APPENDIX F
SEDIMENT CONTRIBUTION FROM STREAMBANK EROSION

Approach

Application of the BEHI method (Rosgen 2001) allowed estimation of sediment delivery from stream banks. This methodology predicts stream erosion rate to sampled stream banks, creating an extrapolation factor from the results, and applying this extrapolation factor to the total length of streams in each 6th code HUC sub-watershed (as modified to break out 303d listed streams). The BEHI method is an empirical technique based on bank erosion rate data recorded in the Lamar River watershed of Yellowstone National Park and a variety of streams in the Colorado Front Range. Rosgen (2001) found a statistically significant relationship between the BEHI rating and bank erosion rate in the absence of any data representing the near bank shear stress. The method allows for prediction of bank erosion rates based on BEHI ratings developed from data collected in the field.

Methods

Field data collection

Field data for BEHI parameters were collected in the fall of 2004 following the quality assurance project plan (Confluence 2005). Parameters such as length of eroding bank, height of eroding bank, bankfull height, root depth, root density, bank angle, and surface protection (**Figure F-1**) were collected for each eroding bank within each assessment reach according to methods outlined by Rosgen (2004). Locations of sample reaches are shown in **Figure F-2**.

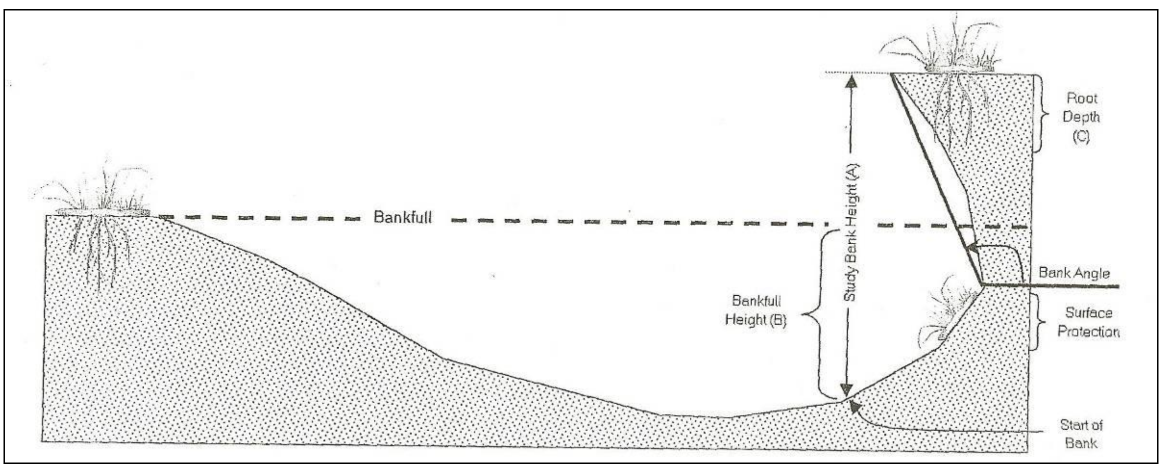

Figure F-1. BEHI Field Data Collection Methods
(Rosgen 2004)

