**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 Vineyard 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 Vineyard FRS for future hydrologic conditions. The initial evaluation of sediment carried to the Vineyard 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 0.61ac-ft/mi$^2$ for an area of 53.078 mi$^2$, equivalent to 32.37 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 3,237 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 17 shown in Figure 2) that contribute sediment to the FRS Vineyard.



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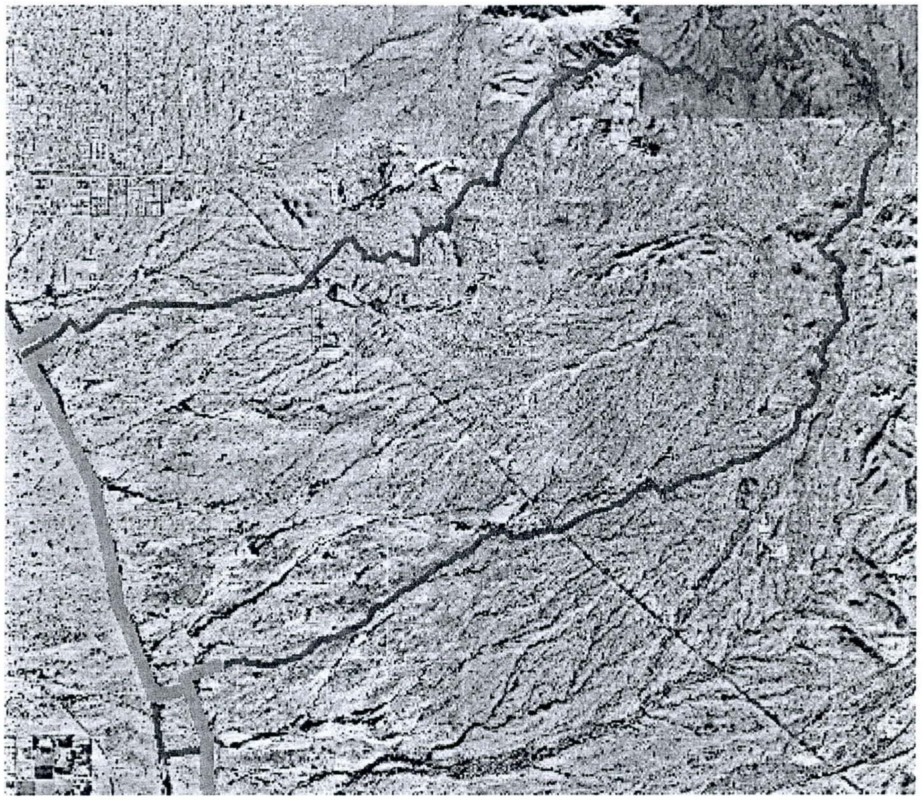
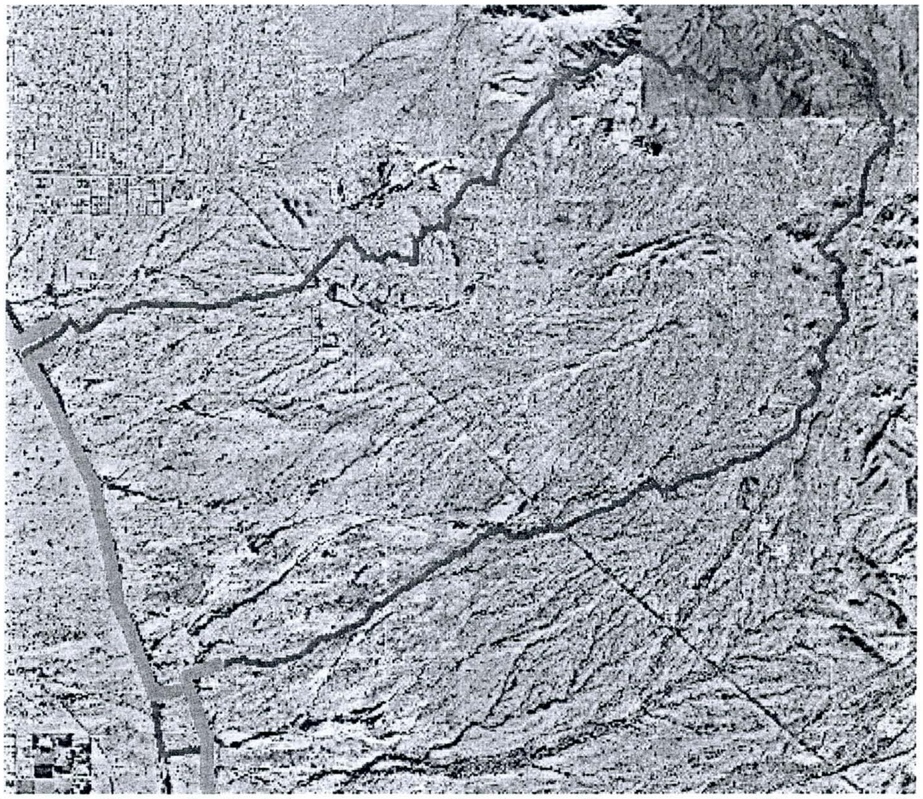


