APPENDIX G
STREAM CONDITIONS

This appendix addresses existing channel, floodplain, fish habitat and upland conditions along with a general discussion on human activities and potential linkages between these activities and existing conditions. The focus is on non-point sources of pollution, links with riparian vegetation condition and stream morphology, and the relation of riparian and stream morphology conditions to land use practices in the Grave Creek Watershed. Data assessment methods summarized in Appendix F provides the basis for the following discussion.

G.1 General Summary of Natural and Human Impacts Linked to Sediment Loading

Due to local geology and climate, streams of northwestern Montana have naturally evolved under an above average bed load availability and a high runoff regime with periodic rain-on-snow events. This has led to stream systems that are very dynamic in that they naturally adjust to facilitate the deviations in flow and sediment produced by natural processes in the watershed. Grave Creek has not only adjusted to periodic flood events, but also to timber harvest and road development in the headwaters as well as agriculture, grazing, riparian vegetation losses, and channel alterations along the downstream reaches. These underlying conditions can impact stream channel stability, the quantity and quality of available fish habitat, and the structure and composition of the riparian community, particularly in the lower portions of the drainage. A review of the historical aerial photograph series and existing data indicate that reaches of Grave Creek are currently functioning below their geomorphic and riparian health potentials (WCI, 2000). Biological function is also likely below potential because of the association of habitat with geomorphology and riparian health.

Sediment production and transport is a natural occurrence within watersheds. A significant challenge to the formulation of this TMDL was to partition the natural, background loads from human-induced loads and to then determine the extent even those loads associated with human activities can be controlled via BMPs and reasonable land, soil and water conservation practices. This is an important distinction in light of Montana’s water quality standards and the use of reference conditions. For example, some of the narrative standards are based on increases above “naturally occurring” concentrations of sediment that can negatively impact beneficial uses. The multiple lines of evidence to assess sources and potential for delivery of sediment (summarized in Section 6.0) provide the basis for discriminating among natural and human-related sources.

There are several potential natural sources of sediment in the Grave Creek Watershed. Erosion and ultimate delivery of sediment from hillslopes to streams is a potentially significant natural source, especially in areas of the watershed that are characterized by the rain-on-snow zone (elevations ranging from 3,500 ft to 5,500 ft), erodible soils, and low vegetation cover. Mass wasting is an extreme form of hillslope erosion that can contribute substantial sediment to streams. Mass wasting events are a relatively frequent phenomenon in the Grave Creek Watershed. Eighty-six out of 133 – 65%- sediment sources identified along streams in Grave Creek were described as mass wasting, some of which are linked to natural occurring avalanche chutes or slide areas (Photos 4 and 5). Additional upland mass wasting sites were also identified. Section 6.0 and Appendices H, I and J describe the source assessment and sediment loading analysis in more detail. Finally, stream bank erosion is to some extent, a natural occurrence within streams that contributes to the system's sediment load.

Human activities can accelerate natural erosion and sediment loading processes that contribute excess sediment to the stream system. Human activities within the Grave Creek Watershed that have increased sediment production and delivery include riparian vegetation removal, road building, improper bank stabilization, channelization, large woody debris removal from the channel, and surface water diversions. Land use practices that reduce riparian vegetation and/or cause channel encroachment can increase the rate and pattern of bank erosion (Photos 6 and 7) and can increase the extent of mass wasting in the watershed (Photos 8, 9 and 10). Channel changes, such as historical channel straightening or activities that prevent natural channel movements, also cause accelerated erosion (Photo 5). Removal or alterations in vegetative cover on uplands, or high road densities that capture and route surface water runoff, have the potential to increase hillslope erosion and frequency of surface erosion and mass wasting events. Similarly, increased water yield from vegetation removal can accelerate bank erosion downstream through increased peak flows. Erosion from the surface of roads is another potential source of sediment to streams. This also includes sediment contributed from cut and fill slopes along roads, road surface sanding, and impacts associated with culverts and bridges. Removal of large woody debris from the stream channel and riparian areas reduces the opportunities for woody debris recruitment to the channel, decreases channel roughness, and impairs the stream's sediment storage capacity. Finally, significant surface water diversions during the receding limb of the hydrograph and base flow periods may increase sedimentation by reducing stream competency. At such reduced flows, the stream is not capable of carrying its sediment load therefore sediment is deposited.

Several decades have passed since many of the accelerated erosion and mass wasting events described above occurred. However, bed load transport rates are typically very low (especially in C, D and some B and F stream types) (Rosgen, 1996). Coarse sediment loads from historical events can remain within a stream system for long periods, potentially resulting in persistent, degraded water quality or habitat conditions. Other types of impacts from historical activities, such as a reduction in LWD, LWD recruitment, and associated channel adjustments can also last for extended periods, again producing negative impacts to water quality and habitat over those time frames.

Spatial analyses of land uses in the watershed are detailed in several Appendices: timber harvest (Appendix A), roads (Appendix B), and water yield, ECA, and activities in the rain-on-snow zone (Appendix C).

G.2 General Discussion of Fish Habitat, Assessment Methods, and Linkage to Human Activities

In western Montana rivers large woody debris is often essential for creating and maintaining complex habitats necessary for supporting fluvial populations of bull trout (*Salvelinus confluentus*) and westslope cutthroat (*Oncorhynchus clarki lewisi*). Grave Creek fisheries information, including species composition, population estimates, redd count results, and macroinvertebrate data, are discussed in more detail in Appendix D. Nodal habitats (those containing migratory corridors, over wintering areas, and other critical habitat) are essential for maintaining well-connected and sustainable populations. For bull trout and westslope cutthroat trout (WCT), nodal habitats must contain deep pools and complex aquatic habitat. Abundant large woody debris and deep pools provide cover, protection from predators, and stable environments for bull trout (Jakober et al., 1997). These habitats are especially critical for over-winter survival when harsh wintertime conditions make shallow river reaches inhospitable for large fish. Land use activities that remove riparian vegetation, straighten the stream channel, and/or introduce sediment to streams can simplify the stream channel and reduce the persistence of habitats necessary for sustaining healthy bull trout populations (MBTSG, 1998).

Furthermore, large woody debris was systematically removed from the Grave Creek channel prior to the 1990s (Photo 11) on the premise that woody debris degraded water quality, fish habitat, and fish passage (Bohn, 1998, unpublished report data). Wood removal reduced channel stability and the availability of quality aquatic habitat. Bulldozing in-channel and adjacent to Grave Creek main stem to remove wood after flooding in the 1970’s also contributed to channel instability and degraded habitat. LWD removal from tributary streams may have also occurred, but on a much smaller scale than the main stem. Clarence Creek is the most likely tributary to have had wood removal from the stream channel (USFS, 2004).

Potential primary limiting factors in Grave Creek are related to the distribution of deep pool habitats. Adult holding habitats that are essential for fish during fall spawning migrations are infrequently distributed in the lower reaches of Grave Creek due to poor pool development, insufficient woody debris, and homogenous riffle habitat. Poor pool development and distribution degrade the value of the main stem Grave Creek as nodal habitat. Ice formation during the winter and inhospitable summer water temperatures are both attributed, at least in part, to shallow riffle habitats and the absence of complex aquatic habitat typified by large woody debris-generated cover. These conditions may preclude bull trout persistence during stressful summer and winter periods. Shallow riffle habitats devoid of complex woody debris also increase the susceptibility of large fish to terrestrial and avian predators, as well as poachers. Poor riparian vegetation conditions may contribute to elevated water temperatures, poor woody debris recruitment, and inadequate in-stream cover for WCT and bull trout.

Historically, channel morphology created a diversity of complex habitat that provided specific habitat requirements for the various age classes of fish utilizing the main stem of Grave Creek. The apparent changes in riparian vegetation condition, including species diversity and age class, and changes in channel pattern, are the most significant factors affecting both the quantity and quality of available in-stream habitat. Based on review of streams of similar size and morphology, riparian zones were likely comprised of forested riparian community types typified as a mosaic of intermingling riparian forest and deciduous shrub land. Undisturbed riparian stands in a few sections of the project area are well developed, with multi-canopied conditions and a high degree of canopy cover. In these sections, in-stream habitat complexity is significantly improved and characterized by deep pools and complex lateral channel margin habitats with undercut banks, overhanging vegetation, and decadent, recruiting large woody debris.

Data from several sources were reviewed for evaluating the fish habitat conditions on main stem Grave Creek. USFS R1/R4 data characterized habitat in Grave Creek main stem from Highway 93 up to Fondation Creek, as well as in the primary tributaries. Bankfull channel surveys were completed by USFS, MFWP, and private contractors on both privately owned and publicly managed lands. Appendix F describes in detail the methods used to collect each type of data.

G.3 Stream Stratifications

The following section summarizes existing channel geomorphology and fish habitat for Grave Creek and its primary tributaries including Stahl Creek, Clarence Creek, Williams Creek, Blue Sky Creek, Foundation Creek, and Lewis Creek. This information is then used to compare these existing conditions to reference data to update water quality impairment determinations within the watershed (Section 5.0). Appendices I and J provide detailed sediment source loading information consistent with sediment TMDL development requirements. Biological indicators including fisheries and macroinvertebrates are summarized in Appendix D.

To facilitate this effort, two levels of stream channel stratification were used for data collection and analysis of existing channel morphology and habitat conditions. A third level of stratification was used for departure analysis (Section 5.0).

The first level of stratification groups Grave Creek and its tributaries by valley type and associated dominant channel bedforms. This stratification allows for general description of the basin characteristics and associated stream channels. This stratification applies to large stream segments (multiple reaches), which may be further divided according the second level of stratification.

The second, more specific, level of stratification used is the Rosgen stream type classification (Rosgen, 1996). The results of all channel morphogology and habitat data are presented by Rosgen stream types also referred to in this document as “stream types” or “reach types” or “channel types.” The Rosgen stream type classification is based on geomorphologic parameters including entrenchment ratio, width-to-depth ratio, sinuosity, and slope.

All streams have one or more reaches having different Rosgen stream types. Data collection and analysis focused on the middle and lower reaches of each tributary where fish and aquatic habitat is most important and most sensitive to impacts from human activities. All reaches of main stem Grave Creek are included.

The third level of stratification further separates Rosgen stream type reaches by stream size using either average stream width or stream order. This stratification is applied in the Water Quality Protection Goals and Targets section (Section 5.0), which includes development of reference reach conditions and departure analysis. Departure analysis is the comparison of observed conditions (presented in this appendix and summarized in Section 4.0) to reference reach conditions. This third level of stratification was necessary because morphology and habitat measures may be very different for streams with the same stream type but different order/width. For example, pool frequency for higher order C streams is typically lower than lower order C streams, although total pool volume may compensate for lower pool frequency.