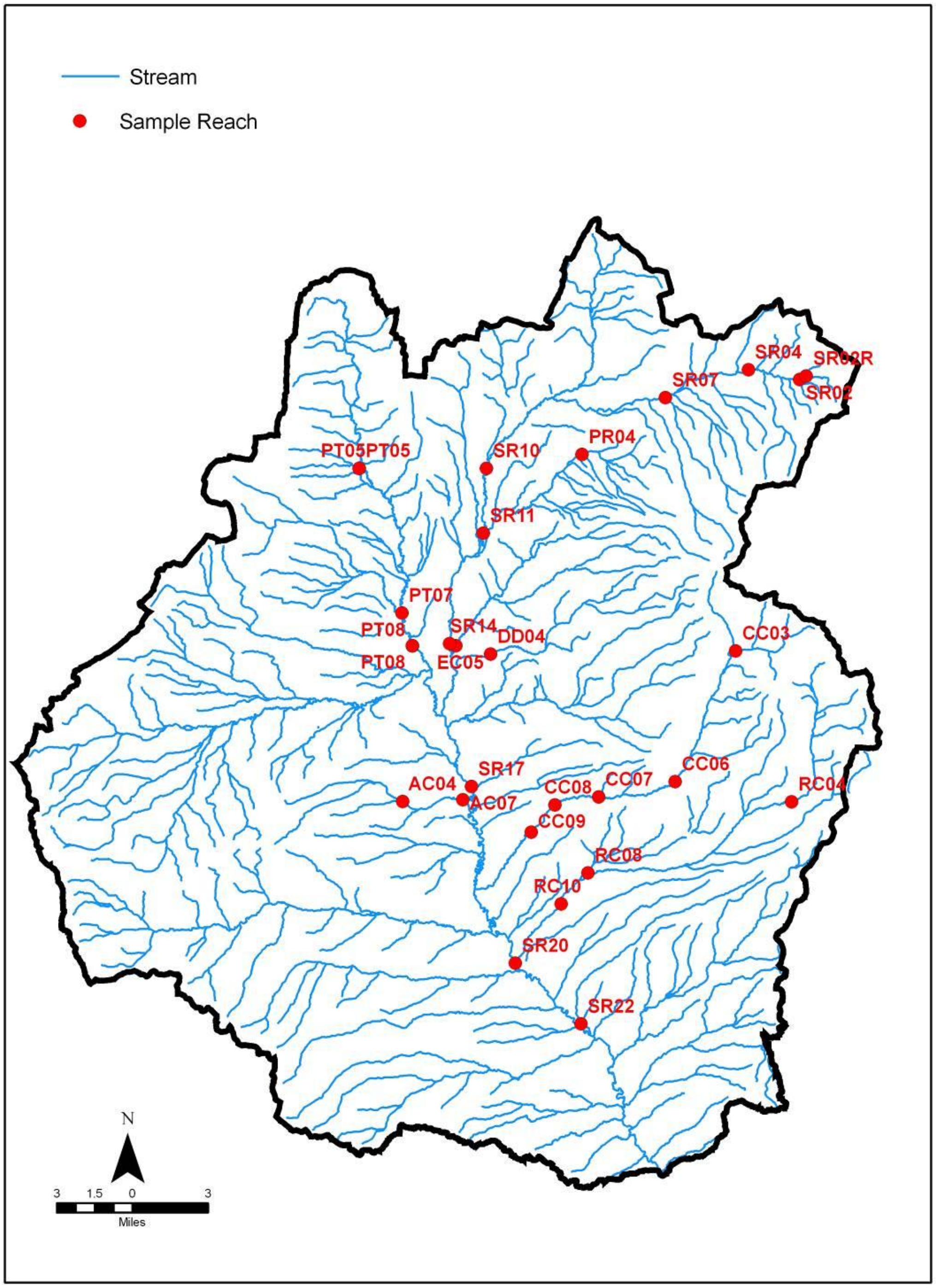

Figure F-2. Bank Erosion Assessment Sample Reach Locations

<u>Calculation of sediment contribution from field data</u>
Data collected in the field were used to predict the BEHI. The following data were collected for each bank.

- Bank Height, A (ft)
- Bankfull Height, B (ft)
- Root Depth, C (ft)
- Root Density, D (%)
- Bank Angle (deg.)
- Surface Protection (%)

The following erodibility variables (values) were computed and considered in ranking each bank as per Rosgen (2004).

- Bank Height / Bankfull Height, (A/B)
- Root Depth / Bank Height, (C/A)
- Weighted Root Density, (D*C/A)
- Bank Angle (deg.)
- Surface Protection (%)

The erodibility variable values were converted to numerical indices for bank erosion potential based on the relationships determined by Rosgen (2004) (**Table F-1**).

Table F-1 Conversion from Erodibility Variable Index to Numerical Bank Erosion Potential Values
(Rosgen 2004)

			Bank Erosion Potential					
Erodibility Variable			*Very Low*	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
	Bank Height / Bankfull Height	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	21. - 2.8	> 2.8
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Root Depth / Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	< 0.05
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	< 5.0
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	> 119
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	< 10
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

The BEHI method also allows the practitioner to modify the score based on bank material and bank material stratification. Rationale for exclusion of these factors from data collection and analysis related to the use of an average retreat rate assigned to each BEHI ranking. Addition of the bank material and bank material stratification to this analysis would have greatly complicated analyses without a commensurate increase in certainty in the results. Moreover, these qualitative assessments likely have low replicability. Therefore, the expense of collecting the additional data, combined with the lack of reliability in the results, justified the omission of these parameters.

