APPENDIX E
MODELING APPROACH

A simplistic modeling approach was applied to the Big Springs Creek watershed to estimate the natural and anthropogenic pollutant sources in the drainage, and provide insight on how loading reductions could be achieved through the implementation of best management practices (BMPs). The Spreadsheet Tool for Estimating Pollutant Loads (STEPL) was selected due to its relative ease in application, and the minimal driving data requirements. Different from many of its complex counterparts, STEPL calculates watershed loads on a yearly basis, neglecting process components such as infiltration, evaporation, and nutrient cycling. The model was initially developed to estimate load reductions for the Grant Reporting and Tracking System (GRTS) and was applied to the main stem of Big Springs Creek to provide a coarse numerical estimate of the pollutant load entering the stream. Implementation of the model is best suited for assessing the general source contribution of sediment and nutrient delivery from various land cover and land use.

To compliment the STEPL overland loading model, a secondary model component was added to estimate stream bank erosion. Stream bank erosion is typically omitted in most simple watershed-loading models and STEPL is no exception, accounting only for erosion that originates from raindrop impact and sheet flow. To assess the relative contribution of in-stream sources to the overall load in Big Springs Creek, the empirical Bank Erosion Hazard Index (BEHI) model (Rosgen, 2001) was used. The BEHI method is especially attractive due to the absence of site-specific recession data in the area. Used in combined with STEPL, a rudimentary estimate of the overall sediment and nutrient delivery to Big Springs Creek is possible. It is important to note that the empirical nature of STEPL and BEHI make the tools applicable for pollutant loading estimation only, not for direct TMDL target development or allocation of pollutant loads. Further descriptions of each of the models are provided in the following sections.

STEPL Model Description

The Spreadsheet Tool for Estimating Pollutant Loads (STEPL) was developed by the Environmental Protection Agency (EPA) to compute non-point source pollutant loads originating from urban, agricultural, and forested land use. The model employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that would result from the implementation of various best management practices (BMPs). For each watershed, nitrogen, phosphorus, and 5-day biological oxygen demand (BOD-5) are estimated using surface water runoff volumes derived by the SCS runoff method and the pollutant concentrations in the runoff water. The annual sediment load from the various land use distribution and management practices is calculated using a sediment delivery ratio and the Universal Soil Loss Equation (USLE). Pollutant sources incorporated into the model include farm animals, feedlots, agriculture, urban runoff, and failing septic systems.

BEHI Model Description

The Bank Erosion Hazard Index (BEHI) provides a quantitative prediction of stream bank erosion rates and is an effective tool to allocate sediment contribution of stream bank sediment sources to the total sediment load. It is particularly advantageous for TMDL development (Rosgen, 2001). The premise of the model/classification system is that stream bank erosion is related to two factors: stream bank characteristics (erodibility potential) and hydraulic forces. The bank characteristics form the BEHI rating and incorporate such aspects as bank height to bankfull depth ratio, rooting depth to bank height ratio, slope steepness, root density, and percent of surface area of bank protected. A secondary index called Near Bank Stress (NBS) relates to the hydraulic forces within the channel and includes the vertical velocity gradient and the ratio of near-bank stress to overall shear stress. The BEHI system is collectively used to determine stream bank recession rates in feet per year. A more comprehensive description of the model is found in "Applied River Morphology" 2001.

Model Setup and Parameters

In order to speed the model setup process and increase the resolution of the driving data, the GIS interface for the Soil and Water Assessment Tool (SWAT) was utilized to determine land use and land cover information, soil erodibility and hydrologic soil group, watershed subbasin areas, and topographic factors. Raster datasets used during the process included the USGS Landcover and National Elevation Dataset (NED) and NRCS STATSGO soils grid. Rainfall intensity-depth-frequency (IDF), animal density, and septic contribution were provided through the STEPL Model Input Data Server or internal tables included in the STEPL worksheet.

