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# Landslide Monitoring in S.F. Elk River, Humboldt County 2024 Report

# Pursuant to Monitoring and Reporting Program (MRP) No. R1-2020-0001

Submitted: December 27, 2024

**Prepared By:**
**Green Diamond**

## 1.0 INTRODUCTION

As part of the Landslide Inventory Quality Assurance Project Plan (QAPP), this document represents a summary report of landslide processes within the South Fork (S.F.) Elk River drainage. It is further limited to the portions of the drainage owned and managed by Green Diamond.

For the 2024 reporting period, Green Diamond utilized multiple sources of remotely sensed data to compile our landslide inventory ranging from 2018-2023. Since the previous report in 2018, Green Diamond acquired the United States Department of Agriculture's (USDA) high resolution National Agriculture Imagery Program (NAIP) orthorectified imagery and our own LiDAR and aerial imagery. For field surveys, we conducted helicopter reconnaissance, and ground-based field surveys for two timber harvest plans between 2021 and 2024. The following sections summarize our findings regarding these data.

## 2.0 SITE SELECTION

Green Diamond's landslide inventory encompasses the S.F. Elk River ownership block. Our ownership is a relatively small portion of the S.F. Elk River watershed, which is about 1,890 acres (2.95 $mi^2$). For sampling, Green Diamond is required to incorporate a subsample of field inventories of the newly delineated landslides observed from the recently acquired imagery. Due to the relatively small area involved, all newly delineated landslides were reviewed. Additionally, we take into account the WDR reporting requirements when reviewing areas for Timber Harvest planning. As a result, we reviewed approximately 315 acres of the subject property for historical and recent landslide activity.

## 3.0 DATA COLLECTION AND ANALYSIS ACTIVITIES

For the 2024 S.F. Elk River landslide monitoring report, we reviewed the USDA's NAIP orthorectified aerial imagery from 2018, 2020, and 2022, Google Earth aerial imagery from 2023, and Green Diamond LiDAR and aerial imagery from 2018 (Geo Terra, Inc.). Although it is outside of the scope for this WDR, Green Diamond conducts helicopter surveys to assess mass wasting events. These surveys are not scheduled regularly, they are instead typically conducted following elevated winter rain seasons. For this reporting period, we incorporated data obtained from aerial helicopter surveys of the S.F. Elk ownership from flights that were conducted in August 2023 and July of 2024. In addition to the review of aerial imagery and helicopter flight reconnaissance for assessment of Green Diamond's S.F. Elk River ownership, we included landslide data from timber harvest plan layouts conducted in 2021 and 2024. Table 1 summarizes our survey methods and areas reviewed between 2018 and 2024.

*Table 1*

| **Year** | **Survey Method (Source)** | **Percent of S.F. Elk River Ownership Reviewed** |
|---|---|---|
| 2018 | Orthophoto Imagery (NAIP & Green Diamond) | 100% |
| 2018 | LiDAR (Green Diamond) | 100% |
| 2020 | Orthophoto Imagery (NAIP) | 100% |
| 2021 | THP Fieldwork | 10% (180 acres) |
| 2022 | Orthophoto Imagery (NAIP) | 100% |
| 2023 | Helicopter flight/Google Earth Imagery | 100% |
| 2024 | Helicopter flight | 100% |
| 2024 | THP Fieldwork | 7% (135 acres) |

### 3.1 Landslide Database

As noted in our previous reports, the historical inventory mapping was compiled by Pacific Watershed Associates (PWA) for use in Hart Crower's 2004 Elk River watershed analysis for the Pacific Lumber Company. That data was integrated with Green Diamond's landslide database, and as a result, our previous estimates of delivery rates were largely based on external data. For this report, we were able to expand this dataset and compile a larger in-house dataset that includes a review of historical aerial imagery as well as landslides from field-based reconnaissance (largely from timber harvest plan review). For the field-based landslides, we recorded landslide measurements and site characteristics to determine if the landslides should be attributed to historical management practices (pre-1998, Historical Era.) or modern management practices (1998 to present, Modern Era.). Landslides characterized by thick vegetation, sub-rounded margins, and straight advanced second-growth conifer were typically characterized as belonging to the Historical Era. Grouping landslides into historical and modern management practice eras allowed us to compare and gauge Historical and Modern Era management practices and their influence on delivery rates and locations of mass wasting events. This is an effective method that highlights distinct time periods relative to regulation and management practices in the forest industry. This method was recently used to show significant differences in shallow landslide erosion rates, throughout this region (Woodward, 2023) and in the pacific northwest (Seixas and Veldhuisen, 2023), in response to evolving management practices and associated reductions in ground disturbance.