A total score for each bank was developed by summing the bank erosion potential indices determined in the previous step. Finally, a BEHI ranking was assigned to the bank based on the following classification developed by Rosgen (2004).

Total Score	5 - 9.9	10 - 19.9	20 - 29.9	30 - 39.9	40 - 45	45.1 - 50
BEHI Rating	*Very Low*	*Low*	*Moderate*	*High*	*Very High*	*Extreme*

This classification was modified slightly to allow for analysis based on the Rosgen Colorado data set (**Figure F-3**). Shown here, the modification included elimination of the *Very Low* category (which was not recorded in either the Colorado data set or in the Shields Watershed sampling), and combining the *High* and *Very High* categories into one. The BEHI score and modified adjective rating for sample reaches are shown in **Table F-2**.

Total Score	10 - 19.9	20 - 29.9	30 - 45	45.1 - 50
BEHI Rating	*Low*	*Moderate*	*High - Very High*	*Extreme*

Table F-2. BEHI scores and ratings for assessment reaches

Reach	BankID	BEHI Score	Adjective Rating
AC04	AC04-1	0.0	low
AC07	AC07-1	37.0	high
PT05	PT05-1	0.0	low
PT07	PT07-1	0.0	low
PT08	PT08-1	42.9	high
PT08	PT08-2	40.9	high
PT08	PT08-3	31.4	high
PT08	PT08-4	39.2	high
PT08R	PT08R-1	32.5	high
PT08R	PT08R-2	40.1	high
PT08R	PT08R-3	42.3	high
PT08R	PT08R-4	41.4	high
SR02	SR02-1	10.5	low
SR02R	SR02R-1	29.9	high
SR02R	SR02R-2	37.2	high
SR02R	SR02R-3	40.1	high
SR02R	SR02R-4	29.1	moderate
SR02R	SR02R-5	43.8	high
SR04	SR04-1	0.0	low
SR07	SR07-1	41.9	high
SR07	SR07-2	39.3	high
SR07	SR07-3	41.0	high
SR07	SR07-4	44.3	high
SR07	SR07-5	34.4	high
SR10	SR10-1	35.7	high
SR11	SR11-1	26.2	moderate
SR14	SR14-1	41.9	high
SR14	SR14-2	38.6	high
SR14	SR14-3	35.4	high
SR14	SR14-4	26.0	moderate
SR17	SR17-1	30.8	high
SR17	SR17-2	31.3	high

Table F-2. BEHI scores and ratings for assessment reaches

Reach	BankID	BEHI Score	Adjective Rating
SR20	SR20-1	40.6	high
SR20	SR20-2	28.6	moderate
SR22	SR22-7	27.2	moderate
SR22	SR22-1	33.0	high
SR22	SR22-2	27.5	moderate
SR22	SR22-3	33.0	high
SR22	SR22-4	26.4	moderate
SR22	SR22-5	23.7	moderate
SR22	SR22-6	26.2	moderate

Near bank shear stress was estimated for each sampled eroding bank by using method 5 from Rosgen (2004). This method estimates the near bank shear stress of a bank segment from the ratio of near-bank maximum depth to bankfull mean depth according to the relationship expressed below.

Method Number	1	2	3	4	5	6	7
Rating*							
Very Low	N/A	>3.0	< 0.20	< 0.4	<1.0	<0.8	<1.0
Low		2.21 - 3.0	0.20 - 0.40	0.41 - 0.60	1.0 - 1.5	0.8 - 1.05	1.0 - 1.2
Moderate		2.01 - 2.2	0.41 - 0.60	0.61 - 0.80	1.51 - 1.8	1.06 - 1.14	1.21 - 1.6
High	See (1) Above	1.81 - 2.0	0.61 - 0.80	0.81 - 1.0	1.81 - 2.5	1.15 - 1.19	1.61 - 2.0
Very High		1.5 - 1.8	0.81 - 1.0	1.01 - 1.2	2.51 - 3.0	1.20 - 1.60	2.01 - 2.3
Extreme		< 1.5	> 1.0	> 1.2	> 3.0	> 1.6	> 2.3

*Circle the dominant near-bank stress rating selected.

