MEMO

To: Beth Christman, Truckee River Watershed Council

From: Brian Hastings, PG, and Erika Groh

Date: October 10, 2022

Subject: Prosser Creek Watershed Roads and Trails Assessment

Purpose

Balance Hydrologics (Balance) conducted a watershed assessment of Prosser Creek above Prosser Creek Reservoir in eastern Nevada County, California from 2019 through 2020 (Hastings and others, 2022). The assessment identified channel and meadow degradation characterized by channel incision, widening, and desiccation using the following lines of evidence: (1) documentation of historical land-use changes (Lindstrom, 2020), (2) review of historical aerial photographs from 1939 through 2020, (3) visual analysis of bare-earth imagery derived from LiDAR (USFS, 2014), and (4) hydrologic analysis of altered runoff patterns. The latter suggested that a network of roads, trails, and railroad grades is likely a major contributor of increased runoff and erosion and subsequent channel and meadow degradation over time. Before channel and meadow restoration can be pursued, sources of degradation need to be identified and addressed. As such, a recommendation to further assess roads and trails and their condition was adopted by the Truckee River Watershed Council (TRWC) and stakeholders.

This report outlines the methods used to evaluate road and trail condition, and details results of our findings. We identify areas for future management using analysis for prioritization.

Background

Prosser Creek watershed is a headwater catchment of the Truckee River Basin with elevations exceeding 9,000 feet. Much of the watershed is steep and comprised of first-order streams that receive over 40 inches of annual precipitation (USGS, 2021). Headwater streams, beginning as spring seeps and first-order stream channels in a stream and river network, have an immediate and intimate connection with the terrestrial environment, forming an extensive terrestrial/aquatic mosaic. However, the very attributes of headwaters that make them critical to the health of stream networks also make them exceedingly vulnerable to degradation when landscapes are altered by roads, trails, and grades.

The Prosser Creek Watershed has an extensive history of logging as documented by Lindstrom (2020; in Hastings and others, 2022). Logging operations required the construction of narrow-gauge railroads, skid trails, log landings, and logging roads. The 1960 Donner Ridge Fire severely burned over 20 percent of the watershed and post-fire salvage logging operations—which is the practice of removing fire-killed trees over exposed soils—further destabilized hillsides and likely contributed to erosion (Atkinson, 1960).

The impacts of forest roads on hydrological processes are well documented (Kastridis, 2020; MacDonald and Coe, 2008). Roads and trails having high hydrologic connectivity with streams and sensitive habitat impose the most impacts. Therefore, we focused our assessment on areas that may exhibit high hydrologic connectivity using desktop analysis and field verification.

Based on historical aerial photographs, historical photographs, and the recorded history of logging and road building in the watershed, we speculate that Prosser Creek and its tributaries exhibited two distinct periods of degradation: (1) early 20th century logging (1900-1936) and (2) post-1960 fire runoff and salvage logging. These two periods coincide with some of the largest regional floods in 1937, 1963 and 1964 (Kattleman, 1997) and exacerbated erosion. A watershed with reduced canopy from both logging and wildfire, high density of road construction and compaction of soils likely created prime conditions during excessive rainfall to degrade channel and meadow environments. The magnitude and severity of these impacts were lessened over time; however, areas where excess runoff and chronic erosion persist should be identified and treated.

Methods

The goals and objectives of this assessment parallel the primary goals and objectives of the Tahoe National Forest (TNF), East Zone project (USDA, 2020) located adjacent to the Prosser Creek watershed. These include reducing impacts to natural resources and enhancing quantity, quality, and diversity of recreation opportunities. The methods used under this assessment follow similar methods, including use of similar terminology. Below, we provide definitions of terms used and adapted from TNF efforts:

- *Roads*: defined as any unpaved, double-track linear feature created by altering natural topography; these include existing access roads, fire roads, as well as historical or current logging and skid roads.

- *Trails*: defined as any single-track linear feature created for pedestrian, horse or bicycle access and/or recreation.

- *Railroad Grades*: defined as historical linear features constructed to support logging operations in the late 1800s and early 1900s.

- *Culverts:* pipe or other structure used to convey streamflow under a road, trail or grade.

Maps of roads and trails were obtained from landowners and publicly available online databases. Many roads, trails, and grades in Prosser Creek watershed are not mapped, but were identified using a digital elevation model (DEM) generated from 2018 LiDAR imagery (OCM Partners, 2021).

The following terms, adapted from USFS (USFS, 2020), were used to define conditions:

- *Functional*: road/trail/grade segments that are currently meeting objectives for hydrologic and sediment control. Culverts can convey range of anticipated or observed flow and show no sign of backwatering or channel scour at its outlet.

- *At-Risk*: road/trail/grade segments in need of maintenance; have the potential to increase runoff and sediment to active channels. Culverts may only convey a portion of anticipated or observed flow, shows signs of damage, collapse or evidence of backwatering or scour.

- *Impaired*: road/trail/grade segments that are actively contributing excess runoff and sediment to active channels; requires maintenance and drainage improvements or, if not in use, decommissioned. Culverts show complete failure, clogged with sediment, or severely undersized and express evidence of frequent backwatering and/or downstream scour.

- *Not Evaluated*: road/trail/grade segments that are visible in a LiDAR bare-earth model, but were inaccessible or our flow accumulation analysis did not suggest disturbance to natural flow paths.

Criteria for Road, Trail and Railroad Grade Field Verification

As part of the Prosser Creek Watershed Assessment (Hastings and others, 2022), Balance performed a flow-accumulation analysis using the digital elevation model (DEM) derived from 2014 LiDAR imagery (USFS, 2014) and processed in GlobalMapper® with a sensitivity of 1-acre drainage area to identify and delineate flow lines and their intersection with roads, trails, and grades. This allowed us to identify potential areas of disturbance defined by road-related flow line modifications or stream capture. These areas were prioritized for further verification in the field.