Table G-1: Stream Stratifications in the Grave Creek Watershed.

Segment	Location	Valley Type	Dominant Bedform	Rosgen Stream Types
Lower Grave Creek	Fortine upstream to canyon	Unconfined, fluvial	Pool-riffle	C3/4 and D3/4
Lower Grave Creek	Canyon reach	Bedrock controlled	Step-pool	Fb
Lower Grave Creek	Canyon upstream to Williams Creek	Unconfined and Semi-confined	Pool-riffle with Step-pool inclusions	Fb, C3/4, B3/4
Middle Grave Creek	Williams Creek to Blue Sky Creek	Confined and Semi-confined	Step-pool with Step-pool to Riffle-pool transitions	B3/4 and C/3/4
Upper Grave Creek	Blue Sky Creek to Lewis Creek	Semi-confined, Alluvial	Riffle-pool with Step-pool transitions	C3/4 and B3/4
Upper Reaches of Tributaries	Tributary headwaters	Confined	Cascade and Step-pool	A, G
Lower Reaches of Tributaries		Confined and Semi-confined	Step pool with Riffle-pool inclusions	B3/4 also A, Ba, Cb

Inputs of coarse and fine sediment and large woody debris as well as peak flows and catastrophic events including periodic rain-on-snow events and fire, influence channel stability and response to perturbations. Sensitivity to such disturbances varies by dominant bedform and valley type and Rosgen stream types (Table G-2).

Table G-2: Stream Type Sensitivity Characteristics (Based on Morphological Descriptions in Rosgen, 1996).

Stream Types	Bank Erosion Susceptibility	Sediment Supply	Other
A3/4	High	High	High bedload transports rates; debris torrents, avalanches, mass wasting common
B3/4	Low	Low	
C3/4	Moderate to High	Moderate to High	C4 susceptible to vertical adjustment; bank erosion depends upon amount and condition of vegetation
D3/4	High	High	Indicates “flashy” runoff regime
F2	Low	Low	
F4	High	Moderate to High	

G.4 Main Stem Grave Creek Conditions

As discussed above, the main stem of Grave Creek is divided into three major segments due to the varied physical habitat conditions defining main stem Grave Creek (Map 13). The first segment spans from the mouth of Grave Creek to the confluence of Williams Creek and Grave Creek, and includes both private and publicly managed land. There are no substantial tributaries to lower Grave Creek. The second segment (middle Grave Creek) spans from the Williams Creek confluence upstream to the Blue Sky Creek confluence. Middle Grave Creek includes the Clarence Creek-Stahl Creek confluence with Grave Creek. The third segment (upper Grave Creek) covers the remaining portion of Grave Creek upstream from the Blue Sky Creek to the confluence with Foundation Creek. Foundation Creek and Lewis Creek are the largest tributaries in upper Grave Creek.

G.4.1 Lower Grave Creek

G.4.1.1 Lower Grave Creek General Description

For this analysis, lower Grave Creek (Fortine to Williams Creek) is further divided into three sub-sections according to valley type, dominant channel bedforms, and Rosgen stream types as identified below.

- The downstream section of lower Grave Creek from the Fortine Creek confluence to the GLID diversion is characterized by unconfined to semi-confined pool-riffle channel morphology. Below Vukonich Bridge the stream is generally unconfined, has a broad floodplain, and is generally a Rosgen C4d stream type, Above Vukonich Bridge, the channel is semi-confined, has a narrower floodplain is generally a Rosgen B4 stream type.

- Upstream of the GLID diversion Grave Creek is confined by a bedrock canyon for approximately 2,000 feet. This section is generally a Rosgen Fb stream type.
- Upstream of the bedrock canyon to the Williams Creek confluence Grave Creek is again characterized by an unconfined to moderately-confined pool-riffle morphology and narrow floodplain. This section includes Rosgen Fb and B4 stream types.

Each of these three sections and varying stream types maintain different types of fish habitat and channel conditions that support different fish life stages. Unconfined channel morphologies (usually Rosgen C streams) are typically characterized by alternating pool and riffle habitat features. Pools provide deep-water habitat for large adult fish as well as refuge for all life stages during stressful winter and summer periods. Riffles are food production areas and habitat for benthic fish species, juvenile fish, and individuals of smaller fish species. Shallow channel margins, large woody debris accumulations, vegetation, and varied substrate also provide varied habitats for various life stages.

Moderately confined and confined reaches (Rosgen B or F types) also provide important habitat for fish depending on the composition of habitat features. Bedrock scour pools or pools formed by boulders provide diverse flow paths and deep water for fish. Woody debris accumulations may also improve fish habitat diversity in moderately confined and confined channel segments. Where these types of habitats are absent, fish may use moderately confined and confined reaches as migration corridors between higher quality habitat channel segments. A general discussion on the water quality and habitat conditions observed in each section of lower Grave Creek is provided below.

G.4.1.1.1 Fortine Creek to GLID

Below the GLID diversion, Grave Creek is formed in glacio-fluvial landforms characterized by terraces, moraines, and glacial and alluvial outwash deposits. As noted in Tables G-2, the stream types in this reach (C3/4 and D3/4) are highly susceptible to bank erosion and have a high sediment supply. As a result, there is a high potential for response to changes in discharge, sediment, and large woody debris due to its low gradient, riffle-pool morphology and dependence on vegetation for stability. Due to its unconfined nature, the channel is free to adjust its boundaries in response to either increased discharge or sediment supply (Photo 12). This unit has the potential to increase sediment delivery to the channel when the stream banks are eroded or the channel form is altered.

Comprised of mostly private land, this channel unit includes agricultural and residential land uses within the watershed. This reach was extensively modified in the early 1900s to accommodate agricultural development. The historical condition was characterized by multiple channels developed within a vast, well-vegetated spruce bottom wetland. The system may have resembled a stable anastamosed stream (multiple channels, braided) developed on a non-building, stable alluvial fan. This multiple channel system was systematically filled in the early 1900s, diverting the combined flow of all braids into the existing Grave Creek channel.

In the past, portions of lower Grave Creek were bulldozed to “speed up” the water so the channel could maintain its ability to convey the floodwater, sediment, and debris produced by the watershed. In-channel bulldozing compounded flood effects and lengthened the Grave Creek’s recovery time following high magnitude flood events. These activities also inhibited Grave Creek’s natural recovery process following floods and caused the channel to deviate from its potential geomorphic state. Channelization has also resulted in a substantial reduction in floodplain and streamside vegetation, and alteration of the stream’s natural dimension and geometry. Grave Creek is therefore less stable than it generally was historically as exhibited by accelerated lateral erosion rates and excessive sediment delivery to the channel (WCI, 2000), both conditions are further evaluated in this appendix.

Accelerated sediment delivery from historical activities in upstream reaches has likely contributed large quantities of bedload size sediment to lower Grave Creek. Grazing and other impacts to riparian areas has reduces the stream’s ability to resist accelerated bank erosion. Loss of large woody debris in this channel unit may also result in significant morphological channel adjustment affecting the biological community, although large woody debris concentration is expected to be lower in a higher order C-type stream channel. Example channel adjustments would tend to include pool loss, increased effective shear stress, increased stream width and width to depth ratios, and the potential conversion to a plane bed morphology (Montgomery and Buffington, 1997). These processes have likely reduced the frequency of deep pool habitat for native bull trout, westslope cutthroat trout, and other fish species inhabiting or migrating through lower Grave Creek.

G.4.1.1.2 GLID Through the Canyon

This section corresponds to stream reaches located from the Glen Lake Irrigation District point of diversion upstream through the Grave Creek canyon. The channel is formed in a structurally controlled and confined bedrock valley that precludes major shifts in channel plan form and dimensions. Bedrock channels are generally resistant to short-term changes in sediment supply or peak flows. Rosgen stream type is primarily an Fb channel. This channel type is very stable with very low susceptibility to bank erosion and very low sediment supply due to the boulder and bedrock materials and to the lateral confinement of the valley.

G.4.1.1.3 Canyon to Williams Creek

Similar to the lowest section of Grave Creek, Grave Creek from the head of the canyon upstream to the confluence with Williams Creek is formed in coarse glacial moraine deposits and therefore has the potential to contribute significant amounts of sediment to the channel network. Stream reaches are characterized by pool-riffle morphology in both unconfined and moderately confined segments dominated by F stream types with inclusions of C reaches. There are also confined B inclusions.

With the exception of the B type inclusions, the stream types in this reach have a moderate to high sensitivity to sediment and debris loading, peak flows, and periodic catastrophic events. Bank erosion susceptibility and sediment supply are moderate to high. Erosion depends upon the amount and condition of vegetation (Table G-2).

While mass wasting of morainal deposits is common and natural in these channel units, upland harvest activities have the potential to compound any existing sediment supply problems. Additionally, channeled colluvial valleys (face drainages) contribute debris into the reach through various erosional processes including dry ravel, fluvial entrainment, mass wasting, and gravitational failure. Loss of large woody debris in this section of Grave Creek can result in significant morphological changes, including pool loss, increased effective shear stress, and the potential conversion to a plane bed morphology (Montgomery and Buffington, 1993).

Historically, the hillsides adjacent to this unit experienced frequent fires as evident in the historical aerial photo record and from the writings of early travelers in the area (B. Bohn, USFS, personal communication). The suppression of fires during the last 60 years has allowed riparian and hillside vegetation to become denser, with the exception of logged face drainages located south of the Williams Creek confluence.

Historical timber harvest and road construction upstream have increased sediment delivery and peak flows to this section, with the potential for impacts to bank stability (Photo 13). Several timber harvest units situated on lateral moraines adjacent to the channel have accelerated side slope erosion, and in some instances, triggered rotational slumps that have contributed sediment and logging slash directly to Grave Creek (Bohn, 1998, unpublished report). Subsurface flow interception by road cut slopes has the potential to exacerbate slope instability in some areas. Section 6.0 and Appendices I and J describe the source assessment and sediment loading analysis in more detail.

G.4.1.2 Aerial and Physical Assessment Results for Lower Grave Creek

These following subsections provide a summary of aerial and physical assessment data for lower Grave Creek. Reference Appendix F for a description on methodologies.

G.4.1.2.1 Aerial Assessment Results

A comprehensive overview of the geomorphic response(s) of lower Grave Creek to land uses was conducted by RDG using historical and current aerial photography with field verification. Historical photograph review indicated that the project area has been sensitized over time by the cumulative effects of channel alterations, timber harvest, road construction, flow diversions, riparian grazing, and agriculture.

