APPENDIX J
IN-STREAM SEDIMENT SOURCE ANALYSIS

J.1 Methods

Data collected during the 2003 bank erosion inventory provided the basis for estimating sediment loading from stream banks on main stem Grave Creek and tributary streams. Two different source types were identified during the bank erosion inventory. Collectively, these two sources are referred to as “in-stream sediment sources” (Figure J-1). The first source type was eroding banks. The second source type was slope failures that extend down to stream channels. While the second source type is typically not the same as a disturbed stream bank, for sediment loading purposes, the slope failures, particularly the slope toes, have replaced the stream banks or the toe area of the accessible floodplain. These eroding toe slopes are contributing sediment to the channel network in a similar way as a disturbed bank would.

Actual bank erosion sites were found almost exclusively in Grave Creek main stem reaches 1 and 2. Nearly all other in-stream sediment sources were related to mass wasting failures that are contributing sediment directly to the stream. Where in-stream sources in the upper watershed were similar to an eroding bank, it was determined that the mass wasting modeling approach adequately captured sediment loading. Eroding bank material and slope failure material is composed of a mixture of both fine and coarse sediment sizes ranging from silt to boulder usually with a concentration of sand, gravel and cobble.

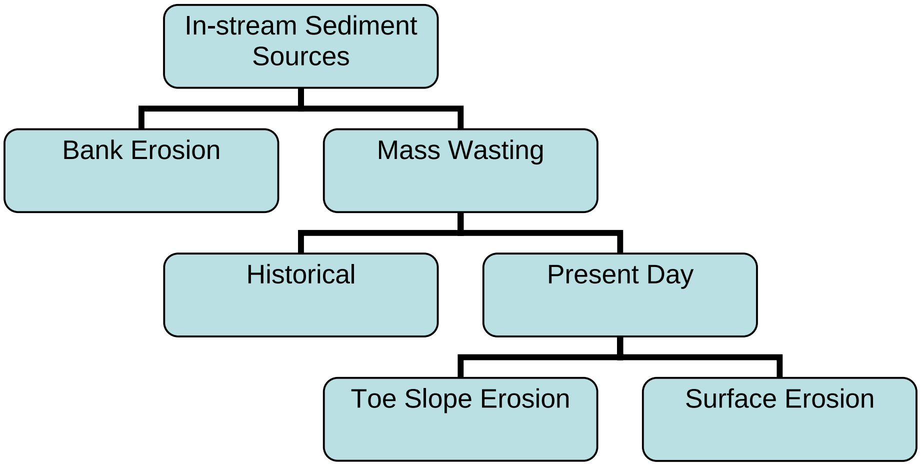

Figure J-1: Hierarchical Organization of In-Stream Sediment Sources.

RDG inventoried approximately 20 miles of main stem Grave Creek, including 100 percent Grave Creek below the canyon, representing approximately 60 percent of the main stem. An additional 8.5 miles (36 percent) of the tributary streams were also inventoried. Sites characterized as sediment sources were defined according to the following variables:

- Site length
- Site height
- Qualitative erosion risk assessment based on bank materials, the bank height ratio, vegetation condition, bank angle, and flow vectors relative to the site (modified BEHI)
- Land ownership
- Primary and secondary causes of erosion (e.g. natural, riparian modification)
- Overstory, understory, and herbaceous vegetation coverage
- Canopy density

Riparian modification included any type of alteration of the natural riparian community. Examples of riparian modifications included conversion to pasture or cropland, land clearing for development and residential construction, alterations for access (recreation, diversion, transportation, etc), and timber harvest.

J.1.1 Bank Erosion Sources

To estimate the annual sediment load produced by the first source type, eroding banks, an average rate of bank erosion was estimated for each inventoried bank erosion site. Because there were no field measures of bank erosion rates, literature references were used to determine a range of bank erosion rates measured on other gravel bed, moderate gradient streams. A similar analysis was completed for the *Blackfoot River Headwaters Planning Area Water Quality and Habitat Restoration Plan and TMDL for Sediment* (MDEQ, 2004b).

Bank erosion rates calculated by Rosgen for the Colorado Front Range (Rosgen, 2001) were selected. Glaciated, metasedimentary belt rock geology characterizing the Colorado Front Range is similar to the geology of the Grave Creek drainage. Table J-1 includes the stream bank erosion rates used for the Grave Creek bank erosion analysis. Near bank sheer stress data were not collected in Grave Creek, but in general near bank stress conditions ranged between moderate and extreme. Therefore, bank erosion rates were interpolated from Colorado Front Range data, approximately midway between moderate and extreme near bank stress categories.

Table J-1: Bank Erosion Rates Based on Bank Erosion Hazard Index (BEHI) Scores From the Colorado Front Range (Rosgen, 2001).

Bank Erosion Hazard Index (BEHI)	Predicted Stream Bank Erosion Rate based on Lamar River Data Set (ft/yr)
Low	0.2
Moderate	0.6
High	1.1
Extreme	2.3

Soil bulk densities were required to determine the tonnage of sediment delivered to stream channels from eroding banks. Soil bulk densities were interpreted from the *Soil Survey Kootenai National Forest Area, Montana and Idaho* (USFS, 1995a). Because the mapped soil unit information did not include bulk densities, similar soil series with calculated saturated bulk densities were substituted for the mapped soil units (C. Sibley, NRCS, personal communication). Saturated bulk densities were similar for the three soil series (Table J-2).