The lateral bank erosion rate was predicted using the modified BEHI rating, the estimated NBS rating, and rating curves developed by Rosgen from the Colorado dataset (**Figure F-3**).

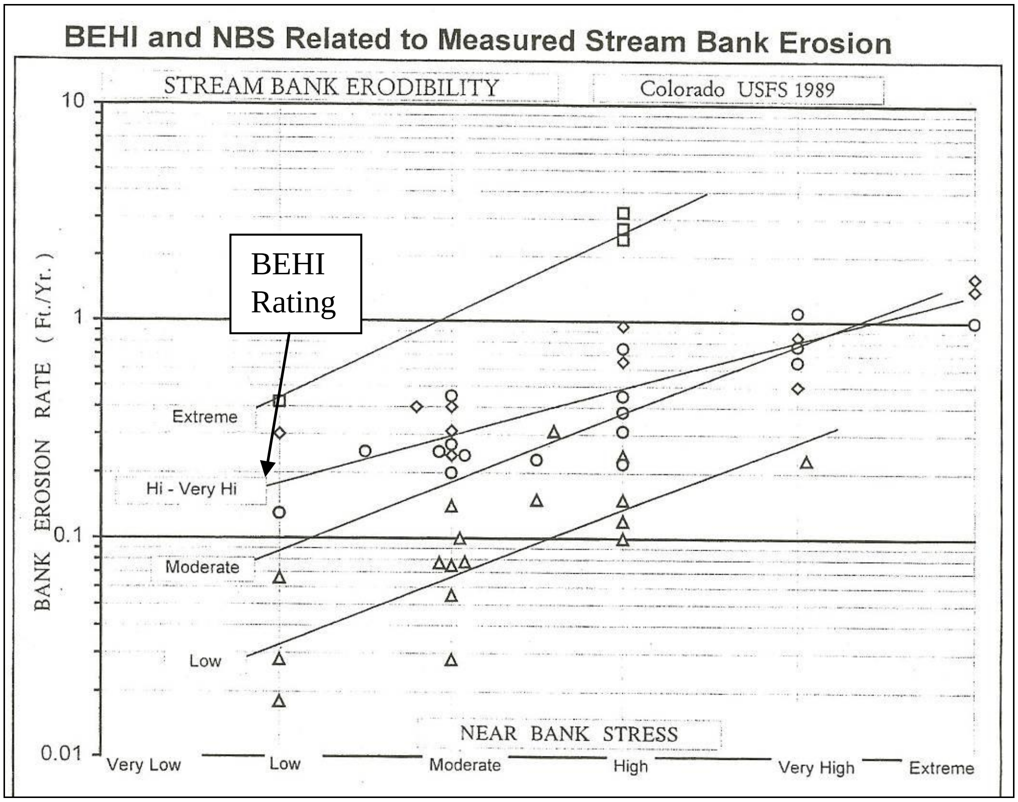

Figure F-3. Rosgen BEHI-NBS Model Developed from Colorado data
(Rosgen 2001)
Triangle (Δ) represents Low BEHI rating. Circle (○) represents Moderate BEHI rating. Diamond (◊) represents High/Very High BEHI rating. Square (□) represents Extreme BEHI rating.

Mean erosion rate values were determined for each of the combinations of BEHI and NBS ratings that appear in the sample data (**Table F-3**), and assigned to each sampled eroding bank on that basis.

Table F-3. Mean Bank Erosion Rate Based on BEHI Rating and Near Bank Shear Stress

		Near Bank Shear Stress Rating					
		Very low	Low	Moderate	High	Very high	Extreme
BEHI RATING	Extreme		0.45	1.05	2.3		
	Very high/High	*	0.18	0.29	0.5	0.8	
	Moderate	*	0.09	0.18	0.38	0.79	
	Low		0.03	0.06	0.12	0.27	

Sediment contribution from measured bank erosion sites was then estimated by applying Equation 1.

$$S = c \times R \times A \qquad (1)$$

Where: S = sediment load (ton/year)
c = bulk density of soil (0.084 ton/cubic foot)
R = bank erosion rate (feet/year)
A = eroding bank area (square feet)
And: A = eroding bank length (feet) x eroding bank height (feet)

The volume of all observed eroding banks was summed for each sampling reach, and divided by the length of the sampled stream reach, to arrive at an annual sediment contribution from that reach in tons/ft/yr.

