

Appendix L

Cost Estimate to Construct Rock Grade-Control Structures on Tributaries to the Missouri River

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MEMORANDUM FOR RECORD

SUBJECT: Missouri River Bed Degradation Feasibility Study - Cost Estimate to Construct Rock Grade Control Structures on Tributaries to the Missouri River

1. Purpose and Background: The Missouri River Bed Degradation Feasibility Study (Degradation Study) is quantifying the costs of bed degradation on the Missouri River for the study period (years 2015-2065) along the reach of the river (river miles 498 to 293) included in the study. As the river bed of the Missouri River degrades, the tributaries that discharge into the Missouri River also experience degradation. The degradation on the tributaries can cause adverse economic impacts to property located adjacent to the tributary such as bank erosion and undercutting of infrastructure such as bridge piers and drainage pipes. Approximately 118 tributaries with potential for damage from degradation enter the Missouri River within the study reach. Analyzing the impacts from degradation on each tributary is impractical due to the large geographic extent of the study area and the lack of sufficient data. The approach used in this analysis is to calculate the cost to prevent damage by constructing rock filled grade control structures in each tributary to prevent degradation from moving upstream of the structures and thereby preventing damage. However, upstream stakeholders would not likely construct grade control at the mouth of each tributary; rather, they would react by setting back levees, rebuilding roads, and protecting bridges and other investments as each feature was threatened. The actual cost of this type of reactionary approach is impossible to calculate, but would be significantly higher than grade control. Therefore, the costs presented in this memorandum, while sufficient in detail for comparison of alternatives in the SMART planning environment, are not to be construed as fully representing the actual costs that would be incurred as degradation progresses upstream. The purpose of this document is to quantify the costs associated with constructing rock grade control structures on tributaries of the Missouri River within the study reach to prevent damage due to future degradation on the tributaries. The SMART planning environment requires that assumptions be made when data is not available or cost/time prohibitive to collect and therefore this cost analysis contains a number of stated assumptions.

2. Inclusion Criteria: Future costs will be calculated for degradation on the main-stem Missouri River that is projected to occur over the study period and propagate up the tributaries. After discussion with members of the PDT, any tributary that extends beyond the floodplain of the Missouri River and therefore drains more land area than the floodplain itself was included. This criteria excludes any drainage that only drains the floodplain itself such as most levee drainage ditches. Floodplain drainage ditches were excluded due to their small size and the observation that most or all of these

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ditches need to be routinely cleaned of sediment deposition and are therefore unlikely to experience degradation. Some of the tributaries included have fairly small drainage areas and it is unknown if grade control would in fact be economically justified. However, the SMART planning process requires simplifying assumptions due to the lack of available data.

3. Tributary Geometry: Tributaries included were identified along the study reach using aerial photography. Three-meter LIDAR data collected in 2013 was used to determine tributary top-width. For each tributary, a cross-section near the Missouri River was cut from LIDAR and the top-of-bank located for both banks of the tributary. LIDAR does not penetrate the water surface in the tributaries, so it was not possible to obtain the invert elevation of each tributary and there is no other available data set which contains this information. Therefore, all tributaries were assumed to have invert elevations 5 feet below the Construction Reference Plane (CRP) of the Missouri River. This assumption is based on the observation that the water surface in tributaries along the Missouri River are not perched above the base water surface (CRP) of the Missouri River and must have sufficient cross-sectional area to allow flow. It is likely that larger tributaries are deeper but 5 feet was selected as the likely average. This is a reasonable assumption as the tributaries within the floodplain are often navigable by small boat when the Missouri River stage is a few feet below CRP. Conversely, a review of the cross sections showed the height of the banks above CRP to be approximately 10-15 feet. The tributary width was measured as the distance between the top-of-bank points.

4. Extrapolation to Upstream: The Degradation Study employed a mobile-bed model to predict the amount of future degradation within the study reach. However, the model only extends to river mile 448 (St. Joseph, MO) while the study reach extends to river mile 498. The model predicts significant degradation near river mile 448, which geomorphic principles indicate will migrate upstream and cause some level of degradation between river miles 448 and 498. For purposes of this and other Degradation Study economic analysis, the degradation level from river mile 448 to 498 was found by using the model results at river mile 448, assuming zero degradation at river mile 498, and using linear interpolation between these two points to determine the amount of degradation at each location.

