APPENDIX H
REFERENCE VALUE DEVELOPMENT FOR THE GRAVE CREEK WATERSHED

Reference development is focused on those parameters that can be linked closely to the beneficial use support (Figure H-1). Ideally, the best parameters would include robust measures of fishery and aquatic life from reference water bodies where all sediment and habitat conditions are functioning at their potential given historic land uses and the application of all reasonable land, soil and water conservation practices. There has been and continues to be significant progress toward the development of macroinvertebrate and periphyton reference values throughout Montana. These reference values, along with reference values for habitat parameters such as percent fines, can provide vital information to make aquatic life beneficial use determinations. On the other hand, a robust reference data set to represent the primary species of cold-water fish found in the Grave Creek Watershed represents a difficult challenge given the multitude of variables that can influence fishery data. For this reason, cold-water fish beneficial use support decisions linked to sediment and habitat impairments often rely on fish habitat and channel condition parameters because of the impact that these parameters, represented within Figure H-1, can have on fishery health.

Reference values were developed and/or discussed for the following parameters to help determine impairment for cold water-fish and/or aquatic life:

- Pool Frequency (number of pools per unit length)
- Large Woody Debris (amount of large woody debris per unit length)
- Macroinvertebrate Metrics
- Percent Substrate Fines (McNeil Core results for percent < 6.38 mm in glide areas (pool tails))
- Percent Surface Fines (pebble count results for fines < 2 mm and < 6.4 mm in riffles and grid toss results for percent fines < 6.4 mm in glide areas)
- Width to Depth Ratio (ratio of bankfull width to bankfull depth at riffle cross sections)
- Sinuosity
- Meander Length Ratio

The above parameters cover a broad range of direct habitat measures and measures of channel conditions, as well as a direct measure of aquatic life (macroinvertebrate metrics).

Management activities, natural events, watershed and riparian processes, and stream inputs such as sediment loading also play an important role in the watershed cause and effect pathway (Figure H-1). Most of these must be considered when evaluating the applicability of reference values, when making impairment determinations, and when applying the adaptive management approach discussed in Section 5.2.1. This includes consideration of historical land use and linkages to sediment loading and habitat impacts, as well as consideration of anticipated natural variability as part of the process of selecting, developing and applying reference parameters to the Grave Creek Watershed. Data to incorporate these considerations were presented and discussed within Sections 2.0 and 4.0 and their accompanying appendices.

The following subsections provide details on reference value development for each of the above parameters. Many parameters such as pool frequency were stratified by bankfull width and/or stream order since stream size represents an important stratification. Stream order is an indicator of stream size, with lower stream orders representing smaller tributary or headwater stream segments. Another important stratification includes Rosgen channel types, referred to as either A, B or C reaches or stream types.

The goal is to apply a primary approach for reference development (Section 3.2.3.1). Given the potential widespread historical human impacts throughout the Grave Creek Watershed, the use of internal reference values from within the watershed for reference development cannot be justified for many parameters, and historical data is not available for many parameters. This leaves the use of regional reference data as a remaining primary approach used in many of the following sections.

