CENWK-ED-HR

OCT 2 4 2012

MEMORANDUM FOR RECORD

SUBJECT: History of Analyses for Kansas River Dredging Monitoring Program

1. Executive Summary: The methodology for assessing degradation on the Kansas River has undergone several changes since the start of the 1990 regulatory plan. The current methodology reduces subjectivity and increases efficiency when compared to the previous methods. For purposes of this memo, the reaches in the 2011/2012 survey which exhibited more than 2 ft of degradation were re-analyzed using the older methods. The change in methodologies does not change the status of any dredging reach with respect to the 2-ft degradation threshold.

2. Purpose and Introduction: According to "Dredging Restrictions, Section I. Restrictions Concerning Riverbed Degradation", Commercial Dredging Activities on the Kansas River, Appendix A: Regulatory Plan, Page A-3 (USACE 1990), "...if the average reduction of riverbed elevations in a 5-mile-long reach of river attains 2 feet (regardless of cause), dredging activities which adversely affect bed elevations in that reach will be terminated." The exact methodology for computing degradation over 5-mile-long reaches is not specified in the regulation, and like many engineering methodologies, has changed over time. The purpose of this memorandum is to document and compare the methodologies used to assess bed degradation on the Kansas River for the regulation of commercial dredging.

3. Computation of Average Bed Elevations: The computation of the average reduction in riverbed elevations in 5-mile-long reaches includes two steps. First, the change in bed elevation at individual cross-sections is computed. Second, an average is taken of bed change values over 5-mile-long reaches. A survey conducted in 1992 established baseline average bed elevations for each cross-section. The average bed elevations for each cross-section from the 1992 survey and subsequent surveys have been calculated by Equations 1 and 2.

$$Average\ Bed = Baseline\ Water\ Surface\ Elevation - Average\ Depth \qquad \text{Eq (1)}$$

$$Average\ Depth = Area\ Below\ Baseline\ Water\ Surface\ Elevation / Top\ Width \qquad \text{Eq (2)}$$

4. Bed Method #1 Analysis: The baseline water surface elevation (BWSE) at a given cross-section is the same from year to year. For the 1992 survey, the station and elevation points were imported into a CAD program, which was used to compute the area and top width of the cross-

section, as shown in Enclosure 1. The resulting average bed elevations were stored in tabular form and were used as the baseline elevation to assess bed change for the 1995 – 2001 surveys. This method will be referred to as Bed Method #1 for the remainder of this memo.

5. Bed Method #2 Analysis: For the surveys from 2003 to 2009, the use of CAD was replaced by a Visual Basic macro to compute the average bed. The macro also used Equations 1 and 2 and generated average bed elevations equivalent to the CAD calculated values, except in cross-sections with bars or islands above the BWSE. This special case will be considered later in this memo. The macro significantly decreased processing time by automatically computing the area, top width, and average bed. This method will be referred to as Bed Method #2 for the remainder of this memo.

6. Bed Method # 3 Analysis: In 2010, a survey was conducted over a smaller segment of river. An Excel spreadsheet was written to compute the area, top width, and resulting average bed without macros. This spreadsheet computed the area as the sum of small trapezoids, as depicted in Enclosure 2. This method also generated average bed elevations equivalent to the CAD (Bed Method #1) and macro (Bed Method #2) calculated values, except in cross sections with bars or islands. This method will be referred to as Bed Method #3 for the remainder of this memo.

7. General Cross-Section Calculations: For most cross-sections, the calculation of area, top width, and average bed elevation is a matter of simple geometry that yields identical results by using any of the three methods. To compare, the 1992 cross-section at river mile 29.9, shown in Enclosure 1, was re-assessed using the three methods. As seen in Table 1 (all tables attached), the three methods produced the same values for area, top width and average bed elevation.

8. Split Channel Area and Top Width Methodology Comparison: While the three computational tools yield identical results for most cross-sections, the special case of sections with large sand bars or islands that rise above the BWSE causing a split channel is handled differently in the methods. Table 2 shows all cross-sections in the 2011/2012 and 1992 surveys that have mid-channel features that rise above the BWSE. Only the cross-section at river mile 86.8 has a split channel both years. At river miles 29.3 and 15.75, the bars or islands present in 1992 dropped below the BWSE in 2011/2012; whereas, the bars or islands below the BWSE in 1992 emerged above the BWSE in the 2011/2012 survey at river miles 96.5, 85.2, 84.8, 80, 16.75, 13.8, and 12.1.