In lower Grave Creek below the canyon, the channel resembled a Rosgen C stream type prior to 1947. When stream bank vegetation was further displaced and the stream was further channelized to support logging drives, stream banks began to lose their competency to resist the erosive forces produced in the channel during floods. Excess upstream sediment loading from historical harvest activities would have contributed to increased erosive forces and increased peak flood flows. Stream channel widening occurred. It is likely that the stream initially began to migrate laterally at an accelerated rate, transitioning from a moderate width/depth ratio, stable C4 stream type to an over-widened, braided, high width/depth ratio D4 stream type (Rosgen, 1994). Over time, and primarily due to accelerated downstream meander migration and bank erosion, the channel eroded through the outside bend of several meanders. This process, referred to as an “avulsion”, decreased the channel length. From 1947 to 1992, channel sinuosity in the section of lower Grave Creek primarily from Highway 93 to Vukonich Lane decreased by approximately 15 percent, from 1.23 to 1.08, and average riffle width increased from 60 feet to 130 feet (WCI, 2000). The resulting over-steepened bed profile and widened condition have increased the hydraulic capacity of the channel, thereby increasing the shear stress applied to the channel perimeter. Under this condition, the stream banks and channel bed become significant sources of sediment to the channel system.

In the canyon section, no changes in channel pattern, geometry, or riparian vegetation conditions were documented from 1954 to 1992 (WCI, 2000). During this same period, the reach from the upper part of the canyon to Williams Creek experienced an increase in average bankfull channel width through bank erosion and lateral adjustment. This would tend to decrease the channel’s sediment transport capacity.

From the top of the canyon reach up to Williams Creek, upland forest activities and in-stream habitat alterations have apparently affected channel stability (Bohn, 1998, unpublished report). Removal of large woody debris from the channel has reduced sediment sorting capacity and energy dissipation formerly provided by woody debris. Channel features are largely associated with extended riffles and infrequent pools generally formed by unstable, smaller diameter logging slash and debris and/or boulders.

G.4.1.2.2 Fish Habitat – Pools

The moderately confined B reaches and confined F reaches maintain higher quality pool habitat in the upper portions of lower Grave Creek than the C reaches below the GLID (Table G-3). Pool characteristics measured during the USFS R1/R4 surveys indicated that the most frequent pools were located in the B inclusions while the deepest pools were found in the F reaches (Table G-3). The shallow, over-widened channel in the disturbed C reaches (see G.4.1.2.5) provides less high quality habitat.

Table G-3: Pool Characteristics from R1/R4 Data (USFS, 2001). Median (Min, 75th Percentile, Max) Lower Grave Creek.

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Lower Grave Creek	C	9	90 (35, 113, 250)	3.8 (3.0, 4.7, 5.6)	2.7 (1.4, 3.3, 4.7)
	F	9	67 (22, 77, 91)	5.1 (2.9, 5.8, 6.7)	3.5 (1.5, 4.5, 5.2)
	B	19	60 (17, 81, 131)	3.7 (2.8, 4.2, 5.3)	2.1 (0.6, 2.7, 3.5)

G.4.1.2.3 Fish Habitat – Large Woody Debris

USFS evaluated large woody debris accumulations in the three stream types characterizing lower Grave Creek (USFS, 2001, unpublished data provided by P. Price; Table G-4). For each reach, large woody debris counts were made for the number of single pieces, the number of LWD aggregates, and the number of LWD rootwads.

Rootwads and large woody debris aggregates were most frequent in the B reaches of lower Grave Creek (Table G-4). Lower large woody debris counts in the F reaches may be attributed to more efficient debris transport especially in the canyon. Lower counts in the unconfined downstream segment may be due to large woody debris removal (via bulldozing and other means) and riparian clearing that occurred throughout the 1900s.

Table G-4: Lower Grave Creek Woody Debris Concentrations from R1/R4 Data (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Count	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Lower Grave Creek	C	77	20 (0, 65, 344)	9 (0, 59, 226)	29 (0, 60, 304)	101 (0, 171, 607)
	F	64	5 (0, 45, 217)	0 (0, 9, 278)	58 (0, 114, 304)	106 (0, 158, 555)
	B	33	61 (0, 119, 192)	0 (0, 15, 244)	0 (0, 9, 83)	81 (0, 159, 305)

G.4.1.2.4 Sediment Particle Size Monitoring Results

Sediment transport capacity is highly variable in lower Grave Creek. Channel and valley morphologies influence the transport and storage of sediment and debris through the reach. Sediment particle sizes influence spawning redd success, larval fish rearing, juvenile fish survival, and aquatic macroinvertebrate production.

Particle size distributions and percent surface fines were derived from data collected by the USFS and WCI using Wolman Pebble counts (Table G-5). Values for 2 mm and 6.35 mm size classes were interpolated from cumulative percent-finer-than plots. Percent surface fines in pool tailouts (glides) where spawning would tend to occur was determined using the 49-point grid toss method during USFS R1R4 surveys (Table G-6).

The highest percentages of fine particles less than 6.4 millimeters measured by either method were in the B and C reaches (Table G-5 and G-6). Increasing percent fines is one indicator of channel response to upland activities and can indicate an increase in sediment supply and /or a decrease in channel transport capacity. Median percent of fines in pool tails was less than 10% for all stream types. Maximum percent of tail out fines was greatest in the lower gradient C and F reaches (Table G-6).

Table G-5: Lower Grave Creek Composite Particle Size Distribution and Percent Surface Fines.

Stream Location	Stream Type	% < 2 mm	% < 6.35 mm	D16 (mm)	D50 (mm)	D84 (mm)	Collected by
Below Canyon	C	≤ 11	≤ 12	18	81	146	WCI (2000)
Canyon	F	3	7	11	60	180	USFS
Above Canyon	F	5	11	not available	not available	not available	USFS

Table G-6: Lower Grave Creek Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, Unpublished Data).

Stream	Stream Type	Count	Minimum % Fines	Median % Fines	75th Percentile Fines	Max % Fines
Lower Grave Creek	C	42	0	10	20	80
	F	18	0	5	10	40
	B	35	0	7.5	15	25

G.4.1.2.5 Channel Morphology

Existing channel dimensions and potential channel dimensions were developed by WCI for the Grave Creek Demonstration Project downstream from Vukonich Lane (Table G-7). Potential channel dimensions were developed from reference reach data collected on Grave Creek downstream from the Highway 93 crossing. Bankfull channel characteristics measured in the unconfined C stream type segment of lower Grave Creek suggest the channel conditions are functioning below their historical potential due to excessive channel widths and elevated width/depth ratios (Table G-7).

Table G-7: Existing and Potential Channel Conditions (Riffle), and Channel Departure Analysis for Lower Grave Creek Below the Canyon (WCI, 2000) Average (Range).

Bankfull Variable	Existing Dimensions	Potential Dimensions	Departure
Bankfull Discharge (cfs) (Ave)	660	660	-
Cross-sectional Area (ft^2)	145	120 (108-132)	+25
Width (ft)	116	52 (50-54)	+64
Hydraulic Depth (ft)	1.24	2.3 (2.2-2.4)	-1.06
Width/Depth Ratio	93.5	20 (18-22)	+73.5
Sinuosity	1.08	>1.4	-32%
Meander Length Ratio	6.7 (5.2-8.2)	16.5 (13.8-19.2)	+9.8

Table G-8 provides a summary of channel metrics from USFS monitoring in portions of lower Grave Creek. Channel stability ratings for the F segment above the canyon rated good (Table G-8). No rating was provided for the already stable canyon reach. Table G-9 provides a summary of the riffle characteristics for the F reach cross section above the canyon.

Table G-8: Channel Metrics Summary (USFS, 2003). Lower Grave Creek Canyon Reach (XS 2) and Above the Canyon (XS3).

XS	Channel	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
2	F4b	n/a	42.3	19
3	F2b	82 (good)	52.3	15

Table G-9: Lower Grave Creek Riffle Characteristics (Bankfull Channel Dimensions Data; USFS, 2003).

Stream	Stream Type	Channel Width (ft)	Channel Area (ft^2)	Mean Depth (ft)	Width/ Depth	Channel Slope (ft/ft)
Lower Grave Creek	C	No Data Collected				
	F	42.3	93.1	2.2	19	0.028

G.4.1.3 Other Assessment Results for Lower Grave Creek

G.4.1.3.1 Temperature Monitoring Results from 2003

The USFS installed a DEQ temperature logger in Grave Creek near Highway 93. Temperature was recorded daily at 30-minute intervals from the beginning of July 2003 through the beginning of October 2003. From August 8 to September 15, data more closely reflect air temperature and is therefore not included here. It is possible that the stream either went dry or some other problem occurred. Before and after this erroneous timeframe, temperatures in Figure G-1 are considered representative of actual stream temperatures at that location.

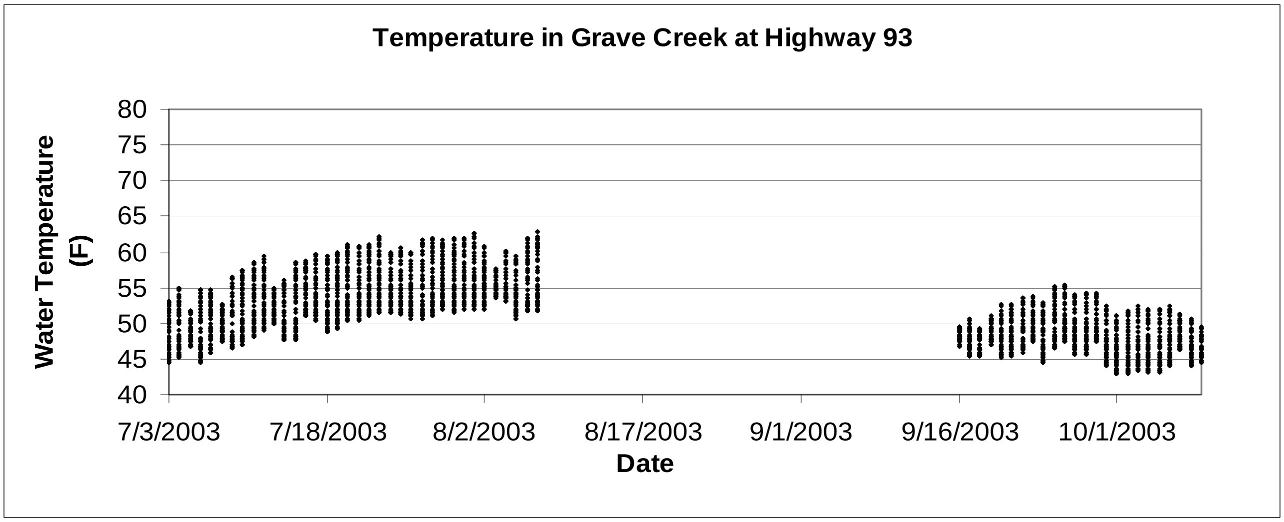

Figure G-1. Daily Temperature of Grave Creek at Highway 93. Temperature Recorded at 30-Minute Intervals. (MDEQ Unpublished Data).