Table J-2: Saturated Bulk Densities for the Three Substituted Soil Series Characterizing Floodplain Soils on Main Stem Grave Creek and the Primary Tributaries.

Channel Segment	Soil Map Unit	Substituted Soil Series	Bulk Density
Lower Grave Creek (Reaches 1-2)	**103** – Andic Dystrochrepts, alluvial terraces	Backroad and Halfmoon soil series	1.5
Middle Grave Creek (Reaches 4-8) and Upper Grave Creek (Reaches 9-11)	**108** – Andic Dystric Eutrochrepts, lacustrine terraces-Andic Dystrochrepts, glacial outwash terraces complex	Beaverdump soil series	1.6
Tributaries	**407** – Andic Cryochrepts, moraines	Ashworth soil series	1.55

Sediment loading was estimated by multiplying the length and height of each eroding bank by the predicted erosion rate and the bulk density of the substituted soil series (Figure J-2).

Sediment Load from Eroding Banks (tons/yr) =

Eroding Bank Length (ft) * Eroding Bank Height (ft) * Erosion Rate (ft/yr) * Bulk Density (tons/ft^3)

Figure J-2: General Equation for Calculating Sediment Delivery from Eroding Bank Sites.

At the time of road building and riparian modification, particularly timber harvest, there may have been an initial pulse of sediment from bank erosion. It is expected that this pulse is primarily a result of removal of bank-stabilizing trees. In some cases, sediment sources from such activity may have recovered over time via revegetation. In other cases, these bank erosion sources may have been exacerbated into larger sources now recognized as mass wasting.

J.1.2 Mass Wasting Sources

Sediment loading from mass wasting sites (also referred to as historic mass wasting sites or events) was categorized in several ways. First, a temporal distinction was made to separate historic loads from present day loading.

For the initial mass wasting events, the sediment pulse produced by the event is estimated. For present day erosion from these sites, loading is separated by erosion mechanism into surface erosion and toe slope erosion categories (Figure J-1).

J.1.2.1 Initial In-stream Sediment Loading from Historic Mass Wasting Events

It is important to note that the current sediment load contributed from surface and toe slope erosion of the historic mass wasting sites is relatively small in comparison to the sediment contributed during and immediately after the events occurred. For example, in Williams Creek, 4.6 acres of mass failure was observed. Assuming the average depth of failure was 5 feet and assuming a bulk density of 1.6 g/cc, failures in Williams Creek would have moved 59,371 tons of material. Field observations of remnant failure material are evidence that not all of the material moved was delivered to the stream. Assuming only fifty percent of the failure was delivered during and shortly after the event, 30,000 tons would have been delivered initially to Williams Creek. The total initial load throughout the watershed is estimated at 115,000 tons since the human caused mass wasting sites in Williams Creek represent about 26% of the total human caused mass wasting contributions based on the Table 6.2 results. While the mass wasting sites continue to contribute sediment to the stream channel network (404 tons annually in Williams Creek as determined in the below sections), the initial mass wasting pulse produced the majority of the coarse and fine sediment contributed to the channel network in comparison to current yearly loading from these sites. Sediment loading from the mass wasting sites continues to occur (Section J.1.2.2), diminishing over time with revegetation and stabilization. This initial mass wasting pulse load is also significantly higher than the lower Grave Creek bank erosion loads identified below.

It is assumed that most of the fine sediment from the initial pulse has been transported out of the system. However, the coarse material likely remains in the bed material load, as bedload transport rates can be very low and limited to fewer flow events than required for transport of finer and/or suspended sediment loads (Leopold, 1994; Watson et al., 1998; Dunne et al., 1980). As a result, the coarse sediment from these events, which remains in the system, can contribute to a loss of pool habitat due to pool filling by the excess bed material load as discussed in Section 5.4 and Appendix G.

Most of the historic mass-wasting sites are attributed to human causes. Historic natural loads are assumed similar to present day natural loads.

J.1.2.2 Current In-stream Sediment Loading from Remnants of Historic Mass Wasting Events

Presently at these mass-wasting sites, two mechanisms of continued sediment contribution were observed. The first mechanism is hillslope erosion from the slumped mass of material and scarp, also referred to as surface erosion. The second mechanism is toe slope erosion. During field observation it was noted that while some of the wasted material has partially revegetated, inchannel and above bank streamflows could potentially activate the toes of the failed material, thereby increasing sediment loading on occasion.

J.1.2.2.1 Surface Erosion

For the natural mass wasting sites length and height dimensions were also collected. A sediment load for the contributing area was calculated using an annual erosion rate of 24 tons/mi^2/year and a delivery ratio of 60% (USFS, 1991). For human caused mass wasting sites the Disturbed WEPP model (Elliot et al., 2000) was used to determine erosion rates and sediment delivery. Inputs to WEPP for both upper and lower hillslope facets included 65% gradient, 20% cover and 20% rock. For the treatment variable, “low severity fire” was used. The Disturbed WEPP model documentation explains that the low severity treatment is similar to “a sparsely vegetated, newly exposed surface following excavation where material has not been highly compacted, such as a road cut”. This scenario was deemed most similar to the slope failures being modeled. Other variable inputs included soil texture and climate. The same climate file and soil texture used for the WEPP: Road runs for road surface erosion analysis were also used here for the slope failure erosion analysis (See Appendix B).

