APPENDIX D - REFERENCE CONDITIONS AND TARGET VALUE RATIONALE FOR SEDIMENT

D1.0 REFERENCE CONDITIONS AND DATA SOURCES

Montana Department of Environmental Quality (DEQ) applies a reference condition to determine if narrative water quality standards are being achieved. The term "reference condition" is defined as the condition of a waterbody capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, reference condition reflects a waterbody's greatest potential for water quality given historic land use activities.

Waterbodies used to determine reference condition do not necessarily reflect pristine or pre-settlement conditions, or display conditions that meet all possible beneficial uses. A reference condition is intended to differentiate between natural conditions and widespread or significant alterations of biology, chemistry or hydrogeomorphology due to human activity. Therefore, reference conditions should reflect minimum impacts from human activities. Reference conditions look to accommodate natural variations in biological communities, water chemistry, etc., due to climate, bedrock, soils, hydrology and other natural physiochemical differences. A reference condition attempts to identify the potential condition that could be attained (given historical land use) by the application of reasonable land, soil and water conservation practices. DEQ recognizes that pre-settlement water quality conditions usually are not attainable.

The following methods may be used to determine reference conditions:

Primary Approaches

- Regional Approach:
  Compare conditions in a waterbody to baseline data from reference waterbodies that are in a nearby watershed or in the same region having similar geology, hydrology, morphology, and/or riparian habitat.
- Historical Approach:
  Evaluate historical data relating to condition of the waterbody in the past.
- Internal Reference Approach:
  Compare conditions in a waterbody to conditions in another portion of the same waterbody, such as an unimpaired segment of the same stream.

Secondary Approaches

- Literature Approach:
  Review literature (e.g. review of studies of fish populations, etc. that were conducted on similar waterbodies.)
- Professional Judgment Approach:
  Seek expert opinion (e.g. expert opinion from a regional fisheries biologist who has a good understanding of the waterbody's fisheries health or capability).
- Modeling Approach:
  Apply quantitative modeling (e.g. applying sediment transport models to determine how much sediment is entering a stream based on land use information, etc.).

DEQ prefers to use the primary approach for determining reference condition, particularly where adequate regional reference data are available. Secondary approaches are often necessary to estimate reference condition when there is no regional reference data. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent. This is particularly true where the translation of a narrative standard may involve multiple target indicator parameters. Some parameters may have good regional or internal reference information; whereas regional or other primary reference information may be lacking for other parameters. Historical quantitative reference condition information is rarely available; however, historical information can supplement secondary approaches with qualitative data and best professional judgment.

Three main sources of data served as information to help identify reference conditions in the Boulder-Elkhorn TPA. Target values for the parameters of interest were based on unpublished data from the Beaverhead-Deerlodge National Forest, data from the USFS PIBO program, and from data collected during the 2010 DEQ Boulder-Elkhorn TPA sediment/habitat field study.

Beaverhead Deerlodge Regional Reference Data Regional reference data are available from the Beaverhead Deerlodge National Forest (BDNF). BDNF data were collected between 1991 and 2002 from approximately two hundred reference sites: seventy of the sites are located in the Greater Yellowstone Area and the remaining sites are in the BDNF, which is also located in southwestern Montana (Bengeyfield, 2004). Due to the size of the BDNF, a subset of sites from the dataset were selected that were located within the Boulder-Elkhorn TPA or adjacent watersheds. Applicable reference data are width/depth ratios, entrenchment ratios, and percent fine sediment <6mm from pebble counts.

United States Forest Service Pacfish/Infish Biological Opinion (PIBO) data (2010) was reviewed for the following parameters: percent fines less than 6mm in pool tails, residual pool depth, pool frequency, and large woody debris frequency. In the PIBO dataset, two sets of data were reviewed, data from managed sites, and data from reference sites. PIBO classifies their reaches as follows: “Watersheds are considered reference if there had been no livestock grazing within the past 30 years, less than 10% of the watershed had undergone timber harvest, there was no evidence of mining in proximity to riparian areas, and road density was less than 0.5 km/km2. Managed watersheds included a full complement of management activities, including timber harvest, road building and maintenance, livestock grazing, mining, and recreation” (Kershner et al., 2004). For analysis purposes, data from managed sites were selected from watersheds within the Beaverhead Deerlodge National Forest and Helena National Forest, and from similar level IV ecoregions to what is found in the Boulder Ellkhorn TPA. However, due to the small number of PIBO reference sites within the Boulder Elkhorn area, analysis of reference data includes sites from the similar, but broader encompassing Middle Rockies ecoregion, although not necessarily within or adjacent to the TPA. Data was used from 32 managed sites, and 72 reference sites.