G.4.1.3.2 Fish Passage Information and Flow Alteration (Dewatering)

The GLID diversion is the primary diversion on Grave Creek. Removal of the historical log crib diversion dam has improved fish passage from the lower to the upper watershed as discussed in Appendix D. Fish passage at this location is no longer considered a habitat alteration impairment, although there may still be room for improvements in areas such as reducing entrainment of young fish.

Although GLID has a water right for 220 cfs, typically less than 60 cfs is withdrawn from Grave Creek. As identified in Appendix E, a minimum discharge of 70 cfs, based on a wetted perimeter-discharge relationship and fish passage needs, was recommended by fishery biologists during low flow below the GLID. Flow for September 1986 was at 43 cfs (Marotz and Fraley, 1986), and similar low flow conditions were observed in lower Grave Creek by DEQ assessment personnel during summer, 2003.

G.4.1.3.3 Grave Creek Restoration Project Data

KRN, USFWS, and MFWP have initiated a comprehensive stream restoration program on lower Grave Creek. Three channel reconstruction projects; GLID dam removal and reconstruction (discussed above); the Grave Creek Demonstration Project; and the Grave Creek Phase 1 Project, have been completed to improve channel stability, reduce sediment sources, and to enhance aquatic habitat in lower Grave Creek. The Grave Creek Demonstration Project stabilized a high terrace that was eroding at an accelerated rate. Grave Creek Phase 1 reconstructed nearly a mile of channel and floodplain to improve channel-floodplain connectivity, fish habitat, and sediment transport in the focus reach. Future projects will address other portions of lower Grave Creek to meet similar fisheries and channel stability objectives.

Post run-off monitoring data have been collected by MFWP on the Grave Creek Demonstration Project (MFWP, unpublished data). Based on the post-runoff survey, the total number of pools before and after project construction was similar, but total pool length increased slightly (16.6 percent), and both mean and maximum pool depths increased substantially (36.8 and 53.5 percent, respectively). The total number of pools from 2001 to 2002 decreased because of channel adjustments at bankfull discharge. However, the total length of pools remained similar between the two years. The loss of pools between 2001 and 2002 may partially be explained by the loss of some of the pool tailouts. The large woody debris stems and rootwads used during project construction also likely increased cover available to rearing and migrating salmonids within lower Grave Creek.

Pre and post-construction surveys were also completed in the Grave Creek Phase 1 Project. The baseline channel condition (pre-construction) was characterized by multiple channel braids, shallow pool depths, and poor aquatic habitat (Table G-10). Channel construction increased pool depths, narrowed and deepened the over-widened channel, and increased aquatic habitat complexity with the addition of woody debris and increased habitat volumes (Table G-11).

Table G-10: Lower Grave Creek Bankfull Channel Characteristics in the Phase 1 Restoration Project Reach Prior to Project Construction (MFWP, Unpublished Data).

Cross-section	Feature	Channel Width (ft)	Channel Area (ft^2)	Mean Depth (ft)	Max Depth (ft)	Width/ Depth
4+48	Pool	83.6	170.0	2.0	2.6	
7+51	Riffle	91.0	117.6	1.3	2.3	70.4
13+79	Riffle	149.8	241.7	1.6	4.7	92.8
23+87	Riffle	149.1	188.0	1.3	2.9	118.2
37+00	Pool	87.4	151.5	1.7	3.4	

Table G-11: Lower Grave Creek Bankfull Channel Characteristics in the Phase 1 Restoration Project Reach Measured After Project Construction (MFWP, Unpublished Data).

Cross-section	Feature	Channel Width (ft)	Channel Area (ft^2)	Mean Depth (ft)	Max Depth (ft)	Width/ Depth
4+48	Pool	118.0	151.0	1.3	5.2	
7+51	Riffle	48.0	104.8	2.2	3.3	22.0
13+79	Riffle	48.0	186.4	3.9	6.6	12.4
17+90	Riffle	47.0	126.1	2.7	3.8	17.5
23+87	Riffle	48.0	134.7	2.8	5.6	17.1
37+00	Pool	98.0	173.4	1.8	5.1	

G.4.2 Middle and Upper Grave Creek

This section includes discussion on both the middle and upper Grave Creek segments due to similar land use characteristics and due to the fact that some data is presented for the combined lengths of these stream segments.

G.4.2.1 Middle and Upper Grave Creek General Description

Middle Grave Creek extends from the Williams Creek confluence with Grave Creek, upstream to the Blue Sky Creek confluence with Grave Creek. Middle Grave Creek exhibits two general stream types:

- From Williams Creek to the Clarence-Stahl Creek confluence, Grave Creek is a moderately confined step-pool system with a narrow floodplain.
- From the Clarence-Stahl Creek confluence upstream to the Blue Sky Creek confluence, Grave Creek is characterized by alternating unconfined and moderately confined pool-riffle and step-pool morphology reaches. Narrow floodplain areas border the channel.

The upper Grave Creek area extends from the Blue Sky Creek confluence with Grave Creek, upstream to the confluence with Foundation Creek. Primary tributaries within the reach include Foundation, Lewis, and Drip creeks. Channel conditions in upper Grave Creek are generally characterized by unconfined and moderately confined reaches with pool-riffle morphology (Photo 14). Narrow floodplain areas border the channel.

Due to the confined and semi-confined nature of the landforms in middle and upper Grave Creek, sensitivity to peak flows and catastrophic events such as floods was rated moderate (Bohn, 1998, unpublished report). Due to the high-energy nature of these reaches, sensitivity to decreasing levels of large woody debris is high and typically results in pool filling, riffle extension, and a reduction in channel roughness.

Historically, this channel unit likely produced minimal in-channel sediment due to channel stability provided by dense, healthy riparian vegetation and structural controls of the valley and landforms. Engelmann spruce (*Picea engelmannii*) was the dominant riparian tree species prior to large-scale clearcutting by the USFS in the 1950s. Riparian harvesting has increased the proportion of small diameter spruce and Douglas fir (*Psuedotsuga menziesii*) within riparian stands (Photo 3).

Aerial photo records from 1954 to 1992 indicate spruce logging and road building began in the upper basin during the early 1950s. By 1954, all major arterial roads up main stem Grave Creek and major tributaries were constructed. The road supported an extensive spruce logging effort in the basin (Bohn, 1998, unpublished report). During the 1950s, a majority of the riparian areas along this unit of Grave Creek had been salvage logged at some level (Appendix A). Logging often consisted of removing the largest, most merchantable trees and leaving the smaller less valuable trees. Skidding operations by bulldozers were conducted without using the BMPs applied today to protect channel stability and reduce soil erosion. For example, skidding occurred on steep, sensitive slopes sometimes exceeding 40 percent, across stream channels, and through riparian areas (Bohn, 1998, unpublished report). Further harvest activity occurred in the 1980s, creating additional potential for impacts to the main stem and tributary channels. In these segments, channel braiding was common, with excessive in-stream deposition, floodplain cutting, and unstable large woody debris jams composed of short, small diameter logging slash. Localized bed load aggradation, similar to the type of aggradation shown in Photo 15, resulted in channel avulsions and bank erosion (Bohn, 1998, unpublished report).

While stream types like those found in middle and upper Grave Creek are inherently stable and maintain a high sediment transport capacity, increases in sediment loads can result in pool filling, a reduction in channel roughness, and the potential for bank erosion (Whittaker, 1987). Likewise, increased flows can have similar detrimental effects. The effects of spruce logging were manifested in an increase in peak flows and sediment yields and a decrease in the density of riparian areas along this unit of Grave Creek (Bohn, 1998, unpublished report). Increased peak flows and sediment yields from tributary logging likely contributed sediment loads to main stem Grave Creek well above the natural background rate of sediment loading.

Large woody debris removal, direct channel modifications and effects from the main Grave Creek road have also created potential impacts to reaches of Grave Creek. The resiliency of these channel units typically results in minimal plan form modification; although a reduction in large woody debris can reduce the sediment storage potential and pool formation potential. In the 1970s, USFS biologists were concerned that large woody debris would adversely impacts fish passage and channel stability. As a result, a systematic program to remove large woody debris was initiated on the main stem in the middle and upper watershed.

In the1970s, 1980s and early 1990s, the USFS installed numerous log and rock gabion check structures in an attempt to create pool habitat (Photo 16). Fifteen structures were observed and recorded by field crews in the fall 2003. A majority of these structures have failed and/or caused upstream aggradations and lateral cutting. Road fill encroachment has confined the channel in several locations, reducing the width of the floodplain and in some instances, disconnecting the entire floodway from the active channel. Road fill slope erosion has been addressed through riprap bank stabilization, gabion basket installation (Photo 17), and other hardened approaches that have generally reduced habitat quality. Bank armoring and road maintenance sites are most concentrated upstream of the confluence of Blue Sky Creek and Grave Creek.

Spatial analyses of land uses in the watershed are detailed in several Appendices: timber harvest (Appendix A); roads (Appendix B); and water yield, ECA, and activities in the rain-on-snow zone (Appendix C). Based on professional observations and documented impacts from logging activities in the Western U.S., human activities from 1954 to the present would have reduced available complex habitat and channel stability, particularly during the period when most harvest occurred, which was prior to widespread adoption of forestry best management practices in Montana. Much of the stream system in the upper Grave Creek Watershed has likely recovered, with the extent of recovery uncertain based on observations alone.

G.4.2.2 Physical Assessment Results for Middle and Upper Grave Creek

These following subsections provide a summary of physical assessment data for middle and upper Grave Creek segments. Reference Appendix F for a description on methodologies.

G.4.2.2.1 Fish Habitat – Pools

In middle Grave Creek (between Williams Creek and Blue Sky Creek confluences) pool characteristics measured during the USFS R1/R4 surveys indicated that pools were more frequent in the B reaches than the C reaches (Table G-12). Average pool length and maximum depth were similar between the two stream types. The residual pool average maximum depths were higher for the B vs. C reaches.

