Scotchman Creek Watershed Assessment: A Focus on Abandoned Mine Impacts

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2018

Acknowledgments

SYRCL wishes to thank the following individuals and organizations who provided helpful contributions, field data collection, and comments on this report: Rorie Lin Gotham, Brennan Johnston, Cordi Craig, Betsy Harbert, Johan Ehde, Jess Swigonski, Sarah Phillips, Anna Schwyter, Mo Loden, Balance Hydrologics, Carrie Monohan, The Sierra Fund, Gary Reedy, Rick Weaver, and the Tahoe National Forest. We would also like to acknowledge our funders: The California Department of Water Resources and the Cosumnes American Bear Yuba Integrated Regional Water Management Group (CABY IRWMG).

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Executive Summary

The objective of this watershed assessment was to understand the potential sources of contamination from past mining activities in the Scotchman Creek watershed through stakeholder outreach and the identification and quantification of mercury and turbidity within the watershed. The Scotchman Creek watershed is a tributary to the South Yuba River, a 303(d)-listed river for mercury. Ongoing erosion and sedimentation throughout the sub-watershed creates turbid surface water that carries particulate-bound mercury. The watershed contains two major hydraulic mine sites, Alpha Diggins and Omega Diggins, in addition to the Scotchman Debris Dam and many smaller mine sites and gravel deposits. The Omega Diggins hydraulic mine site is not remediated and privately owned while the Alpha Diggins hydraulic mine site is in the process of being remediated and is owned by the Tahoe National Forest. In addition to quantifying mercury and sediment levels across the watershed, we compared the contribution of mercury and total suspended solids (TSS) during storm events directly downstream from Alpha and Omega Diggins, at an upstream control point and the mouth of the watershed to understand whether mine remediation actions were effective at reducing contaminant sources.

Stakeholders, which included local community members and landowners, were interviewed to determine their perspectives on mining related issues within the Scotchman Creek watershed. Their responses to this survey indicated that the following issues were of concern:

- Water quality contamination
- Loss of aquatic habitat
- Erosional issues
- Trespassing and vandalism
- Continued mining practices
- Public safety issues from the aging Scotchman Debris Dam

Quantification of mercury and TSS from water samples concluded that:

- The Red Creek sub-watershed, which includes Omega Diggins, is a high priority for future remediation efforts.
- Heavy metal testing should be conducted within the mine tailings above the Scotchman Debris Dam to determine the potential threat of contamination from these tailings to the South Yuba River.
- Annual loading estimates for mercury and sediment will require additional sampling.

Introduction

The Gold Rush in California brought miners and settlers to the Sierra Nevada, dispersing native peoples and resulting in a landscape which is still impacted by hydraulic mining and clearcutting. Clearcutting and hydraulic mining were two of the largest impacts on the landscape that continue to impact the Sierra today. Hydraulic mining entailed redirecting and pressurizing surface water through water cannons to break down placer ores and wash away gravel deposits. Once washed off the hillsides, slurries abundant with placer gold from weathered gold-quartz veins were directed through sluices in an effort to locate gold. To extract the gold from the sluices, liquid elemental mercury was used to make a gold-mercury amalgam. This amalgam was recovered and then heated in order to volatilize the mercury leaving the gold behind. This process released mercury vapor into the air and lost liquid elemental mercury into the surrounding environment. Loss of mercury during the Gold Rush was estimated to be 10 to 30 percent per season (Bowie 1905), totaling about 10,000,000 pounds across California (Churchhill 2000).

The Scotchman Creek watershed contains two major hydraulic mine sites, Alpha Diggins and Omega Diggins, in addition to the Scotchman Debris Dam and many smaller mine sites and gravel deposits. The Omega Diggins hydraulic mine site is not remediated and privately owned while the Alpha Diggins hydraulic mine site is in the process of being remediated and is owned by the Tahoe National Forest.

The mercury lost to the environment during the hydraulic mining era still persists in the Sierra Nevada (Figure 1; James 2005). Today, hundreds of abandoned hydraulic mine sites remain, leaving thousands of acres of largely barren soil contaminated with mercury and exposed during large storms. During rain events, these areas are highly susceptible to surface erosion, creating highly turbid run-off that contributes elevated levels of metals and sediments to our headwater tributary streams.

While it is generally understood that there is a linear relationship between sediment and streamflow, hillslope runoff begins only after enough precipitation has fallen to saturate the soil and mobilize sediments (Bryan 2000; Wu 2018). The sediment runoff relationship is complex as sediment runoff rates can slow during large events and can also be accelerated by sloughing of exposed soils common within abandoned mine sites. In addition, the amount of rainfall, duration, and locale of a single rain event can impact where within a landscape sediment runoff occurs (Wu 2018).

For a long time, the mercury found at hydraulic mine sites was ignored, in part because mercury found in soil remained at very low levels. However, new research on the transport of mercury from mine sites into streams of rivers makes these low levels a serious public health concern once they reach aquatic environments. Low levels of mercury can bioaccumulate and biomagnify to dangerously high levels in top predatory fish (Fleck et al 2011).

One of the most toxic forms of mercury is known as methylmercury (CH_3Hg^+), which is ingested by humans through the consumption of mercury-contaminated fish and can be detrimental to human fetuses, young children, and wildlife (Figure 1) (Davidson et al. 1998; Wolfe et al. 1998).

> *The transformation from elemental mercury to methylmercury is a complex biogeochemical process that requires at least two steps: (1) Oxidation of Hg(0) to Hg(II), followed by (2) Transformation from Hg(II) to CH_3Hg^+; step "2" is referred to as methylation. The concentration of CH_3Hg^+ generally increases by a factor of ten or less with each step up the food chain, a process known as biomagnification. Therefore, even though the concentrations of Hg(0), Hg(II), and CH_3Hg^+ in water may be very low and deemed safe for human consumption as drinking water, CH_3Hg^+ concentration levels in fish, especially predatory species such as bass and catfish, may reach levels that are considered potentially harmful to humans and fish-eating wildlife, such as bald eagles.*
> Alpers and Hunerlach, 2000

In 2000, The United States Environmental Protection Agency (USEPA) published The California Toxic Rules (CTR)[1] which establishes ambient water quality criteria for priority toxic pollutants in California's inland surface waters, enclosed bays, and estuaries under the Clean Water Act (USEPA 2000). The CTR established a human health criterion (HHC) for mercury of 50 ng/L for water. Fish consumption advisories are issued by the Office of Environmental Health Hazard Assessment (OEHHA) and are based on the relationship between mercury concentrations in fish tissue by species to "Advisory Tissue Levels" for methylmercury (OEHHA 2008). Most OEHHA advisories are site specific, but sufficient fish tissue data is needed. For waterbodies without sufficient fish tissue data, a "Statewide Advisory" was developed with samples from hundreds of California water bodies (Lim et al. 2013).

[1] Title 40 of the Code of Federal Regulations, Part 131.38

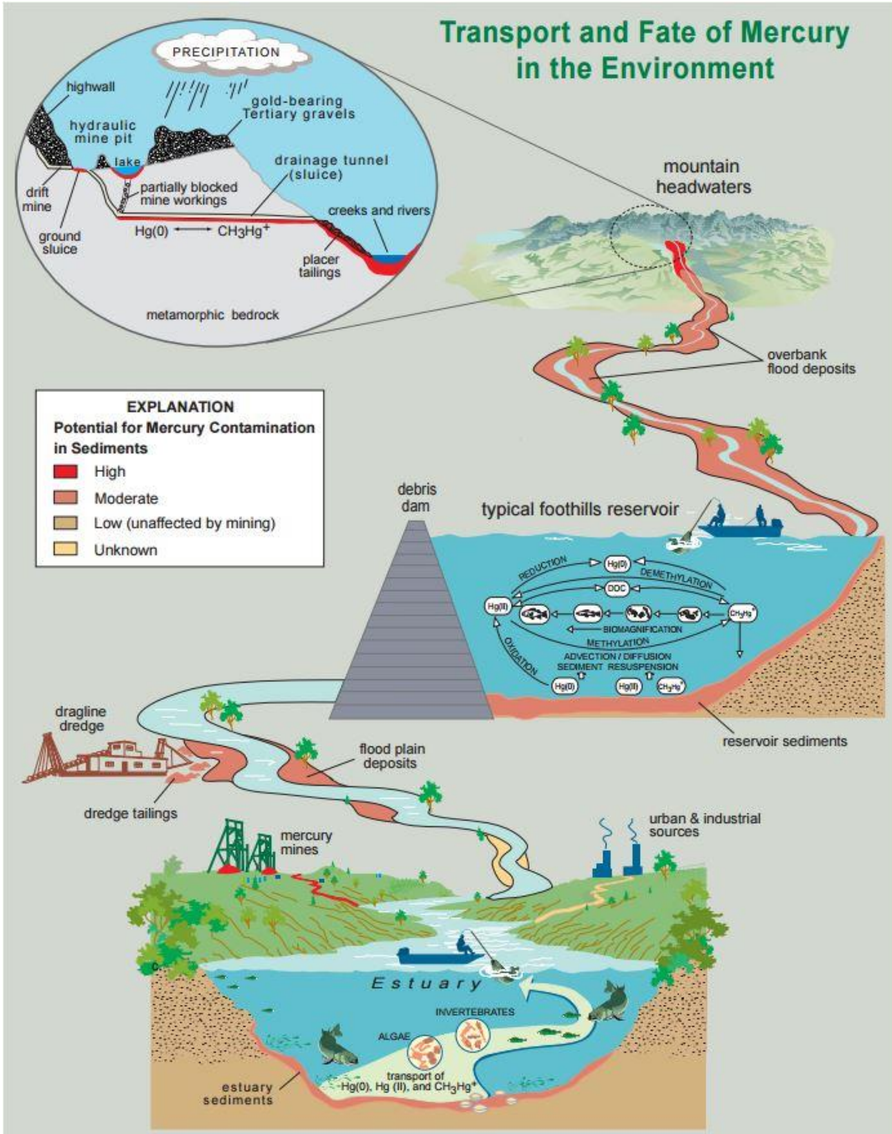


Figure 1. A simplified diagram from a USGS Factsheet showing the transportation of mercury through the environment. Hg(0), elemental mercury; Hg(II), ionic mercury; CH_3Hg^+, methylmercury; DOC, dissolved organic carbon (Alpers and Hunerlach, 2000).

In addition to the impacts of mercury contamination, suspended sediment from erosion and deposition is another common issue that arose from historic hydraulic mining. Sediment mobilization and deposition, although beneficial to nutrient replenishment and creation of benthic habitat, at high rates can cause issues related to oxygen and habitat availability for aquatic species (Czuba et al. 2011). Water quality is diminished with unusually high fine suspended sediment transport and deposition including increased temperatures from sediment absorbing solar heat, dissolved oxygen levels dropping from warmer waters, and decreased photosynthetic rates for submerged plants (Chesapeake Bay Program 2012). For example, specific sediment sizes are required for spawning habitats and too fine of sediment can smother eggs and other benthic inhabitants (EPA 2012). The foothill yellow-legged frog, a California species of special concern, still utilize tributary creeks and rivers impacted by fine sediments from hydraulic mining including Scotchman Creek (Nevada Irrigation District and Pacific Gas and Electric Company 2009). Methylation primarily takes place in low gradient, slower moving water and is particularly prevalent in the California Bay-Delta at the terminus of the San Joaquin and Sacramento watersheds. In an unpublished study conducted by USGS, 6 trout were sampled below Scotchman Falls and all fell beneath the 0.3 ppm (wet) criterion (Alpers, pers comm) set by the USEPA (USEPA 2001). Protection of species from high suspended sediment concentrations and associated turbidity is crucial in conserving the rich diversity of California's native species in headwater streams and rivers.

To understand the impact of abandoned mines on the local community and water quality in Scotchman Creek watershed, we conducted outreach with landowners and stakeholders, identified potential sources of contamination in the watershed, and conducted water quality monitoring to better understand how Alpha and Omega Diggins were contributing to turbidity and mercury contamination. In particular, we were interested in whether mercury in Scotchman Creek was transported primarily as particulate-bound mercury, what the annual and storm event sediment and mercury loads were, whether suspended sediment was directly correlated with flow, if the rest of the watershed dilutes the Omega Diggins drainage named "Red Creek", and how significant Alpha Diggins was to the sediment and mercury levels in Scotchman Creek.

Methods

Study Area

The Scotchman Creek watershed comprises all drainage regions into Scotchman Creek, and ends at its confluence with the South Yuba River, east of the town of Washington, CA. The watershed is at 5,000 feet of elevation and occupies nearly 3,200 acres of the South Yuba River watershed. The east fork drains the 200-acre Omega Diggins hydraulic mine and the west fork is sourced from the 66-acre Alpha Diggins hydraulic mine. Additionally, there is a middle fork originating from Sardine Spring near State Route 20 (see Appendix I). Red Creek, named during this study for the rust colored iron reducing bacteria that populate the small seasonal drainage, drains directly off Omega Diggins, where exposed sediments, hydraulically washed walls and peaks erode during rain events. Bright Creek, downstream from Zeibright Mine a lode and placer mine, was named during this study for its clear water and was used as the upstream control for all sites sampled in this study. Alpha Diggins, owned by the Tahoe National Forest and recently remediated using a series of check dams and revegetation measures, is an additional source of potential contaminants to the watershed. In August 2008, TNF implemented a pilot revegetation project on the Alpha Diggins mine site. A seed mix of California brome, Blue wild rye, Annual lotus, Bluegrass, Yarrow, and Regreen were broadcasted with a belly grinder over the soils. The following year all species from the seed mix were present. Additionally, there was evidence of wildlife utilization of the site evident by scat and burrows. These amendments made a revegetation of a small area of the site possible.

Land ownership is primarily public land (69% of the total area) owned by the Tahoe National Forest (TNF) with the remaining 31% in private ownership (Appendix I). Additionally, the Scotchman Creek watershed boundary includes 12 placer and 32 hard rock active mining claims

(Appendix I). The geologic setting of the Scotchman Creek watershed includes Argillite/Quartzite rock and secondary Andesite/Rhyolite rock formations in the upper watershed. The watershed contains colluvial and eroding hillslopes into an inner gorge containing the main stem of Scotchman Creek (Appendix I). Vegetation found throughout the watershed is dominated by dry mixed conifer, moist mixed conifer, montane chaparral, yellow pine, chaparral and mixed evergreen plant communities (Appendix I). Precipitation in the Scotchman Creek watershed is representative of California's Mediterranean climate consisting of cool, wet winters and warm, dry summers. It is approximated that 90% of California's precipitation falls during the cool season months between October 1^{st} and April 30^{th}. During this period, moisture comes from the Pacific Ocean occasionally from atmospheric rivers delivering large amounts of precipitation producing high run-off events.

Stakeholder Outreach

Stakeholder outreach was conducted by contacting residents and agencies that own land within the Scotchman Creek watershed in 2011. Interview questions were crafted to better understand values and major concerns in the local community (Appendix II). In addition, a stakeholder meeting and field tour were held in 2011 to discuss issues and gather input from community members, interested organizations and agencies. Outreach to individual landowners continued after this initial effort, including to the largest landowners in the watershed, the US Forest Service, the owners of Alpha Diggins, Omega Diggins and Sierra Pacific Industries.

Source Identification

Aerial imagery, available GIS data layers, results from stakeholder surveys, on the ground surveys, and site visits were used to identify potential sources of pollution. Potential pollution sources included abandoned mines, culverts, sediment deposits, historic debris dams, and roads (Figure 2). This information was used to target areas for water quality monitoring and to prioritize recommended actions. Two of the larger landowners, Sierra Pacific Industries and the owner of Omega Diggins, did not allow field surveys or site visits.

Figure 2. Aerial photo of Omega Diggins with the South Yuba River to the left.

Discharge

Streamflow data was collected in two locations to measure stream flow just below Omega Diggins on Tahoe National Forest property and above the confluence with the South Yuba River (Figure 3). A gaging station could not be established below Alpha Diggins due to steep terrain and dangerous conditions.

