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Garrapata Watershed, California:

Water and Sediment Monitoring in 2004-2005

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Preface

Dr. Douglas Smith, Watershed Institute staff, and students in the Division of Science and Environmental Policy at CSU-Monterey Bay have monitored the flow of sediment and water from the Garrapata Watershed since August 20, 2001. Smith et al. (2005) provided an assessment of the hydrologic and sediment resources of Garrapata Creek Watershed as part of the Garrapata Creek Watershed Council's assessment and restoration process. That report analyzed the water and sediment flow from 2001 to 2004. The present report adds to the initial report by analyzing the 2004-2005 water year and the early months of the 2005-2006 water year.

This report is written for the Garrapata Watershed Council as part of their watershed assessment funded by California Department of Fish and Game.

This report may be cited as:
Smith, D.P., Casagrande, J., and Ramsey-Wood, C., 2006, Garrapata Watershed, California: Water and Sediment Monitoring in 2004-2005. Prepared for the California Department of Fish and Game and the Garrapata Creek Watershed Council. The Watershed Institute, California State University Monterey Bay, Publication No. WI-2006-2, 27 pp.

Errata from Smith et al. (2005)
Table 10 is for "Garrapata Creek," not "Joshua Creek." Table 11 shows a bedload measurement for Joshua Creek of 228 g/s on 2/26/04. That value is corrected in Table 8 of the present report.

Acknowledgements

This work was funded by a grant from California Department of Fish and Game to The Garrapata Watershed Council. We would like to acknowledge the following people and organizations.

Ken Ekelund
Big Sur Land Trust
Glen Deven Ranch
Residents of Garrapata Watershed
Garrapata Watershed Council and Technical Advisory Committee.

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1 Summary

The 2004-2005 water year brought 37 inches of rainfall to the Garrapata Watershed gauge. This value is approximately 7 inches above the 24 year average (29.95 inches). High precipitation produced three high flow peaks, with one exceeding 100 cfs, corresponding to the 3 year flow event. The two other significant peaks exceeded 80 cfs, corresponding to 2 year flow events. The watershed produced approximately 8840 acre-ft of surface water that flowed to the sea. This value is more than the sum of the previous three years. Evapo-transpiration is estimated at 75% of rainfall based upon two years of records. This leaves 25% of the annual rainfall to recharge groundwater, maintain aquatic habitat, and supply human needs

The high water flows of 2004-2005 cleared out the excess sand fraction that had been filling pool habitat in Joshua Creek in previous years. Based upon the experiences of 4 years of monitoring, it is predicted that both Joshua and Garrapata Creeks will continue to experience sporadic variation in sediment load through time, in concert with variation in both sediment input and variation in rainfall. We predict that the patterns of variability in sediment transport rate will be complex; therefore, monitoring programs in Garrapata Creek that are designed to detect changes in sediment load due to either negative or positive impacts will have to employ a large number of transport readings that take into account natural variability associated with seasons and changes in rainfall. Although suspended sediment from watershed impacts travel quickly down the watershed to our monitoring site, we do not know how fast excess bedload sediment resulting from negative impacts will reach the monitoring site following the impact. In other words, what is the lag-time between watershed impact and changes in bedload transport rates load at the monitoring site? If the lag-time is on the order of years, then monitoring programs need to be designed to last for years.

2 Introduction

Smith et al. (2005) produced assessed the hydrologic and physical conditions in the Garrapata Watershed (Fig. 1) which drains 27.5 km^2 (10.7 mi^2) of the northern part of the Santa Lucia Range (Fig. 1).

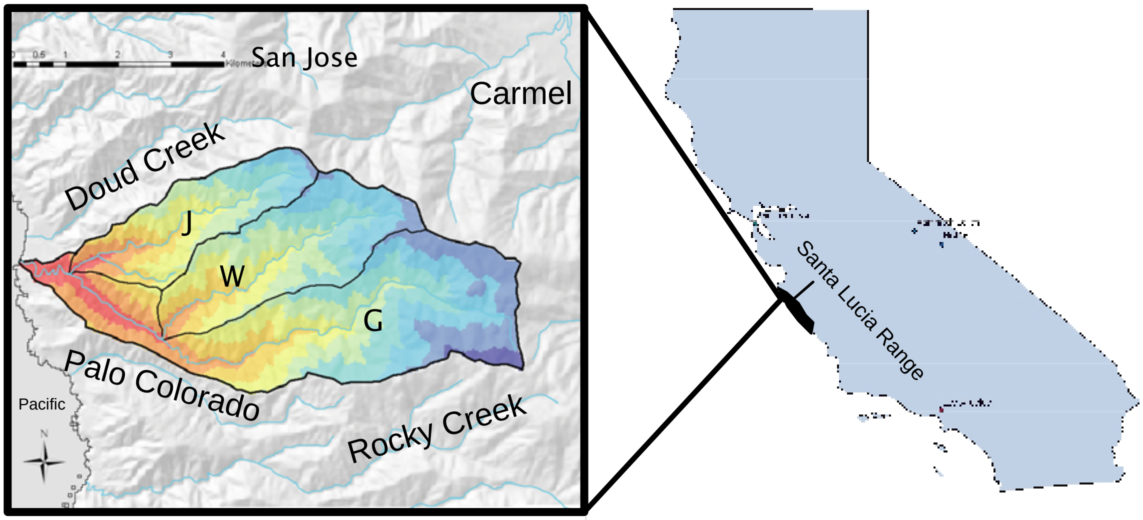

Figure 1: Location of Garrapata Watershed (colored by elevation) within the northern Santa Lucia Range. Principle tributaries to the trunk Garrapata channel (G) are Wildcat Creek (W) and Joshua Creek (J).