<u>Extrapolation</u>
The average annual sediment contribution of the sampled stream reaches was used, in combination with data from an aerial photo based assessment of the streams of the Shields River Watershed, to create a matrix of extrapolation factors. These extrapolation factors were then multiplied by the total length of streams within each extrapolation classification, and the results broken out by 6^{th} Code HUC boundary (modified to reflect 303d listed stream drainages) to arrive at a predicted annual sediment contribution for each watershed.

To derive and apply the extrapolation factors, an aerial photo based assessment was performed on stream channel data for the entire Shields River Watershed using the National Hydrologic Dataset (NHD), overlain on DOQQ aerial photos. Similar stream segments were stratified by the following attributes:

- current Rosgen stream channel type
- potential Rosgen stream channel type
- current near bank vegetation density
- potential near bank vegetation density
- current near bank vegetation type
- potential near bank vegetation type
- current landuse

Rosgen level 1 channel types were assigned to reaches based on the following criteria:

- B channels – low sinuosity, relatively confined, narrow floodplain, no extensive bar formation, relatively narrow channel widths.

- C channels – moderate sinuosity, gravel deposition common on point bars.

- E channels – high sinuosity, wide, unconfined floodplain, few observable gravel point bars.

- F channels – areas obviously altered by mechanical channelization. Although it is impossible to determine entrenchment ratio by aerial photos, channelized reaches are typically incised due to vertical erosion resulting from channelization and artificial berms along the channel margin placed during the channelization process.

- G channels – areas obviously altered by mechanical channelization and are much wider than adjacent reaches. These channels have begun the evolution from an F channel to a stable channel type and are widening to establish an inset floodplain.

The Rosgen classification assigned to each reach was ultimately not used in extrapolating sediment loads between sampled and non-sampled reaches.

The potential condition for Rosgen channel type, near bank vegetation density and near bank vegetation type were intended to reflect the state that could be achieved under best management practices. Possible values for the vegetation density assessments (both current and potential) were ‘sparse,’ ‘moderate,’ and ‘dense.’ Possible values for the vegetation type assessments (both current and potential) were ‘coniferous trees,’ ‘deciduous trees,’ ‘willow shrubs,’ and ‘herbaceous vegetation.’ Possible values for the land use assessment were ‘crop,’ ‘forested,’ ‘grazing,’ ‘hay,’ ‘logging,’ and ‘residential.’

This same aerial assessment was performed on the stream reaches that had been field sampled for bank erosion. Deriving extrapolation factors from these sample data involved looking for relationships between combinations of aerial assessment attributes and the measured erosion rate for those combinations on the sample reaches. For example, one might examine the combination of current vegetation density and land use. Given three possible values for current vegetation density (sparse, moderate, dense) and five possible values for land use (crop, forested, grazing, hay, logging, and residential) there are fifteen possible combinations of these two attributes. One may then divide the sample reach data into those fifteen categories, calculate measured bank erosion for each category, and evaluate the results to determine if the relationship between the categories and their measured erosion rates is appropriate for use in extrapolating the sample results to the watershed as a whole.

Examination of the sample data in this manner showed the best relationship between the aerial assessment parameters and measured erosion rates involved the combination of current vegetation density, current vegetation type, and potential vegetation type. We believe this reflects the known effect of vegetation density and type on stream bank stability (e.g. dense willow stands hold banks more strongly than sparse herbaceous vegetation) as well as the effect that riparian land cover modification has on stream bank stability (e.g. streams that developed their morphology in an area of sparse herbaceous vegetation are likely to be more stable than those that developed in an area of dense woody vegetation that has since been removed).