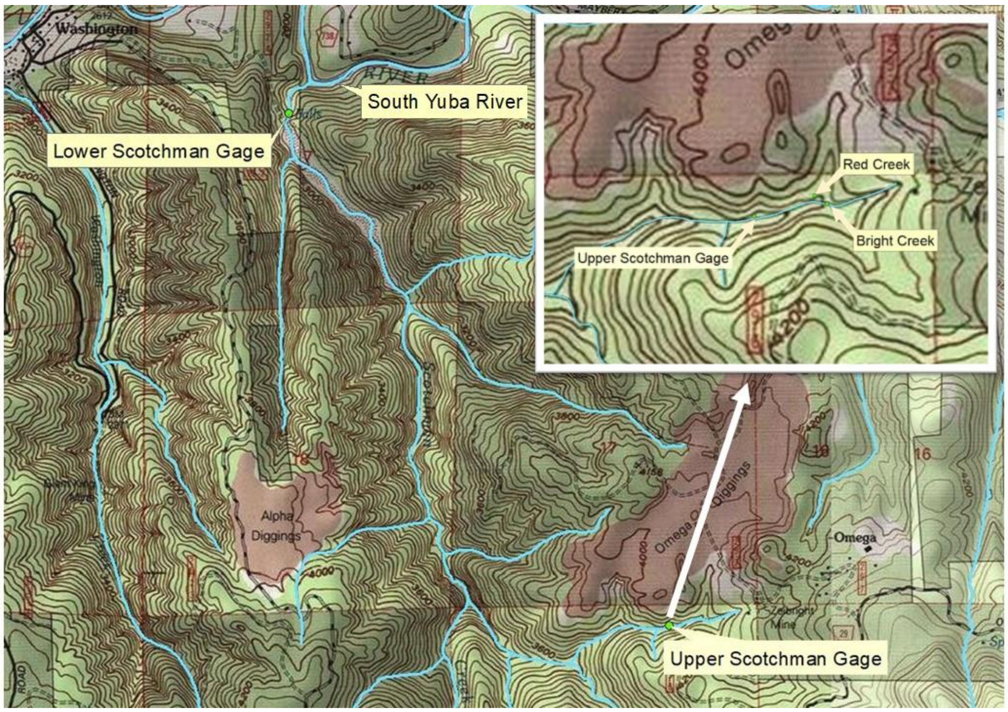


Figure 3. Scotchman Creek Stream Gaging Locations with associated Red and Bright Creek tributaries.

The Upper Scotchman Gage (SCG1) is located downstream of the confluence of "Red Creek" and "Bright Creek" (two unnamed tributaries) at 3,600 feet of elevation, just below Tahoe National Forest road 29-06. This gaging station was installed using a PVC stilling well anchored with rebar to the stream bank equipped with a 3.3-foot staff plate (Figure 4). This reach drains a 1.7 square mile sub-watershed that includes Omega Diggins and Zeibright Mine. The gaging reach was incised, which was likely caused by upstream hydraulic mining activity.

Figure 4. Upper Scotchman gage location (SCG1).

The Lower Scotchman gaging station (SCG2) was installed at 767 feet of elevation just upstream from Scotchman Falls above the old Scotchman Debris Dam (Figure 5). This gaging station was installed using a galvanized steel pipe stilling well anchored to bedrock with a 5-foot staff plate. The entire Scotchman Creek watershed, including Alpha and Omega Diggins, drain to this location. The stream gage was co-located with SYRCL's monthly monitoring "Site 25" on Tahoe National Forest land (visit www.yubashed.org to view data collected since 2001). The site was easily accessed from the Scotchman Falls Road, which ends above the dam beside a gravel bed.

Figure 5. Lower Scotchman gage location (SCG2).

A stage-discharge relationship or rating curve was created to estimate the annual water flow. Baseline discharge, storm event discharge, and stage data were collected throughout each year of the study (2015-2016) to create these relationships. A Marsh-McBirney Flo-mate and a top setting wading rod were used to collect discharge measurements while wading in the creek. Discharge measurements followed the protocols outlined in Rantz et al. (1982) for measurement of discharge by current meter methods. A cross section was established at the sample location across a portion of stream in uniform flow using a tape measure and rebar. The total width of the creek was recorded and used to divide the creek into 25-30 subsections. The depth, width, and velocity of the stream was recorded at each section. Staff plate readings occurred before and after discharge measurements.

Discharge was calculated using the following equation:

$$Q = \sum (a * v)$$

where Q is total discharge, a is the cross-sectional area of an individual subsection, and v is the velocity of the flow in the subsection. Discharge measurements follow the midsection method for current meter measurement outlined in Figure 6 (Rantz et al. 1982). Velocity measurements were made using the six-tenths depth method, where an observation of velocity was made with the current meter at 0.6 the depth below the water surface, and representative of the mean velocity for the individual vertical or subsection. For depths greater than 2.5 ft when flows were not rapidly changing, the two-point method was used, in which velocity observations were made at 0.2 and 0.8 the depth below the water surface. Standard USGS procedures of 25-30 subsection measurements, with closer spacing of subsections in areas of greater depth and velocity were utilized. Total discharge for the creek was then calculated as the summation of discharges for all the subsections.

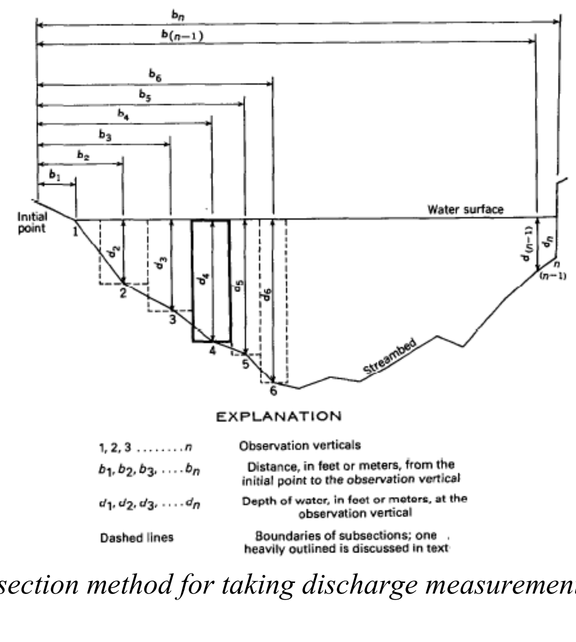


Figure 6. Sketch of the midsection method for taking discharge measurements (From Rantz et al. 1982).

Rating Curves

Rating curves were established to estimate annual water flow by creating a relationship between stage and discharge (Rantz 1982b). The rating curve was constructed in the statistical program "R" by plotting the data on an X-Y scatter plot, with Stage (ft) as the X variable, and Discharge (cfs) as the Y variable. After plotting the data, a trend line was plotted against the data with an equation,

R^2 and corresponding p-value. This equation was used to calculate discharge values using the generated stage data from the Levelogger vs. Staff Plate linear relationship. Collecting data on discharge and stage over time allows for a relationship to be developed between the two variables, so that discharge can be estimated from stage data.

Figure 7. Discharge measurements at the Upper Scotchman Creek Gaging Station.

Mercury and TSS Sampling

To understand the contribution of mercury and sediment from Alpha and Omega Diggins, water quality samples were collected below Omega Diggins at Red Creek, Bright Creek, below the confluence of Red and Bright creeks at the Upper Scotchman Gage (SCG1), below Alpha Diggins at Alpha North and Alpha Northeast, and at the bottom of the watershed at the Lower Scotchman Creek Gage (SCG2) (Figure 8). Bright Creek was utilized as the upstream control as it was upstream from the outflow from Omega Diggins and generally ran clear during field reconnaissance efforts. Additional sampling locations at Alpha Diggins were deemed unsuitable due to lack of flow or originated from a non-impacted drainage. To determine physical water quality conditions, monthly water temperature, dissolved oxygen, pH, turbidity and conductivity were collected using a YSI Professional Plus.

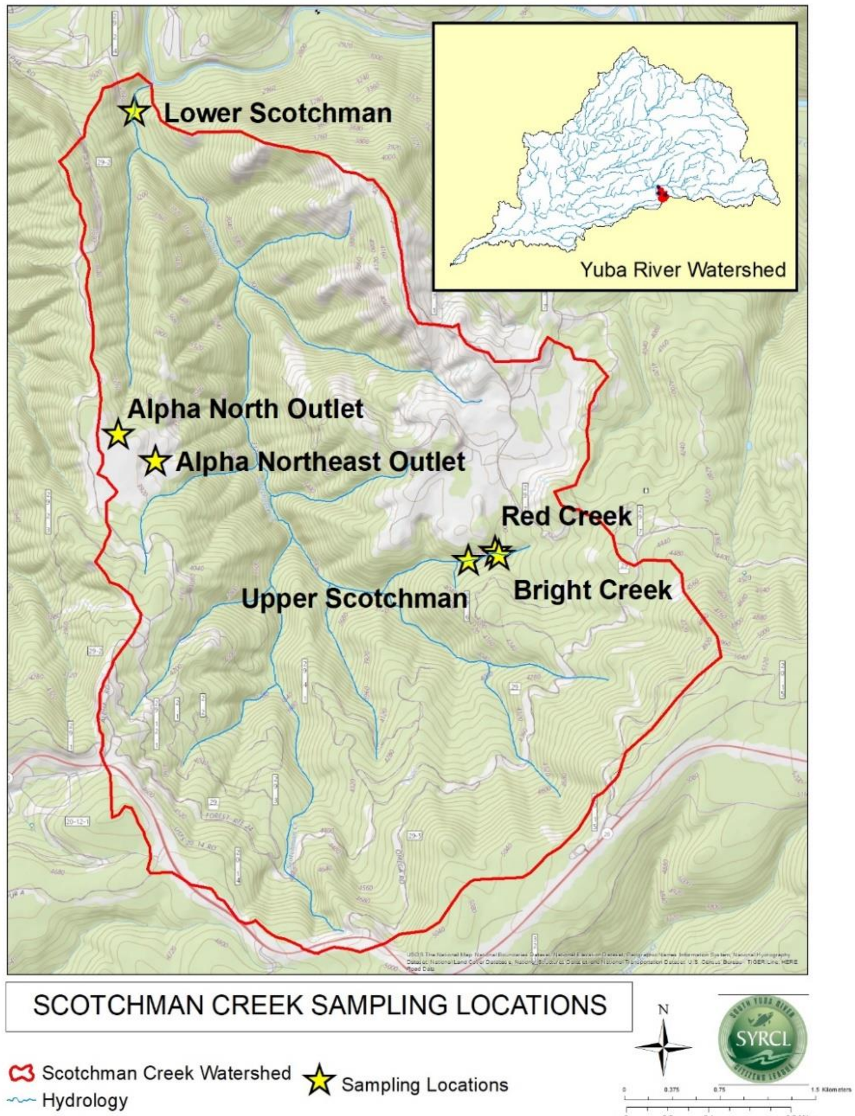


Figure 8. Scotchman Creek Sampling Locations.

Table 1. Scotchman Creek Sampling Location Coordinates

Location	**Latitude**	**Longitude**
Red Creek	39.331233	-120.759150
Bright Creek	39.331035	-120.758785
Upper Scotchman	39.330748	-120.760995
Lower Scotchman	39.355125	-120.784442
Alpha North Outlet	39.337590	-120.785567
Alpha Northeast Outlet	39.336148	-120.782985

Mercury and sediment transported in Scotchman Creek during storm events were collected using grab samples. Samples included total mercury, dissolved mercury (not for all sampling events), and TSS. Mercury samples were collected using Clean Hands/Dirty Hands EPA 1669 Method for sampling ambient water for trace metals (USEPA 1996). Each sampling event resulted in a 250 mL grab sample for trace-level mercury and a 1L TSS sample. A duplicate 250 mL grab sample for trace-level mercury was collected during a single storm event. Lab filtering, rather than field filtering, was necessary due to storm conditions associated with sampling, which made field filtering impractical; this was a modification to EPA method 1669 which was considered appropriate as long as lab filtering took place within required holding times.

A field blank was collected during the first storm event to ensure data quality from a random location at the field site. For field blanks, water provided by Brooks Rand Labs was transported into the field and handled with ultraclean techniques, uncapped and rinsed three times before capping. Mercury and TSS samples were sent to Brooks Rand Labs, an EPA certified lab. Put simply, field blanks help to detect contamination that might come from how samples are being transported or handled in the field.

Grab samples were collected within the Alpha Diggins mine site to determine the mercury and TSS contribution to the Scotchman Creek watershed (Appendix I). A sub-objective of this effort was to determine if remediation efforts at Alpha Diggins had been successful. During a single storm event total mercury and TSS samples were collected at Red Creek, Bright Creek, the Upper Scotchman Gage, Lower Scotchman Gage, at Alpha North Outlet, and at Alpha Northeast Outlet.

Mercury Form and TSS Relationship

Duplicate mercury samples were collected during the peak of a single storm event at Red Creek, Bright Creek, the Upper Scotchman Gage, and the Lower Scotchman Gage (Figure 8) to understand what form mercury was in at each sampling location. Determining the form mercury was being transported in can help inform future remediation actions. Calculation of particulate-bound mercury was calculated by subtracting dissolved (filtered) from total mercury (not filtered) concentrations. The difference is the mercury that is associated with the fines that are filtered out, also known as particulate-bound mercury. Additionally, to establish whether TSS could be utilized as a predictor of total or particulate bound mercury, a linear regression was used to develop a predictive relationship between total mercury and TSS. The data was natural log transformed to normalize the data for analysis.

Annual and Storm Event Loading

A Teledyne ISCO portable sampler was used to collect hourly TSS samples for loading estimates during two separate storm events for the Upper and Lower Scotchman Creek Gages. To calculate the load on an annual and storm event basis, stream discharge was multiplied by the concentration of either TSS or mercury, as follows:

$$\text{Load (mass/time)} = \text{Discharge (volume/time)} * \text{Concentration (mass/volume)}$$

The load of total mercury and TSS was calculated by analyzing data points collected at set intervals in relation to the discharge data, which was collected via Levelogger at 15-minute intervals. Data collection efforts coincided with runoff events, when the highest concentration of mercury and TSS are likely to be moving downstream. In order to determine if total mercury loading at the upstream and downstream sampling locations could be predicted by TSS, a statistical relationship was built to estimate mercury loads and TSS at the upper and lower stream gages for specific storm events. Estimates of annual loading could not be calculated due to the non-significant relationship between TSS and discharge.

To measure the direct contribution of sediment and mercury from Red Creek into Scotchman Creek, the ISCO collected hourly samples for TSS throughout a storm event. Grab samples for mercury were collected on the ascending, peak, and recession limb of the hydrograph at Red Creek, Bright Creek, and below the confluence of Red and Bright Creek (Figure 8). An additional sample was collected at the Lower Scotchman Gage near the peak of the storm. This information was used to calculate storm event loading.

The Lower Scotchman Gage site was used to represent the cumulative impact of the upstream abandoned mines and other potential mercury and sediment sources. During a single storm event, the ISCO was installed and collected TSS samples hourly. In addition, three mercury samples were coordinated with the autosampler to determine the relationship between mercury concentration in water and TSS throughout a storm event on the ascending, peak, and recession limb of the hydrograph. A mercury and TSS sample were collected during the peak of the storm at the Upper Scotchman Gage, Red, and Bright Creeks.

Results

Stakeholder Outreach

Thirteen interviews were conducted with 11 residents and 2 non-residents who have owned property in the watershed between 5 to 74 years in order to understand what they considered to be important in the watershed (Appendix II). These participants came from various professions and backgrounds including finance, firefighting, postal service, forestry, hydrology, and carpentry. The residents were interviewed and supplied supporting information to help describe the condition of Scotchman Creek watershed.

High Turbidity; Heavy Sediment Loading

Eight of the thirteen interviewed residents stated the sediment eroding away into Scotchman Creek was of concern in relation to water quality and aesthetics (Figure 9). One resident's property overlooks Scotchman Creek Waterfalls and has been dismayed by the sight of the muddy waters spilling and entering the South Yuba River. Another land owner expressed an interest in alleviating erosion issues in the watershed. At the 2011 stakeholder meeting, landowners brainstormed potential actions that could be taken to address their concerns.

Figure 9. Scotchman Falls during (Left) and a day after (Right) the storm event on December 10th, 2015.

Exposure to Mining Waste

Heavy metal and mercury contamination issues in the food chain concerned 62% of residents. The residents expressed concern over the contaminated lands they live on, knowing the impact to water quality. One resident shared a unique concern over the release of mercury during restoration actions, stating the consequences of remediation could be positive in the long run, but worried about the immediate release of mercury. This is in reference to removing debris dams and/or removing the nearly one mile of gravels that are privately owned yet are believed to contain contaminated sediments.