J.1.2.2.2 Toe Slope Erosion

For each mass wasting site, erosion of the toe slopes by stream flow is another source of sediment loading. An estimate of annual sediment load from erosion of toe slope by streamflow was generated by applying a BEHI erosion rate to the area of toe slope exposed to the most frequent flows. Based on field observations of toe slope stability, angle, and revegetation, it was determined that most toe slope are relatively stable and a BEHI rating of Low (0.2 feet of erosion per year) would be appropriate. The area of toe slope susceptible to this type of erosion was determined by multiplying the length of the failure by a height of 5 feet. Five feet was selected based on the average height at which bankfull flows and slightly out of bank flows would impact the mass wasting site.

J.1.3 Total Sediment from In-Stream Sources

The field inventory covered a majority of the Grave Creek main stem and portions (lower and middle) of each tributary stream. Although the inventoried channel lengths likely captured the majority of the sediment sources on each tributary, sediment sources in the uninventoried reaches likely exist. To account for the sediment loading attributed to the uninventoried reaches, inventoried reach results were extrapolated to the portions of each tributary that were not field inventoried. A correction factor was applied to the total sediment loading per mile calculated for the inventoried reaches before applied the inventoried load rate to the uninventoried reaches (Figure J-3). The correction factor was deemed necessary because it is believed that a different proportion of human caused versus natural loads was inventoried. For example, it is likely that approximately 70% of the human caused erosion sites were inventoried due to a focus in areas with historical timber harvest; therefore a correction factor of 30% was applied to the inventoried load rate before applying that load rate to the uninventoried stream lengths. Similarly, it is believed that approximately 50% of the natural sources were captured in the inventoried reaches. Therefore a 0.5 correction factor was applied to the inventoried load rate before applying that load rate to the uninventoried stream lengths for these natural loads.

Total Sediment Load from In-stream Sediment Sources (tons/yr) =

Inventoried Sediment Load (tons/yr) + (**CF** * (Inventoried Sediment Loading (tons/mile/yr) * Uninventoried Channel Length (mile))

Figure J-3: The Total Sediment Load Equation that was Used to Estimate Total Sediment Load from In-Stream Sediment Sources in the Grave Creek Tributaries. CF is a Correction Factor of 0.3 for Human Caused Sources and 0.5 for Natural Sources.

J-2 Results

J.2.1 Grave Creek Watershed

J.2.1.1 Comparison of Human and Natural In-stream Sediment Loading by Stream

The total calculated (inventoried segments) and extrapolated (uninventoried segments) sediment loading was combined to get a total load for human caused sediment sources. A comparison of human-caused versus natural sediment loading from mass wasting sites is presented in Table J-3. A total of 2,253 tons of sediment from mass wasting sites is contributed to lower Grave Creek. Human caused sources account for 1,547 tons of sediment from mass wasting sites. An additional 706 tons is associated with natural sediment sources.

Combining the Table J-3 sediment loading from mass wasting sites with the total sediment load in lower Grave Creek results in approximately 11,686 tons/year of sediment delivered to the Grave Creek drainage network from in-stream sediment sources (Table J-4, Figure J-4). These results strongly suggest that human influences are increasing sediment inputs to the channel network. Approximately 10,940 tons of the total annual sediment loading from in-stream sources in the Grave Creek watershed is attributed to human activities. For the inventoried segments, this load is broken down further by cause in the following section. Sediment loading in Lewis Creek is predominantly linked to natural sources, mainly avalanche chutes.

It is recognized that even though natural mass wasting loads were not identified in the lower portions of the other tributary drainages, such sites could exist in the middle and upper tributary reaches. The sediment sources identified by air photo interpretation (Map 15) provide an idea of the frequency of similar mass wasting sites where the middle and upper tributary reaches were not inventoried. Based on this map, it appears that Williams would have an extrapolated natural mass wasting load of about 31 tons similar to the extrapolated load for Blue Sky. Map 15 shows few sediment sites in the upper watersheds for Stahl, Clarence and Foundation at about 15% of the number seen in Williams or Blue Sky. This is consistent with the less steep and shorter steep slope lengths found in Stahl and Clarence compared to Williams, Blue Sky and Lewis (Map 15 topography). Based on this observation, a natural mass-wasting load of about 4.6 tons (15% of 31) is added to the total modeled load for Stahl, Clarence and Foundation. These additional loads are not reflected in Table J-3, and would result in an additional 44.8 tons to the total watershed values of 2253 total tons with 1547 tons attributed to human-related mass wasting sites and 752 tons from natural mass wasting sites.

Mass Wasting Sites

Table J-3: Summary of Sediment Load From Mass Wasting Sites in the Grave Creek Watershed.

