Flood Control District
of Maricopa County

INTEROFFICE MEMORANDUM

Date: December 30, 2010

To: Tom Renckly, PE, Structure Management Branch Manager, Project Planning and Management Division
Felicia Terry, PE, Regional Planning Manager, Planning Branch, Project Planning and Management Division

From: J. Rafael Pacheco, Engineering Application Development and River Mechanics Branch, Engineering Division

CC: Bing Zhao, PhD, PE, Engineering Application Development and River Mechanics Branch Manager, Engineering Division
Dave Degerness, PE, Project Manager, Dam Safety and Structure Branch, Project Planning and Management Division

Subject: Sediment yield estimation for Rittenhouse Flood Retarding Structures (FRS).

1. Study Purpose and Scope:

The purpose of the sediment yield study is to re-evaluate the amount of sediment transported to the Rittenhouse FRS for future hydrologic conditions. The initial evaluation of sediment carried to the Rittenhouse FRS is contained in the `Desert Drive Area Study, Vol. II Existing Conditions Inundation and Sedimentation by Fuller Inc. 2007 (Fuller 2007b)'. The amount of sediment yield in Fuller's study was found to be 0.53ac-ft/mi^2 for an area of 42.47 mi^2, equivalent to 22.47 ac-ft of annual sediment. If we consider the design life of the FRS to be 100 years, the total amount of sediment would be 2,247 ac-ft (for the design life of the FRS), which seems excessive when compared to the amount of sediment yield for other studies (see the excel spreadsheet attached to this document for a comparison of the sediment yield values for different FRS). The outline shown in Figure 1 below represents the boundary of the sub-basins (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 shown in Figure 2) that contribute sediment to the FRS Rittenhouse.

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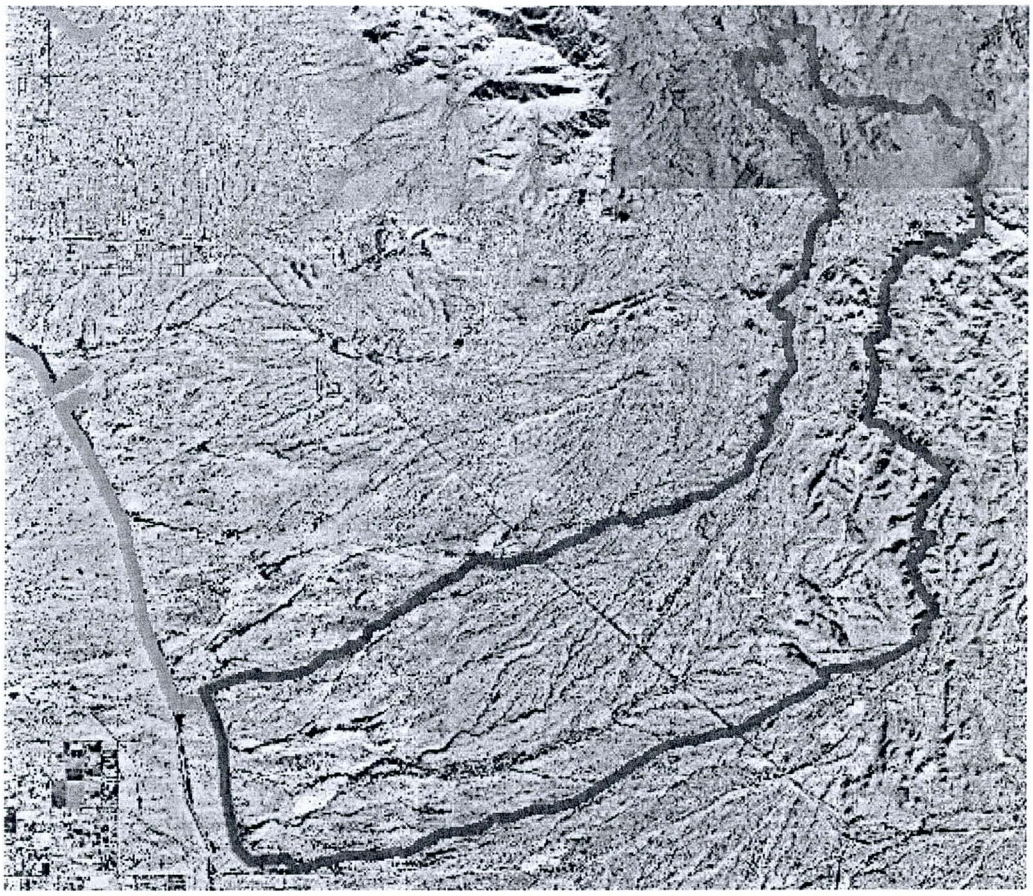

Figure 1. Watershed of the area contributing sediment to the Rittenhouse FRS.