Our Historical Era landslide inventory was based on aerial photos from the 1940's through 1990's while the Modern Era included aerial imagery from 2000 to present. Landslides observed in aerial photographs and orthorectified imagery are commonly masked by overstory canopy and are not always visible in aerial photographs. However, recent work on our ownership suggests that landslides are readily detectable down to 178 yds$^2$ (Woodward, 2023). Landslides of this size are detectable in both stereo paired and orthographically rectified aerial imagery. Additionally, that study also suggests that

landslides greater than or equal to 178 ft² account for 99 percent of the cumulative volume of sediment (total volume displacement) associated with shallow landslides observed in that study. As a result, we are confident that our methods are capturing the vast majority of sediment associated with shallow landslides in the study area.

A total of nine landslides have been observed in aerial imagery during the Modern Era (post-2000). One of those was attributed to management practices of the Historical Era. Four of the landslides were road related and four were thought to be naturally occurring. Of the nine, three landslides resulted in sediment delivery. Only one new shallow-seated landslide was observed during the current reporting period (2018-2024). We first observed this new landslide during our 2023 helicopter field reconnaissance. The landslide was later confirmed during our review of the 2023 Google Earth Imagery which did not become available until after our helicopter field reconnaissance. No deep-seated landslides were observed.

### 3.2 Maps

There are two Maps included in this report. All landslides that have been compiled from LiDAR interpretation, historic aerial photographs, Green Diamond field investigations and the landslide inventories are shown on Map 1. The new landslide observed in 2023 is labeled as LS16925 and shown in greater detail on Map 2. We discuss this landslide in more detail under Sediment Delivery Estimates.

### 3.3 Sediment Delivery Estimates

***New Slide(s)***

A debris slide, LS16925 (Map 2), was observed during our 2023 helicopter reconnaissance. Aerial images taken of the slide during our helicopter reconnaissance are shown in Figure 1. This landslide is located within the McCloud Creek Sub-basin, in the northern portion of Green Diamond's ownership of S.F. Elk River.

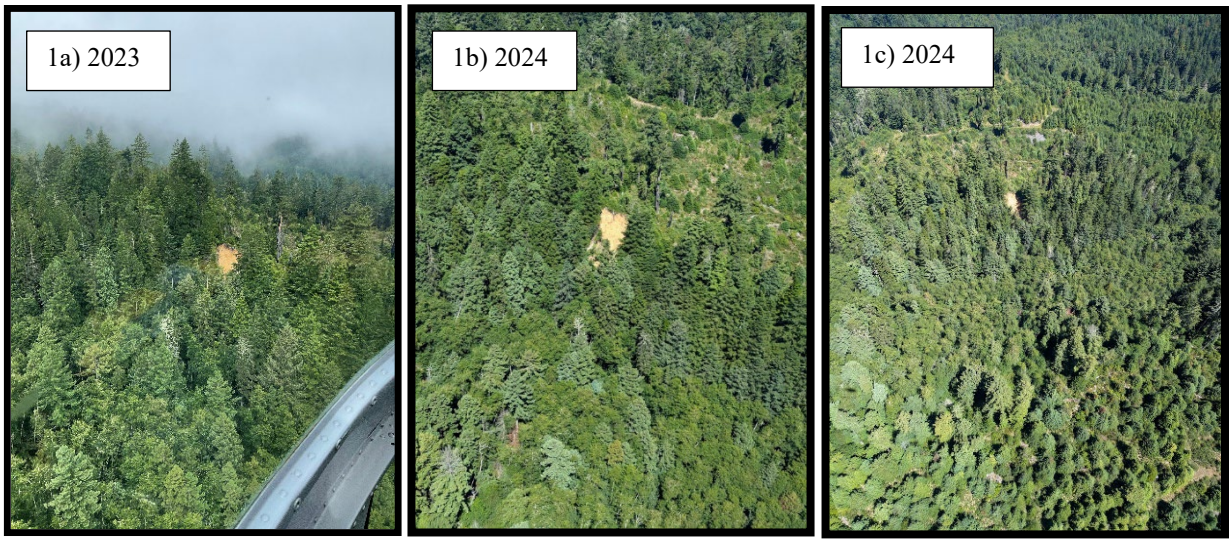



Figure 1 – Helicopter images of LS16925.