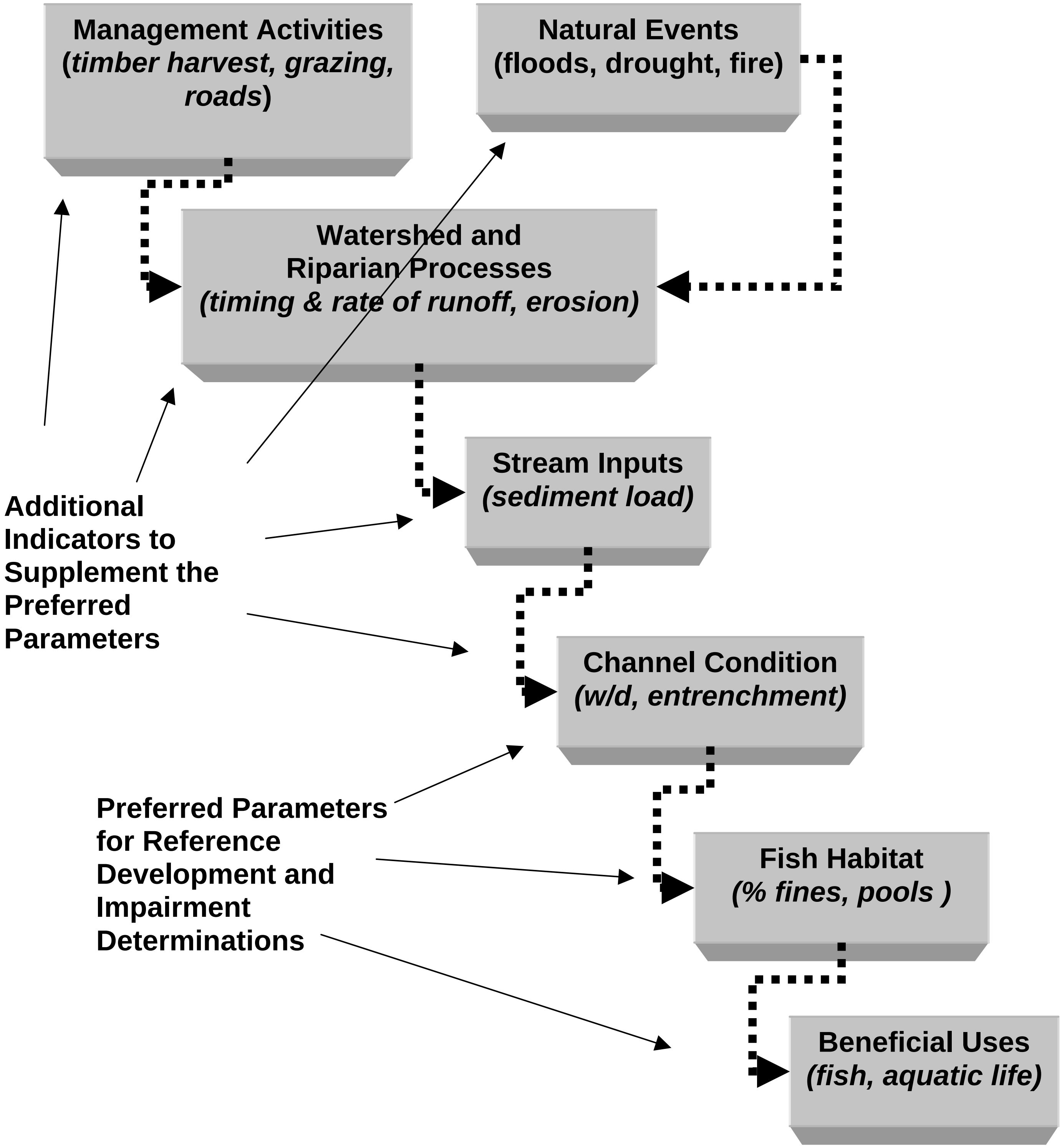

Figure H-1: How various measures and potential reference parameters fit in the watershed cause and effect pathway for Sediment and Habitat Measures.

H.1 Pool Frequency

Pool frequency (pools/mile) is an important physical habitat parameter. Pools provide critical habitat for cold-water fish and are linked to the storage, deposition, and sorting of sediment within the channel. Several sources were used to develop pool reference values. These include: 1) data from the Swan Lake Watershed used for TMDL development (MDEQ, 2004d), 2) unpublished reference data provided by the Libby Ranger District of the KNF, 3) unpublished reference data provided by the Rexford Ranger District of the KNF, 4) reference data from the Lolo National Forest (USFS, 1998), 4) interim INFISH Riparian Management Objectives (RMOs) from the National Forest (USFS, 2000), and 5) an internal reference reach for lower Grave Creek. Methods varied between studies although the various methods can result in similar values, particularly for the 2nd and 3rd order streams and smaller 4th order streams. Appendix F provides a summary of methodologies. Table H-1 presents the pool frequency data from many of the above reference sources.

The development of pool reference values are focused on identifying a reference range, with focus on the minimum level that should exist in each stream category to fully support cold-water fish. This is because the higher the pool frequency, the better the habitat conditions within the ranges discussed in this section. Therefore, values above the high end of the reference range would be desirable in most situations, and values below the low end suggest a potential problem.

Based on a review of the Grave Creek Watershed assessment results (Section 4.0 and Appendix G), and a review of the reference data sets, reference development was broken into four categories for applying pool reference conditions to streams in the Grave Creek Watershed. These categories include 2nd and 3rd order B and C streams with bankfull widths that tend to range from 10 to 20 feet; 3rd and 4th order B and C streams where bankfull widths tend to range from 20 to 35 feet; 4th order B and C streams where bankfull widths tend to range from greater than 35 to 50 feet; and wider B, C or F streams similar to the width of lower portions of Grave Creek.

H.1.1 Pool Frequency Reference Values for B & C Streams with Bankfull Widths of about 10 to 20 Feet (Typically 2nd and 3rd Order Streams)

The data in Table H-1 show that the smaller streams tend to have larger pool frequency values. The Libby Ranger District values for B and C streams with a 10 to 20 feet bankfull width had an average value of 106, a median of 102 a 25th percentile of 77 pools per mile, and a 75th percentile of about 118. For the Rexford Ranger District data set, streams approximately 10 to 20 feet bankfull width had an average value of 73 pools per mile. Data from the Lolo NF indicate an average of 39 and 37 pools per mile for B and C streams respectively although results were not differentiated by stream width. The RMO values represent a range of 96 to 56 pools per mile, with a midpoint of about 73 pools per mile. No data for streams with bankfull widths less than 19 feet in the Swan Lake Watershed were collected.

The Table H-1 data allows for application of a primary reference development approach based on regional data. The Libby and Rexford Ranger District Data appear to be most robust, with a preference for the Libby data because of the ability to apply a non-parametric statistical approach as discussed in Section 3.2.3.2.2 and due to the similarity to RMOs. Also note the similarity between B and C results in Table H-1 for this data set. Application of this data would result in a reference range of 77 to 118 pools per mile, representing the 25th to 75th percentile range from the Libby reference data set. This value is modified to 73 to be consistent with the Forest Service RMOs, and where streams widths approach 20' the range can be lowered to as much as 56 pools per mile. This provides a higher range than the Lolo data and helps provide a margin of safety for stream protection, although the Swan data for larger streams does suggest a potentially higher achievable pool range.

Variations between reference stream data add uncertainty to chosen values. These and similar uncertainties exist throughout the development of reference conditions and are further addressed within the adaptive management approach for applying reference values as beneficial use support objectives, including the application of TMDL targets.

H.1.2 Pool Frequency Reference Values for B and C Streams with 20 to 35 Feet Bankfull Width (Generally 3rd and 4th Order Streams)

For B and C streams with 20 to 35 feet bankfull width, the data in Table H.1 show a median value of 80 for Swan tributaries with a 25th to 75th percentile range of 70 to 95 pools per mile. The Table H.1 data for Libby reference streams greater than 20 feet wide (and generally less than 30 feet wide) show a median value of 60 for B and C streams with a 25th to 75th percentile range of 47 to 66 pools per mile. The Rexford database average pool frequency implies lower values of 48 pools per mile for streams with approximately 20 to 30 feet bankfull width, as does the Lolo data although the Lolo data is not stratified by width. Whereas the Libby data show consistent results for B and C streams in the 10 to 20 feet wide range, the data for C and B streams greater than 20 feet suggests that the C streams have significantly fewer pools. The Libby C stream results are based on only three data points, with one result for the widest stream of the three (32 feet) contributing significantly to the low statistical values, possibly due to the requirement that pools must be equal to one-third the bankfull width per the Libby pool counting method. The RMO range for this width category would be 56 to about 35 pools per mile, with 47 pools per mile at the 25' midpoint, about 42 pools per mile at 30' width, and about 35 pools per mile at about 35' width.

