Inventory of Major Active Landslides in the Redwood Creek Basin

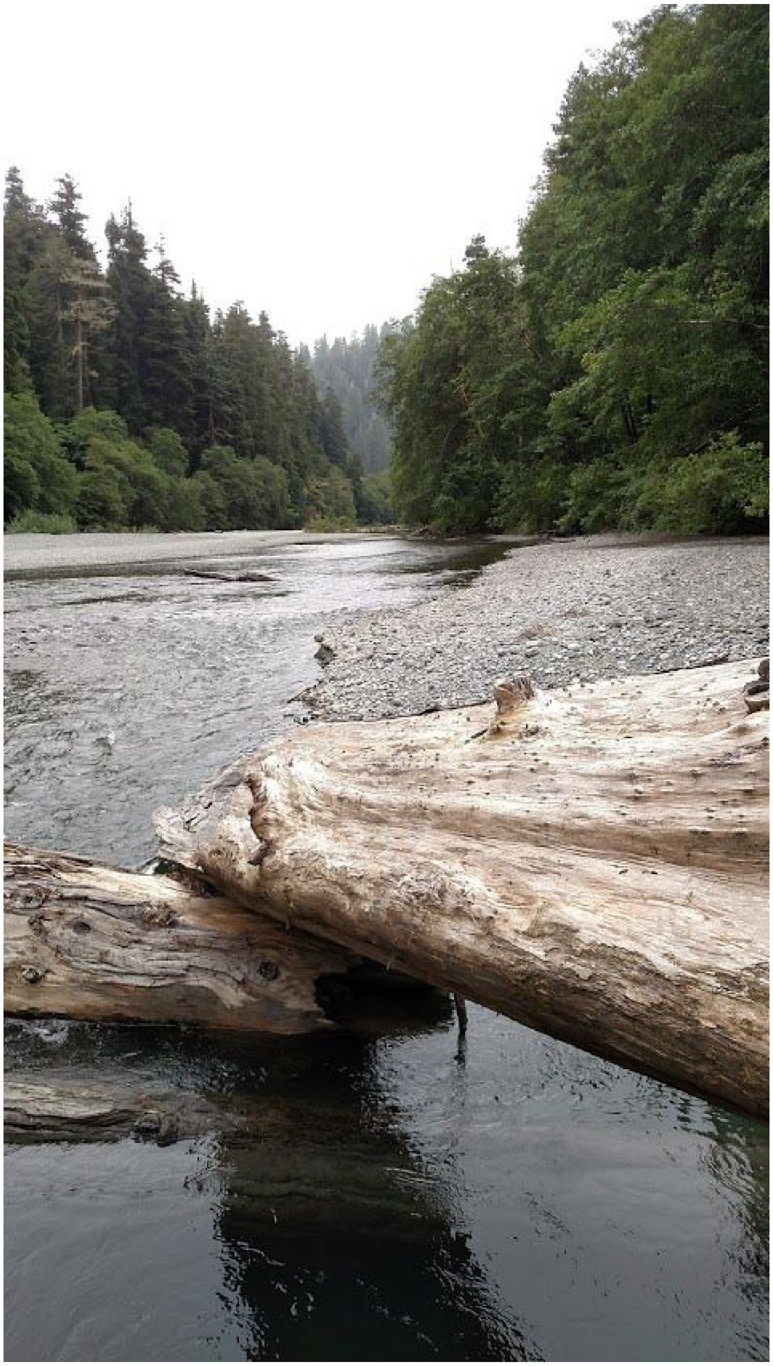

Photo by Lillebaek Anderson

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Abstract

The Redwood Creek Basin in Humboldt County, Northern California, has been affected by an abundance of landslides within the past century. The purpose of this project was to create an inventory of active landslides in the Redwood Creek Basin, which could then be assigned priority designation based on the size of the slide and proximity to streams. Datasets of Humboldt County Boundary, California Hydrography, Landslide GIS Data, and ESRI topographic maps were used for analysis and map creation. The active landslide layers were combined to form one layer, and using select by location only the streams in the Redwood Creek watershed were selected. Only landslides that were within 25 feet of a stream and were over 490,000 square meters were selected. Our results found 10 priority landslides within the watershed that were all on the tributaries of Redwood Creek. The map can potentially serve as a restoration, management, or informational tool.

