MAD RIVER SEDIMENT SOURCE ANALYSIS

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1.0 INTRODUCTION

The purpose of this report is to document the data, results, and findings of the Mad River Sediment Source Analysis. As part of Mad River Total Maximum Daily Load (TMDL) development funded by the U.S. Environmental Protection Agency, a sediment source analysis was conducted by Graham Matthews & Associates (GMA). The Mad River Watershed is subdivided into 4 planning areas and 39 sub-watersheds for which the various analyses were completed (Plate 1).

The sediment source analysis is designed to qualify and quantify the relative sediment contribution from different erosion sources, identify which of the Mad River subwatersheds produce the most suspended sediment, and provide land managers a tool to develop strategies to prevent and reduce erosion sources created by anthropogenic activities. The sediment source analysis includes direct turbidity and suspended sediment monitoring data, an inventory of upslope natural and management related erosion sources, and evaluates which sources produce the most sediment.

The results are reported using three methods of analysis: (1) computed loads from measured turbidity and suspended sediment concentration from a network of continuous and periodic sampling sites, (2) an inventory of upslope sediment sources (e.g. landslides, surface erosion from roads and other land disturbance, bank erosion) used to develop a traditional upslope sediment budget, and (3) the output from a GIS based terrain model NetMap calibrated by the data collected in (1) and (2).

The inventoried and modeled erosion sources are an “average” year (based on the average of a 31 year analysis period (1976-2006), which includes elements of both chronic and acute erosion. Chronic erosion occurs frequently and delivers fine sediment during annual high intensity rainfall-runoff events. Common forms of chronic erosion include fluvial and surface erosion that occur on natural hillslopes, active landslide surfaces, and areas disturbed by management (e.g., roads and urban areas). Fine sediment eroded during frequent rain-fall runoff events accounts for most of the annual sediment load (Lehre, 1993). Conversely, acute erosion is used to categorize large infrequent events triggered during wet water years and associated rain-on-snow events. These events tend to trigger landslides that deliver large quantities of sediment infrequently to the stream network. Landslides can be triggered naturally or by land use activities depending on factors like climate, bedrock geology, tectonics, soil properties, and slope steepness. Acute erosion events commonly account for a large portion of the long-term coarse sediment load.

The sediment budget was developed using existing data, measured turbidity, suspended sediment concentration and load, upland erosion inventories, and a GIS based terrain model NetMap. The measured sediment load and upland erosion rates were used to calibrate the sediment budget model. The sediment budget was developed for the post-1975 time period (1976-2006, or 31 years). The probability of sediment delivery from inventoried erosion sources was calculated for each subwatershed in this time period.

The likelihood of sediment delivery was estimated for background and existing conditions and the average annual sediment load.

A preliminary version of this report, prepared in September 2007, was circulated along with the draft TMDL in October 2007. This final version was developed in response to public comments and incorporates a variety of revised assumptions and results, primarily related to landslides, modeling of surface erosion, and the NetMap model, which cumulatively result in changes to the classical sediment budget. Changes occurred in Chapter 2 – Methods and Chapter 4 – Sediment Budget. No changes were made in Chapter 3 – Streamflow and Sediment Transport.

2.0 METHODS

The following section summarizes the sediment source analysis methods, data, and information. This sediment source analysis follows hydrologic and geologic analysis methods outlined in McCammon et. al. (1998) and CDC (2001) and sediment budget methods described by Reid and Dunne (1996), Washington Department of Natural Resources (1995), and USDA Forest Service (2004) to identify the controllable sediment sources in the Mad River watershed. GIS is used to process the data layers, and Excel is used to calculate the amount and probability of sediment delivery. The models estimate the background and management related sediment delivery from landslide, surface, and fluvial erosion processes.

This sediment source analysis attempts to account for the short- and long-term sediment input to the stream network average and episodic rainfall-runoff and snowmelt-driven flood events. For the classical and NetMap sediment budgets described below, sediment load is expressed as an annual average load. This analysis compares the background and existing sediment delivery rates for the design flood event (average annual event for the basin).

2.1 Hydrologic Methods

The purpose of this section is to provide an overview of the methods used for analysis of precipitation and streamflow data. Existing precipitation, streamflow, and sediment transport data were summarized for the project area and used to characterize the ranges of air temperature, precipitation, and streamflow magnitude, timing, duration, and frequency. Data from the US Geological Survey (USGS), USDA Forest Service (FS), California Department of Water Resources (CDWR), Humboldt Bay Municipal Water District, and Blue Lake Rancheria were gathered and summarized for this analysis. The Log Pearson Type III and graphical flood frequency analysis methods were used to estimate the flood magnitude for various recurrence intervals between two and one hundred years.

2.1.1 Precipitation Data

Long-term precipitation data for the project area were obtained and annual totals and cumulative departure were plotted to evaluate trends over time. The total daily precipitation data for the Eureka and Forest Glen gages were obtained from the USDA, Forest Service.

2.1.2 Streamflow Data

The US Geological Survey (USGS) presently operates two gages on the Mad River, near the mouth (Mad River near Arcata) (#11481000) and above Ruth Reservoir (#11480390). Mad River near Arcata has longest streamflow record of 57 years. Graham Matthews and Associates (GMA) operated one continuous streamflow gage on the North Fork Mad River during the course of this study. Flow data from gages for Water Years 2006 and 2007 are included in this analysis. Synthetic streamflow records for ungaged sites were developed from USGS records of the Mad River near Arcata, Mad River above Ruth Reservoir, or the Little River near Trinidad, as appropriate, scaled by drainage area.

2.1.3 Flood Frequency

Annual flood frequency analysis uses statistics to calculate the probability of peak high streamflow for a given return period. This analysis used the HEC FFA program to calculate flood magnitude and frequency (USACE, 1982) and followed guidelines developed by the US Water Resources Council (USWRC, 1981). The likelihood that a peak flow (equaling or exceeding a certain magnitude) will occur in a given year, as the annual flood peak, can be computed using annual maximum daily discharge. The method assigns probabilities to flood magnitudes, expressed as recurrence interval (the average period in years between peaks of a given size or larger), or exceedance probability (the percent chance a peak will be equaled or exceeded in any year). The type of flood frequency method applicable to a given dataset depends on the distribution of the data. Each peak flow record was tested for normality as part of this analysis. Annual maximum daily streamflow data were obtained from the USGS for the USGS gages. The maximum and mean daily flows were regressed to characterize the rise and fall rate and daily variability of the flood hydrograph.

2.1.4 Flow Duration

Flow Duration analysis relates mean daily discharge to its frequency of occurrence, based on the complete record of mean daily flows. All mean daily flows are ranked by magnitude and the exceedance probability of each discharge value is computed. Flow duration analysis results are used to calculate non-parametric statistics (median, 5th, and 95th percentiles). Streamflow durations are used in parallel with duration analyses of turbidity, suspended sediment concentration, and suspended sediment discharge to describe flow and sediment characteristics at a given site or to compare sites.

2.2 Drainage Basin Characteristics

2.2.1 Watershed Stratification

The 39 subwatersheds delineated as part of this sediment source analysis are listed in Table 1 and shown on Plate 1. Land form and land use data are summarized for each of the subwatersheds.

Table.1. List of Mad River subwatersheds and corresponding drainage areas.

NAME	BASIN ID	ACRES	SQUARE MILES
Mud River	1001	8,474	13.2
Lost Creek	1002	16,727	26.1
South Fork Mad River	1003	10,202	15.9
Barry Creek	1004	6,511	10.2
Armstrong Creek	1005	6,346	9.9
Deep Hollow Creek	1006	2,612	4.1
Deep Hollow Creek West	1007	2,973	4.6
Bear Creek	1008	5,216	8.1
Pilot Creek	1009	25,430	39.7
Hastings Creek	1010	7,099	11.1
Holm Creek	1011	5,140	8.0
Olmstead Creek	1012	7,263	11.3
Showers Creek	1013	1,701	2.7
Deer Creek	1014	4,403	6.9
Bug Creek	1015	6,198	9.7
Morgan Creek	1016	5,547	8.7
Wilson Creek	1017	5,992	9.4
Graham Creek	1018	8,385	13.1
Goodman Prairie Creek	1019	6,425	10.0
Boulder Creek	1020	12,169	19.0
Barry Ridge	1021	5,832	9.1
Maple Creek	1022	10,013	15.6
Blue Slide Creek	1023	3,878	6.1
Devil Creek	1024	12,140	19.0
Cannon Creek	1025	10,484	16.4
Dry Creek	1026	4,507	7.0
North Fork Mad River	1027	31,246	48.8
Powers Creek	1028	13,314	20.8
Lindsay Creek	1029	11,331	17.7
Deer Creek2	1030	4,565	7.1
Showers Creek2	1031	3,345	5.2
Bear Creek2	1032	2,635	4.1
Tompkins Creek West	1033	3,113	4.9
Tompkins Creek	1034	5,713	8.9
Hetten Creek West	1035	7,639	11.9
Hetten Creek	1036	6,833	10.7
Olsen Creek West	1037	5,795	9.1
Olsen Creek	1038	8,214	12.8
Hastings Creek West	1039	2,074	3.2
TOTAL		**307,484**	**480.1**

2.2.2 Watershed Morphometry

The shape, texture, drainage pattern, and drainage efficiency of the subwatersheds are used to qualify and quantify the frequency and magnitude of upland sediment flux and instream sediment transport and storage. Watershed morphometry features are measured using NetMap (described in Section 2.6, below), topographic maps, aerial photos, and 10-meter Digital Elevation Models (DEMs) to include: drainage area, maximum and minimum elevation, basin length, stream network length and channel type. The NetMap model was used to measure the longitudinal profile, distribution of hillslope parameters like gradient, and drainage efficiency of each subwatershed and the entire basin.

2.2.3 Mainstem Sediment Storage and Bank Erosion

The relative amount of sediment storage within the mainstem Mad River was measured to help verify sediment budget results in four reaches: Mad River near Blue Lake; Mad River above Maple Creek; Mad River near Highway 36; and Mad River above Ruth Lake, and to verify bank erosion estimates. This methodology estimates the volume and composition of sediment stored in the sampled reach and follows procedures described by Llanos and Cook (2001) and Montgomery and Buffington (1993). The sediment volume and composition is estimated for different process domains (chronic and episodic sediment transport and storage) active within the Mad River watershed. The reach types range from steep narrow bedrock channels to low gradient alluvial channels. The reach locations were non-randomly selected to represent the lower, middle, and upper Mad River stream network.

Reach length was typically a minimum of 45 times bankfull channel width. The active channel was defined as the bankfull channel with recent scour and/or deposition and is generally free of riparian vegetation. The upper bank, lower bank, and channel bottom were walked and measured moving upstream with left and right bank defined looking downstream. The reach beginning and ending points were located using a GPS and/or plotted on a topographic map. The total reach length and drop were measured using a tape and altimeter. Three cross-sections were surveyed using the tape, rod, and hand level at the beginning, middle, and end of the reach. Stream gradient was measured with a hand level and rod at each cross-section. Pictures were taken looking upstream, downstream, and across at each cross-section.

The reach was broken into active and inactive feature types or “sediment reservoirs.” The dimensions of each reservoir were measured or estimated using the tape, range finder, rod, hand level, and Brunton compass. Some of the feature dimensions, mainly depth, were ocular estimates. Where the channel thalweg is scoured to bedrock, the total deposit depth was estimated by subtracting the surface and thalweg elevations.

The active features that store sediment measured as part of this procedure include: bars, fans, active channel, and wedges (e.g., deposit behind boulders and large wood). Generally, these features occur on the bottom or lower bank of the stream channel. Fans and deposits created by landslides are generally connected to the upper bank. Volume is estimated for inactive features like terraces, dormant landslide deposits, and mine tailings. Each feature type was simplified into a “sediment reservoir.” Different volume equations were used depending on the shape of a given sediment reservoir. For example, the volume of the wedge sediment reservoir is estimated by measuring its length, width, and depth. The volume of a wedge (V) is calculated using the following equation:

$$V = 0.5*L*W*D$$

L = feature length
W = feature width

D = feature depth

The sediment composition was estimated using pebble counts and bulk samples. The sedimentary facies of each sediment reservoir was visually estimated. Pebble counts and/or bulk samples were taken at each of the three cross-sections. Each sediment reservoir was classified into one of seven categories:

- bedrock-boulder;
- boulder-cobble;
- cobble-large gravel;
- large gravel-medium gravel;
- medium gravel-fine gravel;
- fine gravel-coarse sand; and
- coarse sand-silt/clay.

The age of each sediment reservoir was estimated using relative bed mobility, weathering and staining, and vegetation age. In high order alluvial channels, vegetation age is the most valuable measurement. The ages of Alders on the sediment deposits were used to identify relative ages of deposits whenever possible. There are four age categories:

- Active, 1-5 years;
- Semi-active, 5-20 years;
- Inactive, 20-100 years; and
- Stable, > 100 years.

The volume of sediment stored is summed for each reach by the state of activity. For this analysis, the active and semi-active sediment reservoirs were used to verify sediment budget results. In addition, these data were used to evaluate relative stream bank stability and average annual erosion rates.

The total amount of fluvial bank erosion was estimated for the Mad River using stream order assigned using NetMap and erosion rates (tons/mi^2/year) used by Raines (1998) as follows:

Stream Order	**Erosion Rates (tons/mi^2/year)**
1	0.006
2	1
3	25
4	75
5	8
6	250
7	100

2.3 GMA Suspended Sediment and Turbidity Monitoring and Analysis Methods

Five continuous turbidity sites were originally established with corresponding suspended sediment and turbidity sampling sites, along with 10 synoptic sites (Table 2 and Plate 2a,b,c). Data collected at the Blue Lake Rancheria Site (MRBLR), maintained by the Blue Lake Rancheria Tribe, are summarized with the MRALM data. The upper and lower sites are located near USGS continuous stream gages:

- MRALM: (MAD R NR ARCATA CA (11481000))
- MRRTH: (MAD R AB RUTH RES NR FOREST GLEN CA (11480390))

For the sites without continuous stream flow instrumentation, stage reference points (e.g., staff gages or fence post) were installed to provide a long-term stage datum. The sites were established and measured to facilitate development of synthetic hydrographs. A station benchmark was established and used as a reference for the stream stage datum.

Table 2. Mad River turbidity and SSC sampling site list.

Site Code	Watershed Code	Site Description	Drainage Area (mi2)	Elevation (feet)
MRALM [1]	C1	Mad River near Arcata below Highway 299 Bridge	485.0	31
MRHRB [2]	C1A	Mad River at Hatchery Road Bridge	447.1	78
MRBVR [2]	C2	Mad River near Maple Creek below Butler Valley Bridge	351.4	323
NFMKB [2,3]	C3	North Fork Mad River at Korbel Bridge	44.5	128
MR36 [2]	C4	Mad River at Highway 36 Bridge	138.4	2,457
MRRTH [2]	C5	Mad River above Ruth Lake at County Road 514 Bridge	93.6	2,690
LCGRB	S1	Lindsay Creek at Glendale Road Bridge	17.8	57
MCMCB	S2	Maple Creek at Maple Creek Road Bridge	12.2	449
BCMCB	S3	Boulder Creek at Maple Creek Road Bridge	18.8	405
LMC36	S4	Lamb Creek	3.1	2,470
OCLM	S5	Olsen Creek	1.6	2,495
TB3LM	S6	Unnamed Tributary 3	0.3	2,568
HCLM	S7	Hobart Creek	1.6	2,693
BCLM	S8	Blue Slide Creek	1.0	2,715
ACLM	S9	Anada Creek	1.0	2,699
CCRTH	S10	Clover Creek	0.5	2,707

[1] dropped -- assumed redundant with MRHRB
[2] continuous turbidity station
[3] continuous streamflow station

Depth integrated samples (DIS) and grab suspended sediment and turbidity samples were taken at the sampling sites during periods of high stream flow. Each site has a designated Box sample location. Box samples (single vertical depth integrated samples) were collected in conjunction with full cross section depth integrated samples. The Box and grab samples were collected in an attempt to establish a statistical relationship between Box and DIS samples. This relationship can be used to reduce the number of DIS samples by using the Box sample suspended sediment and turbidity values to predict the corresponding DIS value. For the first sampling season (WY 2006), box samples were taken at the stage reference location along the stream cross-section, and grab samples were taken from the bank.

Suspended sediment and turbidity are sampled with depth-integrating samplers (DH-48, D-59, or D-74), using procedures standardized by the USGS (Guy and Norman, 1970 and Edwards and Glysson, 1998). The samples are taken to a suspended sediment lab for analysis and reported as suspended sediment concentration (SSC) in mg/l. Turbidity values are either measured in the field or lab shortly after data collection in order to meet the 48-hr EPA time frame for sample analysis. The turbidity results were reported in NTU (for lab-analyzed samples) or FNU (for continuous turbidimeter sites). Relationships between lab-analyzed turbidity and continuous turbidity were developed on a site by site basis (discussed further in Results section). All samples were analyzed for both turbidity and SSC following EPA and USGS/ASTM protocols. Per GMA protocols, a minimum of 10 percent of the samples had field replicates for QA/QC purposes.

The five continuous sampling sites had a datalogger and recording turbidimeter stored in a small equipment house. The dataloggers (Campbell Scientific CR510 units) are installed in 2’x3’ steel enclosures to prevent vandalism and provide a secure area to hold deep cycle batteries, and excess cable. The turbidity sensors are Forest Technologies Systems DTS-12 units with wipers to clean the probe.

2.3.1 Streamflow

2.3.1.1 Streamflow Measurements

At all sites, the water level or stage was measured to the water surface from a fixed location on a bridge using a surveyors tape with a weighted end. The North Fork Mad River at the Korbel Bridge (NFMKB) had two USGS style A staff plates installed for stage height observations, and on February 14, 2006, a Design Analysis Associates, Inc. H-310 SDI-12 pressure transducer and Campbell Scientific, Inc. datalogger were installed. The recording interval was set to 15 minutes. Batteries were replaced and dataloggers were downloaded to a laptop computer on a regularly scheduled basis. Gage height records were checked against observed staff height to verify proper gage operation. Corrections were applied to the gage height record when necessary. Additional continuous gaging records used for analysis in the Mad River TMDL were collected and computed by the United States Geological Survey.

Streamflow measurements were taken at the NFMKB site by GMA employees using standard USGS methods. Measurements were performed by either wading at the gage location or from the bridge. Streamflow equipment for wading measurements included a 4ft top-set wading rod, JBS Instruments AquaCalc 5000 - Advanced Stream Flow Computer, and either a Price AA or Pygmy magnetic head current meter. High flow measurements were made using an A-55 reel, a USGS Type A Crane with Four-Wheel Truck, and either a 30 or 50 pound sounding weight.

The only site where GMA developed a rating curve was NFMKB because this was the only site for which discharge had to be directly computed from a stage-discharge relation. Discharge measurements were entered and cataloged using a form similar to the standard USGS 9-207 discharge measurement summary form. After collection of the discharge measurements, a discharge-rating curve was developed by plotting the stage/discharge pairs and electronically hand fitting a curve. Stage/discharge pairs were evaluated and the rating was developed within the WISKI Suite of software. The WISKI Suite is a comprehensive hydrologic time-series database management system developed by Kisters AG. The suite consists of three parts, WISKI, BIBER, and SKED. WISKI manages and computes all time-series data, BIBER is used to evaluate and catalog discharge measurements, and SKED is used to develop and manage rating curves. The WISKI Suite includes complete USGS standards for surface computations. These standards include USGS computational methods according to WSP 2175, Measurement and Computation of Streamflow vols.1 and 2, Multiple Ratings with log offsets, shifts and stage adjustments, gage height and datum correction, and standard printouts such as primary computation sheets, mean daily value summaries, rating tables, and shift tables.

The accuracy of streamflow records depends primarily on (1) the stability of the stage-discharge relation or, if the control is unstable, the frequency of discharge measurements, and (2) the accuracy of observations of stage, measurements of discharge, and interpretation of records (Rantz, 1982). To improve accuracy, a concerted effort was made to obtain discharge measurements over a wide range of flows, primarily during periods of sediment transport.

2.3.1.2 Discharge Records and Hydrographs

Four sites, MRHRB, NFMKB, MRBVR and MRRTH, had fifteen minute discharge records produced either synthetically from USGS gage relationships or from a site-specific rating curve. Discharge record methods and procedures are explained on a site-specific basis as follows.

MRHRB (Mad River at Hatchery Road Bridge)

Discharge was used directly, with no adjustments, from the USGS site Mad River near Arcata, CA. The site was not adjusted by drainage area because differences in drainage area are small enough to lie within the error associated with the discharge computations. At most flows transporting sediment, inflow from this 39 mi^2 area between MRHRB and Mad River near Arcata is only a few percent of the mainstem flow, due to low relief and lower precipitation rates than other upper watershed areas. Continuous turbidity records were collected just downstream of the USGS gage at a GMA site referred to as MRALM; however, all samples were collected at the Hatchery Road Bridge, which was the closest location available for high flow sample collection.

NFMKB (North Fork Mad River at Korbel Bridge)

Discharge from December 20, 2005, to February 14, 2006, was produced by taking the discharge record from the USGS site Little River near Trinidad, CA (#11481200) and adjusting it by drainage area then fitting it proportionally to the beginning of the GMA computed record. This is the only other continuous gage in the vicinity with similar geology and precipitation. From February 14, 2006, to March 20, 2007, discharge was computed from a rating curve produced by GMA (see appendix for rating curve and discharge measurements taken). No shifts were applied to the GMA discharge rating during the period of record.

MRBVR (Mad River at Butler Valley Ranch)

Discharge was obtained by adjusting the USGS site Mad River near Arcata, CA discharge record by the ratio of drainage area (MRBVR DA = 352 mi^2, Mad River near Arcata DA = 485 mi^2) and applying a one hour temporal adjustment.

MRRTH (Mad River above Ruth Lake)

Discharge was used directly, with no adjustments, from the USGS site Mad River above Ruth Lake, CA. GMA samples and continuous turbidity were collected within a short distance of the USGS gage.

2.3.2 Sediment Transport

2.3.2.1 Turbidity and Suspended-Sediment Sampling

Depth-integrated turbidity and suspended-sediment concentration (SSC) sampling was performed at all monitoring stations. Sediment samples were collected either from a bridge or by wading the stream channel. Bridge samples involved using a US D-74, an A-55 reel and a USGS Type A Crane with Four-Wheel Truck. Wadeable samples or bank grab samples were collected using a US DH-48 Depth-Integrating Suspended-Sediment Sampler.

Standard methods according to Edwards and Glysson (1988) were generally used for sampling. Although transit rates were not always determined using actual water velocity, the manual method was employed to determine transit rates to ensure iso-kinetic sampling conditions (a requirement to meet protocols, where the rate of water/sediment mixture entering the sample bottle must match the rate of air being displaced). In addition, a tag line was not always set during sampling; instead, the distance between verticals was estimated. For each sample the location, time, stage, number of verticals, distance between verticals and bottle # were recorded, along with whether a field replicate had been taken. Full cross sectional depth integrated samples were collected in conjunction with a depth integrated sample taken at a single fixed point in the cross section (referred to informally as a box sample). SSC at the fixed point was compared with the cross-section SSC to derive a regression for adjustment of the samples. Regression comparisons can be found in the appendix.

Samples were kept chilled after collection and stored in ice chests. Turbidity values obtained from suspended-sediment samples are referred to as lab turbidities. Lab turbidity values were obtained within 48 hours, unless otherwise noted, using a Hach 2100AN or 2100P turbidimeter. The handbook for water-resources investigations (USGS 1998), chapter 6.7, states that values obtained from the HACH 2100AN turbidimeter should be reported in Nephelometric Turbidity Units (NTU) and values obtained from the HACH 2100P turbidimeter should be reported in Nephelometric Turbidity Ratio Units (NTRU) (Anderson 2004). Suspended-sediment concentrations were determined in the GMA sediment lab following USGS and ASTM D-3977 protocols. The GMA lab participates in the USGS Sediment Lab Quality Assurance Program and has been inspected and approved by the USGS. A laboratory QAPP is available to interested parties.

2.3.2.2 Continuous Turbidity Sampling

Continuous turbidity sensors were installed and operated at MRHRB, NFMKB, MRBVR, MRRTH and MR36. Continuous turbidity sensors used were the Forest Technology Systems DTS-12 turbidity sensor. Turbidity sensors were attached to a fixed-bracket that was mounted within a metal housing. The housing and sensor were mounted in the channel, at varying heights above the streambed. Data were recorded from the DTS-12 into a Campbell Scientific CR200, CR10X or CR510 data logging platform with a recording interval set to 15 minutes. Turbidity values obtained from the sensors are referred to as field turbidity. Turbidity is reported in units which correspond to the instrument design as defined in the USGS TWRI Book 9-A6, chapter 6.7. The handbook for water-resources investigations reports that the Forest Technology Systems DTS-12 turbidity sensors are designed to record in Formazin Nephelometric Units (FNU) (Anderson 2004). Relationships were developed to establish the correlation of FNU, NTU, and NTRU turbidity units at the sites with continuous turbidity sensors.

2.3.2.3 Sediment Transport Rates and Loads

Turbidity and suspended-sediment concentration data were analyzed by developing relationships for SSC versus turbidity and SSC versus discharge for all sites. Data pairs were plotted against each other and a computer-generated power equation was produced in order to define the relationship. Suspended sediment discharge and load estimates were computed in WISKI using either turbidity or discharge as a surrogate for suspended-sediment concentration, based on the developed correlations.

2.3.2.4 Comparison to Historic Sediment Transport Rates and Loads

Results from WY2006 and 2007 sampling were compared to historic data from the USGS and DWR.

2.3.2.5 Analysis of Continuous Turbidity Data

Continuous records of turbidity at the various sites were analyzed for magnitude and duration and compared to reference streams and the Severity of Ill Effects methodology (Newcombe and Jensen 1996).

2.4 Landslide Source Analysis

2.4.1 Landslide Inventory

2.4.1.1 Data Sources

This landslide inventory uses data from CDWR (1982), USDA Forest Service (2005), and GMA desktop and field landslide inventory data. The desktop phase identified and inventoried landslides discernable from remote sensing data to include: aerial photographs, digital ortho photos, existing GIS data, and satellite images. A pre 1975 landslide GIS polygon layer was created by digitizing features from a hard copy map created by CDWR (1982). These active and inactive landslides were mapped from the 1974 aerial photographs. A post 1975 landslide GIS polygon layer was created by digitizing features mapped from 2003 and 2005 aerial photographs, low elevation flight, and field inventory. In the upper watershed, 1975 and 1998 aerial photographs were used to track the activity of landslides included in the field verification. The field phase consisted of field-verifying 15.5 percent of the landslides that had been mapped using remote sensing data. The field inventory was used to measure the depth of different landslide types, texture of landslide and bedrock material, and small landslides not recognizable from the available remote sensing data. The GIS and Excel files created as part of the desktop and field landslide inventories are stored electronically in the project file.

2.4.1.2 Landslide Inventory Methods

The GMA landslide inventory was performed in two phases. The inventory was completed using desktop and field methods, and it focused on mapping natural and management related active landslides.

Phase 1: Desktop Analysis

The first phase of the landslide inventory was desktop based and obtained existing data and landslide maps. The most complete historical landslide map available was published by CDWR (1982) and was from analysis of 1974 aerial photos. This map was digitized by GMA and was updated using stereographic pairs of black and white and color aerial photos. The most recent aerial photos were taken in 2003 and 2005 and are at a scale of about 1:18,000 (1 inch equals 1,500 feet).

GMA summarized and compiled data from the California Department of Water Resources (CDWR, 1982), California Department of Mines and Geology (DMG, 1999), Green Diamond Resources, Inc. (GD, 2006), and USDA, Forest Service (USFS) landslide data. The DWR (1982) data is the most comprehensive map and covers the entire Mad River. The DMG (1999) data covers the lower watershed, and the USFS data covers the upper and middle watershed. The GD data covers a limited portion of the middle and lower watershed. Dormant and active landslides were included in the landslide database. Active, pre-1975 landslides mapped by CDWR (1982) were used to create the pre-1975 active landslide map. The post-1975 landslide map includes data from all of the sources listed above in addition to landslides mapped as part of this study. Like CADWR (1982), GMA mapped active landslides with obvious activity from the most recent sets of remote sensing data (i.e., 2003 aerial photographs and 2005 digital ortho photographs). For USFS lands, publicly available aerial photographs were used, and on private lands the digital orthophotographs and hillslope relief maps were used to map active landslide following methods described by Turner and Schuster (1996). All of the active landslides included in the pre-1975 time period were assumed to have failed between 1944 and 1975, and the total mass of sediment delivery was averaged for this time period. The post-1975 time period includes landslides that continued to enlarge (originally mapped as pre-1975) as well as new landslides that were triggered within the last 31 years.

The aerial photo landslide inventory documented the location, type, geometry, and time period of each landslide in the watershed. This information was used to estimate sediment input to streams and assess relationships between land use and landslide activity. A mirror stereoscope was used to identify landslides on the aerial photos, and landslide location was found on the corresponding USGS 7.5-minute topographic map (i.e., 1:24,000, or 1 inch equals 2,000 ft). For a given landslide, the dimensions were measured (i.e., length and width), scaled from the photo scale to 1:24,000. The landslide outline was then hand-drawn on an acetate sheet overlaid on the topographic map. After being mapped on the acetate overlay, the landslide was measured a second time to check the scaling. The landslide was then numbered and classified based on attributes visible on the photo. The overlays were then digitized into the GIS.

Within the lower watershed where a complete aerial photograph coverage is not available, 2005 National Agriculture Imagery Program (NAIP) digital orthophotographs and 10 meter DEM hillshade relief maps were used to map and delineate active landslides. The landslide perimeter was directly digitized into the GIS landslide database.

For each landslide identified on the aerial photos, the following information was recorded in the landslide database:

- Landslide number.
- Year of the aerial photo on which the landslide first appears.
- Number and flight line of the aerial photo on which the landslide first occurs.
- Landslide classification (described below).
- Certainty of identification: d = definite, p = probable, q = questionable.
- Activity level using the following categories: active, inactive, or relict
- Landslide width and length
- Sediment delivery to streams (described below)
- Landslide triggering mechanism (described below)

Phase 2: Field Verification

The second phase of the landslide inventory was field based and inventoried a representative sample of the aerial photo mapped landslides. The field work was preceded by a low elevation fixed wing aircraft flight. Data were collected on landslide dimensions and the percentage of sediment entering streams. This fieldwork included documentation, measurement, and description of the smaller landslides that cannot be identified with certainty on aerial photos. The results were used to help verify aerial photo measurements and interpretations, and to document the size of landslides that can reasonably be identified on aerial photos. The field sampling also mapped smaller landslides that cannot be identified on the aerial photos. Typically, only landslides with areas of at least 3,000 to 5,000 square feet can be reliably and consistently identified on 1:10,000 to 1:24,000 scale aerial photos in most terrains. The actual size of landslides that can reliably be identified varies with the scale and quality (black and white or color, age, and resolution) of the aerial photos.

About 15.5 percent of the landslides mapped from aerial photos were field verified. The sample size was primarily a function of access (i.e. permission, distance from road access, etc. The landslide characteristics mapped during the field inventory include the following:

- Landslide area, volume, and surface erosion estimates, as appropriate.
- Land use associated with landslide activity (e.g. forest harvesting, road fills and cuts).
- Triggering mechanisms that contributed to the initiation or reactivation of landslides (e.g. overloading, saturation from redirected surface water, root strength deterioration).
- Delivery of landslide sediment to streams.

Data and techniques suitable for field analysis and measurements of landslides followed those outlined in Turner and Schuster (1996).

2.4.1.3 Landslide Classification

The landslide classification system used for the landslide inventory follows Crudden and Varnes (1996), which use material type, movement type, and activity level to classify the landslide type. The material types include rock, debris, and earth, and movement types include fall, flow, landslide, spread, and topple. Activity level is not critical here because all of the landslides included in the inventory are assumed to be active. A simplified landslide classification system was used because most of the inventory was completed using aerial photos and certain details of landslide features could not be measured (Turner and McGuffey, 1996). Five functional categories of mass movement are used to broadly classify mass wasting features within the Mad River:

- Shallow, rapid landslides (debris slides and flows);
- Rapid, deep slides and flows (rotational and translational);
- Slower, deep seated landslides (slumps, earth flows, and lateral spreads); and
- Surficial mass wasting (dry ravel and rock fall).

Landslide movement types interpreted from the remote sensing data include falls, slides, and flows. Slides and flows are differentiated based on the water content and rate of movement and the surficial features, visible from the air, that result from sliding. Earth and debris slides tend to have a lower water content and move slower than flows. Flows tend to move as a liquid and have a longer run-out pattern. The type of landslide can change downslope depending on soil type, slope, and water content, and there may be different types of slides within an actively unstable hillslope. Falls and topples are similar movement mechanisms and could not be distinguished on the aerial photos, and only fall was used for this analysis. No spreads or earth slides were interpreted in the mapping area.

The following describes the different types of landslide classifications used for this landslide inventory:

- **Rock Fall (RF)**: made up of bedrock material and moves as a fall, moderate to rapid rate of movement, moist to wet, and generally on steep slopes.
- **Rock Slide (RS)**: made up of bedrock material and moves as a landslide.
- **Debris Slide (DS)**: made up of coarse material, moves as a landslide, has a slow to rapid rate of movement, is wet to very wet, and confined vertically and laterally by stable material;
- **Debris Flow (DF)**: made up of coarse material, moves as a flow, has a rapid rate of movement, is moist to wet, and tends to bulk or grow downslope;
- **Earth Slide (ES)**: made up of earth (i.e., fine) material, moves as a slide, and has a slow rate of movement, may be rotational (ESR) or translational (EST);
- **Earth Flow (EF)**: made up of earth (i.e., fine) material, moves as a flow, and has a slow rate of movement; and
- **Inner Gorge Debris Landslide (IG)**: made up of coarse material, moves as a landslide along the upper and lower channel bank, has a rapid rate of movement, and is confined by the valley walls.

2.4.1.4 Landslide Volume and Mass

The displaced landslide volume and mass are the product of landslide area (A) and average depth (D) and rock type. The landslide area is estimated using the mapped landslide polygon connecting the head, margins, and toe of each feature. The landslide area is for a horizontal plane and does not account for the landslide travel angle (Cruden and Varnes, 1996). As a result, the actual landslide area is underestimated for steep slopes, much like the actual drainage area of a watershed would be underestimated.

Each type of landslide was assigned an average depth. Field verification data show that landslide depth has a wide range for the same material and movement type (Table 3). The sediment delivery potential is assigned to each portion of the landslide features. One landslide can have several different delivery potentials, and most of the delivery occurs near the toe or lower facets of a given slide. The sediment delivery coefficient ($SD_{(coeff)}$) is based on hillslope position, slope steepness, and proximity to an active stream channel. In the case of large landslides (i.e., > 30 acres), which have a wide range of movement rates, the $SD_{(coeff)}$ was manually adjusted to match unit delivery rates measured in the field, from remote sensing data, and results from other studies.

Using the field verified data, GMA found a reasonable relationship between debris flow and slide measured landslide depth and slide area (i.e., y = 6.7994*x0.3898, R^2 = 0.8443). However, when this equation was used to predict depth for the remaining landslides, the predicted sediment delivery seemed unusually high (e.g., > 500,000 tons/mi^2/year). The rates for large debris flows were comparable to massive landslides measured in New Zealand (1x10^6 tons/mi^2/year) (Sidle and Ochiai, 2006). Subsequently, measured rates in the Redwood Creek basin (Sidle and Ochiai, 2006) of 90,000 tons/mi^2/year were used to adjust the landslide volumes so that they did not exceed measured values in Redwood Creek. The reason that the slide area versus depth relationship listed above over predicted landslide depth and sediment delivery is because three of the field verified debris flows have an average measured depth of over 30 feet.

Revised depth assumptions are shown in Table 3. This analysis assumes a constant average depth for each landslide type. Like the landslide area, the actual depth is not accurately represented. The average landslide depth was measured as part of field verification and these values were used in the volume and mass calculations. For rock falls and slides, this analysis assumes that 50 percent of the feature area moves downslope.

Table 3. Estimated average landslide depth by type.

Landslide Type	Lumped Geology	Average Depth (feet)
Debris Flow (DF)	FR	6
	M	6
	QA	5
DF Average		6
Debris Slide	FR	6
	M	7
	QA	3
	SC	9
DS Average		6
Earthflow (EF)	DG	12
	FR	12
	M	12
	QA	12
	SC	12
EF Average		12
Inner Gorge (IG)	FR	8
	M	8
	QA	8
	SC	8
IG Average		8
Rock Fall (RF)	FR	3
	M	3
RF Average		3
Rock Slide (RS)	FR	3
RS Average		3

Where FR = Franciscan, M = Mélange, QA = Quaternary, SC = South Fork Mountain Schist, and DG = All intrusive and extrusive are the Lumped Geology codes

Table 3a. Estimated average landslide sediment delivery by type.

Landslide Type	Average Sediment Delivery (tons/mi^2/year)
Debris Flow	41,332
Debris Slide	49,610
Earthflow	28,825
Inner Gorge	79,299
Rock Fall	130
Rock Slide	130

2.4.1.5 Landslide Delivery

The volume and weight of sediment delivery to the stream network is estimated for each landslide type (Table 3a). Each feature is classified according to its delivery potential. Sediment delivery was mapped where there was an obvious connection with the stream network. If a landslide appeared to deliver sediment to the stream network, the percentage of sediment delivered was estimated as one of 12 volume classifications (Table 3b). Each feature was assigned a Grid Code and concatenated with landslide type. All inner gorge debris slides are assumed to deliver 98 percent of the original landslide volume, and earthflows with connection to the stream network are assumed to deliver five percent of the displaced volume. Landslides with no sediment delivery potential were removed from the landslide analysis. Table 3b lists the average sediment delivery coefficient by landslide type. Once sediment delivery calculations were made, landslides that accounted for a large portion of the total delivery were checked and adjusted if necessary. Several adjustments were made to large earthflows, and they are noted in the Excel landslide database.

Table 3b. Average landslide sediment delivery coefficient by type and topographic position for this analysis.

Topographic Position Index	Grid Code
Inner Gorge (>65%)	1
Gentle Slope (35%-65%)	2
Steep Slope (>35%)	3
Ridgeline (<35%)	4

LS_Type/TPI	Delivery Coeff
DF/1	0.85
DF/2	0.17
DF/3	0.3
DF/4	0.05
DS/1	0.85
DS/2	0.17
DS/3	0.3
DS/4	0.05
EF/1	0.05
EF/2	0.03
EF/3	0.01
EF/4	0.001

Where DF = Debris Flow, DS = Debris Slide, EF = Earthflow, and TPI is Topographic Position Index

2.4.1.6 Landslide Triggering Mechanism

The landslide triggering mechanism is defined by the process(s) that initiated landslide activity: natural or management-related. Some of the natural triggering mechanisms include reduced soil strength due to slope saturation, removal of lateral support by stream downcutting, and reduced root strength after severe wildland fire. Some of the management related triggering mechanisms include removal of lateral support above road cuts, increased weight from road fills, reduced soil strength due to slope saturation from road drainage or timber harvest, and reduced root strength after timber harvest (CDC, 1999).

For this analysis, the mechanism that triggered a given landslide is classified into three categories: natural, road related, and timber harvest related. Ground disturbance associated with forest roads and timber harvest activities are commonly landslide triggering mechanisms; however, other non-forest land uses like grading associated with urban development do contribute to slope instability (CDC, 1999).

Although large earthquakes do trigger landslides, especially near the coast where there are active faults, GMA did not investigate earthquakes or seismicity as a measurable triggering mechanism. Given the uncertainty of seismic events, it is difficult to assign a seismic triggering mechanism (Sidle and Ochiai, 2006). Other large resource analyses in the area, such as Green Diamond's Habitat Conservation Plan (HCP) landslide investigation (Green Diamond, 2006, Appendix F), do not mention the role of earthquakes relative to landslide activity.

2.4.1.7 Landslide Inventory Data Analysis Assumptions

The landslide inventory analysis only included landslides that were definitely or probably present as interpreted from aerial photos and field verification. Questionable landslides were not included in the inventory dataset unless they were field verified and determined to be present and active. In addition, the inventory dataset did not include landslides that do not deliver sediment to the stream network, which were very few for the Mad River. The remaining landslide dataset was sorted by subwatershed, landslide type, year active, ownership, and lithotopo unit.

Summary tables for the Mad River and subwatersheds were prepared for use in interpreting the data and performing volume and mass calculations. The volume of delivering landslides in each subwatershed was computed based on delivery percentage multiplied by landslide area and landslide thickness. Temporally, the landslides are assumed to deliver the evacuated volume over a 31 year period from 1976-2006. Landslide volumes were converted from cubic yards to tons based on a soil bulk density factor (1.3 tons/yd^3). This allows comparison of sediment inputs to sediment transport values, which are usually computed in terms of weight rather than volume.

The following assumptions were made as part of this landslide inventory:

- The analysis only used those slides assigned a "definite or probable" certainty, unless after the field verification, a questionable slide was found to be present and delivering. All other questionable slides were discarded from further consideration.
- The analysis used the average landslide thicknesses from GMA field inventory combined with the GIS area to estimate landslide volume.
- The analysis assumed that the average delivery rates for the two types (i.e., debris slides and earthflows) from field data were applicable to all of the 1975 CDWR slides.
- The analysis intersected road and harvest coverages applicable to the post 1975 time period to determine a land use category for each landslide. Slides that are intersected by roads or timber harvest units were assumed to be road-related or harvest-related. All other slides were assumed to be non-management related.

2.5 Surface and Fluvial Erosion

2.5.1 Data Sources

The surface and fluvial erosion analysis relied on readily available information with limited field inventory and predicts the amount of erosion from roads and timber harvest activities. Public and private roads were digitized in ArcGIS from the 2005 NAIP digital orthophoto quads and historic aerial photographs. Not every road or disturbance activity was verified on the aerial photographs, and there are several line errors, missing roads, or roads in the coverage that are not present on the ground. The road mapping scale ranged from 1:3,500 to 1:24,000. The timber harvest history was developed from publicly available information which included: USDA Forest Service, CDF Forestry Resource Assessment Project (FRAP), and Multi Resolution Land Cover (MRLC) data.

GMA completed a rapid reconnaissance of the road system and drove about 300 miles of roads within the Mad River watershed. There are about 2,187 miles of mapped road within the Mad River watershed, so GMA rapidly inventoried about 14% of the road system. Ocular observations were made of road surface type, width, gradient, shape, cutbank height and vegetation cover, soil texture, bedrock type, traffic patterns, and erosion severity. These data were used to improve the road layer where possible; however, most of the road system was not field verified and the model relied on the existing, limited information.

2.5.2 Surface and Fluvial Erosion Model

The WEPP model, the Washington State surface erosion module, and measured data were used to estimate surface erosion and sediment delivery from roads. The road data available at the time of this analysis were limited, and the only data for road type or condition was the surface type (i.e., native, gravel, or paved). The lack of data on road shape (i.e., insloped versus outsloped), vegetation cover, drainage features, traffic level, etc. greatly limits the model input. New, or more detailed information that is available in the future, can be used to further inform the model and assumptions, or to revise it on a subwatershed or ownership basis in the future.

Given the large road network (over 2,000 miles of road), GMA classified the road system using the available data by surface type and lithotopo unit which include bedrock geology, slope stability, and topographic steepness and position. Using GIS, GMA segregated the data into 58 unique road types. The number of road types was reduced from the original analysis, which included 166 road types, by aggregating similar bedrock geology types.

The probability and volume of sediment delivery to the stream network from surface and fluvial erosion was quantified using the amount of material delivered to the stream network on average during flood events for background and existing watershed conditions. The Watershed Erosion and Prediction Model (WEPP) Road Batch (Elliot et. al., 2000) was used to estimate the amount of sediment delivery from the different sources.

The WEPP model uses the following physical processes to predict the probability of erosion and sediment delivery: infiltration and runoff, soil detachment, transport, deposition, and revegetation with time. WEPP does not route sediment once sediment is delivered to the stream network and it has an error of plus or minus 50% (Elliot et. al., 2000). There are seven input variables to include: climate, soil texture, type of treatment, gradient, horizontal length, percent cover, and percent rock. Within the model, ground cover is a driving variable where erosion decreases as ground cover increases. Like other erosion models, WEPP is best used as a comparative tool between different land disturbances (e.g., background versus existing conditions). The erosion rates by road type are listed in Appendix A.

The WEPP Road Batch model was run for the 58 unique road types for a unit road length (i.e., 500'). The model produced relatively high unit sediment delivery rates by road type; however, these results are comparable to sediment delivery rates reported in other surface erosion investigations (e.g., Washington Department of Natural Resources, Surface Erosion Module, 1995 and USDA Forest Service, 1991). This analysis used WEPP to develop an understanding of the relative input of sediment from roads and timber harvest activities by roughly quantifying the amount of sediment delivered to streams by disturbance type and lithotopo unit. The road and timber harvest surface erosion estimates are compared to the estimated sediment delivery rates for natural and other erosion sources associated with land management activities (i.e., bank erosion and creep).

GMA ran WEPP using different assumptions for road design, condition, and traffic levels. The model was first run as a sensitivity analysis to determine which factors were most influential in sediment production and found that vegetated versus unvegetated inboard ditches were the main drivers. GMA completed four WEPP runs to define a range of potential sediment delivery values by road type. The assumptions for the sensitivity runs, and ultimately for developing the final sediment budget in the SSA were adopted in consultation with Bill Elliot, one of the developers of WEPP (Elliot, personal communication, 2007) and this analysis occurred between the draft (September 2007) and final (December 2007) versions of the Sediment Source Analysis.

In order to ensure that the results were still realistic (because WEPP is known to overestimate road erosion), GMA decided to use a combination of WEPP model results and road erosion values reported in the Washington Department of Natural Resources, Surface Erosion Module (1995) to predict road erosion. The revised road surface erosion sediment delivery rates are reported in Appendix A and were used to revise the overall sediment budget for the Mad River. For the first model runs, the average road surface erosion sediment delivery rate was 20 tons/acre/year; the revised results averaged 8 tons/acre/year for all road types. The highest erosion rates (30-45 tons/acre/year) are for #30 (31% of the road system), #31 (1% of the road system), and #23-25 (that dissect mélange, and together comprise about 2% of the road system). Mélange within inner gorge terrain represents about 3% of the road system (Appendix A). Most of the road system (31%) occurs on Franciscan Mélange on steep slopes (>35%) with native road surfaces.

2.5.3 Road Surface and Fluvial Erosion

The approach used to estimate the surface erosion rate for a given type of road was to examine road segments for characteristics of the road prism, drainage system, and traffic as they influence the delivery of sediment to the stream system, and calculate road sediment load based on them. Factors were applied for differing conditions of the road tread, cut-slopes, and traffic use that increase or decrease the estimated sediment load of that segment. The result is an estimate of sediment load for each road segment. The sediment *load* estimate was further modified according to the estimated sediment *delivery* to the stream network along that segment.

Data were compiled for the following factors and road attributes that influence the amount of sediment delivered to streams from roads:

- The erodibility of the soil/geology the road is built upon
- Precipitation amount, frequency, and intensity (data from the Forest Glen weather station was used)
- The age of the road was not available
- Road drainage pattern (insloped/outsloped/crowned): all roads were considered insloped with a ditch
- Probability that sediment from road reaches stream (depends on distance and slope between road drain and stream, amount of obstructions to trap sediment, and road area that collects water and sediment)
- Length of road that delivers to stream
- Width, surface type and durability, traffic use, and slope of road tread

The total amount of erosion from each drainage segment was calculated as the sum of tread erosion, cut-bank erosion, and other sources of erosion using the WEPP model. Total erosion was then divided by the planar road area. Total erosion from each site was then summed for each of the road types and lithotopo units and the results were used to develop surface erosion rates (tons/acre/year). These were applied to data extracted from the project GIS.

2.5.4 Timber Harvest Surface and Fluvial Erosion

Surface and fluvial erosion from areas disturbed by timber harvest activities is most often related to several different surface disturbance activities, primarily skid trails and harvest operations that result in impervious surfaces and increased rainfall-runoff. WEPP was used to predict erosion from harvested areas for high, medium, and low disturbance levels. The rate varied by the type of harvest (e.g., clearcut versus thin), the yarding method (e.g., tractor versus cable), and type of lithotopo unit. Surface and fluvial erosion from harvest areas was estimated for the 31 year period.

2.5.5 Model Assumptions

The following is a list of the assumptions made as part of the erosion potential modeling process.

- A large portion of the material delivered to the stream network during frequent flooding is transported by the stream network.
- Background surface erosion rates are based on undisturbed conditions, and active landslides associated with land use are not included.
- Roads that cross dissected erodible bedrock and soils have higher sediment delivery.
- Upland sediment delivery potential is a function of slope steepness, slope position, and proximity to the stream network.
- The volume (yds^3) of sediment delivered is converted to weight (tons) using the bulk density of partially saturated loose earth (i.e., 1.3 $tons/yds^3$)

2.6 NetMap Sediment Budget

2.6.1 Overview

NetMap is a complex tool used for watershed characterization, sediment budgeting and routing. For the Mad River TMDLs, NetMap was used to develop estimates of background surface erosion (creep from active and inactive, or slow-moving, earthflows), bank erosion, and for watershed characterization (topographic indices, Digital Elevation Models, or DEMs, developing mean annual flow, and channel classification). In the sediment budget portion of the SSA, it contributes the estimates of background creep and bank erosion.

NetMap can be used to develop a sediment budget at the smallest scale (e.g., a GIS pixel) in the watershed; the program models the delivery of that sediment to the stream and the routing of that sediment through the stream system. In the draft SSA, EPA intended to use the NetMap model to develop the sediment budget; however, several problems were encountered. For example, as described in the original SSA and draft TMDL, the results of the NetMap sediment budget diverged widely from the sediment yield estimates derived from measured suspended sediment concentration (SSC) and associated suspended sediment load (SSL) estimates. Accordingly, the SSA relies primarily on the development of a classical sediment budget to estimate sediment production and delivery to the stream system in the Mad River basin. EPA revised the text in the final TMDL document to distinguish between what NetMap *was* used for (contributing creep and bank erosion to the classical sediment budget, and assisting with watershed characterization) and what it *could be* used for in the future (e.g., developing sediment budgets based on different design flows, for example, and targeting areas for watershed improvement). We also included text in Chapter 4 to suggest its further development and use as a tool for implementation.

Two methods were used to model NetMap for the Mad River basin. The first uses a Generic Erosion Potential, or GEP factor. It is based on the DEM, and factors in topographic slope (steepness) and slope convergence, which are two factors that are known to contribute to the initiation of landslides. This method does not work well in hummocky terrain, such as the large landslide-prone, earthflow terrain comprised of unstable Franciscan and Schist found in parts of the Mad River basin. GEP is driven by slope convergence, which is not an equally strong factor in earthflow terrain. These areas are driven more by other factors. Thus, for these terrains, NetMap is used without GEP. The second method uses a modified GEP developed from average sediment delivery by slide type and geology.

The final SSA and TMDL document uses revised inputs to NetMap based on other revisions to the SSA inputs. For example, NetMap uses surface erosion estimates from the WEPP model to modify the GEP in the NetMap model. It also uses the revised area/volume relationships developed in the landslide analysis. The revised assumptions are probably a reason that the NetMap results now being much closer to the monitored results (see Appendix B).

While it is used in the TMDL document simply to characterize the watershed and produce estimates of creep and bank erosion, this is also essentially one of the initial steps that can be taken to further develop NetMap to refine the sediment budget in the future, if that is desired by the Regional Water Board or other organizations in the implementation phase.

2.6.2 Data Sources

The NetMap model uses the 10 meter DEMs to measure hillslope and stream channel parameters and predict local sediment delivery and watershed-wide sediment load. The hillslope and stream channel data are synthesized and refined using the stream, erosion source, and landslide field data collected as part of this analysis. The geology, landslide, and land use GIS layers are used to refine the NetMap sediment budget. The intersected layer is called the litho-land use layer. The Mad River subwatersheds are used to stratify the analysis area and summarize the sediment budget results. All of the GIS and Excel files are stored electronically in the project file and are available on CD.

2.6.3 NetMap Model

This analysis uses the NetMap model developed by the Earth Systems Institute (ESI). NetMap is a watershed analysis system that is comprised of a point and click watershed catalogue (map databases), a set of automated analysis tools, hyperlinked users manuals and technical materials, and Google Earth visualization (Benda et al. 2007). NetMap can evaluate key environmental attributes, on a watershed-by-watershed basis, including spatial relationships among the best and most sensitive habitats and erosion potential, sediment delivery, wood recruitment, temperature sensitivity, road density, vegetation age, and fire risk, among other factors. NetMap can also be used to examine environment and land use patterns relevant to conservation, habitat management, land use activities, restoration, and monitoring.

The NetMap model was used to develop the background creep and fluvial bank erosion component of the classical sediment budget. NetMap was also used to develop a sediment budget. This model was run using the best available data and information. In the future, more detailed information can be used to further inform this model and improve the overall accuracy of sediment load predictions. NetMap is used to increase the spatial resolution of erosion sources to better identify upland areas with high sediment delivery potential. Results are tabulated and displayed in map form.

NetMap generates a parameter referred to as generic erosion potential (GEP), an erosion index that is based on slope gradient and slope curvature. GEP is calculated as $(A_L*S)/b$, where A_L is a measure of local contributing area (within one pixel length), and S is slope gradient (Miller and Burnett 2007), and b is a measure of local topographic convergence (the length of an elevation contour crossed by flow out of the pixel; values less than one pixel length indicate convergent topography; GEP is similar in form to other models that predict shallow failures based on some measure of slope gradient and curvature (i.e., Shaw and Johnson 1995, Montgomery and Dietrich 1994, Pack et al. 1998). GEP is applicable to many landscapes since steep, convergent areas are preferential locations for erosion in the form of shallow failures, gullies, and even surface erosion (e.g. following fires). However, predicted erosion potential (such as GEP) should be considered only in the context of additional information on geology, climate and vegetation, among other factors. For example, steep and convergent areas in humid landscapes are more susceptible to shallow landslides and debris flows due to heavy rain and rain-on-snow, compared to similar landforms in semi-arid landscapes where convergent landforms may pose less of an erosion hazard due to gradual spring snowmelt runoff, with the exception of post-fire gullying. Importantly, GEP does not address erosion sources such as large debris flows and slides, deep-seated slides, and earthflows.

In NetMap, GEP can be converted to annual sediment load by directly scaling GEP values to known (or estimated) erosion rates or basin sediment loads (information often collected while developing a sediment budget). Predicted sediment load values are reported on hillslopes and also to channels, and predicted values are accumulated downstream and scaled by drainage area.

GEP in NetMap can apply to surface erosion mechanisms on landslide-prone terrain since hillslope gradient and surface topography should govern shallow failures and surface erosion. However, when GEP is converted to sediment load it cannot be applied directly to large landslide prone terrain since the sediment load is driven by non-GEP processes (e.g., deeper seated failures and flows). Thus in sediment load terms, landslide-prone terrain is given a sediment-budget derived annual sediment load, irrespective of GEP values.

To conduct the GEP and terrain conversion to sediment load, polygons are draped onto the predicted GEP maps in the Mad River basin (but only in areas where slope steepness and convergence relates to erosion potential, and then the model associates the polygons with factors of erosion intensity or sediment load, high or low values (based on the sediment budget). Thus in areas of the basin with predicted high GEP but low erosion potential or sediment loads, NetMap downgraded the GEP values and reported the results in terms of pixel-scale sediment load. Alternatively, in areas of rock with high erosion potential (reflected by slope and convergence - shallow failure, gullying, surface erosion post fire), the GEP values were increased or were transformed into relatively high sediment load values.

To reiterate, the GEP conversion to sediment loads does not apply to large landslides. Landslide prone areas were mapped as polygons and assigned measured rates of erosion and sediment delivery. However, it is important to note that landslide prone areas with high sediment loads results in the remainder of the GEP-mapped landscape having a lowered erosion or sediment delivery potential. This is necessary for the GEP analysis to maintain consistency with the overall basin's sediment budget.

For the Mad River, NetMap was used to model upland sediment delivery and instream sediment load for natural (background) and existing (disturbed) conditions. The background and disturbed model runs are for a 31 year period over which average (i.e., frequent) and infrequent flooding and sedimentary events occur. This model, like the rest of the sediment source analysis, estimates the sediment load for average conditions, like most sediment source analyses, although we recognize that episodic events deviate significantly from the average over the modeled time period.

Lithotopo units are used to classify and analyze natural and human altered geomorphic processes (Montgomery, 1999). These domains or units are presumed to be spatially and temporally a function of climate, bedrock geology, tectonic setting, soil type, ground cover, slope stability, slope steepness and convergence, and stream network geometry (Benda et. al., 2004). Lithotopo units are classified by mapping individual polygons with similar erodibility and topography. Data sources used to stratify the Mad River into lithotopo units include: 1) bedrock geology, 2) dormant and active landslides, and 3) topography generated from 10 meter DEM. A GIS project was used to generate the lithotopo unit polygons, and sediment source inventory data were used to refine the polygon's erosion and sediment delivery rate.

The GEP is used to predict the probability of surface and fluvial erosion for landforms that are stable or have shallow debris flow potential (small features not recognizable at the landslide inventory mapping scale). For locations on the landscape where surface and fluvial erosion are the dominant erosional processes, the GEP is modified using results from the upland sediment budget. For large landslide prone areas, which include dormant and active landslides, the landslide sediment delivery rates measured as part of the landslide inventory are used instead of GEP. This eliminates the problem of using GEP on large landslide prone terrain where slope steepness and convergence are not driving erosion and sediment delivery. The factors and sediment delivery rates calculated for each geologic, landslide, and land use disturbance type are summarized in Appendix B.

The predicted basin average sediment load ($Q_{SL(Basin)}$) for the Mad River is the sum of sediment delivery from large landslide prone terrain ($Q_{SD(Landslide)}$) (sediment delivery Method 1) and GEP terrain ($Q_{SD(GEP)}$) (sediment delivery Method 2). The sediment load is calculated using the following equation:

$$Q_{SL(Basin)} = Q_{SD(Landslide)} + Q_{SD(GEP)}$$

To calculate surface and fluvial erosion ($Q_{SD(GEP)}$), the GEP is adjusted using an erosion potential factor (F). This factor is calculated by dividing the average sediment delivery for a given lithotopo unit ($Q_{SD(unit)}$) by the measured or estimated basin average sediment load $Q_{SLM(basin)}$ where:

$$F = Q_{SD(unit)} / Q_{SLM(basin)}$$

This analysis used the following estimated and measured sediment loads for background and disturbed conditions, respectively:

$$Q_{SLM(basin)} = 780 \text{ tons/mi}^2\text{/year}$$

$$Q_{SLM(basin)} = 2{,}600 \text{ tons/mi}^2\text{/year}$$

The background sediment load was estimated at 30% of the existing sediment load using results of the upland sediment budget's natural versus management related sediment delivery. The existing sediment load was the average load measured as part of this study. These values are the basis for scaling the basin sediment delivery ratio and converting GEP to units of sediment delivery. The $Q_{SD(unit)}$ is calculated for each lithotopo unit and is varied depending on surface and fluvial erosion potential. For background or natural conditions, F ranges from 1 (i.e., unadjusted GEP) to 108 with an average of 66. Franciscan and Franciscan mélange geologic types have the highest factors (>100) (Appendix B). On naturally stable vegetated hillslopes where very little natural surface or fluvial erosion occurs except after wildland fire, the GEP remains unadjusted. For disturbed or managed conditions, F ranges from 1 to 32 with an average of 17 . On natural or disturbed erodible hillslopes (e.g., convergent slopes in mélange) with no landslide activity, the GEP is adjusted using the factor (F>1) to account for the erodibility of different rock types. For lithotopo units with a $Q_{SD(unit)} < Q_{SLM(basin)}$, F =1.

The GEP of each lithotopo unit is then converted into sediment delivery units using the following scaling factor:

$$Q_{SD(GEP)} = Q_{SLM(basin)}/GEP_{(basin)}, \text{ where}$$

$$GEP_{(basin)} = \text{basin average GEP}$$

For landslide prone areas, the GEP is not used to predict erosion and sediment delivery. The average measured landslide sediment delivery rate ($Q_{SDR(Landslide)}$) by landslide type, bedrock geology, and disturbance type is used to develop the non-GEP portion of the sediment budget (Table 4). The sediment delivery rate was held constant for each type of landslide-prone lithotopo unit. The sediment delivery from each landslide was calculated using the following equation:

$$Q_{SD(Landslide)} = Q_{SDR(Landslide)} * A_{(Landslide)}, \text{ where}$$

$$A_{(Landslide)} = \text{mapped landslide area.}$$

Table 4. Average unit sediment delivery (tons/acre/year) from large landslides by landslide type and lumped geologic type.

Landslide Type	Lumped Geology	Natural	Harvest	Road	Grand Total
Debris Flow (DF)	FR	173	176	147	169
	M	191	96	123	145
	QA	133	82	91	103
DF Total		177	153	127	155
Debris Slide (DS)	FR	196	139	256	202
	M	197		259	239
	QA	134		81	119
	SC		330		330
DS Total		191	187	252	219
Earthflow (EF)	DG	41	170		133
	FR	142	244	188	179
	M	227	17	138	155
	QA	24			24
	SC	244	21	213	202
EF Total		188	150	159	165
Inner Gorge (IG)	FR	373		360	367
	M	352	383	347	363
	QA	343		349	347
	SC			406	406
IG Total		369	383	357	364
Rock Fall (RF)	FR	0.2			0
	M	0.2			0
RF Total		0.2			0
Rock Slide (RS)	FR	0.2			0
RS Total		0.2			0
Grand Total		178	184	169	172

NetMap takes the predicted sediment delivery from Methods 1 and 2 and delivers sediment to the channel network. It then routes the delivered sediment through the network to the basin outlet. NetMap does not predict sediment storage within the network; rather, it assumes equilibrium conditions between sediment supply and storage. As stated above, for stable terrain, slope steepness and convergence are used with the measured basin sediment load to predict erosion potential and sediment delivery to the stream network (Benda et. al., 2007). NetMap aggregates sediment delivery rates downstream to the basin outlet. The total cumulative sediment load is estimated at the basin outlet and for each of the subwatersheds and erosion source type.

3.0 STREAMFLOW, TURBIDITY, AND SEDIMENT TRANSPORT RESULTS

3.1 Hydrology

3.1.1 Precipitation

The magnitude, frequency, duration, intensity, and timing of precipitation events directly influence streamflow attributes, which the sediment source analysis models use to qualify and quantify erosion and sediment delivery potential. For the Mad River, the average annual precipitation is about 70 inches at 4,000 feet, with 90 percent falling between October and April (Plate 3). Long duration snow and rain storms are common. Short duration thunderstorms occur infrequently during the summer and fall. Average annual precipitation within the Mad River watershed ranges from about 45 inches near sea level to over 75 inches near the headwaters, which originate above 6,000 feet. Most of the precipitation above 5,000 feet is in the form of snowfall and below is a mix of snow and rain. The frequency and intensity of the 100 year, 24 hour storm event is between 7 and 10 inches of precipitation, and the 2 year, 6 hour event is between 1.6 and 2.2 inches.

3.1.2 Streamflow

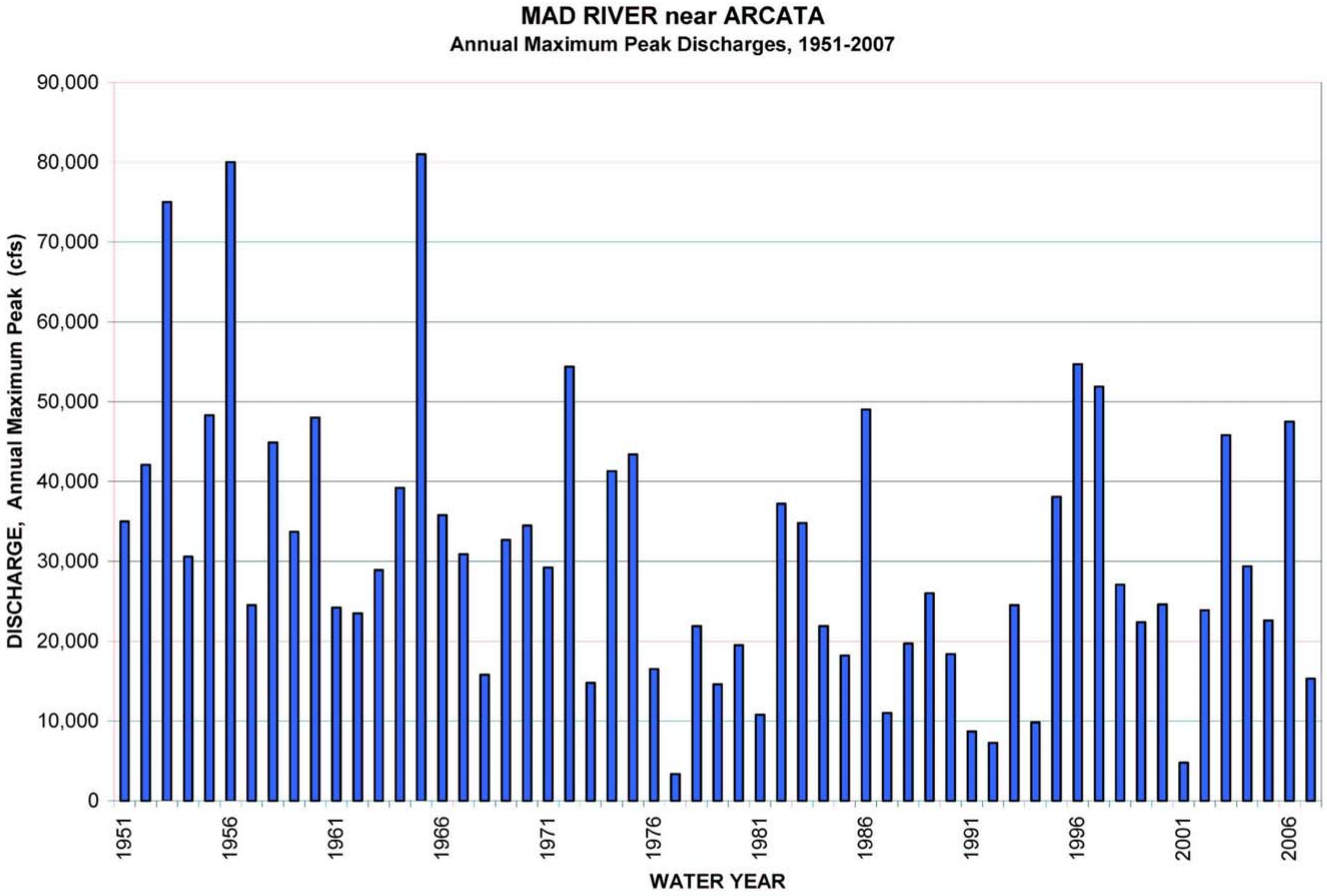
The streamflow magnitude, frequency, duration, intensity, and timing are used to help qualify and quantify the sediment transport and storage potential of the Mad River. Since the 1940s, a variety of streamflow records have been collected for the Mad River. Presently, the US Geological Survey operates two continuous streamflow gages in the basin: one in the lower watershed near Highway 299 and one above Ruth Lake. For this study, GMA operated one continuous streamflow gage on the North Fork Mad River. Since stream discharge is fundamental to the computation of sediment loads, the relevance of WY 2006-2007 streamflow is discussed in Section 3.3.