2010 DEQ field data was used for the development of all parameter values. All streams were stratified into reaches using four main criteria: valley gradient, valley slope, stream order, and ecoregion. These reaches were further subcategorized based on adjacent land use and vegetation. 23 reaches were selected, and data from sites within each of the selected reaches was collected on streams throughout the Boulder River watershed. No reference reaches were identified from the reaches that were sampled; however, in the sampling analysis design for the 2010 field data study, sites were chosen to try to represent the variability among reach type categories and stratification parameters, and therefore include reaches that characterize a range of conditions. Sampled sites were also dependent on landowner permission and accessibility. Most of the reaches assessed in the Boulder-Elkhorn study represent conditions where past or present human activities have left signs of significant to moderate effects, however a few of the reaches do reflect healthy conditions in the study area that may be representative of all reasonable land, soil, and water conservation practices, with limited land use effects on the stream.

D2.0 TARGET VALUE DEVELOPMENT

Target values are often presented for a range of conditions based on stream size, parent geology, or other significant factors that influence stream function and response. For instance, depending on the setting, sediment and habitat conditions in a 5th order stream may vary considerably from those in a 2nd order stream and therefore assessing the respective condition of each against the same target values would be inappropriate for some target parameters. In the Boulder-Elkhorn TPA, data was sorted and analyzed based on reach type, level of impact (reference vs. non-reference), stream gradient and stream size (bankfull width); and target values were determined based on the best approach for analysis for a given parameter.

The use of median and percentiles in statistical analysis is often employed when data, such as water quality data, tend to have a non-normal distribution. Also, limited amounts of data can sometimes result in skewed results if using normal distribution statistics. For these reasons, it is more appropriate to use non-normal or non-parametric statistics for setting reference conditions and determining target values for most parameters.

The use of a non-parametric statistical distribution for interpreting narrative water quality standards or developing numeric criteria is consistent with EPA guidance for determining 'water quality' criteria (U.S. Environmental Protection Agency, 1999). Therefore, the selection of the applicable statistics from a data set is consistent with ongoing development of DEQ and EPA guidance for interpreting narrative water quality standards.

If parameters are used where lower values represent better water quality conditions, then typically the 75th percentile of the reference data set is used as a potential target value. If higher values represent better water quality conditions then the 25th percentile would apply. If a dataset is known to represent a variety of conditions, and not just reference conditions, or where there is less confidence in the data to represent reference conditions, the median may be used. If a dataset is known to largely represent impacted conditions, then the opposite percentiles as mentioned above can be used, e.g. the 25th percentile of an impacted data set may be used to develop a percent fines target value (where lower values represent more desired conditions).

As described in Section D1.0, no reference sites were identified from the DEQ data set when developing target values. However most sites that were investigated represented conditions affected by human influence of varying degrees, with few sites representative of a desired to near-desired condition. Because of this, generally the quartile of the population of the DEQ data was the primary value of interest (opposite the quartile that would be reviewed under reference conditions). The USFS PIBO data contains both reference and non-reference (managed) data. The Beaverhead-Deerlodge NF data also contains reference and non-reference data sets. These data sets were reviewed and comparisons between the median of non-reference and quartiles of the reference data sets were used to help inform the target development. Medians were used from these data sets because it is assumed that managed or non-reference contains a wide range of variability that includes a relatively balanced spectrum of desired and undesired condition. The statistics from both the DEQ and PIBO or BDNF data were then compared and target values determined based on these comparisons, best professional judgment, and relation to commonly accepted literature values.

Information and rationale used to derive target values follow below. Target parameter description and rationale for inclusion is presented in **Section 5.4**.

D2.1 Width Depth Ratio

Width to depth ratios provide a metric by which we can assess the form, and therefore, relative function of a given reach. Lower values signify a narrow, deep channel, whereas larger values may indicate unnatural overwidening and shallowing of a reach. Criteria based on Rosgen stream type classification for width to depth ratios gives guidance of <12 for A, G and E stream types, and >12 for F, B and C stream types. While the upper limits are not provided for values >12, data from BDNF and DEQ can be reviewed to provide a range of targets that better represent desired conditions.

For the width/depth parameter, BDNF data was organized and reviewed according to reference sites, and managed sites. The 75th percentile of the reference sites served as the focus for evaluating a target value. The median value for managed site groupings was also reviewed, as it is assumed that the median represents desired width/depths when investigating a variety of conditions which encompass a varying level of response.

Width/depth ratios for F, B, C stream types are defined as >12, where 12 serves as the low end of the width/depth ratio range. The upper end of the range for a stream type is not defined by Rosgen classification, however it is understood that the higher the width depth ratio value, the more likely it represents conditions of disturbance to the natural form and function of the stream. Therefore, targets are developed here to provide a guideline for the upper limit of width depth ratios for the Boulder-Elkhorn watershed for B and C channels, and thereby signal when stream channel dimensions may be out of proportion.

