EMC-2016-003: EFFECTIVENESS MONITORING COMMITTEE PROJECT PROPOSAL – October 20, 2017

Proposed Project: REPEAT LIDAR SURVEYS TO DETECT STORM-TRIGGERED LANDSLIDES. This project is a precursor supporting study for Project Proposal EMC-2016-3 Conceptual Design and Implementation Planning for Evaluation of Effectiveness of FPR's for Unstable Areas.

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Introduction

For FY 2017, we propose acquisition of new LiDAR (Light Detection and Ranging; see section "LiDAR Basics" below for a brief description) data for one or more areas to develop and test specifications and analytical methods regarding temporal comparison of LiDAR (LiDAR differencing) for identification and characterization of landslides. This effort would improve our technical understanding of the requirements, limitations, and advantages of comparing a time series of LiDAR data to map and characterize landslides. This is the keystone methodology for a subsequent EMC project (EMC 2016-03) designed to evaluate effectiveness of Forest Practice Rules that address timber harvest and forest management in or near "Unstable Areas". The use of LiDAR to map landslides and identify potential Unstable Areas is of special interest because of the potential for identification and early warning of mass wasting hazards to the public and public resources.

We intend to test the process of LiDAR differencing in timberlands that have recently experienced a broad range of storm impacts and landslide activities to determine detection limits of landslides (size or area), to evaluate discrimination of landslide age (particularly, differentiation of new landslides from older landslides), to observe accuracy of landslide characterization (determination of physical dimensions, sediment deposition/delivery to streams and lakes, mass wasting process classification, landform and geomorphic setting as observed in the field compared to LiDAR interpretation), and to evaluate overall reliability of LiDAR as a landslide inventory tool.

To test the LiDAR differencing method, we need a site or sites which have the following characteristics:

1. Recent LiDAR data that predates a candidate rain-storm event. Candidate rain-storms are any that occur in areas of interest for this study and will be evaluated against a variety of criteria.
2. Ready access to ground locations to conduct field-based surveys which may be restricted in the case of private land or remote sites.
3. Proximity to staff offices and bases of operations to facilitate field surveys.
4. Presence of cold water fishery resources and associated aquatic habitat.
5. Timberland that has experienced a range of management (e.g. timber harvest practices covered by California FPR's) prior to the candidate storm
6. Susceptibility to shallow and deep-seated landslides and surface erosion (generally present in California forested uplands).
7. Additional support from other stakeholders, especially land managers and owners. This may come in the form of cost-sharing or in-kind contributions to planning and implementing the study.
8. Public benefit to the degree that public funds are required.

In this document, we describe two geographic areas of interest that we have selected as meeting our criteria to varying degrees. We then provide basic descriptions of the technologies and how we intend to use them.

Objective

The objective of this proposed pilot study is to compare two LiDAR acquisitions that bracket stressing event(s) (storm event(s) that triggers mass wasting events) to determine the activity and characteristics of mass wasting features (e.g. unstable areas and unstable soils). Our ultimate goal is to evaluate effectiveness of FPRs applicable in unstable areas in green tree harvest areas and on along roads to reduce sediment impacts to water quality, fish habitat, and promote WLPZ function. Additional data to classify (stratify) the area of interest with respect to forest stand history, land use, climate, and geologic factors will be needed to test the effectiveness of FPRs; while some effort will be made to develop these data for the pilot study, this is a secondary objective of the pilot study. This pilot phase will be focused on using LiDAR as a remote sensing tool to provide accurate maps locating and characterizing mass wasting features and unstable areas.

Background

The EMC Mass Wasting subcommittee (EMC members Matt O'Connor and Drew Coe), assisted by staff from California Geological Survey (CGS), CALFIRE, and the Central Valley RWQCB, is engaged in developing a study plan to determine the effectiveness of the California Forest Practice Rules at reducing or minimizing sediment impacts derived from management-related mass wasting. The proposed approach for this future study is comparable to a study with similar objectives published in 2013 by the State of Washington Department of Natural Resources[1]. That study combined classification of the study area landscape into forest stand classes with comparable management history and geomorphic characteristics with a comprehensive inventory of landslides that occurred during a storm event that produced widespread mass wasting (landslides) so that statistical inference methods could be employed to test for differences in landslide response among different landscape classes. The proposed study presented here is intended to lay technical groundwork for the study of FPR effectiveness by developing a method (LiDAR differencing) to inventory landslides efficiently and accurately.

