HUMBOLDT STATE UNIVERSITY

Humboldt Redwood™

Annual Report (WY 2014, 2015)

Railroad Gulch Best Management Practices Evaluation
Elk River Watershed

Monitoring In-Stream Effectiveness and Timber Harvest Plan Implementation

Andrew P. Stubblefield, Associate Professor of Hydrology and Watershed Management,
Humboldt State University
Shane Beach, Geologist, Humboldt Redwoods Co.
Nick Harrison, Lead Hydrologist, Humboldt Redwoods Co.
Michelle Haskins, Graduate Student, Humboldt State University

May 10, 2016

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report contains a review of methods, status, and discussion of sampling results for the Railroad Gulch BMP Effectiveness Monitoring Project for WY 2014 and WY 2015. It is organized by hypothesis. Two hypotheses have been added to the project since the submittal of the project work plan, one concerning peak flow changes, and one evaluating long term erosion rates using Be-10. At this point, the project has run for two water years prior to the treatment, roads and harvest, being applied.

A preliminary assessment of the data indicates that the methods are working well, and being collected with a good standard of care. The two watersheds appear to be behaving similarly for both a low sediment load year, WY 2014, and a moderately-high sediment load year, WY 2015 which triggered debris torrents and bank erosion. Accurate stage-discharge rating curves, and turbidity/suspended sediment concentration regressions have been developed for each watershed, and within each storm event. Autosamplers collected samples during the majority of storm events, occasionally missing rising limbs and smaller storms. Examination of Grab samples collected along the stream, above and below tributary inputs, and within the tributaries themselves suggest that sample labels may have been switched during a few storm events. This issue will be addressed with better training of field staff. Sampling at site 3 on the West Branch and site 5 on the East Branch indicated tributary streams with high turbidities. Detailed field investigation will be conducted to determine possible causes. Rainfall data collection was incomplete for much of the time period due to debris plugging inside the collection buckets and infrequent site visits. This issue has been addressed by installation of duplicate collection buckets at each site and implementation of a biweekly site inspection schedule.

A large storm event on 2/2-9/15 (6 inches recorded at the West Branch rain gage) caused debris torrents and bank erosion. Turbidities exceeded the operational range of the in situ turbidimeter. Turbidity during the event had to be reconstructed by correlation with samples taken by the autosampler. The resulting turbidity record closely fits the samples collected by the autosampler, which

improves confidence in the accuracy of sediment load estimation. Grab samples taken above and below road crossings showed slightly elevated turbidities below the crossings suggesting some chronic erosion was occurring. Site 11 showed dramatically high turbidities as the result of a debris torrent triggered by the 2/6/15 storm. At this point in the experiment, as we head into the road and harvest time periods, we are confident that we have good methods in place to monitor changes and have two solid years of pre-treatment data

INTRODUCTION

This study is designed to evaluate the effectiveness of Humboldt Redwood Company's (HRC) Habitat Conservation Plan (HCP), the California Forest Practice Rules, and Elk River Watershed Analysis-derived prescriptions in minimizing sediment delivery to watercourses in response to timber harvest activities through the integration of compliance and effectiveness monitoring. HRC's HCP requires monitoring to evaluate the effectiveness of timber harvest prescriptions in preventing the delivery of management-related sediment to watercourses. Monitoring requirements include implementation of a Best Management Practices Evaluation Program (BMPEP) (HCP §6.3.5.1.3) and Instream Effectiveness Program (HCP §6.3.5.2). This study will be conducted at the scale of a single Timber Harvesting Plan (THP), 1-12-110HUM (McCloud Shaw).

The study area is located in Railroad Gulch, a tributary to the Lower South Fork Elk River which flows south of the city of Eureka, CA. Following initial clear-cutting and railroad harvesting including the use of 'steam donkeys' in the early 1900's, this sub-basin became restocked with dense second-growth stands comprised of various types of conifer and hardwoods. Selection and even-aged silvicultural practices were applied to the second growth stands within the study area between 1987 and 2002. Sixty- four acres, distributed between both forks, were clearcut between 2001 and 2008 under Pacific Lumber Company ownership. Stands are currently composed of approximately 85% redwood (*Sequoia sempervirens*), 12% Douglas-fir (*Pseudotsuga menziesii*), 2% grand fir (*Abies grandis*) and Sitka spruce (*Picea sitchensis*), and 1% hardwoods (primarily red alder, *Alnus rubra*). Current stands are primarily single tiered and even aged. Railroad Gulch is underlain by sediments associated with the Middle to Late Pleistocene aged Hookton Formation and the Miocene to Late Pliocene aged Undifferentiated Wildcat sediments. These bedrock types are highly erosive and subject to both shallow and deep-seated mass movements.

The road network accessing the sub-basin consists of a mix of seasonal storm-proofed roads and abandoned/closed roads. Watercourse crossings associated with abandoned/closed roads have been removed, partially removed, or left untreated depending on site-specific conditions.

Railroad Gulch consists of an East and West Branch, with the West Branch draining an area of 366 acres (1.48 km^2) and the East Branch 317 acres (1.28 km^2). This pair of basins offers a good opportunity to evaluate HRC's current management and silvicultural practices. Unit 2 of THP 1-12-110HUM (McCloud Shaw) covers nearly half (47%) of the East Branch (treatment), while the West Branch will not be subject to management activities (control) other than stormproofing and the use of approximately 1,700 feet of existing haul road near the West Branch/East Branch confluence (U06.08 road). Because of the similarities in geology, topography, drainage networks, and the THP activities being limited to one basin, the proposed project area is suited for a paired watershed design study, where effectiveness of HCP prescriptions can be thoroughly evaluated.

Slopes within the 149 acre Unit 2 plus approximately four acres associated with new road construction will be subjected to varying degrees of forest management including:

- 80 acres of single tree selection
- 45 acres of group selection
- 24 acres of no harvest
- 4 acres of ridge top new road construction right-of-way harvest necessary for the construction of approximately 2,750 feet of new seasonal road

Logs will be moved to landings primarily by cable yarding (114 acres), with the remaining acreage operated on with ground-based equipment (15 acres). Road construction and upgrading activity in the basin took place in the summer of 2015 and logging operations are scheduled to begin in the summer of 2016.

The objective of this project is to collect and evaluate specific sediment production, storage, and delivery data to test the effectiveness of HCP prescriptions in limiting sediment production and delivery from potential sources (roads, landslides, bank erosion, upslope stream channel head-cutting, and harvest unit surface erosion) as it relates to land management. The project will evaluate ten (10) hypotheses that are intended to test whether the combination of THP-related California Forest Practice Rules, HRC HCP, and Watershed Analysis harvest prescriptions and requirements are effective at minimizing the impact that land management has on the delivery rate of fine sediment to Railroad Gulch. Hypotheses are listed below. For each hypothesis, this report contains a review of methods, status, and discussion of sampling results from WY 2014 and WY 2015. Hypotheses 9 and 10 have been added to the project from the originally proposed work.

HYPOTHESES

1. *Properly implemented Best Management Practices (BMP's) for new or reconstructed road stream crossings will not increase watercourse turbidity directly below the crossing by greater than 20%.*
2. *Properly implemented sediment-related BMP's on THP-related road segments are effective in preventing road surface erosion and related sediment delivery to watercourses.*
3. *Due to the erosive nature of the Hookton Formation and Undifferentiated Wildcat sediments, existing untreated Humboldt Crossings in Railroad Gulch have less erosion than treated ones.*
4. *There will be no increase in the rate of landslide occurrence or volume of landslide-related sediment delivery to watercourses originating from within or immediately adjacent harvested areas outside of identified unstable areas within 10 years following harvest. No landsliding will occur from within or immediately adjacent the unit in areas not identified as unstable per Figure 5.*

5. *The rate of retreat of channel initiation points at the head of watercourses from the East Branch will not migrate upslope at a faster rate compared to the West Branch, after the implementation of the THP 1-12-110HUM.*

6. *The number, area, and activity of small streamside landslides (SSLS) in the East Branch will not increase during the 3 years following harvest in comparison to the control basin.*

7. *The mean change in bankfull area from each set of cross sections should not significantly differ (>8%) post-harvest between the East Branch and the West Branch.*

8. *Post-harvest turbidity and suspended sediment yield within the East Branch will not increase compared to the West Branch following implementation of the McCloud-Shaw THP.*

9. *Peak flows in years subsequent to the road construction and selective harvest of the East Branch will not significantly increase relative to the untreated West Branch watershed.*

10. *Current erosion rates measured over the study period are within 20% of long term erosion rates as determined by Be-10 isotope analysis.*

HYPOTHESIS 1 EFFECTIVENESS OF ROAD CONSTRUCTION PRACTICES IN MINIMIZING SEDIMENT DELIVERY

Methods: Grab samples are collected above and below eight (8) road construction sites and measured for turbidity. These sites were addressed under THP 1-12-110HUM. Collection takes place once 1" of rain has accumulated at the NOAA Woodley Island Weather Station, Eureka, CA during a 24 hour period.

Status: In WY 2014, eight sites were geo-referenced, characterized and flagged. Grab samples were collected for 5 events in WY 2014 and 8 events in WY 2015. At several of the sites samples could not be collected as the sampling threshold of one inch of rain was not sufficient to initiate flow. Road construction sampling sites are shown as Sites A, B, C, 17, 18, 19, 20, and 22 on Figure 1. Two samples were collected at each site. Road construction and clearing operations occurred on the U06.0825 and U06.082517 roads in summer of WY 2015. The majority of the sites were treated in general accordance with the road work order attached to THP1-12-110HUM. Specific comments are given in Table 1.

Table 1. Road Construction Monitoring Site Comments.

Site #	Comment
A	Removed from the study as it is very stable and well-vegetated and will not need any remedial treatment when the road is opened for truck traffic related to the planned harvest. The crossing consists of a 36-inch corrugated metal pipe with rock armored embankments. The embankment and adjoining streamside slopes/ channel support a thick assemblage of ground cover species in addition to dense stands of alder.
B,C,22	Inspection of Sites B, C, and 22 prior to the initiation of the WY 2014 monitoring season revealed an absence of near surface channels that could be sampled. Consequently, they were excluded from the monitoring program for WY 14 and WY 15.
22	Grading activities required for the installation of a rocked dip at Site 22 appear to have exposed an above ground channel. As a result, turbidity samples will be collected at this site during WY 2016 to the extent that water is present.
17	Decommissioned during WY 2015. Approximately 30 cubic yards of fill material were removed from the waterway and the site was subsequently mulched and seeded with straw and large woody debris.
18	Required some clearing and minor amount of rock placement to armor the spillway inlet and outlet.
19,20	Graded and rocked.

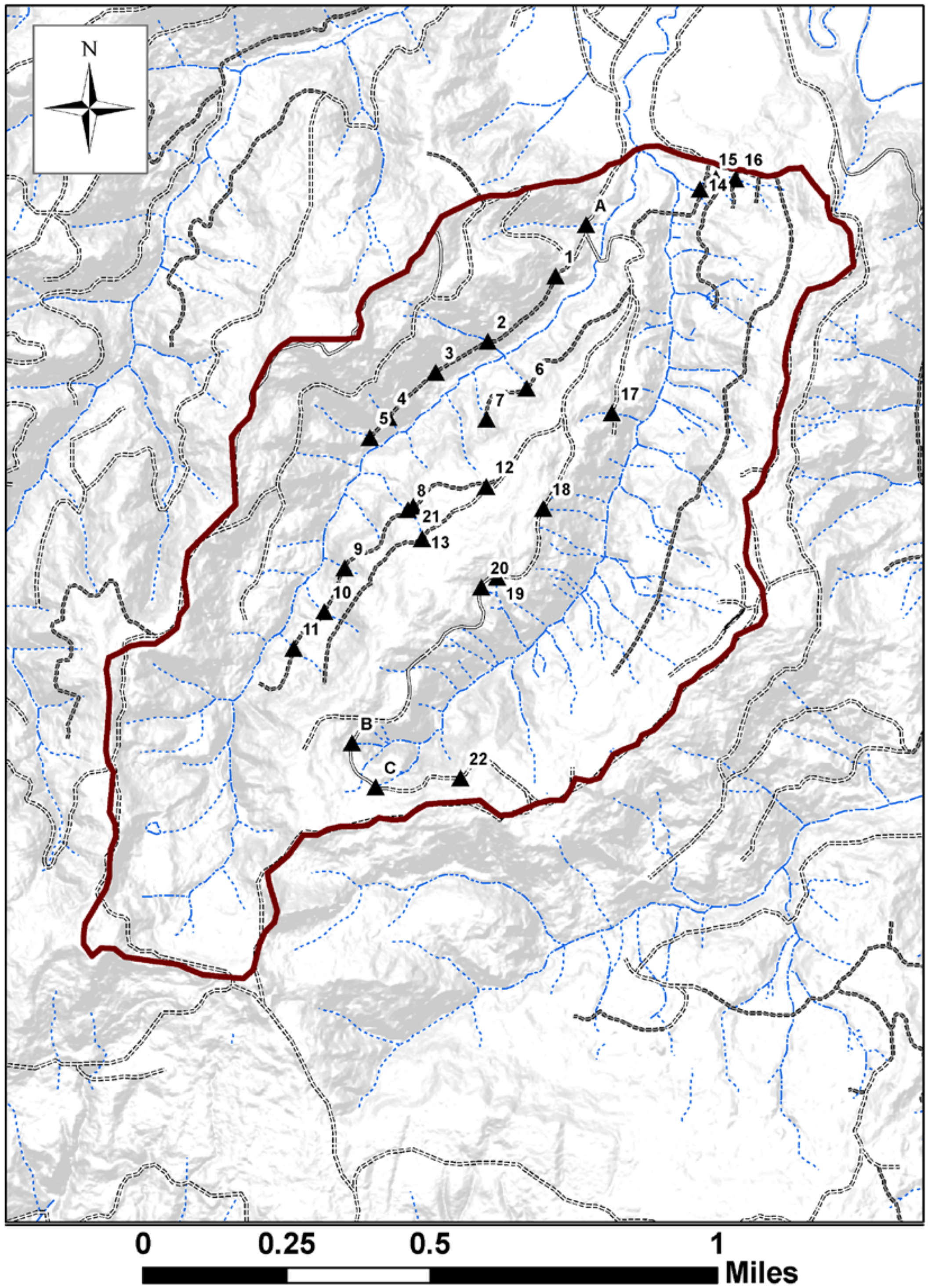


Figure 1. Synoptic Sampling Locations at Road Construction Sites, Railroad Gulch, Elk River, CA. Brown line: project boundary; blue lines: watercourses; dashed black lines: roads; black triangles: synoptic sampling locations at road construction sites.

HYPOTHESIS 2 ROAD SURFACE EROSION

Methods: Road condition described for each road segment.

Status: In WY 2015 a pre-construction inventory was conducted for all road segments that will be part of the study in both watersheds. Figure 1 illustrates the location of inventoried road segments. Road segments consist of sections of roads located between prominent drainage features. A field inventory form (Appendix A) was developed with assistance from Dr. Lee MacDonald that characterizes road condition, the presence of rills and gullies, the potential for sediment delivery into a watercourse, and other relevant variables. Road surveys that characterized general conditions in the West and East Branch of Railroad Gulch were completed in early fall 2014, before the start of the water year (Oct 1, 2014) and before the summer 2015 road re-construction. A total of 267 road segments have been surveyed. The general condition of the road segments have been good, with rocked or native bed surfaces that were lightly vegetated throughout the basin. The roads have seen little use over the previous two decades, with the exception of light traffic from all-terrain vehicles (ATVs). Almost all drainage features within the road segments are present and functional. Trace amounts of erosion were observed on the road surfaces and below drainage features. Sediment plumes were found to extend beyond drainage feature outlets, but not far enough to deliver sediment to watercourses. Certain mapped road-watercourse crossings may deliver some sediment to watercourses, but the general lack of flow (i.e drought conditions) at many crossings during the previous water year makes delivery difficult to pinpoint. There have been some observations of ATV tracks developing into potential erosion features following a storm event. The amount of erosion due to this type of traffic is difficult to quantify, but for the most part is localized to very steep road segments.

A portion of the road segments that were re-graded in summer 2015 to prepare for the harvest of the East Branch are located within the West Branch control basin. Road surfaces that fall within HRC HCP Riparian Management Zone (RMZ) buffers were fully rocked and wattles (rolls of absorbent coconut fiber batting) were installed across water bar, critical dip, and rolling dip outfalls to discourage road-derived sediment from entering the West Branch (Figure 10). Three new synoptic sample sites will be installed in WY 2017 to monitor the effectiveness of these remedial treatments in ensuring that truck traffic through the control basin is not contributing sediment to the waterway (Figure 10; RS-1 through RS-3).

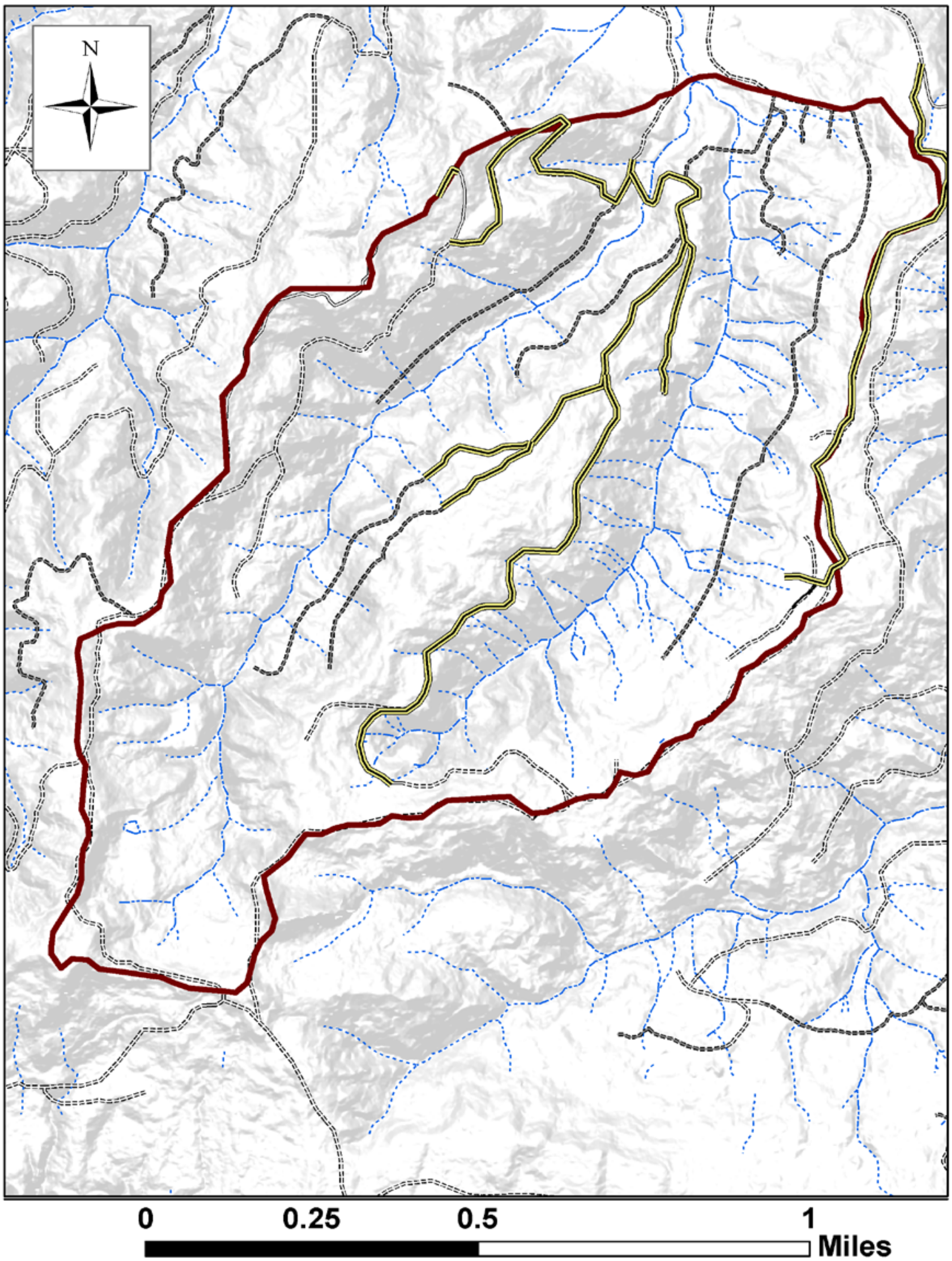


Figure 2. Inventoried Road Segments, Railroad Gulch, Elk River, CA. Brown line: project boundary; blue lines: watercourses; dashed black lines: roads; yellow lines: inventoried road segments.

HYPOTHESIS 3 ROAD TREATMENT STRATEGY

Methods: Grab samples of overland flow are collected at 17 road crossing sites where road treatments were applied. The samples are measured for turbidity in the HRC sediment laboratory. Collection takes place after 1” of rain has accumulated in 24 hours at the NOAA Woodley Island Weather Station, Eureka, CA.

Status: In WY 2014, 13 synoptic sampling sites were geo-referenced and characterized. Grab samples were collected for 5 events in WY 2014 and 8 events in WY 2015. Synoptic sampling sites for road treatment strategy are shown in Figure 1. Hypothesis 3 locations correspond to Sites 1 through 16 and 21 in Figure 1. Two in-stream Grab samples were collected from each site, above and below road crossings, unless otherwise specified. Comments relating to specific sites are provided in Table 2.

Turbidities were higher below road crossings than above for numerous locations and events. Differences ranged from zero to 110 NTU. These results would suggest chronic sediment loading from road crossings is occurring. The method appears to be effective in detecting watershed disturbances as detailed in Table 2.

Table 2. Road Treatment Sampling Site Comments.

Site #	Comment
5	High turbidities observed below the crossing (~5000 NTU) as compared to above (~1800 NTU) as a result of 2/6/15 storm event.
8	High turbidities observed below the crossing (~8000 NTU) as compared to above (~4000 NTU) as a result of 2/6/15 storm event.
11	Altered by a debris flow (Slide 1501) during early February 2015 storm events. After February 6, 2015, only one instream grab sample was collected per event from this site. The debris torrent produced from the 2/6/15 storm discharged woody debris and sediment onto and across the crossing resulting in a significant change in sediment inputs from those documented during the previous sampling periods. Grab samples showed very high turbidity above the crossing resulting from the torrent, ~16,000 NTU on 2/6/15 and ~26,000 NTU on 2/7/15. Turbidity prior to the event was in line with other sites (~40-120 NTU).
12	This new Class I synoptic site (SW-12) was installed at the Site 11 confluence with the West Branch to evaluate the impact the debris torrent (Slide 1501) will have on turbidity within the main watercourse.
21	Added to the monitoring program following the February 2015 storm events. Site was installed to monitor turbidity below the active streamside failure (Slide 1504) in order to document recovery time (channel clearing) and potential impact on downslope water quality. The streamside failure diverted water away from Site 8, thereby reducing flow to that location. Only one instream Grab sample will be collected per event from this site. Two samples are still collected at Site 8.
TBD	A new site will be added prior to WY 2016. This site will be located above the confluence of the watercourse associated with Site 8. It will allow for the sampling of water quality impacts of the debris flow from the water quality of the upper portion of the watershed, sampled at locations SW-11.

HYPOTHESIS 4 LANDSLIDE OCCURRENCE & DELIVERY

Methods: An analysis of stereo-paired aerial photographs covering both branches was conducted in 2014. Historic aerial photographs between 1948 and 2010 were evaluated for the presence of recently active landslides. Regions identified on the aerial photographs as potential slide areas were plotted on scaled topographic base maps with the corresponding aerial photograph year. A similar assessment was recently conducted in the West Branch for slopes enveloped by THP 1-12-110 HUM (Oswald Geologic, 2012). A draft map containing all previous and recently identified landslides (Kilbourne, 1985; John Colye Associates, 2002:, HartCrowser, 2002; Marshall and Mendes, 2005; Oswald Geologic, 2012) was produced following the completion of our aerial photo analysis. Information contained in this map assisted in and directed our initial field surveys.

The intent of the field surveys was to: 1) confirm the accuracy and validity of previous landslide mapping, 2) acquire site-specific data on existing individual landslides, and 3) to inventory unrecognized failures. During our assessment of the pre-mapped slide areas, we encountered a large quantity of previously unrecognized failures. Because many landslides, especially smaller landslides, can be difficult to observe in aerial photography due to canopy coverage and relatively small size, a more thorough ground reconnaissance phase is currently being implemented and is in the process of being completed.