In preparation for our field investigation, we used more recent (2018) bare-earth imagery derived from LiDAR (OCM Partners, 2021) as a second criterion to identify other possible key areas of disturbance even if our flow accumulation analysis did not detect stream capture. This criterion helped identify road-related landslides or other sources of excess sediment that may have been initiated by large-magnitude rain-on-snow events that occurred in January and February of 2017 which caused 10- to 20-year recurrence flood responses regionally.

Finally, while in the field, we used observations of channel condition as a third criterion to identify possible road-related impacts within the watershed. If channels exhibited visible active bank and bed erosion and abundant sediment deposition, then roads, trails, and grades above that point in the channel were also evaluated.

Data Collection

In the field, Balance used ArcGIS Field Maps™ to digitize road/trail/grade segments and assign current condition. For each segment we identified its condition, key observations, and captured representative photographs. Field evidence of impairment included visible rilling or scouring of road/trail surface, erosion of an inboard or outboard ditch, and/or diversion of a stream by a road/trail/grade and concentration and redirection of the stream flow line (also known as stream capture). Other indicators included water bar failures or sedimentation of water dips. Separately, we collected culvert point data only for locations where conditions of those features were classified as 'At-Risk' or 'Impaired'.

Timing of Data Collection

Many of the road and trail conditions in Prosser Creek watershed were assessed in the 6-week period following a major rainfall event that occurred on October 24 to 25, 2021, when local and regional weather stations recorded between 5 and 8 inches of rain (NRCS, 2021). This event was characterized as a between 25- and 50-year, 24-hour storm based on several regional rain gages (NOAA, 2021), and resulted in measurable runoff and impacts to improved and unimproved roads regionally. Thus, it provided an opportunity to observe runoff patterns and potential sediment sources in the watershed. Areas not assessed during this time period were evaluated between May and July 2022, immediately following the peak snowmelt runoff period.

Analysis

Using GIS, we quantified length and density of road/trail/grade segments by condition and landowner. We further delineated the study watershed into subwatersheds to identify areas where management actions could be focused to protect or improve sensitive areas (e.g., meadows). Subwatersheds with 'functional' road/trail/grade conditions were classified as 'no action'. Subwatersheds with 'at-risk' and 'impaired' conditions were further overlaid with NRCS mapped soil erodibility ranking (after Crosby and others, 1983) and evaluated with hydrologic connectivity (number of stream crossings and/or direct discharge to sensitive meadow habitat). Subwatersheds with low soil erodibility AND low hydrologic connectivity were classified as "secondary management priority"; whereas subwatersheds with moderate to high soil erodibility AND/OR moderate to high hydrologic connectivity were classified as "primary management priority" (**see Figure 1**).

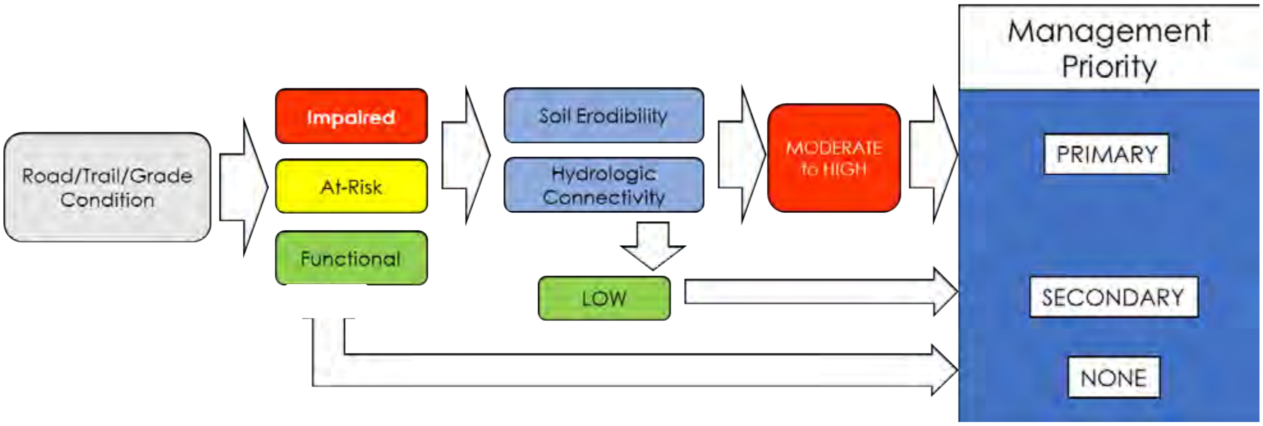

Figure 1. Schematic diagram showing method used for selecting management priority

Results

Existing roads, trails, railroad grades, and culverts[1] and their current condition are shown in **Figure 2.** Culverts classified as 'at-risk' and/or 'impaired' are shown in **Figure 3**. Key metrics for roads/trails/grades are provided in **Table 1**, while key metrics for culverts are provided in **Table 2**. Prosser Creek watershed includes 168.3 miles of roads, trails, and railroad grade segments in the watershed or a density of 4.9 miles per square mile. Of these, we assessed 120.9 miles or roads, trails, and railroad grades or 72 percent of all features in the watershed. The remaining 28 percent included paved roads and features that did not meet our criteria for field verification and, therefore, were not evaluated. We identified 26 culverts categorized as 'at-risk' and/or 'impaired'.

Based on our assessment, 75 percent of linear features we assessed were characterized as 'functional', while 16 percent were 'at-risk', and 9 percent were 'impaired'. Roads are the dominant linear feature in the watershed accounting for 82.5 miles or 68 percent of the total assessed features; trails totaled 32.9 miles or 27 percent; railroad grades totaled 4.2 miles or 3.5 percent (see Table 1). 16 culverts were identified as 'impaired', while 10 were identified as 'at-risk' (see Table 2).