Landslide LS16925 is nested within the scarp of a dormant-historic earthflow which has shown indications of historical activity, mostly in the 1960's and 1970's. The area is currently characterized by a dense stand of conifers and understory shrubbery. It is situated on very steep slopes (upwards of 50 degrees), along the south side of a narrow east-west-trending ridge. Undifferentiated Miocene to late Pleistocene sandstone of the Wildcat Group is exposed in the slide scar and is dipping steeply out of slope. The slide is roughly 13.3 yards wide and 30 yards long and one yard thick. We estimate that roughly 204 $yds^3$ of sediment was mobilized. The nearest watercourse is more than 116 yards to the east and separated by thickly vegetated, low gradient slopes. No sediment delivery occurred as a result of this failure.

Timber harvesting activities have not been conducted on this slope in over 50 years. Slopes to the north and adjacent to the main scarp were harvested in 2018. No ground-based harvesting was conducted in this area. The 2018 harvest utilized cable-yarding methods and there was no indication of ground disturbance in the vicinity of the landslide. Those slopes are now characterized by dense understory vegetation and abundant young conifers which can be seen in Figures 1b and 1c.

***Historical and Modern Era Delivery Estimates***

Previous reports have shown a downward trend in landslide occurrence across Green Diamond's ownership. Our current assessment of landslides within the S.F. Elk River portion of Green Diamond lands suggests this trend has continued since our previous report in 2018. Figure 2 shows the updated distribution of landslides over time within the S.F. Elk River ownership.

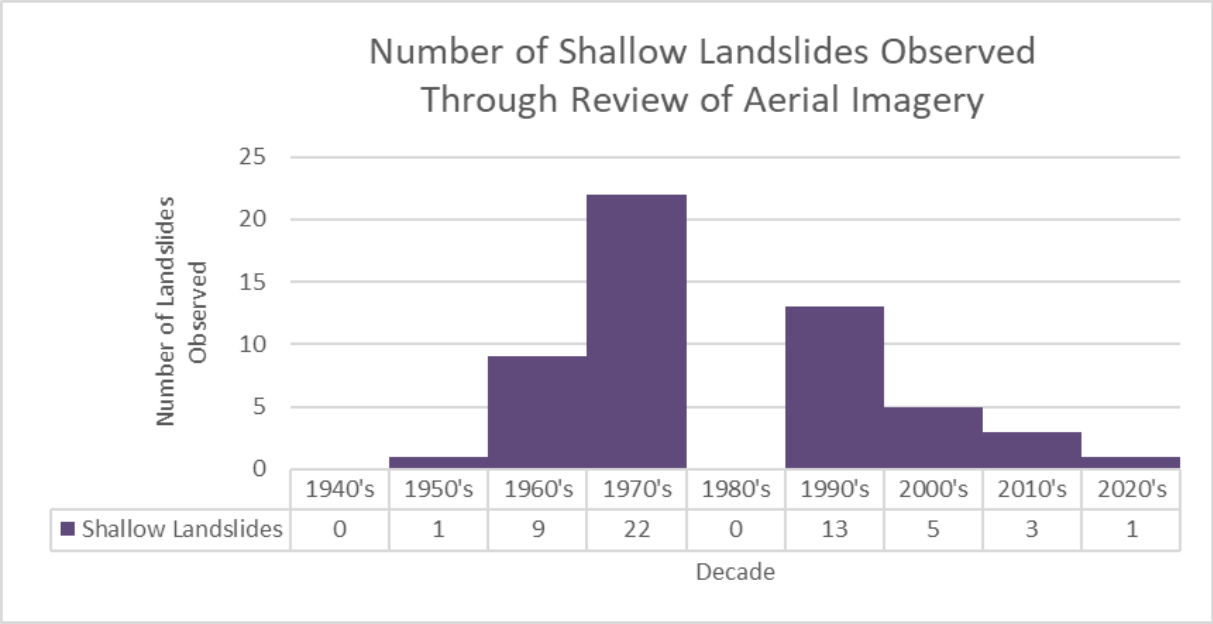



Figure 2 – Landslides observed in aerial imagery over time.

In 2018 we reported long term average rates based on external data (Tetra Tech 2015) as well as long term rates for the Humboldt Bay Hydrographic Planning Area (HPA, which includes Elk River and similar sub basins). The HPA rates were calculated as part of our preliminary Mass Wasting Assessment for our AHCP. At that time, using data based on the Upper Elk River TMDL (Tetra Tech 2015), we estimated a sediment delivery rate for Tom Gulch and McCloud Creek to be 361 $yd^3/mi^2$/year for natural and management related shallow landslide sediment for the period of 1955 to 2011. A more generalized long-term estimate for the subject area was reported for the Humboldt Bay HPA with a delivery rate of 102 $yds^3/mi^2/yr$.

