Eastern Oregon Steep Slopes: Scoping Proposal

Independent Research and Science Team

Institute for Natural Resources – Oregon State University

Scoping Proposal

Submitted to

The Adaptive Management Program Committee

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Authors

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Prepared by

The Institute for Natural Resources

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Disclaimer

This scoping proposal is submitted to the Adaptive Management Program Committee as a requirement of the Oregon Department of Forestry Adaptive Management Program rules (Chapter 629, Division 603).

The contents of this report reflect the views of the Independent Research and Science Team (IRST), which is solely responsible for the facts and accuracy of the material presented. This scoping proposal does not constitute a standard, specification, or regulation.

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Abbreviations and Acronyms

AI	Artificial intelligence
AMPC	Adaptive Management Program Committee
BGO	Biological, Goals, and Objectives
CEE	Collaboration for Environmental Evidence
CMER	Washington State's Cooperative Monitoring, Evaluation, and Research Committee
EMC	California's Effectiveness Monitoring Committee
HCP	Habitat Conservation Plan
INR	Institute for Natural Resources
IRST	Independent Research and Science Team
OSU	Oregon State University
PFA	Private Forest Accord
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
ROSES	RepOrting standards for Systematic Evidence Syntheses

Executive Summary

COMPLETE AFTER IRST MEETING

The Independent Research and Science Team (IRST) was established to support the work of the Oregon Department of Forestry Adaptive Management Program Committee (AMPC) by responding to AMPC-developed research question packages. The AMPC submitted preliminary research questions pertaining to Eastern Oregon. They were:

> Overarching Question: What impact do hillslope processes have on the covered species included in the draft HCP and their habitats in Eastern Oregon?
>
> - Primary Focus: What does the literature say about upslope initiated shallow rapid slides and how timber harvesting may impact these in Eastern Oregon environments?
> - Secondary Focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft Habitat Conservation Plan (HCP) and are these processes changed by forest practices?

Amphibians and salmonids are the species relevant to the overarching question.

The IRST was asked to prepare a research scoping proposal framing how these questions could be addressed using literature reviews, which would include assessment of the robustness of conclusions based on the literature and identification of key gaps that may prompt the need for additional research. Through the Institute for Natural Resources (INR) – the housing agency of the IRST – the IRST conducted a scoping review to characterize the potential amount and nature of the existing scientific literature that is available for a literature review. The scoping review described the extent, geographic range, and nature of research activities in the available literature. The scoping review was intended to support the development of a research proposal package that will inform the AMPC and Board of Forestry decisions about the utility of soliciting a further literature review or research via requests for proposals.

Seven systematic searches were performed across three database sources, plus two document repositories were scanned, and a more traditional search performed. Approximately 141 documents were screened (not including the Google search; leaving many more unread), resulting in 39 documents that were found to have potential relevance to the research questions. Of those documents, 20 were potentially relevant to the primary focus research question, four to the secondary focus question, and 19 as potentially relevant to mass wasting processes on forested lands but not including forest harvest-related practices.

Primary Focus. A total of 20 publications were deemed potentially relevant to the primary focus question and included content on hillslope processes and shallow rapid slides; three of these publications were studies focused in eastern Oregon and two of the publications were focused in eastern Washington.

Secondary Focus. Four publications were relevant to the secondary focus question and included content on mass wasting processes apart from shallow rapid landslides, such as more deep-seated earthflows, slumping, and soil bulking debris flows. Two publications described studies in Idaho; two throughout the western United States, and one was in British Columbia. All four publications included information about hillslope processes, four included information on including forest harvesting impacts, four included studies in semi-arid forest environments, and one included mention of aquatic species and fire.

....

~~The results of the initial scoping literature review indicate that limited information exists that describes the interactions among forest harvest, shallow rapid slides or other hillslope processes and the covered species. Therefore, we do not suggest developing and executing an RFP for an additional literature review.~~

1. Introduction

1.1 Background and Project Purpose

The Independent Research and Science Team (IRST) was established via Senate Bill 1501 as part of the Oregon Department of Forestry's Adaptive Management Program. The IRST supports the work of the Adaptive Management Program Committee (AMPC) by responding to AMPC-developed research questions packages. Per rule, and in consultation with the AMPC, the IRST refines preliminary research questions into final research questions, then develops scoping proposal(s) to address those questions. The scoping proposal(s) need(s) to include:

- A literature review that specifies the need for, or the type of, monitoring, research, commissioned studies, or other means of scientific inquiry necessary to answer the finalized research questions mentioned above;
- A preliminary estimate of the budget for each year of the research, and a timeline to complete the research project with specific deliverables; and,
- A preliminary description of research project requirements, scope of work including an estimate of the timeline and key milestones, and an estimate of the degree to which knowledge may be improved if the research proposal is implemented.

As per OAR 629-603-0200, the IRST develops requests for proposals (RFP) in an open, competitive process after the AMPC and Board of Forestry approve an AMPC research agenda that is based on IRST scoping proposal(s). See Figure 1.

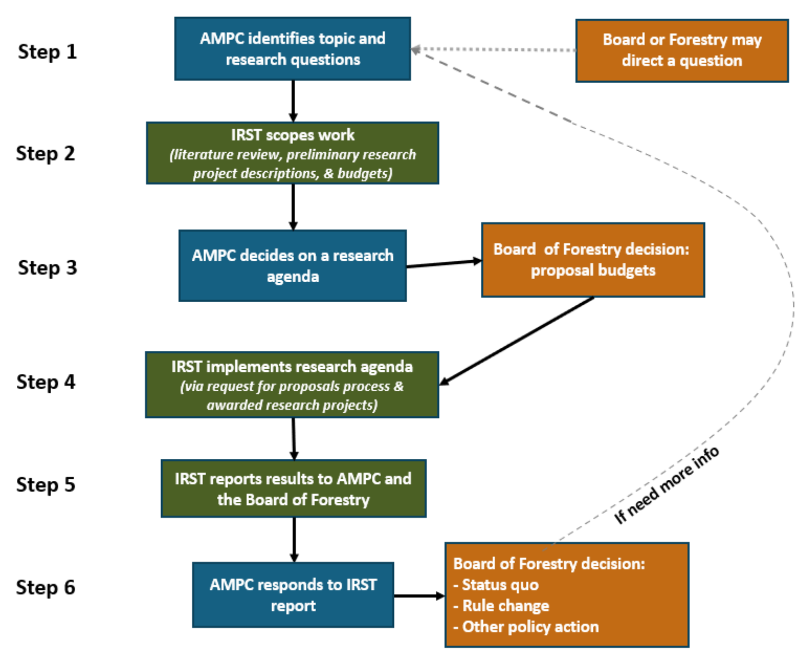

Figure 1. Adaptive Management Process.

With these requirements, the purpose of this effort was to conduct a scoping review that provides an initial characterization of the potential amount and nature of existing literature in relation to the AMPC research questions (see section 1.2) and to determine if there are enough publications to warrant a full literature review through the required RFP process.

1.2 Research Questions

On July 11, 2024, the AMPC submitted the research questions package (Appendix A) pertaining to the geographic region [1] of Eastern Oregon. The IRST was asked to address the questions using literature reviews, assess the robustness of conclusions based on the literature, and identify key gaps that may prompt the need for additional research.

Overarching Question: What impacts do hillslope processes have on the covered species in the draft HCP and their habitats in Eastern Oregon?

- Primary Focus: What does the literature say about upslope initiated shallow rapid slides and how timber harvesting may impact these in Eastern Oregon environments?
- Secondary Focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft Habitat Conservation Plan (HCP) and are these processes changed by forest practices?

1.3 Types of Literature Reviews

Different types of literature reviews have been described. Those most relevant to preparing a scoping proposal are briefly described here. Unless otherwise noted, much of the text below is summarized from the National Library of Medicine (2017):

Scoping reviews, such as the one conducted for this scoping proposal (see below), provide an initial assessment of the potential amount and nature of the extant literature on an emergent topic. A scoping review may be conducted to examine the extent, range and types of studies in a particular area to determine the value of undertaking a more comprehensive review or to identify research gaps in the available literature (Paré et al., 2015). Scoping reviews are intended to broadly characterize the information related to a particular question or set of questions and so consider non-peer reviewed "grey literature" such as working papers, technical reports, and conference proceedings. Inclusion and exclusion criteria are established to help eliminate literature that is not relevant to the question(s) being examined. Consistent with their main objective, scoping reviews usually conclude by presenting an agenda for future work along with potential implications for both practice and research.

Narrative reviews tend to be mainly descriptive and often focus on a subset of studies in an area chosen based on availability or author selection. A narrative review summarizes or synthesizes what has been written on a particular topic but does not seek generalization or cumulative knowledge from what is reviewed. This type of review is found in the Introduction section of peer-reviewed journal articles that report on research studies.

[1] Note: The Oregon Department of Forestry maintains a regulatory Geographic Information Systems layer of the Forest Practices Act delineation between eastern and western Oregon.

Descriptive Reviews determine the extent to which a body of knowledge on a particular topic reveals any interpretable pattern or trend with respect to pre-existing propositions, theories, methodologies or findings. Descriptive reviews typically provide a qualitative, narrative summary of the relevant literature. An example of a descriptive review is provided by "Literature Review: Effects of Salvage Logging on Riparian Zones in Coniferous Forests of Eastern Washington and Adjacent Regions" (Barrett and Reilly 2017). Descriptive reviews follow a systematic and transparent procedure, including searching, screening and classifying studies but they exclude a critical appraisal of study methods for quality. Structured search methods are used to form a representative sample of a larger group of published works. Extracted from each study are certain characteristics of interest, such as publication year, research methods, data collection techniques, and direction or strength of research outcomes (e.g., positive, negative, or non-significant). These are presented in the form of frequency analysis to produce quantitative results. Each study in a descriptive review is treated as a unit of analysis and the published literature as a whole provides a database from which the authors attempt to identify any interpretable trends or draw overall conclusions about the merits of existing conceptualizations, propositions, methods or findings.

Systematic reviews apply explicit and reproducible methods to systematically search, aggregate, critically appraise study validity, and synthesize all empirical evidence that meets a set of previously specified eligibility criteria to answer a clearly formulated and often narrow research question on a particular topic to support evidence-based practices. Two of the better-known systematic literature review protocols developed for the field of environmental management are the Collaboration for Environmental Evidence (CEE 2022) and the RepOrting standards for Systematic Evidence Syntheses (ROSES, Haddaway et al. 2018). These build on methods developed in the 1980s to enhance objectivity and rigor in synthesis of studies in clinical medicine and are used extensively in the context of biomedical research (e.g., Page et al. 2021; Higgins et al. 2024). Systematic reviews typically seek to identify causation or the effectiveness of a specific intervention by aggregating and synthesizing results from similar studies in the primary literature. A detailed and comprehensive plan and search strategy derived a priori are applied with the goal of reducing bias. Often, systematic reviews include a meta-analysis component, which uses statistical techniques to synthesize the data from several similar studies into a single quantitative estimate or summary effect size (CCE, 2022). The recent systematic review conducted by the Oregon Department of Forestry is a useful illustration. Its purpose was "to determine whether the post-catastrophic event alternative vegetation retention prescriptions described in Oregon Administrative Rules (OAR) 629-643-0300(3) are effective in avoiding, minimizing, or mitigating effects on riparian areas and aquatic habitat" (Thompson et al. 2024). The review by Thompson et al. generally followed CEE protocol but recommendations for publications were requested from external experts in addition to those discovered by systematic searching and some of the more time-consuming procedures required for a systematic review were excluded.

Systematic maps retain many of the methodological requirements and benefits of systematic reviews but offer greater flexibility (Haddaway et al. 2016). For example, systematic maps are useful for addressing a wider array of questions, can include more types of studies (e.g., primary, secondary, quantitative, or qualitative), and are intended to identify knowledge gaps. Systematic mapping aims to collate, describe, and catalogue available evidence relating to a topic of interest prompted by an open-framed question, such as the primary and secondary focus questions above. Open-framed questions are appropriate for synthesizing broad areas of science that have not been extensively studied and about which the key structural elements (e.g., population (P), intervention

(I) or exposure (E), comparator (C) and outcome (O)) needed to support a systematic review cannot be specified. ~~These elements comprise the closed-framed questions that are necessary to aggregate and synthesize results from similar studies in a systematic review.~~ Thus, a systematic map summarizes and describes the existing evidence related to an open-framed question versus pooling together results of closely related individual primary studies to examine the overall effect through a systematic review (Haddaway et al. 2018).

Rapid reviews are "a form of knowledge synthesis that accelerates the process of conducting a traditional systematic review through streamlining or omitting a variety of methods to produce evidence in a resource-efficient manner (Smela et al 2023)." Similar time-saving modifications also can be applied to systematic maps. Although it may increase bias, one of the more common modifications is to have only one reviewer, rather than two or more independent reviewers, consider and extract information from each publication. Limiting the number of databases searched can also help accelerate the process but may return fewer publications, posing concerns about the reliability and validity of the results. Less effort can be expended in the stage during which the (optional) critical appraisal of study validity is undertaken, however lower quality studies with less reliable findings may be included that may influence conclusions drawn from evidence synthesis.

1.4 Search strategies

To achieve as rigorous of a review as possible, regardless of the type of review, literature searches that are transparent and reproducible will help reduce bias. Literature searches aim to be as extensive as possible to capture all available studies relevant to the research questions, striving for comprehensiveness (sensitivity) while maintaining relevance (precision).[2] Precise or focused searches retrieve fewer irrelevant results but have a higher risk of missing relevant literature. Sensitive or broad searches retrieve more documents but ~~may~~ return more irrelevant results. Increasing the comprehensiveness or sensitivity of a search will reduce its precision and retrieval of relevant studies. The sensitivity and precision of a search strategy are determined by the search concepts and terms. The more concepts that are added to the strategy with Boolean terms, such as AND, the more precise and fewer results. The more search terms or synonyms that are added to the strategy with OR, the greater the sensitivity and more results.

[2] https://laneguides.stanford.edu/LitSearch/step4

2. Scoping Review

2.1 Introduction

This scoping review, as the first step in developing the eastern Oregon steep slopes proposal, was undertaken to help determine the value of contracting a more in-depth review and/or identify gaps in the existing literature (Paré and Kitsiou 2016). It is intended to serve, not as a comprehensive literature review, but rather to understand which literature might be available to support the development of a research proposal package and help the AMPC determine next steps in investing resources.

This scoping review does not directly address the broad, overarching question in Section 1.2. Instead, for the primary focus question, the scoping review provides a preliminary indication of the existing scientific research available that could potentially determine if shallow rapid slides are prevalent enough to be an important driver of stream habitats in eastern Oregon and if forest harvest is likely to influence characteristics (e.g., initiation rate, size, runout distance) of these slides. The scoping review uses a similar approach for the secondary focus question but considers other potentially important mass wasting processes and the influence of forest practices on these processes. Consistent with Appendix A, Section 3.3.8 from the Private Forest Accord Report (2022), the only hillslope processes considered for the secondary focus question are related to mass wasting.

2.3 Methods

This scoping review used a systematic search strategy and traditional literature searches to assess the amount and nature of existing literature that may be available to subsequently answer the AMPC's primary and secondary focus questions (Section 1.2) via a more comprehensive review.

Search strategy

The search strategy was adopted by INR with input and revisions from the IRST. Searching was conducted from September to December 2024.

Systematic search

The systematic search for potentially relevant literature was conducted using three electronic literature databases

(Web of Science, Google Scholar, and the OSU Scholars Archive)

The core topic areas and search terms were derived from the research questions (Table 1).

Table 1. Core topic areas and search terms.

Core Topic Area	Search Terms
Hillslope processes-mass wasting	mass wasting, "debris flow", landslid*, landslide, "debris slide", "hillslope process"
Environmental similarity to eastern Oregon	semi-arid, east, eastern, eastside, "eastern Oregon", Oregon, "eastern Washington", Washington, Idaho, Montana,

	Wyoming, Colorado, Utah, Nevada, Oregon, California, “British Columbia”, OR “Sierra Nevada” OR Alberta
Forest harvest-related activities	forest
HCP covered species and their habitats	*(No specific terms were searched for, rather this topic was used in the review)*

Because of the paucity of literature directly addressing eastern Oregon in our initial search, we broadened the search terms to include other western states with environments that are similar to eastern Oregon.

Search terms were combined in searches using Boolean operators. Examples include: forest* AND hillslope AND (arid OR semi-arid OR dry), hillslope AND (trout OR salmon* OR salamander) AND (eastern AND (Oregon OR Washington)). Given guidance in the PFA Report (Appendix X), search terms related to “roads” as a forest-harvest activity were not considered.