2. Methodology:

The methodology for estimating sediment yield can be found in River Mechanics Manual for DDMSW 2010. We have used the DDMWS version 4.6.0 (with river mechanics) to determine total sediment yield in a manner that is detailed in the following sections. The total sediment yield consists of wash load and total bed material load. The *wash load* is calculated with the MUSLE method, and the *total bed material load* is calculated with the Zeller-Fullerton equation (Zeller and Fullerton, 1983), which is based on the assumption that the reach is at an equilibrium condition. The sediment yield for a particular frequency (return period) = SDR*Wash+BedL, where SDR is the sediment delivery ratio, Wash and BedL are, respectively, the wash load and total bed material load based on the MUSLE and the Zeller-Fullerton equation for a flood of a particular return period.

3. Procedure:

3.1 Shape Files Preparation for Washload

In order to use the DDMSW software the user has to provide three shapefiles, i.e. a soils shapefile, and landuse shapefile and a shapefile that should include all the sub-basins contributing sediment. The shapefiles of the area of study, soils and landuse (future conditions) were obtained from Kimley-Horn (2010) via Dave Degerness in an email dated 10/7/2010. From these sets of shapefiles for all the sub-basins, we selected only those labeled R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_10, R_11, R_12, R_13, R_14, and R_15, because those are the sub-basins that contribute sediment to the FRS (Fuller, 2007b). The outline of the shapefile resulting from the union of these sub-basins is shown in figure 1. The shapefile information should include the areas (in ft^2) for each sub-basin.

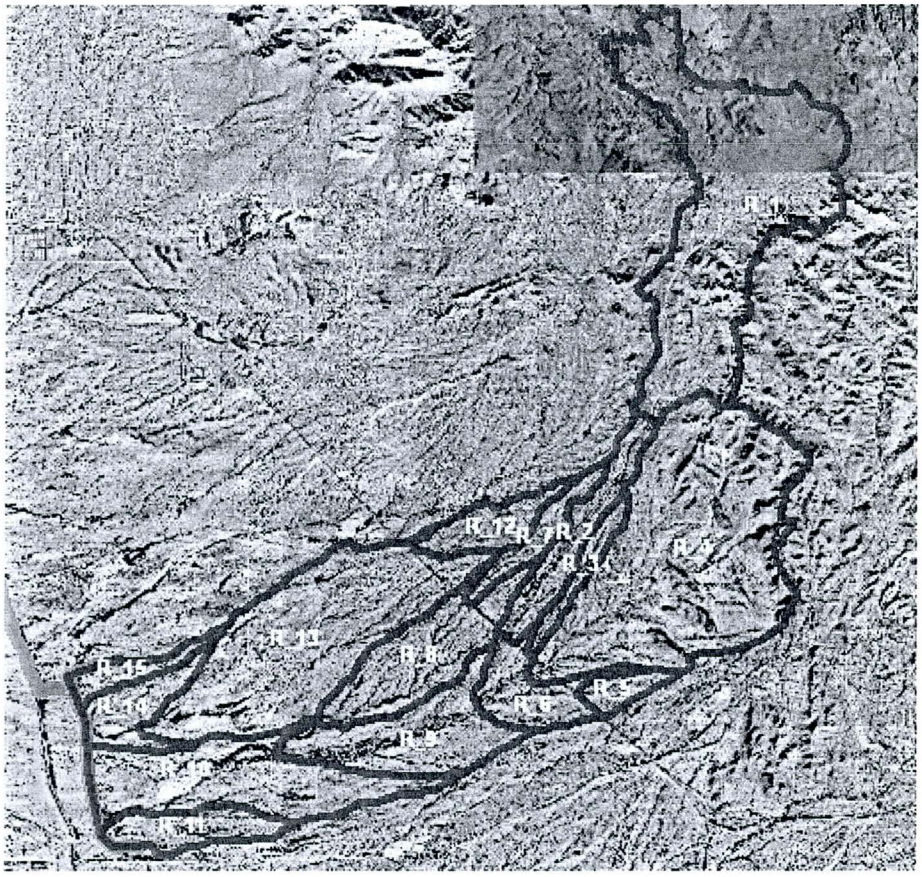

Figure 2. Sub-basins contributing sediment to the Rittenhouse FRS.