For the purpose of modeling, the Big Springs Creek HUC (10040103) was subdivided into four subbasins to reflect the various changes in land use and their spatial distribution within the watershed. Criteria include major tributaries to Big Springs Creek, and known point sources. Table E-1 summarizes watershed parameters for each of the subbasins. Watershed boundaries are shown in Figure E-1.

Table E-1.

WATERSHED	AREA (ACRES)	HYDROLOGIC SOIL GROUP	LAND USE DISTRIBUTION	K [1]	CN[2]	TOPOGRAPHY S [3]	L [4]
W1	88495	C	RANGE	0.29	74	9%	80
			CROP	0.32	82	4%	80
			FOREST	0.20	70	14%	80
			URBAN	---	88	---	---
			*USER DEF	0.35	99	1%	20
W2	77637	C	RANGE	0.20	74	8%	60
			CROP	0.30	82	4%	60
			FOREST	0.20	70	16%	60
			URBAN	---	88	---	---
			*USER DEF	0.35	99	1%	20
W3	71317	C	RANGE	0.25	74	8%	60
			CROP	0.31	82	5%	60
			FOREST	0.20	70	13%	60
			URBAN	---	88	---	---
			*USER DEF	0.35	99	1%	20
W4	18086	C	RANGE	0.35	74	9%	80
			CROP	0.30	82	4%	80
			FOREST	0.20	70	17%	80
			URBAN	---	88	---	---
			*USER DEF	0.35	99	1%	20

(1) Soil erodibility factor (from NRCS STATSGO grid)
(2) SCS curve number (McCuen, 1998)
(3) Slope steepness (GIS calculated from USGS LULC and DEM)
(4) Avg. slope length (GIS calculated from USGS DEM)

*USER DEF – combination of water and wetland LULC

Sediment Modeling

Modeling of the overall sediment delivery and load in the Big Springs Watershed was divided into two separate components. STEPL was used to assess sheet flow derived erosion (raindrop detachment and rill and interill erosion) originating from pervious land surfaces. BEHI was then applied to provide supporting information on stream bank erosion rates. The summation of the pollutant estimates from STEPL and BEHI result in a cumulative numerical load for each of the watersheds based on a given land use scenario (tons/year). Urban values are determined from a simple wash-off function and include the addition of known point sources, specifically the City of Lewistown wastewater treatment plant (WWTP). The applicability of the load value to the relative pollutant source contribution is for assessment purposes only, not to develop a numerical waste load target for TMDL planning.

Rill and Interill Erosion

STEPL computes rill and interill erosion using the Universal Soil Loss Equation (USLE). The generalized equation is one of the most widely used sheet erosion equations where soil loss (A) is a function of the rainfall erosivity index (R), soil erodibility factor (K), overland flow slope and length (LS), crop management factor (C), and conservation practice factor (P). The USLE is shown below.

$$A = RK(LS)CP \text{ (in tons/acre/year)}$$

Although USLE calculates soil erosion for a given slope, much of the eroded soil in a watershed is not delivered to a point downstream. Rather, it is re-deposited at locations where the momentum of transporting water is insufficient to keep the material in suspension or to move the soil particles along the watershed surface. To compensate for deposition, a sediment delivery ratio (SDR) is applied to the USLE estimate to determine gross erosion for the watershed. The SDR is based entirely on watershed area and reflects the actual percentage of sediment that it delivered to the waterway. The value is then combined with stream bank erosion and urban sediment sources to determine the total sediment load for the watershed.

Erosion Scenarios

Due to the uncertainty in applying empirically based models to watershed specific conditions and the wide range of USLE variables, sediment pollutant loads were estimated for several different scenarios. These include:

- Natural conditions with no urban or agricultural influence.
- Existing conditions based on low erosion potential.
- Existing conditions based on high erosion potential.

Assumptions made for each of the scenarios above are presented in Table E-2. Existing conditions reflect the probable field conditions and variation of literature based modeling coefficients. Default export mean coefficient (EMC) model values were used for impervious surfaces and calculation of total suspended solids (TSS) loading from urban runoff.

