APPENDIX C – ROAD SEDIMENT ASSESSMENT

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ACRONYM LIST

Acronym	Definition
AOP	Aquatic Organism Passage
BMP	Best Management Practices
CMP	Corrugated Metal Pipe
DEM	digital elevation model
DEQ	Department of Environmental Quality (Montana)
EPA	Environmental Protection Agency (US)
GIS	Geographic Information System
HUC	Hydrologic Unit Code
MDT	Montana Department of Transportation
MSU	Montana State University
NHD	National Hydrography Dataset
SAP	Sampling and Analysis Plan
TMDL	Total Maximum Daily Load
TPA	TMDL Planning Area
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
WET	Water and Environmental Technologies

C1.0 Introduction

This appendix is derived from a roads assessment report prepared by Water and Environmental Technologies (WET)(2010a) for the Montana Department of Environmental Quality (DEQ). This report presents a sediment load analysis and culvert assessment of the road network within listed watersheds of the Lower Gallatin River TMDL Planning Area (TPA) performed to assist with sediment TMDL development. Roads located near stream channels can impact stream function through degradation of riparian vegetation, channel encroachment, and sediment loading. The degree of impact is determined by a number of factors, including road type, construction specifications, drainage, soil type, topography, precipitation, and the use of best management practices (BMPs). Through a combination of GIS analysis, field assessment, and computer modeling, estimated sediment loads were developed for road crossings and unpaved parallel segments. Existing road conditions were modeled and future road conditions were estimated after the application of sediment-reducing BMPs. Additionally, paved segments of road were evaluated for loading from traction sand and existing culverts were assessed for fish passage and potential loading during failure associated with runoff events.

The 2010 303(d) List includes the following stream segments for sediment/siltation impairment: Bear Creek, Bozeman Creek, Camp Creek, Dry Creek, Godfrey Creek, Jackson Creek, Rocky Creek, Smith Creek, Stone Creek, and Thompson Creek. Modeling efforts to quantify sediment loads focused on these watersheds. Additionally, the Smith Creek watershed is subdivided into areas draining into Ross, Reese and Smith creeks.

C2.0 Data Collection

The Lower Gallatin Road Sediment Assessment consisted of four primary tasks:

1) GIS layer development and summary statistics,
2) Field assessment and sediment modeling,
3) Sediment load calculations and load reduction allocations for sediment listed watersheds, and
4) Traction sand assessment on paved road surfaces.

The first task was completed by DEQ and results are included in this report. Additional information on assessment techniques is available in the following prior reports for this project: Road GIS Layers and Summary Statistics (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010), and Task 2. Sampling and Analysis Plan (Water & Environmental Technologies, 2010b).

C2.1 Spatial Analysis

Using road layers derived from the State of Montana Base Map Service Center Transportation Framework Theme and stream layers from the National Hydrography Dataset (NHD) high-resolution (1:24,000) flowline layer, crossings and parallel segments in the road network were identified and classified relative to 6th code subwatershed, Level IV Ecoregion, ownership, and road surface type (**Figures C1-4**). Based on GIS analysis, there are approximately 333 total unpaved crossings, 105 paved crossings and 60 miles of parallel road segments within 150 feet of surface water. Summarizing all crossings by these classifications allowed assessment sites to be chosen representative of the greater watershed (**Tables C2-1**). Summaries of road crossings and parallel segments by watershed and ownership are contained in **Tables CA-1, CA-2, and CA-4**).

Table C2-1. Summary of Crossings and Assessment Sites

Road Class	Total Road Crossings	% Total Road Crossings	Number of Assessment Sites	% Total Assessment Sites
Paved	105	24%	7	26%
Gravel	277	63%	14	52%
Native	56	13%	6	22%
Maintenance Ownership				
Federal	23	5%	2	7%
State	52	12%	5	19%
County	236	54%	15	56%
City	18	4%	2	7%
Private	109	25%	3	11%
Ecoregion				
17g	51	12%	3	11%
17i	37	8%	2	7%
17y	5	1%	0	0%
17w	345	79%	22	81%