3.2 Cross-Sections Preparation for Bedload

Once the shapefile '*basin_area*' was created, it was used to help generate a 'TIN' from the topographic contour (2-ft contour interval, Project Name: Lost Dutchman Heights Mapping, Topographical date 5/25/2007, vertical datum NADV88). The purpose is to extract the cross-sections required to determine the bed-load using Zeller-Fullerton equation. The location of the cross-sections used is shown in Figure 3. These cross-sections were selected by visually inspecting the well-defined washes that possibly contribute bed-load sediment (see Figure 3).

The volumetric flow rate for the cross-sections labeled R9, R10, R11, R13, R14 and R15 in Figure 3 were obtained from the corresponding concentration points R9, R10, R11, R13, R14 and R15 respectively in the HEC-1 identifier and shown in Table 2. The cross-sections and their corresponding flow rates, friction factors and slopes were entered into DDMWS in the cross-section hydraulics and cross-section geometry.

Figure 3. Location of the cross-sections used for bed-load sediment calculations.

3.3 Two scenarios

We performed analysis for two different scenarios. One scenario is to estimate the wash-load from individual sub-basins and then obtain a total amount of sediment load. The second is to estimate the wash-load for one watershed that encloses all individual sub-basins. Within DDMSW, we created two different projects. In the first scenario, we computed the wash-load using the shapefile '*area*' for each sub-basin (R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_10, R_11, R_12, R_13, R_14, and R_15). The flow rate and volume for the 2, 5, 10, 25, 50 and 100 year for each sub-basin were reported in the 'Desert Drive Area Study, 2010'. The values of these

parameters reported in the study were verified by comparing them to the corresponding values from the HEC-1 models included in the study. The HEC-1 models were provided by Dave Degerness via email on 9/10/2010. The files corresponding to 2, 5, 10, 5, 50 and 100 year are R0224FN.dat, RR0524FN.dat, R1024FN.dat, R2524FN.dat, R5024FN.dat, R1_24FN.dat respectively (Kimley-Horn, 2010).

In the second scenario, the wash-load was obtained by considering one shapefile (*area_basin*) that included the sub-basins mentioned above.

In both scenarios the shapefiles for area, soil and landuse were entered into the DDMWS. The DDMSW then intersected the soil and landuse shape files with the area shape file and obtain the C factor and erosion factor values from the default landuse and soil tables. However, DDMSW only contains the data within Maricopa County. Some of the drainage areas are outside Maricopa County. They are located inside Eastern Pinal and Southern Gila Counties based on NRCS soil survey areas. Fuller (2007a) digitized NRCS' "unofficial" soil images and developed soil shape files. The unique soil_lid was developed by combining the book number (661) with the map unit symbols at that time. It should be pointed out that the map unit symbols then are different from those on the current NRCS web site (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx). However, this does not affect the results as long as the soil_lids are unique and consistent within the project. In the current study, the soil_lids developed by Fuller (2007a) are used. Confusion may arise in the future when new soil_lid is developed based on the current map unit symbols.

The soil-erosion factors (*K*) for "Easter Pinal and Southern Gila Counties" (661) and General Arizona (Statsgo 999) were manually entered into DDMSW for the current study. The soil-erosion factors for were obtained from the USDA Soil conservation service'. The website address for downloading these values is http://websoilsurvey.nrcs.usda.gov/app/. We recommend using the soil erosion factors which may be obtained from the URL mentioned above. Table 1 below lists soil-erosion factor values that were manually entered into DDMSW.

The soil-gradation for computing the bed-load was taken from the *Final Investigation Work Plan for Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project* (AMEC 2010) report. The following values were used in the computation of the bed-load: D_{16}=0.04mm; D_{50}=0.074mm; and D_{84}=0.595mm, where the sample from point PD-4 was used for the various diameters.

