APPENDIX A
SEDIMENT CONTRIBUTION FROM HILLSLOPE EROSION

Introduction
Upland sediment loading due to hillslope erosion was modeled using the Universal Soil Loss Equation (USLE), and sediment delivery to the stream was predicted using a sediment delivery ratio. This model provided an assessment of existing sediment loading from upland sources and an assessment of potential sediment loading through the application of Best Management Practices (BMPs). For this evaluation the primary BMP evaluated includes the modification in upland management practices. When reviewing the results of the upland sediment load model it is important to note that a significant portion of the remaining sediment loads after BMPs in areas with grazing and/or silvicultural land-uses is also a component of the “natural upland load”. However, the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

A list of land cover classifications used in the USLE model is presented in **Table A-1**, along with a description of which land-use was associated with each cover type for the purposes of sediment source assessment and load allocations.

Table A-1. Land Cover Classifications for the USLE Model.

Land Cover Classifications	Land-use / Sediment Source
Bare Rock/Sand/Clay	Natural Source
Deciduous Forest	Natural Source
Evergreen Forest	Natural Source
Mixed Forest	Natural Source
Woody Wetlands	Natural Source
Logging	Silviculture
Grasslands/Herbaceous	Agriculture
Shrubland	Agriculture
Pasture/Hay	Agriculture
Small Grains	Agriculture
Fire	Fire

Universal Soil Loss Equation (USLE)
The general form of the USLE has been widely used for erosion prediction in the U.S. and is presented in the National Engineering Handbook (1983) as:

(1) $A = RK(LS)CP$ (in tons acre^{-1} year^{-1})

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) (Wischmeier and Smith 1978, Renard et al. 1991). The USLE estimates average soil loss from sheet and rill erosion but does not estimate soil loss from gully erosion. USLE was selected for the upper Big Hole watershed due to its relative simplicity, ease in parameterization, and the fact that it has been integrated into a number of other erosion prediction models. These include: (1) the Agricultural Nonpoint Source Model (AGNPS), (2) Areal Nonpoint Source Watershed Environment Response Simulation Model (ANSWERS), (3) Erosion Productivity Impact Calculator (EPIC), (4) Generalized Watershed Loading Functions (GWLF), and (5) the Soil Water Assessment Tool (SWAT) (Doe, 1999). A detailed description of the general USLE model parameters is presented below.

The R-factor is an index that characterizes the effect of raindrop impact and rate of runoff associated with a rainstorm. It is a summation of the individual storm products of the kinetic energy in rainfall (hundreds of ft-tons acre-1 year-1) and the maximum 30-minute rainfall intensity (inches hour-1). The total kinetic energy of a storm is obtained by multiplying the kinetic energy per inch of rainfall by the depth of rainfall during each intensity period.

The K-factor or soil erodibility factor indicates the susceptibility of soil to resist erosion. It is derived by measurement of soil particle size (texture), percent organic matter, structure, and permeability. It is a measure of the average soil loss (tons acre-1 hundreds of ft-tons-1 per acre of rainfall intensity) from a particular soil in continuous fallow. The K-factor is based on experimental data from the standard SCS erosion plot that is 72.6 ft long with uniform slope of 9 percent.

The LS-factor is a function of the slope and overland flow length of the eroding slope or cell. For the purpose of computing the LS-value, slope is defined as the average land surface gradient. The flow length refers to the distance between where overland flow originates and runoff reaches a defined channel or depositional zone. According to McCuen, (1998), flow lengths are seldom greater than 400 or shorter than 20 feet.

The C-factor or crop management factor is the ratio of the soil eroded from a specific type of cover to that from a clean-tilled fallow under identical slope and rainfall. It integrates a number of factors that effect erosion including vegetative cover, plant litter, soil surface, and land management. The original C-factor of the USLE was experimentally determined for agricultural crops and has since been modified to include rangeland and forested cover. It is now referred to as the vegetation management factor (VM) for non-agricultural settings (Brooks, 1997).

Three different kinds of effects are considered in determination of the VM-factor. These include: (1) canopy cover effects, (2) effects of low-growing vegetal cover, mulch, and litter, and (3) rooting structure. A set of metrics has been published by the Soil Conservation Service (SCS) for estimation of the VM-factors for grazed and undisturbed woodlands, permanent pasture, rangeland, and idle land. Although these are quite helpful for the upper Big Hole watershed, Brooks (1997) cautions that more work has been carried out in determining the agriculturally based C-factors than rangeland/forest VM-factors. Because of this, the results of the interpretation should be used with discretion.

The P-factor (conservation practice factor) is a function of the interaction of the supporting land management practice and slope. It incorporates the use of erosion control practices such as strip-cropping, terracing, and contouring, and is applicable only to agricultural lands. Values of the P-factor compare straight-row (up-slope down-slope) farming practices with that of certain agriculturally-based conservation practices.

Modeling Approach
Sediment delivery from hillslope erosion was estimated using a Universal Soil Loss Equation (USLE) based model to predict soil loss, along with a sediment delivery ratio, (SDR) to predict sediment delivered to the stream. This USLE based model is implemented as a watershed scale, grid format, GIS model using ArcView v 9.0 GIS software.

Desired results from the modeling effort include the following: (1) annual sediment load from each of the water quality limited segments on the state's 303(d) List, and (4) the mean annual source distribution from each land category type. Based on these considerations, a GIS-modeling approach (USLE 3-D) was formulated to facilitate database development and manipulation, provide spatially explicit output, and supply output display for the modeling effort.

Modeling Scenarios
Two upland management scenarios were proposed as part of the Upper Big Hole River modeling project. They include: (1) an existing condition scenario that considers the current land use cover and management practices in the watershed and (2) an improved grazing and cover management scenario.