Table G-12: Middle Grave Creek Pool Characteristics from R1/R4 Data (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Middle Grave Creek	C	12	23 (12, 35, 46)	2.9 (2.6, 3.3, 3.5)	1.2 (0.5, 1.5, 2.5)
	B	62	21 (9, 38, 67)	3.0 (1.4, 3.4, 5.4)	1.5 (0.5, 1.9, 3.5)

For upper Grave Creek (above Blue Sky confluence), pool characteristics measured during the USFS R1/R4 surveys indicated that pools were slightly more frequent in the unconfined C stream type sections than in the moderately confined B sections (Table G-13). Average pool length, average maximum pool depth, and average maximum residual pool depth were greater in the C reaches.

Table G-13: Upper Grave Creek Pool Characteristics from R1/R4 Data (USFS, 2001).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Upper Grave Creek	C	26	27 (8, 34, 108)	2.2 (1.3, 2.6, 4.9)	1.4 (0.6, 1.7, 4.1)
	B	24	10 (6, 12, 20)	1.6 (1.3, 1.8, 3.3)	0.8 (0.5, 1.0, 2.6)

G.4.2.2.2 Fish Habitat – Large Woody Debris

Large woody debris accumulation data in middle Grave Creek (USFS, 2001 unpublished data) are presented in Table G-14. The data show higher total LWD values in the C stream type portion of middle Grave Creek. Maximum LWD counts were higher in the B stream type portion of middle Grave Creek compared to the C stream type reaches.

Table G-14: Middle Grave Creek Woody Debris Concentrations from R1/R4 Data (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Count*	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Middle Grave Creek	C	20	29.8 (0, 80, 467)	0 (0, 3, 230)	39 (0, 152, 288)	105 (0, 256, 467)
	B	78	0 (0, 99, 2810)	0 (0, 0, 832)	0 (0, 119, 1807)	56 (0, 233, 5366)

*The "count" is the number of habitat units; there were 20 C habitat units in middle Grave Creek for example.

Large woody debris accumulation data in upper Grave Creek (USFS, 2001, unpublished data) are shown in Table G-15. The data show LWD values in all categories were greater in the C reaches than in the B reaches.

Table G-15: Upper Grave Creek Woody Debris Concentrations from R1/R4 Data (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Count	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Upper Grave Creek	C	133	15 (0, 87, 528)	0 (0, 56, 619)	74 (0, 194, 671)	189 (0, 307, 1320)
	B	43	12 (0, 50, 1870)	0 (0, 21, 619)	0 (0, 49, 619)	61 (0, 174, 894)

G.4.2.2.3 Sediment Particle Size Monitoring Results

McNeil Core Results

MFWP monitors streambed substrate at various sites within the Kootenai River Basin using McNeil core samples. For Grave Creek, MFWP uses McNeil core samples to measure percent fine sediment (< 6.35 mm) in the upper 10 inches of streambed substrate. Cores are collected near bull trout spawning redds located in spawning monitoring reaches on the main stem of Grave Creek in the vicinity of Clarence Creek. MFWP has sampled and reported percent of streambed material less than 6.35 mm in size for 3 of the past 9 sampling years. Median McNeil core results include 22 percent, 25.3 percent and 20.4 percent for the years 1998, 2000, and 2001 respectively (Table G-16).

Table G-16. Median Percentage of Streambed Material Smaller than 6.35 mm in McNeil Core Samples Collected from Bull Trout Spawning Areas in Tributary Streams to the Kootenai River Basin, 1994 – 2002. (MFWP, 2003).

	1994	1995	1996	1997	1998	1999	2000	2001	2002*
Grave Creek					22.0		25.3	20.4	

*Data not yet analyzed.

Pebble Count Results

Pebble count percent fines data are presented in Table G-17 for both middle and upper Grave Creek. B4 reaches tend to have higher values than B3 reaches as would generally be expected. Percent fines were highest upstream of Lewis Creek. In this segment, avalanche debris paths and direct sediment from eroding road fill slopes were identified as primary impacts to water quality and channel stability.

Table G-17: Particle Size Distribution and Percent Fines for Middle and Upper Grave Creek Segments (<6.35 mm) (USFS, 2003).

Channel Type	D16 (mm)	D50 (mm)	D84 (mm)	%< 2 mm	% < 6.35 mm
B4	11	51	94	10	15
B3	7	90	250	0	6
B4c	8	58	170	6	13
B3	16	88	256	5	13
C4	7	47	115	5	15
B4	6	40	185	5	15
C4	9	35	80	6	13
B4	4.5	42	175	12	18

In middle Grave Creek, average sediment particle sizes were larger in the B stream type reaches relative to the C stream type reaches, as would be expected by the steeper channel gradients and more confined channel morphologies of the B reaches (Table G-18). Table G-19 shows the same relationship for upper Grave Creek, although the smaller size D16 of the C channel units was twice that of the B channel units.

Table G-18: Middle Grave Creek Composite Particle Distribution Measured via the Wolman Pebble Count Method (USFS, 2003).

Stream	Stream Type	D16 (mm)	D50 (mm)	D84 (mm)
Middle Grave Creek	C	7	47	115
	B	10.5	71.8	192.5

Table G-19: Upper Grave Creek Composite Particle Distribution from Wolman Pebble Count Data (USFS, 2003).

Stream	Stream Type	D16 (mm)	D50 (mm)	D84 (mm)
Upper Grave Creek	C	9	35	80
	B	4.5	42	175

Grid Toss Results

Tables G-20 and G-21 present percent surface fines values < 6.35 mm measured during the R1/R4 surveys using the 49-point particle grid method for middle and upper Grave Creek. The median values were 5% for both B and C stream types in middle Grave Creek (Table G-20). The Table G-21 data show the median percent surface fines in pool tails of upper Grave Creek was lowest for the B reaches (0%) and greatest for the C reaches (10%).

Table G-20: Middle Grave Creek Percentage of Surface Fines (<6.35 mm) in Pool Tails Measured using the 49-point Particle Grid Method (USFS, 2001).

Stream	Stream Type	Count	Minimum % Fines	Median % Fines	75th Percentile Fines	Max % Fines
Middle Grave Creek	C	10	0	5	8.8	10
	B	44	0	5	5	25

Sediment transport capacity is variable in upper Grave Creek. Channel and valley morphologies influence the transport of sediment and debris through the reach. Survey results determined that sediment particles are generally larger in the more competent moderately-confined B stream type reaches relative to the less competent unconfined C stream type reaches. This is apparent by the higher frequency of fine sediment (< 6.35 mm) measured in the unconfined C stream type reaches versus the B reaches. This is shown by the higher grid toss results in Table G-21 and the higher D16 results in Table G-19.

Table G-21: Upper Grave Creek Percentage of Surface Fines (<6.35 mm) in Pool Tails Measured Using the 49-point Particle Grid Method (USFS, 2001).

Stream	Stream Type	Count	Minimum % Fines	Median % Fines	75th Percentile Fines	Max % Fines
Upper Grave Creek	C	70	0	10	15	80
	B	21	0	0	5	15

G.4.2.2.4 Channel Morphology

Table G-22 presents channel morphology data for middle and upper Grave Creek. B stream type reaches are located throughout middle Grave Creek, whereas upper Grave Creek has primarily C stream type reaches. Channel morphology is largely characterized by gravel-dominated and some cobble-dominated, moderately confined reaches. Between Williams and Clarence Creek step-pool features are dominant. From Clarence to Blue Sky Creek, middle Grave Creek transitions from step-pool to riffle pool morphology. Above Blue Sky Creek, riffle–pool morphology is dominant. Pfankuch channel stability ratings ranged from 60 to 91, with the highest scores (higher degree of instability) associated with the C stream types. As would be expected, bankfull width is highest at the lowest cross section (XS 4) and decreases in the upstream direction for middle Grave Creek. Upper Grave Creek has lower bankfull widths than middle Grave Creek. Bankfull width to depth ratio values vary between 13 and 29, with the two highest values found in the lower portions of middle Grave Creek. Tables G-23 and G-24 provide some averaged riffle characteristics for middle and upper Grave Creek.

Table G-22: Channel Metrics Summary for Middle and Upper Grave Creek Segments (USFS, 2003).

XS	Channel	Pfankuch Score	Bankfull Width (ft)	W/D
4 Middle	B4	97 (poor)	79.5	26
5 Middle	B3	60 (good)	49.2	29
6 Middle	B4c	66 (fair)	50.2	13
7 Middle	B3	62 (fair)	50.8	18
8 Middle	C4	84 (good)	37.7	21
9 Upper	B4	75 (fair)	26.2	13
10 Upper	C4	91 (fair)	34.4	20
11 Upper	B4	83 (fair)	29.5	17

Table G-23: Middle Grave Creek Riffle Characteristics (Bankfull Channel Dimensions Data; USFS, 2003).

Stream	Stream Type	Channel Width (ft)	Channel Area (ft^2)	Mean Depth (ft)	Width/ Depth	Channel Slope (ft/ft)
Middle Grave Creek	C	37.7	67.7	1.8	21.0	0.007
	B	57.4	153.4	2.7	21.5	0.023

Table G-24: Upper Grave Creek Riffle Characteristics (Bankfull Channel Dimensions Data; USFS, 2003).

Stream	Stream Type	Channel Width (ft)	Channel Area (ft^2)	Mean Depth (ft)	Width/ Depth	Channel Slope (ft/ft)
Upper Grave Creek	C	34.4	59.2	1.7	20	0.02
	B	29.5	51.2	1.7	17	0.019

G.4.2.2.5 Fish Passage Information

There are not any physical fish passage problems noted within middle or upper Grave Creek. .

G.4.2.3 Section 7 Bull Trout Habitat Assessment for Grave Creek

The summary results from the USFS Section 7 consultation (USFS 2000) are presented in Table G-25. In general, most habitat indicators were classified as Functioning at Risk. Note that the sediment category is noted as functioning appropriately/functioning at risk. Review of the analysis used to reach this conclusion shows that the focus was on fine sediment contributions and impacts. This also applies somewhat to the analysis on substrate that also concluded functioning appropriately (FA). The large woody debris (LWD) functioning at risk (FAR) determination is based primarily on a lack of stable LWD.