Soil_lid (Fuller, 2007a)	Map unit name	Erosion factor (K) – obtained from NRCS web site	Eastern Pinal and Southern Gila Counties (661)	Map unit symbol (NRCS, 12/19/2005, draft)	Map unit symbol (NRCS, April 28, 2009)
661605	Beardsley-Suncity complex, 1 to 10 percent slopes	0.32	661	605	4
661250	Carrizo family-Brios-Riverwash complex, 0 to 5 percent slopes	0.28	661	250	11
661260	Cellar-Anklam-Rock outcrop complex, 20 to 70 percent slopes	0.15	661	260	15
661250	Cellar-Rock outcrop complex, 20 to 70 percent slopes	0.1	661	250	16
661570	Contine loam, 0 to 3 percent slopes	0.32	661	570	24
661265	Coolidge-Gunsight complex, 1 to 5 percent slopes	0.28	661	265	25
661345	Dateland loam, 0 to 2 percent slopes	0.32	661	345	26
661430	Delnorte-Nahda complex, 3 to 20 percent slopes	0.1	661	430	27
661205	Denure sandy loam, 1 to 3 percent slopes	0.24	661	205	31
661206	Denure-Dateland complex, 0 to 3 percent slopes	0.28	661	206	32
661595	Denure-Mohall complex, 1 to 5 percent slopes	0.24	661	595	33
661580	Ebon very gravelly loam, 1 to 8 percent slopes	0.1	661	580	35
661610	Gachado-Lomitas-Rock outcrop complex, 7 to 55 percent slopes	0.1	661	610	41
661335	Laveen fine sandy loam, 0 to 2 percent slopes	0.28	661	335	59
661575	Mohall clay loam, 0 to 5 percent slopes	0.32	661	575	65
661215	Mohall sandy loam, 0 to 3 percent slopes	0.24	661	215	66
661216	Momoli-Carrizo family complex, 1 to 8 percent slopes	0.15	661	216	68
661240	Pantano-Anklam-Rock outcrop complex, 3 to 20 percent slopes	0.1	661	240	74
661565	Tremant-Pinamt complex, 1 to 10 percent slopes	0.24	661	565	97
661625	Wikieup family very channery sandy loam, 10 to 60 percent slopes	0.1	661	625	105
999457	Spudrock-Rock outcrop-Cellar	0.26	999	s457	999457
999286	Tremant-Pinamt-Ebon	0.26	999	s286	999286
999456	Torriorthents-Cellar	0.26	999	s456	999456
999449	Rock outcrop-Garr	0.26	999	s449	999449

Table 1. The soil-erosion factors for "Easter Pinal and Southern Gila Counties" (661) and General Arizona (Statsgo 999) were taken from the USDA Soil conservation service.

Future Landuse Peak Flows and Volumes 24 hr													
		2y		5y		10y		25y		50y		100y	
Yellow dot	HEC-1 Identifier	Flow rate (cfs)	Volume (ac-ft)	Flow rate (cfs)	Volume (ac-ft)	Flow rate (cfs)	Volume (ac-ft)	Flow rate (cfs)	Volume (ac-ft)	Flow rate (cfs)	Volume (ac-ft)	Flow rate (cfs)	Volume (ac-ft)
R9	R_9	1127	139.55	1580	190.85	1946	232.66	2445	291.2	2837	338.85	3353	403.8
R10	R_10	1223	215.4	1711	291.18	2106	352.95	2660	439.71	3092	507.78	3667	599.63
R11	R_11	449	55.99	661	76.45	827	92.71	1071	116.88	1263	136.15	1514	161.32
R13	R_13	1945	279.24	2808	390.38	3513	482.04	4481	608.22	5247	709.61	6265	848.08
R14	R_14	494	48.52	747	67.4	950	82.83	1249	106.16	1479	124.29	1784	148.5
R15	R_15	219	22.88	347	32.56	445	40.13	587	51.46	700	60.76	848	72.85

Table 2. HEC-1 values for some concentration points (see Figure 3 above and Kimley-Horn 2010.).

4. Results

The results from the bed-load do not change from scenario 1 to scenario 2. However, the results for wash-load may change. The combined results from the bed-load and wash-load are shown in table 3 below for Scenario 1. The total annual sediment yield is 7.52 ac-ft/year, 6.838 ac-ft/year for the washload and 0.67 ac-ft/year for the bedload. These results include the bed-load sediment yield from cross-sections R9, R10, R11, R13, R14 and R15.