Trespassing and Vandalism

The Scotchman Creek watershed contains waterfalls, natural springs, the Wild and Scenic designated South Yuba River, and public trails that many people from out of town are drawn to explore. According to 45% of the residents interviewed, a lot of these visitors do not respect the land. The TNF has dealt with illegal dumping, spray paint, defecation, and trash at mine sites and nearby campgrounds.

In the past, residents concerned with trespassing and vandalism came together to close the local Kehler Campground. Tourists were trespassing beyond the campground onto private land, with trash being left behind. However, a few residents in the watershed share a reminiscent feeling about the campground, recalling going there when they first moved into the area, but sympathize with their neighbors in the idea of deterring trespassing and vandalism by shutting it down. The

Kehler Campground currently allows public access for hiking, but visitors can no longer park their vehicles or camp on site.

Other issues include, public safety concerns in reference to the aging Scotchman Debris Dam, continued mining, and further spread of invasive terrestrial and aquatic plants. Stakeholders suggested locations to visit within the watershed and people to contact for more history and background information.

Source Identification

Within the subwatershed, identification of sources of contaminated water and sediment were restricted to areas that were publicly accessible and parcels where private residents allowed access. In addition, the areas that were permissible had even further restricted access because of steep slopes. The watershed consists of ten main tributaries that either dilute or add to the sediment and mercury pollution throughout the watershed.

Upstream from the Scotchman Creek Debris Dam, hydraulic mine tailings have settled behind the dam (Figure 10). The dam was built in 1895 for retaining sediment produced during the hydraulic mining process at Omega Diggins (Pasternack 2011). The dam failed and was rebuilt multiple times. Today it is constructed of concrete and is filled with sediment. Prior to the Scotchman Debris Dam, there were earlier log, brush, and gravel dams constructed for the Omega Diggins mine operation (Figure 11).

Figure 10. Relative position of the primary tailings storage.

Figure 11. Old log dam (Photo by R Gotham).

An evaluation of the Scotchman Debris Dam was conducted by the USDA Forest Service staff due to concerns from the public (Romero et al. 2011). This report notes long-term seepage identified by the presence of efflorescence, which indicates some form of degradation in the concrete. The efflorescence covers the entire face of the dam but is mainly concentrated in the upper portion. Erosion was also noted from a combination of flow above the dam, freezing and thawing, and potential exfoliation below the west abutment. The report concluded that seismic risks are relatively low at the dam location given the distance from fault lines (Appendix I). The static analysis was well below tensile and compressive yield conditions and no seismic event has loaded the dam since it's construction. The overall conclusion was the Scotchman Debris Dam is stable, the top portion of the dam is at risk in the near future and could potentially lead to a small release of sediment, but the bottom of the structure is robust. However, the ageing infrastructure will continue to degrade, and routine evaluation of the structure is warranted.

Investigating one of the tributaries to Scotchman Creek resulted in the identification of a potential source of heavy metals from Red Creek (Figure 8). The Red Creek sub-watershed makes up just 4% (128 acres) of the Scotchman Creek watershed and drains off Omega Diggins. Bright Creek, which drains Zeibright Mine and is the upper main stem of Scotchman Creek, makes up 11% or 376 acres of the watershed. The confluence of Red and Bright creeks was tracked upstream from the turbid waters of Scotchman Falls during a storm event. Turbid water flows from Red Creek when compared directly to Bright Creek during storm events (Figure 12). This location was used to sample for mercury, TSS, discharge, and physical water quality parameters due to the consistency of turbid flows during storms events.

Figure 12. Confluence of Red and Bright Creek.

Discharge

Manual discharge measurements were collected 7 times at Upper Scotchman and 6 times at Lower Scotchman Creek (Table 2). Dataloggers were downloaded annually, at the end of the water year.

Table 2. Upper and Lower Scotchman flow data used in the calculation of a rating curve for each site.

Gage	Date	Levelogger Water Level (ft)	Staff Plate (ft)	Discharge (cfs)
SCG1	11/18/2015	0.4319	0.34	0.0222
SCG1	12/10/2015	0.8209	0.78	1.6527
SCG1	1/18/2016	1.2069	1.1	7.5087
SCG1	3/5/2016	1.4146	1.3	16.529
SCG1	4/8/2016	0.7669	0.76	1.1162
SCG1	11/11/2016	0.4836	0.54	0.1276
SCG1	12/10/2016	1.6427	1.68	32.2896
SCG2	11/18/2015	3.8198	2.6	0.9077
SCG2	12/10/2015	4.478	3.18	15.097
SCG2	12/21/2015	5.7892	4.7	77.2752
SCG2	1/18/2016	5.5578	4	54.0046
SCG2	3/5/2016	4.9339	3.73	40.2338
SCG2	11/11/2016	3.8027	2.8	2.6166

Rating curves for each gage presented a strong relationship between stage and discharge (R^2 = 0.996, p-value< 0.0001 at Upper Scotchman; R^2 = 0.990, p-value < 0.0001 at Lower Scotchman), indicating that the manual staff plate measurements were accurately predicting stream flow data. Based on the evaluation of the rating curves, the polynomial curve represented the measured discharge data best, and was used to estimate discharge from stage data. In order to compute stage data over time, linear relationships were built between observed staff plate readings, to the 15-minute levelogger data. The rating curves were then used to estimate discharge values from stage data to develop annual flows for each creek (Figure 13&14).

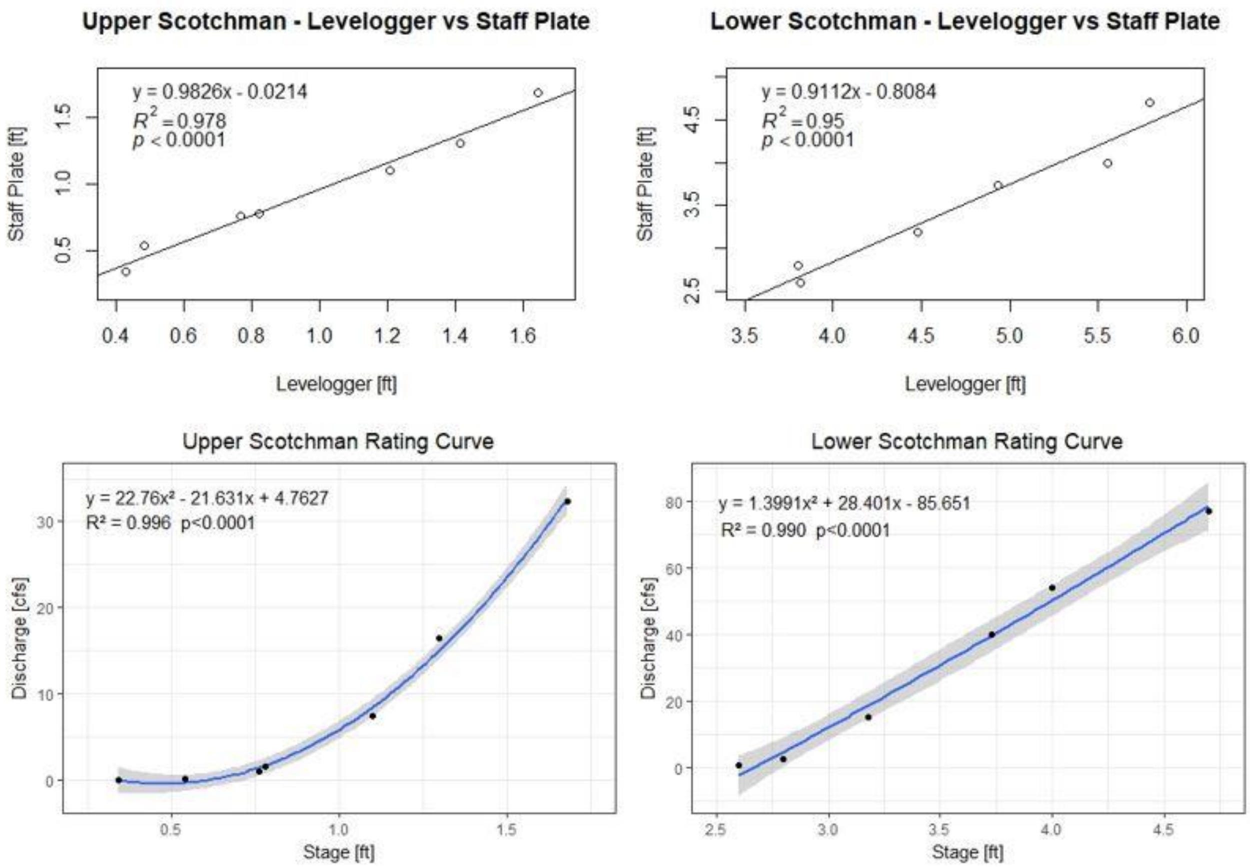
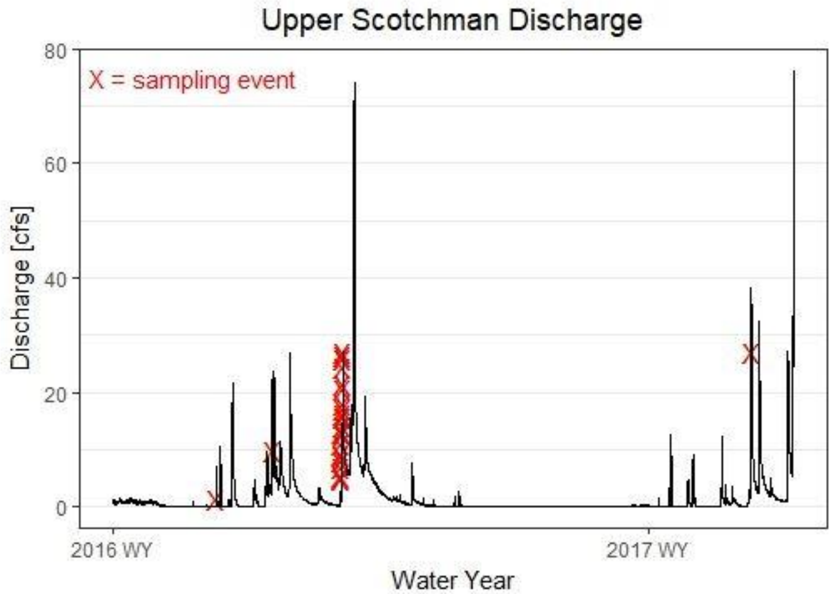


Figure 13. Rating curves and Levelogger vs. Staff Plate relationships for Upper and Lower Scotchman Gaging Locations.



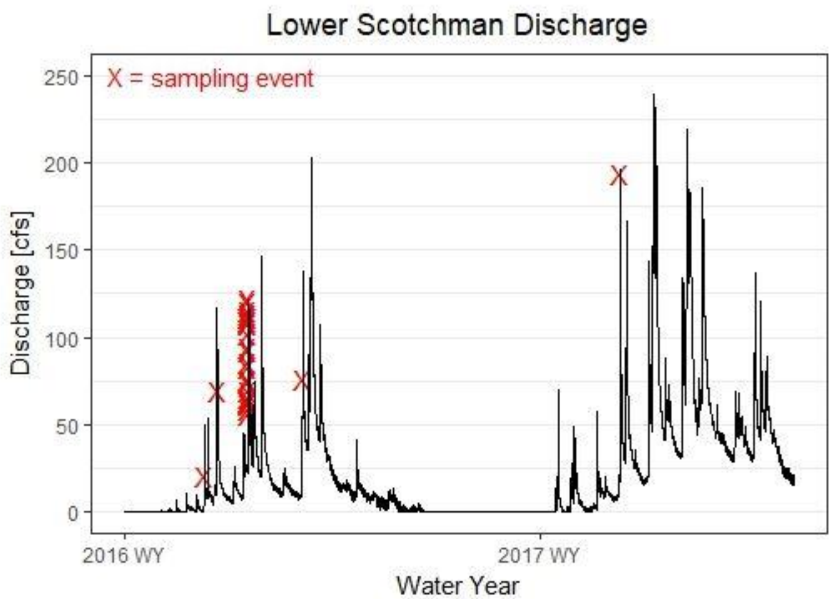


Figure 14. Upper and Lower Scotchman Creek discharge data in the 2016 and 2017 water years. The Upper Scotchman gage data were compromised during January of the 2017 water year due to high flows and was omitted.

Mercury and TSS Sampling

Throughout the Scotchman Creek watershed, 23 samples were collected for mercury and 65 samples were collected for TSS analysis. Monthly water quality data collection from the YSI Professional Plus can be found in Appendix III and online at www.Yubashed.org.

All mercury samples from Red Creek were above the 50 ng/L threshold (Figure 15). Upper Scotchman Creek, just below Red Creek, was above this threshold during the first sampling event and Lower Scotchman Creek, at the base of the watershed, was above this threshold during the final sampling event.

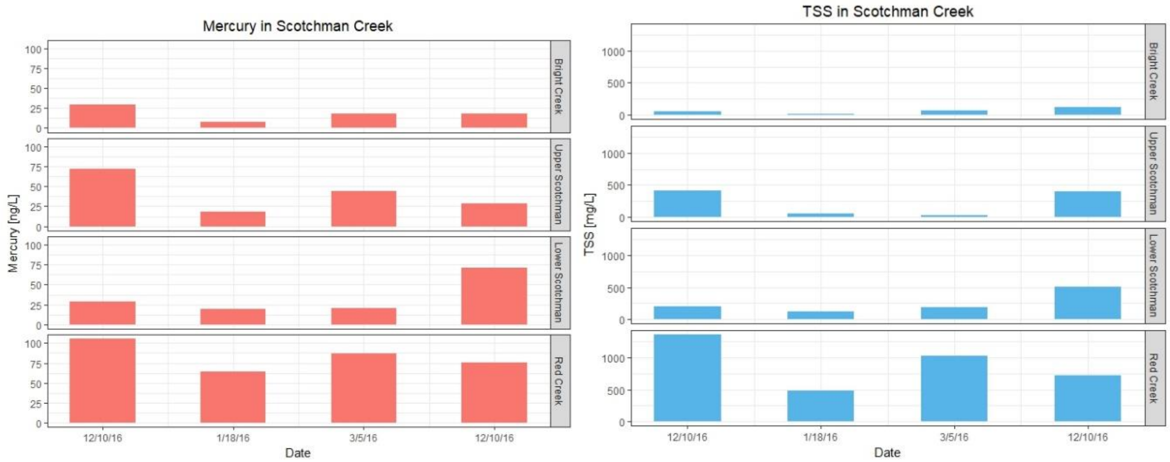


Figure 15. Total mercury with corresponding TSS samples at Upper Scotchman, Lower Scotchman, Red Creek and Bright Creek.

Although Bright Creek was from the outflow of Zeibright Mine, the mercury and sedimentation from this tributary were minimal (Figure 16). Red Creek exceeds the HHC for mercury of 50 ng/L in all sampled storm events, while Bright Creek remained below the 50 ng/L threshold. In addition, Red Creek produced the highest concentrations of mercury on a consistent basis in all sampling locations (Figure 15). On average, Red Creek's TSS concentrations made up 94% of the sum between Red and Bright Creek.

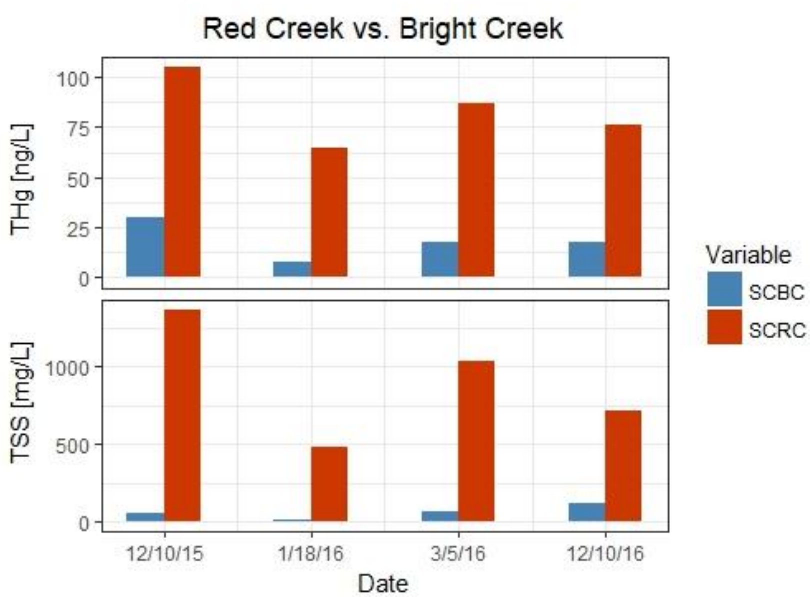


Figure 16. Red Creek (SCRC) vs Bright Creek (SCBC) with associated total mercury and TSS values.

