Flood Control District
of Maricopa County

Date: December 6, 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 Powerline Flood Retarding Structures (FRS). Revised version (December 6, 2010).

1. Study Purpose and Scope:

The purpose of the sediment yield study is to re-evaluate the amount of sediment transported to the Powerline FRS for future hydrologic conditions. The initial evaluation of sediment carried to the Powerline 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 0.82ac-ft/mi^2 for an area of 34 mi^2, equivalent to 27.54 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 2,754 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, 9 and 11) that contribute sediment to the FRS Powerline.

The following assumption was made:

> The Desert Drive Area Study (Fuller, 2007b) states that: `*Additionally, runoff from Subbasins P6, P7, P8, and P10 is intercepted and detained in large detention basins along the north side of the freeway and therefore, the transported sediment from these basins is not expected to reach the Powerline FRS'.* After reviewing the HEC-1 models, I found that the

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runoff from *Subbasins P6, P7, P8, and P10* contributes to the FRS but the sediment is being captured in the detention basins. In the Desert Drive Area Study (Fuller, 2007b), the runoff volume and peak include the areas from P6, P7, P8, and P10 for wash load estimation based on MUSLE method. In this study, we follow Desert Drive Area Study's assumption.

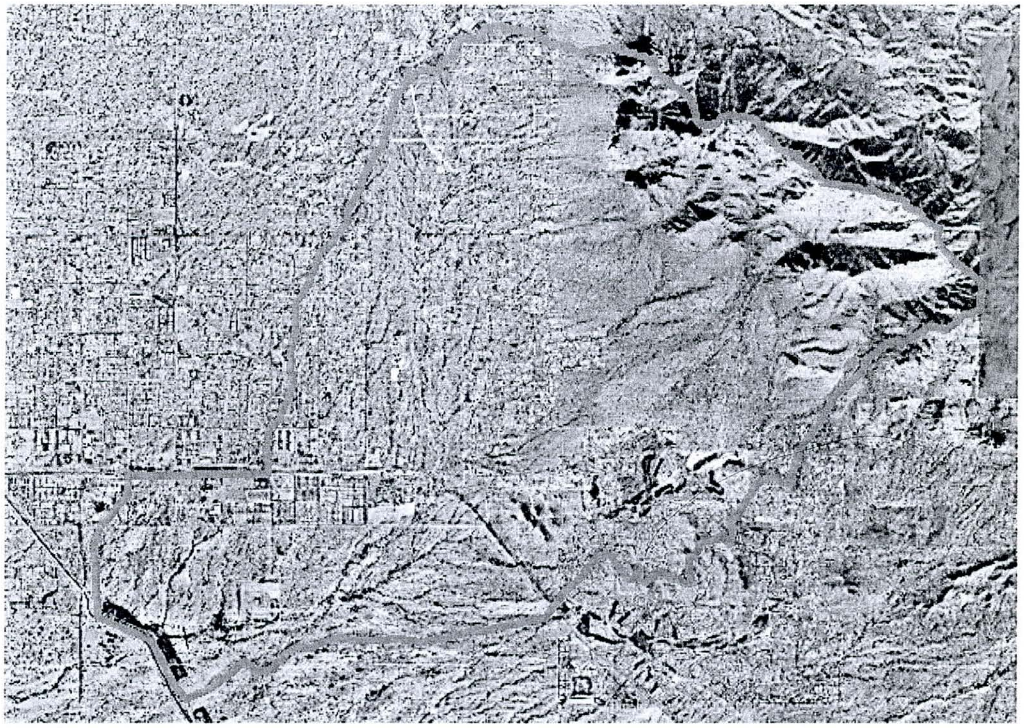

Figure 1. Locus of the area contributing sediment to the Powerline FRS.

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 9/10/10. From these sets of shapefiles for all the sub-basins, we selected only those labeled P_1, P_2, P_3, P_4, P_5 and P_11, 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 2. The shapefile information should include the areas (in ft^2) for each sub-basin (P_1, P_2, P_3, P_4, P_5 and P_11).