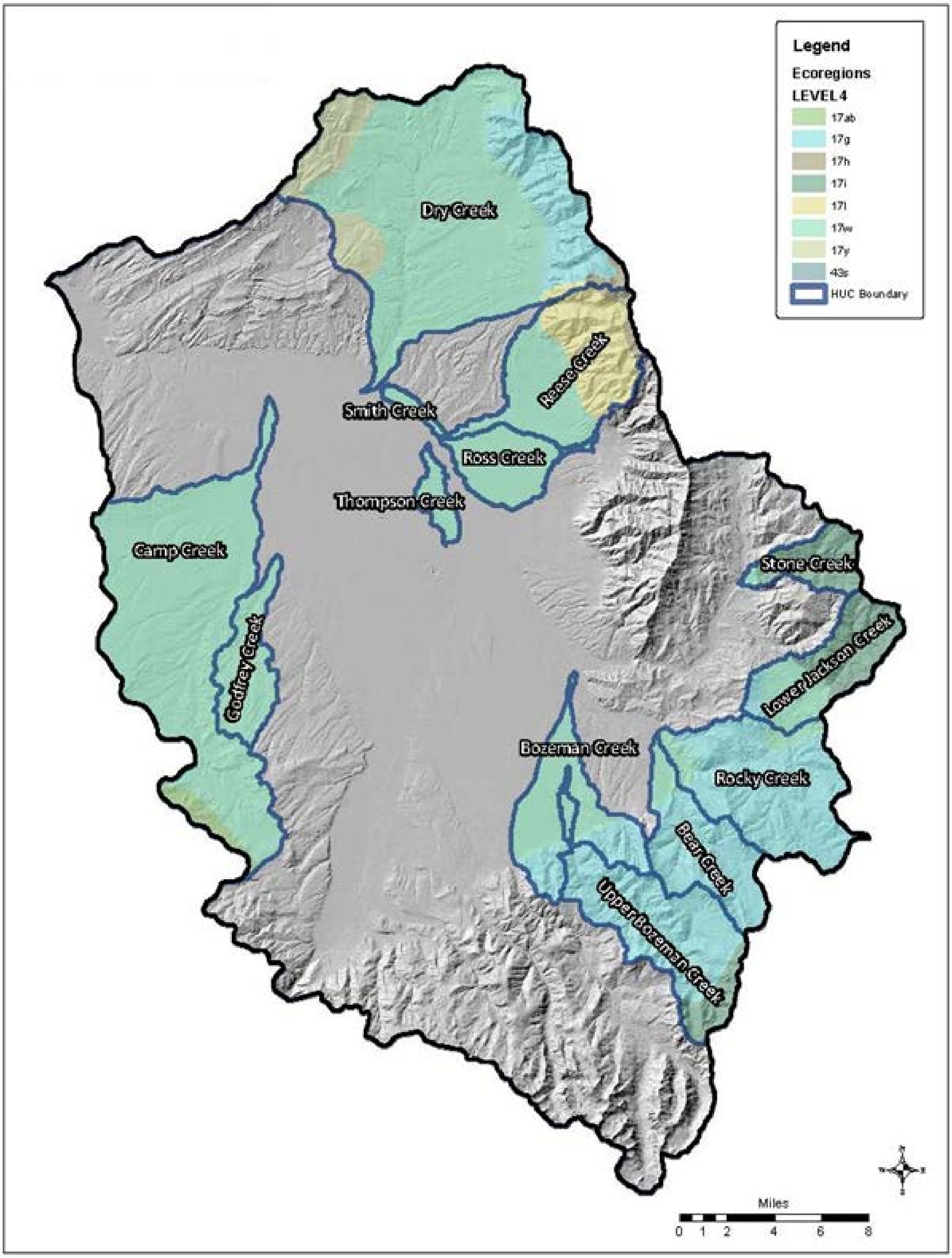

Figure C1. Lower Gallatin TPA EPA Ecoregion

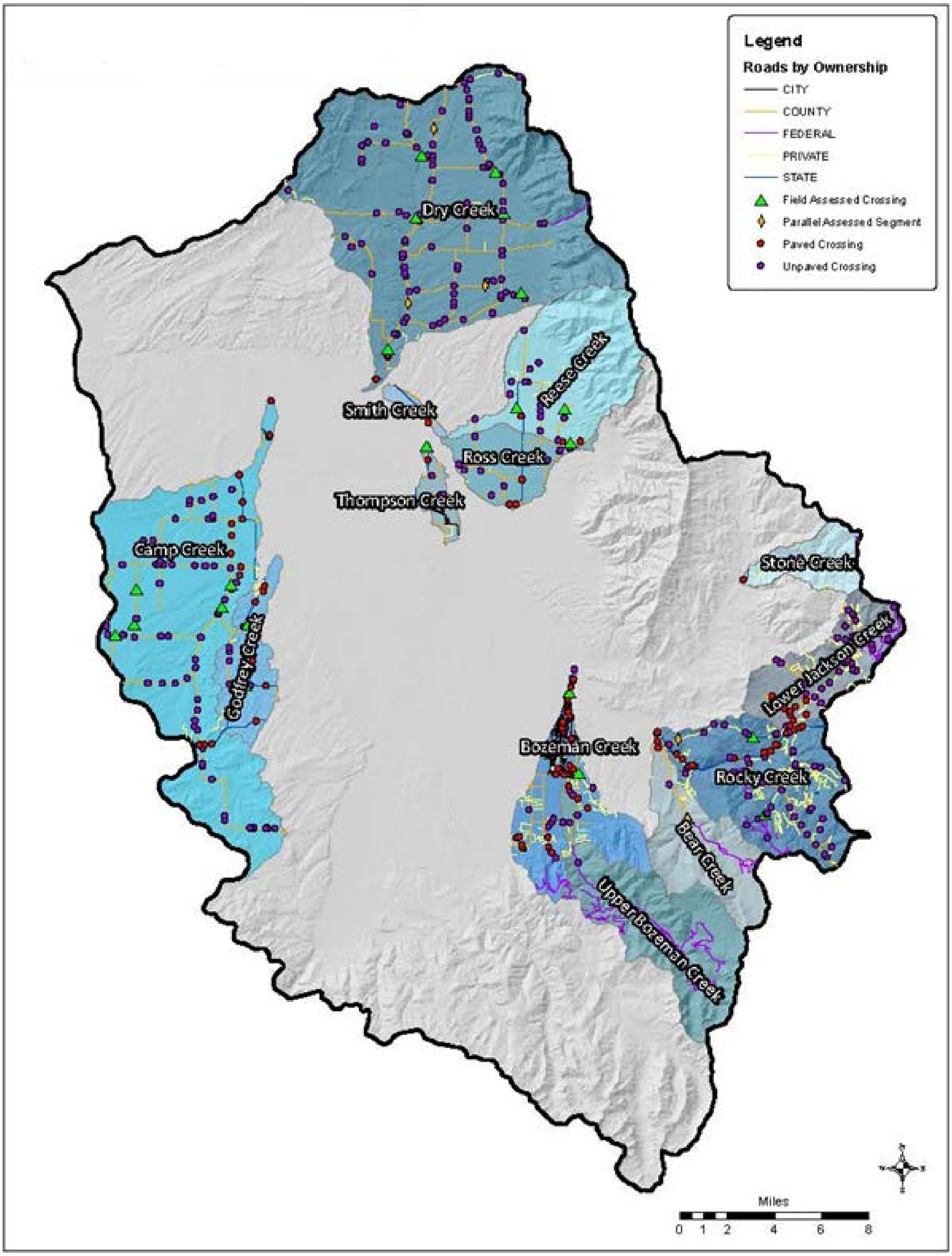

Figure C2. Lower Gallatin TPA Road maintenance Ownership

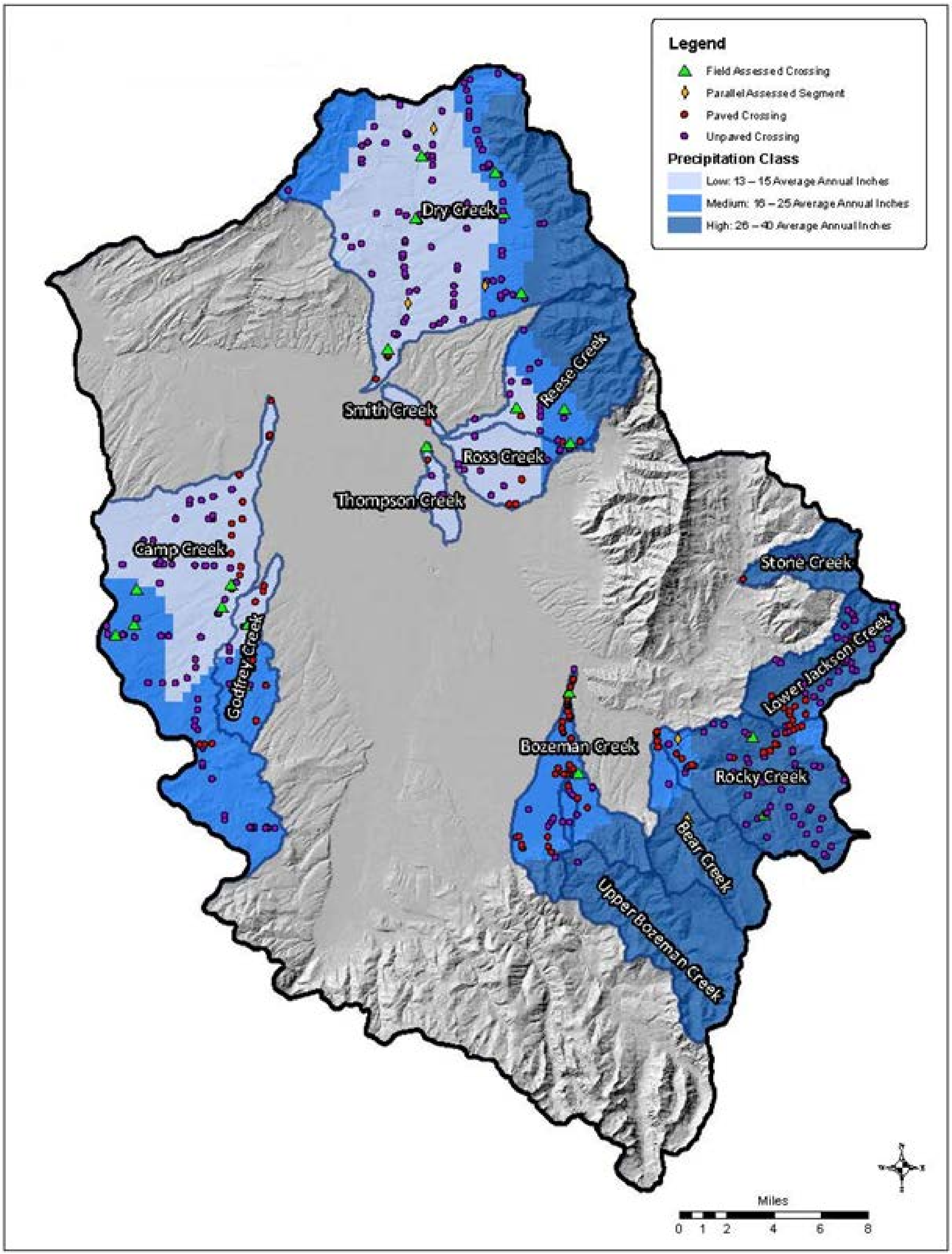

Figure C3. Lower Gallatin TPA Precipitation Classes

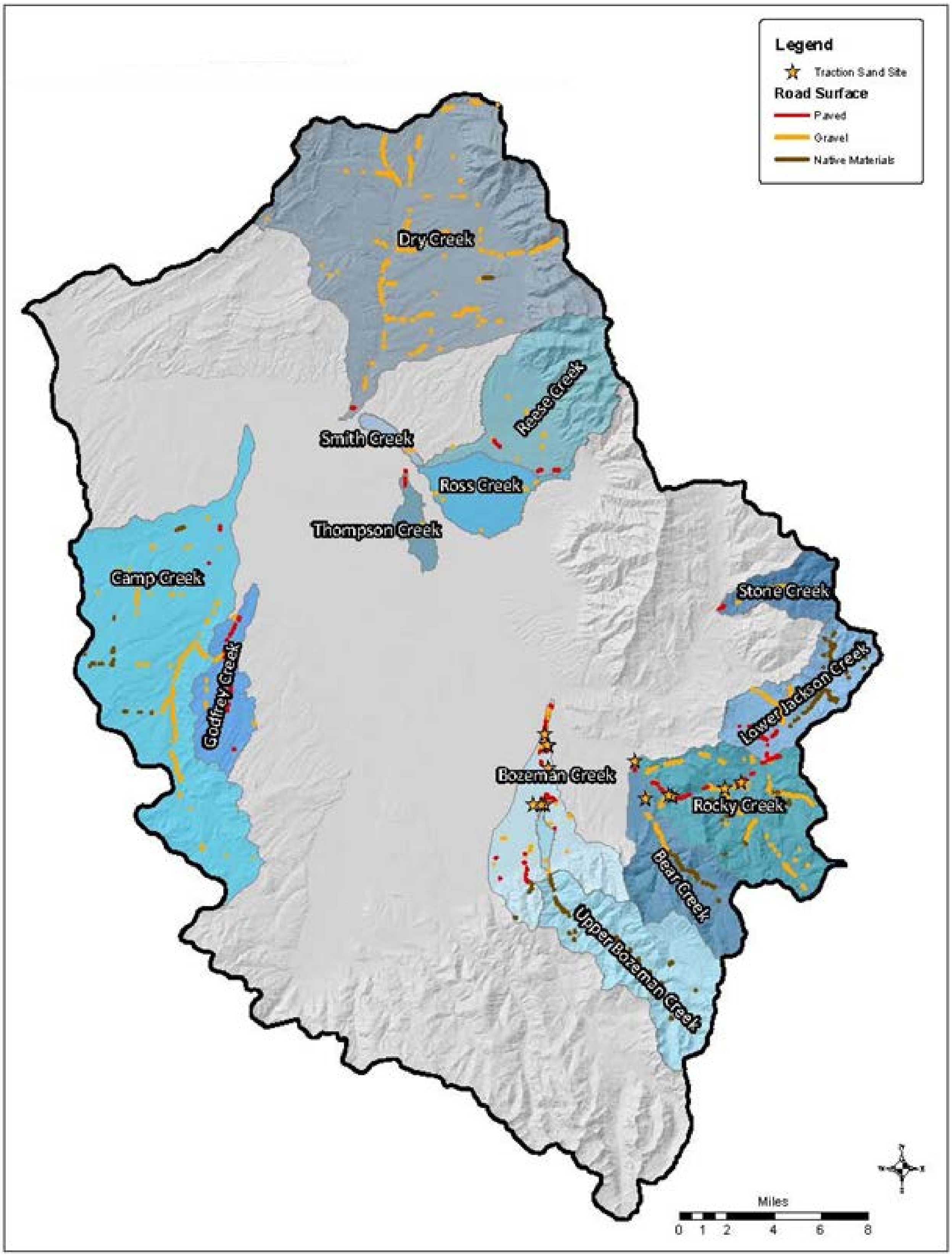

Figure C4. Lower Gallatin TPA Paved Roads Within 150 Feet of Surface Water

C2.2 Field Data Collection

The goal of the field effort was to characterize approximately five percent of the road network. A random subset of 27 of the total 438 crossing sites (6.1%) were chosen for field assessment based on the proportion of total crossings within category (**Table C2-1**). Parallel segments were selected based on best professional judgment while traveling roads on which specific crossings were selected for assessment. Parallel segments were evaluated on gravel or native surfaced roads only. Four sites had to be relocated during the field effort due to ownership restrictions or dry stream channels. A total of 20 unpaved crossings, 7 paved crossings and 6 parallel segments were evaluated in the field (**Figure C2-3** and **Table CB-1** (**Attachment CB**)). Traction sand was assessed on paved crossings and parallel segments (**Figure C4**).

Gravel and native surfaced roads are considered unpaved. Fourteen crossings were assessed in the gravel road class and six crossings were assessed in the native road class. Generally, the majority of parallel road segments are located in narrow stream valleys or canyons in foothill and mountain landscapes, where roads are constructed near streams. Four parallel segments were assessed in the gravel road class and two segments were assessed in the native road class.

Crossing and parallel sites were named with the first two to three letters representing the 6th code hydrologic unit (HUC), the following three letters and numbers represents the Level IV Ecoregion, the following letter represents the road surface type (Paved, Gravel, or Native) and the final letter represents the site type (crossing, X, or parallel segment, P). The last three numbers were automatically assigned through GIS software to ensure that each site is unique.

An example of the naming convention is RCC-17g-G-X-108:

RCC = Rocky Creek
17g = Level IV Ecoregion 17g
G = Gravel road surfacing
X = Road crossing
108 = Unique numerical identifier

C2.3 Sediment Assessment Methodology

The road sediment assessment was conducted following a Sampling and Analysis Plan (Water & Environmental Technologies, 2010b), which was based on inputs needed for the WEPP:Road forest road erosion prediction model (http://forest.moscowfsl.wsu.edu/fswepp/). WEPP:Road is an interface to the Water Erosion Prediction Project (WEPP) model (Flanagan and Livingston, 1995), developed by the USDA Forest Service and other agencies, and is used to predict runoff, erosion, and sediment delivery from forest roads. The model predicts sediment yields based on particular soil, climate, ground cover, and topographic conditions. Specifically, the following model input data was collected in the field: soil type, percent rock, road surface, road design, traffic level, and specific road topographic values (road grade, road length, road width, fill grade, fill length, buffer grade, and buffer length). In addition, supplemental data was collected for evidence of erosion from the road system or traction sand, the presence of road BMPs, and potential for fish passage and culvert failure.

Site-specific climate profiles were created in WEPP by modifying the NORRIS MADISON PH MT climate station with data from the three climate stations located within the Lower Gallatin TPA. The three stations encompass a wide range of annual precipitation, with averages ranging from 14 to 34 inches per year (**Table C2-2**). Each stream crossing and parallel segment visited was assigned one of these three modified climate stations.

Table C2-2. Climate Stations in Lower Gallatin TPA

Climate Station	Station ID	Elevation (ft)	Annual Precipitation (in)	Assessment Precipitation Grouping
Belgrade Airport	240622	4,460	14.0	Low
Bozeman MSU	241044	4,860	18.5	Medium
Bozeman 12NE	241050	5,950	34.6	High

Per WEPP:Road documentation, 30 year simulations were run for road crossings and parallel segments within the Bozeman 12NE climate station since the quantity of precipitation exceeded 500 millimeters (19.69 inches). Fifty year simulations were run for crossings and parallel segments within the Belgrade Airport and Bozeman Montana State University climate stations.

Some road conditions encountered in the field are not accurately represented in the WEPP:Road design options; as a result, some adjustments were made to the model to more appropriately represent these types of roads. **Attachment CC** contains a description of model or site condition adjustments, as recommended by WEPP:Road technical documentation, the model author or by best professional judgment. **Attachment CC** also includes a summary of each climate station model (**Tables CC-1** through **CC-7**).

C2.4 Mean Sediment Loads from Field Assessed Sites –Stream Crossings

Field assessment data and WEPP:Road modeling results were used to develop existing sediment loads based on various watershed criteria. A standard statistical breakdown of loads from the road network within each sediment-listed watershed was generated using the applicable dataset of field assessed crossing. Mean sediment load and contributing length, median, maximum and minimum loads, and 25th and 75th percentile loads were calculated for road crossings within each road surface-precipitation class that was the basis of the field assessment, and totaled by road surface type. Mean sediment loads from road crossings were estimated at 0.20 tons/year on native surfaced roads, 0.34 tons/year on gravel roads, and 0.03 tons/year on paved roads (**Table C2-3**). Site BC-17g-G-X-34 was neither included in **Table C2-3** nor used for statistical extrapolation because the site was not randomly selected following SAP protocols and not necessarily representative of conditions throughout the Lower Gallatin TPA. The site was intentionally chosen to assess Bear Creek since road-related sediment was previously identified as a probable source of its nutrient and sediment listing.

Table C2-3. Current Crossing Sediment Load by Road Surface-Precipitation Class

Class (Surface-Precip.)	Number of Sites	Mean Contributing Length (ft)	Mean Load	Median Load	Max Load	Min Load	25th %	75th %
Native - High	2	645	0.36	0.36	0.67	0.05	0.20	0.51
Native - Medium	0*	645	0.48	0.48	0.89	0.06	0.27	0.69
Native - Low	4	781	0.08	0.07	0.19	0.00	0.04	0.11
NATIVE TOTAL	6	735	0.20	0.08	0.67	0.00	0.05	0.19
Gravel - High	3	458	0.37	0.14	0.98	0.00	0.07	0.56
Gravel - Medium	4	728	0.55	0.65	0.88	0.04	0.37	0.83
Gravel - Low	6	675	0.17	0.12	0.42	0.02	0.05	0.27
GRAVEL TOTAL	13	641	0.34	0.14	0.98	0.00	0.04	0.48
Paved - High	1	1000	0.17	0.17	0.17	0.17	0.17	0.17
Paved - Medium	2	610	0.02	0.02	0.04	0.00	0.01	0.03

Table C2-3. Current Crossing Sediment Load by Road Surface-Precipitation Class

Class (Surface-Precip.)	Number of Sites	Mean Contributing Length (ft)	Mean Load	Median Load	Max Load	Min Load	25th %	75th %
Paved - Low	1	1000	0.02	0.02	0.02	0.02	0.02	0.02
PAVED TOTAL	4†	805	0.06†	0.03	0.17	0.00	0.01	0.07

*None of the randomly selected sites fell into the Native Surface-Medium Precipitation class, so the two sites in the Native-High class were modeled under a medium precipitation scenario.
†Three of seven paved crossings visited were not modeled because the sediment load derived from these sites was deemed negligible (i.e., 0 tons/year) due to existing curbs and/or lush grass berms. Including these sites reduces the mean load from 0.06 tons/year to a more accurate 0.03 tons/year.

Due to the elevation differences and impacts from rain-on-snow events, the medium precipitation class produces greater runoff than the higher precipitation class for unpaved roads. The sediment load summary shows similar values between the median and mean statistics. This is most likely due to the low sample numbers in each class. Because the values for the gravel sites and native sites were similar for high and medium precipitation classes, the mean load was averaged for unpaved roads in those precipitation classes. The mean sediment loads shown for these refined classes are shown in **Table C2-4**.

Table C2-4. Current Crossing Sediment Load Summary

Class	Mean Load (tons/yr)
Unpaved - High Precip	0.37
Unpaved - Medium Precip	0.53
Native - Low Precip	0.08
Gravel - Low Precip	0.17
Paved - All Precip	0.03

For the purposes of estimating the sediment load from each road crossing in the Lower Gallatin River TPA, the average of all field sites by road type-precipitation class assumes that the random subset of crossings assessed as part of this study is representative of road crossing conditions in the TPA. Average road surface-precipitation class loading rates were not used to estimate loading at BC-17g-G-X-34, instead the crossing's WEPP model results were used because of the site's noted road sediment related contribution.

C2.5 Mean Sediment Loads from Field Assessed Sites – Parallel Segments

Mean sediment loads were calculated for unpaved parallel road segments, and loads were then normalized to a per-mile value to account for differences in contributing road length. During field sampling, paved parallel segments determined to be a negligible sediment source and were not sampled or included in the loading extrapolation. In general, parallel road segments tend to contribute a smaller sediment load to streams than road crossings; because of this and the small number of native and gravel parallel segments evaluated in the field, they were not segregated by precipitation class. Mean sediment loads from unpaved parallel road segments were estimated at 0.06 tons/year/mile on gravel roads and 0.08 tons/year/mile on native roads (**Table C2-5**). A detailed summary of modeling results from field assessed sites is located in **Attachment CD (Tables CD-1 and CD-2)**.

Table C2-5. Current Parallel Segment Load Summary by Road Surface

Statistical Parameter	Native	Gravel
Number of Sites (n)	3	3
Mean Contributing Length (ft)	791	764
Mean Road Gradient (%)	5	3.6
Mean Buffer Length (ft)	115	48.3
Mean Buffer Gradient (%)	25.3	2.3
Mean Load (tons/year/mile)	0.08	0.06
Median Load (tons/year/mile)	0.08	0.03
Maximum Load (tons/year/mile)	0.1	0.16
Minimum Load (tons/year/mile)	0.07	0.02

For the purposes of estimating the sediment load from each parallel segment in the Lower Gallatin River TPA, the average of all field sites by road type assumes that the random subset of crossings assessed as part of this study is representative of the parallel segment conditions in the listed watersheds.