Our revised volume estimates provided herein are now largely based on in-house review of landslides over time through review of aerial photos and timber harvest plans solely within the subject area. Our dataset now has 85 shallow landslides specific to the S.F. Elk River ownership with aerial photo detection between 1954 and 2023. A review of these data gives us a more focused look at erosion and delivery rates across the ownership in this area. The lengths and widths of the landslides in this dataset were recorded in the field; however, depths were not available for the majority of the dataset. A model for estimating depth based on length, width and slope inclination was developed in 2019 (Woodward and House, 2019) that was based on over 3,000 landslides across Green Diamond ownership. Using that model we have estimated depths for each of the landslides in the S.F. Elk River dataset that allows us to estimate total displaced volumes. From those landslide displacement volumes, we utilized an average delivery rate of 52 percent which was observed in shallow landslides regionally (Woodward, 2023). With these data we have calculated Historical (1954-1997) and Modern Era (1998 – 2023) delivery rates for the subject area which is shown in Table 2. These time periods are based on key changes in industrial timberland management (pre 2000 and post 2000) but are also constrained by the timing of available aerial photographs in that range. As a result, the 1997 and 2000 aerial photographs impact the transition timing of these eras.

*Table 2 - Delivery Rates of Shallow Landslides.*

| Era | Number of Landslides Observed | Delivery Vol $yds^3$ | Delivery $yds^3/mi^2/yr$ |
|---|---|---|---|
| Historical Era 1954-1997 | 76 | 41,258 | 325 |
| Modern Era 1998-2023 | 9 | 4,592 | 62 |

Note: Data includes field-based observations of landslides during THP review. Those slides were attributed to either the historical (1954-1997) or modern (1998-2023) era based on site characteristics including vegetation and professional judgment.

These data highlight a significant decline in both cumulative volume delivered and delivery rates. Comparing the Historical Era with the Modern Era we are seeing greater than 80 percent reduction in delivery rates and nearly 90 percent reduction in cumulative volume delivered as shown in Table 3.

*Table 3 – Reduction in sediment delivered when comparing Historical Era and Modern Era Cumulative Volume and delivery rates associated with sediment generated from shallow landslides.*

| | Reduction in Delivered Sediment |
|---|---|
| Cumulative Volume $yds^3$ | 89% |
| Rate $yds^3/mi^2/yr$ | 81% |

***Discussion***

The estimates of watershed-wide shallow landslide sediment delivery rates obtained from the TMDL (361 $yd^3/mi^2$/year, 1955-2011) differ only slightly from our Historical Era estimates of shallow landslides in this area. One key difference between those rates is the timeframe reviewed. For the TMDL, an average rate was calculated for the entire time, which includes a portion of the Modern Era. Given that time frame we would expect similar rates as it includes only a small portion of the Modern Era. If anything, we might expect lower rates from the TMDL calculations since it does include a portion of the Modern Era which is experiencing significantly lower rates. Topography is also likely a factor as Green Diamond's portion of the S.F. Elk is characterized by more subdued topography. A review of the 2018 LiDAR shows a much higher concentration of Steep Streamside Slopes (SSS) (slopes greater than 55 percent) in the areas outside of Green Diamond's ownership. During Green Diamond's SSS delineation project these areas were determined to contain 70 percent of the cumulative volume of sediment related to shallow landsliding (Woodward, House, & Lamphear 2016). Other factors, such as differences in calculation methods can also result in variations and may also be a factor.

As shown in Figure 2 and Table 2, there is a downward trend in the number of landslides observed over time. This is also true for sediment delivery rates across the ownership which we also observed in our Preliminary Mass Wasting Assessment (Green Diamond, 2016). Our updated database now allows us to evaluate landslide occurrence and delivery rates based on Historical and Modern Eras as well as on a decadal scale. The evolution of timber harvesting over time, which includes regulatory changes as well as self-imposed changes in management practices, has been cited as a significant factor for the downward trend in shallow landslide erosion rates regionally (Woodward, 2023). We would expect delivery rates to follow this trend as well.

Within the SF Elk River basin, early logging practices took place around the turn of the century and again in the 1960s and 1970s. Each of these entries involved intense ground-based harvesting that involved clear cutting of the basin followed by broadcast

burning. At the turn of the century, streams were heavily impacted by railroad construction which was often situated within or immediately adjacent to a watercourse. Also, un-engineered side-cast road construction was the common practice in the 1960's and 1970's which contributed to significant sediment delivery as well as landsliding. Road building practices began to change on Green Diamond lands in the early 1980s, which reduced and eventually eliminated side-cast road construction. This change in road building practice greatly reduces the potential for road-related landsliding, which has been observed in other studies (Bawcom 2007) including our preliminary mass wasting assessment in 2016 (Green Diamond 2016).