Erosion was differentiated into two source categories for each scenario: (1) natural erosion that occurs on the time scale of geologic processes and (2) anthropogenic erosion that is accelerated by human-caused activity. A similar classification is presented as part of the National Engineering Handbook Chapter 3 - Sedimentation (USDA, 1983). Differentiation is necessary for TMDL planning.

Data Sources
The USLE-3D model was parameterized using a number of published data sources. These include information from: (1) USGS, (2) Spatial Climate Analysis Service (SCAS), and (3) Soil Conservation Service (SCS). Additionally, local information regarding specific land use management and cropping practices was acquired from the Montana Agricultural Extension Service and the Natural Resource Conservation Service (NRCS). Specific GIS coverages used in the modeling effort included the following:

R – Rainfall factor. Grid data of this factor was obtained from the NRCS, and is based on Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation data. PRISM precipitation data is derived from weather station precipitation records, interpolated to a gridded landscape coverage by a method (developed by the Spatial Climate Analysis Service of Oregon State University) which accounts for the effects of elevation on precipitation patterns.

K – Soil erodibility factor. Polygon data of this factor was obtained from the NRCS General Soil Map (STATSGO) database. The USLE K factor is a standard component of the STATSGO soil survey. STATSGO soils polygon data were summarized and interpolated to grid format for this analysis.

LS – Slope length and slope factors. These factors were derived from 30m USGS digital elevation model (DEM) grid data, interpolated to a 10m pixel.

C – Cropping factor. This factor was estimated using the National Land Cover Dataset (NLCD), using C-factor interpretations provided by the NRCS and refined by Montana DEQ using SCS C-factor tables (Brooks et al. 1997). C-factors are intended to be conservatively representative of conditions in the Big Hole valley.

P – Management practices factor. This factor was set to 1, as consultation with the NRCS State Agronomist suggests that this value is the most appropriate representation of current management practices in the Big Hole valley (i.e. no use of contour plowing, terracing, etc).

Method

An appropriate grid for each factors' values was created, giving full and appropriate consideration to proper stream network delineation, grid cell resolution, etc. A computer model was built using ArcView Model Builder to derive the five factors from model inputs, multiply the five factors and arrive at a predicted sediment production for each grid cell. The model also derived a sediment delivery ratio for each cell, and reduced the predicted sediment production by that factor to estimate sediment delivered to the stream network.

Specific parameterization of the USLE factors was performed as follows:

Upper Big Hole DEM

The digital elevation model (DEM) for the upper Big Hole watershed (**Figure A-2**) was the foundation for developing the LS factor, for defining the extent of the bounds of the analysis area (the upper Big Hole watershed), and for delineating the area within the outer bounds of the analysis for which the USLE model is not valid (i.e. the concentrated flow channels of the stream network). The USGS 30m DEM (level 2) for the upper Big Hole was used for these analyses. First the DEM was interpolated to a 10m analytic grid cell to render the delineated stream network more representative of the actual size of upper Big Hole watershed streams and to minimize resolution dependent stream network anomalies. The resulting interpolated 10m was then subjected to standard hydrologic preprocessing, including the filling of sinks to create a positive drainage condition for all areas of the watershed.

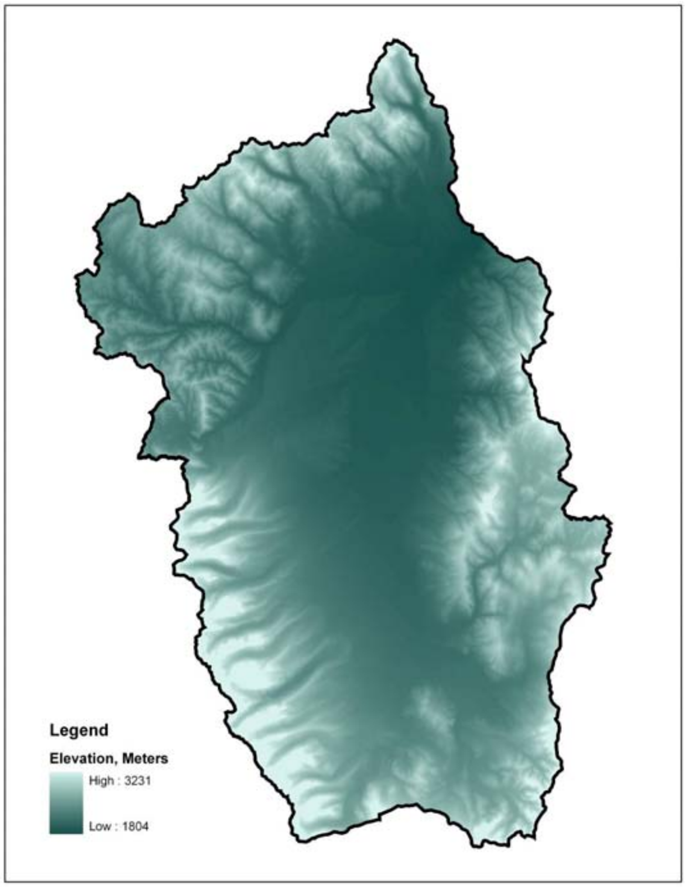


Figure A-1. Digital Elevation Model (DEM) of the upper Big Hole watershed, prepared for hydrologic analysis.