Traditional searches

We also conducted traditional searches, which included searching with the Google search engine, mining references from relevant publications, soliciting the IRST for known publications, and examining repositories of two related programs for potentially relevant publications. The two repositories examined were Washington State’s Cooperative Monitoring, Evaluation, and Research Committee (CMER) and California’s Effectiveness Monitoring Committee (EMC).

For the Google search, the search terms “debris flows”, “landslides”, “mass wasting”, “semi-arid”, “steep slopes”, “hillslopes,” “forest practices”, “forest management”, “lumbering”, and “timber harvest” were input in combination with: a) individual names of four mountain ranges in eastern Oregon (specifically, Ochocos, Blue, Wallowa, and Strawberry); b) individual western state names of Idaho, Montana, Washington, Oregon, Utah, Colorado, and Wyoming; and, c) individual eastern Oregon national forests (specifically, Wallowa-Whitman, Deschutes, Malheur, Ochoco, and Umatilla). Not all eastern Oregon mountain ranges, federal lands, or national forests were included in this scoping effort.

Review strategy, inclusion criteria, and relevance

Consistent with the *Standards for Best Available Science: A Guidance Document* produced by the IRST, the potential relevance of each study was assessed based on the level of congruence between the study subject matter and the research questions of interest as well as the spatial and temporal scales of a study versus the research questions of interest (including location of each study). Three of the four core topic areas were considered to be essential inclusion criteria for determining potential relevance to the AMPC questions (Table 2). The fourth, HCP covered species and their habitat, was not considered essential because studies meeting the other criteria could be connected to species impacts via the processes described in the draft HCP biological goals and objectives (Appendix A, Section B.2).

Table 2. Core topic areas and related keywords for review.

Core Topic Area (Inclusion Criteria)	Related Keywords
Hillslope processes-mass wasting	shallow rapid slides/landslides, landslides, debris flows, mass wasting, hillslope failure, slope stability, soil bulking, geologic mapping, geologic-mapped landslides, landslides with geologic map

Environmental similarity to eastern Oregon	semi-arid systems, arid systems, dry-side, arid environments, snow-dominated systems
Forest harvest-related activities	timber harvesting, harvest, clear cutting, thinning, fire, fuel treatment
HCP covered species and their habitats	aquatic & riparian biota, cutthroat trout, bull trout, rainbow trout, salmonids, salmon, Torrent salamander, Giant salamander

The results of INR's systematic searches using the electronic databases (e.g., Google Scholar and Web of Science) were reviewed to identify literature documented to date and to help inform conceptual saturation (i.e., the point where the same citations were being referenced on a regular basis or where no new potentially relevant literature was identified during any one search (e.g., search that included a particular state name or eastern Oregon national forest)). Types of literature reviewed included peer reviewed journal articles, dissertations and theses, government office or agency reports, technical reports, conference proceedings, and book chapters.

For the systematic searches, the first 20 results from each search were screened by INR staff for potential relevance to the four core topics by reading the abstracts or introductions, and searching keywords within each document (Table 2).

If there were fewer than 20 search results, all were screened. If the abstract of an article indicated the content of the article was potentially relevant to the primary or secondary focus questions, the conclusion was read. If the conclusion of the article informed at least one of the focus questions, the entire article was skimmed for potential relevance to the two questions.

All the documents in the repositories of two programs similar to the AMP were screened for relevance (Washington State's Cooperative Monitoring, Evaluation, and Research Committee (CMER) and California's Effectiveness Monitoring Committee (EMC)). Titles were screened first, and if these seemed relevant, the full document was screened the same way as was done for the literature from the database search results. If an article in a repository was potentially relevant, the references were skimmed. Potentially relevant articles were identified, downloaded, and reviewed using the process described for systematic searches to determine relevance and inclusion in literature review results. In numerous cases, articles in references cited led to other articles in which the content relevance led to review of references listed in those articles; these were in addition to the top 20 articles from the database searches. Documents that did not address any of the first three inclusion criteria were dropped.

Data extraction

When potentially relevant literature was found via any of the above search and review processes, the reference was entered into an Excel spreadsheet, along with a Yes/No indication for each of the screening criteria and questions addressed. The general location and text clips of the potentially relevant content were also recorded. These metadata were used to generate document counts by various categories.

2.4 Findings

General characterization of the publications

Seven systematic searches were performed across three database sources, plus two document repositories were scanned, and a more traditional search performed (Table 3). Approximately 141 documents were screened (not including the Google search); very few of the top 20 results from the different literature database searches were found to be potentially relevant to the research questions. In total, 39 documents were found to have potential relevance to the research questions. A number of documents were found that focused on mass wasting after wildfires or in a historical context, but without any direct connection to forest management. These were seen as containing potentially useful context information and so were assigned to a third category (apart from questions 1-2) named "process relevant". Of those documents, 20 were potentially relevant to the primary focus research question, four to the secondary focus question, and 19 as potentially relevant to mass wasting processes on forested lands but not including forest harvest-related practices. Abstracts or summaries of the potentially relevant literature can be found in Appendix B and C.

The greatest number of potentially relevant articles were detected using a traditional search (Google search engine) for one or more terms and following the leads to different types of publications.

Table 3. Search results.

Source	Search Terms Strings	Total Articles	Articles Examined	Q1 Relevant Articles	Q2 Relevant Articles	Process Relevant[3]
Google Scholar	mass wasting OR "debris flow" forest semi-arid	7,170	20	1	0	1
Google Scholar	landslide forest Idaho OR Montana OR Wyoming OR Colorado OR Utah OR Nevada	41,200	20	3	1	3
Google Scholar	landslide forest "eastern Oregon" OR "eastern Washington"	4,280	20	2	0	0
Web of Science	(landslid* OR "debris flow") AND (Oregon OR Washington OR California OR "British Columbia") AND (east OR eastern OR eastside) AND forest*	10	10	0	0	0
Web of Science	(landslid* OR "debris flow") AND (Idaho OR Montana OR Wyoming OR Colorado OR Utah OR Nevada OR "Sierra Nevada" OR Alberta) AND forest*	31	20	1	0	4
OSU ScholarsArchive	forest AND (landslide OR "mass wasting" OR "debris flow" OR "debris slide" OR "hillslope process")	1	1	0	0	0
OSU ScholarsArchive	landslide OR "mass wasting" OR "debris flow" OR "debris slide" OR "hillslope process"	5	5	0	0	0

[3] "Process relevant" articles are not referenced in the body of the report; however, they are in the references (Section 5) indicated by the authors' names being in red italic font. Abstracts or summaries of these articles appear in Appendix D.

CA BoF EMC	[reviewed projects list on website]	18	18	0	0	0
WA CMER	[reviewed publications list on website]	27	27	1	0	0
Google Search + Reference Mining		NA	NA	10	3	11
IRST Contributions		2	2	2	0	0
Totals			**141**	**20**	**4**	**19**

The following chart (Figure 2) depicts the number of potentially relevant publications (39) in 25-year increments:

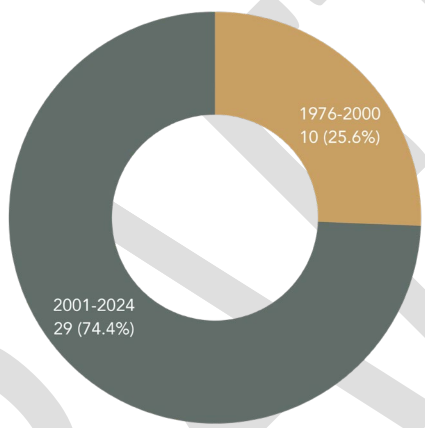

Figure 2. Number and percent of potentially relevant publications by publication year.

Figure 3 shows where the studies were located and Table 4 shows which studies were in eastern Oregon.

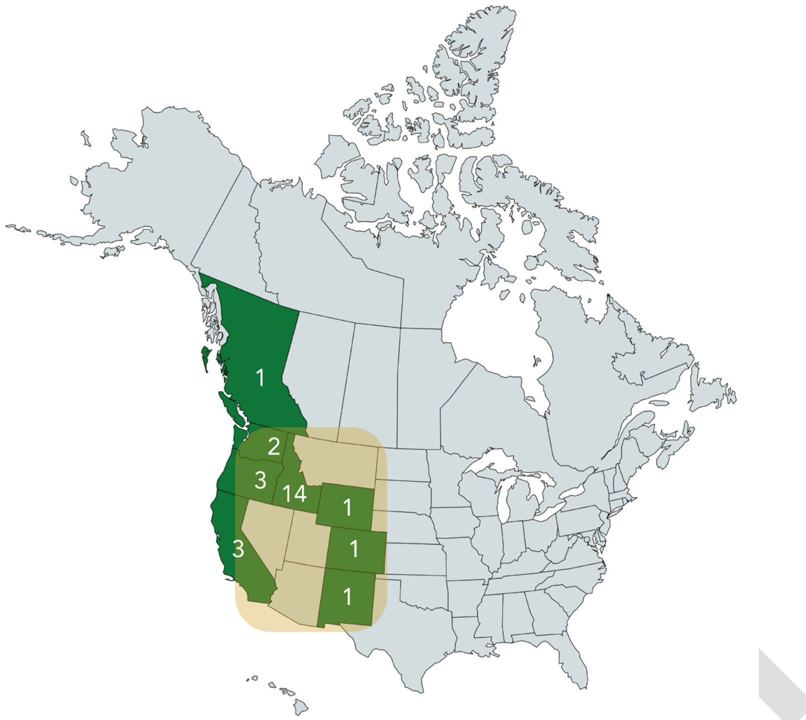

Figure 3. Location of 39 studies included in eastern Oregon steep slopes scoping review by state and province. In addition to locations depicted on the map, 12 studies were located in the western United States (depicted by tan box) and one study included numerous locations not specific to any state, province, or region.

Table 4. Studies located in eastern Oregon.
Fitzgerald, J., and C. Clifton 1997. Flooding, land use, and watershed response in the Blue Mountains of northeastern Oregon and southeastern Washington. In: Inland Northwest Water Resources Conference, Program and abstracts. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5208929.pdf
Halofsky, J.E. and D.L. Peterson. 2017. Climate change vulnerability and adaptation in the Blue Mountains region. Pacific Northwest Research Station General Technical Report, PNW-GTR-939. 331 p. https://doi.org/10.2737/PNW-GTR-939
Wondzell. S.M. 2001. The influence of forest health and protection treatments on erosion and stream sedimentation in forested watersheds of eastern Oregon and Washington. *Northwest Science* 75:128-140. https://rex.libraries.wsu.edu/esploro/outputs/journalArticle/The-influence-of-forest-health-and/99900501658801842

In addition to location, each study was assessed to determine its potential relevance to core research question topics (Figure 4):

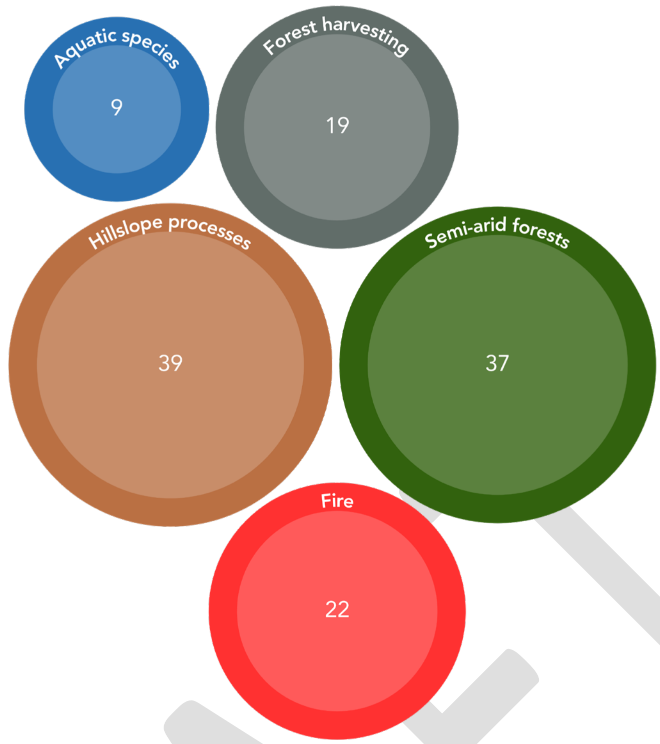

Figure 4. The 39 studies in the eastern Oregon steep slopes scoping review included information on mass wasting-related hillslope processes (39), semi-arid forests (37), forest harvesting (19), fire (22), and aquatic species or habitats (9).

Characterizing the publications in relation to the AMPC questions

Primary focus: What literature exists relating to upslope initiated shallow rapid slides and how timber harvesting may impact these in eastern Oregon environments?

A total of 20 publications (Table 5) were deemed potentially relevant to the primary focus question and included content on hillslope processes and shallow rapid slides; three of these publications were studies focused in eastern Oregon and two of the publications were focused in eastern Washington.

Abstracts or summaries of the potentially relevant literature can be found in Appendix B.

Table 5. Publications potentially relevant to the primary focus.

Publication	Location	Forest harvesting	Hillslope-mass wasting	Semi-arid	Aquatic species	Fire
Fitzgerald and Clifton (1997)	Eastern Oregon					
Halofsky and Peterson (2017)						
Wondzell (2001)						
Harp et al. (1996)	Eastern Washington					
Klock and Helvey (1976)						
Gorsveski et al. (2006)	Idaho					
Istanbulluoglu et al. (2004)						

Ketcheson et al. (1999)						
Lineback Gritzner et al. (2001)						
McClelland et al. (1999)						
Megahan et al. (1978)						
Platts et al. (1989)						
Goode et al. (2012)	Western U.S.					
Herrera Environmental Consultants (2004)						
Luce et al. (2012)						
McGreer et al. (1998)						
Peterson et al. (2009)						
Wondzell and King (2003)						
Jordan et al. (2010)	**British Columbia**					
Sidle (2005)	**Various**					

All 20 publications included content relating to hillslope processes, 19 articles included content relating to forest harvest-related practices, and 20 articles included information about semi-arid forest environments. Six of the 20 publications referenced aquatic species and eight included content regarding fire. Forest harvest-related topics included skid trails, logging with ground-based equipment and cable yarding, fuel treatments, stand density management, regeneration, preventing damage from disturbance, clearcutting, and harvest methods that (a) increase soil moisture levels, ~~(b) significantly increase hydrologic sensitivity of a watershed,~~ (b) reduce the accumulation of debris within the stream channel, and (c) minimize disturbance to understory vegetation.

The eight publications that included content on wildfire characterized potential sediment yield change in semi-arid basins influenced by wildfire, the potential consequences to aquatic habitats and/or species, and forest management strategies to mitigate sediment yields and lessen ecological disturbance from wildfire; prevention or control of wildfire to reduce the probability of debris torrents; the causes of post-fire debris flows (initiation by landslides, initiation by bulking during gully erosion); and factors contributing to the degree of post-wildfire forest harvest (e.g., patterns of burn severity, operational aspects of tree removal)

The six publications that included content on aquatic species are briefly described here:

- Halofsky and Peterson (2017), in a climate change vulnerability assessment for the Blue Mountains national forests, suggested that landslides and debris flows following wildfires are an issue based in this area of eastern Oregon. They do not specifically link forest harvesting to mass wasting processes, but they do mention the potential for climate change to affect mass wasting impacts on aquatic species and recommend the need for debris flow / landslide hazard mapping as part of post-fire response approaches.
- Luce et al. (2012) described the nexus among physical processes, biological interactions, and management decisions as well as potential interactions of fish populations with wildfire.
- McClelland et al. (1997) investigated the extent of mass wasting in the Blue Mountains of eastern Washington after a severe rainfall event in 1996. They described the relative abundance and volume of sediment delivered by landslides and debris flows associated with natural areas (no

management), roads, and timber harvest, and described “aquatic habitat parameters” that either degraded, were unchanged, or improved because of flooding or flooding with landslide sediment.

- McGreer et al. (1998) summarized results of mass wasting analyses of 23 watersheds in forested areas of eastern Washington, Idaho, and western Montana. In the original studies, landslide inventories were used to associate geology, geography, and forest management activities (both road- and non-road-related) with mass wasting events and their potential effects on aquatic resources, per the State of Washington’s Watershed Analysis process.
- Peterson et al. (2009) assessed the effects of post-fire logging based on the biophysical setting of the forest, pattern of burn severity, operational aspects of tree removal, and other management activities (e.g., removal of snags, road construction, logging with ground-based equipment, cable yarding) in dry forests of the western United States. They describe potential effects on aquatic systems and species in relation to the intensity and extent of post-fire logging.
- Platts et al. (1989) documents sediment delivery to spawning and rearing areas for Chinook salmon and Steelhead, noting logging and road construction, in combination with large storm events in a two-year period, resulted in increased amounts of fine sediment delivery to an Idaho River.