Table E-2.

SCENARIO	CROPLAND (1)	RANGELAND (2)	FOREST (3)
Natural Conditions	• Canopy cover; short brush (20 inch fall height) 25% • Surface cover; grass/litter layer • Percent ground cover; 70-80%	• Canopy cover; short brush (20 inch fall height) 25% • Surface cover; grass/litter layer • Percent ground cover; 70-80%	• Undisturbed woodlands • Effective canopy cover; 70-80% • Forest litter; 90-100%
	C value = 0.02	**C value = 0.02**	**C value = 0.001**
Existing Conditions – Low Sediment Delivery	• 4 year rotation cycle, wheat (1) - alfalfa (3) • Intermediate spring wheat stubble between plantings	• Canopy cover; short brush (20 inch fall height) 25% • Surface cover; grass/litter layer • Percent ground cover; 60-70%	• Undisturbed woodlands • Effective canopy cover; 50-60% • Forest litter; 70-80%
	C value = 0.05	**C value = 0.03**	**C value = 0.003**

Table E-2.

SCENARIO	CROPLAND [1]	RANGELAND [2]	FOREST [3]
Existing Conditions – High Sediment Delivery	• 50% spring wheat, stubble with fall turnplow • 50% alfalfa	• Canopy cover; short brush (20 inch fall height) 25% • Surface cover; grass/litter layer • Percent ground cover; 50-60%	• Undisturbed woodlands • Effective canopy cover; 30-40% • Forest litter; 50-60%
	C value = 0.14	**C value = 0.06**	**C value = 0.006**

(1) McCuen, 1998
(2) Brooks, 1997
(3) Maidment, 1993

The remaining USLE parameters were developed through GIS spatial analyses including (LS)-overland flow length and slope and (K)-soil erodibility factor. These have been identified as part of the subbasin parameters in Table E-1. The rainfall erosivity index values (R) were taken from the STEPL database and vary by land use, roughly correlating to topography and orographic influences in the watershed. All conservation practice factors (P) were set to unity, meaning no conservation practice was applied.

Stream Bank Erosion

The BEHI stream bank erosion model relies on empirically based bank recession studies and field interpretation of the various components of the stream system. BEHI scoring results (depend on stream bank characteristics) and the NBS rating (hydraulic forces) result in a cumulative index that translates to a category of either low, moderate, high, very high, or extreme stream bank erosion. Bank recession values are than determined from one of four different regression curves that vary in magnitude from between 0.02-3 feet per year. The NBS ratings for Big Springs Creek were developed from surveyed cross sections in watershed W1, W3, and W4 and cumulative BEHI scores for each subbasin were estimated using the DEQ aerial assessment and NRCS ground truth. Although certain parameters required professional judgment due to a lack of site-specific data, it is assumed that the model provides a reasonable estimate of stream bank erosion. Many of the logistics of the BEHI model are beyond the scope of this document and the reader is recommended to consult the appendix for further information.

Nutrient Modeling

The nutrient modeling capability of STEPL is limited to the use of event mean concentration (EMC) coefficients to calculate the total load of nitrogen, phosphorus, and 5-day BOD in stormwater runoff. The underlying premise is that overland flow from various land uses produces a specific mass of pollutant per unit runoff volume. Excess rain values are derived from the SCS curve number method and the total EMC pollutant load (mg/L) is applied to this volume. Additional mass is introduced to the system through soil erosion from USLE, stream bank erosion, and City of Lewistown WWTP discharge effluent. Soil loss loading (both sheet flow and stream bank erosion) is identified by the relative nutrient enrichment ratio of the eroded soil and the specific percentage of N, P, and BOD in the soil matrix (N-0.01%, P-0.004%, and BOD-0.02% for the Lewistown area). Yearly nutrient loads of N and P were provided by the City of Lewistown and BOD demand was based off of daily per capita average (Chapra, 1997).