A primary reference development approach based on regional data is used. The Libby and Rexford Ranger District Data appear to be most robust, with a preference for the Libby data because of the ability to apply a non-parametric statistical approach and due to the similarity to RMOs. Application of this data would result in a reference value range of 47 to 66 pools per mile, representing the 25th to 75th percentile range from the Libby reference data set. The low end of 47 is consistent with the Forest Service RMO, and where streams widths approach 35' the range can be lowered to as low as 35 pools per mile on a case by case basis. This provides a higher range than the Lolo data and helps provide a margin of safety for stream protection, although the Swan data does suggest a potentially higher achievable pool range.

H.1.3 Pool Frequency Reference Development for B and C Stream Reaches Generally 35 to 50 Feet Wide (Generally 4^{th} or 5^{th} Order Streams)

For B and C stream reaches 35 to 50 feet bankfull width, pool frequency ranges from 21 to 52 with both a median and average value of 38 in Swan tributaries. The 25^{th} percentile is 29 and the 75^{th} percentile is 47. Rexford data for streams greater than 29.5 feet wide is consistent with the Swan values at an average pool frequency of 32 pools per mile. The Lolo data is also similar with average values of 39 and 37 for B and C streams respectively, although the Lolo data are not stratified by width. The Libby data did not include streams within this width range. The Forest Service RMOs would result in a range of 35 pools per mile at 35' width, to 26 pools per mile at 50' width.

The preferred primary reference value development approach is the application of the Swan data due to the available statistical distribution and also due to the fact that the Swan median and average values (38 pools per mile) are both similar to the Rexford average value of 32 pools per mile for wider streams, and similar to the RMOs. Application of this data would result in a reference value range of 29 to 47 pools per mile, representing the 25^{th} to 75^{th} percentile range from the Swan reference data. The low end of the range can be decreased down to 26 pools per mile consistent with the RMO values at the 50' width. Again the higher range is used to help provide a margin of safety for stream protection.

H.1.4 Lower Grave Creek Pool Frequency Reference Development

Lower Grave Creek consists of some Rosgen C, B and F reaches that tend to fall between 40 to 60 feet wide, although some C reaches below the GLID are even wider. One primary target development approach would be to use data from the lower Grave Creek internal reference reach, suggesting a value of 12 pools per mile for the C stream type. A secondary target development approach for the C stream reaches is to apply a literature value of 3 to 4 pools per meander wave length (Rosgen, 1996), based on one to two pools per meander bend. Using the Section G.4.1.2.5 design/reference dimensions, the meander wavelength would ideally be about 858 feet long, or about 6 meanders per mile for a pools per mile range of about 12 to 24 if it assumed that the meanders would form one to two pools each. This value is consistent with the low end of the design range. There is also the potential for additional pool development due to large woody debris in the channel. Therefore, for the C stream reaches of lower Grave Creek, the reference target range is 12 to 24 pools per mile based on a combination of internal reference data (primary approach) and applied literature (secondary approach).

The 29 to 47 target range developed for 35 to 50 foot wide streams is applied to the B and F reaches of lower Grave Creek due to size similarities, with potential modifications to be consistent with RMOs as discussed above. Although not presented in Table H.1, Libby reference data from two F stream reaches greater than 30 feet wide result in pool frequency values of 39 and 48. Both results are consistent with the 29 to 47 reference range.

Table H-1: Pool Frequency Reference Sources.

Source	Stream Type and/or Bankfull Width	Pool Frequency (pools/mile)			
Swan River Tributaries: Piper, Goat, Jim and Elk Creeks	B & C 19’-35’ (generally 3^{rd} order)	Range: 52-114 25^{th} Percentile: 70 75^{th} Percentile: 95 Median: 80 Average: 85			
Four Swan River Tributary Reaches in Jim, Elk, & Goat Creeks;	B & C 35’-45’ (generally 3^{rd} and 4^{th} order)	Range: 21– 52 25^{th} Percentile: 29 75^{th} Percentile: 47 Median: 38 Average: 38			
Lolo NF Undeveloped Conditions	B C	39 (average value) 37 (average value)			
Kootenai NF, Libby RD		**Range**	**25^{th}/75^{th}**	**Median**	**Average**
	B < 20’	47-251	78/116	100	109
	C < 20’	55-120	79/112	103	93
	B&C < 20’ (& > 10’)	47-251	77/118	102	106
	B > 20’	42-110	52/71	61	65
	C > 20’	8-64	16/44	23	32
	B&C >20’ (& < 32”)	8-110	47/66	60	56
Kootenai NF, Rexford RD	< 9.8’	113 (average value)			
	9.8 - 19.7’	73 (average value)			
	19.7 - 29.5’	48 (average value)			
	> 29.5’	32 (average value)			
INFISH RMOs	10’	96			
	20’	56			
	25’	47			
	50’	26			

H.1.5 Reference Values Summary

Table H.2 provides a summary of pool frequency reference values/ranges applied to the Grave Creek Watershed. As additional reference data become available, pool frequency reference values/ranges may be refined. Furthermore, pool frequency reference application may be supplemented and/or replaced by additional pool reference values or additional analysis based on measures such as residual pool depth or residual pool volume. This is further discussed under the beneficial use support objectives (Section 5.2). Note that application of the pool frequency reference values allow for some overlap, particularly in the 3^{rd} order streams with widths ranging from 15 to 20 feet. This is because of the desired grouping of assessment results by longer stream segments as reported within Section 4.0. Under these conditions, specific application of RMO reference values that fall between the two pool frequency ranges should be incorporated. This is discussed more within the target development Section 5.2.