	Calculated Load (for inventoried segments)				Predicted Load (extrapolation to uninventoried segments)				Total Load from Mass Wasting Sites					
	Surface		Toe		Surface		Toe		Surface		Toe		Total	
Stream	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)
Foundation*														
Human					2.2	100	39.4	100	2.2	100	39.4	100	41.6	100
Natural					0	0	0	0	0	0	0	0	0	0
Total					2.2	100	39.4	100	2.2	100	39.4	100	41.6	100
Clarence														
Human	8.1	100	143.2	100	3.8	100	67.5	100	11.9	100	210.7	100	222.6	100
Natural	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0.0	0
Total	8.1	100	143.2	100	3.8	100	67.5	100	11.9	100	210.7	100	222.6	100
Stahl														
Human	7.4	100	101.1	100	9.1	100	124	100	16.5	100	225.1	100	241.6	100
Natural	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0.0	0
Total	7.4	100	101.1	100	9.1	100	124	100	16.5	100	225.1	100	241.6	100
South Fork Stahl														
Human	2.4	100	71.4	100	1	100	28.8	100	3.4	100	100.2	100	103.6	100
Natural	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0.0	0
Total	2.4	100	71.4	100	1	100	28.8	100	3.4	100	100.2	100	103.6	100
Lewis														
Human	1.7	2	34.7	13	0.8	1	16.5	8	2.5	2	51.2	11	53.7	9
Natural	84.2	98	225.3	87	66.9	99	178.9	92	151.1	98	404.2	89	555.3	91
Total	85.9	100	260.0	100	67.7	100	195.4	100	153.6	100	455.4	100	609.0	100
Blue Sky														
Human	2.8	100	56.9	82	4.2	100	85.7	73	7	100	142.6	77	149.6	77
Natural	0.0	0	12.4	18	0	0	31.1	27	0	0	43.5	23	43.5	23

Table J-3: Summary of Sediment Load From Mass Wasting Sites in the Grave Creek Watershed.

	Calculated Load (for inventoried segments)				Predicted Load (extrapolation to uninventoried segments)				Total Load from Mass Wasting Sites					
	Surface		Toe		Surface		Toe		Surface		Toe		Total	
Stream	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)
Total	2.8	100	69.3	100	4.2	100	116.8	100	7.0	100	186.1	100	193.1	100
Williams														
Human	17.5	100	189.8	100	16.6	100	179.8	100	34.1	100	369.6	100	403.7	100
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
Total	17.5	100	189.8	100	16.6	100	179.8	100	34.1	100	369.6	100	403.7	100
Middle and Upper Main stem														
Human	3.3	65	251.2	79	0.9	53	75.3	66	4.2	62	326.5	76	330.7	76
Natural	1.8	35	66.4	21	0.8	47	38.3	34	2.6	38	104.7	24	107.3	24
Total	5.1	100	317.6	100	1.7	100	113.6	100	6.8	100	431.2	100	438.0	100
Total Mass Wasting Site Load to Lower Grave Creek														
Human	43.2		848.3		38.6		617.0		81.8		1465.3		1547.1	
Natural	86.0		304.1		67.7		248.3		153.7		552.4		706.1	
Total	129.2		1152.4		106.3		865.3		235.5		2017.7		2253.2	

Mass Wasting Sites and Bank Erosion Sites

Table J-4: Total In-stream Sediment Load Calculated for Inventoried In-Stream Segments and Extrapolated to Uninventoried Segments.

Reach	Human-Induced Sediment Loading (tons/yr)			Natural Sediment Loading (tons/yr)	Total (tons/yr)
	Bank Erosion	Mass Wasting	Total Human		
Lower Grave	9393		9393	40	9433
Middle-Upper Grave		331	331	107	438
Foundation		42	42		42
Lewis		54	54	555	609
Blue Sky		150	150	44	193
Williams		404	404		404
Clarence		223	223		223
Stahl		242	242		242
SF Stahl		104	104		104
Total	9393	1547	10940	746	11686