3.1.2.1 Peak Discharge

The largest recorded instantaneous discharge for the Mad River near Arcata occurred in December 1964 (WY1965), when the river crested at 81,000 cubic feet per second (cfs), according to USGS records. The annual maximum peak discharges for the period of record for this gage, Water Year 1951 to 2007, are shown in Figure 2. Other very large storms (greater than 70,000 cfs) occurred in December 1955 (WY1956) and in WY1953. Three other events, in 1972, 1996, and 1997, exceeded 50,000 cfs. The largest recorded instantaneous discharge for the Mad River above Ruth Reservoir occurred in February 1986 (WY1986), when the river crested at 15,000 cfs, according to USGS records. The annual maximum instantaneous discharges for the period of record for this gage, Water Year 1981 to 2007, are shown in Figure 3. The relationship between the annual maximum instantaneous discharges at these two gages is shown in Figure 4. Although a relationship clearly exists, the correlation is not that strong ($r^2 = 0.64$), indicating that precipitation events that drive these large flows are quite variable in their distribution throughout the watershed. A 4,000 cfs peak flow at MRRTH may produce a peak flow of 10,000 cfs or 25,000 cfs at MRALM.

3.1.2.2 Flood Frequency

Flood frequency analysis is a method used to predict the magnitude of a flood that would be expected to occur, on average, in a given number of years (recurrence interval) or to



TETRA TECH, Inc.

MAD RIVER SEDIMENT SOURCE ANALYSIS

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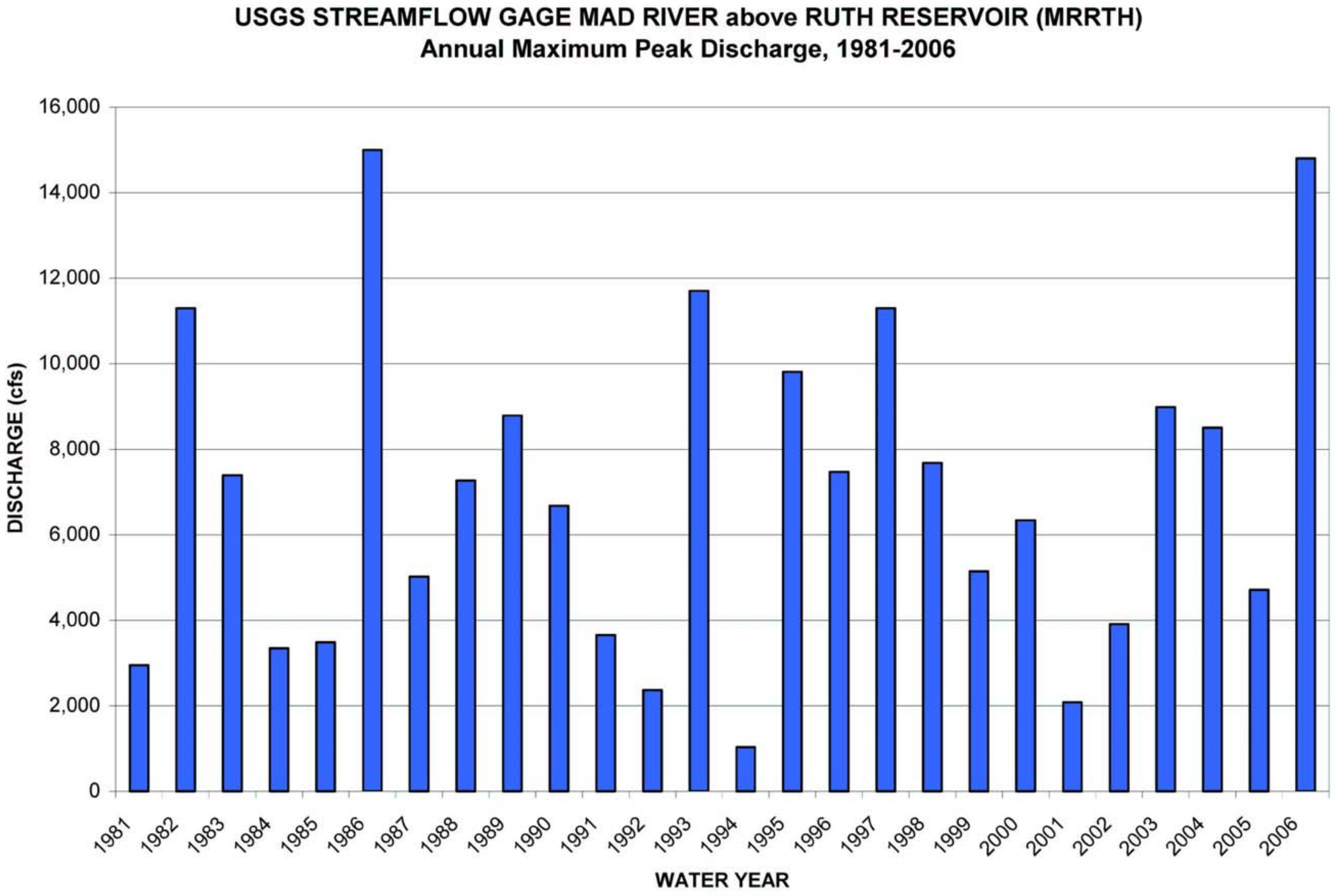
FIGURE

2



USGS STREAMFLOW GAGE MAD RIVER above RUTH RESERVOIR (MRRTH)
Annual Maximum Peak Discharge, 1981-2006

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FIGURE

3

COMPARISON OF ANNUAL MAXIMUM PEAK DISCHARGES
Mad River above Ruth Reservoir vs. Mad River near Arcata, 1981-2006

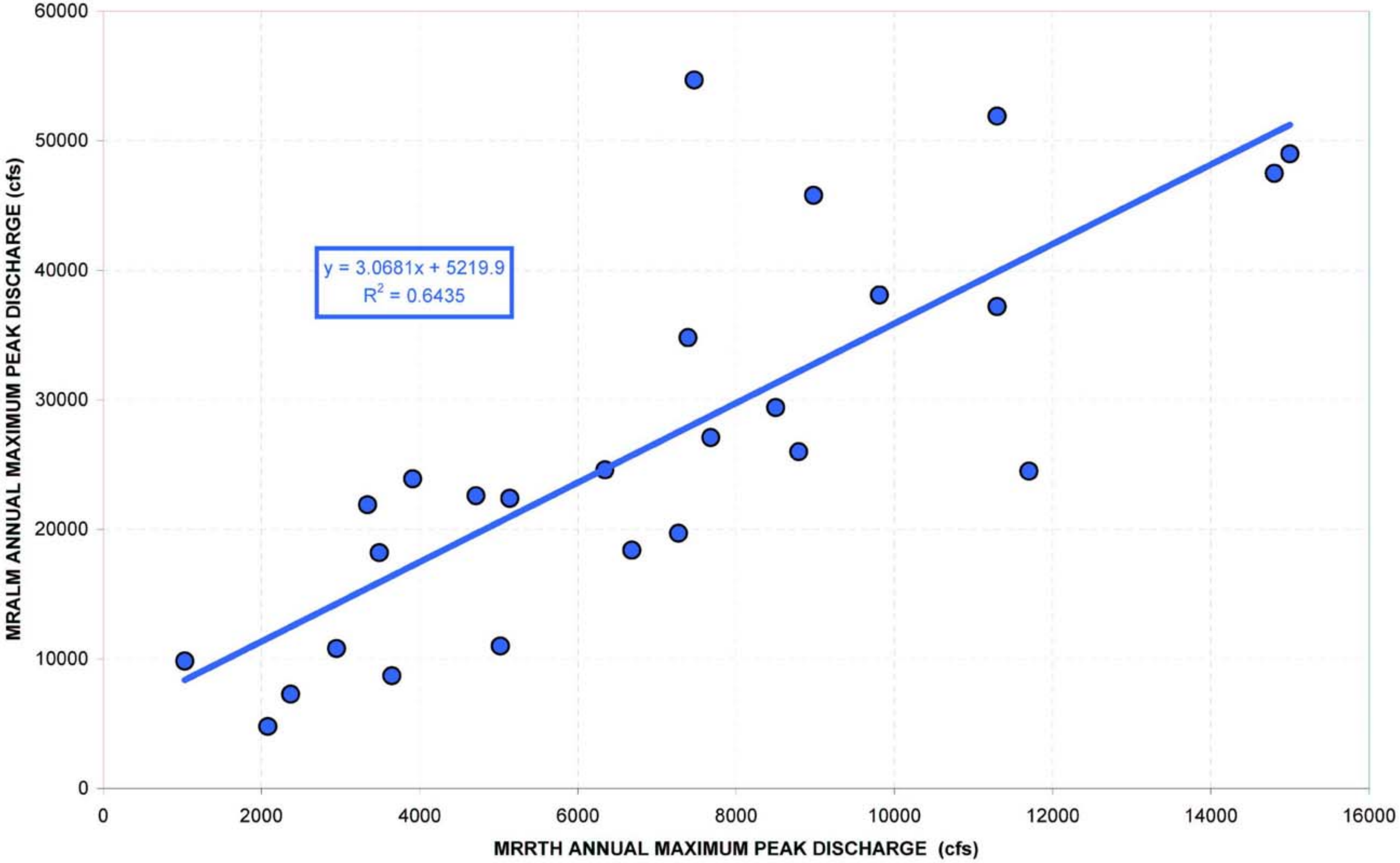

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FIGURE

4

have a specific probability of occurrence in any one year (1% chance event, for example). Typically, the observed annual maximum peak discharges are fitted to the log-Pearson Type III distribution using a generalized or station skew coefficient. The results of a LPIII analysis on the two USGS gages are shown in Figure 5 and summarized in Table 5 below. For example, the Q_2 event at MRRTH is predicted to be 6,100 cfs, while at MRALM it is 27,000 cfs.

Table 5. Log Pearson III Analysis of Annual Maximum Peak Discharges

Return Period	**Exceedence Probability**	**MRRTH Predicted Discharge**	**MRALM Predicted Discharge**
(years)	(%)	(cfs)	(cfs)
1.2	83.3%	3,100	13,700
1.5	66.7%	4,500	20,300
2	50.0%	6,100	27,000
2.33	42.9%	6,800	30,100
5	20.0%	10,200	44,200
10	10.0%	13,100	57,000
25	4.0%	16,900	69,800
50	2.0%	19,800	79,900
100	1.0%	22,700	89,600

3.1.2.3 Historic Floods

Although the Mad River has a relatively short period of streamflow records, the dates of significant floods years are generally known, due to regional data. Known large flood events in the region or the watershed have occurred in Water Years 1861, 1881, 1890, 1914, 1938, 1953, 1956, 1965, 1972, 1996, and 1997. The largest of these were likely to have been the 1861 and 1965 events, followed by the 1956 and 1953 events. For this study, which subdivides sediment production into pre and post 1975 time periods, it is important to note that the peak events were much larger between 1951 and 1975, than after 1975.

3.1.2.4 Mean Daily Discharge

The USGS publishes mean daily discharge records for each of its gages on an annual basis. These values are typically used to construct annual streamflow hydrographs and perform flow duration analyses. Minimum, mean, and maximum daily flows are shown in Figure 6. The range of possible flows during the winter is extreme: in a very wet year, mean daily flows could exceed 30,000 cfs, while in a very dry year well under 1,000 cfs. High flows during storms are of very short duration, one to two days at most generally, and flows rapidly return to typical winter base flow within one week after the peak. Almost all significant runoff events occur between December and April.

3.1.2.5 Flow Duration

A flow duration analysis was performed using mean daily discharge for the two USGS gages for their respective periods of record, 1951-2007 for MRALM, and 1981-2007 for MRRTH. 2007 values are provisional. The flow duration curves are shown in Figure 7. This analysis shows that there is, for example, a 50% probability that the mean daily flow will exceed 305 cfs at MRALM, while only 33 cfs at MRRTH. A flow of 2000 cfs

USGS STREAMFLOW GAGES IN MAD RIVER WATERSHED

Flood Frequency Analysis for Mad River near Arcata (MRALM) and Mad River above Ruth Reservoir (MRRTH)

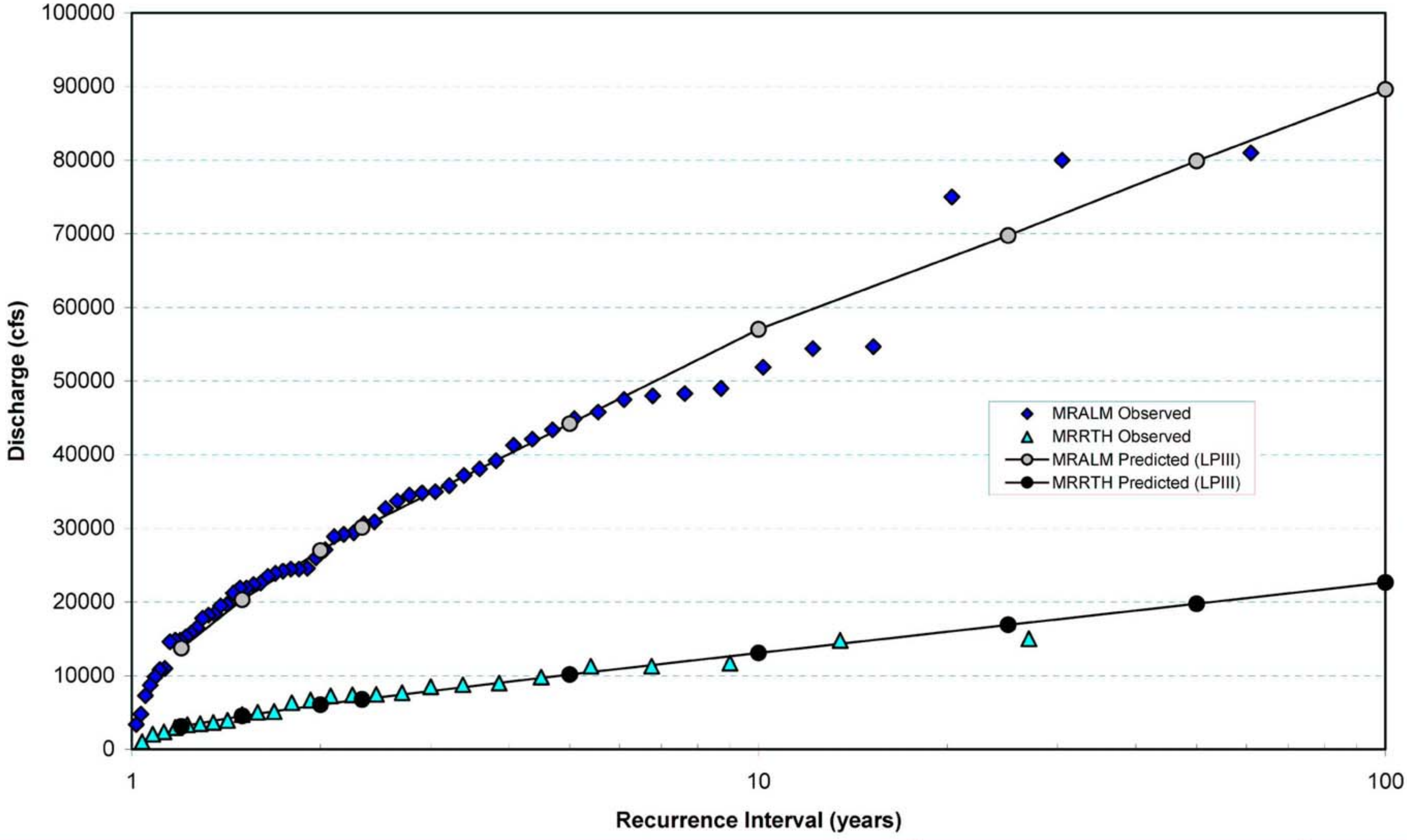

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FIGURE

5

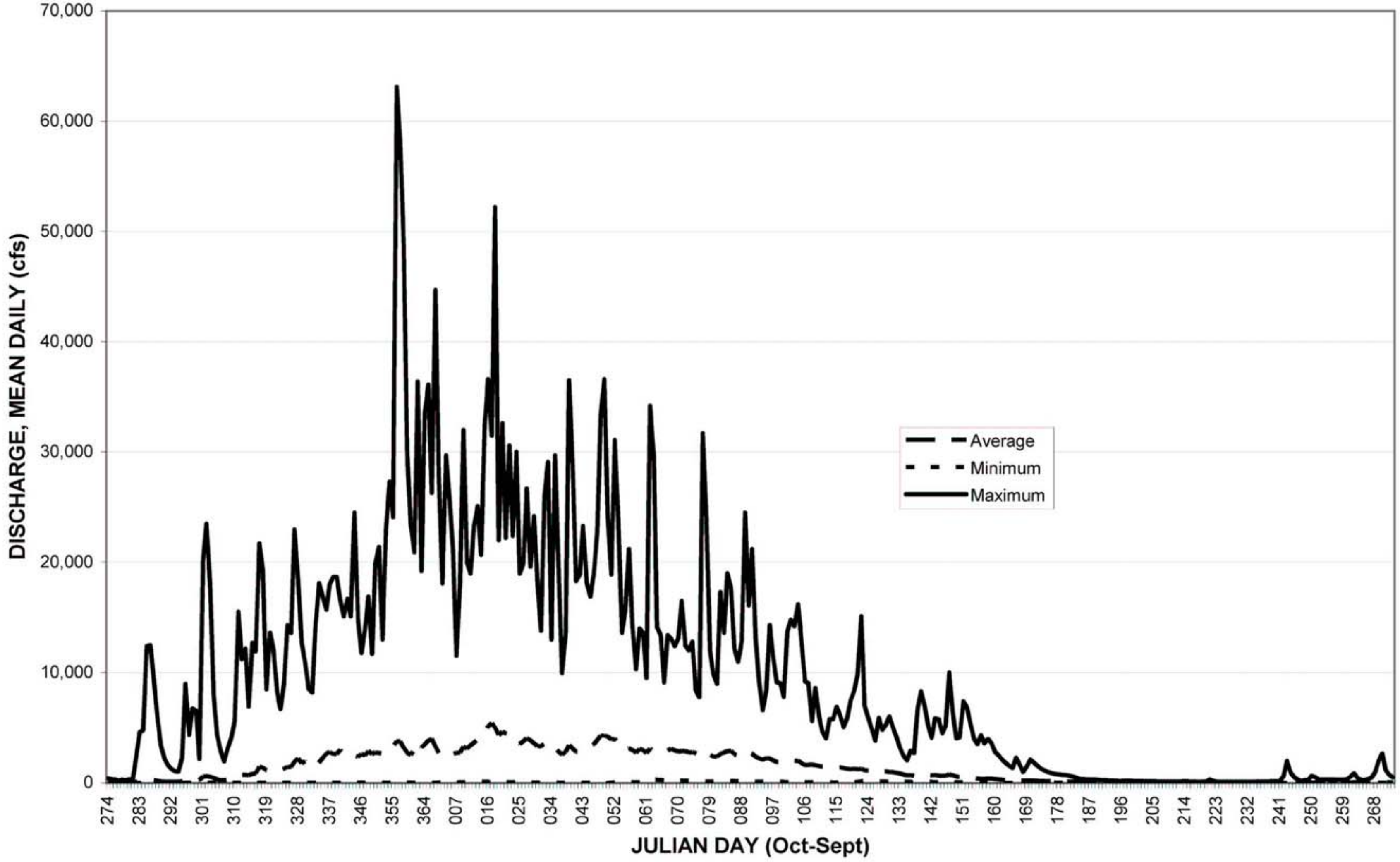
MAD RIVER NEAR ARCATA
Average, Minimum and Maximum Mean Daily Discharge, 1951-2007

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FIGURE

6

USGS STREAMFLOW GAGES MEAN DAILY FLOW DURATION CURVES
Mad River near Arcata (MRALM) and Mad River above Ruth Reservoir (MRRTH)

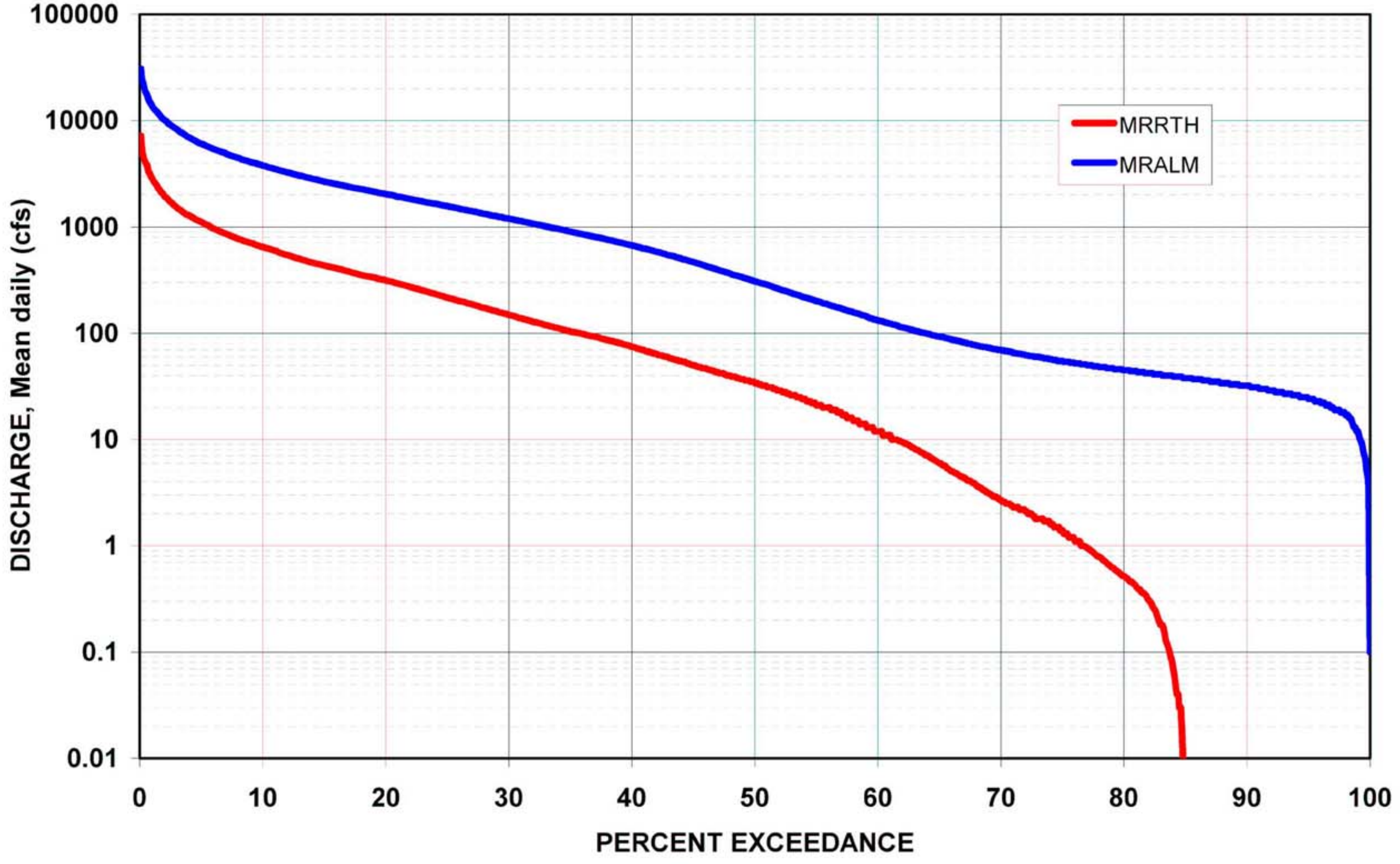

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FIGURE

7

occurs about 2% of the time at MRRTH, but 20% of the time at MRALM. Relatively little sediment transport probably occurs below 6000 cfs at MRALM, thus all of the geomorphic work accomplished by the river occurs in less than 5% of the time, with most concentrated in the top 1% of the flows.

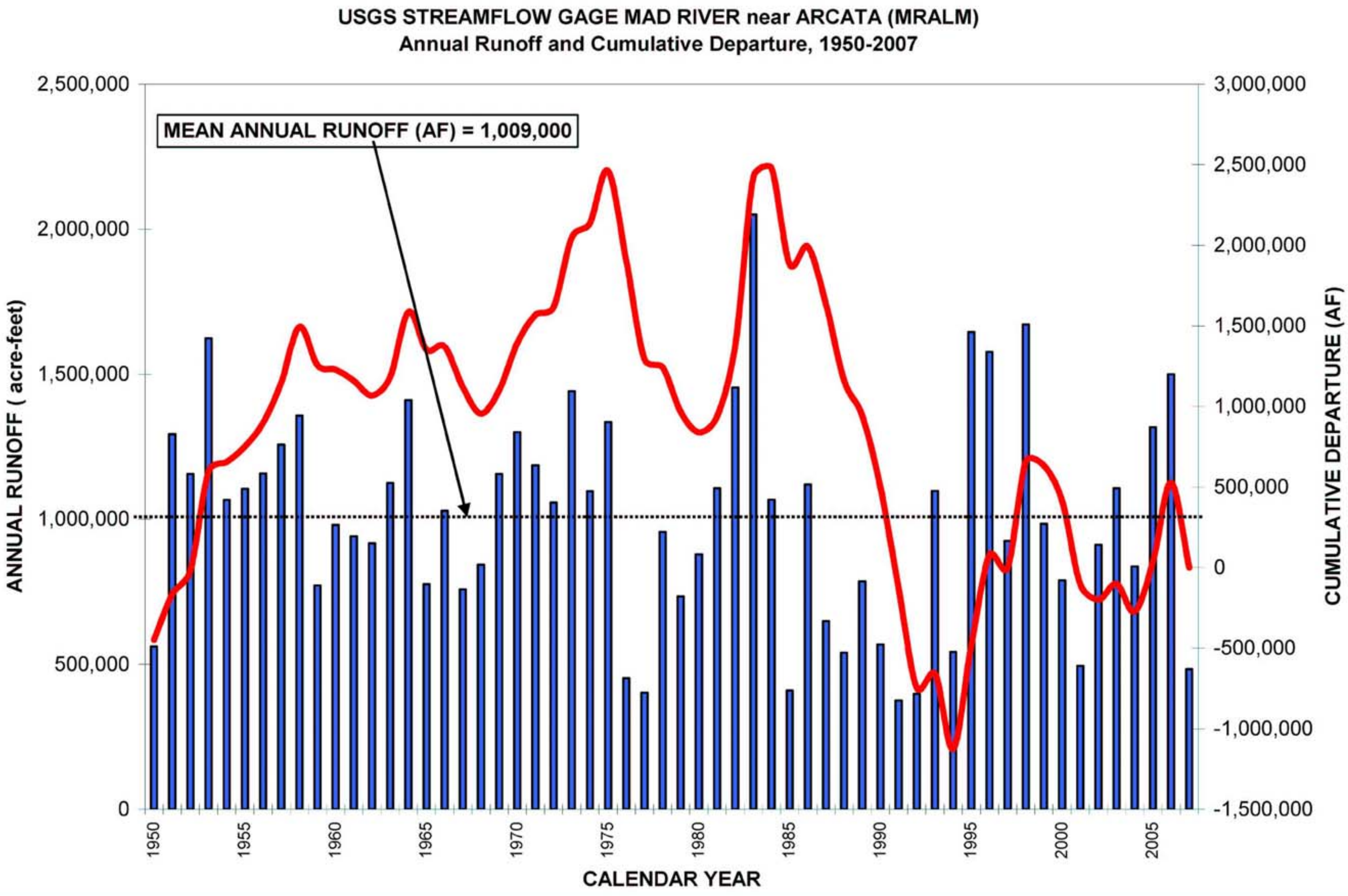
3.1.2.6 Annual Runoff

Annual runoff has been measured in the Mad River watershed with the various USGS streamflow gages. The mean annual runoff MRALM for the WY1951-2007 period is 1,009,000 acre-feet (Figure 8). Large volumes of runoff are often associated with both large flood years and years with high annual precipitation. The largest annual runoff years were 1983, followed by 1953, 1998, and 1995.

Cumulative departure from the mean is a measure of the consecutive and cumulative relationship of each year's rainfall to the long-term mean. When the cumulative departure line is descending (left to right), there is a dryer than normal period, while an ascending line denotes wetter then normal. This type of analysis assists in the consideration of long-term trends that could relate to hydrologic and/or biologic changes observed on the property. This allows evaluation of the hydrologic context of "snapshot" historical records, such as aerial photographs.

Wet periods include 1951-1958, 1969-1975, 1981-1984, and 1995-1998. One particularly dry period stands out of the cumulative departure analysis: 1985-1994. The 1976-1980 period was not nearly as severe.

The annual runoff data and cumulative departure analysis (1980-2007) for MRRTH are shown in Figure 9.



USGS STREAMFLOW GAGE MAD RIVER near ARCATA (MRALM)
Annual Runoff and Cumulative Departure, 1950-2007

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FIGURE

8

USGS STREAMFLOW GAGE MAD RIVER above RUTH RESERVOIR (MRRTH)
Annual Runoff and Cumulative Departure, 1980-2007

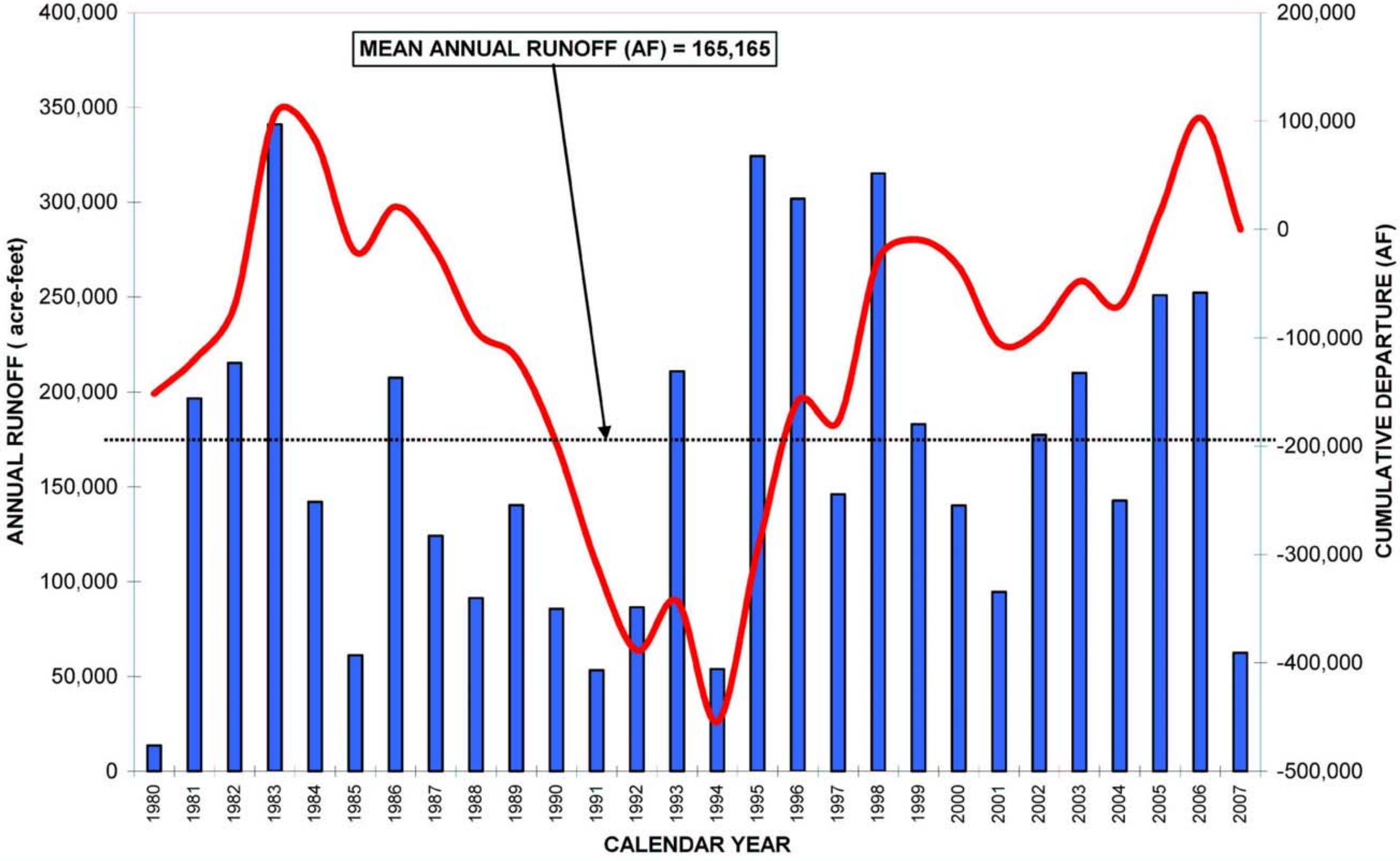

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FIGURE

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3.2 Drainage Basin Characteristics

3.2.1 Watershed Morphometry

The slope elements, shape, texture, and drainage pattern of the stratified subwatersheds are used to characterize sediment delivery and transport and to quantify sediment load. The Mad River drains 499 mi^2 of planar land area and flows from the southeast to the northwest with an elevation range of 6,022 feet. The average subwatershed slope or relief ratio is 17 percent and ranges from five to 23 percent. The headwaters above Ruth Lake have a smooth, concave longitudinal profile, whereas the mid-watershed displays several flat benches, steep inflections and exhibits a convex profile, which ultimately transitions to a smoother, concave profile in the lower watershed (Figure 10). The benches appear to be created by large deep seated earthflows that confine the valley bottom, creating vertical control points.

According to the NHD stream layer, there are 1,073 miles of stream channel draining the Mad River watershed. The watershed has a contorted drainage pattern that trends along more resistant rock types, contacts, and fault zones. Areas with a steep and dense drainage network result from heavy precipitation, shallow erosion-resistant bedrock, and tectonic uplift (Plate 6), whereas areas with gentle to steep slope and immature drainage patterns result from large earthflows.

Digital Elevation Model (DEM) analysis of the stream network indicates that during fully saturated conditions, the total stream network length may be about 2,377 miles with 64 percent of the channels steeper than 10 percent slope and nine percent less than 1.5 percent slope. The average drainage density derived from the USGS blue line streams is 2.2 miles per square mile, while the average density from the DEM stream network is five miles per square mile. The DEM network represents the active drainage network during large flood events and is used as a measure of drainage efficiency. The Mad River has high drainage efficiency, which means that the majority of the stream network produces and transports sediment and a small percentage stores massive quantities of delivered sediment.

In the headwaters, the drainage network is primarily made up of steep *source-type* channels (i.e., slope > 10 percent) with narrow valleys, where the potential stream energy exceeds upland sediment delivery. As a result, most of the sediment delivered to the headwaters drainage network is rapidly transported downstream. Upper and lower bank erosion and failure are common.

About 13 percent of the drainage network is made up of *transport-type* channels (i.e., slope between 1.5 and 10 percent). These channels tend to transport and store punctuated coarse sediment inputs as a function of large woody debris dams and bedrock constrictions. During flooding, the stream power of Mad River source and transport channels can move six foot boulders as bedload.

The *response-type* (i.e., *storage*) channels (slope < 1.5 percent), with wide valleys, make up a small percentage of the drainage network but store a large portion of total sediment input.

Longitudinal Profile for the Mainstem Mad River showing GMA continuous monitoring sites

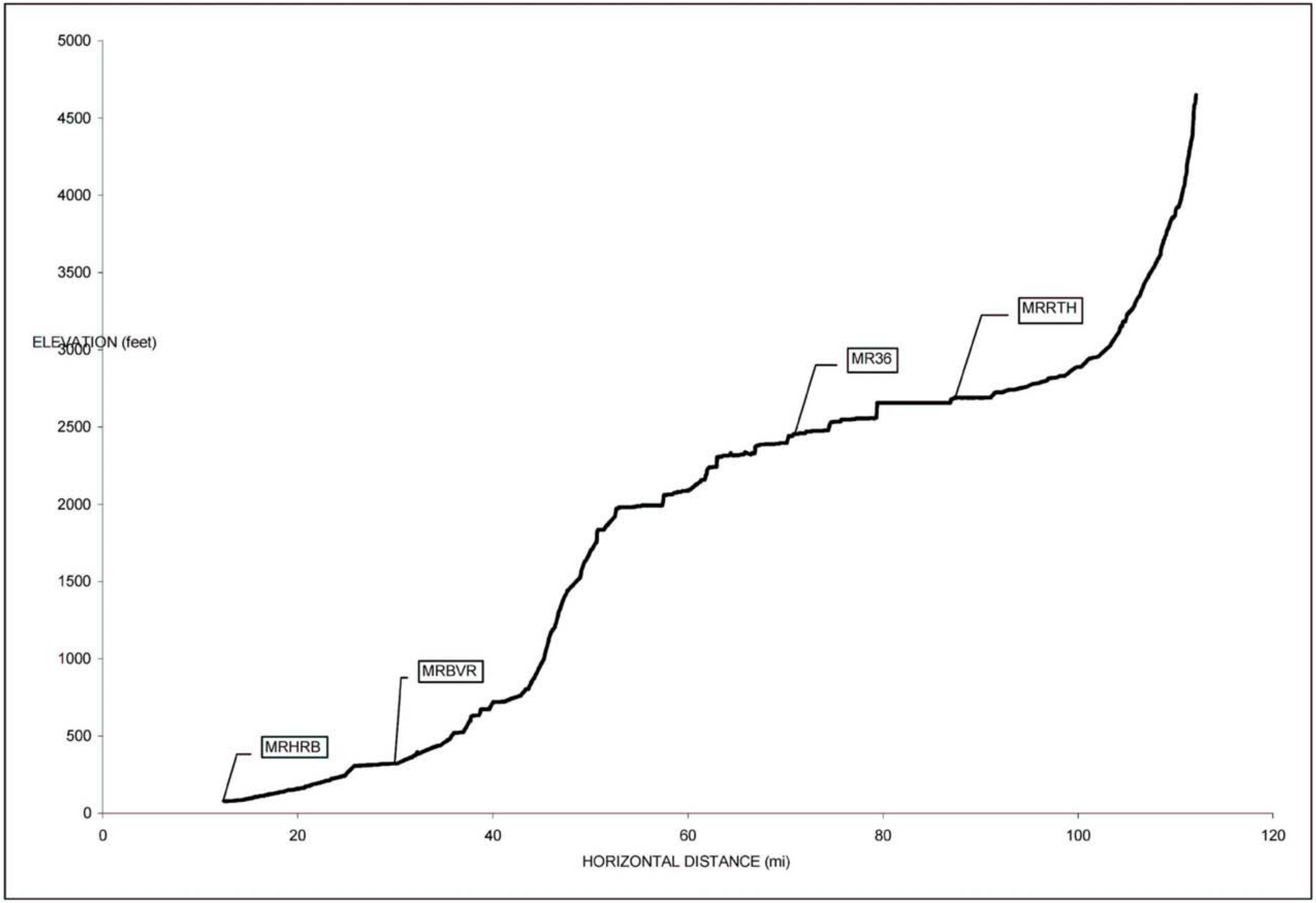

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FIGURE

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Because the volume of sediment input exceeds the transport capacity in these reaches, the response channels tend to be wide and braided with natural levees and meanders.

These observations are critical to understanding the sediment delivery, transport, and load dynamics of the Mad River, and show that both natural and management-related upland sediment sources have a high probability of being delivered to the low-gradient channels.

3.2.2 Characteristics of Sampling Sites

Table 6 summarizes selected characteristics of the watersheds above the various GMA sampling sites located throughout the watershed, includes minimum, mean, and maximum precipitation, drainage areas in acres and square miles, minimum, maximum and mean subbasin elevations, the max and min elevation difference, and the valley length.

3.2.3 Mainstem Sediment Storage

The sediment storage inventory data show that the low gradient alluvial reaches in the upper and lower watershed store the majority of the active and semi-active instream sediment. Two reaches, one just above Ruth Reservoir and a second in the lower Mad River near Arcata, had the highest total sediment storage: between 2 and 6 tons/ft/mi^2 over the river reach length. The lower Mad River had the highest active sediment storage volume at about 500 tons/ft/mi^2. The middle reaches with higher stream gradient and confined valleys had substantially less active sediment storage with between 0.1 and 0.2 tons/ft/mi^2. These results were used to calibrate the sediment load predictions made as part of the NetMap model.

SUB-BASIN CHARACTERISTICS FOR STUDY SAMPLING SITES

Name	Sub-Basin Precipitation			Drainage Area		Sub-Basin Elevations			Zdiff	Valley Length
	Mean	Min	Max			Min	Max	Mean		
	(inches)	(inches)	(inches)	(acres)	(mi2)	(ft)	(ft)	(ft)	(ft)	(mi)
ACLM	60.77	55	65	651	1.02	2697	5609	4179	2912	1.43
BCLM	62.95	59	67	670	1.05	2715	5297	4100	2582	1.65
BCMCB	79.55	57	89	12004	18.76	404	5097	3135	4693	10.42
CCRTH	57.52	57	59	299	0.47	2706	3538	2948	832	1.12
HCLM	65.75	63	69	1040	1.62	2692	5762	4372	3070	1.92
LCGRB	54.73	47	65	11320	17.69	56	2193	560	2137	6.70
LMC36	62.23	59	65	1997	3.12	2480	5613	4017	3133	2.32
MCMCB	73.32	59	87	7841	12.25	450	4603	2346	4153	7.64
MR36	61.04	55	71	88588	138.42	2457	6022	3610	3565	37.86
MRALM	63.58	45	89	310326	484.88	32	6022	2624	5990	96.09
MRBVR	64.09	55	89	225229	351.92	320	6022	3207	5702	76.28
MRHRB	64.37	47	89	285355	445.87	77	6022	2802	5945	91.37
MRRTH	60.89	55	71	59911	93.61	2689	6022	3704	3333	22.29
NFMKB	66.83	49	79	28468	44.48	128	3394	1465	3266	12.07
OCLM	62.32	61	65	1047	1.64	2496	4810	3650	2314	1.61
TB3LM	61.00	61	61	179	0.28	2573	4412	3461	1839	0.86

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TABLE

6

3.3 Turbidity, Suspended Sediment, and Suspended Sediment Load

3.3.1 Measured Streamflow

Mad River SSA suspended sediment and streamflow monitoring spanned two water years and measured SSC and turbidity for both winter periods. Water Year 2006 was wet and produced above normal runoff (Figure 11). The lower Mad River near Highway 299 (MRALM) peaked at 47,500 cfs, a 6.0 year flood event, and the upper Mad River above Ruth Lake peaked at 14,800 cfs, a 15 year flood event. This storm series, which occurred from December 27-31, 2005, proved to be the dominant event during the study period. WY 2007 was dry and produced below normal runoff (Figure 12). The lower Mad River near Highway 299 peaked at 15,300 cfs, a 1.3 year flood event, and the upper Mad River above Ruth Lake peaked at 2,080 cfs, a 1.0 year flood event. Hence, phenomena observed and relationships developed in WY 2006 not only span a much wider range but the higher sampling intensity (number of storm-driven sampling efforts) provided much higher resolution in the data (Figure 13).

The relative recurrence intervals for the WY 2006 peak illustrate that the storm was much bigger in the upper watershed. The downstream site has a much longer period of record than the site above Ruth Lake (57 vs. 26 years), and thus the recurrence intervals may not be directly comparable. An examination of the last 26 years of record shows that the Ruth Lake site has received one other peak flow comparable to WY 2006 (15,000 cfs in 1986) while three more occurred at the Arcata site (Figures 2 and 3), indicating that even though the recurrence intervals may not be directly comparable, the WY 2006 peak flow magnitude was greater for the upper watershed than for the lower.

3.3.2 Measured Turbidity

Considerable turbidity data were collected for the Mad River SSA during the two-year study period. Continuous turbidity data were collected at MRRTH, MRBVR, and MRALM on the mainstem and NFMKB on the largest tributary. Due to equipment problems, the MR36 station had a shorter period of record than the other sites, and the MRHRB site was combined with MRALM (streamflow and turbidity were collected at MRALM and manual samples were collected at MRHRB). Thus, four stations were operated for continuous turbidity on the mainstem and one on the North Fork Mad River.

Data spikes and dropouts in the continuous turbidity records were removed and filled by either linear or spline interpolation. Gaps in the turbidity record were filled by using the best available data. When SSC samples were available, turbidity values were converted to probe (DTS-12) turbidity values using a regression of DTS-12 turbidity versus sample turbidity. The resulting values were hand plotted into the turbidity record and when possible, peaks and troughs were manually shaped to resemble the sedigraph to hydrograph relationship. A temporally relevant relationship between SSC and discharge was developed and used to proportionally fit the gaps between the sample values. During a gap with no samples, in periods less than a month, a relationship between SSC and discharge was proportionally fit into the gap.

Instream turbidimeters (continuously recorded in FNU) and DIS/Box/Grab samples (lab-processed in NTU) were used to evaluate turbidity for both water years' winter-storm periods. Turbidity data from manual samples was transformed from NTU to FNU using

USGS MAD RIVER GAGES -- WY2006 DISCHARGE

Mad River Near Arcata (#11481000, MRALM) and Mad River Above Ruth Reservoir (#11480390, MRRTH)

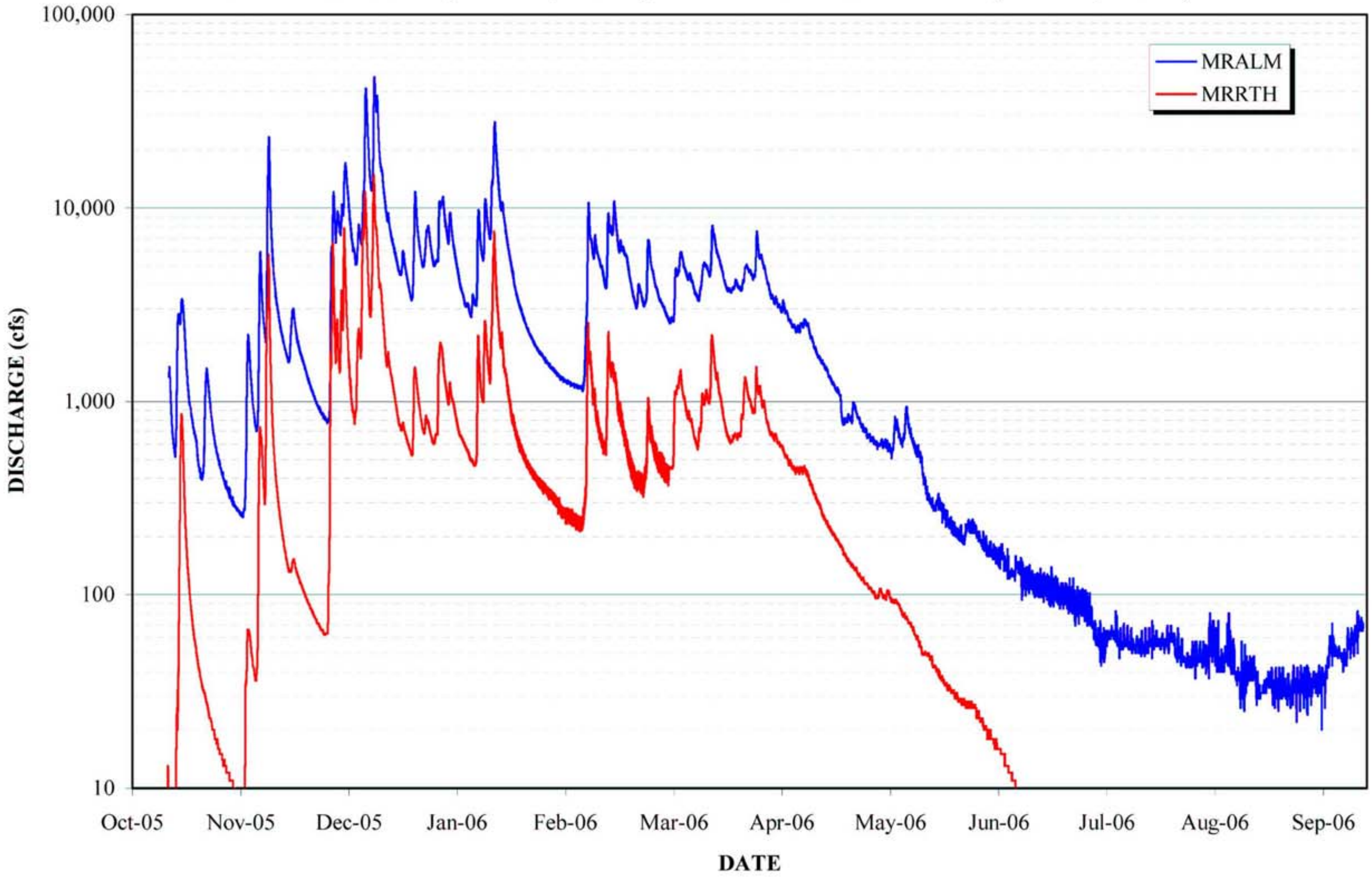

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FIGURE

11

USGS MAD RIVER GAGES -- WY2007 DISCHARGE

Mad River Near Arcata (#11481000, MRALM) and Mad River Above Ruth Reservoir (#11480390, MRRTH)

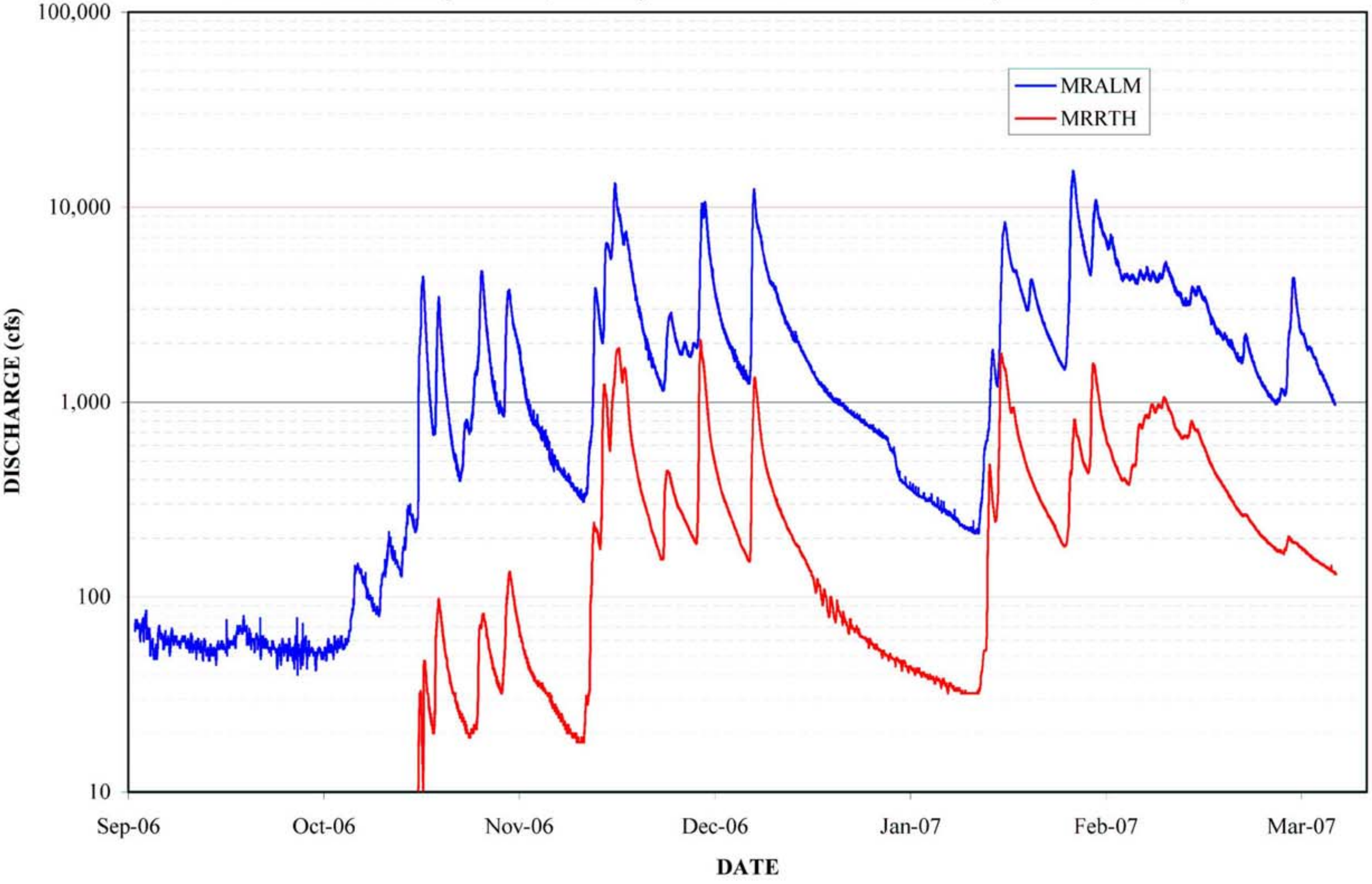

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FIGURE

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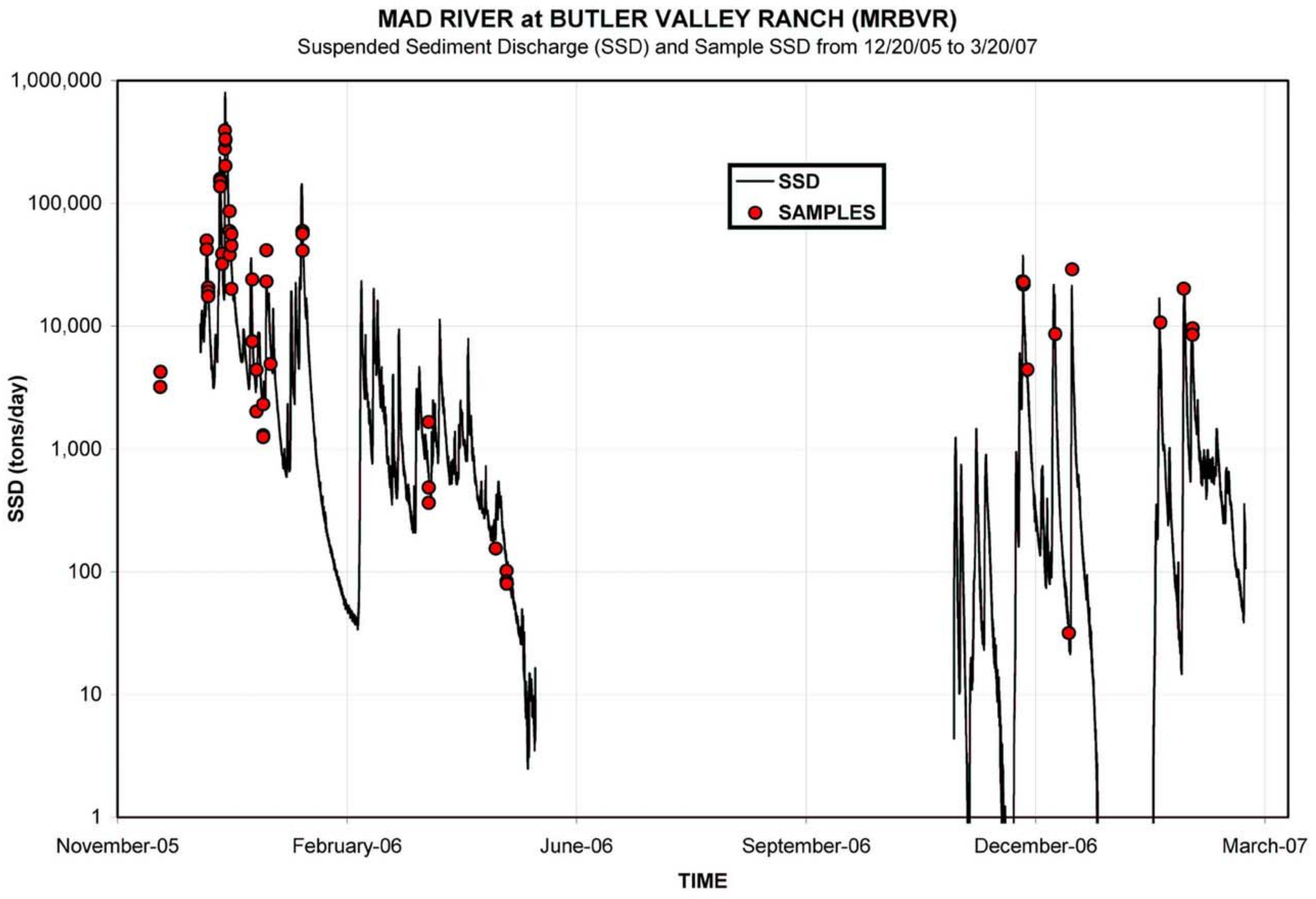

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FIGURE
13

site-specific log-log regressions (R^2 = 0.94-0.99, Figure 14) (Lewis et al., 2006). Sample data for Mad River continuous turbidity stations are summarized in Appendix C.

For general comparison purposes, continuous turbidity data are plotted in Figures 15-17. Detailed views are shown in Figures 18-23. The storm occurring from December 30-31, 2005 produced most (but not all) of the highest turbidities observed during the study. In general, turbidity increased in the downstream direction. The highest turbidities measured in the mainstem Mad River occurred at the lowest site near Arcata with a maximum of 4,820 FNU recorded on the continuous turbidimeter at MRHRB. The North Fork continuous turbidimeter recorded a maximum of 1,580 FNU for the Dec 30-31, 2005 event. Boulder Creek at Maple Creek Road Bridge (BCMCB) was the most turbid tributary. Anada Creek (ACLM) had the highest sampled turbidity reading in the upper watershed, (2,850 NTU); the mainstem site MR36 had the lowest measured turbidity (120 NTU). In the upper watershed, synoptic sites LMC36, HCLM, BCLM, and ACLM within the South Fork Mountain Schist geology had measurably higher turbidity values ranging from 930 to 2,850 NTU. The maximum observed values for these same stations in WY 2007 ranged from 5 to 120 NTU, although very few samples were collected in WY 2007 due to infrequency of sediment-producing storms (Figure 16).

Some storms produced higher turbidities in the upper watershed than in the lower, such as the February 8-9, 2007 storm. Continuous turbidimeters recorded 248, 50 and 111 FNU in the mainstem from upstream to downstream (Figure 16). This was a small storm, peaking at 503 and 1,850 cfs above Ruth Lake and at Highway 299 respectively. The downstream reduction and subsequent increase in turbidity illustrates the sensitivity of turbidity as a metric for detecting temporal and longitudinal variation in sediment production that is not associated with the progressive downstream increase in discharge.

Figure 18 shows a detail of the WY2006 continuous turbidity record at the 3 sites (MRRTH, MRBVR, and MRHRB) for the period of December 14, 2005 through January 31, 2006. The turbidity at MRRTH is consistently an order of magnitude or more lower than the other two sites and recovers to levels of 5-10 FNU between storms, while the lower sites only recover to the 70-200 FNU range depending on storm. In this period, the turbidity at MRBVR mostly peaks lower than MRHRB and is sometimes higher on the falling limb and other times lower. Generally, however, these sites track fairly closely.

Figure 19 provides even greater detail for the 12/28/05 and 12/30/05 storm peaks, and includes the maximum value associated with each site for the two peaks. Figure 20 provides a view of the turbidity recession during February 2006, when there was no precipitation for essentially the entire month. Turbidities at MRBVR and MRHRB receded to levels of 15-25 FNU, while MRRTH dropped below 1 FNU less than 3 weeks after the small storm on February 2. Figure 21 shows the March to May period in WY2006, when a series of small storms occurred in March through mid-April. In this time period, the lower sites never went lower than 40 FNU and MRHRB was typically around 10 FNU higher than MRBVR. Figure 22 shows the response during December 2006 and early January 2007, which were fairly small storms. In Figure 23, the turbidity recession curves after the 1/3/07 peak are seen. MRRTH was down to less than 1 FNU in less than a week, while it took until the end of the month for the other two sites.