We understand that some land managers have completed or are in the process of completing road maintenance and drainage improvements since our assessment was conducted. We also note that existing roads may have been modified or improved since our assessment for the purposes of forest management or fuel reduction. Therefore, some of our assessment findings and recommended management priorities may have already been addressed or may not capture areas recently disturbed.

[1] Only culverts identified as 'at-risk' and 'impaired' were mapped; functional culverts were not mapped.

Table 1. Length, density and condition of roads, trails, and grades, Prosser Creek Watershed, Nevada County, California

Metric	Condition	Length (mi)
Total Unimproved Roads, Trails, and Railroad Grades within the Watershed	Study Watershed*	168.3
	Assessed	120
	Impaired	11.3
	At Risk	20.1
	Functional	89.5
	Not Evaluated	47.4
Roads	Assessed	82.5
	Impaired	9.2
	At Risk	15.9
Trails	Assessed	32.9
	Impaired	1.8
	At Risk	1.9
Railroad Grades	Assessed	4.2
	Impaired	0.1
	At Risk	1.5
Paved Roads (not included in study)	NA	5.8

*Includes mapped and unmapped roads with condition "not evaluated" and/or does not include paved roads or roads on private property

NA = Not assessed

Table 2. At-risk and impaired culverts Prosser Creek Watershed, Nevada County, CA

ID	Lat	Long	Road Name	Condition	Notes
1	39.416689N	120.196842W	Old Highway 89	Impaired	Filled with sediment
2	39.374751N	120.312389W		At Risk	Unimproved crossing. Stable. At risk of erosion in big event
3	39.374736N	120.312888W	Prosser Creek Trail	At Risk	Small timber bridge. Signs of significant flow and sediment coming down tributary with direct input in creek
4	39.376137N	120.309353W	NFR-89-33-06-05	At Risk	Approx. 18-in CMP. May have overtopped. Channel upstream is in coding and widening. Suggest armor road for high flow spill.
5	39.376281N	120.30997W	Firewalker	At Risk	Erosion upstream of inlet, gully erosion below
6	39.381822N	120.279927W	Firewalker	Impaired	Buried or no culvert, erosion of road prism
7	39.394381N	120.276124W		At Risk	Head cut, erosion,
8	39.395789N	120.274622W	S. Euer Valley Road	Impaired	Partially clogged culvert, road capture
9	39.400886N	120.203878W	Frog Lake Road	At Risk	No culvert, but road crosses active erosional gully
10	39.374141N	120.301443W	Frog Lake Road	Impaired	Buried, partial road capture
11	39.370023N	120.29966W	Frog Lake Road	Impaired	Buried, road capture
12	39.371119N	120.296534W	Frog Lake Road	At Risk	Partially buried
13	39.378555N	120.308394W		Impaired	No culvert, but road could've decommissioned here and topography restored, road capture, channel scour
14	39.373142N	120.292569W	Frog Lake Road	Impaired	Buried
15	39.374158N	120.292209W	Frog Lake Road	Impaired	Buried
16	39.368802N	120.284008W	Frog Lake Road	Impaired	Buried
17	39.369327N	120.267214W	Frog Lake Road	Impaired	Culvert buried in sediment
18	39.382313N	120.197276W	Frog Lake Road	At Risk	Inlet partially sedimented in, inboard ditch and culvert relocate natural drainage into willow forest
19	39.362602N	120.290255W	Frog Lake Road	Impaired	Buried, road now captures stream
20	39.361629N	120.286114W	Frog Lake Road	At Risk	Road runoff entering channel at culvert
21	39.384379N	120.307601W		Impaired	Undersized
22	39.392423N	120.263139W		Impaired	Covered in debris from large colluvial channel
23	39.385587N	120.193185W	Crabtree Canyon	Impaired	No culvert, road dip is also tributary crossing, excess runoff and sediment to creek
24	39.37337N	120.308507W		Impaired	Inlet of culvert covered in sediment
25	39.375287N	120.308693W	Carpenter Valley Road	Impaired	Buried
26	39.370839N	120.305198W	Carpenter Valley Road	At Risk	Filled with sediment and vegetation

Since roads were the dominant feature in our assessment, we compared the road density to other watersheds in the Middle Truckee River Basin (**Table 3**). Prosser Creek watershed exhibits a road density (3.1 miles/sq. mile) similar to other nearby watersheds, but less than half of that reported for Martis Creek watershed, which is more heavily impacted by legacy land-use activities.

Table 3. Road Density within Prosser Creek Watershed compared to that of other selected watersheds in the Middle Truckee River Basin, California

Watershed	Area	Road Density	Source
	(mi^2)	(mi/mi^2)	
Martis Creek	42.7	6.9	Shaw and others, 2011
Bear Creek	5.2	4.5	Hastings and others, 2018
Prosser Creek*	**34.3**	**3.1**	**This study**
Lacey Creek	9.3	2.4	Hastings and Shaw, 2013

*density value includes all roads in the watershed, but excludes trails and railroad grades.

Figure 4 shows road/trail/grade conditions relative to property boundaries and land ownership in the Prosser Creek watershed. **Table 4** provides lengths of 'impaired' and 'at-risk' road/trail/grade conditions and density for each landowner. USFS (Tahoe National Forest) manages the majority of lands in the watershed and includes the bulk of road/trail/grade miles; however, based on feature density, TDA and TDLT manage lands with higher road/trail/grade densities, including those features with 'at-risk' and impaired' conditions.