Table 4 shows the results of sediment transported considering one large basin. In this case the sediment delivery ratio was 42%. The flow rate and volume were taken from the HEC-1 concentration point CRFRS. The arithmetic average of the annual sediment yield (ac-ft/mi2) in table 5 above renders an average sediment yield 0.13 ac-ft/mi2. If we multiply this number by the total area of the basin (42.47 mi2) the total annual sediment yield would be 5.52 ac-ft.

The Desert Drive Area Study 2007 (Fuller 2007b pp 15) indicated that: `the initial sediment yield computations resulted in large sediment yield estimates for the subbasins representing the mountain headwater locations...'. These subbasins were identified as V1 and V12 (for the Rittenhouse FRS). The results for these three subbasins were discarded in Fuller, 2007b. They argued that deposition of the heavy sediment prior to reaching the FRS would occur due to significant changes in slope and transport capacity at the transitions from the steep mountainsides to the flat alluvial plain surface at the FRS structure (Foster 2005, Hickey 2000).We agree with this approach. Furthermore, MUSLE method may be only applicable to slope less than 20% (Foster 2005). Therefore, the estimated sediment yield from this study was calculated by averaging the sediment yield (in ac-ft/mi2) from sub-basins R_2, R_3, R_5, R_6, R_7, R_8, R_9, R_10, R_11, R_12, R_13, R_14, and R_15.

Once this estimate was obtained (0.53 ac-ft/mi2), the total amount of sediment was computed by multiplying the estimate times the area of each sub-basin, i.e. R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_10, R_11, R_12, R_13, R_14, and R_15. The total sediment load was the sum of the sediment yield from each sub-basin and the average total was adjusted based on the USBR correction factor of 1.35, i.e. the average annual total sediment load was 0.72 ac-ft/mi2. Thus the total sediment yield for the entire basin would be 0.72 ac-ft/mi2 *42 mi2 = 30.24 ac-ft. This result is much higher compared to those obtained by FCD (7.52 ac-ft, 3.02 ac-ft, and 5.52 ac-ft). One of the reasons is the use of the sediment delivery ratio in the analysis performed by FCD, i.e. only a portion of the eroded sediment from the watershed can be transported to the structure.

If we also discard the extremely high sediment contribution from sub-basins R1 and R4 as argued in Desert Drive Area Study (Fuller, 2007b) and calculate the average sediment yield per unit area based on the remaining basins, we obtain 0.123 ac-ft/mi2 (scenario 2). Thus the total sediment yield for the entire basin would be 0.123 ac-ft/mi2*42.47 mi2 = 5.22 ac-ft. This result is smaller than those by Fuller (2007b) and FCD. A comparison of this result with those from other structures (see table 6 below) suggests that some type of average may be needed. Table 6 lists the computed sediment yield results for several flood structures.

For purposes of this study, we have averaged the results from 7.52 ac-ft (Scenario 1 above) with 5.22 ac-ft (described in previous paragraphs) to yield estimated annual sediment of 6.37 ac-ft. If we consider 100 years design life (NRCS National Engineering Handbook, Section 3 NEH-3 1983), the estimated total sediment volume would be 637 ac-ft. This is equivalent to 0.1517 ac-ft/mi2. This final value seems is of the same order of magnitude as compared with other studies (see table 6). Table 7 summarizes the results of this study and other studies.

Total yield ac-ft															
Sub-basin->	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
year															
2	1.56	0.19	0.09	1.71	0.06	0.21	0.12	0.36	0.30	0.40	0.13	0.20	0.84	0.15	0.06
5	2.54	0.29	0.12	2.61	0.09	0.30	0.19	0.52	0.43	0.58	0.19	0.30	1.25	0.22	0.10
10	3.31	0.38	0.16	3.42	0.11	0.37	0.24	0.65	0.55	0.72	0.24	0.39	1.59	0.28	0.13
25	4.40	0.51	0.20	4.57	0.15	0.48	0.32	0.84	0.70	0.93	0.32	0.51	2.08	0.38	0.17
50	5.38	0.61	0.24	5.51	0.19	0.56	0.39	1.00	0.83	1.10	0.39	0.62	2.47	0.46	0.20
100	6.70	0.75	0.29	6.78	0.22	0.68	0.47	1.21	1.01	1.33	0.47	0.75	3.02	0.56	0.25
Annual	1.76	0.20	0.09	1.85	0.06	0.21	0.13	0.37	0.31	0.41	0.14	0.21	0.88	0.16	0.07
Total annual	**6.84** ac-ft														
area mi^2	9.73	1.67	0.67	10.52	0.53	1.55	0.89	2.90	3.00	4.35	1.28	1.13	7.08	1.30	0.67

Table 3.Total sediment yield: Scenario 1.