Secondary focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft Habitat Conservation Plan (HCP) and are these processes changed by forest practices?

Four publications (Table 6) were deemed potentially relevant to the secondary focus question and included content on mass wasting processes apart from shallow rapid landslides, such as deep-seated earthflows, slumping, and soil bulking debris flows. Two of these publications were studies in Idaho; two were in the western United States, and one was in British Columbia. All four publications included information about hillslope processes, three included information on forest harvest, three included studies in semi-arid forest environments, and one included mention of aquatic species and fire.

Abstracts or summaries of the potentially relevant literature can be found in Appendix C.

Table 6. Publications potentially relevant to the secondary focus.

	Location	Forest harvesting	Hillslope-mass wasting	Semi-arid	Aquatic Species	Fire
Lineback Gritzner et al. (2001)	Idaho					
Megahan et al. (1978)						
Luce et al. (2012)	Western U.S.					
Jordan et al. (2010)	British Columbia					

Other process relevant studies

Nineteen documents found were classified as “process relevant,” that is, they were focused on mass wasting on forestlands but without any direct connection to forest management activities. They are summarized here because they demonstrate the role that mass wasting can play post-wildfire, and that the processes driving these post-fire landslides can include forest management activities. The largest number of studies came from Idaho (7), followed by studies spanning multiple western states (6); three were located in California and one each in Colorado, Wyoming, and New Mexico. None were located in eastern Oregon or Washington. By definition, none of these addressed forest harvest activities but all addressed hillslope processes and all overlapped with semi-arid environments. Most of these studies (14) involved investigations of post-wildfire surficial erosion and mass wasting.

Studies with potentially useful literature review methods

Two literature reviews were found (Barrett and Reilly 2017; Herrera Environmental Consultants Inc. 2004) that described methods that could be useful in conducting a comprehensive literature review. Herrera (2004) included both project initiation and mid-project workshops in which information and feedback was solicited from broader user groups, whereas Barrett and Reilly (2017) gave a final presentation to the sponsoring group. Both reviews were focused on eastern Washington, but because of the paucity of literature directly addressing this area, they broadened their searches to similar environments in other western states and Canada. Both reviews researched literature databases and solicited documents from subject matter experts. These 2 reviews are also useful for estimating the time and cost of this type of work. Further details on the review steps used in each of these literature reviews can be found in Appendix D.

2.5 Insights

The scoping review provided an indication of the ~~potential~~ size, nature, and relevance of the existing potential literature to the primary focus and the secondary focus of the AMPC research questions. Implementing a combination of systematic and traditional literature searches, including scanning the bibliographies of potentially relevant literature and soliciting relevant literature from experts, yielded 39 publications.~~ of which only three, or 8%, were conducted within eastern Oregon.~~ Three publications (8%) reported results from eastern Oregon.

Some ~~of the most~~ relevant studies ~~came from the~~ were grey literature~~—sources that include information~~ that was produced outside of traditional commercial, academic, ~~and other~~ or publishing ~~and distribution~~ channels, and may not be peer-reviewed. Examples include working papers, technical reports, conference proceedings, or oral presentations. Grey literature may be more effectively found through additional exploration via citations from existing papers and discussions with experts (both academic and practitioners). Existing literature reviews could be mined to identify additional publications ~~for further studies to review~~. ~~However, based on the scoping review, the IRST does not expect many more studies that have been conducted in eastern Oregon specific to the research questions to be discovered.~~

The search for literature conducted for this scoping review was not exhaustive and was not intended to be a full synthesis of existing information relative to the Research Questions. Thus, a more comprehensive search that includes other search terms may incorporate publications not considered here. A subsequent literature review would synthesize across the best available science and has the potential to develop different conclusions than the scoping insights that follow. However, the IRST does not expect expanded searches to discover substantially more studies conducted in eastern Oregon and specific to the research questions to be discovered. Based on the limited amount of literature identified and presented earlier, we provide the insights from the scoping review.

1. The scoping review identified few published studies that addressed the research questions, and only Fitzgerald and Clifton (1997) explicitly examined mass wasting in eastern Oregon.
2. In-unit (vs. road-related) shallow-rapid landslides and associated debris flows have occurred in eastern Oregon. Many of the relevant publications reported findings from mass wasting that occurred in northeastern Oregon, southeastern Washington, and Idaho following an intense storm event in February 1996.

3. Several landslide inventories generally indicated that fewer landslides and debris flows occur in arid and semi-arid environments east of the Cascade Mountain Crest compared to west of the Crest.
4. The factors that drive debris flows in eastern Oregon appear similar to those that drive debris flows and other forms of mass wasting in western Oregon, which include steepness of slopes and heavy precipitation.
5. The effects of changing climate and weather patterns on intensity and frequency of precipitation events and mass wasting in eastern Oregon are unclear but may be an important consideration for evaluating landslide susceptibility and risk to covered species in eastern Oregon. References included in the Scoping Review report that climate change impacts to precipitation, plant communities, and wildfires may also contribute to mass movement susceptibility.
6. The influence of timber harvesting on number and frequency of debris flows in semi-arid environments is less well- understood than on west side forests. Watershed Analyses of eastside basins of eastern Washington, Idaho, and western Montana explicitly examined the role of forest management on landslides. Landslide inventories conducted as part of these assessments may be a source of information for addressing the Research Questions. On the secondary question **ELLEN TO REWRITE THIS SECTION – do not include roads; include debris flows initiated by processes other than shallow rapid landslides prevalent in E. Oregon (soil bulking)**: "Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft Habitat Conservation Plan (HCP) and are these processes changed by forest practices" research suggests that other processes, including slope creep, shallow and deeper rotational slumps, and failures instigated by reactivating dormant mass movement by road construction or removal of stabilizing vegetation are present in eastern Oregon and similar landscapes, though not as prevalent as in "westside" landscapes.. (See, for example: Megahan 2021; or Swanson and Swanson 2020., Swanson and Swanson 1977, and Adams 1988) Gonsior and Gardner (1971) determined that the stability of both natural and constructed slopes steeper than 35 degrees is largely due to temporary sources of additional strengths such as live tree roots." Megahan, et al., 1978 reported that 60 percent of landslides studied in two areas of Idaho occurred on slopes of about 30 degrees while 90 percent of landslides were on slopes of less than 41 degrees.) Scalan (1988) reported that in the Dunnigan Creek area of Idaho, any slope over 30 degrees was potentially susceptible to landslides. Slope aspect is also recognized as a factor in mass movements (Prellwitz,1983). As in debris flow studies, there are few studies of these events in eastern Oregon, but others that review events in other, similar locations. However, mass movements other than rapid, shallow debris flows have significant potential to impact both landscape and ecosystems.
7. The impacts of debris flows and other hillslope processes on habitat characteristics or their influence on demographics and persistence of covered amphibian and fish species in eastern Oregon has not been researched extensively. Limited studies identified in the scoping review examined changes to in-stream habitat conditions following mass wasting events. Other studies from semi-arid regions broadly infer habitat responses to changes in sediment levels related to climate change, forest management practices, and in particular the frequency, extent and severity of wildfires (e.g., Goode et al. 2012, Halofsky et al. 2017, Luce et al. 2012). The eastside Watershed Analyses may contain information on fish habitat as related to mass wasting, but this has not yet been explored.

3. Scoping Proposal

3.1 Introduction

Although few studies that related forest harvest to mass wasting hillslope processes in eastern Oregon and similar environments were found in the IRST's initial scoping review, it is expected that additional relevant literature would be found with more intensive searching, particularly in grey literature and state-sponsored technical reports. Based on the results of this scoping review, four options are presented to address the AMPC research questions: 1) a full systematic mapping review following the Collaboration for Environmental Evidence (CEE) process, 2) a more rapid systematic mapping review following the corresponding CEE advice, 3) a more standard but less rigorous descriptive review, 4) a descriptive review of current results only, and 5) do not invest in further literature review. The following information describes these options in more detail.

3.2 Scoping proposal: Systematic map

Scope of work

TEXT BLOCK A (for consideration)

A systematic mapping approach, following the CEE process, could be used to more fully describe the extent, range, and nature of the literature on forest harvest practices related to hillslope processes in eastern Oregon and to identify potential knowledge gaps. Given that the Private Forest Accord (PFA) identified the differences in climates and geologies in eastern Oregon as important, part of the systematic mapping process could more fully describe these differences along with corresponding data sources. To best access grey literature, a list of organizational and individual experts should be developed and contacted. This option would have the most iterative interaction with the IRST, for example having IRST review the search and screening protocols, the experts contact list, initial search results, data coding plan, and draft final results. Screening and coding/analysis of publications would be done by multiple independent reviewers with checks for consistency. A full database of the publications found, including those accepted and rejected, and other coding fields would be delivered, as well as a list of accepted publications in Zotero or a common bibliographic interchange format (RIS, Bibtex).

The core elements, milestones, and timelines of the scope of work are documented in Figure 5, showing a maximum estimated duration of 18 months, not including administrative startup and closeout.

TEXT BLOCK B (for consideration)

A systematic mapping approach, following the CEE process, could be used to more fully describe the extent, range, and nature of the literature on forest harvest practices related to hillslope processes in eastern Oregon. The search could be designed to identify available susceptibility and/or risk models for hillslope mass wasting as well as acquiring and documenting empirical databases. These databases could be made available for use in future research, particularly in developing and calibrating new models for application in eastern Oregon if deemed appropriate. The results could be foundational in filling observed knowledge gaps. Given that the Private Forest Accord (PFA) identified the differences in climates and geologies in eastern Oregon, part of the systematic mapping process could describe these differences, corresponding data sources,. Similarly, a section related to the aquatic/riparian species of most concern and their habitat needs in relation to mass wasting processes could be included. To best access grey literature, a list of organizational and individual experts could be developed and contacted. IRST will review the search and screening protocols, the experts contact list, initial search results, data coding plan, and draft final results. This option could include workshops for input and broad participation, beyond iterative interaction with the IRST.

Screening and coding/analysis of publications would be done by multiple independent reviewers with checks for consistency. A full database of the publications found, including those accepted and rejected, and other coding fields would be delivered, as well as a list of accepted publications in Zotero or a common bibliographic interchange format (RIS, Bibtex). Critical appraisal of study validity and data would be described (e.g., model v. empirical datasets; experimental design v. opportunistic assessment; statistical analysis and sample size). Empirical databases that can be used for later model calibration and/or mapping purposes would be compiled and made available (possibly using GitHUB).

The core elements, milestones, and timelines of the scope of work are documented in Figure 5, showing a maximum estimated duration of 18 months, not including administrative startup and closeout.

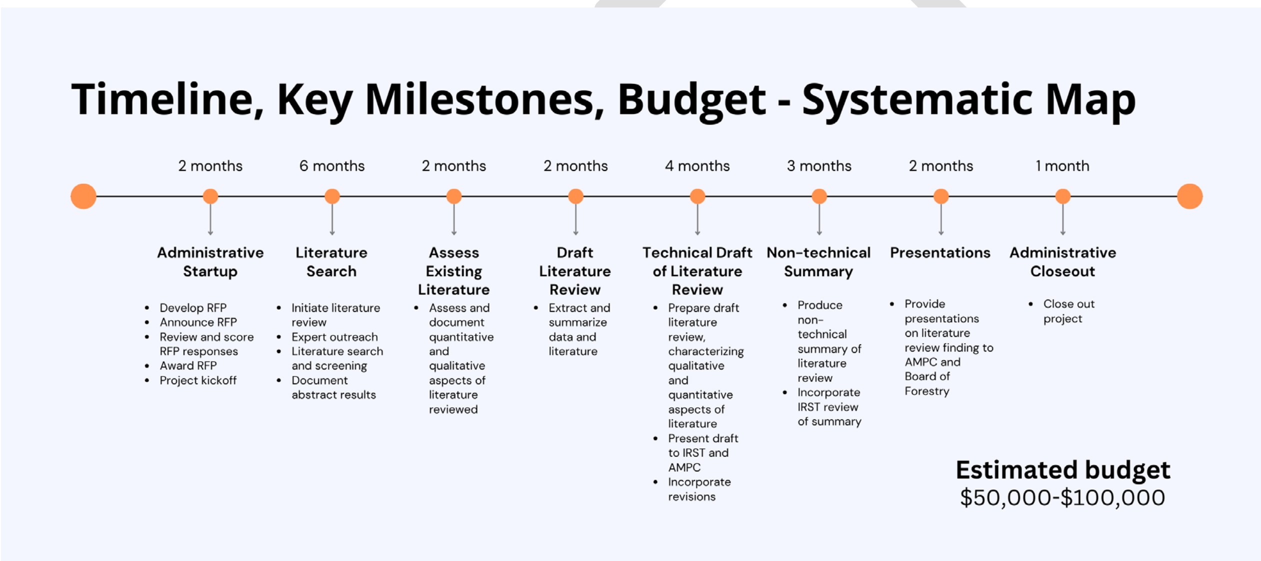

Figure 5. Timeline and key milestones for a systematic map.

Knowledge contribution

A systematic map is intended to inform the AMPC on the extent of knowledge about whether forest practices on private lands in eastern Oregon are affecting hillslope processes that in turn may affect HCP-covered species. A full mapping would be expected to uncover all the literature available on the topic, particularly the harder to find grey literature. It would identify important gaps and compile relevant empirical data that could be used in later analysis/research efforts (as in model calibration for landslide susceptibility/risk assessment). This option may also further describe the differences in the drivers of mass wasting processes eastside vs. westside, and what is known about related species habitat vulnerabilities on the eastside. This information on knowledge gaps and environmental condition differences could inform the need for future policy and research.

Budget

The estimated budget for the full systematic mapping review ranges from an estimated $50,000 to $100,000, excluding indirect costs which vary among institutions.

3.3 Scoping proposal: Rapid systematic map

Scope of work

Conduct a more rapid systematic mapping review following the corresponding CEE advice. The process would be simplified from the full option by:

1) Reducing review and inputs beyond the IRST (e.g., no external workshops);
2) Reducing the number of databases searched and experts consulted;
3) Relying on only one reviewer, rather than two or more independent reviewers, when screening and extracting information from each publication;
4) Limiting the critical appraisal of study validity;
5) A database of only the accepted publications, rather than also including those that were rejected, and;
6) No compilation of available empirical datasets.

The core elements, milestones, and timelines of the scope of work are documented in Figure 6, showing a maximum estimated duration of 4-8 months, not including administrative startup and closeout.

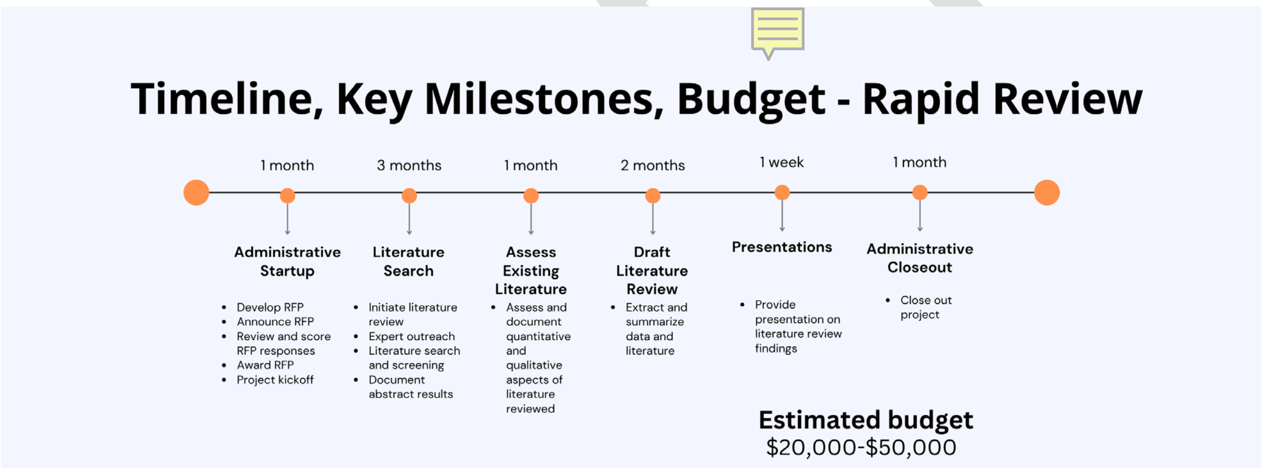

Figure 6. Timeline and key milestones for a rapid review.