9. Bed Method Comparison: Each method treats the bars or islands differently. Bed Method #1 subtracts the area of the bar that falls above the BWSE from the area computed below BWSE and includes the bar width in the total top width computation, as demonstrated by Enclosure 3. Bed Method #2 does not subtract the area above the BWSE from the area computed below the BWSE and excludes the bar width from the total top width computation, as depicted in Enclosure 4. Bed Method #3 does not subtract the area above the BWSE from the area computed below the BWSE and includes the bar width in the total top width computation, as seen in Enclosure 5. Table 3 shows the different resulting average bed elevations using the three different methodologies for the cross-sections listed in Table 2. In all three methodologies, if the survey points ended prior to reaching the baseline water surface elevation, a line was extended vertically from the last survey point. Another important calculation is the change in average bed elevation from a given year to the 1992 baseline. The 1992 baseline and the 2011/2012 surveys were re-computed using each of the three methods at the cross-sections with islands or bars. Table 4 shows the bed elevation change using the different methodologies and the differences in the results of the analysis. As seen in Table 4, the choice of bed method influences the computed bed change value. This difference is reduced, however, by averaging over 5-mile reaches, which is explained in the following sections of this memo.

10. Original 5-Mile Reach Averaging (Reach Method #1): The second step in the assessment of bed degradation is to combine the bed change values at individual cross-sections into 5-mile-long reaches. The assessments prior to 2010, referred to here as Reach Method #1, used a slightly different methodology than the 2011/2012 assessment (Reach Method #2). Reach Method #1 used an approximately 5-mile-long reach instead of an exactly 5-mile-long reach. Equations 3 through 9 below explain the calculations involved in Reach Method #1. In these equations, Cross Section 2 is the upstream cross-section and Cross Section 1 is the downstream cross-section.

Incremental reach length = River Mile 2 – River Mile 1 Eq (3)

Bed Change = Avg. Bed Elev. 1 (current survey) – Avg. Bed Elev.1 (1992 Survey) Eq (4a)

Bed Change = Avg. Bed Elev.2 (current survey) – Avg. Bed Elev. 2 (1992 Survey) Eq (4b)

Average Bed Change for Incremental Reach = (Bed Change 2 + Bed Change 1) / 2 Eq (5)

*Inc. Weighted Bed Change = Avg. Bed Change for Inc. Reach * Inc. Reach Length* Eq (6)

Total Weighted Bed Change = ∑ *Inc. Weighted Bed Changes* Eq (7)

Actual Reach Length = *River Mile at Top of Reach* – *River Mile at Bottom of Reach* Eq (8)

Reach Average Bed Change = *Total Bed Change / Actual Reach Length* Eq (9)

Example Calculation RM 9.4 – 14.7 (Note: RM 14.1 could have been chosen as the final cross section instead of 14.7). Additional values can be found in Table 5.

Incremental Reach Length (RM 9.4-9.5) = 9.5 - 9.4 = **0.1 [mi]** Eq (3)

Bed Change (RM 9.4) = 715.24 – 719.68 = **-4.44 [ft]** Eq (4a)

Bed Change (RM 9.5) = 714.81 – 720.02 = **-5.21 [ft]** Eq(4b)

Ave Bed Change for Inc. Reach (RM 9.4-9.5) = [(-4.44) + (-5.21)] / 2 = **-4.82 [ft]** Eq (5)

Incremental Weighted Bed Change = -4.82 * 0.1 = **-0.482 [ft*mi]** Eq (6)

Total Weighted Bed Change (see Table 5) = **-3.12 [ft*mi]** Eq (7)

Actual Reach Length = 14.7 – 9.4 = **5.3 [mi]** Eq (8)

Average Bed change over 5.3-mile Reach = -3.12/ 5.3 = **-0.589 [ft]** Eq (9)

Reach Method #1 requires manual selection of the starting and ending cross-sections. Due to varying cross-section spacing, the reach analyzed was rarely an exact 5-mile reach. In this example, for a starting river mile of 9.4, the analyzing engineer must choose between river mile 14.1 and 14.7, which yield different average bed changes.