In order to compensate for some of the underlying deficiencies in the STEPL nutrient model, EMCs were calibrated to existing water quality/discharge data to provide site-specific loading coefficients. Although this procedure largely neglects in-stream nutrient cycling processes, calibrated EMCs for Big Springs Creek are well within the limits of the available literature sources, including the PLOAD user's manual (developed for EPA) and guidance documents published by the EPA Nationwide Urban Runoff Program (NURP). Event mean concentration values used during Big Springs Creek Modeling are shown in Table E-3. Default model values were used for urban lands.

Table E-3.

SCENARIO	LAND USE	TOTAL N (MG/L)	TOTAL P (MG/L)	BOD-5 (MG/L)
NATURAL CONDITIONS	RANGE	1.1	0.10	4
	CROP	1.1	0.10	4
	FOREST	1.1	0.10	4
	WETLAND-WATER	0	0	0
EXISTING CONDITIONS	RANGE	1.9	0.15	5
	CROP	2.2	0.15	5
	FOREST	1.1	0.10	5
	WETLAND-WATER	0	0	0

PLOAD user manual values (CH2M HILL, 2000)

Modeled results should be used with discretion due to a limited number of published EMC values and the underlying assumptions regarding in-stream processes. Actual loading values may vary significantly due to pollutant uptake by biomass.