Knowledge contribution

A rapid systematic mapping review should provide a ~~reasonable~~ collation of the ~~sparse~~ literature on this topic, but may not capture some of the grey literature that could be identified in workshops of subject experts ~~especially older studies or those from other states~~. The search and review process would be well documented for transparency and replicability, but relying only on one or two reviewers without consistency checking increases the potential influence of individual biases. Because relevant empirical databases will not be compiled, later use in model calibration for risk or susceptibility assessment will not be possible.

Budget

The estimated budget for the rapid review ranges from an estimated $20,000 to $50,000, excluding indirect costs which vary among institutions.

3.4 Scoping proposal: Descriptive review

Scope of work

A descriptive review would spend less effort on documenting a systematic and transparent procedure, but would still include a knowledge synthesis some information on searching, screening and classifying methods. ~~Less interaction with the IRST would be expected, perhaps just an initial discussion based on the original proposal and then a presentation and discussion of final results.~~ Multiple literature sources would be searched, but expert contacts ~~may or may not be included~~ would be limited. Characteristics of the review literature ~~interest~~ would be summarized, such as publication year, research methods, data collection techniques, and general research outcomes. ~~but an overall synthesis of findings may or may not be expected~~ No empirical data would be compiled; literature validity would not be assessed

The core elements, milestones, and timelines of the scope of work are documented in Figure 7, showing a maximum estimated duration of 3-6 months, not including administrative startup and closeout.

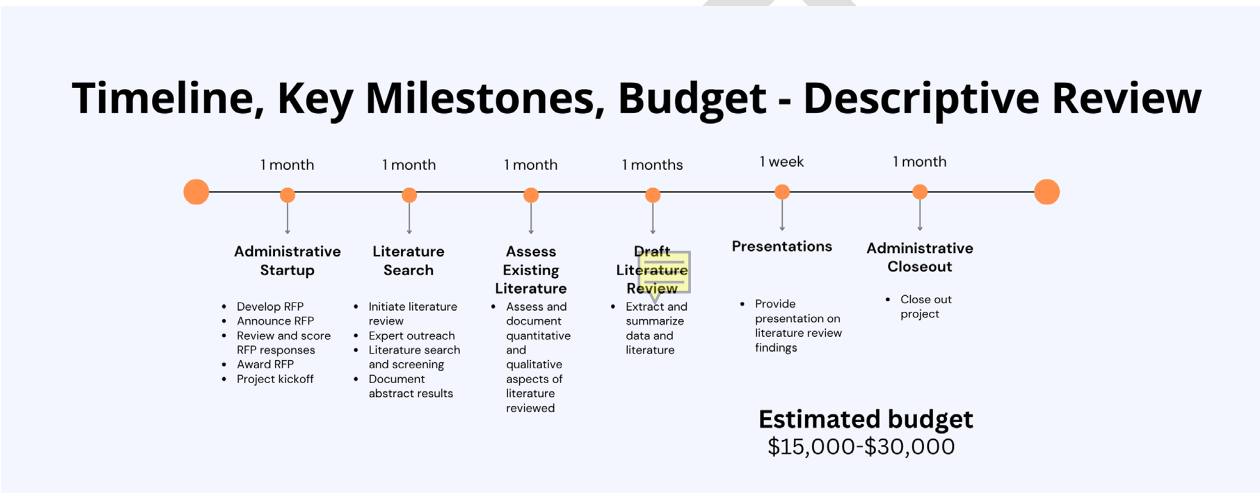

Figure 7. Timeline and key milestones for a descriptive review.

Knowledge contribution

As with the rapid systematic mapping, this option should provide a reasonable collation of the literature on this topic, ~~but may not capture some of the grey literature, especially older studies or those from other states~~ but will likely not capture some of the grey literature because the focus will be on peer-reviewed and journal published sources. The searching, screening and review methods would not be as thoroughly documented as in the full systematic map or the rapid review, so the product will be less transparent and replicable, so the product will be less transparent and replicable. ~~A synthesis of findings could be requested but would be more limited than for the full systemic mapping option~~. Only a narrative synthesis of findings would be presented without a quantitative summary of the literature. A data compilation for use in model calibration would not be produced.

Budget

The estimated budget for the narrative review ranges from an estimated $15,000 to $30,000, excluding indirect costs which vary among institutions.

3.5 Scoping proposal: No additional review

The results of the scoping review suggest that mass wasting can be an issue in eastern Oregon and can be influenced by forest removal by both management activities and natural disturbance. Although only 5 percent of the area of private lands in eastern Oregon has slopes exceeding 65 percent, a full characterization of the drivers that might render locations susceptible to mass wasting, how forest-harvest activities may affect susceptibility, and where covered species might be most at risk are not well represented in this cursory scoping review of the literature. This may indicate the absence of studies addressing such issues, but a more thorough search (e.g., including search terms of landslide susceptibility) and review process is likely to find additional policy relevant studies and help characterize.

3.6 Summary

Table 7 provides a summary of the scoping proposal options. The cost does not include indirect costs which vary among institutions; and the time does not include administrative start up and close out.

Table 7: Summary of scoping proposal options' costs and timeframes (excluding indirect costs and administrative startup and closeout time).

Option	Timeframe	Cost	Knowledge Contribution
Full systematic map	12-18 mo.	$50,000-$100,000	This option would identify important knowledge gaps, compile any existing data for future use, and further describe differences in the drivers of mass wasting processes east vs. west of the Cascade Mt. crest in Oregon and what is known about covered species habitat vulnerabilities in eastern Oregon. The information on knowledge gaps and environmental condition differences could inform needs for future policy and research.
Rapid systematic map	4-8 mo.	$20,000-$50,000	This option would provide a reasonable collation of the literature on this topic, but may not capture some of the grey literature, especially older studies or those from other states. The search and review process would still be well documented for transparency and replicability, but relying only on one or two reviewers without consistency checking increases the potential influence of individual biases.
Descriptive review	3-6 mo.	$15,000-$30,000	This option would collate the literature on this topic, but may not capture some of the grey literature, especially older studies or those from other states. The searching, screening and review methods would not be as thoroughly documented, so less transparent and replicable. A synthesis of findings could be requested but would be more limited than for the full systematic mapping option.
No further review	0 mo.	N/A	This option provides the literature garnered from the preliminary scoping review (Appendix B and C).

4. References

NOTE: *Articles with authors' names in red italic are "process relevant" articles that are not referenced in the body of the report; however, "process relevant" articles are a column in Table 3 (Search results). Abstracts or summaries of these articles appear in Appendix D.*

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5. Appendices

Appendix A. AMPC Research Questions Package

Appendix B. Abstracts or Summary of Publications Potentially Relevant to the Primary Focus

Appendix C. Abstracts or Summary of Publications Potentially Relevant to the Secondary Focus

Appendix D. Abstracts or Summary of "Process Relevant" Publications

Appendix E. Literature Review Examples

Appendix A. Key Aspects of the AMPC Research Questions Package

A. Final research questions

These preliminary research questions were approved by the AMPC as a substantial decision at their July 2, 2024 meeting. These questions apply east of the crest of the Cascades[4] in Oregon and are to be answered via literature reviews. In addition to an overview of literature, the review should provide an assessment of how robust the conclusions from the literature are and where there may be need for additional research.

Overarching Question:

What impacts do hillslope processes have on the covered species in the draft HCP and their habitats in eastern Oregon?

Primary Focus: What does the literature say about upslope initiated shallow rapid slides and how timber harvesting may impact these in eastern Oregon environments?

Secondary Focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft HCP and are these processes changed by forest practices?

B. Contextual information

The remainder of this document provides contextual information that details the context for the preliminary research questions, as required by rule[5]. The following are organized per the elements in this rule.

B.2 The rule, biological goals and objectives (BGOs), or other issue being studied[6]

AMPC response: The BGOs[7] are listed below with those applicable to these questions [in orange font]:

"Overarching Goal: Forest practices that support the survival and recovery of the covered species by providing clean, cool, connected, and complex habitats.

Goal 1: Provide clean water and substrate for the covered species.

- *Objective 1.1 - Forest practices near streams minimize sediment delivery.*
- *Objective 1.2 – Slope Retention Areas reduce episodic sediment delivery to fish-bearing streams.*
- *Objective 1.3 – Road runoff directly to streams is minimized.*
- *Objective 1.4 – Roads are not a significant source of episodic sediment delivery to streams.*

Goal 2: Shade and watershed processes controlling stream temperature provide cool water compatible with the needs of the covered species.

- *Objective 2.1 – Forest practices maintain stream shade sufficient to support desired cool water temperatures on fish-bearing streams.*
- *Objective 2.2 – No-harvest RMAs maintain stream shade sufficient to support desired cool water temperatures for covered amphibians.*

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[4] Note: ODF maintains a regulatory GIS layer of the FPA delineation between eastern and western Oregon.

[5] OAR 629-603-0200 (3)(a)

[6] OAR 629-603-0200(3)(a)(B)

[7] The most recent version of the BGOs is in the Dec. 2022 draft HCP. The BGOs will be finalized within the HCP due Dec. 31, 2027.

- *Objective 2.3 – Forest practices near non-fish-bearing perennial streams do not notably increase water temperatures in fish-bearing streams.*

Goal 3: Stream network connectivity satisfies freshwater habitat needs for covered species.

- *Objective 3.1 – Road crossings on fish-bearing streams are passable by the covered fish species.*
- *Objective 3.2 – Forest practices maintain the hydrologic continuity of stream-associated wetlands and stream-adjacent seeps and springs to stream habitats.*
- *Objective 3.3 – Timber harvest maintains stream-associated connectivity in riparian areas along non-fish streams sufficient to support covered amphibians.*

Goal 4: Riparian areas function to support complex habitats for the covered species.

- *Objective 4.1 – Mature, complex riparian forests are fostered in no-harvest zones of RMAs.*
- *Objective 4.2 – Forest practices within tree retention areas of RMAs promote delivery of large wood.*
- *Objective 4.3 – Designated Debris Flow Traversal Areas function to deliver large wood to fish-bearing streams.*
- *Objective 4.4 – Forest practices maintain stream-associated wetlands and stream-adjacent seep and spring habitat for amphibians."*

B.3 The objective of the research[8]

The objective of this research is to inform deliberations about whether rules or other policies are needed regarding timber harvest and other forest practices on steep slopes in eastern Oregon to protect HCP-covered species.

B.4 A brief description of the context of the research question[9]

The following direction was provided in the PFA Report and provides the foundation for these research questions:

"CHAPTER 3. TIMBER HARVEST ON STEEP SLOPES

3.2 Goals

The goals of the PFA commitments regarding timber harvest on steep slopes is to provide large wood and sediment consistent with maintaining or improving aquatic habitat within large basins over long timeframes. (For the purposes of this Chapter, large basins are those of a size equivalent to those supporting independent populations of Oregon coastal coho salmon. In modeling to support the PFA, these are USGS HUC 4th Field [8-digit] basins). To accomplish this, sediment sources and debris flow runout paths will be identified and a subset of these will be managed during timber harvest activities to retain trees and other vegetation. These actions, together with other HCP commitments, are intended to provide high-quality habitat to support recovery and long-term conservation of the species covered by this HCP on private forestlands.

3.2.1 Objectives

[8] OAR 629-603-0200(3)(a)(C)

[9] OAR 629-603-0200(3)(a)(D)

- *Aligned with the overall goals for timber harvest on steep slopes to provide high-quality habitat that supports the recovery, protection, and long-term conservation of covered species on private forestlands, the Authors establish the following objectives under the PFA:*
- *Leave trees in Designated Debris Flow Traversal Areas to help create and maintain high-quality habitat in:*
  - *Type F or Type SSBT streams by delivering large wood and regulating sediment storage and transport.*
  - *Type N streams by creating shade and cover for amphibians covered under the HCP.*
- *Leave trees in Slope Retention Areas to:*
  - *Reduce timber-harvest-related increases in the frequency and volume of sediment delivered to Type F or Type SSBT streams from mass wasting events.*
  - *Contribute large wood to Type F or Type SSBT streams.*
  - *Leave trees on a subset of steep (>70%) slopes immediately adjacent to Type F or Type SSBT streams to:*
  - *Stabilize these areas.*
  - *Contribute large wood to Type F or Type SSBT streams.*

3.3.8 Timber Harvest on Steep Slopes in Eastern Oregon

The Private Forest Accord does not prescribe new management measures for landslide initiation zones or debris flow traversal channels in Eastern Oregon. The Authors agree that Eastern Oregon's unique geologies and climates likely mean that these processes are different in magnitude, frequency, and impact on the covered species, when compared to Western Oregon. Similarly, the impact of timber harvesting on these processes is potentially different in Eastern Oregon. In light of this uncertainty, the Authors agree that the Adaptive Management Program shall, beginning no later than January 1, 2024, examine the scientific literature on the impacts that hillslope processes have on the covered species in Eastern Oregon. The primary focus will be on upslope initiated shallow rapid slides and how timber harvesting may impact these in Eastern Oregon environments. A secondary and more limited focus is whether other hillslope processes that likely affect covered species are changed by forest practices. Findings of the Adaptive Management Program on these topics will be presented to the Board of Forestry. These findings should focus primarily on the importance of shallow rapid landslides in Eastern Oregon to habitat for the covered species and the potential modification of these processes by forest practices or lack thereof. The report on this primary topic may or may not include recommendations as to desirability and relative importance of potential management measures. In addition, the report should convey whether the secondary review of literature on the effect of forest practices on other hillslope processes merits more thorough consideration by the Adaptive Management Program in light of scientific literature on the connection of these processes to covered species. Nothing in this Report should be read to suggest that any additional Eastern Oregon steep slope or other hillslope prescriptions are, or are not, necessary. The timber harvest prescriptions for steep slopes established under Section 3.3.3 of this Chapter for Designated Debris Flow Traversal Areas and under Section 3.3.4 of this Chapter for Designated Sediment Source Areas and Slope Retention Areas do not apply to any private forest ownership class east of the summit of the Cascade Mountains. The timber harvest prescriptions for steep slopes established under Section 3.3.7 Stream Adjacent Failures apply to all private forest ownership classes both west and east of the summit of the Cascade Mountains."

Appendix B. Abstracts or Summaries of Publications Potentially Relevant to the Primary Focus

Primary Focus: What literature exists relating to upslope initiated shallow rapid slides and how timber harvesting may impact these in eastern Oregon environments?

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Fitzgerald, J., and C. Clifton 1997	eastern Oregon	Q1		x	x	x	

Reference

Fitzgerald, J., and C. Clifton. 1997. Flooding, land use, and watershed response in the Blue Mountains of northeastern Oregon and southeastern Washington. In: Inland Northwest Water Resources Conference, Program and Abstracts. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5208929.pdf

Summary

The flood assessment focused on characterizing the events, inventorying mass wasting features, mapping channel perturbations, estimating flood magnitude and frequency, and evaluating performance of instream fish habitat structures and stream-road crossing culverts. Major findings from this assessment include: 1) highest flooding on many streams since 1964; 2) numerous shallow rapid landslides and debris torrents, many reaching stream channels; 3) substantial channel adjustment in main valley streams in response to high flows and tributary mass wasting; 4) high survival rate of instream habitat structures; and, 5) road culvert failure mechanism was by plugging with sediment, rather than being undersized for flow. In the inventoried area, 27% of features were caused by road failure, 10% occurred in clear-cut harvest units, and 63% had no direct association with land use. The major contributing factor causing failure appears to be super-saturation of soils in the transient snow zone.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Goode, J.R. et al 2012	western US	Q1		x	x	x	

Reference

Goode, J.R., C.H. Luce, and J.M. Buffington. 2012. Enhanced sediment delivery in a changing climate in semi-arid mountain basins: implications for water resource management and aquatic habitat in the northern Rocky Mountains. Geomorphology 139: 1–15. https://doi.org/10.1016/j.geomorph.2011.06.021

Abstract

Sediment yields tend to be larger in semi-arid climates than in arid and humid environments due to the regulating effect of vegetation on hillslope stability and soil generation. Sediment yields in semi-arid mountain basins will increase in response to projected warming and increased climate variability. Potential

approaches for reducing sediment through land management include post-fire stabilization, suppression of fire and fire severity, and attention to other anthropogenic sources of sediment (e.g., roads, logging, grazing, mining). Determining the most effective method depends on the relative contribution of each source, management resources and objectives, and feasibility of actions. Increased sediment yields following logging result from vegetation disturbance; exposure of bare soils accelerates surface erosion, loss of forest interception and transpiration increases soil pore pressure, and loss of root strength destabilizes shallow hillslope soils, increasing the potential for shallow land sliding in both humid and semi-arid landscapes. Logging roads exacerbate this erosion and commonly produce greater erosion per unit area, but their overall extent is small compared to the area of timber harvest (Megahan,1986). Although logging has declined in the western US over the last few decades, legacy sediment stored within the fluvial system may continue to affect channel morphology and aquatic habitat. The ecological consequences of sediment chronically supplied from roads may be more detrimental than from sediment periodically supplied from post-fire debris flows. Despite the dramatic nature of debris-flow disturbances and their potential impacts to river corridor infrastructure, salmonids and other aquatic organisms have evolved with, and are adapted to, these disturbances.