C2.6 Paved Roads – Traction Sand

The amount of traction sand applied during winter months to paved roads was also investigated as a potential source of sediment loading to streams. Traction sand was visually assessed in the field at seven sites. The two major applicators of traction sand in the TPA were identified as the City of Bozeman and Montana Department of Transportation (MDT). Per telephone conversation with the City of Bozeman Streets Department, approximately 16 to 23 tons/year/mile of traction sand is applied to 218 miles of city streets. Due to the city's comprehensive street sweeper program, accumulation of traction sand was rarely observed at sites. The presence of curbs and/or stormwater infrastructure installed at most city crossings further limit the amount of sediment reaching streams. MDT provided data to calculate they apply an estimated 348 tons/mile/year on a 35 mile stretch of Interstate-90. The department is employing BMPs to reduce sand application by using a deicer/traction sand mix that has decreased sand usage 14% since 2008.

In order to determine traction sand contributions per HUC for the Lower Gallatin River watershed, the GIS database was queried for paved parallel road lengths within 150 feet of streams. The distance to surface water was not further refined into smaller increments due to the inherent inaccuracies between the GIS road and stream layers.

The TMDL for the St. Regis TPA (Montana Department of Environmental Quality, 2008) included an in-depth study of traction sand and quantified deposits at set distances from the road; field results from the Lower Gallatin TPA were compared to the St. Regis report. Both highways are four-lane roads maintained by MDT. The traction sand application rate as provided by MDT in the TPA is near the mean annual traction sand application rates along Interstate-90 between Saltese and St. Regis and the rates are approximately 70% lower than those provided between Lookout Pass and Saltese (Table K-2 in Montana Department of Environmental Quality, 2008). The St. Regis TMDL results had an average fillslope of 45%; the furthest distance traveled at each site was observed at a minimum 25 feet, at an average 33 feet and at a maximum 45 feet from the shoulder. Depths of traction sand in the St. Regis study varied from 7.9 inches to unobservable. Results from crossings in the Lower Gallatin are described in **Table C2-6**.

Table C2-6. Traction Sand Field Assessment Results

Site (East or West Bound)	Fillslope (%)	Distance from Road Surface (ft)	Depth (in)
RCC-17g-G-X-84	57	9	2.25
RCC-17W-P-X-74 EB	46.5	14.5	1
RCC-17W-P-X-74 EB	46.5	25 near culvert	1-2 inches above rock
RCC-17W-P-X-90	92	20	Minimal
RCC-17W-P-X-80 WB	71	35	1
RCC-17W-P-X-74 WB	Not Assessed	45	Minimal
RCC-17W-P-X-120 WB	1.5	15	Minimal

These results corroborate the findings in the St. Regis study regarding the distance of travel. All of the sites near I-90 had evidence of recent chip sealing activities. Traction sand was deposited on top of the excess chip seal indicating at least one winter has passed since the road resurfacing. The deposition of excess chip seal may have impacted traction sand mobility due to larger particles on the fillslope surface and due to the creation of berms on the road shoulders.

Many of the fillslope lengths and buffer lengths were greater than the extent of the traction sand travel distance as noted in the field. Although there is periodic loading of traction sand, based on the measurements in the field, it is not a significant source of sediment in the watersheds. As a result, sediment loads from traction sand were not included in the load analysis.

C3.0 Road Network Load Analysis

C3.1 Sediment Load from All Road Crossings and Parallel Segments

Mean sediment loads from field assessed sites were used to extrapolate existing loads throughout the sediment-listed watersheds. Loads from refined classes (**Table C2-4**) were applied to the total number of crossings within the specific watersheds, and further classified by 6th code HUC and land ownership. The existing total sediment load from road crossings for listed watersheds within Lower Gallatin River TPA is estimated at 119.88 tons/year, and the total existing load from parallel road segments is estimated at 3.37 tons/year (**Table C3-1**). Paved crossings and parallel segments were not further classified into precipitation classes due to the overall low number of samples sites (seven and six respectively).

Table C3-1. Extrapolated Sediment Load Summary by Road Surface – Precipitation Class

Road Feature	Class (Surface-Precip)	Total Number of Crossings	Mean Sediment Load (tons/yr)	Total Sediment Load (tons/yr)
Crossing	Paved - All	105	0.03	3.15
Crossing	Unpaved – High	96	0.37	35.52
Crossing	Unpaved - Medium	112	0.53	59.36
Crossing	Native - Low	4	0.08	0.32
Crossing	Gravel - Low	120	0.17	20.4
Total:	-	438		118.75*
Road Feature	**Class**	**Total Parallel Distance w/in 150-feet (Mi)**	**Mean Sediment Load (Tons/year/mile)**	**Total Sediment Load (Tons/year)**
Parallel	Gravel – All	37.37	0.06	2.24
Parallel	Native – All	14.23	0.08	1.14
Total:	-	51.6		3.37
Total Existing Sediment Load – Listed Lower Gallatin River TPA watersheds:				122.12*

* The load from Bear Creek crossing BC-17g-G-W-34 (1.13 tons/yr) was not included in these totals since it was not used for extrapolation.

Detailed sediment loads for road crossings classified by ownership, precipitation class and road surface type within each 6th code/303(d) subwatershed are included in **Table CA-3**. Detailed sediment loads for parallel segments classified by ownership and landscape type within each 6th code/303(d) subwatershed are included in **Table CA-5**.

Table C3-2. Extrapolated Sediment Load Summary by HUC (Loads in Tons/Year)

6th Code HUC	Crossings Load	Parallel Segments Load	Current Total Load
Bear Creek	1.78	0.28	2.06
Bozeman Creek	8.65	0.08	8.73
Camp Creek	22.71	0.44	23.15
Dry Creek	31.28	0.84	32.12
Godfrey Creek	5.75	0.11	5.86
Lower Jackson Creek	15.29	0.47	15.76
Reese Creek	6.09	0.02	6.11
Rocky Creek	20.62	0.61	21.23
Smith/Ross Creeks	3.82	0.03	3.85
Stone Creek	2.25	0.08	2.33
Thompson Creek	0.71	0.0	0.71
Upper Bozeman Creek	0.93	0.4	1.33
Sum	119.88	3.37	123.25

Results by watershed (**Table C3-2**) show Dry Creek (32.13 tons/year), Rocky Creek (21.24 tons/year) and Camp Creek (23.16 tons/year) contain the three highest total sediment loads. These three HUCs also contained the most crossings in the TPA (**Table CA-2**). The higher estimated sediment loads in the Dry, Rocky and Camp Creek watersheds is thought to be due to the greater number of crossings, as well as the higher precipitation classes present in the Rocky Creek HUC.

C3.2 Culvert Assessment – Fish Passage

Culverts were analyzed for their ability to allow for fish passage. Measurements were collected at each field assessed crossing site, and these values were used to determine if culverts represented potential fish passage barriers at various flow conditions. Sites with bridges, sites with intermittent or ephemeral channels, and any other sites where the required screening data could not be accurately collected, were removed from list of 27 field assessed road crossings. After removing these sites, 15 culverts were determined to be suitable for fish passage assessment.

The fish passage evaluation was completed using the criteria listed in Table 1 of the document A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on National Forests in Alaska (U.S. Department of Agriculture, Forest Service, Alaska Region, 2002). The analysis uses site-specific information to classify culverts as green (passing all life stages of salmonids), red (partial or total barrier to salmonids), or grey (needs additional analysis). Indicators used in the classification are the ratio of the culvert width to bankfull width (constriction ratio), culvert slope, and outlet drop, with large diameter (>48 in) and small (<48 in) culvert groups evaluated differently. Failure of any one of the three indicators results in a red classification. Using the Alaska fish passage analysis, 13 of 15 culverts (87%) were classified as partial or total fish barriers (red) as shown in **Table C3-3**. None of the field assessed culverts were classified as capable of passing fish at all flows and life stages (green). Detailed fish passage results are included in **Table CA-6**. The predominant cause for preventing fish passage was (relatively) steep culvert gradient. It is important to note that this fish passage assessment is a coarse level evaluation; further study may be necessary to more accurately determine fish passage conditions.

Table C3-3. Fish Passage Analysis for Selected Culverts

Culvert Classification or Indicator	Definition of Indicator	Number of Culverts	Percentage of Total Culverts Assessed (n=15)
Green[1]	High certainty of meeting juvenile fish passage at all flows	0	0%
Grey[2]	Additional and more detailed analysis is required to determine juvenile fish passage ability	2	13%
Red[3]	High certainty of not providing juvenile fish passage at all desired streamflows	13	87%

C3.3 Culvert Assessment – Failure Potential

The annual peak discharge, at various return intervals, of selected streams were determined by using USGS regression equations developed by Parrett and Johnson (Parrett and Johnson, 1998). Independent variables within these equations are drainage area (square miles) and percentage of drainage basin above 6,000 feet elevation. Drainage area above each culvert was calculated using a digital elevation model (DEM) and the ArcSwat extension in GIS.

To estimate the maximum conveyance of each culvert, Manning's equation was used with site-specific culvert information collected in the field. Variables in Manning's equation are culvert cross sectional area, hydraulic radius, slope, and roughness coefficient (based on culvert material). This conveyance value was then compared against the USGS-derived peak streamflow estimates to determine the maximum storm event each culvert could convey without water backup. Nineteen culverts were analyzed for failure potential. The number of culverts passing each specific storm event is shown in **Table C3-4** and **Table CA-7**. Based on the USGS peak flow equation derived from basin characteristics, culverts appear to be sized for the Q10 storm event.

Table C3-4. Culverts Ability to Pass Various Storm Events

Recurrence Interval	Culverts Passing	Culverts Failing	Cumulative Percent Passing
Q2	19	0	100%
Q5	17	2	89%
Q10	13	6	68%
Q25	6	13	32%
Q50	1	18	5%
Q100	0	19	0%

Potential road fill volume at risk for delivery in the event of a culvert failure was calculated using field measurements of the road prism over the culvert. The volumes calculated are conservative, assuming that the entire road prism above the culvert fails to bankfull width and is delivered to the stream. If bankfull width was not available due to the lack of an apparent channel, twice the width of the culvert diameter was used. In the instances of multiple culverts, the width of the culverts plus one half of the diameter on each side was used as the road prism width. Bulk density was assumed to be 1.3 tons/yd3. Results show an average of 61.9 tons of fill at risk per road crossing (**Table CA-7**).

It is difficult to develop a specific road crossing allocation for sediment delivered in the event of a culvert failure, as there are several factors that may impact the accuracy of the data. First, peak flows generated using the USGS regression equations are subject to large standard errors that may substantially over or underestimate peak discharge. In addition, peak flows generated using Manning's equation rely heavily on culvert slope. Slope values measured during field activities were estimated by measuring the height of a laser beam from a laser pointer and level on one side of the culvert to a tape measure on the other side of the culvert. When the culvert was submerged, plugged or experiencing high flows, the slope was estimated by using a handheld inclinometer from the top of the culvert. Visual estimates were recorded where access or use of an inclinometer was not possible. Variations in slope estimates may lead to differences in peak flow calculations. Second, the culvert assessment was conducted on a small subset of culverts, which may not be representative of all the sediment-listed watersheds Lower Gallatin River TPA. Third, it is difficult to estimate which culverts will fail in any given year, and what percentage of at-risk fill material will be delivered to the stream.

Due to these difficulties in sediment delivery estimation, a 25% probability of culvert failure was assigned in **Table CA-8**. This probability assumes that large storm events (>Q25) occur annually across a quarter of the watershed area and that the fill at risk is replaced soon after a failure with the same culvert size and slope. The potential sediment delivery is calculated based on the average fill at risk multiplied by the number of crossings multiplied by the frequency of failure based on the storm recurrence interval and the 25% probability. Under such assumptions, 4,609 tons of sediment are at-risk for a Q25 event in the listed HUCs of the Lower Gallatin TPA.

C4.0 Application of Best Management Practices

Sediment impacts are widespread throughout the listed watersheds in the Lower Gallatin River TPA, and sediment loading from the road network is one of several sources within the watershed. Application of BMPs on the unpaved road crossings will result in decreased sediment loading to streams. BMP reduction scenarios were not developed for paved crossings and unpaved parallel segments due to their minimal contribution to the total sediment load (each approximately 3%).

C4.1 BMP: City, County & State Road Maintenance Scenario

Unpaved roads under city, county and state ownership were modeled with a road maintenance scenario. Based on discussions with the Gallatin County Road Department, regular road maintenance is the BMP most commonly used by Gallatin County. Gallatin County blades and re-grades gravel roads twice per year or twice per month depending on conditions; native roads are resurfaced at most twice per year. The City of Bozeman Street Department similarly maintains their gravel roads on an as-needed basis.

A road maintenance scenario was selected to incorporate regular maintenance, which effectively reduces the time period roads are considered rutted for unpaved crossings. This BMP scenario is represented in the model through the upgrade of rutted roads to an insloped, vegetated road design. Results from modeled sites (**Table CE-1**) were extrapolated for all unpaved-precipitation classes (**Table C4-1**) and ranged from a 12% to 50% reduction.

Table C4-1. Road Maintenance Scenario Load Reductions (Loads in Tons/Year)

Road Surface – Precipitation Class	Current Mean Load	BMP Mean Load	Total Crossing Load Reduction (%)
Unpaved – High	0.37	0.26	30%
Unpaved - Medium	0.53	0.43	19%
Native - Low	0.08	0.04	50%
Gravel - Low	0.17	0.15	12%

Although the unrutted maintenance level may not be achievable on all roads at all times, an equivalent reduction in sediment loading may be achieved through other BMPs such as water bars, cross drains, or check dams in the road ditches. These additional BMPs on city, county and state roads were not modeled and would require assessment on an individual basis.

C4.2 BMP: Federal & Private Road Length Reduction Scenario

Unpaved roads under private or federal (USFS) ownership were modeled with a scenario in which BMPs reduce the contributing road length. Road lengths were reduced to 200 feet; 100 feet on each road for a crossing with two contributing road segments or 200 feet on crossings with one contributing segment. No changes were made to crossings where the contributing road length was less than the 200 foot BMP reduction scenario.