DTS-12 TURBIDITY vs. BOX SAMPLE (LAB) TURBIDITY

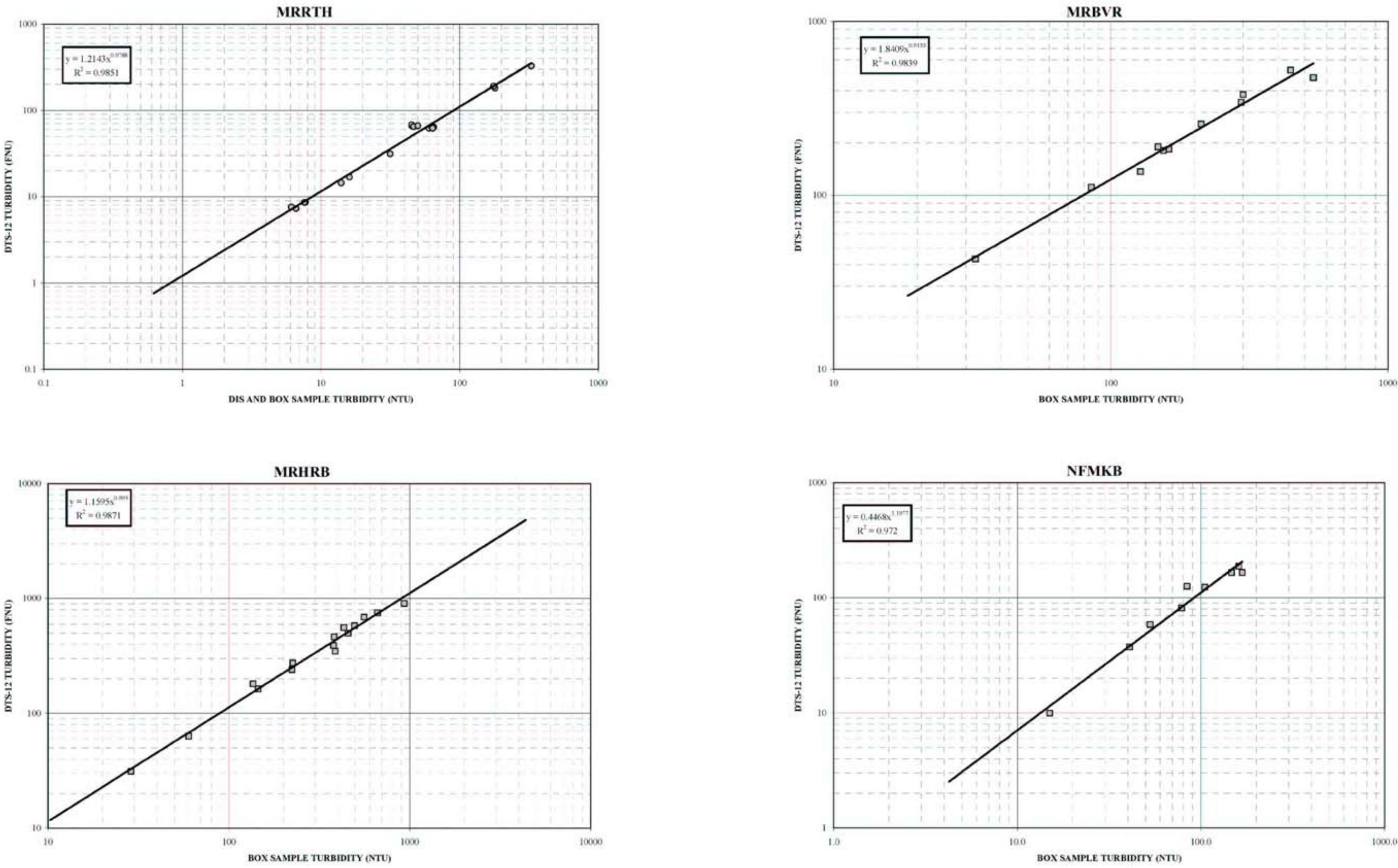

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FIGURE

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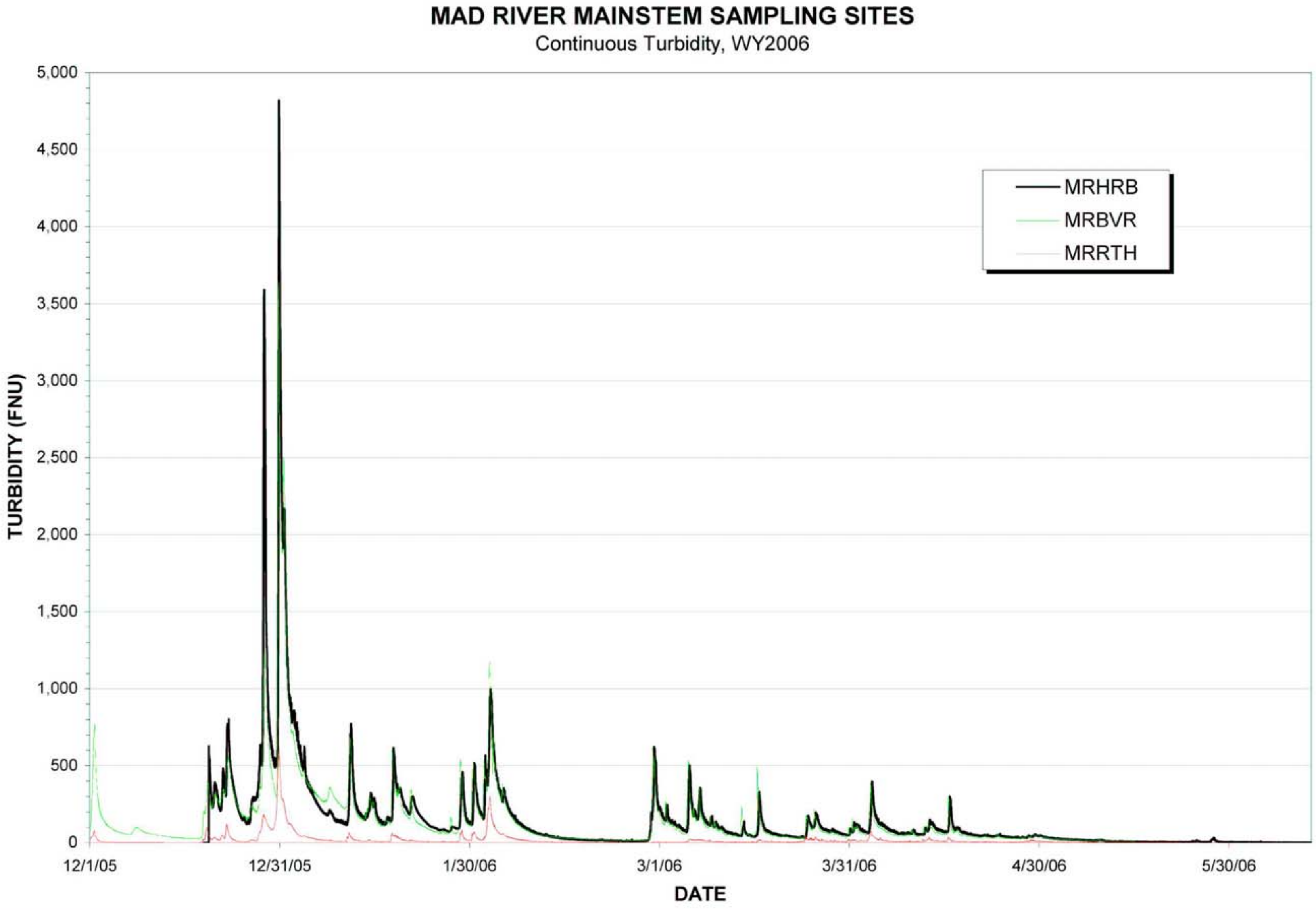

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FIGURE

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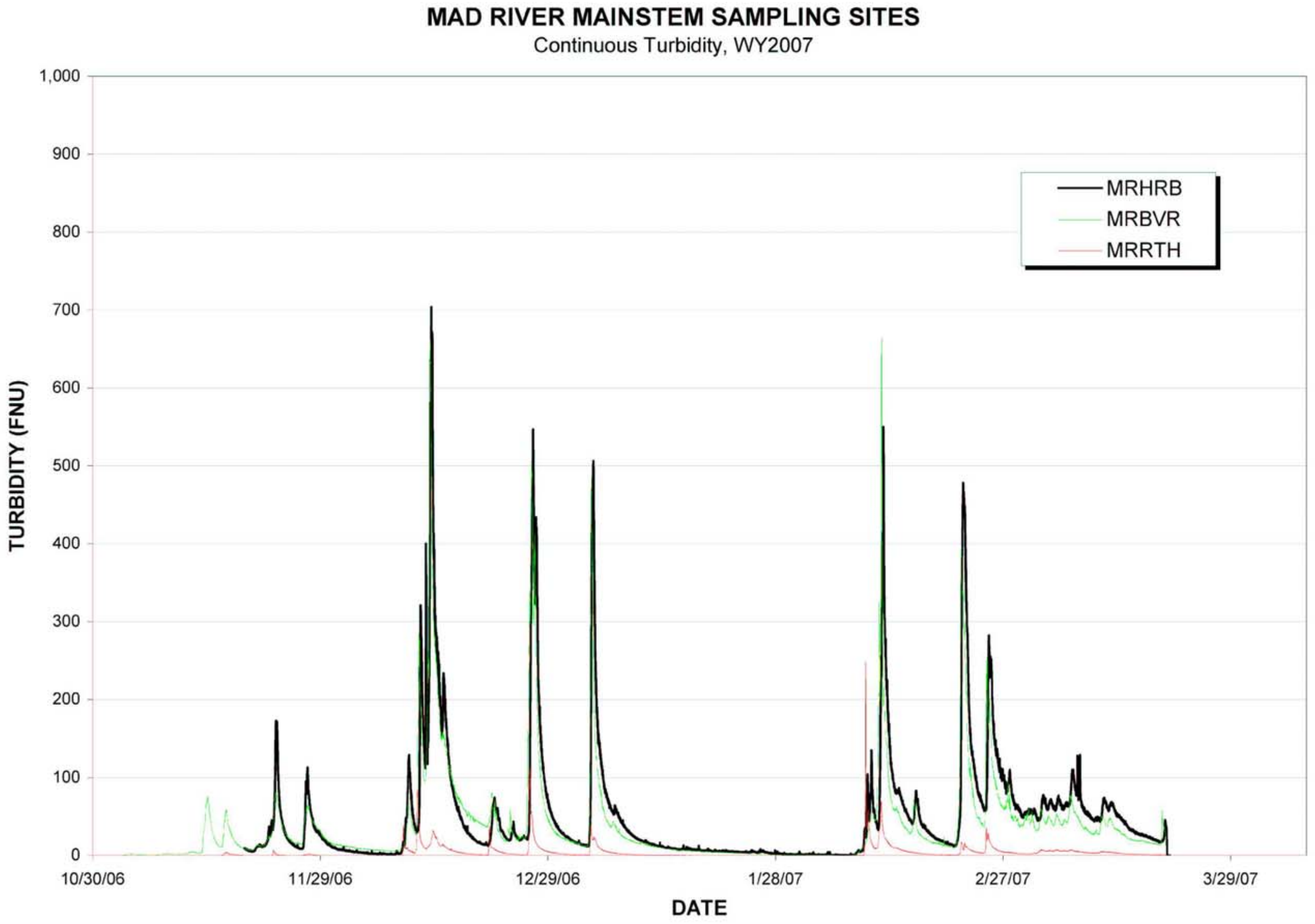

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FIGURE

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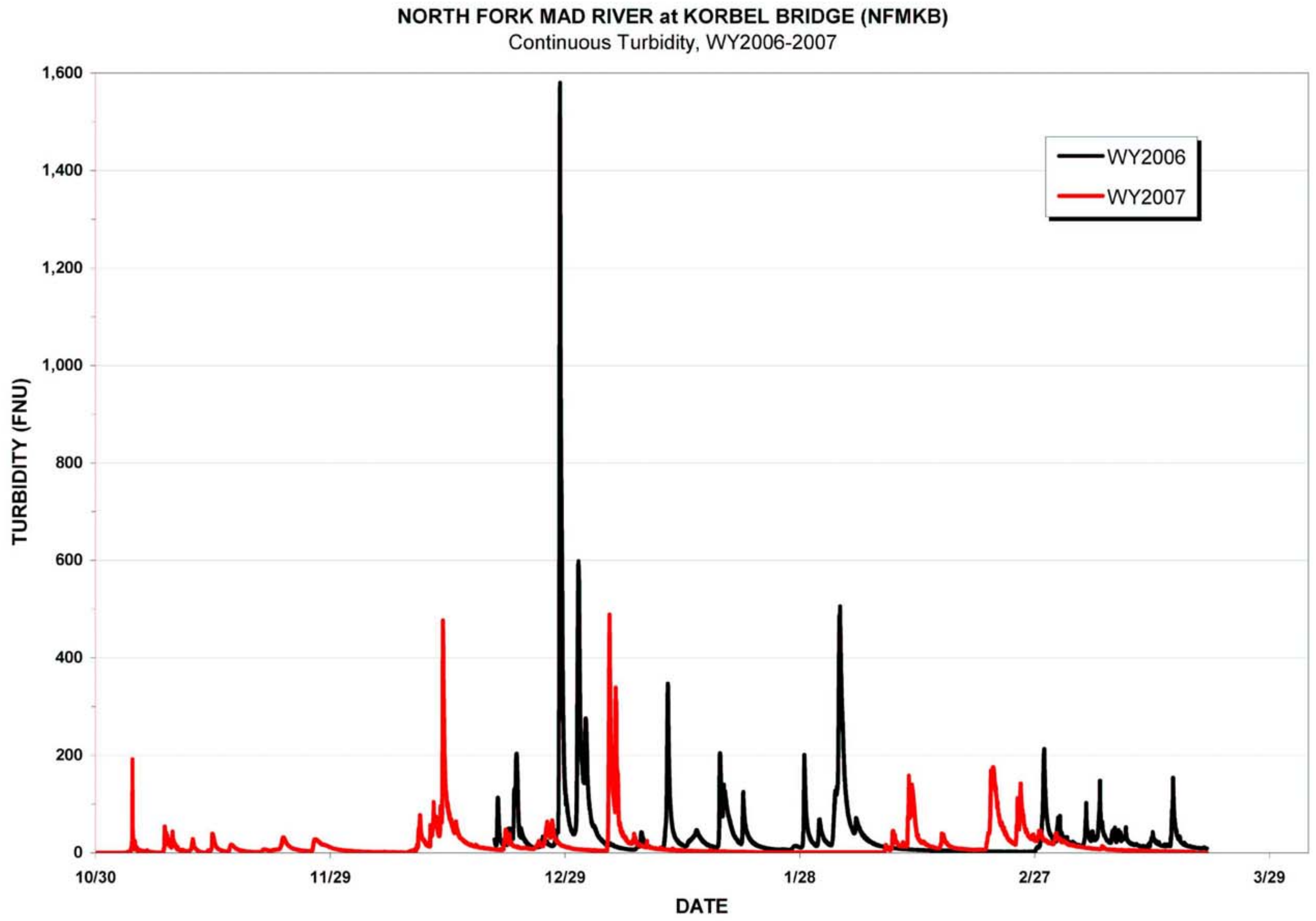

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FIGURE

17

MAD RIVER MAINSTEM SAMPLING SITES

Detail of Continuous Turbidity WY2006, 12/14/05 through 1/31/06

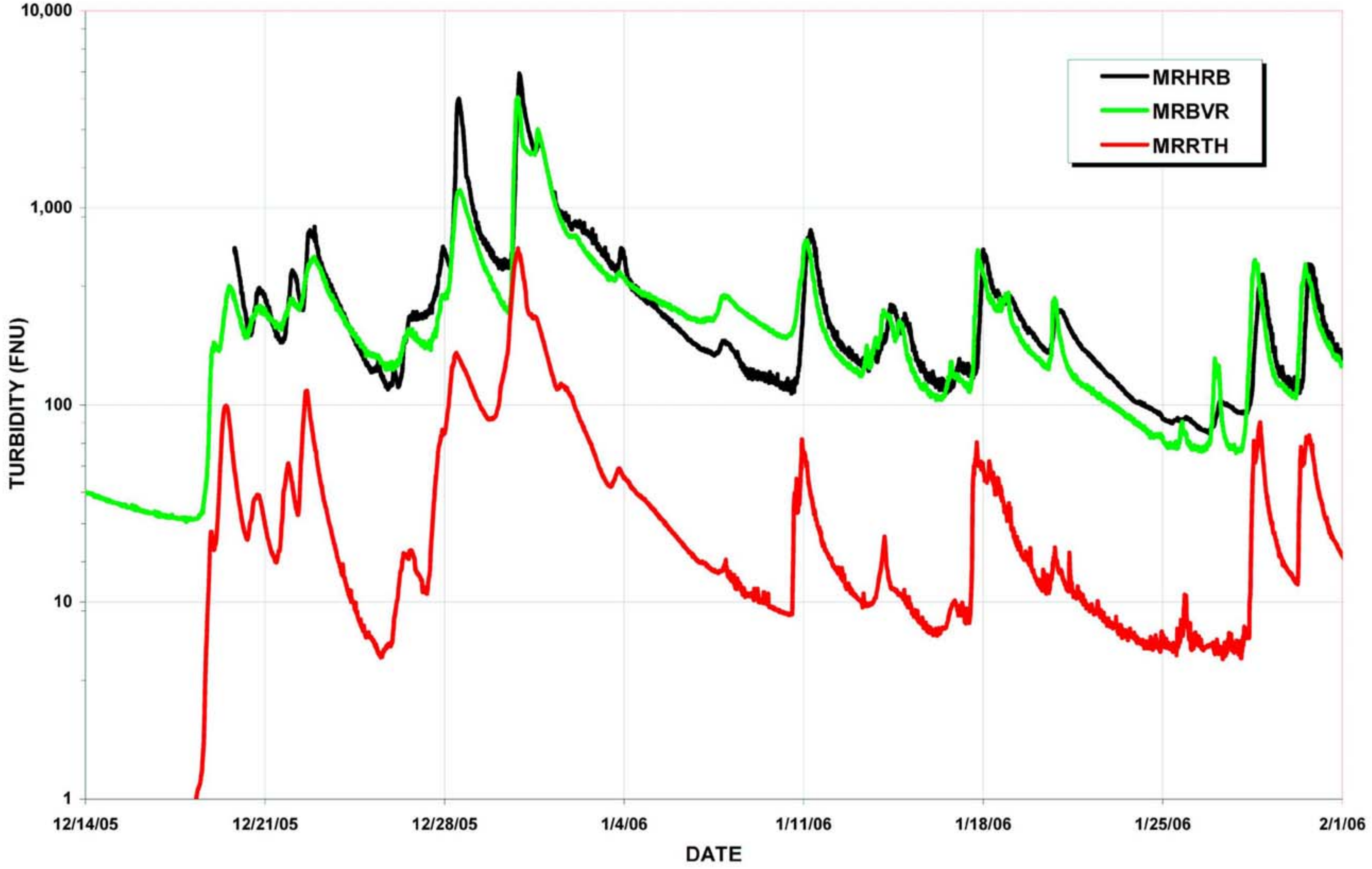

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FIGURE

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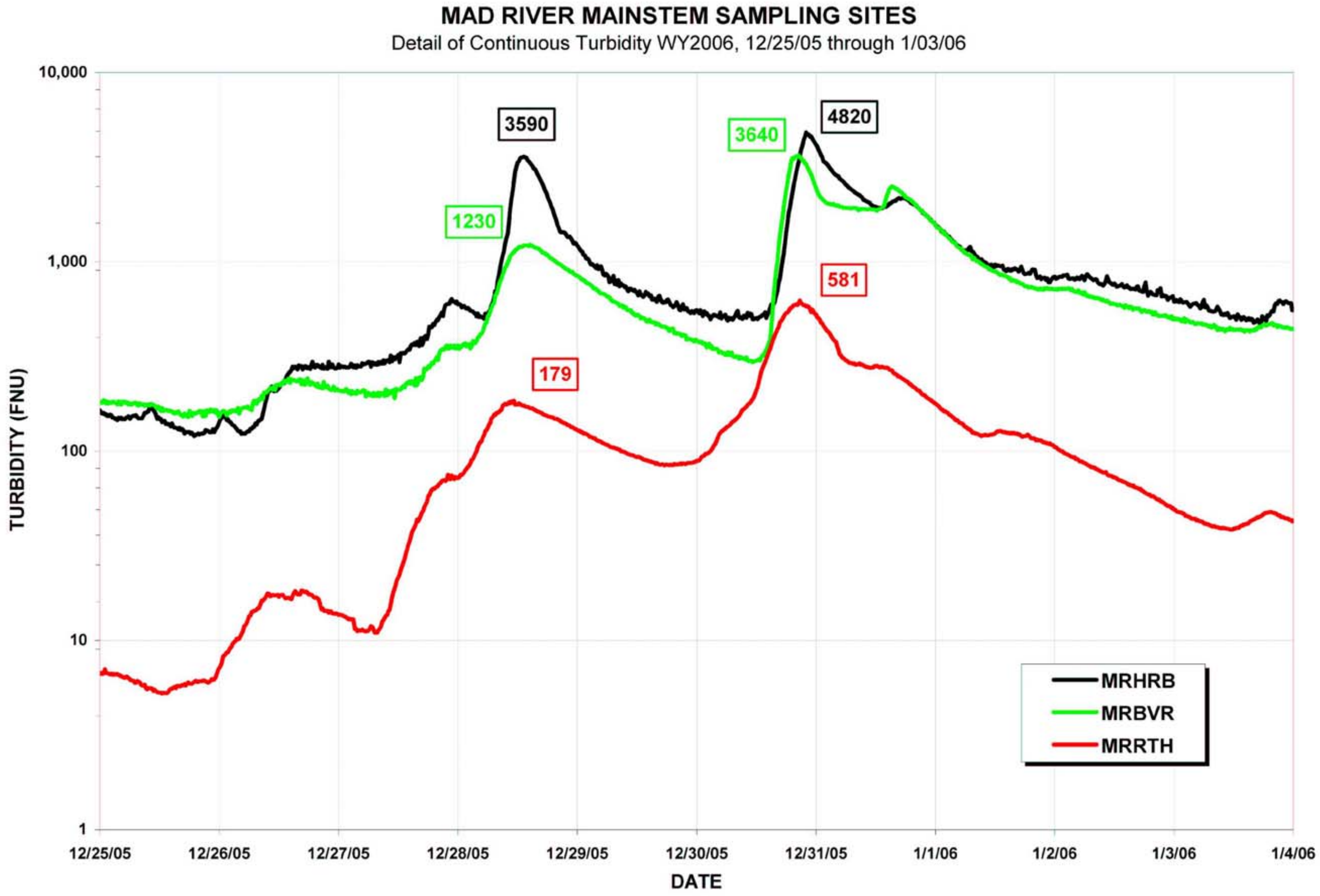

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FIGURE

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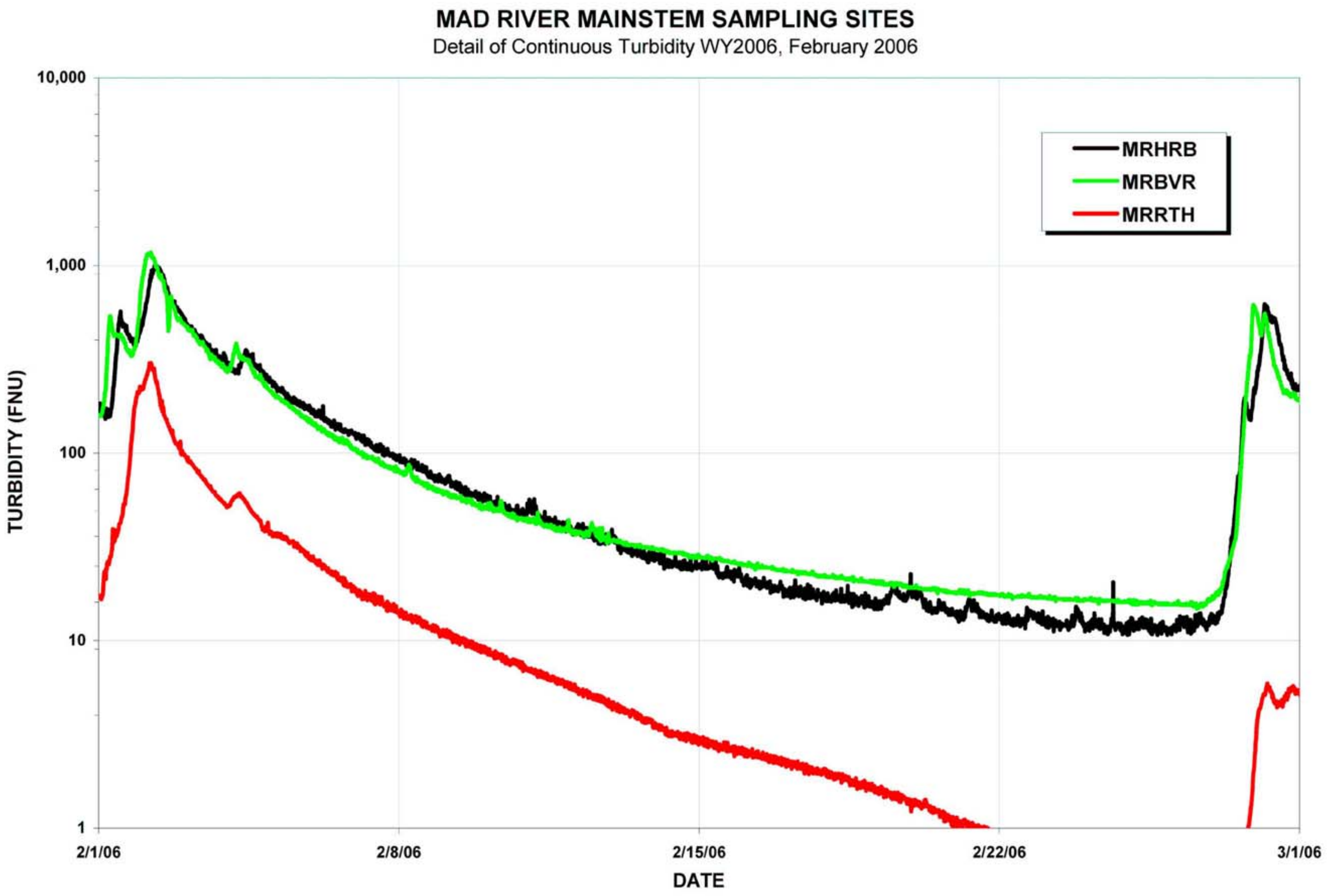

MAD RIVER MAINSTEM SAMPLING SITES

Detail of Continuous Turbidity WY2006, February 2006

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FIGURE

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MAD RIVER MAINSTEM SAMPLING SITES

Detail of Continuous Turbidity WY2006, March-May 2006

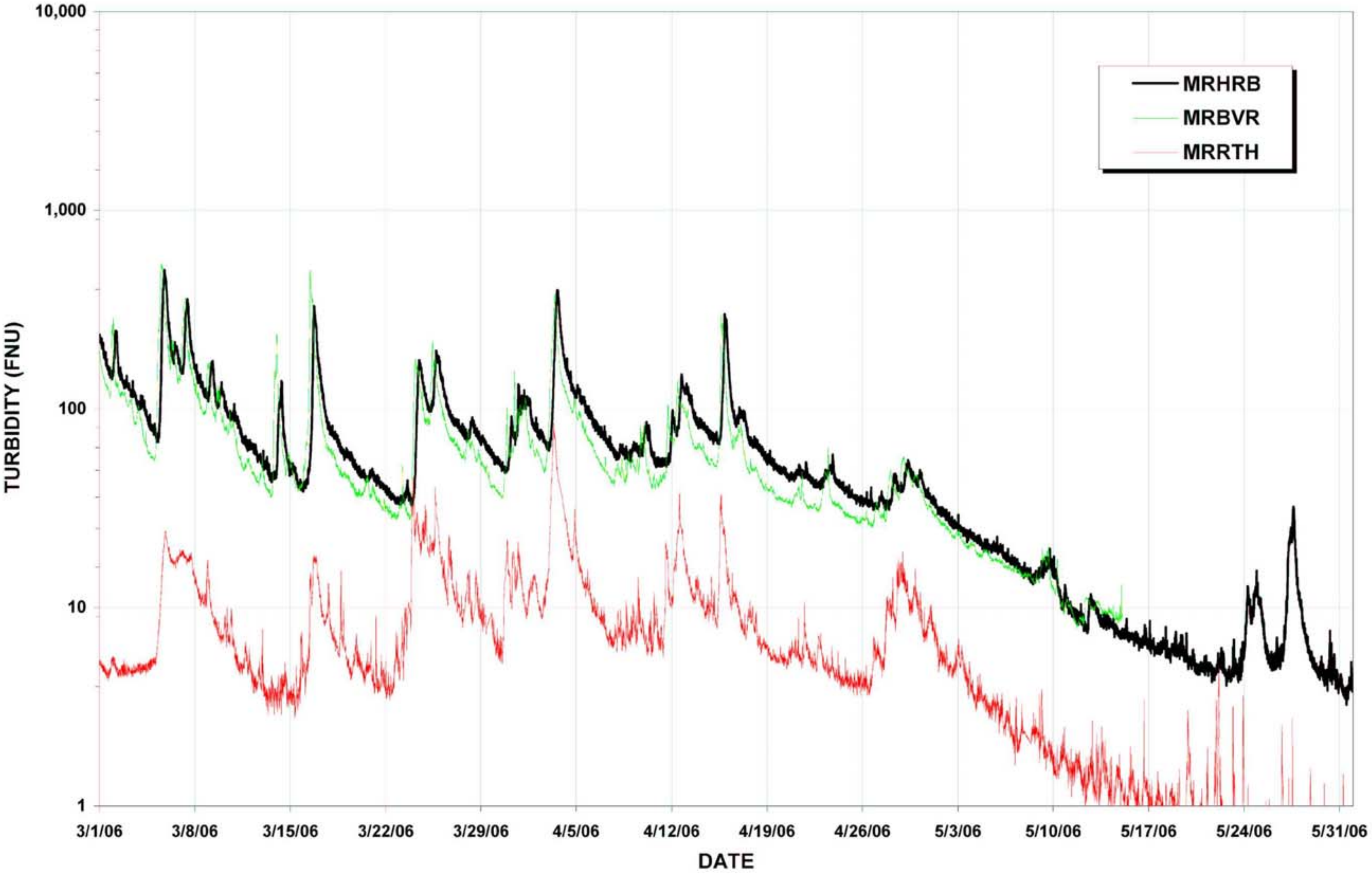

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FIGURE

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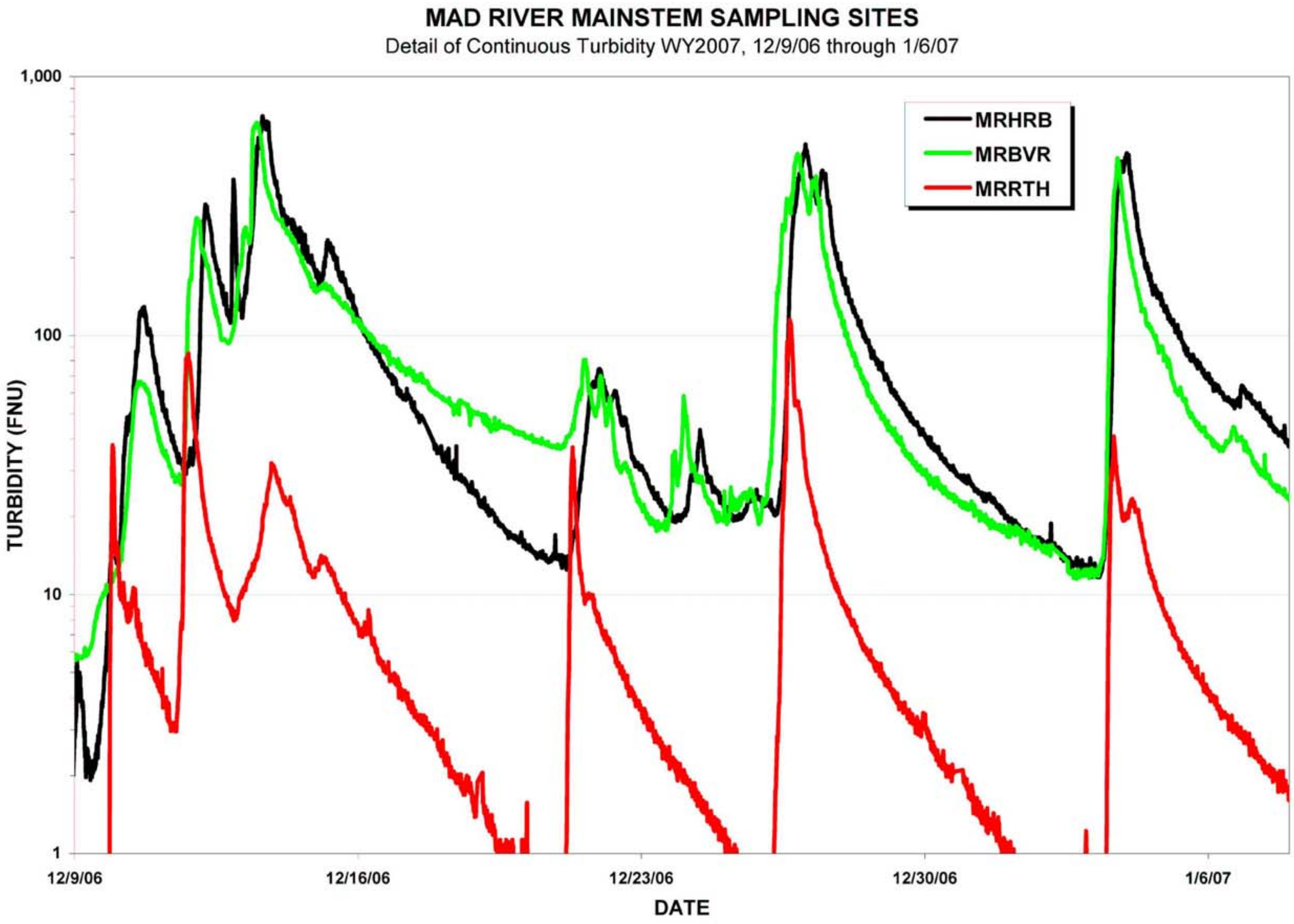

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FIGURE

22

MAD RIVER MAINSTEM SAMPLING SITES

Detail of Continuous Turbidity WY2007, 1/2/07 through 2/8/07

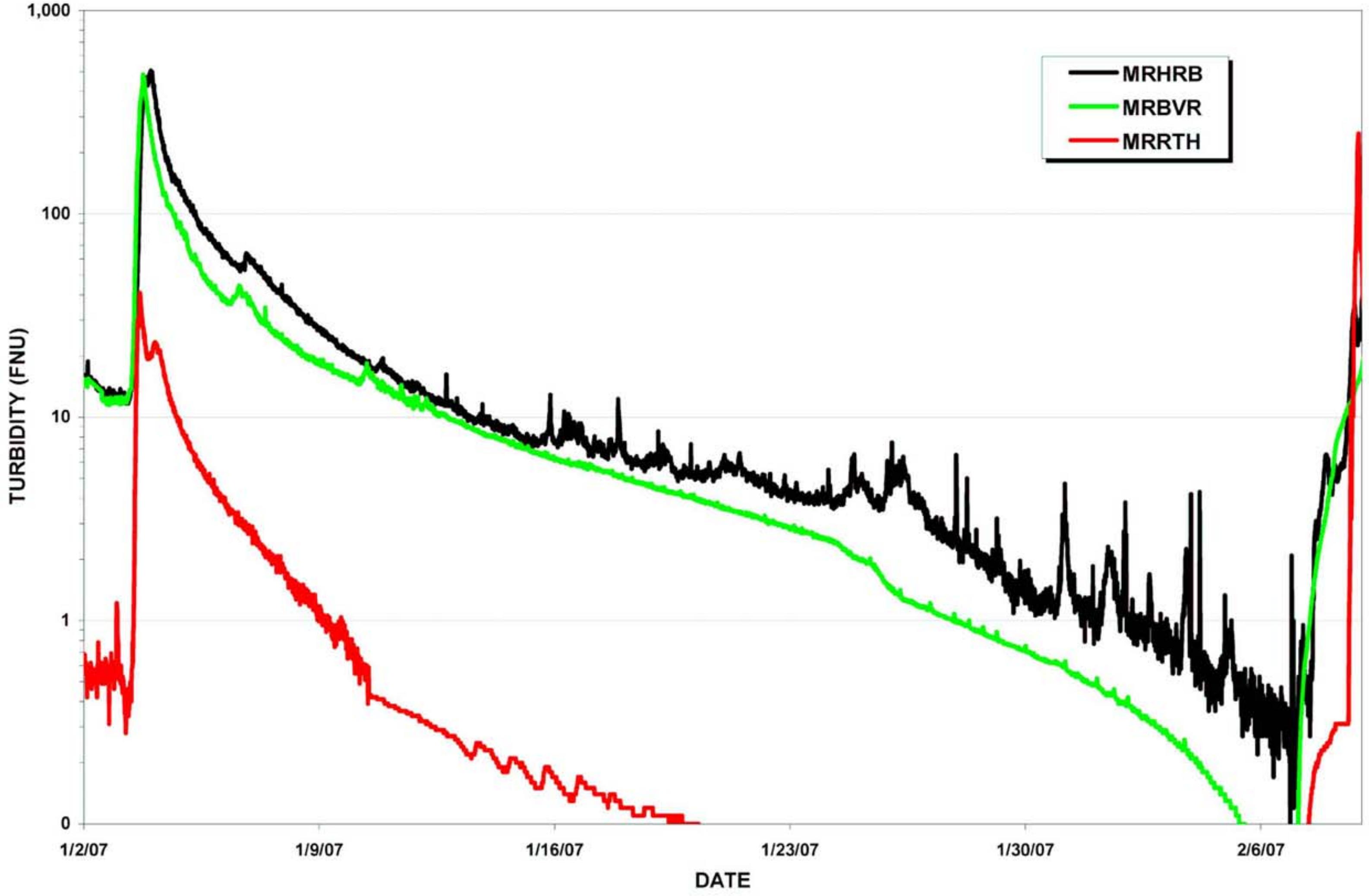

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FIGURE

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3.3.3 Turbidity and Suspended Sediment Concentration Relationships

Turbidity vs. SSC relationships proved adequate for computing suspended sediment discharge at all mainstem sites. Some sites required multiple equations to accommodate inflections in the datasets (Table 7). The Mad River's geologic character (particle size composition within suspended sediment) contributes to favorable relationships with turbidity (R^2 ranges from 0.82-0.99, averaging 0.92). Discharge vs. SSC was infrequently used to fill in a data gap in the turbidity records.

Table 7. Relationship between Turbidity and Suspended Sediment Concentration for Mainstem Mad River Sites

TURBIDITY vs SUSPENDED SEDIMENT CONCENTRATION

Formulae For Continuous Stations

Site Code	Site Description	Notes	Turbidity vs. SSC (y=)	r^2
MRHRB	Mad River at Hatchery Road Bridge		4.3978x0.8813	0.95
MRBVB	Mad River at Butler Valley Ranch	< 300 FNUs	0.449625 * (T)^ 1.3343	0.90
		>300 FNUs	11.1306 * (T)^ 0.76434	0.90
NFMKB	North Fork Mad River at Korbel Bridge		1.4326x1.0465	0.93
MRRTH	Mad River above Ruth Reservoir	< 7 FNUs	1.07089 * (T)^ 0.742104	0.99
		7-49 FNUs	0.140323 * (T)^ 1.78901	0.99
		>49 FNUs	9.56007 * (T) - 317.323	0.82

3.3.4 Measured Suspended Sediment Concentration, Suspended Sediment Discharge

Mad River SSA suspended sediment and streamflow monitoring spanned two water years and measurements of SSC were collected during both winter periods, with an emphasis on WY 2006. Water Year 2006 was very wet and produced above normal runoff and suspended sediment concentrations, while WY2007 was dry and produced relatively little sediment transport. Suspended sediment concentration observations followed a similar pattern as was observed with turbidity (relationships are discussed later). Concentrations generally increased in a downstream direction per a given flow event. The highest sampled concentration at the downstream-most site (MRHRB) was 5,149 mg/l, while the highest concentration at the upstream-most mainstem site (MRRTH) was only 223 mg/l (different sampling events). The wide range of sample values collected over a variety of sediment producing events enhanced turbidity-SSC relationships and facilitated temporal adjustments to load computations (Figure 13).

Computed suspended sediment discharge (SSD) totals for the period December 30, 2005 to January 2, 2006 are provided in Table 8. The importance of this event, in the upper watershed especially, is expressed with 63 percent of the load for the two-year period of record at MRRTH occurring in one storm. The North Fork shows a relatively smaller percentage (13) of its load generated during the period, reflecting spatial variability of storm intensity.

Table 8. Percentage of SSL for WY2006 occurring in the Dec 30, 2005 Storm

GMA MAD RIVER MAINSTEM AND TRIBUTARY SAMPLING SITES

Percent of Suspended Sediment Load During December 30th WY2006 Storm

SITE	WSA (mi^2)	WY 2006 SSL (tons)	Period of Record SSL (Tons)	SSL from 12/30 - 01/02 (tons)	Storm SSY ($tons/mi^2$)	% of the Water Year Load	% of the Period of Record Load
MRHRB	446	2,050,000	2,304,000	769,000	1,724	38	33
NFMKB*	44.5	31,800	42,300	4,670	105	15	11
MRBVR	352	1,400,000	1,540,000	523,000	1,486	37	34
BCMCB	18.76	45,300	68,900	6,984	372	15	10
MCMCB	12.23	12,300	18,510	1,959	160	16	11
MRRTH	93.6	232,000	234,500	144,000	1,538	62	61
MR36	141.54	89,500	96,740	26,460	187	30	27
ACLM	1.02	10,600	11,309	3,374	3,308	32	30
HCLM	1.62	2,190	2,211	1,043	644	48	47
OCLM	1.64	1,550	1,560	770	469	50	49
TB3LM	0.28	37.5	38.7	14.4	51	38	37
LMC36	3.12	17,500	17,588	8,917	2,858	51	51
CCRTH	0.47	15.5	17.3	3.80	8.09	25	22
BCLM	1.05	1,900	1,907	1,000	953	53	52

* Was not the largest storm of the year

The downstream-most site (MRHRB) describes the cumulative expression of basin-wide sediment production with the highest average annual load of over two million tons over the two-year period of record. It also illustrates how little suspended sediment was produced in WY 2007 (90% of the SSL in the period of the study was generated in WY 2006). More useful for comparing sub-watersheds is *yield* (tons per square mile), and the North Fork clearly produces less suspended sediment per unit area than the mainstem sites (Table 9). The mainstem sites show the same downstream progression in load magnitude as was observed in turbidity and suspended sediment concentration.

Table 9. Suspended Sediment Loads for WY2006 and 2007 periods of record

SUSPENDED SEDIMENT LOADS FOR PARTIAL WATER YEARS
PERIOD OF RECORD RANGES FROM 12/01/05 - 3/20/07

		WY2006		WY2007		AVERAGE 2006-2007	
SITE	WSA (mi^2)	SSL (tons)	SSY ($tons/mi^2$)	SSL (tons)	SSY ($tons/mi^2$)	SSL (tons)	SSY ($tons/mi^2$)
MRHRB	446	2,050,000	4,596	254,000	570	1,152,000	2,583
NFMKB	44.5	31,800	715	10,500	236	21,150	475
MRBVR	352	1,400,000	3,977	140,000	398	770,000	2,188
MCMCB	12.2	12,300	1,006	6,210	508	9,255	757
BCMCB	18.8	45,300	2,415	23,600	1,258	34,450	1,836
MR36	141.5	89,500	632	7,240	51	48,370	342
OCLM	1.64	1,550	945	10	6	780	476
TB3LM	0.28	38	134	1.2	4.4	19	69
LMC36	3.12	17,500	5,609	88	28	8,794	2,819
CCRTH	0.47	16	33	1.8	3.8	9	18
BCLM	1.05	1,900	1,810	7.1	6.8	954	908
ACLM	1.02	10,600	10,392	709	695	5,655	5,544
HCLM	1.62	2,190	1,352	21	13	1,105	682
MRRTH	93.6	232,000	2,479	2,500	27	117,250	1,253

3.3.5 Comparison of Turbidity and Suspended Sediment Concentration Relationships to Historic Data

The USGS collected various water quality data at the Mad River near Arcata site from 1958 to 1980. The USGS turbidity data were reported in JTU (Jackson Turbidity Units, roughly equivalent to the NTU data from this study). Data collected by GMA during WY 2006-2007 shows that the SSC vs. discharge relationship (Figure 24) and Turbidity vs. SSC relationship (Figure 25) shifted to the right. Ten thousand cfs historically produced roughly 2,400 mg/l, whereas the current curve predicts only about 800 mg/l. Whether this apparent reduction in sediment production is real or an artifact of different sampling locations (Highway 299 vs. Hatchery Road Bridge) remains unknown, though the magnitude of the apparent shift suggests that it is real.

3.3.6 Comparison of Suspended Sediment Load to Historic Data

Annual suspended sediment loads at the Mad River near Arcata gage have been computed by the USGS (Brown 1973) for the period of 1958-1974 and by Lehre (1993) for the period 1962-1992. Comparison of the overlapping years (1962-1974) for these two datasets reveals considerable discrepancies, apparently due to differing computational methods. Lehre (1993) applied a single equation from Brown (1975) to the mean daily discharge record, while the USGS apparently applied annual Q vs. SSC relationships to the instantaneous discharge record. Figure 26 shows the annual suspended load data and includes GMA computations for 2006 and 2007. WY2006 was quite similar to WY1958 both in the magnitude of the peak discharge and the annual runoff, but the 2006 annual suspended load is 32% less than the 1958 load, likely reflecting the change in the Q vs. SSC relationship described in the previous section.

Annual suspended sediment loads were also computed for the Mad River near Forest Glen Gage (#11480500) for the period 1958 to 1970 apparently by Brown (1973, 1975) and reported by DWR (1982), although it is not entirely clear in their report. If the annual loads are regressed against each other, a fairly strong relationship (r2 = 0.92) is apparent (Figure 27). GMA annual load values for the MRRTH site are also plotted for comparison. The 2006 load lies well off (and to the right) the regression curve indicating that either the near Arcata annual load has decreased substantially compared to the MRRTH load, or the MRRTH load has dramatically increased, which seems unlikely. This analysis also directly compares the USGS near Forest Glen gage (D_A = 143 mi^2) and the GMA MRRTH gage (D_A = 93.6 mi^2) despite the large difference in drainage area. Adjusting for the drainage area would shift the point even further to the right.

3.3.7 Comparison of Turbidity, Suspended Sediment Concentration, and Suspended Sediment Discharge Duration Analyses for 12/24/05 through2/25/06

Four continuous turbidimeters were operated on three mainstem sites and the North Fork in WY2006 and 2007. The turbidimeters were installed in November and December 2005. Significant numbers of samples were collected at additional sites during the high flows of December 2005, which allowed development of continuous turbidity records for the period of 12/24/05 through 2/24/06 using the sedigraph method (Porterfield, 1970). This period contained by far the largest event in the study period and (from Table 8) 30-75% or more of the total sediment transport for the study period. Thus, examining relationships between sites is quite instructive. Obviously, since duration values depend on the length of period being examined, the results from this short period are not

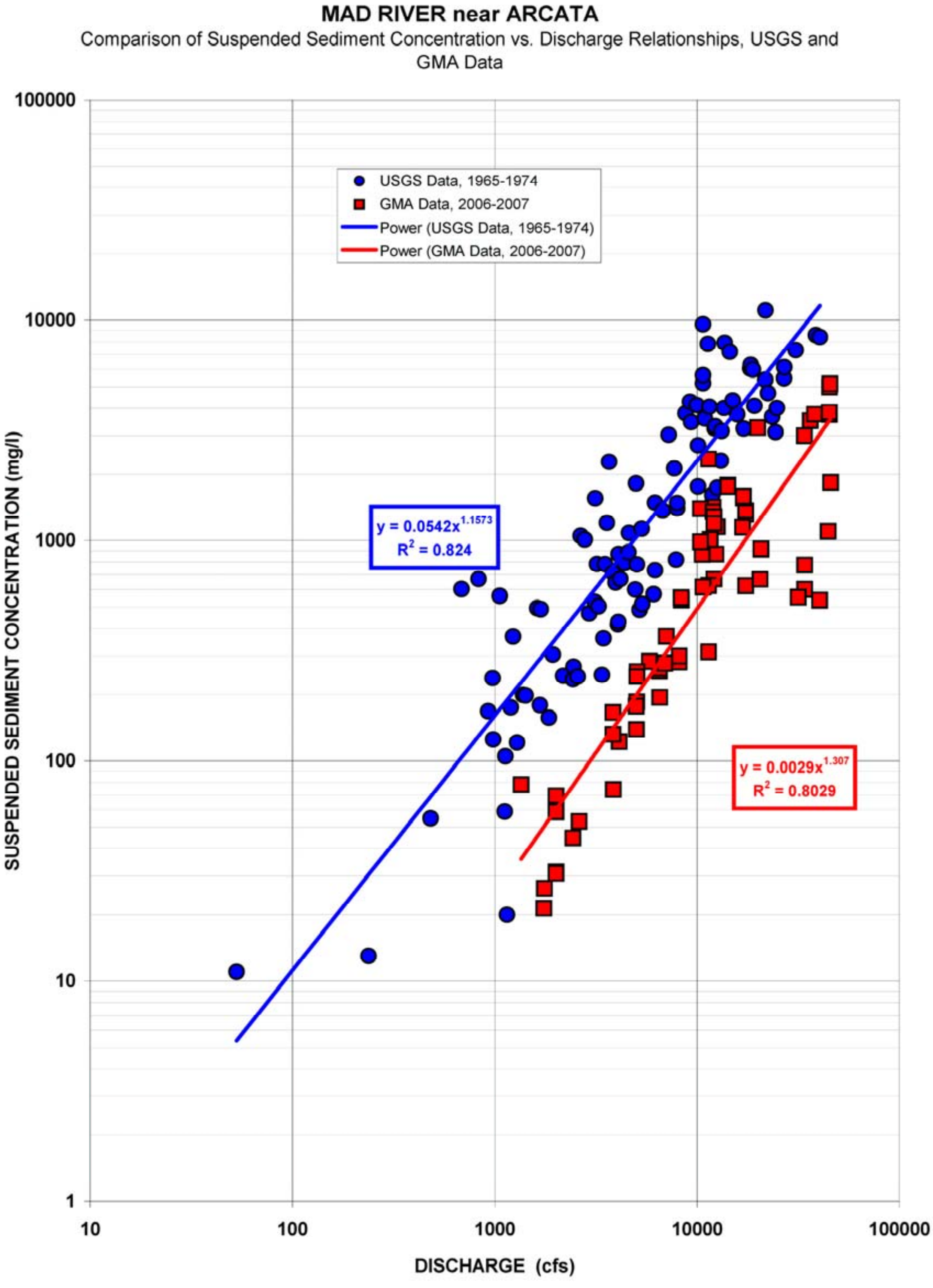

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FIGURE

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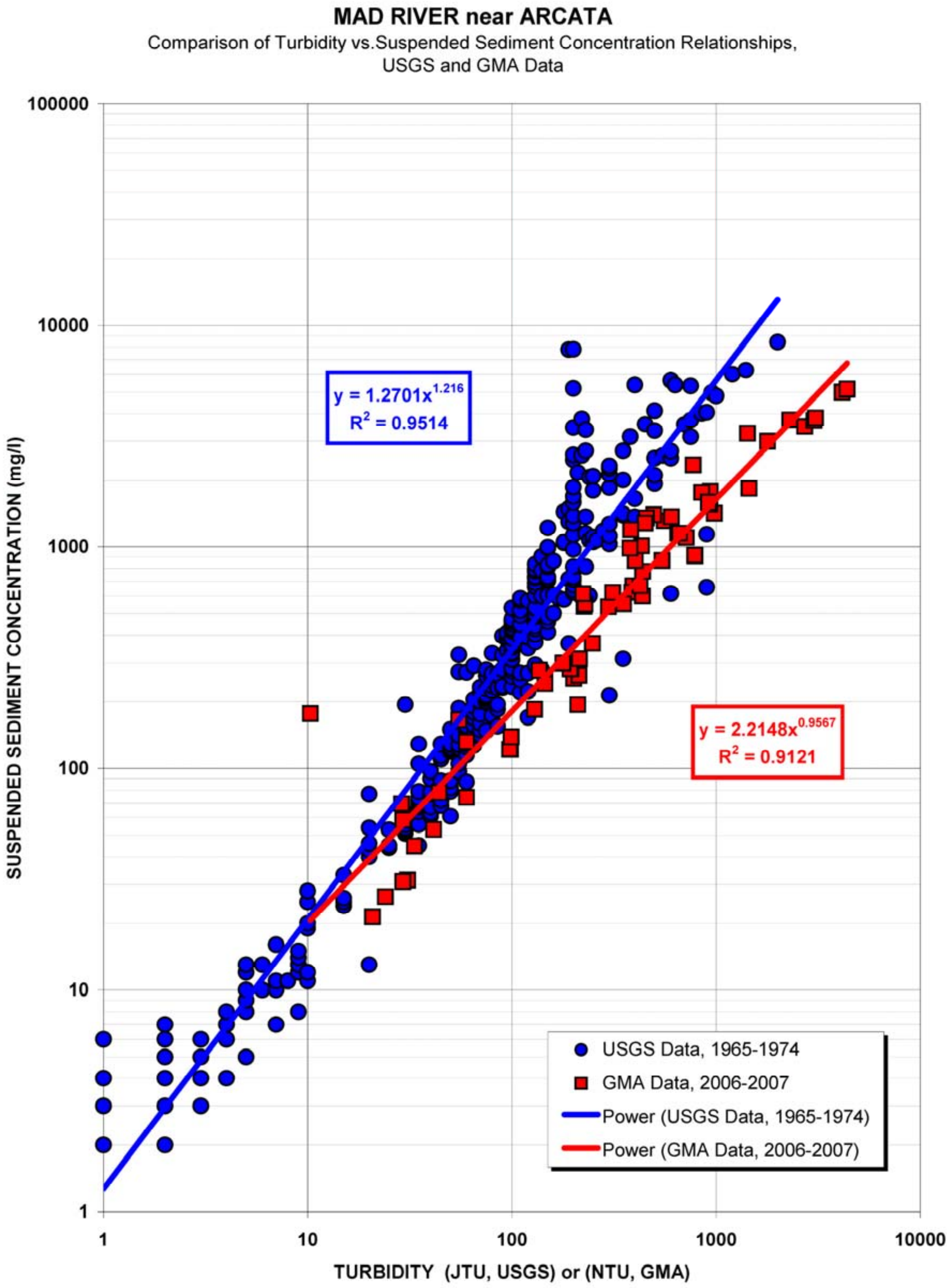

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FIGURE

25

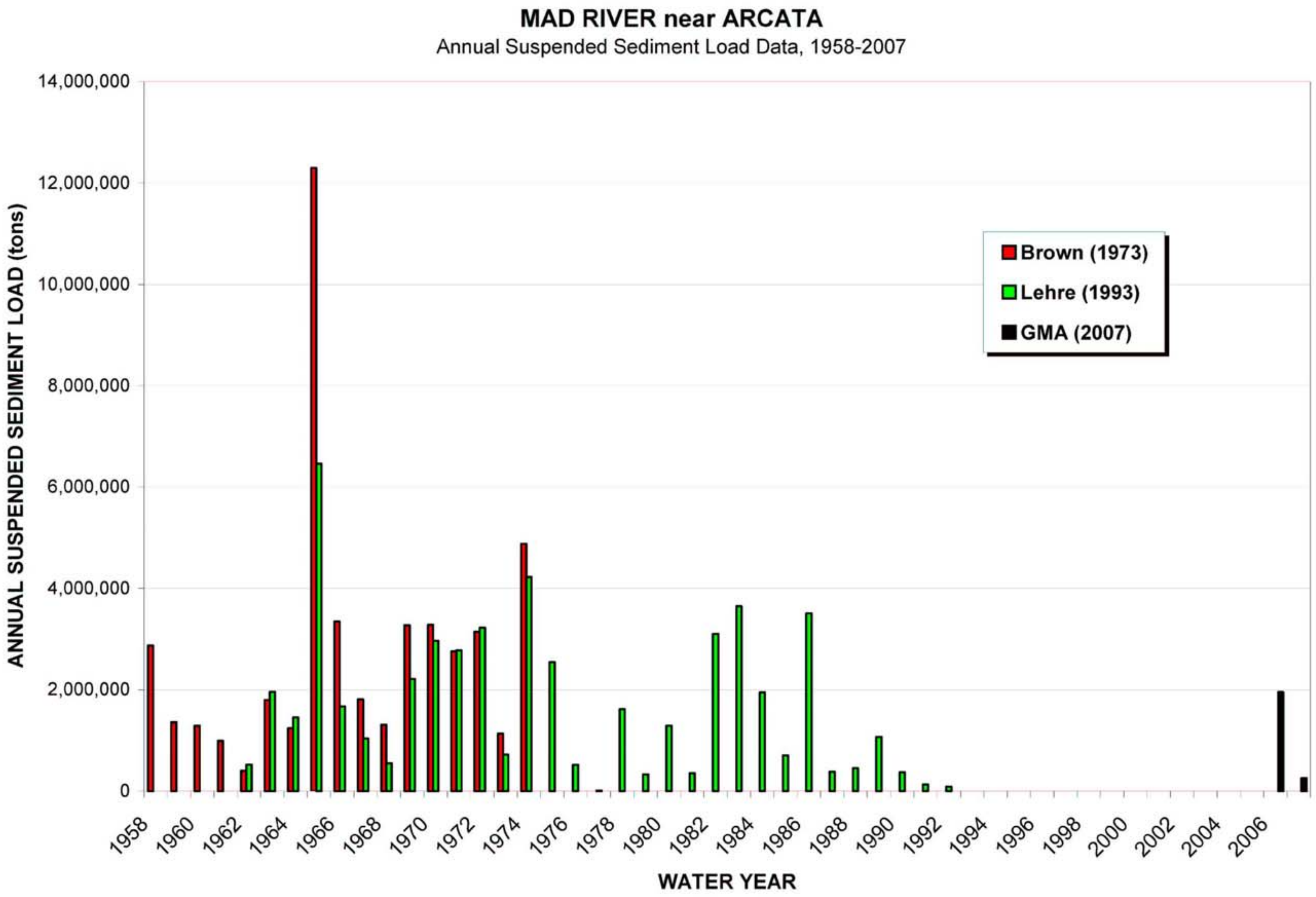

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FIGURE

26

MAD RIVER SEDIMENT TRANSPORT DATA

Relationship between Upper Watershed Annual Suspended Sediment Load and Load near Arcata, USGS Data (1958-1970) and GMA (2006-2007)

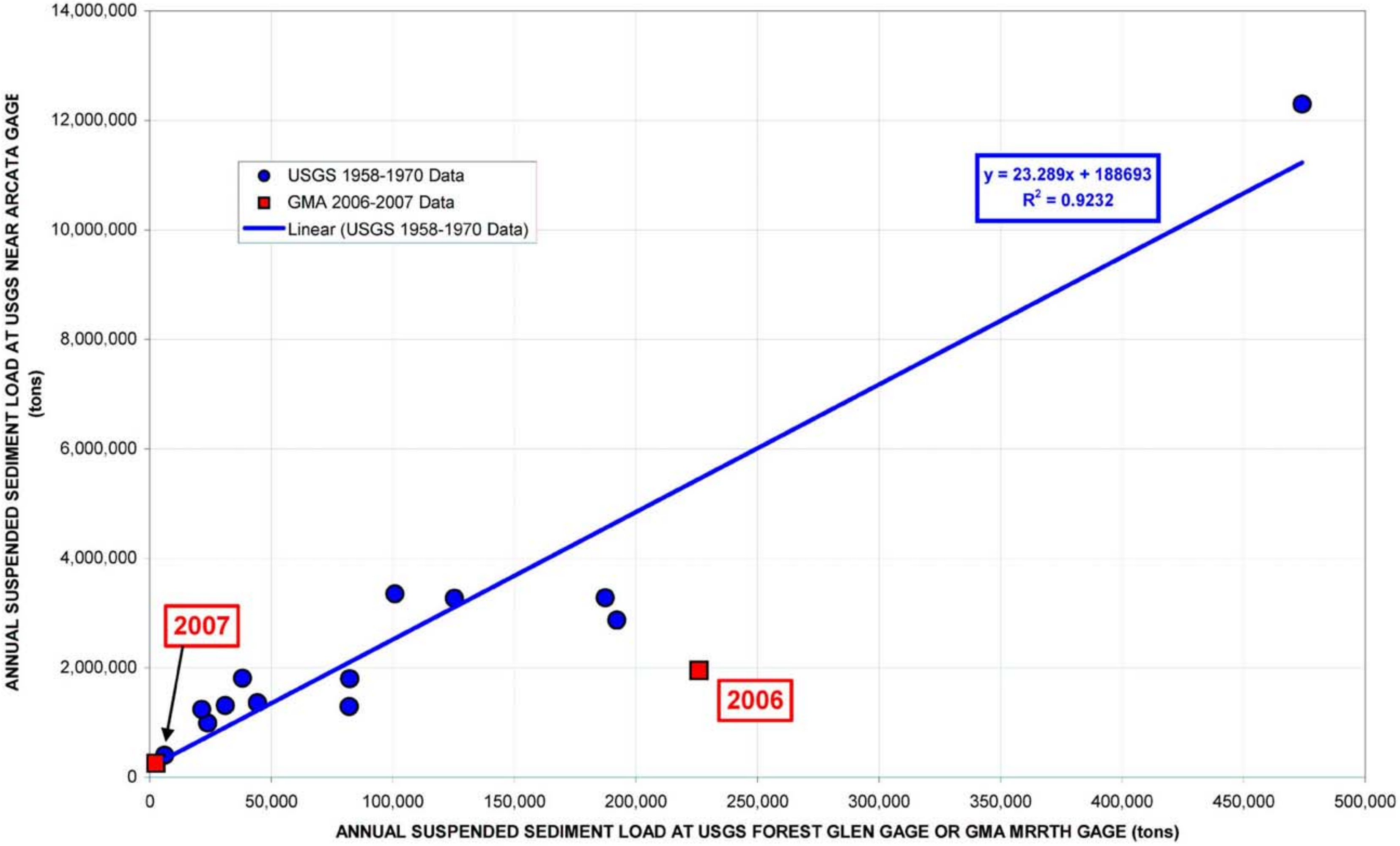

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FIGURE

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comparable to longer durations. However, the durations for all of these sites have been computed for the identical periods.

Continuous turbidigraphs for two additional tributary sites, Anada Creek from the upper watershed, but just downstream of MRRTH, and Maple Creek from the middle watershed and just upstream of MRBVR, were developed from the sample data and the sedigraph method. These continuous curves and the samples are shown compared to the nearby mainstem site, Anada Creek (ACLM) with MRRTH (Figure 28) and Maple Creek (MCMCB) with MRBVR (Figure 29). The differences are instructive: Anada Creek drains a watershed underlain by South Fork Mountain Schist and is an extremely high turbidity and sediment producer, while MRRTH is relatively clean in comparison; Anada Creek is several orders of magnitude more turbid than MRRTH.

In contrast, Maple Creek has only slightly more than half the turbidity of its nearby mainstem site, MRBVR, indicating the extremely high sediment delivery from the middle watershed upstream of MRBVR. Maple Creek is still a significant sediment producer, just less than Anada Creek or the watershed areas draining to mainstem upstream of MRBVR.

Figure 30 provides a turbidity duration analysis for the three tributaries with a continuous record for the 12/24/05 to 2/25/06 period, Anada Creek, Maple Creek, and the North Fork Mad River. Turbidity values for most exceedance probabilities for Anada Creek are 3-50 times higher than those of the North Fork and 2-10 times higher than Maple Creek (Table 10). At the 0.1% exceedance probability for this period, all three sites are fairly similar (i.e., near the peak of the large storm event), but Anada Creek remains quite turbid essentially throughout the period (i.e., well after the peak).

Figure 31 compares the continuous turbidity records for four mainstem sites (MRRTH, MR36, MRBVR, and MRHRB, in downstream order) for the same time period. Problems with the turbidimeter at MR36 prevented a longer record that would compare to those for the other sites, but a short record for the Dec-Feb period was salvageable. The turbidity duration curves for MRBVR and MRHRB are very similar for this period, and quite different from MRRTH and MR36, often about an order of magnitude. MRRTH is more turbid than MR36 for the peak events, but the MR36 curve cross the MRRTH curve at an exceedance probability of around 25%. From then on, MR36 is more turbid than MRRTH, which clears up much more rapidly. These are classic effects from a reservoir: the peak concentrations are reduced downstream of the dam as a portion of the sediment is deposited in the reservoir, however, the reservoir stores a significant amount of turbid water which is then released more slowly, for some time after the large event. The turbidity for the 1% exceedance probability is 310 FNU at MRRTH, 108 FNU at MR36, 2020 FNU at MRBVR, and 2650 FNU at MRHRB for the period examined (Table 10). At the 50% exceedance probability, the values are 11, 21, 159, and 155 FNU, respectively. Obviously, the lower river remains quite turbid for an extended period after a large storm event. Table 12 provides the suspended sediment concentration exceedence probabilities for the sites.

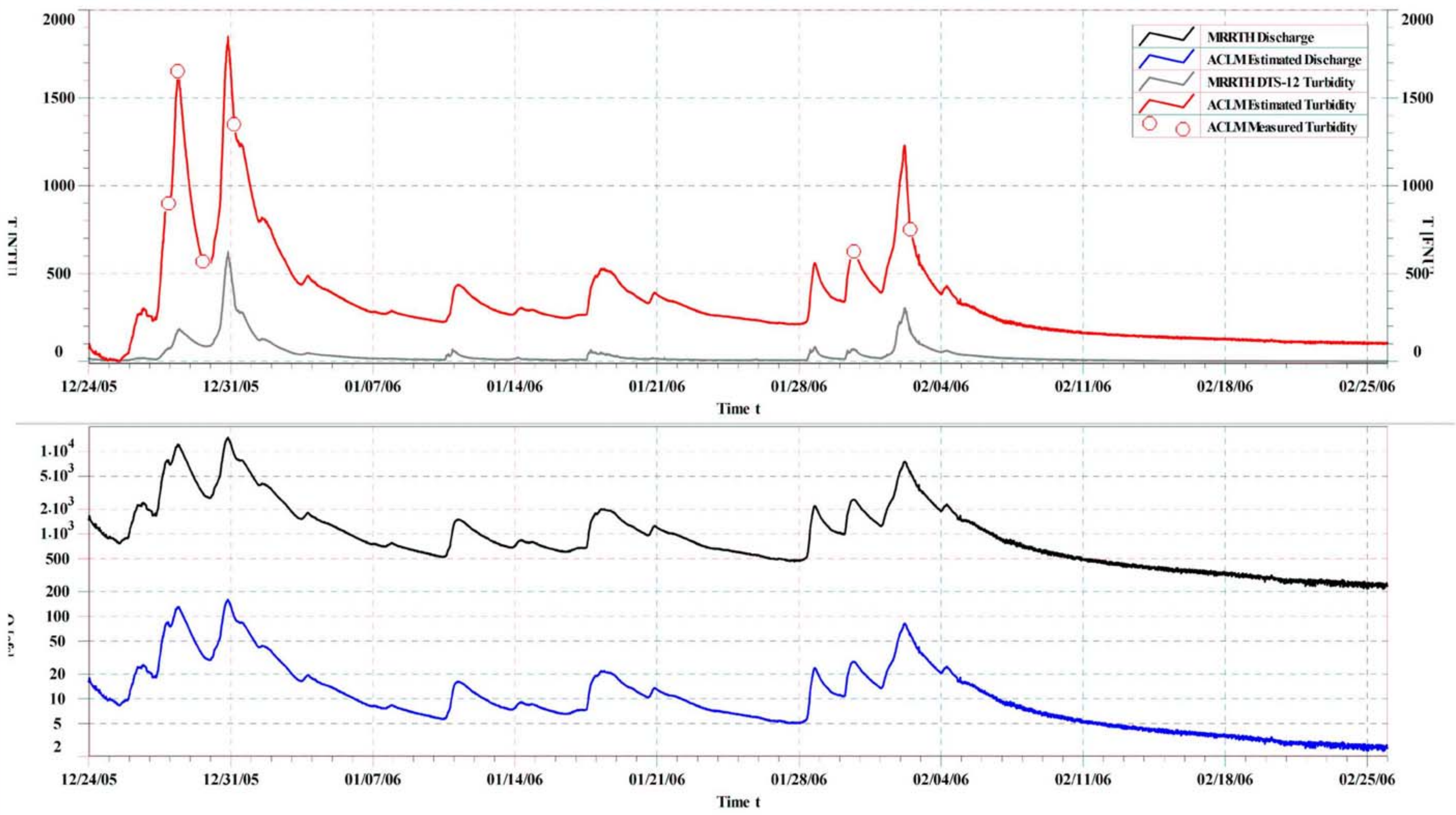 COMPARISON OF ACLM AND MRRTH TURBIDITY AND DISCHARGE, WY2006

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FIGURE

28

COMPARISON OF MCMCB AND MRBVR TURBIDITY AND DISCHARGE, WY2006

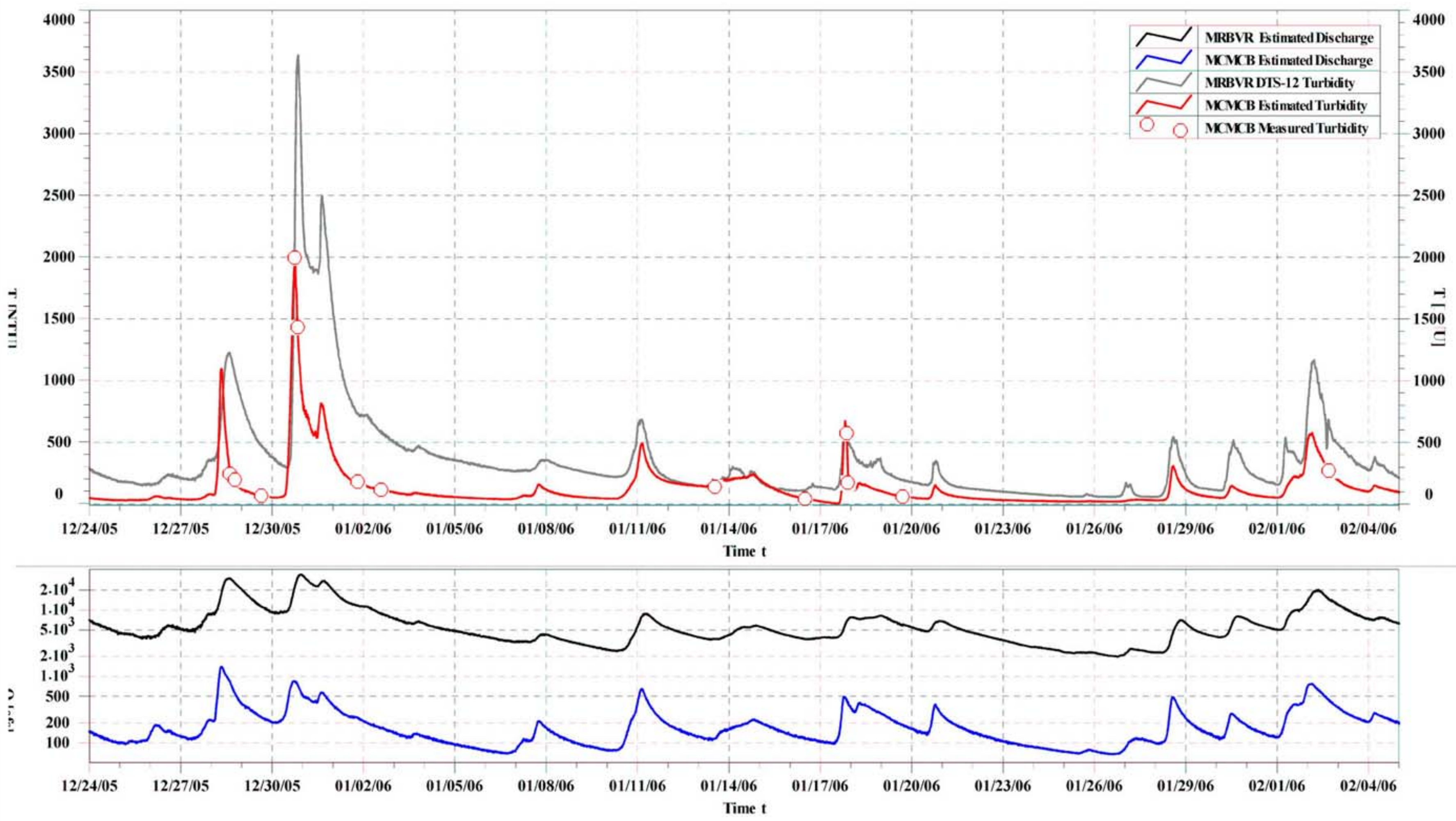

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FIGURE

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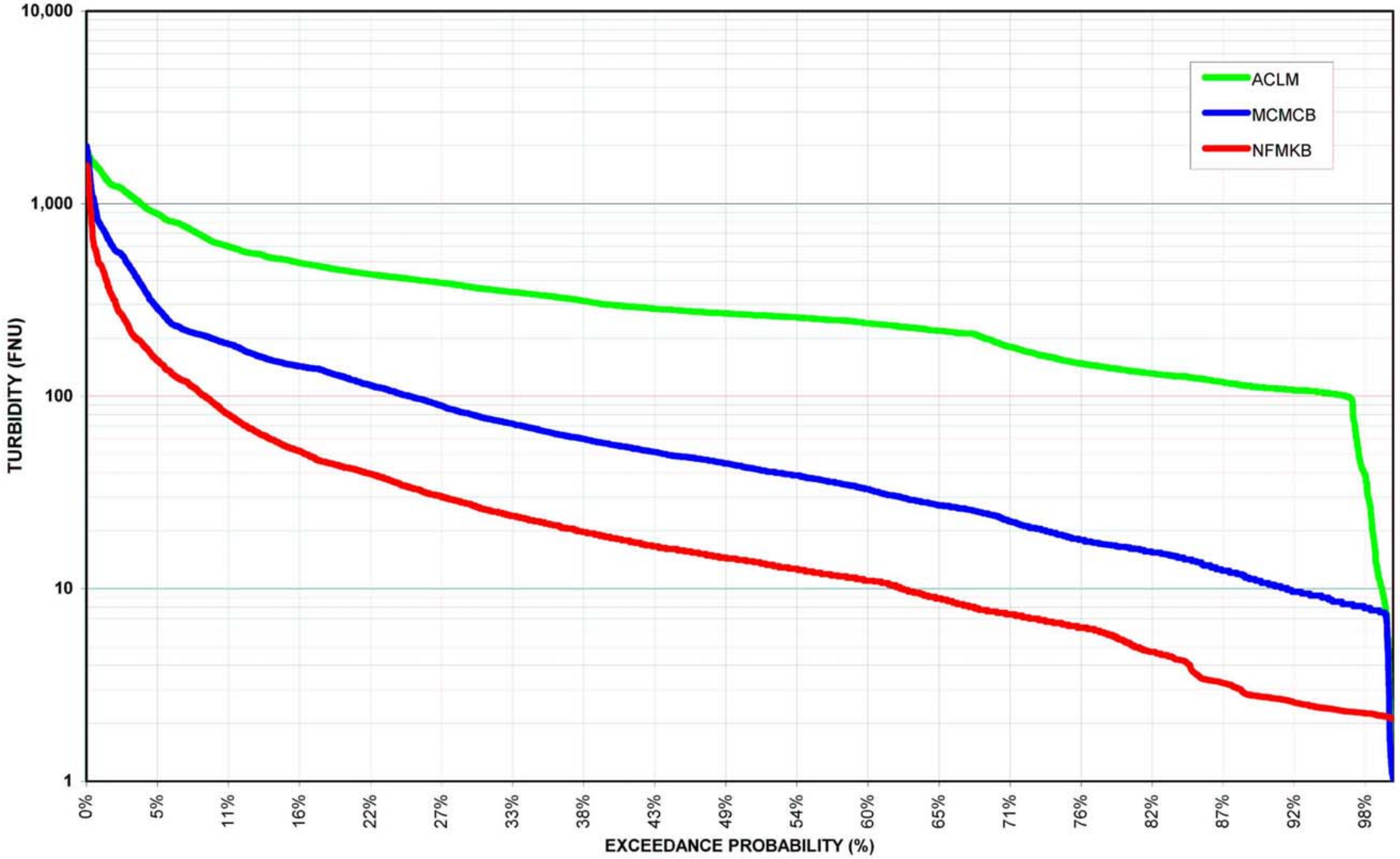

MAD RIVER TRIBUTARY MONITORING SITES

Turbidity Duration Analysis, 12/24/05 through 2/25/06

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FIGURE

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MAD RIVER MAINSTEM MONITORING SITES

Turbidity Duration Analysis, 12/24/05 through 2/25/06

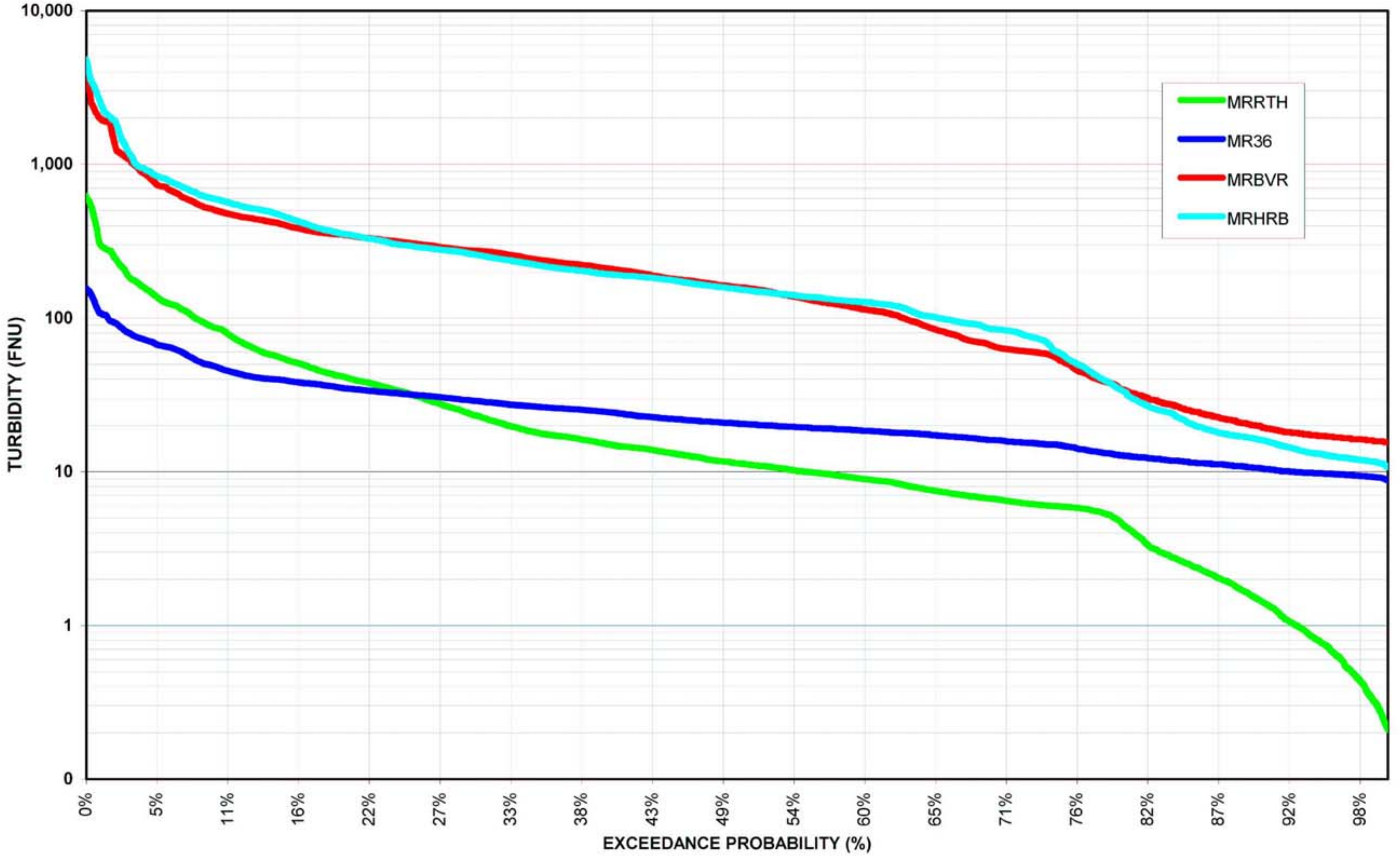

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FIGURE

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TURBIDITY EXCEEDANCE FOR TRIBUTARY AND MAINSTEM SITES

TURBIDITY (FNU)

Partial Record Period 12/24/05 to 2/25/06

SITE	Exceedance Probability (%)						
	0.1	1	2	5	10	50	90
Tributaries							
ACLM	1800	1510	1250	912	623	266	111
MCMCB	1800	791	603	312	195	44	10.7
NFMKB	1470	486	329	163	89	14	2.8
Mainstem							
MRRTH	590	310	261	146	86	11	1.5
MR36	152	108	95	70	48	21	10.6
MRBVR	3520	2020	1600	797	501	159	19.9
MRHRB	4470	2650	1970	887	595	155	16.3

TURBIDITY EXCEEDANCE FOR SITES IN UPSTREAM TO DOWNSTREAM ORDER

TURBIDITY (FNU)

Partial Record Period 12/24/05 to 2/25/06

SITE	Exceedance Probability (%)						
	0.1	1	2	5	10	50	90
MRRTH	590	310	261	146	86	11	1.5
ACLM	1800	1510	1250	912	623	266	111
MR36	152	108	95	70	48	21	10.6
MCMCB	1800	791	603	312	195	44	10.7
MRBVR	3520	2020	1600	797	501	159	19.9
NFMKB	1470	486	329	163	89	14	2.8
MRHRB	4470	2650	1970	887	595	155	16.3

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TABLE

10

Continuous records of turbidity (T), suspended sediment concentration (SSC), and suspended sediment discharge (SSD) were analyzed for duration by site for the partial period of 12/24/05 to 2/24/06 for all gages for which continuous SSC records were developed. Each site is examined separately (Figures 32-38), while results are summarized by site in Table 11.