Core elements of the FPRs focus on protecting resources at risk (i.e., cold water fisheries, aquatic habitat, riparian and channel migration zones) and maintaining water quality standards as outlined in Regional Basin Plan objectives. Although the full scope of the California Forest Practice Rules mass wasting effectiveness monitoring project remains in development, we seek to implement a pilot project to demonstrate and develop LiDAR differencing techniques to identify and characterize landslides and geomorphic landforms. This technique will be critical for the effectiveness monitoring project. This pilot phase will evaluate appropriate methodologies that promote accurate identification of watershed-wide mass wasting disturbance with LiDAR data supported by efficient field survey sampling to calibrate/validate LiDAR data interpretation.

[1] Stewart, G. et al. 2013. The Mass Wasting Effectiveness Monitoring Project: An examination of the landslide response to the December 2007 storm in Southwestern Washington. Cooperative Monitoring, Evaluation and Research Report CMER 08-802, Washington Department of Natural Resources, Olympia, WA. 118 p. plus Appendices.

The primary goal of this pilot phase is to document the mass wasting response to a stressing event such as a storm and its interaction across a range of current and historic land uses. In addition, the analysis will evaluate approaches to classify forest stands (stratify the sample frame) by stand age and harvest history, other land use and disturbance factors, climate (hydrologic forcing), and geologic/geomorphic factors that will ultimately contribute to the effectiveness monitoring investigation of potential management factors affecting the frequency and magnitude of mass wasting. The relationship of the project to EMC strategic plan themes and critical questions is summarized in an appendix.

CGS staff is presently engaged in evaluating LiDAR as a landslide mapping tool in comparison to maps from prior ground and aerial-photo based surveys; this work will help inform the approach used in this proposed pilot study for detection and mapping of shallow landslides (debris slides and debris flows). Prior work with LiDAR to develop automated procedures to map deep-seated landslide features (rockslides and earthflows per CGS definitions) developed and used by Oregon Department of Geology and Mineral Industries[2] will be tested for suitability for this project. Suitability will be judged by use of visual inspection by California Professional Geologists. If deemed suitable the automated process may be employed across larger regions to assist in the identification of mass wasting features.

LiDAR Basics

LiDAR data consists of an array of return times for reflected light pulses that are mapped with very precise latitude and longitude coordinates. The return times correlate to the elevation of the reflecting surface. Thus, each reflection (e.g. return) is represented as a precise point with latitude (x), longitude (y), and elevation (z) coordinates. The array of points is referred to as a point cloud which consists of all the reflections of the survey. The most distinct returns in the cloud are the first returns which may have reflected off of tree tops, water, or the ground. In forested areas, the first returns compose the canopy surface. Last returns typically are reflections off the ground unless blocked, which may occur in thick forest settings where the only remedy is to survey at a very high laser pulse rate to ensure a minimal number of ground returns.

Digital Elevation Models (DEM)

LiDAR vendors process the point cloud data to select first and last returns to produce canopy surface models and “bare earth” models, respectively. These products are digital elevation models (DEM) which are a raster table of precisely mapped elevations at sub-meter scales that can be displayed as a map. A process known as “map algebra” allows for simple mathematical comparisons between multiple DEMs. For example, tree height is determined by subtracting the last return from the first return. In cases, where two DEMs represent different surveys, such as a baseline survey and a post-event survey, subtraction of the two yields a “difference model” in which negative values reflect decreases in elevation and positive values reflect elevation increases. In the case of comparing of two acquisitions of bare earth models, elevation changes represent changes in the ground surface. Alternatively, comparison of two canopy surface models over a period of time may represent canopy growth or loss or slope deformation.

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[2] Protocol for deep landslide susceptibility mapping, Oregon Department of Geology and Mineral Industries, Special Paper 48

Justification

LiDAR provides a very effective means to identify unstable landforms and capture the occurrence of mass wasting over broad regions rapidly and accurately. LiDAR facilitates more accurate and detailed quantitative identification and mapping of mass wasting features than any other method. Comparable data cannot be obtained by on-the-ground or conventional aerial photography. LiDAR is extremely cost effective for these purposes.