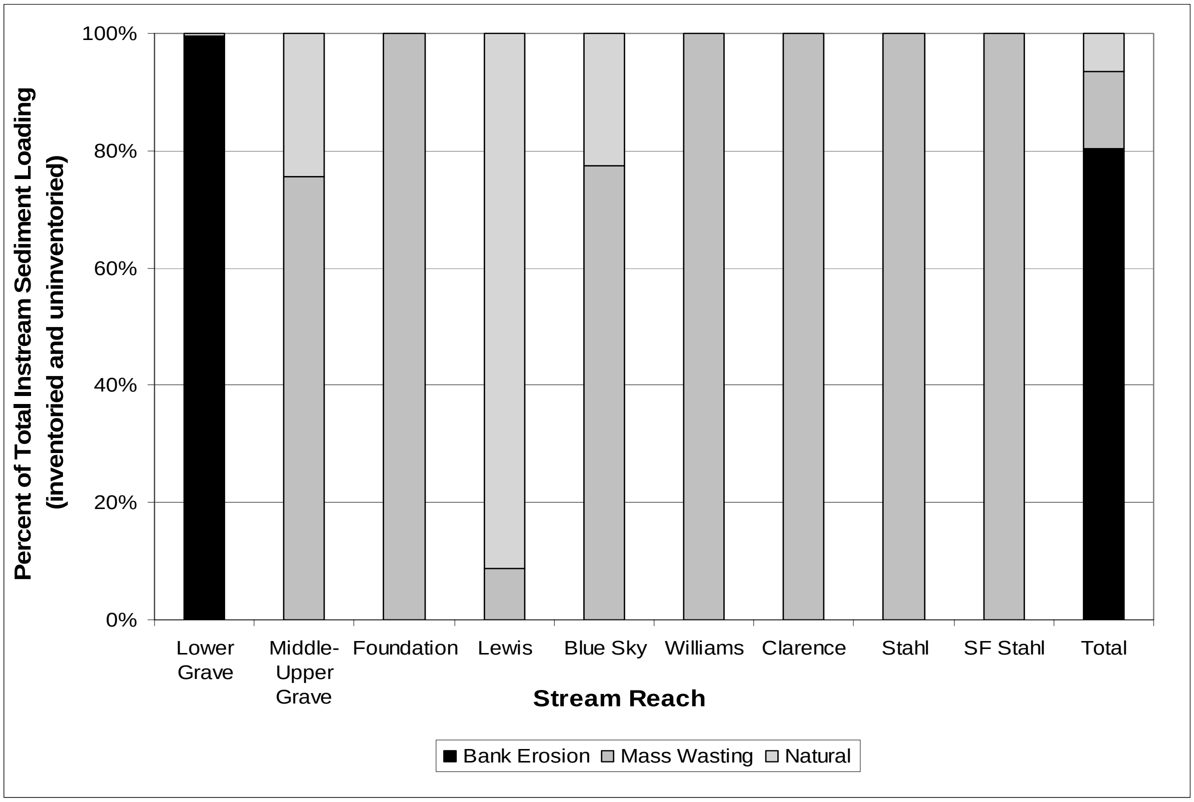

Figure J-4: Histogram of Total In-Stream Sediment Load (Mass Wasting and Bank Erosion) for Inventoried Segments and Extrapolated to Uninventoried Segments (Does Not Include Small Extrapolated Natural Background Loads of about 3 to 5% for Stahl, S. Fk. Stahl, Clarence and Foundation, and about 5 to 10% for Williams).

J.2.1.2 Distribution of In-stream Sediment Sources and Loading by Cause and by Stream

The inventoried in-stream sediment sources were stratified by primary cause. Causes include road encroachment, riparian modifications, channel alteration, bank armoring and bridges. Most sites were affected by multiple causes, for this portion of the sediment loading analysis, only the primary cause is considered.

Table J-5 presents a tally and percent distribution of the inventoried in-stream sediment sources. Of the 126 sources identified, most sources were related to human-caused sediment sources. Natural sources of in-stream sediment contribution accounted for 13 of the 126 sites primarily in Lewis Creek and in upper main stem and Foundation Creek. The total load for each cause was also calculated for the inventoried in-stream sediment sources and is described below.

Table J-5: Count of In-Stream Sediment Source Sites by Sub-Watershed and Cause. Percent of Total Eroding Area Within Sub-Watershed is also given by Cause.

Stream		Riparian Modifications	Natural	Roads	Channel Alterations	Bank Armoring	Bridges	Total
Lewis								
	#	2	6		1			9
	% area	*60.1*	*39.4*		*0.5*			
Blue Sky								
	#	5	1					6
	% area	*98*	*2*					
Clarence								
	#	7		3				10
	% area	*80.7*		*19.3*				
Stahl								
	#	9		2		1	1	13
	% area	*55*		*37.9*		*< 0.1*	*6.6*	
South Fork Stahl								
	#	11		2				13
	% area	*91*		*9.1*				
Williams								
	#	11		9				20
	% area	*37*		*63*				
Main Stem Grave/Foundation								
	#	39	7	6	3			55
	% area	*73*	*13.5*	*10.8*	*2.7*			
Total								
	#	84	13	22	4	1	2	126

Riparian Modification

Over 92% (9,753 tons) of the total inventoried load (10,549) from in-stream sources was attributed to riparian modification (Table J-6, Figure J-5). Most of this load (9,139 tons) from riparian modifications is contributed from bank erosion in lower Grave Creek. Riparian modification in middle and upper Grave Creek is attributed to the next largest load from inventoried in-stream sources, 184 tons, followed by Clarence Creek with 124 tons. The remaining load from inventoried in-stream sites due to riparian modification ranges from 33 tons in Lewis Creek to 98 tons in Williams Creek.

Table J-6: In-stream Sediment Source Loading* of Inventoried Segments By Stream and By Cause.

Reach	Sediment Source Cause					Total Sediment Loading (tons/yr)		
	Riparian Modification	Natural	Road Encroachment	Channel Alteration	Bank Armoring	Total	Human	Natural
Lower Grave	9139.0	40.0	105.5	148.0	0.0	9432.5	9392.5	40.0
Middle Upper Grave	183.6	66.4	61.1	6.6	0.0	317.7	251.2	66.4
Lewis	33.0	225.3		1.7		259.9	34.7	225.3
Blue Sky	56.9	12.4				69.3	56.9	12.4
Williams	97.8		92			189.8	189.8	0.0
Clarence	124.2		19			143.2	143.2	0.0
Stahl	61.5		33		6.6	101.1	101.1	0.0
SF Stahl	57.3		14			71.4	71.4	0.0
Total	9753.3	344.0	324.6	156.3	6.6	10584.8	10240.7	344.0

* Only includes toe slope erosion contributions from mass wasting sites; the smaller hillslope surface erosion component is not incorporated into the values within this table

Natural Sources

In-stream sediment from natural sources in the inventoried segments is 344 tons per year Table J-6). This does not include the modeled natural background surface erosion load (Table 6-1) or other sources of natural sediment loading such as those in uninventoried reaches (sediment loading was not extrapolated by cause) and natural background bank erosion. The modeled load from natural sources in inventoried segments represents a little over 3% of the total load from inventoried sources. Most of this load is associated with mass waste loading from avalanche locations in Lewis Creek (225 tons). When computed for the watershed above GLID, the natural sources percentage is of greater significance at about 45% of the load from inventoried sources.

Road Encroachment

Road encroachment on the stream channel, whether by a bridge or other crossing or road fillslope causing erosion or mass wasting contributes 325 tons of sediment per year. This road related load is in addition to sediment from road surface erosion presented in Appendix I. Sediment from road encroachment accounts for another 3% of the total in-stream sediment load from inventoried stream segments, with a higher percentage of contribution in upper areas of the watershed.

