring Trends in Burn Severity
NLCD	National Land Cover Database
NST	Network Sediment Transporter
PRISM	Parameter-Elevation Regressions on Independent Slopes Model (Climate Group)
RUSLE	Revised Universal Soil Loss Equation
SBS	Soil Burn Severity
SR	State Route
STATSGO	State Soil Geographic Database
UDOT	Utah Department of Transportation
USDA	United States Department of Agriculture
USGS	United States Geological Survey

EXECUTIVE SUMMARY

Wildfires are increasing in frequency and severity across the western United States, posing significant risks to transportation infrastructure due to post-wildfire erosion and sedimentation hazards. Increased runoff from burned landscapes can trigger debris flows, accelerate hillslope erosion, and transport large volumes of sediment. These hazards threaten roads, bridges, and culverts, necessitating both rapid post-fire assessments and long-term proactive planning to mitigate risks. To address these challenges, the UDOT Post-Wildfire Geohazard Assessment Toolkit was designed to evaluate post-fire sediment hazards. While originally developed for emergency response applications, the toolkit also supports proactive planning, allowing transportation agencies to assess potential sediment hazards before wildfires occur.

This report focuses on the application of the toolkit for proactive planning assessments, enabling transportation planners to anticipate geohazards in advance and implement risk mitigation strategies. The toolkit integrates machine learning-based burn severity modeling with geospatial post-fire sediment hazard assessments to estimate erosion potential and sediment delivery to river networks. It consists of two primary components:

- Direct Geohazard Impact Tools, which estimate debris flow initiation and sediment erosion along transportation corridors based on predicted wildfire burn severity scenarios.
- Downstream Impact Tools, which assess sediment delivery from debris flows and hillslope erosion to river networks, allowing for integration with external sediment transport models (e.g., NST) to evaluate downstream infrastructure risks.

The toolkit utilizes a combination of precompiled geospatial datasets and machine learning-derived burn severity projections to automate the assessment process. Key inputs include topography, precipitation intensity, annual precipitation, land cover, soil properties, and predictive burn severity data. The workflow is designed for intuitive use within ArcGIS, enabling rapid dataset extraction and automated post-wildfire hazard computations under different fire severity scenarios.

To demonstrate the toolkit's capabilities, we applied it to five transportation corridors in Utah, assessing wildfire sedimentation risks under various burn severity scenarios:

- SR 39 (Ogden to Pineview, UT)
- I-80 (Salt Lake City to Park City, UT)
- SR 14 (Cedar Canyon, UT)
- US 89 (Logan Canyon, UT)
- I-84 (Weber Canyon, UT)

Results from these case studies highlight the effectiveness of the toolkit in identifying high-risk locations where sediment deposition could impact transportation infrastructure. By simulating multiple wildfire scenarios, the toolkit provides planners with actionable insights for implementing strategic mitigation measures.

1.0 INTRODUCTION

1.1 Problem Statement

Wildfire frequency and severity have increased dramatically over the past four decades in the western United States (Murphy et al., 2018), with projected climate warming expected to further intensify fire activity (Abatzoglou & Williams, 2016). Following a wildfire, burned hillslopes experience substantial hydrologic changes leading to increased rainfall runoff and erosion (DeLong et al., 2018; Mcguire et al., 2024; Murphy et al., 2019a). These post-wildfire erosion and sedimentation risks pose potential threats to transportation infrastructure (Fraser et al., 2022).

Post-fire sediment hazards impact roads, bridges, and culverts through direct deposition of sediment and debris as well as downstream sediment pulses that overwhelm hydraulic structures. These hazards can lead to costly damage, prolonged road closures, and increased maintenance demands. Currently, transportation agencies primarily assess these risks after a fire has occurred, limiting their ability to implement effective mitigation strategies in advance. While emergency response efforts are essential, a more proactive approach is needed to identify at-risk transportation corridors before wildfires occur, allowing for targeted interventions that reduce long-term infrastructure damage.

To address this challenge, this report integrates predictive wildfire severity modeling with post-fire sediment hazard assessment tools. We leveraged machine learning-based burn severity predictions (Klimas et al., 2025) to estimate potential wildfire impacts under different fire severity scenarios. These predictions are incorporated into a geospatial modeling framework that evaluates post-wildfire erosion and sedimentation risks to transportation infrastructure, allowing transportation agencies to prioritize mitigation strategies for vulnerable locations. Additionally, we demonstrate the application of this framework for predicting post-wildfire hazards at five locations in Utah.

1.2 Objectives

The primary objective of this study is to develop a predictive geospatial modeling framework that allows transportation planners to assess post-wildfire sedimentation risks before a fire occurs. The key goals of this study include:

1. Develop and implement a machine learning-based model to predict burn severity in areas that have not recently burned.
2. Integrate predicted burn severity with a geospatial post-fire geohazards model to estimate erosion and sediment delivery risks at high priority transportation infrastructure locations.
3. Provide transportation agencies with a decision-support tool that enables targeted mitigation efforts to reduce infrastructure vulnerability to post-fire sedimentation hazards.

By incorporating machine learning techniques, the best available geospatial and weather data, and sophisticated mathematical modeling algorithms within a simple user interface, this approach allows planners to evaluate different wildfire scenarios and identify high-risk locations where preemptive infrastructure modifications or mitigation measures can be implemented.

A secondary objective of this report is to demonstrate the application of the toolkit through five proactive planning case studies in Utah:

1. State Route 39 (Ogden to Pineview)
2. Interstate 80 (Salt Lake City to Park City)
3. State Route 14 (Cedar Canyon)
4. U.S. Route 89 (Logan Canyon)
5. Interstate 84 (Weber Canyon)

1.3 Scope

This research develops a predictive modeling approach for proactive wildfire sedimentation risk assessment. The toolkit integrates machine learning-based burn severity predictions with a geospatial sediment transport model to estimate post-fire erosion and sediment delivery before fires occur. The study consists of two primary components:

Predictive Burn Severity Model – A machine learning model that predicts burn severity under hypothetical wildfire scenarios based on climate, vegetation, topography, and historical fire data (Klimas et al., 2025). This model provides key inputs for post-fire sedimentation risk assessments.

Geospatial Modeling Framework – A sediment transport model that uses predicted burn severity, topography, land cover, and hydrologic parameters to estimate erosion and sediment delivery to river networks. This framework builds upon the previously developed UDOT Post-Wildfire Geohazard Assessment Toolkit, modifying it for proactive planning applications.

The toolkit is designed for transportation agencies and land managers to assess infrastructure vulnerabilities and prioritize mitigation strategies. The outputs from this model can inform decision-making by identifying locations where road or culvert modifications, sediment detention structures, or vegetation management strategies can reduce future post-fire hazards.

2.0 RESEARCH METHODS

2.1 Overview

This chapter presents the methodologies used to assess post-wildfire geohazards in transportation corridors before a fire occurs. The research integrates predictive wildfire severity modeling with a geospatial framework for estimating sediment hazards and their downstream impacts on infrastructure.

Section 2.2 details the Predictive Soil Burn Severity Model, which uses a machine learning approach to forecast wildfire burn severity. The model outputs continuous differenced Normalized Burn Ratio (dNBR) and classified burn severity maps, which serve as inputs for sediment hazard assessments.

Section 2.3 introduces the UDOT Post-Wildfire Geohazard Assessment Toolkit, a geospatial modeling framework for estimating post-fire sediment hazards. This framework consists of two core components:

- Direct Geohazard Impacts (Section 2.3.1) – Estimates the probability and magnitude of debris flow erosion along transportation corridors based on predicted burn severity scenarios.
- Downstream Impacts (Section 2.3.2) – Evaluates how post-wildfire sediment from debris flows and hillslope erosion is delivered to river networks allowing users to assess risks to bridges and culverts.

Together, these methods allow for proactive identification of high-risk areas, enabling transportation planners to implement mitigation measures before wildfires occur.

2.2 Predictive Wildfire Severity Modeling

Wildfire burn severity is a critical factor influencing post-fire hydrology and sedimentation processes. To assess post-fire geohazards before a fire occurs, it is essential to estimate how severely the landscape will burn. To address this challenge, we developed a machine learning model, using Random Forest, to predict continuous differenced Normalized Burn Ratio (dNBR) under hypothetical wildfire scenarios. By forecasting burn severity, this model enables transportation planners to proactively identify areas at risk of post-fire sedimentation impacts.

The model was trained using supervised machine learning techniques on historical wildfire data, incorporating key environmental predictors such as climate, vegetation, topography, and soil properties (Klimas et al., 2025). The model was initially developed with a comprehensive set of predictor variables, which were refined through feature selection to optimize accuracy. For a full list of variables and additional result analysis, see Klimas et al. (2025). The final model incorporates topographic variables (e.g., elevation, slope, aspect, and terrain ruggedness), vegetation and fuel load data (e.g., land cover type, vegetation density, and biomass), climatic conditions (e.g., historical temperature, precipitation, and energy release component (ERC) values), and soil properties (e.g., soil texture, moisture content, and organic matter). The model was trained and validated on 203 historical wildfires, using differenced Normalized Burn Ratio (dNBR) as the response variable. It achieved an out-of-bag R^2 of 67.1% and an overall classification accuracy of 85% when dNBR values were grouped into three severity classes: unburned/low, moderate, and high (Figure 1).

For pre-fire applications, predicted dNBR values classified into burn severity categories using the Burned Area Reflectance Classification 4 (BARC 4) scheme (Figure 2). Following established protocols (Eidenshink et al., 2007), dNBR thresholds were calibrated using Composite Burn Index (CBI) field plots, applying the severity class thresholds proposed by Miller & Thode (2007). The resulting classification bins were: Unburned (−145 to 124), Low Severity (125 to 283), Moderate Severity (284 to 424), and High Severity (>425). Pixels with dNBR < −145 were classified as increased greenness and excluded from the accuracy assessment.

Given this report focuses on a pre-fire assessment, the classified outputs represent predicted burn severity rather than field-validated Soil Burn Severity (SBS). In the absence of post-fire field data, we use BARC 4 as a proxy for SBS, while acknowledging that the two products can differ significantly in some cases.

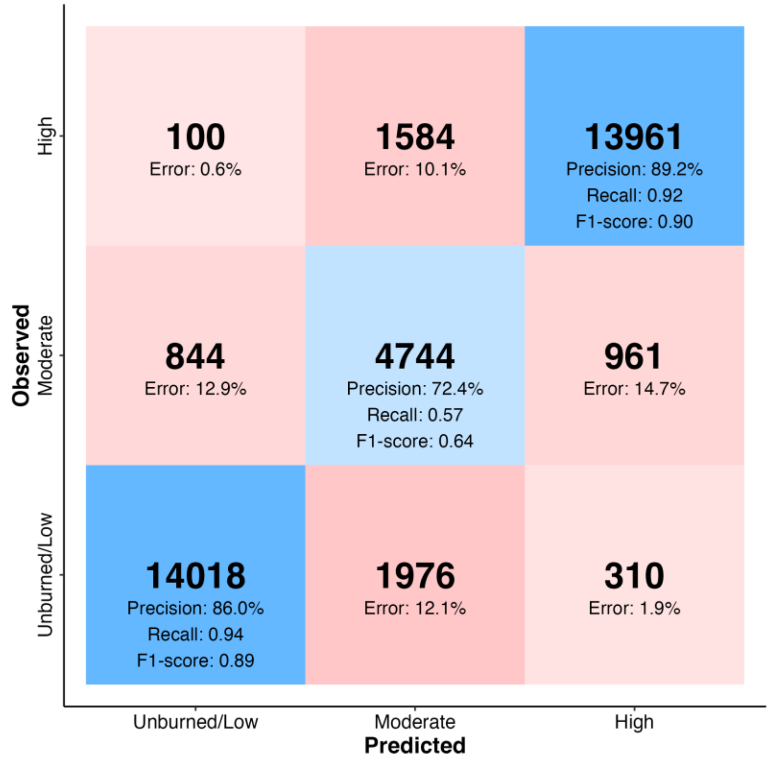

Figure 1. Three-class confusion matrix comparing observed vs. predicted classified dNBR values (Klimas et al., 2025). The matrix displays classification accuracy, error rates, precision, recall, and F1-scores for unburned and low, moderate, and high severity classes, with an overall accuracy of 85%.

To facilitate scenario-based planning, the model integrates ERC values sampled at the 5th, 50th, and 95th percentiles (Figure 2), creating a low, moderate, and high burn severity scenario outputs. The final model outputs are spatially explicit dNBR and SBS maps for forested regions of Utah (Klimas et al., 2025), which can be directly integrated into geospatial tools to assess post-fire sedimentation risks before a fire occurs.

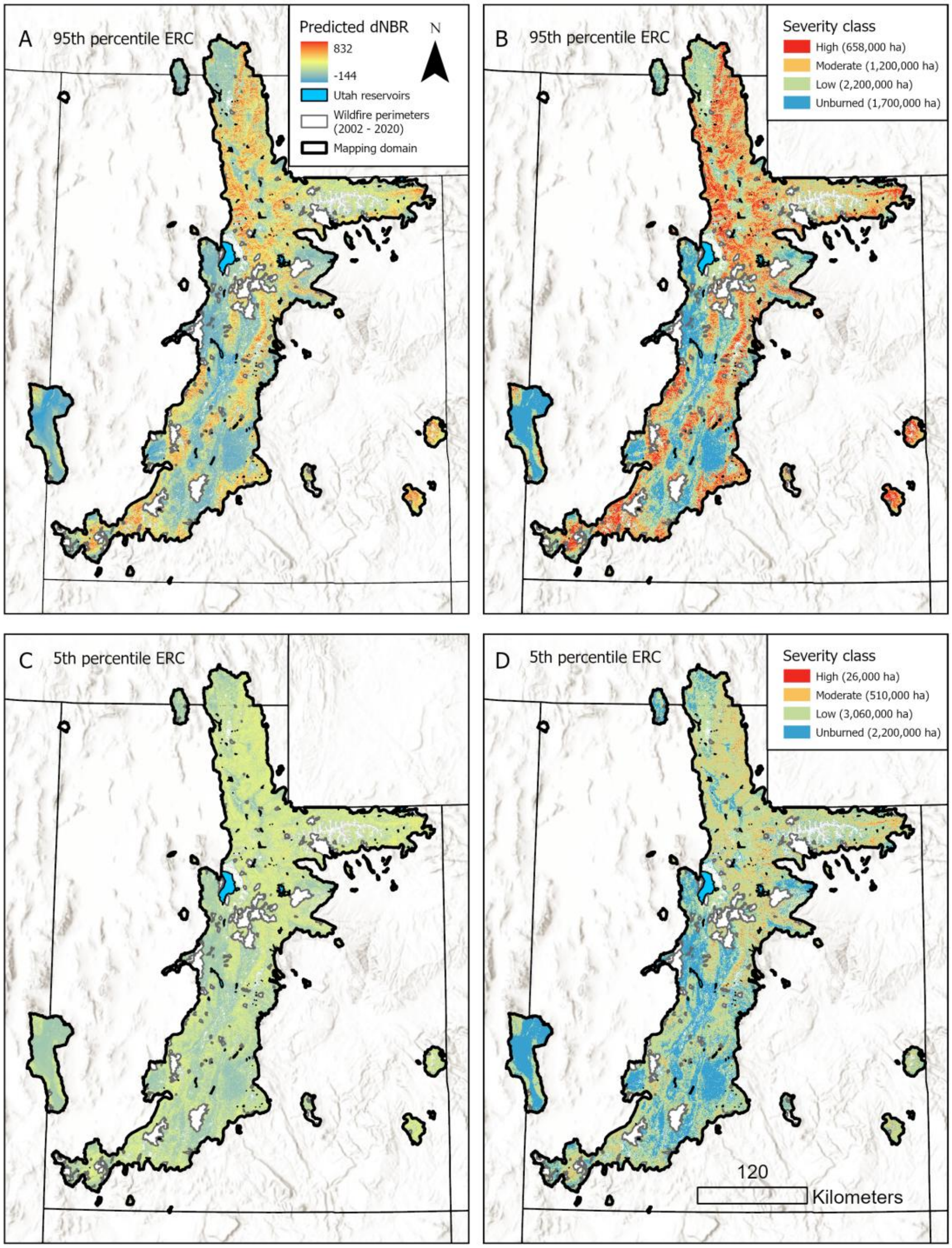

Figure 2: Predicted dNBR and SBS maps for Utah under two fire weather scenarios (Klimas et al., 2025). Panels A and C show continuous dNBR predictions at the 95th and 5th percentile Energy Release Component (ERC), respectively. Panels B and D classify dNBR into burn severity categories. Areas without dNBR or SBS predictions represent non-burnable land cover types or regions excluded from model training.