Identification and mapping of mass wasting features based upon a single LiDAR survey cannot reveal landscape changes over time that are necessary to determine which features were triggered or reactivated by a particular stressing event. Moreover, within a single LiDAR acquisition, a bare earth model can vary in quality depending on the density of ground returns as influenced by dense low-growing vegetation (e.g. blackberry thickets), stand density and foliage, and thickness of duff and litter cover overlying the soil surface.

Approach

A minimum of two LiDAR surveys are required to allow comparisons before and after storm event(s) that triggers mass wasting events (i.e. a stressing event). The timing of surveys relative to the event(s) and the duration of time between the pre-event and post-event surveys are the primary controls regarding the validity of before-and-after comparisons. The potential of including mass wasting features that are unrelated to the stressing event(s) presents a potential problem. The potential of this confounding factor is reduced when the timing between surveys and the event(s) are tightly constrained. Field verification and use of aerial photographs will aid in determining which features are linked to a specific event.

For this pilot project we propose to compare forest/vegetation canopy surface and bare earth models for both pre- and post-event acquisitions to produce watershed-wide comparative analyses of mass wasting as a forensic tool to provide data that can be used to monitor effectiveness of FPRs and the influence of management practices with respect to mass wasting. Anomalous distortions of the canopy surface in forested areas would be detected and may indicate ground movement (or stand disturbance such as fire or timber harvest). Because canopy models are based on first returns, signal loss is minimal and the resolution is highest.

Distortions as revealed in the bare earth models would also be detected and may indicate mass wasting. While the difference models could detect change, they need to be visually inspected for the identification and mapping of mass wasting features. Visual (on-site and remote-sensed) and computer-assisted inspection may be required to distinguish false detections due to potential quality or alignment differences between DEMs.

Challenges

To succeed in this project, both technical and administrative challenges must be addressed. The most demanding of the technical challenges is that LiDAR surveys require specialized equipment and processes that are deployed from aircraft. This requires reliance on experienced vendors. Each vendor uses proprietary processes to produce the LiDAR products. Comparisons of LiDAR acquisitions between different vendors may result in difficulties due to the potential uniqueness of the combination of equipment, settings, and processing. Therefore, it is preferable to use the same vendor if possible. If not, it may be important to be able to provide a vendor the original raw LiDAR for both surveys for their processing. Existing LiDAR acquisitions may have use restrictions depending on the original contracts.

Geographic Scope: (See attached maps)

Below we describe two sites (the Bagley Fire burned area and the collective burned area of the Fred's and Power Fires) that meet some or all of the desirable criteria listed above. Each of these sites have experienced wildland fires after which LiDAR data was collected. Each of the sites experienced recent storm damage and a range of land use conditions that may relate to the extent and magnitude of storm damage. Burned areas are preferred over heavily timbered areas as environments to test methods because the accuracy of bare earth DEMs will be optimized without the interference of tall and dense vegetation.

Post-fire erosion is strongly related to the soils and parent rock types. Each of the sites consist of different rock types and related geologic conditions. Evaluating the methods over a suite of rock types and conditions would test the efficacy of LiDAR across a variety of soils and parent rock types.

For both areas of interest (AOI), we provide maps that illustrated property ownership, fire perimeters, recent storm damage on US Forest Service lands, and vegetation types.

Boggs Mountain Demonstration Forest AOI

The Boggs Mountain Demonstration Forest AOI consists of mixed volcanic and sedimentary, and serpentinitic rock types that characterize much of the timber producing regions of the Cascades, Klamath, and Modoc Geomorphic Provinces.

- Pre-storm QL1 LiDAR exists
- Dates
  - Valley Fire: 2016
  - LiDAR: 2017 (LiDAR collected 1 year after Valley Fire)
- Types of Movement
  - Subject of ongoing CGS mapping: rock slide, debris slides, debris flows, cut slope/fill slope failures
- Potential Causal Mechanisms
  - Excess moisture during 2016-17 storm season following the Valley Fire
- Watersheds of Interest
  - Putah Creek
  - Kelsey and Cole Creeks and Clear Lake
- Aquatic Habitat
  - The streams are trout fisheries.
- Ownership
  - Mixed public and private timberland, predominantly private
- Public Benefit Elements
  - Water quality, fisheries, and aquatic habitat
  - Site lies immediately upstream of reservoirs and provide limited cold water fisheries and aquatic habitat.

- Public Safety Issues
    - Post-fire debris flows

Freds/Power Fires AOI

The primary rock type of the Freds/Power Fires AOI is granodiorite that extends throughout the timbered portions of the Sierra Nevada Geomorphic Province.