Figure 32 shows the family of T, SSC, and SSD curves for the Mad River above Ruth Reservoir (MRRTH). The slopes and shapes of the T, SSC, and SSD duration curves indicate that this site cleared up reasonably quickly, even after a large event. SSD is higher than SSC for most of the period simply because the duration of streamflow is higher than that of SSC: in other words, the upper watershed produced a significant amount of runoff from this large event, both in peak and in duration, which resulted in greater total discharge of sediment and lower concentrations over a longer period of time.

Comparing the appearance of the MRRTH curve (which drops off relatively quickly) with that of Anada Creek (ACLM) (Figure 33), the slope drops very slowly: T and SSC remain very high, with turbidities remaining over 100 FNU for essentially the entire period. In contrast, the SSD duration curve for Anada Creek has an initial steep decline then diminishes throughout the period, reflecting a steady drop in streamflow rates to low levels.

Mainstem sites Mad River at Highway 36 (MR36) (Figure 34), Mad River at Butler Valley Ranch (MRBVR) (Figure 36), and Mad River at Hatchery Road Bridge (MRHRB) (Figure 38) generally behave similarly except that the T, SSC, and particularly SSD duration curves for the lower two sites (MRBVR and MRHRB) are shifted upward almost an order of magnitude compared to MR36 (note the differences in the vertical scale for the lower sites relative to MR36), indicating high sediment discharge for the entire period.

Tributary sites Maple Creek at Maple Creek Bridge (MCMCB) (Figure 35) and the North Fork Mad River at Korbel Bridge (NFMKB) (Figure 37) had somewhat similar curves, except that the SSD curve crossed the other curves at 7-15% exceedance probability for MCMCB, but it crossed at 43-63% exceedance for NFMKB, indicating that T and SSC curves cleared up faster on NFMKB than for MCMCB.

Figure 39 compares the SSD duration curves for the 4 mainstem sites over the 12/24/05 to 2/25/06 period. Although the turbidity duration (Figure 31) was higher at MRBVR than at MRHRB for part of the time, the suspended sediment discharge (Figure 39) is always higher at MRHRB than at MRBVR due to the increase in streamflow. In fact, the curves separate and MRHRB is twice as high or greater from the 60-99% exceedance probabilities. The difference between SSD at MRRTH and MR36 also diverges, with higher loads at MR36, although the shapes of both curves are similar, with higher T and SSD values at MRRTH in the lowest exceedance probabilities (i.e., the larger, but less frequent events), and higher values at MR36 for exceedance probabilities greater than about 25% (T) and 16% (SSD), suggesting that sediment and corresponding turbidity can be higher at MRRTH for high-intensity events, but they drop off quickly relative to MR36, where the values remain high for longer periods.

SSC EXCEEDANCE FOR TRIBUTARY AND MAINSTEM SITES

SUSPENDED SEDIMENT CONCENTRATION (mg/l)

Partial Record Period 12/24/05 to 2/25/06

SITE	Exceedance Probability (%)						
	0.1	1	2	5	10	50	90
Tributaries							
ACLM	9640	7540	5700	4060	2300	5940	237
MCMCB	2690	1150	849	490	304	65	14.0
NFMKB	2960	928	616	295	158	23	4.1
Mainstem							
MRRTH	5320	2650	2180	1080	504	11	1.4
MR36	506	408	319	237	144	44	19.7
MRBVR	5720	3740	3130	1840	1290	389	24.3
MRHRB	7260	4570	3520	1740	1220	374	51.5

SSC EXCEEDANCE FOR SITES IN UPSTREAM TO DOWNSTREAM ORDER

SUSPENDED SEDIMENT CONCENTRATION (mg/l)

Partial Record Period 12/24/05 to 2/25/06

SITE	Exceedance Probability (%)						
	0.1	1	2	5	10	50	90
MRRTH	5320	2650	2180	1080	504	11	1.4
ACLM	9640	7540	5700	4060	2300	5940	237
MR36	506	408	319	237	144	44	19.7
MCMCB	2690	1150	849	490	304	65	14.0
MRBVR	5720	3740	3130	1840	1290	389	24.3
NFMKB	2960	928	616	295	158	23	4.1
MRHRB	7260	4570	3520	1740	1220	374	51.5

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TABLE

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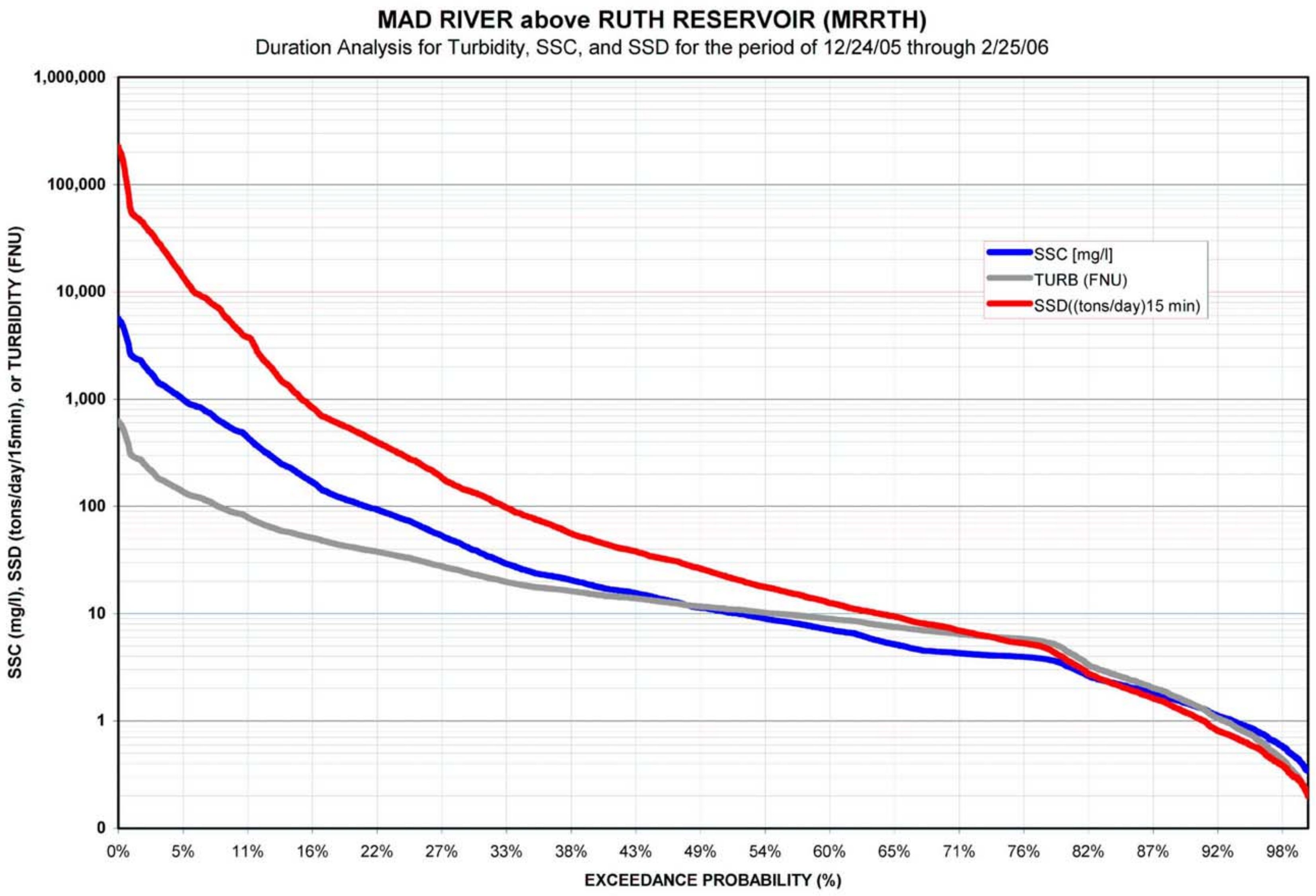

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FIGURE

32

ANADA CREEK (ACLM)

Duration Analysis for Turbidity, SSC, and SSD for the period of 12/24/05 through 2/25/06

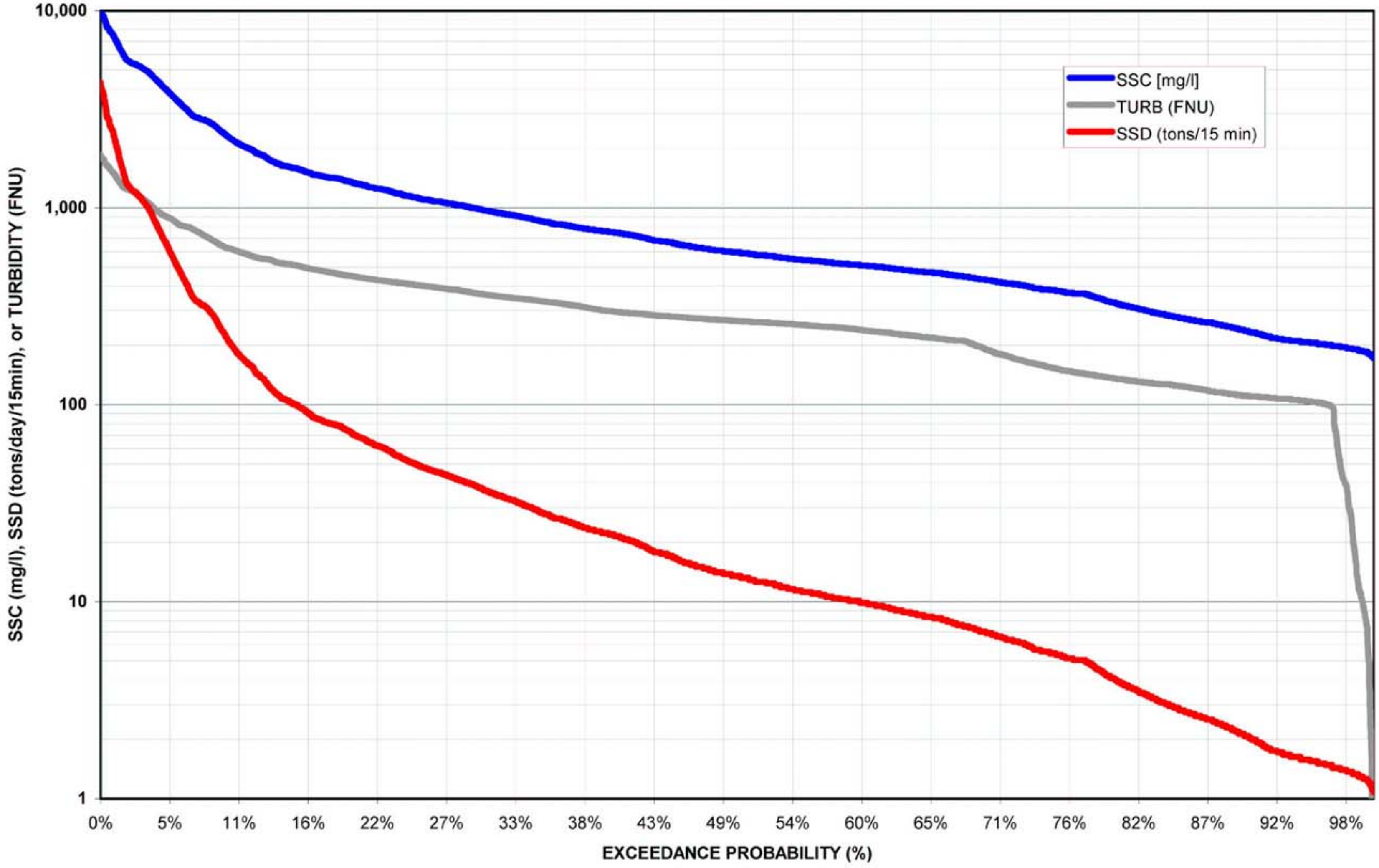

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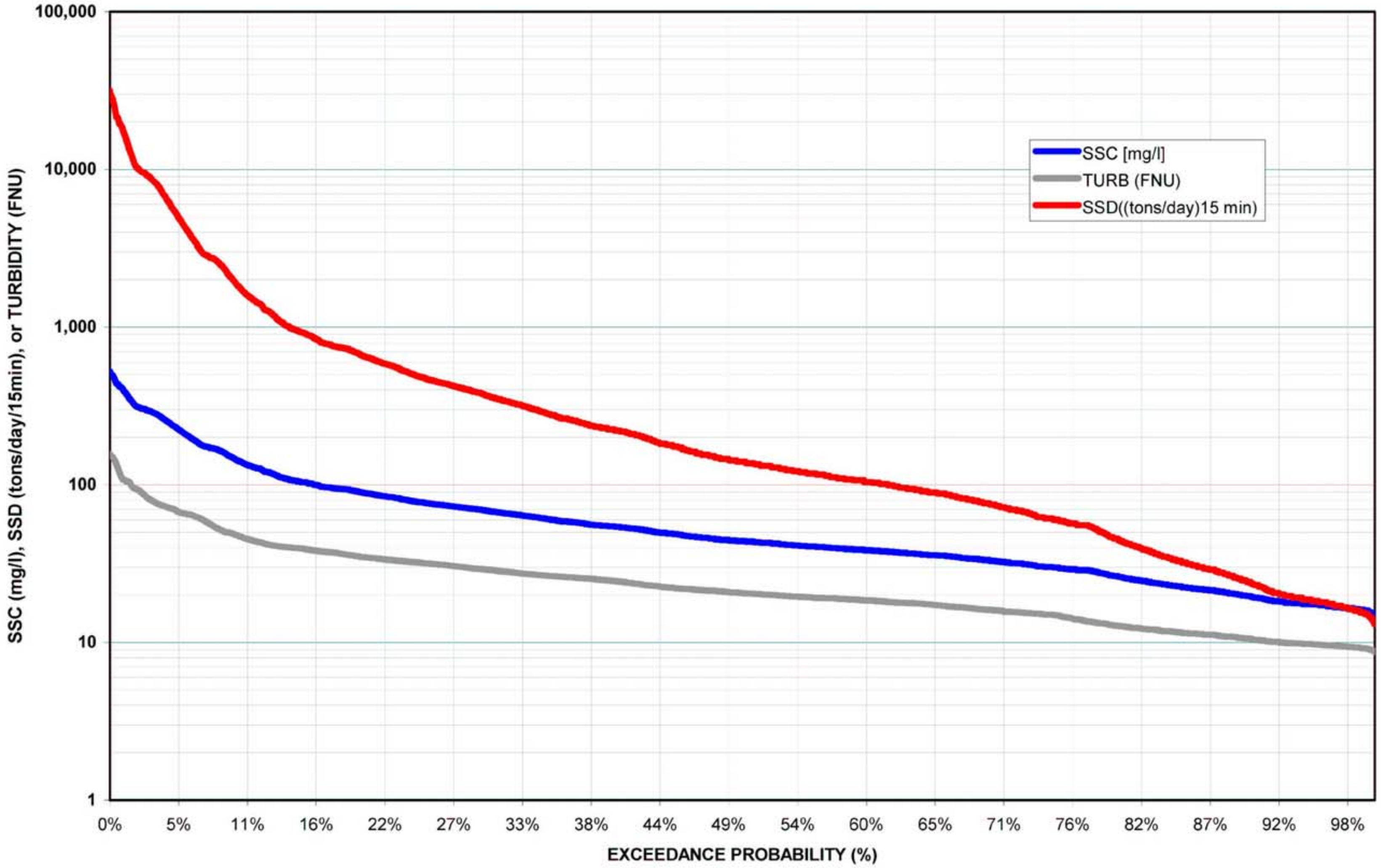
FIGURE

33



MAD RIVER at HIGHWAY 36 (MR36)

Duration Analysis for Turbidity, SSC, and SSD for the period of 12/24/05 through 2/25/06

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FIGURE

34

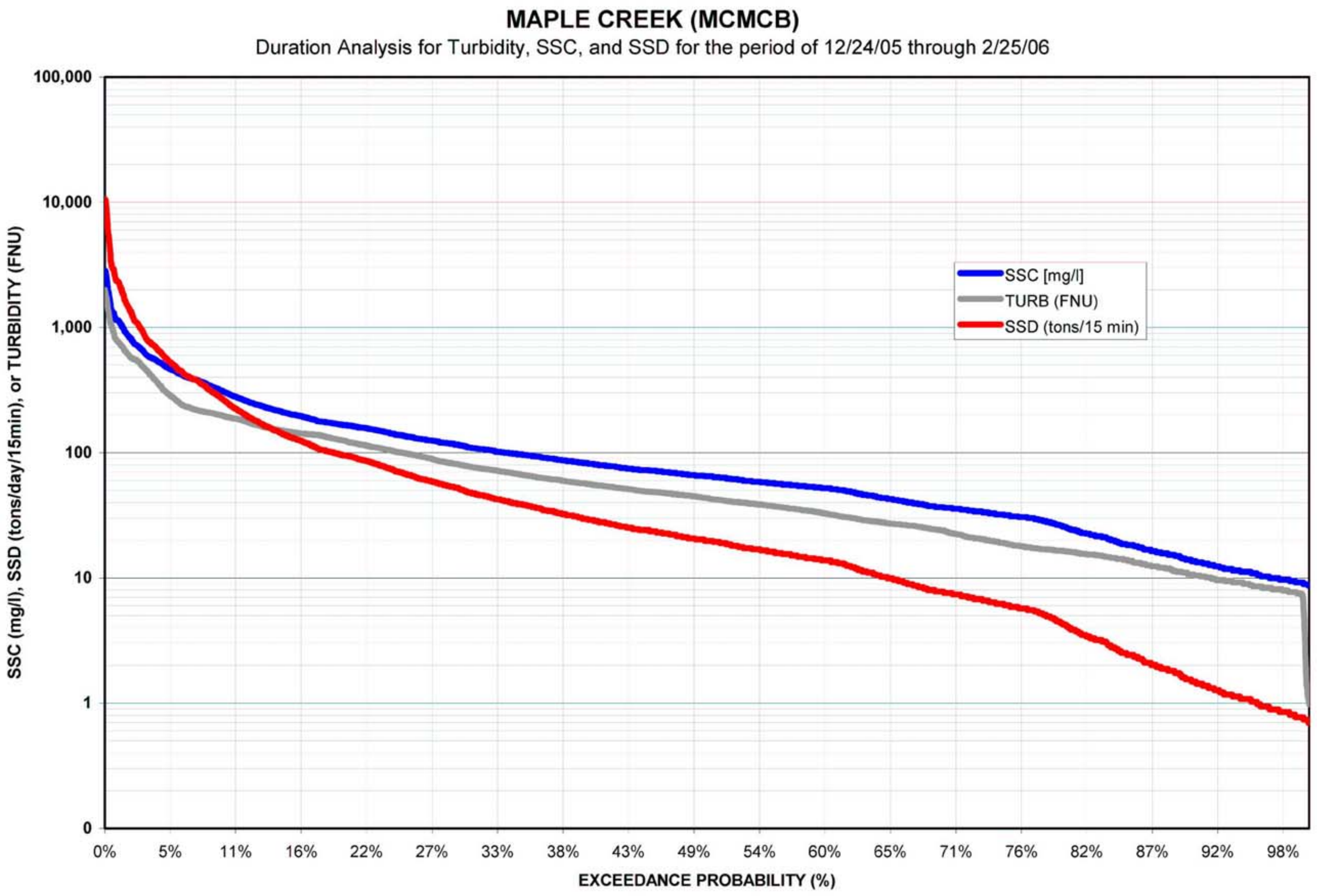

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FIGURE

35

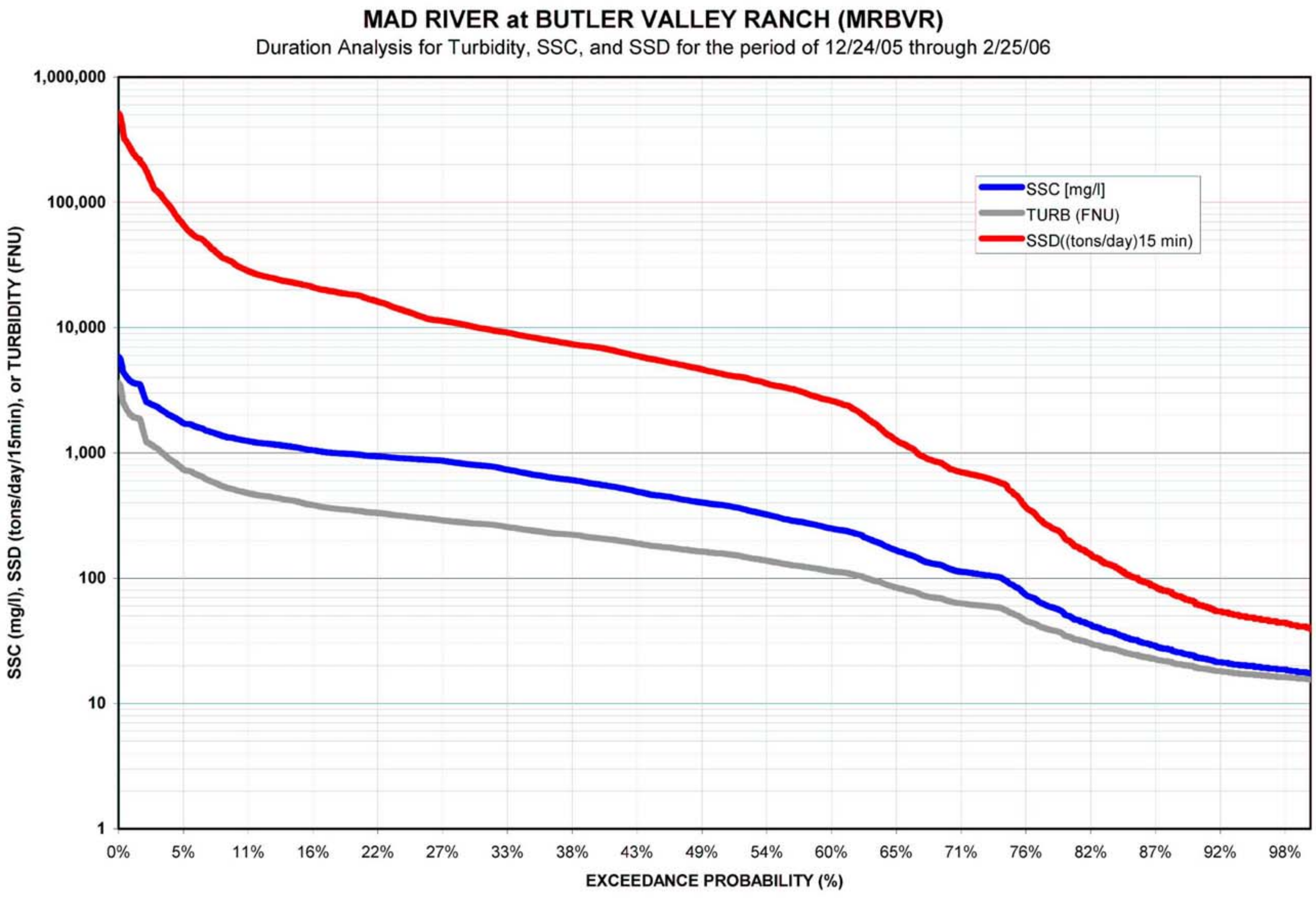

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FIGURE

36

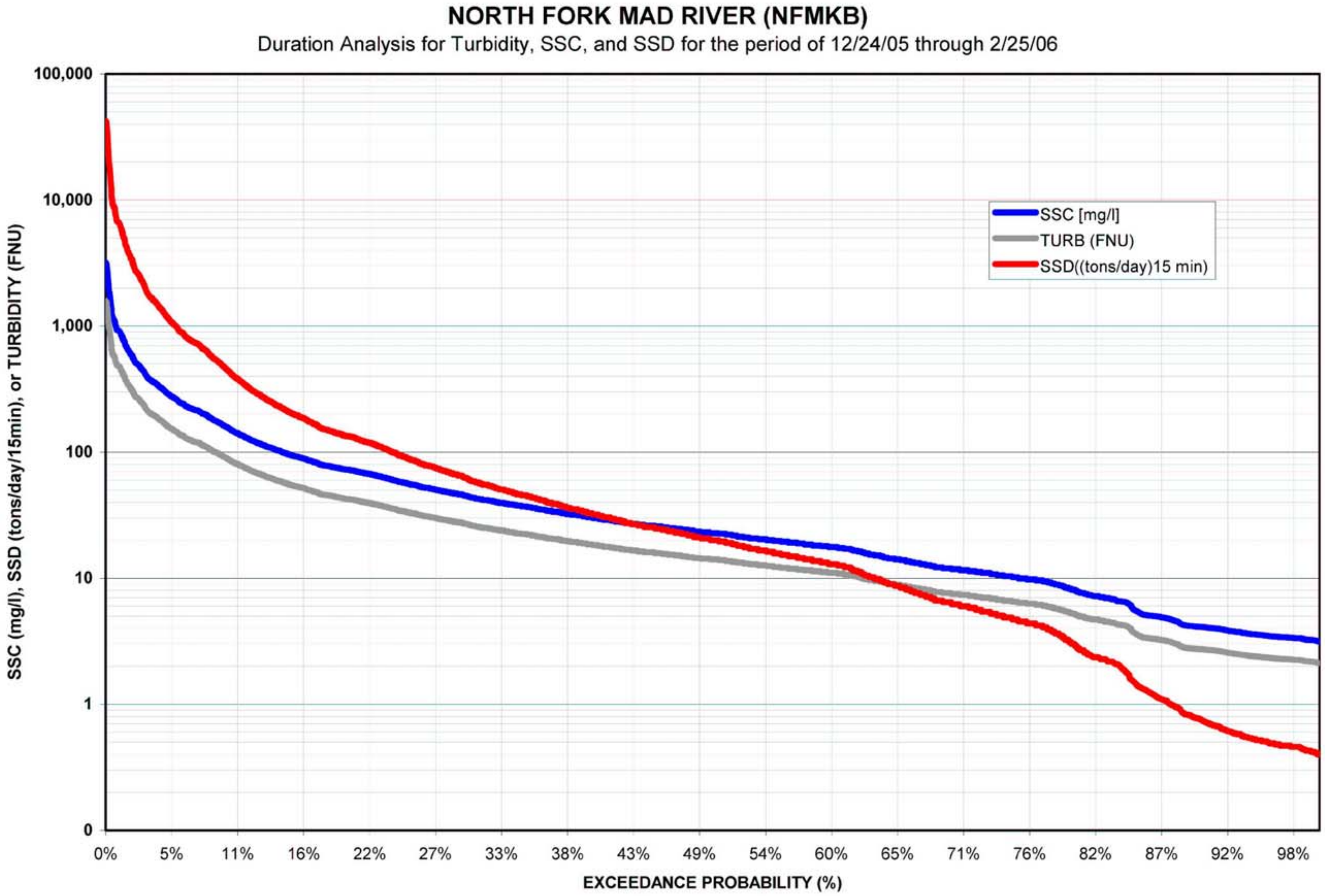

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FIGURE

37

MAD RIVER at HATCHERY ROAD BRIDGE (MRHRB)

Duration Analysis for Turbidity, SSC, and SSD for the period of 12/24/05 through 2/25/06

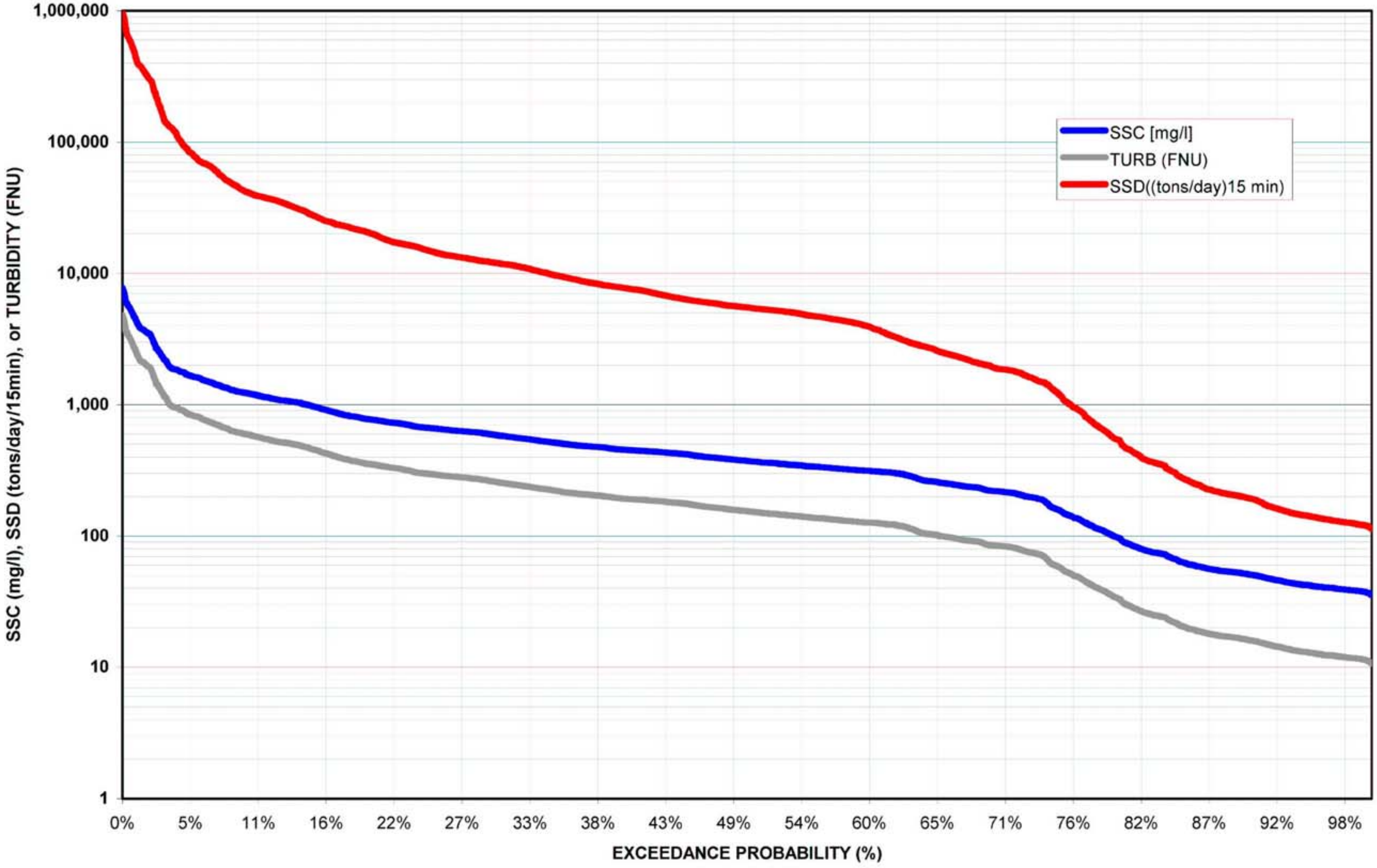

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FIGURE

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MAD RIVER MAINSTEM MONITORING SITES

Suspended Sediment Discharge Duration Analysis, 12/24/05 through 2/25/06

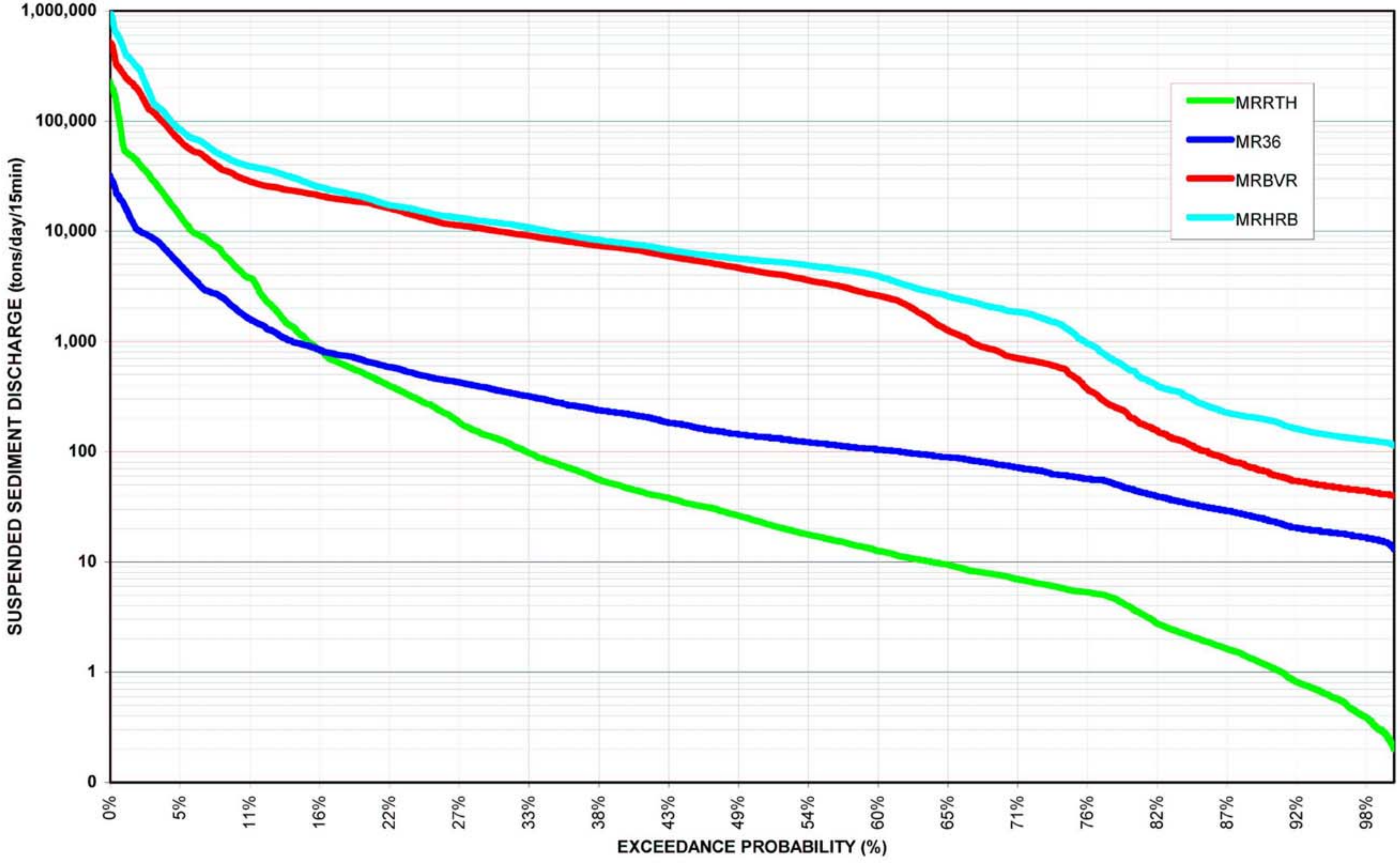

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FIGURE

39

MAD RIVER TRIBUTARY MONITORING SITES

Unit Suspended Sediment Discharge Duration Analysis, 12/24/05 through 2/25/06

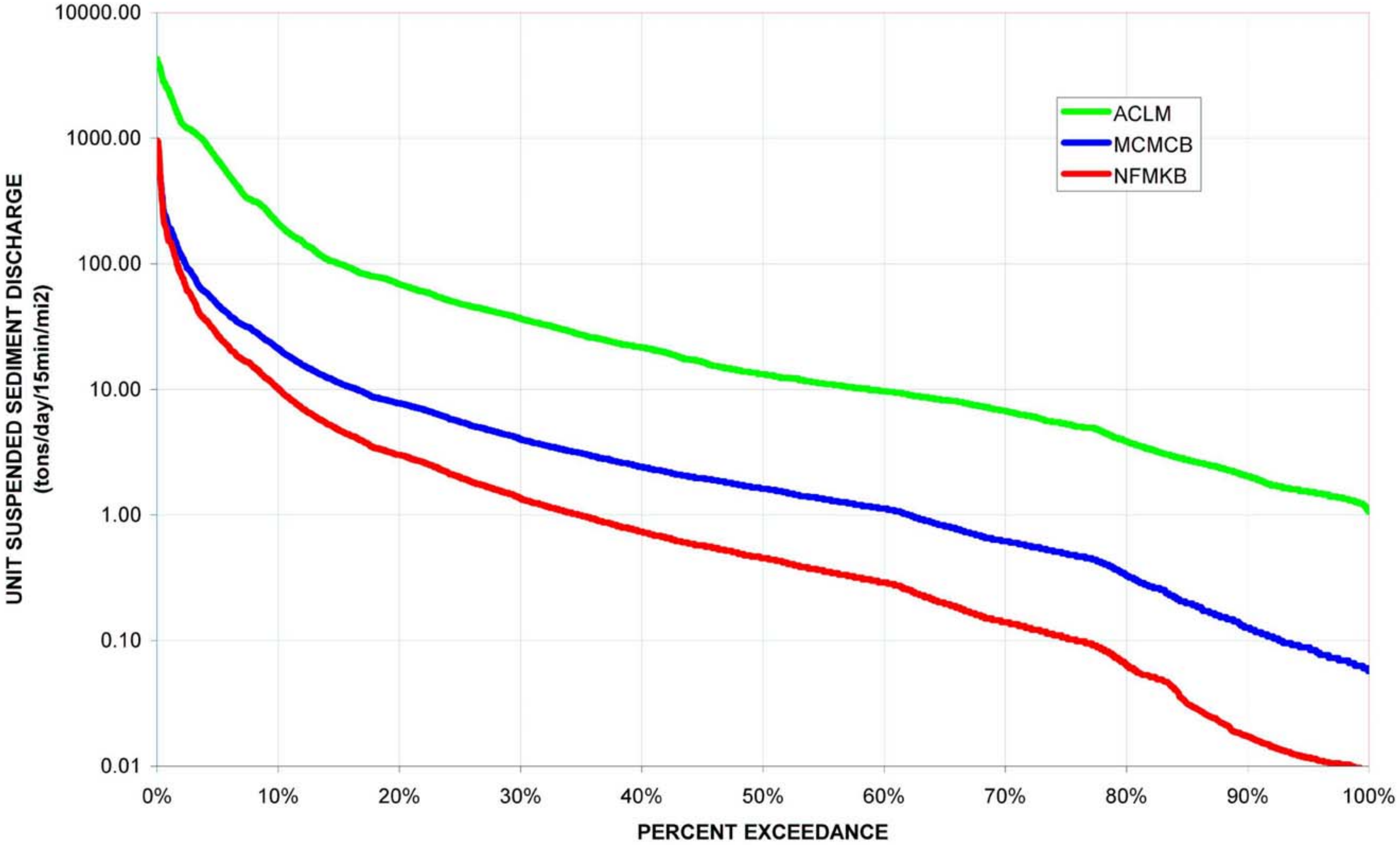

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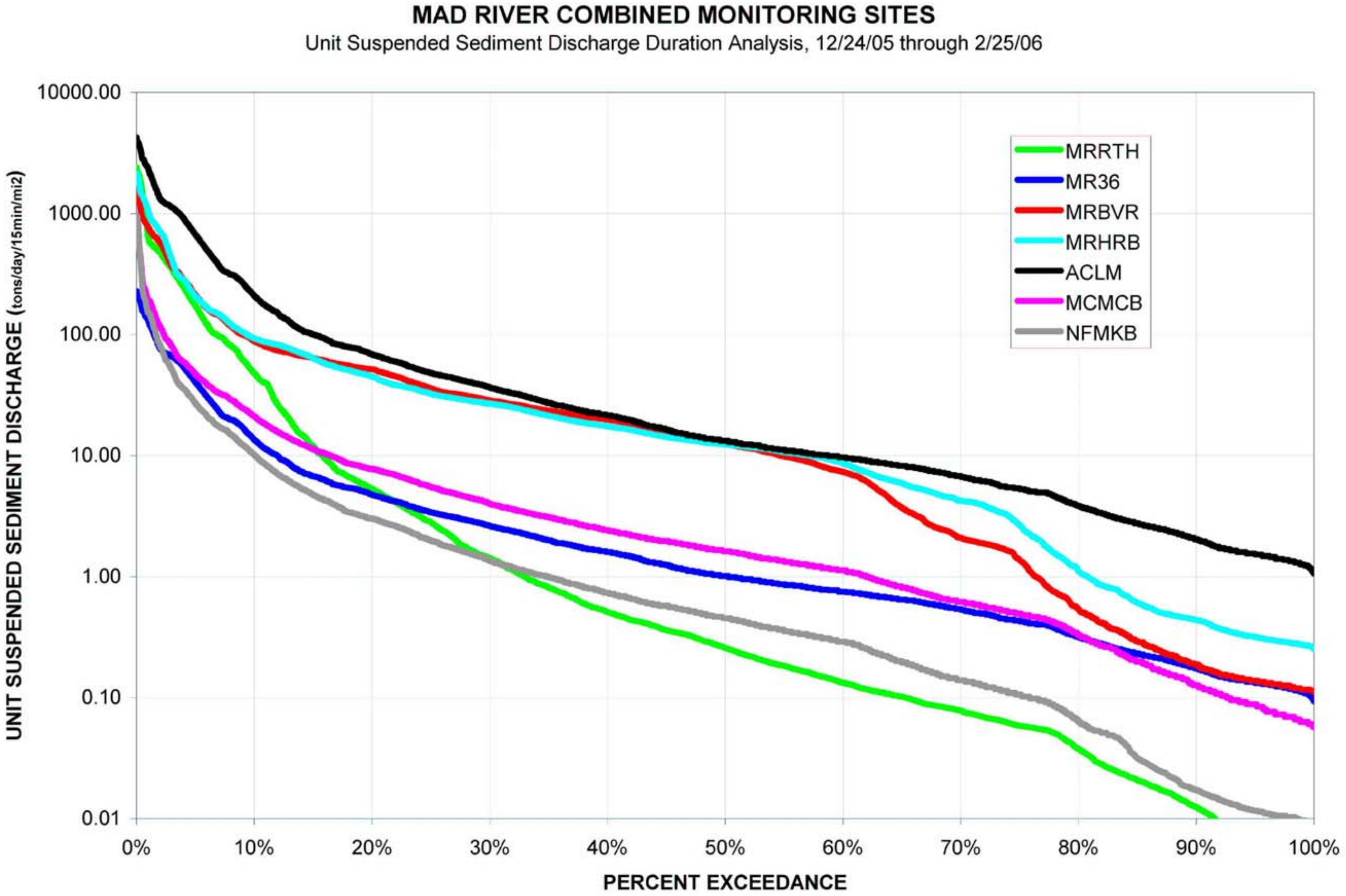
FIGURE

40


MAD RIVER COMBINED MONITORING SITES

Unit Suspended Sediment Discharge Duration Analysis, 12/24/05 through 2/25/06

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FIGURE

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Unit suspended sediment discharge (i.e., SSD relative to watershed size) is compared between the three tributaries in Figure 40. This highlights the extremely high unit loads from Anada Creek (ACLM), as compared to Maple Creek (MCMCB) and North Fork Mad River (NFMKB), which are about an order of magnitude and one and one-half orders of magnitude lower than ACLM, respectively.

Figure 41 compares all unit SSD curves for all seven tributary and mainstem sites. ACLM is higher than all other sites, including the lowermost mainstem sites, MRBVR and MRHRB. After about 30% exceedance probability, MRRTH has the lowest loads, indicating how quickly (compared to others) this portion of the watershed "cleans up." NFMKB has the lowest loads from 3-30% exceedance, and over 30% is the site next higher than MRRTH. MR36 is next, followed by MCMCB. A large gap then exists between these sites and the sites with the highest unit sediment discharges (MRBVR, MRHRB, and ACLM).

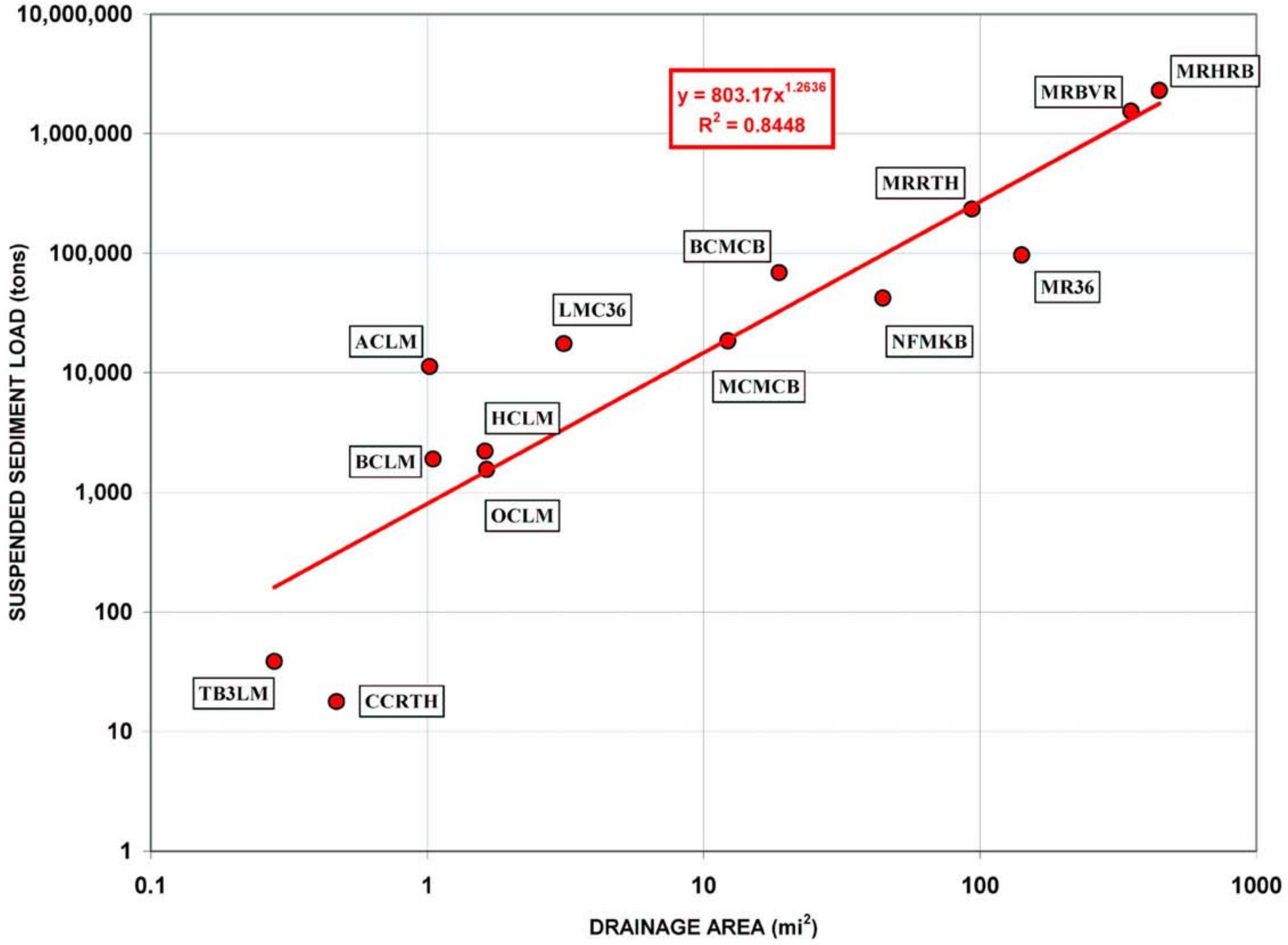
3.3.8 Suspended Sediment Load or Concentration vs. Drainage Area Relationships

Figure 42 plots the two-year total suspended sediment load measured by GMA versus drainage area for the 14 sites for which such computations were developed. A reasonable relationship exists between the points, but the combination of simply using total load and log scale appears to mask significant differences between sites. In addition, it would appear from the plot that MRRTH, MRBVR, and MRHRB all produce sediment at the same unit rate, given their difference in drainage area. This would obviously be quite a different result from the T, SSC, and SSD durations analyzed and described in the previous sections. Thus, Figure 42a was developed to evaluate the relationships when unit sediment load is used instead of total. In Figure 42a, larger differences between the sites are apparent and a qualitative subdivision of the data has been included to identify the degree of impairment.

A similar analysis using unit suspended sediment concentration is shown in Figure 43. This analysis is based on the maximum observed SSC measurement at each site normalized by drainage area (Table 12). The results are generally similar to unit load, but tend to differentiate sites even further because discharge is not included (sediment loads are computed from SSC by multiplying by the discharge) and are simply the maximum sediment concentration.

3.3.9 Turbidity and Suspended Sediment Reference Watersheds

Data and relationships from four reference watersheds (R. Klein, personal communication, 2007) were used to develop reference turbidity, suspended sediment concentration, and suspended sediment discharge duration curves. The reference watersheds were selected from a more extensive dataset of Klein as being the only pristine (i.e., essentially completely undisturbed) watersheds in the area. The analysis of these "reference" watersheds did not include watersheds that were recovered or minimally managed.



WY 2006-2007 SUSPENDED SEDIMENT LOADS vs WATERSHED AREA

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FIGURE

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WY 2006-2007 UNIT SUSPENDED SEDIMENT LOADS vs. WATERSHED AREA

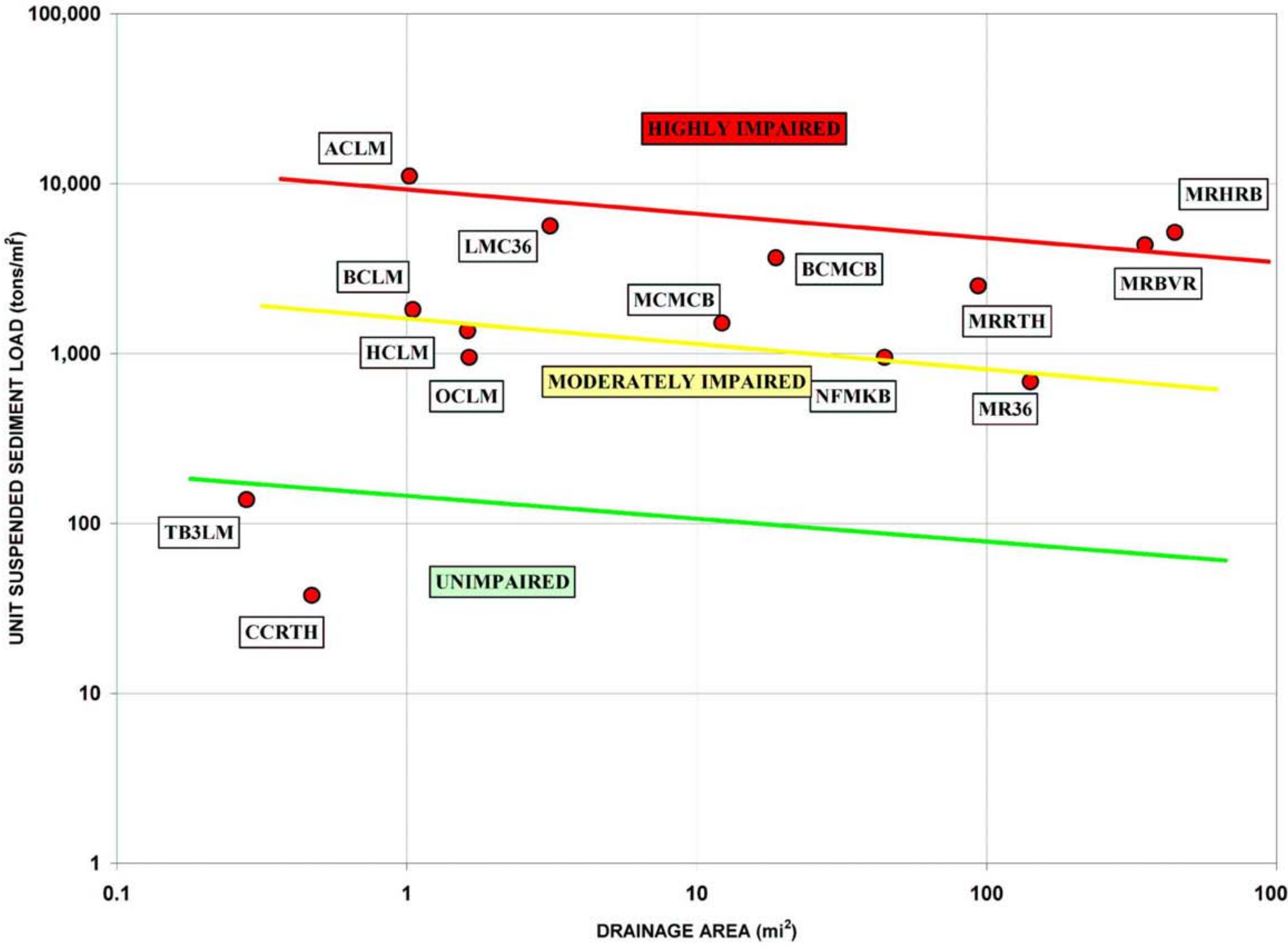

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FIGURE

42a

GMA SAMPLING SITE OBSERVED MAXIMUM TURBIDITY AND SSC

Site Code	Watershed Code	Site Description	Drainage Area (mi^2)	Maximum Turbidity (NTU) [4]	Maximum SSC (mg/l)	Unit Max SSC (mg/l)/mi^2
MRHRB [2]	C1A	Mad River at Hatchery Road Bridge	447.1	4,383	5,149	12
MRBVR [2]	C2	Mad River near Maple Creek below Butler Valley Bridge	351.4	3,421	5,213	15
NFMKB [2,3]	C3	North Fork Mad River at Korbel Bridge	44.5	668	1,620	36
MRRTH [2]	C5	Mad River above Ruth Lake at County Road 514 Bridge	93.6	370	1,609	17
MR36 [2]	C4	Mad River at Highway 36 Bridge	138.4	223	223	2
LCGRB	S1	Lindsay Creek at Glendale Road Bridge	17.8	170	184	10
MCMCB	S2	Maple Creek at Maple Creek Road Bridge	12.2	345	879	72
BCMCB	S3	Boulder Creek at Maple Creek Road Bridge	18.8	4,382	6,686	356
LMC36	S4	Lamb Creek	3.1	1,950	10,776	3,476
OCLM	S5	Olsen Creek	1.6	200	1,817	1,136
TB3LM	S6	Unnamed Tributary 3	0.3	40	417	1,390
HCLM	S7	Hobart Creek	1.6	1,800	4,461	2,788
BCLM	S8	Blue Slide Creek	1.0	930	10,619	10,619
ACLM	S9	Anada Creek	1.0	2,850	11,745	11,745
CCRTH	S10	Clover Creek	0.5	20	19	38

[2] continuous turbidity station

[3] continuous streamflow station

[4] maximum turbidity and SSC did not always come from the same sample

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TABLE

12

MAD RIVER SAMPLING WATERSHEDS

UNIT MAXIMUM SUSPENDED SEDIMENT CONCENTRATION vs. DRAINAGE AREA

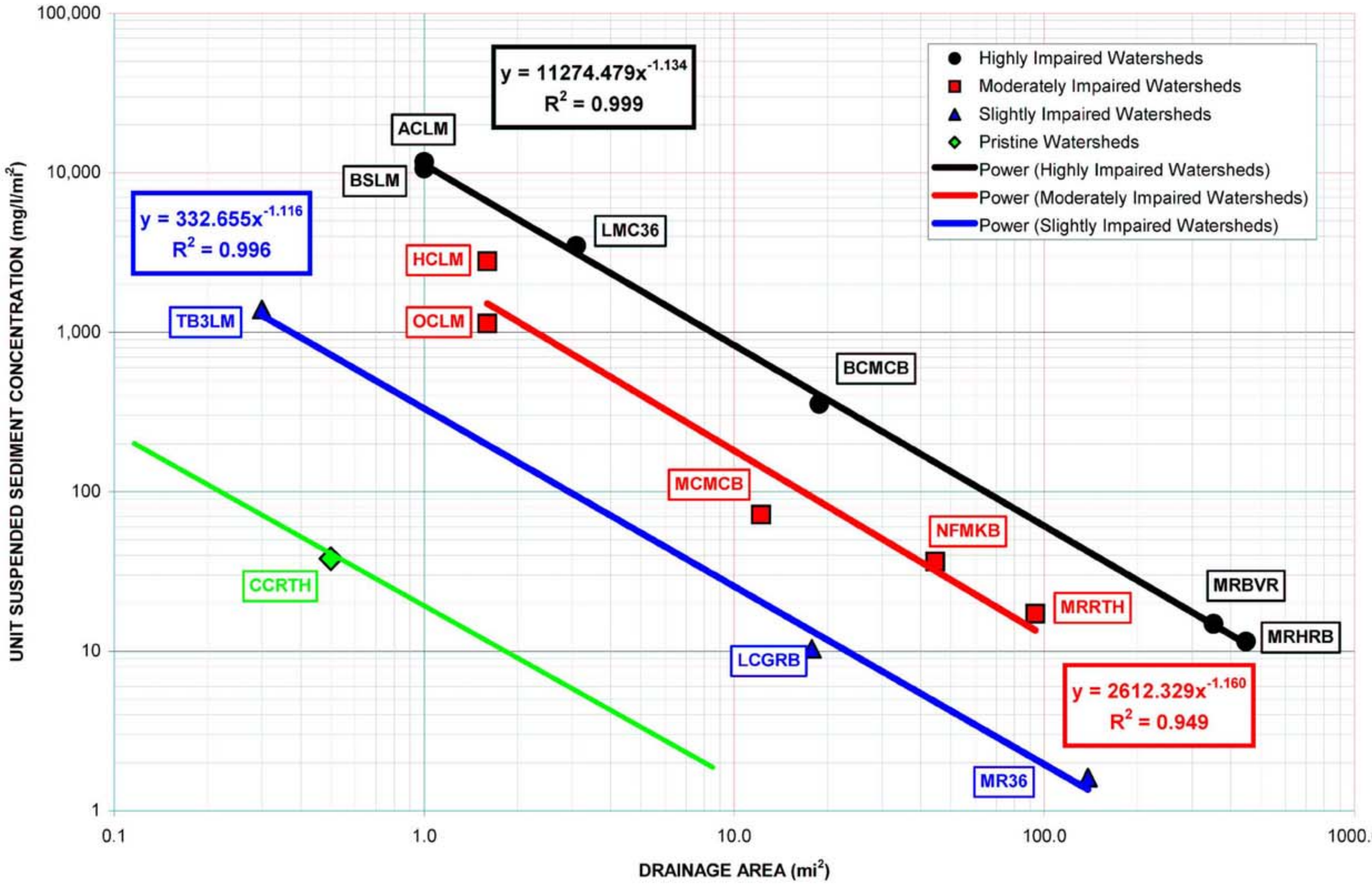

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FIGURE

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The results of the turbidity, SSC, SSD, and unit SSD duration analyses from these reference watersheds were summarized by comparison of values at several exceedance probabilities: 0.1%, 1%, 2%, 5%, and 10%. While the lower exceedance probabilities (e.g., 0.1%, 1%) include primarily moderate to large (and infrequent) stormflow conditions, the 10% exceedance probability extends the data to include lower stormflows and late recessional flows that would better reflect chronic turbidity and sediment concentrations/loads. The analysis of the reference data used exactly the same period as was available for the continuous GMA gages in the Mad River watershed. Average values for each parameter (turbidity, SSC, SSD, unit SSD) and each exceedance probability were computed from the four reference sites.

3.3.10 Turbidity and Suspended Sediment Mad River versus Reference Watersheds

Table 13 compares the four mainstem Mad River continuous sites to the Klein et al reference sites for the different turbidity, SSC, load, and unit load exceedance probabilities and their averages. There are substantial differences between the background parameters and those found in the Mad River mainstem, with the Mad values all significantly greater than these pristine reference conditions.

There are some readily apparent limitations on this approach:

(1) the drainage basin size disparity between the reference sites and the Mad River watershed sites is very large. Of course, there are essentially no watersheds the size of the Mad that do not have a substantial amount of disturbance in them, so comparable reference watersheds do not exist. However, the size disparity casts a considerable amount of uncertainty on the appropriateness of the comparison.

(2) although the time period for background and Mad River sites is identical, as required by the analysis, this short period of record from a very wet year although not a big flood year at least in the lower Mad, raises questions regarding the length of record and the nature of the period on which the analysis is based. Such a short period of record would obviously bias the results relative to the characteristics of the study period, compared to that which would be obtained from a longer period of record.

3.3.11 SEV Analysis of SSC Durations

3.3.11.1 Introduction to SEV

The magnitude and duration of sediment concentrations are among the most critical factors affecting the health of coldwater fish. Fish have been shown to respond negatively when exposed to increasing concentrations of suspended sediments with increasing duration of exposure (Newcombe and MacDonald 1991). Various investigators have developed models relating concentration and duration of exposure to physiological fish responses (Newcombe and MacDonald 1991; Newcombe and Jensen 1996). The following section is based on the Newcombe and Jensen “Severity of Ill Effects” concentration/ duration model.