The 200 foot BMP scenario was evaluated using the WEPP:Road model, so potential sediment load reductions could be estimated. The model assumes that the contributing length above the BMP does not discharge into the ditch next to the road. Thus BMPs would have to include a break in runoff along the road and ditch surface. One example would be a water bar or drive through dip with a ditch sediment detention basin. There were five private or federal unpaved crossings assessed in the field. Of the five crossings, three had road lengths in excess of 200 feet. With the road length reduction scenario, the overall average annual sediment load per crossing changed dramatically: 0.15 tons/year to 0.02 tons/year. The results were heavily influenced by LJC-17i-N-X-204 which had a field assessed road length of 1000 feet. Due to this influence, the percentage change from each of the five crossings (0%, 0%, 98%, 49% and 50%) were averaged to estimate the percentage improvement of BMPs on private and federally maintained roads (39%). Results from modeled sites (**Table CE-2**) were extrapolated for all unpaved-precipitation classes (**Table C4-2**).

Table C4-2. Road Length Reduction Scenario Load Reductions (Loads in Tons/Year)

Road Surface – Precipitation Class	Current Mean Load	BMP Mean Load	Total Crossing Load Reduction (%)
Unpaved – High	0.37	0.22	39%
Unpaved - Medium	0.53	0.32	39%
Native - Low	0.08	0.05	39%
Gravel - Low	0.17	0.1	39%

C4.3 Summary of Total Loads and Potential Reductions

Assuming no culverts fail and all crossings are fully BMP'd, the total sediment load from all crossings and parallel segments would be reduced from 123.25 to 92.49 tons/year (25% reduction). Reductions by watershed are shown in **Table C4-3** and a full summary of loading for each watershed by road source type is presented in **Table CA-10**.

Table C4-3. Current Total Loads vs. Potential BMP Loads in Tons/Year

6th Code HUC	Current Load	BMP Load	Percent Reduction (%)
Bear Creek	2.06	1.51	27%
Bozeman Creek	8.73	6.34	27%
Camp Creek	23.15	19.33	17%
Dry Creek	32.12	26.01	19%
Godfrey Creek	5.86	4.88	17%
Lower Jackson Creek	15.76	9.86	37%
Reese Creek	6.11	4.61	25%
Rocky Creek	21.23	13.73	35%
Smith/Ross Creeks	3.85	3.12	19%
Stone Creek	2.33	1.43	39%
Thompson Creek	0.71	0.58	18%
Upper Bozeman Creek	1.33	1.08	19%
Sum	123.25	92.49	25%

Due to the uncertainty associated with estimates of the average fill-at-risk, the load from failing culverts is not included in the summary of **Table 4-3**.

C4.4 Assessment of Existing BMPs

The only type of water-diversion BMPs noted in the field assessment were cross drains. The minimal BMP presence and variety is likely due to the large percentage of low gradient, valley bottom roads, and roads within urban areas. Many cross drains were marked with reflectors or poles which might indicate planned maintenance. Of the 27 crossings and six parallel segments assessed in the field, two crossings and three parallel segments had cross drains. However, the heavily vegetated road ditches and swales also represent important BMPs and should be maintained.

USFS documentation (U.S. Department of Agriculture, Forest Service, 1995) recommends that culverts are designed to pass the 100-year flow event. In the Lower Gallatin TPA, it is recommended that culvert replacements be upgraded to pass the Q25 flood event at a minimum. Approximately two thirds of the culverts that were assessed did not convey the 25-year event.

On fish bearing streams, it is also recommended that culvert replacements be completed in a manner that allows for full fish and Aquatic Organism Passage (AOP). Specifically, culverts would be sized with constriction ratios at 1.0 or greater, and with a goal of re-creating the stream channel through the crossing to match those channel conditions outside of the crossing influence.

The identification of priority culverts for replacement should be on the following factors:

1.) Inability to pass the Q25 design flow;
2.) Constriction ratio <0.70; and
3.) Location on a perennial fish bearing stream.

Achieving full culvert replacement will take many years to complete, and some culverts on private land may never be replaced. This will result in continued loads from culvert failures in the foreseeable future; however, continued investment in the replacement of culverts failing the above criteria will significantly reduce sediment loads over time.

C5.0 Quality Assurance/Quality Control Results

C5.1 Representativeness

Representativeness refers to the extent to which measurements represent an environmental condition in time and space. Spatial representation was achieved through the Lower Gallatin TPA Roads field assessment. Twenty five sites were randomly selected through GIS based on watershed and road surface type categories. A total of 27 road crossings were visited in the field, with complete model parameters for 24 of the 27 sites. Three sites were deemed minimal delivery sites due to the paved road surface and limited connectivity of runoff from the road to the stream. Spatial representation is shown in **Table C2-1** and **Figures C1-C3**. Adequate coverage of road surface types was achieved in the watershed. Temporal variations were not accounted for in this study, as the field data collected at road crossing locations does not change during the year.

C5.2 Comparability

Comparability is the applicability of the project's data to the WEPP:Road model input data. The WEPP:Road model includes a high and low data value for each input parameter. Field data was compared to the model input range and sites with data outside these ranges were flagged for additional evaluation through the review of photographs, field comments, personal communication and other field data. No sites were determined to have unacceptable field data for the WEPP:Road model. A review of comparability of field data is shown in **Table CA-11**.

C5.3 Completeness

Completeness is a measure of the amount of data prescribed for assessment activities and the usable data actually collected, expressed as a percentage.

Completeness as % = (# of Valid Data Points or Samples/Total # Data Points or Samples) x 100

As documented in **Table CA-9**, and **Attachment CC**, all sites were deemed valid initially or were validated through data adjustments based on comments, conversations with the field crew and through analysis of photographs for input into the WEPP:Road model. This equates to a completeness of 100%.

C6.0 References

Flanagan, Dennis C. and Stanley J. Livingston. 1995. WEPP User Summary. West Lafayette, IN: USDA-ARS National Soil Erosion Research Laboratory. Report NSERL Report 11.

Montana Department of Environmental Quality. 2008. St. Regis Watershed Total Maximum Daily Loads and Framework Water Quality Restoration Assessment - Sediment and Temperature TMDLs. Helena, MT: Montana Department of Environmental Quality.

Montana Department of Environmental Quality, Water Quality Planning Bureau. 2010. Road GIS & Summary Statistics, Road Sediment Assessment & Modeling: Lower Gallatin TMDL Planning Area 303(D) Listed Tributary Streams. Helena, MT: Montana Department of Environmental Quality.

Parrett, Charles and B. R. Johnson. 1998. Methods for Estimating Flood Frequency in Montana Based on Data Through Water Year 1998. Report U.S. Giological Survey Water -Resources Investigations Report 03-4308.

U.S. Department of Agriculture, Forest Service. 1995. Inland Native Fish Strategy Environmental Assessment: Decision Notice and Finding of No Significant Impact. Washington, DC: U.S. Department of Agriculture, Forest Service.

U.S. Department of Agriculture, Forest Service, Alaska Region. 2002. A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on the National Forests of Alaska a Supplement to the Alaska's Region's June 2, 2002 Briefing Paper Titled Fish Passage on Alaska's National Forest. http://www.fs.fed.us/r10/ro/policy-reports/wfew/fish_blockage_at_culverts.pdf.

Water & Environmental Technologies. 2010a. Road Sediment Assessment & Modeling: Lower Gallatin River TPA. Butte, MT: Water & Environmental Technologies, PC. Report Contract # 210138.

-----. 2010b. Task 2. Sampling and Analysis Plan, Lower Gallatin River TPA.

C7.0 Traction Sand References

Bozeman City Streets Superintendent, John Vandelinder, personal communication, 406-582-3200

Erdall, Mitch, Gallatin County Road Department, personal communication regarding Bear Canyon Creek Road, 406-580-9802

Stocks, Ray, Montana Department of Transportation, Maintenance Chief, personal communication, 406-581-0732

Juelfs, Justun, Montana Department of Transportation, Winter Maintenance Specialist - Helena - personal communication, 406-444-7604

Traction Sand Material Safety Data Sheet, 2006, http://lanemt.com/msds.htm, last assessed March, 11, 2009.

Montana Department of Environmental Quality. 2008. St. Regis Watershed Total Maximum Daily Loads and Framework Water Quality Restoration Assessment – Sediment and Temperature TMDLs. September, 2008.

ATTACHMENT CA - ATTACHED TABLES

Table CA-1. Lower Gallatin River TPA Road Summary by 6th Code Subwatershed (USGS HUC 12)

6th Code Subwatershed (USGS HUC 12)	Area (Mi2)	Stream Miles (Mi)	Unpaved Crossings	Unpaved Crossing Density (Crossing/Mi2)	Paved Crossings	Total Crossings	Total Road Length (Mi)	Total Road Density (Mi/Mi2)	% of Total Roads which are unpaved	Total Unpaved Road Length w/in 150 ft Streams (Mi)	Field Assessed Crossing Sites	Field Assessed Parallel Segment Sites
Bear Creek	19.85	26.75	2	0.10	4	6	13.90	0.70	33%	3.84	1	1
Bozeman Creek	31.27	46.22	14	0.45	41	55	90.10	2.88	25%	5.09	-	-
Camp Creek	74.75	180.54	69	0.92	12	81	67.28	0.90	85%	7.34	5	-
Dry Creek	106.35	255.33	103	0.97	1	104	80.78	0.76	99%	14.11	6	3
Godfrey Creek	12.64	31.04	13	1.03	10	23	18.55	1.47	57%	3.65	2	-
Lower Jackson Creek	18.79	42.23	40	2.13	11	51	46.95	2.50	78%	7.22	3	1
Reese Creek	31.13	61.23	17	0.55	4	21	17.10	0.55	81%	0.88	3	-
Rocky Creek	34.51	64.03	52	1.51	14	66	95.02	2.75	79%	12.73	2	1
Smith/Ross Creeks	13.71	26.85	11	0.80	5	16	21.94	1.60	69%	0.53	1	-
Stone Creek	8.75	17.32	6	0.69	1	7	5.20	0.59	86%	1.43	-	-
Thompson Creek	3.84	9.44	4	1.04	1	5	14.10	3.67	80%	0.37	1	-
Upper Bozeman Creek	20.71	35.46	2	0.10	1	3	39.22	1.89	67%	2.89	-*	-
Total	376.28	796.44	333	0.88	105	438	1587.43	4.22	76%	60.10	24*	6

* Three paved sites in Bozeman Creek were deemed to deliver negligible sediment upon field assessment and were not evaluated for WEPP input variables

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Table CA-2. Road Crossings by HUC/303(d) Subwatershed, Precipitation Class and Road Surface Type

Ownership	Federal - USFS					State					County					City					Private					Total Crossings
6th Code/303(d) Subwatershed	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	
Precipitation Class	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	
Bear Creek	-	-	-	-	-	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	-	1	-	-	6
Bozeman Creek	-	-	1	-	-	7	-	-	-	-	8	-	3	-	-	16	-	2	-	-	10	-	8	-	-	55
Camp Creek	-	-	-	-	-	9	-	-	-	-	3	-	30	37	2	-	-	-	-	-	-	-	-	-	-	81
Dry Creek	-	-	-	-	-	1	-	-	-	-	-	3	32	56	-	-	-	-	-	-	-	-	5	5	2	104
Godfrey Creek	-	-	-	-	-	9	-	4	-	-	1	-	5	4	-	-	-	-	-	-	-	-	-	-	-	23
Lower Jackson Creek	-	11	-	-	-	-	-	-	-	-	7	4	-	-	-	-	-	-	-	-	4	24	1	-	-	51
Reese Creek	-	-	-	-	-	2	-	-	-	-	2	1	5	6	-	-	-	-	-	-	-	-	3	2	-	21
Rocky Creek	-	10	-	-	-	8	4	-	-	-	-	7	2	-	-	-	-	-	-	-	6	25	4	-	-	66
Ross Creek	-	-	-	-	-	3	-	-	-	-	1	-	4	6	-	-	-	-	-	-	-	-	1	-	-	15
Smith Creek	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Stone Creek	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	7
Thompson Creek	-	-	-	-	-	1	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	1	-	5
Upper Bozeman Creek	-	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3
Total	0	22	1	0	0	44	4	4	0	0	24	16	82	112	2	16	0	2	0	0	21	55	23	8	2	438

Table CA-3. Detailed Extrapolated Sediment Load From Road Crossings by HUC/303(d) Subwatershed, Precipitation Class and Road Surface Type – Existing Conditions

Ownership	Federal - USFS					State					County					City					Private					Total Load t/y
6th Code/303(d) Subwatershed	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	
Precipitation Class	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	
Bear Creek	0	0	0	0	0	0.06	0	0	0	0	0.03	1.13	0	0	0	0	0	0	0	0	0.03	0	0.53	0	0	1.78
Bozeman Creek	0	0	0.53	0	0	0.21	0	0	0	0	0.24	0	1.59	0	0	0.48	0	1.06	0	0	0.3	0	4.24	0	0	8.65
Camp Creek	0	0	0	0	0	0.27	0	0	0	0	0.09	0	15.9	6.29	0.16	0	0	0	0	0	0	0	0	0	0	22.71
Dry Creek	0	0	0	0	0	0.03	0	0	0	0	0	1.11	16.96	9.52	0	0	0	0	0	0	0	0	2.65	0.85	0.16	31.28
Godfrey Creek	0	0	0	0	0	0.27	0	2.12	0	0	0.03	0	2.65	0.68	0	0	0	0	0	0	0	0	0	0	0	5.75
Lower Jackson Creek	0	4.07	0	0	0	0	0	0	0	0	0.21	1.48	0	0	0	0	0	0	0	0	0.12	8.88	0.53	0	0	15.29
Reese Creek	0	0	0	0	0	0.06	0	0	0	0	0.06	0.37	2.65	1.02	0	0	0	0	0	0	0	0	1.59	0.34	0	6.09
Rocky Creek	0	3.7	0	0	0	0.24	1.48	0	0	0	0	2.59	1.06	0	0	0	0	0	0	0	0.18	9.25	2.12	0	0	20.62
Ross Creek	0	0	0	0	0	0.09	0	0	0	0	0.03	0	2.12	1.02	0	0	0	0	0	0	0	0	0.53	0	0	3.79
Smith Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03
Stone Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.22	0	0	0	2.25
Thompson Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0.51	0	0	0	0	0	0	0	0	0	0.17	0	0.71
Upper Bozeman Creek	0	0.37	0	0	0	0	0	0	0	0	0.03	0	0.53	0	0	0	0	0	0	0	0	0	0	0	0	0.93
Total	0	8.14	0.53	0	0	1.32	1.48	2.12	0	0	0.72	5.92	43.46	19.04	0.16	0.48	0	1.06	0	0	0.63	20.35	12.19	1.36	0.16	119.88