Width/depth ratio is a dimensionless ratio that is therefore applicable regardless of stream size. However it is theorized here that larger rivers may have a somewhat higher upper range of width/depth values than smaller streams (3rd order or less). From Rosgen's Applied River Morphology textbook:

> "The distribution of energy within channels having high W/D ratios (i.e., shallow and wide channels) is such that stress is placed in the near bank region. As the W/D ratio value increases (i.e., the channel grows wider and more shallow), the hydraulic stress against the banks also increases and bank erosion is accelerated. The accelerated erosion process is generally the result of high velocity gradients and high boundary stress, as mean velocity, stream power, and shear stress decrease in the presence of an increase in width/depth ratio values. Increases in the sediment supply to the channel develop from bank erosion, which – by virtue of becoming an over widened channel – gradually loses its capability to transport sediment. Deposition occurs, further accelerating bank erosion, and the cycle continues."

Due to the years of disturbance and accelerated bank erosion in many places throughout the Boulder River watershed, it is expected that high width/depth ratios will be observed. However, it is also expected that under naturally occurring conditions, the stream size and sediment loads that exist in the

Boulder watershed may result in higher width/depth ratios than might be found in the smaller tributaries. For that reason, a width/depth ratio target for the Boulder River has been selected to account for this possibility. However, the Boulder River width/depth ratio is developed based on professional judgment and literature research as no data from streams the size of the Boulder River existed in the reference data set, other than five reaches from the Boulder River itself collected during DEQ's field effort. It is acknowledged that due to the scale of bank erosion and other sediment sources from the Boulder River watershed to the Boulder River, recovery of width/depth ratios in the Boulder River will take a significant effort and many years to accomplish.

Upon review of the width depth ratio results (**Table D-1**), a width/depth ratio of ≤13 is selected for the target value for tributary B streams, and <18 is selected for the target value for tributary C streams. For B streams, a value of 13 is roughly consistent with the 25^{th} percentile of the field data, the 75^{th} percentile of BDNF reference, and near in value to the median of the BDNF managed. The value of <18 for C stream is selected largely because the 75^{th} percentile of the BDNF reference data. Although the 25th percentile of DEQ field data and the median of BDNF managed are both near 15, knowing that C channels are typically classified as having width/depth ratios >12, and B channels are defined as <13, using the BDNF reference value provides some acceptable variability in C stream width/depth ratios while using known reference reaches to define the upper limit.

Due to the increasing size and stream power for the Boulder River, the width/depth target for the mainstem Boulder River is <30. As there were only 5 sites that were sampled on the Boulder River, all of which were 4^{th} order or larger, best professional judgment and recognition that these sites have been affected by past anthropogenic activities was factored into the determination of ≤30 as a conservative target value. Values used as width to depth targets in prior TMDLs dealing with similarly sized streams (e.g., Prospect Creek, width/depth target of <30; St. Regis, width/depth target of <30) also suggest <30 is appropriate.

Table D-1. Width to Depth Values

B Channels	**25^{th} Percentile**	**Median**	**75^{th} Percentile**
DEQ Field Data (n=45)	**12.9**	16.4	21.9
BDNF Reference (n=18)	9	10.4	**12.9**
BDNF Managed (n=156)	7.3	**10.9**	15.8
C Channels			
DEQ Field Data (n=35)	**14.5**	18.2	36.5
BDNF Reference (n=10)	10.2	13.1	**17.9**
BDNF Managed (n=53)	12.6	**15**	18.5

*Width to depth of <12 applies to low gradient E channels based on Rosgen stream classification criteria.

D2.2 ENTRENCHMENT

Criteria from Rosgen stream type classification for entrenchment gives guidance of <1.4 for A, F and G streams, 1.4-2.2 for B streams, and >2.2 for C, E streams. These literature values will serve as the target ranges for entrenchment in the Boulder-Elkhorn TPA as well. Entrenchment values >2.2 for C and E stream types are described by Rosgen as slightly entrenched to non-entrenchment as the values increase. The higher the entrenchment value the greater accessibility of streamflow to the floodplain at or greater than bankfull flow, and therefore, high entrenchment values are for C, E stream types are not considered to indicate instability. While there is no upper limit to an entrenchment value, typical entrenchment values for stable C and E streams in the Boulder-Elkhorn watershed are expected to be around 3.0 or greater, as observed in the data set (**Table D-2**).