The minimum size feature mapped in the field is about 90 square feet (30 feet by 30 feet). In addition to landslides, we also recorded prominent erosional features and historic anthropogenic structures. Field work was conducted in general accordance with HRC Standard Operation Protocol #50, *Field Verification of Landslides for Watershed Analysis, v2.2* (PALCO, 2005b). Landslide attributes have been (and will be) collected from the each of the mapped landslides and subsequently transferred into HRC's GIS Landslide Layer data base. Attributes include but will not be limited to:

- Slide type

- Activity status
- Dimensional data (surface area)
- Geomorphic association (inner gorge, headwall swale, planar slope, etc.)
- Stream class of affected watercourses if delivered
- Association to various land uses (haul road, skid trail, etc.)

This evaluation has resulted in the development of a compilation map that displays all those failures identified during recent and past investigations as dormant-historic in age (equal to or less than 100 years in age per Keaton and DeGraff [1996]). As the project progresses the inventory will be continually updated as unmapped slides are encountered or pre-mapped landslide are verified. Landslide locations for the Railroad Gulch basin are shown on Figure 3-A.

Landslide activity in the project area appears to be concentrated along roadways and the sidewalls/headwalls of the more deeply entrenched draws. Movement is dominated by landslide mechanisms affiliated with translational failures, therefore the majority of the slides on Figure 3-A have been classified as debris slides/flows. A number of previously unrecognized historically-active, deep-seated compound failures (earthflows, trans/rotational, etc.,) were also encountered within the study basins. Although smaller in number, these failures are significantly larger in magnitude compared to their debris slide counterparts. These larger events are commonly confined to slopes along the inner valley walls of both basins. Previous investigations noted a similar type and distribution of landslide activity, in that a bulk of the mass movements were shallow and initiated on steep slopes near waterways and along roads, while upland open slope failures were fairly uncommon.

At the completion of this report we have identified/verified the presence of 71 historically active landslides within the project area (West Branch = 34; East Branch = 37). The size of the landslides in project area is relatively diverse, ranging from very small (100 yd^2) to covering multiple acres (8,000+

yd^2). The slides, in total, cover nearly 45 acres which represents approximately 6 percent of the study area (5% West Branch; 7% East Branch). About 13 percent of the study area is underlain by landslide deposits that were identified by previous work as dormant-young or older age. Many of these landforms have not, to date, been substantiated.

Hillslopes that have been modified by translational slide events are characterized by fresh to highly weathered scarps, torrent tracks, dense hardwood patches, disturbed and bare soils, abundant bedrock exposures, tilted old growth stumps, and jackstraw second growth timber. Most of the slides (active or dormant-historic) we identified in the THP area were confined to the colluvial mantle and the upper 3 feet of the underlying bedrock. In most cases, the translational slides were less than 6 feet deep. Slopes that supported coalescing groups of debris slides are classified on our area of concern maps as debris slide slopes or inner gorges. Debris slide slopes include those aggregates of shallow landslides that were triggered by mechanisms unrelated to fluvial processes. Hillsides destabilized by fluvial process were mapped as inner gorges (relatively rare and localized).

Most of these compound type failures are presently in a period of suspension, but have been active in the recent past (based on vegetation and slope morphology). In plan view, these deep-seated slides have a subtle lens-shaped expression with source areas that expand towards the distal margins of the features. At the heads of these slides are moderately weathered scarps and headwalls (steep pitches) that range between 4 and 15 feet in height. Typically, the head scarps, which are commonly arcuate-shaped, grade into moderate-sized (less than 10 feet high) semi-linear lateral scarps. The surface expressions of scarps (head and lateral) vary based on their age and the magnitude of ground movement in that segment of the landslide. In recently active, faster-moving areas, we observed fresher unvegetated scarps; in less mobile regions of the slides, these scarps have a more subdued weathered expression.

The middle and distal margins of these slides are characterized by low to moderate gradient (10% to 50%) slopes with irregular and hummocky surface expressions. Dense to open stands of alder, thick patches of ground cover, warped and jackstrawed conifers (second growth and residual), tilted stumps, irregular topographic bulges, and closed depressions are common on the surfaces of these slides as well. A majority of the skid trails and haul roads that contour across these areas of historic instability have experienced a significant level of deformation and in some instance are no longer recognizable.

An aerial photography review will be conducted this year using 2015 photographs in conjunction with a helicopter aerial survey in April, 2016. A more detailed discussion relating to ground movement in the two basins will be produced in the WY 2016 Annual Report. During this investigation a geologic map is being developed.

Status: An inventory of historically active landslides within Railroad Gulch is in the process of being completed. This inventory combines existing landslide mapping with image interpretation of historic aerial photographs and field surveys. Materials used to develop the inventory include:

- Published geologic and geomorphic maps
- Pertinent California Geologic Survey Note 45 geologic reports
- Grayscale/ color aerial photographs
- Color orthophotos (2010 and 2015)
- Google earth image
- LiDAR topographical maps
- Hill shade maps

Five (5) active failures have been encountered during the project period; two in WY 2014 and three in WY 2015. Only two of these events (Feature #'s 1501 and 1505) delivered sediment to a downslope waterway, while debris associated with the other slides was captured by roadways or forested midslopes. All of the events were classified as debris slides/flows with three of them being reactivation of older events.

The debris torrent at 1501 is the largest of the recent failures and is estimate to have displaced about 40 yards^3. This slide occurred following heavy rainfall between February 5 and 6, 2015. The rain gage position in the headwater of the West Branch recorded 3.57 inches of precipitation between the 5th and 6th. Slides at 1502 (10 yds^3) and 1503 (20 yds^3) also occurred in response to this precipitation. The failure at 1501 initiated in a large fill embankment that crossed the head of the Class III watercourse associated with Synoptic Crossing Site 11. A single Grab sample was collected at Site 11 closely following the initiation of this event (turbidity = 26,000 NTU). Single Grab samples were collected at this site throughout the remainder of WY 2015.

A Class I Synoptic site (SW-12) was established at the confluence between the disturbed Class III watercourse and the mainstem of the West Branch prior to WY 2016. The intent of this site is to evaluate the influence Slide 1502 has on the turbidity of the Class I watercourse over time and to assess the recovery time of the impacted Class III watercourse.

Slide 1501 initiated along the Class III measured at Synoptic Crossing Site 8. Slide debris diverted the Class III channel and directed flow to the north, away from Site 8. Synoptic Crossing Site 21 was subsequently installed and measured for the remainder of the winter. The intent of Site 21 is to evaluate recovery time of the impacted Class III watercourse.

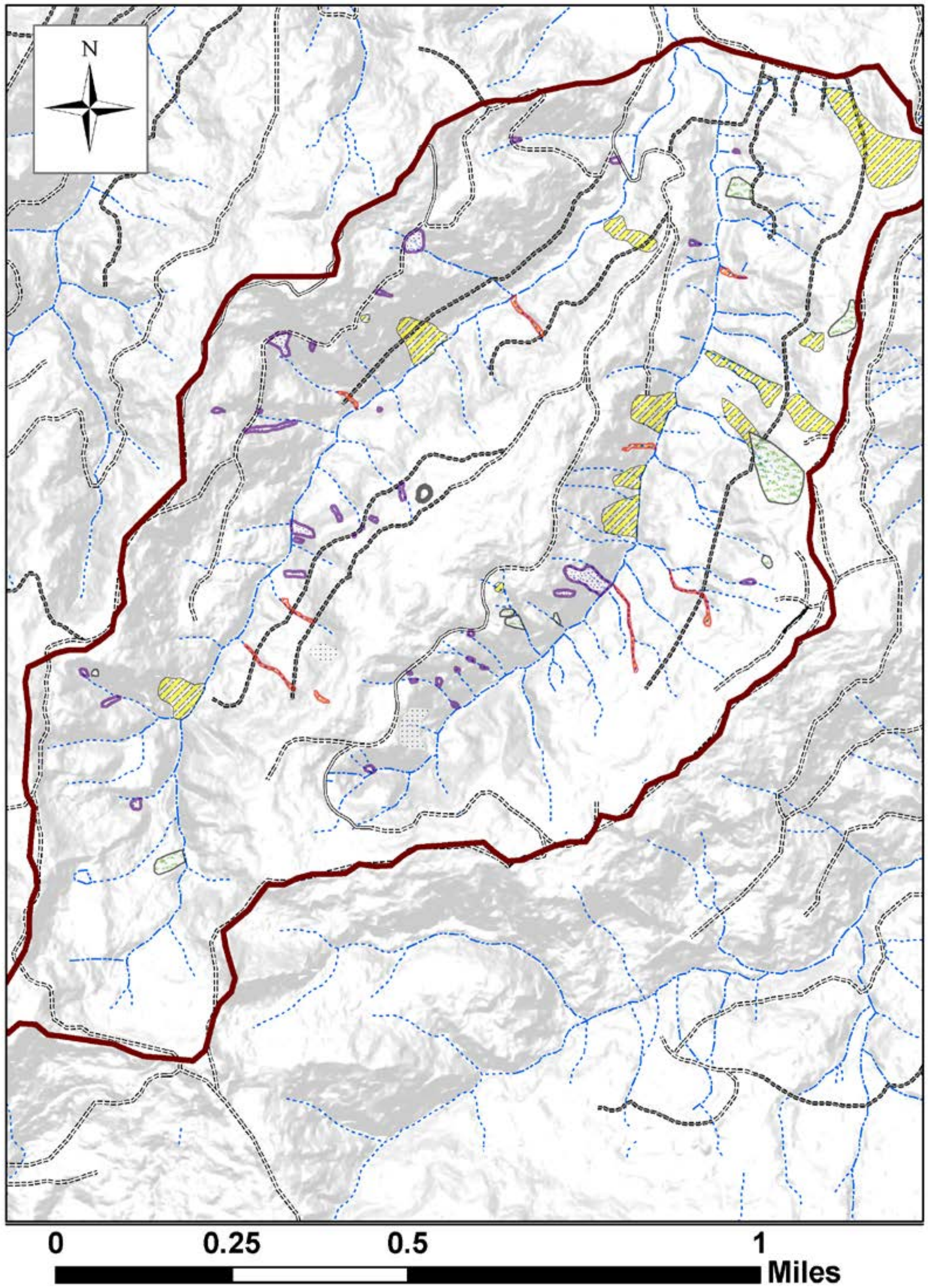


Figure 3-A. Landslide Locations, Railroad Gulch, Elk River, CA. Brown line: project boundary; blue lines: watercourses; dashed black lines: roads; red outlines: debris flows; thick grey outlines: disrupted ground; polka dots with purple outlines: debris slides; polka dots (no outline): debris slide slopes; yellow patterns: earthflows; green patterns: trans/rotational landslides.

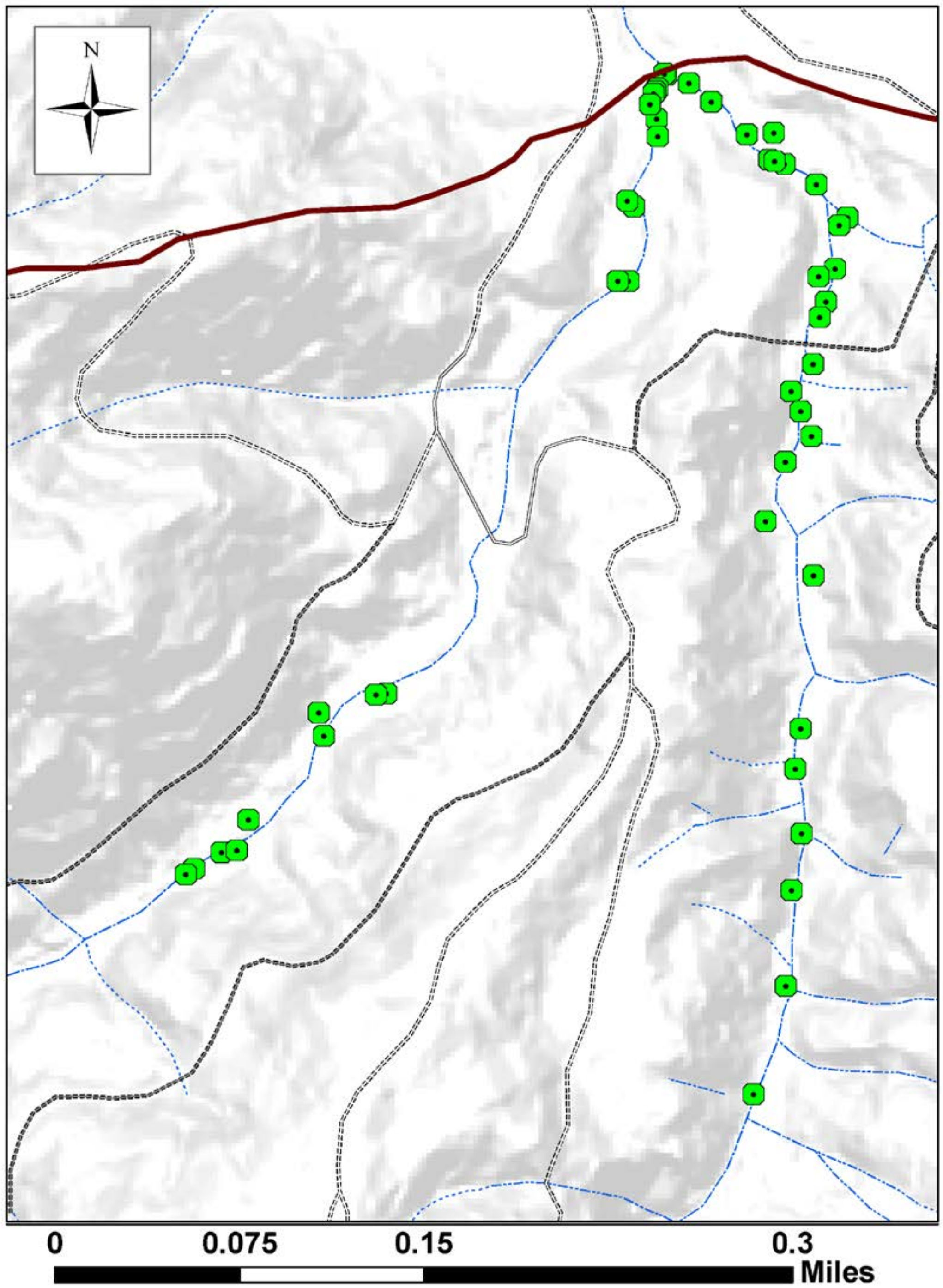


Figure 3-B. Streamside Landslide Locations, Railroad Gulch, Elk River, CA. Brown line: project boundary; blue lines: watercourses; dashed black lines: roads; green octagons: delineated streamside landslides.

HYPOTHESIS 5 CHANNEL HEAD MIGRATION

Methods: Permanent rebar monuments are installed on either side of the upper most point of recognizable erosion (nick point, rill, soil pipe, etc.) at the top of a first order watercourse. First order waterways in the study area include both Class II and III watercourses. Channel plots are flagged, geo-referenced, and visited annually until completion of the study. General site conditions have been recorded for each plot. Attributes include, but are not limited to:

- Geomorphic feature
- Underlying geology
- Slope/ channel gradients
- Watercourse type
- Relation to road if present
- Exposed soil type (fill, colluvium, bedrock, etc.)

An example of characteristics collected at each site is presented in Table 3. Thirty eight (38) plots were installed in WY 2013 and revisited in WY 2015. In WY 2015 an additional 20 plots were installed. New plots were located on newly identified watercourses as well as above and below existing monuments.

Status: Fifty-eight (58) sites have been geo-referenced, characterized, and flagged to date. Their location and relationship to mapped waterways and roads is shown on Figure 4. Several of the WY 2013 plots were found during the WY 2015 survey to terminate in some type of hardscape (woody debris, bedrock, etc.,) or were not located at the upper most point of erosion. In response to these observations, several supplementary surveys were conducted to find new plots and/or to install additional monuments at some of the existing plots. None of the initial 38 plots have been removed from the study.

The post-WY 2014 survey found no evidence of erosion. Many of the Class III watercourses channels did not appear to have passed much if any surface flow during WY 2014. During the post-WY 2015 survey, lengths of road surface segments that appear to be contributing overland flow to the channel head sites will be measured. Upstream basin areas will be calculated for each plot using 10-foot LiDAR and the ArcView Spatial Analyst toolset. This information will be added to the current data base and be included in subsequent reports.

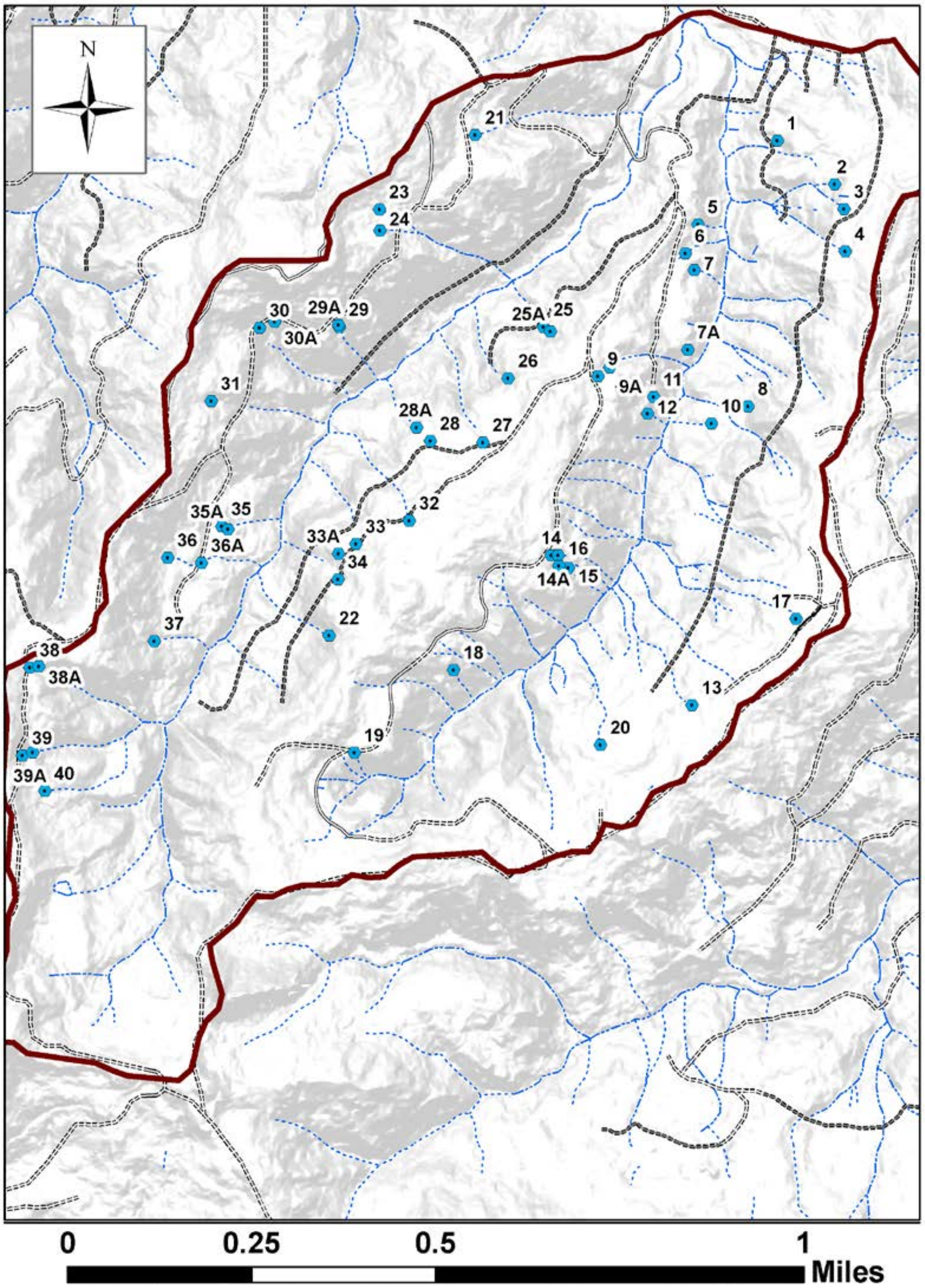


Figure 4. Channel Head Monitoring Sites, Railroad Gulch, Elk River, CA. Brown line: project boundary; blue lines: watercourses; dashed black lines: roads; blue octagons: Class III channel head monitoring sites.

Table 3. Description of Channel Head Migration Sites with Post-WY 2014 Monitoring Notes, Railroad Gulch, Elk River, CA.

Site #	Installation date	Geomorphic Feature	Geology	Soil	Channel/ Adjoining Hillside gradient (%)	Watercourse	Staked	Road	Quality	General Site Notes	2015 Inspection Notes (inspection date)
32	2013	Soil Pipe Outlet	Hookton	Colluvium	20%/ 5-10%	2	yes	30 feet above pulled crossing	good	Just above crossing sample site 13. Site is associated with seep and positioned near old growth stump. Lot of ground disturbance above site.	Passed water this winter. (6/17/15)
33	2013	channel	Hookton	Fill	50%/ 10-50%	3	yes	located at water bar outlet	fair	Located at outboard edge of road. Watercourse may not connect. Lots of soil pipes and woody debris in channel. 12% road grade feds water to site.	Passed water this winter. (6/17/15)
33A	2015	Soil Pipe Outlet	Hookton	Fill	30%? 5-15%	3	yes	old landing	good	Hookton is siltstone. Lots of disturbance above outlet. Headwall swale directly below site.	Passed water this winter. (6/17/15)
34	2013	weakly developed channel	Hookton	Fill	35-40%/ 35-45%	3	yes	located at water bar outlet	good	Located at outboard edge of road. Watercourse may not connect. Lots of soil pipes and woody debris in channel. 15% out sloped road grade feds water to site.	Passed water this winter. (6/17/15)
34A	2015	Soil Pipe Outlet	Hookton	Colluvium	15-20%/ 35%	3	yes	road cut bank	good	Day lighted by road cut. Lots of subsurface water upslope.	Passed water this winter. (6/17/15)
35	2013	Rounded Swale	Hookton	Colluvium		3	yes	skid trail influence	poor	At skid trial crossing. Fairly flat site and has wood in channel.	Passed limited amount of water this winter (4/16/15)
35A	2015	Nick point	Hookton	Colluvium		3	yes	NA	fair	no notes	Passed water this winter (4/16/15)
36	2013	Rounded channel	Hookton	Colluvium	35%/ 35%	3	yes	NA	poor	Weakly develop nick point.	Channel and covered with forest litter. Does not appear to have convey much if any water this winter (4/17/15)
36A	2015	Rounded channel	Hookton	Colluvium	40%/ 40%	2	yes	NA	fair	Small off channel spring.	Passed water this winter (4/16/15)
37	2013	Nick point	Hookton	Colluvium	55%/ 65%	3	yes	NA	poor	Piece of wood forms nick point. Some undercuting observed.	Painted undercut face with white paint. Channel and covered with forest litter. Does not appear to have convey much if any water this winter. (4/17/15)

HYPOTHESIS 6 BANK EROSION/STREAMSIDE LANDSLIDE

Methods: A field-base inventory of active streamside landslides is conducted annually along the lowest reaches of the East and West Branch (Figure 3-B). Streamside surveys were conducted in WY 2013, WY 2014, and WY 2015 along an approximately 2,600 foot reach of each basin. The survey starts at the West/East branch confluence and extends to a pre-designated location as identified in the initial work plan.

Field work is conducted in general accordance with HRC SOP-51, *Reconnaissance Level Streamside Landslide and Bank Erosion Inventory for Watershed Analysis (Ver. 2.2).* Landslide attributes are collected from each landslide and subsequently recorded in the Railroad Gulch Effectiveness Streamside Landslide data base. Attributes include, but are not limited to:

- Slide type
- Dimensional data
- Geomorphic association (inner gorge, headwall swale, planar slope, etc.)
- Stream morphology
- Primary and secondary causes
- Anthropogenic influence (haul road, skid trail, etc.)

Volumes are determined by measuring the void created by the streamside mass movement. Movement depth was estimated by visually reconstructing the pre-slide slope configuration and estimating the maximum thickness of the material lost. Percent delivery was based on ocular estimates and the amount of debris remaining at the toe of the subject failures. In nearly all instances percent delivery was determined to be 100%.

Active slides (points of scour) covering less than about 2.25 square feet (1.5 feet by 1.5 feet) were left unmapped, but were flagged for future identification. Flagging was labeled with the water year in which the feature was observed. Recorded slides are photographed, flagged, labeled, and painted for identification on subsequent site visits. Examples of descriptive and quantitative attributes collected at each site are provided in Table 4. General locations of streamside landslides are shown in Figure 3-A. As the project progresses, this inventory will be continually updated as new slides occur and old ones are reactivated.