The FA determination for pool frequency is based on 1992, 1993 and other historical survey data that indicates a pool frequency of 35 to 36 pools per mile. It is concluded that these values generally meet INFISH standards. It is further noted that approximately 25 log/pool structures were installed in these reaches to improve pool habitat during the 1980's, and because of the high volume of bedload movement (large cobbles) through these reaches, a number of these structures filled and/or failed over time. Based on 2002 data, Tables G-3, G-12 and G-13 show pool frequency values of 12, 19, 24, 26, and 62 pools per mile for the B and C reaches of lower, middle, and upper Grave Creek.

The FAR determination for pool quality is based on 1992 and 1993 surveys that concluded that most pools were generally shallow, less than three feet deep. This seems consistent with 2002 values (Tables G-3, G-12, and G-13) showing average maximum depths generally less than three feet and average maximum residual pool depths of less than or equal to 1.5 feet for middle and upper Grave Creek.

The FAR determination for off-channel habitat is attributed to conditions in lower Grave Creek along private lands where limited off-channel cover is expected. In the discussion on the FAR determination for prime habitat (refugia), it is noted that the majority of Riparian Habitat Conservation Areas along Grave Creek are intact, although other concerns are noted to justify the FAR determination.

The FAR determination for streambank conditions is linked to bank instability in portions of the Grave Creek drainage. It is noted that over the past 30 years, Grave Creek has experienced a number of small slumps, some of which have altered streambank conditions. The discussion goes on to note that even though most of the channel substrate is comprised of large cobble and boulders, a significant portion of this moves yearly, especially in those reaches (of lower Grave Creek) modified by channel work after the 1974 floods.

Table G-25: Bull Trout Species Indicators for the Tobacco/Grave Subpopulation (USFS, 2000).

Indicator Metric	Condition
Temperature	FA
Sediment	FA/FAR
Nutrients and Contaminants	FA
Physical Barriers	FAR
Substrate	FA
Large Woody Debris	FAR
Pool Frequency	FA
Pool Quality	FAR

Table G-25: Bull Trout Species Indicators for the Tobacco/Grave Subpopulation (USFS, 2000).

Indicator Metric	Condition
Off-channel Habitat	FAR
Refugia Habitat	FAR
Pool Width/Depth Ratio	FAR
Streambank Conditions	FAR
Floodplain Connectivity	FAR
Peak and Base Flows	FA
Drainage Network	FAR
Road Network	FAR
Disturbance History	FAR
RCHAs	FAR
Disturbance Regime	FAR

FA = Functioning Appropriately, FAR = Functioning at Risk

G.5 Tributary Overview

G.5.1 General Description of Tributary Stream Types and Potential Land Use Impacts

The tributary streams can be divided into three general categories.

1) The lower sections of the primary tributaries to Grave Creek (Stahl Creek, Clarence Creek, Foundation Creek, Lewis Creek, Blue Sky Creek, and Williams Creek). These lower stream sections tend to be characterized by step-pool channel types with riffle-pool inclusions developed in alluvial and semi-confined or transitional valleys landforms These sections also tend to be either Rosgen B or C stream types. Large woody debris and coarse sediment (e.g. boulders) provide the dominant pool forming structure.

2) Upper and middle sections of the tributaries with residual soils occurring as colluvium, landslide debris, glacial till, and other similar depositional materials typically form channel types classified as A and G types according to Rosgen (1996). While fluvial sediment transport does occur, the dominant mechanism by which colluvial sediments are transported downstream is through mass wasting. Intermittent scour by debris flows govern valley form and incision (Montgomery and Buffington, 1993). Because of their colluvial nature, these sections produce high sediment supply for downstream reaches, especially in the presence of disturbance.

In the absence of disturbance these channels are inherently stable (Table G-2). The bedform morphology of these channel units is largely maintained by the presence of large, stable woody debris and coarse substrate. Changes in sediment supply and woody debris delivery can alter channel stability and pool habitat formation. Therefore, channel conditions in the A and G stream types

> above the lower tributary reaches have a strong influence on the lower tributary channel condition. Some of the A3/4 and G3/4 channel types in the upper tributaries; particularly first order drainages are extremely sensitive and tend to provide a high natural bed load supply to downstream reaches. In the presence of disturbance, this sediment supply may become excessive and beyond the transport capacity of the downstream reaches. This excess supply coupled with other impacts to the lower tributary reaches can result in channel instability and degraded habitat conditions.
>
> 3) Upper and middle sections of the tributaries with bedrock and other structural control are characterized by more stable, low sediment supply cascade channels. These are typically steep, deeply entrenched, and confined channels associated with structurally controlled first and second order drainages (also Rosgen A, B, and G stream types). Landforms supporting these channel units include bedrock canyons, steep side slopes, talus fields, and coarse colluvial deposition. Due to stable nature of these structurally controlled landforms, these cascade channel types are generally resistant to altered sediment supplies and flow volumes (Montgomery and Buffington, 1993). Due to their location high in the watershed, they are subject to debris flow impacts (Montgomery and Buffington, 1993).

Spatial analyses of land uses in the watershed are detailed in several Appendices: timber harvest (Appendix A), roads (Appendix B), and water yield, ECA, and activities in the rain-on-snow zone (Appendix C). These land uses have the potential to still impact water quality and overall physical habitat in the tributaries in the same manner that impacts could occur to the main stem of Grave Creek, particularly in the lower sections of the tributaries with Rosgen B and C stream types. This includes extensive road and skid trail networks within the tributary drainages built during the 1950s and 1980s. Many historical harvest units were fairly large averaging approximately 40 acres and oftentimes-spanned colluvial draws and intermittent drainages, in addition to removal of riparian trees along some lower tributary reaches. During the 1950s harvest activities, stream crossings typically consisted of placing logs in the active channel to provide a road surface, a practice commonly referred to as “corduroying” (S. Johnson, USFS Kootenai National Forest Watershed Program Manager, personal communication, July 21, 2004 stakeholder meeting). The lack of BMPs during historical logging would have contributed large amounts of fine and coarse sediment load to the tributaries and Grave Creek downstream. Mass wasting locations still provides evidence of some of this loading. Much of the harvests in the 1980s were concentrated in several of the primary tributaries, including Stahl Creek, Clarence Creek, and Foundation Creek.

Following completion of harvest activities, most of the road network was left in place with minimal effort made to minimize the long-term impacts on basin hydrology and sediment regimes (Bohn, 1998, unpublished report). Today, many of these jammer and skid roads may still be functioning, at least in part, as ephemeral drainages, increasing drainage efficiency and peak flows.

Tributary reaches are labeled from the downstream to upstream, reach 1 being the most downstream reach.

G.5.2 Physical Assessment Results for Tributaries

G.5.2.1 Williams Creek

Williams Creek, a fourth order tributary to Grave Creek, flows approximately 5.9 miles from its headwaters at Mt. Locke and Mt. Petery through USFS-managed lands to its confluence with main stem Grave Creek, defining the division between lower and middle Grave Creek main stem. Management activities in the watershed date back to 1952 when the original access road was constructed off FS Road 114 north of the confluence of Williams Creek and Grave Creek. The original road crossed main stem Grave Creek, switch-backed to the south and entered the Williams Creek drainage in the northeast corner of Section 26. This original access route was apparently abandoned between 1954 and 1992 following construction of FS Road 7019.

FS Road 7019 was constructed adjacent to main stem Williams Creek and in many locations, encroaches on the channel with little to no buffer between the bankfull channel and road fill slope. Commercial logging in 1957 and 1965-1967 included construction of an extensive skid trail and jammer road network to access spruce basins and riparian zones in the upper watershed. The vast road network is still visible in the 1998 photo series.

G.5.2.1.1 Fish Habitat – Pools

Pools in Williams Creek are related to step pool channel morphology in the A stream type reach. Pools in the B stream type reach are associated with large substrate and possibly large woody debris accumulations. Pools were moderately frequent in Williams Creek relative to pool frequencies in other tributaries in the Grave Creek Watershed (Table G-26).

Table G-26: Williams Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Williams Creek	B	38	16 (4, 21, 45)	2.1 (1.2, 2.6, 3.9)	1.3 (0.5, 1.8, 3.4)
	A	40	16 (9, 18, 36)	2.5 (1.3, 2.9, 5.1)	1.5 (0.5, 1.9, 4.2)

G.5.2.1.2 Fish Habitat – Large Woody Debris

Large woody debris accumulations were most frequent in the B stream type sections of Williams Creek (Table G-27). Total woody debris accumulations were moderate to high relative to accumulations measured in other tributaries in the watershed.

Table G-27: Williams Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Williams Creek	B	0 (0, 168, 4308)	0 (0, 0, 4261)	88 (0, 355, 8389)	239 (0, 594, 12697)
	A	0 (0, 0, 350)	0 (0, 0, 447)	0 (0, 140, 519)	55 (0, 187, 894)

G.5.2.1.3 Sediment Particle Size Monitoring Results

Sediment gradation data for Williams Creek based on pebble count results are summarized in Table G-28.

Table G-28: Williams Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).

Reach	D16	D50	D84	% < 2 mm	% < 6.4 mm
1	26	80	200	6	7
2	17	70	270	3	6
3	23	65	150	6	7
4	27	102	200	1	4
5	18	80	310	1	7

Percent fines values < 6.35 from grid toss sampling are presented in Table G-29. Median percent surface fines in pool tails was highest in the Williams Lake tributary, possibly linked to the upstream lake in the drainage. Median percent pool tail out fines in Williams Creek reaches (A and B) was relatively low (5%).

Table G-29: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, 2001). Williams Creek.

Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Williams Lake Creek	B	0.0	10.0	10.0	23.8	65.0
Williams Creek	A	0.0	0.0	5.0	5.0	20.0
	B	0.0	5.0	5.0	10.0	70.0

G.5.2.1.4 Channel Morphology

Table G-30 presents morphology data for Williams Creek. Bankfull channel widths ranged from 17.3 ft to 38.7 ft and width/depth ratios ranged from 15 to 35 with all values below 20 except the one high value of 35 for a steep A stream type. Channel stability rated fair to good, with the most unstable segments occurring in the upper reaches of the watershed.

Table G-30: Williams Creek Channel Metrics Summary.				
Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B3a	76 (fair)	28.1	15
2	A3a+	76 (good)	38.7	35
3	B3a	63 (fair)	22.6	18
4	B3	71 (fair)	17.3	20
5	A3a	63 (good)	15.7	17

G.5.2.2 Clarence Creek

Clarence Creek headwaters in a series of first order ephemeral channels at elevations ranging from 7,203 feet at Mt. Wam to 7,435 feet at Stahl Peak. A primary tributary to Grave Creek and the most important bull trout spawning tributary in the watershed, land management in Clarence Creek dates back to the 1950s when major arterial roads were constructed in the basin to facilitate logging in response to the spruce bark beetle epidemic.