Table H-2: Summary of Pool Frequency Reference Values for Grave Creek Watershed.

Stream Order & Type (Bankfull Width)	Streams	Pool Frequency (pools/mile)
B & C, Mostly B, 10'-20' (generally 2nd and 3rd order)	Williams Lake; Clarence (14'-17', 7'); Stahl (12'-20', 40'); S. Fk. Stahl (12'); Lewis (7'-16'); Foundation (7'-18')	73 – 118 Low end of range can be modified down to 56 when streams approach 20' width
B & C 20'-35' (generally 3rd and 4th order)	Upper Grave (30'-34'); Williams (16'-39'); Clarence below Stahl; Blue Sky (17'-23')	47 – 66 Low end of range can be modified down to 35 when streams approach 35' width
B & C; 35'-50' (generally 4th or 5th order)	Middle Grave (38'-57');	29 – 47 Low end of range can be modified down to 26 when streams approach 50' width
Lower Grave Creek B & F (> 40")	Lower Grave Creek	29 – 47 Low end of range can be modified down to 26 or lower when streams approach or exceed 50' width
Lower Grave Creek C (>40')	Lower Grave Creek	12 - 24

H.2 Large Woody Debris (LWD)

Large woody debris frequency (total pieces of LWD/mile) is a parameter used as a physical habitat indicator. Large woody debris (LWD) is considered an important habitat feature for cold-water fish, particularly for bull trout. In many streams, LWD can play an important role in forming pools or creating pools with greater residual pool depths. LWD can also help establish streambed stability, dissipate energy, and directly influence sediment storage (Rosgen, 1996).

The same sources for developing pool reference data were used for developing large woody debris reference values. Additional sources of information include information in the Plum Creek Timber Company Habitat Conservation Plan (Plum Creek Timber Company, 2000), which includes reference data from Western Montana streams.

Factors that can influence a stream's ability to retain LWD within the active channel will be a function of stream size, stream gradient, and the overall size of the LWD piece (both diameter and length) relative to stream size and energy. Higher numbers of LWD are typically associated with narrower and lower order streams. Overall, the LWD results tend to show high variability within data sets.

Streams were broken into the same size categories for developing and applying LWD reference values as was done for pool reference development (Section H.1.1). Similar to pool frequency, the higher the number of LWD, the better the habitat conditions within the ranges discussed in this section. Therefore, values above the high end of the reference range would be considered desirable in most situations, and values below the low end of the reference range would typically be considered undesirable. Table H.3 presents the LWD frequency data from the reference sources. Not included is the Forest Service RMO of about greater than 20 pieces greater than bankfull width per mile since this value is not protective given the much higher reference range results.

H.2.1 Large Woody Debris Reference Values for B & C Streams with Bankfull Widths of about 10 to 20 Feet (Generally 2nd and 3rd Order Streams)

Data in Table H-3 show that the smaller streams tend to have larger numbers of LWD. The Libby Ranger District values for B and C streams 10 to 19 feet in bankfull width had an average of 293, a median of 252, a 25th percentile of 163, and a 75th percentile of 371. The Rexford streams less than 20 feet wide had an average LWD value of 181, less than the Libby average possibly due to the 1910 fire impacts discussed above. Data from the Lolo National Forest shows an average value of 772 for 2nd order B and C streams, implying much higher obtainable values in small streams. For the Table H-3 results not stratified by size, the Hayes western streams data has a median of 450 with a 25th to 75th percentile range of about 290 to 820; and the Plum Creek HCP streams east of the Cascades have a median value of 290 with a 25th to 75th percentile range of 105 to 450. Data were not collected for streams less than 19 feet in bankfull width in the Swan watershed.

The Libby reference information was chosen as the best representation of reference conditions based on a regional information approach for primary reference development and available statistics. Using the 25th to 75th percentile from this data set results in a LWD reference range of 163 to 371 pieces per mile.

H.2.2 Large Woody Debris Reference Values for B and C Streams with 20 to 35 Feet Bankfull Width (Generally 3rd and 4th Order Streams)

The data in Table H-3 show the Libby Ranger District Data for B and C streams with widths between 20 and 32 feet had an average of 301, a median of 264, a 25th percentile of 112 and a 75th percentile of 443. The Lolo results for 3rd and 4th order streams averaged 156 pieces per mile, and the Rexford average for streams greater than 20 feet was 152. In the Swan, 3rd and 4th order streams with bankfull widths between 19 and 35 feet had an average of 336, a median of 259, a 25th percentile of 123, and a 75th percentile of 507. Other data in Table H-3 also show relatively high values with significant variability.

The Libby reference information was chosen as the best representation of reference conditions based on a regional information approach for primary reference development and the availability of non-parametric statistics. Using the 25^{th} to 75^{th} percentile from this data set results in a LWD reference range of 112 to 443 LWD pieces per mile. Although there are only three C stream values from the Libby data set, the Table H-3 results suggest much higher LWD values for wider C streams. This may be due to high gradient, relatively wide upstream B reaches that are efficient at transporting LWD to the lower gradient C reaches.