Aquatic Species: The authors generally reference aquatic species, fish, and salmonids.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Gorsevski, P.V. et al. 2006	Idaho	Q1		x	x	x	

Reference

Gorsevski, P.V., P.E. Gessler, J. Boll, W.J. Elliot, and R.B. Foltz. 2006. Spatially and temporally distributed modeling of landslide susceptibility. Geomorphology 80(3): 178–198. https://doi.org/10.1016/j.geomorph.2006.02.011

Summary

Mapping of landslide susceptibility in forested watersheds is important for management decisions. In forested watersheds, especially in mountainous areas, the spatial distribution of relevant parameters for landslide prediction is often unavailable. This paper presents a GIS-based modeling approach that includes representation of the uncertainty and variability inherent in parameters. In this approach, grid-based tools are used to integrate the Soil Moisture Routing (SMR) model and infinite slope model with probabilistic analysis. The SMR model is a daily water balance model that simulates the hydrology of forested watersheds by combining climate data, a digital elevation model, soil, and land use data. The infinite slope model is used for slope stability analysis and determining the factor of safety for a slope. Monte Carlo simulation is used to incorporate the variability of input parameters and account for uncertainties associated with the evaluation of landslide susceptibility. This integrated approach of dynamic slope stability analysis was applied to the 72-km2 Pete King watershed located in the Clearwater National Forest in north-central Idaho, USA, where landslides have occurred. A 30-year simulation was performed beginning with the existing vegetation covers that represented the watershed during the landslide year. Comparison of the GIS-based approach with existing models (FSmet and SHALSTAB) showed better precision of landslides based on the ratio of correctly identified landslides to susceptible areas. Analysis of landslide susceptibility showed that (1) the proportion of susceptible and non-susceptible cells changes spatially and temporally, (2) changed cells were a function of effective precipitation and soil storage amount, and (3) cell stability increased over time especially for clear-cut areas as root strength increased and vegetation transitioned to regenerated forest. Our modeling results showed that landslide susceptibility is strongly influenced by natural processes and human activities in space and time; while results from simulated outputs show the potential for decision-making in effective forest planning by using various management scenarios and controlling factors that influence landslide susceptibility. Such a process-based tool could be used to deal with real-dynamic systems to help decision-makers to answer complex landslide susceptibility questions.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Halofsky, J.E., and D.L. Peterson 2017	eastern Oregon	Q1		x	x	x	x

Reference

Halofsky, J.E., and D.L. Peterson. 2017. Climate change vulnerability and adaptation in the Blue Mountains region. Pacific Northwest Research Station General Technical Report, PNW-GTR-939. 331 p. https://doi.org/10.2737/PNW-GTR-939

Summary

This study was focused on three eastern Oregon national forests (Malheur, Umatilla, and Wallowa-Whitman) and included a state-of-the-science climate change vulnerability assessment as well as adaptation options for national forests in the Blue Mountain Region of Oregon. The vulnerability assessment indicated that effects of climate change on hydrology in the Blue Mountains will be especially significant. Decreased snowpack and earlier snowmelt will shift the timing and magnitude of streamflow; peak flows will be higher, and summer low flows will be lower. Projected changes in climate and hydrology will have far-reaching effects on aquatic and terrestrial ecosystems, especially as frequency of extreme climate events (drought) and associated effects on ecological disturbance (wildfire, insect outbreaks) increase. Abundance and distribution of spring Chinook salmon (*Oncorhynchus tshawytscha*), redband trout/steelhead (*O. mykiss gibsii*), and especially bull trout (*Salvelinus confluentus*) will be greatly reduced, although effects will differ by location as a function of both stream temperature and competition from nonnative fish species. Increasing air temperature, through its influence on soil moisture, is expected to cause gradual changes in the abundance and distribution of tree, shrub, and grass species throughout the Blue Mountains, with drought-tolerant species becoming more competitive. Ecological disturbance, including wildfire and insect outbreaks, will be the primary facilitator of vegetation change. High-elevation forest types will be especially vulnerable to disturbance. Forest management tactics proposed include: Tactics include using silvicultural prescriptions (especially stand density management) and fuel treatments to reduce fuel continuity, reducing populations of nonnative species, potentially modifying seed zones for tree species, and revising grazing policies and practices. Rare and disjunct species and communities (e.g., whitebark pine, aspen, alpine communities) require adaptation strategies and tactics focused on encouraging regeneration, preventing damage from disturbance, and establishing refugia.

Aquatic Species: The authors reference chinook salmon (*Oncorhynchus tshawytscha*), redband trout/steelhead (*O. Mykiss*), bull trout (*Salvelinus confluentus*), and other aquatic species that are not on the HCP list.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Harp, E.L. et al. 1996.	eastern Washington	Q1		x	x	x	

Reference

Harp, E.L., A.F. Chleborad, R.L. Schuster, S.H. Cannon, M.E. Reid, and R.C. Wilson. 1996. Landslides and landslide hazards in Washington State due to February 5-9,1996 storm. U.S. Geological Survey Administrative Report. 33 p. https://faculty.washington.edu/kramer/522/USGS1996StormSlides.pdf

Summary

This report documents the landslides that occurred throughout Washington State, including in the Blue Mountains of SE Washington during the 4 February 1996 storms, where up to 23 inches of rain fell in the Pacific Northwest states. The highest concentrations of landslides occurred at the northwest edge of the Blue Mountains of southeastern Washington near Walla Walla, which is outside the landslide limits drawn for western Washington. Here, debris flows reached concentrations exceeding 100 individual failures per square mile. Sizes ranged from small flows from road cuts to long flows of several miles in length in which entire drainage channels failed from the drainage divide to the stream bottom. In the Blue Mountains of southeastern Washington where clear cutting was not presently being done, they saw debris flows both in areas of timber and on slopes that were almost free of timber. The only major difference they saw in this area was that slopes completely free of timber tended to have high concentrations of smaller, very shallow debris flows, while slopes with mixed forest and grassland had somewhat lower concentrations of debris flows in which longer debris flows with deeper channels occurred. They determined no conclusive statement could be made regarding the effects of logging or clear-cutting on the distribution of landslides.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Herrera Environmental Consultants Inc. 2004		Q1		x	x	x	

Reference

Herrera Environmental Consultants Inc. 2004. Review of the Available Literature Related to Wood Loading Dynamics in and around Streams in Eastern Washington Forests.
https://www.dnr.wa.gov/publications/fp_cmer_03_308.pdf

Summary

This study identified the current state of knowledge regarding instream wood, wood recruitment and fluxes, and the function of wood in streams in eastern Washington based on 41 research questions in nine focal areas: wood loading, wood distribution in streams, in-stream manipulation of wood, decay rates of wood in streams, transport of wood in streams, role of wood in pool formation in streams, role of wood in bedload transport and sediment sorting, riparian and channel conditions, and wood recruitment and mortality. HEC contacted 47 institutions and 43 individuals and searched 39 databases of relevant literature. They developed a source tracking log to document databases collected and searched (Appendix B-1), individual scientists and land managers possibly involved in eastern Washington research (Appendix B-2), and institutions included in the search for available information (Appendix B-3). Literature sources were categorized into the three categories: 1) studies conducted in eastern Washington, 2) studies conducted in analogous regions, and 3) studies not in analogous regions but relevant to the question's topic. A summary of quantitative information directly related to the question and eastern Washington is provided. Each relevant literature source that contains quantitative data is briefly discussed with a preliminary assessment of whether data collected for the question responses covers all of eastern Washington stream channel sizes and forest types

Specific location: eastern WA and similar ecoregions

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Istanbulluoglu, E. et al. 2004	Idaho	Q1		x	x	x	

Reference

Istanbulluoglu, E., D. Tarboton, R. Pack, and C. Luce. 2004. Modeling of the interactions between forest vegetation, disturbances, and sediment yields. Journal of Geophysical Research-Earth Surface 109(F1) https://doi.org/10.1029/2003JF000041

Abstract

The controls of forest vegetation, wildfires, and harvest vegetation disturbances on the frequency and magnitude of sediment delivery from a small watershed (similar to3.9 km(2)) in the Idaho batholith are investigated through numerical modeling. The model simulates soil development based on continuous bedrock weathering and the divergence of diffusive sediment transport on hillslopes. Soil removal is due to episodic gully erosion, shallow landsliding, and debris flow generation. In the model, forest vegetation provides root cohesion and surface resistance to channel initiation. Forest fires and harvests reduce the vegetation. Vegetation loss leaves the land susceptible to erosion and landsliding until the vegetation cover reestablishes in time. Simulation results compare well with field observations of event sediment yields and long-term averages over similar to10,000 years. When vegetation is not disturbed by wildfires over thousands of years, sediment delivery is modeled to be less frequent but with larger event magnitudes. Increased values of root cohesion (representing denser forests) lead to higher event magnitudes. Wildfires appear to control the timing of sediment delivery. Compared to undisturbed forests, erosion is concentrated during the periods with low erosion thresholds, often called accelerated erosion periods, following wildfires. Our modeling suggests that drainage density is inversely proportional to root cohesion and that reduced forest cover due to wildfires increases the drainage density. We compare the sediment yields under anthropogenic (harvest) and natural (wildfire) disturbances. Disturbances due to forest harvesting appear to increase the frequency of sediment delivery; however, the sediment delivery

following wildfires seems to be more severe. These modeling-based findings have implications for engineering design and environmental management, where sediment inputs to streams and the fluctuations and episodicity of these inputs are of concern.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Jordan, P. et al. 2010	British Columbia	Q1, Q2		x	x	x	

Reference

Jordan,P., T.H. Millard, D. Campbell, J. W. Schwab, D.J. Wilford, D. Nicol, and D. Collins. 2010. Forest Management Effects on Hillslope Processes (Chapter 9, page 275-330). In: Compendium of Forest Hydrology and Geomorphology in British Columbia Volume 1 of 2. (Eds) R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winkler, and K. D. Bladon. Ministry of Forests and Range Forest Science Program. British Columbia https://fews.forestry.oregonstate.edu/publications/AA_LMH66_volume1of2.pdf

Summary

This chapter provides an overview of the effects of historic forest management practices in the Interior and coast of British Columbia and how newer practices address issues related to slope stability, sediment production, and alluvial fans. One section of the chapter is focused on harvesting-caused landslides. The authors describe an important difference in study results for interior and coastal British Columbia - in the Interior, most development-related landslides are caused by roads (about 80%) and most cutblock related landslides are caused by skid trails. On the coast, some studies indicate that most landslides are caused by clearcuts whereas others show that roads and harvesting are of about equal importance.

Specific location: Interior British Columbia

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Ketcheson, G.L. et al.1999	Idaho	Q1		x	x	x	

Reference

Ketcheson, G.L., W.F. Megahan, and J.G. King. 1999. “R1–R4” and “BOISED” sediment prediction model tests using forest roads in granitics. Journal of the American Water Resources Association 35, 83–98. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1752-1688.1999.tb05454.x

Summary

This study predicts logging road erosion and sediment delivery from research watersheds in the Silver Creek Study Area in central Idaho. Three small watersheds were instrumented and monitored such that erosion from newly constructed roads and sediment delivery to the mouths of the watersheds could be measured for four years following road construction. Predicted sediment yields were consistently greater (average of 2.5 times) than measured sediment yields. Hillslope sediment delivery coefficients appear to be overly conservative to account for average site conditions and road locations, and thus over-predict sediment delivery. Mass erosion predictions appear to predict volume well over 15 to 20 years, however mass wasting is more episodic than the model predicts.

Specific location: Silver Creek, central Idaho

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Klock, G.O., and J.D. Helvey 1976	eastern Washington	Q1		x	x	x	

Reference

Klock, G.O., and J.D. Helvey. 1976. Debris flows following wildfire in north central Washington. Proceedings of the Third Inter-agency Sedimentation Conference. US Water Resources Council, Sedimentation Committee, Washington DC. x1-91–1-98.
https://babel.hathitrust.org/cgi/pt?id=umn.31951000143903p&seq=109

Summary

This study documented a combination of rapid snowmelt, high intensity rainstorms, and fire-denuded watersheds resulted in massive debris torrents from numerous tributary streams of the Entiat River in north-central Washington during the spring and summer of 1972. Debris torrents are summarized by location, soil type, topography, and land use history for five adjacent watersheds. Alternative forest management recommendations are suggested for minimizing the impact of possible future debris torrents within the study area. Their investigation pointed out several areas where forest management can reduce, but not eliminate, the hazards of debris torrents within the region. The prevention or control of wildfire may reduce the probability of debris torrents. Forest harvest practices that increase soil moisture levels and significantly increase hydrologic sensitivity of a watershed should be carefully studied and evaluated in terms of soils and topographic features for each cutting unit. Management activities within the riparian zone should attempt to reduce the accumulation of debris within the stream channel. Logging slash and road construction debris could possibly increase or even initiative wave action in the stream channel. Increased streamflow volumes can also increase the probability of debris torrents. Road design should be evaluated re: possible effect on streamflow in critical areas, however, even with the best physical land management, there still exists the probability of debris torrents in the area evaluated.

Specific location: north-central Washington (Entiat River Valley 20 miles north of Wenatchee, WA)

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Lineback Gritzner, M. et al. 2001	Idaho	Q1, Q2		x	p		

Reference

Lineback Gritzner, M., W.A. Marcus, R. Aspinall, and S.G. Custer. 2001. Assessing landslide potential using GIS, soil wetness modeling and topographic attributes, Payette River, Idaho. Geomorphology 37(1): 149–165. https://doi.org/10.1016/S0169-555X(00)00068-4

Summary

This study utilizes GIS modeling to determine if the location of 559 landslides in the 875 km2 catchment of the Middle Fork of the Payette River, Idaho can be predicted based on topographic attributes and a wetness index generated by the DYNWET model. Slope and elevation were significantly related to landslide occurrence at this landscape scale. Aspect was also retained as a variable for further analysis because, despite a non-significant chi-square relation to landslide occurrence, graphical analysis suggested a relation between aspect and mass wasting. Chi-square analysis indicated that plan and profile curvature, flow path length, upslope contributing area, and the DYNWET-based moisture index were not significantly related to landsliding. A Bayesian probability model based on combinations of elevation, slope, aspect, and wetness indicates that elevation exhibits the closest relation to landsliding, followed by slope; but that neither aspect nor wetness index values help in prediction. The Bayesian probability model using elevation and slope generates a map of relative landslide risk that can be used to direct activities away from mass wasting prone areas. The association between elevation and landslides is perplexing but is perhaps due to the location of logging road at specific elevations (roads could not be included in the input data for analysis because they have not been adequately mapped). The lack of explanation provided by the DYNWET wetness index was also surprising and may be due to the 30-m digital elevation model (DEM) and the soils data having resolutions too coarse to adequately portray local variations key to mass wasting. We believe the inadequacy of data to drive the models is typical of the majority of catchment scale setting. For now, the ability of researchers to effectively model landscape scale landsliding is more limited by the type, resolution, and quality of available data than by the quality of the landslide models.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Luce, C., et al. 2012	western US	Q1, Q2		x	x	x	x

Reference

Luce, C., P. Morgan, K. Dwire, D. Isaak, Z. Holden, and B. Rieman. 2012. Climate change, forests, fire, water, and fish: building resilient landscapes, streams, and managers. Gen. Tech. Rep. RMRS-GTR-290. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 207 pp https://research.fs.usda.gov/treesearch/41932#

Summary

This study documented that fire will play an important role in shaping forest and stream ecosystems as the climate changes. Historic observations show increased dryness accompanying more widespread fire and forest die-off. These events punctuate gradual changes to ecosystems and sometimes generate stepwise changes in ecosystems. Climate vulnerability assessments need to account for fire in their calculus. The biophysical template of forest and stream ecosystems determines much of their response to fire. This report describes the framework of how fire and climate change work together to affect forest and fish communities. Learning how to adapt will come from testing, probing, and pushing that framework and then proposing new ideas. It comprises three chapters on physical processes, biological interactions, and management decisions, as well as a section addressing interactions of fish populations with wildfire. The authors note that mass wasting events, such as debris flows, directly disrupt aquatic habitat, potentially extirpating local populations and simplifying habitats in the streams where they pass. Yet, these large events also provide large amounts of coarse material such as gravel, cobbles, and logs that ultimately add to the habitat complexity and quality of streams where they deposit. It is the relationship of populations to these reorganizing events, their occurrence and extent, and the recovery over time that the authors state is most critical to aquatic ecology. This conceptualization recognizes a fundamentally different interaction between mass wasting events and aquatic populations and habitats in comparison to sediments detached and transported by water alone. Total sediment over the long term is higher from fire than forest management on low gradient slopes (considering surface erosion only), but there is little difference in estimated sediment mass between fires and forest harvest for steep slopes where mass wasting might occur.