11. New 5-mile Reach Averaging (Reach Method #2): The problem with Reach Method #1 was that the 5-mile-long reaches were constrained to begin and end at measured cross-sections. The irregular spacing of the surveyed cross-sections resulted in reaches for analysis that were between 4 miles and 6.5 miles long rather than the 5-miles specified in the dredging regulation. This introduced unnecessary subjectivity to the process, as the engineer had to decide between a reach that was too short and a reach that was too long. For example, a 4.5-mile reach might be selected for analysis over a 5.4-mile reach if the engineer believed the mandate was to capture the most significant degradation in an approximate 5-mile reach. Whereas, if the engineer

believed the mandate was to analyze reaches that were as close as possible to 5-miles long, the 5.4-mile reach might have been selected instead. To eliminate this subjectivity and allow for less human error, a new averaging methodology was established. This methodology interpolates bed change between cross-sections at 0.1 mile increments, which allows the computation of rolling averages over exact 5-mile-long reaches. The linear interpolation is accomplished for each 0.1 mile increment of river using the standard formula for linear interpolation, provided in Equation 10. The average 5-mile reach bed change is computed as the mean of the bed change values at each 0.1 river-mile increment.

$$\Delta z_{target} = \Delta z_{US} + (RM_{target} - RM_{US}) * (\Delta z_{DS} - \Delta z_{US})/(RM_{DS} - RM_{US}) \qquad Eq(10)$$

where Δz = bed change, ft

RM = river mile, mile

target refers to the location of interest that falls between cross-sections

US refers to the nearest cross-section upstream of the target

DS refers to nearest cross-section downstream of the target

This method will be referred to as Reach Method #2 for the remainder of this memo. Reach Method #2 is considered an improvement over the Reach Method #1 in that it removes subjectivity in choosing reach extents, provides results that conform to the 5-mile-long criteria specified in the dredging regulation, allows calculation of every 5-mile reach covered by the cross-sections which allows more comprehensive reporting of the degradation status of the river, and decreases analysis time. Reach Method #2 was explained to the Kansas River dredging association in August of 2011, prior to the 2011/2012 survey work. Tables 6 and 7 provide an example of these calculations for RM 39.1 to 44.1. Average bed change at individual cross-sections is shown in Table 6. The resulting interpolated values for 0.1 mile incremental lengths and the 5-mile average are included in Table 7.

12. Reach Method Comparison: The most significant average bed change over 5-miles that intersect current dredging reaches was computed using each reach method to determine the impact that the change in methodology had on the degradation assessment of the dredging reaches. As seen in Table 8, while the results from Reach Method #1 and Reach Method #2

differ slightly, they still indicate the same dredging reaches exceeding the 2 ft degradation threshold.

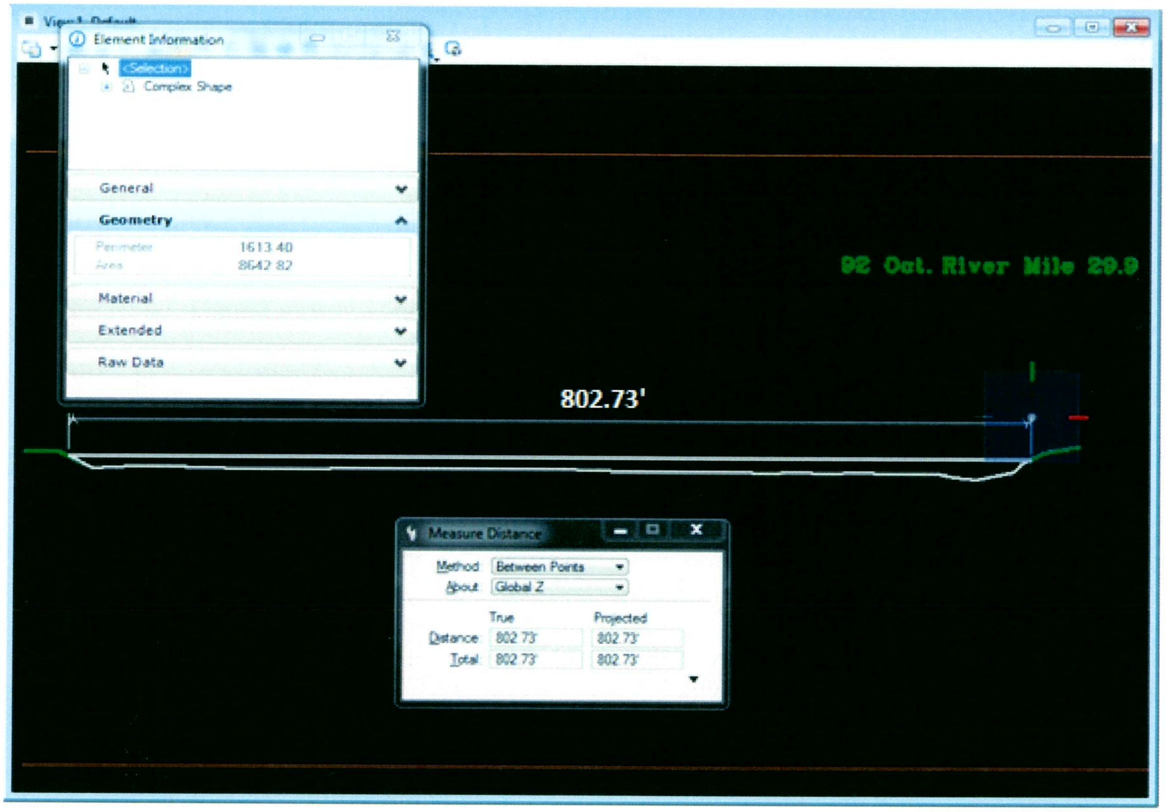
13. Re-assesment of 5-mile Reaches by Each Bed Method, Using Reach Method #2: For each of the dredging reaches, the maximum bed change was calculated over a 5-mile reach using the three Bed Methods. These values are shown in Table 9. The differences in bed methods caused by cross-sections with high mid-channel bars or islands are relatively few, and as such, have only minor effect on the 5-mile reaches. In addition, no dredging reach exceeding the 2 ft degradation threshold is affected by the choice in average bed methodology.