Post-wildfire dNBR and SBS are a critical factor influencing post-fire hydrologic and sedimentation responses. The Predictive Soil Burn Severity Model employs a random forest analysis to forecast burn severity under hypothetical wildfire scenarios. This model is designed to estimate the intensity of soil burn severity before a fire occurs, providing transportation planners with the ability to anticipate post-fire sedimentation hazards in high-risk areas.

2.3 Geospatial Tools for Modeling Post-Wildfire Geohazards

The UDOT Post-Wildfire Geohazard Assessment Toolkit is a geospatial modeling framework designed to evaluate sediment hazards following wildfires. Built on the ESRI ArcGIS platform, the toolkit enables transportation planners to assess post-fire erosion risks and sediment delivery to river networks. The tools in this framework can be applied in two ways:

1. Emergency Response Assessments, which evaluate hazards immediately following a fire to inform rapid response efforts.

2. Proactive Planning Assessments, which identify areas of potential sediment hazards before wildfires occur, allowing for targeted mitigation strategies.

This report focuses on the proactive planning application of the toolkit. A detailed description of the geospatial modeling methods is provided in UDOT Report UT-25.14. The following sections briefly summarize the toolkit’s two core components.

2.3.1 Direct Geohazard Impacts

The Direct Geohazard Impact tools estimate the probability and eroded volumes of post-fire debris flow hazards along transportation corridors. These tools use a probabilistic model (Staley et al., 2017) to determine the 15-minute rainfall intensity threshold required to generate a user-defined probability of debris flow initiation and empirical volume equations (Gartner et al., 2014) to estimate the volume of sediment mobilized by debris flows. For proactive planning applications, these models are run using predicted burn severity scenarios rather than satellite-derived burn severity estimates from actual wildfires. This allows transportation planners to anticipate where debris flows could directly impact roads, bridges, and culverts before a fire occurs.

2.3.2 Downstream Impacts

The Downstream Impact tools estimate how much post-wildfire debris flow and hillslope erosion sediment is transported into, and downstream through, river networks potentially affecting bridges and culverts. These tools help assess the cascading effects of sediment delivery beyond the immediate burn area to downstream transportation infrastructure. The Downstream Impacts analysis is performed using two primary toolkits, Infra-USUAL Watershed Tools and Infra-WEST.

The Infra-USUAL Watershed Tools perform landscape-scale watershed delineations, terrain characterization, and river network attribution to prepare data for sediment transport modeling. This toolkit is an expanded version of the Utah State University AppLied Watershed (USUAL) tools (David et al., 2023), modified to incorporate infrastructure elements and enable users to directly run the same calculations as the USGS StreamStats tool within the geospatial framework.

The Infra-WEST geospatial toolkit extends this analysis by estimating the probability of debris flow occurrence (Staley et al., 2017), as well as predicting eroded sediment volumes from both debris flows (Gartner et al., 2014) and hillslope erosion (Gannon et al., 2019), and their subsequent delivery to river networks (Gannon et al., 2019; Murphy et al., 2019b). By integrating debris flow and hillslope erosion models, Infra-WEST predicts how sediment is delivered to river systems after a wildfire. The outputs from these toolkits are structured for direct integration into 1-D sediment transport models (e.g., the Network Sediment Transport model, NST), enabling further assessment of downstream sediment impacts to infrastructure.

3.0 Model Inputs and Parameterization

3.1 Overview

This section outlines the data sources and model inputs required for proactive post-wildfire geohazard assessments. The Batch Extract Tool automates the retrieval of core datasets, including topography, precipitation, land cover, and soil properties. Additional manually generated inputs such as valley bottom delineations and transportation infrastructure-river intersections are needed to further refine downstream impact assessments. Predictive wildfire burn severity datasets, generated using machine learning-based modeling (Klimas et al., 2025), provide pre-fire burn severity estimates for erosion and sediment delivery calculations. Additionally, this section provides a brief overview of the Network Sediment Transporter (NST) model, which integrates these inputs to simulate sediment transport through river networks. For full methodology and parameterization details, readers are referred to the emergency response report (UT-25.14).

3.2 Data for Post-Wildfire Geohazard Assessment Toolkit Simulations

3.2.1 Automated Input Extraction

Inputs for the Post-Wildfire Geohazard Assessment Toolkit were primarily generated using the Batch Extract Tool, which extracts precompiled geospatial datasets for Utah. Running this tool automatically retrieves all the necessary inputs for an area of interest (AOI) specified by the user. AOI shapefiles can be created in ArcGIS Pro using a polygon that fully encompasses the desired study area, ensuring it has a set projection that will be used to project all data extracted.

The Batch Extract Tool automatically extracts the datasets listed in Table 1, including topography, land cover, precipitation data, soil properties, and burn severity estimates for the state of Utah.

3.2.2 Manually Generated Inputs

For the Downstream Impacts assessment, three additional inputs must be provided beyond those generated by the Batch Extract Tool: 1) Transportation-River Intersection Points, 2) Valley Bottom Delineations, and 3) River Centerline. The transportation infrastructure-river intersection points were manually mapped using aerial imagery in ArcGIS Pro. While an automated approach using the Intersect tool could extract these points, manual mapping ensures greater precision, as flow accumulation-based river delineations do not always align perfectly with transportation datasets. The valley bottom delineations and river centerlines were generated using the Fluvial Corridor Toolbox (Roux et al., 2015).

For the Direct Impacts assessment, all required inputs are automatically extracted by the Batch Extract Tool. However, if users wish to analyze a specific transportation corridor, they may need to filter out extraneous roads from the Primary Roads dataset to focus on relevant infrastructure.

Table 1. List of all datasets that were automatically extracted using the Batch Extract Tool

Dataset Name	Description	Source
Annual Precipitation	Statewide annual precipitation raster	PRISM Climate Group
Landcover	Land cover classification dataset	National Land Cover Database
15-minute precipitation Intensity	15-minute precipitation intensity rasters for multiple return periods	NOAA Atlas 14
Pre-Fire dNBR	Predicted differenced Normalized Burn Ratio (dNBR) dataset	Klimas et al., 2025
Pre-Fire SBS	Predicted Soil Burn Severity (SBS) dataset	Klimas et al., 2025
Primary Roads	Major road network data	TIGER (Census Bureau)
STATSGO Soil Data	Soil properties including erodibility, percent sand, thickness, and bulk density	STATSGO
DEM	Digital Elevation Model (DEM)	USGS

3.3 Network Sediment Transporter Model Parameterization

The Network Sediment Transporter (NST) is a Lagrangian-based sediment transport model that simulates sediment movement through river networks at daily timesteps (Czuba, 2018). NST tracks sediment as discrete parcels, applying a mixed grain-size transport function (Wilcock and Crowe, 2003) to model grain-size-dependent transport capacity. The model operates under unsteady flow conditions, dynamically updating bed elevation to simulate aggradation and erosion processes. However, it assumes static channel width and does not simulate lateral channel migration or floodplain connectivity. NST has been applied in post-wildfire sediment routing studies (Murphy et al., 2019) and provides a framework for watershed-scale sediment transport modeling.

NST requires post-wildfire sediment delivery information derived for the Infra-WEST toolkit, and post-wildfire hydrology to drive sediment transport simulations. Hydrologic inputs are derived from historical streamflow data, selecting representative low, and high flow conditions, which are then scaled based on watershed burn severity. To avoid overestimating sediment transport, flows exceeding bankfull discharge (~2-year recurrence interval) are thresholded, as NST does not model overbank flooding. The full methodology, including further details on input parameterization and assumptions, is provided in the emergency response report (UT-25.14).

4.0 Model Results

4.1 Overview

This section demonstrates how the geospatial toolkit can be applied proactively to evaluate potential sedimentation hazards prior to a wildfire, using hypothetical fire scenarios. To assess the range of possible post-fire conditions, we simulated two bookended scenarios representing low and high soil burn severity across the entire watershed. For each scenario, geospatial hazard models were run with two different rainfall events: a 2-year storm for the low hazard scenario and a 25-year storm for the high hazard scenario. These rainfall events represent typical and extreme post-fire precipitation conditions, respectively.

For all geospatial simulations, we set the probability threshold for debris flow occurrence to 50%, meaning any sub-catchment with a debris flow probability of 50% or greater was assumed to generate a debris flow. This threshold was also applied in the Direct Impact tools to determine the required triggering rainfall intensity. Post-Fire RUSLE-based erosion simulations were conducted for all sub-catchments and interfluves using an annual rainfall raster to assess post-fire erosion and sediment delivery. The high and low soil burn severity rasters were used to simulate erosion under each scenario.

NST sediment routing simulations incorporated scenario-specific grain size distributions and hydrologic conditions. The low hazard scenario used a coarser grain size distribution and a low-flow year, while the high scenario used a finer grain size distribution and a high-flow year. Together, these proactive simulations provide a framework for understanding potential risks and identifying vulnerable infrastructure prior to wildfire events.

4.2 State Route 39 (Ogden to Pineview)

4.2.1 Model Setup

We modeled post-fire sedimentation hazards along State Route 39 in the Ogden River corridor between Pineview Reservoir and Ogden Canyon (Figure 3). Two pour points were specified to delineate upstream and downstream contributing areas, one at the outlet of Pineview

Reservoir and one near the mouth of Ogden Canyon. Infrastructure crossings along SR 39 were manually delineated for sediment routing analysis. For the Direct Impacts analysis, sub-catchments were delineated directly from SR 39 along the corridor (Figures 3 and 4).

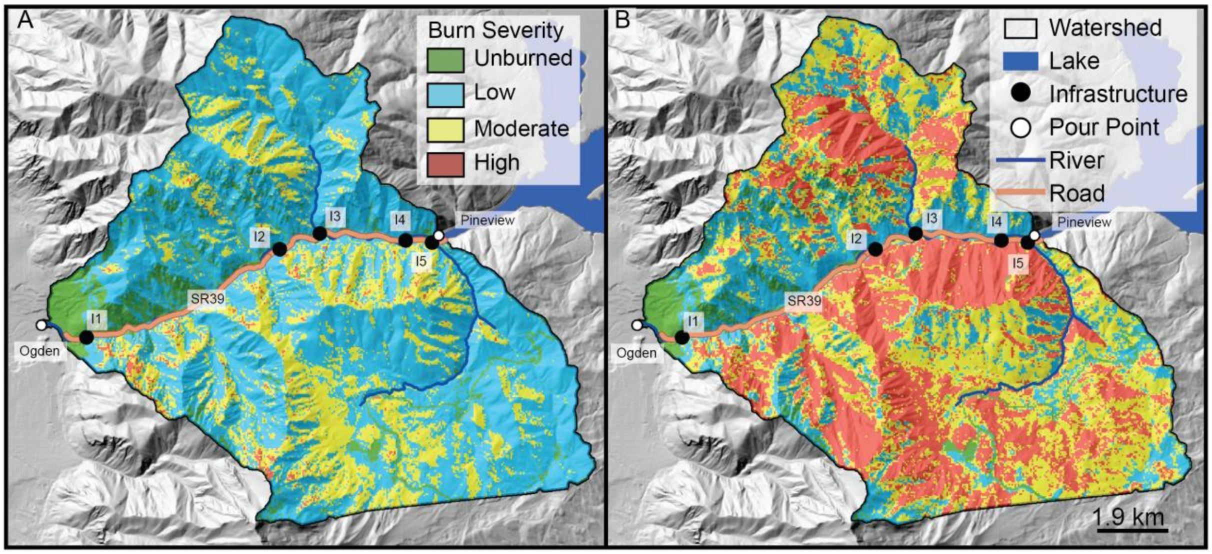

Figure 3. Study area for the State Route 39 site showing watershed extent, transportation corridor, lakes/reservoirs, pour points and infrastructure locations, delineated river network, and low (A) and high (B) soil burn severity input rasters used in the geospatial hazard models.

4.2.2 Direct Impacts Results

The Direct Impacts tools were used to assess debris flow hazards from sub-catchments draining directly to SR 39. Figure 4 summarizes two key model outputs under both low and high soil burn severity scenarios: the 15-minute rainfall intensity required to trigger a debris flow with 50% probability (Figures 4A–B), and the estimated debris flow sediment volume if triggered (Figures 4C–D).

Under the low severity scenario, most sub-catchments require rainfall intensities of 30–40 mm/hr to exceed the 50% debris flow probability threshold, with fewer areas triggering below that range. In contrast, the high severity scenario shows increased susceptibility, with several sub-catchments predicted to trigger at intensities as low as 20–30 mm/hr.

Predicted debris flow volumes range from 5,000 to 50,000 m³ in both scenarios, with greater spatial extent and frequency of higher-volume sub-catchments under the high severity condition. These results highlight the increased risk to SR 39 under severe post-fire conditions, where lower rainfall thresholds and larger sediment yields could pose greater hazards to road infrastructure.

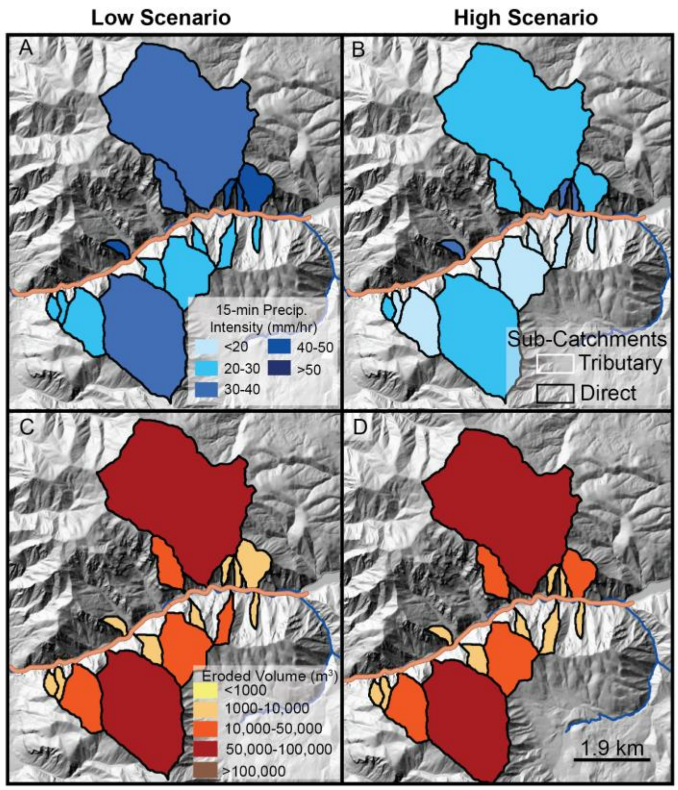

Figure 4. Results of the Direct Impacts analysis for SR 39. Panels A and C show results for the low severity scenario, while panels B and D show results for the high severity scenario. Panels A and B display the rainfall intensity (mm/hr) required to trigger debris flows at 50% probability. Panels C and D show the estimated debris flow sediment volumes (m³).

4.2.3 Downstream Impacts

Infra-USUAL identified 50 sub-catchments contributing to SR 39, all of which were assumed to burn in both scenarios. Under the low fire severity scenario, 30 sub-catchments

(60%) were predicted to generate debris flows with a probability of 50% or greater, increasing to all 50 sub-catchments (100%) under the high severity scenario (Figure 5A–B). Total estimated debris flow sediment erosion increased from approximately 547,594 m^3 under the low scenario to over 3.1 million m^3 under the high scenario, with 116,944 m^3 and 1.34 million m^3 delivered to the channel network, respectively (Figure 5C–F).

RUSLE-based hillslope erosion in the first post-fire year was estimated at 513,529 m^3 under the low severity scenario and 581,561 m^3 under the high scenario (Figure 6A). Sediment delivery to the river network during the first year was 21,170 m^3 (low) and 23,636 m^3 (high), with an additional 123,801 m^3 and 127,152 m^3 delivered over the remaining 9 years, respectively (Figure 6B).