Table 4. Condition, length, and density of roads/trails/grades across different landowners, Prosser Creek watershed, Nevada County, California

Land Ownership	Condition	Length (mi)	Density (mi/mi^2)
TDA Property	All*	36.2	12.1
	Impaired	3.5	1.2
	At Risk	4.8	1.6
TDLT Property	All*	27.9	6.0
	Impaired	1.5	0.3
	At Risk	3.9	0.8
USFS Property	All*	103.5	4.7
	Impaired	5.6	0.3
	At Risk	11.4	0.5

*Includes mapped and unmapped roads with condition "not evaluated" and/or type "unknown" but does not include paved roads or roads on private property

Figure 5 shows road/trail/grade conditions relative to soil erodibility in the Prosser Creek watershed, based on the erosion factor "K" used in the Revised Universal Soil Loss Equation (Renard and others, 1991). The K-factor indicates the susceptibility of a soil to sheet and rill erosion by water. Values of K range from 0.02 to 0.70 with some very rare soils with a value greater than 0.70. The higher the value, the more susceptible the soil is to sheet and rill erosion. It should be noted that these values do not account for the presence of or disturbance from a road, trail or grade. These values also do not capture or identify areas subject to geologic hazards such as landslides and debris flows. Instead, we use these values conservatively to assess potential for erosion if a road, trail or grade discharged runoff to adjacent soils. Soil erodibility classes used in our assessment are provided in **Table 5**. Soils in the watershed are classified as having low to very low erodibility with no soils classified as having moderate, high or very high erodibility.

Table 5. Erodibility factor values for various soil erodibility classes

Soil Erodibility Classes	Soil *K* Factor
Very High	>0.70
High	0.50 - 0.70
Moderate	0.25 - 0.50
Low	0.13 - 0.25
Very Low	<0.13

Adapted from Crosby and others (1983)

Figure 6 shows subwatersheds ranked by management priority: (a) primary, (b) secondary, (c) none. **Table 6** lists each subwatershed with a primary or secondary priority, area, and land ownership. In general, areas identified for primary priority management include:

- Euer Valley including Crabtree Canyon
- Red Mountain (south drainage)
- Carpenter Ridge-draining to Lower Carpenter Valley
- Prosser Hill, West Meadow (improvements completed September 2022)
- Hobart Mills Reservoir

Areas identified for secondary priority management include:

- Red Mountain (south drainage)
- Lower Carpenter Valley (minor drainages)
- Prosser Canyon (below confluence of NF and SF)
- Euer Valley (north-facing drainages)
- Prosser Hill and OHV area

Table 6. Subwatersheds with primary and secondary priorities, Prosser Creek Watershed, Nevada County, California

Basin Number	Priority	General Area Description	Notes	Area (sq. mi)	Land Owner
1	Primary	SF Prosser Creek, Upper Euer Valley	Rilling, stream capture, connectivity to upstream end of meadow	0.56	TDA/USFS
2	Primary	SF Prosser Creek, Upper Euer Valley	Rilling, stream capture, connectivity to upstream end of meadow	0.48	USFS/TDLT
3	Secondary	Red Mountain, south side drainage	Hydrologic connectivity that eventually leads to the meadow but location higher in the	0.26	USFS/TDLT
4	Primary	Red Mountain, south side drainage	Stream capture, major stream crossings show active scour	0.33	USFS/TDLT
5	Primary	Crabtree Canyon	High density of impacted roads, stream capture at major creek crossing, connected to meadow further downstream	0.62	TDA/USFS/TDLT
6	Primary	Crabtree Canyon	Many stream crossings, directly connected to eroded stream and meadow	0.39	TDA/USFS/TDLT
7	Primary	Crabtree Canyon	Culvert in good condition but direct runoff and sediment to creek with direct connectivity to meadow	0.27	TDA
8	Primary	NF Prosser Creek, Lower Carpenter Valley	Low density of impacted roads, but stream capture with direct connectivity to degraded	0.20	TDLT
9	Secondary	NF Prosser Creek, Lower Carpenter Valley	Old logging road with stream capture	0.17	USFS/TDLT
10	Primary	NF Prosser Creek (Canyon)	Informal trail intersects spring flow. Below meadow	0.80	TDA/USFS
11	Secondary	Prosser Creek below confluence of NF and SF	Blown out railroad grade, mountain bike trail switchbacks	0.35	USFS
12	Primary	Prosser Hill West Meadow	Long connected road with runoff directly to meadow; eroding road to Prosser Creek	0.11	USFS
13	Secondary	SF Prosser Creek, Lower Euer Valley	South Euer Road identified as a separate project. Roads in upper portion of subwatershed has rilling and could benefit from more water bars	0.29	TDA
14	Secondary	SF Prosser Creek, Lower Euer Valley	South Euer Road identified as a separate project	0.20	TDA
15	Secondary	SF Prosser Creek, Lower Euer Valley	Minor stream capture, additional water bars for improvement	0.25	TDA
16	Secondary	SF Prosser Creek, Upper Euer Valley	South Euer Road identified as a separate project. Some minor stream capture in subwatershed draining to South Euer Road	0.42	TDA
17	Primary	Hobart Mills Tributary, West Fork, Billy Hill	Heavily disturbed area associated with Hobart Mills Reservoir	0.29	USFS
18	Secondary	Prosser Hill, North Drainage and Reservoir	Water bars need maintenance, excess runoff to reservoir from stream capture	4.08	USFS

See Figure 5 for location of each subwatershed

Wildfire and Roads

It is well documented in the literature that wildfires increase erosion and sediment yields relative to unburned watersheds (Rust and others, 2018). The presence and density of roads can exacerbate runoff and erosion (Kastridis, 2020; and MacDonald and Coe, 2008). While we have documented 'functional' conditions for many roads, wildfire within the watershed could render these conditions at-risk or impaired.