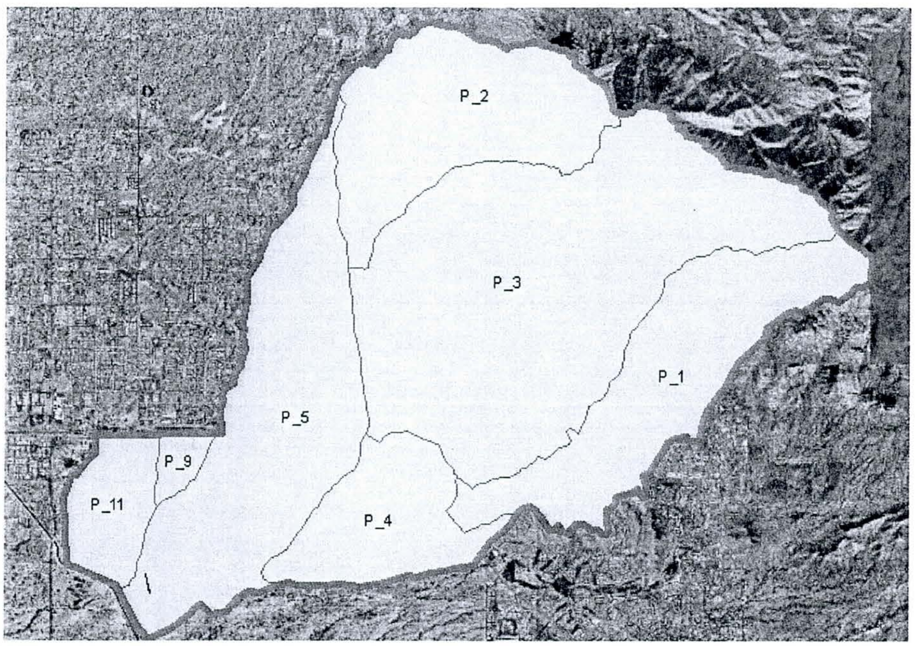

Figure 2. Sub-basins contributing sediment to the Powerline FRS.

Once the shapefile corresponding to the region of interest (*area* shapefile) was created, we post-processed this shapefile by producing another shapefile which combined all the sub-basins into a single basin (*basin_area* shapefile) whose boundary is the red line shown in Figures 1 and 2.

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). To reduce the number of cross-sections, points 3, 4 and 5 were combined into a single point labeled 6 in Figure 3. The cross-sections labeled 1, 2 and 6 below correspond to CP25, CP9 and RRP4 in the HEC-1 identifier.

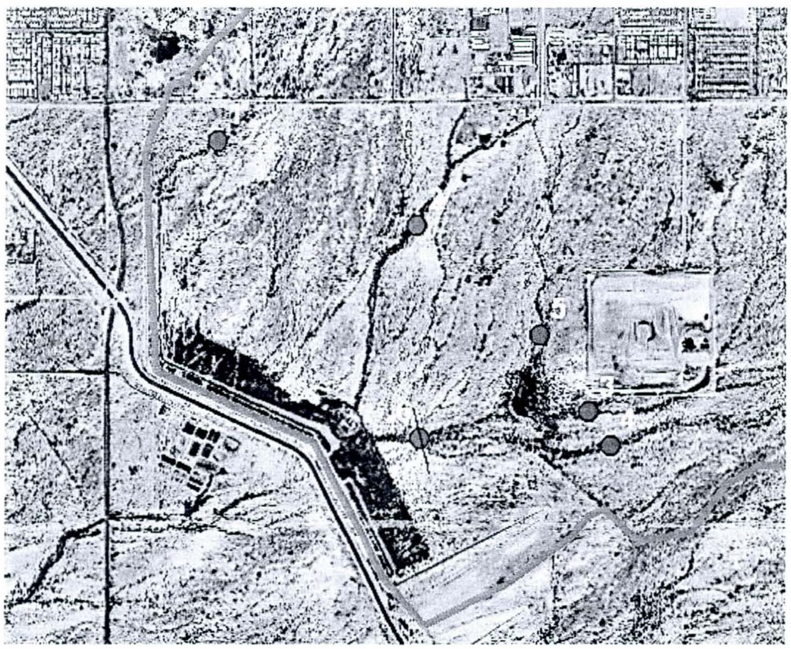

Figure 3. Location of the cross-sections used for bed-load sediment calculations.

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 (P_1, P_2, P_3, P_4, P_5 and P_11). 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 produced by Dave Degerness via email on 9/10/2010. The files corresponding to 2, 5, 10, 5, 50 and 100 year are P0224FN.dat, P0524FN.dat, P1024FN.dat, P2524FN.dat, P5024FN.dat, P1_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.

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.

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.

The volumetric flow rate for the cross-sections labeled 1, 2 and 6 in Figure 3 were obtained from the corresponding concentration points CP25, CP9 and RRP4 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.