14. Associating 5-mile Reaches with Dredging Reaches: At all times since the start of the 1990 regulatory plan, a dredging reach has been regulated based on the most degraded of any 5-mile reach that intersects the dredging reach. For example, degradation over 2 ft within any 5-mile reach that falls between 37.6 and 49.1 is sufficient to trigger suspension of dredging in the 42.6 – 44.1 dredging reach. The most degraded 5-mile reach need not completely envelop the dredging reach; intersecting any part of the dredging reach is sufficient. Multiple dredging reaches that lie in close proximity to each other may be associated with and regulated based on the same 5-mile reaches. Since the implementation of the 1990 regulatory plan, no regulatory action has suspended dredging over part of an authorized dredging reach while allowing dredging in the other part. A reach has either been cleared for dredging or closed completely.

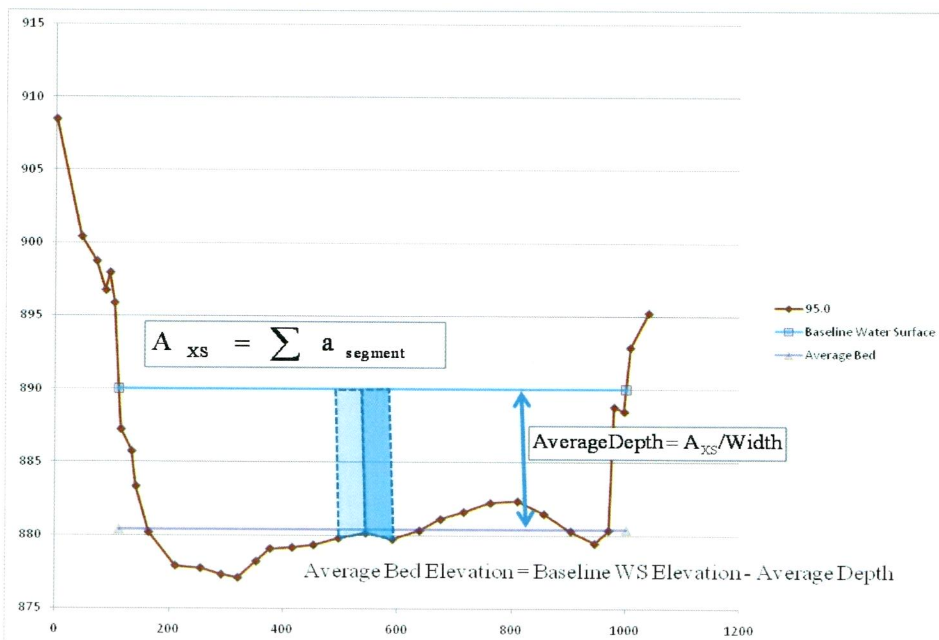
15. Conclusions: This memo documented how average bed elevations and 5-mile-long or approximately 5-mile-long reaches have been calculated for assessment of Kansas River bed degradation. It was shown that the different methodologies yield equivalent results, except for at cross-sections with mid-channel features that rise above the baseline water surface elevation. At those cross-sections differences can be large; however, so few cross-sections contain these features that the overall effect on 5-mile reaches is minor. Furthermore, no difference in methodology changes the status of any dredging reach with respect to the 2-ft degradation threshold. Point of contact for this memo is John Shelley, ED-HR, 816-389-2310.