Given that there are three possible values for current vegetation density (sparse, moderate, dense) and four possible values for both current and potential vegetation type (coniferous, deciduous, willow, herbaceous), there are 48 possible combinations of those three attributes. Some of those combinations do not ‘make sense’ and do not actually occur, however. For example, a stream segment should not have a current vegetation type of ‘willow’ and a potential vegetation type of 'herbaceous' as that does not reflect the expected result of best management practices. This reduces the number of possible combinations to 30, still too many for a meaningful extrapolation based upon 52 sample reaches – most of the possible combinations would have too few (or no) corresponding samples. A further reduction in possible combinations can be achieved by considering that, with respect to current and potential vegetation type, what is important from the standpoint of streambank erosion is whether or not the site is achieving its potential vegetation type. For example, sites that currently have herbaceous vegetation might have the potential to have herbaceous, willow, deciduous, or coniferous vegetation – four potential categories. These four categories can be reduced to two by considering a herbaceous site to be 'achieving its potential' if its potential is to support herbaceous vegetation and 'not achieving' if it has the potential to support any of the other three higher seral stages.

Reclassifying the vegetation type combinations according to 'achieving' or 'underachieving' results in 24 combinations. The number of samples corresponding to each of these 24 combinations is shown in **Figure F-4**.

Vegtype & Vegtype Potential & VegDensity

Sparse Veg

	Herbaceous	Willow	Deciduous	Coniferous
Achieving		1		
Underachieving	1			

Moderate Veg

	Herbaceous	Willow	Deciduous	Coniferous
Achieving	3	1	2	3
Underachieving	2			

Dense Veg

	Herbaceous	Willow	Deciduous	Coniferous
Achieving		1	7	3
Underachieving				

Figure F-4. Extrapolation Matrix Showing the Distribution of Vegetation Type, Density, and Potential for Sample Sites

Of the 24 possible combinations, only ten are represented in the sample data. However, not all of the combinations are found in the watershed, and thus in need of an extrapolation factor. In **Figure F-4**, green cells represent combinations for which samples exist. Grey cells represent combinations which do not appear in the data for the watershed as a whole. Red cells represent combinations which do appear in the data for the watershed as a whole, but for which there are no samples. Thus, the sample data cover ten of the fourteen combinations found in the watershed as a whole. To judge whether or not this coverage is sufficient to develop a meaningful extrapolation, we looked at the proportion of the watershed as a whole that were covered by the sampled combinations.

Vegtype & Vegtype Potential & VegDensity

	Herbaceous	Willow	Deciduous	Coniferous
Sparse Veg				
Achieving	374,478	78,277	11,555	8,183
Underachieving	163,691			
Moderate Veg				
Achieving	115,040	370,583	208,853	300,440
Underachieving	47,965			
Dense Veg				
Achieving	10,899	95,569	4,645	111,725
Underachieving				

Figure F-5. Extrapolation Matrix Showing the Length of Stream Channel for each Vegetation Type, Density, and Potential for the Shields Watershed

As shown in **Figure F-5**, approximately 80% of the stream segments (by length) in the valley were represented by the sampled categories, and more than 90% of the remainder were in a single category (sparse, herbaceous, achieving) for which an appropriate factor could be easily derived from the sample data. Therefore, the sampled sites provide an adequate representation of conditions within the Shields Watershed. The average erosion rate (tons/ft/yr) was calculated for all of the combinations that had been sampled (**Figure F-6**).

Vegtype & Vegtype Potential & VegDensity

	Herbaceous	Willow	Deciduous	Coniferous
Sparse Veg				
Achieving		0.001	*	*
Underachieving	0.045			
Moderate Veg				
Achieving	0.000	0.022	0.019	0.013
Underachieving	0.017			
Dense Veg				
Achieving	*	0.002	0.010	0.013
Underachieving				

Figure F-6. Extrapolation Matrix – The Average Erosion Rate Tons/ft/yr) for each Site Type Sampled
Asterisks denote categories with minimal representation in the watershed.

From this starting point, a final extrapolation factor matrix was derived using best professional judgment, as follows:

- Herbaceous
  In all cases, reaches exhibiting an "achieving" potential were assigned a lower loading rate than those exhibiting an "underachieving" potential. Likewise, reaches exhibiting dense vegetation were assigned a lower erosion rate than moderate and sparse densities. All herbaceous categories were assigned higher sediment loads than the corresponding density and potential for willow stands (i.e. a moderate density, herbaceous reach achieving its vegetation potential was assigned a higher sediment load than a moderate density, willow dominated reach achieving its vegetation potential) because herbaceous stands typically exhibit higher erosion rates than willow stands.