Status: Over 50 independent slides and points of scour have been identified to date. Streamside movement is currently dominated by relatively shallow bank slumps and zones of channel scour. The low relief streamside topography in the study area is a length limiting factor, in that a majority of the slides do not extend much beyond the crown of upper most stream bank slope break. This topographic break is situated 3 to 10 feet above the active channel, before transitioning into a broad streamside flats. Soil/sediment densities were also observed to impose depth limitations. Failures that occurred on stream banks composed of relatively stiff sediment were commonly less than 3-inches deep, while slides in sandier material are up to 2 feet deep.

Bank slumps are a product of stream bank undercutting and not a result of soil saturation from rainfall. These failures are typically discrete landslides that occurred in meander bends in response to flow deflection by large woody debris. Scour tends to occur in areas where streamside slopes are composed of fine grain relatively stiff soils. These erosional features are commonly very shallow (0.10 to 0.25 feet) and less than 15 feet wide. Scouring was observed along straight reaches as well as in meander bends. Woody debris also appears to play role in the location of these erosion points.

Peak flows associated with a February 2015 storm appear to have contributed to the activation/reactivation of 41 landslides in the study area. Over 3.7 inches of rainfall were recorded at the lower Railroad Gulch rain gage between February 5 and 6. Prior to this event, precipitation at Woodley Island was about 80% of normal for the year, implying a relatively unseasonable dry winter.

Table 4. Example of Data Collected for Streamside Landslide Inventory and Eroded Volume Estimates, Railroad Gulch, Elk River, CA.

Station Number	2001
Basin	East Branch
Hydrologic Year	2013
GPS Location (Lat./ Long.)	40.69496/ 124.15414
Location	Left Bank
Geology	T
Geomorphic Association	ST
Feature	BE
Stream Morphology	STR
Length (ft)	2.75
Width (ft)	7.5
Slide Area (ft^2)	21
Depth (max.) (ft)	1.00
Primary Cause	UC
Secondary Cause	NA
Stream Class	1
Road Type	NA
Road Condition	NA
Displaced Volume (max.) (yd^3)	0.76
% Delivered (est.)	100%
Storage	NA
Delivered Volume (yd^3)	0.8
Notes	Lens-shape. Sediment stored in scour location. Channel is confined. High woody debris loading.

Explanation of Abbreviations

Stream Morphology
O = Outside bend
I = Inside bend
S = Straight Segment

Geology
BDRX = Bedrock
C = Colluvium
T = Terrace
F = Fill

Geomorphic Assoc.
SS = streamside
ST = stream bank
IG = Inner Gorge

Observations made during the February 6, 2015 Class I Synoptic Grab sample outing suggests that many of the active failures encountered during the April streamside survey occurred in response this storm event. Three upland failures were also noted during the February synoptic sampling outing.

Streamside landslide sediment loads for all three monitored years is provided in Table 5. The largest sediment load is affiliated with WY 2015, which correspond to the largest peak flows (West Branch = 1.33 cms/km^2; East Branch = 1.22 cms/km^2) recorded in the study area through WY 2014-2015. Due to above normal precipitation levels observed in WY 2016 we propose to conduct four additional streamside surveys. The intent of these new surveys is to increase our coverage as well as capture peak flow impacts on steep streamside slopes (60% average streamside gradient) and deep-seated landforms (earthflows). The proposed location of the new streamside surveys are as follows:

- 500 feet above and below Site SE-9
- 500 feet above and below Site SW-12
- Toe areas of the earthflows mapped between SE-6 and SE-7 (~900 feet long)
- Toe areas of the earthflow mapped between SW-8 and SW-9 (~700 feet long)

Table 5. Sediment (yd^3) Displaced and Delivered from Streamside Landslides and Erosion, 2013-2015, Railroad Gulch, Elk River, CA.

	East Branch		West Branch	
Water Year	Displacement (yd^3)	Delivery (yd^3)	Displacement (yd^3)	Delivery (yd^3)
2013	6.0	6.0	11.4	11.2
2014	0.3	0.3	0.6	0.6
2015	8.8	8.8	20.5	12.8

HYPOTHESIS 7 CHANNEL INCISION/AGGRADATION

Methods: Sets of river cross sections are surveyed at low, middle and upper sections of the main channel for each branch of Railroad Gulch (total = 13 cross sections per branch). Annual surveys allow for the detection of trends in channel incision and aggradation. Pebble count measurements will be conducted annually in order to detect trends in sediment transport. Two hundred (200) sediment particles are measured at pre-specified locations across twenty (20) perpendicular transects placed within the general location of each set of cross sectional survey locations. Transects span the bankfull width of the channel. If the location to be measured contains woody debris, that location will be skipped and measurements will be conducted at the next suitable location upstream. Measurements will be taken during the late summer of each year of the project.

Status: Twenty-six (26) cross sections were installed in the fall of WY 2014, and re-surveyed in fall of WY 2015. The first pebble counts were conducted in fall of WY 2015. Locations of cross sections and pebble counts are shown in Figure 5. The transect lengths are shown in Table 4. East Branch pebble count surveys depicted channel reaches that primarily consisted of medium sand (<2 mm size category). West Branch pebble count surveys depicted channel reaches that were also predominantly made up of coarse sand, however there was a small component (~12%) of gravels (2-4 mm) and pebbles (4-64 mm).

Table 6. Segment Lengths of Pebble Count Sites, Railroad Gulch, Elk River, CA.

Site*	Segment Length (ft.)
EB-1	240
EB-2	400
EB-3	355
WB-1	289
WB-2	390
WB-3A	166
WB-3B	113

*EB and WB refer to East and West Branches, respectively. Site number 1 was located at the lower portion of the watercourse near the confluence, Site 2 was in the middle reach, and Site 3 was located towards the upper extent of the watercourse.

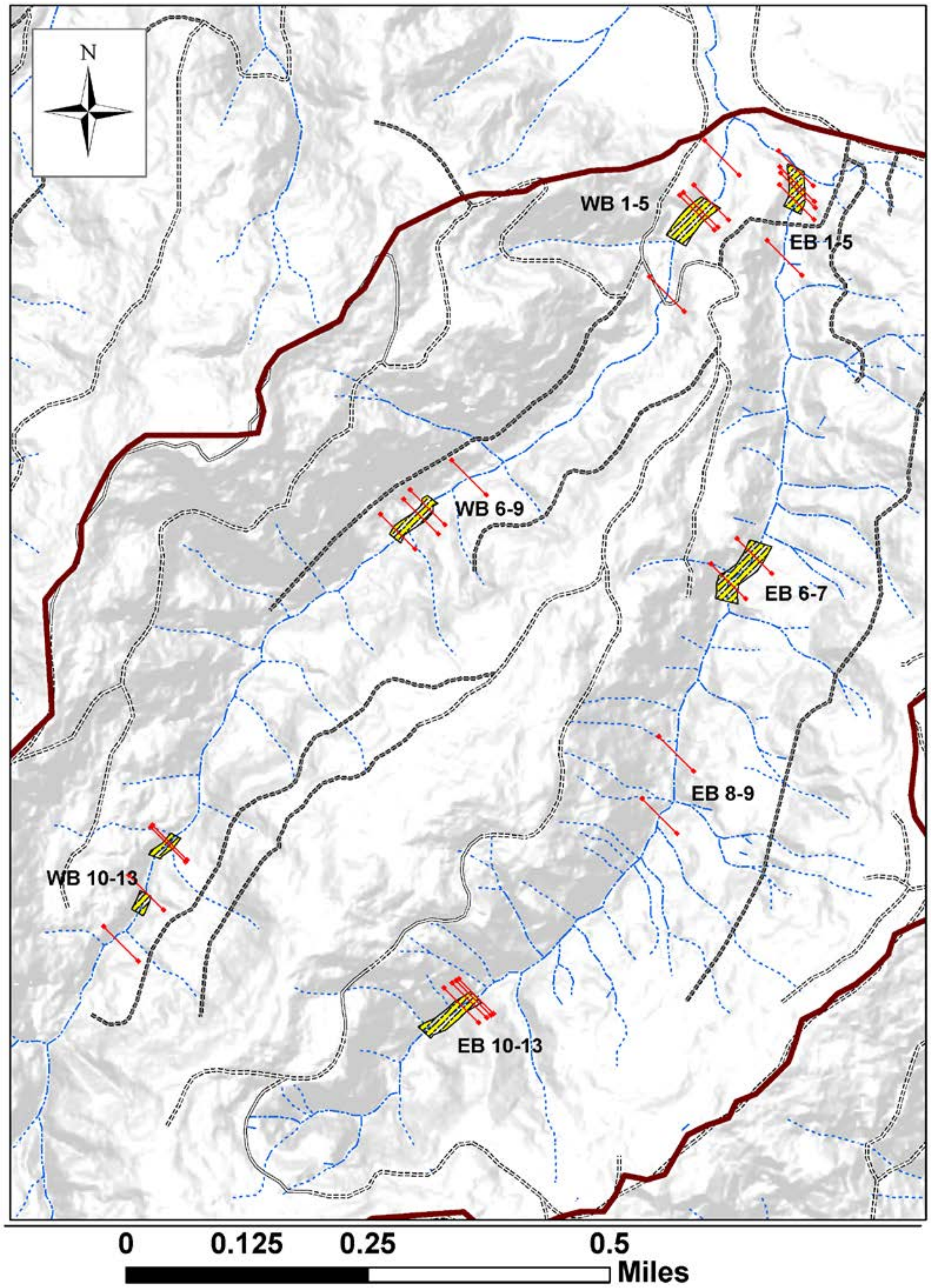


Figure 5. Cross Section and Pebble Count Locations, Railroad Gulch, Elk River, CA. Brown line: project boundary; blue lines: watercourses; dashed black lines: roads; red lines: cross section survey locations (not to scale); yellow polygons: pebble count survey locations (not to scale). Labels denote groups of cross sections (WB = West Branch; EB = East Branch).

East Branch Railroad Gulch Cross sections 2015

The lower (downstream) section of the East Branch appears to have been relatively stable from WY 2014 to WY 2015 with some scour and stream bank erosion occurring at the top of the lower section as illustrated in the cross section 4 profile (Figure 6). This was the only cross section throughout the East Branch where significant bank erosion was documented Overall stream channel conditions in both the East and West Branch appear to be heavily dominated by the presence of in-stream wood. When large wood is present in narrow channels with unconsolidated beds and banks it can obstruct and re-direct streamflow during storm events resulting in reduced bank stabilization due to under-cutting and bed scour

The middle section of the East Branch appears to have remained largely stable as evidenced by profiles from cross section 6 and 7. The uppermost (upstream) reaches experienced some thalweg scour as evidenced by cross section 8, 9, 11, and 12 profiles. However, the channel is more incised in these sections as the stream transitions from a Class I to a Class II watercourse in between cross sections 9 and 10. The gaging station profile (Station 684) was relatively stable between 2014 and 2015 with slight thalweg aggradation and erosion along the left bank.

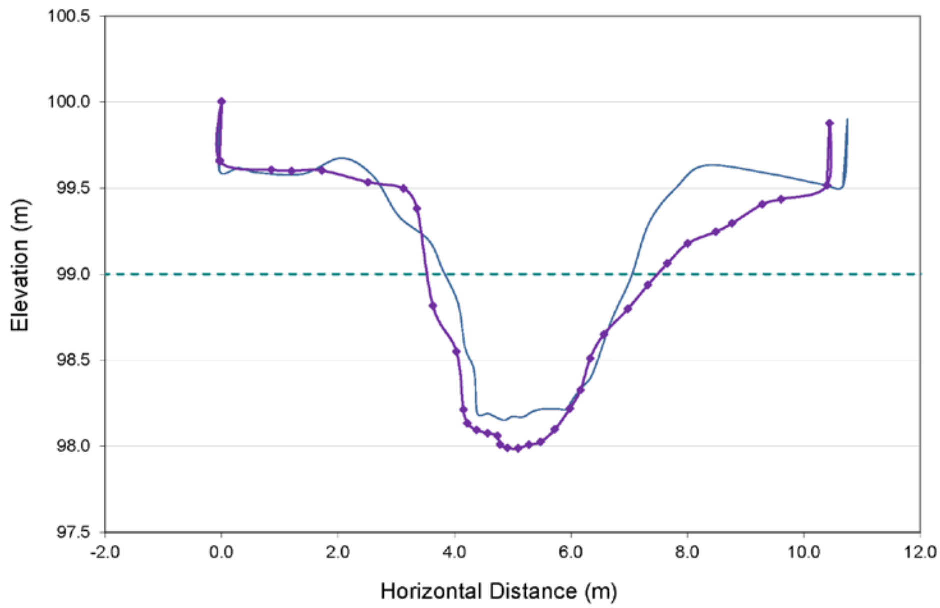


Figure 6. Cross Section 4 profile, East Branch Railroad Gulch, Elk River, CA. Purple line with diamonds: 2015 profile; Solid blue line: 2014 profile; Dashed blue line: Reference elevation (99.0 m) used to detect change in cross sectional area. The profile illustrates varying degrees of scour within the thalweg and along the left and right banks.

West Branch Railroad Gulch Cross sections 2015

Overall scour was minimal and banks were generally stable within the West Branch. The lower (downstream) to middle sections of the West Branch appear to have been very stable both in terms of thalweg elevation and bank stability from 2014 to 2015 with as evidenced by cross section 1-9 profiles. Some thalweg scour was observed in the lower portion of the most upstream section as evidenced by cross section 10-11 profiles (Figure 7). This was not observed in the most upper reaches which remained very stable. Like the East Branch the West Branch transitions from Class I to II between cross sections 9 and 10. This is largely due to the presence of a large landslide with the channel becoming extremely incised above cross section 9. The gaging station profile (Station 683) suggests some bank erosion with minimal thalweg scour. This level of erosion is not particularly large (nor unexpected) given the extreme instability of watershed geology.

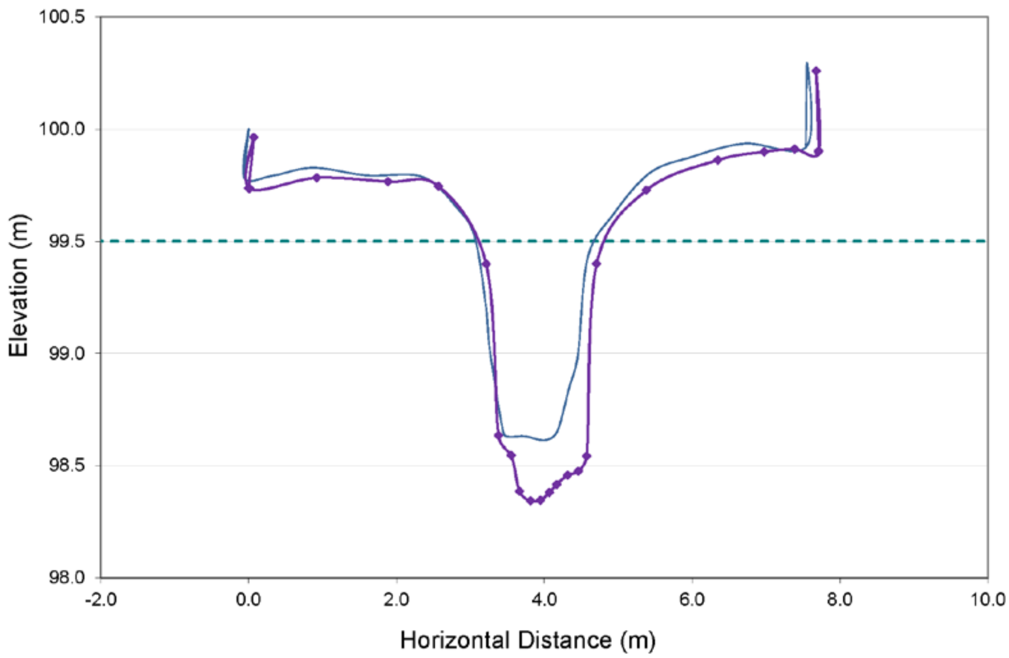


Figure 7. Cross Section 10 profile, West Branch Railroad Gulch, Elk River, CA. Purple line with diamonds: 2015 profile; Solid blue line: 2014 profile; Dashed blue line: Reference elevation (99.5 m) used to detect change in cross sectional area. The profile illustrates scour within the thalweg.

HYPOTHESIS 8 WATER QUALITY – TURBIDITY AND SUSPENDED SEDIMENT

Methods: Two separate data collection efforts are encompassed to evaluate this hypothesis. The first effort involves the installation and maintenance of two hydrologic monitoring stations at the outlets of the East and West Branches of Railroad Gulch, respectively. Continuous stage (the height of the water in the stream above an arbitrary point) is recorded with a pressure transducer (Druck, General Electric Measurement and Control) that is mounted to the streambed and related to gage plates installed in the monitoring reach. Stream discharge is measured at a wide range of stages throughout the water year by applying standard methods involving the use of top-setting rods at established cross sections within each monitoring reach. Stage data from the pressure transducer is converted to streamflow (discharge, cms) by a stage-discharge rating curve that is developed for each station using stream discharge measurements. Continuous turbidity (nephelometric turbidity units, NTU) is recorded with a turbidimeter (DTS-12, Forest Technology Systems, Inc.) that is suspended in the stream at approximately 6/10 water depth (range of measurement = 0-~1600 NTU). This instrument is situated such that it can be raised or lowered as stage rises or falls. Both the pressure transducer and turbidimeter are wired to a datalogger (WaterLOG by YSI) that records stage and turbidity measurements at 15-minute intervals.

Prior to forecasted storm events, HRC staff program automatic pump samplers (Teledyne ISCO Technologies Inc.) located at both East Branch and West Branch stations to begin collecting stream samples at the same time and interval (15-minute) throughout the storm. By synchronizing sampling, any fluctuation in streamflow or sediment delivery can be observed and compared between the two sub-basins throughout the water year. Samples are processed in the HRC sediment laboratory where turbidity (NTU) is measured with a HACH 2100N bench turbidimeter (range of measurement = 0-2000 NTU) and total suspended sediment (SSC, mg/L) is determined through vacuum filtration. Lab turbidity data are used to re-construct periods of erratic field turbidity and to troubleshoot outliers in field turbidity vs SSC regression models used to calculate sediment loads. Each storm that occurs during the water year is assigned a unique ID that is based on order of occurrence (i.e. 1401, 1402, 1403…). Unique relationships between turbidity and SSC are oftentimes observed across different storm events due to seasonal timing, differences in event magnitude, and fluctuation of source materials. In order to derive an annual estimate of concentration that reflects dynamic, storm-based relationships, the monitoring record for the entire water year is divided into distinct segments that bracket each storm event in which sampling occurred. Segment ID's are assigned that match the unique ID of the storm event they include (i.e. 1401, 1402, 1403…). Each segment includes the duration of the storm as well as the inter-storm period leading up to the next storm event. The portion of the water year each segment represents will vary temporally according to storm and inter-storm duration. If sampling does not occur during a designated storm or storms, that time period is grouped into the previous segment. For example, if sampling did not occur during Storms 1411 through 1414, the range of data through that set of events would be included in Segment 1410.

Regression models are developed for each segment using field turbidity and SSC relationships measured in samples collected during the storm event. Model equations derived from these regressions are applied to field turbidity data in order to estimate instantaneous SSC. SSC is multiplied by discharge in order to estimate an instantaneous sediment load for each measurement interval. The summation of each instantaneous load value equals the total sediment load for each segment. The summation of each segment load equals the annual sediment load for each sub-basin, to be expressed in totality (Mg) or per unit watershed area (Mg/km^2). This is known as the" sum of storms" method.

Precipitation is measured within each sub-basin using tipping bucket rainfall gages (Texas Electronics) which are maintained at locations near the top and bottom of each sub-basin as shown in Figure 8.

The second data collection method utilizes Grab samples collected along the main stem of each branch, above and below tributary junctions, and from the tributaries. The sampling locations, referred to as synoptic sampling sites, are shown in Figure 9. Turbidity is determined in the HRC sediment laboratory for each Grab sample that is collected. Grab samples are used to identify specific locations within the watershed that have high turbidity. Field visits can then be used to identify sediment source areas.

Status: Hydrology and synoptic sampling sites were established in WY 2013. Hydrology monitoring sites were operational at the mouth of each branch for WY 2014 and 2015. Rainfall gages were installed at the start of WY 2014, but the data record was incomplete for WY 2014 and 2015 due to mechanical malfunctions. Data collection efforts for the hydrology stations are discussed first, followed by results from the synoptic sites. Starting in WY 2016, approximate dimensions (depth, wetted width) of tributary streams will be measured where samples are collected, and duplicate samples will be collected at three locations (RS-1, RS-2, and RS-3) for each sampling period. SW-12 and SE-11 were added to the program at the end of the WY 2015, in order to capture upstream conditions prior to entering the plan area (Figure 10).

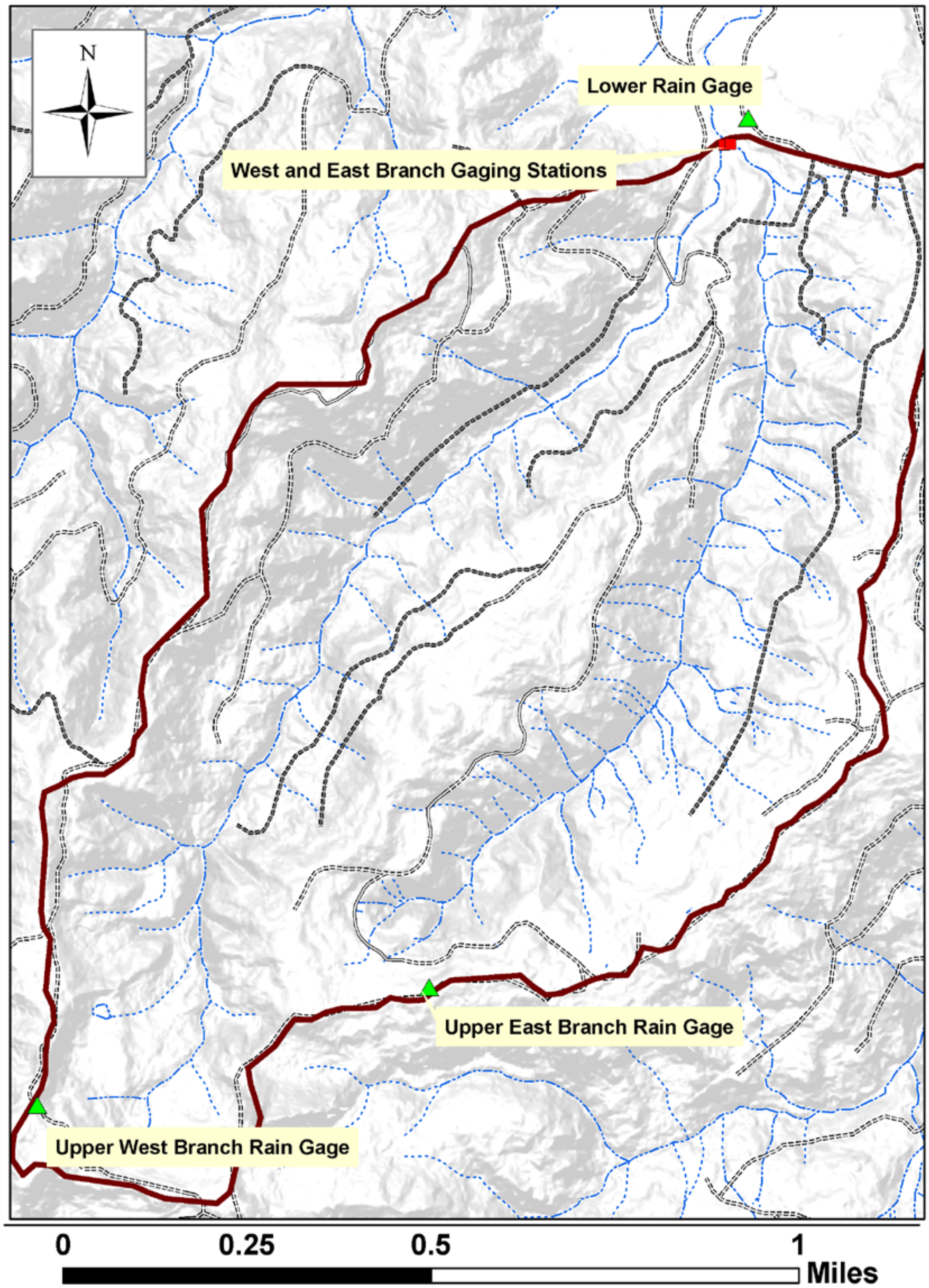


Figure 8. Location of Rain Gages and Hydrologic Monitoring Stations, Railroad Gulch, Elk River, CA. Brown line: project boundary; blue lines: watercourses; dashed black lines: roads; green triangles: rain gages; red squares: hydrologic monitoring stations.