Enclosures

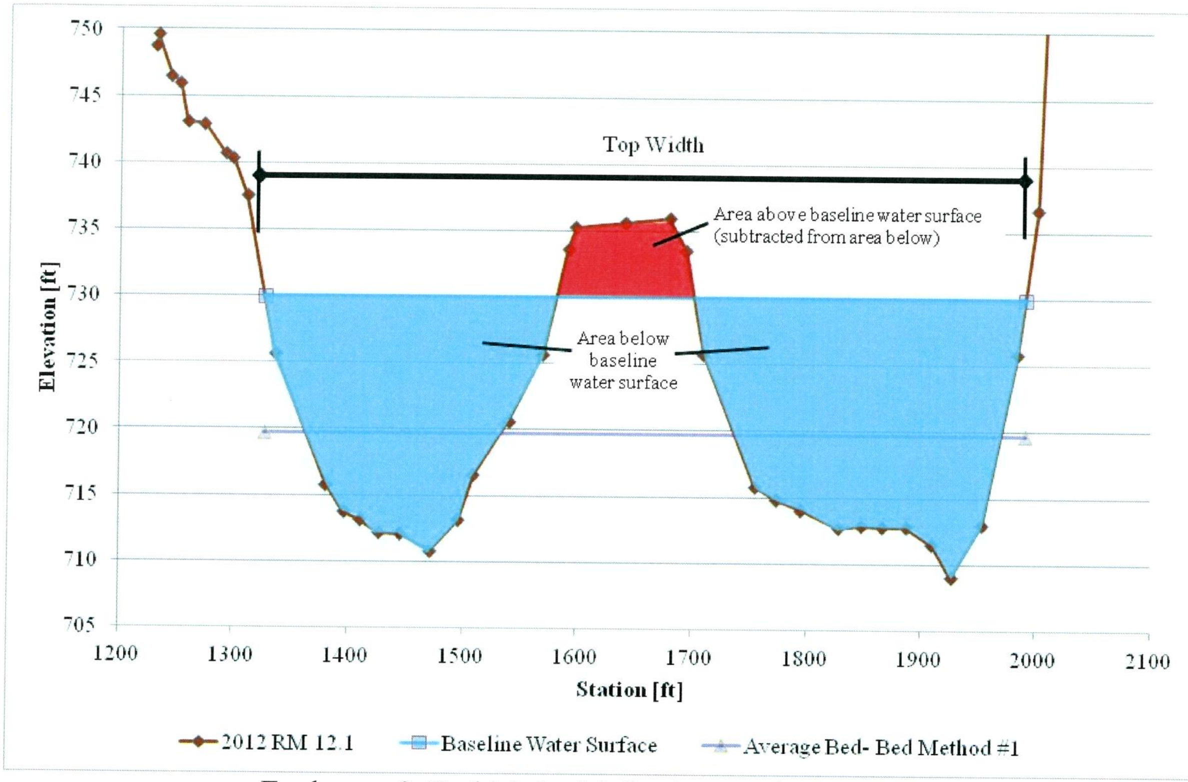
ERIC D. SHUMATE, P.E.
Chief, Hydrologic Engineering Branch