Table CA-4. Mileage of Parallel Segments by HUC/303(d) Subwatershed and Road Surface Type – Existing Conditions

Ownership	Federal - USFS			State			County			City			Private			Total Miles
6th Code/303(d) Subwatershed	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	
Bear Creek	-	-	2.34	0.00	-	-	-	1.46	-	-	-	-	0.03	0.02	-	3.84
Bozeman Creek	-	-	0.44	0.24	0.03	-	0.79	0.05	-	0.46	0.27	-	0.29	0.32	-	2.89
Camp Creek	-	-	-	0.14	-	-	0.00	6.38	0.78	-	-	-	-	0.03	-	7.34
Dry Creek	-	1.39	-	0.03	-	-	-	11.37	0.40	-	-	-	-	0.91	-	14.11
Godfrey Creek	-	-	-	1.95	0.95	-	0.01	0.60	-	-	-	-	0.00	0.14	-	3.65
Lower Jackson Creek	-	-	0.78	-	-	-	0.64	1.40	-	-	-	-	-	0.89	3.50	7.22
Reese Creek	-	-	-	0.33	-	-	0.26	0.14	-	-	-	-	-	0.14	-	0.88
Rocky Creek	-	0.24	0.79	2.23	0.27	-	-	2.11	-	-	-	-	0.64	6.08	0.36	12.73
Ross Creek	-	-	-	-	-	-	-	0.22	-	-	-	-	-	-	-	0.22
Smith Creek	-	-	-	-	-	-	-	0.31	-	-	-	-	-	-	-	0.31
Stone Creek	-	-	-	0.14	-	-	-	-	-	-	-	-	-	1.29	-	1.43
Thompson Creek	-	-	-	0.27	-	-	-	0.05	-	-	0.05	-	-	-	-	0.37
Upper Bozeman Creek	-	-	4.83	-	-	-	-	0.16	-	-	-	-	0.03	0.06	-	5.09
Total	0.00	1.64	9.19	5.34	1.25	0.00	1.70	24.27	1.18	0.46	0.33	0.00	0.99	9.89	3.86	60.10

Table CA-5. Detailed Extrapolated Sediment Load From Parallel Segments by HUC/303(d) Subwatershed and Road Surface Type – Existing Conditions

Ownership	Federal - USFS			State			County			City			Private			Total Load
6th Code/303(d) Subwatershed	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	t/y
Bear Creek	0	0	0.19	0	0	0	0	0.09	0	0	0	0	0	0.00	0	0.28
Bozeman Creek	0	0	0.04	0	0.002	0	0	0.00	0	0	0.02	0	0	0.02	0	0.08
Camp Creek	0	0	0	0	0	0	0	0.38	0.06	0	0	0	0	0.00	0	0.44
Dry Creek	0	0.08	0	0	0	0	0	0.68	0.03	0	0	0	0	0.05	0	0.84
Godfrey Creek	0	0	0	0	0.057	0	0	0.04	0	0	0	0	0	0.01	0	0.11
Lower Jackson Creek	0	0	0.06	0	0	0	0	0.08	0	0	0	0	0	0.05	0.28	0.47
Reese Creek	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0.01	0	0.02
Rocky Creek	0	0.01	0.06	0	0.016	0	0	0.13	0	0	0	0	0	0.36	0.03	0.61
Ross Creek	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0.01
Smith Creek	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
Stone Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0	0.08
Thompson Creek	0	0	0	0	0	0	0	0.00	0	0	0.00	0	0	0	0	0.00
Upper Bozeman Creek	0	0	0.39	0	0	0	0.00	0.01	0	0	0	0	0	0.00	0	0.40
Total	0.00	0.10	0.73	0.00	0.08	0.00	0	1.46	0.09	0.00	0.02	0.00	0.00	0.59	0.31	3.37

Table CA-6. Fish Passage Analysis for Selected Road Crossings Using Alaska Region Criteria

Location ID	Structure Type	Structure Diameter or Dimensions (in)	Width (ft)	Culvert Slope (%)	Bf in Riffle Above Culvert (ft)A	Constriction Ratio: Culvert I.D./BF width	Perch (in)	Streambed Materials in Culvert	Final Classification	Notes/Comments Specific to Fish Crossing Model
Fish passage evaluation criteria: Circular CMP 48" span and smaller										
RCC-17G-G-X-108[3]	cmp	10	0.83	3[1]	5	0.17[1]	0[2]	no	RED	
DC-P-17W-G-X-399[3]	cmp	18	1.5	2[1]	1	1.50[2]	0[2]	yes	RED	
RCC-17G-G-X-38[3]	cmp	24	2	3[1]	2.5	0.80[2]	36[1]	no	RED	
DC-P-17W-G-X-389[3]	cmp	24	2	2[1]	2	1.00[2]	13[1]	no	RED	
REC-17W-G-X-308[3]	cmp	24	2	1[3]	8	0.25[1]	0[2]	N/A	RED	Culvert flowing full, could not assess streambed materials.
LJC-17I-N-X-223[3]	cmp	30	2.5	1[3]	8.5	0.29[1]	0[2]	no	RED	
GC-17W-G-X-172[3]	2 culverts	36	3	2[1]	2.5	2.40[2]	25.2[1]	no	RED	culvert/bf ratio calculated with width of two culverts
GC-17W-G-X-172[3]	2 culverts	36	3	2[1]	2.5	2.40[2]	19.2[1]	no	RED	culvert/bf ratio calculated with width of two culverts
DC-17W-G-X-353[3]	cmp	36	3	3[1]	5	0.60[3]	4[3]	no	RED	
LJC-17I-N-X-204[3]	2 arched culverts	41 x 28	3.42	3[1]	7	0.96[2]	6[1]	no	RED	culvert/bf ratio calculated with width of two culverts
LJC-17I-N-X-204[3]	2 arched culverts	40 x 25	3.33	3[1]	7	0.96[2]	6[1]	no	RED	culvert/bf ratio calculated with width of two culverts
Fish passage evaluation criteria: Circular CMP greater than 48" and less than 100% substrate cover										
CC-17W-G-X-249[3]	3 arch culverts	48 x 72	6	3[1]	4.5	1.33[2]	0[2]	minimal	RED	
LJC-17W-P-X-160[3]	cmp	48	4	1[3]	3.5	1.14[2]	18[1]	no	RED	
BC-17G-G-X-34[3]	cmp	60	5	3[1]	12	0.42[1]	0[2]	no	RED	
TC-17W-G-X-432[3]	2 squash culverts	54 x 48	4.5	1[3]	24	0.38[1]	0[2]	yes	RED	culvert/bf ratio calculated with width of two culverts
TC-17W-G-X-432[3]	2 squash culverts	54 x 48	4.5	1[3]	24	0.38[1]	0[2]	yes	RED	culvert/bf ratio calculated with width of two culverts
REC-17W-G-X-324[3]	arch cmp	96 x 78	8	1[3]	8	1.00[2]	0[2]	yes	GREY	
DC-P-17W-G-X-383[3]	arch cmp/bridge	48 x 156	13	2[3]	9	1.44[2]	0[2]	yes	GREY	
Legend:		[1]High certainty of not providing juvenile fish passage		[2]High certainty of providing juvenile fish passage		[3]Additional and more detailed analysis is required		[4]Flowing water noted at the time of the field assessment		

Table CA-7. Peak Discharges Using USGS Equations WRIR-03-4308 (Upper Yellowstone-Central Mountain Region) and Manning's Equation

Site ID	Formula Variables		Site Information				Peak Discharges Using USGS Equations WRIR-03-4308 (Upper Yellowstone-Central Mountain Region						Peak Discharges Using Manning's Equation, pipes flowing full						Max. Conveyance Manning's > USGS
	Area (sqmi)	E6000	Structure	Fill at Risk (tons)	CMP Diameter or Height (ft)	X-sect Area (ft2)	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)	Streambed Materials in Culvert	NA	Slope %	Velocity (ft/sec)	Peak Flow (cfs)	Sum of Peak Flow (cfs)	
CC-17W-G-X-249	5.89	0.00	3 arch culverts	36.1	4 x 6	19.63	25.5	86.8	162.2	303.0	448.5	628.5	minimal	0.024	2.64	11.7	229.0	364.2	Q25
CC-17W-G-X-249	5.89	0.00	3 arch culverts	incl.	3 x 5	12.57	incl.	incl.	incl.	incl.	incl.	incl.	dry	0.023	1.00	6.5	81.2	incl.	incl.
CC-17W-G-X-249	5.89	0.00	3 arch culverts	incl.	3.25 x 3.5	8.95	incl.	incl.	incl.	incl.	incl.	incl.	dry	0.022	1.00	6.0	54.0	incl.	incl.
CC-17W-N-X-247	1.9	0.00	CMP	15.6	3	7.07	10.0	35.8	68.8	132.2	199.5	284.0	dry	0.018	0.1	2.2	15.2		Q2
GC-17W-G-X-172	1.69	0.00	2 culverts	83.6	3	7.07	9.0	32.7	63.0	121.3	183.5	261.6	no	0.018	1.94	9.5	67.0	135.1	Q25
GC-17W-G-X-172	1.69	0.00	2 culverts	incl.	3	7.07	incl.	incl.	incl.	incl.	incl.	incl.	no	0.018	2.00	9.6	68.1	incl.	incl.
TC-17W-G-X-432	3.78	0.00	2 squash culverts	16.8	4.5 x 4	14.19	17.7	61.4	115.9	218.9	326.5	460.3	yes	0.023	1.14	7.2	101.8	203.6	Q10
TC-17W-G-X-432	3.78	0.00	2 squash culverts	incl.	4.5 x 4	14.19	incl.	incl.	incl.	incl.	incl.	incl.	yes	0.023	1.14	7.2	101.8	incl.	incl.
DC-17W-G-X-335	0.65	0.00	cmp	2.7	2	3.14	4.1	15.5	30.5	60.2	92.6	133.8	no	0.015	2.80	10.5	32.8		Q10
RCC-17G-G-X-38	0.54	0.98	cmp	15.7	2	3.14	3.7	13.1	28.2	47.5	71.6	101.7	no	0.015	2.8	10.4	32.7		Q10
LJC-17I-N-X-223	0.94	1.00	cmp	86.9	2.5	4.91	5.9	20.3	43.0	71.2	106.3	149.7	no	0.017	1.1	6.7	33.1		Q5
LJC-17I-N-X-204	2.54	1.00	arched	128.0	3.3 x 2.1	5.73	13.6	44.1	91.4	147.6	216.5	300.9	no	0.018	2.5	9.9	56.9	124.3	Q10
LJC-17I-N-X-204	2.54	1.00	arched	incl.	3.4 x 2.3	6.49	13.6	44.1	91.4	147.6	216.5	300.9	no	0.018	2.5	10.4	67.3	incl.	incl.
LJC-17W-P-X-160	1.5	0.38	cmp	35.1	4	12.57	8.4	29.5	59.2	106.0	158.9	224.8	no	0.023	0.7	5.3	66.4		Q10
RCC-17G-G-X-108	0.12	0.25	cmp	25.2	0.8	0.55	1.0	4.1	8.7	16.9	26.5	39.0	no	0.014	0.1	1.2	0.6		N/A
BC-17G-G-X-34	10.31	0.93	cmp	228.7	5	19.63	43.4	131.9	263.3	414.4	594.1	810.5	no	0.024	3.4	13.2	260.1		Q5
RSC-17W-X-304	0.36	0.00	cmp	72.8	3.6	10.18	2.5	9.8	19.5	39.1	60.6	88.3	no	0.022	1	6.3	64.1		Q50
REC-17W-G-X-308	0.61	0.10	cmp	80.1	2	3.14	3.9	14.7	29.3	56.7	86.9	125.4	no	0.015	0.5	4.4	13.9		Q2
REC-17W-G-X-323	2.15	0.80	cmp	96.3	3.5	9.62	11.7	38.8	79.7	132.7	195.9	273.6	no	0.022	7.80	17.3	166.0		Q25
REC-17W-G-X-324	21.09	0.44	arch cmp	110.9	8 x 6.5	41.28	76.5	232.9	441.0	731.3	1046.1	1424.8	yes	0.027	1	8.2	337.8		Q5
DC-17W-G-X-353	0.84	0.43	cmp	60.2	3	7.07	5.2	18.7	38.3	68.9	104.2	148.5	no	0.018	2.5	10.8	76.2		Q25
DC-P-17W-G-X-383	35.76	0.17	arch cmp/bridge	97.5	4 x 13	56.75	116.3	354.2	645.7	1110.5	1585.6	2156.6	yes	0.027	2.0	12.9	730.0		Q10
DC-P-17W-G-X-389	0.95	0.19	cmp	6.6	2	3.14	5.7	20.7	41.3	77.5	117.7	168.3	no	0.015	1.7	8.2	25.6		Q5
DC-P-17W-G-X-399	0.1	0.10	cmp	1.2	1.5	1.77	0.9	3.6	7.4	15.1	23.8	35.2	yes	0.013	1.9	8.2	14.6		Q10
DC-P-17W-G-X-410	7.96	0.27	arch	37.0	6 x 9	44.18	33.6	109.1	208.3	364.7	532.8	738.3	yes	0.027	1.0	8.4	369.7		Q25
GC-17W-P-X-230	9.4	0.00	bridge	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A
CC-17W-G-X-242	33.12	0.00	bridge	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A
CC-17-W-N-X-219	0.08	0.00	no culvert	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A
CC-17W-N-X-231	0.7	0.00	no culvert	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A
Average				61.9															

Field notes were adjusted as follows: if slope was not recorded then 0.1% was used. No streambed materials assumed for REC-17W-G-X-308. Slope was recorded as 2-3% at DC-P-17W-G-X-353.
Manning's Equation Roughness Coefficient Reference (Assumed all Corrugated pipe had 2.66 x 0.5 inch corrugations for pipe 10-inch to 36 inch and 3 x 1 inch corrugations for pipe greater than 36-inch diameter:
Modern Sewer Design, 4th Ed. 1999, American Iron and Steel Institute, Washington DC, Copyright 1980.