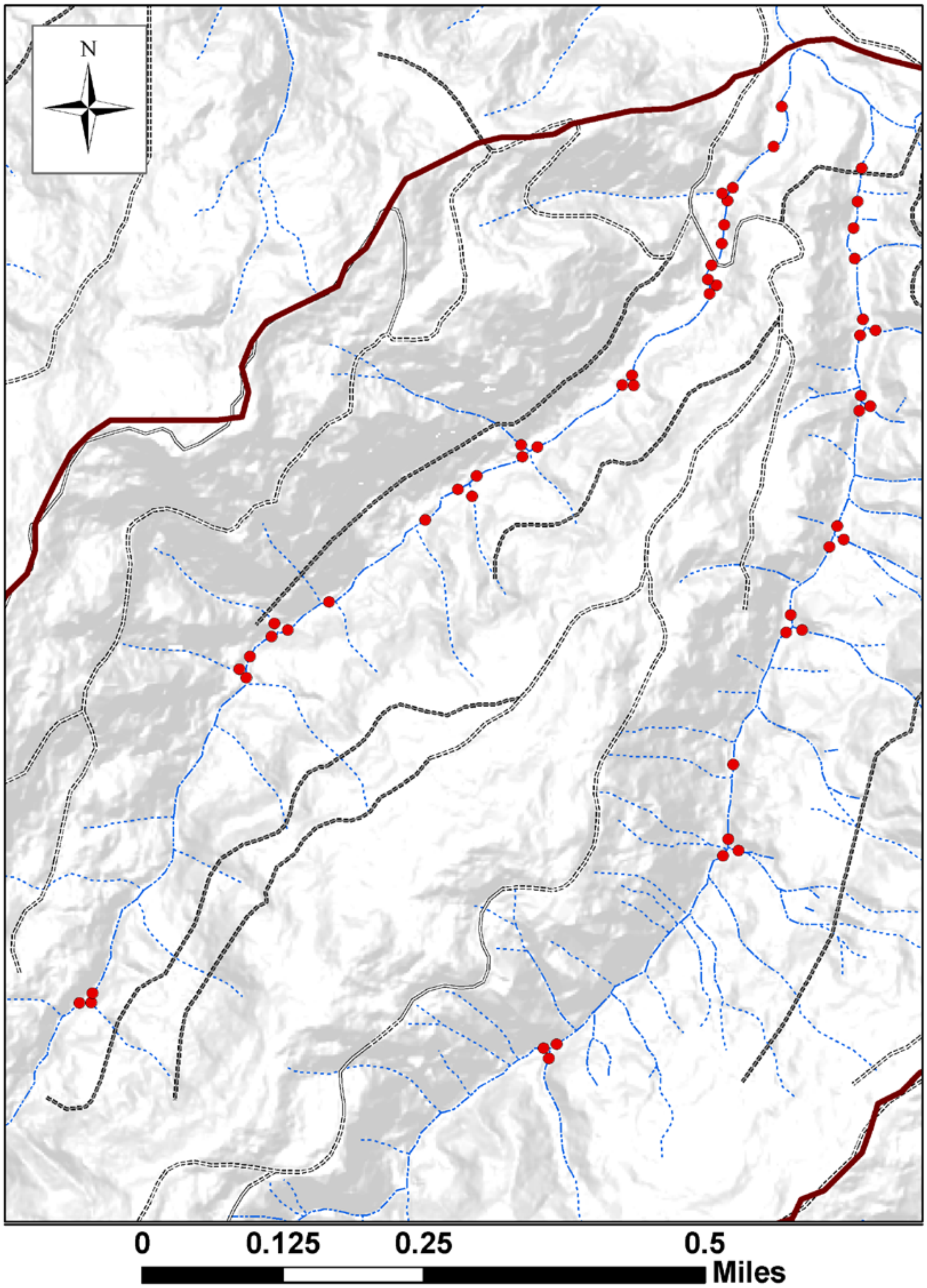


Figure 9. In-stream Class I Synoptic Sampling Locations, Railroad Gulch, Elk River, CA. Brown line: project boundary; blue lines: watercourses; dashed black lines: roads; red dots: in-stream Class I synoptic sampling locations.

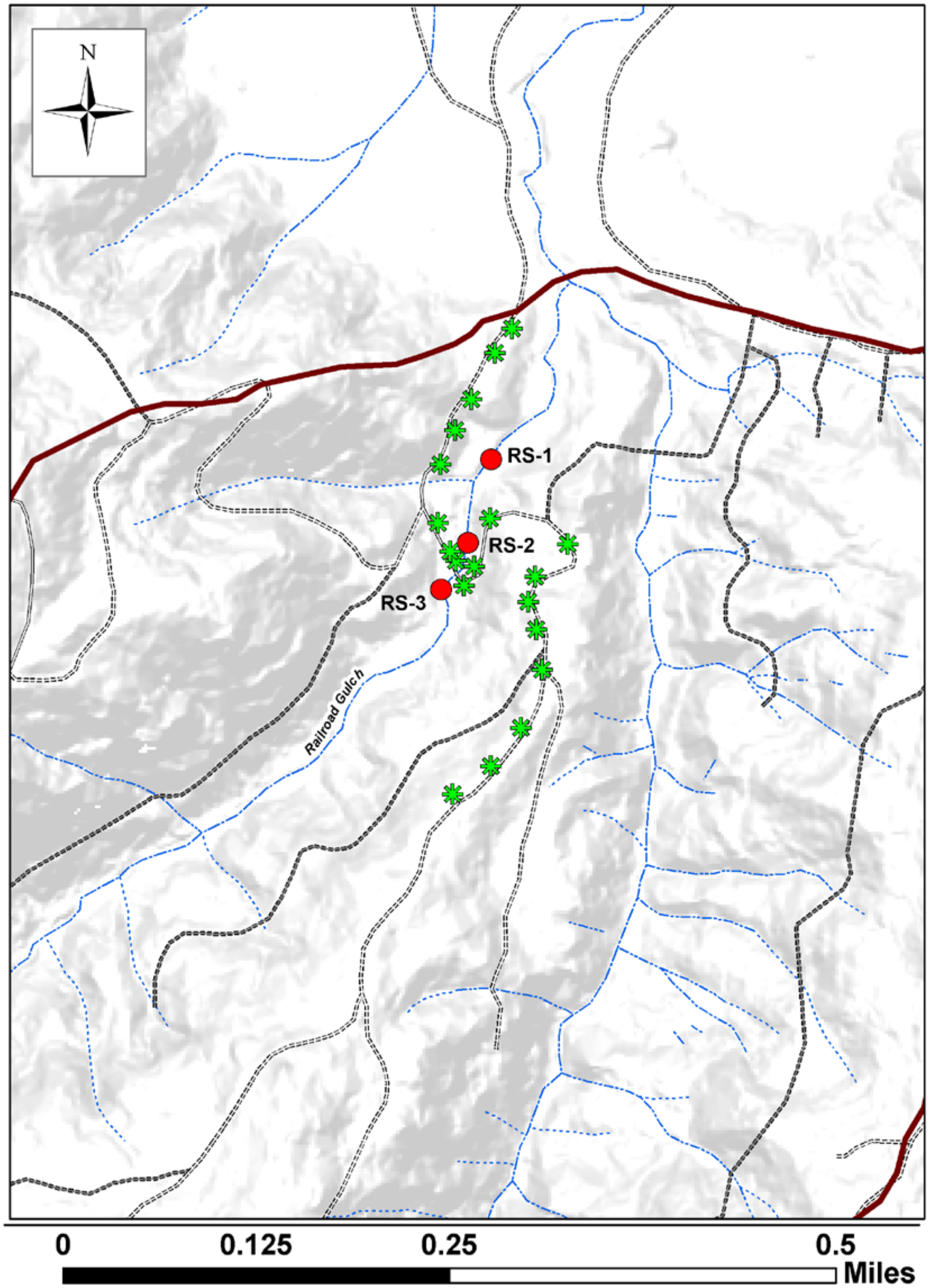


Figure 10. Location of road erosion control wattles and synoptic sites added for WY 2016, Railroad Gulch, Elk River, CA. Brown line: project boundary; blue lines: watercourses; dashed black lines: roads; red dots: new synoptic sampling sites added for WY 2016.

Discussion of East Branch Hydrology Station Data WY 2014

A complete record of turbidity and stage was collected throughout WY 2014 at the East Branch gaging station (Figure 11). Flows were generally low due to drought conditions observed throughout the North Coast. Streamflow, turbidity, and loading results are provided in Table 7. Field turbidity peaked at 1531 NTU and exceeded 25 NTU for 16% of the period of record. The WY 2014 rating curve was fit with a single regression (R^2 = 0.91) and indicates some scatter at lower gage heights (Figure 12). This is not an entirely unexpected finding given the unconsolidated composition of the channel bed within the monitoring reach. The largest streamflow measurement conducted by staff equaled 0.16 cubic meters per second (cms) at 0.49 meters on the gage plate. Peak stage (as recorded by the pressure transducer) equaled 0.68 meters with corresponding peak discharge estimated at 0.42 cms. Continuous discharge that exceeds the highest flow measurement is an extrapolation of empirical data and should be considered somewhat subjective. Future care will be given in WY 2016 to measure streamflow at higher stages in order to improve the upper end of the rating curve and to track any potential rating shifts in greater detail. A point of zero flow (the measured gage height where discharge equals zero) will also be determined in WY 2016 which will improve confidence in the interpretation of rating position, shape, and shift.

Due to equipment malfunctions, large and significant gaps exist in rainfall data collected from the East and West Branch rain gages, including the largest storms of the season. Total annual (17.48 inches) and max daily (2.58 inches on March 9, 2014) precipitation amounts from Woodley Island (Eureka, CA) have been used as a surrogate for both East and West Branch stations, but these totals are not ideal given the proximity of Woodley Island to the Railroad Gulch watershed (approximately 10 miles). Further complications regarding the Woodley Island rain gage also include its proximity to the ocean, which negates orographic effects. Furthermore, personal observations suggest that Railroad Gulch receives a greater amount of rain than Woodley Island during storm events. A relationship will be developed between Woodley Island and Railroad Gulch study site rain gages in order to better estimate WY 2014-15 precipitation. New rain gages were installed prior to WY 2016 that are more reliable and set in pairs to provide better data continuity. Bi-weekly visits to download data and verify correct functioning will also be instituted.

Fourteen individual storms were delineated within the Railroad Gulch basin during WY 2014. At the East Branch gaging station sampling occurred during ten of these events. Ten segments were defined that estimated the sediment load produced during each storm, the summation of which resulted in a total annual estimate of 63 Mg (49 Mg/km^2) (Table 8). Figure 13 illustrates the continuous annual record of concentration and streamflow and Figure 14 depicts sediment load contribution per storm event. The majority of the annual load (approximately 52 Mg, 82% of total) was generated during a single storm event that peaked on March 9, 2014 (Storm 1409). This result is supported by the precipitation record at Woodley Island which indicates that annual maximum daily rainfall occurred on the same date (2.58 inches, 15% of total annual precipitation). The second largest sediment load was measured during Segment 1410 (approximately 6 Mg, 9% of total) due to two relatively large late season storms (Storms 1410 and 1411) which peaked on March 29 and 31, 2014, respectively. Sampling occurred throughout Storm 1410 but all but one sample was collected on the falling limb of Storm 1411. Therefore samples from both Storm 1410 and 1411 were included in the Segment 1410 regression model, which was fit by two unique equations. 1.72 inches of precipitation were recorded at Woodley Island during this period (March 28 – April 1, 2014) which helps explain the relatively high load measured during this segment. Sampling did not occur during the relatively small-scale Storms 1412-1414 which occurred near the end of the monitoring season. This time period was grouped into Segment 1410 in order to estimate late-season loading.

During a storm event, turbidity-SSC relationships oftentimes fluctuate during periods of rising or falling turbidities, a phenomenon that was observed in all but two of the ten WY 2014 delineated storms. During Storm 1404, turbidity-SSC relationships were static throughout the event and data were fit with a single regression. For all other WY 2014 storms, exclusive regressions were fit for unique sets of turbidity and SSC data in order to improve sediment load estimation. Figure 15 provides an example of the latter approach as applied to data collected during Segment 1410 which included samples from Storms 1410 and 1411. Estimated SSC was found to be in close agreement with measured samples.

Total sediment loads were also calculated using a single linear fit and a single power fit through all turbidity-SSC data in order to serve as a comparison to the sum-of-storms method described above. Single regression methods under-predicted total sediment loading in the East Branch as the total load was estimated to equal 44 Mg (42% difference to storm event method) using a single power fit and 53 Mg (19% difference) using a single linear fit. As a result the sum-of-storms method appears to best represent WY 2014 sediment loading in the East Branch.

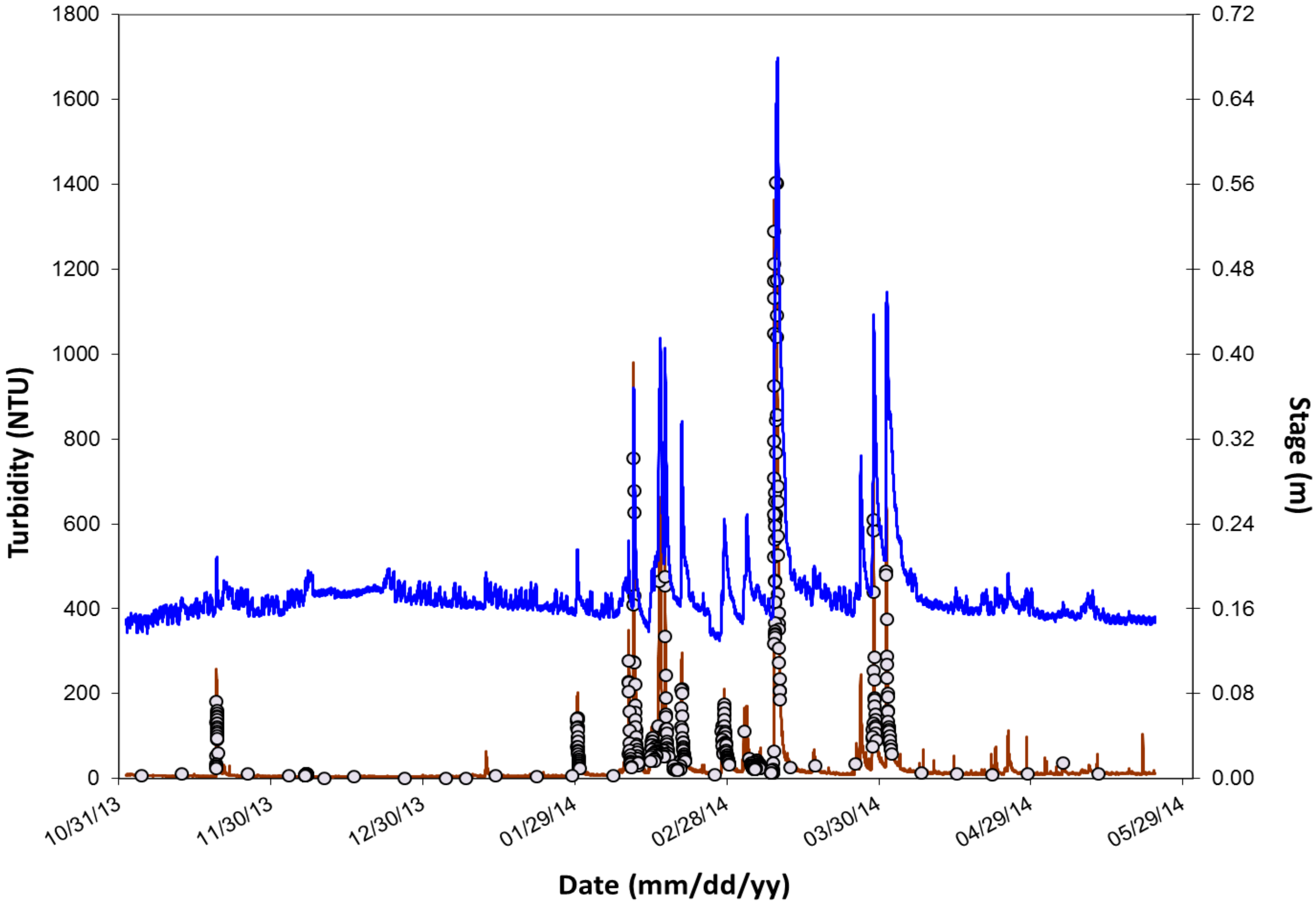


Figure 11. Annual Stage and Turbidity Hydrograph, WY 2014 East Branch Railroad Gulch (Station 684), Elk River, CA. Blue line: stage (m); brown line: turbidity (NTU); white circles: turbidity (NTU) measured in collected stream samples.

Table 7. Hydrologic Statistics for WY 2014 East Branch (Station 684) and West Branch (Station 683), Railroad Gulch, Elk River, CA. Monitoring Period: November 1, 2013 - May 23, 2014.

Station Number	Drainage Area (km^2)	Sediment Load (Mg)	Sediment Yield (Mg/km^2)	% Time Turbidity >25 NTU	Mean Discharge (m^3/s)	Peak Discharge (m^3/s)	Peak Discharge ($m^3/s/km^2$)
684	1.28	63	49	16%	0.01	0.42	0.33
683	1.48	57	38	15%	0.01	0.36	0.24

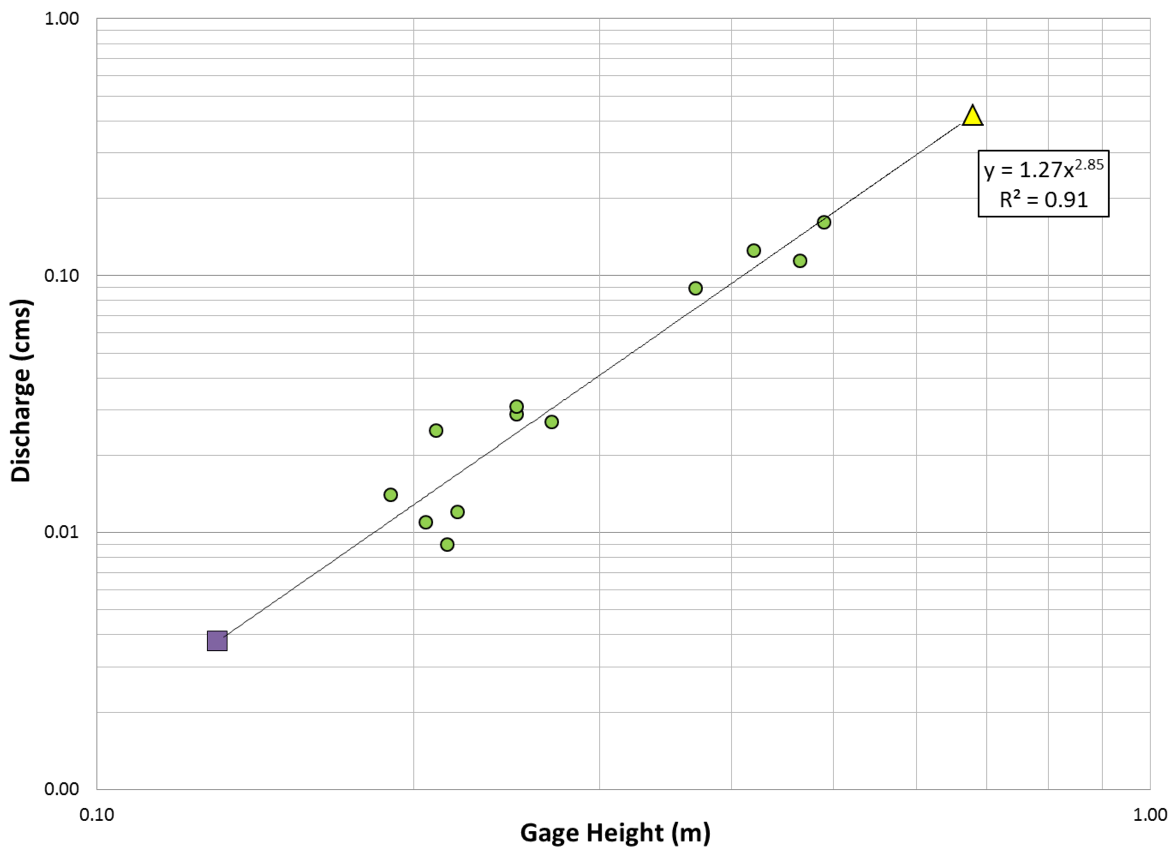


Figure 12. Stage-Discharge Rating Curve, WY 2014 East Branch Railroad Gulch (Station 684), Elk River, CA. Green circles: stream discharge measured at various stages throughout the water year; Purple square: minimum stage vs. minimum discharge; Yellow triangle: maximum stage vs. peak discharge.

Table 8. Sediment load statistics per storm event, WY 2014 East Branch Railroad Gulch, Elk River, CA (Station 684).

Segment Number	Storm Number	Begin Segment Range	End Segment Range	Load (Mg)	Load (Mg/km2)	Percent of Total
1401	1401	11/1/2013 11:45	1/29/2014 06:45	0.36	0.28	0.006
1402	1402	1/29/2014 07:00	2/6/2014 15:30	0.06	0.04	0.001
1403	1403	2/6/2014 15:45	2/9/2014 11:45	0.12	0.10	0.002
1404	1404	2/9/2014 12:00	2/13/2014 16:15	0.99	0.77	0.016
1405	1405	2/13/2014 16:30	2/18/2014 19:15	3.08	2.41	0.049
1406	1406	2/18/2014 19:30	2/26/2014 21:45	0.44	0.35	0.007
1407	1407	2/26/2014 22:00	3/3/2014 05:15	0.22	0.17	0.003
1408	1408	3/3/2014 05:30	3/8/2014 16:30	0.22	0.18	0.004
1409	1409	3/8/2014 16:45	3/28/2014 13:45	51.64	40.34	0.820
1410	1410-1414	3/28/2014 14:00	5/23/2014 12:15	5.87	4.58	0.093
Total				63.00	49.22	1.00

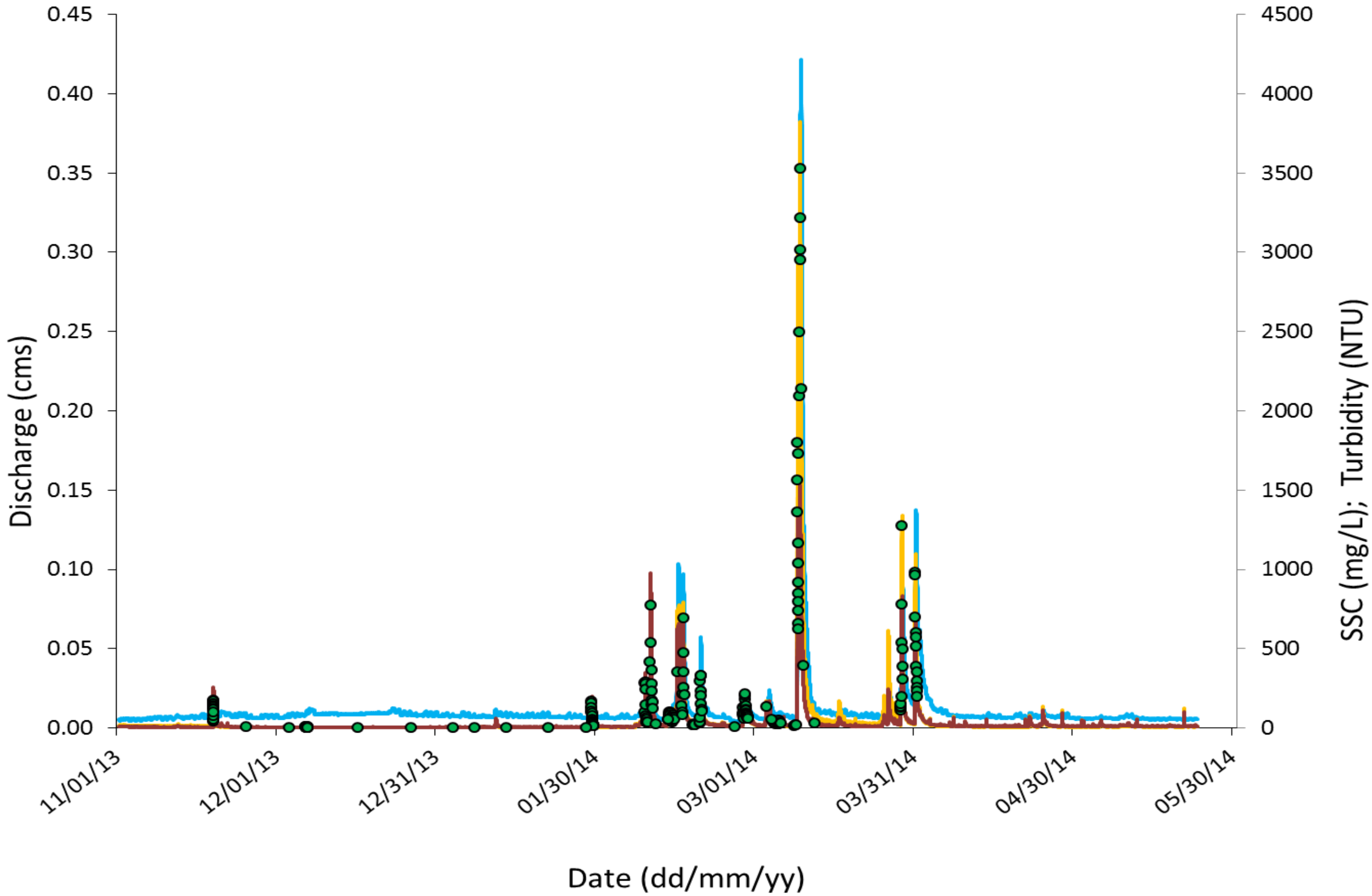


Figure 13. Annual Streamflow and SSC Hydrograph, WY 2014 East Branch Railroad Gulch (Station 684), Elk River, CA. Blue line: discharge (cms); tan line: SSC (mg/L); green circles: SSC measured in collected stream samples.