The first timber harvest entry in Clarence Creek occurred in the mid 1950s following construction of FS Road 7022. The initial road was constructed to the southeast corner of Section 35 (approximately). In the late 1950s, the road network was expanded to include the upper headwaters of the drainage and one major crossing (FS Road 7036) was installed in the northeast corner of Section 2 to access units to the east. A network of jammer roads and skid trails was constructed throughout the upper basin. Still visible in the 1998 photo series, much of the extensive road network is currently overgrown with dense alder, and may no longer serve as a chronic source of sediment to the channel.

Approximately 5.3 miles of channel were surveyed in the Clarence Creek watershed.

G.5.2.2.1 Fish Habitat – Pools

Table G-31 presents pool frequency results. Pools were more frequent in the B stream type section of Clarence Creek although all pool size values were greater for the C stream type portions of Clarence Creek. These higher pool values, particularly the residual pool depth in C reaches may offset the relatively low pool frequency to some extent.

Table G-31: Clarence Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).					
Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Clarence Creek	C	9	19(10, 26, 49)	2.8 (1.6, 3.0, 3.3)	2.0 (0.7, 2.2, 2.4)
	B	29	17 (7, 24, 121)	2.0 (1.2, 2.3, 3.9)	1.5 (0.5, 1.6, 1.9)

G.5.2.2.2 Fish Habitat – Large Woody Debris

Total large woody debris accumulations were most frequent in the B stream type sections of Clarence Creek (Table G-32). Woody debris accumulations were high relative to other tributary accumulations in the watershed, particularly for the B stream type. Wood aggregates, typically the most stable form of woody debris, were the most numerous in the watershed relative to single large woody debris pieces and rootwads.

Table G-32: Clarence Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Clarence Creek	C	20 (0, 37, 393)	20 (0, 60, 310)	95 (0, 260, 537)	167 (0, 329, 619)
	B	0 (0, 163, 3520)	0 (0, 0, 1509)	165 (0, 626, 2347)	571 (0, 993, 4526)

G.5.2.2.3 Sediment Particle Size Monitoring Results

Sediment particle size distributions from pebble counts for Clarence Creek are presented in Table G-33.

Table G-33: Clarence Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).

Reach	D16 (mm)	D50 (mm)	D84 (mm)	% < 2 mm	% <6.35 mm
1	30	64	150	2	3
2	11	38	100	8	10
3	15	56	120	1	5
4	60	150	500	1	2
5	18	50	128	4	5
6	24	62	512	3	3

Percent fines values < 6.35 from grid toss sampling in Clarence Creek are presented in Table G-34. Median percent surface fines values in pool tails was the same for both B and C channel types (5%).

Table G-34: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, 2001). Clarence Creek.

Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Clarence Creek	C	0.0	1.3	5.0	5.0	10.0
	B	0.0	0.0	5.0	5.0	20.0

G.5.2.2.4 Channel Morphology

Channel morphology data for Clarence Creek is presented in Table G-35. Channel stability ratings ranged from 60 (good) to 74 (fair), with channel width/depth ratios ranging from 5 to 14.

Table G-35: Clarence Creek Channel Metrics Summary.

Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B4a	62 (good)	17.0	5
2	C4b	68 (good)	16.4	6
3	B4a	69 (fair)	13.7	11
4	B3a	60 (good)	16.8	14
5	B4a	63 (good)	16.6	12
6	B4a	74 (fair)	6.7	9

G.5.2.3 Stahl Creek and South Fork Stahl Creek

South Fork Stahl Creek originates in a series of first order ephemeral and intermittent channels on the eastern flanks of Mt. Gibraltar at an elevation of 7,313 feet. The most significant impacts to channel conditions in this sub-basin are related to past riparian management and construction, and “reclamation” of FS Road 7029. The road was constructed in the 1980s to facilitate logging activities and included five to six major stream crossings constructed with rock gabions, riprap, and undersized culverts. Following logging activities, many of the roads and crossings were left in place with no mitigation actions or BMPs applied. Those that were obliterated were stabilized with riprap and bridge deck materials. Approach grades were not recontoured according to standard BMPs and may continue to recruit hillslope sediment due to lack of vegetation. Several crossings contain gabion baskets that continue to cause channel aggradation and bank cutting. These structures may impede upstream fish migration.

Stahl Creek headwaters at an elevation of 7,435 feet at Stahl Peak and flows approximately 4.3 miles to its confluence with Clarence Creek. Stahl Creek exhibits channel morphologic characteristics common to steep, mountainous tributaries. Timber harvest in the drainage occurred primarily in 1957 and 1988 with evidence of mass wasting and riparian harvest.

R1/R4 data collected by USFS were used to evaluate fish habitat conditions in Stahl Creek. Approximately 1.7 miles of channel were surveyed in the Stahl Creek watershed.

G.5.2.3.1 Fish Habitat – Pools

Table G-36 provides pool values for Stahl Creek. Pool frequency and volume was greater in A reaches than B reaches. Relatively high pool values may be associated with the relatively high large woody debris frequency values presented below.

Table G-36: Stahl Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Stahl Creek	B	82	17 (9, 22, 42)	2.2 (1.3, 2.6, 4.2)	1.2 (0.4, 1.6, 2.8)
	A	106	16 (8, 21, 53)	2.0 (1.1, 2.4, 5.9)	1.2 (0.3, 1.6, 5.2)

G.5.2.3.2 Fish Habitat – Large Woody Debris

Large woody debris accumulations were most frequent in the A stream type sections of Stahl Creek (Table G-37). Large woody debris accumulations were relatively moderate to high in comparison to other tributaries. Single pieces of wood were the most frequent form of large woody debris in Stahl Creek. Single pieces of large wood are generally less stable than accumulations that can provide complex, persistent habitat features.

Table G-37: Stahl Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Stahl Creek	B	0 (0, 91, 826)	0 (0, 62, 644)	161 (0, 305, 947)	274 (0, 488, 1238)
	A	171 (0, 374, 1558)	0 (0, 0, 671)	115 (0, 285, 947)	377 (0, 596, 1558)

G.5.2.3.3 Sediment Particle Size Monitoring Results

Sediment gradation data from pebble counts for Reaches 1-6 on main stem Stahl Creek and a representative reach in the South Fork Stahl Creek sub-watershed are summarized in Table G-38. Percent fines less than 6.4 mm were highest in Reaches 4 and 6 of Stahl Creek and in the South Fork Stahl Creek.

Table G-38: Stahl Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).

Reach	D16 (mm)	D50 (mm)	D84 (mm)	% < 2 mm	% < 6.35 mm
1	10	40	120	8	9
2	24	100	415	1	4
3	11	100	200	6	7
4	3	35	85	8	17
5	11	80	220	1	7
6	8	50	160	5	14
S. Fork Stahl	8	50	175	9	15

Percent fines values < 6.35 from grid toss sampling in Stahl Creek are presented in Table G-39. The Median percent surface fines in pool tails in Stahl Creek were greater in the B reaches (10%) than the A reaches (5%).

Table G-39: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, 2001). Stahl Creek.						
Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Stahl Creek	A	0.0	0.0	5.0	5.0	40.0
	B	0.0	10.0	10.0	15.0	50.0

G.5.2.3.4 Channel Morphology

Channel morphology data for the main stem Stahl Creek and South Fork Stahl Creek are presented in Table G-40. Bankfull channel widths ranged from 11.9 to 32.9 feet, width/depth ratios ranged from 8 to 18. Channel stability rated fair to good, with the most unstable segments occurring in the South Fork Stahl Creek and Reach 6, or the upper headwaters of the main stem.

Table G-40: Stahl Creek Channel Metrics Data Summary.				
Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B4a	60 (good)	32.9	17
2	A3	65 (good)	19.9	11
3	A3a+	87 (good)	17.0	10
4	A4a+	90 (good)	17.0	8
5	B3a	54 (good)	16.4	13
6	B4a	74 (fair)	12.2	13
S. Fork Stahl	B4a	71 (fair)	11.9	18

G.5.2.4 Blue Sky Creek

Blue Sky Creek is the largest sub-basin tributary to Grave Creek. Comprising over 6.3 stream miles, major tributaries include Jiggs Creek and Kopsi Creek. Management of the Blue Sky Creek drainage followed similar trends observed for the other primary tributaries. Initial timber harvest and road construction activities commenced in 1955, with subsequent management in the 1960s. Extensive skid trails were constructed in the headwaters and in the Kopsi and Jiggs Creek drainages. Skidding occurred on steep slopes oftentimes paralleling ephemeral and intermittent drainages. Numerous crossings of Kopsi Creek and Jiggs Creek are apparent in the 1998 aerial photo series. The crossings likely consisted of corduroying the channel with logs and whole trees. Jammer or temporary roads connected the skid trails to main arterial roads paralleling the main stem Blue Sky Creek. Main arterial roads constructed within the valley bottom of the watershed encroach on the channel with minimal to no buffer provided between the road fill slope and active bankfull channel.

Although the USFS has removed many of the road crossings and the main arterial road paralleling Blue Sky Creek, major sediment sources inventoried during the fall 2003 were associated with road fillslope erosion and slope failures that delivered sediment and debris to the main channel (Section 6.0). Apparently, minimal BMPs or erosion control measures were installed prior to closure.

The combined effects of increased water yield followed by a reduction in root density on steep slopes continue to sensitize riparian units and steep glaciated slopes along Blue Sky Creek to mass wasting (Photo 9). While human caused slope failures are most prevalent in the drainage, natural events continue to cause similar impacts to channel morphology and sediment production. For example in 1998, a major stand replacement wildfire consumed approximately 1,094 acres in the watershed. Several debris flows contributed sediment and debris directly to the channel. It is not documented whether or not historical harvest was linked to any of the debris flows. The slide paths were revegetated by the USFS in 1999. The effectiveness of this mitigation activity in alleviating sediment delivery to the channel is unknown.

Approximately 4.4 miles of channel were surveyed in the Blue Sky Creek watershed.

G.5.2.4.1 Fish Habitat – Pools

Blue Sky Creek pool values for B reaches are summarized in Table G-41. Overall frequency values are similar to other tributary results.

Table G-41: Blue Sky Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Blue Sky Creek	B	24	15 (7, 17, 66)	2.4 (1.5, 2.6, 3.9)	1.5 (0.7, 1.7, 3.1)

G.5.2.4.2 Fish Habitat – Large Woody Debris

Large woody debris accumulations results for Blue Sky Creek are summarized in Table G-42. Median woody debris concentrations are very low, possibly due to riparian harvest.