Introduction

The Redwood Creek basin is a small watershed in Northern California which drains an area of approximately 285 mi² (Figure 1). Geology of the Redwood Creek basin is dominated by the 65 mile long Grogan Fault, which runs in a Northwest to Southeast direction parallel to the creek. Although much of the terrain is steep and mountainous, mainstem Redwood Creek exhibits relatively low topography except in the area of its headwaters (Cannata et. al. 2006). Like much of the tectonically active North Coast region, the basin is naturally unstable. Redwood Creek exhibits 27% large-scale landslides and 19% geomorphic features related to mass wasting events throughout the basin (Falls et. al. 2003). Several species of anadromous salmonids listed as either threatened or endangered under the Endangered Species Act (ESA) are extant in the Redwood Creek drainage, including Coho salmon *(Oncorhynchus kisutch)*, Chinook salmon *(Oncorhynchus tshawytscha)*, and Steelhead trout *(Oncorhynchus mykiss)*. The basin contains

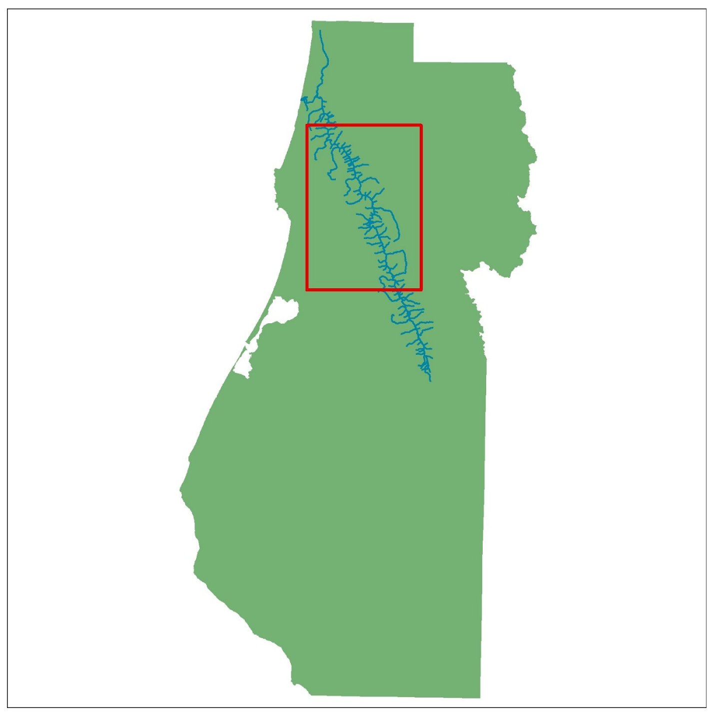

Figure 1: Locator Map of Redwood Creek Basin in Humboldt County, CA

over 120 miles of habitat suitable for these species (NMFS 2014). Redwood Creek is listed as impaired under Section 303(d) of the Clean Water Act (CWA) for temperature and sediment.

The watershed has experienced drastic changes in channel morphology following decades of extensive commercial timber harvest and a series of large flood events that occurred between 1955 and 1975. Timber harvest was operating at a minimal rate throughout the first half of the 20th century, with more than 80% of the basin covered in mixed conifer forest dominated by Redwood *(Sequoia sempervirens)* and Douglas fir *(Pseudotsuga menziesii)*. Areas of Redwood Creek that were not heavily forested consisted of oak woodland and prairie grassland cover types. Large-scale industrial harvest of old growth Redwood began in the early 1950s and continued through 1978, when more than 81% of the original forest had been harvested. (Madej & Ozaki 2009). Construction of roads for timber harvest was occurring at an accelerated rate through much of this time. The majority of 5,000 km of logging roads and 9,000 km of skid roads were built prior to the implementation of forest practice rules concerning road standards (Madej & Ozaki 2009).