3.3.11.2 Description of SEV Method

The sediment concentration/duration relationship developed by Newcombe and Jensen is based on analysis of 80 published reports on fish responses to suspended sediment in streams. Newcombe and Jensen created a quantitative index, the “Severity of Ill Effects” scale (SEV), by which to define the qualitative fish responses to various sediment concentration-duration scenarios. The scale groups the responses into four major effect classes: nil effect, behavioral effects, sublethal effects and lethal effects. These were further categorized into a more detailed 15-point SEV scale. The table below shows the scale used to categorize qualitative response data, and the matrix which follows was then developed to relate concentration-duration into a SEV score.

SEV		**DESCRIPTION OF EFFECT**
Nil effect	**0**	No behavioral effect
Behavioral effects	**1**	Alarm reaction
	2	Abandonment of cover
	3	Advoidance response
	4	Short-term reduction in feeding rates; short-term reduction in feeding success
Sublethal effects	**5**	Minor physiological stress; increase in the rate of coughing; increased respiration rate
	6	Moderate physiological stress
	7	Moderate habitat degradation; impaired homing
	8	Indications of major physiological stress; long-term reduction in feeding rate; long-term reduction in feeding success; poor condition
Lethal and paralethal effects	**9**	Reduced growth rate; delayed hatching; reduced fish density
	10	0-20% mortality; increased predation; moderate to severe habitat degradation
	11	>20%-40% mortality
	12	>40%-60% mortality
	13	>60%-80% mortality
	14	>80%-100% mortality

Source: Newcomb and Jensen, 1996

Duration of Exposure to SS ($\log_e$ hours)

Concentration (mg SS/L)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**($\log_e$ mg SS/L)**
	Average severity of ill effects scores (calculated)											
162755	10	11	11	12	12	13	14	14	-	-	-	**12**
59874	9	10	10	11	12	12	13	13	14	-	-	**11**
22026	8	9	10	10	11	11	12	13	13	14	-	**10**
8103	8	8	9	10	10	11	11	12	13	13	14	**9**
2981	7	8	8	9	9	10	11	11	12	12	13	**8**
1097	6	7	7	8	9	9	10	10	11	12	12	**7**
403	5	6	7	7	8	9	9	10	10	11	12	**6**
148	5	5	6	7	7	8	8	9	10	10	11	**5**
55	4	5	5	6	6	7	8	8	9	9	10	**4**
20	3	4	4	5	6	6	7	8	8	9	9	**3**
7	3	3	4	4	5	6	6	7	7	8	9	**2**
3	2	2	3	4	4	5	5	6	7	7	8	**1**
1	1	2	2	3	3	4	5	5	6	7	7	**0**
	1	**3**	**7**	**1**	**2**	**6**	**2**	**7**	**4**	**11**	**30**	
	Hours			**Days**			**Weeks**		**Months**			

For a given sediment dose, the matrix shows the corresponding SEV score as predicted by the regression model. For example, a suspended sediment concentration of 8,103 mg/L for a period of 2 days would be expected to produce an SEV of 10. The SEV cell values are separated by diagonal terraced lines denoting thresholds of sublethal effects (lower left) and lethal effects (middle diagonal). Axes are shown in logarithmic (top and right side) and absolute (bottom and left side) terms. The concentration and duration values shown in the matrix are the median values of the range of concentrations and durations associated with a predicted SEV.

As expected, the dose matrix shows regular increases of response severity with increasing doses. For example, a sediment concentration between 665 and 1,808 mg/L that lasts for at least a 48-hour period (2 days) might be expected to elicit a physiological response categorized as an ‘9’ on the SEV scale. This would be classified as ranking in the lethal range. Longer exposure durations of the same concentrations are predicted to elicit increasingly deleterious effects. The SEV scores within the dose/response matrix allow for estimating the minimum concentrations and durations that might be expected to trigger sublethal and lethal effects in fish.

3.3.11.3 Application of SEV to the Mad River

The four monitoring sites (MRRTH, MRBVR, NFMKB, and MRHRB) with continuous SSC records for WY2006 and WY2007 were analyzed using the SEV method. However, since the target SEV score for a given watershed must be determined by the various regulatory agencies tasked with protection of the most sensitive beneficial uses, we instead computed the results for SEV 5 through 8. The computations involve assessing how often a threshold is exceeded when compared to the moving average of either mean or maximum daily SSC values for 1, 2, 6, 14, 49, and 120 day durations. Thus, the following tables have 3 columns under each SEV, counts > threshold, count total, and % > threshold and values for each of these associated with the six durations.

Table 13a and 13b provide the results for MRRTH, Tables 13c and 13d for MRBVR, Table 13e and 13f for NFMKB, and Tables 13g and 13h for MRHRB. The two tables at each site are for the mean daily and maximum daily concentrations datasets. Calculations were made for the combined WY2006-2007 period (December 20, 2005 through March 20, 2007, and for WY2006 and WY2007 individually. The individual water years, 2006 was wet and 2007 was dry, provide an assessment of the range of results for different water year types.

The tables show that the Mad River routinely exceeds (i.e. a high percentage of the time the threshold concentration for a given duration was exceeded) SEV 5 and 6 scores in either year type, although the percentage is lower at the upstream-most site, MRRTH.

COMPARISON OF WY2006 MAD RIVER TURBIDITY, SSC, AND SSD DATA WITH REFERENCE SITES

BACKGROUND SITES (Klein, pers com. 2007			Turbidity Exceedance Probability (FNU)					Estimated SSC (mg/l)					Estimated SSD (tons/day)					Estimated SSD (tons/mi2/day)				
Site	Drainage Area (acres)	Drainage Area (mi^2)	0.10	1.0	2	5	10	0.10	1.0	2	5	10	0.10	1.0	2	5	10	0.10	1.0	2	5	10
GOD	947	1.5	29	12	8	5	3	50	13	7	4	3	5	1.2	0.6	0.2	0.1	3.3	0.8	0.4	0.2	0.1
PRU	2,662	4.2	60	24	16	8	4	91	36	24	12	6	58	16.3	9.4	4.1	1.7	14.0	3.9	2.3	1.0	0.4
LLM	2,317	3.6	116	32	21	12	7	227	50	31	18	11	72	10.1	5.3	2.1	0.9	20.0	2.8	1.5	0.6	0.3
PAB	4,915	7.7	45	19	14	7	4	50	19	13	6	4	19	6.5	3.7	1.5	0.6	2.5	0.8	0.5	0.2	0.1
		avg	63	22	15	8	5	105	30	19	10	6	39	9	5	2	1	10.0	2.1	1.1	0.5	0.2
		std dev	38	8	5	3	2	84	17	11	6	4	32	6	4	2	1	8.5	1.5	0.9	0.4	0.2

MAD RIVER SITES (GMA, 2007)			Turbidity Exceedance Probability (FNU)					Estimated SSC (mg/l)					Estimated SSD (tons/day)					Estimated SSD (tons/mi2/day)				
Site	Drainage Area (acres)	Drainage Area (mi^2)	0.10	1.0	2	5	10	0.10	1.0	2	5	10	0.10	1.0	2	5	10	0.10	1.0	2	5	10
MRHRB	310,326	485	3790	1610	865	542	344	6270	2960	1700	1130	756	758094	243643	90170	37324	19036	1563	502	186	77	39
MRBVR	217,387	340	3180	1270	858	497	351	5290	2620	1940	1280	982	452000	182000	86500	30300	18400	1331	536	255	89	54
NFMKB	28,468	44	1050	273	177	90.1	46.1	2090	507	323	159	79	22600	2700	1280	404	141	508	61	29	9	3
MRRTH	59,911	94	565	225	145	70.1	37	5090	1830	1070	353	90	191000	36900	16200	2600	421	2040	394	173	28	4
		avg	2146	845	511	300	195	4685	1979	1258	731	477	355924	116311	48538	17657	9500	1361	373.3	160.6	50.8	25.3
		std dev	1578	702	405	254	177	1805	1090	723	557	462	321079	115097	46380	18895	10648	640.5	217.0	94.9	38.4	25.5

Notes:

GMA Acronym and Site Name

Site	Site Name
MRHRB	Mad River at Hatchery Rd Bridge
MRBVR	Mar River at Butler Valley Ranch
NFMKB	N Fork Mad R at Korbel Bridge
MRRTH	Mad R above Ruth Reservoir

Background Sites

Site	Site Name
GOD	Godwin Creek
PRU	Upper Praire Creek
LLM	Little Lost Man Creek
PAB	Prairie Creek above Boyes

Background data from Klein et al (in review) (Klein, per com. 2007) based on WY2005 SSC Estimation Equations

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TABLE

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SEV ANALYSIS: MAD RIVER ABOVE RUTH RESERVOIR (MRRTH), 2006-2007

Analysis of Moving Average of Mean Daily SSC

Period of Record WY 2006 and WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	2	225	1	6	225	3	26	225	12	50	225	22
2 Day	5	224	2	11	224	5	55	224	25	102	224	46
6 Day	13	220	6	22	220	10	115	220	52	161	220	73
14 Day	12	212	6	70	212	33	129	212	61	173	212	82
49 Day	12	147	8	147	147	100	147	147	100	147	147	100
120 Day	14	22	64	22	22	100	22	22	100	-	-	-

SEV Thresholds

	SEV 8	SEV 7	SEV 6	SEV 5
Duration (days)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)
1	1808	403	55	20
2	665	148	20	7
6	244	55	7	3
14	244	20	7	3
49	90	7	3	1
120	33	3	1	1

Wet Year WY 2006

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	2	141	1	6	141	4	22	141	16	39	141	28
2 Day	5	140	4	11	140	8	44	140	31	78	140	56
6 Day	13	136	10	22	136	16	87	136	64	114	136	84
14 Day	12	128	9	59	128	46	94	128	73	116	128	91
49 Day	12	93	13	90	93	97	93	93	100	93	93	100
120 Day	14	22	64	22	22	100	22	22	100	-	-	-

Dry Year WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	0	84	0	0	84	0	4	84	5	11	84	13
2 Day	0	83	0	0	83	0	11	83	13	24	83	29
6 Day	0	84	0	0	84	0	28	84	33	47	84	56
14 Day	0	84	0	11	84	13	35	84	42	57	84	68
49 Day	0	54	0	41	54	76	54	54	100	54	54	100
120 Day	-	-	-	-	-	-	-	-	-	-	-	-

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MAD RIVER SEDIMENT SOURCE ANALYSIS

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TABLE
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SEV ANALYSIS: MAD RIVER ABOVE RUTH RESERVOIR (MRRTH), 2006-2007

Analysis of Moving Average of Maximum Daily SSC

Period of Record WY 2006 and WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	4	253	2	12	253	5	48	253	19	75	253	30
2 Day	11	255	4	29	255	11	86	255	34	124	255	49
6 Day	23	256	9	67	256	26	153	256	60	177	256	69
14 Day	26	253	10	126	253	50	183	253	72	199	253	79
49 Day	44	188	23	188	188	100	188	188	100	188	188	100
120 Day	46	46	100	46	46	100	46	46	100	-		-

SEV Thresholds

	SEV 8	SEV 7	SEV 6	SEV 5
Duration (days)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)
1	1808	403	55	20
2	665	148	20	7
6	244	55	7	3
14	244	20	7	3
49	90	7	3	1
120	33	3	1	1

Wet Year WY 2006

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	3	159	2	10	159	6	35	159	22	16	159	10
2 Day	9	158	6	21	158	13	63	158	40	96	158	61
6 Day	17	154	11	47	154	31	106	154	69	117	154	76
14 Day	26	146	18	80	146	55	114	146	78	121	146	83
49 Day	44	111	40	111	111	100	111	111	100	111	111	100
120 Day	41	41	100	41	41	100	41	41	100	-	-	-

Dry Year WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	1	94	1	2	94	2	13	94	14	18	94	19
2 Day	2	96	2	8	96	8	23	96	24	28	96	29
6 Day	6	102	6	20	102	20	47	102	46	60	102	59
14 Day	0	107	0	46	107	43	69	107	64	78	107	73
49 Day	0	77	0	77	77	100	77	77	100	77	77	100
120 Day	5	5	100	5	5	100	5	5	100	-	-	-

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TABLE

13b

SEV ANALYSIS: MAD RIVER AT BUTLER VALLEY RANCH (MRBVR), 2006-2007

Analysis of Moving Average of Mean Daily SSC

Period of Record WY 2006 and WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	5	250	2	45	250	18	163	250	65	209	250	84
2 Day	19	249	8	92	249	37	209	249	84	231	249	93
6 Day	59	247	24	174	247	70	235	247	95	239	247	97
14 Day	53	239	22	224	239	94	229	239	96	232	239	97
49 Day	127	179	71	179	179	100	179	179	100	179	179	100
120 Day	36	36	100	36	36	100	36	36	100	-	-	-

SEV Thresholds

	SEV 8	SEV 7	SEV 6	SEV 5
Duration (days)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)
1	1808	403	55	20
2	665	148	20	7
6	244	55	7	3
14	244	20	7	3
49	90	7	3	1
120	33	3	1	1

Wet Year WY 2006

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	5	147	3	39	147	27	111	147	76	133	147	90
2 Day	19	146	13	72	146	49	132	146	90	141	146	97
6 Day	53	142	37	114	142	80	141	142	99	142	142	100
14 Day	53	134	40	132	134	99	134	134	100	134	134	100
49 Day	96	99	97	99	99	100	99	99	100	99	99	100
120 Day	28	28	100	28	28	100	28	28	100	-	-	-

Dry Year WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	0	103	0	6	103	6	52	103	50	76	103	74
2 Day	0	103	0	20	103	19	77	103	75	90	103	87
6 Day	6	105	6	60	105	57	94	105	90	97	105	92
14 Day	0	105	0	92	105	88	95	105	90	98	105	93
49 Day	31	80	39	80	80	100	80	80	100	80	80	100
120 Day	8	8	100	8	8	100	8	8	100	-	-	-

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TABLE

13c

SEV ANALYSIS: MAD RIVER AT BUTLER VALLEY RANCH (MRBVR), 2006-2007

Analysis of Moving Average of Maximum Daily SSC

Period of Record WY 2006 and WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	6	250	2	67	250	27	180	250	72	224	250	90
2 Day	47	249	19	115	249	46	220	249	88	240	249	96
6 Day	114	247	46	196	247	79	237	247	96	242	247	98
14 Day	121	239	51	226	239	95	231	239	97	233	239	97
49 Day	179	179	100	179	179	100	179	179	100	179	179	100
120 Day	37	37	100	37	37	100	37	37	100	-		-

SEV Thresholds

	SEV 8	SEV 7	SEV 6	SEV 5
Duration (days)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)
1	1808	403	55	20
2	665	148	20	7
6	244	55	7	3
14	244	20	7	3
49	90	7	3	1
120	33	3	1	1

Wet Year WY 2006

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	6	147	4	53	147	36	116	147	79	138	147	94
2 Day	39	146	27	89	146	61	136	146	93	145	146	99
6 Day	81	142	57	121	142	85	142	142	100	142	142	100
14 Day	82	134	61	133	134	99	134	134	100	134	134	100
49 Day	99	99	100	99	99	100	99	99	100	99	99	100
120 Day	29	29	100	29	29	100	29	29	100	-	-	-

Dry Year WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	0	103	0	14	103	14	64	103	62	86	103	83
2 Day	8	103	8	26	103	25	84	103	82	95	103	92
6 Day	33	105	31	75	105	71	95	105	90	100	105	95
14 Day	39	105	37	93	105	89	97	105	92	99	105	94
49 Day	80	80	100	80	80	100	80	80	100	80	80	100
120 Day	8	8	100	8	8	100	8	8	100	-	-	-

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TABLE
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SEV ANALYSIS: NORTH FORK MAD RIVER AT KORBEL BRIDGE (NFMKB), 2006-2007

Analysis of Moving Average of Mean Daily SSC

Period of Record WY 2006 and WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	0	309	0	3	309	1	48	309	16	122	309	39
2 Day	0	307	0	12	307	4	126	307	41	210	307	68
6 Day	4	299	1	64	299	21	217	299	73	258	299	86
14 Day	0	283	0	170	283	60	220	283	78	261	283	92
49 Day	9	213	4	213	213	100	213	213	100	213	213	100
120 Day	29	70	41	70	70	100	70	70	100	-	-	-

SEV Thresholds

	SEV 8	SEV 7	SEV 6	SEV 5
Duration (days)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)
1	1808	403	55	20
2	665	148	20	7
6	244	55	7	3
14	244	20	7	3
49	90	7	3	1
120	33	3	1	1

Wet Year WY 2006

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	0	171	0	3	171	2	30	171	18	77	171	45
2 Day	0	170	0	7	170	4	79	170	46	118	170	69
6 Day	4	166	2	40	166	24	120	166	72	145	166	87
14 Day	0	158	0	104	158	66	115	158	73	148	158	94
49 Day	9	123	7	118	123	96	123	123	100	123	123	100
120 Day	29	52	56	52	52	100	52	52	100	-	-	-

Dry Year WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	0	138	0	0	138	0	18	138	13	45	138	33
2 Day	0	137	0	5	137	4	47	137	34	92	137	67
6 Day	0	133	0	24	133	18	97	133	73	113	133	85
14 Day	0	125	0	66	125	53	105	125	84	113	125	90
49 Day	0	90	0	90	90	100	90	90	100	90	90	100
120 Day	0	18	0	18	18	100	18	18	100	-	-	-

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TABLE

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SEV ANALYSIS: NORTH FORK MAD RIVER AT KORBEL BRIDGE (NFMKB), 2006-2007

Analysis of Moving Average of Maximum Daily SSC

Period of Record WY 2006 and WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	1	309	0	9	309	3	89	309	29	153	309	50
2 Day	6	307	2	43	307	14	165	307	54	243	307	79
6 Day	21	299	7	107	299	36	250	299	84	284	299	95
14 Day	9	283	3	207	283	73	259	283	92	275	283	97
49 Day	46	213	22	213	213	100	213	213	100	213	213	100
120 Day	71	71	100	71	71	100	71	71	100	-		-

SEV Thresholds

	SEV 8	SEV 7	SEV 6	SEV 5
Duration (days)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)
1	1808	403	55	20
2	665	148	20	7
6	244	55	7	3
14	244	20	7	3
49	90	7	3	1
120	33	3	1	1

Wet Year WY 2006

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	1	171	1	6	171	4	56	171	33	93	171	54
2 Day	5	170	3	28	170	16	97	170	57	145	170	85
6 Day	13	166	8	68	166	41	147	166	89	166	166	100
14 Day	9	158	6	114	158	72	150	158	95	158	158	100
49 Day	44	123	36	123	123	100	123	123	100	123	123	100
120 Day	53	53	100	53	53	100	53	53	100	-	-	-

Dry Year WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	0	138	0	3	138	2	33	138	24	60	138	43
2 Day	1	137	1	15	137	11	68	137	50	98	137	72
6 Day	8	133	6	39	133	29	103	133	77	118	133	89
14 Day	0	125	0	93	125	74	109	125	87	117	125	94
49 Day	2	90	2	90	90	100	90	90	100	90	90	100
120 Day	18	18	100	18	18	100	18	18	100	-	-	-

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MAD RIVER SEDIMENT SOURCE ANALYSIS

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TABLE

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SEV ANALYSIS: MAD RIVER AT HATCHERY ROAD BRIDGE (MRHRB), 2006-2007

Analysis of Moving Average of Mean Daily SSC

Period of Record WY 2006 and WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	4	362	1	54	362	15	209	362	58	274	362	76
2 Day	20	358	6	146	358	41	274	358	77	325	358	91
6 Day	90	352	26	224	352	64	324	352	92	351	352	100
14 Day	67	336	20	290	336	86	321	336	96	336	336	100
49 Day	197	266	74	266	266	100	266	266	100	266	266	100
120 Day	123	123	100	123	123	100	123	123	100	-	-	-

SEV Thresholds

	SEV 8	SEV 7	SEV 6	SEV 5
Duration (days)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)
1	1808	403	55	20
2	665	148	20	7
6	244	55	7	3
14	244	20	7	3
49	90	7	3	1
120	33	3	1	-

Wet Year WY 2006

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	4	194	2	44	194	23	131	194	68	157	194	81
2 Day	19	192	10	100	192	52	157	192	82	171	192	89
6 Day	68	189	36	131	189	69	169	189	89	188	189	99
14 Day	65	181	36	157	181	87	166	181	92	181	181	100
49 Day	113	146	77	146	146	100	146	146	100	146	146	100
120 Day	75	75	100	75	75	100	75	75	100	-	-	-

Dry Year WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	0	168	0	10	168	6	78	168	46	117	168	70
2 Day	1	166	1	46	166	28	117	166	70	154	166	93
6 Day	22	163	13	93	163	57	155	163	95	163	163	100
14 Day	2	155	1	133	155	86	155	155	100	155	155	100
49 Day	84	120	70	120	120	100	120	120	100	120	120	100
120 Day	48	48	100	48	48	100	48	48	100	-	-	-

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SEV ANALYSIS: MAD RIVER AT HATCHERY ROAD BRIDGE (MRHRB), 2006-2007

Analysis of Moving Average of Maximum Daily SSC

Period of Record WY 2006 and WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	6	361	2	76	361	21	233	361	65	309	361	86
2 Day	47	359	13	160	359	45	310	359	86	351	359	98
6 Day	134	350	38	236	350	67	347	350	99	350	350	100
14 Day	151	335	45	305	335	91	335	335	100	335	335	100
49 Day	230	265	87	265	265	100	265	265	100	265	265	100
120 Day	124	124	100	124	124	100	124	124	100	124	124	-

SEV Thresholds

	SEV 8	SEV 7	SEV 6	SEV 5
Duration (days)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)	Absolute Value SSC (mg/l)
1	1808	403	55	20
2	665	148	20	7
6	244	55	7	3
14	244	20	7	3
49	90	7	3	1
120	33	3	1	1

Wet Year WY 2006

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	6	193	3	58	193	30	137	193	71	164	193	85
2 Day	37	192	19	103	192	54	166	192	86	186	192	97
6 Day	92	188	49	135	188	72	185	188	98	188	188	100
14 Day	99	180	55	159	180	88	180	180	100	180	180	100
49 Day	117	145	81	145	145	100	145	145	100	145	145	100
120 Day	74	74	100	74	74	100	74	74	100	-	-	-

Dry Year WY 2007

	SEV 8			SEV 7			SEV 6			SEV 5		
	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold	Count > Threshold	Count Total	Percent > Threshold
1 Day	0	168	0	18	168	11	96	168	57	145	168	86
2 Day	10	167	6	57	167	34	144	167	86	165	167	99
6 Day	42	162	26	101	162	62	162	162	100	162	162	100
14 Day	52	155	34	146	155	94	155	155	100	155	155	100
49 Day	113	120	94	120	120	100	120	120	100	120	120	100
120 Day	49	49	100	49	49	100	49	49	100	-	-	-

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4.0 SEDIMENT SOURCE ANALYSIS RESULTS

4.1 Landslide Source Analysis

4.1.1 Landslide Inventory Field Verification

For the post-1975 time period, GMA mapped and digitized 200 active landslides. Landslides mapped from aerial photos were given a certainty of recognition rating: 33 percent were classified as definite, 56 percent probable, and 11 percent questionable.

Landslide field-verification surveys were performed to: assess whether the features observed were actually slides, evaluate the state of activity (i.e. active vs. inactive or dormant), establish thickness by landslide type (needed to perform volume calculations), validate the size of landslides mapped from aerial photography, and validate the trigger mechanism assigned to each landslide. Of the 200 post-1975 mapped active landslides, 31 landslides, or 15.5 percent were field verified. All of the “definite” and “probable” field inventoried landslides were indeed slides. Each field verified landslide was mapped and dimensions (width, length, and thickness) measured. With the exception of debris torrents, the observed thicknesses fall within the ranges of other recent sediment source analyses on the north coast.

This landslide analysis was conducted at the basin scale and includes 172 active landslides. For site specific landslide investigations, data at a higher mapping resolution would be more appropriate. For example, this analysis did not undertake a detailed landslide inventory at a scale equal to that used to mitigate landslides hazards associated with timber harvest planning (CDC, 1999). Rather, GMA used the methods similar to those of CADWR (1982) and DMG (1999), since the mapping scale and area were similar.

GMA used the USFS Geomorphology layer (USDA Forest Service, 2006) that was readily available and mapped consistently at the Provincial Level. GMA reviewed the Pilot Creek active landslide map (Dresser, 2003) and found that the landslides were mapped at a finer scale and split features more frequently than this method would allow. For example, the Pilot Creek landslide inventory broke out individual gullies within active earthflows, whereas this inventory lumped gullies into the larger earthflows features and used the lateral extent of the feature to digitize the boundaries. In addition, landslides smaller than five acres could not be accurately mapped given the mapping resolution of this landslide inventory. GMA did not have access to most of Pilot Creek during field verification due to ongoing logging operations on USFS lands, so field verification there was limited. However, where GMA did gain access, along the inner gorge of lower Pilot Creek, they found substantial differences between the USFS landslide data and conditions measured on the ground for the following landslide:

- T02NR05ES14C1-06
- T02NR05ES14D-06
- T02NR05ES14B1-06
- T02NR05ES14B2-06
- T02NR05ES14C3-06

GMA found that large earthflows, active within the last 31 years, appear to be reducing the Mad River valley width, pushing stream energy against opposite stream banks and causing inner gorge debris flows (Plate 10a, 10b, and 10c). Downstream of the Bug Creek subwatershed (ID#: 1015), located in the middle Mad River (Plate 1b), landslide sediment input exceeds the transport capacity of the river resulting in a locally aggraded channel. Large pulses of sediment delivery during wet water years (e.g., 1996) have episodically dammed this reach of the Mad River. Most inner gorge debris flows and rock slides occur on steep slopes (i.e., > 65%) and have high sediment delivery potential. In contrast, dormant Quaternary landslides commonly occur on mélange terrain with parallel drainage pattern and relatively low relief.

Within the Pilot Creek subwatershed (ID#: 1009), one of the larger earthflows (i.e., Slide ID = T02NR05ES12C-06) is dissected by several roads, causing a small amount of gully erosion. GMA reviewed this feature since it was predicted to produce a substantial amount of material relative to other landslides within this subwatershed. Further review of the remote sensing data showed that the stability of this feature has not been substantially reduced as a result of the road network. Though this feature has not been field verified, GMA revised the assigned triggering mechanism in the database accordingly changing it from road related to natural. This change greatly reduced the management related sediment contribution from landslides in Pilot Creek. This made a substantial difference between the original and revised sediment budget for this subwatershed, but it did not substantially alter the overall sediment budget. Pilot Creek is not a major sediment producer relative to downstream subwatersheds.

4.1.2 Landslide Inventory Results

The landslide database was sorted first by certainty and all of the questionable slides that were not field verified were eliminated from the analysis. The database was filtered again based on the analysis of sediment delivery, and features mapped as non-delivering were eliminated. Results from field verification show that six of the “questionable” features were not slides, and they were discarded from further analysis. Several new features were mapped during verification and included in the active, delivering database. Determination of sediment delivery status is based on the judgment of the Professional Geologist performing the mapping and takes into account landslide position relative to the adjacent watercourse, slope at terminus of landslide or run-out area, and slope elements.

The filtered landslide inventory layer was intersected in GIS with the lithotopo units, which include: subwatersheds, bedrock geology, and dormant landslides. The landslide lithotopo units were then intersected with the road and timber harvest layers. Summary tables for the subwatersheds were prepared to help interpret the data and perform sediment volume and weight calculations (Table 14, Table 15, and Table 16).

Table 14. List of the number and spatial area of Mad River landslide types.

LS_Type	Landslide Type	Number	Percent of Number	Area (acres)	Percent of Area
DF	debris flow	77	45%	821	10%
DS	debris slide	31	18%	326	4%
EF	earthflow	42	24%	6441	81%
IG	inner gorge	14	8%	187	2%
RF	rock fall	7	4%	62	1%
RS	rock slide	1	1%	97	1%
Grand Total		172	100%	7953	100%

Using the landslide count, almost half of mapped active landslides (45 percent) were debris flows, followed by earthflows at 24 percent and debris slides at 18 percent (Table 14). Relative to the other landslide types, earthflows cover the most planar land area (81 percent) and have delivered most of the sediment to the stream network over the last 31 years (Table 15). Three geology types (all Franciscan types) explain 99 percent of landslides. About 57 percent of the landslides occur in the Franciscan Mélange, and are mainly earthflows (Table 15). The Franciscan Mélange covers about 37 percent of the Mad River watershed, but accounts for 57 percent of the landslides; most of the slides are concentrated in the lower-gradient, moderately dissected lithotopo units (Plate 10b). About 40 percent of the landslides occurred in other Franciscan rock, while 2 percent occur in South Fork Mountain Schist, and only 0.5 percent occurred in the other geologic types (Table 15).

Table 15. Bedrock geology versus active landslide type sorted by spatial area covered.

PTYPE	Geology Type	DF	DS	EF	IG	RF	RS	Grand Total	Percent Total
DG	All intrusive and extrusive			7				7	0.1
FR	Franciscan	419	63	2,480	134	14	97	3,206	40.3
M	Franciscan Melange	376	251	3,812	37	47		4,522	56.9
QA	Quaternary	13	2	0	13			29	0.4
SC	South Fork Mountain Schist		11	176	3			189	2.4
	Grand Total	808	326	6,474	187	62	97	7,953	
	Percent Total	10.2	4.1	81.4	2.3	0.8	1.2		

The landslide data were also sorted by triggering mechanism and related land use (Table 16). The inventory shows that over half of the total number of mapped active landslides were triggered by natural processes. Roads have produced about 33 percent of the slope failures, and timber harvest activities about 8 percent. The percentage attributable to roads and timber harvest is within the range reported in other landslide inventories (e.g., Raines, 1998, Sidle and Ochiai, 2006, and Green Diamond, 2006, Appendix F).

Table 16. Count of landslide type sorted by triggering mechanism as related to land use.

	Natural		**Road**		**Timber Harvest**		**Grand Total**	
Landslide Type	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Debris Flow	49	49%	21	37%	7	50%	77	45%
Debris Slide	15	15%	12	21%	4	29%	31	18%
Earthflow	21	21%	19	33%	2	14%	42	24%
Inner Gorge	8	8%	5	9%	1	7%	14	8%
Rock Fall	7	7%		0%		0%	7	4%
Rock Slide	1	1%		0%		0%	1	1%
Total	101	59%	57	33%	14	8%	172	100%

The frequency and volume of sediment derived from active landslides varies spatially within the Mad River watershed. Unit landslide volumes for the post-1975 period by associated land use (triggering mechanism) are listed by subwatershed in Table 17. The Holm Creek, Showers Creek, Goodman Prairie Creek, Deer Creek, Bug Creek, Morgan Creek, Bear Creek2, Graham Creek, Dry Creek, Tompkins Creek, Olsen Creek, Wilson Creek, Boulder Creek, Bear Creek, Barry Ridge, and Devil Creek subwatersheds (Plates 1a, 1b, and 1c) have the highest sediment delivery per unit drainage area and deliver at least 2,000 tons/mi^2/year (Table 18). The top three, Holm Creek, Showers Creek, and Goodman Prairie Creek deliver over 10,000 tons/mi^2/year. Of those sixteen subwatersheds listed above, all but two are within the middle Mad planning area.

Overall, 39 percent of the total annual landslide sediment delivery is from background sources, comprised of naturally occurring slides and creep from deep seated features, 59 percent from road related landslides, and only 1.7 percent from harvest related landslides. Thus, management related landslides result in 61 percent of the total annual sediment delivery.

MAD RIVER SEDIMENT SOURCE ANALYSIS
UNIT SEDIMENT DELIVERY FROM LANDSLIDES BY TYPE BY SUB-WATERSHED

BASIN_ID	Watershed Name	Drainage Area (mi2)	Background, Creep and Landslides (tons/mi2/yr)	Road Related (tons/mi2/yr)	Timber Harvest Related (tons/mi^2/yr)	Total Management Sediment Delivery (tons/mi2/yr)	Total Landslide Related (tons/mi^2/yr)
1001	Mud River	13.2	50	-	-	-	50
1002	Lost Creek	26.1	122	-	4	4	126
1003	South Fork Mad River	15.9	43	-	-	-	43
1004	Barry Creek	10.2	133	-	-	-	133
1005	Armstrong Creek	9.9	79	230	12	242	321
1006	Deep Hollow Creek	4.1	307	413	-	413	720
1007	Deep Hollow Creek West	4.6	69	-	-	-	69
1008	Bear Creek	8.1	748	2,607	-	2,607	3,355
1009	Pilot Creek	39.7	1,936	-	2	2	1,938
1010	Hastings Creek	11.1	1,057	354	-	354	1,410
1011	Holm Creek	8	4,042	7,136	-	7,136	11,178
1012	Olmstead Creek	11.3	636	1,093	-	1,093	1,729
1013	Showers Creek	2.7	1,362	9,235	-	9,235	10,597
1014	Deer Creek	6.9	3,663	5,813	-	5,813	9,475
1015	Bug Creek	9.7	3,906	5,193	-	5,193	9,100
1016	Morgan Creek	8.7	1,894	6,494	130	6,624	8,517
1017	Wilson Creek	9.4	923	2,818	-	2,818	3,741
1018	Graham Creek	13.1	1,903	3,378	-	3,378	5,280
1019	Goodman Prairie Creek	10	1,726	8,297	-	8,297	10,024
1020	Boulder Creek	19	2,140	1,345	142	1,487	3,627
1021	Barry Ridge	9.1	1,278	1,771	-	1,771	3,049
1022	Maple Creek	15.6	122	-	-	-	122
1023	Blue Slide Creek	6.1	260	3	-	3	262
1024	Devil Creek	19	189	1,759	149	1,908	2,097
1025	Cannon Creek	16.4	281	-	-	-	281
1026	Dry Creek	7	246	4,076	500	4,576	4,823
1027	North Fork Mad River	48.8	311	62	0	62	373
1028	Powers Creek	20.8	397	-	147	147	544
1029	Lindsay Creek	17.7	177	-	-	-	177
1030	Deer Creek2	7.1	183	68	-	68	251
1031	Showers Creek2	5.2	344	-	-	-	344
1032	Bear Creek2	4.1	97	7,964	-	7,964	8,061
1033	Tompkins Creek West	4.9	159	-	-	-	159
1034	Tompkins Creek	8.9	851	3,175	-	3,175	4,026
1035	Hetten Creek West	11.9	211	-	-	-	211
1036	Hetten Creek	10.7	644	-	-	-	644
1037	Olsen Creek West	9.1	917	-	-	-	917
1038	Olsen Creek	12.8	1,111	2,407	362	2,769	3,879
1039	Hastings Creek West	3.2	1,266	-	-	-	1,266

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TABLE

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MAD RIVER SEDIMENT SOURCE ANALYSIS

UNIT SEDIMENT DELIVERY FROM LANDSLIDES BY TYPE BY SUB-WATERSHED RANKED BY TOTAL

BASIN_ID	Watershed Name	Drainage Area (mi2)	Background, Creep and Landslides (tons/mi2/yr)	Road Related (tons/mi2/yr)	Timber Harvest Related (tons/mi^2/yr)	Total Management Sediment Delivery (tons/mi2/yr)	Total Landslide Related (tons/mi^2/yr)
1011	Holm Creek	8.0	4,042	7,136	-	7,136	11,178
1013	Showers Creek	2.7	1,362	9,235	-	9,235	10,597
1019	Goodman Prairie Creek	10.0	1,726	8,297	-	8,297	10,024
1014	Deer Creek	6.9	3,663	5,813	-	5,813	9,475
1015	Bug Creek	9.7	3,906	5,193	-	5,193	9,100
1016	Morgan Creek	8.7	1,894	6,494	130	6,624	8,517
1032	Bear Creek2	4.1	97	7,964	-	7,964	8,061
1018	Graham Creek	13.1	1,903	3,378	-	3,378	5,280
1026	Dry Creek	7.0	246	4,076	500	4,576	4,823
1034	Tompkins Creek	8.9	851	3,175	-	3,175	4,026
1038	Olsen Creek	12.8	1,111	2,407	362	2,769	3,879
1017	Wilson Creek	9.4	923	2,818	-	2,818	3,741
1020	Boulder Creek	19.0	2,140	1,345	142	1,487	3,627
1008	Bear Creek	8.1	748	2,607	-	2,607	3,355
1021	Barry Ridge	9.1	1,278	1,771	-	1,771	3,049
1024	Devil Creek	19.0	189	1,759	149	1,908	2,097
1009	Pilot Creek	39.7	1,936	-	2	2	1,938
1012	Olmstead Creek	11.3	636	1,093	-	1,093	1,729
1010	Hastings Creek	11.1	1,057	354	-	354	1,410
1039	Hastings Creek West	3.2	1,266	-	-	-	1,266
1037	Olsen Creek West	9.1	917	-	-	-	917
1006	Deep Hollow Creek	4.1	307	413	-	413	720
1036	Hetten Creek	10.7	644	-	-	-	644
1028	Powers Creek	20.8	397	-	147	147	544
1027	North Fork Mad River	48.8	311	62	0	62	373
1031	Showers Creek2	5.2	344	-	-	-	344
1005	Armstrong Creek	9.9	79	230	12	242	321
1025	Cannon Creek	16.4	281	-	-	-	281
1023	Blue Slide Creek	6.1	260	3	-	3	262
1030	Deer Creek2	7.1	183	68	-	68	251
1035	Hetten Creek West	11.9	211	-	-	-	211
1029	Lindsay Creek	17.7	177	-	-	-	177
1033	Tompkins Creek West	4.9	159	-	-	-	159
1004	Barry Creek	10.2	133	-	-	-	133
1002	Lost Creek	26.1	122	-	4	4	126
1022	Maple Creek	15.6	122	-	-	-	122
1007	Deep Hollow Creek West	4.6	69	-	-	-	69
1001	Mud River	13.2	50	-	-	-	50
1003	South Fork Mad River	15.9	43	-	-	-	43

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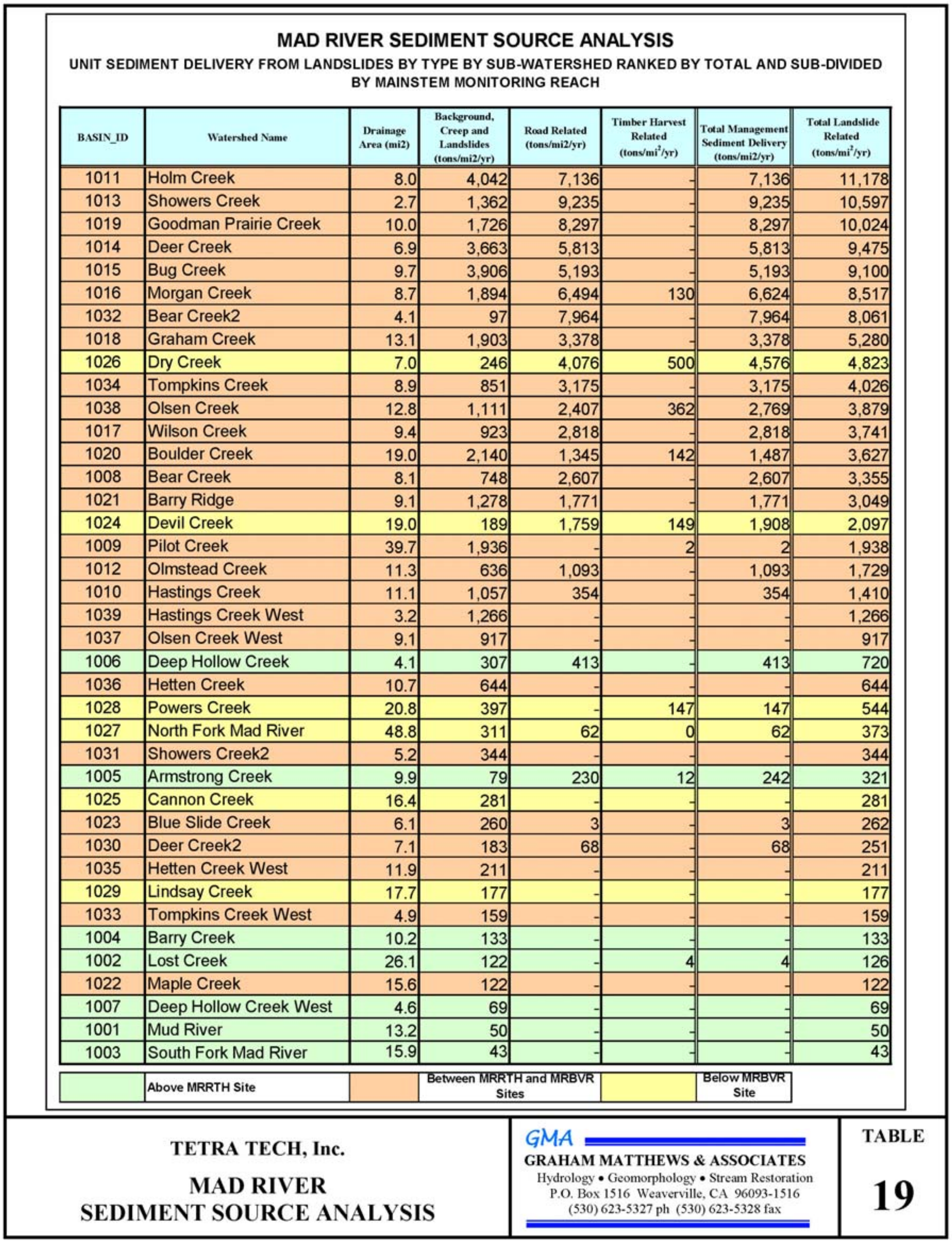
Table 19 highlights the distribution of subwatersheds ranked by unit landslide volume relative to the mainstem Mad River monitoring sites. Green highlights are located upstream from the MRRTH site, orange are located between the MRRTH and MRBVR sites, while yellow are located downstream of MRBVR. It is readily apparent that virtually all of the larger producers of landslide related sediment come from the central portion of the watershed.



MAD RIVER SEDIMENT SOURCE ANALYSIS

UNIT SEDIMENT DELIVERY FROM LANDSLIDES BY TYPE BY SUB-WATERSHED RANKED BY TOTAL AND SUB-DIVIDED BY MAINSTEM MONITORING REACH

BASIN_ID	Watershed Name	Drainage Area (mi2)	Background, Creep and Landslides (tons/mi2/yr)	Road Related (tons/mi2/yr)	Timber Harvest Related (tons/mi^2/yr)	Total Management Sediment Delivery (tons/mi2/yr)	Total Landslide Related (tons/mi^2/yr)
1011	Holm Creek	8.0	4,042	7,136	-	7,136	11,178
1013	Showers Creek	2.7	1,362	9,235	-	9,235	10,597
1019	Goodman Prairie Creek	10.0	1,726	8,297	-	8,297	10,024
1014	Deer Creek	6.9	3,663	5,813	-	5,813	9,475
1015	Bug Creek	9.7	3,906	5,193	-	5,193	9,100
1016	Morgan Creek	8.7	1,894	6,494	130	6,624	8,517
1032	Bear Creek2	4.1	97	7,964	-	7,964	8,061
1018	Graham Creek	13.1	1,903	3,378	-	3,378	5,280
1026	Dry Creek	7.0	246	4,076	500	4,576	4,823
1034	Tompkins Creek	8.9	851	3,175	-	3,175	4,026
1038	Olsen Creek	12.8	1,111	2,407	362	2,769	3,879
1017	Wilson Creek	9.4	923	2,818	-	2,818	3,741
1020	Boulder Creek	19.0	2,140	1,345	142	1,487	3,627
1008	Bear Creek	8.1	748	2,607	-	2,607	3,355
1021	Barry Ridge	9.1	1,278	1,771	-	1,771	3,049
1024	Devil Creek	19.0	189	1,759	149	1,908	2,097
1009	Pilot Creek	39.7	1,936	-	2	2	1,938
1012	Olmstead Creek	11.3	636	1,093	-	1,093	1,729
1010	Hastings Creek	11.1	1,057	354	-	354	1,410
1039	Hastings Creek West	3.2	1,266	-	-	-	1,266
1037	Olsen Creek West	9.1	917	-	-	-	917
1006	Deep Hollow Creek	4.1	307	413	-	413	720
1036	Hetten Creek	10.7	644	-	-	-	644
1028	Powers Creek	20.8	397	-	147	147	544
1027	North Fork Mad River	48.8	311	62	0	62	373
1031	Showers Creek2	5.2	344	-	-	-	344
1005	Armstrong Creek	9.9	79	230	12	242	321
1025	Cannon Creek	16.4	281	-	-	-	281
1023	Blue Slide Creek	6.1	260	3	-	3	262
1030	Deer Creek2	7.1	183	68	-	68	251
1035	Hetten Creek West	11.9	211	-	-	-	211
1029	Lindsay Creek	17.7	177	-	-	-	177
1033	Tompkins Creek West	4.9	159	-	-	-	159
1004	Barry Creek	10.2	133	-	-	-	133
1002	Lost Creek	26.1	122	-	4	4	126
1022	Maple Creek	15.6	122	-	-	-	122
1007	Deep Hollow Creek West	4.6	69	-	-	-	69
1001	Mud River	13.2	50	-	-	-	50
1003	South Fork Mad River	15.9	43	-	-	-	43

🟩	Above MRRTH Site	🟧	Between MRRTH and MRBVR Sites	🟨	Below MRBVR Site

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4.1.3 Confidence in Analysis

Given the mapping scale and available data, the confidence in this analysis is considered medium to high, since at least 15% of the mapped active landslides were field verified. There are, however, several sources of uncertainty in the landslide inventory. The active landslides were mapped from aerial photos at different scales. There was no one consistent set of aerial photographs for the entire Mad River watershed except for the 2005 NAIP Digital Orthophotographs. For areas without complete aerial photograph coverage, this analysis relied on remote sensing data and DEM generated hillslope relief maps. Landslide inventory field verification improved the reliability of the landslide data as described above.

Comparison to mass wasting rates developed in other north coast California watersheds with similar geology suggests that the results of this analysis are reasonable (Sidle and Ochiai, 2006). Recent work within the adjacent South Fork Trinity River, the Van Duzen River, and Redwood Creek watersheds provides the best basis for comparison. Raines (1998) estimated rates of mass wasting for the South Fork Trinity River watershed at between 21 and 1,985 tons/mi^2/year for four planning watersheds for a 47-year period between 1944 and 1990. In Grouse Creek, Raines and Kelsey (1991) estimated rates at 4,330 tons/mi^2/year for budget period of 1960-1989. PWA (1999) estimated average sediment rates from all sources of 2,690 tons/mi^2/year for the Van Duzen River. CRWQCB estimated mass wasting in Redwood Creek at 2,050 tons/mi^2/year for the period 1954-1997. The average rate for this analysis is about 2,895 tons/mi^2/year, with a maximum of 11,178 tons/mi^2/year. The maximum value is above the reported averages, however, it is similar to those reported in Redwood Creek to the north (Sidle and Ochiai, 2006).

4.2 Surface and Fluvial Erosion Analysis

The surface and fluvial erosion analysis included a screening level erosion source inventory that focused on roads and a modeling exercise intended to predict the relative amount of sediment coming from background sources (i.e., fluvial bank erosion), roads, and timber harvest areas.

4.2.1 Surface and Fluvial Erosion Inventory Results

GMA completed an inventory of fluvial bank erosion on four reaches of the mainstem and several headwater tributaries. The measured rate of fluvial bank erosion varied by watershed area, with the highest rates occurring along stream channels within mélange terrain. These results are incorporated into the traditional sediment budget presented in a section 4.4.

GMA also completed a rapid reconnaissance of the road system, driving about 300 miles of the road network within the Mad River watershed. There are about 2,187 miles of mapped roads within the Mad River watershed, therefore about 14% of the road system was inventoried. The inventory results show that the roads layer used in the analysis is accurate for the main road system on both public and private lands. Data for low level roads associated with timber harvest activities were found to be less accurate or missing.

For example, several of the spur roads shown on the map were not recognizable in the field and were removed from the GIS database. Roads not included in the GIS database were found along the powerline corridors and areas that were recently harvested. To the extent possible, the missing roads were added to the database; however, it is likely that there are quite a few more roads that are not included in the analysis. The distribution of road types by subwatershed is shown in Table 20. Road densities vary from 0.8 to 8.4 miles/mi^2, and average 4.2 miles/mi^2 for the entire watershed. 74% of the roads are native, 20% are rocked, and 6% are paved.

Road surface type listed in the GIS database was found to be a reliable indicator of road width and was used as a surrogate for road width in the WEPP model. The road condition was found to be a function of the bedrock geology and traffic level. Heavily traveled native surface roads that dissect the Franciscan mélange tended to have the most erosion and drainage problems and commonly caused gully erosion. Gully erosion was especially present were roads drained into active earthflows within the lower Mad River. As a result, roads that dissect mélange terrain were assigned a higher erosion rate within the WEPP model. Within the upper Mad River above Ruth Lake, the road system was found to be very stable and very few erosion problems were measured.

GMA also measured road erosion directly during storm runoff in December 2005. Results of this sampling show that the measured load from cutbank and ditch erosion ranged from 361 to 6,925 tons/mi^2/year (3 samples). These results were used to help verify erosion rates used in the road erosion model. The highest erosion rates were measured on a road that had been recently used or maintained (Photograph 1 and 2).

Photograph 1. Lower Mad Road (insloped and paved) looking east during December 2005 flood event. Surface erosion from road cutslope actively eroding and delivering sediment to a cross-drain and the Mad River. Measured unit sediment load ranged from 361 to 6,925 tons/mi^2/year.

Photograph 2. Lower Mad Road (insloped and paved) looking east during December 2005 flood event. Surface runoff from road causing gully erosion on road fill and directly delivering sediment to the Mad River. Note silt fence completely inundated in background.

SUMMARY OF ROAD LENGTHS BY SURFACE TYPE BY SUB-BASIN

Sub-Basin Name	Basin ID	Drainage Area (mi²)	Miles of Roads by Surface Type			Total Road Miles	Road Density (mi/mi2)	% of Sub-Basin Total			% Basin Total
			Native	Rocked	Paved			Native	Rocked	Paved	
Mud River	1001	13.2	33.12	1.07	0.72	34.91	2.64	94.9%	3.1%	2.1%	1.74%
Lost Creek	1002	26.1	29.38	53.68	8.67	91.73	3.51	32.0%	58.5%	9.5%	4.58%
South Fork Mad River	1003	15.9	23.61	17.28	4.85	45.75	2.87	51.6%	37.8%	10.6%	2.28%
Barry Creek	1004	10.2	12.16	11.03	8.13	31.32	3.08	38.8%	35.2%	26.0%	1.56%
Armstrong Creek	1005	9.9	12.10	20.80	4.11	37.02	3.73	32.7%	56.2%	11.1%	1.85%
Deep Hollow Creek	1006	4.1	8.56	0.05	1.57	10.18	2.50	84.1%	0.5%	15.4%	0.51%
Deep Hollow Creek West	1007	4.6	10.27	9.93	0.00	20.20	4.35	50.8%	49.2%	0.0%	1.01%
Bear Creek	1008	8.1	30.02	0.79	0.00	30.81	3.78	97.5%	2.5%	0.0%	1.54%
Pilot Creek	1009	39.7	80.13	17.31	6.04	103.48	2.60	77.4%	16.7%	5.8%	5.17%
Hastings Creek	1010	11.1	27.12	7.86	5.56	40.54	3.65	66.9%	19.4%	13.7%	2.02%
Holm Creek	1011	8.0	12.41	0.00	0.00	12.41	1.55	100.0%	0.0%	0.0%	0.62%
Olmstead Creek	1012	11.3	40.35	0.00	0.13	40.48	3.57	99.7%	0.0%	0.3%	2.02%
Showers Creek	1013	2.7	11.04	0.00	0.00	11.04	4.15	100.0%	0.0%	0.0%	0.55%
Deer Creek	1014	6.9	19.98	0.00	0.00	19.98	2.90	100.0%	0.0%	0.0%	1.00%
Bug Creek	1015	9.7	7.47	0.34	0.00	7.82	0.81	95.6%	4.4%	0.0%	0.39%
Morgan Creek	1016	8.7	32.42	0.00	0.00	32.42	3.74	100.0%	0.0%	0.0%	1.62%
Wilson Creek	1017	9.4	26.56	0.21	0.00	26.78	2.86	99.2%	0.8%	0.0%	1.34%
Graham Creek	1018	13.1	37.70	0.00	0.00	37.70	2.88	100.0%	0.0%	0.0%	1.88%
Goodman Prairie Creek	1019	10.0	28.96	0.27	0.00	29.23	2.91	99.1%	0.9%	0.0%	1.46%
Boulder Creek	1020	19.0	53.65	1.54	0.48	55.67	2.93	96.4%	2.8%	0.9%	2.78%
Barry Ridge	1021	9.1	25.15	0.00	0.00	25.15	2.76	100.0%	0.0%	0.0%	1.26%
Maple Creek	1022	15.6	69.22	1.85	1.40	72.47	4.63	95.5%	2.5%	1.9%	3.62%
Blue Slide Creek	1023	6.1	11.88	4.72	0.00	16.60	2.74	71.6%	28.4%	0.0%	0.83%
Devil Creek	1024	19.0	88.70	29.23	4.39	122.32	6.45	72.5%	23.9%	3.6%	6.11%
Cannon Creek	1025	16.4	103.42	6.14	5.03	114.59	7.00	90.3%	5.4%	4.4%	5.72%
Dry Creek	1026	7.0	32.54	26.01	0.45	58.99	8.38	55.2%	44.1%	0.8%	2.95%
North Fork Mad River	1027	48.8	271.13	68.77	19.07	358.97	7.35	75.5%	19.2%	5.3%	17.93%
Powers Creek	1028	20.8	92.08	33.62	6.78	132.48	6.37	69.5%	25.4%	5.1%	6.62%
Lindsay Creek	1029	17.7	96.44	31.82	4.83	133.09	7.52	72.5%	23.9%	3.6%	6.65%
Deer Creek2	1030	7.1	22.68	0.00	1.63	24.31	3.41	93.3%	0.0%	6.7%	1.21%
Showers Creek2	1031	5.2	23.03	0.00	0.00	23.03	4.41	100.0%	0.0%	0.0%	1.15%
Bear Creek2	1032	4.1	13.39	0.00	0.00	13.39	3.25	100.0%	0.0%	0.0%	0.67%
Tompkins Creek West	1033	4.9	6.39	10.23	1.57	18.19	3.74	35.1%	56.2%	8.6%	0.91%
Tompkins Creek	1034	8.9	11.43	5.92	3.85	21.20	2.37	53.9%	27.9%	18.1%	1.06%
Hetten Creek West	1035	11.9	26.42	8.97	3.91	39.30	3.29	67.2%	22.8%	9.9%	1.96%
Hetten Creek	1036	10.7	18.33	2.62	9.37	30.31	2.84	60.5%	8.6%	30.9%	1.51%
Olsen Creek West	1037	9.1	8.23	4.03	0.97	13.24	1.46	62.2%	30.5%	7.3%	0.66%
Olsen Creek	1038	12.8	22.35	14.87	16.04	53.25	4.15	42.0%	27.9%	30.1%	2.66%
Hastings Creek West	1039	3.2	6.27	5.10	0.88	12.25	3.78	51.2%	41.6%	7.2%	0.61%
	Grand Total	480.1	1486.1	396.1	120.4	2002.6	4.17	74.2%	19.8%	6.0%	100.00%

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TABLE

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4.2.2 Surface and Fluvial Erosion Model Results

No management sources of bank erosion were included in this analysis. The location of channel heads, generated using NetMap, represent the point where runoff concentration initiates gully erosion. The stream density calculated from this layer is high (i.e., > 5 mi/mi^2) when compared to the stream density calculated using the blue line stream layer (i.e., <3.5 mi/mi^2). The NetMap stream layer shows that mélange and South Fork Mountain Schist have lower stream density than the Franciscan complex. Steep and convergent slopes have higher stream density. Results from the fluvial bank erosion calculations are included in the background portion of the traditional sediment budget described below.

Results from the road erosion modeling (i.e., WEPP and Washington State Surface Erosion module) show that most of the surface and fluvial erosion occurs on native surface roads that dissect the Franciscan mélange (Table 21). About 75 percent of the mapped road system has a native surface type, and about 50 percent of the native surface roads dissect mélange terrain. The frequency of native surface roads on mélange results in the relatively higher sediment delivery predictions. Roads on the South Fork Mountain Schist also have higher average erosion rates by surface type, but the miles of road that dissect this geology type are less than 3% of the total road system resulting in relatively lower total sediment delivery (Table 21).

Table 21. Average erosion rates and total sediment delivery by lumped geology type and road surface type.

P Type		Native	Paved	Rocked	Grand Total
DG	Average Road Erosion Rate (tons/acre/year)	0	0	0	0
	Total Sediment Delivery (tons/yr)	2	1	0	3
FR	Average Road Erosion Rate (tons/acre/year)	2	3	1	1
	Total Sediment Delivery (tons/yr)	3897	939	956	5792
M	Average Road Erosion Rate (tons/acre/year)	22	27	15	21
	Total Sediment Delivery (tons/yr)	87989	6589	12403	106981
QA	Average Road Erosion Rate (tons/acre/year)	0	0	0	0
	Total Sediment Delivery (tons/yr)	214	81	59	354
SC	Average Road Erosion Rate (tons/acre/year)	13	15	9	12
	Total Sediment Delivery (tons/yr)	1745	681	865	3291
	Average Road Erosion Rate (tons/acre/year)	12	8	6	10
	Total Sediment Delivery (tons/yr)	93846	8291	14284	116421

The initial WEPP model results appeared high relative to measured values. Due to the lack of data on road design and condition, the road system was broken into similar types as described above. Generalizing the entire road system into a limited number of categories limits the accuracy of model results and initially produced very high erosion rates. To define the range of sediment delivery potential, the WEPP model was run for different road condition scenarios (e.g., high versus low traffic, steep versus gentle slope, etc.). The average erosion rate was reduced about 30% by changing the traffic level from high to low and reducing the road slope categories by 50%. Changing the roads from inboard ditch without vegetation to inboard vegetated ditch had the greatest effect on model results. The erosion rates were reduced by at least 50%. Regardless of changes in the model assumptions, erosion from roads on mélange remained high (200 tons/acre/year). For these road types, measured road sediment delivery and erosion rate values reported in the Washington State Surface Erosion module were used instead of the WEPP results, which did not seem reasonable.

Table 21a provides the model results by subwatershed for both average annual road sediment delivery (tons/year) and unit delivery (tons/mi^2/year)

Surface and fluvial erosion from areas harvested for timber is low (Table 21b) relative to background and road erosion sources and accounts for a small fraction of the total sediment delivery. Like other portions of the sediment budget, these results should be viewed as relative indicators of erosion. These results are combined with the other portions of the sediment budget and are discussed below.

4.2.3 Confidence in Analysis

The confidence in this analysis is medium and the accuracy is +/- 150%. There are several sources of uncertainty in the input data to the surface and fluvial erosion model. Due to the large watershed area, the 2,000 plus miles of road, and the lack of various types of road data, the physical shape and condition of the road system had to be generalized. Site specific road condition inventories and analysis by subwatershed would greatly improve the accuracy of model results and provide land managers a clearer picture of sediment sources associated with roads and timber harvest. For this analysis, however, the model precision is high and all calculations are repeatable.

SEDIMENT DELIVERY FROM ROADS BY SUB-BASIN

Basin ID	Watershed Name	Drainage Area (mi^2)	Road Sediment Delivery (tons/yr)	Road Sediment Delivery (tons/mi^2/yr)
1001	Mud River	13.2	242	18
1002	Lost Creek	26.1	685	26
1003	South Fork Mad River	15.9	296	19
1004	Barry Creek	10.2	450	44
1005	Armstrong Creek	9.9	916	92
1006	Deep Hollow Creek	4.1	74	18
1007	Deep Hollow Creek West	4.6	635	137
1008	Bear Creek	8.1	2,583	317
1009	Pilot Creek	39.7	2,960	74
1010	Hastings Creek	11.1	1,177	106
1011	Holm Creek	8.0	331	41
1012	Olmstead Creek	11.3	2,842	250
1013	Showers Creek	2.7	660	248
1014	Deer Creek	6.9	1,304	190
1015	Bug Creek	9.7	705	73
1016	Morgan Creek	8.7	2,886	333
1017	Wilson Creek	9.4	2,196	235
1018	Graham Creek	13.1	3,647	278
1019	Goodman Prairie Creek	10.0	2,673	266
1020	Boulder Creek	19.0	4,009	211
1021	Barry Ridge	9.1	2,422	266
1022	Maple Creek	15.6	5,449	348
1023	Blue Slide Creek	6.1	949	157
1024	Devil Creek	19.0	6,194	327
1025	Cannon Creek	16.4	11,191	683
1026	Dry Creek	7.0	2,225	316
1027	North Fork Mad River	48.8	31,859	653
1028	Powers Creek	20.8	7,452	358
1029	Lindsay Creek	17.7	7,784	440
1030	Deer Creek2	7.1	222	31
1031	Showers Creek2	5.2	2,024	387
1032	Bear Creek2	4.1	1,469	357
1033	Tompkins Creek West	4.9	1,042	214
1034	Tompkins Creek	8.9	234	26
1035	Hetten Creek West	11.9	1,863	156
1036	Hetten Creek	10.7	1,180	111
1037	Olsen Creek West	9.1	366	40
1038	Olsen Creek	12.8	1,133	88
1039	Hastings Creek West	3.2	90	28
	Total:	480.1	116,421	242

SEDIMENT DELIVERY FROM ROADS RANKED BY SUB-BASIN

Basin ID	Watershed Name	Drainage Area (mi^2)	Road Sediment Delivery (tons/yr)	Road Sediment Delivery (tons/mi^2/yr)
1025	Cannon Creek	16.4	11,191	683
1027	North Fork Mad River	48.8	31,859	653
1029	Lindsay Creek	17.7	7,784	440
1031	Showers Creek2	5.2	2,024	387
1028	Powers Creek	20.8	7,452	358
1032	Bear Creek2	4.1	1,469	357
1022	Maple Creek	15.6	5,449	348
1016	Morgan Creek	8.7	2,886	333
1024	Devil Creek	19.0	6,194	327
1008	Bear Creek	8.1	2,583	317
1026	Dry Creek	7.0	2,225	316
1018	Graham Creek	13.1	3,647	278
1019	Goodman Prairie Creek	10.0	2,673	266
1021	Barry Ridge	9.1	2,422	266
1012	Olmstead Creek	11.3	2,842	250
1013	Showers Creek	2.7	660	248
1017	Wilson Creek	9.4	2,196	235
1033	Tompkins Creek West	4.9	1,042	214
1020	Boulder Creek	19.0	4,009	211
1014	Deer Creek	6.9	1,304	190
1023	Blue Slide Creek	6.1	949	157
1035	Hetten Creek West	11.9	1,863	156
1007	Deep Hollow Creek West	4.6	635	137
1036	Hetten Creek	10.7	1,180	111
1010	Hastings Creek	11.1	1,177	106
1005	Armstrong Creek	9.9	916	92
1038	Olsen Creek	12.8	1,133	88
1009	Pilot Creek	39.7	2,960	74
1015	Bug Creek	9.7	705	73
1004	Barry Creek	10.2	450	44
1011	Holm Creek	8.0	331	41
1037	Olsen Creek West	9.1	366	40
1030	Deer Creek2	7.1	222	31
1039	Hastings Creek West	3.2	90	28
1034	Tompkins Creek	8.9	234	26
1002	Lost Creek	26.1	685	26
1003	South Fork Mad River	15.9	296	19
1001	Mud River	13.2	242	18
1006	Deep Hollow Creek	4.1	74	18
	Total:	480.1	116,421	242

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TABLE

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SEDIMENT DELIVERY FROM HARVEST BY SUB-BASIN

Basin ID	Watershed Name	Drainage Area (mi²)	Harvest Sediment Delivery (tons/yr)	Harvest Sediment Delivery (tons/mi²/yr)
1001	Mud River	13.2	6.5	0.5
1002	Lost Creek	26.1	17.9	0.7
1003	South Fork Mad River	15.9	8.1	0.5
1004	Barry Creek	10.2	10.4	1.0
1005	Armstrong Creek	9.9	11.9	1.2
1006	Deep Hollow Creek	4.1	1.7	0.4
1007	Deep Hollow Creek West	4.6	6.3	1.4
1008	Bear Creek	8.1	19.1	2.3
1009	Pilot Creek	39.7	41.1	1.0
1010	Hastings Creek	11.1	5.6	0.5
1011	Holm Creek	8.0	3.3	0.4
1012	Olmstead Creek	11.3	42.3	3.7
1013	Showers Creek	2.7	8.0	3.0
1014	Deer Creek	6.9	30.7	4.5
1015	Bug Creek	9.7	5.3	0.5
1016	Morgan Creek	8.7	4.1	0.5
1017	Wilson Creek	9.4	7.2	0.8
1018	Graham Creek	13.1	34.9	2.7
1019	Goodman Prairie Creek	10.0	4.9	0.5
1020	Boulder Creek	19.0	6.6	0.3
1021	Barry Ridge	9.1	47.7	5.2
1022	Maple Creek	15.6	41.8	2.7
1023	Blue Slide Creek	6.1	6.4	1.1
1024	Devil Creek	19.0	81.3	4.3
1025	Cannon Creek	16.4	82.4	5.0
1026	Dry Creek	7.0	32.6	4.6
1027	North Fork Mad River	48.8	159.8	3.3
1028	Powers Creek	20.8	120.5	5.8
1029	Lindsay Creek	17.7	152.3	8.6
1030	Deer Creek2	7.1	3.5	0.5
1031	Showers Creek2	5.2	47.7	9.1
1032	Bear Creek2	4.1	19.7	4.8
1033	Tompkins Creek West	4.9	5.8	1.2
1034	Tompkins Creek	8.9	3.0	0.3
1035	Hetten Creek West	11.9	8.4	0.7
1036	Hetten Creek	10.7	3.1	0.3
1037	Olsen Creek West	9.1	2.9	0.3
1038	Olsen Creek	12.8	17.2	1.3
1039	Hastings Creek West	3.2	1.6	0.5
	Total or Average:	480.1	1,114	2.3

SEDIMENT DELIVERY FROM HARVEST RANKED BY SUB-BASIN

Basin ID	Watershed Name	Drainage Area (mi²)	Harvest Sediment Delivery (tons/yr)	Harvest Sediment Delivery (tons/mi²/yr)
1031	Showers Creek2	5.2	47.7	9.1
1029	Lindsay Creek	17.7	152.3	8.6
1028	Powers Creek	20.8	120.5	5.8
1021	Barry Ridge	9.1	47.7	5.2
1025	Cannon Creek	16.4	82.4	5.0
1032	Bear Creek2	4.1	19.7	4.8
1026	Dry Creek	7.0	32.6	4.6
1014	Deer Creek	6.9	30.7	4.5
1024	Devil Creek	19.0	81.3	4.3
1012	Olmstead Creek	11.3	42.3	3.7
1027	North Fork Mad River	48.8	159.8	3.3
1013	Showers Creek	2.7	8.0	3.0
1022	Maple Creek	15.6	41.8	2.7
1018	Graham Creek	13.1	34.9	2.7
1008	Bear Creek	8.1	19.1	2.3
1007	Deep Hollow Creek West	4.6	6.3	1.4
1038	Olsen Creek	12.8	17.2	1.3
1005	Armstrong Creek	9.9	11.9	1.2
1033	Tompkins Creek West	4.9	5.8	1.2
1023	Blue Slide Creek	6.1	6.4	1.1
1009	Pilot Creek	39.7	41.1	1.0
1004	Barry Creek	10.2	10.4	1.0
1017	Wilson Creek	9.4	7.2	0.8
1035	Hetten Creek West	11.9	8.4	0.7
1002	Lost Creek	26.1	17.9	0.7
1015	Bug Creek	9.7	5.3	0.5
1003	South Fork Mad River	15.9	8.1	0.5
1010	Hastings Creek	11.1	5.6	0.5
1039	Hastings Creek West	3.2	2	0.5
1001	Mud River	13.2	6.5	0.5
1019	Goodman Prairie Creek	10.0	4.9	0.5
1030	Deer Creek2	7.1	3.5	0.5
1016	Morgan Creek	8.7	4.1	0.5
1006	Deep Hollow Creek	4.1	1.7	0.4
1011	Holm Creek	8.0	3.3	0.4
1020	Boulder Creek	19.0	6.6	0.3
1034	Tompkins Creek	8.9	3.0	0.3
1037	Olsen Creek West	9.1	2.9	0.3
1036	Hetten Creek	10.7	3.1	0.3
	Total or Average:	480.1	1,114	2.3

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4.3 NetMap Sediment Budget

In the original sediment source analysis (September 2007), the NetMap model was used to develop an element of the traditional sediment budget (bank erosion) as well as its own sediment budget for background and existing unit sediment load for both the Q_2 flood event (i.e., chronic delivery) and the Q_{25} flood event (i.e., episodic delivery). In the revised sediment source analysis (December 2007), the NetMap model was now used for several components of the traditional sediment budget (background creep and bank erosion), but its own sediment budget was limited to an average annual frequency event generally representative of the range of events that would occur over the 31-year sediment budget period, incorporating both chronic and episodic elements. This also allowed the NetMap sediment budget to be "calibrated" to the average measured sediment loads for the 2006-2007 period developed as part of this study (Chapter 3).