H.2.3 Large Woody Debris Reference Development for B and C Stream Reaches Generally 35 to 50 Feet Wide (Generally 4^{th} or 5^{th} Order Streams)

In Table H-3, the Swan data set from four stream reaches provides the only reference results for streams with bankfull widths that tend to range from greater than 35 feet to 50 feet. The data show an average value of 206, a median of 108, a 25^{th} percentile of 104, and a 75^{th} percentile of 210. The difference between the median (108) and the average (206) shows the big influence one high result can have on the average value using parametric (normal) statistics, whereas the median value from non-parametric (non-normal) statistics applied to this small data set is not influenced as heavily by one data point.

The Swan reference information was chosen as the best representation of reference conditions using a regional information approach for primary reference development. Using the 25^{th} to 75^{th} percentile from this data set results in a LWD reference range of 104 to 210 LWD pieces per mile.

H.2.4 Lower Grave Creek Large Woody Debris Reference Development

Lower Grave Creek consists of some Rosgen C, B and F reaches that tend to fall between 40 to 60 feet wide, although some C reaches below the GLID are even wider. Due to the similar size ranges, the reference value range of 104 to 210 developed above is also applied to the sections of Grave Creek above the GLID where the riparian forest is similar to the upper watershed. The lower section below the GLID opens into more of a cottonwood – conifer mix, with greater uncertainty about the role of LWD and application of the Table H-3 reference information. The 104 to 210 pieces of LWD per mile reference range is applied only as an indicator to help assess overall conditions in this reach.

H.2.5 LWD Aggregates

An overlooked feature is the importance of LWD aggregates, which also play an important habitat and water quality role similar to individual pieces of LWD. A stream with low LWD values may actually have significant LWD related habitat in the form of LWD aggregates. These aggregates can also play a significant role in establishing streambed stability, dissipating energy, and influencing sediment storage similar to single pieces of LWD. Based on review of the Swan Watershed aggregate data and the large number of aggregates found in the Grave Creek Watershed, an additional LWD related reference condition that incorporates aggregates also applies. This condition requires an additional 40% increase in single pieces of LWD or aggregates above the reference levels defined above. For example, if there was a reference value of 100 pieces of LWD per mile, an additional reference value is 140 pieces of LWD and/or aggregates. The 40% is derived from the average number of aggregates divided by the average number of pieces of LWD in Swan stream reaches where lower levels of LWD were encountered (from 100 to 158 single pieces of LWD). This relatively high percentage of shows that these LWD aggregates play an important habitat role and can compensate for lower single LWD counts in healthy streams. Rootwads also play an important role in habitat formation, similar to LWD. Where assessment data identify rootwads, these can be counted toward the total summary of LWD type features when comparing to reference conditions.

H.2.6 Reference Values Summary

Table H-4 summarizes the LWD reference values developed above. The reference value that includes both the single LWD pieces along with the aggregates is the preferred value where a data set includes both single pieces and aggregates. This is the situation for the Grave Creek Watershed dataset, which also includes rootwads that can be counted toward meeting the reference value.

Similar to the application of pool reference ranges, the LWD reference values also allow for some overlap, particularly in the 3rd order streams with widths ranging from 15 to 20 feet. This is because of the desired grouping of assessment results by larger stream segments as reported within Section 4.0. Under these conditions, values that fall between the two LWD frequency ranges may need to be considered to compensate for this overlap.

Table H.3: Large Woody Debris Reference Sources and Data.					
Source	Stream Order and/or Type (Bankfull Width)	LWD pieces/mile (not including aggregates)			
Swan River Tributaries: Jim, Goat, Piper, and Elk Creeks	B & C, 19'-35' (generally 3rd and 4th order)	Range: 105-734 25th Percentile: 158 75th Percentile: 507 Median: 259 Average: 336			
Four Swan River Tributary Reaches in Jim, Goat, and Elk Creeks;	B & C, 35'-45', (generally 4th or 5th order)	25th Percentile: 104 75th Percentile: 210 Median: 108 Average: 206			
Plum Creek HCP Target	Various streams east of Cascades	412 ± 301			
Reported in PCTC HCP, 2000	Western Montana Streams	25th to 75th Percentile: 290-820 Median: 450			
Unpublished Plum Creek Data	Various streams east of Cascades	25th to 75th Percentile: 105-450 Median: 290			
Lolo NF Undeveloped Conditions	2nd Order B & C	Average: 772			
Lolo NF Undeveloped Conditions	3rd and 4th Order B & C	Average: 156			
Kootenai NF, Libby Ranger District		**Range**	**25th/75th**	**Median**	**Average**
	B < 20' (10' - 17')	100-660	168/409	293	333
	C < 20 (15' – 19')	68-211	119/191	170	150
	B&C < 20' (10' – 19')	68-660	163/371	252	293
	B > 20 (21' – 26')	12-754	74/451	149	274
	C > 20' (23' – 32')	264-480	321/429	377	374
	B&C > 20' (21' – 32')	12-754	112/443	264	301
Kootenai NF, Rexford Ranger District	<19.7'	181			
	>19.7'	152			

Table H-4: Summary of LWD Reference Values for Grave Creek Watershed.			
Stream Order & Type (Bankfull Width)	Streams (Bankfull Width)	LWD / Mile Reference Value (minimum)	LWD and/or Aggregates per Mile Reference Value (minimum)
B & C, mostly B, 10'-20', (generally 2nd and 3rd order)	Williams Lake; Clarence (14'-17', 7'); Stahl (12'-20', 40'); S. Fk. Stahl (12'); Lewis (7'-16'); Foundation (7'-18')	163 - 371	228 - 519
B & C, 20'-35', (generally 3rd and 4th order)	Upper Grave (30'-34'); Williams (16'-39'); Clarence below Stahl; Blue Sky (17'-23')	112 - 443	157 - 620
B and C, 36'-50', generally 4th or 5th order)	Middle Grave (38'-57'); Lower Grave F Reach (42')	104 - 210	146 - 294
Lower Grave Creek C, F & B (40' – 60' and wider)	Lower Grave Creek C, F & B (47'-48'; 50'-54')	104 - 210	146 - 294

H.3 Reference Development for Macroinvertebrate Metrics

Macroinvertebrate metrics are commonly evaluated and used to help with beneficial use support conditions throughout Montana. The MDEQ applies standard protocols for evaluating the macroinvertebrate data based on a primary reference development approach that is commonly updated as more information becomes available. No additional reference development is required within this document; any macroinvertebrate results will be subject to standard MDEQ protocols for evaluating the data against reference conditions. Unfortunately, there are limited macroinvertebrate sample results from the Grave Creek Watershed (Section D.5).