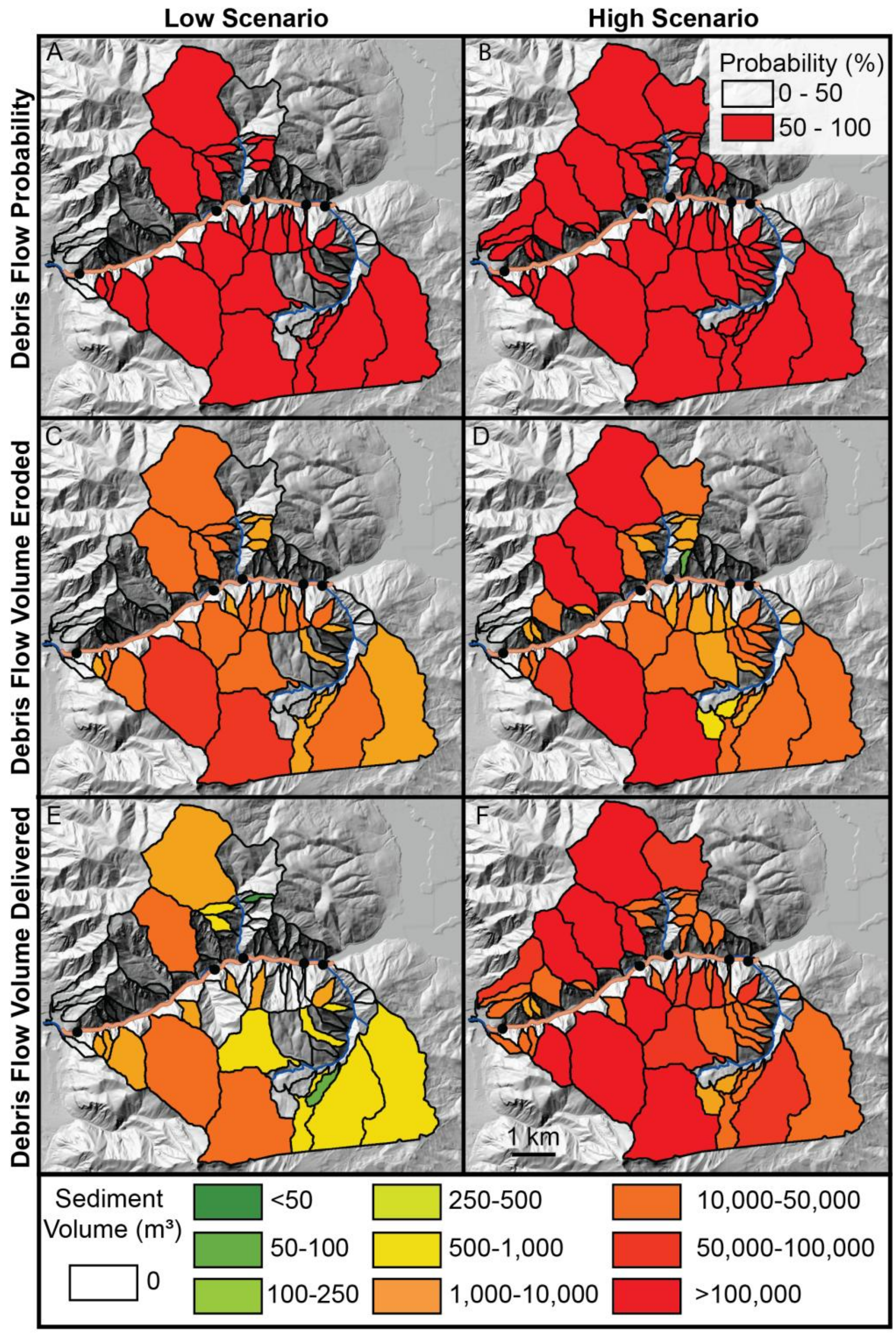

Figure 5. Debris flow hazard estimates for SR 39 under low (left) and high (right) post-fire severity scenarios. Panels A and B show the 15-minute rainfall intensity (mm/hr) required to trigger debris flows with at least 50% probability. Panels C and D show the estimated debris flow sediment volumes (m^3) eroded in each sub-catchment under each scenario.

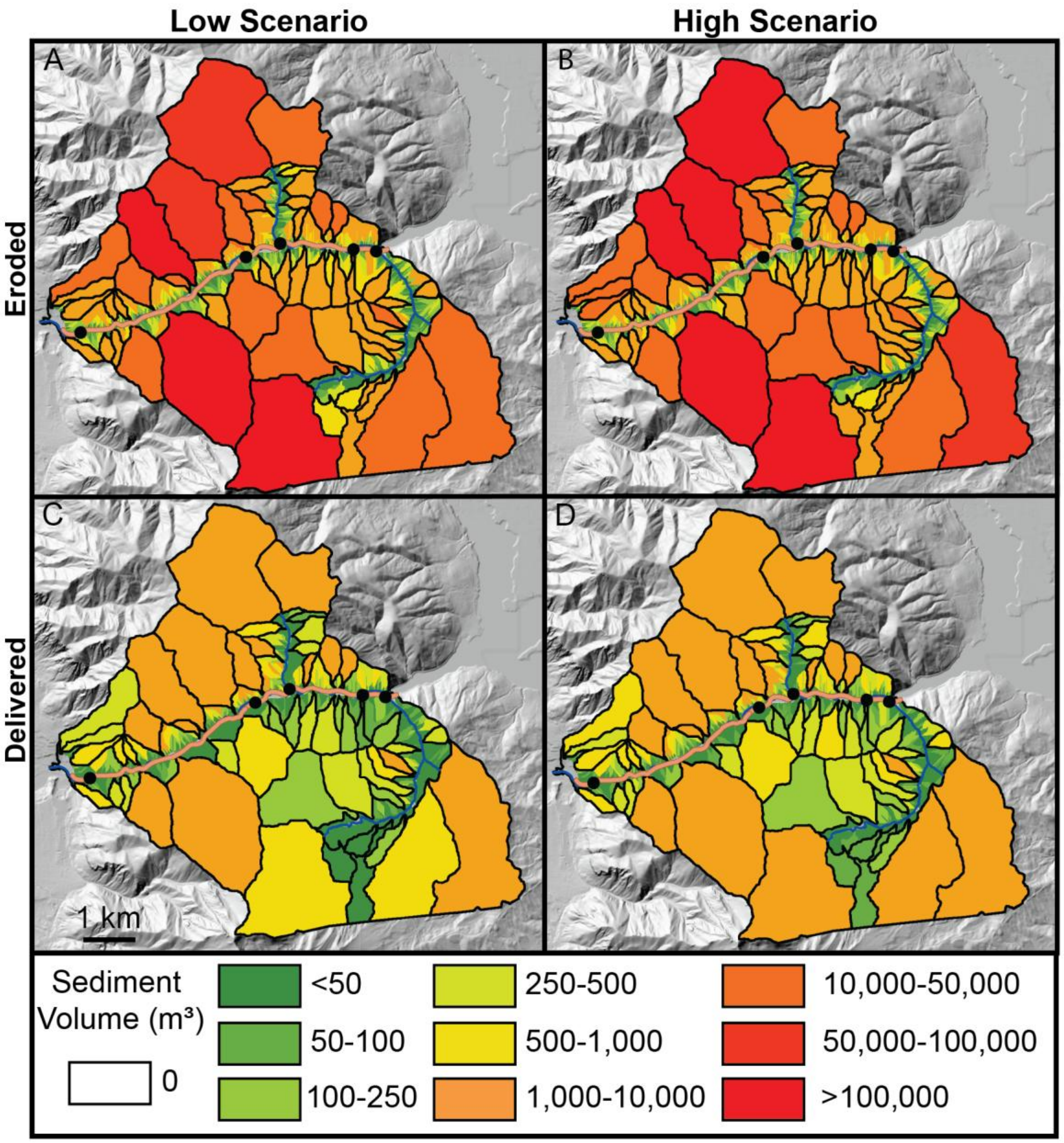

Figure 6. RUSLE-based hillslope erosion results for SR 39. Panels A and B show estimated erosion volumes (m³) in the first post-fire year under the low and high severity scenarios, respectively. Panels C and D show sediment delivery (m³) to the river network for the same time period and scenarios.

Modeled cumulative sediment flux to infrastructure crossings along SR 39 (Figure 7) indicates that sediment delivery was strongly front-loaded, especially under the high scenario. Crossings I1, I2, and I3 received the largest sediment volumes, with delivery exceeding 400,000 m³ in the high scenario. Crossings I4 and I5, which have smaller contributing drainage areas, exhibited much lower total flux. Under the high scenario, sediment delivery remained elevated for approximately three years before tapering off, while in the low scenario, most sediment arrived within the first post-fire year.

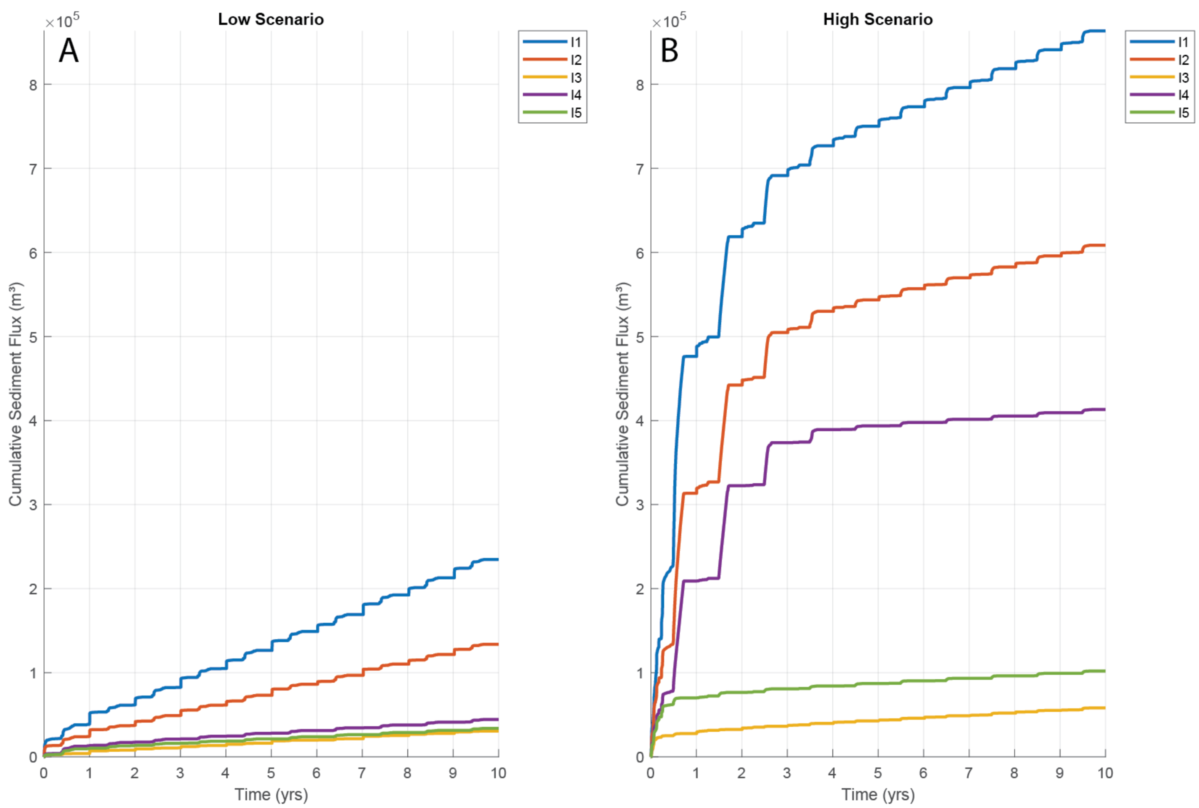

Figure 7. Modeled cumulative sediment flux to infrastructure crossings along SR 39. Panels show low (A) and high (B) scenarios. Locations I1–I5 are shown in Figure 3.

4.3 Interstate 80 (Salt Lake City to Park City)

4.3.1 Model Setup

We modeled post-fire sedimentation hazards along Interstate 80 (I-80), spanning three watersheds between Salt Lake City and Park City (Figure 8). Four pour points were specified to delineate contributing areas: one near Salt Lake City, one at the outlet of Mountain Dell Reservoir, one upstream of Little Dell Reservoir, and one in East Canyon Creek downstream of I-80. This nested basin setup allowed us to isolate contributions from each watershed while excluding areas above Little Dell Reservoir (which I-80 does not cross) and preventing sediment from being routed beyond Mountain Dell Reservoir, as both reservoirs function as sediment traps. Infrastructure crossings along I-80 were manually delineated for sediment routing analysis. For the Direct Impacts analysis, sub-catchments were delineated directly from I-80 along the corridor adjacent to the modeled watersheds (Figures 8 and 9).

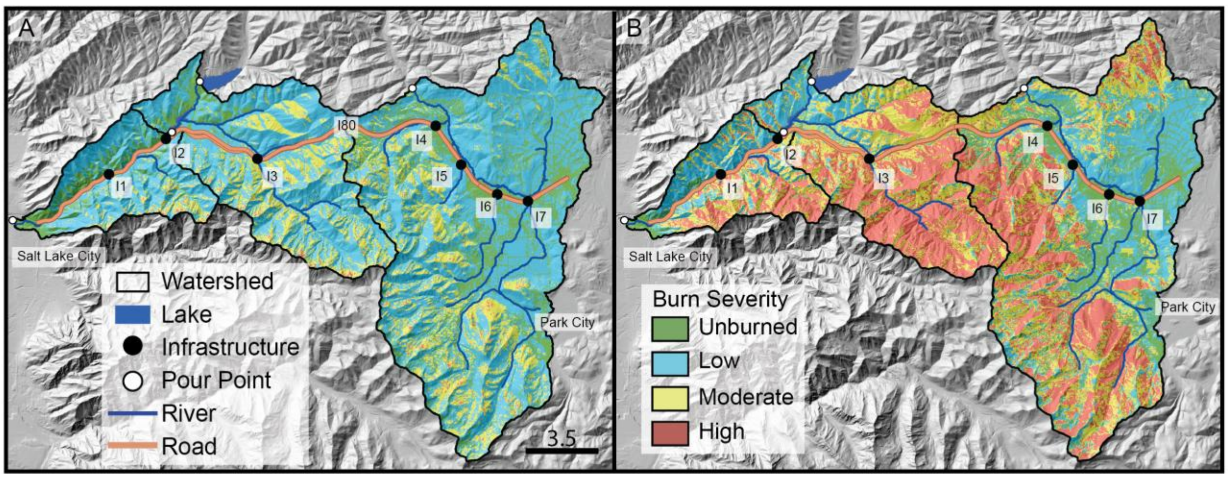

Figure 8. Study area for the Interstate 80 site showing watershed boundaries, transportation corridor, pour points, reservoirs, delineated river network, infrastructure locations, and low (A) and high (B) soil burn severity scenarios within the modeled fire extent.

4.3.2 Direct Impacts Results

The Direct Impacts tools were used to evaluate debris flow hazards from sub-catchments draining directly to the I-80 corridor. Figure 9 presents two key model outputs under low (Panels A and C) and high (Panels B and D) severity fire scenarios: the 15-minute rainfall intensity required to trigger a debris flow at 50% probability, and the estimated sediment volume generated if triggered.

In the low severity scenario, one sub-catchment in the central portion of the Mountain Dell watershed stands out, with a triggering intensity of 20–30 mm/hr and an estimated debris flow volume between 10,000–50,000 m³. This makes it a notable outlier compared to other direct sub-catchments, which generally require 30–40 mm/hr or higher to initiate debris flows. Under the high severity scenario, more sub-catchments in the southwestern portion of the corridor become susceptible, with triggering intensities dropping into the 20–30 mm/hr range and volumes remaining elevated, further increasing the potential risk to infrastructure.