4.3.1 Sediment Budget Results

The NetMap model was rerun for the Mad River using the revised surface and fluvial erosion and landslide sediment delivery rates, and the GEP was not used for landslide prone terrain. Also, the model output was summarized differently to help quantify the relative types, importance, and sources of erosion potential. The sediment load by lithotopo unit was distributed to the upland sources creating a polygon layer of erosion sources and potential. The final sediment source map displays the sediment load by lithotopo unit and disturbance type (i.e., background versus management).

The average measured unit sediment loads, by monitoring site, agree reasonably well with the NetMap model results (Table 22). The percent difference between the modeled and measured sediment load increases as the drainage area decreases (Figure 44). For subwatersheds that drain more than 50 mi^2, the modeled results are +/- 20% of the measured sediment load. For smaller subwatersheds, the error is as much as 125% which likely results from the landslide mapping scale and use of average sediment delivery rates. Most of the difference is from averaging sediment delivery rates by lithotopo unit over the basin. There are 169 different lithotopo unit types within the Mad River, and there are 24,482 discrete unit polygons within the basin. Averaging over this scale will result in more error (Table 22). This model should be field verified and refined as needed at larger scales (subwatersheds draining <50 mi^2). For example, model results indicate that the North Fork Mad River has a substantial amount of surface and fluvial erosion from roads (Table 22a); however, the measured sediment load for the study period is substantially less than the modeled load.

The revised sediment load estimates generated using NetMap indicate that the average background and existing unit sediment load of the Mad River near Arcata are 798 and 2,900 tons/mi^2/year, respectively. The total average annual sediment load predicted using NetMap is 1,336,795 tons/year. For comparison, the average measured sediment load at the basin outlet is 1,152,000 tons/year which is a -16% difference. About 26% of this load is attributable to background erosion sources, 55% from roads, and 19% from timber harvest. The background portion of the load varies by sub area (Table 22a).

The predicted background unit sediment load increases gradually downstream, whereas existing unit sediment load increases sharply due to management contributions (Figure 44a). For background and existing conditions, the slope of the longitudinal profile increases 60 miles upstream from the basin outlet (Figure 44a and Plate 1b). The unit sediment load increase occurs where Franciscan mélange becomes the dominant bedrock type (Plate 6b) and active landslides become more frequent (Plate 10b and Photograph 3). Relative to background, the existing sediment load increases abruptly at this location, showing substantially greater sediment inputs within this area of the watershed (Figure 44a).

Table 22a lists the landslide, surface, and fluvial erosion from background, road, and timber harvest sediment load by GMA monitoring site and sub area. Upstream of Highway 36, most of the sediment load is predicted to come from surface and fluvial erosion sources. Unit sediment load is lowest in the upper watershed with the exception of areas draining the South Fork Mountain Schist. The background sediment load from landslide, surface, and fluvial erosion is throughout the Mad River except in smaller subwatersheds with large active landslides. The sediment load from road related landslides increases and exceeds the road surface and fluvial load in the lower Mad River (Table 22a). Road related landslides increase the load substantially in the lower watershed. The model predicts that most of the road related sediment is a result of roads concentrating runoff within active earthflows causing channel incision (Photograph 3 and 4). Road drainage is causing enlargement of planar channel that are longitudinally incised into the earthflow. Generally, the sediment load from timber harvest is lower than background or road erosion except in smaller subwatersheds that have been extensively harvested.

Photograph 3. Earthflow in mélange with private road dissecting the slide looking oblique to the north west. Surface runoff from roads causing large gully erosion below road prism (arrows) and enlarging intermittent channels relative to channels upstream of road.

Photograph 4. Active earthflow looking obliquely to the south west. Earthflow is enlarging as a result of road drainage.

Table 22. NetMap Model sediment budget results by subwatershed and unit sediment loads. The last column lists the average measured sediment load for the study period (i.e., Table 9 in the SSA Report).

BASIN_ID	**Watershed ID**	**Drainage Area (mi2)**	**Average Modeled Sediment Load (tons/mi2/year)**	**Average Measured Sediment Load (tons/mi2/year)**
1	MRRTH	94	1,289	1,253
2	ACLM	1	2,460	5,544
3	CCRTH	0	2,883	18
4	BCLM	1	3,585	908
5	HCLM	2	1,308	682
	Above Ruth Lake	98	1,333	1,278
6	TB3LM	0	2,678	69
7	OCLM	2	4,233	477
8	MR36	39	1,582	1,249
	Above Highway 36	140	1,440	1,258
9	LMC36	3	4,042	2,818
10	BCMCB	19	2,317	1,837
11	MCMCB	12	2,403	755
12	MRBVR	179	3,759	4,293
	Above Butler Valley Road	354	2,725	2,832
13	NFMKB	44	4,153	475
14	MRHRB	49	3,903	NA
	Basin Outlet	446	2,998	2,584

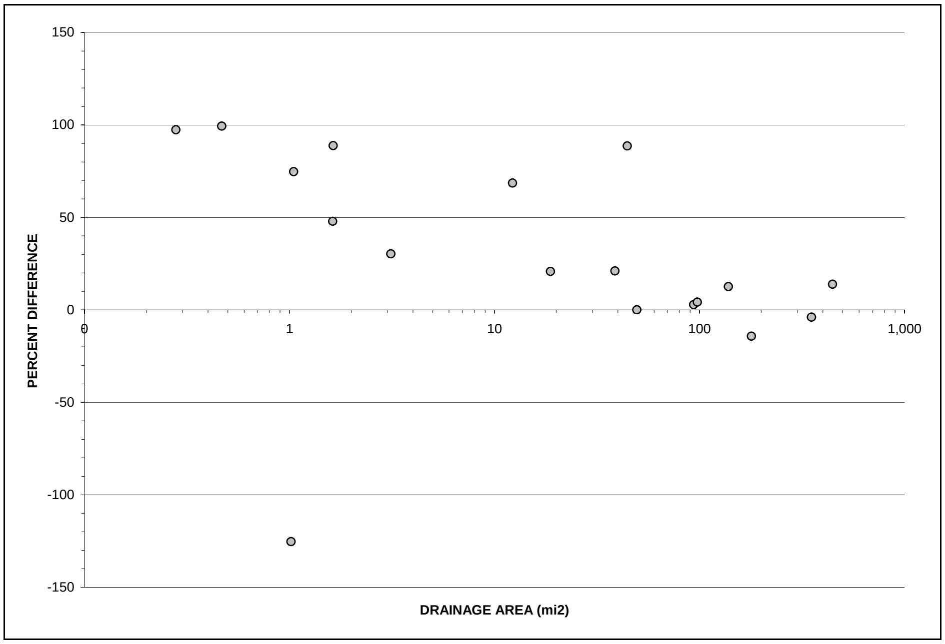


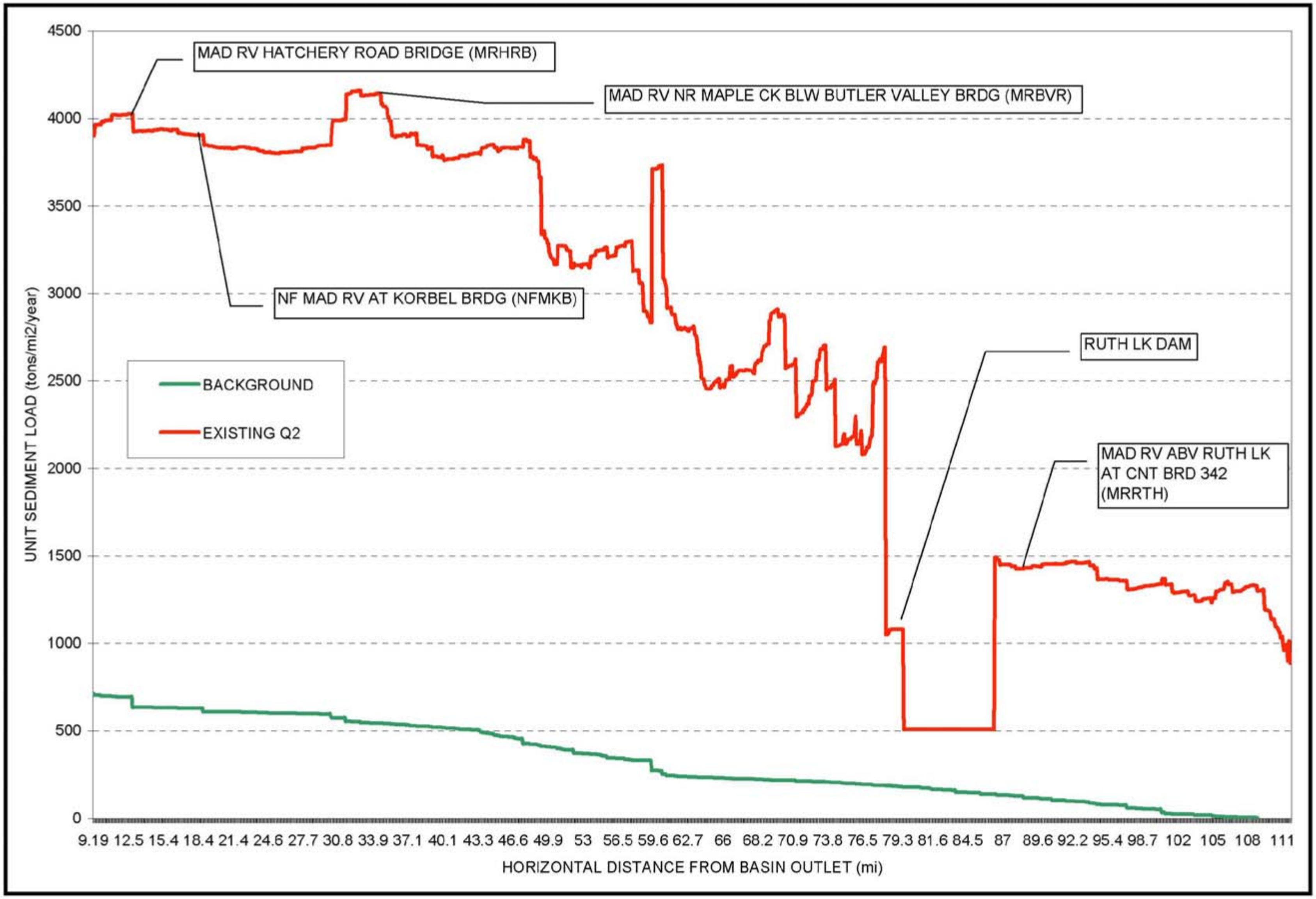
Figure 44. Scatter plot of subwatershed drainage area versus percent difference between modeled and measured average unit sediment load.

Table 22b lists the unit sediment load for background, road, and timber harvest by the 39 subwatersheds. The following subwatersheds have the highest total sediment load per unit drainage area (>3,000 tons/mi2/year): Deer Creek; Bear Creek2; Showers Creek; Goodman Prairie Creek; Holm Creek; Bear Creek; Graham Creek; Dry Creek; Cannon Creek; North Fork Mad River; Barry Ridge; Morgan Creek; Olsen Creek; Devil Creek; and Bug Creek. Over half of the sediment load is predicted to result from management activities. For all the 39 subwatersheds, the North Fork Mad River has the highest predicted sediment load (it has the largest drainage area of the subwatersheds) with the majority of the erosion coming from road surface and fluvial erosion. The predicted value differs by a factor of eight from the load measured by GMA in 2006 and 2007. The large road network on mélange accounts for the large sediment load. This load has high uncertainty and ground verification of model results is likely necessary to determine the actual sediment load relative to other subwatersheds. Table 23 provides the NetMap model results with the subwatersheds highlighted depending on whether they are in the upper, middle, or lower Mad as defined by the sampling locations (MRRTH, MRBVR, and MRHRB, respectively. Most of the highest sediment producers are in the middle and lower Mad sub areas.

4.3.2 Confidence in Analysis

The confidence in this analysis is medium and the accuracy of the results is +/- 150% for subwatersheds less than 50 mi^2 and +/- 20% for subwatersheds greater than 50 mi^2. There are several sources of uncertainty in the input data to the NetMap model. NetMap is able to rapidly summarize and precisely analyze large datasets; however, the data generalized as part of this analysis limit the accuracy of the results. The landslide data has the highest level of accuracy, whereas the road and timber harvest data have the lowest. As mentioned above, the model accuracy could be improved with better road inventory data especially since road erosion represents a large fraction of the total surface and fluvial erosion sediment delivery.

This analysis attempted to proportion the fine sediment load amongst upland sediment sources and use the results to allocate turbidity and suspended sediment load reductions. Due to the lack of detailed road data and the inherent uncertainty associated with sediment budget modeling, this analysis could not accurately make a connection between the measured background and existing suspended sediment load (and corresponding turbidity level) to upland sediment sources. NetMap is a relativistic model and the output should be used to compare the contribution of sediment from different sources both natural and management related. To date, the model is not intended to predict the "actual" sediment load per flood event; therefore it cannot be used to help develop waste load allocations for the 20% over background water quality objective for turbidity.



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MAD RIVER SEDIMENT SOURCE ANALYSIS

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FIGURE

44a

NETMAP MODEL SEDIMENT BUDGET RESULTS BY LANDSLIDE, SURFACE, AND FLUVIAL EROSION BY SUBWATERSHED AND EROSION SOURCE.

			Landslide				Surface and Fluvial Erosion			
BASIN_ID	Watershed ID	Drainage Area (mi^2)	Background Sediment Load (tons/ mi^2/year)	Road Related Sediment Load (tons/ mi^2/year)	Harvest Related Sediment Load (tons/ mi^2/year)	Total Sediment Load (tons/ mi^2/year)	Background Sediment Load (tons/ mi^2/year)	Road Related Sediment Load (tons/ mi^2/year)	Harvest Related Sediment Load (tons/ mi^2/year)	Total Sediment Load (tons/ mi^2/year)
1	MRRTH	94	62	24	51	138	598	251	302	1,151
2	ACLM	1	492	1,735	9	2,236	180	20	24	225
3	CCRTH	0.5	0	0	0	0	466	1,674	744	2,883
4	BCLM	1	2,039	1,244	3	3,286	264	28	6	299
5	HCLM	2	222	23	467	711	144	43	410	596
	Above Ruth Lake	98	90	55	57	202	582	250	300	1,131
6	TB3LM	0.5	265	41	0	306	231	2,141	0	2,373
7	OCLM	2	284	3,263	593	4,141	55	25	13	92
8	MR36	39	445	170	114	729	373	390	90	853
	Above Highway 36	140	192	125	79	396	516	290	237	1,043
9	LMC36	3	1,366	1,480	1,127	3,973	34	22	13	69
10	BCMCB	19	468	299	40	806	636	727	147	1,511
11	MCMCB	12	89	65	78	231	463	1,244	465	2,172
12	MRBVR	179	648	1,821	141	2,610	425	501	222	1,148
	Above Butler Valley Road	354	446	1,009	118	1,573	470	452	231	1,152
13	NFMKB	44	152	280	187	619	405	2,471	659	3,534
14	MRHRB	49	94	413	672	1,179	273	1,602	849	2,724
	Basin Outlet	446	378	870	186	1,434	442	781	342	1,564

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TABLE

22a

NETMAP SEDIMENT BUDGET RESULTS BY SUBWATERSHED

BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Sediment Load (tons/mi2/yr)	Road Sediment Load (tons/mi2/yr)	Timber Harvest Sediment Load (tons/mi2/yr)	Total Management Sediment Load (tons/mi2/yr)	Total Sediment Load (tons/mi2/yr)
1001	Mud River	13.2	797	168	183	351	1,148
1002	Lost Creek	26.1	642	219	343	562	1,205
1003	South Fork Mad River	15.9	703	185	290	475	1,177
1004	Barry Creek	10.2	661	291	545	837	1,497
1005	Armstrong Creek	9.9	677	542	669	1,211	1,888
1006	Deep Hollow Creek	4.1	648	108	337	445	1,094
1007	Deep Hollow Creek Wes	4.6	479	637	378	1,016	1,495
1008	Bear Creek	8.1	1,726	2,636	805	3,441	5,167
1009	Pilot Creek	39.7	918	252	428	680	1,598
1010	Hastings Creek	11.1	878	802	159	961	1,839
1011	Holm Creek	8.0	979	5,599	50	5,649	6,628
1012	Olmstead Creek	11.3	470	1,465	369	1,834	2,304
1013	Showers Creek	2.7	710	7,139	676	7,814	8,524
1014	Deer Creek	6.9	3,420	10,769	530	11,300	14,719
1015	Bug Creek	9.7	2,138	810	48	858	2,996
1016	Morgan Creek	8.7	1,167	2,093	187	2,281	3,448
1017	Wilson Creek	9.4	1,011	1,017	382	1,399	2,410
1018	Graham Creek	13.1	978	3,270	652	3,922	4,900
1019	Goodman Prairie Creek	10.0	1,016	6,189	144	6,333	7,349
1020	Boulder Creek	19.0	1,095	1,040	184	1,225	2,320
1021	Barry Ridge	9.1	1,167	2,033	402	2,435	3,602
1022	Maple Creek	15.6	531	1,387	518	1,906	2,437
1023	Blue Slide Creek	6.1	917	652	117	768	1,686
1024	Devil Creek	19.0	512	1,519	1,317	2,836	3,348
1025	Cannon Creek	16.4	404	2,542	1,366	3,908	4,313
1026	Dry Creek	7.0	246	2,072	2,374	4,445	4,691
1027	North Fork Mad River	48.8	509	2,722	908	3,630	4,139
1028	Powers Creek	20.8	284	1,093	1,169	2,262	2,546
1029	Lindsay Creek	17.7	227	1,355	833	2,188	2,416
1030	Deer Creek2	7.1	542	342	463	805	1,347
1031	Showers Creek2	5.2	328	1,505	504	2,009	2,337
1032	Bear Creek2	4.1	403	8,586	435	9,021	9,424
1033	Tompkins Creek West	4.9	637	764	308	1,072	1,709
1034	Tompkins Creek	8.9	729	428	124	552	1,281
1035	Hetten Creek West	11.9	597	640	182	822	1,419
1036	Hetten Creek	10.7	593	524	279	803	1,396
1037	Olsen Creek West	9.1	989	158	78	236	1,225
1038	Olsen Creek	12.8	1,093	1,720	581	2,301	3,394
1039	Hastings Creek West	3.2	1,229	229	176	405	1,634

NETMAP SEDIMENT BUDGET RESULTS BY SUBWATERSHED RANKED BY TOTAL LOAD

BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Sediment Load (tons/mi2/yr)	Road Sediment Load (tons/mi2/yr)	Timber Harvest Sediment Load (tons/mi2/yr)	Total Management Sediment Load (tons/mi2/yr)	Total Sediment Load (tons/mi2/yr)
1014	Deer Creek	6.9	3,420	10,769	530	11,300	14,719
1032	Bear Creek2	4.1	403	8,586	435	9,021	9,424
1013	Showers Creek	2.7	710	7,139	676	7,814	8,524
1019	Goodman Prairie Creek	10.0	1,016	6,189	144	6,333	7,349
1011	Holm Creek	8.0	979	5,599	50	5,649	6,628
1008	Bear Creek	8.1	1,726	2,636	805	3,441	5,167
1018	Graham Creek	13.1	978	3,270	652	3,922	4,900
1026	Dry Creek	7.0	246	2,072	2,374	4,445	4,691
1025	Cannon Creek	16.4	404	2,542	1,366	3,908	4,313
1027	North Fork Mad River	48.8	509	2,722	908	3,630	4,139
1021	Barry Ridge	9.1	1,167	2,033	402	2,435	3,602
1016	Morgan Creek	8.7	1,167	2,093	187	2,281	3,448
1038	Olsen Creek	12.8	1,093	1,720	581	2,301	3,394
1024	Devil Creek	19.0	512	1,519	1,317	2,836	3,348
1015	Bug Creek	9.7	2,138	810	48	858	2,996
1028	Powers Creek	20.8	284	1,093	1,169	2,262	2,546
1022	Maple Creek	15.6	531	1,387	518	1,906	2,437
1029	Lindsay Creek	17.7	227	1,355	833	2,188	2,416
1017	Wilson Creek	9.4	1,011	1,017	382	1,399	2,410
1031	Showers Creek2	5.2	328	1,505	504	2,009	2,337
1020	Boulder Creek	19.0	1,095	1,040	184	1,225	2,320
1012	Olmstead Creek	11.3	470	1,465	369	1,834	2,304
1005	Armstrong Creek	9.9	677	542	669	1,211	1,888
1010	Hastings Creek	11.1	878	802	159	961	1,839
1033	Tompkins Creek West	4.9	637	764	308	1,072	1,709
1023	Blue Slide Creek	6.1	917	652	117	768	1,686
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1004	Barry Creek	10.2	661	291	545	837	1,497
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1036	Hetten Creek	10.7	593	524	279	803	1,396
1030	Deer Creek2	7.1	542	342	463	805	1,347
1034	Tompkins Creek	8.9	729	428	124	552	1,281
1037	Olsen Creek West	9.1	989	158	78	236	1,225
1002	Lost Creek	26.1	642	219	343	562	1,205
1003	South Fork Mad River	15.9	703	185	290	475	1,177
1001	Mud River	13.2	797	168	183	351	1,148
1006	Deep Hollow Creek	4.1	648	108	337	445	1,094

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TABLE

22b

NETMAP SEDIMENT BUDGET RESULTS BY SUBWATERSHED RANKED BY TOTAL LOAD

BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Sediment Load (tons/mi2/yr)	Road Sediment Load (tons/mi2/yr)	Timber Harvest Sediment Load (tons/mi2/yr)	Total Management Sediment Load (tons/mi2/yr)	Total Sediment Load (tons/mi2/yr)
1014	Deer Creek	6.9	3,420	10,769	530	11,300	14,719
1032	Bear Creek2	4.1	403	8,586	435	9,021	9,424
1013	Showers Creek	2.7	710	7,139	676	7,814	8,524
1019	Goodman Prairie Creek	10.0	1,016	6,189	144	6,333	7,349
1011	Holm Creek	8.0	979	5,599	50	5,649	6,628
1008	Bear Creek	8.1	1,726	2,636	805	3,441	5,167
1018	Graham Creek	13.1	978	3,270	652	3,922	4,900
1026	Dry Creek	7.0	246	2,072	2,374	4,445	4,691
1025	Cannon Creek	16.4	404	2,542	1,366	3,908	4,313
1027	North Fork Mad River	48.8	509	2,722	908	3,630	4,139
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1016	Morgan Creek	8.7	1,167	2,093	187	2,281	3,448
1038	Olsen Creek	12.8	1,093	1,720	581	2,301	3,394
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1028	Powers Creek	20.8	284	1,093	1,169	2,262	2,546
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1029	Lindsay Creek	17.7	227	1,355	833	2,188	2,416
1017	Wilson Creek	9.4	1,011	1,017	382	1,399	2,410
1031	Showers Creek2	5.2	328	1,505	504	2,009	2,337
1020	Boulder Creek	19.0	1,095	1,040	184	1,225	2,320
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1005	Armstrong Creek	9.9	677	542	669	1,211	1,888
1010	Hastings Creek	11.1	878	802	159	961	1,839
1033	Tompkins Creek West	4.9	637	764	308	1,072	1,709
1023	Blue Slide Creek	6.1	917	652	117	768	1,686
1039	Hastings Creek West	3.2	1,229	229	176	405	1,634
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1036	Hetten Creek	10.7	593	524	279	803	1,396
1030	Deer Creek2	7.1	542	342	463	805	1,347
1034	Tompkins Creek	8.9	729	428	124	552	1,281
1037	Olsen Creek West	9.1	989	158	78	236	1,225
1002	Lost Creek	26.1	642	219	343	562	1,205
1003	South Fork Mad River	15.9	703	185	290	475	1,177
1001	Mud River	13.2	797	168	183	351	1,148
1006	Deep Hollow Creek	4.1	648	108	337	445	1,094

🟩	Above MRRTH Site	🟧	Between MRRTH and MRBVR Sites	🟨	Below MRBVR Site

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TABLE

23

4.4 Traditional Sediment Budget

4.4.1 Upland Sediment Budget Results

An alternative method of evaluating the sediment budget data collected in this study involves the development of a traditional sediment budget. By combining unit sediment loads from the landslide analysis with unit sediment loads from road surface erosion modeling and harvest-related surface erosion, and with unit sediment loads from bank erosion, the major sources of sediment delivery by sub-watershed can be evaluated by type and by percentage of the total.

Table 24 presents the 39 sub-watersheds with the various categories of landslide related sediment delivery combined with surface erosion from roads. The total unit sediment delivery by subwatershed is computed and the percentages of the combined total by type are also presented. Percentages by background and management related sources are computed for each subwatershed.

Tables 25 through 29 present these same data sorted and ranked in various ways which allows the relative importance of various sediment delivery mechanisms to be easily compared by subwatershed.

Table 25 ranks the subwatersheds by total unit sediment delivery from all sources combined. Totals for the 39 subwatersheds range from a low of 98 tons/mi^2/year for the Mud River (Basin #1001, above Ruth Lake) to 11,242 tons/mi^2/year for Holm Creek (Basin # 1011, in the middle reach of the mainstem Mad River). The largest producers are Holm Creek, Showers Creek, Goodman Prairie Creek, Deer Creek, Bug Creek, Morgan Creek, Bear Creek 2, Graham Creek, Dry Creek and Tompkins Creek, all of which deliver over 4,000 tons/mi^2/year. Landslide related erosion accounts for the bulk of the sediment in all of these high unit sources, although the relative importance of background slides, road-related slides, and harvest-related slides varies between the subwatersheds. Fourteen of the top 15 subwatershed producers are all in the middle Mad, from Ruth Lake downstream to Butler Valley.

Table 26 ranks the subwatersheds by road-related landslide unit sediment delivery. The range is from 0 to 9,235 tons/mi^2/year. 16 subwatersheds do not have any road-related landslides. Showers Creek, Goodman Prairie Creek, Bear Creek2, and Holm Creek stand out as large sources of road-related unit sediment. Of the ten highest sources of road-related landslide sediment delivery, these slides account for 56-94% of the total sediment produced by each subwatershed.

Table 27 ranks the subwatersheds based on percentage of management related unit sediment delivery. The range is from 2% to 99% of each subwatershed’s unit sediment production is related to management (roads, timber harvest) actions. 5 of the sub-watersheds have over 80% of their sediment production from management-related sources. Subwatersheds with substantial background landslides tend to move to the middle or bottom of the subwatershed list when ranked in this manner.

Table 28 ranks the subwatersheds by surface erosion from roads. The range is from 18 (Mud River and Deep Hollow Creek) to 683 tons/mi^2/year (Cannon Creek). The highest producers from road surface erosion tend to be those in the reach between Butler Valley and the mouth of the basin. For the top 5 in this category, 37-68% of their sediment production comes from road surface erosion. Landslides are typically not important sources in these subwatersheds.

Table 29 sorts the subwatersheds into reaches created by the GMA instream monitoring sites: above MRRTH (upper watershed above Ruth Lake), between MRRTH and MRBVR (middle watershed from Ruth Lake to Butler Valley), and between Butler Valley and the basin outlet. Review of the total unit sediment delivery by subwatershed for each of these categories shows that the upper and lower watershed areas are almost all relatively low unit sediment producers; with Dry Creek being an exception, at 5,171 tons/mi^2/year. The highest in the remaining upper and lower 12 subwatersheds is 2,464 tons/mi^2/year for Devil Creek (which is 16th on the ranked list of highest total unit sediment delivery). All of the large unit sediment producers are located in the large, central portion of the watershed, where the combination of geology, steep slopes, poorly placed roads, and timber harvest, has resulted in high unit sediment yields.

Table 30 ranks the subwatersheds by total sediment delivery in tons per year rather than unit sediment delivery in tons/mi^2/year. In this version, the subwatersheds range from 1,291 tons/year (Mud River) to 103,062 tons/yr (Goodman Prairie Creek). Most of the higher producing subwatersheds are those with high landslide sediment delivery, but larger subwatersheds with high road surface erosion (North Fork Mad River, now 10th up from 22nd) also move up the list. The table also totals sediment production by source and computes the percent by type. Total sediment production is 1,187,928 tons/year, with 89.0% from landslides, 9.8% from road surface erosion, 0.1% from harvest surface erosion, and 1.1% from bank erosion.

Table 31 highlights the subwatersheds ranked by total sediment production in tons/year with the previous color scheme for location within monitoring reaches. The upper watershed subbasins are still towards the low end of the list. Lower watershed basins have moved up the list due to their larger size and higher surface erosion from roads. The middle watershed basins are distributed throughout the ranking with some smaller watersheds with relatively few landslides moving towards the bottom.

Table 32 organizes the subwatersheds into the reaches, then ranks the various subwatersheds within each reach by total sediment production in tons/year. In addition, the total sediment production by reach is computed by summing the individual values within each reach. Thus, the upper watershed of 84 mi^2 produces 1.7% of the total, the middle watershed (266 mi^2) produces 83.1%, and the lower watershed (129.7 mi^2) produces 15.3%. The percentage of the total sediment produced by each subwatershed is also computed. All of the large producers with the exception of the North Fork Mad River, Devil Creek, and Dry Creek are located in the middle watershed.

4.4.2 Comparison of Upland Sediment Budget and Transport Data

By subdividing the upland sediment budget subwatersheds into cells above, or between transport nodes, the volumes of sediment delivery can be compared to the average annual transport at each node from the quantities measured and computed at the GMA monitoring stations.

The nodes are as follows: Above MRRTH is the upper watershed, between MRRTH and MRBVR is the middle watershed, and between MRBVR and MRHRB is the lower watershed, which includes NFMKB. Table 33 presents the results of this analysis. Since Water Year 2006 was a very wet year and Water Year 2007 was a very dry year, the suspended sediment loads were combined and averaged to produce a "typical" year. Loads within each reach are then compared to the average tons/year values from the sediment budget based on 31 years (post 1975).

The average measured load from the upper watershed (above MRRTH) is 114,250 tons/yr, or 10.4% of the basin output. The load for the large reach between MRRTH and MRBVR is computed as the difference between the two measured records with an adjustment (estimated at 20%) to the load passing MRRTH for sediment deposited in Ruth Lake. This computation indicates that 643,600 tons/yr or 58.4% of the basin output is contributed between the two monitoring sites. The gain between MRBVR and MRHRB is computed to be 352,525 tons/yr or 32.0% of the output. Total output at MRHRB is computed to be 1,102,000 tons/yr.

Values from the upland sediment budget are then compared to these measured values. As previously noted, the traditional sediment budget produced 1,187,928 tons/yr total, with 19,628 tons/yr or 1.7% from the upper watershed, 986,982 tons/yr or 83.1% from the middle watershed, and 181,317 tons/yr or 15.3% from the lower watershed. These values compare reasonably well to the measured values, and certainly show that the values are reasonable. When examining a specific subwatershed such as the North Fork Mad River, (the only subbasin for which a load was measured), the two approaches show some differences (14,475 tons/yr measured SSL vs. 50,847 tons/yr from the sediment budget). Upland sediment production rates from the upper Mad are low compared to the measured loads, but this reflects the fact that the December 2005 event was quite a bit more unusual (and therefore a larger sediment producer compared to an average year) in that part of the watershed.

A number of caveats, which may explain much of the difference, must be mentioned in this analysis: (1) Measured values are for suspended sediment load only and do not take into account bedload, which would be incorporated in the computations of upland sediment delivery, (2) measured values did not include the entire water year in either 2006 or 2007, though the vast majority of sediment transporting events were certainly captured in the period of record, and (3) the average of the two measured years may not be representative of the 31 year period (annual load computations by Brown (1973) and Lehre (1993) average from 1,600,000 to 2,600,000 tons/year, although the pre-1975 period was undoubtedly wetter, and produced more sediment (due to fewer regulations and more management activity),than the post-1975 period).

4.4.3 Sediment Source Analysis Synthesis

Sediment source analysis results indicate that most of the natural and management related sediment delivery is from the Franciscan mélange within the middle reach of the Mad River. The measured SSL, NetMap model, and traditional sediment budget show a substantial increase in the sediment load in the middle portion of the Mad River as the mélange terrane becomes more frequent. For chronic sediment delivery, road surface erosion appears to be the major sediment source, whereas for episodic sediment delivery earthflows and debris flows triggered naturally and by roads appear to be the major sediment sources.

It is not possible to directly compare the NetMap model and traditional sediment budget results. The main reason is the way surface and fluvial erosion are factored into the two models. The NetMap model uses the modified GEP (described in the methods section) that predicts surface and fluvial erosion potential across the landscape on non-landslide terrain. Whereas the traditional sediment budget surface and fluvial erosion component includes bank erosion, road erosion, and timber harvest erosion. As a result, the predicted sediment load from surface and fluvial erosion using NetMap is much higher than the traditional sediment budget. The other major difference is how surface and fluvial erosion sediment delivery is predicted where NetMap uses the actual topography to determine the relative likelihood of delivery. The traditional sediment budget uses and index of topography (slope steepness and position classes) to predict delivery.

For the Mad River watershed, sediment source reduction efforts should focus on chronic surface erosion from roads, and episodic erosion from areas where roads dissect landslide prone terrain within the middle reach between Highway 36 and the confluence with Boulder Creek (Plates 1a and 1b). This reach has the highest predicted sediment load as well as habitat needed to support anadromous fish migration, spawning, and rearing.

The NetMap model identifies the relative contribution, by subwatershed, of background and existing erosion potential. It can also be used to predict areas prone to future erosion as land use continues within the watershed. This analysis identified a substantial data gap in road presence and absence as well as condition. Road inventories that measure road condition would greatly improve the accuracy of this analysis and could be used to identify site specific management prescriptions aimed at reducing chronic and episodic sediment delivery.

MAD RIVER SEDIMENT SOURCE ANALYSIS
UNIT SEDIMENT DELIVERY BY TYPE BY SUB-WATERSHED

			Landslide Related Erosion					Surface Erosion		Bank Erosion	Total	Percentage of Total Unit Sediment Delivery					
BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Creep from Deep-Seated Features (tons/mi2/yr)	Background Landslides (tons/mi2/yr)	Road Related Landslides (tons/mi2/yr)	Timber Harvest Related Landslides (tons/mi2/yr)	Total Landslide Related Sediment Delivery (tons/mi2/yr)	Road Sediment Delivery (tons/mi2/year)	Harvest Sediment Delivery (tons/mi2/year)	Bank Erosion (tons/mi2/year)	Grand Total (tons/mi2/year)	Background Landslide + Creep as % of Total	Road Related Landslide as % of Total	Timber Harvest Related Landslide as % of Total	Road Surface Erosion as % of Total	Background (Landslide + Creep + Bank Erosion) as % of Total	Management Related Sources as % of Total
1001	Mud River	13.2	50	0	0	0	50	18	0.5	29	98	51.1%	0.0%	0.0%	18.7%	80.8%	19.2%
1002	Lost Creek	26.1	70	52	0	4	126	26	0.7	24	177	69.0%	0.0%	2.2%	14.8%	82.6%	17.4%
1003	South Fork Mad River	15.9	43	0	0	0	43	19	0.5	65	127	33.8%	0.0%	0.0%	14.6%	85.0%	15.0%
1004	Barry Creek	10.2	133	0	0	0	133	44	1.0	28	206	64.5%	0.0%	0.0%	21.4%	78.1%	21.9%
1005	Armstrong Creek	9.9	79	0	230	12	321	92	1.2	91	506	15.6%	45.5%	2.4%	18.3%	33.6%	66.4%
1006	Deep Hollow Creek	4.1	284	23	413	0	720	18	0.4	14	752	40.8%	54.9%	0.0%	2.4%	42.7%	57.3%
1007	Deep Hollow Creek West	4.6	69	0	0	0	69	137	1.4	120	327	21.1%	0.0%	0.0%	41.8%	57.8%	42.2%
1008	Bear Creek	8.1	461	286	2,607	0	3,354	317	2.3	48	3722	20.1%	70.1%	0.0%	8.5%	21.4%	78.6%
1009	Pilot Creek	39.7	300	1,636	0	2	1,938	74	1.0	17	2031	95.3%	0.0%	0.1%	3.7%	96.2%	3.8%
1010	Hastings Creek	11.1	634	423	354	0	1,411	106	0.5	1	1518	69.6%	23.3%	0.0%	7.0%	69.7%	30.3%
1011	Holm Creek	8	641	3,402	7,136	0	11,179	41	0.4	21	11242	36.0%	63.5%	0.0%	0.4%	36.2%	63.8%
1012	Olmstead Creek	11.3	575	61	1,093	0	1,729	250	3.7	8	1991	31.9%	54.9%	0.0%	12.6%	32.3%	67.7%
1013	Showers Creek	2.7	547	816	9,235	0	10,598	248	3.0	6	10855	12.6%	85.1%	0.0%	2.3%	12.6%	87.4%
1014	Deer Creek	6.9	653	3,010	5,813	0	9,476	190	4.5	8	9678	37.9%	60.1%	0.0%	2.0%	37.9%	62.1%
1015	Bug Creek	9.7	363	3,543	5,193	0	9,099	73	0.5	31	9204	42.4%	56.4%	0.0%	0.8%	42.8%	57.2%
1016	Morgan Creek	8.7	741	1,152	6,494	130	8,517	333	0.5	17	8867	21.3%	73.2%	1.5%	3.8%	21.5%	78.5%
1017	Wilson Creek	9.4	750	174	2,818	0	3,742	235	0.8	15	3992	23.1%	70.6%	0.0%	5.9%	23.5%	76.5%
1018	Graham Creek	13.1	711	1,191	3,378	0	5,280	278	2.7	17	5578	34.1%	60.6%	0.0%	5.0%	34.4%	65.6%
1019	Goodman Prairie Creek	10	775	951	8,297	0	10,023	266	0.5	16	10306	16.7%	80.5%	0.0%	2.6%	16.9%	83.1%
1020	Boulder Creek	19	176	1,963	1,345	142	3,626	211	0.3	20	3857	55.5%	34.9%	3.7%	5.5%	56.0%	44.0%
1021	Barry Ridge	9.1	501	777	1,771	0	3,049	266	5.2	29	3349	38.2%	52.9%	0.0%	7.9%	39.0%	61.0%
1022	Maple Creek	15.6	100	22	0	0	122	348	2.7	33	506	24.1%	0.0%	0.0%	68.8%	30.6%	69.4%
1023	Blue Slide Creek	6.1	260	0	3	0	263	157	1.1	44	465	56.0%	0.6%	0.0%	33.7%	65.4%	34.6%
1024	Devil Creek	19	188	0	1,759	149	2,096	327	4.3	37	2464	7.6%	71.4%	6.1%	13.3%	9.1%	90.9%
1025	Cannon Creek	16.4	281	1	0	0	282	683	5.0	16	986	28.6%	0.0%	0.0%	69.3%	30.2%	69.8%
1026	Dry Creek	7	246	0	4,076	500	4,822	316	4.6	28	5171	4.8%	78.8%	9.7%	6.1%	5.3%	94.7%
1027	North Fork Mad River	48.8	302	9	62	0	373	653	3.3	13	1042	29.8%	5.9%	0.0%	62.6%	31.1%	68.9%
1028	Powers Creek	20.8	397	0	0	147	544	358	5.8	45	953	41.7%	0.0%	15.4%	37.6%	46.4%	53.6%
1029	Lindsay Creek	17.7	177	0	0	0	177	440	8.6	23	648	27.3%	0.0%	0.0%	67.8%	30.9%	69.1%
1030	Deer Creek2	7.1	183	0	68	0	251	31	0.5	18	301	60.8%	22.7%	0.0%	10.3%	66.8%	33.2%
1031	Showers Creek2	5.2	289	55	0	0	344	387	9.1	19	759	45.3%	0.0%	0.0%	51.0%	47.8%	52.2%
1032	Bear Creek2	4.1	97	0	7,964	0	8,061	357	4.8	19	8442	1.1%	94.3%	0.0%	4.2%	1.4%	98.6%
1033	Tompkins Creek West	4.9	64	94	0	0	158	214	1.2	133	507	31.2%	0.0%	0.0%	42.3%	57.5%	42.5%
1034	Tompkins Creek	8.9	378	472	3,175	0	4,025	26	0.3	12	4064	20.9%	78.1%	0.0%	0.6%	21.2%	78.8%
1035	Hetten Creek West	11.9	211	0	0	0	211	156	0.7	11	379	55.7%	0.0%	0.0%	41.2%	58.6%	41.4%
1036	Hetten Creek	10.7	300	344	0	0	644	111	0.3	0	755	85.3%	0.0%	0.0%	14.6%	85.3%	14.7%
1037	Olsen Creek West	9.1	424	493	0	0	917	40	0.3	53	1011	90.7%	0.0%	0.0%	4.0%	96.0%	4.0%
1038	Olsen Creek	12.8	406	704	2,407	362	3,879	88	1.3	6	3974	27.9%	60.6%	9.1%	2.2%	28.1%	71.9%
1039	Hastings Creek West	3.2	651	615	0	0	1,266	28	0.5	48	1342	94.3%	0.0%	0.0%	2.1%	97.9%	2.1%

MAD RIVER SEDIMENT SOURCE ANALYSIS

UNIT SEDIMENT DELIVERY BY TYPE BY SUB-WATERSHED RANKED BY TOTAL UNIT DELIVERY

			Landslide Related Erosion					Surface Erosion		Bank Erosion	Total	Percentage of Total Unit Sediment Delivery					
BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Creep from Deep-Seated Features (tons/mi2/yr)	Background Landslides (tons/mi2/yr)	Road Related Landslides (tons/mi2/yr)	Timber Harvest Related Landslides (tons/mi2/yr)	Total Landslide Related Sediment Delivery (tons/mi2/yr)	Road Sediment Delivery (tons/mi2/year)	Harvest Sediment Delivery (tons/mi2/year)	Bank Erosion (tons/mi2/year)	Grand Total (tons/mi2/year)	Background Landslide + Creep as % of Total	Road Related Landslide as % of Total	Timber Harvest Related Landslide as % of Total	Road Surface Erosion as % of Total	Background (Landslide + Creep + Bank Erosion) as % of Total	Management Related Sources as % of Total
1011	Holm Creek	8	641	3,402	7,136	0	11,179	41	0.4	21	11,242	36.0%	63.5%	0.0%	0.4%	36.2%	63.8%
1013	Showers Creek	2.7	547	816	9,235	0	10,598	248	3.0	6	10,855	12.6%	85.1%	0.0%	2.3%	12.6%	87.4%
1019	Goodman Prairie Creek	10	775	951	8,297	0	10,023	266	0.5	16	10,306	16.7%	80.5%	0.0%	2.6%	16.9%	83.1%
1014	Deer Creek	6.9	653	3,010	5,813	0	9,476	190	4.5	8	9,678	37.9%	60.1%	0.0%	2.0%	37.9%	62.1%
1015	Bug Creek	9.7	363	3,543	5,193	0	9,099	73	0.5	31	9,204	42.4%	56.4%	0.0%	0.8%	42.8%	57.2%
1016	Morgan Creek	8.7	741	1,152	6,494	130	8,517	333	0.5	17	8,867	21.3%	73.2%	1.5%	3.8%	21.5%	78.5%
1032	Bear Creek2	4.1	97	0	7,964	0	8,061	357	4.8	19	8,442	1.1%	94.3%	0.0%	4.2%	1.4%	98.6%
1018	Graham Creek	13.1	711	1,191	3,378	0	5,280	278	2.7	17	5,578	34.1%	60.6%	0.0%	5.0%	34.4%	65.6%
1026	Dry Creek	7	246	0	4,076	500	4,822	316	4.6	28	5,171	4.8%	78.8%	9.7%	6.1%	5.3%	94.7%
1034	Tompkins Creek	8.9	378	472	3,175	0	4,025	26	0.3	12	4,064	20.9%	78.1%	0.0%	0.6%	21.2%	78.8%
1017	Wilson Creek	9.4	750	174	2,818	0	3,742	235	0.8	15	3,992	23.1%	70.6%	0.0%	5.9%	23.5%	76.5%
1038	Olsen Creek	12.8	406	704	2,407	362	3,879	88	1.3	6	3,974	27.9%	60.6%	9.1%	2.2%	28.1%	71.9%
1020	Boulder Creek	19	176	1,963	1,345	142	3,626	211	0.3	20	3,857	55.5%	34.9%	3.7%	5.5%	56.0%	44.0%
1008	Bear Creek	8.1	461	286	2,607	0	3,354	317	2.3	48	3,722	20.1%	70.1%	0.0%	8.5%	21.4%	78.6%
1021	Barry Ridge	9.1	501	777	1,771	0	3,049	266	5.2	29	3,349	38.2%	52.9%	0.0%	7.9%	39.0%	61.0%
1024	Devil Creek	19	188	0	1,759	149	2,096	327	4.3	37	2,464	7.6%	71.4%	6.1%	13.3%	9.1%	90.9%
1009	Pilot Creek	39.7	300	1,636	0	2	1,938	74	1.0	17	2,031	95.3%	0.0%	0.1%	3.7%	96.2%	3.8%
1012	Olmstead Creek	11.3	575	61	1,093	0	1,729	250	3.7	8	1,991	31.9%	54.9%	0.0%	12.6%	32.3%	67.7%
1010	Hastings Creek	11.1	634	423	354	0	1,411	106	0.5	1	1,518	69.6%	23.3%	0.0%	7.0%	69.7%	30.3%
1039	Hastings Creek West	3.2	651	615	0	0	1,266	28	0.5	48	1,342	94.3%	0.0%	0.0%	2.1%	97.9%	2.1%
1027	North Fork Mad River	48.8	302	9	62	0	373	653	3.3	13	1,042	29.8%	5.9%	0.0%	62.6%	31.1%	68.9%
1037	Olsen Creek West	9.1	424	493	0	0	917	40	0.3	53	1,011	90.7%	0.0%	0.0%	4.0%	96.0%	4.0%
1025	Cannon Creek	16.4	281	1	0	0	282	683	5.0	16	986	28.6%	0.0%	0.0%	69.3%	30.2%	69.8%
1028	Powers Creek	20.8	397	0	0	147	544	358	5.8	45	953	41.7%	0.0%	15.4%	37.6%	46.4%	53.6%
1031	Showers Creek2	5.2	289	55	0	0	344	387	9.1	19	759	45.3%	0.0%	0.0%	51.0%	47.8%	52.2%
1036	Hetten Creek	10.7	300	344	0	0	644	111	0.3	0	755	85.3%	0.0%	0.0%	14.6%	85.3%	14.7%
1006	Deep Hollow Creek	4.1	284	23	413	0	720	18	0.4	14	752	40.8%	54.9%	0.0%	2.4%	42.7%	57.3%
1029	Lindsay Creek	17.7	177	0	0	0	177	440	8.6	23	648	27.3%	0.0%	0.0%	67.8%	30.9%	69.1%
1033	Tompkins Creek West	4.9	64	94	0	0	158	214	1.2	133	507	31.2%	0.0%	0.0%	42.3%	57.5%	42.5%
1022	Maple Creek	15.6	100	22	0	0	122	348	2.7	33	506	24.1%	0.0%	0.0%	68.8%	30.6%	69.4%
1005	Armstrong Creek	9.9	79	0	230	12	321	92	1.2	91	506	15.6%	45.5%	2.4%	18.3%	33.6%	66.4%
1023	Blue Slide Creek	6.1	260	0	3	0	263	157	1.1	44	465	56.0%	0.6%	0.0%	33.7%	65.4%	34.6%
1035	Hetten Creek West	11.9	211	0	0	0	211	156	0.7	11	379	55.7%	0.0%	0.0%	41.2%	58.6%	41.4%
1007	Deep Hollow Creek West	4.6	69	0	0	0	69	137	1.4	120	327	21.1%	0.0%	0.0%	41.8%	57.8%	42.2%
1030	Deer Creek2	7.1	183	0	68	0	251	31	0.5	18	301	60.8%	22.7%	0.0%	10.3%	66.8%	33.2%
1004	Barry Creek	10.2	133	0	0	0	133	44	1.0	28	206	64.5%	0.0%	0.0%	21.4%	78.1%	21.9%
1002	Lost Creek	26.1	70	52	0	4	126	26	0.7	24	177	69.0%	0.0%	2.2%	14.8%	82.6%	17.4%
1003	South Fork Mad River	15.9	43	0	0	0	43	19	0.5	65	127	33.8%	0.0%	0.0%	14.6%	85.0%	15.0%
1001	Mud River	13.2	50	0	0	0	50	18	0.5	29	98	51.1%	0.0%	0.0%	18.7%	80.8%	19.2%

Prepared for:

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MAD RIVER SEDIMENT SOURCE ANALYSIS

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TABLE

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MAD RIVER SEDIMENT SOURCE ANALYSIS

UNIT SEDIMENT DELIVERY BY TYPE BY SUB-WATERSHED RANKED BY ROAD RELATED LANDSLIDES

			Landslide Related Erosion					Surface Erosion		Bank Erosion	Total	Percentage of Total Unit Sediment Delivery					
BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Creep from Deep-Seated Features (tons/mi2/yr)	Background Landslides (tons/mi2/yr)	Road Related Landslides (tons/mi2/yr)	Timber Harvest Related Landslides (tons/mi2/yr)	Total Landslide Related Sediment Delivery (tons/mi2/yr)	Road Sediment Delivery (tons/mi2/year)	Harvest Sediment Delivery (tons/mi2/year)	Bank Erosion (tons/mi2/year)	Grand Total (tons/mi2/year)	Background Landslide + Creep as % of Total	Road Related Landslide as % of Total	Timber Harvest Related Landslide as % of Total	Road Surface Erosion as % of Total	Background (Landslide + Creep + Bank Erosion) as % of Total	Management Related Sources as % of Total
1013	Showers Creek	2.7	547	816	9,235	0	10,598	248	3.0	6	10,855	12.6%	85.1%	0.0%	2.3%	12.6%	87.4%
1019	Goodman Prairie Creek	10	775	951	8,297	0	10,023	266	0.5	16	10,306	16.7%	80.5%	0.0%	2.6%	16.9%	83.1%
1032	Bear Creek2	4.1	97	0	7,964	0	8,061	357	4.8	19	8,442	1.1%	94.3%	0.0%	4.2%	1.4%	98.6%
1011	Holm Creek	8	641	3,402	7,136	0	11,179	41	0.4	21	11,242	36.0%	63.5%	0.0%	0.4%	36.2%	63.8%
1016	Morgan Creek	8.7	741	1,152	6,494	130	8,517	333	0.5	17	8,867	21.3%	73.2%	1.5%	3.8%	21.5%	78.5%
1014	Deer Creek	6.9	653	3,010	5,813	0	9,476	190	4.5	8	9,678	37.9%	60.1%	0.0%	2.0%	37.9%	62.1%
1015	Bug Creek	9.7	363	3,543	5,193	0	9,099	73	0.5	31	9,204	42.4%	56.4%	0.0%	0.8%	42.8%	57.2%
1026	Dry Creek	7	246	0	4,076	500	4,822	316	4.6	28	5,171	4.8%	78.8%	9.7%	6.1%	5.3%	94.7%
1018	Graham Creek	13.1	711	1,191	3,378	0	5,280	278	2.7	17	5,578	34.1%	60.6%	0.0%	5.0%	34.4%	65.6%
1034	Tompkins Creek	8.9	378	472	3,175	0	4,025	26	0.3	12	4,064	20.9%	78.1%	0.0%	0.6%	21.2%	78.8%
1017	Wilson Creek	9.4	750	174	2,818	0	3,742	235	0.8	15	3,992	23.1%	70.6%	0.0%	5.9%	23.5%	76.5%
1008	Bear Creek	8.1	461	286	2,607	0	3,354	317	2.3	48	3,722	20.1%	70.1%	0.0%	8.5%	21.4%	78.6%
1038	Olsen Creek	12.8	406	704	2,407	362	3,879	88	1.3	6	3,974	27.9%	60.6%	9.1%	2.2%	28.1%	71.9%
1021	Barry Ridge	9.1	501	777	1,771	0	3,049	266	5.2	29	3,349	38.2%	52.9%	0.0%	7.9%	39.0%	61.0%
1024	Devil Creek	19	188	0	1,759	149	2,096	327	4.3	37	2,464	7.6%	71.4%	6.1%	13.3%	9.1%	90.9%
1020	Boulder Creek	19	176	1,963	1,345	142	3,626	211	0.3	20	3,857	55.5%	34.9%	3.7%	5.5%	56.0%	44.0%
1012	Olmstead Creek	11.3	575	61	1,093	0	1,729	250	3.7	8	1,991	31.9%	54.9%	0.0%	12.6%	32.3%	67.7%
1006	Deep Hollow Creek	4.1	284	23	413	0	720	18	0.4	14	752	40.8%	54.9%	0.0%	2.4%	42.7%	57.3%
1010	Hastings Creek	11.1	634	423	354	0	1,411	106	0.5	1	1,518	69.6%	23.3%	0.0%	7.0%	69.7%	30.3%
1005	Armstrong Creek	9.9	79	0	230	12	321	92	1.2	91	506	15.6%	45.5%	2.4%	18.3%	33.6%	66.4%
1030	Deer Creek2	7.1	183	0	68	0	251	31	0.5	18	301	60.8%	22.7%	0.0%	10.3%	66.8%	33.2%
1027	North Fork Mad River	48.8	302	9	62	0	373	653	3.3	13	1,042	29.8%	5.9%	0.0%	62.6%	31.1%	68.9%
1023	Blue Slide Creek	6.1	260	0	3	0	263	157	1.1	44	465	56.0%	0.6%	0.0%	33.7%	65.4%	34.6%
1009	Pilot Creek	39.7	300	1,636	0	2	1,938	74	1.0	17	2,031	95.3%	0.0%	0.1%	3.7%	96.2%	3.8%
1039	Hastings Creek West	3.2	651	615	0	0	1,266	28	0.5	48	1,342	94.3%	0.0%	0.0%	2.1%	97.9%	2.1%
1037	Olsen Creek West	9.1	424	493	0	0	917	40	0.3	53	1,011	90.7%	0.0%	0.0%	4.0%	96.0%	4.0%
1025	Cannon Creek	16.4	281	1	0	0	282	683	5.0	16	986	28.6%	0.0%	0.0%	69.3%	30.2%	69.8%
1028	Powers Creek	20.8	397	0	0	147	544	358	5.8	45	953	41.7%	0.0%	15.4%	37.6%	46.4%	53.6%
1031	Showers Creek2	5.2	289	55	0	0	344	387	9.1	19	759	45.3%	0.0%	0.0%	51.0%	47.8%	52.2%
1036	Hetten Creek	10.7	300	344	0	0	644	111	0.3	0	755	85.3%	0.0%	0.0%	14.6%	85.3%	14.7%
1029	Lindsay Creek	17.7	177	0	0	0	177	440	8.6	23	648	27.3%	0.0%	0.0%	67.8%	30.9%	69.1%
1033	Tompkins Creek West	4.9	64	94	0	0	158	214	1.2	133	507	31.2%	0.0%	0.0%	42.3%	57.5%	42.5%
1022	Maple Creek	15.6	100	22	0	0	122	348	2.7	33	506	24.1%	0.0%	0.0%	68.8%	30.6%	69.4%
1035	Hetten Creek West	11.9	211	0	0	0	211	156	0.7	11	379	55.7%	0.0%	0.0%	41.2%	58.6%	41.4%
1007	Deep Hollow Creek West	4.6	69	0	0	0	69	137	1.4	120	327	21.1%	0.0%	0.0%	41.8%	57.8%	42.2%
1004	Barry Creek	10.2	133	0	0	0	133	44	1.0	28	206	64.5%	0.0%	0.0%	21.4%	78.1%	21.9%
1002	Lost Creek	26.1	70	52	0	4	126	26	0.7	24	177	69.0%	0.0%	2.2%	14.8%	82.6%	17.4%
1003	South Fork Mad River	15.9	43	0	0	0	43	19	0.5	65	127	33.8%	0.0%	0.0%	14.6%	85.0%	15.0%
1001	Mud River	13.2	50	0	0	0	50	18	0.5	29	98	51.1%	0.0%	0.0%	18.7%	80.8%	19.2%

Prepared for:

TETRA TECH, Inc.

MAD RIVER SEDIMENT SOURCE ANALYSIS

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TABLE

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MAD RIVER SEDIMENT SOURCE ANALYSIS

UNIT SEDIMENT DELIVERY BY TYPE BY SUB-WATERSHED RANKED BY PERCENT MANAGEMENT RELATED

			Landslide Related Erosion					Surface Erosion		Bank Erosion	Total	Percentage of Total Unit Sediment Delivery					
BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Creep from Deep-Seated Features (tons/mi2/yr)	Background Landslides (tons/mi2/yr)	Road Related Landslides (tons/mi2/yr)	Timber Harvest Related Landslides (tons/mi2/yr)	Total Landslide Related Sediment Delivery (tons/mi2/yr)	Road Sediment Delivery (tons/mi2/year)	Harvest Sediment Delivery (tons/mi2/year)	Bank Erosion (tons/mi2/year)	Grand Total (tons/mi2/year)	Background Landslide + Creep as % of Total	Road Related Landslide as % of Total	Timber Harvest Related Landslide as % of Total	Road Surface Erosion as % of Total	Background (Landslide + Creep + Bank Erosion) as % of Total	Management Related Sources as % of Total
1032	Bear Creek2	4.1	97	0	7,964	0	8,061	357	4.8	19	8,442	1.1%	94.3%	0.0%	4.2%	1.4%	98.6%
1026	Dry Creek	7	246	0	4,076	500	4,822	316	4.6	28	5,171	4.8%	78.8%	9.7%	6.1%	5.3%	94.7%
1024	Devil Creek	19	188	0	1,759	149	2,096	327	4.3	37	2,464	7.6%	71.4%	6.1%	13.3%	9.1%	90.9%
1013	Showers Creek	2.7	547	816	9,235	0	10,598	248	3.0	6	10,855	12.6%	85.1%	0.0%	2.3%	12.6%	87.4%
1019	Goodman Prairie Creek	10	775	951	8,297	0	10,023	266	0.5	16	10,306	16.7%	80.5%	0.0%	2.6%	16.9%	83.1%
1034	Tompkins Creek	8.9	378	472	3,175	0	4,025	26	0.3	12	4,064	20.9%	78.1%	0.0%	0.6%	21.2%	78.8%
1008	Bear Creek	8.1	461	286	2,607	0	3,354	317	2.3	48	3,722	20.1%	70.1%	0.0%	8.5%	21.4%	78.6%
1016	Morgan Creek	8.7	741	1,152	6,494	130	8,517	333	0.5	17	8,867	21.3%	73.2%	1.5%	3.8%	21.5%	78.5%
1017	Wilson Creek	9.4	750	174	2,818	0	3,742	235	0.8	15	3,992	23.1%	70.6%	0.0%	5.9%	23.5%	76.5%
1038	Olsen Creek	12.8	406	704	2,407	362	3,879	88	1.3	6	3,974	27.9%	60.6%	9.1%	2.2%	28.1%	71.9%
1025	Cannon Creek	16.4	281	1	0	0	282	683	5.0	16	986	28.6%	0.0%	0.0%	69.3%	30.2%	69.8%
1022	Maple Creek	15.6	100	22	0	0	122	348	2.7	33	506	24.1%	0.0%	0.0%	68.8%	30.6%	69.4%
1029	Lindsay Creek	17.7	177	0	0	0	177	440	8.6	23	648	27.3%	0.0%	0.0%	67.8%	30.9%	69.1%
1027	North Fork Mad River	48.8	302	9	62	0	373	653	3.3	13	1,042	29.8%	5.9%	0.0%	62.6%	31.1%	68.9%
1012	Olmstead Creek	11.3	575	61	1,093	0	1,729	250	3.7	8	1,991	31.9%	54.9%	0.0%	12.6%	32.3%	67.7%
1005	Armstrong Creek	9.9	79	0	230	12	321	92	1.2	91	506	15.6%	45.5%	2.4%	18.3%	33.6%	66.4%
1018	Graham Creek	13.1	711	1,191	3,378	0	5,280	278	2.7	17	5,578	34.1%	60.6%	0.0%	5.0%	34.4%	65.6%
1011	Holm Creek	8	641	3,402	7,136	0	11,179	41	0.4	21	11,242	36.0%	63.5%	0.0%	0.4%	36.2%	63.8%
1014	Deer Creek	6.9	653	3,010	5,813	0	9,476	190	4.5	8	9,678	37.9%	60.1%	0.0%	2.0%	37.9%	62.1%
1021	Barry Ridge	9.1	501	777	1,771	0	3,049	266	5.2	29	3,349	38.2%	52.9%	0.0%	7.9%	39.0%	61.0%
1006	Deep Hollow Creek	4.1	284	23	413	0	720	18	0.4	14	752	40.8%	54.9%	0.0%	2.4%	42.7%	57.3%
1015	Bug Creek	9.7	363	3,543	5,193	0	9,099	73	0.5	31	9,204	42.4%	56.4%	0.0%	0.8%	42.8%	57.2%
1028	Powers Creek	20.8	397	0	0	147	544	358	5.8	45	953	41.7%	0.0%	15.4%	37.6%	46.4%	53.6%
1031	Showers Creek2	5.2	289	55	0	0	344	387	9.1	19	759	45.3%	0.0%	0.0%	51.0%	47.8%	52.2%
1020	Boulder Creek	19	176	1,963	1,345	142	3,626	211	0.3	20	3,857	55.5%	34.9%	3.7%	5.5%	56.0%	44.0%
1033	Tompkins Creek West	4.9	64	94	0	0	158	214	1.2	133	507	31.2%	0.0%	0.0%	42.3%	57.5%	42.5%
1007	Deep Hollow Creek West	4.6	69	0	0	0	69	137	1.4	120	327	21.1%	0.0%	0.0%	41.8%	57.8%	42.2%
1035	Hetten Creek West	11.9	211	0	0	0	211	156	0.7	11	379	55.7%	0.0%	0.0%	41.2%	58.6%	41.4%
1023	Blue Slide Creek	6.1	260	0	3	0	263	157	1.1	44	465	56.0%	0.6%	0.0%	33.7%	65.4%	34.6%
1030	Deer Creek2	7.1	183	0	68	0	251	31	0.5	18	301	60.8%	22.7%	0.0%	10.3%	66.8%	33.2%
1010	Hastings Creek	11.1	634	423	354	0	1,411	106	0.5	1	1,518	69.6%	23.3%	0.0%	7.0%	69.7%	30.3%
1004	Barry Creek	10.2	133	0	0	0	133	44	1.0	28	206	64.5%	0.0%	0.0%	21.4%	78.1%	21.9%
1001	Mud River	13.2	50	0	0	0	50	18	0.5	29	98	51.1%	0.0%	0.0%	18.7%	80.8%	19.2%
1002	Lost Creek	26.1	70	52	0	4	126	26	0.7	24	177	69.0%	0.0%	2.2%	14.8%	82.6%	17.4%
1003	South Fork Mad River	15.9	43	0	0	0	43	19	0.5	65	127	33.8%	0.0%	0.0%	14.6%	85.0%	15.0%
1036	Hetten Creek	10.7	300	344	0	0	644	111	0.3	0	755	85.3%	0.0%	0.0%	14.6%	85.3%	14.7%
1037	Olsen Creek West	9.1	424	493	0	0	917	40	0.3	53	1,011	90.7%	0.0%	0.0%	4.0%	96.0%	4.0%
1009	Pilot Creek	39.7	300	1,636	0	2	1,938	74	1.0	17	2,031	95.3%	0.0%	0.1%	3.7%	96.2%	3.8%
1039	Hastings Creek West	3.2	651	615	0	0	1,266	28	0.5	48	1,342	94.3%	0.0%	0.0%	2.1%	97.9%	2.1%

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TABLE

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MAD RIVER SEDIMENT SOURCE ANALYSIS
UNIT SEDIMENT DELIVERY BY TYPE BY SUB-WATERSHED RANKED BY SURFACE EROSION FROM ROADS