Table CA-8. Culvert Failure Load Potential Per 25% Probability and Per Storm Event (tons/year)

6th Code Subwatershed (USGS HUC 12)	Number of Crossings	Q2	Q5	Q10	Q25	Q50	Q100
Percent of Culverts Failing Storm Event		0%	11%	32%	68%	95%	100%
Bear Creek	6	0	10	30	63	88	93
Bozeman Creek	55	0	94	272	579	809	851
Camp Creek	81	0	138	401	852	1191	1253
Dry Creek	104	0	177	515	1094	1529	1609
Godfrey Creek	23	0	39	114	242	338	356
Lower Jackson Creek	51	0	87	253	537	750	789
Reese Creek	21	0	36	104	221	309	325
Rocky Creek	66	0	112	327	695	970	1021
Smith/Ross Creeks	16	0	27	79	168	235	248
Stone Creek	7	0	12	35	74	103	108
Thompson Creek	5	0	9	25	53	74	77
Upper Bozeman Creek	3	0	5	15	32	44	46
Total	438	0	746	2169	4609	6439	6778

Sample calculation: Bear Creek, Q50 Storm Event

$$\text{Load} = (\text{probability}) \times (\text{percent\_failing}) \times (\#\text{crossings}) \times (\text{average fill at risk TableA} - 10)$$

$$\text{Load} = (0.25) \times (0.95) \times (6\ \text{crossings}) \times (61.9\ \text{tons}) = 88.2\frac{\text{tons}}{\text{year}}$$

Table CA-9. Detailed Extrapolated Sediment Load from Road Crossings by HUC/303(d) Subwatershed, Precipitation Class and Road Surface Type – Insloped, Vegetated Road Design and Road Length Reduction based on Maintenance Ownership

Ownership	Federal - USFS					State					County					City					Private					Total Load t/y
6th Code/303(d) Subwatershed	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	
Precipitation Class	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	
Bear Creek	0	0	0	0	0	0.06	0	0	0	0	0.03	0.79	0	0	0	0	0	0	0	0	0.03	0	0.32	0	0	1.23
Bozeman Creek	0	0	0.32	0	0	0.21	0	0	0	0	0.24	0	1.29	0	0	0.48	0	0.86	0	0	0.3	0	2.56	0	0	6.26
Camp Creek	0	0	0	0	0	0.27	0	0	0	0	0.09	0	12.9	5.55	0.08	0	0	0	0	0	0	0	0	0	0	18.89
Dry Creek	0	0	0	0	0	0.03	0	0	0	0	0	0.78	13.76	8.4	0	0	0	0	0	0	0	0	1.6	0.5	0.1	25.17
Godfrey Creek	0	0	0	0	0	0.27	0	1.72	0	0	0.03	0	2.15	0.6	0	0	0	0	0	0	0	0	0	0	0	4.77
Lower Jackson Creek	0	2.42	0	0	0	0	0	0	0	0	0.21	1.04	0	0	0	0	0	0	0	0	0.12	5.28	0.32	0	0	9.39
Reese Creek	0	0	0	0	0	0.06	0	0	0	0	0.06	0.26	2.15	0.9	0	0	0	0	0	0	0	0	0.96	0.2	0	4.59
Rocky Creek	0	2.2	0	0	0	0.24	1.04	0	0	0	0	1.82	0.86	0	0	0	0	0	0	0	0.18	5.5	1.28	0	0	13.12
Ross Creek	0	0	0	0	0	0.09	0	0	0	0	0.03	0	1.72	0.9	0	0	0	0	0	0	0	0	0.32	0	0	3.06
Smith Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03
Stone Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.32	0	0	0	1.35
Thompson Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0.45	0	0	0	0	0	0	0	0	0	0.1	0	0.58
Upper Bozeman Creek	0	0.22	0	0	0	0	0	0	0	0	0.03	0	0.43	0	0	0	0	0	0	0	0	0	0	0	0	0.68
Total	0	4.84	0.32	0	0	1.32	1.04	1.72	0	0	0.72	4.69	35.26	16.8	0.08	0.48	0	0.86	0	0	0.63	12.1	7.36	0.8	0.1	89.12

Table CA-10. Total Annual Sediment Load from all Sources and Potential BMP Reduction

6th Code Subwatershed (USGS HUC 12)	Total Annual Sediment Load Crossings (t/y)	Total Annual Sediment Load Parallel Segments (t/y)	Sum [A] (Crossings and Parallel Segments)	Sum with All Available Sediment Reductions[B] (t/y)	Percent Reduction[C] (%)	Culvert Failure-per Storm Event (tons/year)					
						Q2	Q5	Q10	Q25	Q50	Q100
Column #	1	2	3	4	5	6	7	8	9	10	11
Bear Creek	1.78	0.28	2.06	1.51	27%	0	10	30	63	88	93
Bozeman Creek	8.65	0.08	8.73	6.43	27%	0	5	15	32	44	46
Camp Creek	22.71	.44	23.15	19.33	17%	0	94	272	579	809	851
Dry Creek	31.28	.84	32.12	26.01	19%	0	138	401	852	1191	1253
Godfrey Creek	5.75	.11	5.86	4.88	17%	0	177	515	1094	1529	1609
Lower Jackson Creek	15.29	0.47	15.76	9.86	37%	0	39	114	242	338	356
Reese Creek	6.09	0.02	6.11	4.61	25%	0	87	253	537	750	789
Rocky Creek	20.62	0.61	21.23	13.73	35%	0	36	104	221	309	325
Smith/Ross Creeks	3.82	0.03	3.85	3.12	19%	0	112	327	695	970	1021
Stone Creek	2.25	0.08	2.33	1.43	39%	0	27	79	168	235	248
Thompson Creek	0.71	0.00	0.71	0.58	18%	0	12	35	74	103	108
Upper Bozeman Creek	0.93	0.40	1.33	1.08	19%	0	9	25	53	74	77
Sum	119.88	3.37	123.25	92.49	25%	0	746	2169	4609	6439	6778

[A]Sum = Column 1+2
[B]Sum = Sediment load per crossing (**Table CA-9** Total Load) + Column 2
[C]Percent Reduction = (Column 3-Column 4)/Column 3

Table CA-11. Comparability of Field Data to WEPP:Road Parameters

WEPP:Road Variable	Road gradient (%)	Road length (ft)	Road width (ft)	Fill gradient (%)	Fill length (ft)	Buff gradient (%)	Buff length (ft)	Rock content (%)
Minimum Value	0.3%	3 ft	1 ft	0.3%	1 ft	0.3%	1 ft	0%
Maximum Value	40%	1000 ft	300 ft	150%	1000 ft	100%	1000 ft	100%
Measured Range from the Field Data	0.5 - 11%	20 – 1000 feet	10-36 ft	0.3 – 145 %	1 – 80 ft	0.3 – 90%	1 – 401 ft	10 – 50%
Non-compliant values	None.	None.	DC-17W-G-X-335 (36 feet – due to road and ditch)	Multiple entries (-)	Multiple entries (-) Heavy Vegetation	Multiple entries (-)	Multiple entries (-)	None.
Action Taken	None.	None.	None – automatically corrected to 33 feet on WEPP	Minimum values entered for (-) entries.	Minimum values entered for (-) entries. Fillslope length minimized for heavy vegetation (>>50%)	Minimum values entered for (-) entries.	Minimum values entered for (-) entries.	None.

ATTACHMENT CB - FIELD ASSESSMENT SITE LOCATION DATA

Table CB-1. Field Assessment Site Location Information

Climate Station	HUC 12 Name	SITE ID	X	Y	Elevation (ft)	Average Precipitation (in)
Belgrade Airport, Montana 240622	Camp Creek	CC-17w-G-X-242	45.7336	-111.3376	4736	14.53
	Camp Creek	CC-17w-G-X-249	45.7474	-111.3305	4779	15.13
	Camp Creek	CC-17w-N-X-219	45.7148	-111.4302	5032	13.45
	Camp Creek	CC-17w-N-X-231	45.7216	-111.4143	4759	14
	Camp Creek	CC-17w-N-X-247	45.7429	-111.4129	4759	14
	Dry Creek	DC-17w-G-X-335	45.8942	-111.1966	4408	14.19
	Dry Creek	DC-17w-G-X-383	45.9747	-111.1751	4795	14.72
	Dry Creek	DC-17w-G-X-389	45.9790	-111.0978	4546	15.21
	Dry Creek	DC-17w-G-X-410	46.0133	-111.1703	4897	14.87
	Godfrey Creek	GC-17w-P-X-230	45.7230	-111.3153	4779	15.13
	Thompson Creek	TC-17w-G-X-432	45.8350	-111.1614	4398	14.43
	Dry Creek	DC-P-1	45.9222	-111.1806	4622	14.6
	Dry Creek	DC-P-7	46.0301	-111.1613	5150	15.21
Bozeman MSU, 241044	Dry Creek	DC-17w-G-X-399	46.0040	-111.1050	5481	17.98
	Godfrey Creek	GC-17w-G-X-172	45.6855	-111.3162	4972	15.94
	Reese Creek	REC-17w-G-X-308	45.8388	-111.0347	5179	19.49
	Reese Creek	REC-17w-G-X-323	45.8596	-111.0399	5179	19.49
	Reese Creek	REC-17w-X-324	45.8597	-111.0821	4766	15.6
	Ross Creek	RSC-17w-X-304	45.8277	-111.0767	4717	15.75
	Dry Creek	DC-P-6	45.9339	-111.1130	5373	18.55
Bozeman 12NE, Montana 241050	Bear Creek	BC-17g-G-X-34	45.6100	-110.9255	6796	35.3
	Dry Creek	DC-17w-G-X-353	45.9301	-111.0801	6990	39.21
	Lower Jackson Creek	LJC-17i-N-X-204	45.7198	-110.7807	6747	35.79
	Lower Jackson Creek	LJC-17i-N-X-223	45.7264	-110.7633	6747	35.79
	Lower Jackson Creek	LJC-17w-X-160	45.6838	-110.8520	5566	25.16
	Rocky Creek	RCC-17g-G-X-108	45.6601	-110.8695	5993	29.42
	Rocky Creek	RCC-17g-G-X-38	45.6127	-110.8579	6416	33.69
	Lower Jackson Creek	LJC-P-3	45.7184	-110.7813	6747	35.79
	Rocky Creek	RCC-P-4	45.6580	-110.9349	5894	24.99
	Bear Creek	BC-P-5	45.6097	-110.9252	6796	35.3

Latitude and Longitude obtained from GIS; Elevation data obtained from WEPP:Road PRISM

ATTACHMENT CC - WEPP: ROAD MODEL ADJUSTMENTS AND CUSTOM CLIMATE PARAMETERS

Heavily Vegetated Fillslope

Heavily vegetated fillslope conditions are not properly represented in the standard WEPP:Road assumption. As a result, William J. Elliott, author of the model, was consulted to determine how best to represent these roads within the confines of the model.

There are three traffic scenarios available in the model that affect fillslope vegetation. All of the crossings and parallel segments in this report were low or high traffic levels. For roads where vegetation is 100% on the fillslope, the fillslope length was minimized and the remainder was added to the buffer length. The following table explains the model assumptions for the three traffic scenarios:

Traffic	High	Low	None
Erodibility	100%	25%	25%
Hydraulic Conductivity	100%	100%	100%
Vegetation on Road Surface	0	0	50%
Vegetation on fill	50%	100% Forested	50%
Buffer	Forested	Forested	Forested

Affected segments:

CC-17W-N-X-247
GC-17W-P-X-230
GC-17W-G-X-172
TC-17W-G-X-432
LJC-17W-P-X-160
RCC-17G-G-X-108
RSC-17W-P-X-304
REC-17W-G-X-323353
DC-P-6
DC-P-17W-G-X-383
DC-P-17W-G-X-389
DC-P-17W-G-X-399
DC-P-7

Traffic Level

High traffic is described in WEPP:Road guidance as “ generally associated with a timber sale, hauling numerous loads of logs over the road, or roads that receive considerable traffic during much of the year”. Low traffic is described as “administrative or light recreational use during the dry season”. Due to the proximity to Bozeman, Belgrade and Manhattan, almost all of the roads receive daily use. Thus all of the sites were updated to high traffic level with the exception of the high bank area of Camp Creek that receives occasional ranch traffic and the parallel segment in Rocky Creek. This area has few homes, two forms of egress, and a private property sign at the entrance.

Maximum Contributing Road Length

The WEPP:Road model has a maximum contributing road length of 1000-feet. According to Dr. Elliott, it is rare that the contributing road length ever exceeds this distance. As a result, any field assessed road crossing or parallel segment in excess of this distance was reduced to 1000-feet for modeling purposes. This includes multiple segments for the same crossing. If both of the segments exceeded 1000 feet, each was reduced to 500 feet. If only one segment exceeded the halfway mark, that segment was reduced so that the total road length was at the maximum.

Affected segments:

DC-17W0G-X-335
DC-P-17W-G-X-410
DC-P-17W-G-X-389
BC-17G-G-X-34
DC-P-17W-G-X-399
GC-17W-G-X-172
LJC-17I-N-X-204
CC-17W-N-X-231
CC-17W-N-X-247
GC-17W-P-X-230
LJC-17W-P-X-160
RSC-17W-P-X-304
DC-P-1
BC-P-5
DC-P-7

Road Crossing Model Adjustments

Some road crossing locations had contributing road length on each side of the crossing, and road conditions were significantly different on each side. In these situations, each road segment was modeled separately and the two segments were then summed to get the total sediment load for the crossing. Also, some crossing locations were located at the convergence of two or more roads, with all roads contributing to sediment load at the crossing. In these cases, road segments were modeled separately and then summed to get the total sediment load for the crossing.

Crowned Roads

A crowned road is not a road design option in WEPP:Road. Each crossing must be considered as an inslope or outslope design with a rutted or unrutted surface. Photographs and field notes were reviewed prior to each assessment. The following is a summary of model changes.

Paved Road Crossing LJC-17W-P-X-160 Adjustment

The annual sediment load from site LJC-17W-P-X-160 without model adjustments, had the highest sediment load of all assessed sites, both paved and unpaved (2.8 tons/year). Per review of the photographs and discussions between WET and DEQ field team members, the results appear to be elevated. Site LJC-17W-P-X-160 consisted of two segments (from the south and from the northwest) contributing to a crossing in the low point of the road. Evidence of erosion and scour was noted in the field on the south side of the contributing length at the slope break between the ditch, fillslope and buffer. This contributing length resulted in 0.15 tons/year annual average sediment load. The contributing length from the northwest did not show evidence of scour or sediment deposits on the buffer length; however, the model results from this segment contributed 2.65 tons/year average annual sediment load. Due to the site conditions and lack of evidence of 2.8 tons/year sediment erosion, the segment from the North West was modeled as an outsloped, unrutted road design. This reduced the total sediment load from this site to 0.17 tons/year. Even with these model changes, the site continues to be the highest contributor of sediment of the four assessed paved crossings; however, the results better reflect actual site conditions.