Aquatic species: fish

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
McClelland, D.E. et al. 1999	Idaho	Q1		x	x	x	x

Reference

McClelland, D.E., R.B. Foltz, C.M. Falter, W.D. Wilson, T. Cundy, R.L. Schuster, J. Saurbier, C. Rabe, and R. Heinemann. 1999. Relative Effects on a Low-Volume Road System of Landslides Resulting from Episodic Storms in Northern Idaho. Transportation Research Record. 1652(1): 235–243. https://doi.org/10.3141/1652-63

Abstract

In late November to early December 1995 and February 1996, northern Idaho was hit by heavy rains on a deep snowpack, resulting in two flood and landslide events of historic magnitude. Each of these storms was larger than the previous significant storm, which occurred in January 1974. A study was initiated by the U.S. Department of Agriculture Forest Service to survey and study the effects of the resultant landslides on the Clearwater National Forest, including the effects on the aquatic ecosystem. The results of this study were compared with the estimated average natural sediment resulting from landslides to evaluate the incremental impacts of these recent episodic landslides. They were also compared with the results of a study conducted on the landslides resulting from the January 1974 storm to determine if the landscape was responding more severely to large storms as a result of Forest Service management activities over the past 21 years. The general results of this study indicate that, of the Forest Service management activities, roads are the major contributor; however, they contribute less sediment than natural landslides. The total resultant sediment appears to be within the transport capacity of the aquatic system, and the landslide response in 1974 was similar to the 1995–1996 response. The results of the aquatic ecosystem study were generally mixed, with some habitat parameters indicating degradation, some unchanged, and some improved as a result of the flooding or flooding with landslide sediment.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
McGreer, D.J. et al. 1998	eastern WA & western MT	Q1		x	x	x	x

Reference

McGreer, D.J., B.D. Sugden, and D.T. Schult. 1998. Surface Erosion and Mass Wasting Assessment and Management Strategies for Plum Creek's Native Fish Habitat Conservation Plan. Native Fish Habitat Conservation Plan Technical Report #3. Columbia Falls, Montana: Plum Creek Timber Company.

Summary

This study served as a technical foundation to inform Habitat Conservation Plan (HCP) strategies that would address erosion associated with forest management activities in eastern Washington and western Montana to minimize effects on salmonid substrate spawning habitats. The authors examined 23 mass wasting assessments completed in the last few years and representative of the area covered by the HCP: the east slope of the Cascades in eastern Washington (11 analyses), northeastern Washington (6 analyses), and western Montana (6 analyses). Roads are the predominant cause of increased rates of mass wasting associated with forest management, with acceleration factors due to roads commonly found in the range of 10–100 times greater for roads than for harvesting. Road fill failures, including fill failures associated with culvert blockages and diversions, are the predominant form of road-associated mass wasting. Westside rates are 3.3 times higher than found for the watersheds located just east of the Cascade crest, where precipitation remains high, and slopes remain very steep for much of the area. In the more eastern areas, total number of failures/mi^2 decreased.

<u>Aquatic Species</u>: Salmonids and fish

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Megahan, W.F. et al. 1978	Idaho	Q1, Q2		x	x		

Reference

Megahan, W.F., N.F. Day, and Bliss, 1978. Landslide occurrence in the western and central northern Rocky Mountain physiographic province in Idaho. In: Youngberg, C.T. (Ed.), Forest Soils and Land Use, Proceedings of the Fifth North American Forest Soils Conference. Colorado State University, Department of Forest and Wood Sciences, Fort Collins, CO, pp. 116–139. https://geodata.geology.utah.gov/pages/view.php?ref=4784&search=&offset=15100&order_by=resourcetype&sort=DESC&archive=0&k=&

Summary

This study documented landslide occurrence in the Clearwater National Forest and Boise National Forest of Idaho. Increased demands for forest resources in recent years have caused road construction and logging activities to progress from the flatter landscapes where landslide hazards are lower to steeper lands that are more vulnerable to landslides. The study was designed to evaluate the nature and extent of slope stability problems in the Northern Rocky Mountains. The objectives of the study were to: (1) quantify the magnitude of landslide occurrence; (2) estimate damages caused by landslides; (3) characterize properties of landslide-prone areas; (4) evaluate mass erosion in relation to various land uses. Slope stability is not a serious problem on undisturbed forested slopes in the western and central portions of the Northern Rocky Mountains. Disturbance in the form of vegetation removal by wildfire, timber cutting, and especially road construction can greatly accelerate landslide activity. Below a crown level of 80%, landslide occurrence seems to be more sensitive to reductions in shrub crown cover than to reductions in tree crown cover, suggesting using timber harvest procedures that minimize disturbance to understory vegetation.

Specific location: Idaho batholith - Clearwater National Forest in northern Idaho and Boise National Forest in west-central Idaho

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Peterson, D.L. et al. 2009	western US	Q1		x		x	x

Reference

Peterson, D.L., J.K. Agee, G.H. Aplet, D.P. Dyskstra, R.T. Graham, J.F. Lehmkuhl, D.S. Pilliod, D.F. Potts, R.F. Powers, and J.D. Stuart. 2009. Effects of timber harvest following wildfire in western North America. General Technical Report PNW-GTR-776. Portland, OR: USDA Department of Agriculture, Forest Service, Pacific Northwest Research Station. 51 p. https://doi.org/10.2737/PNW-GTR-77

Summary

This study documented how timber harvest following wildfire leads to different outcomes depending on the biophysical setting of the forest, pattern of burn severity, operational aspects of tree removal, and other management activities in dry forests of the western United States. Fire effects range from relatively minor, in which fire burns through the understory and may kill a few trees, to severe, in which fire kills most trees and removes much of the organic soil layer. Postfire logging adds to these effects by removing standing dead trees (snags) and disturbing the soil. The influence of postfire logging depends on the intensity of the fire, intensity of the logging operation, and management activities such as fuel treatments. In severely burned forest, timing of logging following fire (same season as fire vs. subsequent years) can influence the magnitude of effects on naturally regenerating trees, soils, and commercial wood value. Removal of snags reduces long-term fuel loads but generally results in increased amounts of fine fuels for the first few years after logging unless surface fuels are effectively treated. By reducing evapotranspiration, disturbing the soil organic horizon, and creating hydrophobic soils in some cases, fire can cause large increases in surface-water runoff, streamflow, and erosion. Through soil disturbance, especially the construction of roads, logging with ground-based equipment and cable yarding can exacerbate this effect, increasing erosion and altering hydrological function at the local scale. Effects on aquatic systems of removing trees are mostly negative, and logging and transportation systems that disturb the soil surface or accelerate road-related erosion can be particularly harmful unless disturbances are mitigated. Cavity-nesting birds, small mammals, and amphibians may be affected by harvest of standing dead and live trees, with negative effects on most species but positive or neutral effects on other species, depending on the intensity and extent of logging. Data gaps on postfire logging include the effects of various intensities of logging, patch size of harvest relative to fire size, and long-term (10+ years) biophysical changes. Uncertainty about the effects of postfire logging can be reduced by implementing management experiments to document long-term changes in natural resources at different spatial scales.

Specific location: western U.S., from the coastal ranges, Cascade Range, and Sierra Nevada east to the Rocky Mountains and associated ranges, and from SW Canada to the SW United States, including dry forests dominated by ponderosa pine, cold forests dominated by Engelmann spruce, fir species and lodgepole pine, and woodlands in the American Southwest

Aquatic species: fish, amphibian, benthic invertebrates

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Platts, et al. 1989	Idaho	Q1		x	x	x	x

Reference

Platts, et al. 1989. Changes in spawning and rearing habitat from increased delivery of fine sediment to the South Fork Salmon River, Idaho. Transactions of the American Fisheries Society 118:274-283. https://doi.org/10.1577/1548-8659(1989)118%3C0274:CISSAR%3E2.3.CO;2

Summary

This study assessed levels of surface and subsurface fine sediment measured annually from 1965 to 1985 in spawning and rearing areas for chinook salmon (*Oncorhynchus tschawytscha)* and steelhead (*O. Mykiss)* in the South Fork Salmon River, Idaho. Between 1950 and 1965, logging and road construction, in combination with large storm events of 1964 and 1965, resulted in the delivery of increased amounts of fine sediments to the South Fork Salmon River. Surface and subsurface fine sediment levels peaked at 46% of the surface area in 1966 and 48% of the volume in 1969, respectively. A logging moratorium initiated in 1965, coupled with natural recovery and watershed rehabilitation, led to significant decreases in the amounts of fine sediments delivered to and stored in the South Fork Salmon River; this reduction led to a limited resumption of logging operations within the watershed in 1978. By 1985, surface and subsurface sediment levels in Chinook Salmon spawning areas averaged 19.7% of the surface area and 25.4% of the volume, respectively. However, additional recovery to pre-logging fine sediment levels is likely contingent on both further watershed recovery and the occurrence of flood flows capable of transporting material downstream.

Specific location: South Fork Salmon River, Idaho

Aquatic species: salmonids

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Sidle, R.C. 2005	various			x	x	p	

Reference

Sidle, R.C. 2005. Influence of forest harvesting activities on debris avalanches and flows. In: Hungr, O., Jacob, M. (Eds.), Debris Flow Hazards and Related Phenomena. Praxis, Springer-Verlag, Berlin, pp. 387-403 https://link.springer.com/content/pdf/10.1007/3-540-27129-5_15.pdf

Summary

This is Chapter 16 in a book about debris flow hazards and the influence of forest harvesting activities on debris avalanches and flows. The chapter references different types of forest practices and how they can contribute to flows, and cites several studies that document debris flows that inflict damage to valuable aquatic habitats and streams. The article distinguishes between landslides that immediately or rapidly mobilize into debris flows and travel downstream versus sediment from smaller hillslope landslides that accumulates in channel heads or at headwater tributary junctions, which is later mobilized into a debris flow once sufficient materials has accumulated and in conjunction with a storm event. There is an entire section of the effects of management practices in forests and landslide susceptibility. Although the author cites studies from westside-type forests, he includes discussion about areas with high snowfall and the interaction of forest ecosystems with geomorphic processes.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Wondzell, S.M., and J.G. King 2003	western US	Q1		x	x	x	

Reference

Wondzell, S.M., and J.G. King. 2003. Postfire erosional processes in the Pacific Northwest and Rocky Mountain regions. Forest Ecology and management 178(1–2): 75–87. https://doi.org/10.1016/S0378-1127(03)00054-9

Summary

This study provides an overview of the influence of wildland fires on erosional processes common to forested landscapes in the Interior Northwest and Northern Rocky Mountains. Wildfire can accelerate erosion rates because of the role of vegetation in controlling erosion. There can be great local and regional differences, however, in the relative importance of different erosional processes because of differences in prevailing climate, geology and topography; because of differences in the degree to which vegetation regulates erosional processes; and because of differences in the types of fire regimes that disrupt vegetative cover. Surface erosion, caused by overland flow, is a dominant response to wildfire in the Interior Northwest and Northern Rocky Mountains (Interior Region). A comparison of measured postfire infiltration rates and long-term records of precipitation intensity suggest that surface runoff from infiltration-excess overland flow should also occur in the Coastal and Cascade Mountains of the Pacific Northwest after fires, but this has not been documented in the literature. Debris slides and debris flows occur more frequently after wildfire in the Interior Region and in the Coastal and Cascade Mountains of the Pacific Northwest (Pacific Northwest Region). Debris flows can be initiated from either surface runoff or from soil-saturation-caused debris slides. In the Pacific Northwest Region, debris flows are typically initiated as debris slides, caused by soil saturation and loss of soil cohesion as roots decay following fire. In the

Interior Region, both overland-flow-caused and debris-slide-caused debris flows occur after wildfire. Surface erosion, debris slides, and debris flows all occur during intense storms. Thus, their probability of occurrence depends upon the probability of intense storms occurring during a window of increased susceptibility to surface erosion and mass wasting following intense wildfire.

Specific location: Pacific Northwest and Rocky Mountains

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Wondzell, S.M. 2001	eastern Oregon	Q1		x	x	x	x

Reference

Wondzell, S.M. 2001. The influence of forest health and protection treatments on erosion and stream sedimentation in forested watersheds of eastern Oregon and Washington. Northwest Science 75:128-140. https://rex.libraries.wsu.edu/esploro/outputs/journalArticle/The-influence-of-forest-health-and/99900501658801842

Summary

This study examined the potential effects of forest health and protection treatments on sediment production in watersheds, channel forming processes, riparian vegetation, and risks posed to riparian zones. Removal of upland forests by clear cut logging or stand-replacing forest fires can significantly increase landslide rates. Proposed forest health and protection treatments may accelerate upland erosion and increase sedimentation of streams. Treatments designed to minimize short-term risks may conflict with activities that will minimize long term risks. To some extent, trade-offs between short and long-term risks can be avoided by considering the spatial component of forest health treatments. The largest risk of accelerated erosion is expected from ground disturbing activities, such as road use and road reconstruction, construction of fire breaks, or off-road use of heavy machinery. Increased landslide rates following loss of forest cover tend to occur in relatively landslide-prone landscapes, and not in areas with more landslide-resistant geology.

Aquatic Species: The author mentions salmonids and the negative effects of sedimentation.

Appendix C. Abstracts or Summaries of Publications Potentially Relevant to the Secondary Focus

Secondary Focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft Habitat Conservation Plan (HCP) and are these processes changed by forest practices?

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Jordan, P. et al. 2010	British Columbia	Q1, Q2		x	x	x	

Reference

Jordan, P., T.H. Millard, D. Campbell, J. W. Schwab, D.J. Wilford, D. Nicol, and D. Collins. 2010. Forest Management Effects on Hillslope Processes (Chapter 9, page 275-330). In: Compendium of Forest Hydrology and Geomorphology in British Columbia Volume 1 of 2. (Eds) R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winkler, and K. D. Bladon. Ministry of Forests and Range Forest Science Program. British Columbia https://fews.forestry.oregonstate.edu/publications/AA_LMH66_volume1of2.pdf

Summary

This chapter provides an overview of the effects of historic forest management practices in the Interior and coast of British Columbia and how newer practices address issues related to slope stability, sediment production, and alluvial fans. One section of the chapter is focused on harvesting-caused landslides. The authors describe an important difference in study results for interior and coastal British Columbia - in the Interior, most development-related landslides are caused by roads (about 80%) and most cutblock-related landslides are caused by skid trails. On the coast, some studies indicate that most landslides are caused by clearcuts whereas others show that roads and harvesting are of about equal importance.

<u>Specific location</u>: Interior British Columbia

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Lineback Gritzner, M. et al. 2001	Idaho	Q1, Q2		x	p		

Reference

Lineback Gritzner, M., W.A. Marcus, R. Aspinall, and S.G. Custer. 2001. Assessing landslide potential using GIS, soil wetness modeling and topographic attributes, Payette River, Idaho. Geomorphology 37(1): 149–165. https://doi.org/10.1016/S0169-555X(00)00068-4

Summary

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Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Luce, C. et al. 2012	western US	Q1, Q2		x	x	x	x

Reference

Luce, C., P. Morgan, K. Dwire, D. Isaak, Z. Holden, and B. Rieman. 2012. Climate change, forests, fire, water, and fish: building resilient landscapes, streams, and managers. Gen. Tech. Rep. RMRS-GTR-290. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 207 pp https://research.fs.usda.gov/treesearch/41932#

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Aquatic species: fish

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Megahan, W.F. et al. 1978	Idaho	Q1, Q2		x	x		

Reference

Megahan, W.F., N.F. Day, and Bliss, 1978. Landslide occurrence in the western and central northern Rocky Mountain physiographic province in Idaho. In: Youngberg, C.T. (Ed.), Forest Soils and Land Use, Proceedings of the Fifth North American Forest Soils Conference. Colorado State University, Department of Forest and Wood Sciences, Fort Collins, CO, pp. 116–139.
https://geodata.geology.utah.gov/pages/view.php?ref=4784&search=&offset=15100&order_by=resourcetype&sort=DESC&archive=0&k=&

Summary

This study documented landslide occurrence in the Clearwater National Forest and Boise National Forest of Idaho. Increased demands for forest resources in recent years have caused road construction and logging activities to progress from the flatter landscapes where landslide hazards are lower to steeper lands that are more vulnerable to landslides. The study was designed to evaluate the nature and extent of slope stability problems in the Northern Rocky Mountains. The objectives of the study were to: (1) quantify the magnitude of landslide occurrence; (2) estimate damages caused by landslides; (3) characterize properties of landslide-prone areas; (4) evaluate mass erosion in relation to various land uses. Slope stability is not a serious problem on undisturbed forested slopes in the western and central portions of the Northern Rocky Mountains. Disturbance in the form of vegetation removal by wildfire, timber cutting, and especially road construction can greatly accelerate landslide activity. Below a crown level of 80%, landslide occurrence seems to be more sensitive to reductions in shrub crown cover than to reductions in tree crown cover, suggesting using timber harvest procedures that minimize disturbance to understory vegetation.