Canopy retention areas such as Riparian Management Zones and Habitat Retention Areas were established as part of the Forest Practice Act of 1973 continued to evolve over time with the implementation of the Watercourse and Lake Protection Zone rules in 1983, the Threatened and Impaired (T&I) Watershed rules in 2000, and the Anadromous Salmonid Protection (ASP) rule package in 2010. Green Diamond's first WDR in 2006 also added protections including addressing road-related sediment sources. In 2007, Green Diamond implemented the AHCP, this added retention of channel zone trees in order to maintain streambank stability in previously unprotected Class III watercourses. It also added additional retention to areas prone to landsliding within headwall swales and SSS. Later, in 2014 the SSS zone slope threshold and widths of the retention zones were modified to more closely represent and prevent localized landsliding. These modifications were the result of the data collected and analyzed during the Green Diamond SSS Delineation Project. Additionally, the Forest Management WDR approved and implemented in 2012 included further revisions and enhancements to our Elk River management plan. Over the years, each of these changes has resulted in increasing tree retention in the most sensitive areas of the landscape and has dramatically reduced the number of streamside landslides and sediment delivered to watercourses over time.

Harvesting itself has also changed significantly. In the Modern Era, harvesting practices on steep slopes are largely limited to cable yarding. Current cable yarding operations typically achieve full suspension, significantly reducing the chance of bare soil being exposed to erosion processes due to yarding. Ground-based shovel yarding utilizes track-mounted machines that operate on top of the slash without the need to cut skid trails. The reduction of exposed bare soil associated with ground-based yarding reduces the potential for surface erosion. This evolution in ground-based yarding began around the year 2004 on Green Diamond lands. Each of these changes contributed to the reduction in the amount of bare soil exposed compared with historical ground-based operations. Both changes in management practices have resulted in reduced ground disturbance due to the reduction in surface water diversions and absence of surface soil manipulation (i.e. cut and fill earthwork) in recent times, which has contributed to the reduction of landslide occurrence in the area.

Our data suggests that Modern Era sediment delivery rates associated with shallow landsliding are down over 80 percent in the S.F. Elk River basin when compared with average Historical Era rates. This is significant as we have only seen such a decline associated with comparisons to peak historical rates, not average historical rates. Evolving regulations associated with the Forest Practice Act, implementation of the T&I rules and the transition to shovel logging in the early 2000's, and self-imposed Habitat Conservation Plans, are likely the key factors driving this decline. Our recent review of aerial photographs in the area supports this declining trend.

## 4.0 PROBLEMS ENCOUNTERED AND RESOLUTION

There are a number of landslides observed in the 1970's and 1990's but no landslides were observed in the 1980's. During our review of landslides across the entire ownership, we did observe a significant decrease in landslide incidence in the 1980's. As such, this may be a reflection of the relatively small area that is the scope of this project. However, based on our experience we would expect to see some landslides in this decade of review. It is our judgement that it is unlikely there were no landslides in this timeframe. As a result, we will need to review additional photo sets within the 1980's to clarify this observation. Should we find additional landslides in this decade, we also expect a slight increase in the delivery rates within the associated Historical Era.

Two landslides occurring in 2011 were added to the database. These were previously omitted as they were associated with active timber harvest plans and not observed on aerial photos, which is the primary method of review for this report. As part of the revised landslide database, we have included all landslides observed in the Modern Era. This may result in biased and slightly elevated delivery rates for the Modern Era. We do, however, consider it important to include all known landslides as feasible and appropriate. We will continue to evaluate these instances and include all the landslides we observe as appropriate.

Sediment delivery rates for deep-seated landslides have yet to be evaluated. No new deep-seated landslides were observed in our review of aerial photography or ground-based reconnaissance. As such it is not expected that deep-seated landslides will be a significant factor in delivery rates within the S.F. Elk basin. These rates will be addressed in the final Mass Wasting Assessment for our AHCP and will be incorporated into the corresponding WDR Landslide Report at that time.

## 5.0 SUMMARY OF MONITORING ACTIVITIES

Our most recent landslide monitoring included a review of the orthorectified imagery from 2018, 2020, 2022 and Google Earth Imagery from 2023. The review of aerial imagery was followed by helicopter reconnaissance in 2023 and 2024 as well as field-based reconnaissance of streamside slopes associated with the layout of timber harvest units. Compared with the Historical Era, there is a downward trend in observable

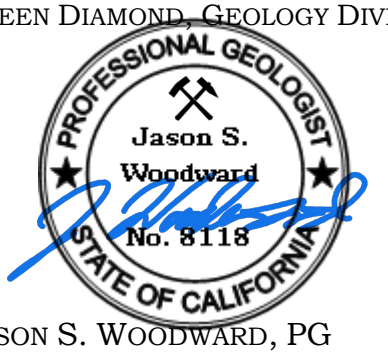
landslides and sediment delivery rates within the Green Diamond portion of the S.F. Elk River drainage. This downward trend is supported by our recent monitoring where only one new landslide was observed on the aerial imagery within the Green Diamond portion of the S.F. Elk River drainage during this reporting period. As previously mentioned, one landslide was observed in the current reporting period and mobilized 204 $yd^3$ of sediment. No delivery to a watercourse was observed.