This report adds the hydrologic and sedimentologic data from water year 2004-2005 to the work of Smith et al. (2005). The combined assessment and monitoring data have been produced in support of the long-term Garrapata Watershed management and restoration plans. In this report we introduce data from a newly-installed continuously-recording stage gauge on Josjua Creek (Fig. 2).

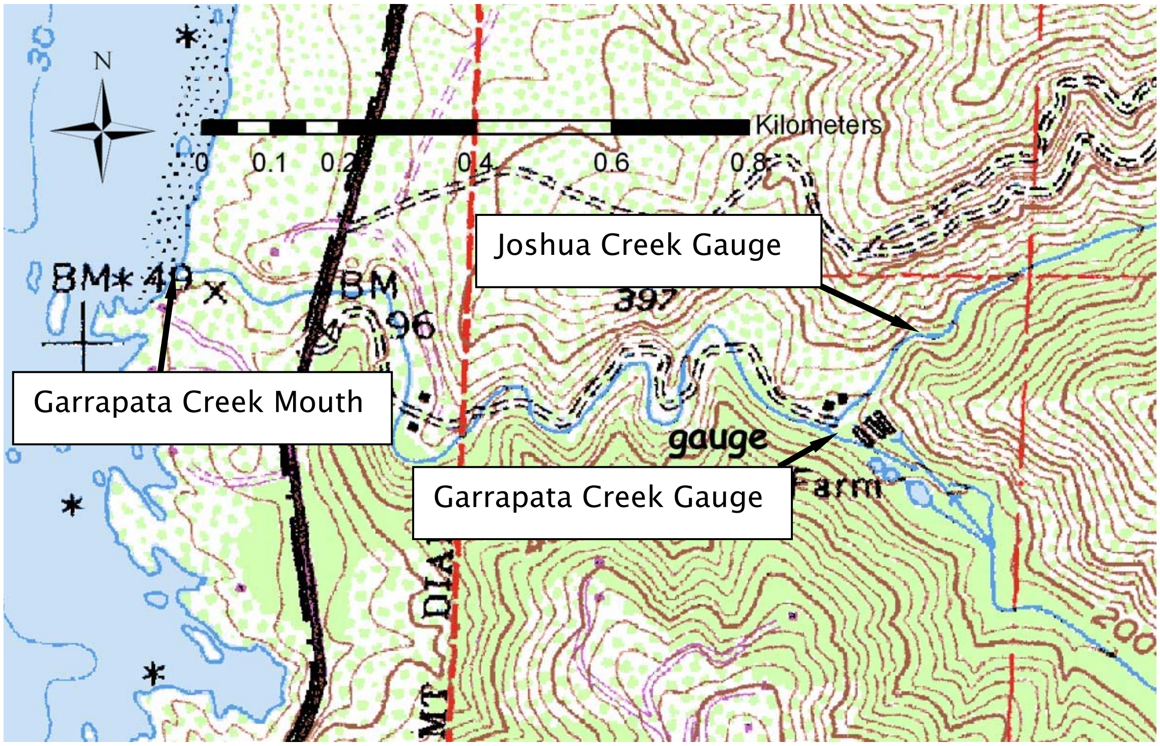

Figure 2: Lower reach of Garrapata Creek showing positions of Garrapata and Joshua Creek continuous-recording gauges.

3 Rain Data

Smith et al. (2005) summarized and analyzed the rainfall data from a rain gauge located along the southern divide of the Garrapata watershed. They also provided an annual precipitation frequency analysis using a long term proxy record in the Carmel Watershed. Figures 3 and 4 graphically summarize the updated rainfall summary in Table 1.