Table D-2. Entrenchment Values

C Channels	**25th Percentile**	**Median**	**75th Percentile**
DEQ Field Data (n=35)	2.3	3.3	**6.3**
BDNF Reference (n=10)	**2.6**	3.2	4.9
BDNF Managed (n=53)	2.4	**3.2**	4.8
E Channels			
DEQ Field Data (n=25)	1.7	3.4	**5.1**
BDNF Reference (n=43)	**3.7**	10.9	26
BDNF Managed (n=183)	2.7	**4**	7.7

D2.3 Percent Fines Analysis

Percent fines provide a measure of substrate composition in key habitat features necessary for fish and aquatic life. Typically, riffles and pool tails are focused on due to their importance as spawning habitat and macroinvertebrate habitat.

DEQ field data and BDNF reference site data was used to develop targets for percent fines <6mm and <2mm in riffles. Percent fines data for the BDNF was only available from reference sites (not managed sites) and only for percent fines less than 6mm. In developing percent fines targets, differences in the data collection methodology between the Beaverhead Deerlodge NF and DEQ datasets necessitates some discretion when comparing results. DEQ collects percent fines data from riffles using the Wolman pebble count method. BDNF percent fine data is collected using a pebble count, but using the zigzag method which is not necessarily confined to riffles and therefore may encompass features like pool and runs that tend to have higher fine percentages.

Data from the DEQ field sites and PIBO sites was used to evaluate percent fines in pool tails. BDNF data did not include pool tail information. Pool tail values are presented as reach averages. DEQ and PIBO data is collected from pool tails using the grid toss method, and assesses those particles less than 6mm. There are some slight differences between DEQ and PIBO methods in the identification of pool tail sampling locations which should be considered: PIBO identifies pools that are wider than 50% of the wetted channel and have a maximum pool depth of 1.5 times the pool tail crest depth, and takes grid toss measurements at locations roughly equivalent to the ¼, ½, and ¾ distance points around the pool tail crest. DEQ also identifies pools that have a maximum pool depth of 1.5 times the pool tail crest depth, but does not distinguish size laterally. In addition, DEQ focuses grid toss measurements on those pool tails where it appears there is spawning potential. Spawning potential is defined as those pool tails that contain substrate size that would be moveable by fish typically found in the stream of interest. DEQ also focuses their grid toss measurements in those locations around the pool tail crest where spawning potential appears to exist. Generally, these differences in methodology may not reflect much difference in results, however it is noted that the PIBO methods are more rigid and easily repeatable, although do not necessarily have a direct relationship to spawning habitat quality; whereas DEQ methods, while more subjective and requiring best professional judgment in the field, are presumed to be a better reflection of the direct linkage between pool tail substrate and spawning potential.

It should also be noted that the percent fines targets described below are appropriate for those stream habitats and stream types that best show the effects of sediment accumulation in spawning areas.

These targets may not apply to Rosgen E channels, which typically exhibit much higher natural values of percent surface fines. Percent fines in E channel reaches should be evaluated on a case by case basis. Percent fines evaluations should occur in riffle and pool tails in Rosgen B and C Reach types as these often most clearly illustrate effects from percent fine accumulation.

D2.3.1 Percent Fines in Riffles (Wolman Method) - <6mm

Percent fines data are reviewed here in relation to the slope of the reach they are taken from. It is expected that in general, higher gradient reaches (slopes greater than 2 percent) act as transport reaches, and the velocity and turbulence within these reaches do not allow for as much sediment accumulation, in comparison to low gradient reaches, which are usually depositional reaches more likely to reflect signs of excess sediment.

In addition, sites from the BDNF reference data set, with bankfull widths less than 5 feet were excluded from the data pool. It is assumed that very small streams such as these have little capacity to move sediment, and in some cases, due to the small size and energy of the streams, the stream bottom material itself is naturally comprised of small particles. Inclusion of these results may skew the data to indicate potential target values which would not be appropriate for those streams.

Upon review of the available data, a value of <16.0 % is chosen for the target of percent fines <6mm. This is based on a review of the median and 75th percentile of the Beaverhead Deerlodge reference values. In this review, the 75th percentile of the BDNF reference data set is considerably higher than values typically cited as target values for percent fines, and is above literature values that look at harmful effects to aquatic life. These higher values may be somewhat a function of the data collection method differences, and therefore further justify the review of the median. These higher values may also be due to some areas of the Boulder River watershed which contain Boulder Batholith geology that is more erosive and produces coarse, small grain material (although this form of geology is not present throughout the entire watershed). The median of the data set however is within a range of typical values for percent fines <6mm, and relates with the 25th percentile from the DEQ field data.

In this case, the BDNF reference data appears to illustrate the concept of slope and transport capability, however the DEQ data does not. DEQ data shows higher fines in higher slope environments than in low slopes. However, since there are no reference sites in the DEQ data the results may be reflective of significant human effects rather than what can be expected under normal (reference) conditions. For this reason the low slope BDNF sites serve as the main reference to select a target value. It is expected that under naturally occurring conditions, transport reaches will have fewer percent fines than depositional reaches.