Figure 1. Watershed of the area contributing sediment to the Vineyard FRS.

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.



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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 V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_10, V_11, V_12, V_13, V_14, and V_17, 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.

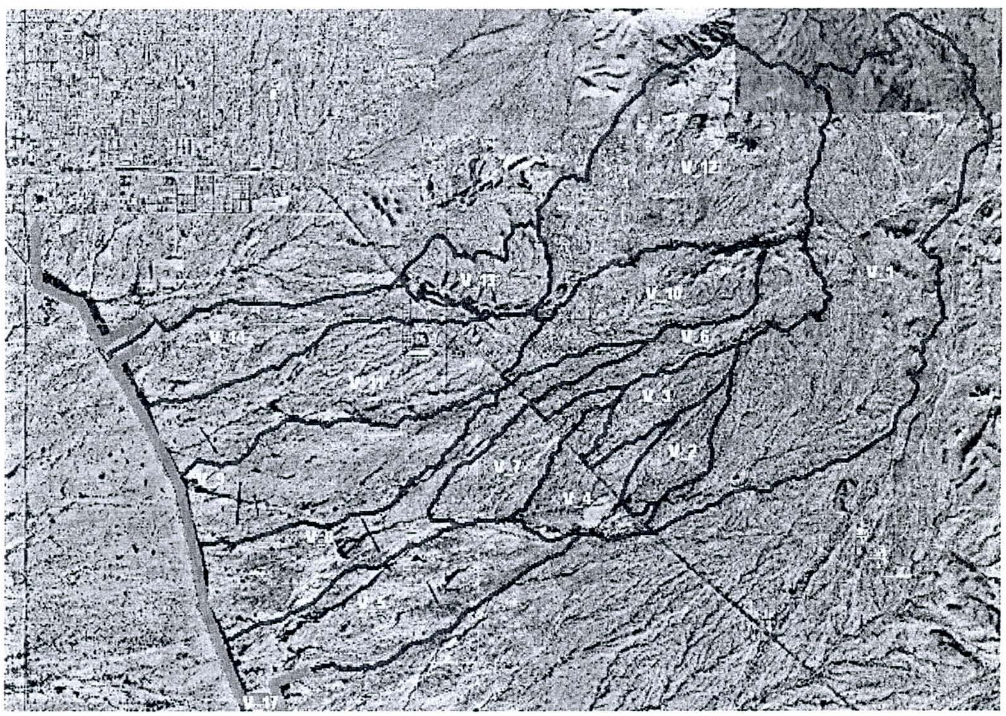

Figure 2. Sub-basins contributing sediment to the Vineyard FRS.

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 cross-sections labeled 1, 2, 3, 4 and 5 below correspond to V14, V11, V9, V8 and V5 respectively in the HEC-1 identifier.