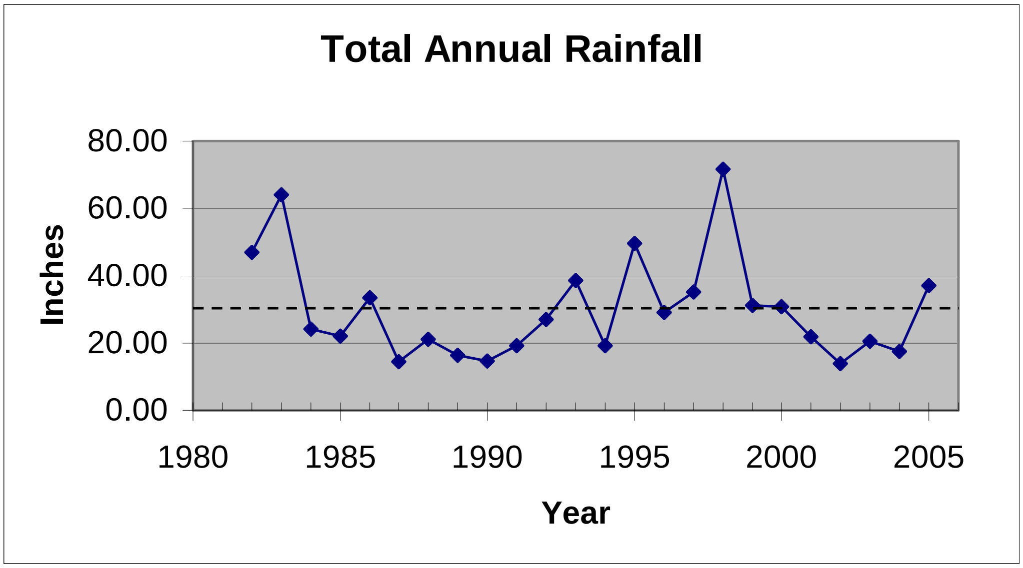

Figure 3: Total annual precipitation at the Garrapata rain gauge located at Glen Deven Ranch. Dashed line is the 24-year average for the gauge.

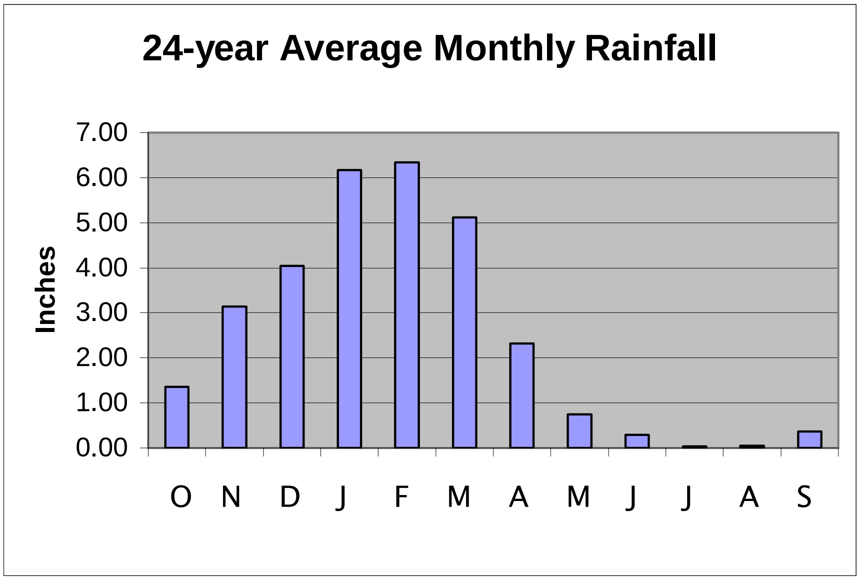

Figure 4: Average distribution of rain throughout the year.

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Table 1: Monthly rainfall data from the Garrapata Watershed Gauge.

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total[1]
1982	4.16	8.43	3.51	9.05	3.73	10.22	5.10	0.00	0.75	0.00	0.00	1.92	46.87
1983	2.55	6.68	3.97	10.70	8.55	21.40	8.03	0.65	0.00	0.00	0.10	1.45	64.08
1984	0.85	9.30	7.75	0.95	3.35	1.40	0.35	0.00	0.00	0.00	0.00	0.10	24.05
1985	2.55	5.89	2.42	0.35	2.20	7.40	0.65	0.00	0.00	0.15	0.00	0.41	22.02
1986	1.70	5.46	2.10	3.15	10.77	7.70	0.66	0.58	0.00	0.00	0.00	1.29	33.41
1987	0.00	0.48	1.37	2.95	4.80	3.07	1.37	0.35	0.00	0.00	0.01	0.00	14.40
1988	1.52	2.97	6.05	3.22	1.79	0.52	3.69	0.95	0.35	0.00	0.00	0.00	21.06
1989	0.00	1.28	4.61	1.88	3.19	3.12	0.84	0.22	0.00	0.00	0.00	1.23	16.37
1990	2.52	1.67	0.15	4.30	2.99	1.25	1.55	0.00	0.00	0.00	0.00	0.12	14.55
1991	0.27	0.55	1.63	0.12	3.65	11.81	0.75	0.35	0.15	0.00	0.00	0.00	19.28
1992	1.76	0.10	4.20	2.35	12.10	5.45	0.38	0.00	0.25	0.25	0.06	0.00	26.90
1993	1.40	0.05	7.30	12.02	9.08	3.96	0.90	2.00	1.35	0.00	0.00	0.50	38.56
1994	0.40	0.80	2.20	3.59	5.50	1.20	3.75	1.35	0.10	0.00	0.00	0.35	19.24
1995	0.50	3.11	3.15	20.31	1.75	12.50	4.30	1.67	2.15	0.10	0.00	0.00	49.54
1996	0.10	0.00	4.75	7.30	9.62	3.50	1.60	2.05	0.00	0.00	0.00	0.22	29.14
1997	1.85	4.50	13.20	13.30	0.55	0.25	0.40	0.10	0.10	0.00	0.90	0.00	35.15
1998	0.85	10.10	3.60	15.55	24.10	5.80	6.15	4.70	0.50	0.20	0.00	0.00	71.55
1999	0.60	4.40	1.35	5.45	6.80	7.65	4.60	0.00	0.00	0.00	0.10	0.25	31.20
2000	0.00	0.50	0.75	10.85	13.45	0.95	2.30	0.70	0.75	0.00	0.00	0.50	30.75
2001	4.55	0.47	0.50	5.53	5.19	2.70	2.79	0.00	0.01	0.00	0.00	0.08	21.82
2002	0.28	3.69	4.08	0.83	1.72	2.25	0.43	0.42	0.04	0.00	0.05	0.04	13.83
2003	0.00	2.82	7.88	1.81	3.00	1.29	2.89	0.73	0.00	0.02	0.00	0.02	20.46
2004	0.19	0.97	1.88	5.84	7.31	0.93	0.00	0.00	0.28	0.00	0.00	0.17	17.57
2005	3.81	1.07	8.69	6.57	6.84	6.54	2.13	1.05	0.36	0.02	0.00	0.00	37.08
Monthly Avg	1.35	3.14	4.05	6.17	6.33	5.12	2.32	0.74	0.30	0.03	0.05	0.36	