Channel Alteration

Channel alteration is attributed to sediment loading of 156 tons per year from in-stream sources of inventoried stream segments. This represents 1.5% of the total inventoried in-stream source load, although there may be much greater impacts due to linkages between historic channel alterations and greater susceptibility to erosion in areas of riparian modifications.

Bank Armoring

Erosion at one in-stream sediment source was associated with bank armoring. A riprapped bank at the Stahl Creek campground was identified as the cause for erosion of the downstream right bank. Over 6.6 tons of sediment per year is the estimated contribution to the channel network at that site. Ten feet of bank retreat was observed over 80 feet in length of the 5 foot-high bank. This one site is responsible for 0.1% of the total load from inventoried segments.

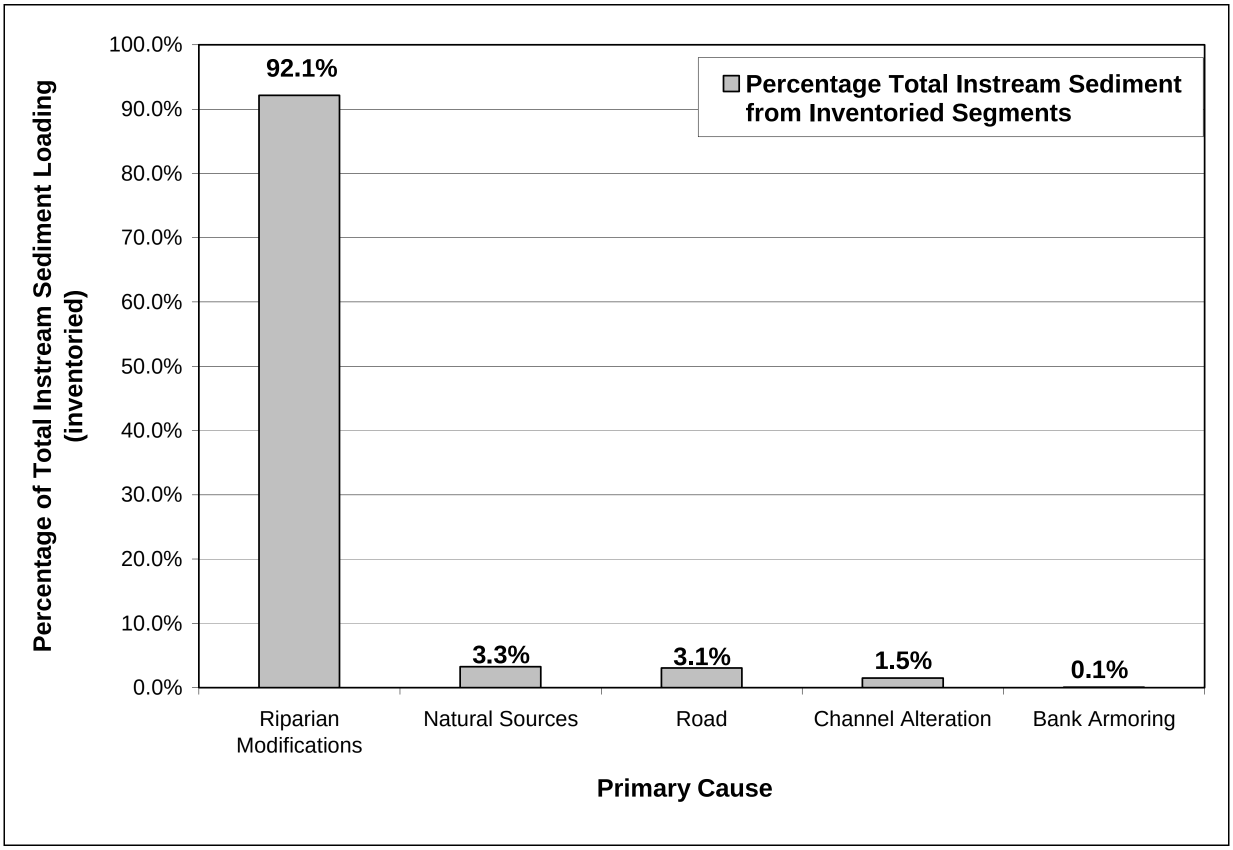

Figure J-5: Percentage of Sediment Loading Related to In-Stream Sediment Sources (Bank Erosion and Mass Wasting) by Sediment Source Cause for Inventoried Segments in the Grave Creek Drainage.