Table D-3. Wolman Pebble Count Percent Fines Values, <6mm (DEQ 2009 Data)

	25th percentile	**Median**	**75th percentile**
0-2% Slope			
DEQ Field Data (n=40)	**14.0**	20.8	33.6
BDNF – Reference; -<5 bkf (n=20)	9.5	**16.0**	32.0
>2% Slope			
DEQ Field Data (n=44)	**19.8**	27.0	35.0
BDNF – Reference; -<5 bkf (n=43)	5.5	**10.0**	21.5

D2.3.2 Percent Fines in Riffles (Wolman Method) - <2mm

No local reference data is available for percent fines <2mm in riffles. For this parameter, review of the 25th percentile of the total DEQ data set was found to be ~8% for both low gradient (0-2% slope) and high gradient (>2% slope) reaches. This value is below the minimum-effect sediment levels for sediment-sensitive species (13%) and aquatic macroinvertebrates (10%) as found by Bryce, Lomnicky, and Kaufmann (2010). Because there is no reference data available to compare field values with, the target for percent fines <2mm is set at <10%. This target value is based on the literature value for minimum-effect sediment levels for macroinvertebrates (10%), and also considers the fact that the 25th percentile of the DEQ data set is under this value (8%).

The target values for percent fine are not separated by gradient, but as discussed in section D2.3, it is expected that measured values in high gradient reaches would tend to be lower than values in low gradient reaches; however in this case, the DEQ data does not illustrate this idea. This may be in part due to the high gradient reaches in the DEQ dataset having a considerable amount of human influence, perhaps more so than the low gradient reaches in this study, which resulted in higher fines overall. It should be noted that high percent fines values in high gradient reaches may indicate increased sediment input and even higher percent fines values in low gradient reaches as well.

Table D-4. Wolman Pebble Count Percent Fines Values, <2mm (DEQ 2009 Data)

	25th percentile	Median	75th percentile
0-2% Slope			
DEQ Field Data (n=20)	**7.5**	11.7	30.2
>2% Slope			
DEQ Field Data (n=44)	**7.5**	14.6	27.5

D2.3.3 Percent Fines in Pool Tails (Grid Toss) - <6mm

In the case of percent fine data in pool tails, data exists for DEQ field sites, and PIBO reference and managed sites. In this case, the PIBO reference data again serves as the primary guide for determining the target value. The 75th percentile of the reaches with 0-2% slope (depositional reaches) is 13.5%. The target is therefore set at <13% percent fines less than 6mm in pool tails. DEQ field data with 0-2% slope did not exceed this target value in any quartiles.

The >2% slope data is presented here only to investigate the differences between transport and depositional reaches. Grid toss percent fines in reaches >2% slope were considerably higher in the PIBO 75th percentile and the majority of DEQ reaches, however, it is somewhat surprising that this would be the case because, as mentioned earlier, it is assumed that reaches of higher slopes have better ability to transport sediment and therefore would result in lower percent fines values. This may be explained in the DEQ data by the fact that a limited number of reaches were sampled, and most reaches were assessed where human activity had a definite impact to the overall quality of the stream, therefore the past or present activities are influencing the observed results, rather than being influenced of gradient. The quartile values from the PIBO reference data set were relatively similar between the 25th percentile and median; however differ sharply in the 75th percentile range. This may however be due to the methods in PIBO protocols, as to which pools are surveyed for percent fines, and where the grid toss occurs. As described above, DEQ data attempts to make a distinction by catering grid toss studies to areas of potential spawning habitat within pool tails. As a result, they may exclude some sites that would be otherwise counted as a part of PIBO methods. Therefore, PIBO may have a broader spectrum of fines witnessed, even in reference streams, which would be reflected in the quartile values.

Table D-5. Pool Tail Percent Fines (Grid Toss) Values, <6mm

	25th Percentile	Median	75th Percentile
0-2% Slope			
DEQ Field Data	2.5	4.0	10.5
PIBO Reference (n=48)	5.2	8.4	**13.5**
PIBO Managed; -<5 bkf (n=21)	17.6	30	68.4
>2% Slope			
DEQ Field Data	7.8	40.0	51.5
PIBO Reference (n=22)	5.4	10.0	28.8
PIBO Managed; -<5 bkf	23.1	33.3	44.8

D2.4 Residual Pool Depth

A slightly different approach was taken when developing target values for residual pool depth. In this case, bankfull width information for the study reaches was available for both DEQ and PIBO data (**Table D-6**). Because pool depths are frequently a function of stream size and volume, it was deemed appropriate to segregate sampled reaches by bankfull width, which provides an indication of general stream dimension and power that may affect pool size and quality.