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[1] Annual total

4 Stream Flow Data

In summer of 2001, a continuously- recording pressure gauge and staff plate were installed on Garrapata Creek approximately 10 m upstream from the mouth of Joshua Creek (Figs. 1 and 2). The pressure gauge is a Telog 2109e-5 series with one channel and 0-10 psi pressure range. The instrument has a stated accuracy of ±0.075% of the reading. The data logger is set to sense water pressure every 500 ms, and record average pressure every 15 minutes. The pressure readings are recorded by the automatic logger as % of 10 psi. The data are downloaded and analyzed several times a year. The gauge is situated approximately 1.5 m upstream from an historic concrete weir structure that was used as part of an earlier "Trout Farm" operation. The weir provides excellent grade control for the pressure sensor. There has been no permanent datum "shift" in the gauge, but debris accumulations have caused temporary shifts of several hundredths of a foot in the gauging pool. Where possible we have eliminated these spurious shifts from the record. Because our maintenance visits are infrequent, we are certain that some spurious data are still present in the record. A staff plate is located on the opposite bank from the recorder.

On March 6, 2005 a one-channel PR 31 continuously-recording pressure sensor and staff plate was installed on Joshua Creek (Figs. 1 and 2), a few meters downstream from the driveway bridge for Ken Ekelund's property. The sensor has a range of 0 to 5 psi and a nominal accuracy of ±0.075% of the reading. The data are recorded and downloaded as psi. The control for the gauge pool is a riffle located about 2 m downstream from the sensor. We are still assessing the long term stability of that control. The stream gradient is step-pool with the steps formed by large, well-lodged boulders, so we believe that the boulders underlying the riffle will be the ultimate grade control for the gauge.

On each visit to the gauging sites the following routine is followed.

1) read staff plate water elevation in the gauge pool
2) read sediment level on staff plate
3) assess condition of pool control and pressure sensor pipes, and clear any debris
4) wait for re-equilibrium in pool elevation, and reread the staff plate water elevation.
5) take suspended sediment samples upstream from any of our in-stream activities that might have disturbed the bottom.
6) take bedload samples upstream from disturbances (as noted above)
7) take discharge measurements

4.1 Hydrology of Garrapata above Joshua Creek

Field techniques for measuring flow in Garrapata Creek are detailed in Smith et al. (2005). The history of measurements is presented in Table 2. A low battery pack resulted in missing gauge depths for the October 2005 and December 2005 measurements. The relationship between staff plate and pressure gauge readings has remained stable (Fig. 5). An R^2 value of 0.97

indicates a very robust equation relating gauge depth to discharge, indicating that the stream geometry has remained stable over the life of the project (Fig. 6). We use the power function equation shown on Figure 6 to convert from continuous gauge depth to continuous discharge (Fig. 7).