Road and Trail Maintenance and Improvements

While it is beyond the scope of this assessment to assign maintenance activities or improvement actions to roads, trails, or grades identified as impaired, we provide a list of common practices and their relative construction costs, frequency of maintenance, and ideal use in **Table 7**. We also understand that each landowner may have developed their own strategies to address road/trail impairments.

Table 7. Comparison of drainage structures used on dirt and gravel roads

Structure type	Ditch relief culverts	Rolling dip	Water bars	Cross road drains
Purpose	Drains the road's inside ditch	Drains the road surface; Only drains the ditch if dip is deep and intersects the ditch	Drains the road surfac	Drains road surface, ditch and springs on decommissioned or closed roads
Construction costs	High	Medium	Low	Low to Medium
Maintenance	Medium Needs frequent inspection and inlet cleaning	Low Needs occasional repair or reshaping	High Needs frequent cleaning, reshaping and replacement	None Should not need any maintenance
When to use	On all road grades On high or low traffic roads with frequent maintenance	On low and moderate grades On high or low traffic roads	On all road grades On low traffice roads or seasonal roads	On all closed or decommissioned roads, especially at springs and seeps
When not to use	On infrequently maintained roads; or wherever they would discharge to streams or onto unstable areas Below unstable or raveling cut slopes	On steep grades (>12% to 18%), depending on traffic type; On curves	On high traffic roads	Where the cross road drain would feed water onto an unstable area or deliver eroded sediment to a stream

Adapted from PWA, 2014, Handbook for forest, ranch and rural roads

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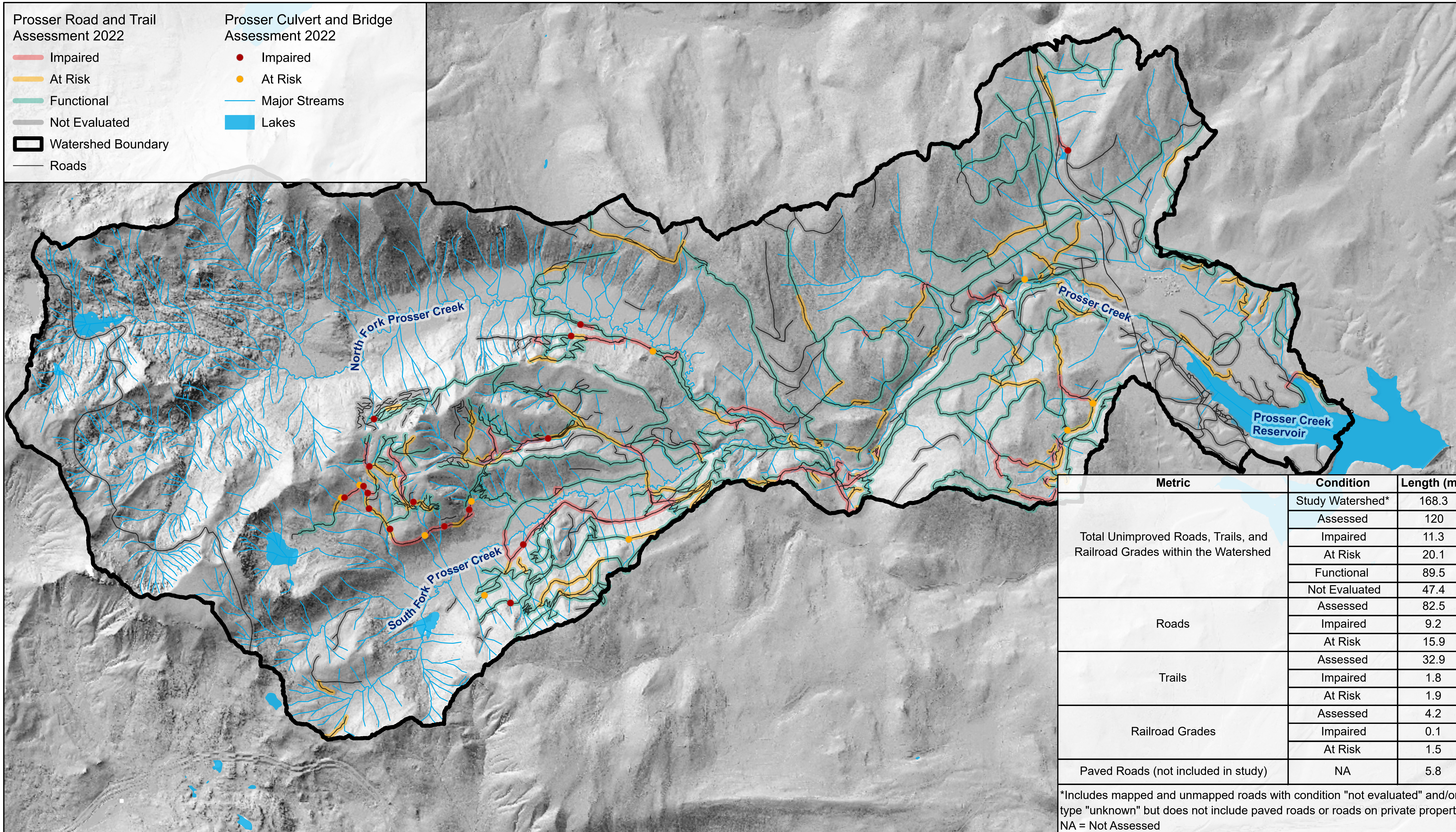