H.4 Substrate and Surface Fine Sediment Measures

Excess fine sediment is typically referred to as a "siltation" cause of impairment on Montana's 303(d) list, with potential impacts often relating to excess subsurface fines in spawning gravels or excess surface fines in riffles. Excessive surface and substrate fines may limit fish egg and embryo survival. Macroinvertebrate richness may also be limited by excess surface fines, thus limiting aquatic life and potentially having a negative impact on cold-water fish that rely on macroinvertebrates as a food source (Suttle et al., 2004).

Fine sediment on the channel bed surface and within the channel substrate may be evaluated in several ways. McNeil core samples may be used to determine the percent of fines in the upper several inches of channel substrate, usually in pool tail outs where fish spawning is likely to occur. The 49-point grid toss method may be used to determine percent surface fines < 6.35 mm at pool tail outs and riffles, although data from pool tail outs is used in this document. Pebble counts may also be used to evaluate surface fines in riffles and pools, with composite data from both riffles and pools used in this document. Grid-toss and pebble count measures of surface fines can also be used as surrogates for assessing substrate fines. For pool tail outs, McNeil coring is believed to be a more consistent method for evaluating the impacts of fines on spawning success than the grid-toss method, and is therefore a preferred method. However, McNeil core data were available for only a few sites in the Grave Creek Watershed, whereas there was significant surface fines data using both the grid toss and pebble count methods

H.4.1 Relationships Between Subsurface and Surface Fine Sediment and Beneficial Uses

A study by Weaver and Fraley (1991) showed a direct correlation between successful fry emergence and fine sediment in spawning gravels, with increases in the percentage of fine sediment < 6.35% resulting in a decrease in fry emergence. Research by macroinvertebrate specialists (EPA, 2004) indicates that surface fines (< 2 mm) need to be elevated to levels between 20 – 40%, based on riffle pebble count data, to result in a decrease in macroinvertebrate richness. Therefore, values less than 20% may not be contributing to impairment, even if elevated at levels greater than comparable reference streams. Fine sediment levels in pool tail outs (glides), riffles, and/or composite pebble count results can be used as an indicator of potentially high levels of surface fines in riffles, as an indicator of impacts to macroinvertebrate, or as an indicator of excess fines in subsurface material where McNeil Core data is not available. Elevated fine sediment results from riffle pebble counts can also be an indicator of a potential impact to fish spawning substrate, even if the values are below the 20% level where impacts to macroinvertebrate populations could be anticipated.

Unlike LWD and pool frequency, where higher values are generally considered better, the development of reference values for surface or subsurface fines is typically based on a maximum value of acceptable fine sediment. This is because lower values are considered more desirable unless the values get so low that the data could be an indication of a different type of sediment and habitat problem such as a degrading system. The reference value development can focus on using a 75th percentile or one standard deviation added to the average of a reference database to determine an acceptable maximum value. The 25th percentile or one standard deviation subtracted from the average of a reference database can be used as a minimum value below which the data may be an indication of a degrading system or other problems.

H.4.2 Reference Development for Substrate Fines < 6.35 mm

Table H-5 presents reference data for substrate fines. MDEQ and the Flathead National Forest established McNeil core percent fine reference conditions for the Big Creek TMDL of less than or equal to 30 percent substrate fines (< 6.35 mm) for a McNeil core sample. This was based on historical data from Big Creek. Other TMDL target conditions are based on local or regional reference conditions typically in the range of

28 to 35 percent fines < 6.35 mm. These reference conditions are generally based on a 75th percentile or upper end of a reference range.

McNeil Core data from Grave Creek (Table 4-3) range from 20 to 25 percent from three recent years of sampling. Results from McNeil Core sampling by the Kootenai National Forest show average percent substrate fines at reference sites monitored from 1997 – 2003 ranged from 17 to 29 percent with similar median values (Table H-5). The 75th percentile values typically fall below 28 percent, and the 25th percentile values are all greater than 15 percent. This data is considered a reasonably applicable representation of expected conditions in Grave Creek. Therefore, for Grave Creek, a McNeil Core sample reference value range of 15 to 28 percent substrate fines < 6.35 mm is selected using a regional reference primary approach, supplemented by the fact that internal reference data suggests that results from Grave Creek should continue to fall within this range. Although the focus is on the upper limit, values below 15 percent should be investigated as a potential problem that could be associated with a lack of adequate spawning sites linked to pool/glide formation problems.

Table H-5: Reference Data for Substrate Fines (< 6.35) Using McNeil Core Sampling.