5. Structure Quantities: Grade control structure design was based on the design of the grade control structures constructed on the Blue River as part of the Blue River Flood Control Project. The structures were a series of rock filled weirs designed to control about 2 feet of channel drop across each structure. Weirs were placed a set distance apart and the channel between the weirs rocked to prevent channel migration. The

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grade control structure design (weir) for this analysis is as follows: The individual weirs are crested structures with a 20H:1V downstream slope and a 4H:1V upstream slope. Minimum thickness is assumed to be 3 feet. This geometry was calculated to extend across the width of each tributary which was found by LIDAR as described above. Both banks alongside each weir are assumed rocked for the entire length of the structure with the rock extending in height from the invert of the tributary (5 feet below CRP) to within approximately 66% to the top-of-bank. This distance was found to vary from 10 feet to 20 feet so 15 feet was used for all structures. See Figures 1 and 2 for cross sections of the design. One structure was assumed needed for every 2 feet of projected degradation so that degradation of 1-2 feet will require one structure, 2-4 feet will require two structures, etc. Multiple structures on one tributary are assumed to be placed 300 feet apart and both banks and the bed between the structures rocked to the same height and width as the weir except rock thickness on the bed is 3 feet without a crest. For the Future Without Project condition, 73 tributaries will require at least one grade control structure (see Table 1 for a complete list). Volumes were converted into tons of rock assuming 1.7 tons per yd^3 .

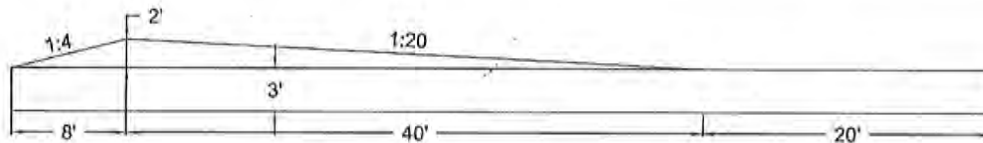


Figure 1. Profile View of Grade Control Structure



Figure 1. Cross-Section View of Grade Control Structure

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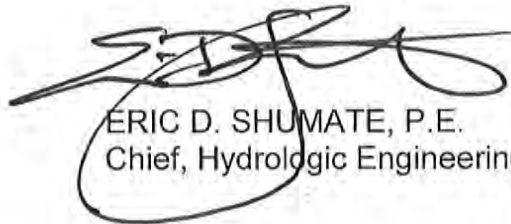
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6. Cost Estimate: The Kansas City District Cost Engineering Section estimates the cost to construct the grade control structures to be \$92.61 per ton of rock. This unit cost is based on bid abstracts from recent Section 14 bank stabilization projects which involved placing riprap on the bed of tributaries to the Missouri River. The market average from those projects has been escalated to current May 2016 dollars. This unit cost rate includes mobilization, construction costs, PED, S&A, and contingency.

7. Results: The estimated cost to construct rock grade control structures on tributaries to the Missouri River in association with future degradation is summarized in Attachment 1.

8. If there are any questions please contact Michael Chapman at 816-389-3310.

Encl

A handwritten signature in black ink, appearing to read "Eric D. Shumate", with a large, stylized flourish at the end.