- Willow
  All three willow vegetation density categories were field measured and assigned an "achieving" potential. However, the sediment load measured for the moderate category of willows indicated a higher sediment load than the sparse density category. Best professional judgment was used to infer that a moderate stand of willows should exhibit a lower sediment load than a sparse stand. Therefore, the moderate and sparse, achieving reaches were reassigned a sediment load rate to reflect lower loads than the dense, achieving reaches. These dense, achieving reaches remained at the measured sediment load of 0.002 tons/ft/year.

- Deciduous
  A similar judgment was used for deciduous stands as was used for willow stands. Best professional judgment was used to infer that a dense stand of deciduous trees would exhibit a lower sediment loading rate than moderate and sparse stands due to the increased amount of root binding mass. Best professional judgment was also used to infer that a dense stand of deciduous vegetation likely exhibits a moderate, herbaceous understory. Therefore, the assigned sediment load rate (0.02 tons/ft/yr) was chosen to closely match the moderate density, achieving potential, herbaceous reaches (0.01 tons/ft/yr). Although deciduous roots provide some bank stability due to their massive root systems, they are typically not as effective as the fibrous network of shrub and herbaceous roots. Therefore a slightly higher loading rate was assigned to the dense, deciduous-dominated stand versus the moderate, herbaceous stand.

- Coniferous
  Reaches in the Shields Watershed exhibiting a coniferous-dominated vegetation type are located in upper elevation areas exhibiting typically steeper channels (A and B types). These steeper streams typically exhibit cobble and boulder bed morphology which generally provide excellent bank stability in the form of narrow, step pools and steep riffles. Erosion rates in these streams are typically very low due to the bed material preventing vertical and lateral scouring. Some coniferous reaches were also found in the transition between B and lower gradient C channels at mid-elevations within the watershed.

  Reaches CC06 and SR02R were removed from the data set due to cases of extremely high eroding bank heights >50 feet. The high bank heights in these reaches caused the average sediment loads for this vegetation category to more than double. Although these bank heights were accurately measured, the entire bank is not actively eroding. Sample reaches included both moderate and dense, achieving coniferous stands, each resulting in a sediment load of 0.013 tons/ft/year. These values were assigned slightly different values (0.015 and 0.010 tons/ft/year respectively) based on the judgment that coniferous stands are more stable due to the majority of the reaches falling in the steeper, cobble and boulder bed morphology areas of the drainage. A sparse, coniferous stand is likely to have a sparse to moderate herbaceous understory. Therefore a load rate was assigned to this category that represented a close value to both of these individual vegetation types (0.02 tons/ft/year). Each sampled site type was assigned an average annual loading rate that was used to extrapolate to the rest of the Shields Watershed (**Figure F-7**).

Vegtype & Vegtype Potential & VegDensity

Sparse Veg	Herbaceous	Willow	Deciduous	Coniferous
Achieving	0.02	0.005	0.04	0.02
Underachieving	0.04			

Moderate Veg	Herbaceous	Willow	Deciduous	Coniferous
Achieving	0.01	0.004	0.03	0.015
Underachieving	0.03			

Dense Veg	Herbaceous	Willow	Deciduous	Coniferous
Achieving	0.005	0.002	0.02	0.01
Underachieving				

Figure F-7. Extrapolation Matrix of the Average Loading Rate (tons/ft/yr) for each Site Type

These factors were applied to all of the stream channel segments for the Shields River Watershed, total sediment load from existing conditions calculated, and the results summarized by sub-watershed.

To estimate the sediment produced under best management practices, each stream segment in the watershed was assigned an extrapolation factor based upon that segment's potential vegetation type and density, total sediment load from BMP conditions calculated, and the results summarized by sub-watershed.

Example: A stream segment was classified by the aerial assessment as currently having moderate, herbaceous vegetation cover. This stream segment was also classified as having the potential to support dense willow cover. This stream segment would be assigned the extrapolation factor for moderate, herbaceous, underachieving (0.03 tons/ft/yr) to reflect its sediment delivery under existing conditions, and the factor for dense, willow, achieving (0.01) to reflect its potential sediment delivery under BMP.