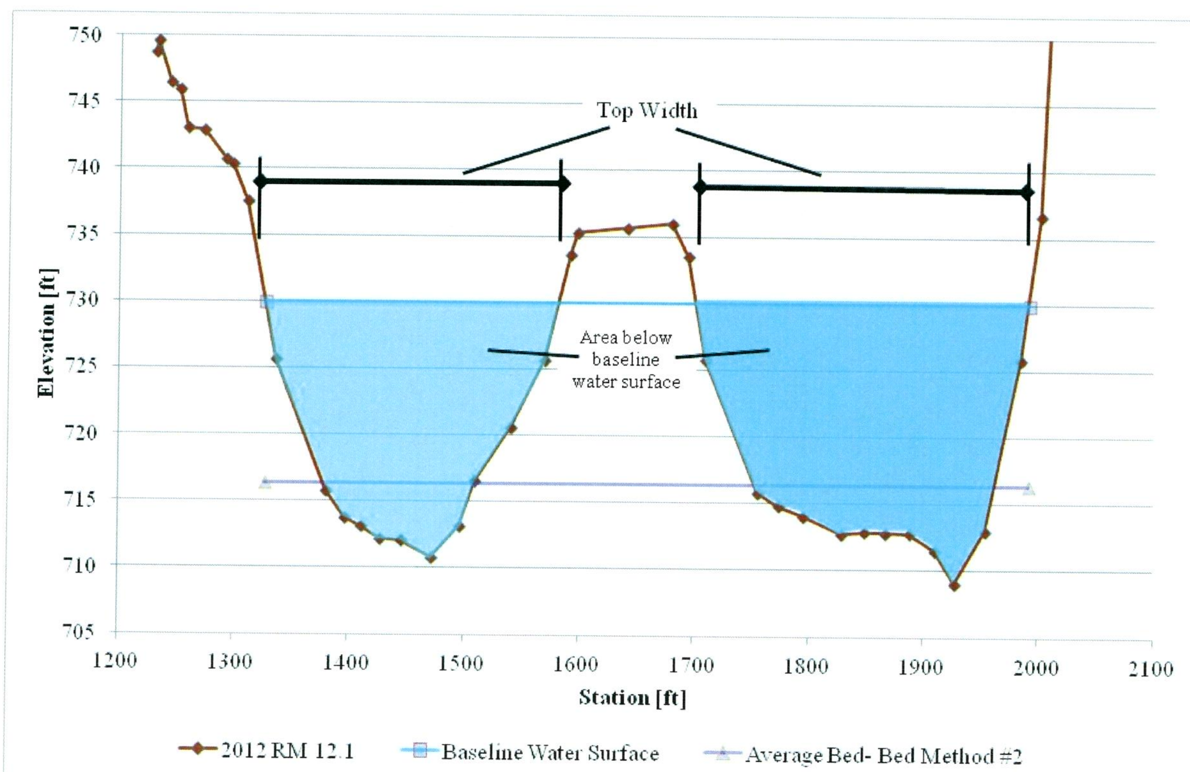
Enclosure 1. Calculation of Area and Top Width using CAD



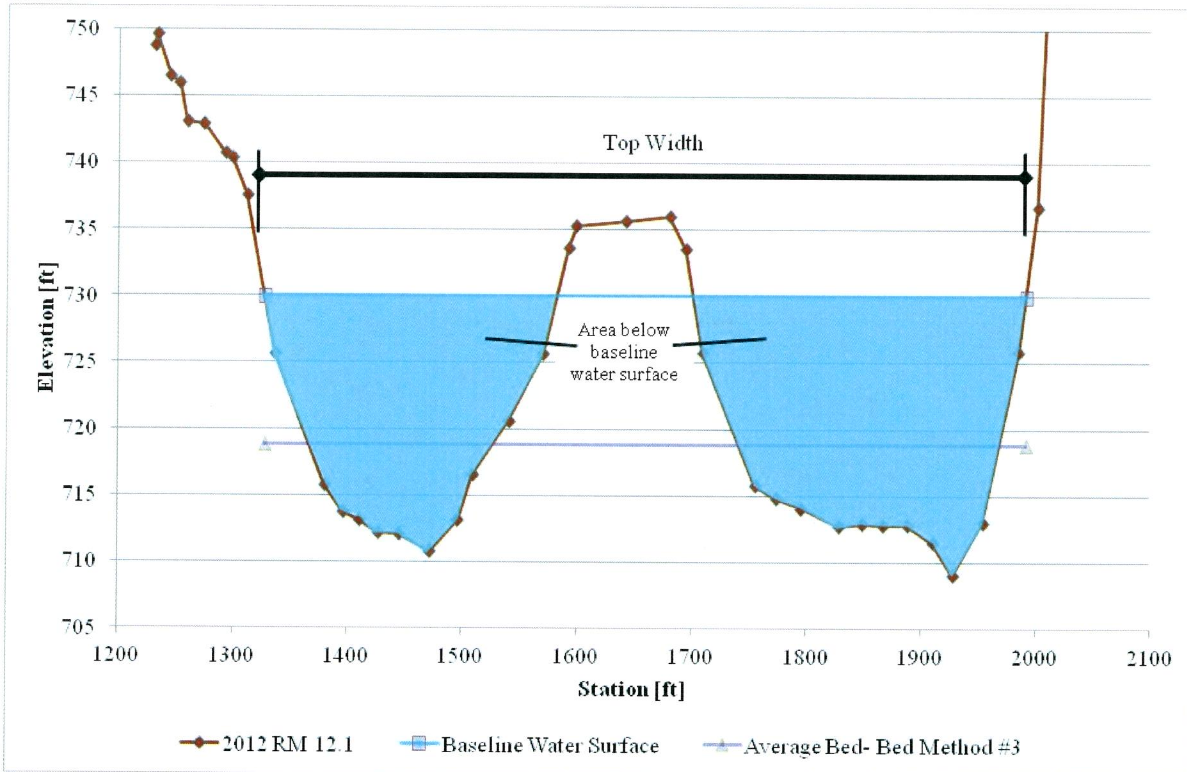
Enclosure 2. Calculation of Average Bed Elevation in Excel