Source	Percent Fines				
Big Creek (Flathead)	30 (based on average plus one standard deviation)				
TMDL Targets from Other Watersheds in Western Montana	28 – 35 (generally based on 75th percentile or upper end of reference range)				
Kootenai Sampling (1997-2003)	**Average**	**Stnd Dev.**	**25th Percentile**	**75th Percentile**	**Median**
Bear Creek	19.0	6.0	16.7	22.5	19.5
Flattail Creek	26.7	7.2	23.2	28.3	26.0
Himes Creek #1	29.1	4.4	26.4	28.2	27.5
Libby	25.4	4.5	24.4	27.9	26.0
West Fork Quartz (Upper)	17.1	3.6	15.2	18.0	16.5
Upper Silver Butte	21.0	4.3	19.2	23	21.5

H.4.3 Reference Development for Surface Fines in Riffles Based on Pebble Count Results

Reference development considered existing watershed conditions and ongoing reference development work in the Yaak Watershed. Pebble count results for surface fines < 2 mm from throughout the Grave Creek Watershed (Table 4-4) are all less than 9 percent except for one 10% and one 12% result from B4 reaches in middle and upper Grave Creek and one 12% result in a B4(a) reach of Blue Sky Creek. In these situations, the < 6.35 mm pebble count results are also relatively high at 15% for the middle Grave Creek reach, 18% for the upper Grave reach and 20% for the Blue Sky reach. All other < 6.35 mm pebble count results are less than or equal to 15% with the exception of one 17% result in Stahl Creek (B3(a) stream type) and one 19% result in Lewis Creek (B4(a) stream type). Since the majority of results for the < 2 mm data are equal to or below 9%, this 9% is chosen as an indicator of potential increasing fine sediment in the watershed. Similarly, the majority of results for the < 6.3 mm data are equal to or below 15%, making this 15% an indicator of potential increasing fine sediment. These are not true reference values since Grave Creek is not a reference stream, but they do represent values that can be tracked to indicate potential increased fine sediment inputs.

The reference development work in the Yaak (EPA and KNF unpublished data) has resulted in < 6.35 mm pebble count percent fines reference data mean values ranging from 10 to 13% for B3, B4, C3 and C4 stream types. These results are similar to the average results for the Grave Creek Watershed. The applicability of the pebble count information will be further discussed in Section 5.2, taking into consideration the apparent 20% threshold for surface fines < 2 mm while also considering the fact that percent fines can be an indicator of other beneficial use support impacts, or lack of such impacts.

H.4.4 Reference Development for Surface Fines in Pool Tails (Glides) Based on Grid Toss Results

Reference development for percent surface fines using the grid-toss method is based on results from several studies (Table H-6). Percent surface fines impairment threshold for the Blackfoot Headwaters TMDL was set at about 6 percent to 8 percent, representing the 75th percentile of the reference condition. This data was collected using a variation of the grid toss approach referred to as a “viewing bucket” approach. Average grid toss reference condition values measured in undeveloped watersheds on the Lolo National Forests (USFS, 1998) ranged from about 6 percent to 8 percent surface fines, with the upper end of one standard deviation values in the approximate range of 15 to 20%. If non-parametric statistical analysis had been performed on this data set, the 75th percentile would be lower than this 15 to 20 percent range, probably in the 10 to 15 percent range. This is based on graphical data presentations from the USFS report and the fact that the low end of one standard deviation is cropped at 0, both of which imply a skewed distribution. The median percent surface fines values collected during R1/R4 surveys (grid toss) along Grave Creek and within tributary streams all range from 0 to 10%, with 75th percentile values typically between 5 and 15% fines < 6.35 mm (Section 4.0).

Based on existing conditions in the watershed, and the reference information presented in Table H-6, a median value of 10% < 6.35 mm is used as a reference condition based on a preference toward using the more robust Lolo data set which used comparable methodology to the data collection in Grave Creek Watershed. The Lolo data suggests a 10 – 15% upper range, which is supplemented by internal Grave Creek Watershed data that suggest the median value from multiple grid tosses in a reach should remain below 10%. Values above this indicate increasing sediment loading in the watershed and can be an indicator of negative impacts to a beneficial use.

Table H-6: Reference Data for Grid Toss Surface Fines (< 6.35 mm)	
Source	Percent Fines
Lolo NF (USFS, 1998)	6 – 8 (Average); 15 – 20 (upper end of one standard deviation); 10 – 15 probable range of 75th percentiles
Blackfoot Headwaters TMDL Reference Condition	6 – 8 (75th percentile)
Grave Creek Watershed median values	5 - 10

H.4.5 Summary of Substrate and Surface Fines Reference Conditions

Table H-7 summarizes the substrate and surface fines reference conditions. It should be noted that the substrate fines (McNeil Core sampling) reference development is based on a primary approach using regional reference streams. The same holds true for the grid toss results. The pebble count reference approach is a combination of internal reference information, limited regional reference data, and professional judgment. The selected pebble reference values can be used as an indicator of increased sediment loading, but needs to be used cautiously for any other reasons. Fortunately, the expected < 2 mm upper range value is well below the 20% value at the lower end of potential impact to aquatic life (EPA, 2004) and all results in Grave Creek are well below 20%. Note that these pebble count results are composite pebble counts as described in Appendix F, and care must be taken in directly comparing these results to the 20% potential impacts to aquatic life value.

Table H-7: Summary of Substrate and Surface Fine Reference Values for the Grave Creek Watershed.	
McNeil Core Substrate Fines (< 6.35 mm)	15 - 28%
Grid-toss Surface Fines (< 6.35 mm)	≤ 10%
Pebble Count Surface Fines (< 2 mm)	≤ 9 - 12%
Pebble Count Surface Fines (< 6.35 mm)	< 10 to 15%

H.5 Width to Depth Reference Development

Width to depth is an important indicator of proper channel function. Rosgen stream types represent important data stratification for any width to depth measures. Also, stream width is an important consideration, with larger, wider streams generally having a naturally higher width to depth ratio. Width to depth is normally measured as bankfull width to average bankfull depth at riffle cross sections.