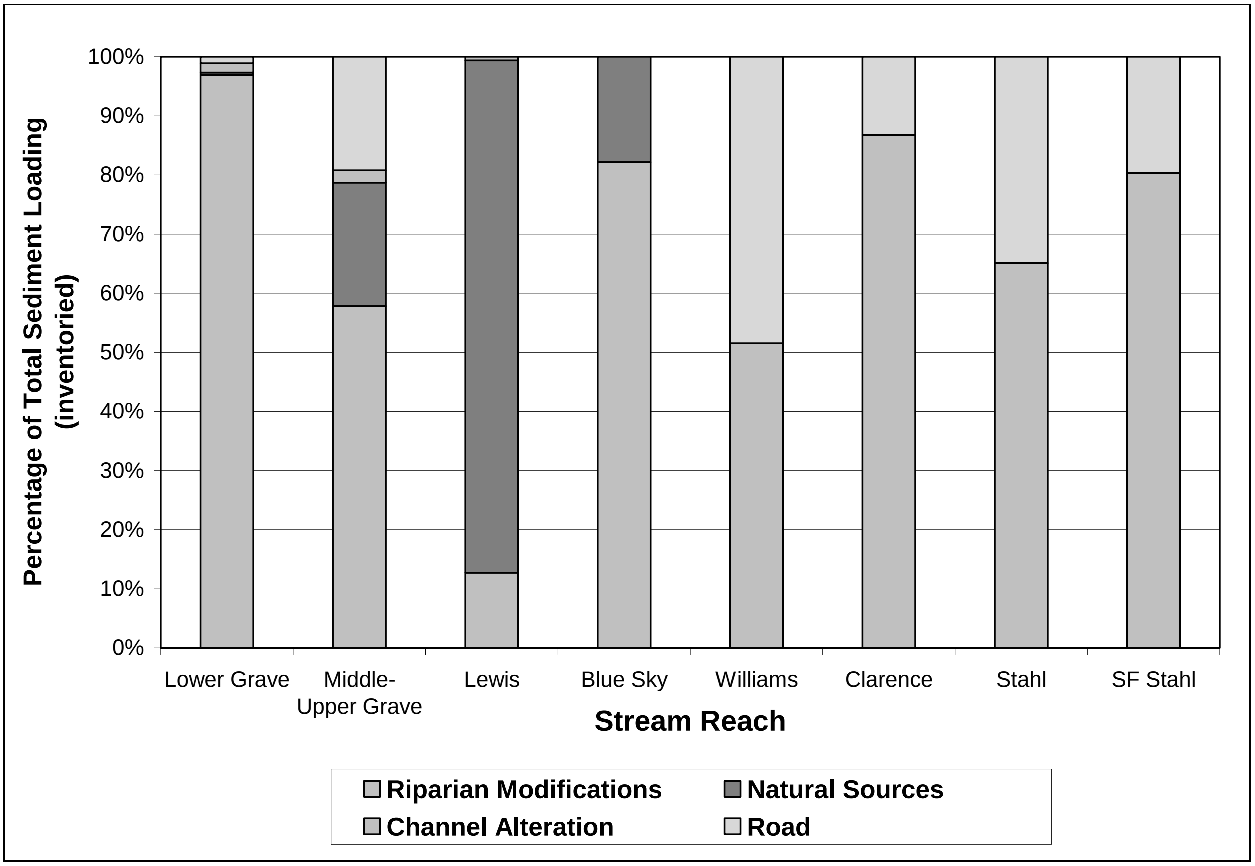

Figure J-6: Percentage of Total Sediment Loading Related to In-Stream Sediment Sources (Bank Erosion and Mass Wasting) by Stream/Reach and Cause of Sediment Source (Inventoried Segments Only).

J.2.1.3 Conditions by Inventoried Segment Length

Channel segment sediment contributions associated with human disturbance vary by tributary and the reaches of main stem Grave Creek. Tables J-7 and J-8 illustrate the relative impacts for the several types of human activities. Human activities associated with in-stream sediment sources include riparian modifications, roads, channel alterations, bank armoring, and bridges. Some of these activities, such as grazing, are likely more controllable via BMPs than other, potentially more permanent impacts such as some types of historical channel alterations. Another important factor than can influence erosion processes in rivers is the influence of sediment from upstream sources. Sediment deposited from upstream sources or delivered from upslope eroding areas, increase bank pressure along downstream reaches, which in turn, contributes to further bank erosion. Some of these upstream and upslope sources are due to controllable human activities, although it is difficult to quantify the impact that these upstream human sources have on downstream bank erosion. Allocations in Section 7.0 and recommended mitigation measures described in Section 8.0 of this document address reducing upstream sediment sources as well as reducing eroding banks in the Grave Creek drainage.

Table J-7: Bank Lengths Affected By Human-related Activities for Inventoried Portions of Main Stem Grave Creek and the Tributary Channels. Percentage Refers to the Relative Percentage of Each Type of Human Disturbance Relative to the Total Inventoried Human-induced Eroding Bank Length.

Reach	Riparian Modifications		Channel Alterations		Road Encroachment		Bank Armoring		Bridges		Total	
	(ft)	(%)	(ft)	(%)	(ft)	(%)	(ft)	(%)	(ft)	(%)	(ft)	(%)
Upper-Middle Grave	2,225	13	80	9	740	27					3,045	15
Lower Grave	9,500	56	800	89	200	7					10,500	51
Lewis	400	2	20	2							420	2
Blue Sky	690	4									690	3
Williams	1,185	7			1,115	40					2,300	11
Clarence	1,505	9			230	8					1,735	8
Stahl	745	4			300	11	80	100	100	100	1,225	6
SF Stahl	695	4			170	6					865	4
Median	965	6	80	9	265	10	80	100	100	100	1,480	
Total	16,945		900		2,755		80		100		20,780	

Table J-8: Total Eroding Bank Lengths of the Inventoried Portions of Main Stem Grave Creek and the Tributary Channels. Percentage Refers to the Relative Percentage of Each Type of Human Disturbance Relative to the Total Inventoried Human-Induced Eroding Bank Length.

Human Disturbance	Length of Human-Influenced Bank Erosion (ft)	Percentage of Total Human-Influenced Eroding Bank Length (%)
Riparian Modification	16,945	81.5
Channel Alterations	900	4.3
Road Encroachment	2,755	13.3
Bank Armoring	80	0.4
Bridges	100	0.5
Total	20,530	100.0

J.3.1 In-stream Sediment Sources and Vegetation

Vegetation data were collected during the in-stream sediment source inventory. Parameters included the cover type (overstory, understory or ground cover) and density or percent cover class for each cover type at each site. Riparian vegetation data collection methods are describe in more detail in Appendix F.