Road-related construction activities have been shown to exacerbate landslide activity (Madej & Ozaki 1996). Although the occurrence of natural landslides is associated with significant storm events, landslide activity has been shown to significantly increase during storms of similar magnitude following decades of intensive timber harvest (Harden et. al. 1978). Naturally occurring landslides and road construction are the dominant sources of sediment inputs to Redwood Creek. Sedimentation has altered the channel morphology of Redwood Creek considerably, resulting in widespread channel aggradation and significant degradation of salmonid habitat (Madej & Ozaki 2009). The National Oceanic and Atmospheric Administration’s West Coast Fisheries program has identified the prioritization of landslides by size and delivery potential as an objective for salmonid restoration (NMFS 2014).

Methods

Data Used

Humboldt County GIS:
Humboldt County Boundary

US Geological Survey- National Hydrography Dataset:
California Hydrography Dataset

California Department of Conservation:
Landslide GIS Data

ESRI:
USA Topographic Maps

Data Collection

The Humboldt County Boundary dataset (CNTYOUTL) was downloaded from the Humboldt County GIS Data Download website. The dataset was a shapefile in NAD 1927 State Plane California Zone 1 and was created 03-03-2004. The California Hydrology dataset was downloaded from the US Geological Survey- National Hydrography Dataset and the shapefile used was NHDFlowline in GCS NAD 1983 and was last updated 17-03-2018. The Redwood Creek Landslide (Albers NAD 27 shapefiles) dataset was downloaded from the California Department of Conservation and was created 10-2002 with NAD 1927 Albers format. The topographical basemap was obtained from ESRI ArcGIS online and was last modified 19-01-2018 and uses WGS 1984 Web Mercator Auxiliary Sphere.

Data Analysis

The topographical basemap from ArcMap could not have its coordinate system changed, so all datasets were projected into WGS 1984 Web Mercator Auxiliary Sphere. All layers were clipped to the 'CNTYOUTL' layer to reduce the layer sizes. Layers containing dormant landslides were removed because these are features that have not exhibited movement within the last 150 years. We combined layers containing active landslides into a single layer using 'Union' and clipped symbology layers to show the outline and movement in only these layers. Using select by attribute, Redwood Creek and its tributaries were selected from NHDFlowline and exported as a new layer that only shows the hydrology of the Redwood Creek basin. We used 'buffer' and 'select by location' to determine which landslides are located within 25 feet of streams, and was exported as a new layer. In the attribute table using 'sort descending' landslides with an area over 490,000 square meters were selected, and these were the final selection of landslides.

Cartographic Procedure

In order to denote the type of landslide and direction of movement, symbology was drawn onto the landslide polygons. The color of Redwood Creek was changed to a darker blue to differentiate it from the lighter colored tributaries.