Enclosure 3. Bed Method 1 for Area and Top Width



Enclosure 4. Bed Method 2 for Area and Top Width



Enclosure 5. Bed Method 3 for Area and Top Width

Table 1: Geometry Comparison for 1992 Cross-Section at RM 29.9 Using Three Methods

Method	Area [ft²]	Top Width [ft]	Ave. Bed Elev. [ft]
Bed Method #1	8,642.82	802.73	759.23
Bed Method #2	8,642.82	802.73	759.23
Bed Method #3	8,642.82	802.73	759.23

Table 2: Cross-Sections with Split Channels in 2011/2012 or 1992 survey

River Miles	
1992	**2011/2012**
	12.1
	13.8
15.75	
	16.75
29.3	
	80
	84.8
	85.2
86.8	86.8
	96.5

Table 3: Average Bed Elevation By Three Methods at Cross-Sections with High Bar or Islands

1992 Ave Bed Elevation (ft)			
River Mile	**Bed Method #1**	**Bed Method #2**	**Bed Method #3**
15.75	731.77	727.40	729.94
29.30	759.88	759.85	759.88
86.80	864.82	860.64	863.19
2011/2012 Average Bed Elevation (ft)			
River Mile	**Bed Method #1**	**Bed Method #2**	**Bed Method #3**
12.10	719.70	716.36	718.82
13.80	723.67	722.92	723.65
16.75	731.91	731.80	731.90
80.00	847.30	847.19	847.29
84.80	855.78	855.60	855.78
85.20	855.58	855.44	855.58
86.80	858.38	857.95	858.30
96.50	886.74	886.54	886.74

Table 4: Bed Degradation Comparison from 1992 to 2011 Using the Three Bed Methodologies

	Bed Change in Feet (2011-1992)		
River Mile	**Bed Method #1**	**Bed Method #2**	**Bed Method #3**
12.10	3.48	0.14	2.60
13.80	1.48	0.73	1.46
15.75	-3.74	0.62	-1.92
16.75	11.72	11.61	11.71
29.30	-4.35	-4.32	-4.35
80.00	-1.28	-1.39	-1.29
84.80	0.16	-0.02	0.16
85.20	-2.87	-3.01	-2.87
86.80	-6.44	-2.69	-4.89
96.50	-0.61	-0.81	-0.61

Table 5: Reach Method #1 Calculation for RM 9.4 – 14.7 (and RM 9.4 – 14.1) using Bed Method #2

River Mile	2012 Avg. Bed Elev. [ft]	1992 Avg. Bed Elev. [ft]	2012 - 1992 [ft]	Inc. Reach Length [mi]	Avg Bed Change for Incr Reach [ft]	Inc. Avg. Bed Change [ft*mi]
9.40	715.24	719.68	-4.44			
9.50	714.81	720.02	-5.21	0.10	-4.82	-0.482
9.95	713.76	716.25	-2.49	0.45	-3.85	-1.733
10.35	715.27	715.53	-0.26	0.40	-1.38	-0.552
10.65	715.27	715.94	-0.67	0.30	-0.47	-0.141
10.90	715.79	717.13	-1.34	0.25	-1.01	-0.253
12.10	716.36	716.22	0.14	1.20	-0.60	-0.720
12.60	717.65	717.92	-0.27	0.50	-0.06	-0.030
13.00	717.69	715.56	2.13	0.40	0.93	0.372
13.30	717.51	718.16	-0.65	0.30	0.74	0.222
13.50	718.12	716.25	1.87	0.20	0.61	0.122
13.80	722.92	722.19	0.73	0.30	1.30	0.390
14.10	721.18	723.69	-2.51	0.30	-0.89	-0.267
14.70	721.39	719.03	2.36	0.60	-0.08	-0.048
			Total Bed Change [ft*mi] (RM9.4 - 14.7)			-3.120
			Reach Length [mi] (RM9.4 - 14.7)			5.30
			Average Bed Change [ft] (RM 9.4 - 14.7)			-0.589
			Total Bed Change [ft*mi] (RM9.4 - 14.1)			-3.072
			Reach Length [mi] (RM9.4 - 14.1)			4.70
			Average Bed Change [ft] (RM 9.4 - 14.1)			-0.654