Figures J-7 and J-8 display the results of the vegetation survey. Results clearly demonstrate a positive correlation between lack of a healthy riparian area and bank erosion. Most of the area of eroding bank is associated with a total lack of overstory cover, with sparse understory and with very heavy ground cover (Figure J-7). This strongly suggest that overstory cover such as larger trees and associated root networks provide a significantly higher level of streambank protection than areas with more understory vegetation and ground cover in the Grave Creek Watershed. Where overstory is removed and ground cover and sparse understory vegetation remains, banks are unstable and susceptible to erosion. As the percent cover class of overstory vegetation increases, the area of eroding bank decreases.

The relationship between cover type and density of vegetation cover is similar. The greatest lengths of eroding bank are associated with absent overstory, sparse understory and very heavy ground cover. Heavy ground cover, usually grasses and forbs do not have the rooting density or depth to stabilize banks. Where overstory and understory is very heavy, there is very small length of eroding bank. Cottonwoods, conifers, alder, willow and dogwood provide greater bank stability with deeper and denser root systems. These are significant findings given historical removals of larger trees in the watershed and ongoing riparian impacts that limit larger trees in places.

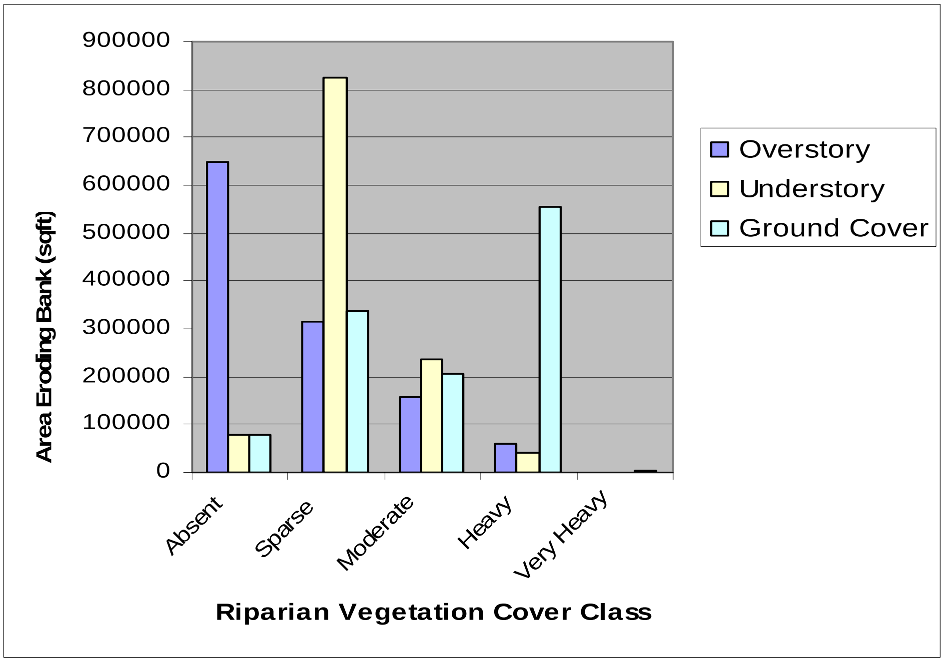

Figure J-7: Area of Eroding Banks by Vegetation Cover Class.

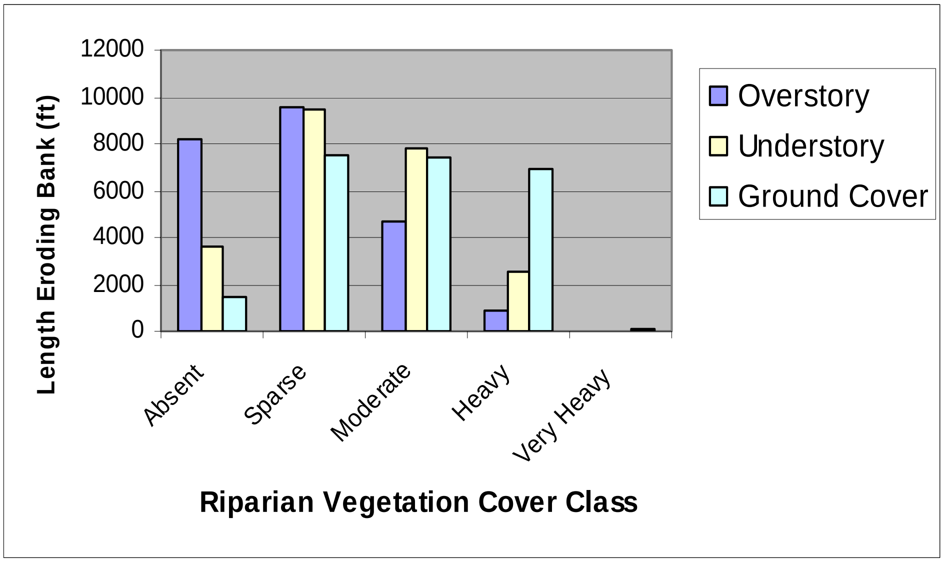

Figure J-8: Length of Eroding Bank by Percent Vegetation Cover Class.