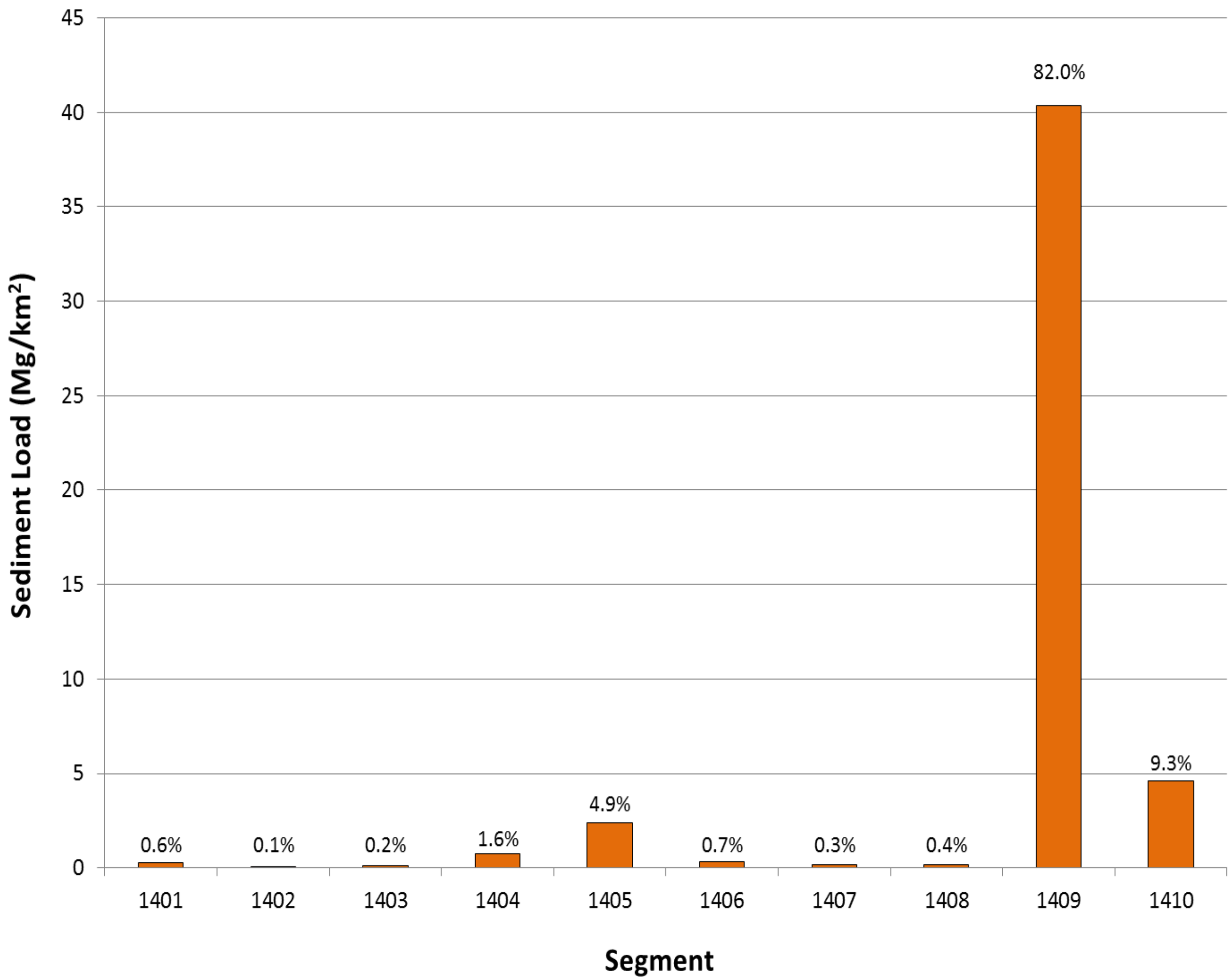
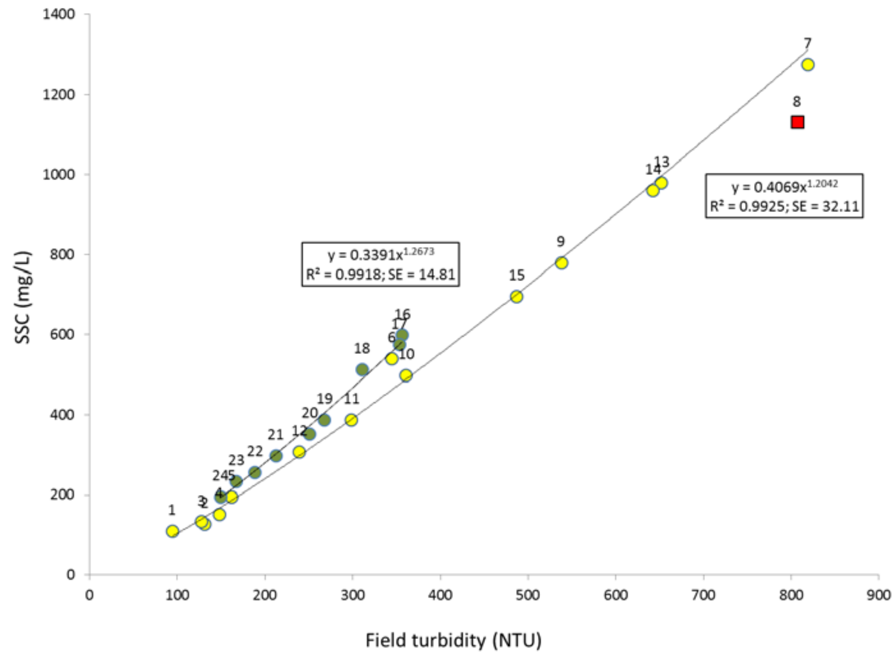


Figure 14. Sediment load (Mg/km^2) per delineated segment of WY 2014 in East Branch Railroad Gulch (Station 684), Elk River, CA. Percentage values above each bar indicate percent contribution of each segment to the annual load.



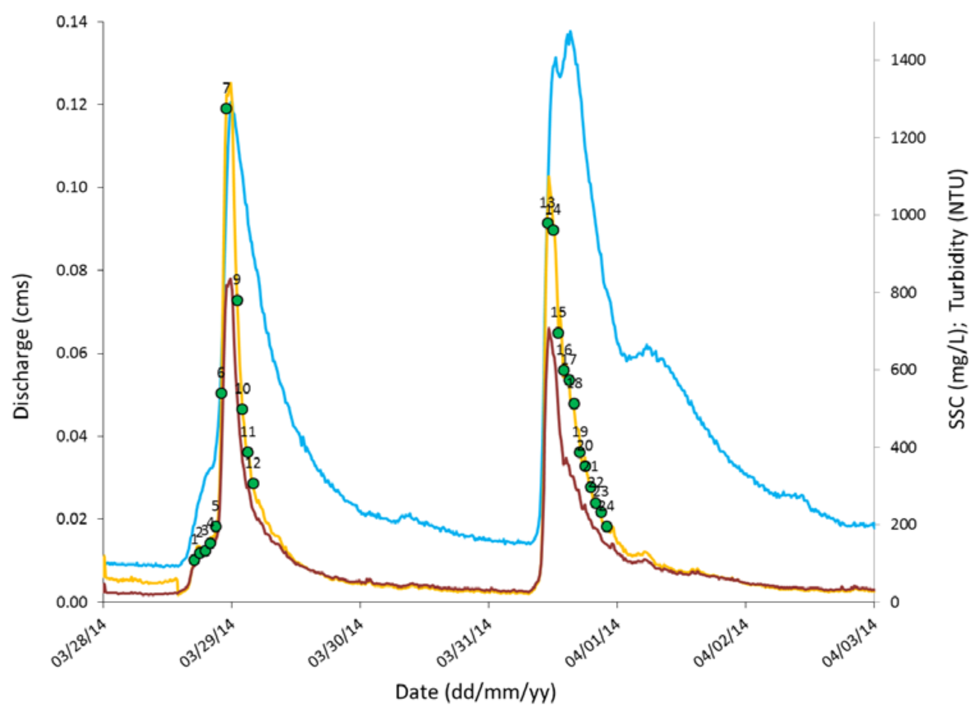


Figure 15 Above: Field turbidity (NTU) vs. measured SSC (mg/L) in samples collected during Storms 1410 and 1411 (March 29-April 2, 2014) in East Branch Railroad Gulch (Station 684), Elk River, CA. Yellow circles: samples collected through Storm 1410 and into the falling limb of Storm 1411. Green circles: the falling turbidity limb of Storm 1411. Red squares: flagged outliers that were not included in the analysis. Below: Measured SSC (mg/L, green circles), estimated SSC (mg/L, yellow line), discharge (cms, blue line), and field turbidity (NTU, red line) throughout Storms 1410 and 1411. Numeric values above each data point indicate the order in which the samples were collected.

Discussion of West Branch Hydrology Station Data WY 2014

A complete record of turbidity and stage was collected throughout WY 2014 at the West Branch gaging station (Figure 16). Flows followed a similar trend as those in the East Branch as they were generally low throughout the water year. Streamflow, turbidity, and loading data are provided in Table 7. Field turbidity peaked at 1733 NTU and exceeded 25 NTU for 15% of the period of record, approximately the same duration as measured in the East Branch. The WY 2014 rating curve was fit with a single regression (R^2 = 0.98) with minimal scatter on both the lower and upper ends (Figure 17). The highest measurement of streamflow conducted by staff equaled 0.12 cms at 0.28 meters on the gage plate. As was the case at the East Branch station, continuous discharge estimation was extrapolated beyond the empirical range as annual peak stage (as recorded by the pressure transducer) equaled 0.36 meters with corresponding peak discharge estimated to equal 0.36 cms. A point of zero flow will be measured in WY 2016 for this station and more high flow discharge measurements will be targeted in order to improve confidence in the lower and upper ends of the rating curve, respectively.

Sampling occurred during eight of the designated fourteen storm events of WY 2014. Eight segments were delineated that estimated the sediment load produced during each storm, the summation of which resulted in approximately 57 Mg (38Mg/km^2) (Table 9). Per unit area, this load was approximately 11% lower than that measured in the East Branch. As was the case in the East Branch, the vast majority of the annual load in the West Branch (approximately 4 Mg, 77% of total) was generated during the March 9, 2014 (Storm 1409) storm event. The second largest sediment load (approximately 6 Mg, 10% of total) was measured at the end of the season during Segment 1410 which included two relatively large late-season storms (Storms 1410 and 1411) which peaked on March 29 and 31, 2014, respectively. As was the case at the East Branch station, sampling occurred throughout Storm

1410 but was incomplete during Storm 1411 as all but one sample was collected on the falling turbidity limb. Therefore samples from both Storm 1410 and 1411 were treated in the same manner as those collected in the East Branch as they were included in the Segment 1410 regression model, which was fit by two unique equations. Sampling did not occur during Storms 1401 or 1406. These time periods were grouped in Segments 1402, 1405, respectively. Sampling also did not occur during three relatively small-scale storms which occurred near the end of the monitoring season (Storms 1412-1414). This time period was grouped into Segment 1410 in order to estimate late-season loading. Figure 18 depicts annual concentration and streamflow and Figure 19 illustrates sediment load contribution per storm event. Turbidity-SSC data were fit with a single regression for Storms 1402, 1404, 1405, and 1408. Multiple regressions were used for all other storm event datasets during which concentration fluctuated relative to rising and falling turbidity. Figure 20 illustrates dynamic turbidity-SSC relationships measured during Storm 1409 where three unique regressions were calculated and applied to different periods of data. Estimated SSC was found to be in close agreement with measured samples.

Total sediment loads were also calculated using a single linear fit through all WY 2015 turbidity-SSC data in order to serve as a comparison to the sum-of-storms method described above. A single regression method under-predicted total sediment loading in the West Branch as the total load was estimated to equal 43 Mg (31% difference to storm event method) using a single linear fit. As was the case in the East Branch, the sum-of-storms method appeared to best estimate sediment loading in the West Branch.

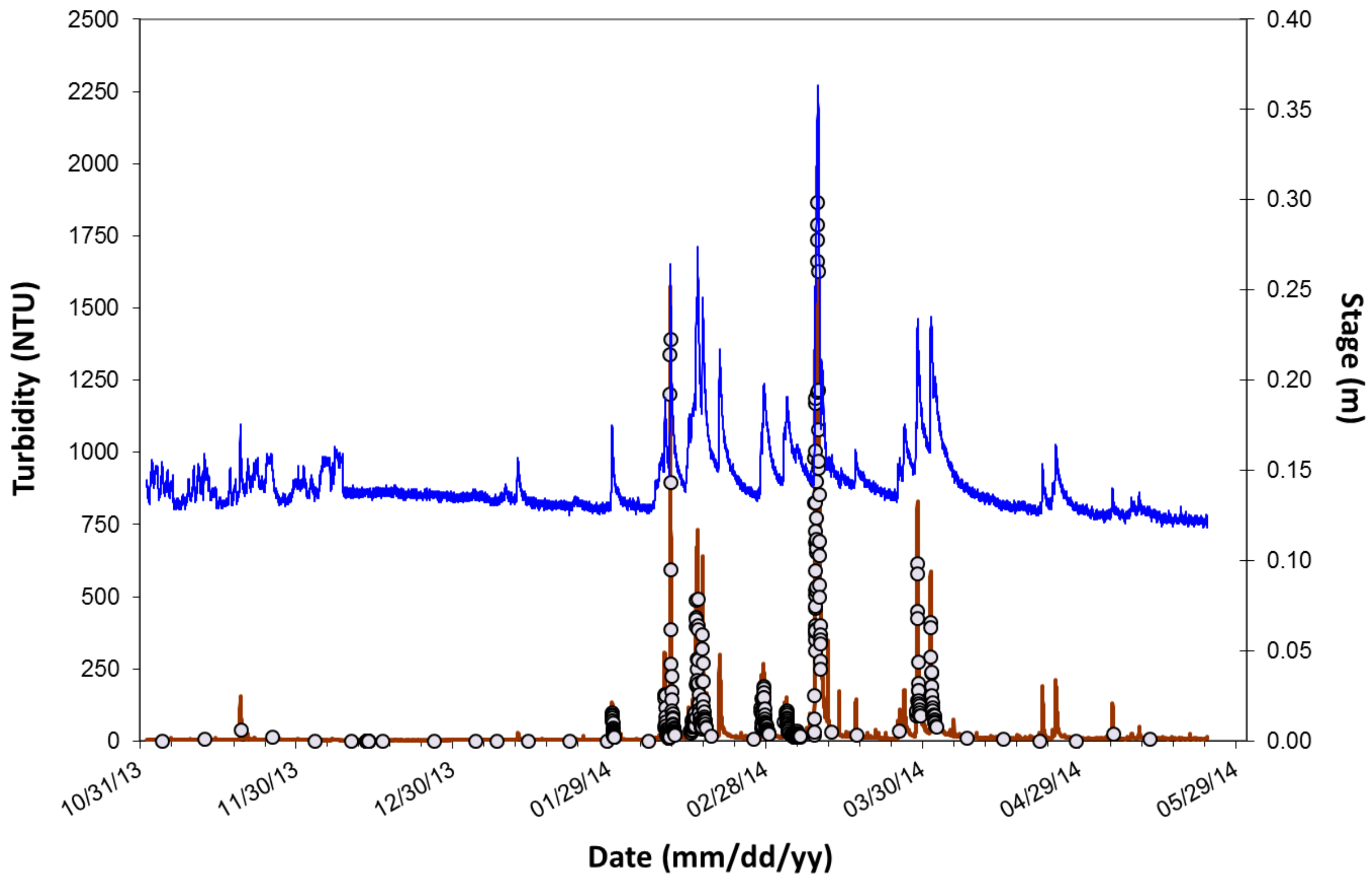


Figure 16. Annual stage and turbidity hydrograph, WY 2014 West Branch Railroad Gulch (Station 683), Elk River, CA. Blue line: stage (m); brown line: turbidity (NTU); white circles: turbidity (NTU) measured in collected stream samples.

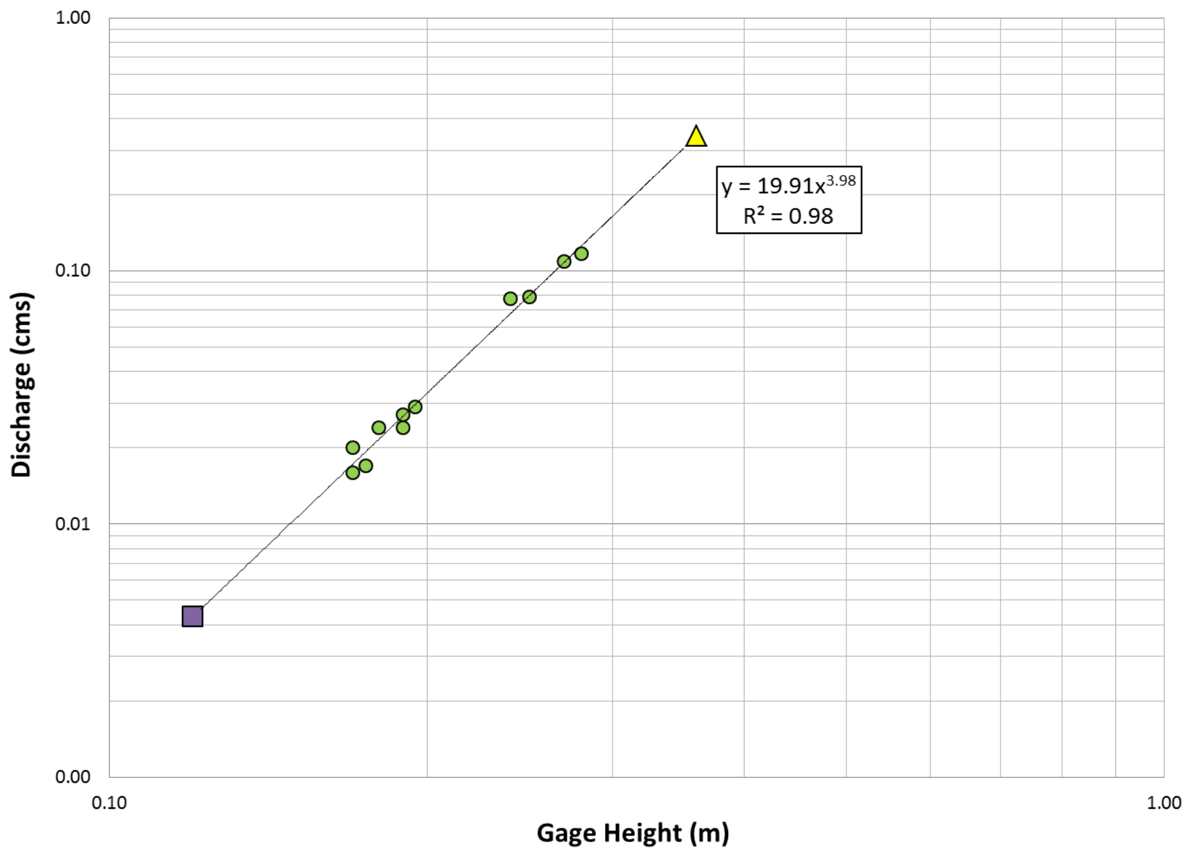


Figure 17. Stage-Discharge Rating Curve, WY 2014 West Branch Railroad Gulch (Station 683), Elk River, CA. Green circles: stream discharge measured at various stages throughout the water year; Purple square: minimum stage vs. minimum discharge; Yellow triangle: maximum stage vs. peak discharge.

Table 9. Sediment load statistics per storm event, WY 2014 West Branch Railroad Gulch, Elk River, CA (Station 683).

Segment Number	Storm Number	Begin Segment Range	End Segment Range	Load (Mg)	Load (Mg/km2)	Percent of Total
1402	1401-1402	11/1/2013 08:45	2/6/2014 15:30	0.25	0.17	0.004
1403	1403	2/6/2014 15:45	2/9/2014 11:45	0.13	0.09	0.002
1404	1404	2/9/2014 12:00	2/13/2014 16:15	1.73	1.17	0.030
1405	1405-1406	2/13/2014 16:30	2/26/2014 21:45	4.81	3.25	0.085
1407	1407	2/26/2014 22:00	3/3/2014 05:15	0.31	0.21	0.005
1408	1408	3/3/2014 05:30	3/9/2014 04:15	0.23	0.15	0.004
1409	1409	3/9/2014 04:30	3/28/2014 13:45	43.57	29.44	0.769
1410	1410-1414	3/28/2014 14:00	5/23/2014 11:30	5.61	3.79	0.099
Total				56.63	38.26	1.00

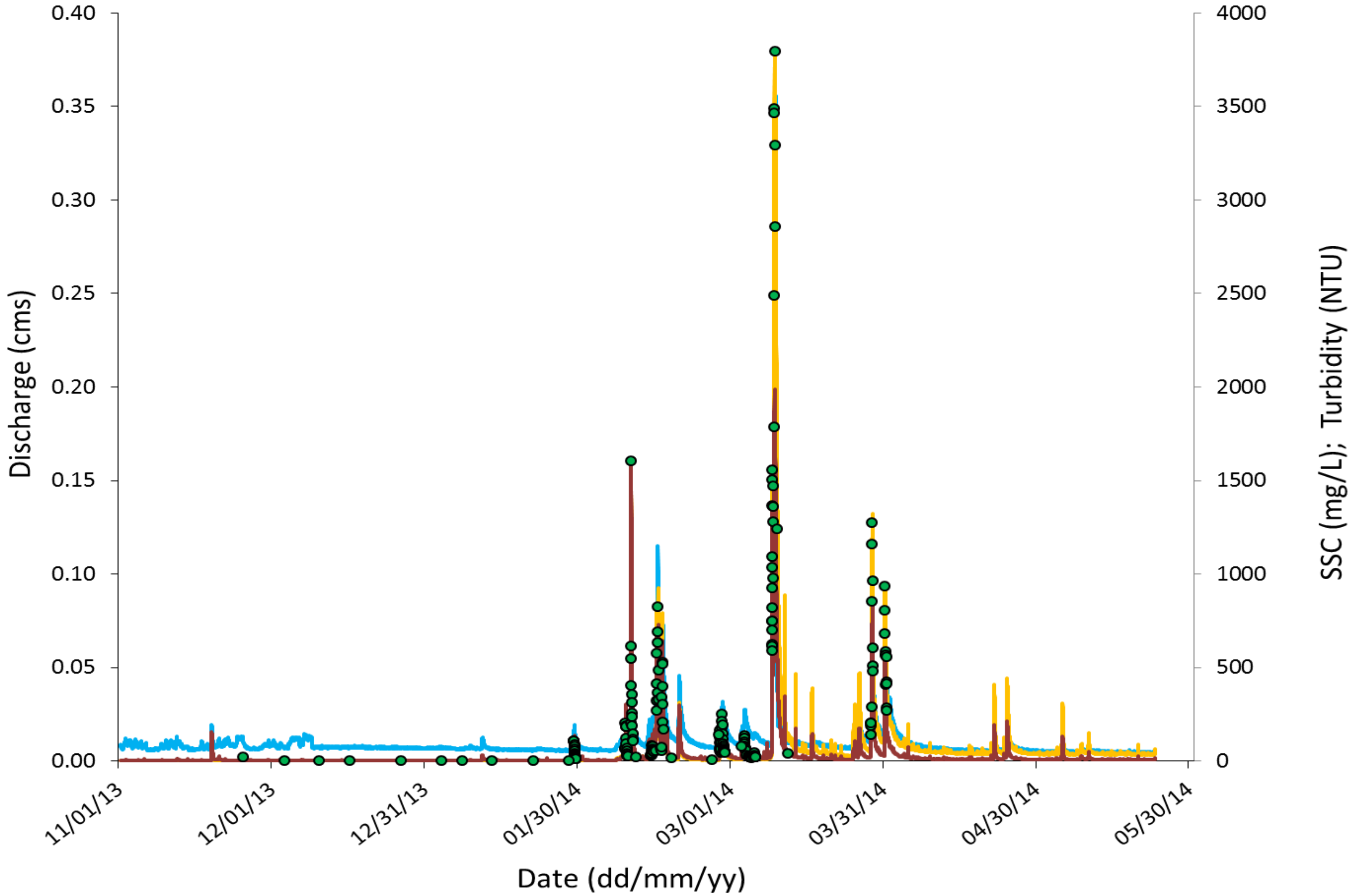


Figure 18. Annual Streamflow and SSC Hydrograph, WY 2014 West Branch Railroad Gulch (Station 683), Elk River, CA. Blue line: discharge (cms); tan line: SSC (mg/L); green circles: SSC measured in collected stream samples.