Metric	Condition	Length (mi)
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	Impaired	11.3
	At Risk	20.1
	Functional	89.5
	Not Evaluated	47.4
Roads	Assessed	82.5
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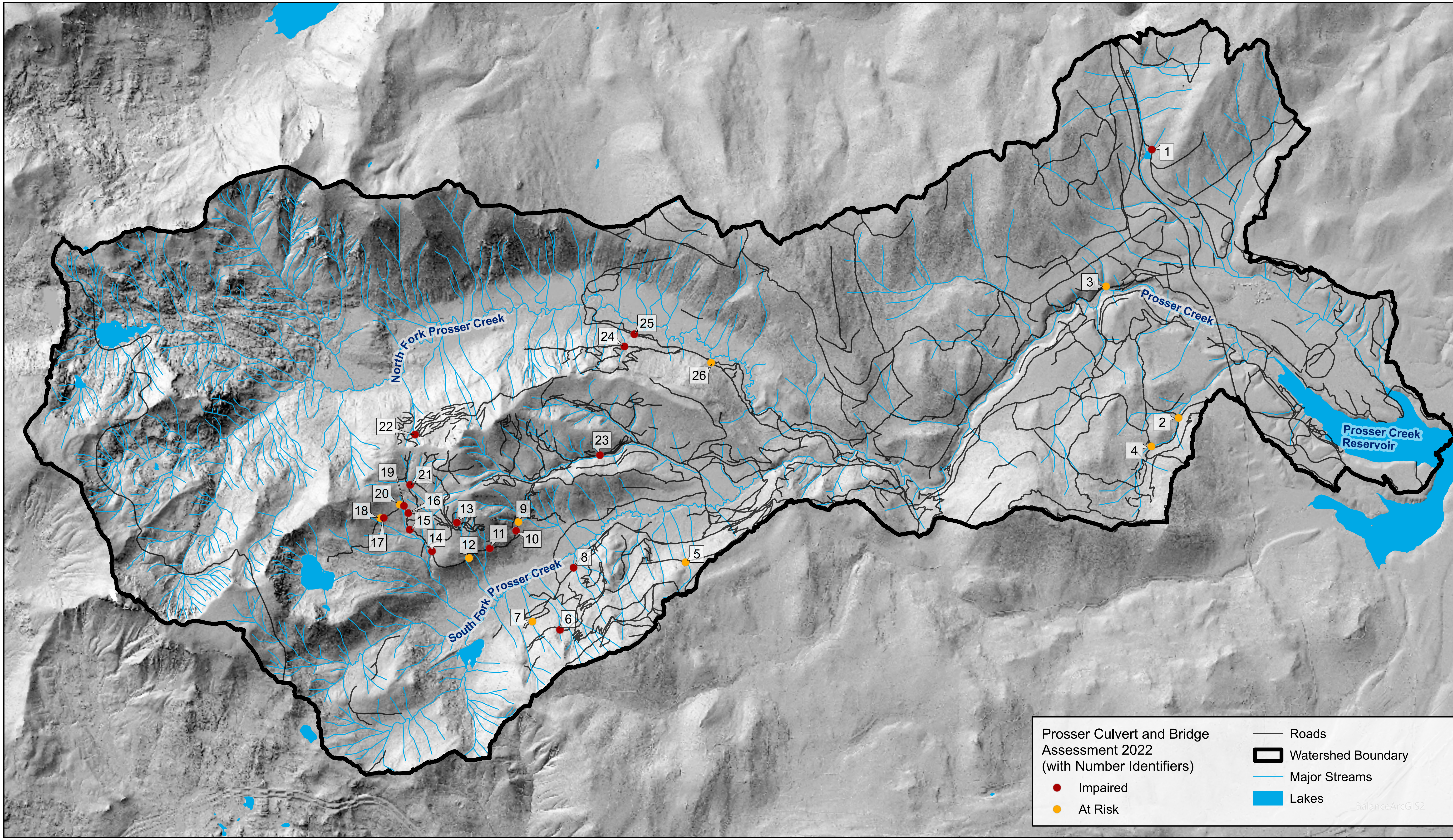
Paved Roads (not included in study)	NA	5.8

*Includes mapped and unmapped roads with condition "not evaluated" and/or type "unknown" but does not include paved roads or roads on private property
NA = Not Assessed

Balance Hydrologics

Figure 2. Roads, Trails, and Railroad Grade Conditions
Prosser Creek Watershed, Above Prosser Creek Reservoir
Nevada County, CA

Path: Y:\GIS\Projects\221156 Prosser Roads+Trails\221156 Prosser Roads and Trails Analysis\221156 Prosser Roads and Trails Analysis.aprx



Balance Hydrologics

Figure 3. Culvert and Bridge Conditions
Prosser Creek Watershed, Nevada County, CA