Specific location: Idaho batholith - Clearwater National Forest in northern Idaho and Boise National Forest in west-central Idaho

Appendix D. Abstracts or Summaries of "Process Relevant" Publications

These documents found were classified as "process relevant," that is they were focused on mass wasting on forestlands but without any direct connection to forest management activities. As these were seen as containing potentially useful context information, they are summarized here. The largest number came from Idaho (7), followed by studies spanning multiple western states (6); three were located in California and one each in Colorado, Wyoming, and New Mexico. None were located in eastern Oregon or Washington. By definition none of these addressed forest practices but all addressed hillslope processes and all overlapped with semi-arid environments. Most of these studies (14) involved investigations of post-wildfire surficial erosion and mass wasting.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Cannon, S.H., and J. DeGraff 2008	California		x		x	x	

Reference

Cannon, S.H., and J. DeGraff. 2008. The increasing wildfire and post-fire debris-flow threat in western USA, and implications for consequences of climate change. In: Sassa, K., Canuti, P. (Eds.), Landslides — Disaster Risk Reduction: Proceedings of 1st World Landslide Forum. Springer-Verlag, Berlin, pp. 177–190. https://link.springer.com/chapter/10.1007/978-3-540-69970-5_9

Summary

This study noted debris flows generated from recently-burned basins in southern California and the intermountain West pose significant hazards. Increases in the frequency and size of wildfires throughout the western USA can be attributed to increases in the number of fire ignitions, fire suppression practices, and climatic influences. Increased urbanization throughout the western U.S., combined with increased wildfire magnitude and frequency, results in increased threat of subsequent debris-flow occurrence. Differences between rainfall thresholds and empirical debris-flow susceptibility models for southern California and the intermountain west indicate a strong influence of climatic and geologic settings on post-fire debris-flow potential. The linkages between wildfires, debris-flow occurrence, and global warming suggests that the experiences in the western United States are highly likely to be duplicated in many other parts of the world, and necessitate hazard assessment tools that are specific to local climates and physiographies.

Specific location: southern California and the intermountain West

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Cannon, S.H., and J.E. Gartner 2005	western US		x		x	x	

Reference

Cannon, S.H., and J.E. Gartner. 2005. Wildfire-related debris flow from a hazards perspective. In: Hungr, O., Jacob, M. (Eds.), Debris Flow Hazards and Related Phenomena. Praxis, Springer-Verlag, Berlin, pp. 363–385 https://link.springer.com/content/pdf/10.1007/3-540-27129-5_15.pdf

Summary

This study provided an overview of the current understanding of post-wildfire debris-flow processes and their occurrence in the western United States. The authors examined the physical processes by which post-wildfire debris flows initiate in different settings, over varying timescales, and in response to variable storm rainfall conditions, describing the lithologic, soil, basin-configuration, and burn-severity conditions known to have produced debris flows following wildfire as well as relations between the magnitude of debris-flow response and storm-rainfall conditions, lithology, basin gradient, and burn severity conditions. The paper references northeastern Oregon forests and communication with William Russell (2003) at Oregon State University.

Specific location: various - data from 95 basins throughout the western United States

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Cannon, S.H. et al. 2003	western US		x			x	

Reference

Cannon, S.H., J.E. Gartner, C. Parrett, and M. Parise. 2003. Wildfire-related debris-flow generation through episodic progressive sediment-bulking processes, western USA. In: Rickenmann, D., Chen, C. (Eds.), Debris-Flow Hazards Mitigation: Mechanics, Prediction, and Assessment. Millpress, Rotterdam, pp. 71–82.

Summary

This study assessed debris-flow initiation processes on hillslopes recently burned by wildfire and how these differ from those generally recognized on unburned, vegetated hillslopes in three locations in the western United States. The authors documented the differences result from fire-induced changes in the hydrologic response to rainfall events. Detailed field and aerial photographic mapping, observations, and measurements of debris-flow events from three sites in the western U.S. were used to describe and evaluate the process of episodic progressive sediment bulking of storm runoff that leads to the generation of post-wildfire debris flows. The data demonstrate the effects of material erodibility, sediment availability on hillslopes and in channels, the degree of channel confinement, the formation of continuous channel incision, and the upslope contributing area and its gradient on the generation of flows and the magnitude of the response are demonstrated. Erodibility of the materials mantling the hillslopes seems to strongly influence the location of debris-flow initiation - debris-flow conditions were attained high on hillslopes (or within the drainages) when the cases were mantled with abundant, loose, unconsolidated, easily erodable materials. Debris flows were not attained until well down the channel in instances in which the case was not nearly as loose and unconsolidated.

Specific location: three sites in the western United States - Hamilton, Montana, Glenwood Springs, Colorado, and Los Alamos, New Mexico

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Cannon, S.H. et al. 2010	western US		x	x	x	x	

Reference

Cannon, S.H., J.E. Gartner, M.G. Rupert, J.A. Michael, A.H. Rea, and C. Parrett. 2010.Predicting the probability and volume of post-wildfire debris flows in the intermountain western United States. Geological Society of America Bulletin 122, 127–144. https://www.researchgate.net/publication/249527492_Predicting_the_probability_and_volume_of_postwildfire_debris_flows_in_the_intermountain_western_United_States

Summary

This study documented the probability and volume of post-wildfire debris flows in the intermountain Empirical models can be used to calculate the probability of debris-flow production from individual drainage basins in response to a given storm - these were based on 388 basins located in 15 burned areas located throughout the Intermountain West. The models describe debris-flow probability as a function of readily obtained measures of areal burned extent, soil properties, basin morphology, and rainfall from short-duration and low recurrence-interval convective rainstorms. A model for estimating the volume of material that may issue from a basin mouth in response to a given storm was developed using multiple linear regression analysis of a database from 56 basins burned by eight fires. This model describes debris-flow volume as a function of the basin gradient, aerial burned extent, and storm rainfall. The mapping approach identifies those basins that are most prone to the largest debris-flow events and provides information necessary to prioritize areas for postfire erosion mitigation, warnings, and pre-fire management efforts throughout the Intermountain West. The relationship of this article to forest practices was the recommendation to consider pre-fire forest management to prevent catastrophic burning.

<u>Specific location</u>: U.S. Intermountain West - Idaho, Montana, Utah, Colorado, and southern California

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Cannon, S.H. et al. 2008	western US				x	x	

Reference

Cannon, S.H., J.E. Gartner, R.C. Wilson, J.C. Bowers, and J.L. Laber. 2008. Storm rainfall conditions for floods and debris flows from recently burned areas in southwestern Colorado and southern California. Geomorphology 96, 250–269.

Summary

The study documented floods and debris flows caused by storm rainfall in burned areas of Colorado and southern California using rain gage and response data. Unlike landslide-triggered debris flows, these events have no identifiable initiation source and can occur with little or no antecedent moisture. The authors document the rainfall conditions that triggered post-fire debris flows and develop empirical rainfall intensity–duration thresholds for the occurrence of debris flows and floods following wildfires in these settings. Debris flows were produced from 25 recently burned basins in Colorado in response to 13 short-duration, high-intensity convective storms. Debris flows were triggered after as little as six to 10 min of storm rainfall. About 80% of the storms that generated debris flows lasted less than 3 h, with most of the rain falling in less than 1 h. The storms triggering debris flows ranged in average intensity between 1.0 and 32.0 mm/h, and had recurrence intervals of two years or less. Debris flows were generated from 68 recently burned areas in southern California in response to long-duration frontal storms. The flows occurred after as little as two hours, and up to 16 h, of low-intensity (2–10 mm/h) rainfall. The storms lasted between 5.5 and 33 h, with average intensities between 1.3 and 20.4 mm/h, and had recurrence intervals of two years or less. Thresholds were significantly lower than most identified for unburned settings, perhaps because of the difference between extremely rapid, runoff-dominated processes acting in burned areas and longer-term, infiltration-dominated processes on unburned hillslopes. smaller, steeper basins generated floods and debris flows in response to lower rainfall totals and intensities over shorter time periods.

Specific location: Colorado and southern California

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
DeGraff, J.V. 1994	California		x	x	x	x	

Reference

DeGraff, J.V. 1994. The geomorphology of some debris flows in the southern Sierra Nevada, California. Geomorphology and Natural Hazards. Elsevier, 1994. 231-252. https://doi.org/10.1016/0169-555X(94)90019-1

Summary

This study documented the geomorphology of some debris flows in the southern Sierra Nevada of California. Observations were made in the Tuolomne, Merced, San Joaquin, and Kings River drainages. Of the 26 debris flows observed, six were examined in detail to provide specific data on this phenomenon. Triggering events for debris flows in the southern Sierra Nevada include intense rainfall, rain-on-snow storms, and seasonal melting of heavy snowpacks. Movement typically occurs at depths between 0.3 and 5 m below ground surface. This is representative of depths for the three interfaces associated with initiation of movement: (1) at the base of the root zone, (2) at the contact of well-weathered and less-weathered soil, and (3) at the contact between soil and unweathered bedrock. Measurement of debris flow velocity based on indirect methods found values ranging from 2.6 m/s to 7.2 m/s (9 km/h to 26 km/h). Recurrence intervals based on radiocarbon dates are between 425 and 500 years BP.

Specific location: southern Sierra Nevada of California, Tuolomne, Merced, San Joaquin, and Kings River drainages

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Dunham, J.B. et al 2007	Idaho		x		x	x	x

Reference

Dunham, J.B., A.E. Rosenberger, C.H. Luce, and B.E. Rieman. 2007. Influences of wildfire and channel reorganization on spatial and temporal variation in stream temperature and the distribution of fish and amphibians. Ecosystems 10:335–346. https://doi.org/10.1007/s10021-007-9029-8

Summary

This study studied stream temperatures in relation to wildfire in small streams in the Boise River Basin, located in central Idaho. They employed three approaches: a pre-post fire comparison of temperatures between two sites (one from a burned stream and one unburned) over 13 years, a short-term (3 year) pre-post fire comparison of a burned and unburned stream with spatially extensive data, and a short-term (1 year) comparative study of spatial variability in temperatures using a "space for time" substitutive design across 90 sites in nine streams (retrospective comparative study). The latter design included streams with a history of stand-replacing wildfire and streams with severe post-fire reorganization of channels due to debris flows and flooding. Results from these three studies indicated that summer maximum water temperatures can remain significantly elevated for at least a decade following wildfire, particularly in streams with severe channel reorganization. They investigated occurrence of native rainbow trout (*Oncorhynchus mykiss*) and tailed frog larvae (*Ascaphus montanus*) in relation to maximum stream temperatures during summer. Both occurred in nearly every site sampled, but tailed frog larvae were found in much warmer water than previously reported. Results showed that physical stream habitats can remain altered (for example, increased temperature) for many years following wildfire, but that native aquatic vertebrates can be resilient. In a management context, this suggests wildfire may be less of a threat to native species than human influences that alter the capacity of stream-living vertebrates to persist in the face of natural disturbance.

Specific location: Boise River basin in central Idaho

Aquatic species: Rainbow trout (*Oncorhynchus mykiss*), Rocky Mountain tailed frog (*Ascaphus montanus*) and bull trout (*Salvelinus confluentus*)

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Gorsevski, P.V. 2023	Idaho		x				

Reference

Gorsevski, P.V. 2023. A free web-based approach for rainfall-induced landslide susceptibility modeling: Case study of Clearwater National Forest, Idaho, USA. Environmental Modelling & Software. 161: 105632. https://doi.org/10.1016/j.envsoft.2023.105632

Summary

This study presents an interactive web-based approach for modeling rainfall-induced landslide susceptibility using Free Open Source Software (FOSS). The design is based on the R statistical framework and Shiny package coupled with the shallow slope stability model (SHALSTAB) from SAGA GIS. The easy-to-use real-time application extends the potential of current modeling efforts to non-expert R and GIS users and can also be used in an educational context for classroom teaching activity and enabling research-informed learning. The parsimonious approach (i.e. few parameter inputs) is accomplished in two sequential steps including modeling and validation by the use of site-specific datasets. The approach was tested in a case study on the Clearwater National Forest and the results from the validation showed an overall accuracy of 0.894, kappa of 0.789 and AUC from ROC curve was 0.715. The modeled landslide potential may be used as a decision-support tool for local planning.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Istanbulluoglu, E. et al. 2003	Idaho		x	x	x	x	

Reference

Istanbulluoglu, E., D.G. Tarboton, R.T. Pack, and C.H. Luce. 2003. A sediment transport model for incision of gullies on steep topography. Water Resources Research 39,1103. https://research.fs.usda.gov/treesearch/8362

Summary

This study described a sediment transport model for the North Fork of the Boise River in SW Idaho. The authors conducted surveys of gullies that developed in a small, steep watershed in the Idaho Batholith after a severe wildfire followed by intense precipitation, measuring gully length and cross sections to estimate the volumes of sediment loss due to gully formation. They estimated the runoff rate and duration associated with the gully-forming event and used the sediment volume measurements to calibrate a general physically based sediment transport equation in this steep, high shear stress environment. Their results suggest that for steep hillslopes, a greater nonlinearity in the sediment transport function exists than that assumed in some existing hillslope erosion models which calculate sediment transport capacity using the bed load equations developed for rivers. They compared the sediment yields under anthropogenic (harvest) and natural (wildfire) disturbances. Disturbances due to forest harvesting appear to increase the frequency of sediment delivery; however, the sediment delivery following wildfires seems to be more severe.

<u>Specific location</u>: Idaho batholith region - Trapper Creek within the North Fork of the Boise River in SW Idaho

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Kirchner, J.W. et al. 2001	Idaho		x		x	x	x

Reference

Kirchner, J.W., R.C. Finkel, C.S. Riebe, D.E. Granger, J.L. Clayton, J.G King, and W.F. Megahan. 2001. Mountain erosion over 10 yr., 10 k.y., and 10 m.y. time scales. Geology 29, 591–594. https://research.fs.usda.gov/treesearch/23971

Summary

This study used cosmogenic 10Be to measure erosion rates over 10 k.y. time scales at 32 Idaho mountain catchments, ranging from small experimental watersheds (0.2 km2) to large river basins (35000 km2). These long-term sediment yields are, on average, 17 times higher than stream sediment fluxes measured over 10–84 yr, but are consistent with 10 m.y. erosion rates measured by apatite fission tracks. The results imply that conventional sediment-yield measurements—even those made over decades—can greatly underestimate long-term average rates of sediment delivery and thus overestimate the life spans of engineered reservoirs. The results also show that the erosional regime of mountain landscapes encompasses two distinct styles of sediment delivery. Incremental erosion prevails most of the time, but accounts for a small fraction of the total sediment yield; by contrast, catastrophic erosion events are rare and brief, but dominate the long-term sediment yield. Aquatic habitats subjected to such catastrophic sediment loads will be episodically disrupted, and the species that recolonize such disturbed habitats may differ from those that thrive under more stable, incremental sediment fluxes.