Table 2: Hydrologic measurements on Garrapata Creek

Date	Staff (ft)	Gage (ft)	Flow (cfs)
10/27/2001	0.647	0.946	0.96
11/3/2001	0.659	1.018	1.30
2/9/2002	0.800	1.342	5.22
3/10/2002	0.840	1.254	5.21
4/29/2002	0.800	1.238	3.74
9/9/2002	0.570	0.902	1.57
2/15/2004	0.815	1.283	3.14
2/19/2004	1.005	1.617	8.17
2/26/2004	1.310	2.310	25.61
3/23/2004	0.850	1.330	4.39
3/24/2004	0.840	1.340	4.86
4/25/2004	0.720	1.122	2.43
10/7/2004	0.420	0.557	0.34
3/11/2005	1.240	1.800	25.60
4/8/2005	1.4	2.409	27.11
5/13/2005	1.1	1.890	11.05
9/20/2005	0.690	1.056	1.78
10/20/2005	0.690	--	1.55
12/1/2005	0.700	--	1.55

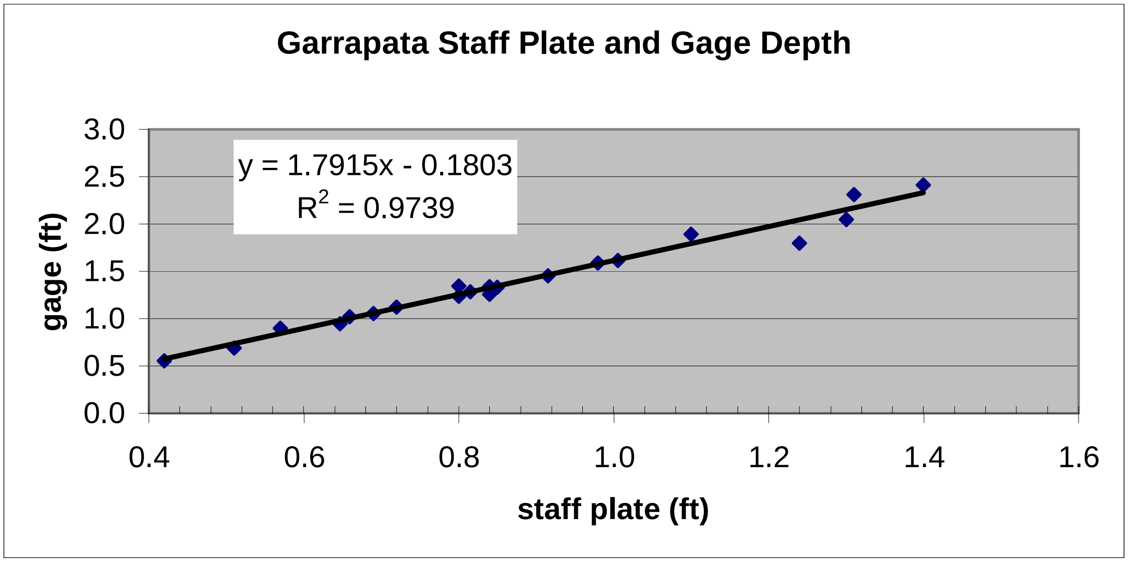

Figure 5: Scatter plot of Garrapata gauge depth and staff plate depth.

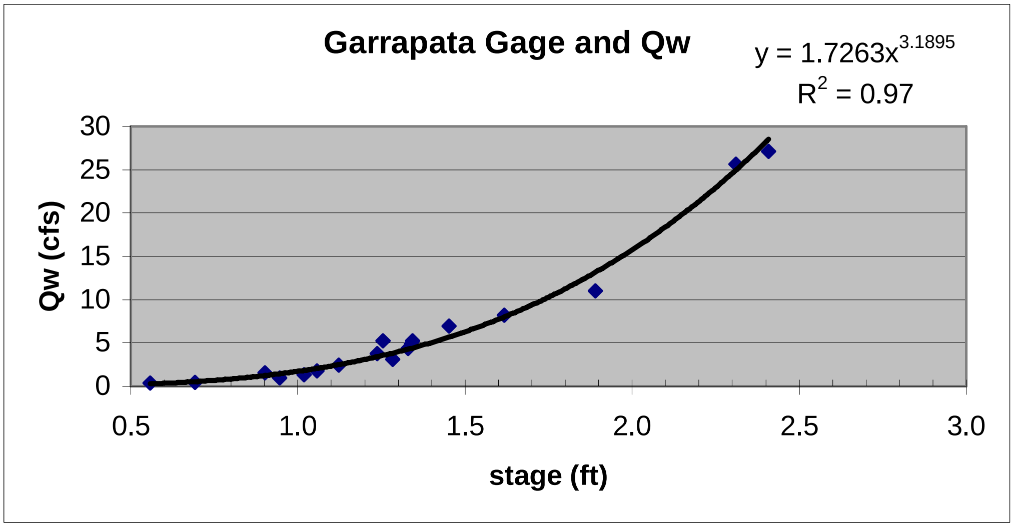

Figure 6: Scatterplot of Garrapata gauge depth and stream discharge. The data collected on 3/11/05 created an obvious outlier and was not used in the calculation.