The volumetric flow rate for the cross-sections labeled 1, 2, 3, 4 and 5 in Figure 3 were obtained from the corresponding concentration points V14, V11, V9, V8 and V5 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 (V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_10, V_11, V_12, V_13, V_14, and V_17). 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 V0224FN.dat, V0524FN.dat, V1024FN.dat, V2524FN.dat, V5024FN.dat, V1_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 line # | 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) |
| 5 | V_5 | 1182 | 195.23 | 1711 | 265.5 | 2112 | 319.52 | 2733 | 402.46 | 3226 | 468.11 | 3894 | 557.56 |
| 4 | V_8 | 1076 | 186.55 | 1510 | 250.67 | 1881 | 305.22 | 2402 | 382.23 | 2819 | 444.12 | 3388 | 528.9 |
| 3 | V_9 | 1204 | 184.04 | 1697 | 248.6 | 2109 | 303.19 | 2690 | 380.45 | 3154 | 442.14 | 3788 | 526.82 |
| 2 | V_11 | 1677 | 261.17 | 2320 | 353.11 | 2822 | 425.33 | 3536 | 530.31 | 4099 | 615.47 | 4872 | 736.06 |
| 1 | V_14 | 912 | 146.33 | 1285 | 196.5 | 1591 | 237.95 | 2036 | 298.66 | 2382 | 345.91 | 2871 | 412.58 |

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. The total annual sediment yield is 16.14 ac-ft/year, 14.04 ac-ft/year for the washload and 2.1 ac-ft/year for the bedload. These results include the bed-load sediment yield from cross-sections 1, 2, 3, 4 and 5. Table 4 shows the results of sediment transported considering one large basin. In this case the sediment delivery ratio was 41.5%. The flow rate and volume were taken from the HEC-1 concentration point CVFRS.

The arithmetic average of the annual sediment yield (ac-ft/mi2) in table 5 above renders an average sediment yield 0.24 ac-ft/mi2. If we multiply this number by the total area of the basin (53.11 mi2) the total annual sediment yield would be 12.7 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 Vineyard 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 V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_10, V_11, V_13, V_14, and V_17. Once this estimate was obtained (0.61 ac-ft/mi2), the total amount of sediment was computed by multiplying the estimate times the area of each sub-basin, i.e. V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_10, V_11, V_12, V_13, V_14, and V_17. 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 0.81ac-ft/mi2. Thus the total sediment yield for the entire basin would be 0.81 ac-ft/mi2 *53.11mi2 = 43 ac-ft. This result is much higher compared to those obtained by FCD (16.14 ac-ft, 8.29 ac-ft, and 12.7 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 V1 and V12 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

0.2046 ac-ft/mi2 (scenario 2). Thus the total sediment yield for the entire basin would be 0.2046 ac-ft/mi2*53.11mi2 = 10.8 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 16.14 ac-ft (Scenario 1 above) with 12.7 ac-ft (described in previous paragraphs) to yield an estimated annual sediment of 14.42 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 1,442 ac-ft. This is equivalent to 0.2715 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 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| Sub-basin-> | v1 | v10 | v11 | v12 | v13 | v14 | v17 | v2 | v3 | v4 | v5 | v6 | v7 | v8 | v9 |
| Year | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft | ac-ft |
| 2 | 0.85 | 0.76 | 1.08 | 6.18 | 0.70 | 0.31 | 0.01 | 0.21 | 0.22 | 0.56 | 0.48 | 0.27 | 0.51 | 0.45 | 0.53 |
| 5 | 1.44 | 1.18 | 1.53 | 9.67 | 1.01 | 0.44 | 0.03 | 0.31 | 0.33 | 0.80 | 0.70 | 0.44 | 0.71 | 0.64 | 0.77 |
| 10 | 1.90 | 1.59 | 1.89 | 12.44 | 1.25 | 0.55 | 0.04 | 0.40 | 0.42 | 1.00 | 0.87 | 0.59 | 0.88 | 0.80 | 0.97 |
| 25 | 2.64 | 2.10 | 2.43 | 17.00 | 1.62 | 0.72 | 0.08 | 0.53 | 0.55 | 1.29 | 1.14 | 0.81 | 1.12 | 1.04 | 1.26 |
| 50 | 3.26 | 2.53 | 2.87 | 20.64 | 1.91 | 0.85 | 0.11 | 0.63 | 0.65 | 1.52 | 1.37 | 0.99 | 1.75 | 1.21 | 1.49 |
| 100 | 4.12 | 3.14 | 3.50 | 25.70 | 2.33 | 1.05 | 0.15 | 0.78 | 0.80 | 1.85 | 1.67 | 1.24 | 1.61 | 1.52 | 1.83 |
| Annual | 1.00 | 0.83 | 1.08 | 6.77 | 0.71 | 0.31 | 0.02 | 0.22 | 0.23 | 0.57 | 0.49 | 0.31 | 0.51 | 0.45 | 0.54 |
| Total annual | **14.04** ac-ft | | | | | | | | | | | | | | |
| Area $mi^2$ | 11.84 | 2.90 | 5.24 | 7.76 | 1.51 | 3.14 | 0.46 | 1.05 | 1.10 | 1.77 | 4.45 | 1.97 | 1.71 | 4.08 | 4.11 |