<u>R-Factor</u>

The rainfall and runoff factor grid was prepared by the Spatial Climate Analysis Service of Oregon State University, at 4 km grid cell resolution. For the purposes of this analysis, the SCAS R-factor grid was reprojected to Montana State Plane Coordinates (NAD83, meters), resampled to a 10m analytic cell size and clipped to the extent of the upper Big Hole watershed, to match the project's standard grid definition. (**Figure A-2**)

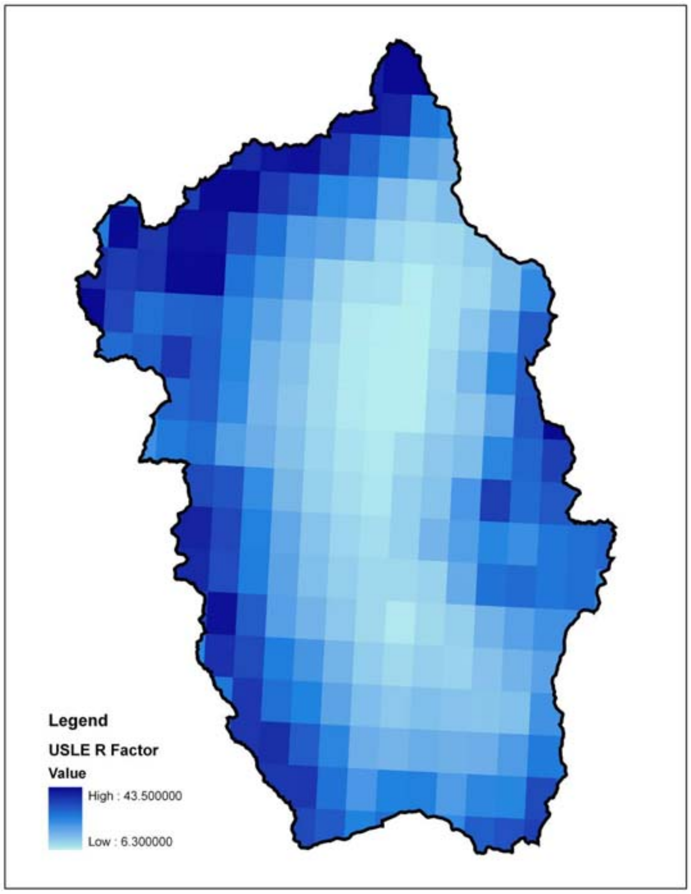


Figure A-2. ULSE R factor for the upper Big Hole Watershed.

K-Factor

The soil erodibility factor grid was compiled from 1:250K STATSGO data, as published by the NRCS. STATSGO database tables were queried to calculate a component weighted K value for all surface layers, which was then summarized by individual map unit. The map unit K values were then joined to a GIS polygon coverage of the STATSGO map units, and the polygon coverage was converted to a 10m analytic grid for use in this analysis. (**Figure A-3**)

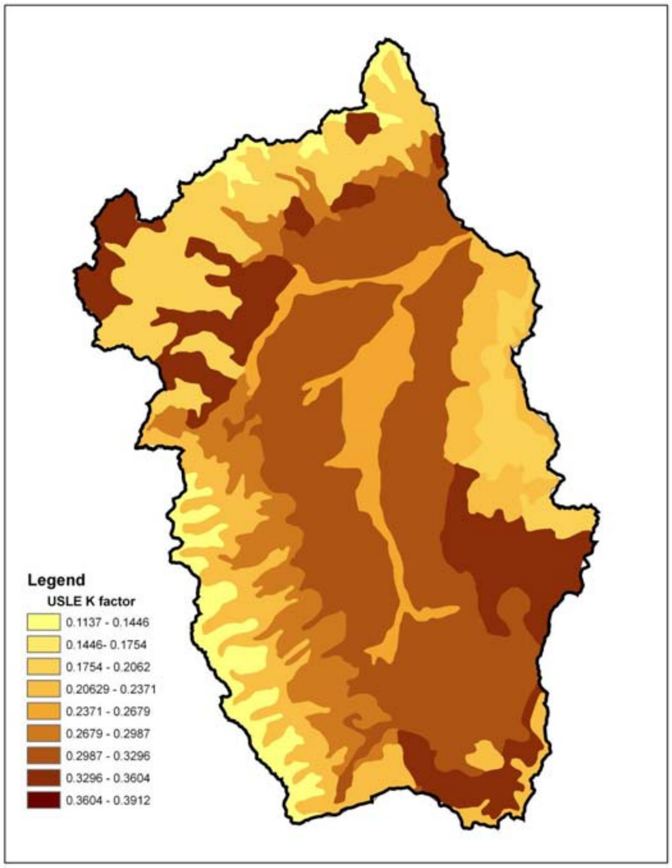


Figure A-3. ULSE K factor for the Upper Big Hole Watershed.

<u>LS- Factor</u>

The equation used for calculating the slope length and slope factor was that given in the updated definition of USLE, as published in USDA handbook #537:

$$LS = (\lambda/72.6)^m\ (65.41 \sin^2\theta + 4.56 \sin\theta + 0.065)$$

Where:

λ = slope length in feet. This value was determined by applying GIS based surface analysis procedures to the upper Big Hole watershed DEM, calculating total upslope length for each 10m grid cell, and converting the results to feet from meters. In accordance with research that indicates that, in practice, the slope length rarely exceeds 400 ft, λ was limited to that maximum value.

θ = cell slope as calculated by GIS based surface analysis procedures from the upper Big Hole watershed DEM

m = 0.5 if percent slope of the cell >= 5
= 0.4 if percent slope of the cell >= 3.5 AND < 5
= 0.3 if percent slope of the cell >= 1 AND < 3.5
= 0.2 if percent slope of the cell < 1

The LS factor grid was calculated from individual grids computed for each of these sub factors, using a simple ArcView Model Builder script.