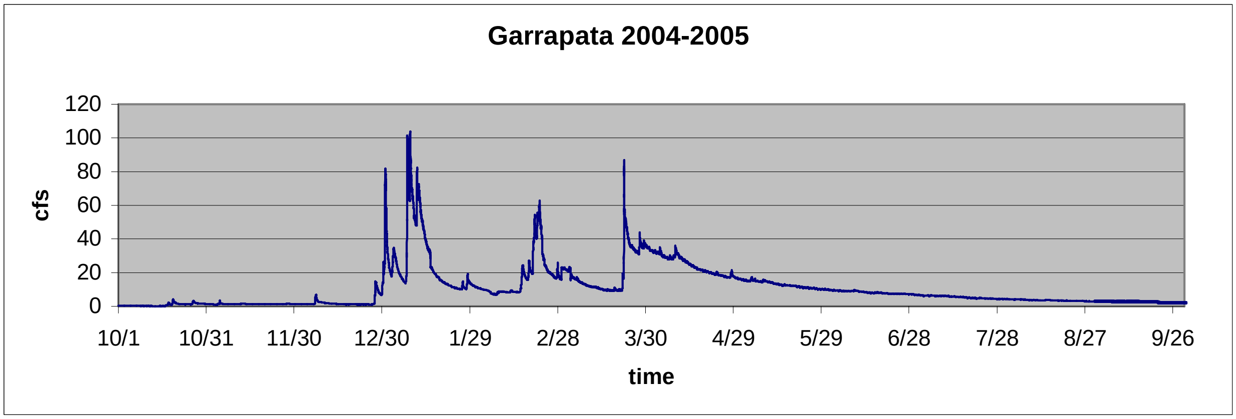

Figure 7: Garrapata discharge between October 1, 2004 and September 30, 2005.

4.2 Hydrology of Joshua Creek Near Confluence with Garrapata

The Garrapata gauge is located upstream from the mouth of Joshua Creek, so hydrologic measurements of Joshua Creek are required to develop an estimate of the total runoff in the watershed. There are no significant tributaries located downstream from the mouth of Joshua Creek, so adding the discharge of Joshua Creek to the discharge calculated at the Garrapata gauge will account for nearly all the surface water flowing from the Garrapata Watershed.

Before October 7, 2004, estimates of flow velocity were made on Joshua Creek at an abandoned foot bridge that includes a broad flat floored cement box culvert. The culvert exit is a short waterfall, so the bottom of the culvert approximates a broad-crested weir, forcing the flow to critical condition. The velocity estimates used to calculate discharge were made by using the theoretical relationship between critical flow depth and critical velocity ($v = \sqrt{(d/g)}$). From October 7, 2004 to the present, flow measurements for Joshua Creek were made with either a Parshall flume or pygmy current meter at a narrow "run" located approximately 25 m upstream from the foot bridge. Table 3 provides the history of measurements at Joshua Creek.

Table 3: Hydrologic measurements on Joshua Creek

Date	Staff (ft)	Gage (ft)	Flow (cfs)
10/27/2001	na	na	0.862
11/3/2001	na	na	0.181
2/9/2002	na	na	1.480
3/10/2002	na	na	0.862
4/29/2002	na	na	0.396
9/9/2002	na	na	0.104
2/15/2004	na	na	0.950
2/19/2004	na	na	1.797
2/26/2004	na	na	7.520
3/23/2004	na	na	0.658
3/24/2004	na	na	0.511
4/25/2004	na	na	0.727
10/7/2004	na	na	0.074
3/11/2005	0.610	0.75	4.500
4/8/2005	0.62	0.72	6.216
5/13/2005	0.47	0.556	2.088
9/20/2005	0.250	0.30	0.230
10/20/2005	0.240	0.27	0.160
12/1/2005	0.240	0.30	0.240

On March 6, 2005 a continuous-recording stage gage was installed 10 m downstream from the intersection of Ken Ekelund's driveway and Joshua Creek (Fig. 2). Staff plate readings and gage depths have been recorded since that time (Table 3). Figure 8 shows a strong relationship between staff plate readings and the gage depths.

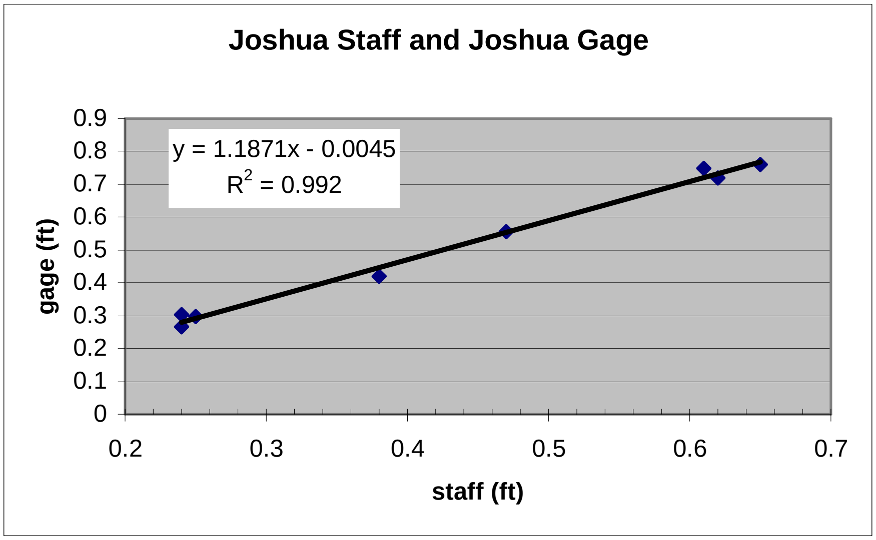

Figure 8: Relationship between Joshua Creek staff plate and Joshua Creek gage.