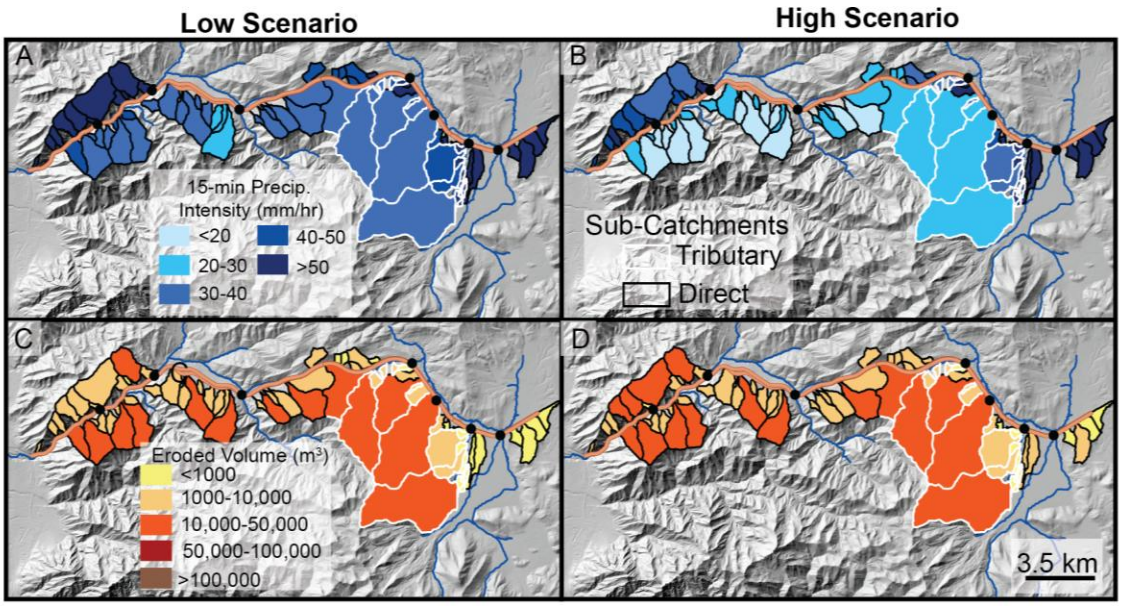

Figure 9. Results of the Direct Impacts analysis for I-80. Panels A and C show the low severity fire scenario; Panels B and D show the high severity scenario. Panels A and B display the 15-minute rainfall intensity (mm/hr) required to trigger debris flows at 50% probability. Panels C and D show the estimated debris flow sediment volumes (m^3) generated if triggered.

4.3.3 Downstream Impacts

Infra-USUAL identified 207 sub-catchments within the modeled I-80 watersheds, all of which were assumed to have burned under both high and low severity scenarios. Under the low severity scenario, 47 sub-catchments (22.7%) were predicted to exceed a 50% probability of generating a debris flow, increasing to 206 sub-catchments (99.5%) under the high severity scenario (Figure 10A–B). Estimated debris flow sediment volumes totaled 478,816 m^3 eroded and 50,929 m^3 delivered to the river network in the low scenario, increasing to 4,792,348 m^3 eroded and 818,994 m^3 delivered in the high scenario (Figure 10C–F).

RUSLE-based hillslope erosion in the first post-fire year was estimated at 711,416 m^3 under the low severity scenario (Figure 11A), with 45,425 m^3 delivered to the river network (Figure 11C). For the high severity scenario, year-1 hillslope erosion increased to 984,128 m^3 (Figure 11B), with 61,009 m^3 delivered (Figure 11D). An additional 259,681 m^3 (low scenario) and 278,343 m^3 (high scenario) were delivered over years 2 through 10.

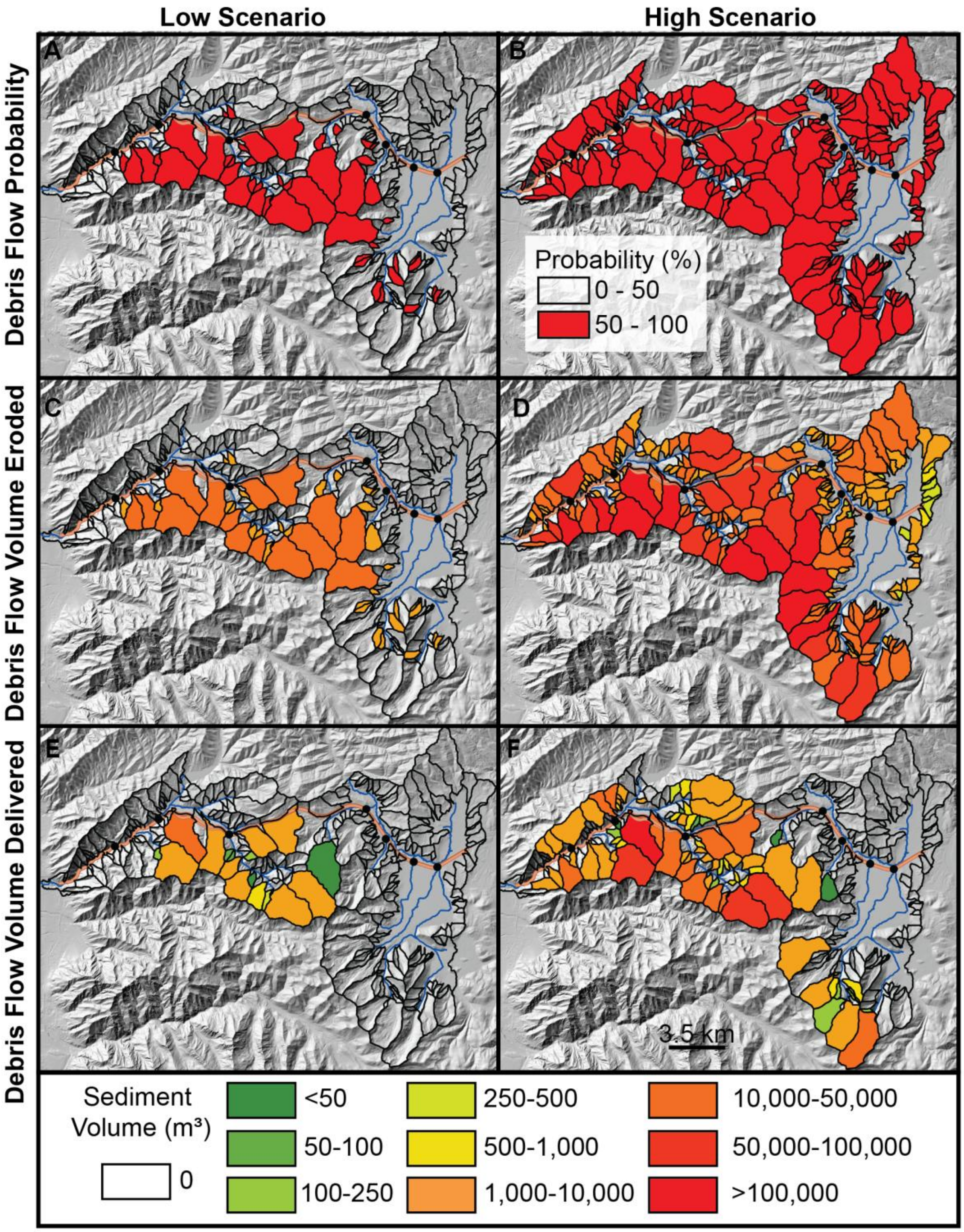

Figure 10. Debris flow hazard estimates for the I-80 site. Panels A, C, and E show results for the low scenario; panels B, D, and F show results for the high scenario. Panels A and B display debris flow probability, C and D show estimated debris flow volumes eroded, and E and F show estimated volumes delivered to the river network.

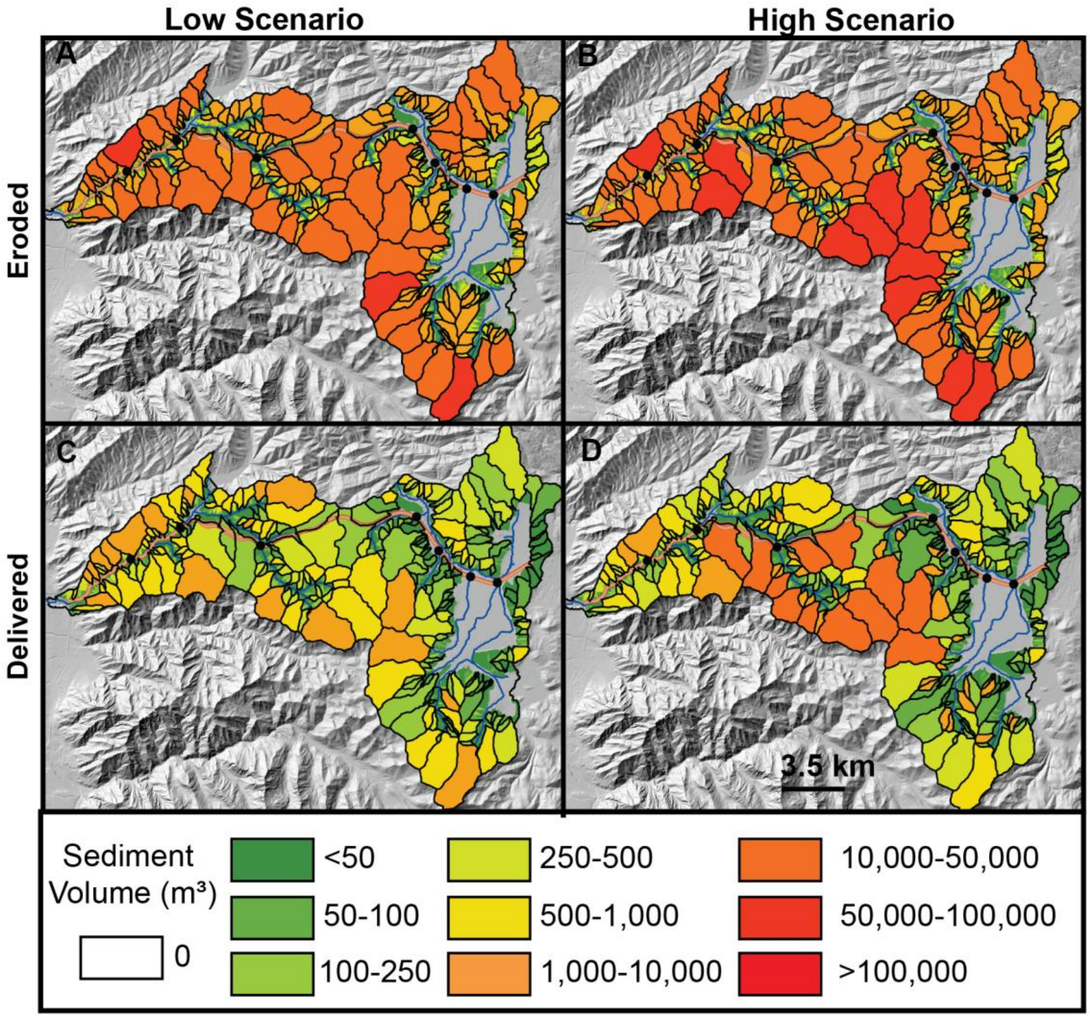

Figure 11. Year-1 RUSLE results for the I-80 site. Panels show hillslope erosion (A–B) and sediment delivery to the river network (C–D) under low (left) and high (right) soil burn severity scenarios.

Modeled cumulative sediment flux to infrastructure crossings along I-80 (Figure 10) shows that sediment delivery is front-loaded in the high post-fire scenario, with the majority of sediment arriving within the first 1–3 years. Crossings I1 and I3 exhibit the highest total fluxes, each receiving over 100,000 m^3 of sediment by the end of the simulation, with sharp delivery peaks during the first post-fire year. I2 shows a similar early delivery pattern, followed by a secondary pulse around Year 5, indicating delayed routing or remobilization of upstream sediment. Crossings I4 through I6, which fall on smaller tributaries, display more gradual and consistent sediment accumulation over time. Under the low post-fire scenario, sediment fluxes are substantially reduced at all locations, with slower and more uniform accumulation over the 10-year period.

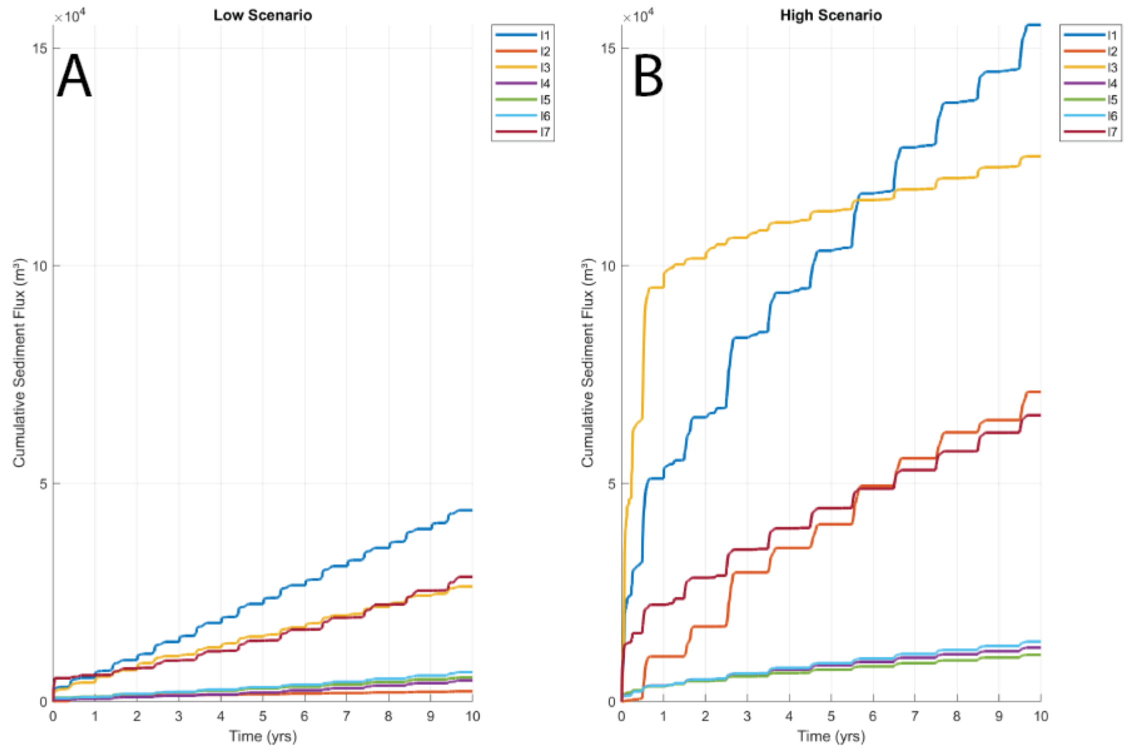

Figure 12. Modeled cumulative sediment flux to infrastructure crossings along I-80. Panels show low (A) and high (B) post-fire scenarios. Infrastructure locations I1–I7 are shown in Figure 8.

4.4 State Route 14 (Cedar Canyon)

4.4.1 Model Setup

We modeled post-fire sedimentation hazards along State Route 14 (SR 14) through Cedar Canyon in southwestern Utah (Figure 13). A single pour point was specified near the mouth of Cedar Canyon to delineate the contributing watershed allowing us to evaluate downstream and direct sediment impacts along the SR 14 corridor. Infrastructure crossings were manually identified for use in the sediment routing analysis. For the Direct Impacts analysis, sub-catchments were delineated directly from SR 14 along the canyon corridor (Figures 13 and 14).

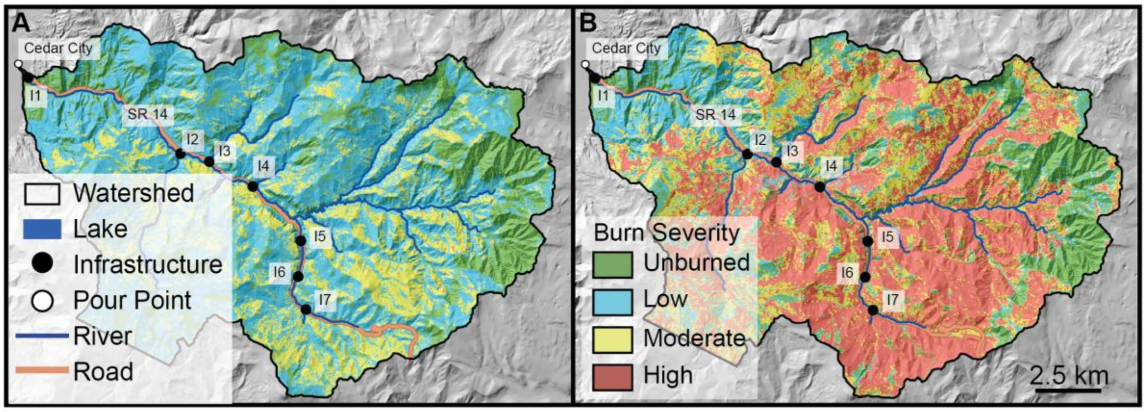

Figure 13. Study area for the State Route 14 site showing watershed boundaries, transportation corridor, pour point, delineated river network, infrastructure locations, and low (A) and high (B) soil burn severity scenarios within the modeled fire extent.