Figures

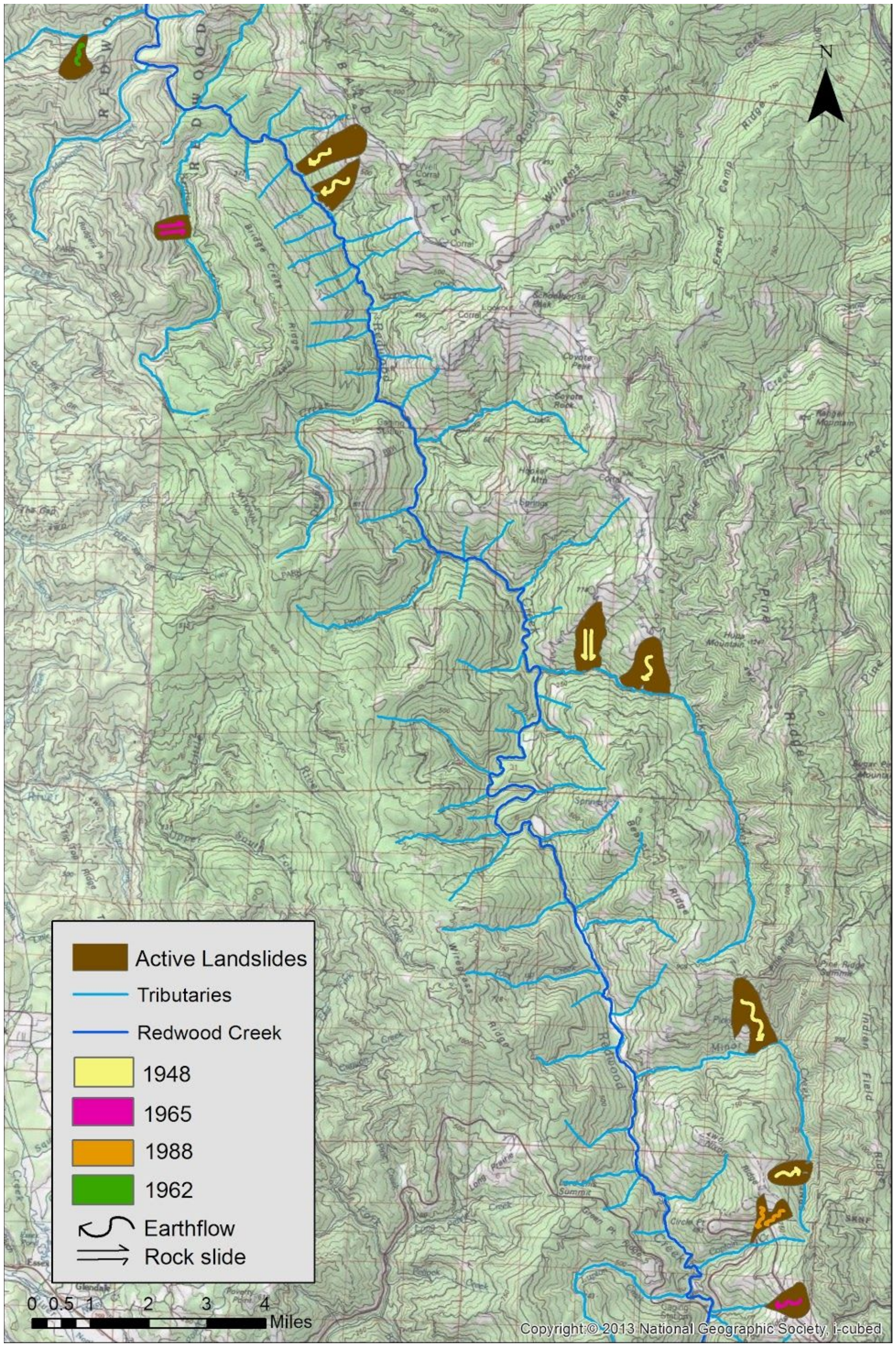

Figure 2: Map of ten landslides in Redwood Creek Watershed

Table 1: Description of selected landslides along Redwood Creek Watershed

FID	Area (m^2)	Type	Year
0	684,199	Earthflow	1962
1	604,188	Rockslide	1965
2	748,363	Earthflow	1965
3	660,458	Earthflow	1988
4	1,326,872	Earthflow	1948
5	894,502	Earthflow	1948
6	1,242,876	Rockslide	1948
7	1,376,253	Earthflow	1948
8	1,538,448	Earthflow	1948
9	691,841	Earthflow	1948

Results

Our results found that there are ten landslides in the Redwood Creek watershed that are top priority. These were selected to be top priority landslides because of they are within 25 feet of a stream and have an area larger than 490,000 square meters. Table 1 shows the area in square meters of each landslide, and the year the landslides were inventoried. Fortunately, most of these major slides (six of the ten) were inventoried in 1948 and the most recent was in 1988. While these landslides are very large in size, the most recent was around 30 years ago, which may indicate more stable current conditions, a result from more strict logging practices, the creation of Redwood National and State Park, and removal/ repair of old skid roads. As seen in Figure 2, all of the landslides are along tributaries of Redwood Creek, but none on Redwood Creek itself, which may be attributed to higher elevation with steeper topography, previous logging practices and the natural geology. All of the landslides come directly in contact with a stream, either ending at the stream or flowing over it. Looking at both Figure 2 and Table 1, eight of the landslides are earthflows, with only two rockslides.