- Pre-storm QL1 LiDAR exists
- Dates

    North Polygon (Freds Fire, King Fire, and Cleveland Fire)
    - Fires: Freds: Oct-Nov 2004, King: Sep-Oct 2014, Cleveland: Oct 1992
    - LiDAR: 10/2014-11/2014, 05/2015-06/2015 (LiDAR collected 10 to 10.5 years after Freds Fire, 1-8

        months after King Fire, and 22 years after Cleveland Fire)

    South Polygon (Power Fire)
    - Fire: Oct-Nov 2004
    - LiDAR: 11/2014, 04/2015-06/2015 (LiDAR collected 10 to 10.5 years after Power Fire)
- Types of Movement
    - Debris flows, earthflows, rotational slides, cut slope/fill slope failures
- Potential Causal Mechanisms
    - Excess moisture during 2016-17 storm season
- Watersheds of Interest
    - SF American River, Mokelumne River
- Ownership
    - Mixed public and private timberland (more balanced mix, with 61% public and 39% private)
    - Ownership distribution not a regular grid, but has balanced coverage throughout AOI
- Public Benefit Elements
    - Water quality and habitat protection
- Aquatic Habitat
    - Considerable, site includes tens of miles of cold water fisheries and aquatic habitat upstream of nearest reservoirs and dams
- Public Safety Issues
    - US Hwy 50
        - Flooding and landsliding

LiDAR Summary

The proposed LiDAR acquisition would advance the goals of the Effectiveness Monitoring Committee (EMC) in developing scientifically sound methods for understanding and monitoring the effects of stressing storms over a variety of terrain, forest stands, and management history. The funds expended for this proposal would: 1) enable preparation of technical specifications and requirements, 2) predict future costs and levels of effort for the storm response study, and 3) advance technical expertise that would be available for other EMC studies. Acquisition would be arranged for the late summer of 2018 once the areas are free of snow pack.

Potential Collaboration

CALFIRE and SWRCB staff may contribute to data processing and analysis and may contribute field personnel for on-the-ground landslide surveys. EMC Member Dr. Matt O'Connor, PG #6847 CEG #2449 will request funding to participate in the data analysis and on-the-ground landslide surveys. Collaboration with other organizations (e.g. timber industry resource managers & geologists) regarding their experience with LiDAR as a landslide-mapping tool would be beneficial for the pilot study and the anticipated subsequent study designed to evaluate FPR effectiveness regarding unstable areas and mass wasting processes.

Resources Required to Implement the Pilot Study

This pilot study has been designed to leverage existing available LiDAR data and cooperating agency professional and staff resources to minimize cost. CGS will provide the professional and staff resources to accomplish the study, assisted by cooperators as available, including EMC member and co-PI Dr. O'Connor in a professional capacity as a contractor (if possible).

CGS expects the study to include the following tasks:

1. Coordinate the data acquisition, and either conduct or coordinate the production of the DEM of difference (DoD).
2. Examine the DoD to select sites that are free of access constraints and that may be diagnostic in the characterization of the following aspects: detection limits, false negatives and false positives for both vertical and horizontal change with emphasis on landslides, forest road systems, and related sedimentation.
3. Conduct further characterization of sites identified in (2) via field evaluation (For both AOI's the sites will likely be restricted to public lands).
4. Reprocessing of the DoD by either CGS or other cooperators (if necessary) to compensate for complexities revealed by (2) and (3).
5. Evaluate potential confounding factors that may cause detection errors.
6. Prepare an internal report describing data validation, characterization and error evaluation, and recommendations for appropriate parameters to be applied across the entire AOI's.
7. Following the recommended criteria, the complete AOI's will be characterized as a digital remote sensing operation.
8. The work product for the complete AOI's will be examined to develop a selection of sites that are either particularly critical or informative to recommend for more detailed evaluation by either CGS or others.
9. A pilot project report will be developed to provide guidance in the application, limitations, costs, and effectiveness using lidar differencing as a tool for the evaluation of the effectiveness of Forest Practice Rules in regard to mass wasting under one or multiple stressing events.

Budget Request:

The costs would range from approximately $50,000 if only one of the proposed areas is funded to $100,000 if both areas are approved Project technical oversight by Dr. Matt O'Connor, O'Connor Environmental, Inc. is estimated at $33,000 based on 220 hours of effort distributed throughout the project.