Table CC-1. Specific WEPP: Road Modeling Adjustments for Crowned Roads

Site Name	Road Design	Model Adjustments
CC-17W-G-X-249	IV	Two segments (both IV) modeled separately and summed
GC-17W-P-X-230	OU	Two paved segments (both OU) modeled separately and summed
RSC-17W-X-304	IV	One segment with two ditches. Modeled as one IV segment with half width of road and doubled result.
REC-17W-G-X-308	OR	One segment with ruts present. Modeled as OR per WEPP Guidance.

Table CC-1. Specific WEPP: Road Modeling Adjustments for Crowned Roads

Site Name	Road Design	Model Adjustments
REC-17W-G-X-323	OR	Two segments with ruts present. Modeled as OR per WEPP Guidance and summed results.
REC-17W-G-324	OU	One paved segments modeled as OU.
DC-17W-G-X-353	OR	One segment with ruts present. Modeled as OR per WEPP Guidance.
DC-P-17W-G-X-389	OR	One segment with ruts present. Modeled as OR per WEPP Guidance.
DC-P-7	OR & IV	Four segments: one OR and three IV. Results averaged to represent the site.

Road crossings and parallel segments that are not listed above were not altered from the field worksheets when entered into the WEPP model.
Road Design options: OU = Outslope unrutted road, OR = Outslope rutted road, IV = Inslope road with vegetated or rocked ditch, IB = Inslope road with bare ditch

Table CC-2. Climate parameters for Belgrade Airport 240622 1971-2 + 45.48°N 111.63°W; 4450 feet elevation 85 years of record[1]

Month	Mean Maximum Temperature(°F)	Mean Minimum Temperature (°F)	Mean Precipitation (in)	Number of wet days
January	30.0	7.4	0.56	8.0
February	36.3	13.3	0.64	7.1
March	45.4	21.6	1.00	9.1
April	55.3	29.3	1.40	10.0
May	64.5	37.3	2.30	12.1
June	74.2	44.1	2.42	12.1
July	83.2	48.7	1.26	7.9
August	82.3	47.7	1.13	8.1
September	70.4	38.5	1.43	8.0
October	57.8	28.9	1.13	7.1
November	39.4	16.6	0.79	7.9
December	30.6	7.6	0.56	7.0
Annual			14.63	104.3

Table CC-3. Interpolated Data

Station	Weighting	Station	Weighting
Wind Stations		**Solar Radiation and Max .5 P Stations**	
BOZEMAN MT	45.3 %	HELENA, MONTANA	51.2 %
DILLON MT	29.1 %	BILLINGS, MONTANA	26.7 %
LIVINGSTON MT	25.6 %	POCATELLO, IDAHO	22.1 %
Dewpoint Stations		**Time-to-Peak Stations**	
BUTTE MT	61 %	CAMERON MT	43.3 %
BILLINGS MT	21.4 %	LOGAN MT	29.2 %
POCATELLO ID	17.5 %	WHITEFALLS 7 E MT	27.5 %

[1] All three climate stations were altered from the NORRIS MADISON PH MT 246157 site. Thus the interpolated data is exactly the same for each of the three climate stations (wind, dew point, solar radiation and time-to-peak) based on the NORRIS latitude, longitude and years of record. Temperature and Precipitation data is unique to each site.

Table CC-4. Climate parameters for BZN MSU 241044 YR 1971-2000 + 45.48°N 111.63°W; 4860 feet elevation 85 years of record

Month	Mean Maximum Temperature (°F)	Mean Minimum Temperature (°F)	Mean Precipitation (in)	Number of wet days
January	33.6	14.0	0.81	9.0
February	38.8	18.3	0.79	7.9
March	46.5	24.4	1.41	10.1
April	55.5	31.4	2.10	11.1
May	64.4	39.4	2.98	13.0
June	73.6	46.3	2.84	12.9
July	81.6	51.6	1.52	8.9
August	81.2	50.6	1.45	8.1
September	71.1	42.0	1.83	8.0
October	58.6	33.1	1.57	7.9
November	41.2	21.8	1.11	7.9
December	33.9	14.6	0.89	8.1
Annual			19.30	112.7

Table CC-5. INTERPOLATED DATA

Station	Weighting	Station	Weighting
Wind Stations		**Solar Radiation and Max .5 P Stations**	
BOZEMAN MT	45.3 %	HELENA, MONTANA	51.2 %
DILLON MT	29.1 %	BILLINGS, MONTANA	26.7 %
LIVINGSTON MT	25.6 %	POCATELLO, IDAHO	22.1 %
Dewpoint Stations		**Time-to-Peak Stations**	
BUTTE MT	61 %	CAMERON MT	43.3 %
BILLINGS MT	21.4 %	LOGAN MT	29.2 %
POCATELLO ID	17.5 %	WHITEFALLS 7 E MT	27.5 %

Modified by Rock:Clime on October 8, 2010 from NORRIS MADISON PH MT 246157 0

Table CC-6. Climate parameters for Bozeman 12NE 241050 YR71-00 + 45.48oN 111.63oW; 5950 feet elevation 85 years of record

Month	Mean Maximum Temperature (oF)	Mean Minimum Temperature (oF)	Mean Precipitation (in)	Number of wet days
January	32.7	8.0	2.40	14.1
February	36.6	11.2	1.94	12.9
March	42.2	16.9	2.72	15.1
April	49.3	23.1	3.60	15.0
May	58.1	30.3	4.48	16.0
June	67.1	36.2	4.35	15.0
July	74.3	39.4	2.44	11.1
August	74.2	38.2	2.41	10.0
September	64.4	31.9	2.80	10.0
October	53.6	25.5	2.60	10.0
November	38.4	15.8	2.48	13.1
December	32.6	8.8	2.40	14.1
Annual			34.60	156.4

Table CC-7. INTERPOLATED DATA

Station	Weighting	Station	Weighting
Wind Stations		**Solar Radiation and Max .5 P Stations**	
BOZEMAN MT	45.3 %	HELENA, MONTANA	51.2 %
DILLON MT	29.1 %	BILLINGS, MONTANA	26.7 %
LIVINGSTON MT	25.6 %	POCATELLO, IDAHO	22.1 %
Dewpoint Stations		**Time-to-Peak Stations**	
BUTTE MT	61 %	CAMERON MT	43.3 %
BILLINGS MT	21.4 %	LOGAN MT	29.2 %
POCATELLO ID	17.5 %	WHITEFALLS 7 E MT	27.5 %

Modified by Rock:Clime on October 8, 2010 from NORRIS MADISON PH MT 246157 0

ATTACHMENT CD - WEPP: ROAD MODELING RESULTS FOR FIELD ASSESSED SITES

Table CD-1. WEPP: Road Modeling Results for Field Assessed Crossings

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
Paved Roads																	
GC-17W-P-X-230	Belgrade	loam	50	Outsloped, unrutted	paved high	0.75	905	23	84	1	84	13.5	10	0.3	0	30	33
GC-17W-P-X-230	Belgrade	loam	50	Outsloped, unrutted	paved high	1	95	23	0.3	1	0.5	10	10	incl.	incl.	incl.	incl.
REC-17W-G-324	MSU	sand	50	Outsloped, unrutted	paved high	4	20	22	100	7	0.3	1	15	1.4	0.1	9	7
RSC-17W-X-304 PAVED	MSU	sand	50	Insloped, vegetated or rocked ditch	paved high	0.5	600	11.5	27	1	27	8	50	8.6	2.2	84	82
RSC-17W-X-304 PAVED	MSU	sand	50	Insloped, vegetated or rocked ditch	paved high	0.5	600	11.5	27	1	27	8	50	incl.	incl.	incl.	incl.
Paved: Medium and Low Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.01**	**75th Perc.**	**0.03**	**Median**	**0.02**	**Max**	**0.04**	**Min**	**0.00**	**Mean**	**0.02**
LJC-17W-P-X-160	BZN 12 NE	loam	30	Outsloped, unrutted	paved high	7	500	33	120	1	0.5	149	50	1	0.4	7538	335
LJC-17W-P-X-160	BZN 12 NE	loam	30	Insloped, vegetated or rocked ditch	paved high	6	500	29	40	1	40	24	50	incl.	incl.	incl.	incl.
Paved: High Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.17**	**75th Perc.**	**0.17**	**Median**	**0.17**	**Max**	**0.17**	**Min**	**0.17**	**Mean**	**0.17**
Gravel Roads																	
CC-17W-G-X-242	Belgrade	loam	50	Outsloped, rutted	graveled high	2.5	160	21	57	13	0.3	1	20	0.8	0.2	242	205
DC-17W-G-X-335	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	2	1000	36	48	3.5	0.3	1	30	0.7	0.2	902	838
DC-P-17W-G-X-383	Belgrade	loam	50	Outsloped, rutted	graveled high	5.5	369	19	46	1	0.3	11	20	0.6	0.2	1271	622
DC-P-17W-G-X-410	Belgrade	loam	50	Outsloped, rutted	graveled high	3	844	21	90	4	1	156	20	0.1	0	1773	75
DC-P-17W-G-X-410	Belgrade	loam	50	Outsloped, rutted	graveled high	3	156	21	0.3	1	1	79	20	incl.	incl.	incl.	incl.
DC-P-17W-G-X-389	Belgrade	sand	50	Outsloped, rutted	graveled high	2.5	1000	21	58	1	0.3	50	30	0.2	0.1	1140	283
CC-17W-G-X-249	Belgrade	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	1	39	31.5	39	12	0.3	1	15	0.3	0.1	849	36
CC-17W-G-X-249	Belgrade	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	4	480	28	0.3	1	2	230	15	incl.	incl.	incl.	incl.
Gravel: Low Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.05**	**75th Perc.**	**0.27**	**Median**	**0.12**	**Max**	**0.42**	**Min**	**0.02**	**Mean**	**0.17**
DC-17W-G-X-353	BZN 12 NE	sand	30	Outsloped, rutted	graveled high	4	288	20	65	1	0.3	16	30	0.6	0.1	624	279
RCC-17G-G-X-108	BZN 12 NE	sand	30	Outsloped, rutted	graveled high	5	306	16	65	1	65	4.5	35	1.9	0.4	1999	1951
RCC-17G-G-X-108	BZN 12 NE	sand	30	Outsloped, rutted	graveled high	3.5	633	16	41	1	41	5	35	incl.	incl.	incl.	incl.
RCC-17G-G-X-38	BZN 12 NE	sand	30	Outsloped, rutted	graveled high	5	148	23	0.3	1	8	108	50	0	0	198	8
BC-17G-G-X-34A	BZN 12 NE	loam	30	Insloped, bare ditch	graveled high	4	1000	11	85	6	0.3	1	50	1.1	0	2391	2261
Gravel: High Precipitation Class Statistics: Annual Sediment Load (tons/year) ABC-17G-G-X-34 not included in extrapolated statistics						**25th Perc.**	**0.07**	**75th Perc.**	**0.56**	**Median**	**0.14**	**Max**	**0.98**	**Min**	**0.00**	**Mean**	**0.37**
DC-P-17W-G-X-399	MSU	sand	50	Outsloped, rutted	graveled high	2.5	1000	21	42	1	0.3	3	30	1.1	0	2017	1768
REC-17W-G-X-308	MSU	sand	50	Outsloped, rutted	graveled high	1.5	180	14	5	6	0.3	1	20	1.2	0	90	78
REC-17W-G-X-323	MSU	silt	50	Outsloped, rutted	graveled high	2.5	504	15	92	1	0.3	7	15	1.9	0	1335	965
REC-17W-G-X-323	MSU	silt	50	Outsloped, rutted	graveled high	1	228	15	92	1	0.3	7	15	incl.	incl.	incl.	incl.
GC-17W-G-X-172	MSU	silt loam	50	Outsloped, rutted	graveled high	2	155	21	90	12	90	11	15	1.3	0	9105	1623
GC-17W-G-X-172	MSU	silt loam	50	Outsloped, rutted	graveled high	8	484	21	70	1	6	60	15	incl.	incl.	incl.	incl.
GC-17W-G-X-172	MSU	silt loam	50	Outsloped, rutted	graveled high	11	361	21	100	1	4	126	15	incl.	incl.	incl.	incl.

Table CD-1. WEPP: Road Modeling Results for Field Assessed Crossings

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
Gravel: Medium Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.37**	**75th Perc.**	**0.83**	**Median**	**0.65**	**Max**	**0.88**	**Min**	**0.04**	**Mean**	**0.55**
Native Roads																	
LJC-17I-N-X-204	BZN 12 NE	loam	30	Outsloped, rutted	native high	9	500	13	2	25	1	26	25	1.4	1.1	13269	1332
LJC-17I-N-X-204	BZN 12 NE	loam	30	Outsloped, rutted	native high	7	500	11	7	80	1	26	25	incl.	incl.	incl.	incl.
LJC-17I-N-X-223	BZN 12 NE	sand	30	Outsloped, rutted	native high	3.5	122	12	0.3	1	0.3	1	30	1	0.5	250	97
LJC-17I-N-X-223	BZN 12 NE	sand	30	Outsloped, rutted	native high	2.5	167	16	0.3	1	6	70	30	incl.	incl.	incl.	incl.
Native: High Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.20**	**75th Perc.**	**0.51**	**Median**	**0.36**	**Max**	**0.67**	**Min**	**0.05**	**Mean**	**0.36**
TC-17W-G-X-432	Belgrade	loam	50	Outsloped, rutted	native high	0.5	89	16	31	1	0.5	100.5	50	0	0	293	2
TC-17W-G-X-432	Belgrade	loam	50	Outsloped, rutted	native high	2	260	16	9	1	0.5	266	50	incl.	incl.	incl.	incl.
CC-17-W-N-X-219	Belgrade	clay	50	Outsloped, rutted	native low	3	468	15	0.3	1	0.3	1	10	5.1	2.4	499	379
CC-17-W-N-X-219	Belgrade	clay	50	Outsloped, rutted	native low	3.5	307	15	0.3	1	0.3	1	10	incl.	incl.	incl.	incl.
CC-17W-N-X-231	Belgrade	clay	50	Outsloped, rutted	native low	5	770	10	0.3	1	1	50	50	3.4	1.7	1144	168
CC-17W-N-X-231	Belgrade	clay	50	Outsloped, rutted	native low	0.5	230	10	0.3	1	1	5	50	incl.	incl.	incl.	incl.
CC-17W-N-X-247	Belgrade	clay	50	Outsloped, rutted	native low	1	144	13	25	1	0.3	11	10	1.2	0.8	1268	105
CC-17W-N-X-247	Belgrade	clay	50	Outsloped, rutted	native low	6	428	13	58	1	1	401	40	incl.	incl.	incl.	incl.
CC-17W-N-X-247	Belgrade	clay	50	Outsloped, rutted	native low	6	428	13	58	1	1	50	40	incl.	incl.	incl.	incl.
Native: Low Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.04**	**75th Perc.**	**0.11**	**Median**	**0.07**	**Max**	**0.19**	**Min**	**0.00**	**Mean**	**0.08**

Shaded cells in the Road Length column represent two upstream sections of the culvert. These cells were summed prior to calculating the average road length for each crossing within a watershed.
Cells with an “incl.” in the last four columns were summed either because the road was crowned and was modeled as two widths (inslope and outslope portion) or because of the two contributing upstream road sections. Cells with an “avg’d” in the last four columns are parallel sections were averaged to present one normalized value for average sediment delivery in tons/mile/year.