Discussion

Of the ten landslides prioritized in this analysis, eight are classified as earthflows and two are classified as rockslides. Earthflows are characterized by large deposits of fine-grained sediments and exceptionally low shear strength. This type of slide is common on shallow slopes (10-30%) in soils with a large percentage of clay. The head of an earthflow generally features a large, irregular scarp that fails rotationally. The overall shape of the slide is often reminiscent of a viscous liquid, due to the constituents and saturation of the material. Rotational failure is exhibited in a series of blocks below the head scarp, resulting in the formation of many 'hummocks' characteristic of large earthflows. These slides are often undercut by multiple planes of failure, leading to sudden destabilization of dormant slides when cut or filled. Earthflows generally move no more than millimeters per day, but under extreme circumstances can move as fast as meters per day.

Rockslides are composed mainly of course debris derived directly from underlying bedrock on steep slopes (35-70%). Intact blocks of material are transported down a plane of movement that has been destabilized by bedding planes, joints, or foliations. The mass may remain intact at the toe of the slide while the block failure at the head creates a depression which typically accumulates more water than the surrounding area. The increased capacity of water in such depressions leads to further destabilization of surrounding slopes (Falls et. al. 2006).

Of the ten active landslides identified in this analysis, eight were located directly adjacent to tributary streams to mainstem Redwood Creek. This could be due to the higher gradient of the tributary streams relative to the low gradient of the mainstem. In 1996, Madej & Ozaki documented the propagation and movement of a sediment wave generated from mass wasting events on upstream slopes in Redwood Creek. The results from this study indicated that much of the sediment that had originated on the upper slopes was transported and deposited in downstream reaches within several decades. Unfortunately, the low gradient mainstem of Redwood Creek is less capable of transporting the sediment generated from upstream landslides (Falls 2003). The accumulation of fine-grained sediments from earthflows in the tributary reaches have resulted in severe channel aggradation in the transport-limited mainstem.

The landslides that were prioritized in this analysis were prodigious, each having an area above 490,000 m^2 and a thickness no less than 3 meters. Six of the slides had a thickness greater than 15 meters, five of these being earthflows. Approximations of the volume of these slides ranged between 1,812,563 m^3 and 23,076,716 m^3 based on the estimate of thickness derived from the metadata for the landslide dataset. Combined, these slides represent roughly 104,412,354 m^3 of mobilized sediment, most of which is fine-grained small particle size with a minimal percentage of course debris and bedrock material. Based on the topography, historic activity, size, and proximity to streams of these features, the landslides that were prioritized in this analysis are highly likely to contribute large amounts of fine-grained sediment to impaired anadromous waterways in the event of severe storm events or other disturbance.

Further analysis should investigate current and historical factors contributing to the mobilization of this sediment as well as the feasibility of mitigating the effects of mass wasting in this watershed. This analysis was based heavily on inventories that were derived from historic aerial photographs ranging in age from 1948 to 1988 and further analysis is required to determine more than a rough approximation of the delivery potential of these slides. Additional GIS work may create an inventory of public roadways as well as historic and active logging and skid roads in tributary reaches to determine if there is a need for continued mitigation of failing roads. This analysis provides a simple prioritization of the largest and most historically active landslides in the Redwood Creek basin with the highest potential of delivery to streams, as well as a rough approximation of the sediment delivery potential of these features.

Conclusion

The Redwood Creek Basin, located in Humboldt County, provides ample habitat for multiple species of threatened and endangered anadromous salmonids, which play an important role within the ecosystem. Due to previous landslide events, Redwood Creek has become listed as impaired under the Clean Water Act for temperature and sediment, making areas throughout the creek less suitable for the fish. The finished map provides a more developed understanding of regions significantly impacted by rock slides and earthflows, historically resulting in channel aggradation and habitat degradation. With this information, people can use the map to prioritize management and restoration for different stretches along the Redwood Creek Basin. Something for users to consider is that the map only displays active landslides and the map may not be helpful to those looking for potential landslide sites or who are interested in prevention.

Acknowledgements

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