Specific location: central Idaho

Aquatic species: species that recolonize disturbed habitats

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
McGuire, L. et al. 2016	Colorado		x	?	x	x	

Reference

McGuire, L., F. Rengers, J. Kean, J. Coe, B. Mirus, R. Baum, and J. Godt. 2016. Elucidating the role of vegetation in the initiation of rainfall-induced shallow landslides: Insights from an extreme rainfall event in the Colorado Front Range. GEOPHYSICAL RESEARCH LETTERS. 43(17): 9084–9092. https://doi.org/10.1002/2016GL070741

Abstract

More than 1100 debris flows were mobilized from shallow landslides during a rainstorm from 9 to 13 September 2013 in the Colorado Front Range, with the vast majority initiating on sparsely vegetated, south facing terrain. To investigate the physical processes responsible for the observed aspect control, we made measurements of soil properties on a densely forested north facing hillslope and a grassland-dominated south facing hillslope in the Colorado Front Range and performed numerical modeling of transient changes in soil pore water pressure throughout the rainstorm. Using the numerical model, we quantitatively assessed interactions among vegetation, rainfall interception, subsurface hydrology, and slope stability. Results suggest that apparent cohesion supplied by roots was responsible for the observed connection between debris flow initiation and slope aspect. Results suggest that future climate-driven modifications to

forest structure could substantially influence landslide hazards throughout the Front Range and similar water-limited environments where vegetation communities may be more susceptible to small variations in climate.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Meyer, G. et al. 2001	Idaho		x	?	x	x	

Reference

Meyer, G., J. Pierce, S. Wood, and A. Jull. 2001. Fire, storms, and erosional events in the Idaho batholith. Hydrological Processes 15(15): 3025–3038. https://doi.org/10.1002/hyp.389

Abstract

In late December 1996, the South Fork Payette River basin in west-central Idaho experienced a prolonged storm that culminated on January 1. 1997, with intense rain on melting snow that triggered slide failures, producing debris flows and sediment-charged floods. Failures occurred in saturated, cohesionless, grussy colluvium derived from Weathered Idaho batholith granitic rocks. Many failures along the South Fork Payette River originated in ponderosa pine forests burned in the 1989 stand-replacing Lowman fire. An example is the 0.49 km(2) 'Jughead' Creek basin. where a single large colluvial failure produced almost 40% of the total volume eroded from the basin and generated a massive and rapid debris flow. Failures also occurred in steep, unburned. and unforested drainages such as Hopkins Creek. In this south-facing 0.58 km(2) basin, 15 colluvial hollows failed. but no single failure produced more than 10% of the total eroded volume. Sediment transport in Hopkins Creek occurred by prolonged sediment-charged sheetflooding. Despite vegetation differences, sediment yields from the geomorphically similar Hopkins Creek (similar to 42 000 Mg km(-2)) and Jughead Creek (similar to 44 000 Mg km(-2)) basins were quite similar. These 1997 erosion events are equivalent to several thousand years of sediment yield at low rates (2.7-30 Mg km(2) year(-1)) measured by short-term sediment trapping and gauging in Idaho batholith watersheds. If similar large events were solely responsible for sediment export. recurrence intervals (Rls) of several hundred years would account for higher sediment yields averaged over similar to 10(4) year from Idaho batholith watersheds. Dating of small fire-induced sheetflooding events in an early Holocene tributary junction fan of Jughead Creek indicates that frequent small sedimentation events (RI approximate to 33-80 year) occurred between 7400 and 6600 cal year BP. with an average yield not greatly exceeding 16 Mg km(-2) year(-1). Compared with the Holocene average, erosion rates during that 800-year period were unusually low, suggesting that sediment yields have not been constant over time, and that climatic variations and related fire regime changes may exert a strong influence on the probability of major erosional events,

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Meyer, G.A. et al. 1992	western US		x		x	x	

Reference

Meyer, G.A., S.G. Wells, R.C. Balling Jr, and A.J.T. Jull. 1992. Response of alluvial systems to fire and climate change in Yellowstone National Park. NATURE. 357(6374): 147–150. https://doi.org/10.1038/357147a0

Abstract

Projections of the ecological effects of global climate change often include increased frequency and/or intensity of forest fires in regions of warmer and drier climate 1-3. In addition to disturbing biological systems, widespread intense fires may influence the evolution of the physical landscape through greatly enhanced sediment transport 4. Debris-flow to flood-streamflow sedimentation events following the 1988 fires in the Yellowstone National Park area (Wyoming and Montana, USA) have allowed us to examine the geomorphological response to fire in a mountain environment. Abundant analogous deposits in older alluvial fan sequences bear witness to past fire-related sedimentation events in northwestern Yellowstone, and radiocarbon dating of these events yields a detailed chronology of fire-related sedimentation for the past 3,500 years. We find that alluvial fans aggrade during periods of frequent fire-related sedimentation events, and we interpret these periods as subject to drought or high climatic variability. During wetter periods, sediment is removed from alluvial fan storage and transported down axial streams, resulting in floodplain aggradation. The dominant alluvial activity is strongly modulated by climate, with fire acting as a drought-actuated catalyst for sediment transport.

Specific location: Montana, Wyoming

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Moody, J.A., and D.A. Martin. 2009	western US		x		x	x	

Reference

Moody, J.A., and D.A. Martin. 2009. Synthesis of sediment yields after wildland fire in different rainfall regimes in the western United States. International Journal of Wildland Fire 18: 96–115. https://doi.org/10.1071/WF07162

Summary

This study compiled, from published literature (1927-2007), post-fire sediment erosion, transport, and deposition collected within 2 years of a wildfire for sites across the western United States, including eastern Oregon and Washington. Annual post-fire sediment yields were computed and grouped into four measurement methods (hillslope point and plot measurements, channel measurements of suspended-sediment and sediment erosion or deposition volumes). Post-fire sediment yields for each method were then grouped into eight different rainfall regimes. Mean sediment yield from channels was significantly greater than from hillslopes, indicating that on the time scale of wildfire, channels were the primary sources of available sediment. A lack of correlation of sediment yield with topographic slope and soil erodibility further suggested that sediment availability may be more important than slope or soil erodibility in predicting post-fire sediment yields. The maximum post-fire sediment yields were comparable to long-term sediment yields from major rivers of the world. Based on 80 years of data from the literature, wildfires have been an important geomorphic agent of landscape change when linked with sufficient rainfall. They noted effects are limited in spatial scale to the immediate burned area and to downstream channel

corridors, suggesting sediment availability may be more important than slope or soil erodibility in predicting post-fire sediment yields, and noting that these results can be used to guide the prioritization of post-fire land management policies.

Specific location: western U.S., including the Sub-Pacific rainfall regime, which spans eastern Oregon and eastern Washington

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Pierce, J. et al. 2004	Idaho		x		x	x	

Reference

Pierce, J., G. Meyer, and A. Jull. 2004. Fire-induced erosion and millennial scale climate change in northern ponderosa pine forests. Nature. 432(7013): 87–90. https://doi.org/10.1038/nature03058

Abstract

Western US ponderosa pine forests have recently suffered extensive stand-replacing fires followed by hillslope erosion and sedimentation(1-4). These fires are usually attributed to increased stand density as a result of fire suppression, grazing and other land use, and are often considered uncharacteristic or unprecedented(1-3). Tree-ring records from the past 500 years indicate that before Euro-American settlement, frequent, low-severity fires maintained open stands(1-3). However, the pre-settlement period between about AD 1500 and AD 1900 was also generally colder than present(5-10), raising the possibility that rapid twentieth-century warming promoted recent catastrophic fires. Here we date fire-related sediment deposits in alluvial fans in central Idaho to reconstruct Holocene fire history in xeric ponderosa pine forests and examine links to climate. We find that colder periods experienced frequent low-severity fires, probably fuelled by increased understory growth. Warmer periods experienced severe droughts, stand-replacing fires and large debris-flow events that comprise a large component of long-term erosion(11) and coincide with similar events in sub-alpine forests of Yellowstone National Park(12). Our results suggest that given the powerful influence of climate, restoration of processes typical of pre-settlement times may be difficult in a warmer future that promotes severe fires.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Rengers, F.K. et al. 2023	New Mexico		x		x	x	

Reference

Rengers, F.K., L.A. McGuire, K.R. Barnhart, A.M. Youberg, D. Cadol, A.N. Gorr, O.J. Hoch, R. Beers, and J.W. Kean. 2023 The influence of large woody debris on post-wildfire debris flow sediment storage. Natural Hazards and Earth System Sciences 23(6): 2075–2088.

Abstract

Debris flows transport large quantities of water and granular material, such as sediment and wood, and this mixture can have devastating effects on life and infrastructure. The proportion of large woody debris (LWD) incorporated into debris flows can be enhanced in forested areas recently burned by wildfire because wood recruitment into channels accelerates in burned forests. In this study, using four small watersheds in the Gila National Forest, New Mexico, which burned in the 2020 Tadpole Fire, we explored new approaches to estimate debris flow velocity based on LWD characteristics and the role of LWD in debris flow volume retention. To understand debris flow volume model predictions, we examined two models for debris flow volume estimation: (1) the current volume prediction model used in US Geological Survey debris flow hazard assessments and (2) a regional model developed to predict the sediment yield associated with debris-laden flows. We found that the regional model better matched the magnitude of the observed sediment at the terminal fan, indicating the utility of regionally calibrated parameters for debris flow volume prediction. However, large wood created sediment storage upstream from the terminal fan, and this volume was of the same magnitude as the total debris flow volume stored at the terminal fans. Using field and lidar data we found that sediment retention by LWD is largely controlled by channel reach slope and a ratio of LWD length to channel width between 0.25 and 1. Finally, we demonstrated a method for estimating debris flow velocity based on estimates of the critical velocity required to break wood, which can be used in future field studies to estimate minimum debris flow velocity values.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Rengers, F.K. 2020	California		x		x	x	

Reference

Rengers, F.K., L.A. McGuire, N.S. Oakley, J.W. Kean, D.M. Staley, and H. Tang. 2020. Landslides after wildfire: initiation, magnitude, and mobility. Landslides 17(11): 2631–2641. https://doi.org/10.1007/s10346-020-01506-3

Abstract

In the semiarid Southwestern USA, wildfires are commonly followed by runoff-generated debris flows because wildfires remove vegetation and ground cover, which reduces soil infiltration capacity and increases soil erodibility. At a study site in Southern California, we initially observed runoff-generated debris flows in the first year following fire. However, at the same site three years after the fire, the mass-wasting response to a long-duration rainstorm with high rainfall intensity peaks was shallow landsliding rather than runoff-generated debris flows. Moreover, the same storm caused landslides on unburned hillslopes as well as on slopes burned 5 years prior to the storm and areas burned by successive wildfires, 10 years and 3 years before the rainstorm. The landslide density was the highest on the hillslopes that had burned 3 years beforehand, and the hillslopes burned 5 years prior to the storm had low landslide densities, similar to unburned areas. We also found that reburning (i.e., two wildfires within the past 10 years) had little influence on landslide density. Our results indicate that landscape susceptibility to shallow landslides might return to that of unburned conditions after as little as 5 years of vegetation recovery. Moreover, most of the landslide activity was on steep, equatorial-facing slopes that receive higher solar radiation and had slower rates of vegetation regrowth, which further implicates vegetation as a controlling factor on post-fire landslide susceptibility. Finally, the total volume of sediment mobilized by the year 3 landslides was much

smaller than the year 1 runoff-generated debris flows, and the landslides were orders of magnitude less mobile than the runoff-generated debris flows.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Welcker, C. 2011	Idaho		x		x	x	x

Reference

Welcker, C. 2011. Bulking debris flow initiation and impacts. PhD Thesis, University of Idaho. 196pp. https://www.academia.edu/89622446/Bulking_Debris_Flow_Initiation_and_Impacts

Summary

This study documents bulking debris flows (BDFs) are generated by infiltration excess (Horton) overland flow, eroding sufficient sediment on steep, sparsely-vegetated hillslopes to achieve debris-flow rheology. BDFs erode sediment from hillslopes and previously unchanneled hollows, entering the perennial stream network and scouring alluvium along their path to junctions with larger streams, where they typically deposit. Although BDFs have been documented in arid or burned sites throughout the western United States for over 100 years, their initiation is poorly understood, as are their geomorphic and ecological effects. The author developed a numerical model of BDF initiation from overland flow to test the hypothesis that BDFs can be generated without mass failure or episodic addition of sediment. The model incorporated erosion of sediment as bedload, transfer of bedload to suspended load, and alteration of fluid properties based on increased suspended load, which in turn increased bedload and suspended sediment transport. The predicted transition to debris-flow sediment concentrations and the pattern of hillslope erosion showed good agreement with field observations. Debris-flow generation in arid landscapes that experience progressive sediment bulking should lead to measurably different slope area trends of channel-head locations and topography than humid landscapes by shallow landslide debris flows (SLDFs). The author documented, and confirmed with field surveys, that the slope area trend of BDF channel heads would follow the underlying hillslope topography. Longitudinal profiles for BDFs were similar to SLDFs, but they did not correspond with the observed extent of BDF erosion. BDF effects on stream temperature lasted for 7-40 years and were found to be greater than for wildfire disturbance alone. Stream temperature was well correlated with solar radiation, but reach heating was complicated by site-specific cooling, which appears to be related to the size of the local, alluvial aquifer.

<u>Specific location</u>: Idaho batholith

<u>Aquatic species</u>: fish

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest	Hillslope-mass wasting	Semi-arid	Aquatic species
Zung, A.B. et al 2009	Wyoming	Q2?			x	x	

Reference

Zung, A.B., C.J. Sorenson, and E. Winthers. 2009. Landslide Soils and Geomorphology in Bridger-Teton National Forest, Northwest Wyoming. Physical Geography. 30(6): 501–516. https://doi.org/10.2747/0272-3646.30.6.501

Summary

The ratio of SOM in the A horizon compared to SOM in the horizon underlying the A on active landslides averaged 1.28, ranging from 0.73 to 2.01. On inactive landslides, this ratio averaged 1.87 and ranged from 1.06 to 2.59. This difference in SOM content is at least partly due to differences in vegetation on active and inactive landslides. Specifically, coniferous species such as Douglas fir (*Pseudotsuga menziesii*) and Engelmann spruce (*Picea engelmannii*) were observed on some inactive landslides, and these vegetative species contribute greater amounts of SOM to soil surfaces than do brush species like sagebrush (*Artemisia tridentata*), antelope bitterbrush (*Purshia tridentata*) and rubber rabbitbrush (*Chrysothamnus nauseosus*), which were commonly observed on active landslides.

Appendix E. Literature Review Examples

Two literature reviews were found: (Barrett and Reilly 2017; Herrera Environmental Consultants Inc. 2004). Both reports were commissioned by Washington's adaptive management program. The following paragraphs summarize key aspects of these studies that may be relevant for the development of IRST's research proposal.

Research questions: Barrett and Reilly (2017) reviewed the potential effects of salvage logging on riparian areas for Washington eastside forests, whereas Herrera (2004) focused on wood loading dynamics in and around streams in eastern Washington forests. Herrera was given a list of 41 specific research questions grouped into nine topic areas. Barrett did not have a list of questions, but they identified five relevant research subthemes (Silviculture/Forest Practices, Fuels/Fire, Erosion/Soils, Riparian/Aquatic, and Biodiversity/Ecosystems).

Process context: The Herrera study was embedded in a broader process, which included a kick-off workshop with the sponsoring committee, followed by the literature search, a broader workshop to review the literature found, consolidation of results in a literature database, and a final report. Barrett did not report on broader process but presented their findings to the sponsoring committee at project conclusion.

Eligibility criteria (Study area): Both studies expanded their search to include similar environments outside of the target state. Barrett's search encompassed Oregon, Idaho, western Montana, northern California, northern Nevada, southeastern British Columbia, and southwestern Alberta and searched for specific forest types. Herrera (2004) described three location categories: eastern Washington, "analogous regions" (they did not further define this), and other studies relevant to the topic.

Search: Both studies searched literature databases and solicited documents from subject matter experts. Barrett mentions searching in Google Scholar and ResearchGate and provided a few keyword examples. Herrera provided an appendix explicitly listing all databases searched (but not keywords) and all individuals and institutions contacted.

Selection (Screening): Barrett includes a short section on screening but without much description of an explicit methodology or number of documents screened. They reviewed 75 documents. Herrera reports compiling more than 5,000 documents, however, no further information on screening is provided.

Data extraction: Barrett was given a number of elements to extract, including topics/keywords, location, forest types, forest practices, and analysis methods. In addition, they assigned studies to five relevant research subthemes (Silviculture/Forest Practices, Fuels/Fire, Erosion/Soils, Riparian/Aquatic, Biodiversity/Ecosystems). They used an Excel workbook to store and analyze the information.

Results: Herrera structured the main body of their report around the 41 specific research questions grouped into nine topic areas, addressing each one in a separate section. Each relevant literature source that contains quantitative data is briefly discussed, and an assessment is made of the extent to which data collected for the question covers eastern Washington stream channel sizes and forest types. Both reports started with a large number of specific questions (15 for Barrett and 41 for Herrera) and summarized the literature for each question. Barrett identified five relevant research subthemes (Silviculture/Forest Practices, Fuels/Fire, Erosion/Soils, Riparian/Aquatic, Biodiversity/Ecosystems) and summarized the literature for each. Barrett mapped the location of each study and noted certain clusters around large fires.

Additional products: Barrett produced a database of publications in Excel format; Herrera compiled the literature found in a Procite bibliographic database.