## 6.0 SUMMARY OF TRAINING & CERTIFICATION

Our geology staff are continually collecting landslide data in the field. Training of new staff geologists includes months of field work with the oversight of licensed professional geologist(s). During our field training individuals learn to identify landslide features such as ground cracks, scarps, back-tilted stumps, skewed trees, hummocky topography, as well as develop cross sections of landslides, which are used to determine landslide erosion and sediment delivery volumes. The geologists who conducted the recent surveys have a combined 36 years of landslide surveying experience.

We have completed our work in accordance with generally accepted professional geology and forest geology practices for the nature and conditions of the work done in the same, or in similar, localities at the time the work was performed. Should you have any questions about this work, feel free to contact us at any time.

Respectfully submitted,
GREEN DIAMOND, GEOLOGY DIVISION

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**REFFERENCES**

Bawcom, Julie A. 2007. Even-Aged Management and Landslide Inventory, Jackson Demonstration State Forest, Mendocino County, California. In: Standiford, Richard B.; Giusti, Gregory A.; Valachovic, Yana; Zielinski, William J.; Furniss, Michael J., technical editors. 2007. Proceedings of the redwood region forest science symposium: What does the future hold? Gen. Tech. Rep. PSW-GTR-194. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; p. 323-334

Green Diamond Resource Company, 2016. Preliminary Mass Wasting Assessment. Prepared for the National Marine Fisheries Service and U.S. Fish and Wildlife Service. November 29, 2016. 39p.

Hart Crowser, 2004, Elk River/Salmon Creek Watershed Analysis, Humboldt County California: Prepared for Pacific Lumber Company (PALCO), 83p with Appendices.

Seixas, G.B. & Veldhuisen, C.N. (2023) Forest management history influences eight decades of shallow landsliding in the northwest Cascade Mountains, USA. Earth Surface Processes and Landforms, 48(14), 2716–2736. Available from: https://doi.org/10.1002/esp.5656

Tetra Tech, 2015. Upper Elk River Technical Analysis for Sediment. Prepared for Environmental Protection Agency, Region 9 and North Coast Regional Water Quality Control Board, October 21, 2015, 85p.