4.4.2 Direct Impacts Results

The Direct Impacts tools were used to evaluate debris flow hazards from sub-catchments draining directly to SR 14. Figure 14 summarizes two key model outputs: the 15-minute rainfall intensity required to trigger a debris flow with 50% probability (Panels A–B) and the estimated sediment volume generated if triggered (Panels C–D). Under the high severity scenario, a cluster of sub-catchments in the southeastern portion of the corridor are predicted to trigger debris flows at relatively low rainfall intensities (20–30 mm/hr), indicating elevated susceptibility to post-fire debris flows in this area. A similar but less widespread pattern is visible under the low severity scenario. Additionally, several sub-catchments are predicted to produce between 50,000–100,000 m^3 of sediment, primarily draining to tributaries. While these sub-catchments drain to tributaries rather than directly to the road, those tributaries intersect the transportation corridor, and the sediment volumes involved may still pose risks to infrastructure.

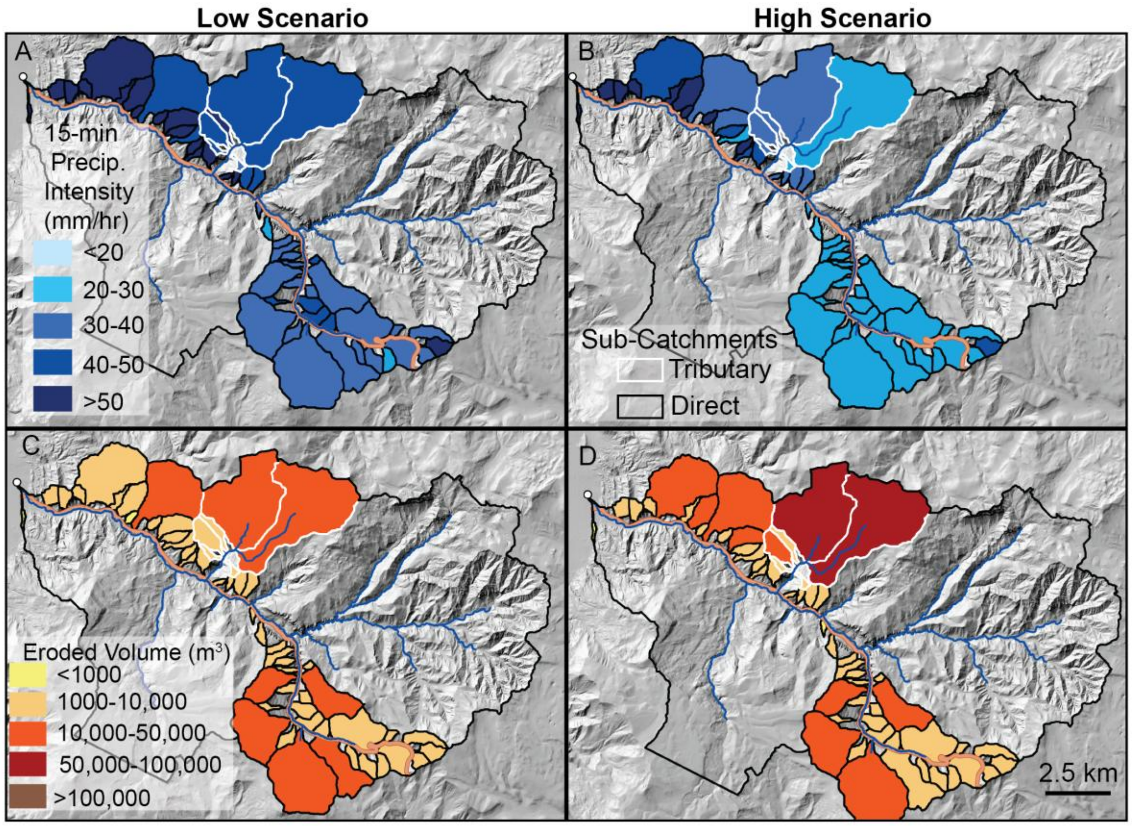

Figure 14. Results of the Direct Impacts analysis for SR 14. Panels A and B show the 15-minute rainfall intensity (mm/hr) required to trigger debris flows at 50% probability under low (A) and high (B) soil burn severity scenarios. Panels C and D show the corresponding estimated debris flow sediment volumes.

4.4.3 Downstream Impacts

Infra-USUAL identified 171 sub-catchments contributing to SR 14, all of which were assumed to burn under both post-fire scenarios. Under the 2-year rainfall scenario, 131 sub-catchments (76.6%) were predicted to exceed the 50% debris flow probability threshold. Under the 25-year rainfall scenario, all 171 sub-catchments (100%) exceeded this threshold (Figure 15A–B). Estimated debris flow volumes increased substantially between scenarios, from 1,416,575 m^3 eroded and 79,631 m^3 delivered in the low scenario, to 9,735,797 m^3 eroded and 2,502,383 m^3 delivered in the high scenario (Figure 15C–F).

RUSLE-based hillslope erosion was estimated at 647,000 m³ in the first post-fire year under the low severity scenario, with 20,697 m³ of that volume delivered to the river network. In the high severity scenario, first-year erosion increased to 763,854 m³ with 24,998 m³ delivered (Figure 16A–B). An additional 130,084 and136,406 m³ of sediment was estimated to be delivered over years 2–10 for the low and high scenario, respectively.

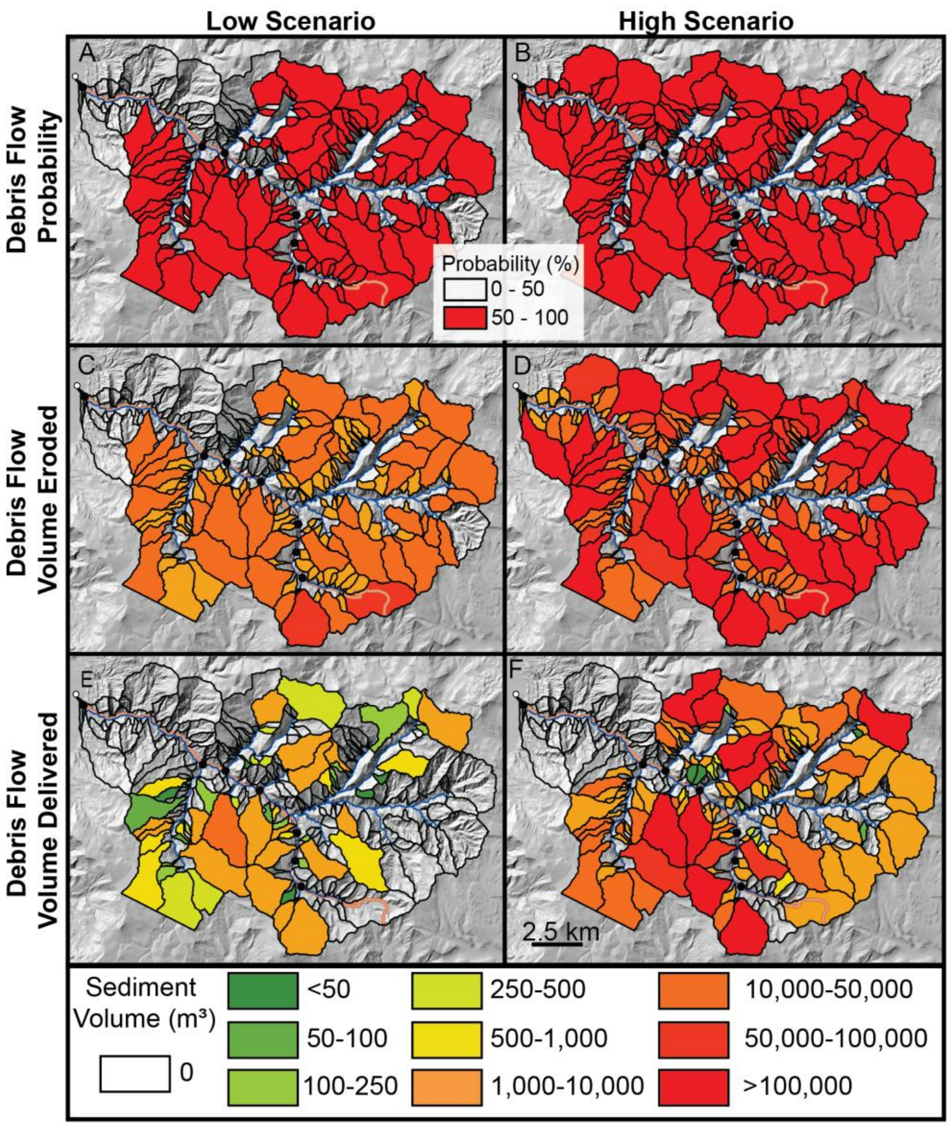

Figure 15. Debris flow hazard estimates for SR 14 under two rainfall scenarios. Panels A, C, and E show results for the 2-year rainfall scenario, while panels B, D, and F show results for the 25-year scenario. Panels A and B show debris flow probability, C and D show estimated debris flow volumes eroded, and E and F show estimated debris flow volumes delivered to the river network.

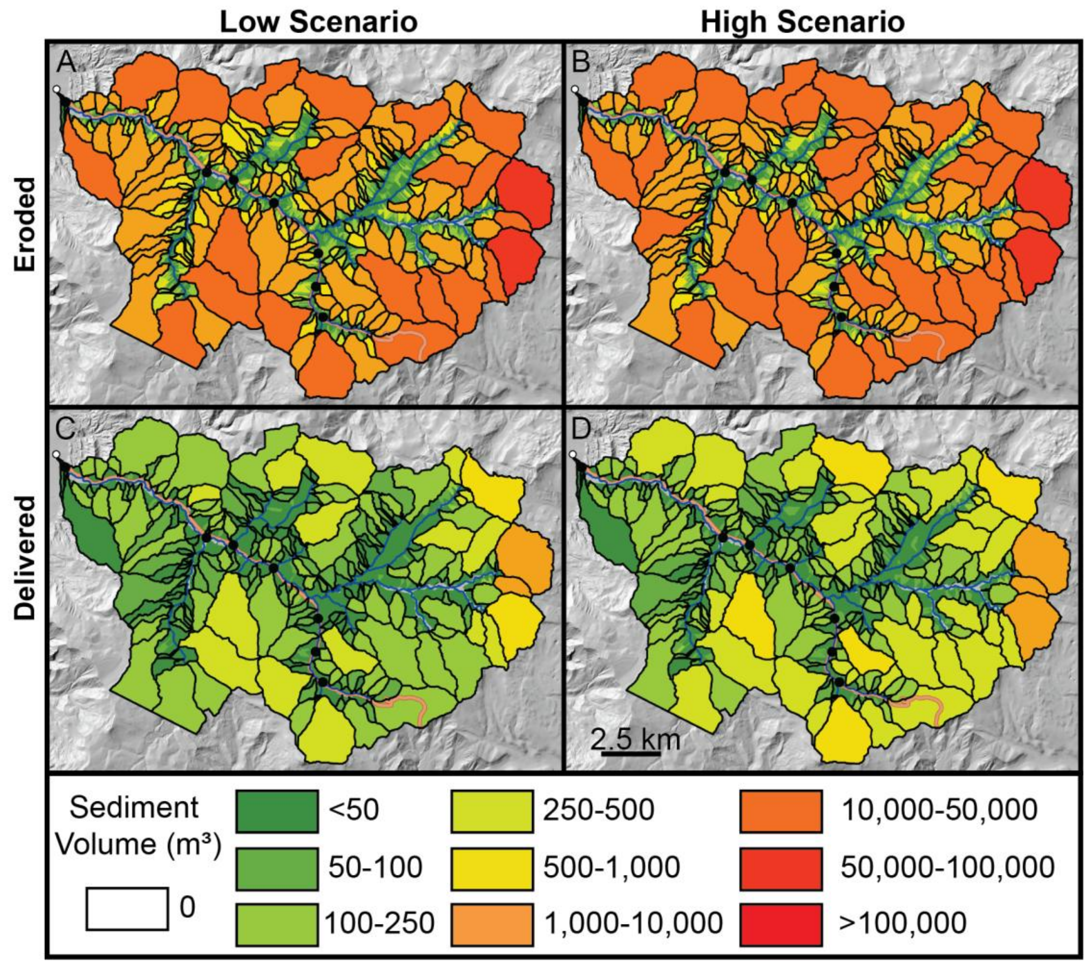

Figure 16. Year-1 RUSLE-based erosion and sediment delivery for SR 14 under two post-fire scenarios. (A) Estimated erosion and delivery volumes under the low severity scenario. (B) Estimated erosion and delivery volumes under the high severity scenario.

Modeled cumulative sediment flux to infrastructure crossings along SR 14 (Figure 17) indicates that sediment delivery was front-loaded under the high hazard scenario, with crossings I1, I2, and I4 receiving sharp sediment pulses within the first year post-fire. After this initial input, fluxes at all locations continued to rise gradually through the end of the 10-year simulation. In contrast, the low scenario showed steady but lower sediment accumulation across all sites, with no major pulses.

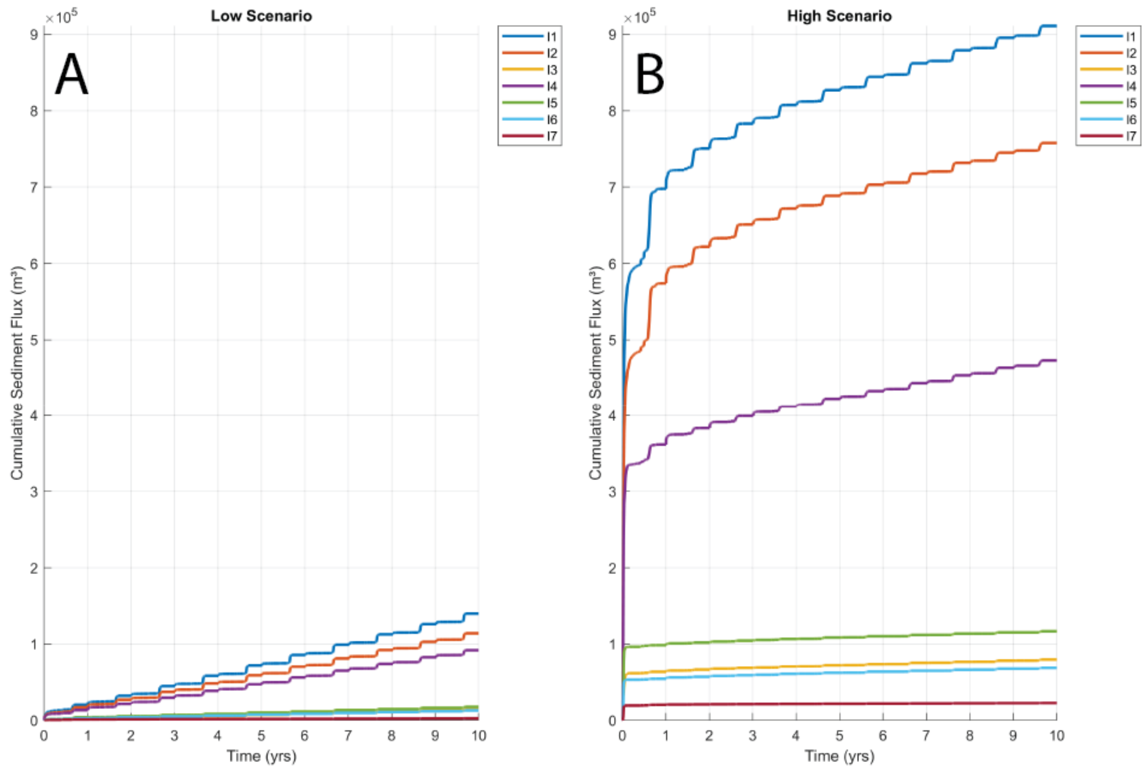

Figure 17. Modeled cumulative sediment flux to infrastructure crossings along SR 14. Panels show low (A) and high (B) post-fire scenarios. Infrastructure locations I1–I7 are shown in Figure 13.