For the PIBO data, three categories were broken out based on the sampled reaches; bankfull widths less than 15 feet, bankfull widths between 15 and 40 feet, and bankfull widths greater than 40 feet. DEQ data were split into those same three categories as well; however reaches greater than 40 feet in the PIBO data set were extremely limited (2) and therefore not used. There are only 5 reaches in the DEQ data over 40 feet; all of which occurred in the Boulder River and at sites with bankfull widths no less than 60 feet. Although no statistical analysis was used to develop these breakouts, generally it was considered that these segregations indicate reasonable size distinctions following the assumption that as size and power increases, so too does the average residual pool depths.

Although the parameter is the same in the DEQ and PIBO datasets, it should be noted that subtle differences exist in the methodology between the DEQ and PIBO to classify pools. Although both methods identify a pool as having a maximum depth 1.5 times the pool tail depth, PIBO further selects those pools that fall within the path of the thalweg and are 50% or greater of the wetted channel width, whereas DEQ methodology includes all pools throughout the channel. As a result of this, PIBO data is likely to reflect slightly deeper average pool depths than the DEQ data. Targets will be set to apply to DEQ methods, and review of PIBO reference data will focus on median values rather than the quartile.

In the <15 feet category, the reference sites exhibit slightly deeper overall pools than non-reference sites. No reference sites were identified within the DEQ reaches. The median value of the PIBO data set is 0.8 feet, whereas the 75th percentile from the DEQ data is 0.9 feet. The PIBO managed data is also reviewed for comparison purposes, looking at the 75th percentile, which is also 0.9 feet. As a result the target value for bankfull widths less than 15 feet is >0.8 feet.

In the 15-40 feet category, the PIBO reference sites again exhibit greater residual pool depth values. The median value of the PIBO reference data is 1.4 feet. The 75th percentile from the DEQ data is also 1.4 feet. Looking at the PIBO managed data; it shows a 75th percentile value of 1.8 feet. With consideration of the slight differences between PIBO and DEQ pool classification, the PIBO managed site appears to follow similarities with the DEQ and PIBO reference data. As a result of this review, a target value for bankfull widths between 15 and 40 feet is set at >1.4 feet.

For bankfull widths >40 feet, there was very limited information. DEQ data, which does not include reference sites, was taken from five sites in the Boulder River, and from sites with bankfull widths of 60 feet or greater. There were only two sites greater than 40 feet in the PIBO reference data; too few to infer a reference target. Therefore the DEQ data is assessed with the same assumptions as the other categories and is applied with respect to a presumed difference in reference and non-reference datasets, and ever increasing pool depths as bankfull widths increase. As such, the 75th percentile of the PIBO reference data from the 15-40 feet category is reviewed, and a target value of >1.9 is conservatively set for bankfull widths larger than 40 feet.

Because of the lack of good information for residual pool depth from streams with bankfull widths greater than 40 feet, some discretion must be used when applying these targets. For instance, a stream with a bankfull width of 45 feet may not achieve the target value of 1.9 for average residual pool depth, but that does not necessarily indicate the stream is impaired. There is expected to be a gradual increase in residual pool depths as stream size increases, therefore, a residual pool depth of 1.6 feet may be appropriate for a stream with a bankfull width slightly greater than 40. Conversely, a stream with a bankfull width closer to 80 feet may have an average residual pool depth that is well over 1.9 feet.

As is the case with all target comparisons, because of the interrelated nature between sediment loads, channel shape, and available habitat, all parameters must be reviewed in conjunction with each other before conclusions can be made. For instance, a stream may be meeting residual pool depth targets, but may have very high width to depth ratios. This may suggest that while residual pool depths appear normal, the residual pool depths for that stream could be potentially greater if channel morphology was within the expected target range. Similarly, residual pool depths may be met in a stream; however, those values are only reflected in a small number of pools, where under naturally occurring conditions, the number of pools would be expected to be much higher.

Table D-6. Residual Pool Depth Values

	25th Percentile	Median	75th Percentile
Bankfull Width <15 feet			
DEQ Field Data (n=9)	0.6	0.7	**0.9**
PIBO Reference (n=13)	0.6	**0.8**	1.0
PIBO Managed; -<5 bkf (n=24)	0.5	0.8	**0.9**
Bankfull Width 15-40 feet			
DEQ Field Data (n=9)	0.8	0.9	**1.4**
PIBO Reference (n=51)	1.2	**1.4**	1.7
PIBO Managed (n=8)	1.0	1.2	**1.7**
Bankfull Width >40 feet			
DEQ Field Data (n=5)	1.3	1.7	**2.5**

D2.5 Pool Frequency (Per Mile)

Pool frequency tends to be a function of stream size and power; although other factors also contribute to pool formation, such as geology, riparian condition (large woody debris input), and gradient. As streams increase in size, features such as riffles and pools also tend to increase in size, however those components such as boulders and large woody debris that influence pool development becomes less frequent, resulting in larger but fewer pools over a given distance.