Table G-42: Blue Sky Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Blue Sky Creek	B	0 (0, 0, 732)	0 (0, 0, 460)	0 (0, 67, 732)	36 (0, 320, 732)

G.5.2.4.3 Sediment Particle Size Monitoring Results

Sediment gradation data based on pebble counts are presented in Table G-43 for Blue Sky Creek. Note the relatively high percent fines values for the Reach 3 cross section.

Table G-43: Blue Sky Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).

Reach	D16 (mm)	D50 (mm)	D84 (mm)	% < 2 mm	% < 6.35 mm
1	11	48	115	1	6
2	6	32	100	2	16
3	4	38	120	12	20

Percent fines values < 6.35 from grid toss sampling in Blue Sky Creek are presented in Table G-44. The median percent surface fines in pool tails in Blue Sky Creek were 0%.

Table G-44: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, 2001). Blue Sky Creek.

Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Blue Sky Creek	B	0.0	0.0	0.0	5.0	35.0

G.5.2.4.4 Channel Morphology

Table G-45 presents the channel morphology data for Blue Sky Creek. Bankfull channel widths ranged from 17.0 ft to 23.3 ft, with with/depth rations ranging from 10 to 13. Bank stability ratings were all rated as “good”.

Table G-45: Blue Sky Creek Channel Metrics Summary.

Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B4a	57 (good)	17	10
2	B4a	61 (good)	23.3	13
3	B4a	61 (good)	18.8	11

G.5.2.5 Lewis Creek

Lewis Creek is a third order tributary to the upper Grave Creek sub-watershed, flowing approximately 3.4 miles in a northwesterly direction from its headwaters along the western divide of the Whitefish Range to its confluence with Grave Creek. Construction of FS Road 114 began in the 1950s and extended only a few miles up the drainage. By the mid 1980s, the road was completed and linked with FS Road No. 114 on the Flathead National Forest. The full length of the road is located at mid-slope and bisects numerous first order drainages characterized by residual soils occurring as colluvium, landslide debris, avalanche chutes, glacial till, and other similar depositional materials. Due to the steep nature of the valley, road cut slopes were extensive and resulted in headward erosion of the steep, colluvial draws and avalanche chutes. While these channel units naturally contribute relatively high sediment loads to Lewis Creek via mass wasting, debris flows, and avalanches, road construction appears to have exacerbated channel instability and sediment production.

Road construction facilitated logging in the 1950s and 1980s in response to the spruce bark beetle epidemic. A majority of the harvest units were located on sensitive soil types and in riparian valley bottoms which would be expected to deplete the availability of large woody debris to the channel system. In response to these activities, the USFS initiated a program to reintroduce structure into the channel through installation of high stage log check dams and drop structures, as observed on the main stem Grave Creek. Since installation, the structures have caused segments of the channel to aggrade and laterally migrate causing partial or complete failure of the log dams. These failures have delivered sediment to the channel through floodplain head cutting. The remaining structures will continue to pose a threat to channel stability and sediment routing if left in place.

Approximately 0.9 miles of channel were surveyed in the Lewis Creek watershed.

G.5.2.5.1 Fish Habitat – Pools

Table G-46 presents pool data for Lewis Creek. Pool characteristics were typical compared to other tributaries in the watershed.

Table G-46: Lewis Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Lewis Creek	C	26	11 (9, 16, 45)	1.8 (1.4, 2.1, 2.7)	1.2 (1.0, 1.7, 2.2)
	B	36	14 (7, 17, 35)	2.0 (1.0, 2.3, 3.6)	1.5 (0.7, 1.7, 3.1)

G.5.2.5.2 Fish Habitat – Large Woody Debris

Large woody debris accumulations were most frequent in the B stream type sections of Lewis Creek (Table G-47). Woody debris concentrations reflect mass wasting and channel avulsion processes that contribute sediment and large woody debris to the channel. Single pieces of large wood were most frequent in the B stream type section of Lewis Creek. The frequent distribution of single pieces suggests higher instability of woody debris in this stream type as would be expected due to higher gradients. Lewis Creek had the second highest frequency of large woody debris in the Grave Creek Watershed.

Table G-47: Lewis Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Lewis Creek	C	0 (0, 71, 383)	0 (0, 0, 23)	125 (0, 481, 596)	270 (0, 481, 596)
	B	121 (0, 304, 1288)	0 (0, 0, 644)	34 (0,152, 732)	304 (0, 393, 1932)

G.5.2.5.3 Sediment Particle Size Monitoring Results

Sediment gradation data based on pebble counts for Reaches 1-5 in Lewis Creek are summarized in Table G-48. The highest percent fine levels less than 6.35 mm were measured in Reach 1 and 3, with the Reach 3 value representing one of the highest results in comparison to other streams. The corresponding values for < 2 mm were similar to results for other streams and not particularly high.

Table G-48: Lewis Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).

Reach	D16 (mm)	D50 (mm)	D84 (mm)	% < 2 mm	% < 6.35 mm
1	11	30	88	7	10
2	14	45	98	2	6
3	4.5	21	55	5	19
4	11	40	96	3	8
5	21	75	185	2	3

Percent fines values < 6.35 from grid toss sampling in Lewis Creek are presented in Table G-49. Median percent surface fines values in pool tails in Lewis Creek were greater for C reaches (10%) than for B reaches (5%).

Table G-49: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-Point Particle Grid Data (USFS, 2001). Lewis Creek.

Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Lewis Creek	C	5.0	7.5	10.0	12.5	25.0
	B	0.0	1.3	5.0	8.8	70.0

G.5.2.5.4 Channel Morphology

Table G-50 presents channel morphology results for Lewis Creek. Similar to other tributaries in the Grave Creek Watershed, geomorphic conditions are characterized by moderately entrenched, gravel and cobble dominated channels with average bankfull widths ranging from 6.9 ft to 16.1 feet. Width to depth ratios are all less than 17, and stability ratings (Pfankuch) range from “fair” to “good”.

Table G-50: Lewis Creek Channel Metrics Summary.

Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B4	66 (fair)	11.9	12
2	C4b	78 (good)	13.1	10
3	B4a	n/a	16.1	17
4	B4	69 (fair)	6.9	5
5	B3a	56 (good)	12.3	9

G.5.2.6 Foundation Creek

Foundation Creek originates in a series of small sub alpine lakes situated to the south of Mt. Wam at an elevation of 7,203 feet. A relatively small watershed, Foundation Creek flows approximately 2.5 miles east to its confluence with Grave Creek.

Forest management in Foundation Creek occurred throughout the 1950s in response to the spruce bark beetle epidemic. Approximately 244 acres of timber were harvested, a majority of the units concentrated in the lower to middle reaches of the basin. Harvest units were located on north aspect slopes above the main channel and were accessed by a network of skid trails and jammer roads. Riparian units extended through a majority of the lower reaches and multiple channel crossings are evident in the photo series.

Review of the 1998 aerial photo record indicates that most of the skid trails appear to be fairly well vegetated with alder and other shrubs. While these roads are likely no longer sources of sediment to the system, they likely alter the volume and timing of runoff to Foundation Creek through subsurface flow interception, increased snow pack deposition, and increased drainage efficiency.

The main skid trails traversing the north aspect slopes remain exposed and unvegetated. These particular skid trails may continue to be a sediment source in addition to modifying the hydrology in Foundation Creek.

Approximately 0.4 miles of channel were surveyed in the Foundation Creek watershed.

G.5.2.6.1 Fish Habitat – Pools

Summary pool characteristics for Foundation Creek are included in Table G-51. Pool frequency values are similar to other tributary streams, although pool size values are generally smaller.

Table G-51. Foundation Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Foundation Creek	B	32	14 (9, 16, 27)	1.6 (1.2, 2.0, 3.3)	1.0 (0.7, 1.5, 2.3)

G.5.2.6.2 Fish Habitat – Large Woody Debris

Large woody debris accumulations results for Foundation Creek are summarized in Table G-52. Median woody debris concentrations are very low, possibly due to riparian harvest.

Table G-52: Foundation Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Foundation Creek	B	0 (0, 35, 575)	0 (0, 0, 41)	0 (0, 110, 847)	70 (0, 196, 847)

G.5.2.6.3 Sediment Particle Size Monitoring Results

Sediment gradation data based on pebble counts for Reaches 1-4 in Foundation Creek are summarized in Table G-53. All values have low percent fines results for < 2 mm and < 6.35 mm.

Table G-53: Foundation Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).

Reach	D16 (mm)	D50 (mm)	D84 (mm)	%< 2 mm	% < 6.35 mm
1	14	47	100	6	9
2	12	30	88	4	9
3	10	28	120	4	10
4	21	40	160	2	6

Percent fines values < 6.35 from grid toss sampling in Foundation Creek are presented in Table G-54. Median percent surface fines in pool tails in Foundation Creek were 0%.

Table G-54: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, 2001). Foundation Creek.

Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Foundation Creek	B	0.0	0.0	0.0	0.0	5.0

G.5.2.6.4 Channel Morphology

Table G-55 presents channel morphology results for Foundation Creek. The lower reaches of Foundation Creek are characterized by moderately entrenched, gravel dominated channel types with bankfull widths ranging from 6.3 ft to 18.4 ft. The upper reaches transition to step-pool morphologies, with cobble being the dominant substrate and pool formative structure. The confined valley and structural controls imposed on the channel by the existing landforms make the channel inherently stable. Channel stability rated fair in the lower to middle reaches associated with past harvest activities, and good in the upper unmanaged portion of the drainage. Width to depth ratios are all less than 19.

Table G-55: Foundation Creek Channel Metrics Summary.

Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B4a	84 (fair)	18.4	19
2	B4a	77 (fair)	12.6	11
3	B3a	64 (fair)	6.7	16
4	A3	66 (good)	6.3	10

G.5.2.6.5 Fish Passage

The culvert which passes Foundation Creek on the Grave Creek road is a likely fish passage barrier. It is uncertain how this potential barrier may affect the overall fishery in Grave Creek. It is not known if bull trout use Foundation Creek. It is also unknown whether pure strains of westslope cutthroat (WSCT) may be isolated above the culvert. If pure strains of WSCT do exist above the culvert and the culvert is a fish passage barrier, it may be deemed a positive impact on the WSCT fishery. If, however, critical bull trout habitat is identified above the culvert and the culvert is identified as a barrier restricting access to the critical habitat, then the culvert may be having a negative impact on the bull trout fishery. It may be both a limitation to the bull trout fishery and a positive impact on the WSCT fishery from a genetic perspective. Further investigation is warranted to determine the situation and what possible actions might be taken.