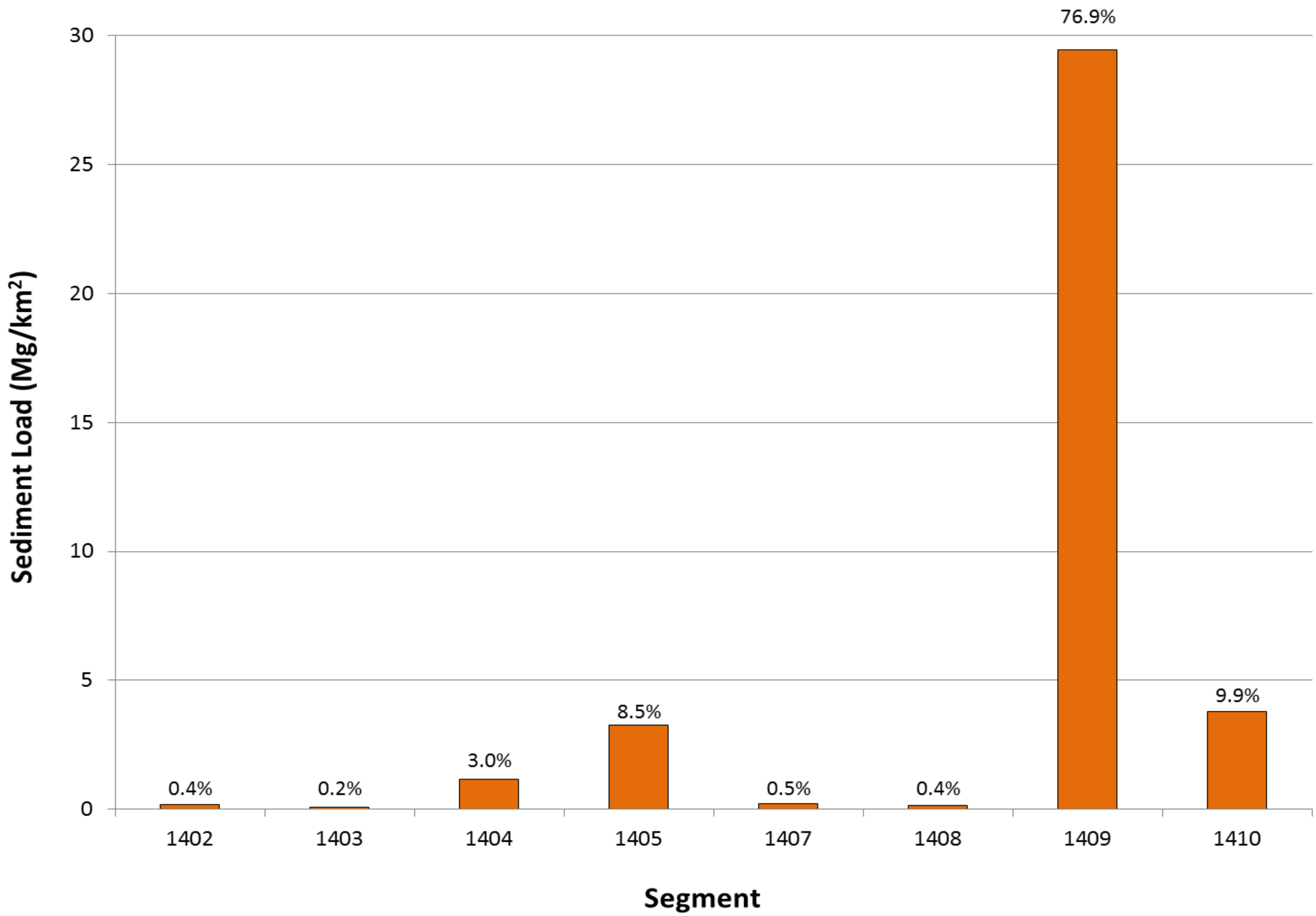


Figure 19. Sediment load (Mg/km²) per delineated segment of WY 2014 in West Branch Railroad Gulch (Station 683), Elk River, CA. Percentage values above each bar indicate percent contribution of each storm to the total annual load.

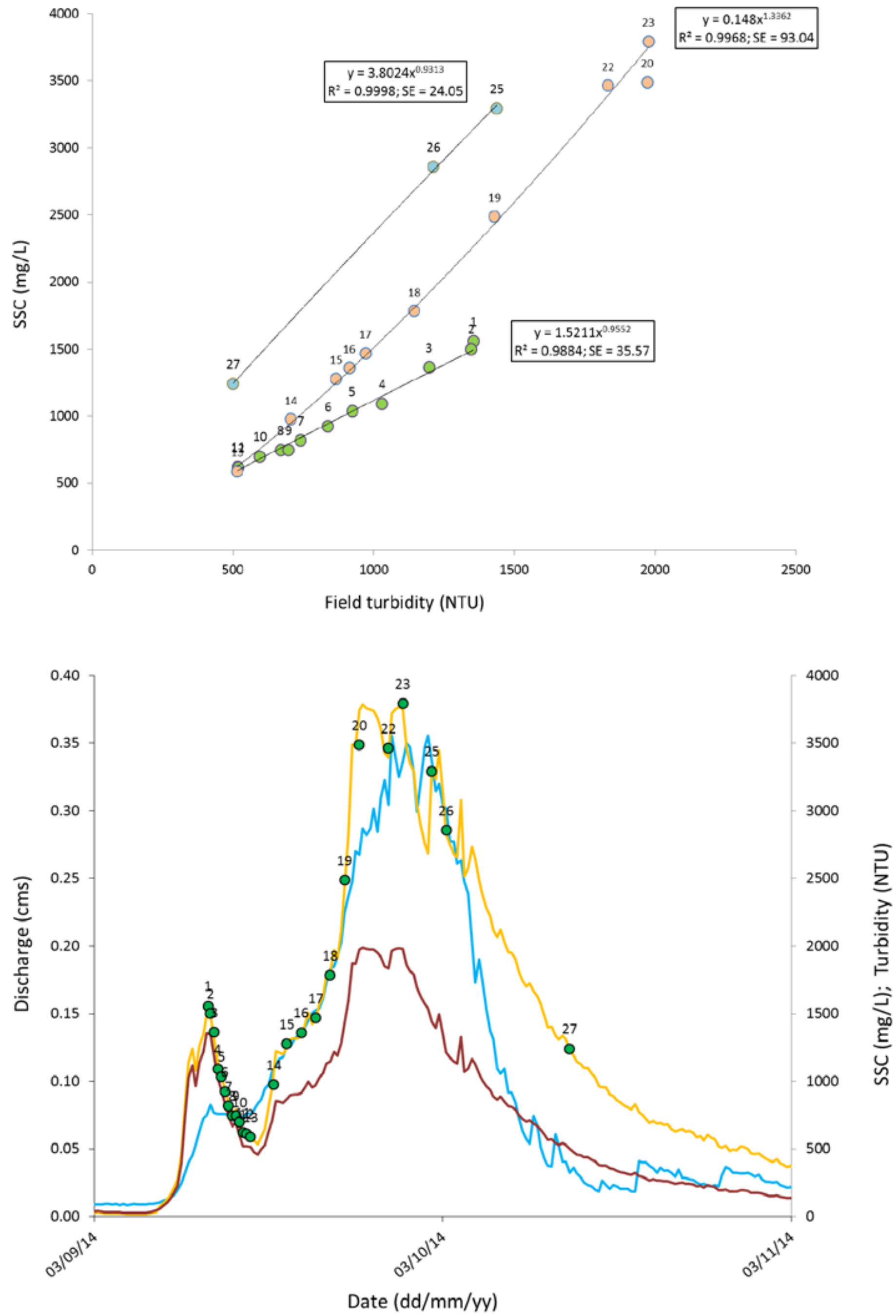


Figure 20. Turbidity (NTU) vs. SSC (mg/L) measured in samples collected during Storm 1409 (March 9, 2014) storm event West Branch Railroad Gulch (Station 683), Elk River, CA. Green circles: the initial falling turbidity limb, pink circles: the second and more pronounced rising turbidity limb and peak, blue circles: the falling turbidity limb. Below: Measured SSC (mg/L, green circles), estimated SSC (mg/L, yellow line), discharge (cms, blue line), and field turbidity (NTU, red line) throughout Storm 1409. Numeric values above each data point indicate the order in which the samples were collected.

Discussion of East Branch Water Quality Data: WY 2015

A complete record of turbidity and stage was collected throughout WY 2015 at the East Branch gaging station (Figure 21). Streamflow increased slightly from WY 2014 to WY 2015 but was still relatively low due to persistent drought conditions. Streamflow, turbidity, and loading results are provided in Table 10. Field turbidity peaked at 4728 NTU and exceeded 25 NTU for 28% of the period of record. The WY 2015 rating curve was fit with a single regression (R^2 = 0.9919) and includes WY 2014 and WY 2015 streamflow measurements (Figure 22). The rating appears to have shifted slightly in WY 2015 as lower discharge was measured relative to gage height in WY 2015 than in WY 2014 at low-to-medium stages. However aggradation was not evidenced at the end of the season during the WY 2015 cross section profile and too few low-flow discharge measurements were conducted to precisely define the low-flow regime. Select WY 2014 streamflow measurements were thus excluded from the WY 2015 rating data as they did not appear to represent WY 2015 channel conditions. The largest streamflow measurement conducted by staff in WY 2015 equaled 0.245 cms at 0.60 meters on the gage plate. Peak stage (as recorded by the pressure transducer) equaled 1.08 meters with corresponding peak discharge estimated at 1.56 cms. These data indicate a significant increase in both peak flow (~375%) and peak turbidity (309%) from WY 2014 to WY 2015 but these are not totally unexpected results given that total measured precipitation increased nearly 75% from WY 2014 (annual total = 17.48 inches) to WY 2015 (annual total = 30.56 inches) as measured at the Woodley Island station in Eureka, CA.

Overall, WY 2015 was a wetter year than WY 2014 with larger and more prolonged storm events. The WY 2015 rainfall dataset is incomplete for both East and West Branch stations due to reasons discussed in the WY 2014 section. Precipitation amounts from the Woodley Island station in Eureka, CA are thus used as a surrogate for both stations but, as previously mentioned these data likely underestimate rainfall in the Railroad Gulch drainage basin. While total annual precipitation was 75%

greater in WY 2015 than in WY 2014, max daily precipitation (1.66 inches on April 6, 2015, 5% of annual total) was approximately 56% lower.

Eighteen individual storms were delineated within the Railroad Gulch basin during WY 2015. At the East Branch gaging station sampling occurred during thirteen of these events. Thirteen segments were delineated that estimated the sediment load produced during each storm, the summation of which resulted in a total annual sediment load of approximately 1102 Mg (861 Mg/km^2) (Table 11). This is more than 17 times higher than that of the previous year. Figure 23 illustrates the continuous annual record of concentration and streamflow. High loading occurred despite minimal precipitation due to two intense rainfall events (Storms 1512 and 1517) that triggered landslides and initiated bed scour. The first, Storm 1512, peaked on February 6, 2015 and generated an estimated sediment load of approximately 437 Mg (40% of annual total). The second (Storm 1517) peaked on April 7, 2015 and delivered an estimated sediment load of approximately 331 Mg (30% of annual total). As discussed above, the maximum annual amount of daily rainfall occurred during Storm 1517 but a total of 4.56 inches (15% of annual total) of rain was recorded from February 2-9, 2015 at Woodley Island which helps explain the high load delivered during Storm 1512 in East Branch Railroad Gulch. Sampling did not occur during Storms 1506 and 1509-1511. Regression models constructed from Segment 1505 and 1508 were used to estimate concentrations during these storms, respectively. Figure 24 illustrates sediment load contribution per storm event during WY 2015. Turbidity-SSC data were fit with a single regression for Storms 1501, 1504, 1515, 1516, 1518. Multiple regressions were used for Storms 1502, 1504, 1505, 1507, 1508, 1512, 1513, 1514, and 1517 during which concentration fluctuated relative to rising and falling turbidity. Figure 25 illustrates dynamic turbidity-SSC relationships measured during Storm 1513 where three unique regressions were calculated and applied to different periods of data. Field turbidity exceeded the range of the DTS-12 turbidimeter (~1600 NTU) during five storm events (1502, 1504, 1508, 1512, and 1517) of WY 2015 (23 total hours, 0.004% of the monitoring period). Lab turbidity analysis of samples collected during these periods indicates that the field sensor was under-predicting turbidity, particularly near the peak of each event. Peak turbidity was re-constructed during these storms using a model that regressed lab turbidity against field turbidity with samples collected during the rest of WY 2015. A linear equation (R^2 = 0.9584) derived from this model was applied to intervals of field turbidity data with an associated lab sample. Linear interpolation was then performed in order to extrapolate field turbidity during intervals between samples.

Total sediment loads were also calculated using a single linear fit and a single power fit through all turbidity-SSC data in order to serve as a comparison to the sum-of-storms method described above. Single regression methods under-predicted total sediment loading in the East Branch as the total load was estimated to equal 818 Mg (35% difference to storm event method) using a single power fit and 797 Mg (38% difference) using a single linear fit.

Other problems encountered during the WY 2015 monitoring season at the East Branch station included a water sampler battery failure during Storm 1512 which prevented sampling during the rising limb and peak of the event. The issue was ultimately resolved and sampling was resumed during the latter half of the storm. Estimated concentration may be over-predicted during the period leading up to peak of the event given this lack of thorough sampling, particularly during the first two pulses of turbidity (Figure 26).

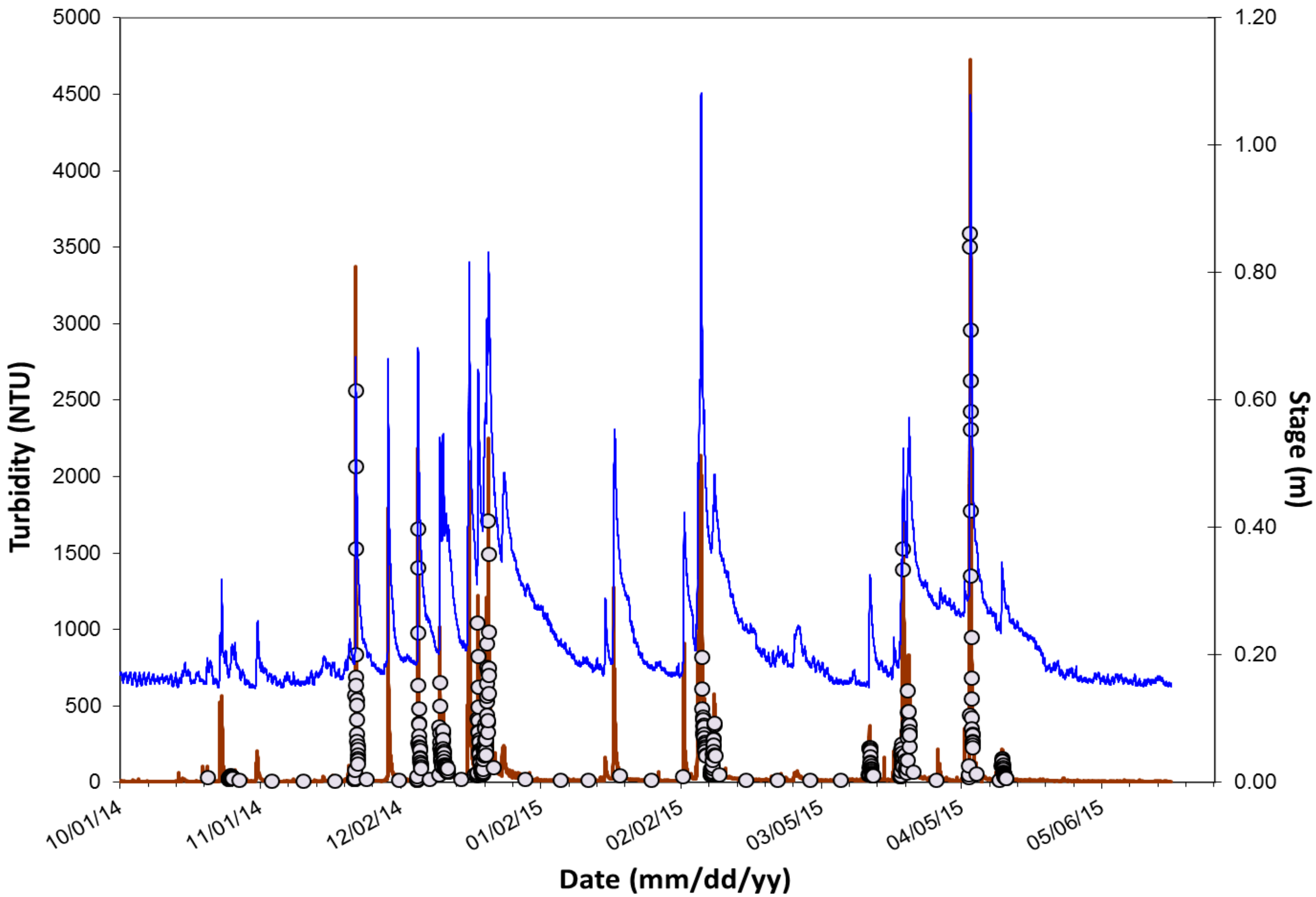


Figure 21. Annual Stage and Turbidity Hydrograph, WY 2015 East Branch Railroad Gulch (Station 684), Elk River, CA. Blue line: stage (m); brown line: turbidity (NTU); white circles: turbidity (NTU) measured in collected stream samples.

Table 10. Hydrologic Statistics for WY 2015 East Branch (Station 684) and West Branch (Station 683), Railroad Gulch, Elk River, CA. Monitoring Period: October 1, 2014 - May 21, 2015.

Station Number	Drainage Area (km^2)	Sediment Load (Mg)	Sediment Yield (Mg/km^2)	% Time Turbidity >25 NTU	Mean Discharge (m^3/s)	Peak Discharge (m^3/s)	Peak Discharge ($m^3/s/km^2$)
684	1.28	1102	861	28%	0.03	1.6	1.2
683	1.48	1060	716	30%	0.04	2.0	1.3

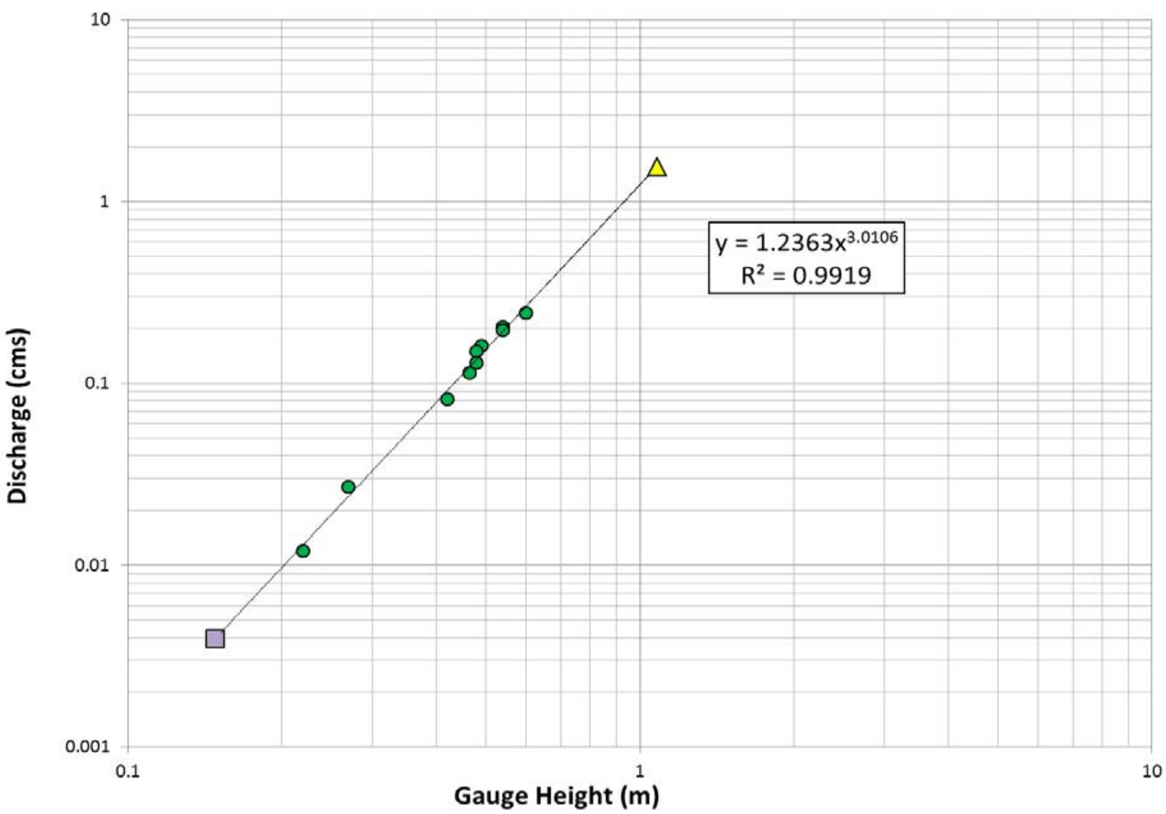


Figure 22. Stage-Discharge Rating Curve, WY 2015 East Branch Railroad Gulch (Station 684), Elk River, CA. Green circles: stream discharge measured at various stages throughout the water year; Purple square: minimum stage vs. minimum discharge; Yellow triangle: maximum stage vs. peak discharge.

Table 11. Sediment load statistics per storm event, WY 2015 East Branch Railroad Gulch (Station 684), Elk River, CA.