On December 10th, 2016, sampling was conducted at Alpha Diggins from multiple locations within the pit, Alpha Northeast Outlet (ANEO) and Alpha North Outlet (ANO). The sampling consisted of grab samples for total mercury and TSS and are compared to the gage sites (SCG1 and SCG2), Red Creek (SCRC) and Bright Creek (SCBC) that were sampled on the same day (Figure 17).

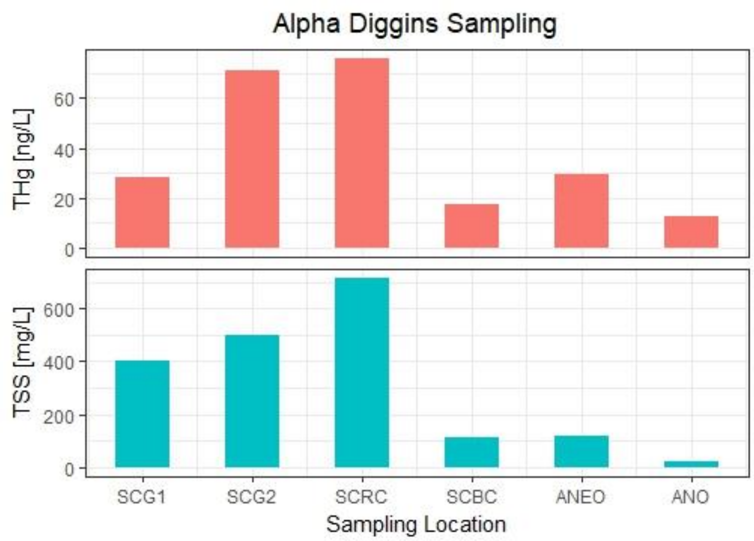


Figure 17. December 10th sampling locations with associated total mercury and TSS values.

The sampling event on December 10th, 2016 contained low concentrations of sediment and mercury in the sampled Alpha Diggins sites. Both mercury samples fell below the 50 ng/L threshold with 29.7 and 12.6 ng/L and TSS values at 117 and 20.4 mg/L collected at Alpha Northeast Outlet (ANEO) and Alpha North Outlet (ANO) respectively.

Mercury Form and TSS Relationship

Throughout all sites in Scotchman Creek, mercury was primarily transported in its particulate bound form (Figure 18). The highest percentage of particulate bound mercury was found in Red Creek at 93%. Dissolved mercury was never greater than 20% in any sample.

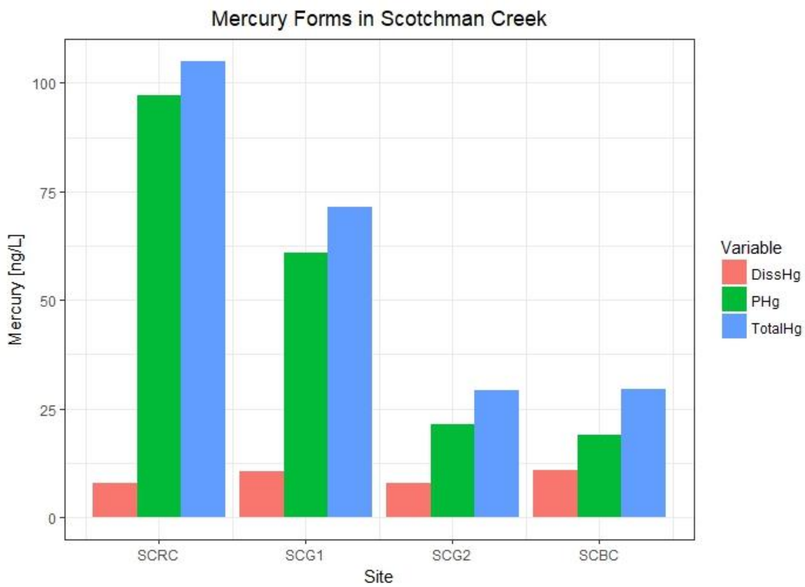


Figure 18. Mercury results from 12/10/2015 grab sampling event including total mercury (blue), dissolved mercury (red), and particulate-bound mercury (green).

Total and particulate-bound mercury correlated well with total suspended sediment at all sampling locations in the Scotchman watershed (Figure 19). Given the low sample size for particulate bound mercury, total mercury had the stronger relationship with TSS (R^2=0.7744, p-value < 0.0001). On an individual site basis, correlations generally increased (SCRC: R^2=0.99; SCBC: R^2= 0.95; SCG2: R^2 = 0.90; SCG1: R^2 = 0.29).

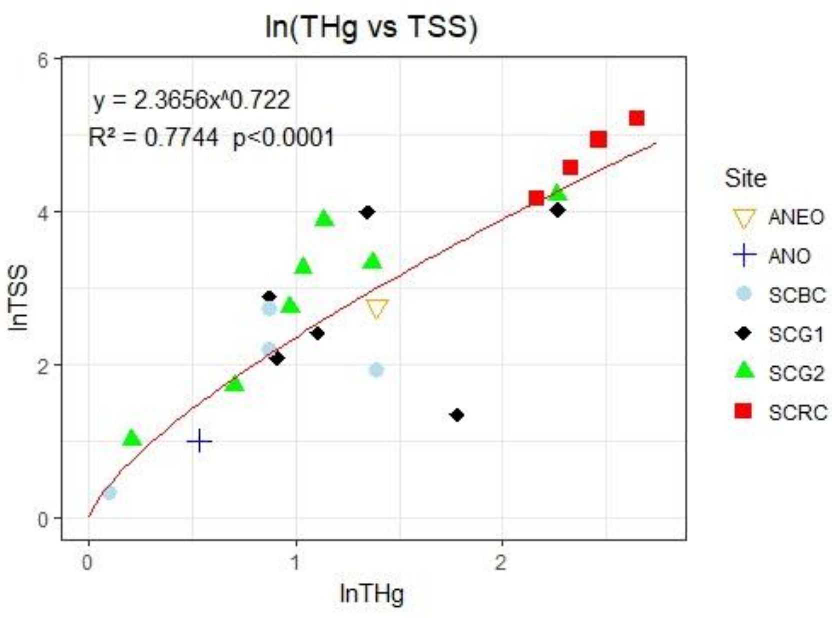


Figure 19. Ln transformed Total mercury vs Ln transformed TSS plotted at all locations including Alpha Northeast Outlet (ANEO), Alpha North Outlet (ANO), Bright Creek (SCBC), Upper Scotchman Gage (SCG1), Lower Scotchman Gage (SCG2) and Red Creek (SCRC).

Annual and Storm Event Loading

The automated ISCO sampler was used during two high flow events on January 17, 2016 and March 5, 2016 at the Upper Scotchman gage. While storm event TSS loads could be generated, annual sediment loads, and therefore mercury loads, for this location were unable to be calculated due to the non-significant correlation between TSS and discharge (Figure 20 and Figure 21).

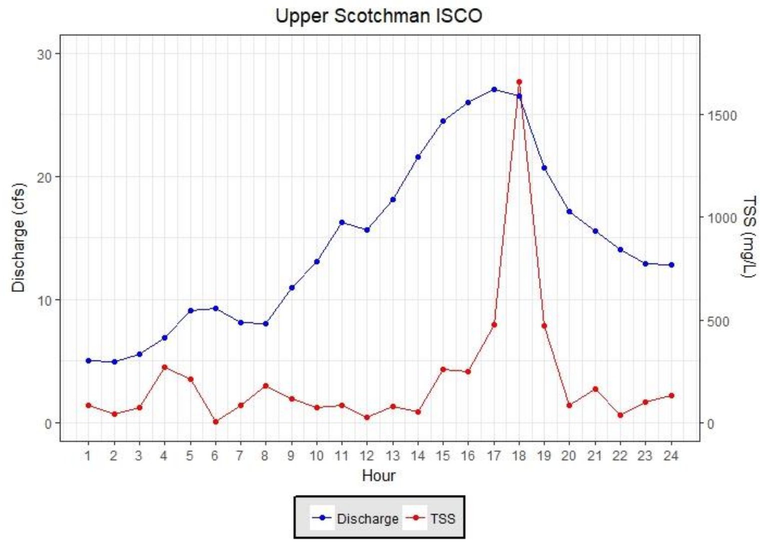


Figure 20. Hourly TSS data and stream discharge data at the Upper Scotchman Gage location during the March 3-6, 2016 storm event.

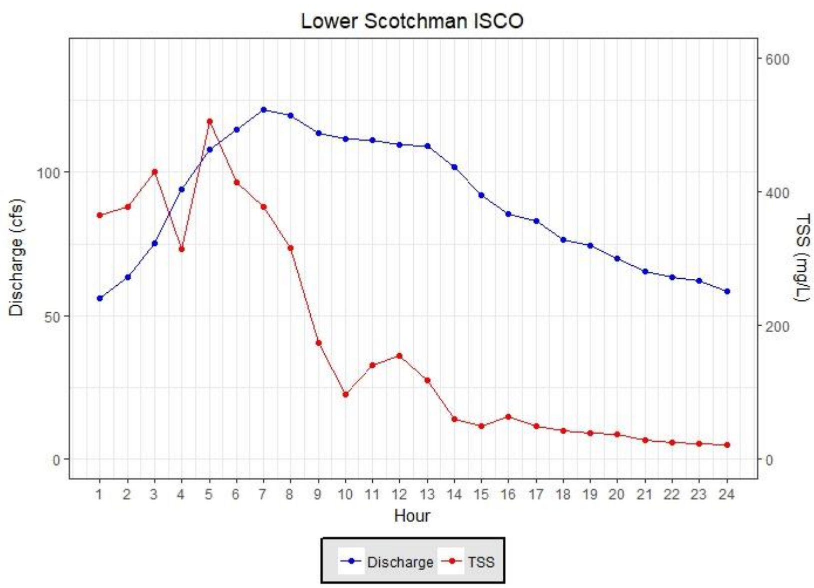


Figure 21. Hourly TSS data and stream discharge data at the Lower Scotchman Gage location during the January 17-18, 2016 storm event.

The next step taken in data analysis was to see whether TSS data collected from the Upper Scotchman Gage could be compared to the data collected at the Lower Scotchman Gage. Using the TSS data collected during the storms of 12/10/15, 1/18/16, 3/5/16 and 12/10/16, suspended load calculations were made with the associated discharge data collected. The data presented a strong relationship between the TSS loads (R2 ~ 0.998; p-value = 0.001), indicating the suspended sediment at each location were strongly correlated to each other (R^2=0.99, p=0.0010).

TSS loads were calculated using the TSS ISCO data and associated discharge values at each location (Figures 20&21). The ISCO data collected during the January 2016 storm at the Lower Scotchman Gage were regressed to predict TSS values at the Upper Scotchman Gage. Similarly, the ISCO data collected during the March 2016 storm event at the Upper Scotchman Gage were used to predict TSS values at the Lower Scotchman Gage.

Since the Upper Scotchman Gage was below the confluence of Red and Bright Creeks, the load percentages shown are from the combination of both creeks. Using the calculation of Upper Scotchman TSS Load divided by the Lower Scotchman TSS Load, the average percent load calculated at the Upper Scotchman Gage was 10%.

Table 3: Load calculations computed from the ISCO TSS and gage discharge data for each gage location by storm. Percent load at the Upper Scotchman Gage is shown as percent load from Red + Bright Creek (% load from RC + BC).

Sample Location	January TSS Load (metric tons)	March TSS Load (metric tons)
Upper Scotchman (SCG1)	4.66	10.27
Lower Scotchman (SCG2)	41.05	91.35
% Load from Red and Bright Creeks	10%	10%

While Red Creek makes up only 4% of the Scotchman watershed area, it is contributing 10% of the load observed at the Lower Scotchman Gage (Table 3). Red Creek is a point source for suspended sediment and mercury contamination.

On December 10th, 2015, the ISCO sampler was set up to pursue an annual loading estimation with turbidity. A peak in flow at ~30 cfs was not indicating a strong relationship with turbidity values (Figure 22). The storm peaked at ~50 cfs 3 hours before the first sample was taken and may have held a closer correlation at that point.

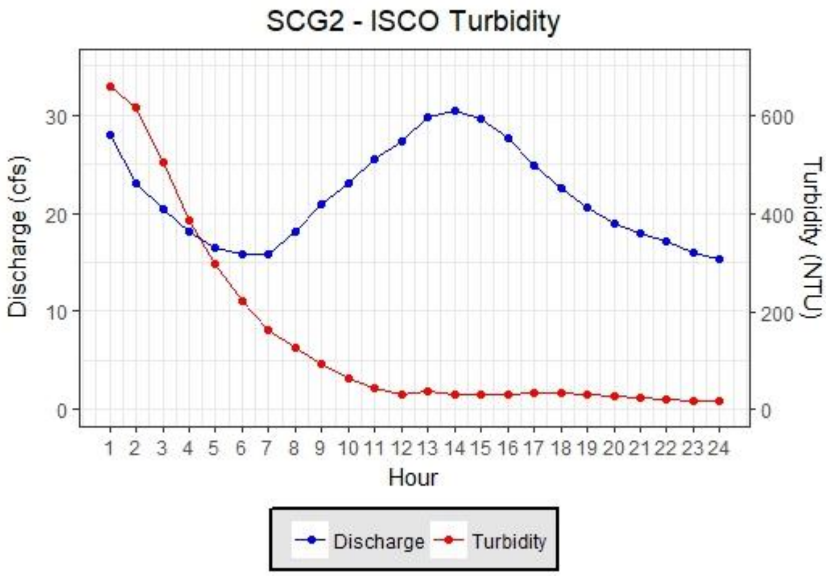


Figure 22. Discharge and Turbidity plotted over a 24-hour period between 12/10/2015-12/11/2015 at SCG2

Discussion

The Scotchman Creek watershed continues to be impacted by historic hydraulic mining activities and a lack of remediation. By assessing the mercury and TSS levels within water flowing directly downstream from Omega Diggins (not remediated) and Alpha Diggins (partial remediation), Omega Diggins contributes more sediment which may correlate to potential higher mercury loading to the watershed. However, additional sampling would be required to determine the actual contamination level and loading of sediments and mercury from Omega and Alpha Diggins.

The results of this study highlight the importance of remediating legacy hydraulic mines in order to protect the Yuba River and downstream watersheds. Locally, contaminated mine waste degrades habitat for aquatic species, through increased sedimentation and accumulation of heavy metals. On a watershed scale, the cumulative impact of many smaller tributaries contributing mine waste places the entire watershed at risk and has resulted in large scale issues, such as contaminated fish stocks that impact the fishing industry and contaminated sediment that reduces the ability for dams to store water.

Identifying direct sources of the contaminated sediment downstream and applying erosion control techniques is beneficial to reduce the impact to downstream waterways. Point sources are difficult to identify and quantify due to private property restrictions. Our investigation of contaminated waterways such as Red Creek could be expanded to include more stream segments to give us a better understanding of the sources of contamination within the Scotchman Creek watershed. In future studies, the sediments should be tested for mercury, iron, lead, arsenic, copper, nickel and zinc.

Every year, contaminated sediment enters the South Yuba River as abandoned mines continue to erode. At present, the Total Maximum Daily Load (TMDL) determination for the Yuba River is not completed, it is unknown if the loads exhibited from Scotchman Creek fall within that TMDL. However, this tributary is at risk given that many of the samples collected during this study exceeded the federal and state recommended criterion for protection of human health and aquatic life (50 ng/L as total Hg in unfiltered water) during high streamflow conditions.