Again, some differences in methodology between DEQ and PIBO do not allow for direct comparison of values. Both methods classify a pool as having a maximum pool depth > 1.5 times the pool tail depth. However, PIBO identifies those pools that fall within the path of the thalweg and that are 50% or greater of the wetted channel width; whereas DEQ methodology identifies *all* pools throughout the channel. As a result, PIBO methodology identifies fewer pools than noted according to DEQ methods. With this in mind, we can review the PIBO data in combination with the DEQ data to derive target values (**Table D-7**). Stream targets are again segregated using the same distinction of bankfull width as residual pool depth. Targets below apply to the DEQ methodology of identifying pools.

For streams with a bankfull width less than 15 feet, the target is set at >120 pools per mile. The 75th percentile of the DEQ data set is 132 and the median of the PIBO reference data set is 108. It is expected that the PIBO pool numbers would be somewhat higher if DEQ protocols were applied in their data collection and therefore in this case would likely be comparable to the DEQ 75th percentile of the data.

For streams with a bankfull width between 15 feet and 40 feet, the median (58) of the PIBO reference data set is considerably lower than the 75th percentile of the DEQ data (106). The median of the DEQ field data is 79, and while there are only 9 sites that make up the data set, most of these sites are influenced to varying degrees by anthropogenic activity, and therefore are more representative of effected conditions. As such it is expected that the target value should be higher than the median of this data range; therefore, best professional judgment is used here to select the target value of >90 pools per mile.

For tributary streams with a bankfull width equal to or greater than 40 feet, the target is set at >50 pools per mile. This is simply an estimate based on the targets from the other bankfull categories. No PIBO data is available in this stream size category for comparison. This target only applies to tributary streams to the Boulder River. The Boulder River target value is set at >30 pools per mile. The 75th percentile of the DEQ data set (28) provides a reference, but again the limited number of reaches (5) may mislead conclusions. All of the reaches reviewed occurred in the Boulder River and from sites with bankfull widths greater than 60 feet, which is why the target category for streams greater than 40 bankfull widths is split into tributary streams, and the Boulder River. Based on the field work conducted in the Boulder River watershed, there are very few, if any, reaches of tributaries to the Boulder River that exceed 60 feet in bankfull width.

Table D-7. Pool Frequency Values (per mile)

	25th Percentile	Median	75th Percentile
Bankfull Width <15 feet			
DEQ Field Data (n=9)	84	106	**132**
PIBO Reference (n=13)	82	**108**	181
PIBO Managed; -<5 bkf (n=24)	117	159	**210**
Bankfull Width 15-40 feet			
DEQ Field Data (n=9)	69	79	**106**
PIBO Reference (n=51)	39	**58**	76
PIBO Managed (n=8)	39	51	**93**
Bankfull Width >40 feet			
DEQ Field Data (Boulder River reaches) (n=5)	24	25	28

D2.6 Greenline – Percent Shrub

Riparian green line is not used as a direct measurement of sediment itself in the Boulder-Elkhorn TPA; however it is reviewed as supplemental information due to its relation to bank erosion and therefore an overall gage of stream health and potential sediment production. Shrub cover in particular provides stronger, more stable streamside woody vegetation, and it often provides an indicator of potential bank stability and temperature variability.

As mentioned in earlier target parameter discussions, there are a variety of conditions accounted for in the DEQ dataset, however few of them represent true desired or reference conditions. Although limited in the amount of available data, values were initially organized by their respective reach types to see if there were any obvious differences or similarities based on the physical characteristics of the stream (**Table D-8**). No true discernable variation in values could be determined based on the stream order, gradient, and confinement – but that is also expected since the riparian robustness is generally more a function of the activities on the land rather than the geologic constraints. As a result, the data shows that a target value can be set based on a review of the total dataset, rather than segregating it into specific categories. In reviewing these results, and knowing anthropogenic influence was common throughout the reaches, relying only on the median values in setting a target value may underestimate the potential quality that should be expected. Therefore, the 75th percentile here represents what may be expected. As such, the target is based on the 75th percentile, and is set at >65.