ERIC D. SHUMATE, P.E.
Chief, Hydrologic Engineering Branch

Attachment 1. FWOP Costs to Construct Grade Control

RM	Tributary Name	Max Deg (ft.)	Year 2'	Quantity for GC (tons)	Year 4'	Quantity for GC (tons)	Quantity for Bank Prot (tons)	Sum of Quantities (tons)
494.9	Big Nemaha River	4.66	2039	4,393	2050	4,393	16053	24838
486.2	Squaw Creek	4.66	2039	1,684	2050	1,684	6403	9772
484.6	Cedar Creek	4.66	2039	2,009	2050	2,009	7565	11584
482.8	Kinsey Creek	4.66	2039	1,684	2050	1,684	6403	9772
480.0	no name	4.66	2039	1,652	2050	1,652	6290	9595
479.3	Mission Creek	4.66	2039	1,954	2050	1,954	7367	11274
478.9	Wolf River	4.66	2039	4,984	2050	4,984	18190	28159
476.0	Mill Creek	4.66	2039	1,525	2050	1,525	5837	8888
472.7	no name	4.66	2039	1,240	2050	1,240	4817	7296
471.3	Mosquito Creek	4.66	2039	1,843	2050	1,843	6970	10656
469.0	Charleston Creek	4.66	2039	2,477	2050	2,477	9237	14192
468.0	no name	4.66	2039	1,541	2050	1,541	5893	8976
466.2	Easter Creek	4.66	2039	1,232	2050	1,232	4788	7252
465.5	McWilliams Creek	4.66	2039	1,510	2050	1,510	5780	8799
463.1	Nodaway River	4.66	2039	4,175	2050	4,175	15300	23650
460.8	Mill Creek	4.66	2039	1,827	2050	1,827	6913	10567
458.0	no name	4.66	2039	1,383	2050	1,383	5327	8092
455.1	no name	4.66	2039	1,557	2050	1,557	5950	9064
453.9	no name	4.66	2039	1,684	2050	1,684	6403	9772
453.8	Mace Creek	4.66	2039	1,986	2050	1,986	7480	11451
452.3	no name	4.66	2039	1,684	2050	1,684	6403	9772
450.1	Roys Branch Creek	4.66	2039	1,049	2050	1,049	4137	6236
449.6	no name	4.66	2039	1,392	2050	1,392	5361	8145
447.3	Whitehead Creek	4.50	2039	1,978	2050	1,978	7452	11407
445.7	no name	4.43	2039	1,240	2050	1,240	4817	7296
445.7	Brown's Branch	4.43	2039	2,316	2050	2,316	8660	13293
444.3	no name	3.91	2040	1,383	0	-	0	1383
441.7	Peters Creek	3.45	2041	1,716	0	-	0	1716
440.1	Walnut Creek	3.41	2032	2,001	0	-	0	2001
439.1	no name	3.35	2033	1,232	0	-	0	1232
437.3	Contrary Creek	3.57	2032	2,327	0	-	0	2327
435.2	no name	3.38	2033	1,851	0	-	0	1851
433.5	Brush Creek	3.02	2037	1,684	0	-	0	1684
433.0	Cloverdale Drain	2.95	2037	1,843	0	-	0	1843
431.3	no name	2.96	2038	1,224	0	-	0	1224
428.0	Lost Creek	3.10	2040	1,549	0	-	0	1549
425.6	no name	3.03	2035	1,541	0	-	0	1541
424.8	no name	2.86	2036	1,525	0	-	0	1525

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424.0	Independence Creek	2.58	2041	1,970	0	-	0	1970
421.9	no name	2.46	2048	1,224	0	-	0	1224
420.9	Whiskey Creek	2.43	2049	1,827	0	-	0	1827
418.2	Sugar Creek	2.16	2063	2,446	0	-	0	2446
417.0	Walnut Creek	2.09	2063	1,867	0	-	0	1867
415.1	no name	1.93	0	-	0	-	0	0
413.8	Little Walnut Creek	1.71	0	-	0	-	0	0
411.0	no name	1.42	0	-	0	-	0	0
410.5	Mission Creek	1.09	0	-	0	-	0	0
407.5	Harpst Chute	0.40	0	-	0	-	0	0
406.2	Salt Creek	0.49	0	-	0	-	0	0
403.3	Bear Creek	0.61	0	-	0	-	0	0
401.3	Bee Creek	0.67	0	-	0	-	0	0
398.5	One Mile Creek	0.43	0	-	0	-	0	0
398.0	Corral Creek	0.43	0	-	0	-	0	0
396.6	Threemile Creek	0.36	0	-	0	-	0	0
395.6	Fivemile Creek	0.29	0	-	0	-	0	0
395.3	no name	0.20	0	-	0	-	0	0
392.9	no name	0.00	0	-	0	-	0	0
391.9	no name	0.00	0	-	0	-	0	0
391.2	Platte River	0.00	0	-	0	-	0	0
389.6	Summerfield Branch	0.00	0	-	0	-	0	0
388.1	Seven Mile Creek	0.00	0	-	0	-	0	0
385.5	Brown Branch	0.11	0	-	0	-	0	0
383.7	Conner Creek	0.05	0	-	0	-	0	0
382.8	Brush Creek	0.11	0	-	0	-	0	0
382.2	Marshall Creek	0.05	0	-	0	-	0	0
381.0	Malone Hollow Creek	0.01	0	-	0	-	0	0
380.5	no name	0.01	0	-	0	-	0	0
378.9	unknown	0.05	0	-	0	-	0	0
378.2	no name	0.03	0	-	0	-	0	0
377.3	White Aloe Creek	0.00	0	-	0	-	0	0
372.8	no name	0.00	0	-	0	-	0	0
372.2	Line Creek	0.00	0	-	0	-	0	0
367.4	Kansas River	0.51	0	-	0	-	0	0
365.3	no name	0.52	0	-	0	-	0	0
364.9	no name	0.59	0	-	0	-	0	0