Table 3.Total sediment yield: Scenario 1.

| SDR=41.5 | | | | | | |
|---|---|---|---|---|---|---|
| One basin | MUSLE | BEDLOAD | | | | |
| year | | c2_v11 | c1_v14 | c5_v5 | c4_v8 | c3_v9 |
| 2 | 5.88 | 0.309 | 0.443 | 0.39 | 0.191 | 0.371 |
| 5 | 8.72 | 0.536 | 0.522 | 0.701 | 0.359 | 0.867 |
| 10 | 11.1 | 0.741 | 0.586 | 1.212 | 0.575 | 1.153 |
| 25 | 14.9 | 1.074 | 0.78 | 1.503 | 0.886 | 1.657 |
| 50 | 18 | 1.229 | 0.946 | 1.955 | 1.22 | 2.133 |
| 100 | 22.7 | 1.355 | 1.314 | 2.684 | 1.189 | 2.439 |
| Annual | 6.19 | 0.372 | 0.394 | 0.523 | 0.266 | 0.549 |
| Total annual | **8.29** ac-ft | | | | | |

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

| Total yield | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sub-basin-> | v1 | v10 | v11 | v12 | v13 | v14 | v17 | v2 | v3 | v4 | v5 | v6 | v7 | v8 | v9 |
| Annual (ac-ft) | 1.00 | 0.83 | 1.08 | 6.77 | 0.71 | 0.31 | 0.02 | 0.22 | 0.23 | 0.57 | 0.49 | 0.31 | 0.51 | 0.45 | 0.54 |
| Area $mi^2$ | 11.84 | 2.90 | 5.24 | 7.76 | 1.51 | 3.14 | 0.46 | 1.05 | 1.10 | 1.77 | 4.45 | 1.97 | 1.71 | 4.08 | 4.11 |
| Annual ac-ft/$mi^2$ | 0.08 | 0.29 | 0.21 | 0.87 | 0.47 | 0.10 | 0.05 | 0.21 | 0.21 | 0.32 | 0.11 | 0.16 | 0.30 | 0.11 | 0.13 |

Table 5. Scenario 1: average sediment yield per unit area for each sub-basin. The average annual is 0.24 ac-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) |
|---|---|---|---|---|---|---|
| Vineyard FRS by Fuller (2007b) | | 0.81 | 53 | 43 | 4301 | 2150 |
| Vineyard FRS by FCD 11/2010 | | 0.3 | 53 | 16.14 | 1614 | 807 |
| Vineyard FRS by FCD 11/2010 (excluding results from mountain head water locations, use low area average and apply it to mountain area) | | 0.24 | 53 | 12.7 | 1270 | 635 |
| **Vineyard FRS by FCD 11/2010 (average of above two)** | | **0.271** | **53** | **14.42** | **1442** | **721** |
| 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.

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