C-Factor

The cover management factor of the USLE reflects the varying degree of erosion protection that results from different cover types. It integrates a number of factors including vegetative cover, plant litter, soil surface, and land management. For the purpose of this study, the C-factor is the only USLE parameter that can be altered by the influence of human activity. Based on this, C-factors were estimated for the existing condition and improved management scenarios (**Table A-2**). The C-factor change for agricultural cover types between management scenarios corresponds to increases in the percent of land cover that are achievable through the application of various best management practices (**Table A-3**). For natural sources (i.e. bare rock, deciduous forest, and evergreen forest), the C-factor is the same for both scenarios. A C-factor slightly higher than deciduous/evergreen forest was used for logged areas because logging intensity within the watershed is generally low and because practices, such as riparian clearcutting, that tend to produce high sediment yields have not been used since at least 1991, when the MT Streamside Management Zone (SMZ) law was enacted. Additionally, the USLE model is intended to reflect long-term average sediment yield, and while a sediment pulse typically occurs in the first year after logging, sediment production after the first year rapidly declines (Rice et al. 1972; Elliot and Robichaud 2001; Elliot 2006). The logging C-factor is the same for both management scenarios to indicate that logging will continue sporadically on public and private land within the watershed and will produce sediment at a rate slightly higher than an undisturbed forest. This is not intended to imply that additional best management practices beyond those in the SMZ law should not be used for logging activities. Because the Mussigbrod fire was in 2000 and the rate of erosion rapidly declines after the first year as vegetation re-establishes (Elliot and Robichaud 2001), the existing C-factor corresponds to the existing C-factor used in logged areas, and the improved C-factor varies depending on the improved C-factor for the underlying land cover type (see **Table A-2**).

C-factors were defined spatially through use of a modified version of the Anderson land cover classification (1976) and the 1992 30m Landsat Thematic Mapper (LTM) multi-spectral imaging (NLDC, 1992) (**Figure A-4**). C-factor values were assigned globally to each land type and range from 0.001 to 1.0. These data were reprojected to Montana State plane projection/coordinate system, and resampled to the standard 10m grid. No field efforts were initiated as part of this study to refine C-factor estimation for the watershed.

Table A-2. Upper Big Hole River C-Factor; Existing and improved management conditions.

NLCD Code	Description	C-Factor	
		Existing Condition	Improved Management Condition
31	Bare Rock/Sand/Clay	0.001	0.001
41	Deciduous Forest	0.003	0.003
42	Evergreen Forest	0.003	0.003
43	Mixed Forest	0.003	0.003
91	Woody Wetlands	0.0001	0.0001
51	Shrubland	0.046	0.031
71	Grasslands Herbaceous	0.042	0.035
81	Pasture /Hay	0.020	0.013
83	Small Grains	0.240	0.015
N/A	Logging	0.006	0.006
N/A	Fire	0.006	Variable*

*Improved C factor depends on the underlying land cover type

Table A-3. Changes in percent ground cover for agricultural land cover types between existing and improved management conditions.

Land Cover	Existing % ground cover	Improved % ground cover
Shrubland	55	65
Grasslands Herbaceous	55	65
Pasture /Hay	65	75
Small Grains	20	40

<u>NLCD – Landcover</u>

In general, the land use classification of the NLCD was accepted as is, without ground truthing of original results or correction of changes over the time since the NLCD image was taken. Given that we are looking for watershed and subwatershed scale effects, this was considered to be a reasonable assumption, given the relative simplicity of the land use mix in the Big Hole valley, and the relative stability of that land use over the 14 years since the Landsat image that the NLCD is based on was shot. Two adjustments were made to the NLCD, however. The first adjustment was to quantify the amount of logging that has occurred since 1992, and to also identify areas that are reforesting over that same period. The other adjustment was to account for change in land cover due to the Mussigbrod fire of 2000.

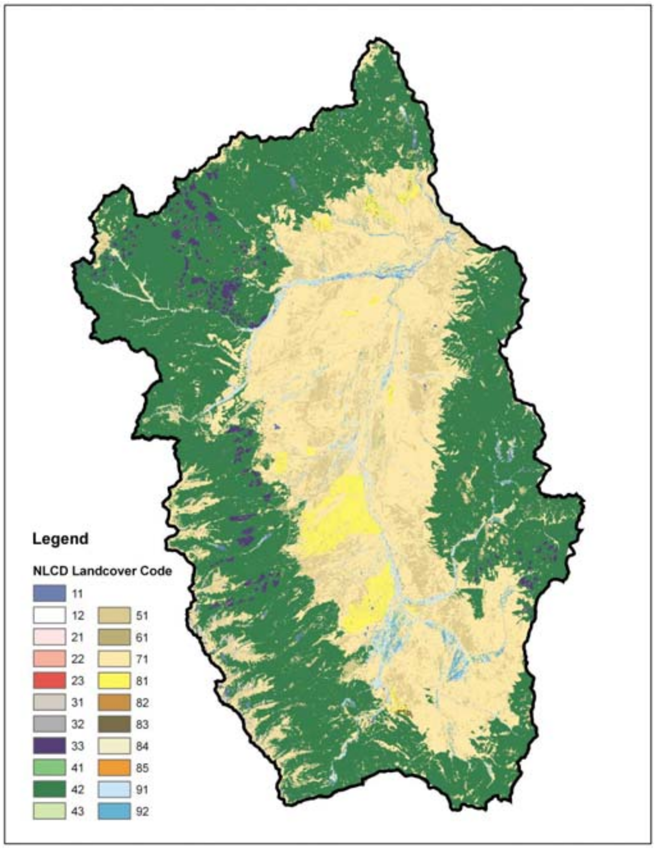


Figure A-4. NLCD Landcover for the Upper Big Hole Watershed.