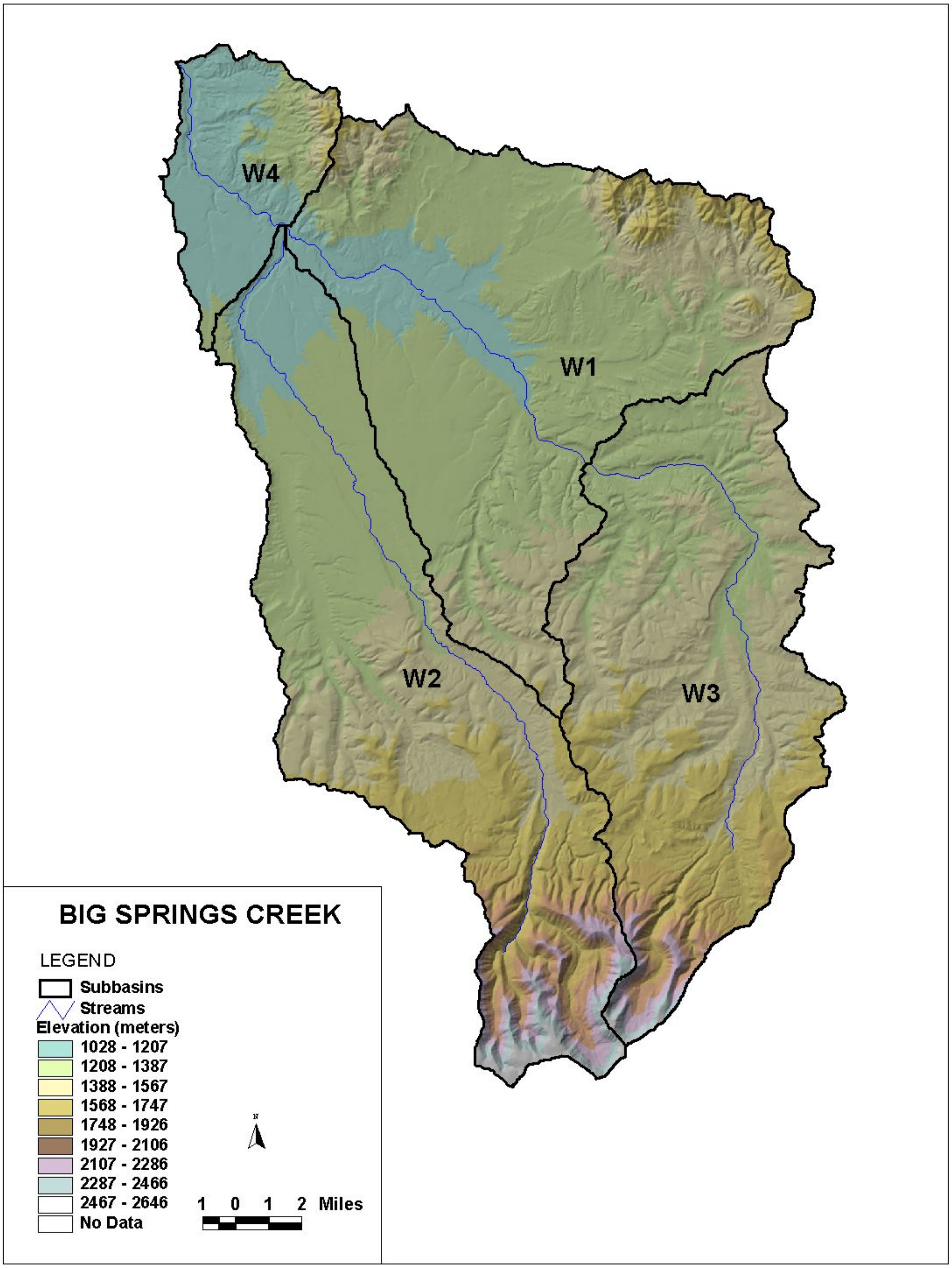

Figure E-1. Watershed Subbasins.

References

Brooks, K.N., 1987, *“Hydrology and the Management of Watersheds”* – second edition, Iowa State University Press, Ames, Iowa 50014

Chapra, S.C., 1997, *“Surface Water Quality Modeling”*, McGraw-Hill Series in Water Resources and Environmental Engineering, McGraw-Hill, Boston, Massachusetts

Maidment, D.R., 1993, “*Handbook of Hydrology”*, McGraw-Hill, Inc., New York, New York

McCuen, R.H., 1998, *“Hydrologic Analysis and Design”* – second edition, Prentice-Hall, Inc., Upper Saddle River, New Jersey 07458

Rosgen, D., 2001, *“Applied River Morphology”*, Wildland Hydrology, Pagosa Springs, Colorado, excerpts from paper entitled *“A Practical Method of Computing Streambank Erosion Rate”*

Environmental Protection Agency, 2001, *“PLOAD Version 3.0, An ArcView GIS Tool to Calculate Nonpoint Sources of Pollution in Watershed and Stormwater Projects - User’s Manual,”* CH2M HILL, Inc.

HUC 10040103, BIG SPRINGS CREEK
MODELING OUTPUT

WATERSHED 1
SCENARIO - LOW SEDIMENT DELIVERY

STREAMBANK MODEL [1]					STEPL MODEL				TOTAL LOAD				DISCHARGE		
	SED (TON/YR)	N [4] (LB/YR)	P [4] (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	Q [5] (AC-FT)	BAS [5] (CFS)	QT (AC-FT)
NATURAL [2]	5,140	20,560	8,224	41,120	900	48,900	5,550	171,950	6,040	69,460	13,774	213,070	15,740	65	62,800
COMBINE W1-W3	5,760	23,040	9,216	46,080	1,400	81,930	9,170	288,790	7,160	104,970	18,386	334,870	26,230	175	152,900
85% STREAMBANK EROSION (W1)					MODELED NATURAL (MG/L)				34	0.25	0.04	0.81			
15% RILL & INTERILL EROSION (W1)															
EXISTING [3]	6,440	25,760	10,304	51,520	1,620	87,500	8,240	231,810	8,060	113,260	18,544	283,330			
WWTP EFFL [6]	0	0	0	0	0	0	0	0	30	48,470	8,100	583,500			
COMBINE W1-W3	7,060	28,240	11,296	56,480	2,440	136,300	12,430	379,420	9,530	213,010	31,826	1.0E+06			
80% STREAMBANK EROSION (W1)					MODELED EXISTING (MG/L)				46	0.51	0.08	2.45			
20% RILL & INTERILL EROSION (W1)					OBSERVED (MG/L)				5**	0.42**	0.05	---			
	SED (TON/YR)	N [4] (LB/YR)	P [4] (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)			
ANTPG LOAD	1,300	5,200	2,080	10,400	720	38,600	2,690	59,860	2,050	92,270	12,870	653,760			
TOTAL LOAD	6,440	25,760	10,304	51,520	1,620	87,500	8,240	231,810	8,090	161,730	26,644	866,830			
PERCENT	20%	20%	20%	20%	44%	44%	33%	26%	25%	57%	48%	75%			