An R^2 value of 0.99 indicates a robust relationship between the Joshua Creek gauge depth to Joshua Creek discharge (Fig. 9). The rating is weakened by the paucity of points, especially at higher flows. Since March 6, 2005, the power function equation shown in Figure 9 was used to convert the continuous gauge depth record to continuous discharge (Fig. 10). During the time period between March 6, 2005 and September 20, 2005, the Joshua Creek and Garrapata Creek gages were simultaneously operating, providing the opportunity to develop an equation that best predicts Joshua Creek discharge from the Garrapata Creek gage record (Fig. 11). For the portion of the water year preceding installation of the Joshua gage, we use that empirical relationship to estimate flow in Joshua creek (Fig. 10).

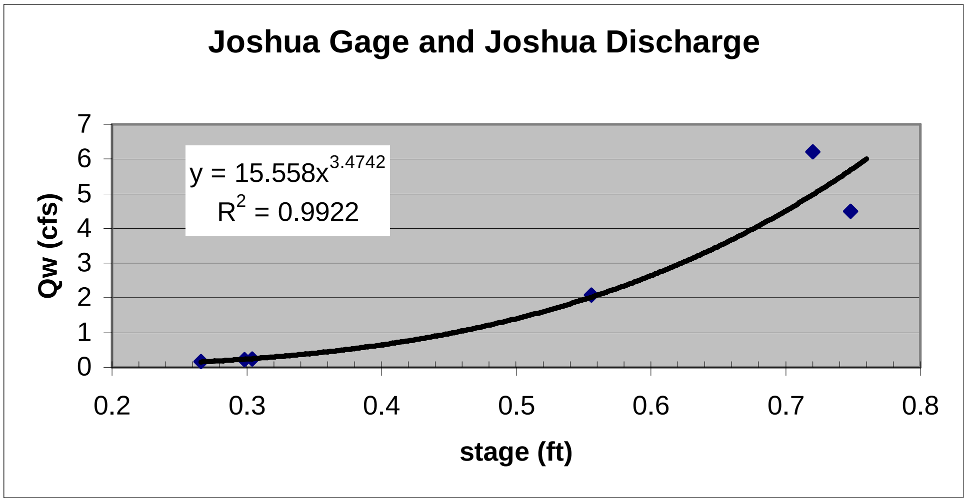

Figure 9: Relationship between Joshua Creek gage depth and measured discharge.

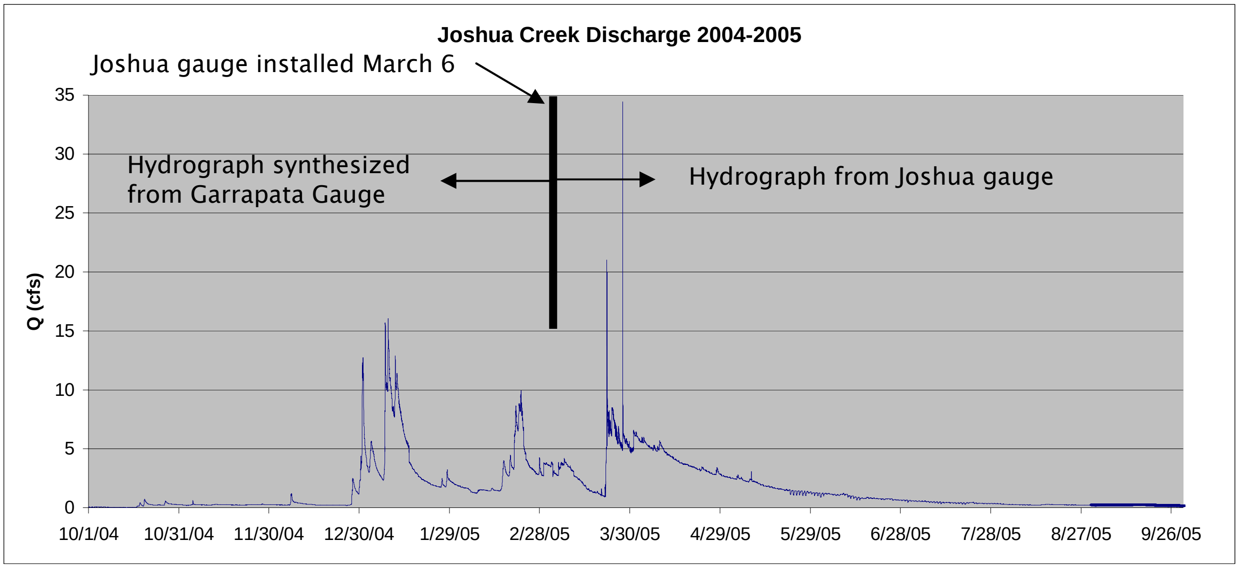

Figure 10: 2004-2005 Annual hydrograph for Joshua Creek.