Table CD-2. WEPP: Road Modeling Results for Field Assessed Parallel Segments

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
Gravel Parallel Segments																	
DC-P-1	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	1.5	1000	24	58	7	1	18	30	0.4	0.1	1678	381
DC-P-1	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	2.5	1000	24	23	5	1	182	30	incl.	incl.	incl.	incl.
BC-P-5	BZN 12 NE	loam	30	Insloped, bare ditch	graveled high	4	1000	11	85	9	0.3	1	50	0.8	0.3	2213	2204
DC-P-6	MSU	sand	50	Outsloped, rutted	graveled high	2.5	500	20	33	1	8.75	23	30	0.4	0.00	1047.3	320.3
DC-P-6	MSU	sand	50	Outsloped, rutted	graveled high	3.5	500	20	23	1	3	126	30	avg'd	avg'd	avg'd	avg'd
DC-P-6	MSU	sand	50	Outsloped, rutted	graveled high	3.5	500	12	56	1	5	78.5	30	avg'd	avg'd	avg'd	avg'd
RCC-P-4	BZN 12 NE	loam	30	Outsloped, rutted	graveled low	5.5	556	16	24	13	5	48	20	0.4	0.1	814	411
Gravel: All Precipitation Classes Statistics: Annual Sediment Load (tons/year/mile)						**25th Perc.**	**0.03**	**75th Perc.**	**0.09**	**Median**	**0.03**	**Max**	**0.16**	**Min**	**0.02**	**Mean**	**0.06**
Gravel Parallel Segments																	
DC-P-7	Belgrade	sand	50	Outsloped, rutted	native high	6	1000	20	16	1	48	33	40	0.25	0.13	2853.8	1336.0
DC-P-7	Belgrade	sand	50	Outsloped, rutted	native high	6.5	1000	12	66	1	2	24	40	avg'd	avg'd	avg'd	avg'd
DC-P-7	Belgrade	sand	50	Outsloped, rutted	native high	7	1000	12	26	1	2	207	40	avg'd	avg'd	avg'd	avg'd
DC-P-7	Belgrade	sand	50	Outsloped, rutted	native high	0.5	1000	14	22	1	2	97	40	avg'd	avg'd	avg'd	avg'd
LJC-P-3	BZN 12 NE	loam	30	Outsloped, rutted	native high	2	582	17	22	1.5	26	105	15	0.4	0.3	1436	870
Native: All Precipitation Classes Statistics: Annual Sediment Load (tons/year/mile)						**25th Perc.**	**0.07**	**75th Perc.**	**0.09**	**Median**	**0.08**	**Max**	**0.10**	**Min**	**0.07**	**Mean**	**0.08**

Cells with an “incl.” in the last four columns were summed either because the road was crowned and was modeled as two widths (inslope and outslope portion) or because of the two contributing upstream road sections. Cells with an “avg’d” in the last four columns are parallel sections were averaged to present one normalized value for average sediment delivery in tons/mile/year.

ATTACHMENT CE - WEPP: ROAD MODELING RESULTS WITH BMP IMPLEMENTATION

Table CE-1. WEPP: Road Modeling Results for Field Assessed Crossings as Insloped, Vegetated Ditch Design

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
Gravel Roads																	
CC-17W-G-X-242	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	2.5	160	21	57	13	0.3	1	20	0.8	0.2	223	185
DC-17W-G-X-335	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	2	1000	36	48	3.5	0.3	1	30	0.7	0.2	902	838
DC-P-17W-G-X-383	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	5.5	369	19	46	1	0.3	11	20	0.6	0.2	717	412
DC-P-17W-G-X-410	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	3	844	21	90	4	1	156	20	0.1	0	1125	77
DC-P-17W-G-X-410	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	3	156	21	0.3	1	1	79	20	incl.	incl.	incl.	incl.
DC-P-17W-G-X-389	Belgrade	sand	50	Insloped, vegetated or rocked ditch	graveled high	2.5	1000	21	58	1	0.3	50	30	0.2	0.1	729	232
CC-17W-G-X-249	Belgrade	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	1	39	31.5	39	12	0.3	1	15	0.3	0.1	849	36
CC-17W-G-X-249	Belgrade	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	4	480	28	0.3	1	2	230	15	incl.	incl.	incl.	incl.
Gravel: Low Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.05**	**75th Perc.**	**0.18**	**Median**	**0.10**	**Max**	**0.42**	**Min**	**0.02**	**Mean**	**0.15**
DC-17W-G-X-353	BZN 12 NE	sand	30	*Insloped, vegetated or rocked ditch*	graveled high	4	288	20	65	1	0.3	16	30	0.5	0.1	359	191
RCC-17G-G-X-108	BZN 12 NE	sand	30	*Insloped, vegetated or rocked ditch*	graveled high	5	306	16	65	1	65	4.5	35	1.9	0.4	1141	1147
RCC-17G-G-X-108	BZN 12 NE	sand	30	*Insloped, vegetated or rocked ditch*	graveled high	3.5	633	16	41	1	41	5	35	incl.	incl.	incl.	incl.
RCC-17G-G-X-38	BZN 12 NE	sand	30	*Insloped, vegetated or rocked ditch*	graveled high	5	148	23	0.3	1	8	108	50	0	0	123	8
BC-17G-G-X-34[A]	BZN 12 NE	loam	30	Insloped, vegetated or rocked ditch	graveled high	4	1000	11	85	6	0.3	1	50	-	-	-	1582
Gravel: High Precipitation Class Statistics: Annual Sediment Load (tons/year) **[A]BC-17G-G-X-34 not modeled with WEPP. Thirty percent reduction employed**						**25th Perc.**	**0.05**	**75th Perc.**	**0.33**	**Median**	**0.10**	**Max**	**0.57**	**Min**	**0.00**	**Mean**	**0.22**
DC-P-17W-G-X-399	MSU	sand	50	*Insloped, vegetated or rocked ditch*	graveled high	2.5	1000	21	42	1	0.3	3	30	1.1	0	1234	1166
REC-17W-G-X-308	MSU	sand	50	*Insloped, vegetated or rocked ditch*	graveled high	1.5	180	14	5	6	0.3	1	20	1.2	0	88	78
REC-17W-G-X-323	MSU	silt	50	*Insloped, vegetated or rocked ditch*	graveled high	2.5	504	15	92	1	0.3	7	15	1.9	0	898	682
REC-17W-G-X-323	MSU	silt	50	*Insloped, vegetated or rocked ditch*	graveled high	1	228	15	92	1	0.3	7	15	incl.	incl.	incl.	incl.
GC-17W-G-X-172	MSU	silt loam	50	*Insloped, vegetated or rocked ditch*	graveled high	2	155	21	90	12	90	11	15	1.3	0	6185	1528
GC-17W-G-X-172	MSU	silt loam	50	*Insloped, vegetated or rocked ditch*	graveled high	8	484	21	70	1	6	60	15	incl.	incl.	incl.	incl.
GC-17W-G-X-172	MSU	silt loam	50	*Insloped, vegetated or rocked ditch*	graveled high	11	361	21	100	1	4	126	15	incl.	incl.	incl.	incl.
Gravel: Medium Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.27**	**75th Perc.**	**0.63**	**Median**	**0.46**	**Max**	**0.76**	**Min**	**0.04**	**Mean**	**0.43**
Native Roads																	
LJC-17I-N-X-204	BZN 12 NE	loam	30	*Insloped, vegetated or rocked ditch*	native high	9	500	13	2	25	1	26	25	1.4	1.1	5376	1166
LJC-17I-N-X-204	BZN 12 NE	loam	30	*Insloped, vegetated or rocked ditch*	native high	7	500	11	7	80	1	26	25	incl.	incl.	incl.	incl.
LJC-17I-N-X-223	BZN 12 NE	sand	30	*Insloped, vegetated or rocked ditch*	native high	3.5	122	12	0.3	1	0.3	1	30	1	0.5	159	61
LJC-17I-N-X-223	BZN 12 NE	sand	30	*Insloped, vegetated or rocked ditch*	native high	2.5	167	16	0.3	1	6	70	30	incl.	incl.	incl.	incl.
Native: High Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.17**	**75th Perc.**	**0.44**	**Median**	**0.31**	**Max**	**0.58**	**Min**	**0.03**	**Mean**	**0.31**
TC-17W-G-X-432	Belgrade	loam	50	*Insloped, vegetated or rocked ditch*	native high	0.5	89	16	31	1	0.5	100.5	50	0	0	197	2
TC-17W-G-X-432	Belgrade	loam	50	*Insloped, vegetated or rocked ditch*	native high	2	260	16	9	1	0.5	266	50	incl.	incl.	incl.	incl.
CC-17-W-N-X-219	Belgrade	clay	50	*Insloped, vegetated or rocked ditch*	native low	3	468	15	0.3	1	0.3	1	10	5.1	2.4	139	91
CC-17-W-N-X-219	Belgrade	clay	50	*Insloped, vegetated or rocked ditch*	native low	3.5	307	15	0.3	1	0.3	1	10	incl.	incl.	incl.	incl.
CC-17W-N-X-231	Belgrade	clay	50	*Insloped, vegetated or rocked ditch*	native low	5	770	10	0.3	1	1	50	50	3.4	1.7	405	114
CC-17W-N-X-231	Belgrade	clay	50	*Insloped, vegetated or rocked ditch*	native low	0.5	230	10	0.3	1	1	5	50	incl.	incl.	incl.	incl.
CC-17W-N-X-247	Belgrade	clay	50	*Insloped, vegetated or rocked ditch*	native low	1	144	13	25	1	0.3	11	10	1.2	0.8	512	90
CC-17W-N-X-247	Belgrade	clay	50	*Insloped, vegetated or rocked ditch*	native low	6	428	13	58	1	1	401	40	incl.	incl.	incl.	incl.
CC-17W-N-X-247	Belgrade	clay	50	*Insloped, vegetated or rocked ditch*	native low	6	428	13	58	1	1	50	40	incl.	incl.	incl.	incl.
Native: Low Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.03**	**75th Perc.**	**0.05**	**Median**	**0.05**	**Max**	**0.06**	**Min**	**0.00**	**Mean**	**0.04**
Gravel Roads																	
RCC-17G-G-X-38	BZN 12 NE	sand	30	Insloped, vegetated or rocked ditch	graveled high	5	148	23	0.3	1	8	108	50	0	0	177	8
REC-17W-G-X-308	MSU	sand	50	Outsloped, rutted	graveled high	1.5	180	14	5	6	0.3	1	20	1.2	0	90	78

Table CE-1. WEPP: Road Modeling Results for Field Assessed Crossings as Insloped, Vegetated Ditch Design

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
All five crossings: Annual Sediment Load (tons/year)						**25th Perc.**	**0.01**	**75th Perc.**	**0.03**	**Median**	**0.02**	**Max**	**0.04**	**Min**	**0.00**	**Mean**	**0.02**

Shaded cells in the Road Length column represent two upstream sections of the culvert. These cells were summed prior to calculating the average road length for each crossing within a watershed.
Cells with an "incl." in the last four columns were summed either because the road was crowned and was modeled as two widths (inslope and outslope portion) or because of the two contributing upstream road sections.

Table CE-2. WEPP: Road Modeling Results for Field Assessed Crossings: 200 Feet Maximum Length

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
Native Roads																	
LJC-17I-N-X-204	BZN 12 NE	loam	30	Insloped, vegetated or rocked ditch	native high	9	100	13	2	25	1	26	25	0.3	0.1	283	26
LJC-17I-N-X-204	BZN 12 NE	loam	30	Insloped, vegetated or rocked ditch	native high	7	100	11	7	80	1	26	25	incl.	incl.	incl.	incl.
LJC-17I-N-X-223	BZN 12 NE	sand	30	Insloped, vegetated or rocked ditch	native high	3.5	122	12	0.3	1	0.3	1	30	1.0	0.5	114.2	49.3
LJC-17I-N-X-223	BZN 12 NE	sand	30	Outsloped, rutted	native high	2.5	78	16	0.3	1	6	70	30	incl.	incl.	incl.	incl.
TC-17W-G-X-432	Belgrade	loam	50	Outsloped, rutted	native high	0.5	89	16	31	1	0.5	100.5	50	0	0	119	1
TC-17W-G-X-432	Belgrade	loam	50	Outsloped, rutted	native high	2	111	16	9	1	0.5	266	50	incl.	incl.	incl.	incl.
All five crossings: Annual Sediment Load (tons/year)						**25th Perc.**	**0.01**	**75th Perc.**	**0.03**	**Median**	**0.02**	**Max**	**0.04**	**Min**	**0.00**	**Mean**	**0.02**

Shaded cells in the Road Length column represent two upstream sections of the culvert. These cells were summed prior to calculating the average road length for each crossing within a watershed.
Cells with an "incl." in the last four columns were summed either because the road was crowned and was modeled as two widths (inslope and outslope portion) or because of the two contributing upstream road sections.