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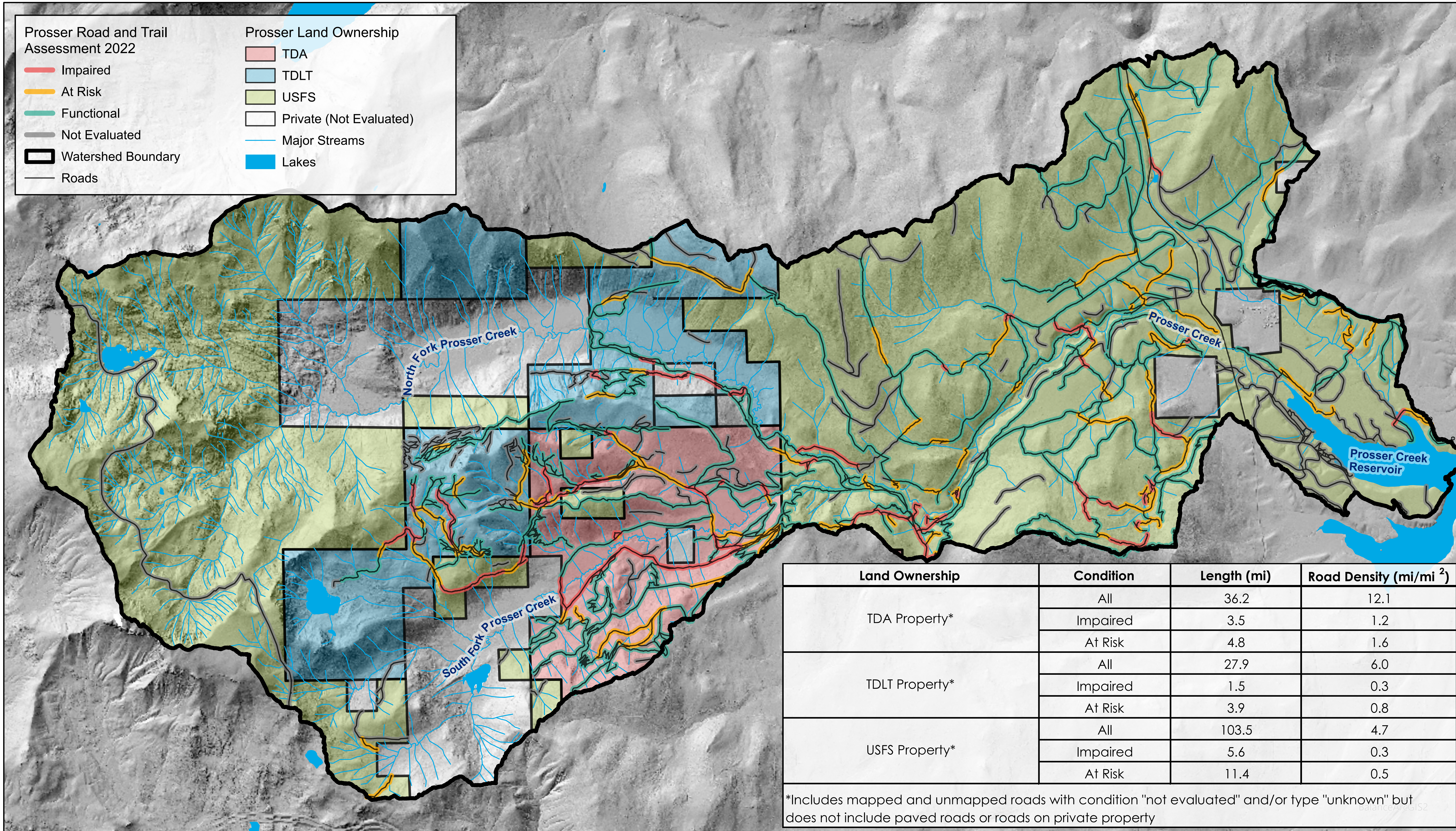


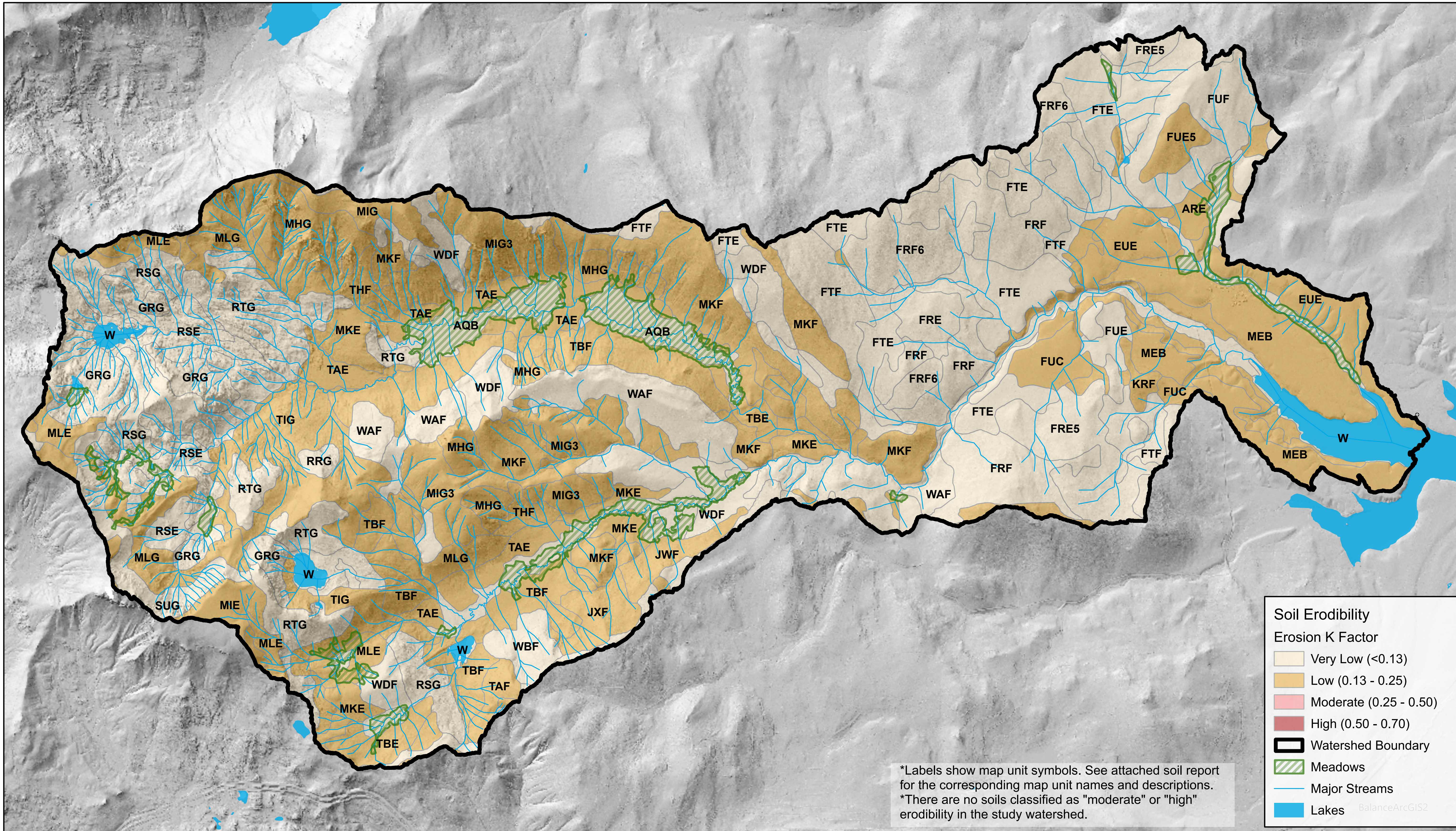
Land Ownership	Condition	Length (mi)	Road Density (mi/mi ^{2})
TDA Property*	All	36.2	12.1
	Impaired	3.5	1.2
	At Risk	4.8	1.6
TDLT Property*	All	27.9	6.0
	Impaired	1.5	0.3
	At Risk	3.9	0.8
USFS Property*	All	103.5	4.7
	Impaired	5.6	0.3
	At Risk	11.4	0.5