SDR=42							
One basin	MUSLE	BEDLOAD					
year		Sect R10	Sect R11	Sect R13	Sect R14	Sect R15	Sect R9
2	2.22	0.021	0.001	0.047	0.328	0.101	0.127
5	3.37	0.032	0.002	0.074	0.50	0.17	0.20
10	4.37	0.041	0.003	0.1	0.65	0.24	0.26
25	5.9	0.056	0.004	0.135	0.89	0.33	0.35
50	7.2	0.068	0.005	0.167	1.08	0.41	0.42
100	9.02	0.085	0.006	0.213	1.34	0.53	0.54
Annual	2.39	0.023	0.001	0.053	0.36	0.12	0.14
Total annual	**3.08** ac-ft						

Table 4. Total sediment yield: Scenario 2 (one large basin).

Total yield															
Sub-basin->	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Annual (ac-ft)	1.76	0.20	0.09	1.85	0.06	0.21	0.13	0.37	0.31	0.41	0.14	0.21	0.88	0.16	0.07
Area mi^2	9.73	1.67	0.67	10.52	0.53	1.55	0.89	2.90	3.00	4.35	1.28	1.13	7.08	1.30	0.67
Annual $ac\text{-}ft/mi^2$	0.18	0.12	0.13	0.18	0.12	0.13	0.15	0.13	0.10	0.09	0.11	0.19	0.12	0.12	0.10

Table 5. Scenario 1: average sediment yield per unit area for each sub-basin. The average annual is 0.13 $ac\text{-}ft/mi^2$.

		Annual sediment (ac-ft/mi^2)	area (mi^2)	Annual sediment total load (ac-ft)	100 years total sediment (ac-ft)	50 years total sediment (ac-ft)
[1]White Tanks No.4		0.12	18.93	2.28	228	114
[2]White Tanks No.3		0.24	21	5	500	250
[3]Buckeye FRS No.1		0.057	76	4.332	433.2	216.6
[4]Cave Creek Dam		0.24	121	29.04	2904	1452
[4]Spookhill FRS		0.15	16.4	2.46	246	123
[4]Saddleback FRS		0.08	30	2.4	240	120

Table 6. Sediment yield values for other studies.

[1] White Tanks FRS #4 Remediation Project - Phase 1, 2010. Wood-Patel Associates.
[2] White Tanks FRS #3 Remediation Project - Phase 1 2005, URS in Cooperation with Geological Consult. Inc. and EH Engineering and Hydrosystem.
[3] Buckeye Flood Retarding Structure # 1 Technical Memorandum for Hydraulic Analyses of Alternatives, 2009. Michael Baker, Jr., Inc.
[4] Flood Control District of Maricopa County (FCDMC), 2010. Drainage Design Manual for Maricopa County (Volume II: Hydraulics); Chapter 11.

		Annual sediment (ac-ft/mi^2)	area (mi^2)	Annual sediment total load (ac-ft)	100 years total sediment (ac-ft)	50 years total sediment (ac-ft)
Rittenhouse FRS by Fuller (2007b)		0.72	42	30	3,000	1,500
Rittenhouse FRS by FCD 11/2010		0.179	42	7.52	752	376
Rittenhouse FRS by FCD 11/2010 (excluding results from mountain head water locations, use low area average and apply it to mountain area)		0.123	42	5.22	522	261
Rittenhouse FRS by FCD 11/2010 (average of above two)		0.151	**42**	**6.41**	**641**	**320**
White Tanks No.4		0.12	18.93	2.28	228	114
White Tanks No.3		0.24	21	5	500	250
Buckeye FRS No.1		0.057	76	4.332	433.2	216.6
Cave Creek Dam		0.24	121	29.04	2904	1452
Spookhill FRS		0.15	16.4	2.46	246	123
Saddleback FRS		0.08	30	2.4	240	120

Table 7. Sediment yield values for this study and other studies.

BIBLIOGRAPHY

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