APPENDIX

Relationship to Strategic Plan Themes and Critical Questions:

This proposed pilot study is intended to support a subsequent study designed to evaluate effectiveness of Forest Practice Rules in reducing erosion and water quality impacts associated with timber harvest and other forest management in or near "Unstable Areas". Below are critical questions within the EMC's Strategic Plan to which the future FPR effectiveness study is relevant; by extension, these critical questions are relevant to the proposed pilot study.

<u>Theme 4. Mass Wasting</u>.

This proposal is most directly related to EMC Strategic Plan Theme 4-Mass Wasting Sediment (directly quoted below): To limit mass wasting sediment from anthropogenic sources, the FPRs require that timber operations be planned and conducted to provide mitigation measures to minimize sediment delivery from unstable geologic features (14 CCR § 923 [943, 953]). While considerable past monitoring efforts have addressed implementation and short-term effectiveness of FPRs designed to limit sediment delivery from surface erosion processes, less documentation has occurred on a statewide basis for success of the FPRs in preventing sediment delivery from management-related mass wasting. This is particularly important in the California Coast Ranges and Klamath Mountains, where landslide features can be the primary sediment delivery mechanism. Achieving this goal is consistent with the goals of FGCom and/or FGCom and Board (Joint) policies, including the Endangered and Threatened Species, Salmon, Water, and Joint Pacific Salmon and Anadromous Trout Policies. In addition, these FPRs will also contribute toward meeting Basin Plan objectives. The critical questions regarding this theme address specific mass wasting related topics to determine if the current rules and regulations are effective in avoiding and reducing management-induced mass wasting.

Critical Questions: Are the FPRs and associated regulations effective in minimizing sediment delivery from…

(a) existing chronic unstable geologic features to maintain water quality?

(b) mass wasting during episodic rare events and/or large storms to maintain water quality (see Section 4.2.2)?

(c) mass wasting from high risk geologic features?

Landslides that do occur have the potential to deliver large wood and sediment to streams, and may cause substantial change in riparian and aquatic habitat. "Rare or large events" that trigger a large number of landslides in a region or watershed provide the opportunity to observe the degree to which WLPZ designs:

- mitigate sediment delivery to streams from landslide,
- mitigate triggering of near-stream landslides,

- provide LWD for recruitment to stream channels[3].

Following are excerpts from the EMC Strategic Plan Themes that are interrelated with this proposed study;

Theme 1: WLPZ Riparian Function

The FPRs have been developed to ensure that timber operations do not potentially cause significant adverse site-specific and cumulative adverse impacts to the beneficial uses of water, native aquatic and riparian-associated species, functions of riparian zones or result in an unauthorized take of listed aquatic species (14 CCR § 916 [936, 956]). The primary objective of the WLPZ FPRs is to maintain or restore riparian and aquatic functions in classified watercourses. This can occur with both passive and active management approaches that may incorporate options ranging from protection (passive no touch) to active manipulation of stand structure and include timber harvest (14 CCR § 916.9 [936.9, 956.9](v)). Key functions of riparian zones include large wood recruitment, watercourse shading, sediment filtration, nutrient input, microclimate control, streambank/hillslope stability, and habitat for terrestrial wildlife species.

Critical Questions: Are the FPRs and associated regulations effective in …

(d) retaining predominant conifers in WLPZs. (Implementation and Compliance) and large woody debris input to watercourse channels?

(e) filtering sediment that reaches WLPZs?

Theme 2: Watercourse Channel Sediment.

Since the implementation of the modern FPRs in 1975, a primary goal of these regulations has been to limit the delivery of management-related sediment to watercourse channels in California. The amount of hillslope erosion and sediment delivery that occurs following timber operations depends on numerous factors, including the site conditions present (e.g. slope, soil type, vegetative cover), soil disturbance, level of proper FPR implementation, and intensity and number of large storm events following the completion of logging. The FPRs have been upgraded numerous times in the past 40 years to reduce management related sediment delivery. Specifically, current silviculture practice regulations (14 CCR § 913 [933, 953]), harvesting practices and erosion control measures (14 CCR § 914 [934, 954]), watercourse and lake protection (14 CCR § 923 [943, 953]) and logging roads, landings and logging road watercourse crossings rules (14 CCR § 923 [943, 953]) provide measures to ensure timber operations meet the goals and intent of the FPRs by limiting sediment delivery to stream channels. These FPRs can contribute toward meeting goals of FGCom and/or FGCom and Board (Joint) policies that address protection of water quality and fish habitat, including the Endangered and Threatened Species, Salmon, Water, and Joint Pacific Salmon and Anadromous Trout Policies. In addition, these FPRs may also contribute toward meeting Basin Plan objectives.