Attempts to quantify annual mercury and sediment loads were challenging. This is potentially due to the fact that there are multiple sources of mercury and sediment in the watershed, including both Alpha and Omega Diggins and deposited sediments on the floodplain. Runoff and turbidity values can be dependent on the intensity and locale of a storm event; if the storm does not hit an exposed slope in the watershed, turbidity values may not increase predictably with streamflow. In addition, hillside sloughing can be triggered by both small and large rain events, resulting in episodic turbidity plumes that are non-linear in relation to the amount of rainfall or runoff occurring during a single storm event (Wu 2018).

Our results highlight the dominance of particulate-bound mercury rather than dissolved mercury at Omega Diggins. Controlling mercury at its source, before it methylates and incorporates into the food web (Slotten et al. 1995) is a key element to protecting the health of an entire watershed. The mercury within mine sites is bound to silt and clay particles and can be managed by decreasing the erosive potential within an abandoned mine.

The primary finding of this assessment is that, based on samples collected at Red Creek, Omega Diggins is a priority for remediation activities to decrease the water quality impacts from sediment and mercury in the Yuba River watershed. The recommended management method is the retention of storm water discharge within Omega Diggins so that it can settle and be put through a filtration process. Additionally, check dams and other erosion control methods should be used within the Red Creek watershed to encourage settling of mercury contaminated sediments. Revegetation techniques used at Alpha Diggins could also aid in the long-term remediation of Omega Diggins due to their ability to increase both soil cover and surface roughness.

Assessing remediation success is a key component to any remediation effort. Establishing clear remediation goals and objectives followed by rigorous monitoring protocols will allow managers to better understand whether the remediation techniques being employed are working. With hundreds of abandoned, unremediated mines littered across the Sierra Nevada we must begin to not only complete remediation projects but show how and why the efforts are working.

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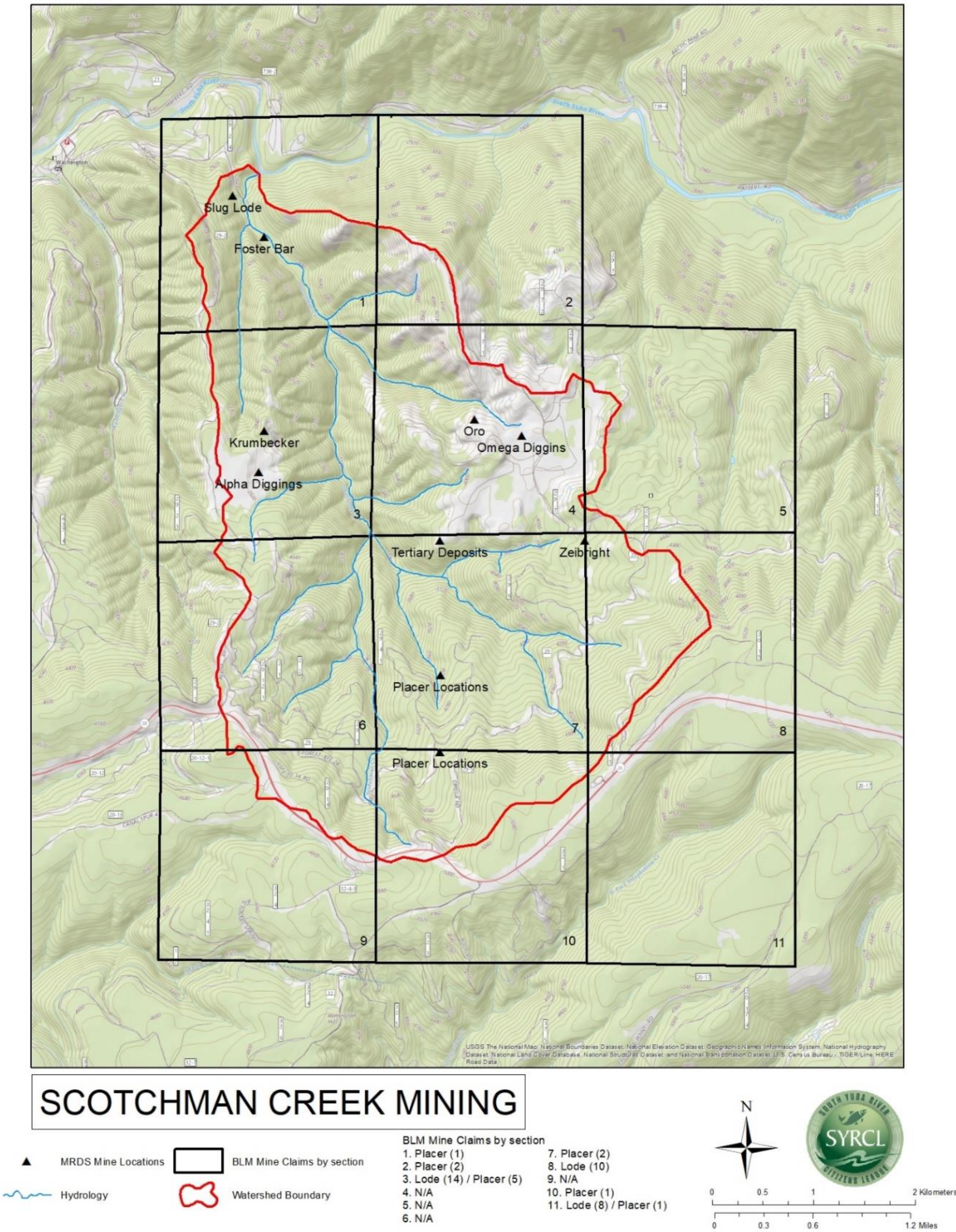
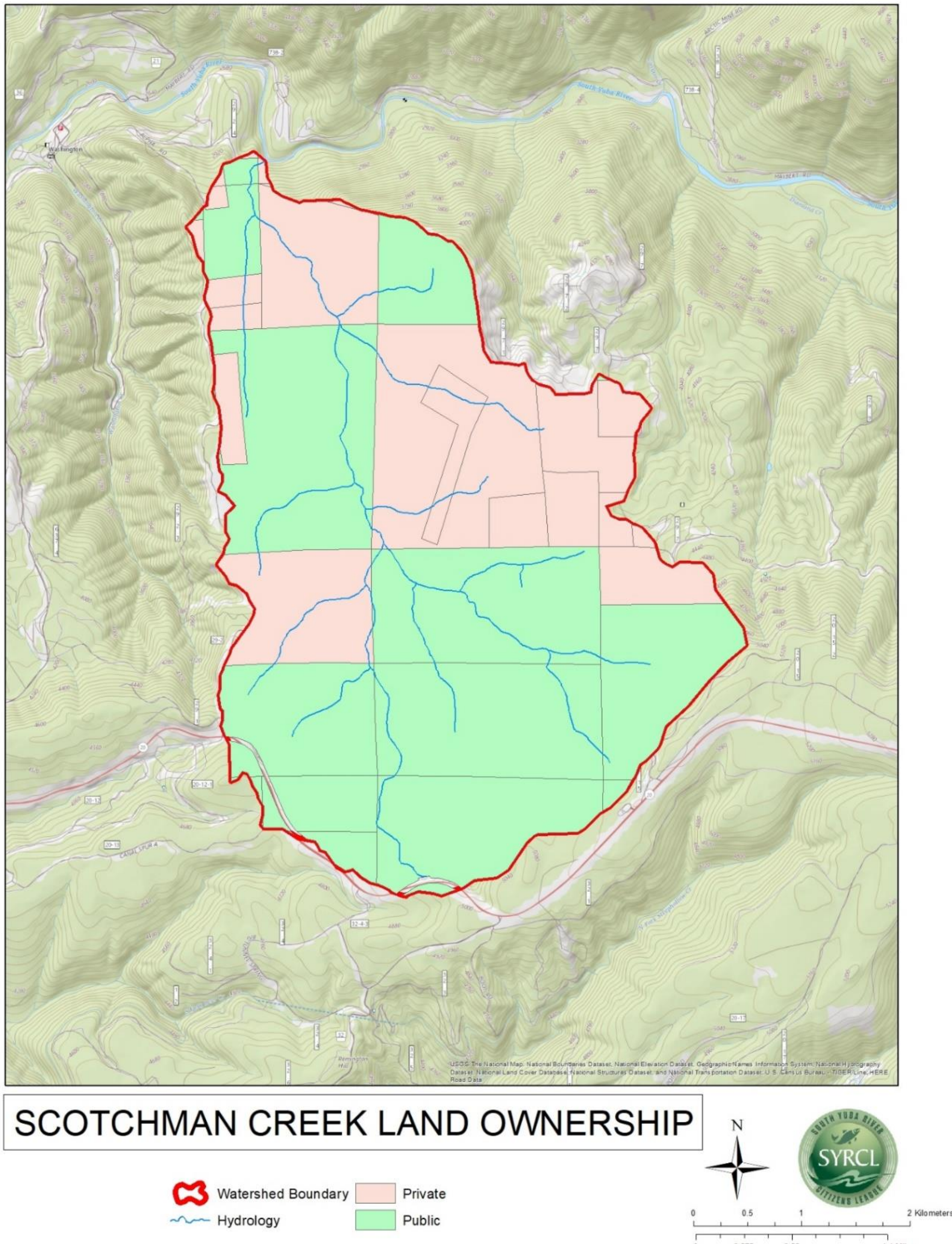
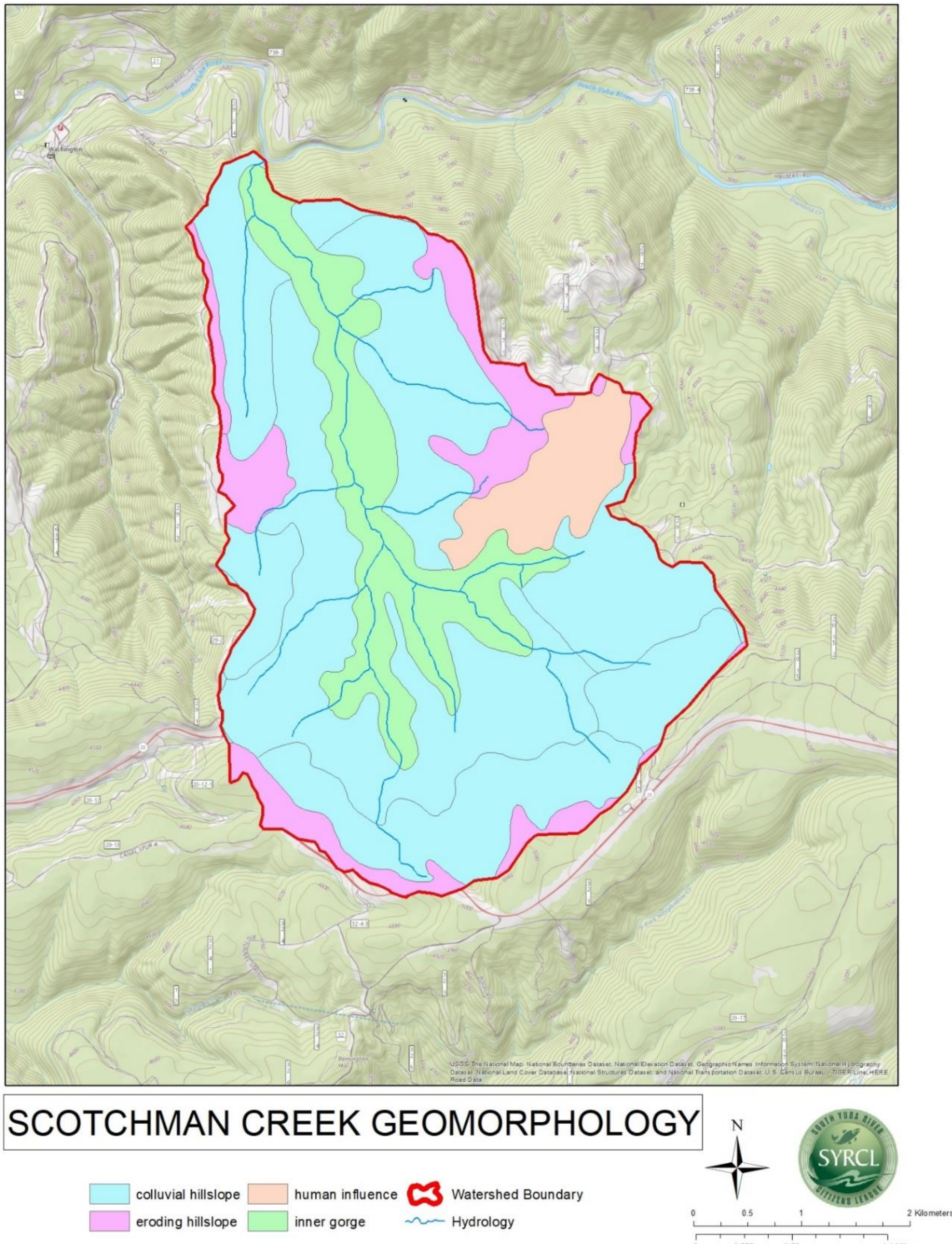
Appendix I: Maps



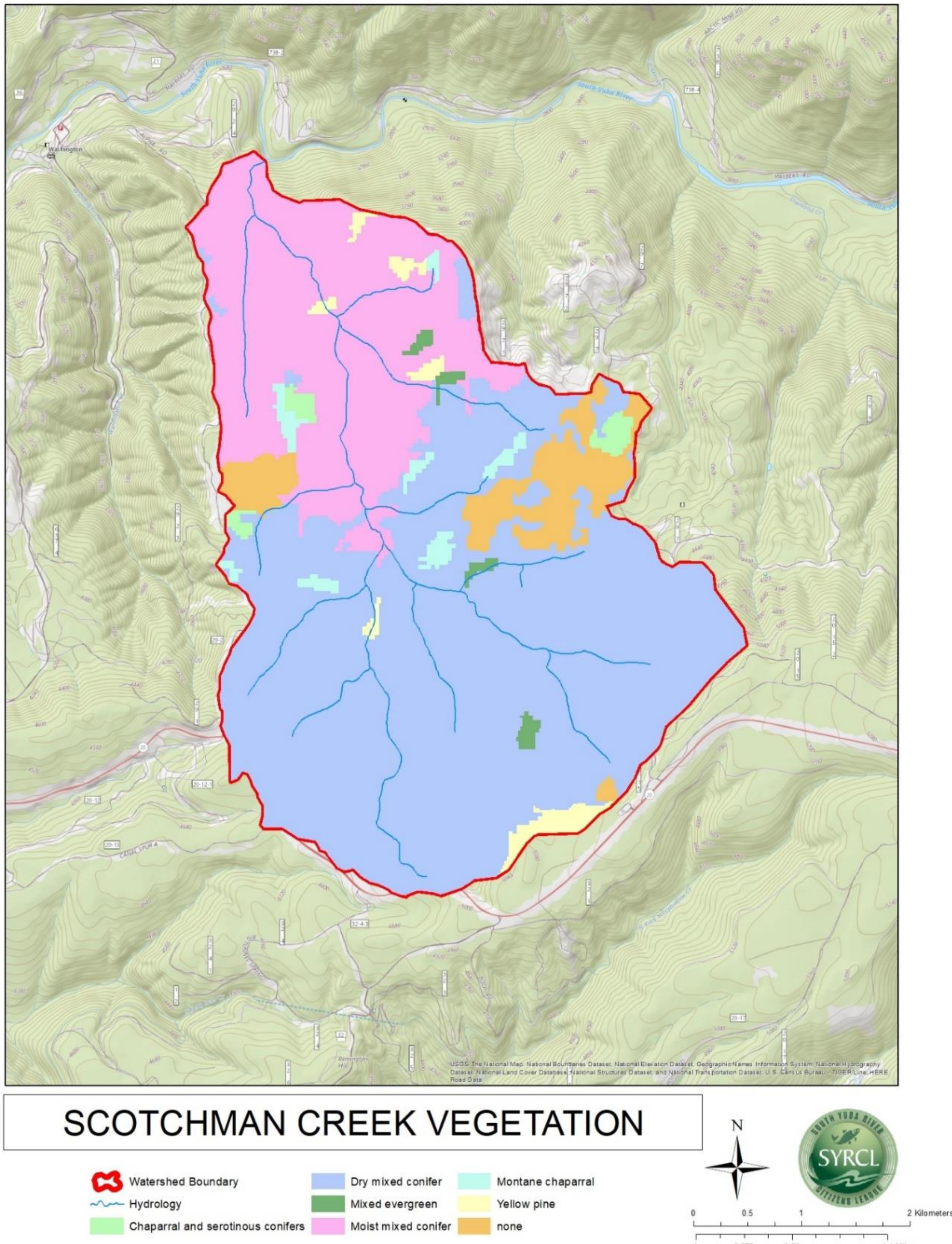
**Data Source- Mineral Locations: MRDS / Land Plots: CA BLM / # of Claims: BLM LR2000*