4.5 U.S. Route 89 (Logan Canyon)

<u>4.5.1 Model Setup</u>

We modeled post-fire sedimentation hazards along U.S. Route 89 (US 89) through Logan Canyon in northern Utah (Figure 18). A single pour point was specified at First Dam near the mouth of Logan Canyon to delineate the contributing watershed. While two reservoirs (Second Dam and Third Dam) are located upstream of First Dam, they are largely filled with sediment and are unlikely to trap additional material. As a result, no additional pour points were used to exclude their contributing areas. Infrastructure crossings along US 89 were manually identified for sediment routing analysis. For the Direct Impacts analysis, sub-catchments were delineated directly from US 89 along the corridor (Figures 18 and 19).

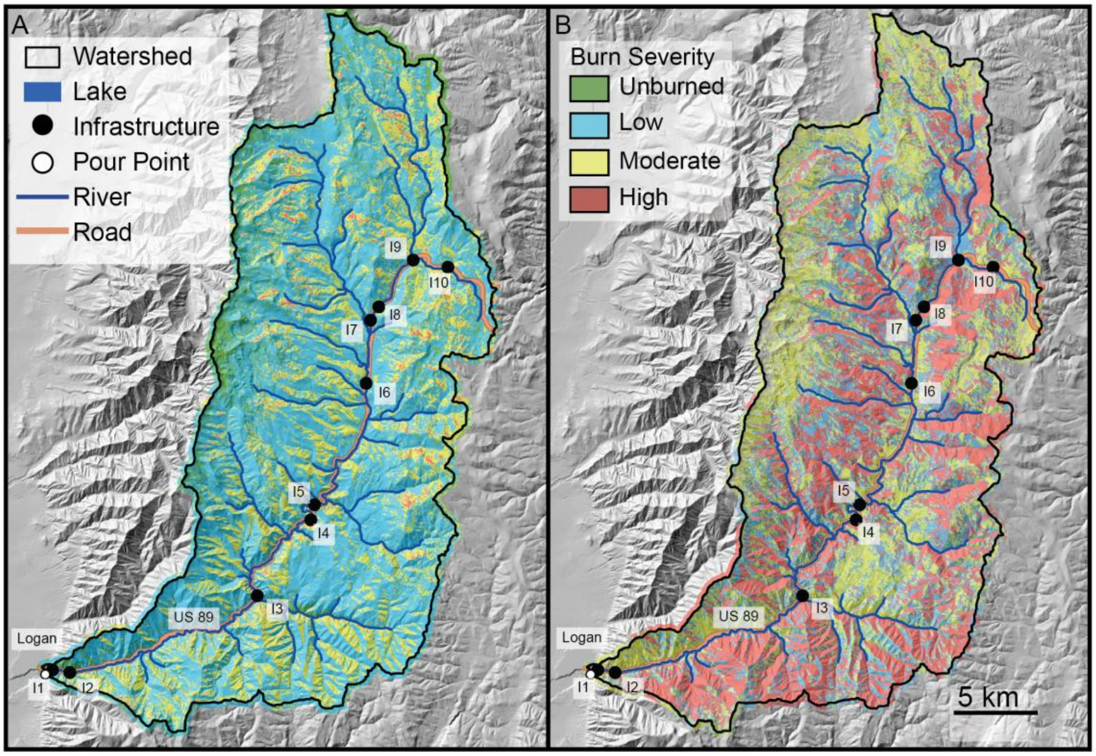

Figure 18. Study area for the U.S. Route 89 site through Logan Canyon, showing watershed boundaries, transportation corridor, pour point, delineated river network, infrastructure locations, and soil burn severity rasters for the low (A) and high (B) scenarios are also shown.

4.5.2 Direct Impacts Results

The Direct Impacts analysis highlights the central portion of the SR 89 corridor as the primary area of concern under both low and high fire severity scenarios (Figure 19). In both cases, several sub-catchments in this section are predicted to generate between 10,000–50,000 m^3 of sediment if triggered, with a few exceeding 50,000 m^3 under both scenarios. Under the high severity scenario, triggering rainfall intensities drop substantially, with many sub-catchments in the central, northern, and southern portions of the corridor reaching the 20–30 mm/hr range.

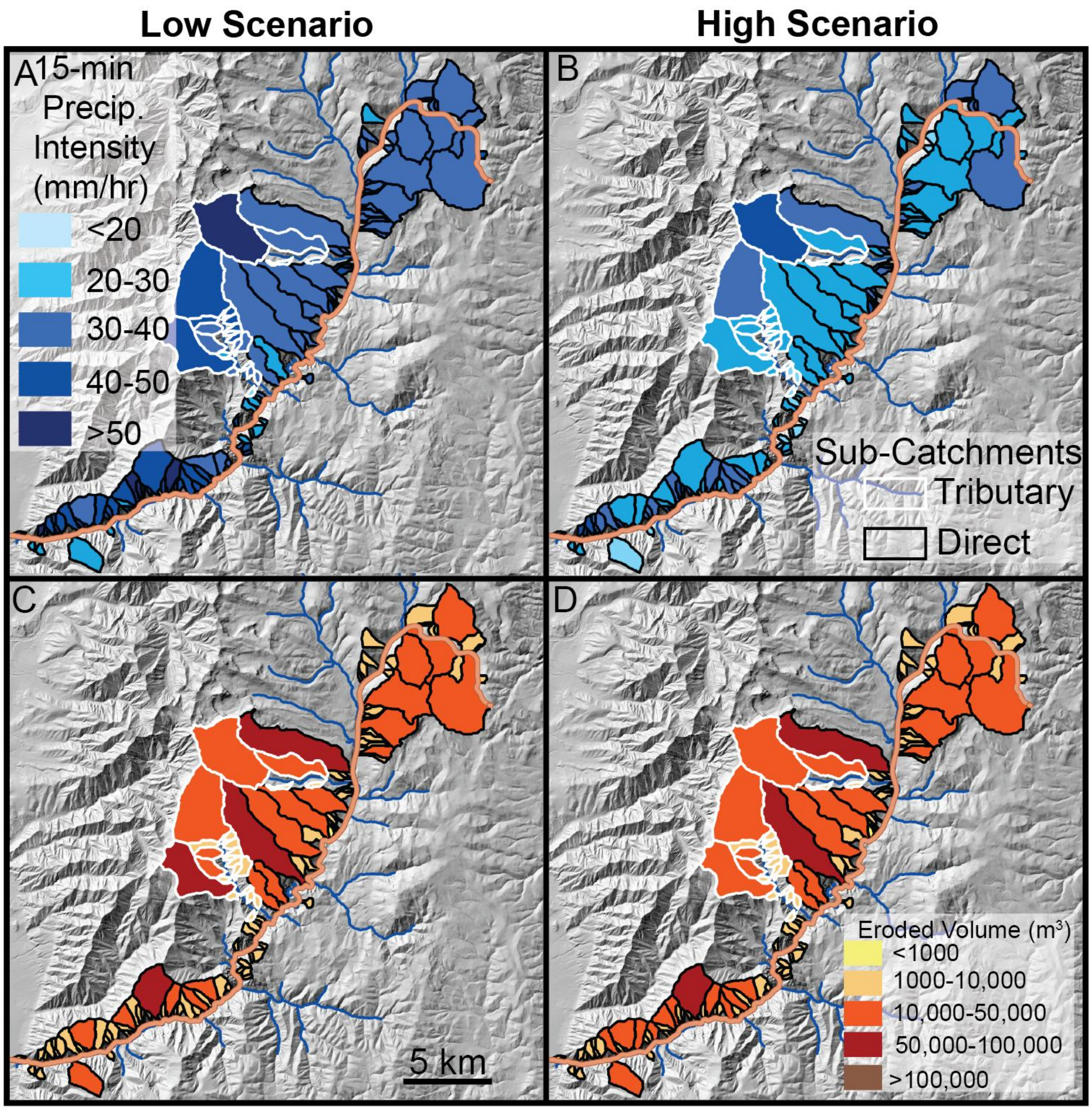

Figure 19. Results of the Direct Impacts analysis for US 89. Panels A and C show low fire severity scenario outputs; panels B and D show the high severity scenario. Panels A and B display the 15-minute rainfall intensity (mm/hr) required to trigger a debris flow at 50% probability. Panels C and D show the estimated debris flow sediment volume (m^3) generated if triggered.

4.5.3 Downstream Impacts

Infra-USUAL identified 473 sub-catchments within the contributing watershed to US 89, all of which were assumed burned in the proactive planning scenario. Under the low fire severity and 2-year rainfall scenario, 121 sub-catchments (25.6%) exceeded the 50% debris flow probability threshold (Figure 20A), while under the high severity and 25-year rainfall scenario, all 473 sub-catchments (100%) surpassed this threshold (Figure 20B). Estimated debris flow sediment volumes increased substantially with scenario severity. The low scenario produced 706,657 m^3 of eroded sediment, with 58,793 m^3 delivered to the river network, while the high scenario produced 10,914,676 m^3 of eroded sediment and 2,895,760 m^3 delivered (Figure 20).

RUSLE-based hillslope erosion was also substantial, with 5,860,338 m^3 eroded under the low scenario and 6,523,636 m^3 under the high scenario. In the first post-fire year, 207,347 m^3 and 233,478 m^3 were delivered to the river network, respectively (Figure 21). Over the remaining 9 years, an additional 1.08 million m^3 of sediment for the low scenario and 1.11 million m^3 of sediment for the high scenario were estimated to be delivered.

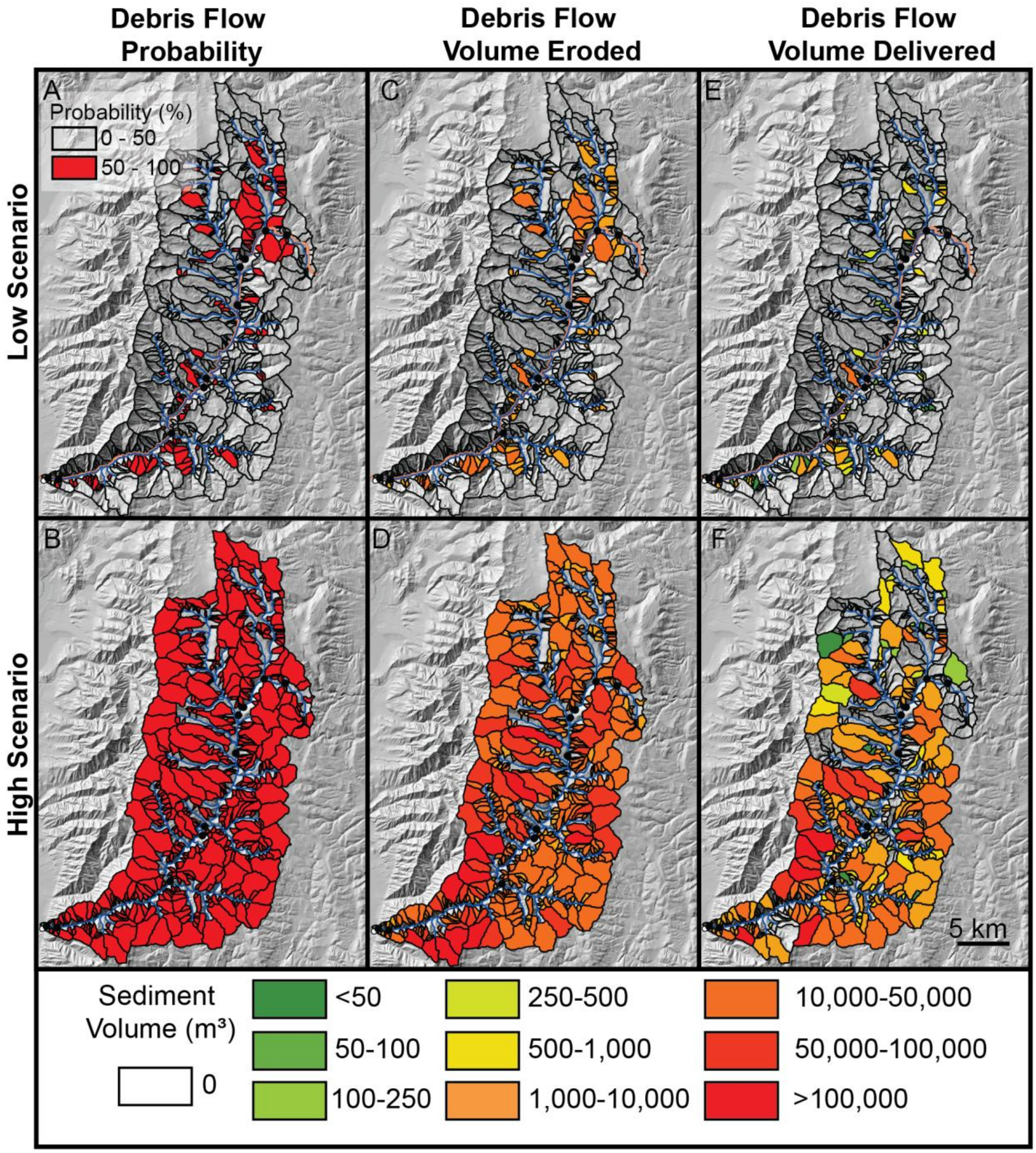

Figure 20. Debris flow hazard estimates for the US 89 corridor under two scenarios. Panels A, C, and E show results for the low scenario; panels B, D, and F show the high scenario. Panels A and B display debris flow probability, C and D show estimated debris flow volumes eroded, and E and F show estimated debris flow volumes delivered to the river network.

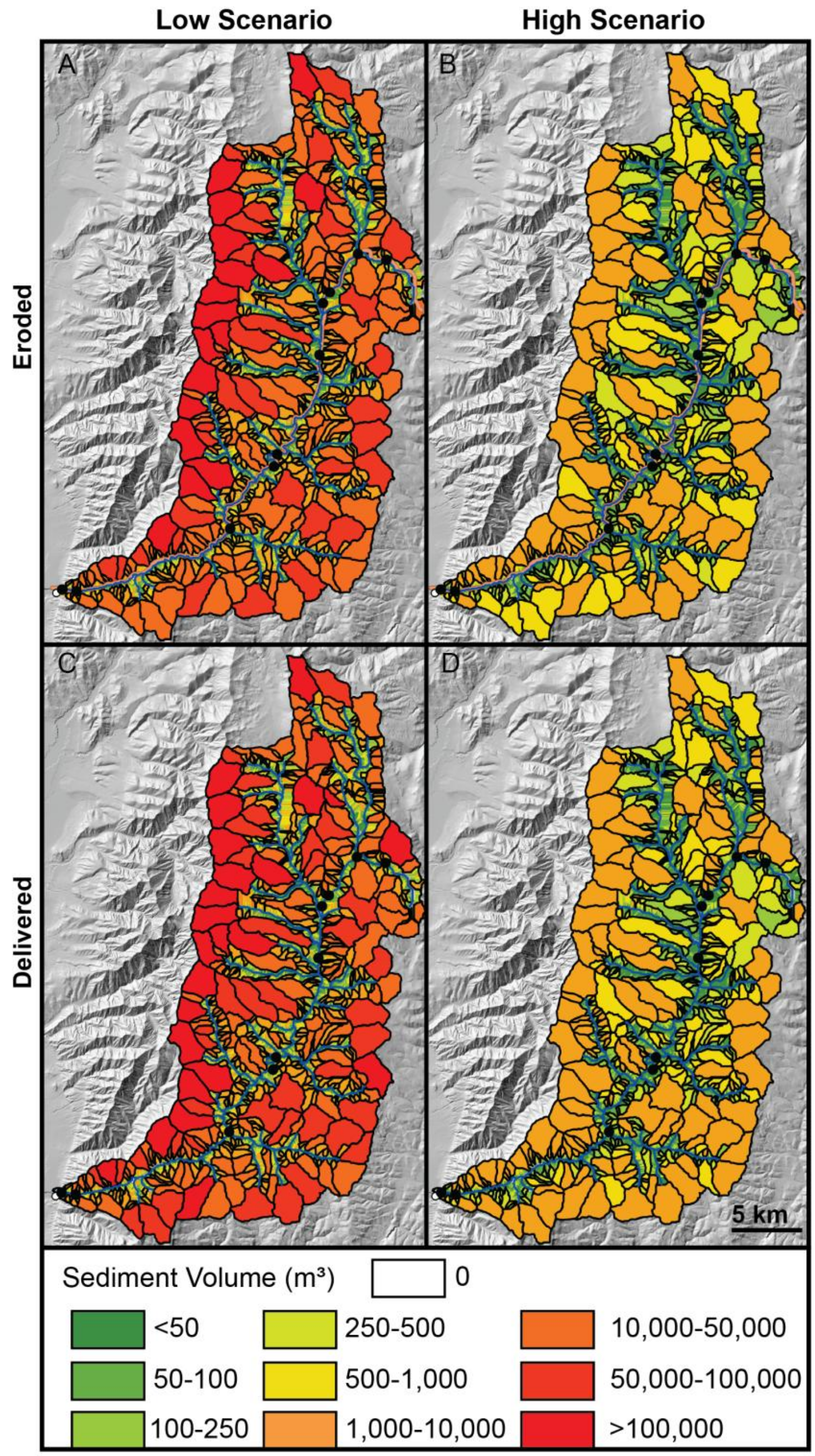

Figure 21. Year-1 RUSLE-based erosion and sediment delivery estimates for the US 89 corridor. Panel A shows estimated hillslope erosion (m³), and Panel B shows sediment delivery to the river network (m³).