*Includes mapped and unmapped roads with condition "not evaluated" and/or type "unknown" but does not include paved roads or roads on private property

Balance Hydrologics

Figure 4. Roads, Trails, and Railroad Grade Conditions and Property Ownership Prosser Creek Watershed, Nevada County, CA

Path: Y:\GIS\Projects\221156 Prosser Roads+Trails\221156 Prosser Roads and Trails Analysis\221156 Prosser Roads and Trails Analysis.aprx



Balance Hydrologics

0 1 2 3
Miles

Figure 5. Soil Erodibility
Prosser Creek Watershed, Nevada County, CA

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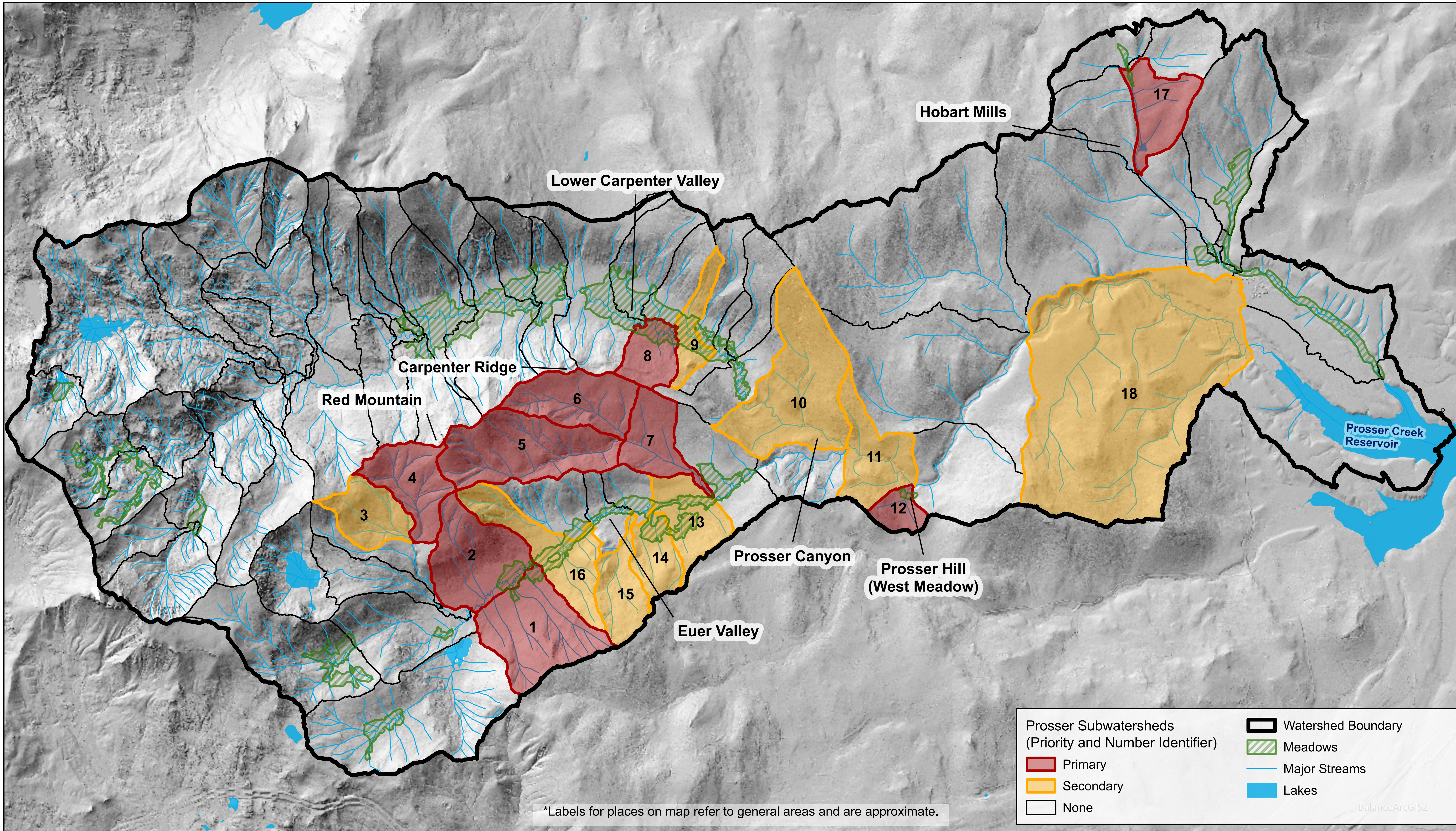

Balance Hydrologics

0 1 2 3
Miles

Figure 6. Priority Subwatersheds Identified in Roads and Trails Assessment
Prosser Creek Watershed, Nevada County, CA

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