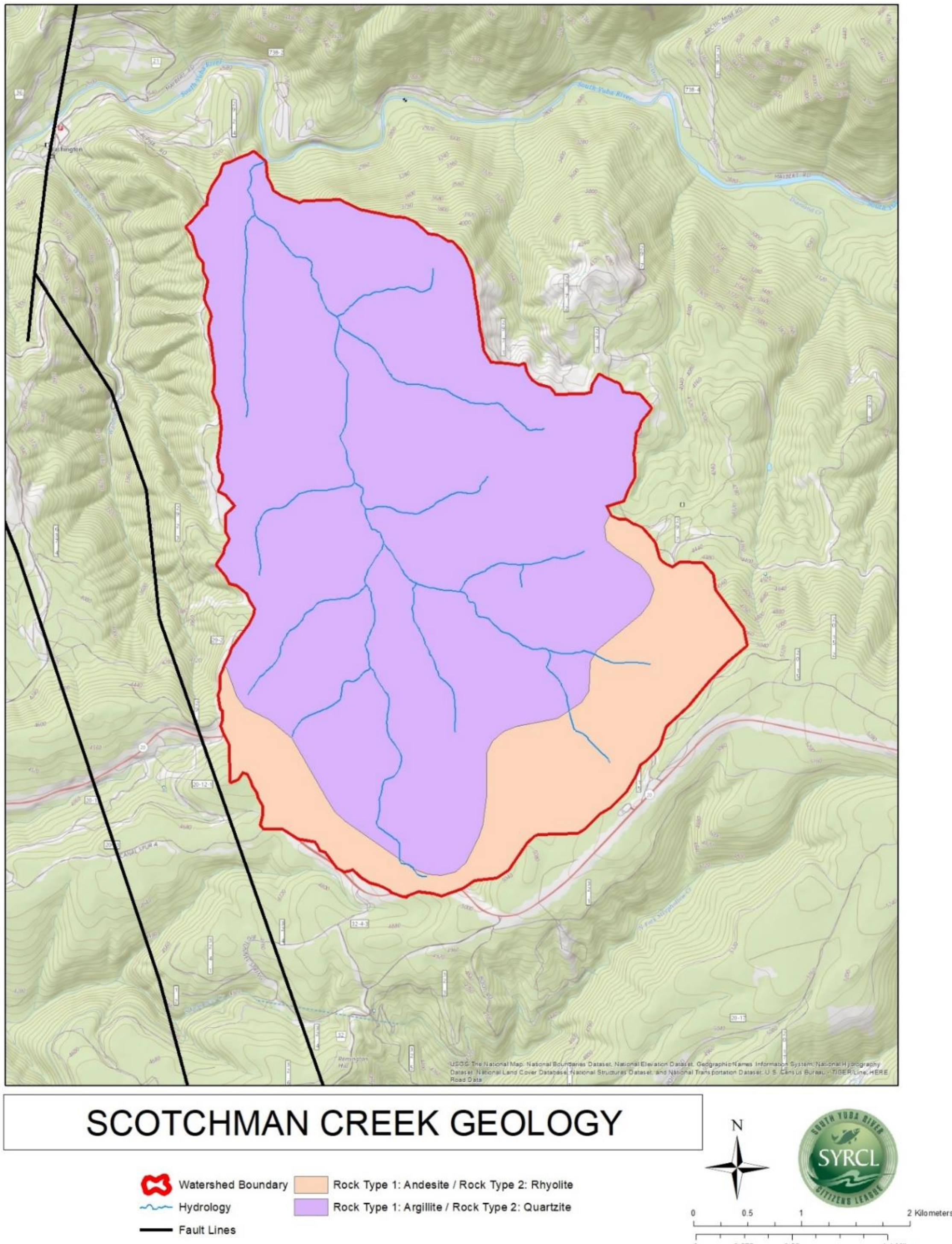
**Data Source- Nevada County Parcel Map*



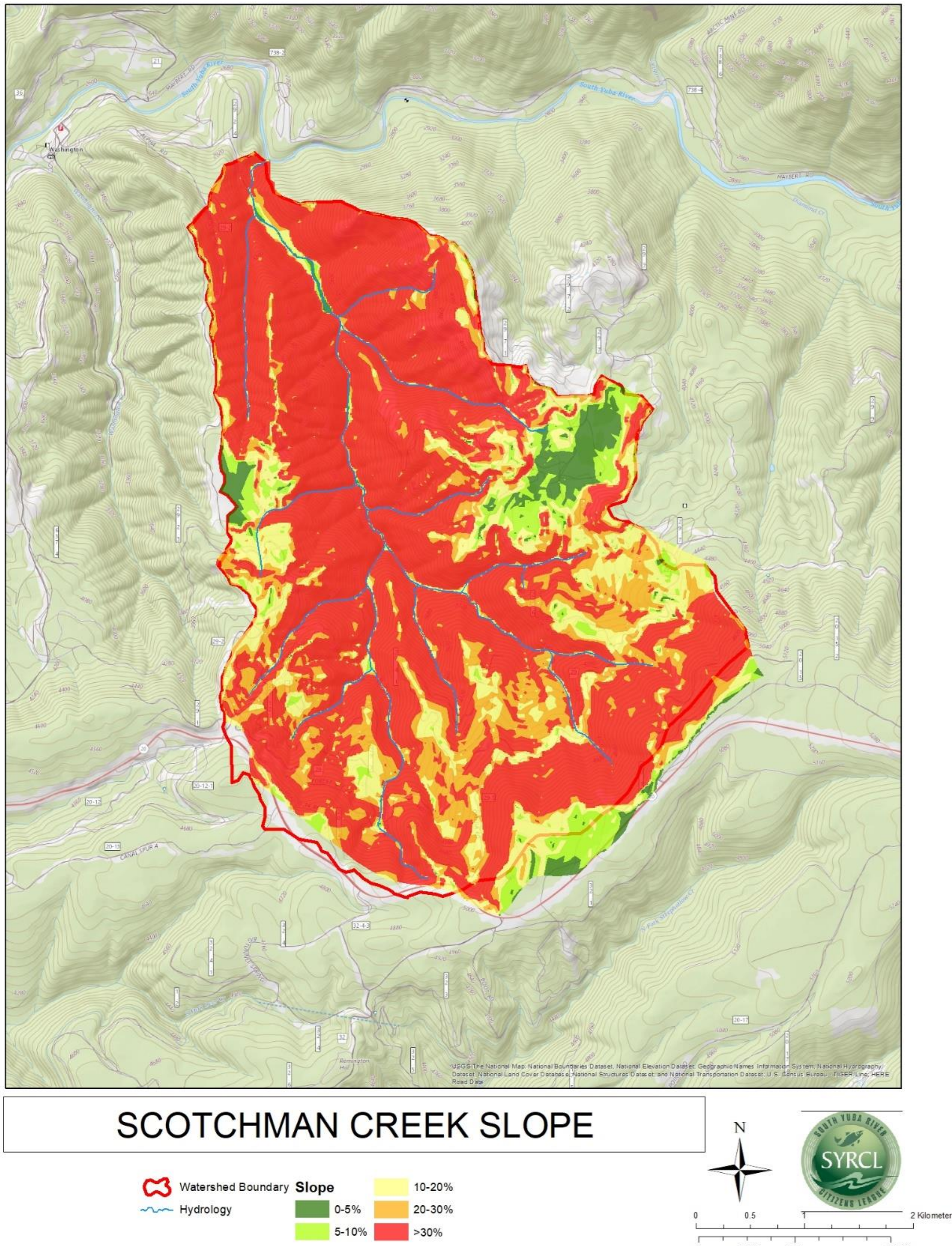
Data Source- Tahoe National Forest GIS Library



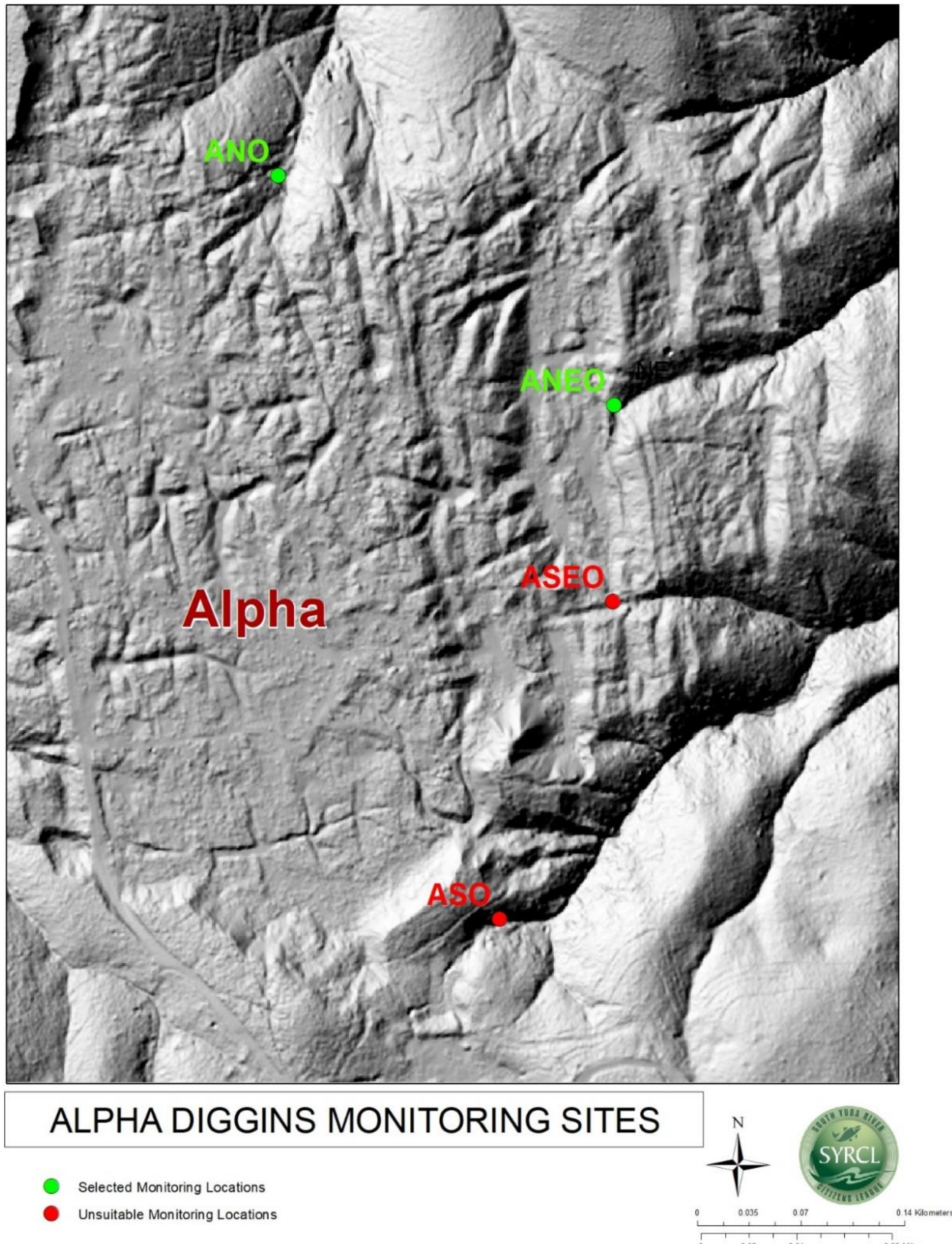
**Data Source: CA Fire Return Interval Departure (FRID) Map Metadata*



**Data Source- CA State Geologic Map Database*



Data Source- USGS 3D Elevation Program


ANO
ANEO
ASEO
Alpha
ASO
ALPHA DIGGINS MONITORING SITES
N
SYRCL
Selected Monitoring Locations
Unsuitable Monitoring Locations
0 0.035 0.07 0.14 Kilometers
0 0.02 0.04 0.08 Miles

Appendix II: Stakeholder Survey and Responses

Q1: How long have you lived in the watershed for?

Q2: What, if any, changes have you seen through time (i.e. Wildlife, plants, human population growth, NID diversions or water flow/clarity)?

Q3: What do you know about the 2008 fires?

Q4: What are your values in the watershed (i.e. wildlife, vegetation, community, creeks/rivers, clean water or stewardship)?

Q5: What are your concerns regarding past, present, and future conditions of the Scotchman Creek watershed?

Q6: What historic information can you share with me about the Scotchman Creek Watershed, including the nearby vicinity of the watershed?

Q7: Do you have any neighbors that would be willing to share their insight with me? (Provide contact info if possible or share mine with them)

Q8: What do you know about the Omega Diggins?

Stakeholder Survey Responses

Q1: How long have you lived in the watershed for?

Interviewee 1: Part time 1951 / Full time 1970 full time.
Interviewee 2: We have lived there for 5 years part time.
Non-resident Interviewee 3: We don't live in the Scotchman Creek watershed. Our cabin is a shared summer home on the Yuba, upstream of Scotchman Creek. We've had it since 1992.
Interviewee 4: Born here in 1937 and spent all my summers here until the age of 12. Our house was originally a mill office and my great-aunt's uncle bought it. He went to Scotchman Falls in early 1921, spent 20 years in the Sierra Outdoors Sportsmen Club and now owns a ton of acreage to the bridge.
Non-resident Interviewee 5: Probably started working there in 1996. I took the lead for the Forest Service in conducting some watershed restoration work at Alpha Diggings to improve the infiltration of precipitation and reduce the runoff of storm water. The project consisted of constructing engineering controls and scarifying compacted areas, adding fertilizers, organic material and seeding to establish native vegetation in the barren soils that were altered by hydraulic mining.
Interviewee 6: I've lived in the watershed for 5 years.
Interviewee 7: I've worked for the fire department since 1988 and used to live at Sky Ranch until 1999. Been visiting the area since 1983 but moved to Washington in 1985. Supported myself as a

‘prospector’ from 1988-1998 until the price of gold went down, then got a job with the fire department, but back into mining lately.
Interviewee 8: I’ve lived in the watershed for 19 years.
Interviewee 9: I’ve worked on the Tahoe National Forest for about 25 years.
Interviewee 10: First visited creek in 1966 and bought a house near Sky Ranch, ½ mile from the creek in 1980. Been visiting a lot since then.
Interviewee 11: Lived in the watershed for 12 years.
Interviewee 12: Lived in the watershed for 12 years.
Interviewee 13: Lived in the watershed for 15 years.

Q2: What, if any, changes have you seen through time (i.e. Wildlife, plants, human population growth, NID diversions or water flow/clarity)?

Interviewee 1: Crows in the area, not here prior to 2000 that I saw. Some other higher altitude birds are now here. We now have otters in this section of the river, I suspect they were here previously, but I believe they move around following the food. We also now have crawdads. Did not have prior to mid-80s, hence the otters. (I believe they always were on the South Fork, but not in this direct area until the crawdads. More people in the area now as opposed to many years ago. Nothing really about PG&E, except their rates are too high.
Interviewee 2: I have seen the creek change every year. Probably the most significant change was this year with the direction of the water.
Non-resident Interviewee 3: Every year has been different. Some years heavy with brown moss, others not. Flow levels and water temperatures varying from year to year. The most dramatic changes, of course, occurred during and after the '97 flood and during and after the fires of 2008 fires: vegetation altered according to water level highs, and of course detritus affected what was in the water as well as what remained on the banks. The year following the closure of the campground we had a great blue heron, and the following year a family of wood ducks. Not any appreciable growth of human population.
Interviewee 4: In 1940, there was still hydraulic mining at Alpha and Omega Diggins. In late 1940, the log dam was built and I couldn’t swim because of the mud. In 1947, all the fish were dead and Yuba-Marysville were complaining about the mud. Fewer people in Washington since the mill shut down.
Non-resident Interviewee 5: There were two major impacts to the watershed that I have observed. One is the Scotchman Fire of June 2008. A good portion of the eastern watershed including part of Omega Diggings hydraulic mine was impacted by the fire. The other is the rain on snow event of late December 1996. This flood scoured out much of the riparian vegetation in the lower watershed just above Scotchman Dam. The watershed appears to be recovering from both of these events.
Interviewee 6: Have seen no changes besides the forest fire in the area a few years back.
Interviewee 7: Not much, only that NID and PGE are up for FERC relicensing. There has been a change of minimum lot acreage because of septic. Regarding population, the town of Washington is surrounded by TNF property with only 10 open parcels unless TNF sells some.
Interviewee 8: When we first started coming up no one was around. The water seems the same.
Interviewee 9: I’ve observed many changes: increased numbers of people living in the area; increased numbers of people using the National Forest System lands; increased demand for

opportunities for motorized recreation and mountain biking; increases in the kinds of weeds that occur in the watershed; increased spread of weeds that already existed in the watershed; decreased clear cutting on National Forest System lands; improved grazing practices; increased collaboration with the Forest Service and outside groups; an increase in the number of ravens and crows; an increase in fungal diseases especially on maples; more shaded fuel breaks along roads; increased use of specialized motorized OHV in remote areas and increased erosion from those trails since the trails were not designed for their use (for example uni-mogs and rock crawlers); earlier blooming of some plant species; and later snows/hail storms in the spring.