Reference data sets for width to depth include the Lolo National Forest information (USFS, 1998), reference summary data from the Kootenai National Forest (unpublished data, 1998), results from within the Grave Creek Watershed, and the internal reference reach results for lower Grave Creek (Section G.4.1.2.5). Historical stream width information from the aerial assessment work (Section G.4.1.2.1) also provides an important indicator of width to depth changes over time from 1947 to 1992 since a significant increase in width can indicate a significant increase in width to depth. This is in realization of the fact that in 1947 the stream may have already been overly wide due to human impacts prior to that date. Table H-8 provides a summary of the reference information.

Table H-8: Width to Depth Reference Sources and Results.

Data Source	Stream Types & Other Stratification	Results
Lolo National Forest Reference Streams (recommended ranges based on reference data sets)	B3 & B4 C3 & C4	12 – 22 10 – 33
Kootenai National Forest Reference Data	B3 (stream widths 18 ± 9) B4 (stream widths 13 ± 4) C3 (stream widths 26 ± 4) C4 (stream widths 15 ± 3)	20.9 ± 9.0 (n = 34) 19.4 ± 6.9 (n = 22) 16.0 ± 7.4 (n = 4) 14.7 ± 3.2 (n = 3)
Grave Creek Watershed	B and C tributary reaches Middle and Upper Grave B & C	All < 20 All < 21 except one value at 29 where width = 49
Lower Grave Design Values from Reference Reach	C (50 – 54 ft design width)	18 – 22
Aerial Assessment Data for Lower Grave Creek	C Section from Canyon to Williams	Width increased 60 – 130 ft from 1947 to 1992; Width increase noted between 1954 and 1992

H.5.1 Lower Grave Creek C Stream Type Width to Depth Reference Development

The internal reference data for lower Grave Creek C reaches; supplemented by historical and regional data, provide primary reference approaches to help identify the width to depth reference range. The internal reference information results in a restoration design reference range of 18 to 22 for width to depth ratio. This range probably does not account fully for potential natural variability that could be experienced over time. To help evaluate this potential variability, the variability in other reference data is used. The standard deviation for the KNF C3 and C4 reference stream data ranges from about 3 to 7. The standard deviation range for B streams is about 7 to 9, with the B streams having much higher number of results. Using this information, “7” is chosen as a typical deviation and is added to the middle of the design range resulting in reference range of 13 to 27. This provides a more reasonable expectation for all of lower Grave Creek, including sections that may not undergo active restoration based on the 18 – 22 width to depth design range. Design values should still shoot for this 18 –22 width to depth ratio, but a measure of success over time would be based more on a 13 to 27 suggested reference range.

H.5.2 Width to Depth Reference Development for Other Stream Reaches in the Grave Creek Watershed

For other streams throughout the watershed, the Kootenai National Forest (KNF) width to depth reference information provides the best reference data due to the presentation of the average values and standard deviations, although the Lolo recommended ranges appear to be based on similar statistics. The KNF data is for streams with mean widths similar to the size of upper Grave Creek and tributaries to Grave Creek. The KNF data shows upper ranges of one standard deviation varying by stream type. The B stream upper width to depth values are 30 (B3) and 26 (B4); whereas the C stream data, based on significantly fewer measures, result in upper width to depth values of 23 (C3) and 18 (C4). This compares to the Lolo upper recommended values of 33 for B reaches and 22 for C reaches.

Review of the Lolo and KNF data suggests a skewed condition that would result in 75th percentile values that would perhaps be about midway between the average and one standard deviation if non-parametric statistics were applied to the data. This 75th percentile value would be close to 25 for both the B and C stream types when both data sets (Lolo and KNF) are considered and weighted by the number of results for each stratification. This 25 is therefore used as the upper end of the reference range for the Grave Creek Watershed above the GLID based on the regional reference data and applied professional judgment. The lower end of the range is 10 based on the lower end of the literature value of 12, with consideration for variability as suggested by the Rosgen classification approach. Therefore, the width to depth reference range is 10 to 25 for all other B and C stream segments other than the lower Grave C reach discussed above in Section H.1.5.1. This range is modified for reaches where existing data shows lower values already exist, as is the case throughout most of Grave Creek. Under these conditions, a 20% increase in width to depth would be considered outside the range of a reference value that is based on known stream conditions.

Table H-9 provides a summary of the reference value ranges for width to depth.

Table H-9: Summary of Width to Depth Reference Ranges.

Stream	Range
Lower Grave Creek	13 - 29
Grave Creek Watershed B & C Reaches	10 – 25; **and** no more than a 20% increase in reaches that currently fall within this range

H.6 Sinuosity

Sinuosity reference data was developed for the lower Grave Creek C section. For sinuosity, a commonly accepted value for C type streams is > 1.2 (Rosgen and Silvey, 1998). A value based on the lower Grave Creek internal reference reach is 1.4. Historical 1947 data showed a sinuosity of 1.23. Even in 1947 the stream had been impacted by channelization, suggesting the possibility of even higher sinuosity values. Therefore, a sinuosity reference range of 1.2 to 1.6 is applied based on internal reference data and the design goal of 1.4 with a plus or minus .2 incorporated. Higher values would likely be acceptable, but care should be taken in using higher values for design purposes. Values below 1.2 suggest an undesirable and over-straightened reach.

H.7 Meander Length Ratio

This parameter is based on the dimensionless ratio of the stream meander divided by the stream width using reference design values for the lower Grave Creek C reaches (Section G.4.1.2.5). It is an important stream restoration design parameter and can be used as an indicator of overall stream health. The meander length design value range of 13.8 to 19.2 will be used for meander length ratio reference value range. This value will only be used as an indicator of potential stream health problems in lower Grave Creek C reaches.