As with other land uses in the valley, logging is a stable land use, but it is a land use that causes a land cover change that may effect sediment production. Similarly wildland fire, while not a landuse per se, is affected by land management decisions and may cause a change in vegetation cover. Adjustment for logging and reforestation was accomplished by comparing the 1992 NLCD grid for the upper Big Hole watershed with the 2005 NAIP aerial photography. Areas which were coded as a forest type (41 or 42) on the NLCD were recoded to 'logged' if:

- They appeared to be otherwise (typically bare ground, grassland, or shrubland) on the NAIP photos, and
- There were indications of indicated logging activity (proximity to forest or logging roads, appearance of stands, etc).

Adjustment for the land cover change caused by the Mussigbrod fire was accomplished by using the USFS mapping of the fire intensity within the burned area. Fire intensities of 'moderate mosaic' or above were considered to be land cover changing, and it was further assumed that these areas will eventually return (through natural processes or management activities) to their pre-fire condition.

Sediment Delivery Ratio

A sediment delivery ratio (SDR) factor was created for each grid cell, based on the relationship between the distance from the delivery point to the stream established by Dube, Megahan &

McCalmon in their development of the WARSEM road sediment model for the State of Washington. This relationship was developed by integrating the results of several previous studies, (principally those of Megehan and Ketchison), which examined sediment delivery to streams downslope of forest roads. They found that the proportion of sediment production that is ultimately delivered to streams declines with distance from the stream (**Table A-4**) with the balance of the sediment being deposited between the point of production and the stream. We believe the use of this relationship to develop a SDR for a USLE based model is a conservative (i.e. tending toward the high end of the range of reasonable values) estimate of sediment delivery from hillslope erosion, especially in light of the fact that the USLE methodology does not account for gully erosion. The SDR factor was applied to the results of the USLE model to estimate sediment delivered from hill slope sources, by calculating the distance from each cell to the nearest stream channel, and multiplying the sediment production of that cell by the corresponding distance based percentage of delivery.

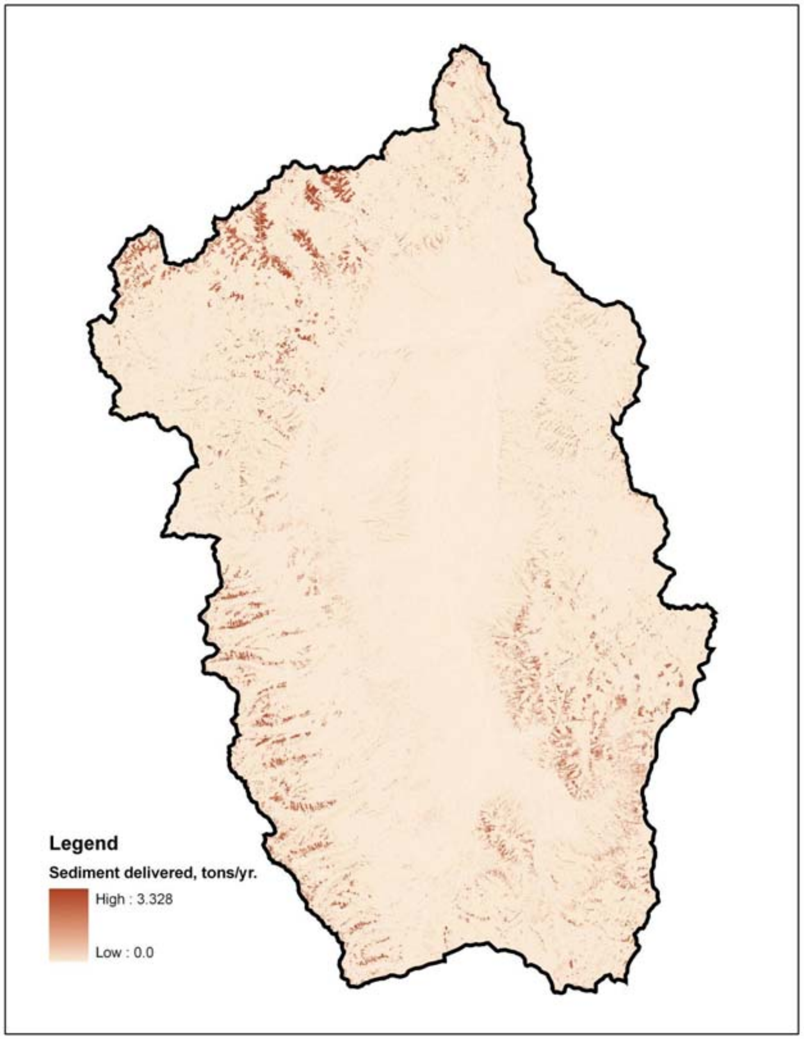
Table A-4. The percent of sediment delivered by distance from a water body.

Distance from Culvert (ft)	Percent of Total Eroded Sediment Delivered
0	100
35	70
70	50
105	35
140	25
175	18
210	10
245	4
280	3
315	2
350	1

Although the SDR factor accounts for the distance of sediment production cells from the stream channel, it does not account for riparian condition and the ability of riparian vegetation to filter out sediment and prevent it from entering the stream. Depending on the vegetation type and buffer width, healthy riparian buffers can remove anywhere from 50-90 percent of sediment (Castelle and Johnson 2000; Hook 2003; MDEQ 2007). Therefore, the USLE model used for source assessment may have overestimated existing loads and underestimated potential reductions due to hillslope erosion.

Results

Figures A-5 and **A-6** present the USLE based hillslope model's prediction of existing and potential conditions for the upper Big Hole watershed. **Table A-5** contains the estimated existing and potential sediment load from hillslope erosion for each 6^{th} code HUC and the upper Big Hole watershed, and it also contains loads normalized by the contributing watershed area. **Table A-6** contains the estimated existing and potential sediment load from hillslope erosion for the upper Big Hole watershed and broken out by 6^{th} code HUC and existing land cover type.