Interviewee 10: I've noticed a shifting in the streambed from the 60's, above the waterfalls- along the gravels. In 1919, the old debris dam consisting of heavy rocks bound by gauged wire washed out, releasing the eroding material built up behind the dam. The habitat has finally stabilized in the last 10-15 years. Lots of alders coming up, of course of creek is different now but still stabilizing. Used to be bare from vegetation, but finally some pioneer species are germinating. The yellow clay previously left over the debris dam is washing out. The gravels have stabilized the area, but now it's more Omega side that's destabilized, creating gullies.

Interviewee 11: Heavy erosion, steep slopes consisting of all clay- no top-soil. Possible contamination due to historical mining from Alpha and Omega mines.

Interviewee 12: The river water is too warm and too low.

Interviewee 13: It has been a whole lot busier with people in the canyon. People come down with their motorcycles and quads racing all around the canyon.

Q3: What do you know about the 2008 fires?

Interviewee 1: The fires were devastating, and caused many folks living in the forest to lose their insurance coverage.

Interviewee 2: I watched the fires.

Non-resident Interviewee 3: Saw them start! The deck of our cabin was used as a staging area during the fire. It was frightening at the time, but undoubtedly a blessing in disguise--a needed clearing of the underbrush.

Interviewee 4: There were seven fires from lightning in the Scotchman Creek Watershed. Good that the understory got burned. Didn't see much change to the creek after the fire. The water used to be gray in color like Poorman Creek between 1940-1960. Now mercury plagues the area.

Non-resident Interviewee 5: A good portion of the eastern watershed including part of Omega Diggings hydraulic mine was impacted by the fire.

Interviewee 6: It burned uncontrolled for 5 days until Firefighters arrived.

Interviewee 7: 9 fires- Alpha ¼ acre. Omega- 4 acres. Scotchman fire- 1,320 acres. 2 fires at Deer Creek under 2 acres. Gaston with 3 acres burned. And Falls fire + Clear fire= 2,520 acres together.

Interviewee 8: Only that we couldn't come up for a month.

Interviewee 9: No response

Interviewee 10: Could visually see 5 fires with clouds of smoke, starting small, but couldn't be dealt with for days due to being understaffed with state-wide fires going on. The fires were on the north side of the ridge. Fire lines were set up, so fires wouldn't cross the Yuba. Overall, a healthy understory fire without any homes being damaged reducing the fuel load besides the south side of Scotchman where it was incinerated by a crown fire.

Interviewee 11: No response

Interviewee 12: No response
Interviewee 13: No response

Q4: What are your values in the watershed (i.e. wildlife, vegetation, community, creeks/rivers, clean water or stewardship)?

Interviewee 1: The whole experience of living in the South Yuba Watershed appeals to me. If I had to choose, I guess it would be the privacy, quietness and beauty it provides. Every day is a new gift. I know these are not good ones, but important to me. I have always loved Scotchman Creek and wore out many a swim suits on the rock slides. I find it beautiful the way it is. I find Alpha diggings to be interesting and tells a story during the mining days. I have found fossilized water plants in the diggings and other un-identified fossils. I know the layer of silt clouds Scotchman Creek during heavy rains, but short of capping multiple acres with an impervious material, I don't know how this can be stopped. The silt is a natural layer deposited as ash during the territory period. Revegetation is a great idea, but it would have to be fast growing ground cover that can manage without much care and water. It gets hotter than heck up there and except for a couple of isolated springs, there is limited surface water. Alpha Diggins used to be one of my favorite playgrounds.

Interviewee 2: My son and I like to play and hike in the creek. We also look for animals, insects and identify flowers, footprints and scat.

Non-resident Interviewee 3: All of the above. I do think it's a shame that there can't be a public picnic area with a ranger on duty.

Interviewee 4: All of the natural beauty and dogwood trees.

Non-resident Interviewee 5: All of these, with the exception of the private lands at Omega Diggings, the watershed is relatively undeveloped compared to other watersheds. The lower watershed appears to be breeding habitat for foothill yellow-legged frogs. There are no fish in the stream above the dam to prey on and compete with the frog population.

Interviewee 6: Nice place to walk.

Interviewee 7: The Springs that come from Burlington Ridge are all volcanic capped and seeping. Gold mining brought me here and historical artifacts. The state of CA has a prospector coalition with 3,500 dredgers involved.

Interviewee 8: Have a nice, clean place to visit.

Interviewee 9: I think the American people are extremely fortunate to have National Forest lands near where they live. I value those lands and the wildlife and plants that use those lands to live. The clean water that comes from Forested lands, the recreational opportunities, and the diversity of plant communities are all important to me. I also value stewardship of those lands both professionally and personally.

Interviewee 10: I came here in the 60's because the South Yuba River was the only Sierra river warm enough to swim in. So I decided to buy some land on the river which happened to be in the Scotchman Creek Watershed. My property was once a ranch/farm, then subdivided it in the 1970's (120 acres subdivided to 10 acre parcels). My kids rode on air mattresses down the South Yuba River and then as they got older they resorted to riding 4x4's and shooting guns. I value my freedom of the area. Now since my kids are grown and gone, I value my quiet time in the forest.

Interviewee 11: The Yuba River in all its beauty.

Interviewee 12: No response

Interviewee 13: A clean Yuba River.

Q5: What are your concerns regarding past, present, and future conditions of the Scotchman Creek Watershed?

Interviewee 1: No response

Interviewee 2: We want to keep going up the creek. It is nice and cool there on the hot days.

Non-resident Interviewee 3: It would be a good thing to get access to the Omega, ascertain what's leaking/eroding into the creek and prevent future contamination.

Interviewee 4: It has been 20+ years since rainbow and brown trout were stocked in the Yuba. Tahoe National Forest has logged the watershed ten times. The continued mining practices of [redacted]. Concerned with the old Scotchman Debris Dam since it was built without proper engineering. If the dam fails, the mercury and sediment can further pollute the South Yuba River.

Non-resident Interviewee 5: Due to its relatively undeveloped nature, the Scotchman Creek watershed has been recovering from the hydraulic mining of the 19th century and barring any catastrophic perturbations. The watershed will continue to provide good habitat for wildlife into the future.

Interviewee 6: Human traffic. Mining Operations.

Interviewee 7: I feel restoration techniques could cause more harm than good by releasing methylmercury. I believe the sediment ponds will eventually fill up and create a need for constant dredging. Additionally, the gravels which cover a 9/10 mile stretch above Scotchman Creek Falls should be removed due to contamination. I am concerned about the residuals from Alpha and Omega Diggins and if Omega mine is still running as private property. I would be disappointed if California decides to outlaw suction dredging for good.

Interviewee 8: We don't go up to Scotchman Creek. Years ago we were up there before [redacted] tore it up.

Interviewee 9: The mining and railroad eras left conditions that are hard to manage. We are now dealing with abandoned mineland issues – especially in regard to water quality. The checkerboard ownership pattern of the lands within the watershed also makes management difficult – especially for species that migrate. One of the biggest concerns I have for the watershed is the introduction and/or spread of weeds. I also see too many fuels on the landscape putting the watershed at risk from a large wildfire. The lack of ground water mapping is a concern due to the number of underground mining tunnels that run water, the lack of information about ground water, and the connection of ground water resources. Increased development points to the need for more water and many of the small communities in the area do not have enough water resources. For example, the town of Washington has a very inadequate water system. Ground water resources are also very important to specific plant communities such as fens. I'm concerned about dumping on National Forest System lands. Illegal dumping frequently increases during poor economic times. Abandoned dumps can be as toxic as abandoned mine lands. I'm concerned about the high ozone levels within the watershed and other air pollutants and their effects on people and various plant communities. I'm concerned about pollinators especially given recent declines.

Interviewee 10: Not really any since my property is not heavily used. But he's sympathetic other neighbors' concerns over the heavy use and vandalism below Scotchman Falls. Used to enjoy camping and recreating at the old Kehler Campground, but is now bummed of its closure.

Interviewee 11: Since the river is advertised now because it is Wild and Scenic there are a whole lot of visitors who do not have much awareness and leave their trash on the roads and on the banks of the river. Additionally, visitors are rather noisy than quiet. Visitors also trespass willingly and aren't very respectful.
Interviewee 12: Seems there are more people coming here making trouble.
Interviewee 13: I would like to see the river clean, clear and pristine rather than yellow and polluted by the diggins. The runoff sure changes the color of the water when it rains.

Q6: What historic information can you share with me about the Scotchman Creek Watershed, including the nearby vicinity of the watershed?
Interviewee 1: No response
Interviewee 2: I don't know of any.
Non-resident Interviewee 3: The whole area was turned upside down by eager miners once upon a time. Would suggest you check out the Jolly Boys Mine sometime--if you can find a vehicle that will take you there.
Interviewee 4: No response
Non-resident Interviewee 5: I did a little research on the history, geologic and hydrologic setting and wrote up my findings in a draft report on the Scotchman Debris Dam.
Interviewee 6: I do not know much history, except there is evidence of old mining operations around the creek. They look old, almost 100 years old maybe.
Interviewee 7: No response
Interviewee 8: No response
Interviewee 9: Historic information about the Scotchman Creek Watershed is summarized in the Forest Service watershed assessment for the South Yuba River.
Interviewee 10: Alpha & Omega mines were both hydraulically mined from 1852-1884, then chose to continue mining and built debris dams to reduce negative impacts to Marysville. The area is a slot canyon which makes it easy to dam. Two levels of the dam were built, first filled up so they built on top of it. Then that filled up, so the 3rd one was built consisting of bound rocks until it washed out. Then the log dam was built upstream from the falls, to hold the remaining debris, once it was filled, the mining ended. The log dam began to fail last year/year before allowing rocks/gravels/sediment to escape. Englebright dam was built to catch all remaining debris from all upstream mining. The bank has been washed out due to the dams and recently as the 3rd rock dam blew out, residents may feel concerned about the vulnerability from the remaining Scotchman Debris Dam.
Interviewee 11: No response
Interviewee 12: No response
Interviewee 13: No response

Q7: Do you have any neighbors that would be willing to share their insight with me? (Provide contact info if possible or share mine with them)
Interviewee 1: No response
Interviewee 2: No response
Non-resident Interviewee 3: No response

Interviewee 4: No response
Non-resident Interviewee 5: I can't think of any off hand.
Interviewee 6: Nope, I think you have all the people that live nearby, not too many.
Interviewee 7: No response
Interviewee 8: No response
Interviewee 9: Our district archeologist, Bill Slater, may have information that is useful to you. Contact: [redacted].
Interviewee 10: [redacted], Lady that owns [redacted] who owns a campground across the River, and [redacted].
Interviewee 11: No response
Interviewee 12: No response
Interviewee 13: No response

Q8: What do you know about the Omega Diggins?
Interviewee 1: No response
Interviewee 2: I haven't been there.
Non-resident Interviewee 3: No response
Interviewee 4: No response
Non-resident Interviewee 5: I do not have any information on the current management of the private lands at Omega. As far as I know, Omega diggings is an abandoned hydraulic mine.
Interviewee 6: Not much, I know it's just above the creek. Have never visited the place, but want to when I have time.
Interviewee 7: The main drainage of Omega is called "Missouri Canyon". Department of Fish and Game used to hire professional dredgers to stir up the river bottom for spawning ground, otherwise it packs down without the natural flood regimes in place due to the dam.
Interviewee 8: We visited there a couple of times. The town is deserted.
Interviewee 9: I'll refer you to the mining and historic professionals. (i.e. Rick and Bill at TNF)
Interviewee 10: Only that the fires hit the Omega Township- houses and cabins.
Interviewee 11: No response
Interviewee 12: The pollution from Omega Diggins is a major problem and a disgrace. SYRCL should give all their information to the state and get this problem solved.
Interviewee 13: No response

Appendix III: Water Quality Data

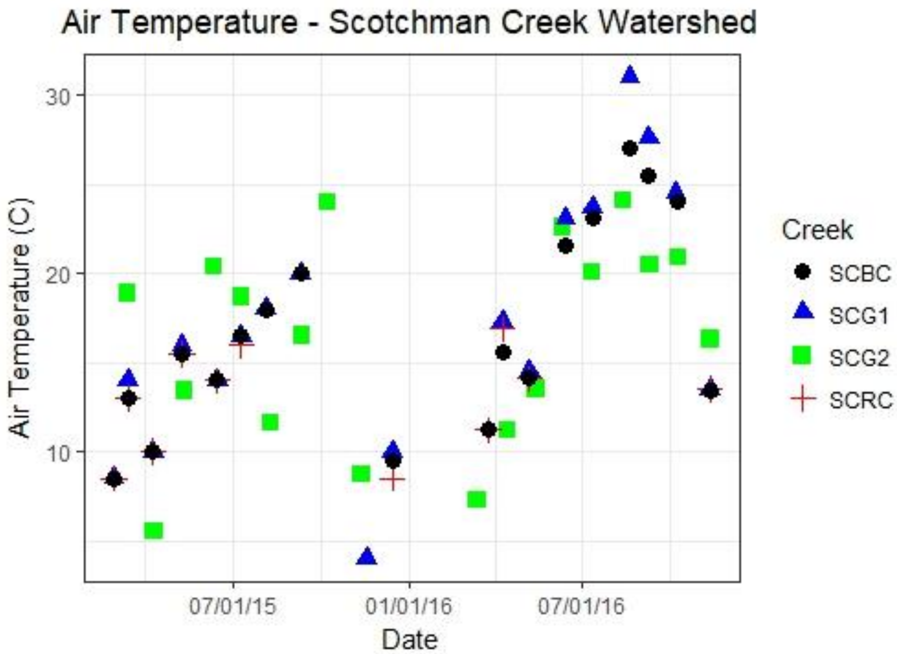


Figure 24: Monthly air temperature plotted at Bright Creek (SCBC), Upper Scotchman Gage (SCG1), Lower Scotchman Gage (SCG2) and Red Creek (SCRC) sampling sites.

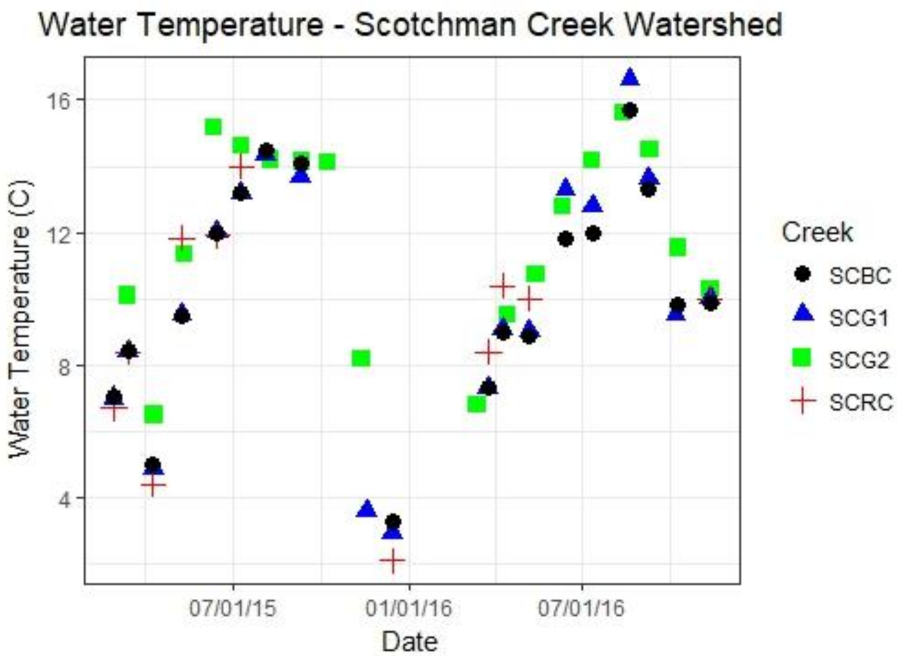


Figure 25: Monthly water temperature plotted at Bright Creek (SCBC), Upper Scotchman Gage (SCG1), Lower Scotchman Gage (SCG2) and Red Creek (SCRC) sampling sites.