Table 6. Changes in Bed Elevation at Individual Cross-Sections

A	B	C	D
	Average Bed Elevation, ft		
Cross-Section River Mile	**2011/2012**	**1992**	**Ave Bed change since 1992, ft**
39.10	769.69	774.10	-4.41
40.50	779.47	777.36	2.11
42.00	780.59	781.40	-0.81
42.40	779.18	779.84	-0.66
43.90	779.75	782.49	-2.74
45.30	781.41	784.64	-3.23

where Column A = River miles of established cross-sections

Column B = Average bed elevations for survey year in question

Column C = Average bed elevations for 1992 survey

Column D = Column B – Column C

Table 7. Linearly-interpolated Values at 0.1-mile Increments

1	2	1 (cont)	2 (cont)
RM	**Bed Change 1992 to 2011/2012**	**RM**	**Bed Change 1992 to 2011/2012**
39.1	-4.41	41.7	-0.23
39.2	-3.95	41.8	-0.42
39.3	-3.48	41.9	-0.62
39.4	-3.01	42	-0.81
39.5	-2.55	42.1	-0.77
39.6	-2.08	42.2	-0.73
39.7	-1.62	42.3	-0.70
39.8	-1.15	42.4	-0.66
39.9	-0.69	42.5	-0.80
40	-0.22	42.6	-0.93
40.1	0.25	42.7	-1.07
40.2	0.71	42.8	-1.21
40.3	1.18	42.9	-1.35
40.4	1.64	43	-1.49
40.5	2.11	43.1	-1.63
40.6	1.91	43.2	-1.77
40.7	1.72	43.3	-1.91
40.8	1.52	43.4	-2.05
40.9	1.33	43.5	-2.18
41	1.14	43.6	-2.32
41.1	0.94	43.7	-2.46
41.2	0.75	43.8	-2.60
41.3	0.55	43.9	-2.74
41.4	0.36	44	-2.77
41.5	0.16	44.1	-2.81
41.6	-0.03		
		Reach Length (39.1 - 44.1)	5 miles
		Average Reach Bed Change	-0.86 ft

Table 8: Reach Method Comparison using Bed Method #2

Dredging Reach	Reach Method #1			Reach Method #2		
	Length (mi)	Worst Approx. 5-mile Reach	Average Change (ft)	Length (mi)	Worst 5-mile Reach	Average Change (ft)
26.1 - 27.6	4.6	27.4 -32	-2.28	5	27.4 - 32.4	-2.19
28.3 - 29.8	4.6	27.4 -32	-2.28	5	27.4 - 32.4	-2.19
42.6 - 44.1	4.6	43.9 -48.5	-2.45	5	43.3 - 48.3	-2.45
47.1 - 48	4.6	43.9 -48.5	-2.45	5	43.3 - 48.3	-2.45
45.2 - 46.7	4.6	43.9 -48.5	-2.45	5	43.3 - 48.3	-2.45
49.6 - 51.35	4.7	45.3 -50	-2.15	5	44.6 - 49.6	-2.27
90.1 - 91.6	5	86.4 -91.4	-1.48	5	86.3 - 91.3	-1.49

As seen, the change in reach method does not alter the status of any dredging reach with respect to the 2-ft degradation threshold.

Table 9. Bed Method Comparison using Reach Method #2

	Bed Method #1	Bed Method #2	Bed Method #3
Dredging Reach	Max Bed Change [ft]	Max Bed Change [ft]	Max Bed Change [ft]
9.40 - 10.40	-0.12	-0.73	-0.27
12.80 - 13.90	-0.12	-0.73	-0.27
15.40 - 16.90	0.29	0.19	0.40
18.65 - 20.15	-0.78	-0.78	-0.78
20.55 - 20.60	-0.97	-0.97	-0.91
21.00 - 21.15	-0.78	-1.14	-1.09
26.10 - 27.60	-2.19	-2.19	-2.19
28.30 - 29.80	-2.19	-2.19	-2.19
42.60 - 44.10	-2.45	-2.45	-2.45
47.10 - 48.00	-2.45	-2.45	-2.45
45.20 - 46.70	-2.45	-2.45	-2.45
49.60 - 51.35	-2.27	-2.27	-2.27
77.10 - 78.60	-0.77	-0.80	-0.77
90.10 - 91.60	-1.82	-1.49	-1.69

As seen, the changes in bed method do not alter the status of any dredging reach with respect to the 2-ft degradation threshold.