			Landslide Related Erosion					Surface Erosion		Bank Erosion	Total	Percentage of Total Unit Sediment Delivery					
BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Creep from Deep-Seated Features (tons/mi2/yr)	Background Landslides (tons/mi2/yr)	Road Related Landslides (tons/mi2/yr)	Timber Harvest Related Landslides (tons/mi2/yr)	Total Landslide Related Sediment Delivery (tons/mi2/yr)	Road Sediment Delivery (tons/mi2/year)	Harvest Sediment Delivery (tons/mi2/year)	Bank Erosion (tons/mi2/year)	Grand Total (tons/mi2/year)	Background Landslide + Creep as % of Total	Road Related Landslide as % of Total	Timber Harvest Related Landslide as % of Total	Road Surface Erosion as % of Total	Background (Landslide + Creep + Bank Erosion) as % of Total	Management Related Sources as % of Total
1025	Cannon Creek	16.4	281	1	0	0	282	683	5.0	16	986	28.6%	0.0%	0.0%	69.3%	30.2%	69.8%
1027	North Fork Mad River	48.8	302	9	62	0	373	653	3.3	13	1,042	29.8%	5.9%	0.0%	62.6%	31.1%	68.9%
1029	Lindsay Creek	17.7	177	0	0	0	177	440	8.6	23	648	27.3%	0.0%	0.0%	67.8%	30.9%	69.1%
1031	Showers Creek2	5.2	289	55	0	0	344	387	9.1	19	759	45.3%	0.0%	0.0%	51.0%	47.8%	52.2%
1028	Powers Creek	20.8	397	0	0	147	544	358	5.8	45	953	41.7%	0.0%	15.4%	37.6%	46.4%	53.6%
1032	Bear Creek2	4.1	97	0	7,964	0	8,061	357	4.8	19	8,442	1.1%	94.3%	0.0%	4.2%	1.4%	98.6%
1022	Maple Creek	15.6	100	22	0	0	122	348	2.7	33	506	24.1%	0.0%	0.0%	68.8%	30.6%	69.4%
1016	Morgan Creek	8.7	741	1,152	6,494	130	8,517	333	0.5	17	8,867	21.3%	73.2%	1.5%	3.8%	21.5%	78.5%
1024	Devil Creek	19	188	0	1,759	149	2,096	327	4.3	37	2,464	7.6%	71.4%	6.1%	13.3%	9.1%	90.9%
1008	Bear Creek	8.1	461	286	2,607	0	3,354	317	2.3	48	3,722	20.1%	70.1%	0.0%	8.5%	21.4%	78.6%
1026	Dry Creek	7	246	0	4,076	500	4,822	316	4.6	28	5,171	4.8%	78.8%	9.7%	6.1%	5.3%	94.7%
1018	Graham Creek	13.1	711	1,191	3,378	0	5,280	278	2.7	17	5,578	34.1%	60.6%	0.0%	5.0%	34.4%	65.6%
1019	Goodman Prairie Creek	10	775	951	8,297	0	10,023	266	0.5	16	10,306	16.7%	80.5%	0.0%	2.6%	16.9%	83.1%
1021	Barry Ridge	9.1	501	777	1,771	0	3,049	266	5.2	29	3,349	38.2%	52.9%	0.0%	7.9%	39.0%	61.0%
1012	Olmstead Creek	11.3	575	61	1,093	0	1,729	250	3.7	8	1,991	31.9%	54.9%	0.0%	12.6%	32.3%	67.7%
1013	Showers Creek	2.7	547	816	9,235	0	10,598	248	3.0	6	10,855	12.6%	85.1%	0.0%	2.3%	12.6%	87.4%
1017	Wilson Creek	9.4	750	174	2,818	0	3,742	235	0.8	15	3,992	23.1%	70.6%	0.0%	5.9%	23.5%	76.5%
1033	Tompkins Creek West	4.9	64	94	0	0	158	214	1.2	133	507	31.2%	0.0%	0.0%	42.3%	57.5%	42.5%
1020	Boulder Creek	19	176	1,963	1,345	142	3,626	211	0.3	20	3,857	55.5%	34.9%	3.7%	5.5%	56.0%	44.0%
1014	Deer Creek	6.9	653	3,010	5,813	0	9,476	190	4.5	8	9,678	37.9%	60.1%	0.0%	2.0%	37.9%	62.1%
1023	Blue Slide Creek	6.1	260	0	3	0	263	157	1.1	44	465	56.0%	0.6%	0.0%	33.7%	65.4%	34.6%
1035	Hetten Creek West	11.9	211	0	0	0	211	156	0.7	11	379	55.7%	0.0%	0.0%	41.2%	58.6%	41.4%
1007	Deep Hollow Creek West	4.6	69	0	0	0	69	137	1.4	120	327	21.1%	0.0%	0.0%	41.8%	57.8%	42.2%
1036	Hetten Creek	10.7	300	344	0	0	644	111	0.3	0	755	85.3%	0.0%	0.0%	14.6%	85.3%	14.7%
1010	Hastings Creek	11.1	634	423	354	0	1,411	106	0.5	1	1,518	69.6%	23.3%	0.0%	7.0%	69.7%	30.3%
1005	Armstrong Creek	9.9	79	0	230	12	321	92	1.2	91	506	15.6%	45.5%	2.4%	18.3%	33.6%	66.4%
1038	Olsen Creek	12.8	406	704	2,407	362	3,879	88	1.3	6	3,974	27.9%	60.6%	9.1%	2.2%	28.1%	71.9%
1009	Pilot Creek	39.7	300	1,636	0	2	1,938	74	1.0	17	2,031	95.3%	0.0%	0.1%	3.7%	96.2%	3.8%
1015	Bug Creek	9.7	363	3,543	5,193	0	9,099	73	0.5	31	9,204	42.4%	56.4%	0.0%	0.8%	42.8%	57.2%
1004	Barry Creek	10.2	133	0	0	0	133	44	1.0	28	206	64.5%	0.0%	0.0%	21.4%	78.1%	21.9%
1011	Holm Creek	8	641	3,402	7,136	0	11,179	41	0.4	21	11,242	36.0%	63.5%	0.0%	0.4%	36.2%	63.8%
1037	Olsen Creek West	9.1	424	493	0	0	917	40	0.3	53	1,011	90.7%	0.0%	0.0%	4.0%	96.0%	4.0%
1030	Deer Creek2	7.1	183	0	68	0	251	31	0.5	18	301	60.8%	22.7%	0.0%	10.3%	66.8%	33.2%
1039	Hastings Creek West	3.2	651	615	0	0	1,266	28	0.5	48	1,342	94.3%	0.0%	0.0%	2.1%	97.9%	2.1%
1034	Tompkins Creek	8.9	378	472	3,175	0	4,025	26	0.3	12	4,064	20.9%	78.1%	0.0%	0.6%	21.2%	78.8%
1002	Lost Creek	26.1	70	52	0	4	126	26	0.7	24	177	69.0%	0.0%	2.2%	14.8%	82.6%	17.4%
1003	South Fork Mad River	15.9	43	0	0	0	43	19	0.5	65	127	33.8%	0.0%	0.0%	14.6%	85.0%	15.0%
1001	Mud River	13.2	50	0	0	0	50	18	0.5	29	98	51.1%	0.0%	0.0%	18.7%	80.8%	19.2%
1006	Deep Hollow Creek	4.1	284	23	413	0	720	18	0.4	14	752	40.8%	54.9%	0.0%	2.4%	42.7%	57.3%

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TABLE

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MAD RIVER SEDIMENT SOURCE ANALYSIS
UNIT SEDIMENT DELIVERY BY TYPE BY SUB-WATERSHED DIVIDED INTO REACHES CREATED BY MONITORING SITES

			Landslide Related Erosion					Surface Erosion		Bank Erosion	Total	Percentage of Total Unit Sediment Delivery					
BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Creep from Deep-Seated Features (tons/mi2/yr)	Background Landslides (tons/mi2/yr)	Road Related Landslides (tons/mi2/yr)	Timber Harvest Related Landslides (tons/mi2/yr)	Total Landslide Related Sediment Delivery (tons/mi2/yr)	Road Sediment Delivery (tons/mi2/year)	Harvest Sediment Delivery (tons/mi2/year)	Bank Erosion (tons/mi2/year)	Grand Total (tons/mi2/year)	Background Landslide and Creep as % of Total	Road Related Landslide as % of Total	Timber Harvest Related Landslide as % of Total	Road Surface Erosion as % of Total	Background (Landslide + Creep + Bank Erosion) as % of Total	Management Related Sources as % of Total
BASINS ABOVE MRRTH																	
1001	Mud River	13.2	50	0	0	0	50	18	0.5	29	98	51.1%	0.0%	0.0%	18.7%	80.8%	19.2%
1002	Lost Creek	26.1	70	52	0	4	126	26	0.7	24	177	69.0%	0.0%	2.2%	14.8%	82.6%	17.4%
1003	South Fork Mad River	15.9	43	0	0	0	43	19	0.5	65	127	33.8%	0.0%	0.0%	14.6%	85.0%	15.0%
1004	Barry Creek	10.2	133	0	0	0	133	44	1.0	28	206	64.5%	0.0%	0.0%	21.4%	78.1%	21.9%
1005	Armstrong Creek	9.9	79	0	230	12	321	92	1.2	91	506	15.6%	45.5%	2.4%	18.3%	33.6%	66.4%
1006	Deep Hollow Creek	4.1	284	23	413	0	720	18	0.4	14	752	40.8%	54.9%	0.0%	2.4%	42.7%	57.3%
1007	Deep Hollow Creek West	4.6	69	0	0	0	69	137	1.4	120	327	21.1%	0.0%	0.0%	41.8%	57.8%	42.2%
BASINS BETWEEN MRRTH AND MRBVR																	
1008	Bear Creek	8.1	461	286	2,607	0	3,354	317	2.3	48	3722	20.1%	70.1%	0.0%	8.5%	21.4%	78.6%
1009	Pilot Creek	39.7	300	1636	0	2	1938	74	1.0	17	2031	95.3%	0.0%	0.1%	3.7%	96.2%	3.8%
1010	Hastings Creek	11.1	634	423	354	0	1411	106	0.5	1	1518	69.6%	23.3%	0.0%	7.0%	69.7%	30.3%
1011	Holm Creek	8	641	3,402	7136	0	11179	41	0.4	21	11242	36.0%	63.5%	0.0%	0.4%	36.2%	63.8%
1012	Olmstead Creek	11.3	575	61	1093	0	1729	250	3.7	8	1991	31.9%	54.9%	0.0%	12.6%	32.3%	67.7%
1013	Showers Creek	2.7	547	816	9235	0	10598	248	3.0	6	10855	12.6%	85.1%	0.0%	2.3%	12.6%	87.4%
1014	Deer Creek	6.9	653	3,010	5813	0	9476	190	4.5	8	9678	37.9%	60.1%	0.0%	2.0%	37.9%	62.1%
1015	Bug Creek	9.7	363	3,543	5193	0	9099	73	0.5	31	9204	42.4%	56.4%	0.0%	0.8%	42.8%	57.2%
1016	Morgan Creek	8.7	741	1152	6494	130	8517	333	0.5	17	8867	21.3%	73.2%	1.5%	3.8%	21.5%	78.5%
1017	Wilson Creek	9.4	750	174	2818	0	3742	235	0.8	15	3992	23.1%	70.6%	0.0%	5.9%	23.5%	76.5%
1018	Graham Creek	13.1	711	1191	3378	0	5280	278	2.7	17	5578	34.1%	60.6%	0.0%	5.0%	34.4%	65.6%
1019	Goodman Prairie Creek	10	775	951	8297	0	10023	266	0.5	16	10306	16.7%	80.5%	0.0%	2.6%	16.9%	83.1%
1020	Boulder Creek	19	176	1,963	1345	142	3626	211	0.3	20	3857	55.5%	34.9%	3.7%	5.5%	56.0%	44.0%
1021	Barry Ridge	9.1	501	777	1771	0	3049	266	5.2	29	3349	38.2%	52.9%	0.0%	7.9%	39.0%	61.0%
1022	Maple Creek	15.6	100	22	0	0	122	348	2.7	33	506	24.1%	0.0%	0.0%	68.8%	30.6%	69.4%
1023	Blue Slide Creek	6.1	260	0	3	0	263	157	1.1	44	465	56.0%	0.6%	0.0%	33.7%	65.4%	34.6%
1030	Deer Creek2	7.1	183	0	68	0	251	31	0.5	18	301	60.8%	22.7%	0.0%	10.3%	66.8%	33.2%
1031	Showers Creek2	5.2	289	55	0	0	344	387	9.1	19	759	45.3%	0.0%	0.0%	51.0%	47.8%	52.2%
1032	Bear Creek2	4.1	97	0	7964	0	8061	357	4.8	19	8442	1.1%	94.3%	0.0%	4.2%	1.4%	98.6%
1033	Tompkins Creek West	4.9	64	94	0	0	158	214	1.2	133	507	31.2%	0.0%	0.0%	42.3%	57.5%	42.5%
1034	Tompkins Creek	8.9	378	472	3175	0	4025	26	0.3	12	4064	20.9%	78.1%	0.0%	0.6%	21.2%	78.8%
1035	Hetten Creek West	11.9	211	0	0	0	211	156	0.7	11	379	55.7%	0.0%	0.0%	41.2%	58.6%	41.4%
1036	Hetten Creek	10.7	300	344	0	0	644	111	0.3	0	755	85.3%	0.0%	0.0%	14.6%	85.3%	14.7%
1037	Olsen Creek West	9.1	424	493	0	0	917	40	0.3	53	1011	90.7%	0.0%	0.0%	4.0%	96.0%	4.0%
1038	Olsen Creek	12.8	406	704	2407	362	3879	88	1.3	6	3974	27.9%	60.6%	9.1%	2.2%	28.1%	71.9%
1039	Hastings Creek West	3.2	651	615	0	0	1266	28	0.5	48	1342	94.3%	0.0%	0.0%	2.1%	97.9%	2.1%
BASINS BETWEEN MRBVR AND MRALM																	
1024	Devil Creek	19	188	0	1759	149	2096	327	4.3	37	2464	7.6%	71.4%	6.1%	13.3%	9.1%	90.9%
1025	Cannon Creek	16.4	281	1	0	0	282	683	5.0	16	986	28.6%	0.0%	0.0%	69.3%	30.2%	69.8%
1026	Dry Creek	7	246	0	4076	500	4822	316	4.6	28	5171	4.8%	78.8%	9.7%	6.1%	5.3%	94.7%
1027	North Fork Mad River	48.8	302	9	62	0	373	653	3.3	13	1042	29.8%	5.9%	0.0%	62.6%	31.1%	68.9%
1028	Powers Creek	20.8	397	0	0	147	544	358	5.8	45	953	41.7%	0.0%	15.4%	37.6%	46.4%	53.6%
1029	Lindsay Creek	17.7	177	0	0	0	177	440	8.6	23	648	27.3%	0.0%	0.0%	67.8%	30.9%	69.1%

Prepared for:

TETRA TECH, Inc.

MAD RIVER SEDIMENT SOURCE ANALYSIS

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TABLE

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MAD RIVER SEDIMENT SOURCE ANALYSIS

SEDIMENT DELIVERY IN TONS/YEAR BY TYPE BY SUB-WATERSHED RANKED BY TOTAL

			Landslide Related Erosion					Surface Erosion		Bank Erosion	Total	Percentage of Total Sediment Delivery				
BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Creep from Deep-Seated Features (tons/yr)	Background Landslides (tons/yr)	Road Related Landslides (tons/yr)	Timber Harvest Related Landslides (tons/yr)	Total Landslide Related Sediment Delivery (tons/yr)	Road Sediment Delivery (tons/year)	Harvest Sediment Delivery (tons/year)	Bank Erosion (tons/year)	Grand Total (tons/year)	Background Landslide as % of Total	Road Related Landslide as % of Total	Timber Harvest Related Landslide as % of Total	Road Surface Erosion as % of Total	Bank Erosion as % of Total
1019	Goodman Prairie Creek	10	7,750	9,510	82,974	0	100,234	2,663	5	160	103,062	16.7%	80.5%	0.0%	2.6%	0.2%
1011	Holm Creek	8	5,128	27,216	57,090	0	89,434	330	3	168	89,935	36.0%	63.5%	0.0%	0.4%	0.2%
1015	Bug Creek	9.7	3,521	34,367	50,376	0	88,264	706	5	301	89,276	42.4%	56.4%	0.0%	0.8%	0.3%
1009	Pilot Creek	39.7	11,910	64,949	0	80	76,940	2,957	41	675	80,613	95.3%	0.0%	0.1%	3.7%	0.8%
1016	Morgan Creek	8.7	6,447	10,022	56,498	1,130	74,097	2,897	4	148	77,146	21.3%	73.2%	1.5%	3.8%	0.2%
1020	Boulder Creek	19	3,344	37,297	25,561	2,694	68,895	4,006	7	380	73,288	55.5%	34.9%	3.7%	5.5%	0.5%
1018	Graham Creek	13.1	9,314	15,602	44,248	0	69,164	3,646	35	223	73,068	34.1%	60.6%	0.0%	5.0%	0.3%
1014	Deer Creek	6.9	4,506	20,769	40,107	0	65,382	1,308	31	55	66,775	37.9%	60.1%	0.0%	2.0%	0.1%
1038	Olsen Creek	12.8	5,197	9,011	30,810	4,627	49,645	1,130	17	77	50,869	27.9%	60.6%	9.1%	2.2%	0.2%
1027	North Fork Mad River	48.8	14,738	439	3,022	9	18,208	31,845	160	634	50,847	29.8%	5.9%	0.0%	62.6%	1.2%
1024	Devil Creek	19	3,572	0	33,413	2,838	39,824	6,204	81	703	46,813	7.6%	71.4%	6.1%	13.3%	1.5%
1017	Wilson Creek	9.4	7,050	1,636	26,487	0	35,172	2,205	7	141	37,525	23.1%	70.6%	0.0%	5.9%	0.4%
1026	Dry Creek	7	1,722	0	28,531	3,503	33,756	2,212	32	196	36,196	4.8%	78.8%	9.7%	6.1%	0.5%
1034	Tompkins Creek	8.9	3,364	4,201	28,258	0	35,823	233	3	107	36,166	20.9%	78.1%	0.0%	0.6%	0.3%
1032	Bear Creek2	4.1	398	0	32,653	0	33,050	1,463	20	78	34,611	1.1%	94.3%	0.0%	4.2%	0.2%
1021	Barry Ridge	9.1	4,559	7,071	16,113	0	27,743	2,419	48	264	30,474	38.2%	52.9%	0.0%	7.9%	0.9%
1008	Bear Creek	8.1	3,734	2,317	21,119	0	27,170	2,567	19	389	30,144	20.1%	70.1%	0.0%	8.5%	1.3%
1013	Showers Creek	2.7	1,477	2,203	24,933	0	28,613	670	8	16	29,308	12.6%	85.1%	0.0%	2.3%	0.1%
1012	Olmstead Creek	11.3	6,498	689	12,348	0	19,535	2,830	42	90	22,497	31.9%	54.9%	0.0%	12.6%	0.4%
1028	Powers Creek	20.8	8,258	0	0	3,049	11,307	7,450	121	936	19,814	41.7%	0.0%	15.4%	37.6%	4.7%
1010	Hastings Creek	11.1	7,037	4,695	3,927	0	15,660	1,178	6	11	16,854	69.6%	23.3%	0.0%	7.0%	0.1%
1025	Cannon Creek	16.4	4,608	16	0	0	4,625	11,204	82	262	16,173	28.6%	0.0%	0.0%	69.3%	1.6%
1029	Lindsay Creek	17.7	3,133	0	0	0	3,133	7,781	152	407	11,474	27.3%	0.0%	0.0%	67.8%	3.5%
1037	Olsen Creek West	9.1	3,858	4,486	0	0	8,345	368	3	482	9,197	90.7%	0.0%	0.0%	4.0%	5.2%
1036	Hetten Creek	10.7	3,210	3,681	0	0	6,891	1,183	3	0	8,077	85.3%	0.0%	0.0%	14.6%	0.0%
1022	Maple Creek	15.6	1,560	343	0	0	1,903	5,433	42	515	7,893	24.1%	0.0%	0.0%	68.8%	6.5%
1005	Armstrong Creek	9.9	782	0	2,281	119	3,182	915	12	901	5,009	15.6%	45.5%	2.4%	18.3%	18.0%
1002	Lost Creek	26.1	1,827	1,357	0	103	3,287	684	18	626	4,615	69.0%	0.0%	2.2%	14.8%	13.6%
1035	Hetten Creek West	11.9	2,511	0	0	0	2,511	1,857	8	131	4,508	55.7%	0.0%	0.0%	41.2%	2.9%
1039	Hastings Creek West	3.2	2,083	1,968	0	0	4,051	89	2	154	4,295	94.3%	0.0%	0.0%	2.1%	3.6%
1031	Showers Creek2	5.2	1,503	286	0	0	1,789	2,014	47	99	3,949	45.3%	0.0%	0.0%	51.0%	2.5%
1006	Deep Hollow Creek	4.1	1,164	94	1,692	0	2,951	75	2	57	3,085	40.8%	54.9%	0.0%	2.4%	1.9%
1023	Blue Slide Creek	6.1	1,586	0	17	0	1,603	956	6	268	2,834	56.0%	0.6%	0.0%	33.7%	9.5%
1033	Tompkins Creek West	4.9	314	461	0	0	774	1,050	6	652	2,482	31.2%	0.0%	0.0%	42.3%	26.3%
1030	Deer Creek2	7.1	1,299	0	484	0	1,783	221	3	128	2,135	60.8%	22.7%	0.0%	10.3%	6.0%
1004	Barry Creek	10.2	1,357	0	0	0	1,357	451	10	286	2,104	64.5%	0.0%	0.0%	21.4%	13.6%
1003	South Fork Mad River	15.9	684	0	0	0	684	296	8	1,034	2,021	33.8%	0.0%	0.0%	14.6%	51.1%
1007	Deep Hollow Creek West	4.6	317	0	0	0	317	629	6	552	1,504	21.1%	0.0%	0.0%	41.8%	36.7%
1001	Mud River	13.2	660	0	0	0	660	241	6	383	1,291	51.1%	0.0%	0.0%	18.7%	29.7%
	TOTALS:	**480.1**	**151,979**	**264,688**	**622,941**	**18,153**	**1,057,761**	**116,366**	**1,113**	**12,688**	**1,187,928**					
	PERCENT OF TOTAL						**89.0%**	**9.8%**	**0.1%**	**1.1%**	**100.0%**					

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TETRA TECH, Inc.

MAD RIVER SEDIMENT SOURCE ANALYSIS

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TABLE

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MAD RIVER SEDIMENT SOURCE ANALYSIS

SEDIMENT DELIVERY IN TONS/YEAR BY TYPE BY SUB-WATERSHED RANKED BY TOTAL AND HIGHLIGHTED BY MONITORING REACH

			Landslide Related Erosion					Surface Erosion		Bank Erosion	Total	Percentage of Total Sediment Delivery				
BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Creep from Deep-Seated Features (tons/yr)	Background Landslides (tons/yr)	Road Related Landslides (tons/yr)	Timber Harvest Related Landslides (tons/yr)	Total Landslide Related Sediment Delivery (tons/yr)	Road Sediment Delivery (tons/year)	Harvest Sediment Delivery (tons/year)	Bank Erosion (tons/year)	Grand Total (tons/year)	Background Landslide as % of Total	Road Related Landslide as % of Total	Timber Harvest Related Landslide as % of Total	Road Surface Erosion as % of Total	Bank Erosion as % of Total
1019	Goodman Prairie Creek	10	7,750	9,510	82,974	0	100,234	2,663	5	160	103,062	16.7%	80.5%	0.0%	2.6%	0.2%
1011	Holm Creek	8	5,128	27,216	57,090	0	89,434	330	3	168	89,935	36.0%	63.5%	0.0%	0.4%	0.2%
1015	Bug Creek	9.7	3,521	34,367	50,376	0	88,264	706	5	301	89,276	42.4%	56.4%	0.0%	0.8%	0.3%
1009	Pilot Creek	39.7	11,910	64,949	0	80	76,940	2,957	41	675	80,613	95.3%	0.0%	0.1%	3.7%	0.8%
1016	Morgan Creek	8.7	6,447	10,022	56,498	1,130	74,097	2,897	4	148	77,146	21.3%	73.2%	1.5%	3.8%	0.2%
1020	Boulder Creek	19	3,344	37,297	25,561	2,694	68,895	4,006	7	380	73,288	55.5%	34.9%	3.7%	5.5%	0.5%
1018	Graham Creek	13.1	9,314	15,602	44,248	0	69,164	3,646	35	223	73,068	34.1%	60.6%	0.0%	5.0%	0.3%
1014	Deer Creek	6.9	4,506	20,769	40,107	0	65,382	1,308	31	55	66,775	37.9%	60.1%	0.0%	2.0%	0.1%
1038	Olsen Creek	12.8	5,197	9,011	30,810	4,627	49,645	1,130	17	77	50,869	27.9%	60.6%	9.1%	2.2%	0.2%
1027	North Fork Mad River	48.8	14,738	439	3,022	9	18,208	31,845	160	634	50,847	29.8%	5.9%	0.0%	62.6%	1.2%
1024	Devil Creek	19	3,572	0	33,413	2,838	39,824	6,204	81	703	46,813	7.6%	71.4%	6.1%	13.3%	1.5%
1017	Wilson Creek	9.4	7,050	1,636	26,487	0	35,172	2,205	7	141	37,525	23.1%	70.6%	0.0%	5.9%	0.4%
1026	Dry Creek	7	1,722	0	28,531	3,503	33,756	2,212	32	196	36,196	4.8%	78.8%	9.7%	6.1%	0.5%
1034	Tompkins Creek	8.9	3,364	4,201	28,258	0	35,823	233	3	107	36,166	20.9%	78.1%	0.0%	0.6%	0.3%
1032	Bear Creek2	4.1	398	0	32,653	0	33,050	1,463	20	78	34,611	1.1%	94.3%	0.0%	4.2%	0.2%
1021	Barry Ridge	9.1	4,559	7,071	16,113	0	27,743	2,419	48	264	30,474	38.2%	52.9%	0.0%	7.9%	0.9%
1008	Bear Creek	8.1	3,734	2,317	21,119	0	27,170	2,567	19	389	30,144	20.1%	70.1%	0.0%	8.5%	1.3%
1013	Showers Creek	2.7	1,477	2,203	24,933	0	28,613	670	8	16	29,308	12.6%	85.1%	0.0%	2.3%	0.1%
1012	Olmstead Creek	11.3	6,498	689	12,348	0	19,535	2,830	42	90	22,497	31.9%	54.9%	0.0%	12.6%	0.4%
1028	Powers Creek	20.8	8,258	0	0	3,049	11,307	7,450	121	936	19,814	41.7%	0.0%	15.4%	37.6%	4.7%
1010	Hastings Creek	11.1	7,037	4,695	3,927	0	15,660	1,178	6	11	16,854	69.6%	23.3%	0.0%	7.0%	0.1%
1025	Cannon Creek	16.4	4,608	16	0	0	4,625	11,204	82	262	16,173	28.6%	0.0%	0.0%	69.3%	1.6%
1029	Lindsay Creek	17.7	3,133	0	0	0	3,133	7,781	152	407	11,474	27.3%	0.0%	0.0%	67.8%	3.5%
1037	Olsen Creek West	9.1	3,858	4,486	0	0	8,345	368	3	482	9,197	90.7%	0.0%	0.0%	4.0%	5.2%
1036	Hetten Creek	10.7	3,210	3,681	0	0	6,891	1,183	3	0	8,077	85.3%	0.0%	0.0%	14.6%	0.0%
1022	Maple Creek	15.6	1,560	343	0	0	1,903	5,433	42	515	7,893	24.1%	0.0%	0.0%	68.8%	6.5%
1005	Armstrong Creek	9.9	782	0	2,281	119	3,182	915	12	901	5,009	15.6%	45.5%	2.4%	18.3%	18.0%
1002	Lost Creek	26.1	1,827	1,357	0	103	3,287	684	18	626	4,615	69.0%	0.0%	2.2%	14.8%	13.6%
1035	Hetten Creek West	11.9	2,511	0	0	0	2,511	1,857	8	131	4,508	55.7%	0.0%	0.0%	41.2%	2.9%
1039	Hastings Creek West	3.2	2,083	1,968	0	0	4,051	89	2	154	4,295	94.3%	0.0%	0.0%	2.1%	3.6%
1031	Showers Creek2	5.2	1,503	286	0	0	1,789	2,014	47	99	3,949	45.3%	0.0%	0.0%	51.0%	2.5%
1006	Deep Hollow Creek	4.1	1,164	94	1,692	0	2,951	75	2	57	3,085	40.8%	54.9%	0.0%	2.4%	1.9%
1023	Blue Slide Creek	6.1	1,586	0	17	0	1,603	956	6	268	2,834	56.0%	0.6%	0.0%	33.7%	9.5%
1033	Tompkins Creek West	4.9	314	461	0	0	774	1,050	6	652	2,482	31.2%	0.0%	0.0%	42.3%	26.3%
1030	Deer Creek2	7.1	1,299	0	484	0	1,783	221	3	128	2,135	60.8%	22.7%	0.0%	10.3%	6.0%
1004	Barry Creek	10.2	1,357	0	0	0	1,357	451	10	286	2,104	64.5%	0.0%	0.0%	21.4%	13.6%
1003	South Fork Mad River	15.9	684	0	0	0	684	296	8	1,034	2,021	33.8%	0.0%	0.0%	14.6%	51.1%
1007	Deep Hollow Creek West	4.6	317	0	0	0	317	629	6	552	1,504	21.1%	0.0%	0.0%	41.8%	36.7%
1001	Mud River	13.2	660	0	0	0	660	241	6	383	1,291	51.1%	0.0%	0.0%	18.7%	29.7%
	TOTALS:	**480.1**	**151,979**	**264,688**	**622,941**	**18,153**	**1,057,761**	**116,366**	**1,113**	**12,688**	**1,187,928**					
	PERCENT OF TOTAL						**89.0%**	**9.8%**	**0.1%**	**1.1%**	**100.0%**					

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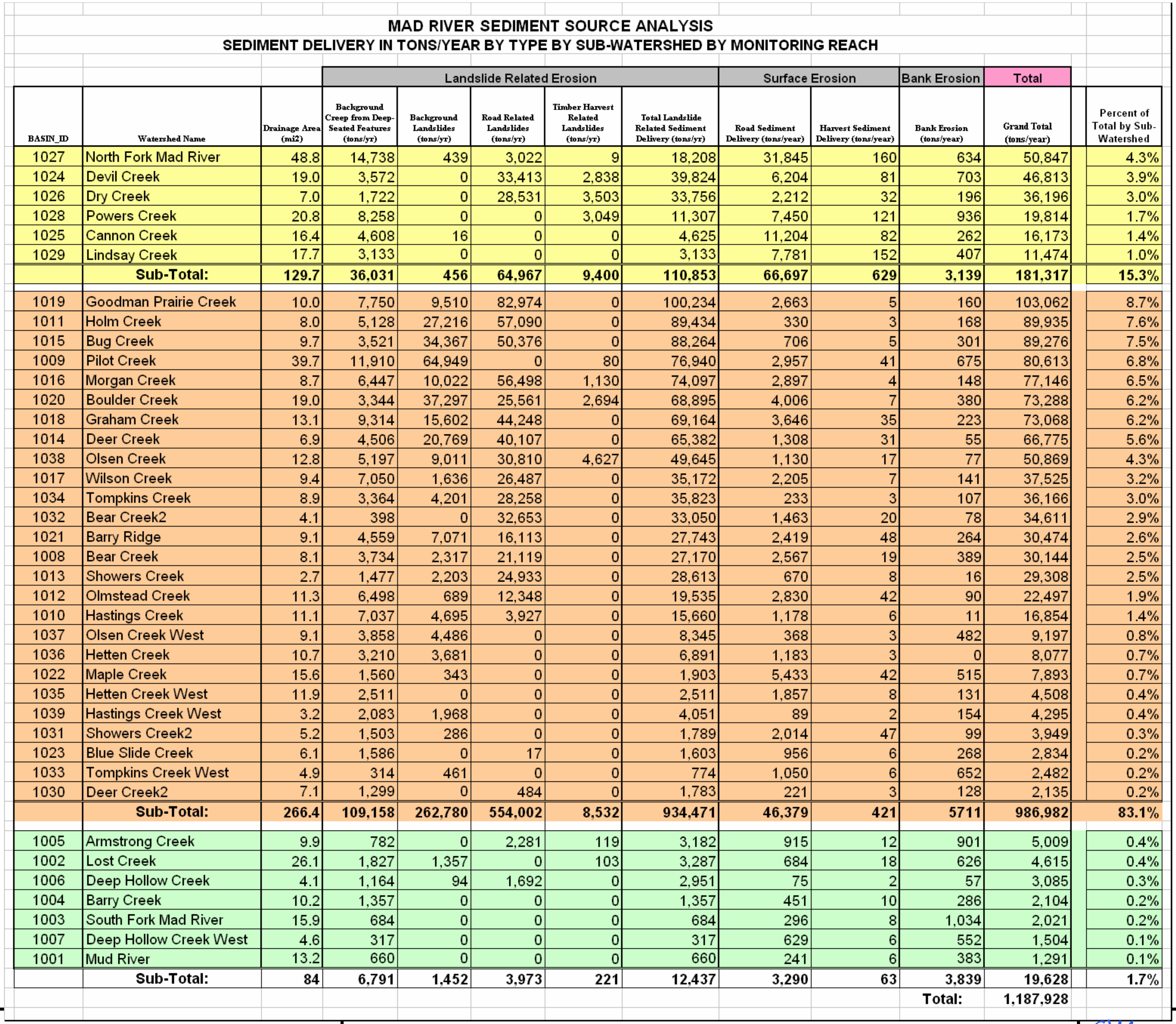

MAD RIVER SEDIMENT SOURCE ANALYSIS

SEDIMENT DELIVERY IN TONS/YEAR BY TYPE BY SUB-WATERSHED BY MONITORING REACH

			Landslide Related Erosion					Surface Erosion		Bank Erosion	Total	
BASIN_ID	Watershed Name	Drainage Area (mi2)	Background Creep from Deep-Seated Features (tons/yr)	Background Landslides (tons/yr)	Road Related Landslides (tons/yr)	Timber Harvest Related Landslides (tons/yr)	Total Landslide Related Sediment Delivery (tons/yr)	Road Sediment Delivery (tons/year)	Harvest Sediment Delivery (tons/year)	Bank Erosion (tons/year)	Grand Total (tons/year)	Percent of Total by Sub-Watershed
1027	North Fork Mad River	48.8	14,738	439	3,022	9	18,208	31,845	160	634	50,847	4.3%
1024	Devil Creek	19.0	3,572	0	33,413	2,838	39,824	6,204	81	703	46,813	3.9%
1026	Dry Creek	7.0	1,722	0	28,531	3,503	33,756	2,212	32	196	36,196	3.0%
1028	Powers Creek	20.8	8,258	0	0	3,049	11,307	7,450	121	936	19,814	1.7%
1025	Cannon Creek	16.4	4,608	16	0	0	4,625	11,204	82	262	16,173	1.4%
1029	Lindsay Creek	17.7	3,133	0	0	0	3,133	7,781	152	407	11,474	1.0%
	Sub-Total:	**129.7**	**36,031**	**456**	**64,967**	**9,400**	**110,853**	**66,697**	**629**	**3,139**	**181,317**	**15.3%**
1019	Goodman Prairie Creek	10.0	7,750	9,510	82,974	0	100,234	2,663	5	160	103,062	8.7%
1011	Holm Creek	8.0	5,128	27,216	57,090	0	89,434	330	3	168	89,935	7.6%
1015	Bug Creek	9.7	3,521	34,367	50,376	0	88,264	706	5	301	89,276	7.5%
1009	Pilot Creek	39.7	11,910	64,949	0	80	76,940	2,957	41	675	80,613	6.8%
1016	Morgan Creek	8.7	6,447	10,022	56,498	1,130	74,097	2,897	4	148	77,146	6.5%
1020	Boulder Creek	19.0	3,344	37,297	25,561	2,694	68,895	4,006	7	380	73,288	6.2%
1018	Graham Creek	13.1	9,314	15,602	44,248	0	69,164	3,646	35	223	73,068	6.2%
1014	Deer Creek	6.9	4,506	20,769	40,107	0	65,382	1,308	31	55	66,775	5.6%
1038	Olsen Creek	12.8	5,197	9,011	30,810	4,627	49,645	1,130	17	77	50,869	4.3%
1017	Wilson Creek	9.4	7,050	1,636	26,487	0	35,172	2,205	7	141	37,525	3.2%
1034	Tompkins Creek	8.9	3,364	4,201	28,258	0	35,823	233	3	107	36,166	3.0%
1032	Bear Creek2	4.1	398	0	32,653	0	33,050	1,463	20	78	34,611	2.9%
1021	Barry Ridge	9.1	4,559	7,071	16,113	0	27,743	2,419	48	264	30,474	2.6%
1008	Bear Creek	8.1	3,734	2,317	21,119	0	27,170	2,567	19	389	30,144	2.5%
1013	Showers Creek	2.7	1,477	2,203	24,933	0	28,613	670	8	16	29,308	2.5%
1012	Olmstead Creek	11.3	6,498	689	12,348	0	19,535	2,830	42	90	22,497	1.9%
1010	Hastings Creek	11.1	7,037	4,695	3,927	0	15,660	1,178	6	11	16,854	1.4%
1037	Olsen Creek West	9.1	3,858	4,486	0	0	8,345	368	3	482	9,197	0.8%
1036	Hetten Creek	10.7	3,210	3,681	0	0	6,891	1,183	3	0	8,077	0.7%
1022	Maple Creek	15.6	1,560	343	0	0	1,903	5,433	42	515	7,893	0.7%
1035	Hetten Creek West	11.9	2,511	0	0	0	2,511	1,857	8	131	4,508	0.4%
1039	Hastings Creek West	3.2	2,083	1,968	0	0	4,051	89	2	154	4,295	0.4%
1031	Showers Creek2	5.2	1,503	286	0	0	1,789	2,014	47	99	3,949	0.3%
1023	Blue Slide Creek	6.1	1,586	0	17	0	1,603	956	6	268	2,834	0.2%
1033	Tompkins Creek West	4.9	314	461	0	0	774	1,050	6	652	2,482	0.2%
1030	Deer Creek2	7.1	1,299	0	484	0	1,783	221	3	128	2,135	0.2%
	Sub-Total:	**266.4**	**109,158**	**262,780**	**554,002**	**8,532**	**934,471**	**46,379**	**421**	**5711**	**986,982**	**83.1%**
1005	Armstrong Creek	9.9	782	0	2,281	119	3,182	915	12	901	5,009	0.4%
1002	Lost Creek	26.1	1,827	1,357	0	103	3,287	684	18	626	4,615	0.4%
1006	Deep Hollow Creek	4.1	1,164	94	1,692	0	2,951	75	2	57	3,085	0.3%
1004	Barry Creek	10.2	1,357	0	0	0	1,357	451	10	286	2,104	0.2%
1003	South Fork Mad River	15.9	684	0	0	0	684	296	8	1,034	2,021	0.2%
1007	Deep Hollow Creek West	4.6	317	0	0	0	317	629	6	552	1,504	0.1%
1001	Mud River	13.2	660	0	0	0	660	241	6	383	1,291	0.1%
	Sub-Total:	**84**	**6,791**	**1,452**	**3,973**	**221**	**12,437**	**3,290**	**63**	**3,839**	**19,628**	**1.7%**
										Total:	**1,187,928**	

Prepared for:

TETRA TECH, Inc.

MAD RIVER SEDIMENT SOURCE ANALYSIS

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TABLE

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COMPARISON OF MEASURED SSL AND UPLAND SSA BY MONITORING REACH

SITE	WSA	2006-2007 AVG MEASURED SSL	COMPUTED SSL FOR REACH	% OF OUTPUT	NOTES	COMPARE TO RATES FROM UPLAND SSA	
	(mi2)	(tons/yr)	(tons/yr)	(%)		(tons/yr)	(%)
MRHRB	446	1,102,000		100%	Output from System	1,187,928	100%
NFMKB	44.5	14,475		1.3%		50,847	4.3%
Gain between MRBVR and MRHRB Sites			352,525	32.0%	Subtracted NFMKB to obtain reach gain	181,317	15.3%
MRBVR	352	735,000					
Gain between MRRTH and MRBVR Sites			643,600	58.4%	Adjusted for est. 20% deposit in Ruth Lake	986,982	83.1%
MRRTH	93.6	114,250		10.4%	Input from Upper Watershed	19,628	1.7%

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TABLE

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APPENDIX A

Rank	Dist Code	Percent of Total	Erosion Rate (tons/acre/year)
1	DG/1/N	0.00%	0.3
2	DG/1/P	0.00%	0.4
3	DG/2/G	0.00%	0.1
4	DG/2/N	0.01%	0.1
5	DG/2/P	0.00%	0.2
6	DG/3/G	0.01%	0.1
7	DG/3/N	0.07%	0.2
8	DG/3/P	0.02%	0.3
9	DG/4/G	0.00%	0.2
10	DG/4/N	0.01%	0.5
11	FR/1/G	0.33%	2
12	FR/1/N	1.02%	3
13	FR/1/P	0.16%	4
14	FR/2/G	0.35%	0.5
15	FR/2/N	1.88%	1
16	FR/2/P	0.45%	2
17	FR/3/G	6.93%	1
18	FR/3/N	19.50%	2
19	FR/3/P	1.74%	3
20	FR/4/G	1.74%	0.5
21	FR/4/N	3.36%	0.7
22	FR/4/P	0.17%	0.9
23	M/1/G	0.34%	30
24	M/1/N	1.36%	40
25	M/1/P	0.05%	45
26	M/2/G	0.83%	5
27	M/2/N	3.07%	10
28	M/2/P	0.16%	15
29	M/3/G	4.97%	20
30	M/3/N	31.05%	30
31	M/3/P	1.33%	35
32	M/4/G	0.35%	4
33	M/4/N	2.40%	6
34	M/4/P	0.06%	7
35	QA/1/G	0.09%	0.1
36	QA/1/N	0.17%	0.2
37	QA/1/P	0.06%	0.3
38	QA/2/G	1.68%	0.1
39	QA/2/N	3.55%	0.2
40	QA/2/P	0.96%	0.3
41	QA/3/G	1.18%	0.3
42	QA/3/N	4.64%	0.4
43	QA/3/P	0.62%	0.5
44	QA/4/G	0.13%	0.1
45	QA/4/N	0.70%	0.2
46	QA/4/P	0.01%	0.3
47	SC/1/G	0.00%	20

TPI Description	Road Grad	Grid Code
Ridgeline	1	4
Gentle Slope	3	2
Steep Slope	6	3
Canyon Bottom	10	1

Surface Description	Surface Type	
Native	N	
Paved	P	
Rocked	G	

Road Type	Road Widths (feet)	Explanation
G	45	G=Rocked
N	35	N=Native
P	55	P=Paved (or chip-sealed)

48	SC/1/N	0.01%	30
49	SC/1/P	0.00%	40
50	SC/2/G	0.01%	3
51	SC/2/N	0.06%	6
52	SC/2/P	0.03%	7
53	SC/3/G	0.77%	10
54	SC/3/N	1.28%	15
55	SC/3/P	0.23%	20
56	SC/4/G	0.01%	2
57	SC/4/N	0.04%	5
58	SC/4/P	0.01%	7

Appendix A
WEPP Road Surface and Fluvial Erosion Rates

Road Design	Road Surface Type	Traffic Level	Road Gradient (%)	TPI	Road Surface/ TPI	Ptype	Road Length (ft)	Road Width (ft)	Fill Gradient (%)	Fill Length (ft)	Buffer Gradient	Buffer Length (ft)	Rock Fragment (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb)	Average annual sediment leaving buffer (lb)	Road Area	Erosion rate (tons/ac/yr)
IB	G	H	10	1	G/1	2	500	15	60	15	65	1	35	11	17.2	60383	54926	0.41	66
IB	G	H	10	1	G/1	3	500	15	60	15	65	1	35	9.7	16.5	33517	31803	0.28	58
IB	G	H	10	1	G/1	5	500	15	60	15	65	1	35	9.1	14.1	32385	28100	0.41	34
IB	G	H	10	1	G/1	6	500	15	60	15	65	1	35	8.1	13.4	17600	15762	0.28	29
IB	G	H	10	1	G/1	7	500	15	60	15	65	1	35	11.4	19	55396	55171	0.28	100
IB	G	H	10	1	G/1	8	500	15	60	15	65	1	35	13	20.2	98320	97115	0.41	118
IB	G	H	10	1	G/1	11	500	15	60	15	65	1	35	6.7	4.5	17435	17300	0.34	25
IB	G	H	10	1	G/1	10	500	15	60	15	65	1	35	5.7	9.1	8278	5908	0.28	11
IB	G	H	3	2	G/2	1	500	12	60	12	25	35	35	3.9	2	5097	4404	0.34	6
IB	G	H	3	2	G/2	1	500	15	60	15	25	35	35	3.9	2	5097	4404	0.34	6
IB	G	H	3	2	G/2	2	500	15	60	15	25	35	35	11	17.2	60383	54926	0.41	58
IB	G	H	3	2	G/2	3	500	15	60	15	25	35	35	9.7	16.5	33517	31803	0.28	14
IB	G	H	3	2	G/2	4	500	15	60	15	25	35	35	7.6	5.4	27034	27041	0.34	39
IB	G	H	3	2	G/2	5	500	15	60	15	25	35	35	9.1	14.1	32385	28100	0.41	34
IB	G	H	3	2	G/2	6	500	15	60	15	25	35	35	8.1	13.4	17600	15762	0.28	29
IB	G	H	3	2	G/2	7	500	15	60	15	25	35	35	11.4	19	55396	55171	0.28	58
IB	G	H	3	2	G/2	8	500	15	60	15	25	35	35	13	20.2	98320	97115	0.41	100
IB	G	H	3	2	G/2	12	500	15	60	15	25	35	35	5.6	3.5	9921	9668	0.34	14
IB	G	H	3	2	G/2	12	500	15	60	15	25	35	35	5.6	3.5	9921	9668	0.34	14
IB	G	H	3	2	G/2	12	500	15	60	15	25	35	35	6.4	9.7	17356	11203	0.41	14
IB	G	H	3	2	G/2	10	500	15	60	15	25	35	35	5.7	9.1	8278	5908	0.28	11
IB	G	H	6	3	G/3	1	500	15	60	15	35	15	35	3.9	2	5097	4404	0.34	6
IB	G	H	6	3	G/3	2	500	15	60	15	35	15	35	11	17.2	60383	54926	0.41	58
IB	G	H	6	3	G/3	2	500	15	60	15	35	15	35	11	17.2	60383	54926	0.41	58
IB	G	H	6	3	G/3	3	500	15	60	15	35	15	35	9.7	16.5	33517	31803	0.28	39
IB	G	H	6	3	G/3	4	500	15	60	15	35	15	35	7.6	5.4	27034	27041	0.34	39
IB	G	H	6	3	G/3	6	500	15	60	15	35	15	35	8.1	13.4	17600	15762	0.28	29
IB	G	H	6	3	G/3	7	500	15	60	15	35	15	35	11.4	19	55396	55171	0.28	39
IB	G	H	6	3	G/3	11	500	15	60	15	35	15	35	6.7	4.5	17435	17300	0.34	25
IB	G	H	6	3	G/3	12	500	15	60	15	35	15	35	5.6	3.5	9921	9668	0.34	14
IB	G	H	6	3	G/3	12	500	15	60	15	35	15	35	6.4	9.7	17356	11203	0.41	14
IB	G	H	6	3	G/3	10	500	15	60	15	35	15	35	5.7	9.1	8278	5908	0.28	11
IB	G	H	6	3	G/3	10	500	15	60	15	35	15	35	5.7	9.1	8278	5908	0.28	11
IB	G	H	1	4	G/4	1	500	15	60	15	15	75	35	3.9	2	5097	4404	0.34	6

IB	G	H	1	4	G/4	2	500	15	60	15	15	75	35	11	17.2	60383	54926	0.41	11
IB	G	H	1	4	G/4	3	500	15	60	15	15	75	35	9.7	16.5	33517	31803	0.28	14
IB	G	H	1	4	G/4	4	500	15	60	15	15	75	35	7.6	5.4	27034	27041	0.34	39
IB	G	H	1	4	G/4	6	500	15	60	15	15	75	35	8.1	13.4	17600	15762	0.28	29
IB	G	H	1	4	G/4	7	500	15	60	15	15	75	35	11.4	19	55396	55171	0.28	29
IB	G	H	1	4	G/4	8	500	15	60	15	15	75	35	13	20.2	98320	97115	0.41	66
IB	G	H	1	4	G/4	11	500	15	60	15	15	75	35	6.7	4.5	17435	17300	0.34	25
IB	G	H	1	4	G/4	10	500	15	60	15	15	75	35	5.7	9.1	8278	5908	0.28	11
IB	N	H	10	1	N/1	2	500	12	60	12	65	1	5	11	17.2	60383	54926	0.41	66
IB	N	H	10	1	N/1	3	500	12	60	12	65	1	5	9.7	16.5	33517	31803	0.28	58
IB	N	H	10	1	N/1	4	500	12	60	12	65	1	5	7.6	5.4	27034	27041	0.34	39
IB	N	H	10	1	N/1	5	500	12	60	12	65	1	5	9.1	14.1	32385	28100	0.41	34
IB	N	H	10	1	N/1	6	500	12	60	12	65	1	5	8.1	13.4	17600	15762	0.28	29
IB	N	H	10	1	N/1	7	500	12	60	12	65	1	5	11.4	19	55396	55171	0.28	100
IB	N	H	10	1	N/1	8	500	12	60	12	65	1	5	13	20.2	98320	97115	0.41	118
IB	N	H	10	1	N/1	11	500	12	60	12	65	1	5	6.7	4.5	17435	17300	0.34	25
IB	N	H	10	1	N/1	12	500	12	60	12	65	1	5	6.4	9.7	17356	11203	0.41	14
IB	N	H	10	1	N/1	10	500	12	60	12	65	1	5	5.7	9.1	8278	5908	0.28	11
IB	N	H	10	1	N/1	10	500	12	60	12	65	1	5	5.7	9.1	8278	5908	0.28	11
IB	N	H	3	2	N/2	2	500	12	60	12	25	35	5	11	17.2	60383	54926	0.41	66
IB	N	H	3	2	N/2	3	500	12	60	12	25	35	5	9.7	16.5	33517	31803	0.28	58
IB	N	H	3	2	N/2	3	500	12	60	12	25	35	5	9.7	16.5	33517	31803	0.28	58
IB	N	H	3	2	N/2	5	500	12	60	12	25	35	5	9.1	14.1	32385	28100	0.41	34
IB	N	H	3	2	N/2	5	500	12	60	12	25	35	5	9.1	14.1	32385	28100	0.41	34
IB	N	H	3	2	N/2	6	500	12	60	12	25	35	5	8.1	13.4	17600	15762	0.28	29
IB	N	H	3	2	N/2	7	500	12	60	12	25	35	5	11.4	19	55396	55171	0.28	100
IB	N	H	3	2	N/2	8	500	12	60	12	25	35	5	13	20.2	98320	97115	0.41	118
IB	N	H	3	2	N/2	11	500	12	60	12	25	35	5	6.7	4.5	17435	17300	0.34	25
IB	N	H	3	2	N/2	12	500	12	60	12	25	35	5	5.6	3.5	9921	9668	0.34	14
IB	N	H	3	2	N/2	12	500	12	60	12	25	35	5	6.4	9.7	17356	11203	0.41	14
IB	N	H	3	2	N/2	10	500	12	60	12	25	35	5	5.7	9.1	8278	5908	0.28	11
IB	N	H	6	3	N/3	1	500	12	60	12	35	15	5	3.9	2	5097	4404	0.34	6
IB	N	H	6	3	N/3	2	500	12	60	12	35	15	5	11	17.2	60383	54926	0.41	66
IB	N	H	6	3	N/3	3	500	12	60	12	35	15	5	9.7	16.5	33517	31803	0.28	58
IB	N	H	6	3	N/3	4	500	12	60	12	35	15	5	7.6	5.4	27034	27041	0.34	39
IB	N	H	6	3	N/3	5	500	12	60	12	35	15	5	9.1	14.1	32385	28100	0.41	34
IB	N	H	6	3	N/3	6	500	12	60	12	35	15	5	8.1	13.4	17600	15762	0.28	29
IB	N	H	6	3	N/3	7	500	12	60	12	35	15	5	11.4	19	55396	55171	0.28	100
IB	N	H	6	3	N/3	8	500	12	60	12	35	15	5	13	20.2	98320	97115	0.41	118
IB	N	H	6	3	N/3	11	500	12	60	12	35	15	5	6.7	4.5	17435	17300	0.34	25
IB	N	H	6	3	N/3	11	500	12	60	12	35	15	5	6.7	4.5	17435	17300	0.34	25
IB	N	H	6	3	N/3	12	500	12	60	12	35	15	5	5.6	3.5	9921	9668	0.34	14

IB	N	H	6	3	N/3	12	500	12	60	12	35	15	5	5.6	3.5	9921	9668	0.34	14
IB	N	H	6	3	N/3	12	500	12	60	12	35	15	5	6.4	9.7	17356	11203	0.41	14
IB	N	H	6	3	N/3	10	500	12	60	12	35	15	5	5.7	9.1	8278	5908	0.28	11
IB	N	H	1	4	N/4	1	500	12	60	12	15	75	5	3.9	2	5097	4404	0.34	6
IB	N	H	1	4	N/4	2	500	12	60	12	15	75	5	11	17.2	60383	54926	0.41	66
IB	N	H	1	4	N/4	3	500	12	60	12	15	75	5	9.7	16.5	33517	31803	0.28	58
IB	N	H	1	4	N/4	4	500	12	60	12	15	75	5	7.6	5.4	27034	27041	0.34	39
IB	N	H	1	4	N/4	5	500	12	60	12	15	75	5	9.1	14.1	32385	28100	0.41	34
IB	N	H	1	4	N/4	5	500	12	60	12	15	75	5	9.1	14.1	32385	28100	0.41	34
IB	N	H	1	4	N/4	6	500	12	60	12	15	75	5	8.1	13.4	17600	15762	0.28	29
IB	N	H	1	4	N/4	7	500	12	60	12	15	75	5	11.4	19	55396	55171	0.28	100
IB	N	H	1	4	N/4	8	500	12	60	12	15	75	5	13	20.2	98320	97115	0.41	118
IB	N	H	1	4	N/4	11	500	12	60	12	15	75	5	6.7	4.5	17435	17300	0.34	25
IB	N	H	1	4	N/4	12	500	12	60	12	15	75	5	5.6	3.5	9921	9668	0.34	14
IB	N	H	1	4	N/4	12	500	12	60	12	15	75	5	5.6	3.5	9921	9668	0.34	14
IB	N	H	1	4	N/4	12	500	12	60	12	15	75	5	6.4	9.7	17356	11203	0.41	14
IB	N	H	1	4	N/4	10	500	12	60	12	15	75	5	5.7	9.1	8278	5908	0.28	11
IB	P	H	10	1	P/1	1	500	18	60	18	65	1	25	3.9	2	5097	4404	0.34	6
IB	P	H	10	1	P/1	2	500	18	60	18	65	1	25	11	17.2	60383	54926	0.41	66
IB	P	H	10	1	P/1	3	500	18	60	18	65	1	25	9.7	16.5	33517	31803	0.28	58
IB	P	H	10	1	P/1	3	500	18	60	18	65	1	25	9.7	16.5	33517	31803	0.28	58
IB	P	H	10	1	P/1	5	500	18	60	18	65	1	25	9.1	14.1	32385	28100	0.41	34
IB	P	H	10	1	P/1	6	500	18	60	18	65	1	25	8.1	13.4	17600	15762	0.28	29
IB	P	H	10	1	P/1	7	500	18	60	18	65	1	25	11.4	19	55396	55171	0.28	100
IB	P	H	10	1	P/1	8	500	18	60	18	65	1	25	13	20.2	98320	97115	0.41	118
IB	P	H	10	1	P/1	11	500	18	60	18	65	1	25	6.7	4.5	17435	17300	0.34	25
IB	P	H	10	1	P/1	12	500	18	60	18	65	1	25	6.4	9.7	17356	11203	0.41	14
IB	P	H	10	1	P/1	10	500	18	60	18	65	1	25	5.7	9.1	8278	5908	0.28	11
IB	P	H	3	2	P/2	1	500	18	60	18	25	35	25	3.9	2	5097	4404	0.34	6
IB	P	H	3	2	P/2	2	500	18	60	18	25	35	25	11	17.2	60383	54926	0.41	66
IB	P	H	3	2	P/2	3	500	18	60	18	25	35	25	9.7	16.5	33517	31803	0.28	58
IB	P	H	3	2	P/2	3	500	18	60	18	25	35	25	9.7	16.5	33517	31803	0.28	58
IB	P	H	3	2	P/2	5	500	18	60	18	25	35	25	9.1	14.1	32385	28100	0.41	34
IB	P	H	3	2	P/2	5	500	18	60	18	25	35	25	9.1	14.1	32385	28100	0.41	34
IB	P	H	3	2	P/2	6	500	18	60	18	25	35	25	8.1	13.4	17600	15762	0.28	29
IB	P	H	3	2	P/2	7	500	18	60	18	25	35	25	11.4	19	55396	55171	0.28	100
IB	P	H	3	2	P/2	8	500	18	60	18	25	35	25	13	20.2	98320	97115	0.41	118
IB	P	H	3	2	P/2	11	500	18	60	18	25	35	25	6.7	4.5	17435	17300	0.34	25
IB	P	H	3	2	P/2	12	500	18	60	18	25	35	25	5.6	3.5	9921	9668	0.34	14
IB	P	H	3	2	P/2	12	500	18	60	18	25	35	25	5.6	3.5	9921	9668	0.34	14
IB	P	H	3	2	P/2	12	500	18	60	18	25	35	25	6.4	9.7	17356	11203	0.41	14
IB	P	H	3	2	P/2	10	500	18	60	18	25	35	25	5.7	9.1	8278	5908	0.28	11

IB	P	H	6	3	P/3	1	500	18	60	18	35	15	25	3.9	2	5097	4404	0.34	6
IB	P	H	6	3	P/3	2	500	18	60	18	35	15	25	11	17.2	60383	54926	0.41	66
IB	P	H	6	3	P/3	2	500	18	60	18	35	15	25	11	17.2	60383	54926	0.41	66
IB	P	H	6	3	P/3	3	500	18	60	18	35	15	25	9.7	16.5	33517	31803	0.28	58
IB	P	H	6	3	P/3	4	500	18	60	18	35	15	25	7.6	5.4	27034	27041	0.34	39
IB	P	H	6	3	P/3	5	500	18	60	18	35	15	25	9.1	14.1	32385	28100	0.41	34
IB	P	H	6	3	P/3	6	500	18	60	18	35	15	25	8.1	13.4	17600	15762	0.28	29
IB	P	H	6	3	P/3	8	500	18	60	18	35	15	25	13	20.2	98320	97115	0.41	118
IB	P	H	6	3	P/3	11	500	18	60	18	35	15	25	6.7	4.5	17435	17300	0.34	25
IB	P	H	6	3	P/3	11	500	18	60	18	35	15	25	6.7	4.5	17435	17300	0.34	25
IB	P	H	6	3	P/3	12	500	18	60	18	35	15	25	5.6	3.5	9921	9668	0.34	14
IB	P	H	6	3	P/3	12	500	18	60	18	35	15	25	5.6	3.5	9921	9668	0.34	14
IB	P	H	6	3	P/3	10	500	18	60	18	35	15	25	5.6	3.5	7367	7205	0.28	13
IB	P	H	6	3	P/3	10	500	18	60	18	35	15	25	5.7	9.1	8278	5908	0.28	11
IB	P	H	1	4	P/4	2	500	18	60	18	15	75	25	11	17.2	60383	54926	0.41	66
IB	P	H	1	4	P/4	4	500	18	60	18	15	75	25	7.6	5.4	27034	27041	0.34	39
IB	P	H	1	4	P/4	5	500	18	60	18	15	75	25	9.1	14.1	32385	28100	0.41	34
IB	P	H	1	4	P/4	5	500	18	60	18	15	75	25	9.1	14.1	32385	28100	0.41	34
IB	P	H	1	4	P/4	6	500	18	60	18	15	75	25	8.1	13.4	17600	15762	0.28	29
IB	P	H	1	4	P/4	7	500	18	60	18	15	75	25	11.4	19	55396	55171	0.28	100
IB	P	H	1	4	P/4	8	500	18	60	18	15	75	25	13	20.2	98320	97115	0.41	118
IB	P	H	1	4	P/4	10	500	18	60	18	15	75	25	5.7	9.1	8278	5908	0.28	11

WEPP Road Topographic Position Index and Road Gradient

Topographic Position Index Description	**Road Gradient (%)**	**Grid Code**
Ridgeline	1	4
Gentle Slope	3	2
Steep Slope	6	3
Canyon Bottom	10	1

Appendix A

WEPP Timber Harvest Surface and Fluvial Erosion Rates

Disturbance Type/Brx	DIST LEVEL	Lumped Geology	EROSION RATE Q2	EROSION RATE Q25
4111/430/FR	M	FR	2.5	2.5
4113/000/FR	L	FR	2.5	2.5
4113/000/FR/DS	M	FR	25	50
4113/000/M	L	M	15	15
4113/000/SC	L	SC	10	10
4113/420/DG	H	DG	1.25	1.25
4113/420/FR	H	FR	2.5	2.5
4113/420/M	H	M	15	15
4113/420/M/IG	H	M	150	300
4113/420/QA	H	QA	1	1
4113/420/SC	M	SC	10	10
4113/420/SC/EF	H	SC	25	25
4113/430/FR	M	FR	2.5	2.5
4113/430/FR/DF	H	FR	25	50
4113/430/M	M	M	10	10
4113/430/QA	M	QA	0.75	0.75
4113/430/SC	M	SC	7.5	7.5
4113/460/DG	M	DG	1.25	1.25
4113/460/FR	M	FR	2.5	2.5
4113/460/M	L	M	10	10
4113/460/QA	M	QA	0.75	0.75
4113/460/SC	M	SC	7.5	7.5
4114/000/FR	L	FR	2.5	2.5
4114/000/M	M	M	15	15
4114/420/DG	H	DG	1.25	1.25
4114/420/FR	H	FR	2.5	2.5
4114/420/M	H	M	15	15
4114/420/SC	H	SC	10	10
4114/460/FR	L	FR	2.5	2.5
4114/460/FR/DF	M	FR	25	50
4114/460/SC	M	SC	7.5	7.5
4114/460/SC/DS	M	SC	25	25
4117/420/FR	H	FR	2.5	2.5
4117/420/M	H	M	15	15
4117/420/SC	H	SC	10	10
4117/430/FR	M	FR	2.5	2.5
4117/430/SC	M	SC	7.5	7.5
4132/400/FR	L	FR	2.5	2.5
4132/400/FR/DF	M	FR	25	50
4132/420/DG	H	DG	1.25	1.25
4132/420/FR	H	FR	2.5	2.5
4132/420/M	H	M	15	15
4132/420/QA	H	QA	1	1
4132/420/SC	H	SC	10	10
4132/430/FR	M	FR	2.5	2.5
4132/430/QA	M	QA	0.75	0.75
4132/460/DG	M	DG	1.25	1.25
4132/460/FR	M	FR	2.5	2.5
4132/460/M	L	M	10	10

4132/460/QA	M	QA	0.75	0.75
4132/460/SC	M	SC	7.5	7.5
4141/400/FR	M	FR	2.5	2.5
4141/400/SC	M	SC	10	10
4141/400/SC/IG	M	SC	25	25
4141/420/DG	H	DG	1.25	1.25
4141/420/FR	H	FR	2.5	2.5
4141/420/M	H	M	15	15
4141/460/FR	M	FR	2.5	2.5
4141/460/M	M	M	10	10
4141/460/QA	M	QA	0.75	0.75
4143/400/FR	M	FR	2.5	2.5
4143/420/FR	H	FR	2.5	2.5
4143/420/FR/DF	H	FR	25	50
4143/420/M	H	M	15	15
4143/430/FR	M	FR	2.5	2.5
4151/400/FR	M	FR	2.5	2.5
4151/420/DG	M	DG	1.25	1.25
4151/420/FR	H	FR	2.5	2.5
4151/420/FR/DF	H	FR	25	50
4151/420/FR/EF	H	FR	25	75
4151/420/M	H	M	15	15
4151/420/QA	H	QA	1	1
4151/420/SC	H	SC	10	10
4151/420/SC/IG	H	SC	25	25
4151/460/FR	M	FR	2.5	2.5
4151/460/FR/DF	M	FR	25	50
4151/460/FR/EF	M	FR	25	75
4151/460/FR/IG	M	FR	125	250
4151/460/M	M	M	10	10
4151/460/QA	M	QA	0.75	0.75
4151/460/SC	M	SC	7.5	7.5
4152/420/DG	H	DG	1.25	1.25
4152/420/FR	H	FR	2.5	2.5
4152/420/M	H	M	15	15
4152/420/SC	H	SC	10	10
4152/460/FR	M	FR	2.5	2.5
4210/460/FR	M	FR	2.5	2.5
4220/400/SC	M	SC	10	10
4220/420/DG	H	DG	1.25	1.25
4220/420/FR	H	FR	2.5	2.5
4220/420/M	H	M	15	15
4220/420/QA	H	QA	1	1
4220/420/SC	H	SC	10	10
4220/430/DG	M	DG	0.75	0.75
4220/430/FR	M	FR	2.5	2.5
4220/430/M	M	M	10	10
4220/430/QA	M	QA	0.75	0.75
4220/430/SC	M	SC	7.5	7.5
4220/430/SC/EF	M	SC	25	25
4220/480/FR	L	FR	2.5	2.5
4220/480/M	M	M	10	10

4220/480/SC	L	SC	7.5	7.5
4230/420/FR	H	FR	2.5	2.5
4230/420/QA	M	QA	1	1
4230/420/SC	H	SC	10	10
4230/430/FR	M	FR	2.5	2.5
4230/430/M	M	M	10	10
4230/430/QA	M	QA	0.75	0.75
4230/430/SC	M	SC	7.5	7.5
4232/400/FR	M	FR	2.5	2.5
4232/420/FR	H	FR	2.5	2.5
4232/420/M	H	M	15	15
4232/420/SC	H	SC	10	10
4232/460/FR	M	FR	2.5	2.5
4232/460/QA	M	QA	0.75	0.75
4240/420/SC	H	SC	10	10
4240/430/SC	M	SC	7.5	7.5
4240/480/DG	M	DG	0.75	0.75
4240/480/FR	M	FR	2.5	2.5
4240/480/SC	M	SC	7.5	7.5
ALPR/CS/FR	M	FR	2.5	2.5
ALPR/TC/M	H	M	15	15
ALPR/TR/DG	M	DG	1.25	1.25
ALPR/TR/FR	H	FR	2.5	2.5
ALPR/TR/FR/EF	H	FR	25	75
ALPR/TR/M	H	M	15	15
ALPR/TR/QA	H	QA	1	1
ALPR/TR/SC	H	SC	10	10
ARTN/CS/FR	M	FR	2.5	2.5
ARTN/CS/M	M	M	10	10
ARTN/TC/FR	H	FR	2.5	2.5
cable-g/cc/FR	M	FR	2.5	2.5
cable-g/cc/M	M	M	10	10
cable-g/cc/QA	H	QA	0.75	0.75
cable-g/wlpz/M	M	M	10	10
cable-h/cc/M	M	M	10	10
cable-s/altp/M	M	M	10	10
cable-s/cc/DG	M	DG	1	1
cable-s/cc/FR	M	FR	2.5	2.5
cable-s/cc/FR/DF	M	FR	25	25
cable-s/cc/FR/DS	M	FR	25	25
cable-s/cc/FR/IG	M	FR	125	125
cable-s/cc/M	H	M	10	10
cable-s/cc/M/DF	M	M	150	300
cable-s/cc/M/DS	M	M	150	300
cable-s/cc/QA	H	QA	0.75	0.75
cable-s/cc/QA/DF	M	QA	7.5	7.5
cable-s/cc/QA/DS	M	QA	7.5	7.5
cable-s/ct/FR	M	FR	2.5	2.5
cable-s/ct/FR/DF	M	FR	25	25
cable-s/ct/M	M	M	10	10
cable-s/hra/FR	M	FR	2.5	2.5
cable-s/hra/FR/DS	M	FR	25	25

cable-s/hra/FR/IG	M	FR	125	125
cable-s/hra/M	M	M	10	10
cable-s/hra/M/DF	M	M	150	300
cable-s/hra/QA	M	QA	0.75	0.75
cable-s/rehb/FR	M	FR	2.5	2.5
cable-s/rehb/M	M	M	10	10
cable-s/salv/FR	M	FR	2.5	2.5
cable-s/salv/QA	M	QA	0.75	0.75
cable-s/sel/FR	M	FR	2.5	2.5
cable-s/sel/FR/DF	M	FR	25	25
cable-s/sel/M	M	M	10	10
cable-s/soz/M	M	M	10	10
cable-s/spec/M	M	M	10	10
cable-s/st-s/FR	M	FR	2.5	2.5
cable-s/st-s/M	M	M	10	10
cable-s/sw-p/M	M	M	10	10
cable-s/sw-s/FR	M	FR	2.5	2.5
cable-s/sw-s/M	M	M	10	10
cable-s/wlpz/FR	M	FR	2.5	2.5
cable-s/wlpz/FR/DF	M	FR	25	25
cable-s/wlpz/FR/DS	M	FR	25	25
cable-s/wlpz/FR/EF	H	FR	25	25
cable-s/wlpz/FR/IG	M	FR	125	125
cable-s/wlpz/M	M	M	10	10
cable-s/wlpz/M/DF	M	M	150	300
cable-s/wlpz/M/DS	M	M	150	300
cable-s/wlpz/QA	M	QA	0.75	0.75
cable-s/wlpz/QA/DF	M	QA	7.5	7.5
cable-s/wlpz/QA/DS	M	QA	7.5	7.5
CLCT/BH/FR	M	FR	2.5	2.5
CLCT/BH/FR/EF	M	FR	25	25
CLCT/BH/M	M	M	10	10
CLCT/BH/M/EF	M	M	150	450
CLCT/CH/FR	M	FR	2.5	2.5
CLCT/CH/M	M	M	10	10
CLCT/CS/FR	H	FR	2.5	2.5
CLCT/CS/M	M	M	10	10
CLCT/CS/M/EF	M	M	150	450
CLCT/TC/FR	H	FR	2.5	2.5
CLCT/TC/M	H	M	15	15
CLCT/TC/QA	H	QA	1	1
CLCT/TH/M	M	M	15	15
CLCT/TR/DG	H	DG	1.25	1.25
CLCT/TR/FR	H	FR	2.5	2.5
CLCT/TR/FR/EF	M	FR	25	25
CLCT/TR/FR/IG	H	FR	125	125
CLCT/TR/M	H	M	15	15
CLCT/TR/QA	H	QA	1	1
CMTH/CS/FR	M	FR	2.5	2.5
CMTH/CS/M	M	M	10	10
CMTH/TC/FR	M	FR	2.5	2.5
CMTH/TC/M	H	M	15	15