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364.8	no name	0.61	0	-	0	-	0	0
362.6	Rock Creek	1.03	0	-	0	-	0	0
362.2	no name	1.07	0	-	0	-	0	0
361.2	Buckeye Creek	1.18	0	-	0	-	0	0
360.4	unknown	1.26	0	-	0	-	0	0
359.3	no name	1.39	0	-	0	-	0	0
357.9	Blue River	1.38	0	-	0	-	0	0
356.9	Rock Creek	1.64	0	-	0	-	0	0
356.7	Sugar Creek	1.69	0	-	0	-	0	0
351.8	Shoal Creek	2.20	2056	2,160	0	-	0	2160
350.7	Mill Creek	2.24	2056	1,819	0	-	0	1819
347.9	Rush Creek	2.00	2065	1,994	0	-	0	1994
345.6	Dry Creek	2.10	2063	1,859	0	-	0	1859
345.2		2.08	2063	462	0	-	0	462
345.1	Rose Branch	2.07	2063	1,700	0	-	0	1700
339.5	Little Blue River	1.21	0	-	0	-	0	0
337.2	Beasly Creek	1.94	0	-	0	-	0	0
337.0	unknown	2.13	2056	1,510	0	-	0	1510
335.7	unknown	2.35	2056	1,351	0	-	0	1351
335.1	no name	2.44	2055	1,383	0	-	0	1383
334.1	Fishing River	2.83	2051	3,112	0	-	0	3112
330.6	Fire Praire Creek	3.47	2044	2,176	0	-	0	2176
328.9	Hicklin Branch	4.01	2038	1,978	2065	1,978	7452	11407
328.7	no name	3.98	2038	1,970	0	-	0	1970
327.7	unknown	3.68	2042	1,700	0	-	0	1700
323.9	Cravens Creek	3.52	2042	2,120	0	-	0	2120
322.5	Sin-A-Bar Creek	3.54	2045	3,398	0	-	0	3398
321.5	Little Sin-A-Bar Creek	3.40	2044	2,009	0	-	0	2009
317.6	unknown	2.83	2049	1,224	0	-	0	1224
317.1	no name	2.76	2049	1,224	0	-	0	1224
314.6	unknown	2.37	2056	1,399	0	-	0	1399
313.7	Crooked River	2.33	2056	3,667	0	-	0	3667
312.3	unknown	2.17	2059	1,700	0	-	0	1700
310.0	no name	2.36	2051	1,660	0	-	0	1660
307.0	Tabo Creek	2.57	2040	2,446	0	-	0	2446
305.5	unknown	3.49	2031	2,001	0	-	0	2001
304.3	unknown	3.58	2031	1,819	0	-	0	1819
301.1	unknown	2.93	2033	1,700	0	-	0	1700
300.3	unknown	2.70	2033	1,232	0	-	0	1232
299.2	Baltimore Chute	2.48	2037	1,399	0	-	0	1399
298.6	Dirt Slough	2.45	2037	1,867	0	-	0	1867
295.9	unknown	0.95	0	-	0	-	0	0
294.5	no name	0.29	0	-	0	-	0	0
				7			394,473	
						@ \$92.61/ton ->	\$36,532,183	