Table D-8. Greenline Percent Shrub Cover by Reach Type

Reach Type	25th	Median	75th
MR-0-2-U (3)	5	10	30
MR-0-3-U (4)	5	43.8	67.5
MR-0-4-U (5)	7.5	25	52.5
MR-2-1-C (1)	17.5	30	52.5
MR-2-1-U (1)	1.3	2.5	5.0
MR-2-2-U (2)	40.6	61.3	73.1
MR-2-3-C (2)	48.1	75.0	82.5
MR-2-3-U (1)	72.5	80.0	91.3
MR-4-2-C (1)	81.3	92.5	96.3
MR-4-2-U (3)	15.0	35.0	60.0
Total	15	40	65
Target Value			**>65**

D2.7 Greenline – Percent Bare Ground

As described for the Greenline – Percent Shrub Cover, riparian green line is not used as direct target of sediment analysis in the Boulder-Elkhorn TPA; however it is reviewed as supplemental information because of its relation to potential sediment production and overall gage of stream health. Bare ground along the riparian is the most unstable and most indicative display of streamside sediment sources. Similar to the percent shrub analysis, the statistics for percent bare ground are only used as a relative gage by which to select an appropriate value. In this case, lower percentages of percent bare ground are the expected and desired condition. Based on a review of the data and on-the-ground knowledge of the watershed (**Table D-9**), the Boulder-Elkhorn TPA would not expect to see any bare ground under most normal conditions. As such, the target for bare ground in conjunction with anthropogenic activities is 0%. However, it is acknowledged that some natural conditions such as talus slopes, recent landslide/avalanche chutes, and wildfire may result in small percentages of bare ground near the bank and therefore, this target is not absolute and will allow for some variance under specific naturally occurring conditions.

Table D-9. Greenline Percent Bare Ground by Reach Type

Reach Type	25th	Median	75th
MR-0-2-U (3)	0.0	0.0	0.0
MR-0-3-U (4)	0.0	5.0	11.3
MR-0-4-U (5)	7.5	40.0	42.5
MR-2-1-C (1)	0.0	0.0	0.0
MR-2-1-U (1)	37.5	52.5	63.8
MR-2-2-U (2)	0.0	10.0	17.5
MR-2-3-C (2)	1.9	5.0	10.6
MR-2-3-U (1)	43.8	47.5	52.5
MR-4-2-C (1)	10.0	15.0	22.5
MR-4-2-U (3)	0.0	5.0	10.0
Total	0.0	7.5	25.0
Target Value			**>0**

D2.8 Large Woody Debris

Large woody debris is not a direct measure of sediment. However, the quantification of instream large wood is reviewed as supplemental information because of its relation to riparian condition and the associated sediment production that can occur in degraded riparian environments. Large woody debris also has affect on pool formation and habitat creation for both fish and macroinvertebrates and has been shown to be an indicator of overall stream health.

A mature and healthy streamside vegetative community plays a significant role in the numbers of large woody debris found in a stream. This is apparent in comparing reference with managed PIBO data (**Table D-10**). As a result, we can presume that land management and impacts to the riparian community have a significant effect to the amount of large wood in the stream, and thereby the habitat complexity and overall health of the stream.

In addition to the quality of the riparian condition, large woody debris numbers also relate to stream size and power. Therefore, smaller streams with good riparian health would be more likely to hold pieces of large wood that fall into the stream. As the stream sizes increase, the wider and deeper channels and associated flows mobilize more wood resulting in fewer identified pieces per reach.

No large woody debris targets were selected for the Boulder Elkhorn TPA, but a review of large woody debris data illustrates the range in numbers of wood found from the various sites used in the watershed analysis. Interestingly, for streams with bankfull width <15, the DEQ field data provided the highest values and widest range between 25th and 75th percentiles (169-655 pieces per mile). This may be, in part, due to a few sites of particularly small size in heavily wooded environments. In contrast, the reference sites from PIBO had values ranging from 179-354 pieces per mile. For streams with bankfull widths 15-40 feet, the ranges in large wood for the various data types seem to follow a more intuitive pattern, where DEQ field sites range from 79-380 pieces per mile, PIBO managed sites range from 143-266 pieces per mile, and PIBO reference sites range from 239-645 pieces per mile. Although only a small number of sites can be reviewed for bankfull widths >40 feet, it does follow the thought that larger rivers have the capacity to move wood, and thereby fewer pieces are found within the channel.

Table D-10. Large Wood Values (per mile)

	25th Percentile	Median	75th Percentile
Bankfull Width <15 feet			
DEQ Field Data (n=9)	169	507	655
PIBO Reference (n=13)	179	315	354
PIBO Managed; -<5 bkf (n=22)	70	141	219
Bankfull Width 15-40 feet			
DEQ Field Data (n=9)	79	158	380
PIBO Reference (n=51)	239	350	645
PIBO Managed (n=8)	143	220	266
Bankfull Width >40 feet			
DEQ Field Data (Boulder River reaches) (n=5)	17	71	87

D3.0 References

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