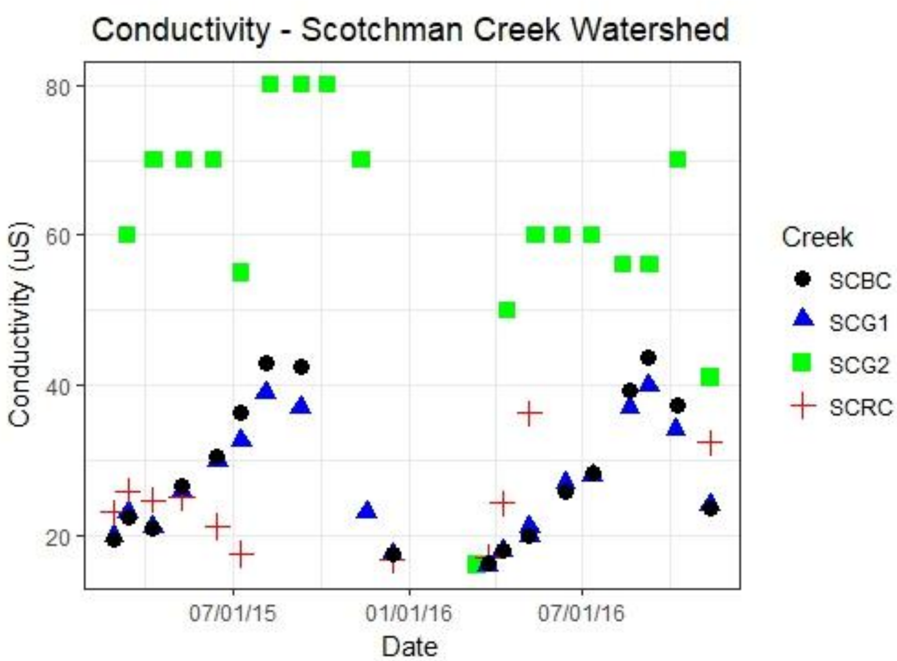


Figure 26: Monthly conductivity plotted at Bright Creek (SCBC), Upper Scotchman Gage (SCG1), Lower Scotchman Gage (SCG2) and Red Creek (SCRC) sampling sites.

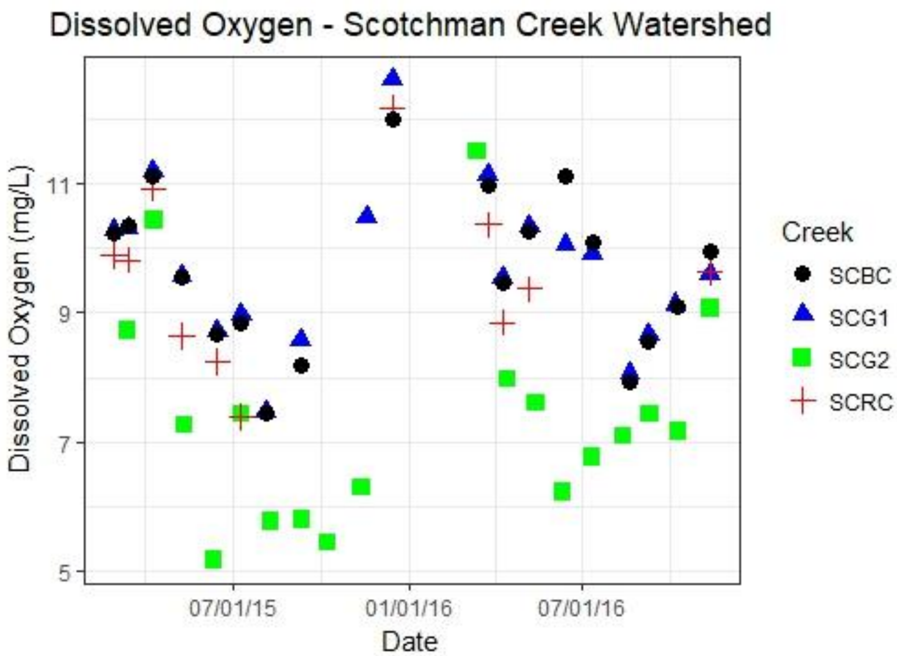


Figure 27: Monthly dissolved oxygen plotted at Bright Creek (SCBC), Upper Scotchman Gage (SCG1), Lower Scotchman Gage (SCG2) and Red Creek (SCRC) sampling sites.

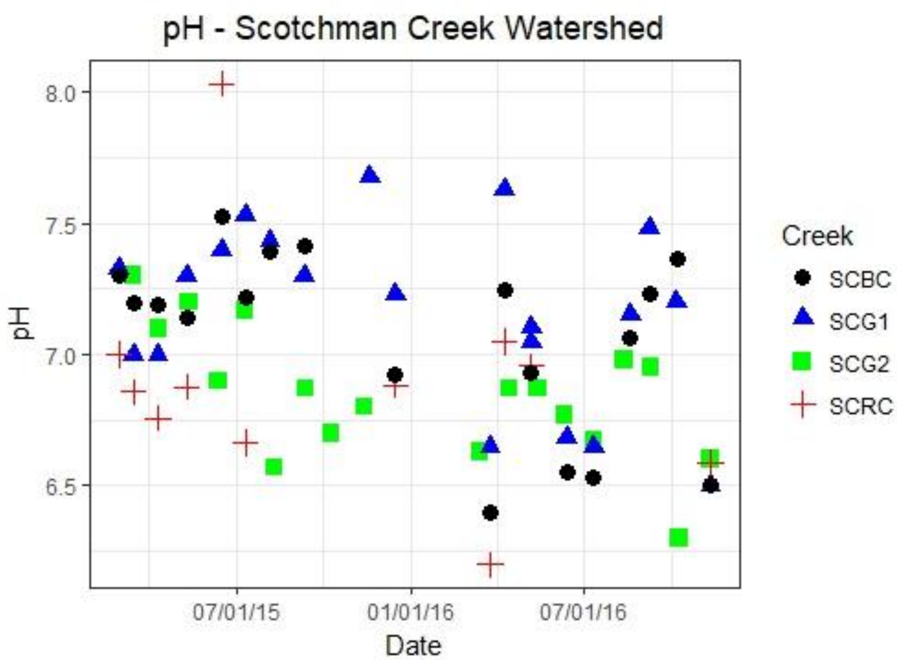


Figure 28: Monthly pH plotted at Bright Creek (SCBC), Upper Scotchman Gage (SCG1), Lower Scotchman Gage (SCG2) and Red Creek (SCRC) sampling sites.

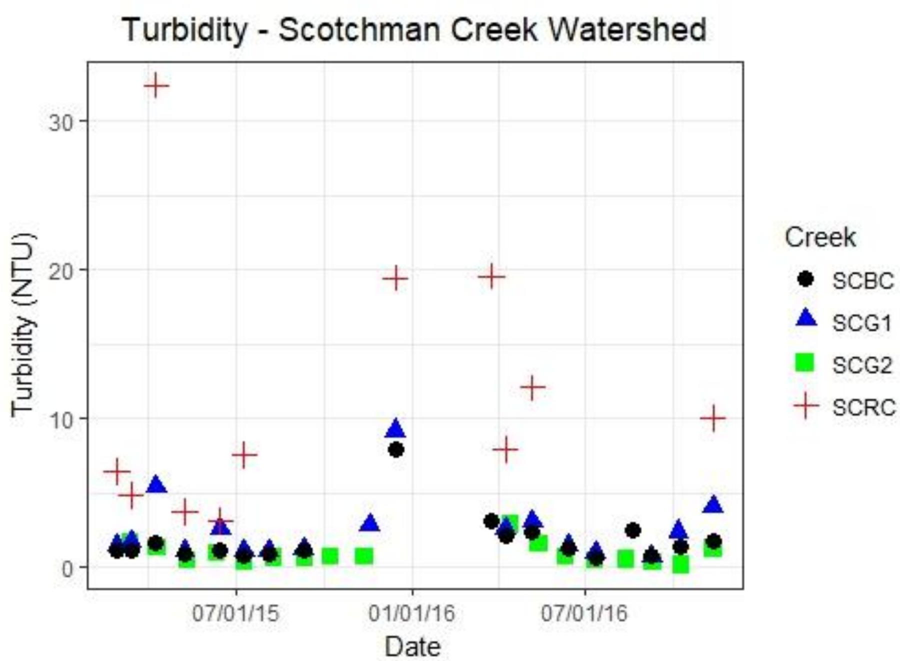


Figure 29: Monthly turbidity plotted at Bright Creek (SCBC), Upper Scotchman Gage (SCG1), Lower Scotchman Gage (SCG2) and Red Creek (SCRC) sampling sites.

Table 4: Mercury and Total Suspended Solid Data

Site	Sample Date	Sample Time	Analyte	Fraction	Result	Units
SCBC	12/10/2015	11:02	Hg	T	29.6	ng/L
SCBC	12/10/2015	11:04	Hg	D	10.8	ng/L
SCBC	12/10/2015	11:07	TSS	T	51.6	mg/L
SCG1	12/10/2015	10:23	Hg	T	71.5	ng/L
SCG1	12/10/2015	10:25	Hg	D	10.5	ng/L
SCG1	12/10/2015	10:28	TSS	T	416	mg/L
SCG2	12/10/2015	13:20	Hg	T	29.1	ng/L
SCG2	12/10/2015	13:22	Hg	D	7.74	ng/L
SCG2	12/10/2015	13:25	TSS	T	208	mg/L
SCRC	12/10/2015	10:43	Hg	T	105	ng/L
SCRC	12/10/2015	10:46	Hg	D	7.8	ng/L
SCRC	12/10/2015	10:49	TSS	T	1360	mg/L
SCG2	12/21/2015	21:36	TSS	T	41.8	mg/L
SCG2	12/21/2015	21:36	Hg	T	14.9	ng/L
SCG2	01/17/2016	17:00	TSS	T	364	mg/L
SCG2	01/17/2016	17:00	Hg	T	23	ng/L
SCG2	01/17/2016	18:00	TSS	T	376	mg/L
SCG2	01/17/2016	19:00	TSS	T	430	mg/L
SCG2	01/17/2016	20:00	TSS	T	314	mg/L
SCG2	01/17/2016	21:00	TSS	T	505	mg/L
SCG2	01/17/2016	22:00	TSS	T	413	mg/L
SCG2	01/17/2016	23:00	TSS	T	376	mg/L

SCG2	01/17/2016	24:00	TSS	T	316	mg/L
SCG2	01/18/2016	01:00	TSS	T	173	mg/L
SCG2	01/18/2016	02:00	TSS	T	96.5	mg/L
SCG2	01/18/2016	03:00	TSS	T	140	mg/L
SCG2	01/18/2016	04:00	TSS	T	155	mg/L
SCG2	01/18/2016	05:00	TSS	T	117	mg/L
SCG2	01/18/2016	05:07	Hg	T	19.5	ng/L
SCG2	01/18/2016	06:00	TSS	T	59.9	mg/L
SCG2	01/18/2016	07:00	TSS	T	49.4	mg/L
SCG2	01/18/2016	08:00	TSS	T	63.8	mg/L
SCG2	01/18/2016	09:00	TSS	T	48.6	mg/L
SCG2	01/18/2016	10:00	TSS	T	42.8	mg/L
SCG2	01/18/2016	11:00	TSS	T	38.9	mg/L
SCG2	01/18/2016	12:00	TSS	T	36.6	mg/L
SCG2	01/18/2016	13:00	TSS	T	28.7	mg/L
SCG2	01/18/2016	14:00	TSS	T	25.2	mg/L
SCG2	01/18/2016	15:00	TSS	T	22.3	mg/L
SCG2	01/18/2016	16:00	TSS	T	20.4	mg/L
SCG2	01/18/2016	16:00	Hg	T	9.07	ng/L
SCRC	01/18/2016	11:12	Hg	T	64.4	ng/L
SCRC	01/18/2016	11:15	TSS	T	477	mg/L
SCBC	01/18/2016	11:24	Hg	T	8.16	ng/L
SCBC	01/18/2016	11:27	TSS	T	10.3	mg/L
SCG1	01/18/2016	10:55	Hg	T	18.4	ng/L
SCG1	01/18/2016	10:58	TSS	T	59.8	mg/L
SCBC	03/05/2016	21:27	Hg	T	17.7	ng/L
SCBC	03/05/2016	21:30	TSS	T	67.1	mg/L
SCG1	03/05/2016	10:00	TSS	T	83	mg/L
SCG1	03/05/2016	10:00	Hg	T	22.3	ng/L
SCG1	03/05/2016	11:00	TSS	T	45	mg/L
SCG1	03/05/2016	12:00	TSS	T	74.9	mg/L
SCG1	03/05/2016	13:00	TSS	T	271	mg/L
SCG1	03/05/2016	14:00	TSS	T	215	mg/L
SCG1	03/05/2016	15:00	TSS	T	3.8	mg/L
SCG1	03/05/2016	16:00	TSS	T	85.1	mg/L
SCG1	03/05/2016	17:00	TSS	T	183	mg/L
SCG1	03/05/2016	18:00	TSS	T	115	mg/L
SCG1	03/05/2016	19:00	TSS	T	74.2	mg/L
SCG1	03/05/2016	20:00	TSS	T	82.7	mg/L
SCG1	03/05/2016	21:00	TSS	T	28.7	mg/L
SCG1	03/05/2016	21:00	Hg	T	43.8	ng/L
SCG1	03/05/2016	22:00	TSS	T	78.5	mg/L
SCG1	03/05/2016	23:00	TSS	T	51.6	mg/L
SCG1	03/06/2016	00:00	TSS	T	261	mg/L
SCG1	03/06/2016	01:00	TSS	T	249	mg/L
SCG1	03/06/2016	02:00	TSS	T	476	mg/L
SCG1	03/06/2016	03:00	TSS	T	1660	mg/L
SCG1	03/06/2016	04:00	TSS	T	473	mg/L
SCG1	03/06/2016	05:00	TSS	T	84.8	mg/L
SCG1	03/06/2016	06:00	TSS	T	165	mg/L
SCG1	03/06/2016	07:00	TSS	T	36	mg/L
SCG1	03/06/2016	08:00	TSS	T	102	mg/L
SCG1	03/06/2016	09:00	TSS	T	133	mg/L
SCG1	03/06/2016	09:00	Hg	T	17.7	ng/L

SCG2	03/05/2016	19:41	Hg	T	20.8	ng/L
SCG2	03/05/2016	19:43	TSS	T	192	mg/L
SCRC	03/05/2016	21:17	Hg	T	87	ng/L
SCRC	03/05/2016	21:20	TSS	T	1030	mg/L
ANEO	12/10/2016	13:42	Hg	T	29.7	ng/L
ANEO	12/10/2016	13:42	TSS	T	117	mg/L
ANO	12/10/2016	13:18	Hg	T	12.6	ng/L
ANO	12/10/2016	13:18	TSS	T	20.4	mg/L
SCBC	12/10/2016	16:36	Hg	T	17.6	ng/L
SCBC	12/10/2016	16:36	TSS	T	115	mg/L
SCG1	12/10/2016	16:18	Hg	T	28.4	ng/L
SCG1	12/10/2016	16:18	TSS	T	403	mg/L
SCG2	12/10/2016	11:59	Hg	T	71.1	ng/L
SCG2	12/10/2016	11:59	TSS	T	501	mg/L
SCRC	12/10/2016	16:29	Hg	T	75.9	ng/L
SCRC	12/10/2016	16:29	TSS	T	715	mg/L