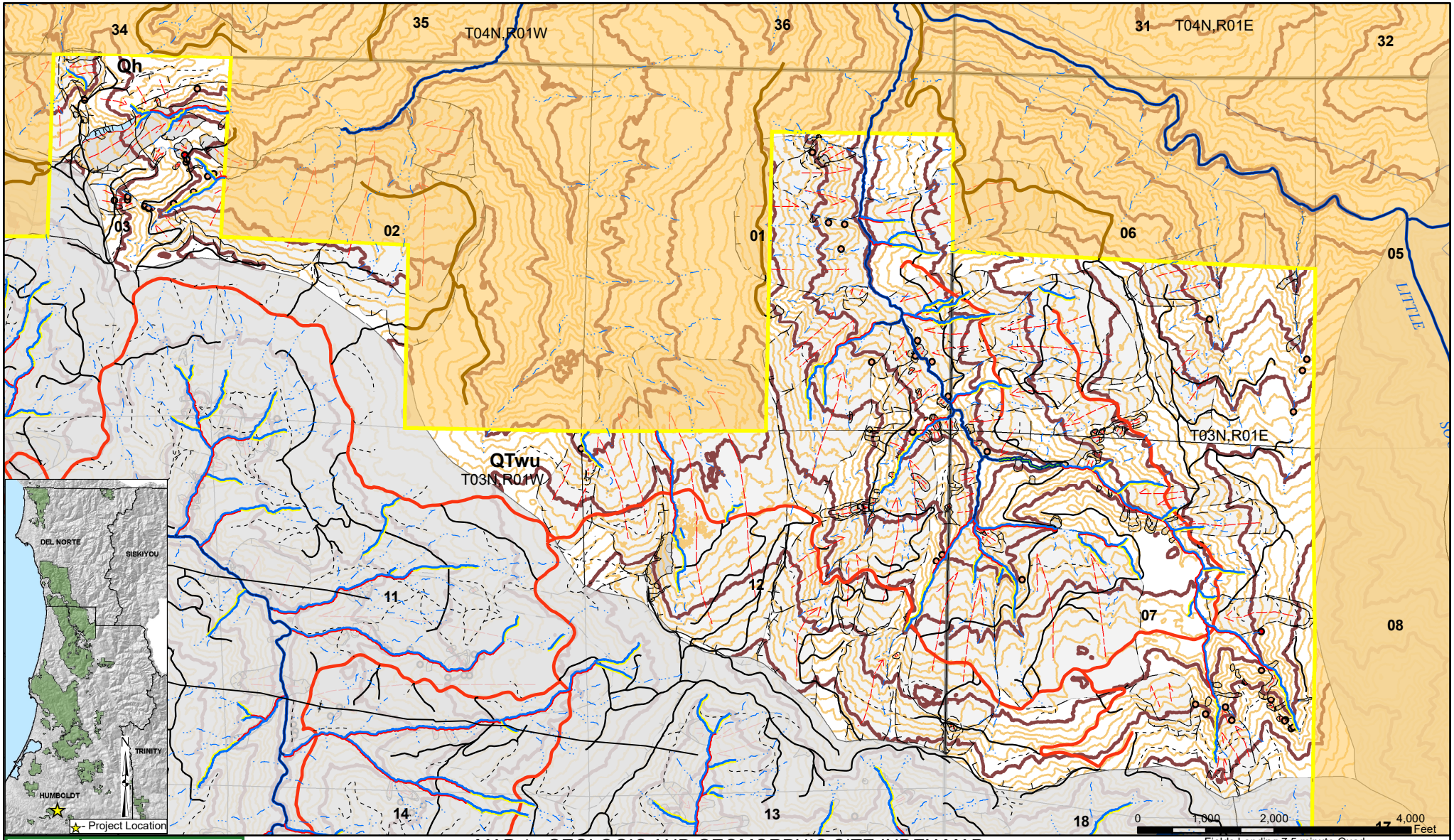
WOODWARD, J.S., HOUSE, M.R., LAMPHEAR, D.L., 2016, Development of Preventative Streamside Landslide Buffers on Managed Timberlands in Northern CA. Proceedings of the Coast Redwood Sciences Symposium, 2016: Past Successes and Future Directions. General Technical Report, PSW-GTR-258, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA., pp. 149-161.

Woodward, J.S., House, M.R., 2019, Landslide Geometry: Modeling Landslide Depths. Presentation at Association of Environmental & Engineering Geologist Annual Meeting, Technical Session No 13, September 20, 2019, Ashville, NC.

Woodward, J. S., 2023, Shallow Landslide Erosion Rates on Industrially Managed Timberlands: Key Factors Affecting Historical and Contemporary Rates. Environmental & Engineering Geoscience 2023, vol 29, no 2; doi: https://doi.org/10.2113/EEG-D-22-00005

**MAPS**

1 Geologic and Geomorphic Site Index Map
2 Detailed Site Map, LS16925

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# MAP 1 , GEOLOGIC AND GEOMORPHIC SITE INDEX MAP
## South Fork Elk River WDR 2024 Landslide Monitoring Report
## MRP No R1-2020-0001

Fields Landing 7.5 minute Quad
T3N, R1W; Sections: 1, 2, 3, 11, & 12
Mc Whinney Creek 7.5 minute Quad
T3N, R1E; Sections: 6 & 7
Contour Interval = 40 ft