Future Landuse Peak Flows and Volumes													
		2Yr 24Hr	Volume	5Yr 24Hr	Volume	10Yr 24Hr	Volume	25Yr 24Hr	Volume	50Yr 24Hr	Volume	100Yr 24Hr	Volume
Green dot #	HEC-1 Identifier	(cfs)	(ac-ft)	(cfs)	(ac-ft)	(cfs)	(ac-ft)	(cfs)	(ac-ft)	(cfs)	(ac-ft)	(cfs)	(ac-ft)
1	CP25	114	35	289	47	460	56	672	70	835	80	947	91
2	CP9	805	319	961	410	1157	492	1438	611	1762	718	2119	838
6	RRP4	2958	702	5113	1028	7053	1305	9674	1701	11754	2016	13818	2366

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 15.779 ac-ft/year. These results include the bed-load sediment yield from cross-sections 1, 2 and 6. Table 4 shows the results of sediment transported considering one large basin. In this case the sediment delivery ratio was 43.6%. The flow rate and volume were taken from the HEC-1 concentration point CPFRS.

Total yield							
Sub-basin->	P_1	P_2	P_3	P_4	P_5	P_9	P_11
Year	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
2	1.273	1.636	4.877	0.053	0.069	0.008	0.027
5	3.528	4.601	13.624	0.146	0.191	0.021	0.078
10	5.128	6.692	19.847	0.214	0.278	0.031	0.113
25	8.525	11.108	32.918	0.355	0.461	0.051	0.189
50	12.056	15.724	46.584	0.503	0.653	0.073	0.266
100	16.646	21.682	64.272	0.693	0.901	0.1	0.368
Annual	2.397	3.115	9.242	0.1	0.13	0.015	0.053
Area (mi^2)->	5.2	4.9	12.27	2.78	7.09	.36	1.44
Total annual sediment	**15.05 ac-ft**						

Table 3.Total sediment yield: Scenario 1 (sub-basins 1, 2, 3, 4, 5, 9 and 11).

SDR=43.6				
One basin	MUSLE (ac-ft)	BEDLOAD (ac-ft)	BEDLOAD (ac-ft)	BEDLOAD (ac-ft)
year		Cross-section 1	Cross-section 2	Cross-section 6
2	12.9	0.006	0.001	0.008
5	20.555	0.037	0.007	0.032
10	27.946	0.071	0.011	0.048
25	38.541	0.171	0.023	0.109
50	47.14	0.608	0.04	0.198
100	56.551	0.522	0.065	0.341
Annual	14.607	0.035	0.005	0.026
Total annual	**14.673 ac-ft**			

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

Total yield							
Sub-basin->	P1	P2	P3	P4	P5	P9	P11
Annual (ac-ft)	2.397	3.115	9.242	0.1	0.13	0.015	0.053
area (mi^2)	5.2	4.9	12.27	2.78	7.09	0.36	1.44
Annual (ac-ft/mi^2)	0.460962	0.635714	0.753219	0.035971	0.018336	0.041667	0.036806

Table 5. Scenario 1: average sediment yield per unit area for each sub-basin.

The arithmetic average of the annual sediment yield (ac-ft/mi^2) in table 5 above renders an average sediment yield 0.2832 ac-ft/mi^2. If we multiply this number by the total area of the basin (34.04 mi^2) the total annual sediment yield would be **9.64 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 P1, P2 and P3 (for the Powerline 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 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/mi^2) from sub-basins P4, P5, P9 and P11. Once this estimate was obtained (0.61 ac-ft/mi^2), the total amount of sediment was computed by multiplying the estimate times the area of each sub-basin, i.e. P1, P2, P3, P4, P5, P9 and P11. 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/mi^2. Thus the total sediment yield for the entire basin would be 0.81 ac-ft/mi^2 *34mi^2 = **27.54** ac-ft. This result is much higher compared to those obtained by FCD (15.779 ac-ft, 15.058 ac-ft, and 10.24 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 P1, P2 and P3 as argued in *Desert Drive Area Study* (Fuller, 2007b) and calculate the average sediment yield per unit area based on P4, P5, P9, and P11, we obtain 0.0331 ac-ft/mi^2 (scenario 2). Thus the total sediment yield for the entire basin would be 0.0331 ac-ft/mi^2*34mi^2 = **1.129** ac-ft. This result is an order of magnitude 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 **15.058 ac-ft** (Scenario 1 above) with **1.129 ac-ft** (described in the previous paragraph) to yield an estimated annual sediment of **8.092 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 **810 ac-ft**. This is equivalent to 0.238 ac-ft/mi^2. 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.

		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/Sun Valley Area Drainage Master Study Vol. VI: Sediment Transport Studies 2004. PBS&J in Association with LTM, EPG, Ayers, and Entellus.
[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)
Powerline FRS by Fuller (2007b)		0.81	34	27.54	2754	1377
Powerline FRS by FCD 9/2010		0.44	34	15.04	1504	752
Powerline FRS by FCD 9/2010 (excluding results from mountain head water locations, use low area average and apply it to mountain area)		0.036	34	1.24	124	62
Powerline FRS by FCD 9/2010 (average of above two)		**0.238**	**34**	**8.092**	**810**	**405**
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
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