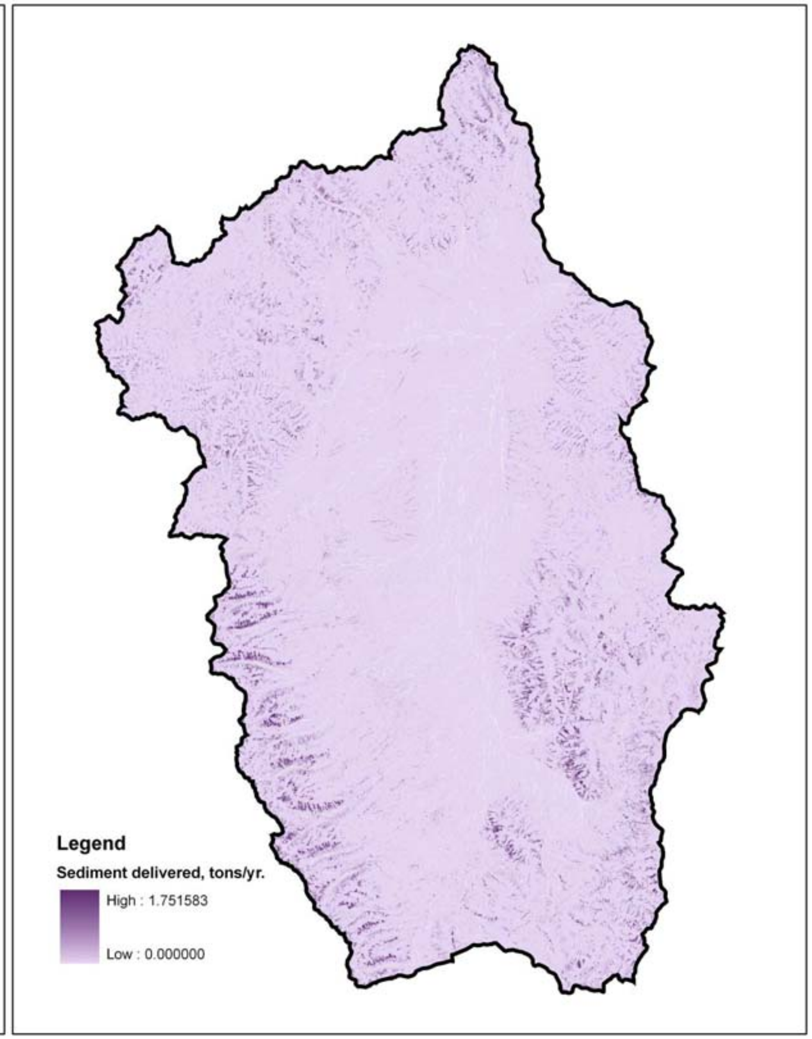


Figure A-5. Estimated sediment delivery from hill slopes, existing conditions.

Figure A-6. Estimated sediment delivery from hill slopes, BMP conditions.

Table A-5. Total and normalized existing and potential sediment loads from upland erosion for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs). The upper Big Hole watershed is bolded.

6th Code HUC Subwatershed	Acres	Existing Load (tons/yr)	Potential Load (tons/yr)	Normalized Existing Load (tons/acre/yr)	Normalized Potential Load (tons/acre/yr)
Andrus Creek	12658	1250	1047	0.099	0.083
Berry Creek	9132	859	698	0.094	0.076
Big Swamp Creek	15256	1451	1170	0.095	0.077
Big Hole River-Big Swamp Creek	20532	524	423	0.026	0.021
Big Hole River-McVey Homestead	17216	184	146	0.011	0.009
Big Hole River-Saginaw Creek	14824	1085	756	0.073	0.051
Big Hole River-Spring Creek	20144	983	761	0.049	0.038
Big Hole River-Squaw Creek	8565	168	130	0.020	0.015
Big Hole River-Wisdom	17787	563	446	0.032	0.025
Big Lake Creek	28043	2246	1826	0.080	0.065
Bull Creek	30605	3067	2520	0.100	0.082
Doolittle Creek	13822	620	536	0.045	0.039
Englejard Creek	17476	1081	871	0.062	0.050
Fox Creek	7805	1062	870	0.136	0.111
Francis Creek	16143	584	502	0.036	0.031
Headwaters Big Hole River	20967	2237	1802	0.107	0.086
Howell Creek	12859	505	432	0.039	0.034
Johnson Creek	22269	1115	873	0.050	0.039
Joseph Creek	8004	322	301	0.040	0.038
Little Lake Creek	14775	1375	1108	0.093	0.075
Lower Governor Creek	17789	1166	911	0.066	0.051
Lower Rock Creek	10099	107	84	0.011	0.008
Lower Trail Creek	16558	729	655	0.044	0.040
Lower Warm Springs Creek	29047	2756	2248	0.095	0.077
May Creek	9839	414	387	0.042	0.039
McVey Creek	9426	369	310	0.039	0.033
Miner Creek	18088	2332	1892	0.129	0.105
Mussigbrod Creek	16207	1049	809	0.065	0.050
North Fork Big Hole River	26228	292	234	0.011	0.009
Old Tim Creek	14172	695	606	0.049	0.043
Pine Creek	3938	352	289	0.089	0.073
Pintlar Creek	17779	1513	1290	0.085	0.073
Plimpton Creek	28627	929	789	0.032	0.028
Ruby Creek	23915	1465	1272	0.061	0.053
Schulz creek	2383	80	54	0.034	0.023
Stanley Creek	11772	366	311	0.031	0.026
Steel Creek	17968	714	609	0.040	0.034
Swamp Creek	31427	1634	1312	0.052	0.042
Tie Creek	19561	854	759	0.044	0.039
Upper Governor Creek	10763	600	498	0.056	0.046
Upper Rock Creek	27615	1955	1606	0.071	0.058
Upper Trail Creek	16149	805	644	0.050	0.040
Upper Warm Springs Creek	12404	386	331	0.031	0.027

Table A-5. Total and normalized existing and potential sediment loads from upland erosion for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs). The upper Big Hole watershed is bolded.