CMTH/TC/QA	L	QA	1	1
CMTH/TH/M	M	M	15	15
CMTH/TR/FR	H	FR	2.5	2.5
CMTH/TR/M	H	M	15	15
CMTH/TR/M/EF	M	M	150	450
CMTH/TR/QA	M	QA	1	1
CONV/TR/M	H	M	15	15
CONV/TR/QA	M	QA	1	1
GSLN/TR/FR	M	FR	2.5	2.5
GSLN/TR/FR/EF	H	FR	25	25
GSLN/TR/FR/IG	H	FR	125	125
GSLN/TR/M	H	M	15	15
GSLN/TR/QA	H	QA	1	1
GSLN/TR/SC	H	SC	10	10
heli/cc/FR	L	FR	2.5	2.5
heli/cc/FR/DS	L	FR	25	25
heli/cc/FR/EF	L	FR	25	25
heli/cc/M	L	M	7.5	7.5
heli/hra/FR	L	FR	2.5	2.5
heli/hra/M	L	M	7.5	7.5
heli/spec/FR	L	FR	2.5	2.5
heli/spec/FR/DS	L	FR	25	25
heli/sw-p/M	L	M	7.5	7.5
heli/wlpz/FR	M	FR	2.5	2.5
heli/wlpz/FR/DS	M	FR	25	25
heli/wlpz/FR/EF	L	FR	25	25
heli/wlpz/M	L	M	7.5	7.5
REHB/CS/FR	M	FR	2.5	2.5
REHB/TC/FR	L	FR	5	5
REHB/TC/M	M	M	5	5
REHB/TR/FR	H	FR	5	5
REHB/TR/FR/EF	H	FR	25	25
REHB/TR/M	H	M	5	5
REHB/TR/M/EF	M	M	150	450
REHB/TR/QA	M	QA	2.5	2.5
REHB/TR/SC	H	SC	10	10
SASV/TR/FR	H	FR	2.5	2.5
SASV/TR/M	H	M	15	15
SHPC/CS/M	M	M	10	10
SHPC/TR/DG	H	DG	1.25	1.25
SHPC/TR/FR	H	FR	2.5	2.5
SHPC/TR/M	H	M	15	15
SHRC/BH/M	M	M	10	10
SHRC/CH/M	M	M	10	10
SHRC/CS/FR	M	FR	2.5	2.5
SHRC/CS/FR/DF	M	FR	25	25
SHRC/CS/M	M	M	10	10
SHRC/CS/M/DF	M	M	150	300
SHRC/CS/M/EF	H	M	150	450
SHRC/HT/FR	L	FR	5	5
SHRC/HT/M	L	M	10	10
SHRC/TC/FR	H	FR	12.5	12.5

SHRC/TC/M	H	M	15	15
SHRC/TC/M/EF	H	M	150	450
SHRC/TC/QA	H	QA	1	1
SHRC/TR/DG	H	DG	1.25	1.25
SHRC/TR/FR	M	FR	2.5	2.5
SHRC/TR/FR/EF	M	FR	25	25
SHRC/TR/FR/IG	H	FR	125	125
SHRC/TR/M	H	M	15	15
SHRC/TR/M/EF	H	M	150	450
SHRC/TR/QA	H	QA	1	1
SHRC/TR/SC	H	SC	10	10
SHSC/CS/M	M	M	10	10
SHSC/TR/FR	H	FR	2.5	2.5
SHSC/TR/FR/DF	H	FR	25	25
SHSC/TR/M	H	M	10	10
SLCN/BH/M	M	M	15	15
SLCN/CS/FR	M	FR	2.5	2.5
SLCN/CS/FR/DF	M	FR	25	25
SLCN/CS/M	L	M	10	10
SLCN/CS/M/DF	M	M	150	300
SLCN/CS/M/EF	M	M	150	450
SLCN/TC/FR	M	FR	2.5	2.5
SLCN/TC/M	H	M	15	15
SLCN/TC/M/DF	H	M	150	300
SLCN/TC/M/DS	H	M	150	300
SLCN/TC/M/EF	H	M	150	450
SLCN/TC/QA	H	QA	1	1
SLCN/TH/FR	M	FR	2.5	2.5
SLCN/TH/M	M	M	15	450
SLCN/TH/QA	L	QA	1	1
SLCN/TR/FR	H	FR	2.5	2.5
SLCN/TR/FR/EF	H	FR	25	25
SLCN/TR/M	H	M	15	15
SLCN/TR/M/DF	H	M	150	300
SLCN/TR/M/EF	H	M	150	450
SLCN/TR/QA	H	QA	1	1
STRC/BH/FR	M	FR	2.5	2.5
STRC/BH/M	M	M	10	10
STRC/BH/M/EF	H	M	150	450
STRC/CH/M	M	M	10	10
STRC/CS/FR	M	FR	2.5	2.5
STRC/CS/M	M	M	10	10
STRC/TC/M	H	M	15	15
STRC/TH/FR	M	FR	2.5	2.5
STRC/TH/M	M	M	15	15
STRC/TR/DG	H	DG	1.25	1.25
STRC/TR/FR	H	FR	2.5	2.5
STRC/TR/FR/EF	H	FR	25	25
STRC/TR/M	H	M	15	15
STRC/TR/M/EF	H	M	150	450
STRC/TR/QA	H	QA	1	1
STRC/TR/SC	H	SC	10	10

STSC/CS/FR	M	FR	2.5	2.5
STSC/TC/FR	H	FR	2.5	2.5
STSC/TC/M	H	M	15	15
STSC/TR/FR	H	FR	2.5	2.5
STSC/TR/M	H	M	15	15
STSC/TR/M/EF	H	M	150	450
STSC/TR/QA	H	QA	1	1
tra-cab/altp/M	H	M	15	15
tra-cab/altp/QA	M	QA	1	1
tra-cab/cc/FR	H	FR	2.5	2.5
tra-cab/cc/FR/DS	H	FR	25	50
tra-cab/cc/FR/EF	H	FR	25	75
tra-cab/cc/FR/IG	H	FR	125	250
tra-cab/cc/M	H	M	15	15
tra-cab/cc/M/DF	H	M	125	250
tra-cab/cc/M/DS	H	M	125	250
tra-cab/cc/QA	L	QA	1	1
tra-cab/cc/QA/DS	H	QA	7.5	7.5
tra-cab/ct/FR	H	FR	2.5	2.5
tra-cab/ct/FR/DF	H	FR	25	25
tra-cab/ct/M	H	M	15	15
tra-cab/ct/QA	L	QA	1	1
tra-cab/hra/FR	M	FR	2.5	2.5
tra-cab/hra/M	H	M	15	15
tra-cab/hra/QA	H	QA	1	1
tra-cab/rehb/FR	M	FR	2.5	2.5
tra-cab/rehb/M	H	M	15	15
tra-cab/sel/M	H	M	15	15
tra-cab/sel/QA	H	QA	1	1
tra-cab/spec/M	H	M	15	15
tra-cab/spec/QA	H	QA	1	1
tra-cab/st-r/FR	H	FR	2.5	2.5
tra-cab/st-s/FR	H	FR	2.5	2.5
tra-cab/st-s/M	H	M	15	15
tra-cab/st-s/SC	H	SC	10	10
tra-cab/sw-p/M	H	M	15	15
tra-cab/sw-r/FR	H	FR	2.5	2.5
tra-cab/sw-r/M	H	M	15	15
tra-cab/wlpz/FR	H	FR	2.5	2.5
tra-cab/wlpz/FR/DS	H	FR	150	300
tra-cab/wlpz/FR/IG	H	FR	25	25
tra-cab/wlpz/M	H	M	15	15
tra-cab/wlpz/M/DS	H	M	150	250
tra-cab/wlpz/QA	H	QA	1	1
tractor/altp/FR	H	FR	2.5	2.5
tractor/altp/M	H	M	15	15
tractor/cc/FR	H	FR	2.5	2.5
tractor/cc/FR/IG	H	FR	125	250
tractor/cc/M	H	M	15	15
tractor/cc/QA	H	QA	1	1
tractor/cc/SC	H	SC	10	10
tractor/ct/FR	M	FR	2.5	2.5

tractor/ct/M	M	M	15	15
tractor/hra/FR	H	FR	2.5	2.5
tractor/hra/M	H	M	15	15
tractor/hra/QA	H	QA	1	1
tractor/rehb/FR	L	FR	2.5	2.5
tractor/rehb/M	H	M	15	15
tractor/salv/M	H	M	15	15
tractor/sel/FR	H	FR	2.5	2.5
tractor/sel/M	H	M	15	15
tractor/soz/M	H	M	15	15
tractor/st-r/DG	H	DG	1.25	1.25
tractor/st-r/QA	M	QA	1	1
tractor/st-r/SC	H	SC	10	10
tractor/st-s/DG	H	DG	1.25	1.25
tractor/st-s/FR	H	FR	2.5	2.5
tractor/st-s/FR/DF	H	FR	25	50
tractor/st-s/M	H	M	15	15
tractor/sw-p/DG	H	DG	1.25	1.25
tractor/sw-p/FR	H	FR	2.5	2.5
tractor/sw-p/M	H	M	15	15
tractor/sw-r/FR	H	FR	2.5	2.5
tractor/sw-r/M	H	M	15	15
tractor/sw-r/M/DS	H	M	150	300
tractor/sw-s/DG	M	DG	1.25	1.25
tractor/sw-s/FR	H	FR	2.5	2.5
tractor/sw-s/M	H	M	15	15
tractor/undf/M	H	M	15	15
tractor/undf/QA	H	QA	1	1
tractor/wlpz/DG	H	DG	1.25	1.25
tractor/wlpz/FR	H	FR	2.5	2.5
tractor/wlpz/M	H	M	15	15
tractor/wlpz/QA	H	QA	1	1
tra-end/sel/M	M	M	15	15
tra-end/wlpz/M	M	M	15	15
TRAN/TR/FR	H	FR	2.5	2.5
undf/cc/DG	H	DG	1.25	1.25
undf/cc/FR	H	FR	2.5	2.5
undf/cc/FR/DF	H	FR	25	50
undf/cc/FR/DS	H	FR	25	50
undf/cc/FR/IG	H	FR	125	250
undf/cc/M	H	M	15	15
undf/cc/M/DF	M	M	150	300
undf/cc/M/DS	H	M	150	300
undf/cc/QA	H	QA	1	1
undf/cc/QA/DF	H	QA	7.5	7.5
undf/salv/M	M	M	15	15
undf/salv/QA	M	QA	1	1
VRTN/CS/FR	M	FR	2.5	2.5
VRTN/TC/FR	H	FR	2.5	2.5
VRTN/TR/M	H	M	15	15

Appendix B

NetMap Factor Worksheet: converts the GEP FACTOR to sediment load

		BACKGROUND Q2	EXISTING Q2
FACTOR CUM SUM		31881592	79435405
SEDIMENT LOAD (tons/year)		347880	1159600
DRAINAGE AREA (MI2)		446	446
EST SEDIMENT LOAD (tons/mi2/year)		780	2600
Multiplier (FACTOR TO LOAD)		1.191E-05	2.38647E-05

NetMap Background FACTOR by Lumped Geology Type

RANK	DIST1	DIST2	DIST3	Dist Factor	Land Use	SEDIMENT YIELD (tons/acre/year)	SEDIMENT YIELD (tons/km2/year)	SEDIMENT YIELD Factor	SEDIMENT YIELD (tons/mi2/year)
1		FR		/FR/	Natural	0.5	124	1	320
73		FR	DF	/FR/DF	Natural	70	17297	1	44800
76		FR	DS	/FR/DS	Natural	85	21004	1	54400
74		FR	EF	/FR/EF	Natural	41	10131	1	26240
77		FR	IG	/FR/IG	Natural	132	32618	2	84480
78		FR	RF	/FR/RF	Natural	0	49	1	128
83		FR	RS	/FR/RS	Natural	0	49	1	128
2		M		/M/	Natural	1	247	1	640
75		M	DF	/M/DF	Natural	78	19274	1	49920
79		M	DS	/M/DS	Natural	65	16062	1	41600
72		M	EF	/M/EF	Natural	60	14826	1	38400
80		M	IG	/M/IG	Natural	122	30147	2	78080
81		M	RF	/M/RF	Natural	0	49	1	128
3		QA		/QA/	Natural	0.05	12	1	32
82		QA	DF	/QA/DF	Natural	67	16556	1	42880
87		QA	DS	/QA/DS	Natural	60	14826	1	38400
84		QA	EF	/QA/EF	Natural	41	10031	1	25980
85		QA	IG	/QA/IG	Natural	101	24958	2	64640
4		SC		/SC/	Natural	0.75	185	1	480
86		SC	EF	/SC/EF	Natural	69	17050	1	44160
48	Qef	FR		Qef/FR/	Natural	0.5	124	1	320
49	Qef	FR	IG	Qef/FR/IG	Natural	132	32618	2	84480
50	Qef	M		Qef/M/	Natural	1	247	1	640
51	Qef	M	DS	Qef/M/DS	Natural	65	16062	1	41600
52	Qef	M	EF	Qef/M/EF	Natural	60	14826	1	38400

53	Qef	M	IG	Qef/M/IG	Natural	122	30147	2	78080
54	Qls	FR		Qls/FR/	Natural	0.5	124	1	320
55	Qls	FR	DF	Qls/FR/DF	Natural	70	17297	1	44800
56	Qls	FR	DS	Qls/FR/DS	Natural	85	21004	1	54400
57	Qls	FR	EF	Qls/FR/EF	Natural	52	12849	1	33280
58	Qls	FR	IG	Qls/FR/IG	Natural	132	32618	2	84480
59	Qls	FR	RF	Qls/FR/RF	Natural	0.2	49	1	128
60	Qls	M		Qls/M/	Natural	1	247	1	640
61	Qls	M	DF	Qls/M/DF	Natural	70	17297	1	44800
62	Qls	M	DS	Qls/M/DS	Natural	65	16062	1	41600
63	Qls	M	EF	Qls/M/EF	Natural	60	14826	1	38400
64	Qls	M	IG	Qls/M/IG	Natural	122	30147	2	78080
65	Qls	M	RF	Qls/M/RF	Natural	0.2	49	1	128
66	Qls	QA		Qls/QA/	Natural	0.05	12	1	32
67	Qls	QA	DS	Qls/QA/DS	Natural	60	14826	1	38400
68	Qls	QA	IG	Qls/QA/IG	Natural	101	24958	2	64640
69	Qls	SC		Qls/SC/	Natural	0.75	185	1	480
70	Qls	SC	DS	Qls/SC/DS	Natural	65	16062	1	41600
71	Qls	SC	EF	Qls/SC/EF	Natural	69	17050	1	44160

NetMap Existing Condition FACTOR by Disturbance Type Lookup Table

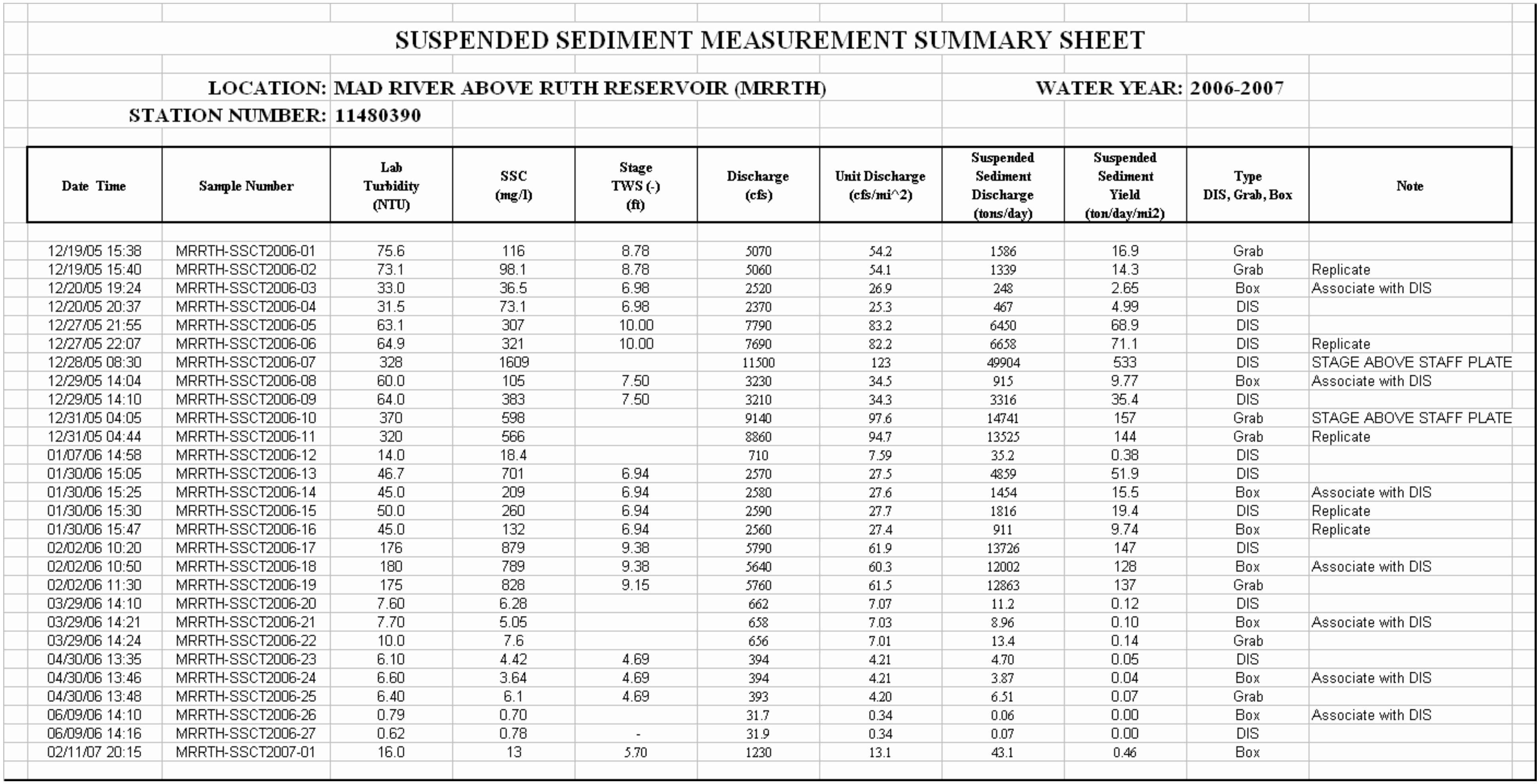
RANK	DIST1	DIST2	DIST3	Dist Factor	Land Use	SEDIMENT YIELD (tons/acre/year)	SEDIMENT YIELD (tons/km2/year)	SEDIMENT YIELD Factor	SEDIMENT YIELD (tons/mi2/year)
1		FR		/FR/	Natural	0.5	124	1	320
73		FR	DF	/FR/DF	Natural	70	17297	35	44800
76		FR	DS	/FR/DS	Natural	85	21004	43	54400
74		FR	EF	/FR/EF	Natural	41	10131	21	26240
77		FR	IG	/FR/IG	Natural	132	32618	66	84480
78		FR	RF	/FR/RF	Natural	0	49	1	128
83		FR	RS	/FR/RS	Natural	0	49	1	128
2		M		/M/	Natural	1	247	1	640
75		M	DF	/M/DF	Natural	78	19274	39	49920
79		M	DS	/M/DS	Natural	65	16062	33	41600
72		M	EF	/M/EF	Natural	60	14826	30	38400
80		M	IG	/M/IG	Natural	122	30147	61	78080
81		M	RF	/M/RF	Natural	0	49	1	128
3		QA		/QA/	Natural	0.05	12	1	32
82		QA	DF	/QA/DF	Natural	67	16556	34	42880
87		QA	DS	/QA/DS	Natural	60	14826	30	38400
84		QA	EF	/QA/EF	Natural	41	10031	20	25980

85		QA	IG	/QA/IG	Natural	101	24958	51	64640
4		SC		/SC/	Natural	0.75	185	1	480
86		SC	EF	/SC/EF	Natural	69	17050	35	44160
5	G	FR		G/FR/	Road	5	1236	3	3200
6	G	FR	DF	G/FR/DF	Road	55	13591	28	35200
7	G	FR	DS	G/FR/DS	Road	75	18533	38	48000
8	G	FR	EF	G/FR/EF	Road	51	12602	26	32640
9	G	FR	IG	G/FR/IG	Road	118	29158	59	75520
10	G	M		G/M/	Road	40	9884	20	25600
11	G	M	DF	G/M/DF	Road	55	13591	28	35200
12	G	M	DS	G/M/DS	Road	75	18533	38	48000
13	G	M	EF	G/M/EF	Road	38	9390	19	24320
14	G	QA		G/QA/	Road	0.05	12	1	32
15	G	QA	EF	G/QA/EF	Road	35	8649	18	22400
16	G	SC		G/SC/	Road	30	7413	15	19200
17	G	SC	DS	G/SC/DS	Road	75	18533	38	48000
96	H-H	FR		H-H/FR/	Harvest	3	741	1	1920
115	H-H	FR	DF	H-H/FR/DF	Harvest	70	17297	35	44800
111	H-H	FR	DS	H-H/FR/DS	Harvest	70	17297	35	44800
112	H-H	FR	EF	H-H/FR/EF	Harvest	52	12849	26	33280
147	H-H	FR	IG	H-H/FR/IG	Harvest	132	32618	66	84480
95	H-H	M		H-H/M/	Harvest	5	1236	3	3200
155	H-H	M	DF	H-H/M/DF	Harvest	70	17297	35	44800
153	H-H	M	DS	H-H/M/DS	Harvest	70	17297	35	44800
113	H-H	M	IG	H-H/M/IG	Harvest	132	32618	66	84480
114	H-H	QA		H-H/QA/	Harvest	0.5	124	1	320
97	H-H	SC		H-H/SC/	Harvest	4	988	1	2560
156	H-H	SC	DF	H-H/SC/DF	Harvest	70	17297	35	44800
154	H-H	SC	DS	H-H/SC/DS	Harvest	70	17297	35	44800
116	H-L	FR		H-L/FR/	Harvest	2	494	1	1280
149	H-L	FR	DF	H-L/FR/DF	Harvest	70	17297	35	44800
150	H-L	FR	DS	H-L/FR/DS	Harvest	70	17297	35	44800
162	H-L	FR	EF	H-L/FR/EF	Harvest	52	12849	26	33280
151	H-L	FR	IG	H-L/FR/IG	Harvest	132	32618	66	84480
117	H-L	M		H-L/M/	Harvest	5	1236	3	3200
148	H-L	M	DS	H-L/M/DS	Harvest	70	17297	35	44800
159	H-L	M	EF	H-L/M/EF	Harvest	52	12849	26	33280
118	H-L	QA		H-L/QA/	Harvest	0.5	124	1	320
119	H-L	SC		H-L/SC/	Harvest	4	988	1	2560
18	H-M	FR		H-M/FR/	Harvest	10	2471	5	6400
19	H-M	FR	DS	H-M/FR/DS	Harvest	70	17297	35	44800
20	H-M	FR	EF	H-M/FR/EF	Harvest	52	12849	26	33280

21	H-M	FR	IG	H-M/FR/IG	Harvest	132	32618	66	84480
22	H-M	M		H-M/M/	Harvest	15	3707	8	9600
23	H-M	M	EF	H-M/M/EF	Harvest	52	12849	26	33280
24	H-M	QA		H-M/QA/	Harvest	0.5	124	1	320
25	H-M	SC		H-M/SC/	Harvest	10	2471	5	6400
26	H-M	SC	DF	H-M/SC/DF	Harvest	70	17297	35	44800
133	L-H	FR		L-H/FR/	Harvest	1	247	1	640
142	L-H	FR	DS	L-H/FR/DS	Harvest	70	17297	35	44800
143	L-H	FR	EF	L-H/FR/EF	Harvest	52	12849	26	33280
110	L-H	M		L-H/M/	Harvest	2	494	1	1280
158	L-H	M	EF	L-H/M/EF	Harvest	52	12849	26	33280
166	L-H	QA		L-H/QA/	Harvest	0.3	74	1	192
144	L-H	SC		L-H/SC/	Harvest	1	247	1	640
103	L-L	FR		L-L/FR/	Harvest	1	247	1	640
164	L-L	FR	DS	L-L/FR/DS	Harvest	70	17297	35	44800
104	L-L	FR	EF	L-L/FR/EF	Harvest	52	12849	26	33280
168	L-L	FR	IG	L-L/FR/IG	Harvest	132	32618	66	84480
105	L-L	M		L-L/M/	Harvest	1	247	1	640
163	L-L	M	DS	L-L/M/DS	Harvest	70	17297	35	44800
106	L-L	QA		L-L/QA/	Harvest	0.3	74	1	192
107	L-L	SC		L-L/SC/	Harvest	1	247	1	640
88	L-M	FR		L-M/FR/	Harvest	1	247	1	640
157	L-M	FR	DF	L-M/FR/DF	Harvest	70	17297	35	44800
167	L-M	FR	DS	L-M/FR/DS	Harvest	70	17297	35	44800
91	L-M	FR	EF	L-M/FR/EF	Harvest	52	12849	26	33280
165	L-M	FR	IG	L-M/FR/IG	Harvest	132	32618	66	84480
89	L-M	M		L-M/M/	Harvest	2	494	1	1280
108	L-M	M	DF	L-M/M/DF	Harvest	70	17297	35	44800
109	L-M	M	EF	L-M/M/EF	Harvest	52	12849	26	33280
90	L-M	QA		L-M/QA/	Harvest	0.5	124	1	320
92	L-M	SC		L-M/SC/	Harvest	1	247	1	640
93	M-H	FR		M-H/FR/	Harvest	2	494	1	1280
130	M-H	FR	DF	M-H/FR/DF	Harvest	70	17297	35	44800
135	M-H	FR	DS	M-H/FR/DS	Harvest	70	17297	35	44800
131	M-H	FR	EF	M-H/FR/EF	Harvest	52	12849	26	33280
132	M-H	FR	IG	M-H/FR/IG	Harvest	132	32618	66	84480
94	M-H	M		M-H/M/	Harvest	4	988	1	2560
136	M-H	M	DF	M-H/M/DF	Harvest	70	17297	35	44800
145	M-H	M	DS	M-H/M/DS	Harvest	70	17297	35	44800
160	M-H	M	EF	M-H/M/EF	Harvest	52	12849	26	33280
122	M-H	QA		M-H/QA/	Harvest	0.5	124	1	320
123	M-H	SC		M-H/SC/	Harvest	2	494	1	1280

169	M-H	SC	DF	M-H/SC/DF	Harvest	70	17297	35	44800
146	M-H	SC	DS	M-H/SC/DS	Harvest	70	17297	35	44800
120	M-L	FR		M-L/FR/	Harvest	1	247	1	640
121	M-L	FR	DF	M-L/FR/DF	Harvest	70	17297	35	44800
137	M-L	FR	DS	M-L/FR/DS	Harvest	70	17297	35	44800
129	M-L	FR	EF	M-L/FR/EF	Harvest	52	12849	26	33280
127	M-L	FR	IG	M-L/FR/IG	Harvest	132	32618	66	84480
124	M-L	M		M-L/M/	Harvest	3	741	1	1920
138	M-L	M	DF	M-L/M/DF	Harvest	70	17297	35	44800
139	M-L	M	DS	M-L/M/DS	Harvest	70	17297	35	44800
161	M-L	M	EF	M-L/M/EF	Harvest	52	12849	26	33280
125	M-L	QA		M-L/QA/	Harvest	0.5	124	1	320
126	M-L	SC		M-L/SC/	Harvest	2	494	1	1280
140	M-L	SC	DF	M-L/SC/DF	Harvest	70	17297	35	44800
141	M-L	SC	DS	M-L/SC/DS	Harvest	70	17297	35	44800
101	M-M	FR		M-M/FR/	Harvest	2	494	1	1280
128	M-M	FR	DF	M-M/FR/DF	Harvest	70	17297	35	44800
152	M-M	FR	EF	M-M/FR/EF	Harvest	52	12849	26	33280
98	M-M	M		M-M/M/	Harvest	4	988	1	2560
134	M-M	M	DF	M-M/M/DF	Harvest	70	17297	35	44800
102	M-M	M	EF	M-M/M/EF	Harvest	52	12849	26	33280
99	M-M	QA		M-M/QA/	Harvest	0.5	124	1	320
100	M-M	SC		M-M/SC/	Harvest	3	741	1	1920
27	N	FR		N/FR/	Road	10	2471	5	6400
28	N	FR	DF	N/FR/DF	Road	55	13591	28	35200
29	N	FR	DS	N/FR/DS	Road	75	18533	38	48000
30	N	FR	EF	N/FR/EF	Road	50	12355	25	32000
31	N	FR	IG	N/FR/IG	Road	118	29158	59	75520
32	N	M		N/M/	Road	70	17297	35	44800
33	N	M	DF	N/M/DF	Road	55	13591	28	35200
34	N	M	DS	N/M/DS	Road	75	18533	38	48000
35	N	M	EF	N/M/EF	Road	60	14826	30	38400
36	N	QA		N/QA/	Road	0.1	25	1	64
37	N	QA	IG	N/QA/IG	Road	118	29158	59	75520
38	N	SC		N/SC/	Road	40	9884	20	25600
39	N	SC	DF	N/SC/DF	Road	55	13591	28	35200
40	P	FR		P/FR/	Road	12	2965	6	7680
41	P	FR	EF	P/FR/EF	Road	50	12355	25	32000
42	P	FR	RF	P/FR/RF	Road	0.2	49	1	128
43	P	M		P/M/	Road	75	18533	38	48000
44	P	M	DS	P/M/DS	Road	75	18533	38	48000
45	P	QA		P/QA/	Road	0.3	74	1	192

46	P	QA	IG	P/QA/IG	Road	118	29158	59	75520
47	P	SC		P/SC/	Road	43	10625	22	27520
48	Qef	FR		Qef/FR/	Natural	0.5	124	1	320
49	Qef	FR	IG	Qef/FR/IG	Natural	132	32618	66	84480
50	Qef	M		Qef/M/	Natural	1	247	1	640
51	Qef	M	DS	Qef/M/DS	Natural	65	16062	33	41600
52	Qef	M	EF	Qef/M/EF	Natural	60	14826	30	38400
53	Qef	M	IG	Qef/M/IG	Natural	122	30147	61	78080
54	Qls	FR		Qls/FR/	Natural	0.5	124	1	320
55	Qls	FR	DF	Qls/FR/DF	Natural	70	17297	35	44800
56	Qls	FR	DS	Qls/FR/DS	Natural	85	21004	43	54400
57	Qls	FR	EF	Qls/FR/EF	Natural	52	12849	26	33280
58	Qls	FR	IG	Qls/FR/IG	Natural	132	32618	66	84480
59	Qls	FR	RF	Qls/FR/RF	Natural	0.2	49	1	128
60	Qls	M		Qls/M/	Natural	1	247	1	640
61	Qls	M	DF	Qls/M/DF	Natural	70	17297	35	44800
62	Qls	M	DS	Qls/M/DS	Natural	65	16062	33	41600
63	Qls	M	EF	Qls/M/EF	Natural	60	14826	30	38400
64	Qls	M	IG	Qls/M/IG	Natural	122	30147	61	78080
65	Qls	M	RF	Qls/M/RF	Natural	0.2	49	1	128
66	Qls	QA		Qls/QA/	Natural	0.05	12	1	32
67	Qls	QA	DS	Qls/QA/DS	Natural	60	14826	30	38400
68	Qls	QA	IG	Qls/QA/IG	Natural	101	24958	51	64640
69	Qls	SC		Qls/SC/	Natural	0.75	185	1	480
70	Qls	SC	DS	Qls/SC/DS	Natural	65	16062	33	41600
71	Qls	SC	EF	Qls/SC/EF	Natural	69	17050	35	44160



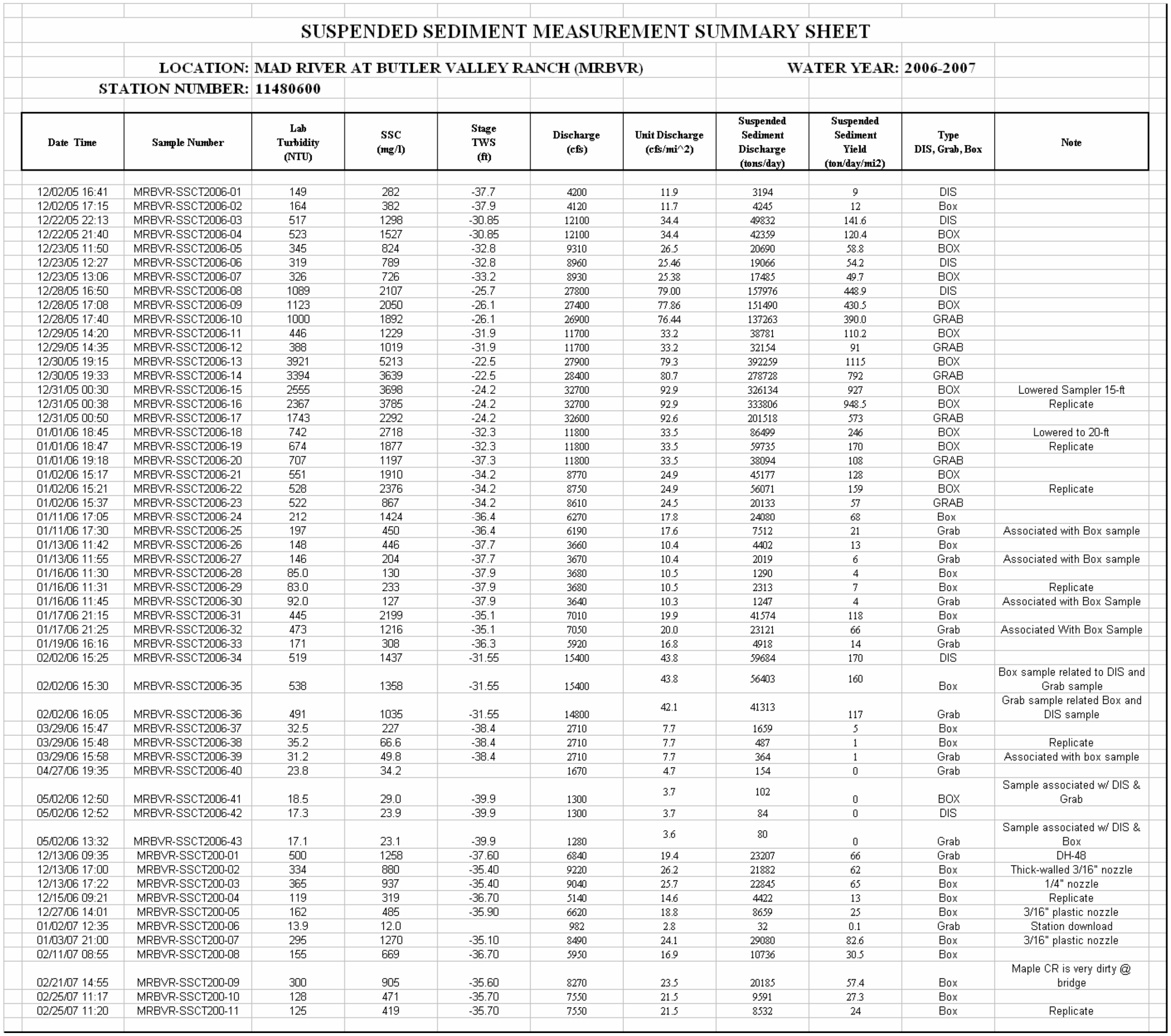
SUSPENDED SEDIMENT MEASUREMENT SUMMARY SHEET

LOCATION: MAD RIVER ABOVE RUTH RESERVOIR (MRRTH)

WATER YEAR: 2006-2007

STATION NUMBER: 11480390

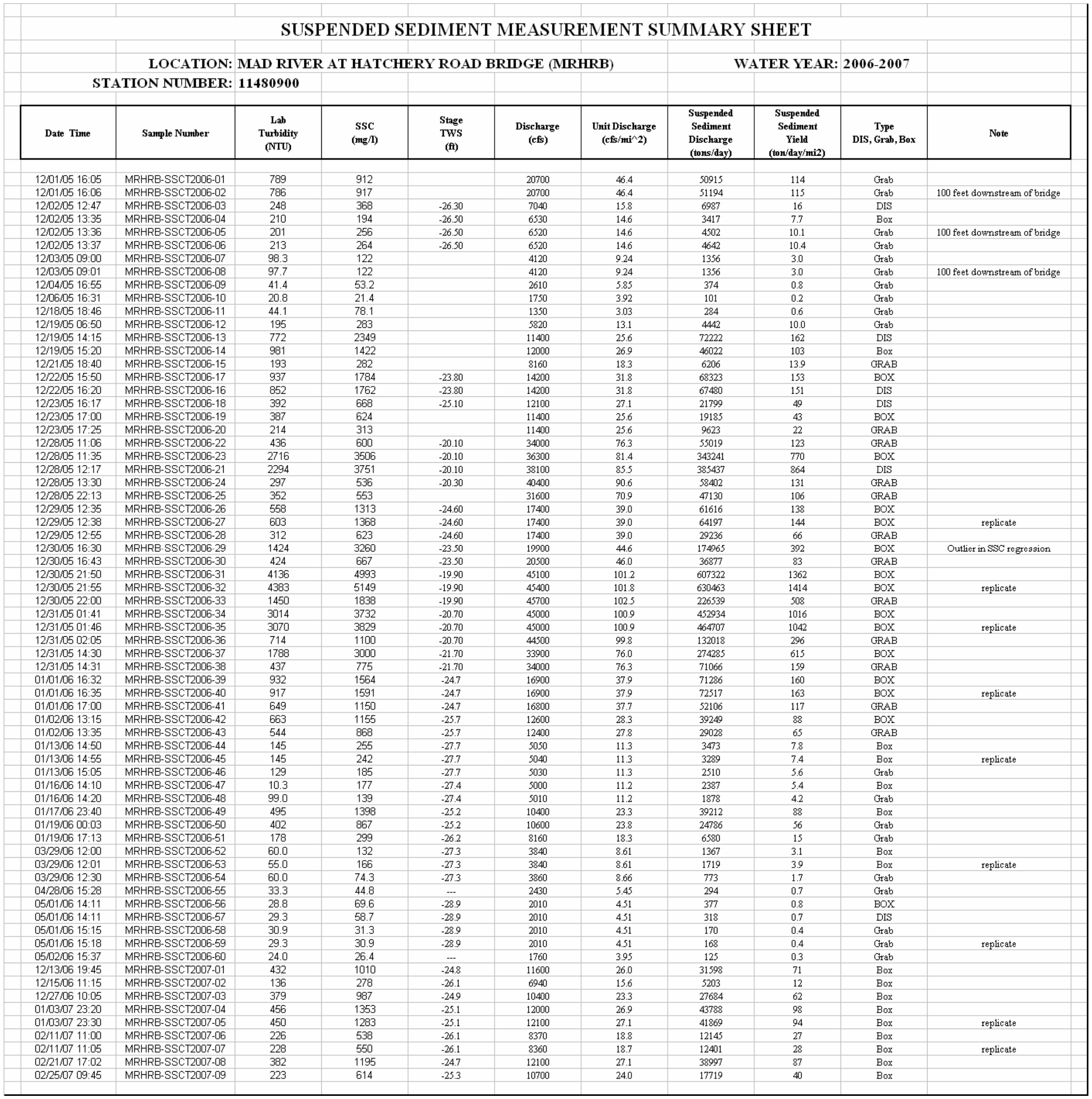
Date Time	Sample Number	Lab Turbidity (NTU)	SSC (mg/l)	Stage TWS (-) (ft)	Discharge (cfs)	Unit Discharge (cfs/mi^2)	Suspended Sediment Discharge (tons/day)	Suspended Sediment Yield (ton/day/mi2)	Type DIS, Grab, Box	Note
12/19/05 15:38	MRRTH-SSCT2006-01	75.6	116	8.78	5070	54.2	1586	16.9	Grab	
12/19/05 15:40	MRRTH-SSCT2006-02	73.1	98.1	8.78	5060	54.1	1339	14.3	Grab	Replicate
12/20/05 19:24	MRRTH-SSCT2006-03	33.0	36.5	6.98	2520	26.9	248	2.65	Box	Associate with DIS
12/20/05 20:37	MRRTH-SSCT2006-04	31.5	73.1	6.98	2370	25.3	467	4.99	DIS	
12/27/05 21:55	MRRTH-SSCT2006-05	63.1	307	10.00	7790	83.2	6450	68.9	DIS	
12/27/05 22:07	MRRTH-SSCT2006-06	64.9	321	10.00	7690	82.2	6658	71.1	DIS	Replicate
12/28/05 08:30	MRRTH-SSCT2006-07	328	1609		11500	123	49904	533	DIS	STAGE ABOVE STAFF PLATE
12/29/05 14:04	MRRTH-SSCT2006-08	60.0	105	7.50	3230	34.5	915	9.77	Box	Associate with DIS
12/29/05 14:10	MRRTH-SSCT2006-09	64.0	383	7.50	3210	34.3	3316	35.4	DIS	
12/31/05 04:05	MRRTH-SSCT2006-10	370	598		9140	97.6	14741	157	Grab	STAGE ABOVE STAFF PLATE
12/31/05 04:44	MRRTH-SSCT2006-11	320	566		8860	94.7	13525	144	Grab	Replicate
01/07/06 14:58	MRRTH-SSCT2006-12	14.0	18.4		710	7.59	35.2	0.38	DIS	
01/30/06 15:05	MRRTH-SSCT2006-13	46.7	701	6.94	2570	27.5	4859	51.9	DIS	
01/30/06 15:25	MRRTH-SSCT2006-14	45.0	209	6.94	2580	27.6	1454	15.5	Box	Associate with DIS
01/30/06 15:30	MRRTH-SSCT2006-15	50.0	260	6.94	2590	27.7	1816	19.4	DIS	Replicate
01/30/06 15:47	MRRTH-SSCT2006-16	45.0	132	6.94	2560	27.4	911	9.74	Box	Replicate
02/02/06 10:20	MRRTH-SSCT2006-17	176	879	9.38	5790	61.9	13726	147	DIS	
02/02/06 10:50	MRRTH-SSCT2006-18	180	789	9.38	5640	60.3	12002	128	Box	Associate with DIS
02/02/06 11:30	MRRTH-SSCT2006-19	175	828	9.15	5760	61.5	12863	137	Grab	
03/29/06 14:10	MRRTH-SSCT2006-20	7.60	6.28		662	7.07	11.2	0.12	DIS	
03/29/06 14:21	MRRTH-SSCT2006-21	7.70	5.05		658	7.03	8.96	0.10	Box	Associate with DIS
03/29/06 14:24	MRRTH-SSCT2006-22	10.0	7.6		656	7.01	13.4	0.14	Grab	
04/30/06 13:35	MRRTH-SSCT2006-23	6.10	4.42	4.69	394	4.21	4.70	0.05	DIS	
04/30/06 13:46	MRRTH-SSCT2006-24	6.60	3.64	4.69	394	4.21	3.87	0.04	Box	Associate with DIS
04/30/06 13:48	MRRTH-SSCT2006-25	6.40	6.1	4.69	393	4.20	6.51	0.07	Grab	
06/09/06 14:10	MRRTH-SSCT2006-26	0.79	0.70		31.7	0.34	0.06	0.00	Box	Associate with DIS
06/09/06 14:16	MRRTH-SSCT2006-27	0.62	0.78	-	31.9	0.34	0.07	0.00	DIS	
02/11/07 20:15	MRRTH-SSCT2007-01	16.0	13	5.70	1230	13.1	43.1	0.46	Box	



SUSPENDED SEDIMENT MEASUREMENT SUMMARY SHEET

LOCATION: MAD RIVER AT BUTLER VALLEY RANCH (MRBVR) **WATER YEAR:** 2006-2007
STATION NUMBER: 11480600

Date Time	Sample Number	Lab Turbidity (NTU)	SSC (mg/l)	Stage TWS (ft)	Discharge (cfs)	Unit Discharge (cfs/mi^2)	Suspended Sediment Discharge (tons/day)	Suspended Sediment Yield (ton/day/mi2)	Type DIS, Grab, Box	Note
12/02/05 16:41	MRBVR-SSCT2006-01	149	282	-37.7	4200	11.9	3194	9	DIS	
12/02/05 17:15	MRBVR-SSCT2006-02	164	382	-37.9	4120	11.7	4245	12	Box	
12/22/05 22:13	MRBVR-SSCT2006-03	517	1298	-30.85	12100	34.4	49832	141.6	DIS	
12/22/05 21:40	MRBVR-SSCT2006-04	523	1527	-30.85	12100	34.4	42359	120.4	BOX	
12/23/05 11:50	MRBVR-SSCT2006-05	345	824	-32.8	9310	26.5	20690	58.8	BOX	
12/23/05 12:27	MRBVR-SSCT2006-06	319	789	-32.8	8960	25.46	19066	54.2	DIS	
12/23/05 13:06	MRBVR-SSCT2006-07	326	726	-33.2	8930	25.38	17485	49.7	BOX	
12/28/05 16:50	MRBVR-SSCT2006-08	1089	2107	-25.7	27800	79.00	157976	448.9	DIS	
12/28/05 17:08	MRBVR-SSCT2006-09	1123	2050	-26.1	27400	77.86	151490	430.5	BOX	
12/28/05 17:40	MRBVR-SSCT2006-10	1000	1892	-26.1	26900	76.44	137263	390.0	GRAB	
12/29/05 14:20	MRBVR-SSCT2006-11	446	1229	-31.9	11700	33.2	38781	110.2	BOX	
12/29/05 14:35	MRBVR-SSCT2006-12	388	1019	-31.9	11700	33.2	32154	91	GRAB	
12/30/05 19:15	MRBVR-SSCT2006-13	3921	5213	-22.5	27900	79.3	392259	1115	BOX	
12/30/05 19:33	MRBVR-SSCT2006-14	3394	3639	-22.5	28400	80.7	278728	792	GRAB	
12/31/05 00:30	MRBVR-SSCT2006-15	2555	3698	-24.2	32700	92.9	326134	927	BOX	Lowered Sampler 15-ft
12/31/05 00:38	MRBVR-SSCT2006-16	2367	3785	-24.2	32700	92.9	333806	948.5	BOX	Replicate
12/31/05 00:50	MRBVR-SSCT2006-17	1743	2292	-24.2	32600	92.6	201518	573	GRAB	
01/01/06 18:45	MRBVR-SSCT2006-18	742	2718	-32.3	11800	33.5	86499	246	BOX	Lowered to 20-ft
01/01/06 18:47	MRBVR-SSCT2006-19	674	1877	-32.3	11800	33.5	59735	170	BOX	Replicate
01/01/06 19:18	MRBVR-SSCT2006-20	707	1197	-37.3	11800	33.5	38094	108	GRAB	
01/02/06 15:17	MRBVR-SSCT2006-21	551	1910	-34.2	8770	24.9	45177	128	BOX	
01/02/06 15:21	MRBVR-SSCT2006-22	528	2376	-34.2	8750	24.9	56071	159	BOX	Replicate
01/02/06 15:37	MRBVR-SSCT2006-23	522	867	-34.2	8610	24.5	20133	57	GRAB	
01/11/06 17:05	MRBVR-SSCT2006-24	212	1424	-36.4	6270	17.8	24080	68	Box	
01/11/06 17:30	MRBVR-SSCT2006-25	197	450	-36.4	6190	17.6	7512	21	Grab	Associated with Box sample
01/13/06 11:42	MRBVR-SSCT2006-26	148	446	-37.7	3660	10.4	4402	13	Box	
01/13/06 11:55	MRBVR-SSCT2006-27	146	204	-37.7	3670	10.4	2019	6	Grab	Associated with Box sample
01/16/06 11:30	MRBVR-SSCT2006-28	85.0	130	-37.9	3680	10.5	1290	4	Box	
01/16/06 11:31	MRBVR-SSCT2006-29	83.0	233	-37.9	3680	10.5	2313	7	Box	Replicate
01/16/06 11:45	MRBVR-SSCT2006-30	92.0	127	-37.9	3640	10.3	1247	4	Grab	Associated with Box Sample
01/17/06 21:15	MRBVR-SSCT2006-31	445	2199	-35.1	7010	19.9	41574	118	Box	
01/17/06 21:25	MRBVR-SSCT2006-32	473	1216	-35.1	7050	20.0	23121	66	Grab	Associated With Box Sample
01/19/06 16:16	MRBVR-SSCT2006-33	171	308	-36.3	5920	16.8	4918	14	Grab	
02/02/06 15:25	MRBVR-SSCT2006-34	519	1437	-31.55	15400	43.8	59684	170	DIS	
02/02/06 15:30	MRBVR-SSCT2006-35	538	1358	-31.55	15400	43.8	56403	160	Box	Box sample related to DIS and Grab sample
02/02/06 16:05	MRBVR-SSCT2006-36	491	1035	-31.55	14800	42.1	41313	117	Grab	Grab sample related Box and DIS sample
03/29/06 15:47	MRBVR-SSCT2006-37	32.5	227	-38.4	2710	7.7	1659	5	Box	
03/29/06 15:48	MRBVR-SSCT2006-38	35.2	66.6	-38.4	2710	7.7	487	1	Box	Replicate
03/29/06 15:58	MRBVR-SSCT2006-39	31.2	49.8	-38.4	2710	7.7	364	1	Grab	Associated with box sample
04/27/06 19:35	MRBVR-SSCT2006-40	23.8	34.2		1670	4.7	154	0	Grab	
05/02/06 12:50	MRBVR-SSCT2006-41	18.5	29.0	-39.9	1300	3.7	102	0	BOX	Sample associated w/ DIS & Grab
05/02/06 12:52	MRBVR-SSCT2006-42	17.3	23.9	-39.9	1300	3.7	84	0	DIS	
05/02/06 13:32	MRBVR-SSCT2006-43	17.1	23.1	-39.9	1280	3.6	80	0	Grab	Sample associated w/ DIS & Box
12/13/06 09:35	MRBVR-SSCT200-01	500	1258	-37.60	6840	19.4	23207	66	Grab	DH-48
12/13/06 17:00	MRBVR-SSCT200-02	334	880	-35.40	9220	26.2	21882	62	Box	Thick-walled 3/16" nozzle
12/13/06 17:22	MRBVR-SSCT200-03	365	937	-35.40	9040	25.7	22845	65	Box	1/4" nozzle
12/15/06 09:21	MRBVR-SSCT200-04	119	319	-36.70	5140	14.6	4422	13	Box	Replicate
12/27/06 14:01	MRBVR-SSCT200-05	162	485	-35.90	6620	18.8	8659	25	Box	3/16" plastic nozzle
01/02/07 12:35	MRBVR-SSCT200-06	13.9	12.0		982	2.8	32	0.1	Grab	Station download
01/03/07 21:00	MRBVR-SSCT200-07	295	1270	-35.10	8490	24.1	29080	82.6	Box	3/16" plastic nozzle
02/11/07 08:55	MRBVR-SSCT200-08	155	669	-36.70	5950	16.9	10736	30.5	Box	
02/21/07 14:55	MRBVR-SSCT200-09	300	905	-35.60	8270	23.5	20185	57.4	Box	Maple CR is very dirty @ bridge
02/25/07 11:17	MRBVR-SSCT200-10	128	471	-35.70	7550	21.5	9591	27.3	Box	
02/25/07 11:20	MRBVR-SSCT200-11	125	419	-35.70	7550	21.5	8532	24	Box	Replicate



SUSPENDED SEDIMENT MEASUREMENT SUMMARY SHEET

LOCATION: **MAD RIVER AT HATCHERY ROAD BRIDGE (MRHRB)** **WATER YEAR:** **2006-2007**

STATION NUMBER: **11480900**

Date Time	Sample Number	Lab Turbidity (NTU)	SSC (mg/l)	Stage TWS (ft)	Discharge (cfs)	Unit Discharge (cfs/mi^2)	Suspended Sediment Discharge (tons/day)	Suspended Sediment Yield (ton/day/mi2)	Type DIS, Grab, Box	Note
12/01/05 16:05	MRHRB-SSCT2006-01	789	912		20700	46.4	50915	114	Grab	
12/01/05 16:06	MRHRB-SSCT2006-02	786	917		20700	46.4	51194	115	Grab	100 feet downstream of bridge
12/02/05 12:47	MRHRB-SSCT2006-03	248	368	-26.30	7040	15.8	6987	16	DIS	
12/02/05 13:35	MRHRB-SSCT2006-04	210	194	-26.50	6530	14.6	3417	7.7	Box	
12/02/05 13:36	MRHRB-SSCT2006-05	201	256	-26.50	6520	14.6	4502	10.1	Grab	100 feet downstream of bridge
12/02/05 13:37	MRHRB-SSCT2006-06	213	264	-26.50	6520	14.6	4642	10.4	Grab	
12/03/05 09:00	MRHRB-SSCT2006-07	98.3	122		4120	9.24	1356	3.0	Grab	
12/03/05 09:01	MRHRB-SSCT2006-08	97.7	122		4120	9.24	1356	3.0	Grab	100 feet downstream of bridge
12/04/05 16:55	MRHRB-SSCT2006-09	41.4	53.2		2610	5.85	374	0.8	Grab	
12/06/05 16:31	MRHRB-SSCT2006-10	20.8	21.4		1750	3.92	101	0.2	Grab	
12/18/05 18:46	MRHRB-SSCT2006-11	44.1	78.1		1350	3.03	284	0.6	Grab	
12/19/05 06:50	MRHRB-SSCT2006-12	195	283		5820	13.1	4442	10.0	Grab	
12/19/05 14:15	MRHRB-SSCT2006-13	772	2349		11400	25.6	72222	162	DIS	
12/19/05 15:20	MRHRB-SSCT2006-14	981	1422		12000	26.9	46022	103	Box	
12/21/05 18:40	MRHRB-SSCT2006-15	193	282		8160	18.3	6206	13.9	GRAB	
12/22/05 15:50	MRHRB-SSCT2006-17	937	1784	-23.80	14200	31.8	68323	153	BOX	
12/22/05 16:20	MRHRB-SSCT2006-16	852	1762	-23.80	14200	31.8	67480	151	DIS	
12/23/05 16:17	MRHRB-SSCT2006-18	392	668	-25.10	12100	27.1	21799	49	DIS	
12/23/05 17:00	MRHRB-SSCT2006-19	387	624		11400	25.6	19185	43	BOX	
12/23/05 17:25	MRHRB-SSCT2006-20	214	313		11400	25.6	9623	22	GRAB	
12/28/05 11:06	MRHRB-SSCT2006-22	436	600	-20.10	34000	76.3	55019	123	GRAB	
12/28/05 11:35	MRHRB-SSCT2006-23	2716	3506	-20.10	36300	81.4	343241	770	BOX	
12/28/05 12:17	MRHRB-SSCT2006-21	2294	3751	-20.10	38100	85.5	385437	864	DIS	
12/28/05 13:30	MRHRB-SSCT2006-24	297	536	-20.30	40400	90.6	58402	131	GRAB	
12/28/05 22:13	MRHRB-SSCT2006-25	352	553		31600	70.9	47130	106	GRAB	
12/29/05 12:35	MRHRB-SSCT2006-26	558	1313	-24.60	17400	39.0	61616	138	BOX	
12/29/05 12:38	MRHRB-SSCT2006-27	603	1368	-24.60	17400	39.0	64197	144	BOX	replicate
12/29/05 12:55	MRHRB-SSCT2006-28	312	623	-24.60	17400	39.0	29236	66	GRAB	
12/30/05 16:30	MRHRB-SSCT2006-29	1424	3260	-23.50	19900	44.6	174965	392	BOX	Outlier in SSC regression
12/30/05 16:43	MRHRB-SSCT2006-30	424	667	-23.50	20500	46.0	36877	83	GRAB	
12/30/05 21:50	MRHRB-SSCT2006-31	4136	4993	-19.90	45100	101.2	607322	1362	BOX	
12/30/05 21:55	MRHRB-SSCT2006-32	4383	5149	-19.90	45400	101.8	630463	1414	BOX	replicate
12/30/05 22:00	MRHRB-SSCT2006-33	1450	1838	-19.90	45700	102.5	226539	508	GRAB	
12/31/05 01:41	MRHRB-SSCT2006-34	3014	3732	-20.70	45000	100.9	452934	1016	BOX	
12/31/05 01:46	MRHRB-SSCT2006-35	3070	3829	-20.70	45000	100.9	464707	1042	BOX	replicate
12/31/05 02:05	MRHRB-SSCT2006-36	714	1100	-20.70	44500	99.8	132018	296	GRAB	
12/31/05 14:30	MRHRB-SSCT2006-37	1788	3000	-21.70	33900	76.0	274285	615	BOX	
12/31/05 14:31	MRHRB-SSCT2006-38	437	775	-21.70	34000	76.3	71066	159	GRAB	
01/01/06 16:32	MRHRB-SSCT2006-39	932	1564	-24.7	16900	37.9	71286	160	BOX	
01/01/06 16:35	MRHRB-SSCT2006-40	917	1591	-24.7	16900	37.9	72517	163	BOX	replicate
01/01/06 17:00	MRHRB-SSCT2006-41	649	1150	-24.7	16800	37.7	52106	117	GRAB	
01/02/06 13:15	MRHRB-SSCT2006-42	663	1155	-25.7	12600	28.3	39249	88	BOX	
01/02/06 13:35	MRHRB-SSCT2006-43	544	868	-25.7	12400	27.8	29028	65	GRAB	
01/13/06 14:50	MRHRB-SSCT2006-44	145	255	-27.7	5050	11.3	3473	7.8	Box	
01/13/06 14:55	MRHRB-SSCT2006-45	145	242	-27.7	5040	11.3	3289	7.4	Box	replicate
01/13/06 15:05	MRHRB-SSCT2006-46	129	185	-27.7	5030	11.3	2510	5.6	Grab	
01/16/06 14:10	MRHRB-SSCT2006-47	10.3	177	-27.4	5000	11.2	2387	5.4	Box	
01/16/06 14:20	MRHRB-SSCT2006-48	99.0	139	-27.4	5010	11.2	1878	4.2	Grab	
01/17/06 23:40	MRHRB-SSCT2006-49	495	1398	-25.2	10400	23.3	39212	88	Box	
01/19/06 00:03	MRHRB-SSCT2006-50	402	867	-25.2	10600	23.8	24786	56	Grab	
01/19/06 17:13	MRHRB-SSCT2006-51	178	299	-26.2	8160	18.3	6580	15	Grab	
03/29/06 12:00	MRHRB-SSCT2006-52	60.0	132	-27.3	3840	8.61	1367	3.1	Box	
03/29/06 12:01	MRHRB-SSCT2006-53	55.0	166	-27.3	3840	8.61	1719	3.9	Box	replicate
03/29/06 12:30	MRHRB-SSCT2006-54	60.0	74.3	-27.3	3860	8.66	773	1.7	Grab	
04/28/06 15:28	MRHRB-SSCT2006-55	33.3	44.8	---	2430	5.45	294	0.7	Grab	
05/01/06 14:11	MRHRB-SSCT2006-56	28.8	69.6	-28.9	2010	4.51	377	0.8	BOX	
05/01/06 14:11	MRHRB-SSCT2006-57	29.3	58.7	-28.9	2010	4.51	318	0.7	DIS	
05/01/06 15:15	MRHRB-SSCT2006-58	30.9	31.3	-28.9	2010	4.51	170	0.4	Grab	
05/01/06 15:18	MRHRB-SSCT2006-59	29.3	30.9	-28.9	2010	4.51	168	0.4	Grab	replicate
05/02/06 15:37	MRHRB-SSCT2006-60	24.0	26.4	---	1760	3.95	125	0.3	Grab	
12/13/06 19:45	MRHRB-SSCT2007-01	432	1010	-24.8	11600	26.0	31598	71	Box	
12/15/06 11:15	MRHRB-SSCT2007-02	136	278	-26.1	6940	15.6	5203	12	Box	
12/27/06 10:05	MRHRB-SSCT2007-03	379	987	-24.9	10400	23.3	27684	62	Box	
01/03/07 23:20	MRHRB-SSCT2007-04	456	1353	-25.1	12000	26.9	43788	98	Box	
01/03/07 23:30	MRHRB-SSCT2007-05	450	1283	-25.1	12100	27.1	41869	94	Box	replicate
02/11/07 11:00	MRHRB-SSCT2007-06	226	538	-26.1	8370	18.8	12145	27	Box	
02/11/07 11:05	MRHRB-SSCT2007-07	228	550	-26.1	8360	18.7	12401	28	Box	replicate
02/21/07 17:02	MRHRB-SSCT2007-08	382	1195	-24.7	12100	27.1	38997	87	Box	
02/25/07 09:45	MRHRB-SSCT2007-09	223	614	-25.3	10700	24.0	17719	40	Box	

DISCHARGE SUMMARY SHEET

STATION: NORTH FORK MAD AT KORBEL BRIDGE **WATER YEAR: 2006-2007**

STATION NUMBER: 11480800

Measurement Number	WY Msmt #	Date	Made By	Width (feet)	Mean Depth (feet)	Area (ft2)	Mean Velocity (ft/sec)	Staff Height (feet)	Gage Height (feet)	Discharge (cfs)	Rating 1.0			Method	Begin Time (hours)	End Time (hours)	Msmt Rating	Water Temp (F)	GZF (feet)	Comments
											Comp. Shift (feet)	Used Shift (feet)	% Diff.							
01	**2006-01**	8/3/2006	I. Pryor	21.0	0.33	6.99	0.32	0.66	---	2.20	0.00	0.00	-1	Wading	13:05	14:09	Poor			Very shallow
02	**2006-02**	8/3/2006	I. Pryor	21.0	0.33	6.88	0.37	0.66	---	2.52	-0.01	0.00	12	Wading	14:15	14:55	Poor			Check Measurement, not used for rating development or shifts
03	**2007-01**	12/17/2006	I. Pryor	60.9	2.14	130.63	2.28	2.55	2.54	298	0.01	0.00	-1	Wading	13:15	14:23	Good		0.25	
04	**2007-02**	1/2/2007	I. Pryor	53.7	1.78	95.85	1.22	1.72	1.74	116	-0.01	0.00	2	Wading	15:15	16:17	Fair		-0.53	Salmon spawning on control
05	**2007-03**	1/3/2007	I. Pryor / T. Grey	92.0	6.20	570.63	6.25	8.27	8.22	3560	0.10	0.00	-3	Bridge	16:16	17:22	Poor			No wet line correction used
06	**2007-04**	2/22/2007	I. Pryor / T. Grey	74.0	3.94	291.69	5.26	5.27	5.29	1530	-0.08	0.00	3	Bridge	09:59	11:08	Good			

***Staff heights are corrected by one foot**

MAD RIVER SEDIMENT SOURCE ANALYSIS

2007 REPORT

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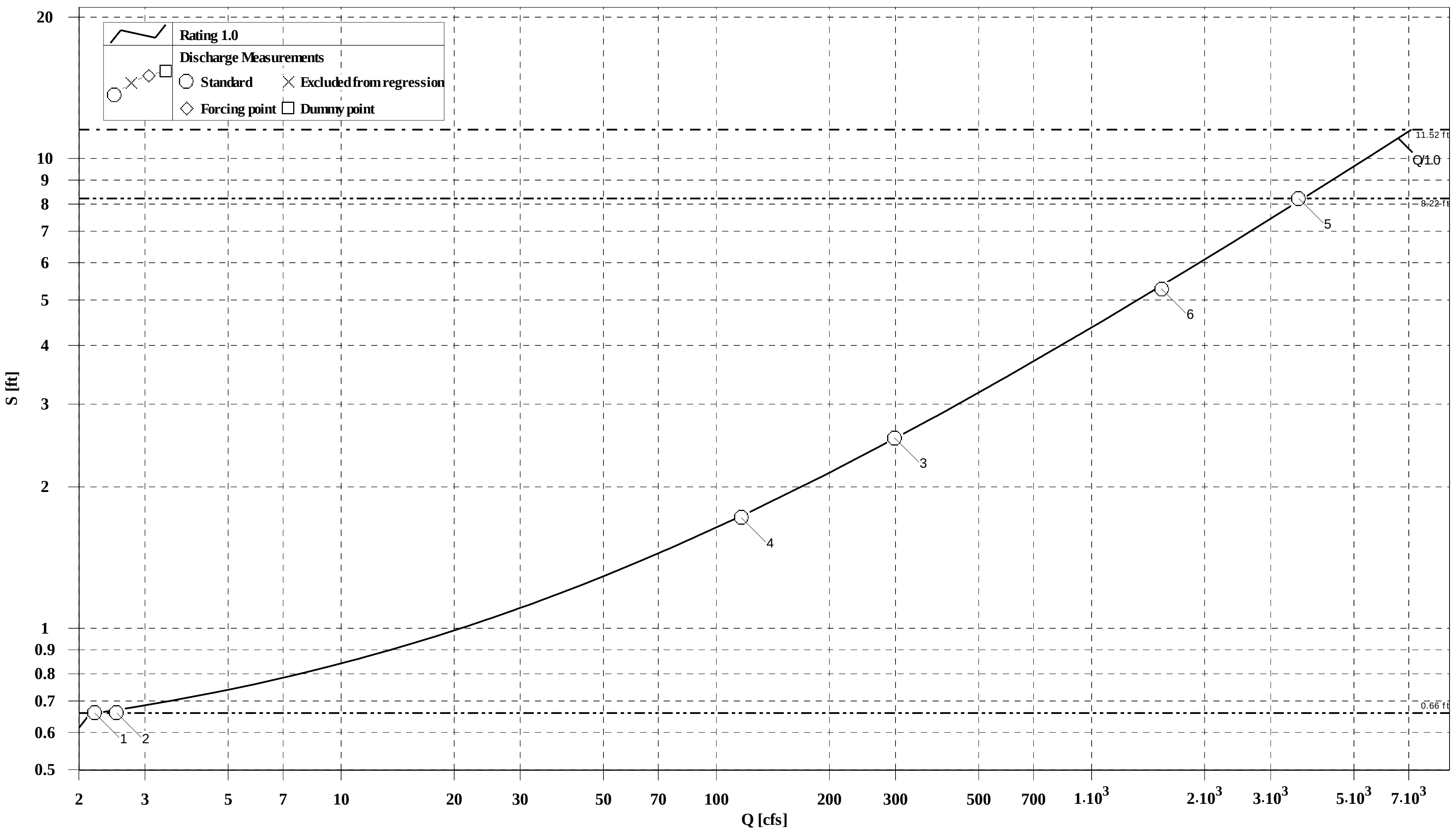
NORTH FORK MAD AT KORBEL BRIDGE (NFMKB) RATING CURVE



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APPENDIX

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