## EXPLANATION

### Earth Materials

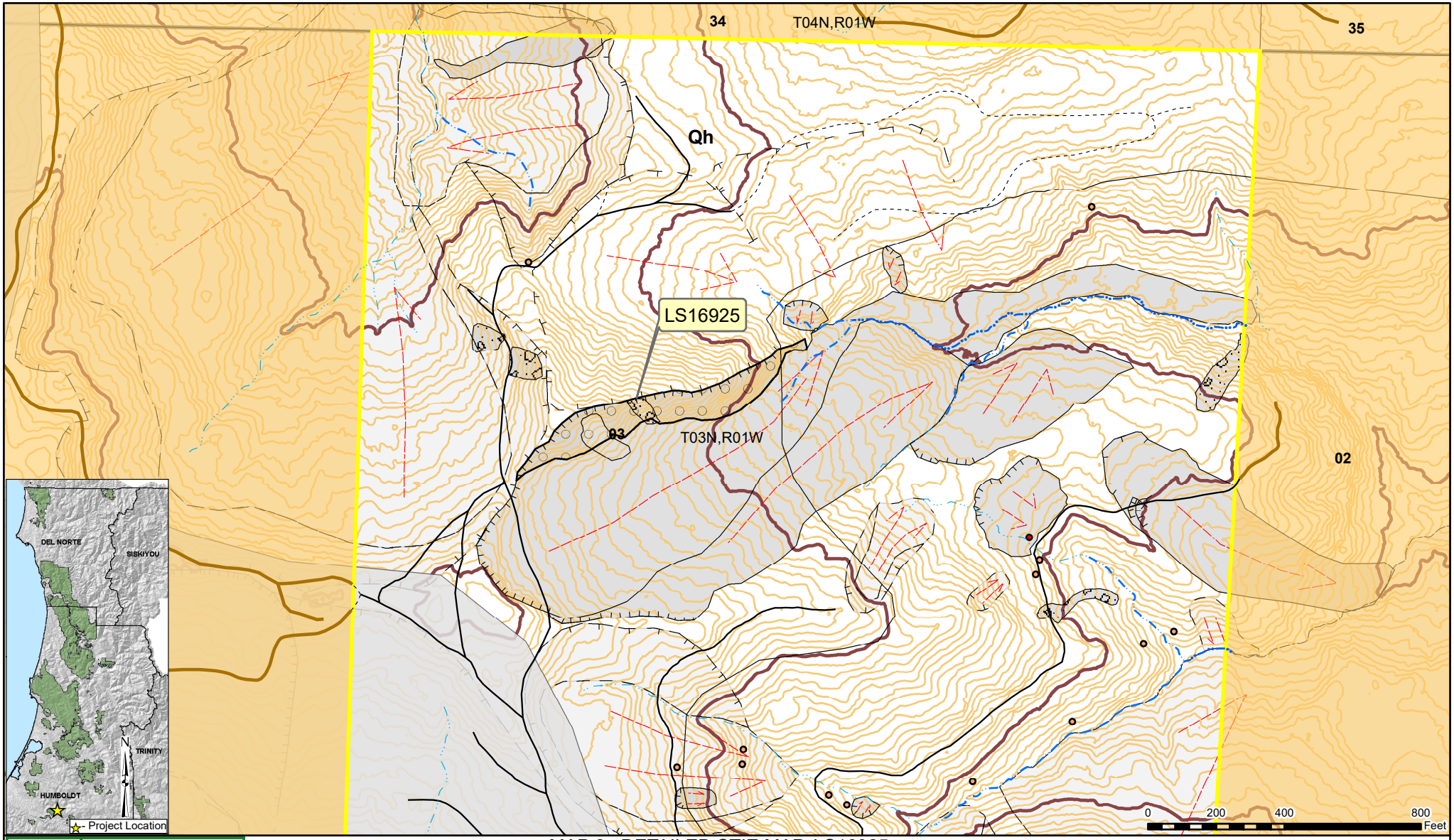
Qh - Hookton Formation
QTwu - Wildcat Group undifferentiated

**Watercourse Class**
- I-F
- I-R
- II-2
- II-1
- III

**Road Class**
- Mainline
- Secondary
- Temporary
- Public
- ProposedPermanent
- ProposedSeasonal

### Symbols

- Property Boundary, non-GDRCo Property shaded in orange
- Approximate Watershed Boundary - non Elk River watersheds shaded in grey
- Earthflow - Arrow indicates direction of movement solid where active to historic, dashed where dormant
- Rotational/translational Landslide - Arrows show direction of movement solid where active to historic, dashed where dormant.
- Anticline
- Syncline
- Landslide too small to map w/ torrent track
- Debris slide (Recently mapped slide in bold)
- Scarp - Solid where historic to active, dashed where dormant

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# MAP 2 , DETAILED STIE MAP, LS16925
## South Fork Elk River WDR 2024 Landslide Monitoring Report
## MRP No R1-2020-0001

Fields Landing 7.5 minute Quad
T3N, R1W; Section(s): 3
Contour Interval = 10 ft

## EXPLANATION

**Earth Materials**

Qh - Hookton Formation
QTwu - Wildcat Group undifferentiated

**Watercourse Class**
- II-2
- II-1
- III

**Road Class**
- Mainline
- Secondary
- Temporary
- Public
- ProposedPermanent
- ProposedSeasonal

Symbols

- Property Boundary, non-GDRCo Property shaded in orange
- Approximate Watershed Boundary - non Elk River watersheds shaded in grey
- Earthflow - Arrow indicates direction of movement solid where active to historic, dashed where dormant
- Rotational/translational Landslide - Arrows show direction of movement solid where active to historic, dashed where dormant.
- Landslide too small to map w/ torrent track
- Debris slide slope - solid where active to historic
- Debris slide (Recently mapped slide in bold)
- Scarp - Solid where historic to active, dashed where dormant