6th Code HUC Subwatershed	Acres	Existing Load (tons/yr)	Potential Load (tons/yr)	Normalized Existing Load (tons/acre/yr)	Normalized Potential Load (tons/acre/yr)
West Fork Ruby Creek	10202	570	499	0.056	0.049
Upper Big Hole Watershed	**730837**	**43414**	**35618**	**0.059**	**0.049**

Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs). The upper Big Hole watershed is bolded.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Andrus Creek	Evergreen Forest	292	292
	Grasslands/Herbaceous	684	570
	Shrubland	274	185
Andrus Creek Total		1250	1047
Berry Creek	Bare Rock/Sand/Clay	5	5
	Evergreen Forest	153	153
	Grasslands/Herbaceous	425	354
	Shrubland	275	186
Berry Creek Total		859	698
Big Swamp Creek	Bare Rock/Sand/Clay	9	9
	Evergreen Forest	216	216
	Grasslands/Herbaceous	654	545
	Pasture/Hay	1	<1
	Shrubland	525	354
	Logging	46	46
Big Swamp Creek Total		1451	1170
Big Hole River-Big Swamp Creek	Evergreen Forest	77	77
	Grasslands/Herbaceous	286	239
	Pasture/Hay	21	14
	Shrubland	139	94
Big Hole River-Big Swamp Creek Total		524	423
Big Hole River-McVey Homestead	Evergreen Forest	2	2
	Grasslands/Herbaceous	143	119
	Pasture/Hay	1	<1
	Shrubland	38	26
Big Hole River-McVey Homestead Total		184	146
Big Hole River-Saginaw Creek	Evergreen Forest	114	114
	Grasslands/Herbaceous	521	434
	Logging	6	6
	Pasture/Hay	13	8
	Shrubland	273	184
	Small Grains	160	10
Big Hole River-Saginaw Creek Total		1085	756

Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs). The upper Big Hole watershed is bolded.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Big Hole River-Spring Creek	Evergreen Forest	23	23
	Grasslands/Herbaceous	554	461
	Logging	8	8
	Pasture/Hay	14	9
	Shrubland	383	258
	Woody Wetlands	1	1
Big Hole River-Spring Creek Total		983	761
Big Hole River-Squaw Creek	Evergreen Forest	4	4
	Grasslands/Herbaceous	99	83
	Shrubland	65	44
Big Hole River-Squaw Creek Total		168	130
Big Hole River-Wisdom	Evergreen Forest	27	27
	Grasslands/Herbaceous	361	301
	Shrubland	176	118
Big Hole River-Wisdom Total		563	446
Big Lake Creek	Bare Rock/Sand/Clay	5	5
	Evergreen Forest	351	351
	Grasslands/Herbaceous	1194	995
	Pasture/Hay	17	11
	Shrubland	661	445
	Logging	18	18
Big Lake Creek Total		2246	1826
Bull Creek	Emergent Herbaceous Wetlands	2	2
	Evergreen Forest	202	202
	Grasslands/Herbaceous	2293	1908
	Logging	70	70
	Shrubland	499	336
	Woody Wetlands	1	1
Bull Creek Total		3067	2520
Doolittle Creek	Evergreen Forest	246	246
	Grasslands/Herbaceous	239	199
	Shrubland	134	91
Doolittle Creek Total		620	536
Englejard Creek	Bare Rock/Sand/Clay	4	4
	Evergreen Forest	153	153
	Grasslands/Herbaceous	581	484
	Pasture/Hay	2	<1
	Shrubland	342	230
Englejard Creek Total		1081	871

Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs). The upper Big Hole watershed is bolded.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Fox Creek	Evergreen Forest	190	190
	Grasslands/Herbaceous	574	478
	Shrubland	296	200
	Woody Wetlands	1	1
Fox Creek Total		1062	870
Francis Creek	Evergreen Forest	186	186
	Grasslands/Herbaceous	291	242
	Logging	6	6
	Shrubland	100	67
Francis Creek Total		584	502
Headwaters Big Hole River	Bare Rock/Sand/Clay	4	4
	Evergreen Forest	439	439
	Grasslands/Herbaceous	945	787
	Shrubland	849	572
Headwaters Big Hole River Total		2237	1802
Howell Creek	Evergreen Forest	219	219
	Grasslands/Herbaceous	133	111
	Pasture/Hay	2	1
	Shrubland	149	100
	Small Grains	2	<1
Howell Creek Total		505	432
Johnson Creek	Evergreen Forest	343	343
	Fire	318	168
	Grasslands/Herbaceous	266	220
	Logging	50	50
	Shrubland	138	93
Johnson Creek Total		1115	873
Joseph Creek	Evergreen Forest	230	230
	Grasslands/Herbaceous	35	29
	Shrubland	47	32
	Logging	6	6
	Woody Wetlands	4	4
Joseph Creek Total		322	301
Little Lake Creek	Bare Rock/Sand/Clay	10	10
	Evergreen Forest	179	179
	Grasslands/Herbaceous	748	623
	Shrubland	438	295
Little Lake Creek Total		1375	1108

Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs). The upper Big Hole watershed is bolded.