Segment Number	Storm Number	Begin Segment Range	End Segment Range	Load (Mg)	Load (Mg/km2)	Percent of Total
1501	1501	10/1/2014 0:00	11/21/2014 17:30	1.05	0.82	0.001
1502	1502-1503	11/21/2014 17:45	12/5/2014 16:45	31.53	24.63	0.029
1504	1504	12/5/2014 17:00	12/10/2014 13:45	16.90	13.20	0.015
1505	1505-1506	12/10/2014 14:00	12/18/2014 23:30	37.87	29.59	0.034
1507	1507	12/18/2014 23:45	12/19/2014 17:45	19.21	15.00	0.017
1508	1508-1511	12/19/2014 18:00	2/5/2015 5:30	190.23	148.62	0.173
1512	1512	2/5/2015 5:45	2/8/2015 20:30	437.21	341.57	0.397
1513	1513	2/8/2015 20:45	3/15/2015 9:45	4.05	3.17	0.004
1514	1514	3/15/2015 10:00	3/20/2015 20:30	0.39	0.30	0.000
1515	1515	3/20/2015 20:45	3/23/2015 21:00	12.48	9.75	0.011
1516	1516	3/23/2015 21:15	4/5/2015 11:30	19.27	15.06	0.017
1517	1517	4/5/2015 11:45	4/13/2015 17:00	330.85	258.48	0.300
1518	1518	4/13/2015 17:15	5/21/2015 8:15	0.48	0.37	0.0004
Total				1101.51	860.55	1.00

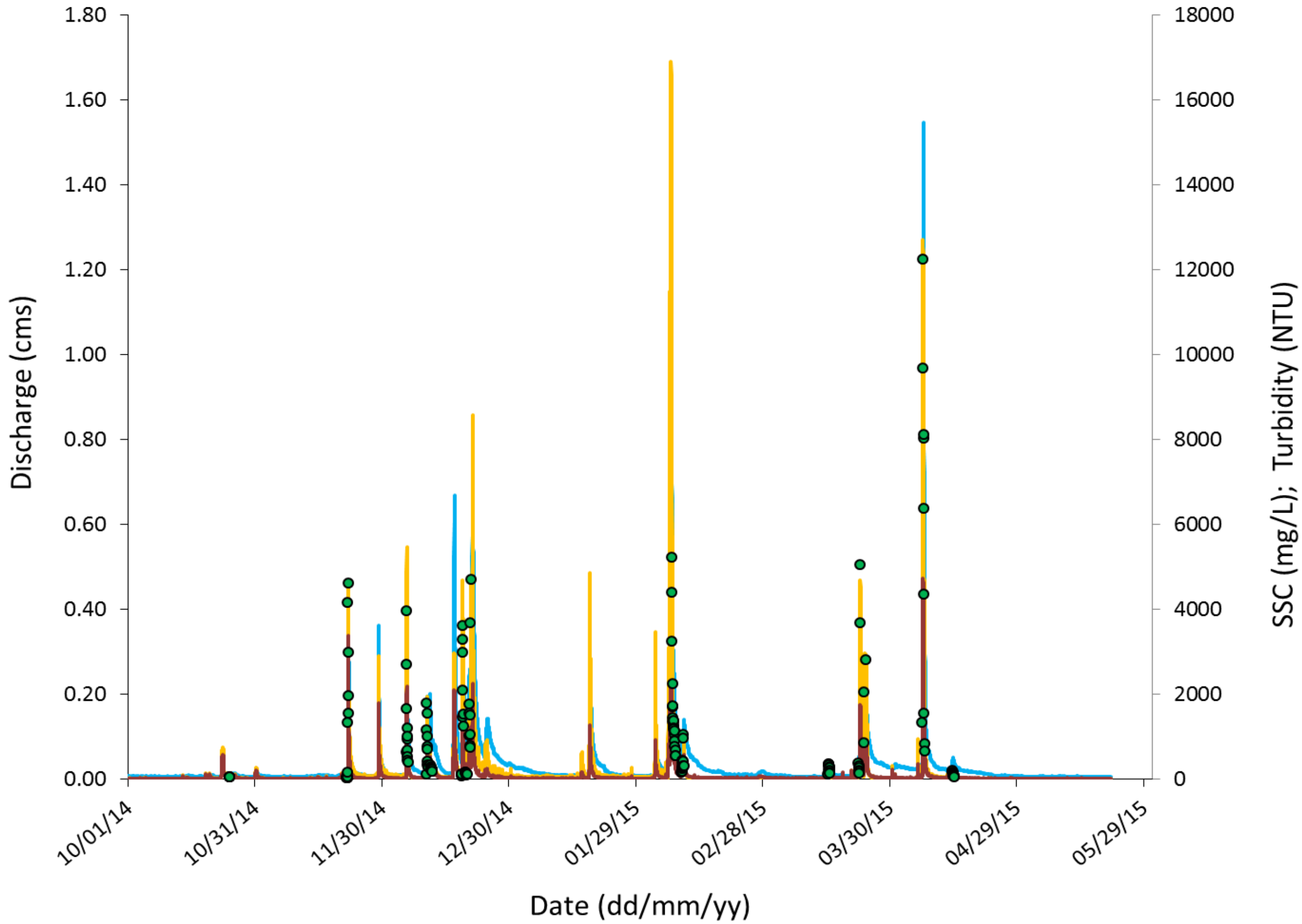


Figure 23. Annual Streamflow and SSC Hydrograph, WY 2015 East Branch Railroad Gulch (Station 684), Elk River, CA. Blue line: discharge (cms); tan line: SSC (mg/L); green circles: SSC measured in collected stream samples.

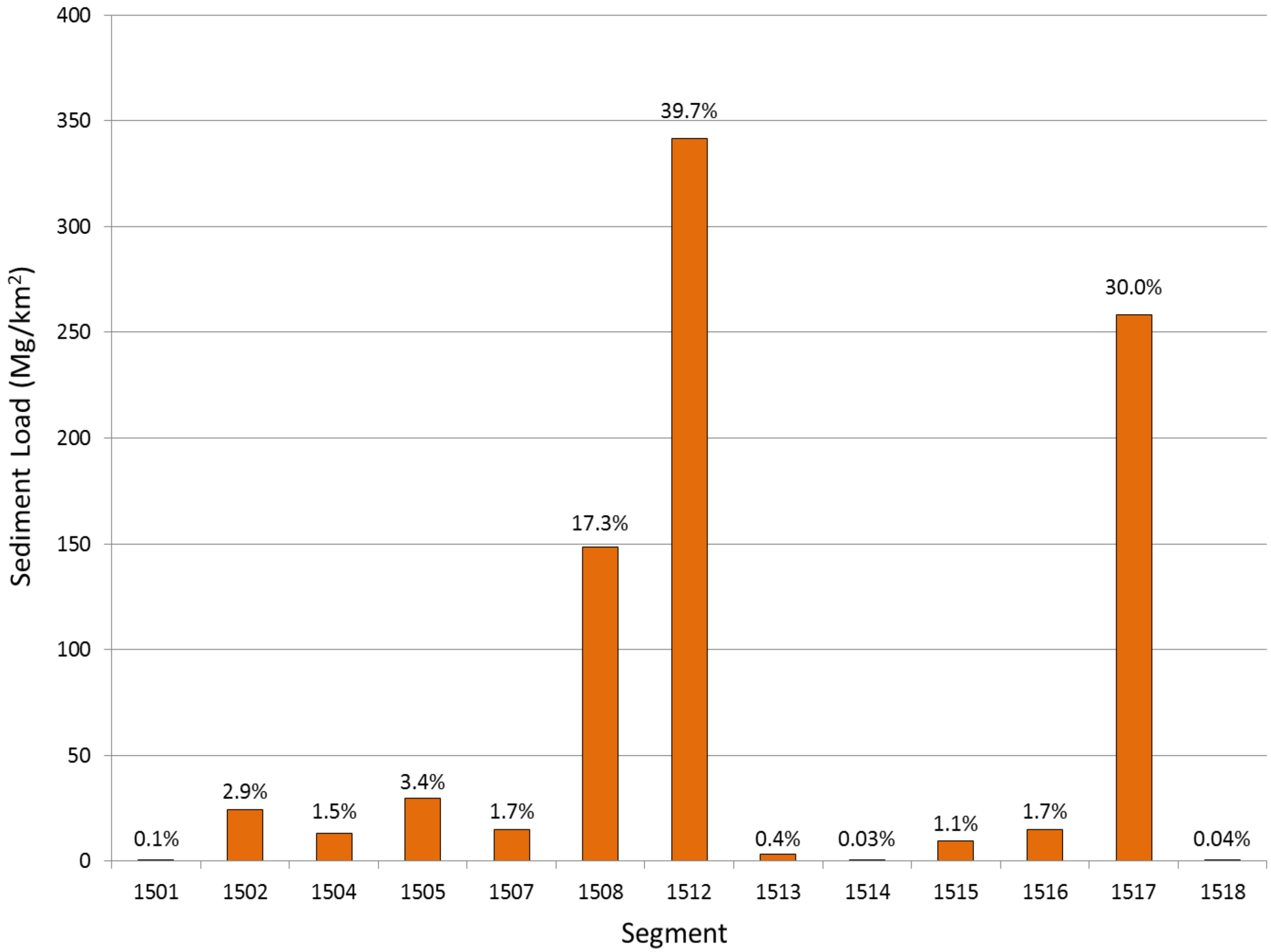


Figure 24. Sediment load (Mg/km^2) per delineated segment of WY 2015 in East Branch Railroad Gulch (Station 684), Elk River, CA. Percentage values above each bar indicate percent contribution of each storm to the total annual load.

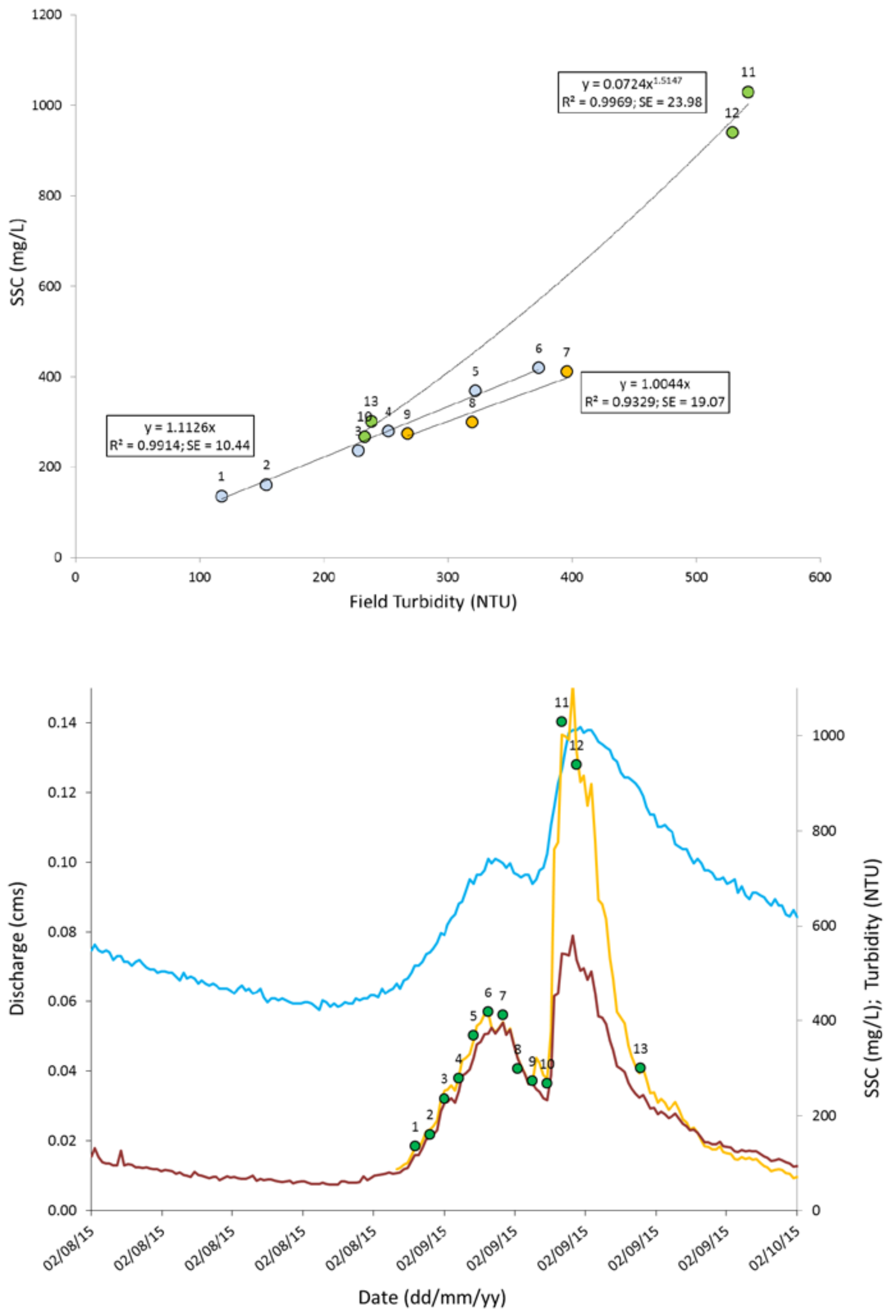


Figure 25. Above: Field turbidity (NTU) vs. measured SSC (mg/L) in samples collected during Storm 1513 (February 9, 2015) in East Branch Railroad Gulch (Station 684), Elk River, CA. Light blue circles: the initial rising turbidity limb of event, orange circles: the initial falling limb, green circles: the second rising limb, peak turbidity, and falling limb of the event. Below: Measured SSC (mg/L, green circles), estimated SSC (mg/L, yellow line), discharge (cms, blue line), and field turbidity (NTU, red line) throughout Storm 1513. Numeric values above each data point indicate the order in which the samples were collected.

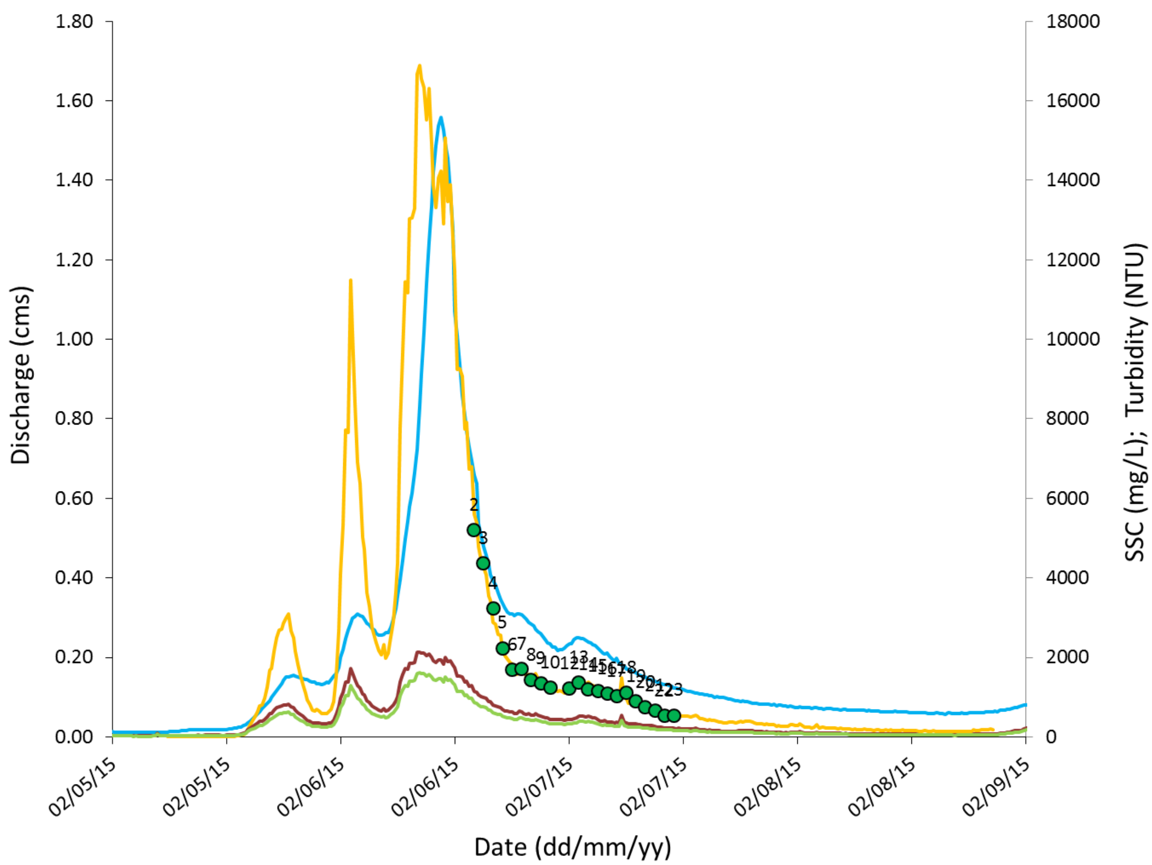


Figure 26. Measured SSC (mg/L, green circles), estimated SSC (mg/L, yellow line), discharge (cms, blue line), and field turbidity (NTU, red line) during Storm 1512 (February 6, 2015) at East Branch Railroad Gulch (Station 684), Elk River, CA. Numeric values above each data point indicate the order in which the samples were collected. Sampling was incomplete during this storm due to a water sampler power failure.

Discussion of West Branch Water Quality Data Collection: WY 2015

A complete record of turbidity and stage was collected throughout WY 2015 at the West Branch gaging station (Figure 27). Streamflow increased overall from WY 2014 to WY 2015 but was still relatively low. Streamflow, turbidity, and loading results are provided in Table 10. Peak field turbidity (8092 NTU) greatly exceeded that recorded in the East Branch and was >25 NTU for a slightly higher portion of the monitoring period (30%). The WY 2015 rating curve was fit with a single regression (R^2 = 0.9717 and includes WY 2014 and WY 2015 streamflow measurements (Figure 28). A slight shift in rating may have occurred during a relatively large storm on December 21, 2014 (Storm 1508). As is the case in the East Branch, more measurements are necessary to denote and validate potential rating shifts. The largest streamflow measurement conducted by staff in WY 2015 equaled 0.296 cms at 0.36 meters on the gage plate. Peak stage (as recorded by the pressure transducer) equaled 0.62 meters with corresponding peak discharge estimated at 1.97 cms. These data indicate a significant increase in both peak flow (~450%) and peak turbidity (~300%) from WY 2014 to WY 2015 but as was the case in the East Branch these are not totally unexpected results given the increase in annual precipitation. When normalized for upstream drainage area, peak flow (cms/km^2) was approximately 9% higher in the West Branch than in the East Branch in WY 2015.

Sampling occurred during thirteen of the designated fourteen storm events of WY 2015. Thirteen segments were delineated that estimated the sediment load produced during each storm, the summation of which resulted in approximately 1060 Mg (716 Mg/km^2) (Table 12). This total load was very close to that measured in the East Branch (4% less in the West Branch). While the total load measured between the two sites was similar, load contribution per storm event varied (Figure 29). The greatest contribution to the West Branch annual load (approximately 478 Mg, 45% of total) was generated during the April 6, 2015 storm event (Storm 1517). The second largest sediment load (approximately 269 Mg, 25% of total) was measured during the February 6, 2015 storm (Storm 1512). As discussed above, Storms 1512 and 1517 generated the highest and second highest loads in the East Branch, respectively. These results suggest that, in addition to precipitation, unique hillslope and/or in-channel conditions present within each sub-basin play a fundamental role in sediment delivery. Further analysis will be conducted that aims to identify specific sources of sediment inputs using synoptic sampling data as well as road and landslide inventories. Sampling did not occur during Storms 1503 and 1509-1511. Regression models calculated in Segment 1502 and 1508 were used to estimate concentration during these storms, respectively. Figure 30 illustrates the continuous annual record of concentration and streamflow throughout WY 2015. Comparison of single regression fits to sum-of-storms methods suggest that a single regression under-predicts total sediment loading. Turbidity-SSC data were fit with a single regression for Storms 1502 and 1518. Multiple regressions were used for Storms 1501, 1504, 1505, 1507, 1508, and 1512-1517 during which concentration fluctuated relative to rising and falling turbidity. Figure 31 illustrates dynamic turbidity-SSC relationships measured during Storm 1514 where two unique regressions were calculated and applied to different periods of data. Extrapolated concentration relative to measured samples indicates a reasonable estimate of continuous SSC.

Total sediment loads were also calculated using a single linear fit and a single power fit through all WY 2015 turbidity-SSC data in order to serve as a comparison to the sum-of-storms method. Single regression methods under-predicted total sediment loading in the West Branch. The total load was estimated to equal 832 Mg (27% difference to storm event method) using a single power fit and 929 Mg (14% difference) using a single linear fit. Overall this finding has been consistent throughout WY 2014 and WY 2015 at each monitoring station and confirms the efficacy of sum-of-storm methodology as it applies to sediment loading estimation in Railroad Gulch.

Field turbidity exceeded the range of the DTS-12 turbidimeter (~1600 NTU) during eleven (11) storm events (1502-1504, 1506, 1508, 1510-1513, 1515, and 1517) of WY 2015 (45 total hours, 0.01% of the monitoring period or record). Laboratory analysis of samples collected during these periods indicates that the sensor was under-predicting turbidity, particularly near the peak of each event. Peak turbidity was re-constructed for each of these storms using the same methods as those described in the above East Branch discussion. It is important to note that the WY 2015 instantaneous maximum turbidity (8092 NTU) was a result of field turbidity re-construction during the peak of the 2/6/14 storm event (Storm 1512).

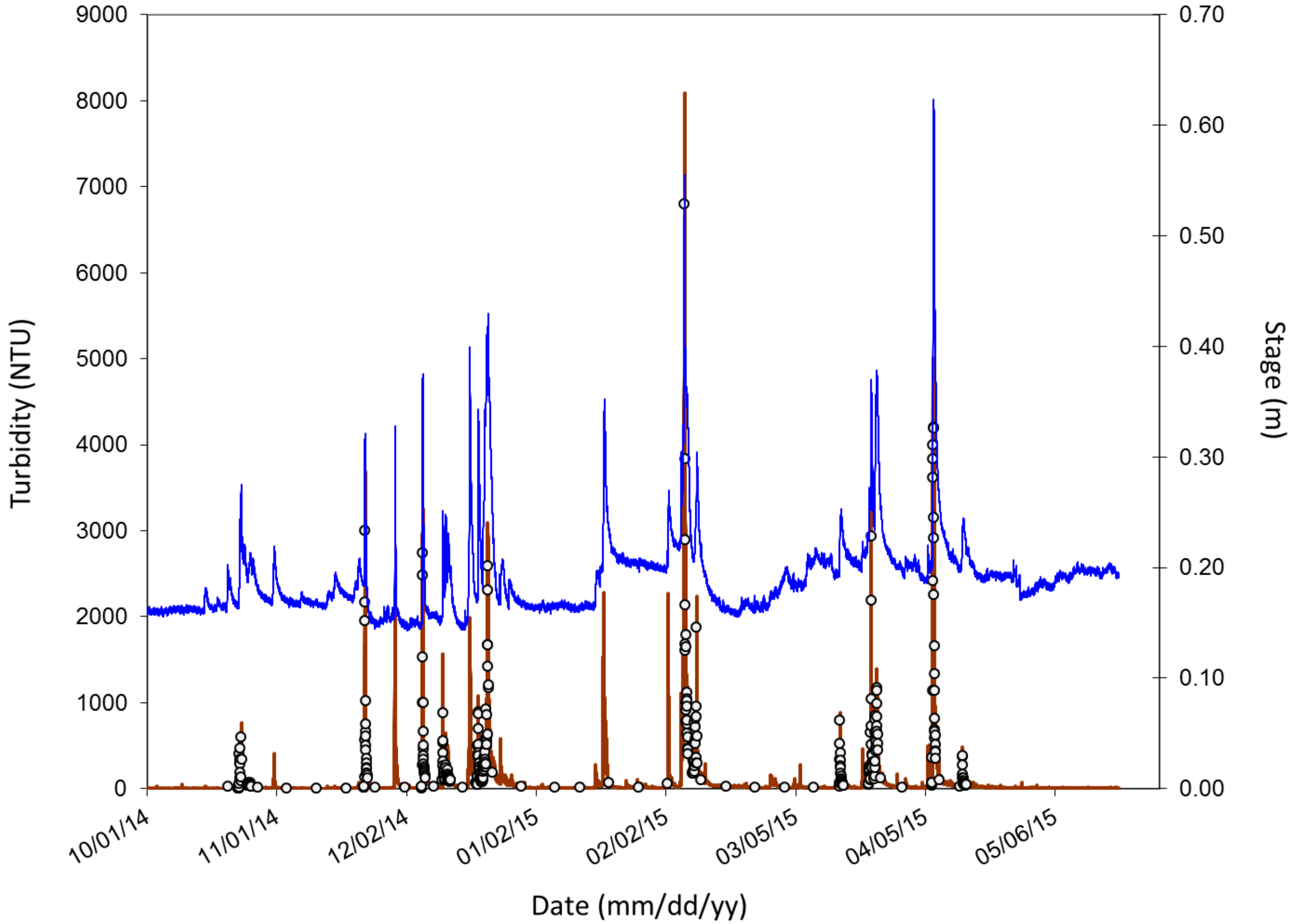


Figure 27. Annual Stage and Turbidity Hydrograph, WY 2015 West Branch Railroad Gulch (Station 683), Elk River, CA. Blue line: stage (m); brown line: turbidity (NTU); white circles: turbidity (NTU) measured in collected stream samples.