Modeled cumulative sediment flux to infrastructure crossings along US 89 (Figure 22) shows a consistent pattern under both hazard scenarios. In the high scenario, a large volume of sediment is delivered during the first 3.5 years post-fire, with the steepest increases occurring in the first year. After year 3.5, the curves continue to rise at a more uniform and reduced rate. While early delivery is not as extreme as at some other sites, the initial post-fire years still represent the highest sediment fluxes. Under the low scenario, total delivery is smaller overall, and sediment input occurs at a more steady rate throughout the 10-year period, with a noticeable reduction in flux after year two.

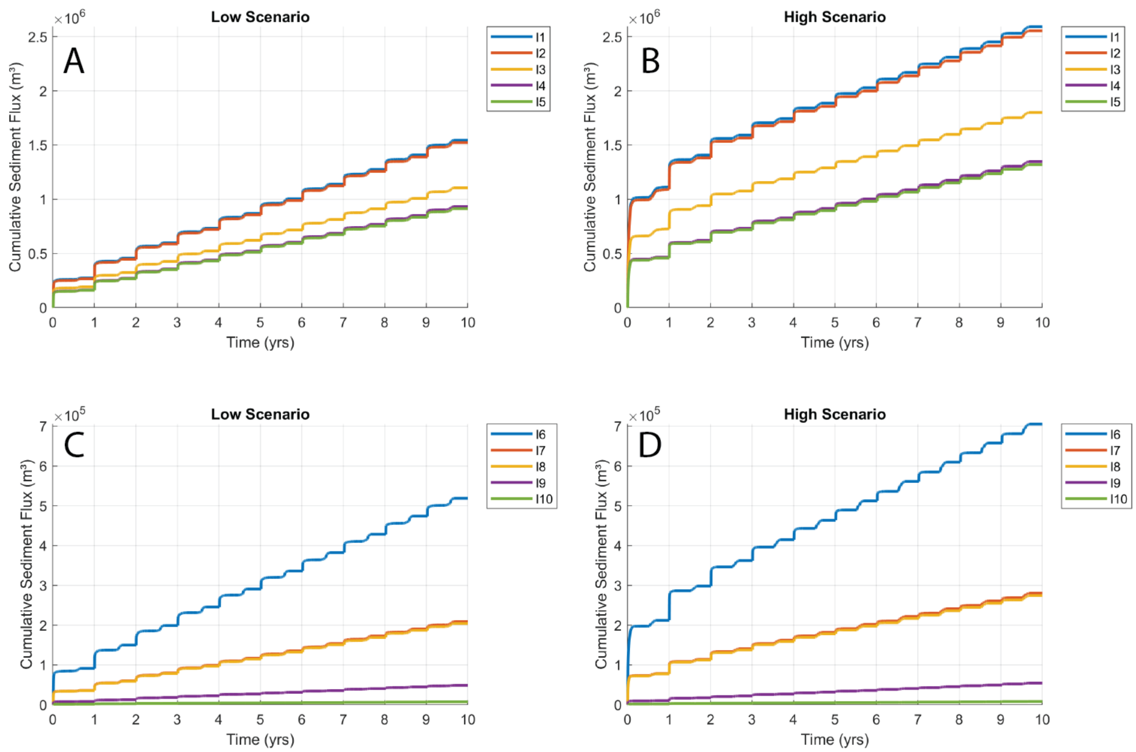

Figure 22. Modeled cumulative sediment flux to infrastructure crossings along US 89. Panels show low (A, C) and high (B, D) flow scenarios for crossings I1–I5 (A-B) and I6–I10 (C-D).

4.6 Interstate 84 (Weber Canyon)

4.6.1 Model Setup

We modeled post-fire sedimentation hazards along Interstate 84 (I-84) through Weber Canyon in northern Utah (Figure 22). Two pour points were specified to delineate the contributing watershed: one near Henefer at the eastern end of the canyon, and one near Ogden at the western outlet. Infrastructure crossings along I-84 were manually delineated for sediment routing analysis. For the Direct Impacts analysis, sub-catchments were delineated directly from I-84 along the canyon corridor (Figures 23 and 24).

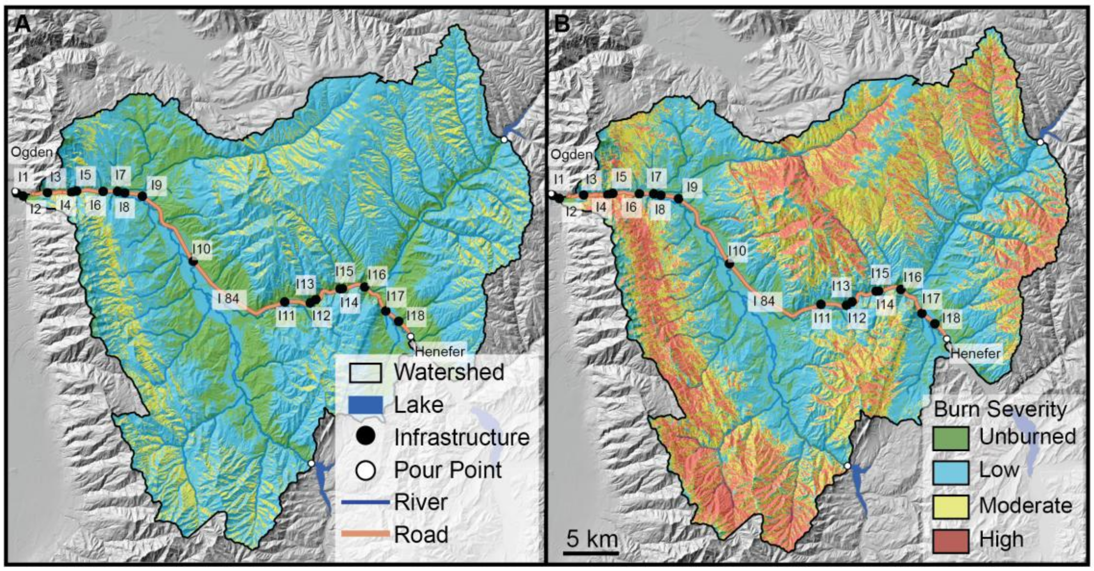

Figure 23. Study area for the Interstate 84 (Weber Canyon) site showing watershed boundaries, transportation corridor, pour points, delineated river network, infrastructure locations, and low (A) and high (B) soil burn severity scenarios within the model domain.

4.6.2 Direct Impacts Results

Figure 24 summarizes two key model outputs: the 15-minute rainfall intensity required to trigger a debris flow at 50% probability (Panels A–B) and the estimated debris flow sediment volume if triggered (Panels C–D). Under the low severity scenario, most direct sub-catchments require 40–50 mm/hr rainfall intensities to trigger debris flows, with only a few dropping below this range. However, in the high severity scenario, several of these same catchments are predicted to trigger at lower thresholds (20–30 mm/hr) and generate large sediment volumes (10,000–50,000 m^3).

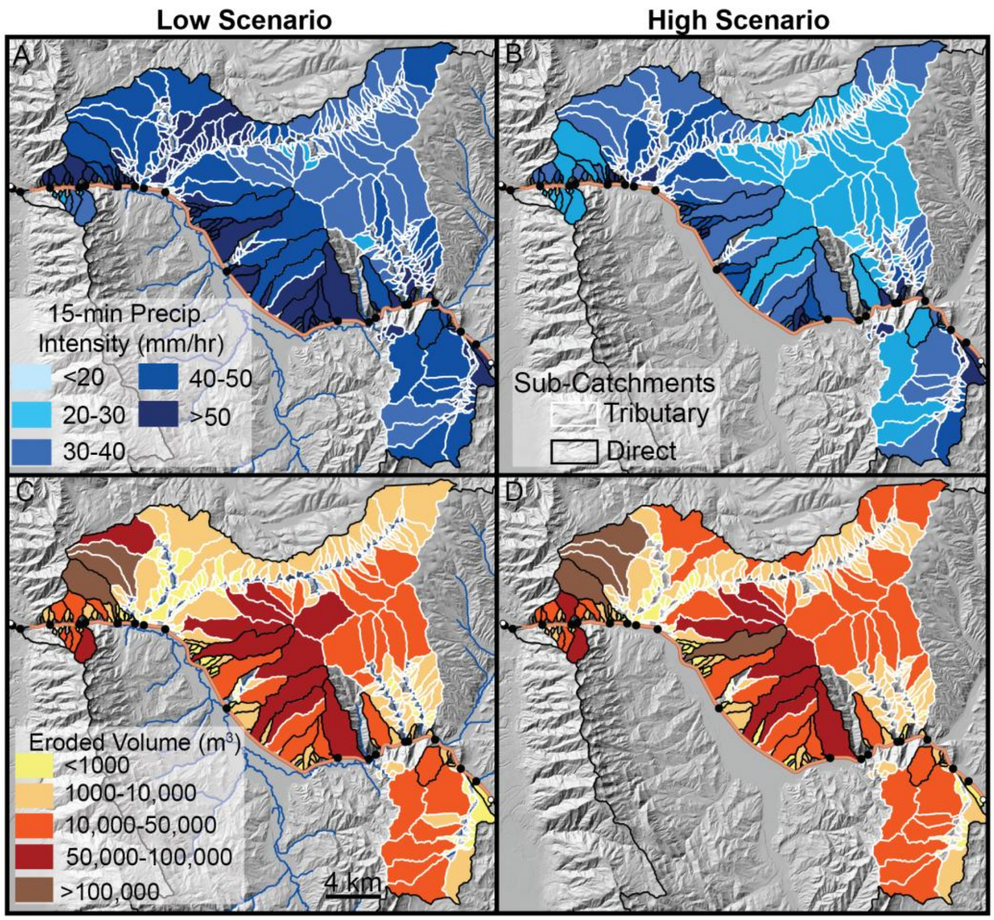

Figure 24. Results of the Direct Impacts analysis for I-84. Panels A and B show the rainfall intensity (mm/hr) required to trigger debris flows with at least 50% probability under low (A) and high (B) burn severity scenarios. Panels C and D show the estimated sediment volumes eroded (m^3) if triggered.

4.6.3 Downstream Impacts

Infra-USUAL identified 972 sub-catchments contributing to the I-84 corridor in Weber Canyon, all of which were assumed burned under the simulated wildfire scenarios. In the low severity scenario, 238 sub-catchments (24.5%) exceeded the 50% probability threshold for debris flow generation, contributing an estimated 2,885,315 m^3 of sediment eroded, with 663,572 m^3 delivered to the river network (Figure 25 A, C, F). Under the high severity scenario, nearly all sub-catchments (99.9%) exceeded the threshold, producing a total of 26,633,730 m^3 of sediment, with 9,383,740 m^3 delivered downstream (Figure 25B, D, E).

RUSLE-based hillslope erosion was also substantial, with 8,669,786 m^3 of sediment eroded under the low scenario and 9,975,513 m^3 under the high scenario (Figure 26 A, B). In the first post-fire year, 327,921 m^3 (low) and 376,229 m^3 (high) were delivered to the network (Figure 26 C, D). Sediment delivery continued over the subsequent nine years, with an additional 1,991,663 m^3 (low) and 2,043,085 m^3 (high) reaching the channel network.

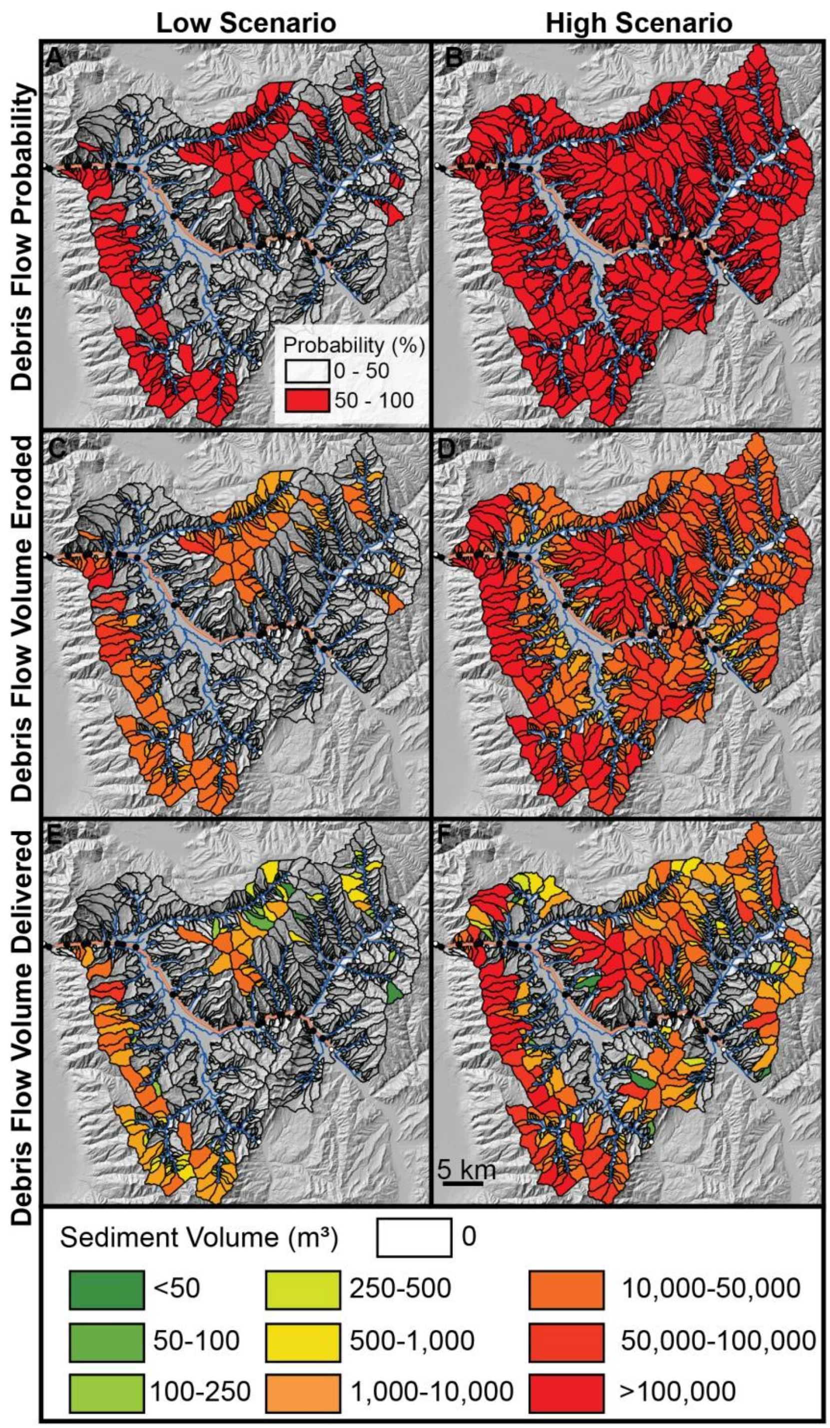

Figure 25. Debris flow hazard estimates for I-84 under two rainfall scenarios. Panels A, C, and E show results for the 2-year (low severity) scenario, while panels B, D, and F show results for the 25-year (high severity) scenario. Panels A and B display debris flow probability, C and D show estimated sediment volumes eroded, and E and F show volumes delivered to the river network.