Subwatershed	**Land Cover Classification**	**Existing Sediment (tons/yr)**	**Potential Sediment (tons/yr)**
Lower Governor Creek	Emergent Herbaceous Wetlands	1	1
	Grasslands/Herbaceous	779	649
	Shrubland	385	260
	Woody Wetlands	1	1
Lower Governor Creek Total		1166	911
Lower Rock Creek	Grasslands/Herbaceous	77	64
	Shrubland	29	20
Lower Rock Creek Total		107	84
Lower Trail Creek	Evergreen Forest	398	398
	Grasslands/Herbaceous	95	79
	Logging	55	55
	Shrubland	179	121
	Woody Wetlands	2	2
Lower Trail Creek Total		729	655
Lower Warm Springs Creek	Deciduous Forest	1	1
	Emergent Herbaceous Wetlands	2	2
	Evergreen Forest	488	488
	Grasslands/Herbaceous	1398	1164
	Logging	14	14
	Shrubland	844	569
	Woody Wetlands	10	10
Lower Warm Springs Creek Total		2756	2248
May Creek	Evergreen Forest	308	308
	Grasslands/Herbaceous	47	39
	Shrubland	60	40
May Creek Total		414	387
McVey Creek	Evergreen Forest	100	100
	Grasslands/Herbaceous	180	150
	Shrubland	89	60
McVey Creek Total		369	310
Miner Creek	Bare Rock/Sand/Clay	13	13
	Evergreen Forest	257	257
	Grasslands/Herbaceous	1460	1217
	Pasture/Hay	2	1
	Shrubland	600	404
Miner Creek Total		2332	1892
Mussigbrod Creek	Evergreen Forest	303	303
	Fire	317	168
	Grasslands/Herbaceous	297	247
	Logging	5	5
	Shrubland	127	85
Mussigbrod Creek Total		1049	809

Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs). The upper Big Hole watershed is bolded.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
North Fork Bighole River	Evergreen Forest	26	26
	Grasslands/Herbaceous	193	161
	Logging	6	6
	Pasture/Hay	5	3
	Shrubland	58	39
	Small Grains	4	<1
North Fork Bighole River Total		292	234
Old Tim Creek	Evergreen Forest	336	336
	Grasslands/Herbaceous	151	126
	Shrubland	194	131
	Logging	13	13
Old Tim Creek Total		695	606
Pine Creek	Evergreen Forest	141	141
	Grasslands/Herbaceous	33	28
	Shrubland	178	120
Pine Creek Total		352	289
Pintlar Creek	Evergreen Forest	520	520
	Fire	10	5
	Grasslands/Herbaceous	638	532
	Logging	1	1
	Shrubland	344	232
Pintlar Creek Total		1513	1290
Plimpton Creek	Evergreen Forest	290	290
	Fire	2	<1
	Grasslands/Herbaceous	452	377
	Logging	1	1
	Pasture/Hay	3	2
	Shrubland	177	120
	Small Grains	4	<1
Plimpton Creek Total		929	789
Ruby Creek	Evergreen Forest	571	571
	Grasslands/Herbaceous	573	477
	Logging	21	21
	Shrubland	296	199
	Woody Wetlands	4	4
Ruby Creek Total		1465	1272
Schulz creek	Evergreen Forest	6	6
	Fire	56	30
	Shrubland	1	1
	Logging	18	18
Schulz creek Total		80	54

Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs). The upper Big Hole watershed is bolded.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Stanley Creek	Evergreen Forest	91	91
	Grasslands/Herbaceous	223	186
	Logging	1	1
	Pasture/Hay	1	<1
	Shrubland	50	34
Stanley Creek Total		366	311
Steel Creek	Evergreen Forest	275	275
	Grasslands/Herbaceous	237	197
	Logging	1	1
	Shrubland	201	136
Steel Creek Total		714	609
Swamp Creek	Bare Rock/Sand/Clay	3	3
	Evergreen Forest	201	201
	Grasslands/Herbaceous	893	744
	Logging	6	6
	Shrubland	531	358
Swamp Creek Total		1634	1312
Tie Creek	Evergreen Forest	436	436
	Fire	28	15
	Grasslands/Herbaceous	126	104
	Logging	79	79
	Shrubland	186	125
Tie Creek Total		854	759
Upper Governor Creek	Evergreen Forest	63	63
	Grasslands/Herbaceous	458	382
	Logging	2	2
	Shrubland	75	51
Upper Governor Creek Total		600	498
Upper Rock Creek	Bare Rock/Sand/Clay	3	3
	Evergreen Forest	190	190
	Grasslands/Herbaceous	1373	1144
	Logging	21	21
	Pasture/Hay	11	7
	Shrubland	359	242
Upper Rock Creek Total		1955	1606

Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs). The upper Big Hole watershed is bolded.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Upper Trail Creek	Deciduous Forest	1	1
	Evergreen Forest	247	247
	Fire	121	65
	Grasslands/Herbaceous	229	190
	Shrubland	201	135
	Logging	4	4
	Woody Wetlands	2	2
Upper Trail Creek Total		805	644
Upper Warm Springs Creek	Evergreen Forest	154	154
	Grasslands/Herbaceous	132	110
	Shrubland	100	67
Upper Warm Springs Creek Total		386	331
West Fork Ruby Creek	Evergreen Forest	269	269
	Grasslands/Herbaceous	169	140
	Shrubland	132	89
West Fork Ruby Creek Total		570	499
Upper Big Hole Watershed	**Bare Rock/Sand/Clay**	**56**	**56**
	Deciduous Forest	**2**	**2**
	Emergent Herbaceous Wetlands	**5**	**5**
	Evergreen Forest	**9315**	**9315**
	Fire	**851**	**450**
	Grasslands/Herbaceous	**21238**	**17691**
	Logging	**459**	**459**
	Pasture/Hay	**93**	**57**
	Shrubland	**11198**	**7546**
	Small Grains	**170**	**10**
	Woody Wetlands	**27**	**27**
Upper Big Hole Watershed Total		**43414**	**35618**

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