(1) Rosgen BEHI streambank erosion model
(2) Conditions with no agricultural or urban land use practices
(3) Existing land use practices/conditions
(4) Nutrient enrichment ratio of 2; 0.1% N content in soil, 0.04% P, 0.2% BOD
(5) SCS runoff volume (acre-feet); estimated baseflow in cfs (USGS - NRCS records)
(6) Values provided by city of Lewistown (P & N), BOD based on per capita average of 0.275 lb/day for 5813 people (2000 census)
**Approximated on very limited data

*FINAL - CHECKED BY KFF 12/03/2004

HUC 10040103, BIG SPRINGS CREEK
MODELING OUTPUT

WATERSHED 2
SCENARIO - LOW SEDIMENT DELIVERY

STREAMBANK MODEL [1]					STEPL MODEL				TOTAL LOAD				DISCHARGE		
	SED (TON/YR)	N [4] (LB/YR)	P [4] (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	Q [5] (AC-FT)	BAS [5] (CFS)	QT (AC-FT)
NATURAL [2]	0	0	0	0	400	39,000	4,040	139,250	400	39,000	4,040	139,250	12,530	10	19,800
EMPHEMERAL					MODELED NATURAL (MG/L)				15	0.72	0.08	2.59			
EXISTING [3]	0	0	0	0	780	63,010	5,350	177,420	780	63,010	5,350	177,420			
EMPHEMERAL					MODELED EXISTING (MG/L)				29	1.17	0.10	3.30			
					OBSERVED (MG/L)				---	---	---	---			
	SED (TON/YR)	N [4] (LB/YR)	P [4] (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)			
ANTPG LOAD	0	0	0	0	380	24,010	1,310	38,170	380	24,010	1,310	38,170			
TOTAL LOAD	0	0	0	0	780	63,010	5,350	177,420	780	63,010	5,350	177,420			
PERCENT	0%	0%	0%	0%	49%	38%	24%	22%	49%	38%	24%	22%			

[1] Rosgen BEHI streambank erosion model
[2] Conditions with no agricultural or urban land use practices
[3] Existing land use practices/conditions
[4] Nutrient enrichment ratio of 2; 0.1% N content in soil, 0.04% P, 0.2% BOD
[5] SCS runoff volume (acre-feet); estimated baseflow in cfs (USGS - NRCS records)

*FINAL - CHECKED BY KFF 12/03/2004

HUC 10040103, BIG SPRINGS CREEK
MODELING OUTPUT

WATERSHED 3
SCENARIO - LOW SEDIMENT DELIVERY

STREAMBANK MODEL [1]					**STEPL MODEL**				**TOTAL LOAD**				**DISCHARGE**		
	SED (TON/YR)	N [4] (LB/YR)	P [4] (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	Q [5] (AC-FT)	BAS [5] (CFS)	QT (AC-FT)
NATURAL [2]	620	2,480	992	4,960	500	33,030	3,620	116,840	1,120	35,510	4,612	121,800	10,490	110	90,100
55% STREAMBANK EROSION (W3)					MODELED NATURAL (MG/L)				9	0.15	0.02	0.50			
45% RILL & INTERILL EROSION (W3)															
EXISTING [3]	620	2,480	992	4,960	820	48,800	4,190	147,610	1,440	51,280	5,182	152,570			
43% STREAMBANK EROSION (W3)					MODELED EXISTING (MG/L)				12	0.21	0.02	0.62			
57% RILL & INTERILL EROSION (W3)					OBSERVED (MG/L)				13	0.26	0.01	---			
	SED (TON/YR)	N [4] (LB/YR)	P [4] (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)			
ANTPG LOAD	0	0	0	0	320	15,770	570	30,770	320	15,770	570	30,770			
TOTAL LOAD	620	2,480	992	4,960	820	48,800	4,190	147,610	1,440	51,280	5,182	152,570			
PERCENT	0%	0%	0%	0%	39%	32%	14%	21%	22%	31%	11%	20%			