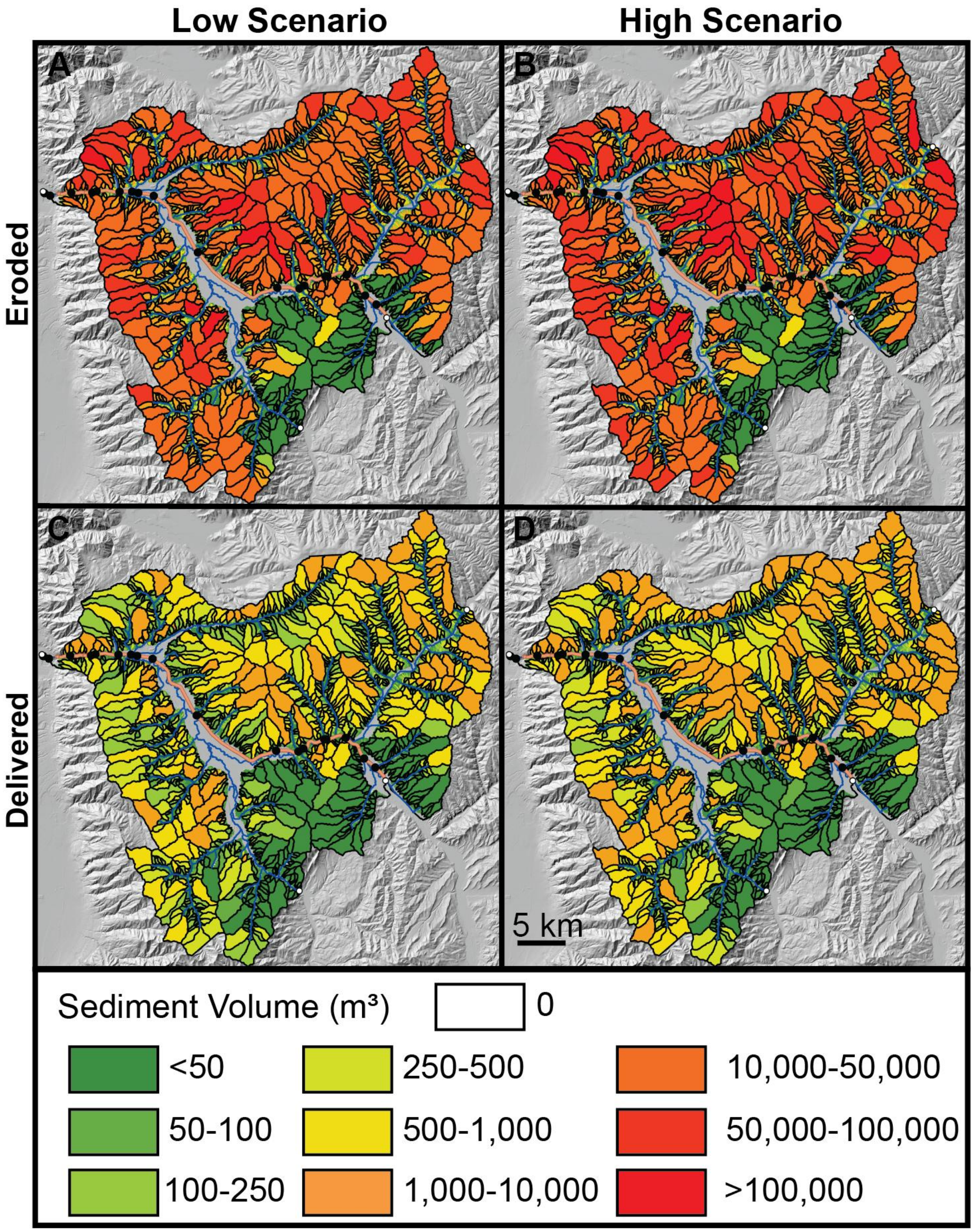

Figure 26. Year-1 RUSLE results for the I-84 watershed. Panels A and B show hillslope erosion under the low and high severity scenarios, respectively. Panels C and D show sediment delivery to the river network in year one under each scenario.

Modeled cumulative sediment flux to infrastructure crossings along I-84 (Figure 27) shows a marked pulse of sediment delivery within the first 3 years post-fire, particularly under the high hazard scenario. Crossings such as I2, I3, and I5 received the largest volumes of sediment, with the steepest delivery curves occurring in the first year. By year 3, delivery rates began to stabilize, with continued but more gradual sediment input throughout the remainder of the 10-year simulation. Under the low hazard scenario, total delivery volumes were notably lower, and sediment arrival followed a more uniform and sustained trend, without sharp peaks.

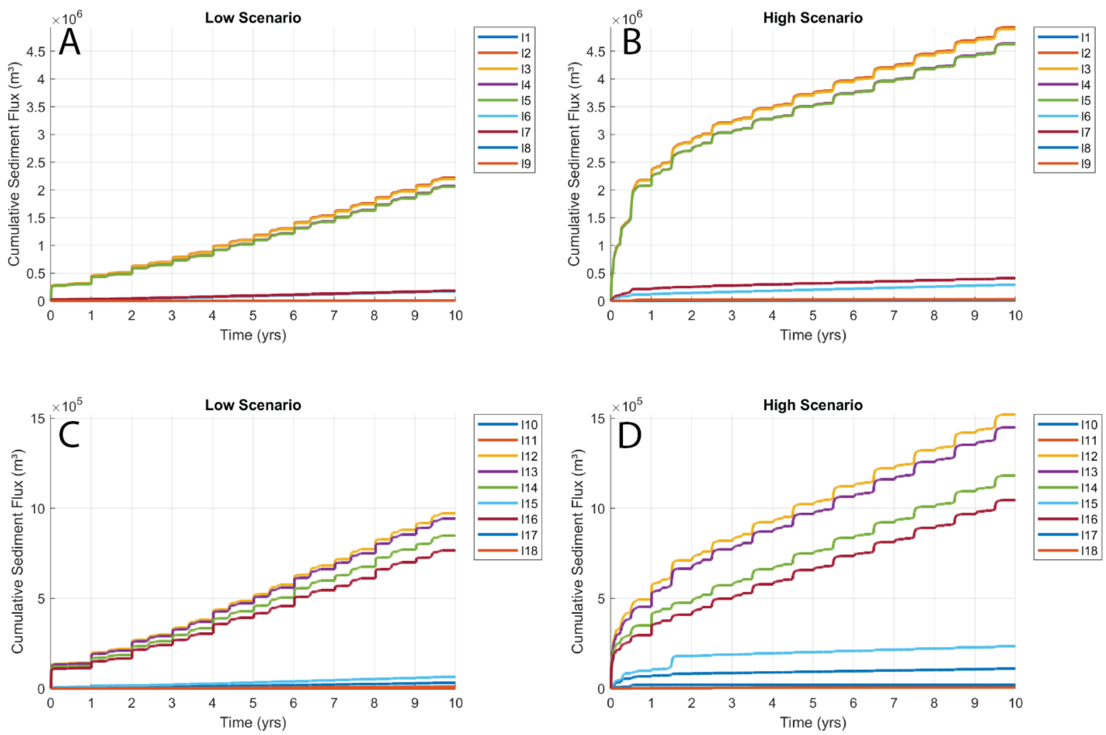

Figure 27. Modeled cumulative sediment flux to infrastructure crossings on I-84. (A–B) Crossings I1–I9; (C–D) Crossings I10–I18. Panels show low (left) and high (right) flow scenarios.

5.0 CONCLUSIONS

5.1 Summary and Findings

Post-wildfire sedimentation hazards can pose significant risks to transportation infrastructure, including road blockages, culvert/bridge damage, and long-term maintenance issues. To date, these hazards are only quantifiable after the fire occurs. However, in this report, we present a new machine learning method that predicts first severity prior to occurrence, allowing users to proactively assess and plan for risks prior to a fire occurring. We demonstrate how predictive dNBR and soil burn severity outputs can be integrated with a new geospatial toolkit presented in an accompanying report (UT-25.14). The toolkit combines wildfire severity predictions, rainfall return periods, and sediment hazard models to simulate post-fire conditions across a range of scenarios. Specifically, we modeled both low and high soil burn severity conditions paired with 2-year and 25-year rainfall events, respectively, to represent a range of potential outcomes. However, users can explore additional rainfall and burn severity combinations to assess a broader range of scenarios.

The case studies in this report highlight the toolkit's ability to identify locations along key transportation corridors that are vulnerable to post-fire debris flows, hillslope erosion, and sediment delivery to infrastructure. These examples demonstrate how the toolkit can be applied as a proactive planning tool to flag high-priority locations before a fire occurs. Utilizing this approach will allow UDOT to conduct pre-fire assessments of post-fire hazards that support long-term planning and foster coordination with land management agencies to reduce risks and costs to transportation infrastructure.

5.2 Limitations and Challenges

While the proactive version of the UDOT Post-Wildfire Geohazard Assessment Toolkit provides a powerful framework for assessing sediment hazards before a fire occurs, it inherits several key limitations from the core modeling framework. These include simplified assumptions related to hydrology, debris flow grain sizes, channel geometry, sediment recovery trajectories, and culvert or bridge behavior. A complete discussion of these limitations is provided in Report

UT-25.14, which outlines assumptions used in each modeling component and identifies opportunities for future improvements to enhance accuracy and applicability.

In addition to these existing considerations, the proactive application requires users to make assumptions about the spatial extent of the burn. In this report, we assumed complete watershed burns to explore sediment contributions across the entire landscape and highlight areas most likely to deliver material to the transportation network. While this approach supports worst-case scenario planning, it may overestimate hazard extent in smaller or patchier fires. Users may instead choose to apply predicted soil burn severity maps across only portions of the watershed, based on local considerations and specific modeling objectives.

While a key outcome of this study is an easy-to-use geospatial toolkit for assessing pre-wildfire sedimentation impacts to transportation corridors, the tools are designed with a streamlined GUI that allows GIS users to operate them without writing code or building custom workflows. This structure improves accessibility for anyone comfortable using GIS software and requires no programming experience. However, it is essential that users understand the underlying models and assumptions to ensure that input parameters are applied correctly and results are interpreted appropriately. The ease of running the models does not guarantee meaningful results, particularly when users deviate from default values without a solid understanding of the tool's logic. In such cases, the models may still execute successfully, but the outputs could be invalid or misleading. Additionally, some model components are sensitive to key inputs such as burn severity classification, flow magnitude, and grain-size assumptions, meaning that data quality and appropriate parameterization are critical to obtaining reliable results. Thus, while the toolkit simplifies execution, responsible and informed use is necessary.

5.3 Toolkit and Data Access

The UDOT Post-Wildfire Geohazard Assessment Toolkit, including the user manual, tutorial videos, and precompiled datasets including predictive dNBR and soil burn severity data for the 5th (low severity), 50th (moderate severity), and 95th (high severity) percentiles of ERC, can be accessed at https://usu.box.com/s/2x89ntse9tmb4ig8zaw7vs4ynzk6gcyt. Efforts are underway to publish the toolkit in peer-reviewed journals to ensure broad accessibility. Upon publication, the tools will be hosted at https://github.com/WatershedsWildfireResearchCollaborative where they will be maintained and updated to ensure compatibility with future versions of ArcGIS Pro.

6.0 RECOMMENDATIONS AND IMPLEMENTATION

6.1 Recommendations and Implementation

This project demonstrates a new approach for proactively assessing post-wildfire sedimentation hazards before a fire occurs. By combining predictive soil burn severity with sediment hazard models, the geospatial toolkit provides a method for identifying locations where transportation infrastructure may be at elevated risk following a future wildfire. We recommend that UDOT consider incorporating this toolkit into a pre-fire hazard assessment framework. While no formal pre-fire workflow currently exists, applying the toolkit across key transportation corridors could help prioritize areas where wildfire impacts may pose a threat to roads, culverts, and bridges. These insights could support longer-term planning efforts, infrastructure design, and emergency preparedness. In addition, early identification of high-risk locations could facilitate collaboration with landowners and other state and federal agencies (e.g., USFS, BLM) to explore potential mitigation options such as fuels reduction, thinning, or prescribed burns. Establishing such partnerships in advance could improve wildfire resilience and reduce costs associated with post-fire damages.

REFERENCES

Abatzoglou, J. T., & Williams, A. P. (2016). Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences*, *113*(42), 11770–11775. https://doi.org/10.1073/pnas.1607171113

David, S. R., Murphy, B. P., Czuba, J. A., Ahammad, M., & Belmont, P. (2023). USUAL Watershed Tools: A new geospatial toolkit for hydro-geomorphic delineation. *Environmental Modelling & Software*, *159*, 105576. https://doi.org/10.1016/j.envsoft.2022.105576

DeLong, S. B., Youberg, A. M., DeLong, W. M., & Murphy, B. P. (2018). Post-wildfire landscape change and erosional processes from repeat terrestrial lidar in a steep headwater catchment, Chiricahua Mountains, Arizona, USA. *Geomorphology*, *300*, 13–30. https://doi.org/10.1016/j.geomorph.2017.09.028

Eidenshink, J., Schwind, B., Brewer, K., Zhu, Z.-L., Quayle, B., & Howard, S. (2007). A Project for Monitoring Trends in Burn Severity. *Fire Ecology*, *3*(1), 3–21. https://doi.org/10.4996/fireecology.0301003

Fraser, A. M., Chester, M. V., & Underwood, B. S. (2022). Wildfire risk, post-fire debris flows, and transportation infrastructure vulnerability. *Sustainable and Resilient Infrastructure*, *7*(3), 188–200. https://doi.org/10.1080/23789689.2020.1737785

Gannon, B. M., Wei, Y., MacDonald, L. H., Kampf, S. K., Jones, K. W., Cannon, J. B., Wolk, B. H., Cheng, A. S., Addington, R. N., & Thompson, M. P. (2019). Prioritising fuels reduction for water supply protection. *International Journal of Wildland Fire*, *28*(10), 785. https://doi.org/10.1071/WF18182

Gartner, J. E., Cannon, S. H., & Santi, P. M. (2014). Empirical models for predicting volumes of sediment deposited by debris flows and sediment-laden floods in the transverse ranges of southern California. *Engineering Geology*, *176*, 45–56. https://doi.org/10.1016/j.enggeo.2014.04.008

Klimas, K. B., Yocom, L. L., Murphy, B. P., David, S. R., Belmont, P., Lutz, J. A., DeRose, R. J., & Wall, S. A. (2025). A machine learning model to predict wildfire burn severity for pre-fire risk assessments, Utah, USA. *Fire Ecology*, *21*(1), 8. https://doi.org/10.1186/s42408-024-00346-z

Mcguire, L., Ebel, B., Rengers, F., Vieira, D., & Nyman, P. (2024). Fire effects on geomorphic processes. *Nature Reviews Earth & Environment*, *5*. https://doi.org/10.1038/s43017-024-00557-7

Miller, J. D., & Thode, A. E. (2007). Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). *Remote Sensing of Environment*, *109*(1), 66–80. https://doi.org/10.1016/j.rse.2006.12.006

Murphy, B. P., Czuba, J. A., & Belmont, P. (2019a). Post-wildfire sediment cascades: A modeling framework linking debris flow generation and network-scale sediment routing. *Earth Surface Processes and Landforms*, *44*(11), 2126–2140. https://doi.org/10.1002/esp.4635

Murphy, B. P., Czuba, J. A., & Belmont, P. (2019b). Post-wildfire sediment cascades: A modeling framework linking debris flow generation and network-scale sediment routing. *Earth Surface Processes and Landforms*, *44*(11), 2126–2140. https://doi.org/10.1002/esp.4635

Murphy, B. P., Yocom, L. L., & Belmont, P. (2018). Beyond the 1984 Perspective: Narrow Focus on Modern Wildfire Trends Underestimates Future Risks to Water Security. *Earth's Future*, *6*(11), 1492–1497. https://doi.org/10.1029/2018EF001006

Roux, C., Alber, A., Bertrand, M., Vaudor, L., & Piégay, H. (2015). "FluvialCorridor": A new ArcGIS toolbox package for multiscale riverscape exploration. *Geomorphology*, *242*, 29–37. https://doi.org/10.1016/j.geomorph.2014.04.018

Staley, D. M., Negri, J. A., Kean, J. W., Laber, J. L., Tillery, A. C., & Youberg, A. M. (2017). Prediction of spatially explicit rainfall intensity–duration thresholds for post-fire debris-flow generation in the western United States. *Geomorphology*, *278*, 149–162. https://doi.org/10.1016/j.geomorph.2016.10.019