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[3] mass wasting is an important process that moves LWD from the terrestrial to the aquatic environment; WLPZ is a critical source area for LWD recruitment to streams, and stream disturbance associated with mass wasting episodes may cause channel shifts and overbank flow that recruits LWD to the aquatic environment.

Critical Questions: for Theme 2 address erosion and sediment monitoring at both the watershed (or sub-watershed) scale and Plan scale. Critical Questions:

(f) Are the FPRs and associated regulations effective in minimizing management related sediment delivery from forest management activities to watercourse channels?

<u>Theme 3: Road and WLPZ Sediment</u>

Similar to Theme 2, the Road and WLPZ Sediment theme has been developed to answer critical questions regarding management-related hillslope erosion and sediment delivery to watercourse channels in forested watersheds. Theme 3 focuses on critical questions related to the effectiveness of FPR requirements included in the recently implemented Road Rules 2013 requirements (14 CCR § 923 [943, 953]). These FPRs also contribute toward meeting goals of FGCom and/or FGCom and Board (Joint) policies that address protection of water quality and fish habitat listed above. In addition, these FPRs may also contribute toward meeting Basin Plan objectives.

Critical Questions: Are the FPRs and associated regulations effective in …

(g) reducing or minimizing management-related generation of sediment and delivery to watercourse channels?

(h) reducing generation and sediment delivery to watercourse channels when timber operations implement the Road Rules 2013 measures?

(i) reducing the effects of large storms on landslides as related to roads, watercourse crossings and landings?

(j) maintaining or improving fish passage through watercourse crossing structures? (see Section 4.2 for discussion of appropriate scale(s))

<u>Theme 5: Fish Habitat</u>

Numerous FPR regulations relate to the protection of fish habitat features in forested watersheds, particularly those found in the WLPZ rule section [14 CCR § 916 (936, 956)]. Specifically, these FPRs require that timber operations shall be planned and conducted to provide protection for water temperature control, streambed and flow modifications by large woody debris, filtration of organic and inorganic material, upslope stability, bank and channel stabilization, and spawning and rearing habitat for salmonids [14 CCR § 916.4 (936.4, 956.4) (b)]. As stated above for the other themes, these rule requirements contribute toward meeting the goals of Fish and Game Commission and/or Fish and Game Commission and Board (Joint) policies, including: Endangered and Threatened Species Policy, Salmon Policy, Water Policy, and Joint Pacific Salmon and Anadromous Trout Policy. In addition, these FPRs may also contribute toward meeting Basin Plan objectives. The critical questions included under this theme relate to maintaining and/or restoring the quality and connectivity of foraging, rearing, and spawning habitat.

Critical Questions: Are FPRs and associated regulations effective in …

(b) maintaining and restoring the distribution of foraging, rearing and spawning habitat for anadromous salmonids? (Note: Monitoring may also be appropriate for the AB1492 Working Groups).

As demonstrated by the emphasized elements of Themes 1, 2, 3 and 5, this proposed project would be expected to contribute substantially to evaluation of FPR effectiveness in terms of those themes and their critical questions. If this proposal is funded, a detailed study plan will be developed and include specific critical questions and working hypotheses.

Finally, this proposed pilot phase could contribute to understanding potential long-range effects of climate change, drought, forest health and increased wildfire severity by including these factors as potential stressors that may influence accelerated mass wasting rates across managed timberlands. In particular, the effects of declining forest health expressed by tree mortality or reduced vigor in response to drought, disease, and insect infestation would be expected to increase the potential for slope instability due to a reduction in root reinforcement and reduced evapotranspiration. As a result, elevated soil moisture may increase the likelihood of a triggering event. Similarly, wildfire is expected to increase the potential for landslides. Landscape response to wildfire would also provide an opportunity to evaluate the effectiveness of site-specific protection measures implemented within fire-scarred WLPZs and logging areas to promote slope stability, reduce sediment delivery to channels, and promote LWD delivery to channels.