Results

Table F-4 presents the bank erosion loads by 6th code HUC sub-watershed and the subwatershed loads normalized by the total stream length in each subwatershed. Loads are also included for the upper and lower Shields, which are comprised of 6th code HUCs. Loads for the lower Shields are cumulative and include sediment loads from the upper Shields. **Table F-5** presents the results reported by surface land ownership classification for the entire Shields River watershed.

Table F-4. Bank Erosion Extrapolation Results by Subwatershed and for the Shields Watershed. Subwatersheds in the upper Shields are denoted with an asterisk (*).

6th Code HUC Subwatershed	Length of Streams in Watershed (ft)	Current Sediment Delivery (tons/yr)	Potential Sediment Delivery (tons/yr)	Normalized Current Sediment Delivery (tons/ft/yr)	Normalized Potential Sediment Delivery (tons/ft/yr)
Adair Creek	169,371	2,200	1,500	0.013	0.009
Bangtail Creek	68,543	300	200	0.004	0.003
Canyon Creek	158,433	1,400	1,100	0.009	0.007
Carrol Creek*	227,679	3,600	1,600	0.016	0.007
Cottonwood Creek East*	246,028	4,500	4,400	0.018	0.018
Cottonwood Creek West*	209,313	2,700	1,100	0.013	0.005
Daisy Dean Creek*	125,185	1,700	1,100	0.013	0.009
Dry Creek*	169,360	3,300	1,600	0.019	0.009
Elk Creek*	214,678	3,200	1,300	0.015	0.006
Falls Creek	208,293	3,500	1,500	0.017	0.007
Horse Creek*	267,955	4,600	2,900	0.017	0.011
Lower Brackett Creek	124,502	2,200	1,300	0.017	0.010
Lower Flathead Creek*	259,458	3,500	1,500	0.014	0.006
Lower Shields River-Chicken Creek	284,351	7,200	4,300	0.025	0.015
Lower Shields River-Crazyhead Creek	223,344	4,500	3,000	0.020	0.014
Meadows Creek*	171,265	1,900	1,500	0.011	0.009
Middle Shields River-Antelope Creek*	395,833	6,000	4,200	0.015	0.011
Middle Shields River-Spring Creek	112,055	3,200	2,000	0.028	0.018
Muddy Creek*	168,914	2,300	1,100	0.013	0.006
Porquepine Creek*	264,224	4,600	2,000	0.017	0.008
Potter Creek*	**468,499**	**8,100**	**4,700**	**0.017**	**0.010**
Rock Creek	373,868	8,300	5,500	0.022	0.015
Upper Brackett Creek	260,278	2,900	2,100	0.011	0.008
Upper Flathead Creek*	142,866	2,100	800	0.015	0.006
Upper Shields River-Antelope Creek*	166,649	2,800	2,100	0.017	0.012
Upper Shields River-Bennett Creek*	387,189	6,500	4,700	0.017	0.012
Upper Shields River-Kavanaugh Creek*	189,374	4,800	3,000	0.025	0.016
Willow Creek	182,330	1,100	800	0.006	0.004
Upper Shields	**4,102,483**	**67,000**	**40,000**	**0.016**	**0.010**
Lower Shields	**6,239,838**	**103,000**	**62,900**	**0.016**	**0.010**

Table F-5. Bank Erosion Extrapolation Results by Land Ownership for the Shields watershed

Ownership Classification	Length of Streams by ownership (ft)	Estimated Current Sediment Delivery (tons/yr)	Estimated Potential Sediment Delivery (tons/yr)
Private	5,201,203	88,050	51,060
Right of Way	6,434	140	120
State Government	146,287	2,450	1,290
Undetermined	40	<10	<10
US Government	50,162	1,000	570
USDA Forest Service	833,880	11,200	9,720
USDI Bureau of Land Management	1,833	20	20
Grand Total	**6,239,838**	**103,000**	**62,900**

REFERENCES

Confluence Consulting Inc. 2004. Quality Assurance Project Plan (QAPP): Shields River TMDL Planning Area.

Rosgen, David L. 2001. A Practical Method of Computing Streambank Erosion Rate. Proceedings of the Seventh Federal Interagency Sedimentation Conference. Reno, NV. 3-25-2001.

Rosgen, David L. 2004. River assessment and monitoring field guide, Lubrecht Forest, MT. Fort Collins, CO, Wildland Hydrology, Inc.