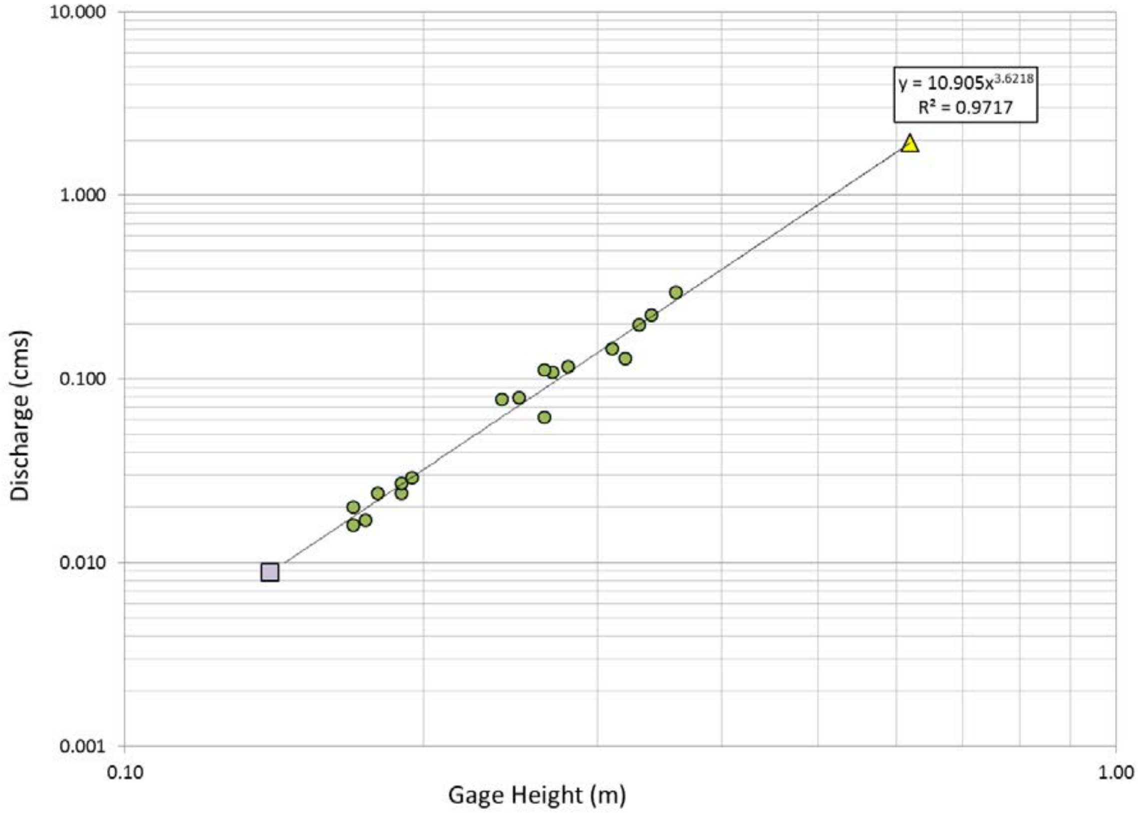


Figure 28. Stage-Discharge Rating Curve, WY 2015 West Branch Railroad Gulch (Station 683), Elk River, CA. Green circles: stream discharge measured at various stages throughout the water year; Purple square: minimum stage vs. minimum discharge; Yellow triangle: maximum stage vs. peak discharge.

Table 12. Sediment load statistics per storm event, WY 2015 West Branch Railroad Gulch (Station 683), Elk River, CA.

Segment Number	Storm Number	Begin Segment Range	End Segment Range	Load (Mg)	Load (Mg/km2)	Percent of Total
1501	1501	10/1/2014 0:00	11/21/2014 17:30	3.4	2.3	0.003
1502	1502-1503	11/21/2014 17:45	12/5/2014 16:45	14.6	9.9	0.014
1504	1504	12/5/2014 17:00	12/10/2014 13:45	20.2	13.6	0.019
1505	1505-1506	12/10/2014 14:00	12/18/2014 19:45	20.2	13.6	0.019
1507	1507	12/18/2014 20:00	12/19/2014 18:00	11.3	7.6	0.011
1508	1508-1511	12/19/2014 18:15	2/5/2015 5:30	174.0	117.6	0.164
1512	1512	2/5/2015 5:45	2/8/2015 20:30	268.9	181.7	0.254
1513	1513	2/8/2015 20:45	3/15/2015 9:45	18.1	12.3	0.017
1514	1514	3/15/2015 10:00	3/20/2015 20:30	1.3	0.9	0.001
1515	1515	3/20/2015 20:45	3/23/2015 21:00	16.6	11.2	0.016
1516	1516	3/23/2015 21:15	4/5/2015 11:30	32.3	21.8	0.030
1517	1517	4/5/2015 11:45	4/13/2015 17:00	477.7	322.8	0.451
1518	1518	4/13/2015 7:30	5/21/2015 8:15	1.2	0.8	0.001
Total				1059.78	716.07	1.00

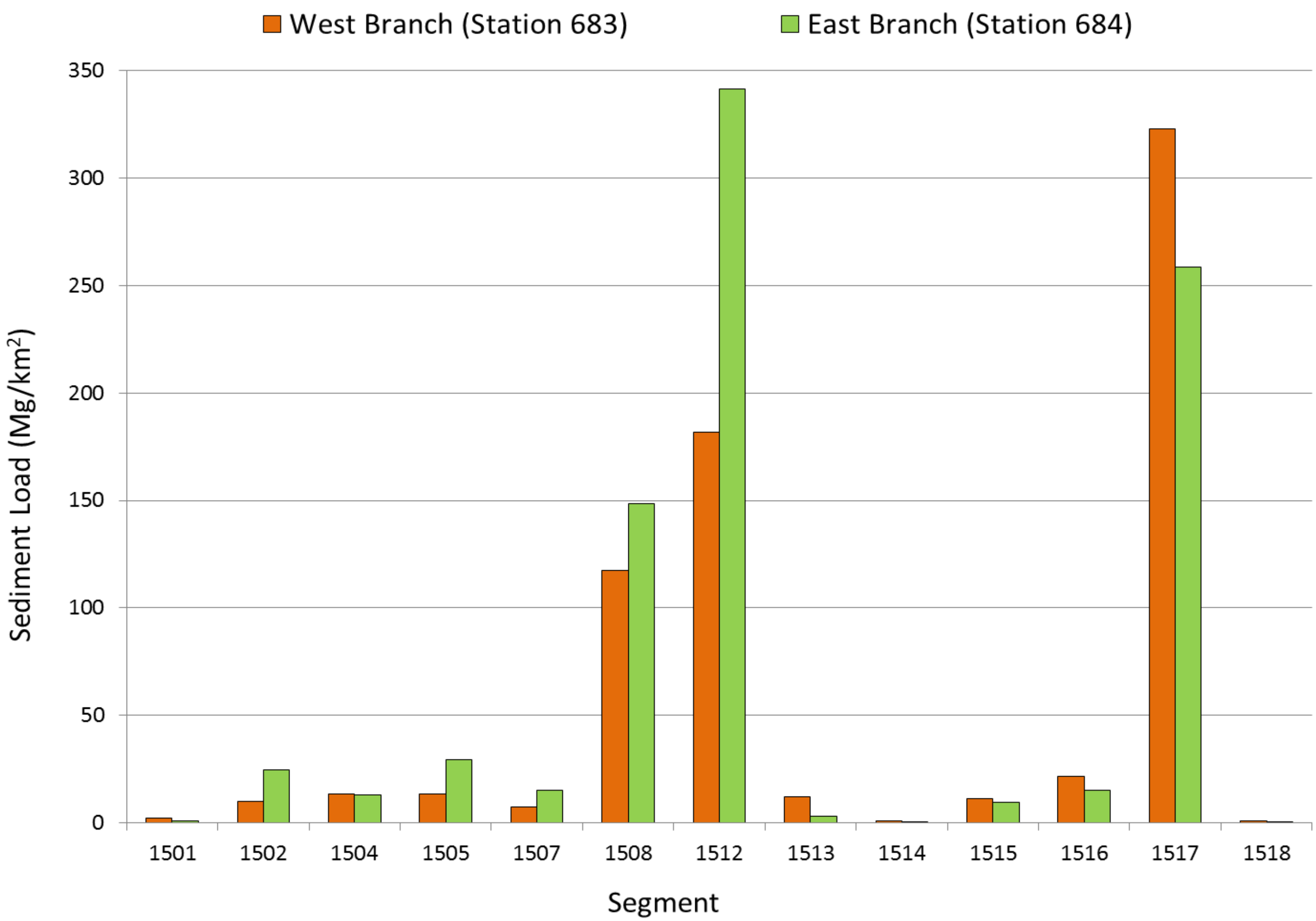


Figure 29. Sediment load (Mg/km^2) per delineated segment per station of WY 2015 in Railroad Gulch, Elk River, CA.

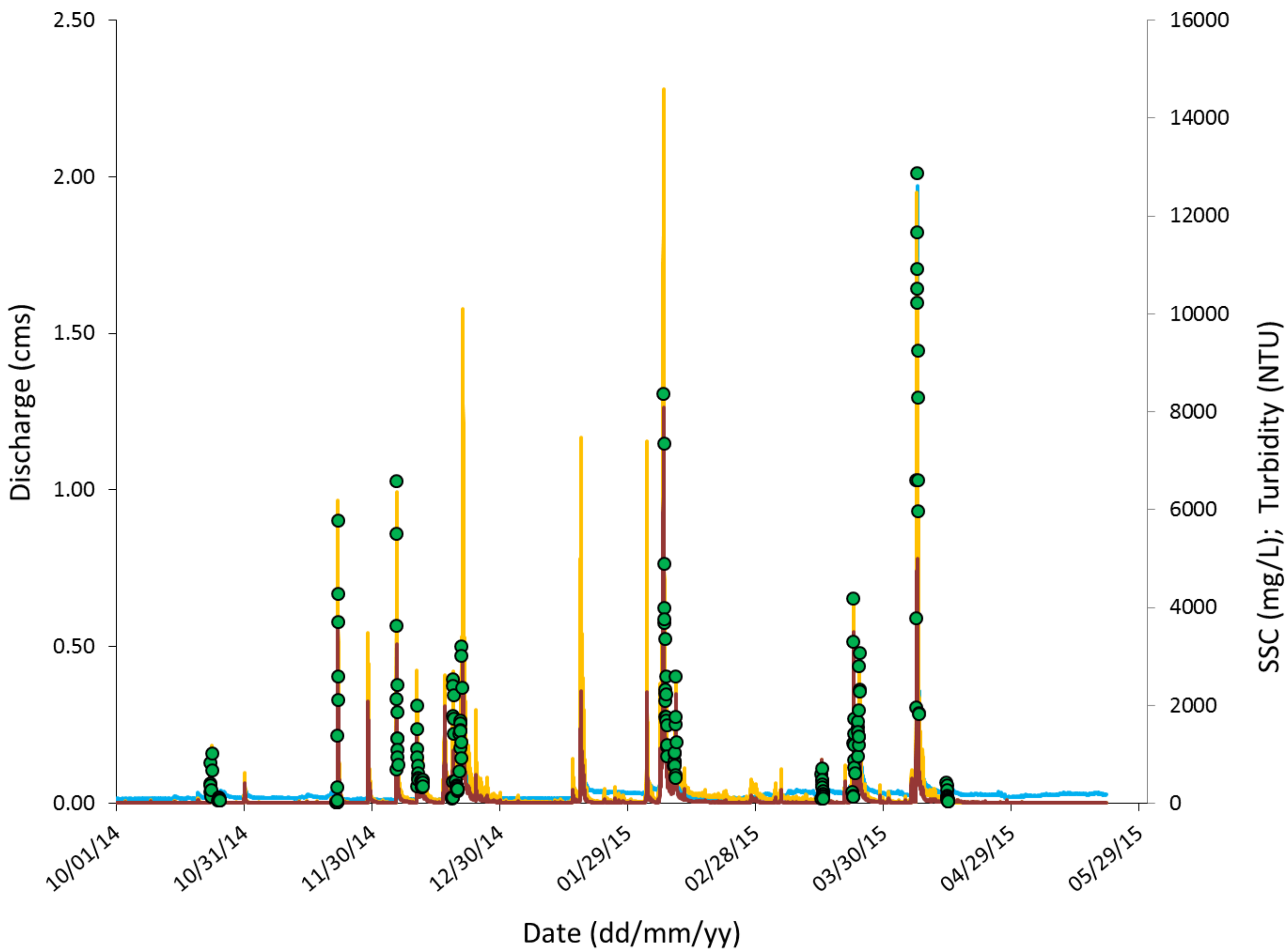
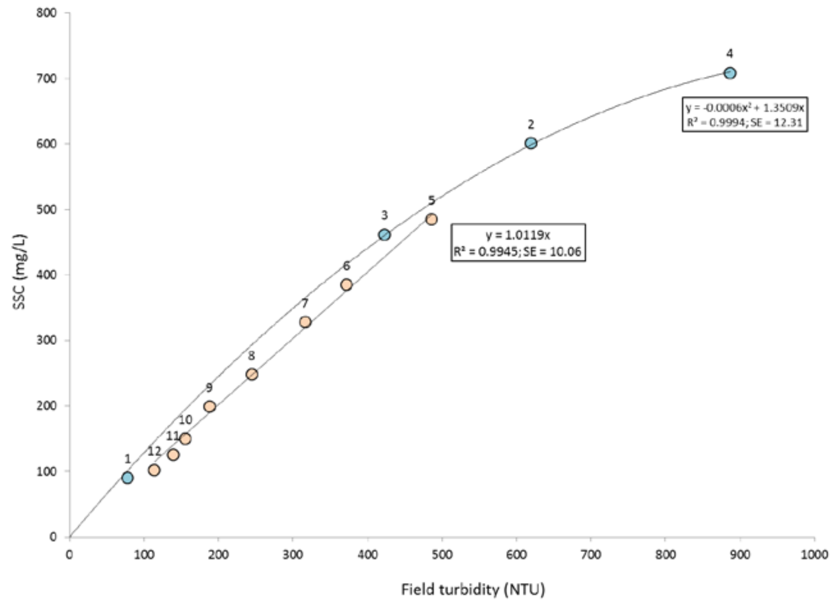


Figure 30. Annual Streamflow and SSC Hydrograph, WY 2015 East Branch Railroad Gulch (Station 684), Elk River, CA. Blue line: discharge (cms); tan line: SSC (mg/L); green circles: SSC measured in collected stream samples.



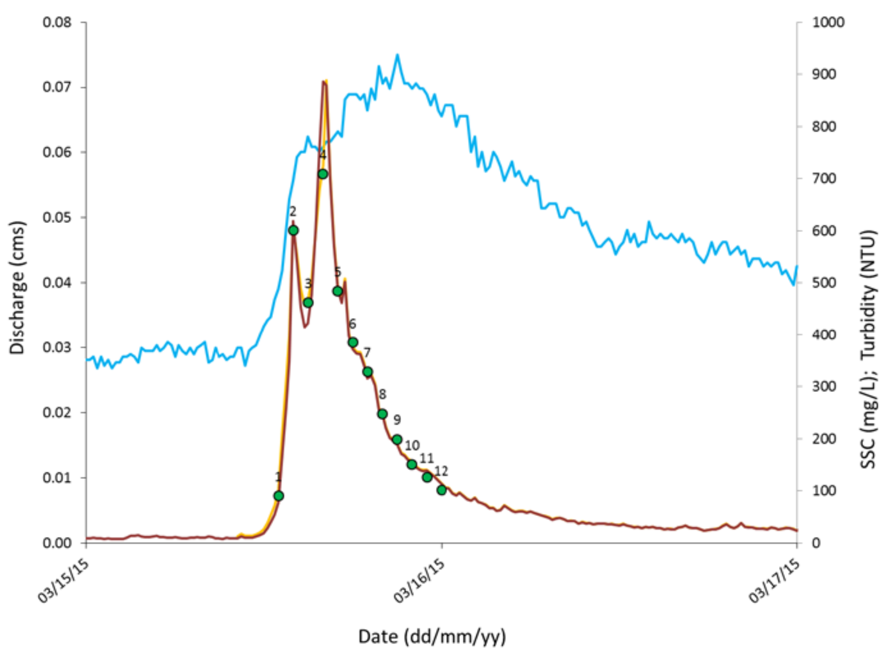


Figure 31. Above: Field turbidity (NTU) vs. measured SSC (mg/L) in samples collected during Storm 1514 (March 15, 2015) in West Branch Railroad Gulch (Station 683), Elk River, CA. Blue circles: the primary and secondary turbidity peak of the event, pink circles: the falling turbidity limb of the event. Below: Measured SSC (mg/L, green circles), estimated SSC (mg/L, yellow line), discharge (cms, blue line), and field turbidity (NTU, red line) throughout Storm 1514. Numeric values above each data point indicate the order in which the samples were collected.

Discussion of Stream Synoptic Sampling Data

Grab samples were collected at synoptic sites for four (4) events in WY 2014 and nine (9) events in WY 2015. Locations are shown in Figure 8. Data supported the general turbidity conditions observed for specific events at the hydrology stations. Turbidity on the West Branch was higher than the East Branch for 2 of the 4 sampled events in WY 2014, and was the same for the other two events. In WY 2015, turbidity on the West Branch was higher for 6 of 9 events. Of the events where turbidity was not higher, one event was very low (10 NTU), and another did not have samples for the West Branch.

On the East Branch, the general trend was that turbidity in the tributaries was less than that in the main channel, and turbidity below the tributaries was similar to the samples taken above. This is what we would expect, as the tributary flows are much smaller than the main channel, and thus less able to influence the turbidity of the main channel. Grab samples from Site 5 tributary were consistently higher than the main stem sites for 7 of 9 events sampled for WY 2015. During one of the storm events it appears that the tributary and above-tributary samples might have been switched, consequently we will emphasize with staff collecting field samples the importance of correct labeling. There were no clear trends moving upstream in turbidity. In most cases turbidity was roughly the same, however in some events the water became slightly more turbid moving downstream. It is difficult to determine whether differences along the stream resulted from spatial differences or temporal differences as the storm hydrograph may have been in the rising or falling limb. This will be investigated more closely and discussed in the WY 2016 Annual Report.

On the West Branch, the general trend of above and below main channel measurements being roughly equivalent was also observed. The Site 3 tributary channel had higher turbidity than the main channel for 4 of 8 events sampled in WY 2015 and 2 of 4 events sampled in WY 2014. The Site 3 tributary had higher turbidity than the other tributaries on 6 of 8 sample dates. This tributary appears to have the largest subwatershed of the sampled tributaries (Figure 8). Other tributaries occasionally (one or two times) had high turbidities compared to the average tributary values for that storm event, but they were less than the main channel turbidities for all but a few sample dates. There are a few dates where sample labels were switched. Site 7 on December 11, 2014 shows 250 NTU turbidity for the tributary and below site, and 80 NTU for the above site. However, sites 6 and 8 have 250 NTU turbidity above and below sites. It is more likely that the samples were switched than that the river suddenly became clearer just above Site 7. The 4/7/15 samples also have large departures between above and below-tributary sample values at six (6) locations that are hard to explain physically. We will discuss ways to assure proper sample labeling moving forward, as it will be hard to draw conclusions from these limited portions of the data.

HYPOTHESIS 9 PEAK FLOW CHANGES FROM HARVEST

Hypothesis: Peak flows in years subsequent to the road construction and selective harvest of the East Branch Railroad Gulch will not increase in relation to the untreated West Branch watershed.

This is a new hypothesis which has been added to the project. Changes to stream flows are a possible impact of forest harvest. The latest revisions to the California Forest Practice Rules require that Timber Harvest Plans consider peak flows when evaluating cumulative watershed effects. Realizing the duration of the experiment is short relative to typical records for peak flow occurrences, it was thought to be useful to conduct analysis of possible changes to peak flows.

Methods: Discharge data collected at the East Branch will be analyzed using a regression equation approach developed at Caspar Creek experimental watershed and applicable to the redwood region by Pete Cafferata and Leslie Reid. The equation uses years since logging occurred, percent of watershed logged, storm size, watershed wetness, and a logging recovery coefficient to predict how harvesting will affect discharge relative to unharvested conditions. Predictions will be compared to observed data.

An additional approach will be to develop a linear relationship for discharge between the two branches. This relationship will then be used to generate predicted values for the harvested watershed. Predicted values are compared to observed values for changes caused by the treatment.

Status: Streamflow (discharge) data has been collected at the outlets of both branches since WY 2014. Status of hydrologic data collection efforts is described under Hypothesis 8.

HYPOTHESIS 10 LONG TERM EROSION RATES

Hypothesis: Current erosion rates measured over the study period are within 20% of long term erosion rates as determined by Be-10 isotope analysis.

This is a new hypothesis which has been added to the project. In conjunction with Lee MacDonald, Patrick Belmont, and Ken Ferrier, we will use isotopic tracers to estimate the long term erosion rate for the watershed. The technique uses concentrations of Be-10 to estimate the rate at which quartz grains approach the surface by hillslope erosion. The general principle is that Be-10 concentrations are inversely proportional to the rate of hillslope erosion. For example, if the stream sediments have high amounts of Be-10, it indicates that erosion rates in the basin that produced those sediments have been low, because the quartz has taken a long time to be exhumed and hence been exposed to cosmogenic radiation for a long time. In contrast, low concentrations of Be-10 in stream sediment indicate fast erosion, because the quartz was exhumed quickly and hence exposed to cosmogenic radiation for a short time.

Methods: Streambed samples and upland samples are collected and mailed to Purdue University Rare Isotope Measurement Lab (PRIME) for analysis. Results are analyzed by Belmont and Ferrier for determination of long term erosion rates.

Status: At this point the samples have been collected and shipped off to PRIME. The lab found that the samples were exceptionally low in quartz and will require extra steps to isolate the granular quartz grains. Results are expected by March 2017.

APPENDIX A ROAD CONDITION SURVEY FORM

Road Survey Categories	Measured (M), Estimated (E), or Observed (O)	Method of Measurement	Record
SEGMENT CHARATERISTICS			
Road Number	__________	Road Segment	___________
GPS waypoint	M	Hand Held	GPS Waypoint # ________ Lat __________ Long _________
Road segment length	M	tape	________ ft
Road segment slope	M	Clinometer	_____ % ___ Upslope ___ Downslope
Segment break feature/ structure	O		__ critical dip/ culvert __ rolling dip __ water bar __ mini water bar (one side) __ hydrologic break __ uncontrolled rill/ gully
Segment drainage feature/structure if segment is downsloped from segment break	O		__ critical dip/ culvert __ rolling dip __ water bar __ mini water bar (one side) __ hydrologic break __ uncontrolled rill/ gully
Segment break feature/ structure rocked	O		__ Yes __ No
Road surface	O		__ Insloped __ Outsloped __ Crowned __ Roughly flat
Total Road width	M	Tape	________ ft
Active Road width	M	Tape	________ ft
Slope above road	M	Clinometer	_____ %
Slope below road	M	Clinometer	_____ %
Road surface type	O		__ native __ rocked __ mixed rock ___ % native ___ %
Segment bare soil	M/E	Cover count	_____ %
Vegetation coverage	M/E	Cover count	_____ %
Fill slope	O		__ No __ Yes ___ standard ___ through fill
Fill length (*ave.*)	E	tape	________ ft
Fill slope gradient (*ave.*)	M	Clinometer	_____ %
Fill slope percent bare soil	E		_____ % ___rock armored
Cut bank	O		__ No __ Yes ___ standard ___ through cut
Cut bank height (*ave.*)	E	tape	________ ft
Cut bank gradient (*ave.*)	M	Clinometer	_____ %
Cut bank percent bare soil	E		_____ %
Ditch	O		__ No __ Yes ___ inboard ___ outboard
Ditch vegetated	O		__ No __ Yes _____ %
Ditch width	M	Tape	________ ft
Ditch depth	M	Tape	________ ft

EROSION INFORMATION			
Erosion	O		__ Yes __ No
Type of Erosion	O		__ rill on road __rill below drainage __ plume __plume below drainage __ instream scour __ cut bank failure
Drain feature at end point of Erosion man-made	O		__ No __ Yes __ critical dip/ culvert __ rolling dip __ water bar
Failed Drainage Features in Segment			__ No __ Yes (___ number) __ critical dip/ culvert __ rolling dip __ water bar
RILL			
Rill below drain feature length	M	Tape	________ ft _______ft _______ft
Rill slope	M	Clinometer	_____ % _____ % _____ %
Rill width	M	Ruler	_____ inch _____ inch _____ inch
Rill max depth	M	Ruler	_____ inch _____ inch _____ inch
Rill on road length	M	Wheel/tape	________ ft ________ ft ________ ft
Rill on road depth (must be at least 5cm deep to be included)	M	Ruler	_____ inch _____ inch _____ inch
Rill threat to road	O		__ Yes __ No
PLUME			
Plume below drain feature length	M	tape	____ft ____ft ____ft
Plume on road length	M	tape	____ft ____ft ____ft
Plume Roughness	O		1 = Mostly smooth; 2 = Litter,small debris 3 = Some blockages 4 = multiple large obstructions (logs, rocks) or deep chips
Culvert			
Culvert percent plugged	E		_____ %
Scour at outlet	O		__ Yes __ No
Scour volume	M	Tape	________ cubic ft
CUT BANK/ FILL SLOPE INSTABILITY			
length	M	Tape	________ ft
Width	M	Clinometer	_____ ft
Depth (max.)	M	Ruler	_____ ft
road length impacted	M	Ruler	_____ ft
Rill on road	O	Wheel/tape	__ No __ Yes (if yes go to rill section)
Plume below road	O	Ruler	__ No __ Yes (if yes go to plume Section)
Connectivity			
Connectivity class (1,2,3,4)	O		1 = no erosion 2 = < 10m length rill or plume 3=>10m rill or plume but doesn't reach stream; 4 = delivers to stream