(1) Rosgen BEHI streambank erosion model
(2) Conditions with no agricultural or urban land use practices
(3) Existing land use practices/conditions
(4) Nutrient enrichment ratio of 2; 0.1% N content in soil, 0.04% P, 0.2% BOD
(5) SCS runoff volume (acre-feet); estimated baseflow in cfs (USGS - NRCS records)

*FINAL - CHECKED BY KFF 12/03/2004

HUC 10040103, BIG SPRINGS CREEK
MODELING OUTPUT

WATERSHED 4
SCENARIO - LOW SEDIMENT DELIVERY

STREAMBANK MODEL [5]					**STEPL MODEL**				**TOTAL LOAD**				**DISCHARGE**		
	SED (TON/YR)	N [4] (LB/YR)	P [4] (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	Q [3] (AC-FT)	BAS [3] (CFS)	QT (AC-FT)
NATURAL [1]	4,780	19,120	7,648	38,240	380	11,070	1,480	37,760	5,160	30,190	9,128	76,000	3,200	5	6,800
COMBINE ALL	10,540	42,160	16,864	84,320	2,180	132,000	14,690	465,800	12,720	174,160	31,554	550,120	41,960	190	179,500
93% STREAMBANK EROSION (W4)					MODELED NATURAL (MG/L)				52	0.36	0.06	1.13			
7% RILL & INTERILL EROSION (W4)															
EXISTING [2]	5,580	22,320	8,928	44,640	650	19,710	2,100	48,570	6,230	42,030	11,028	93,210			
COMBINE ALL	12,640	50,560	20,224	101,120	3,870	219,020	19,880	605,410	16,540	318,050	48,204	1.3E+06			
90% STREAMBANK EROSION (W4)					MODELED EXISTING (MG/L)				68	0.65	0.10	2.64			
10% RILL & INTERILL EROSION (W4)					OBSERVED (MG/L)				---	0.4-0.7**	0.02	---			
	SED (TON/YR)	N [4] (LB/YR)	P [4] (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)	SED (TON/YR)	N (LB/YR)	P (LB/YR)	BOD (LB/YR)			
ANTPG LOAD	800	3,200	1,280	6,400	270	8,640	620	10,810	1,070	11,840	1,900	17,210			
TOTAL LOAD	5,580	22,320	8,928	44,640	650	19,710	2,100	48,570	6,230	42,030	11,028	93,210			
PERCENT	14%	14%	14%	14%	42%	44%	30%	22%	17%	28%	17%	18%			
CUM APG LOAD	2,100	8,400	3,360	16,800	1,690	87,020	5,190	139,610	3,820	143,890	16,650	739,910			
CUM LOAD	12,640	50,560	20,224	101,120	3,870	219,020	19,880	605,410	16,540	318,050	48,204	1.3E+06			
CUM PERCENT	17%	17%	17%	17%	44%	40%	26%	23%	23%	45%	35%	57%			

[1] Rosgen BEHI streambank erosion model
[2] Conditions with no agricultural or urban land use practices
[3] Existing land use practices/conditions
[4] Nutrient enrichment ratio of 2; 0.1% N content in soil, 0.04% P, 0.2% BOD
[5] SCS runoff volume (acre-feet); estimated baseflow in cfs (USGS - NRCS records)
**Approximated on very limited data

*FINAL - CHECKED BY KFF 12/03/2004