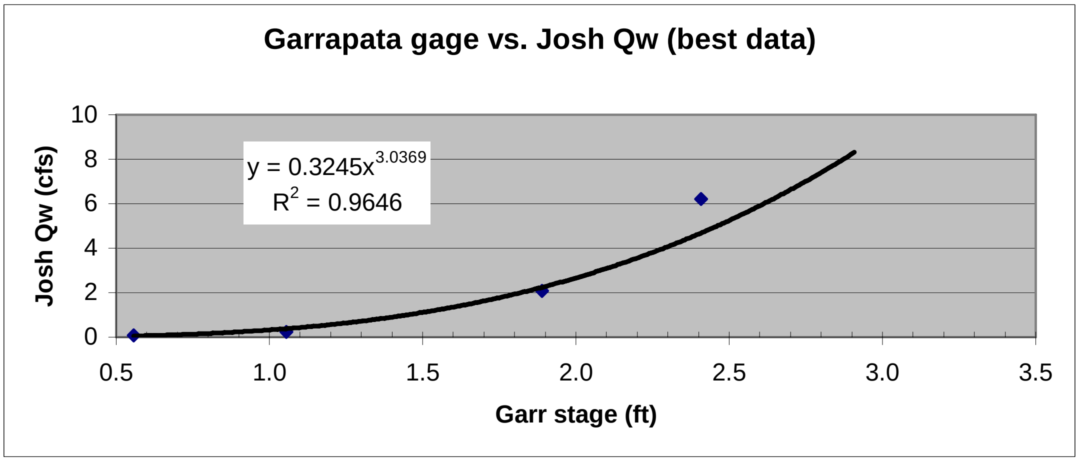

Figure 11: Best fit relationship between Garrapata gauge record and Joshua Creek discharge using most “predictive” subset of all available data points.

4.3 Hydrology Summary for Garrapata Watershed

The peak discharge passing the Garrapata gauge in 2004-2005 is estimated at approximately 100 cfs on January 8, 2005 (Fig. 7). There were also high peaks exceeding 80 cfs on December 31, 2004 and March 22, 2005 (Fig. 7). A peak flow of 100 cfs is estimated as the 3 year flow event (Table 4). The two 80 cfs flows are rated as 2 year events (Table 4). The coincidence of two 2-year events and a 3 year event occurring in the same year is in keeping with the higher than average rainfall of 2004-2005.

Table 4: Calculated discharge recurrence and annual exceedance probabilities for select flows at the Garrapata gauge using Log-Pearson Type III analysis on a 52 year synthetic annual peak record (Smith et al, 2005).

Exceedance Return Period (yrs)	Annual Exceedance (%)	Annual Peak Discharge at Gauge (cfs)
1.5	67%	60
2	50%	80
5	20%	140
10	10%	180
25	4%	230
50	2%	270
100	1%	310
200	0.5%	340

The higher than average peak flows were matched by higher than average annual discharge. The 2004-2005 produced approximately 8836 acre-feet of water, more than the previous three years combined (Table 5). The short-lived (four-year) gauge record is already showing the strong inter-annual variability that is typical of the coastal Santa Lucia watersheds.

Table 5: Volume of surface water (acre-ft) leaving Joshua and Garrapata Creeks. Yield and average yield (acre-ft/mi^2) are the annual and annual average volume of water produced per unit area of watershed

Water year	Garrapata	Joshua	Watershed	Yield	Rain (in)
2001-02	1516	281	1797	105	13.83
2002-03	2534	534	3068	178	20.46
2003-04	1974	425	2399	140	17.57
2004-05	7650	1186	8836	514	37.08
Average volume	3418	606	4025		
Average yield	246	183	234		

The rain falling on the Garrapata Watershed is divided into groundwater storage, evaporation, transpiration, and runoff to the sea. We have precipitation records (Table 1) to compliment the 2002, 2003, 2004, and 2005 water year discharge records. For those years we can calculate the volume of combined evapo-transpiration (ET), by assuming that groundwater recharge is balanced by groundwater discharge on an annual basis (Smith et al., 2005). Given those simplifications, ET = Precipitation - Runoff (Table 6).

Table 6: Estimates of evapo-transpiration (ET) in the Garrapata Watershed (acre-ft).

Year	Precipitation	Runoff	ET	ET%
2001-02	7929	1797	6132	77%
2002-03	11731	3068	8663	74%
2003-04	10074	2399	7675	76%
2004-05	21260	8836	12424	58%

The first three years provide results indicating that ET is roughly 75% of precipitation, whereas the 2005 water year had only 58% ET. The average value is somewhat higher than the ET of 64% estimated for neighboring Garzas watershed (RSC-EIR, 1994). Smith et al. (2005) discuss possible reasons for these differences. We also note that the assumed condition of balanced groundwater storage may be true if averaged over several years, but may not be true for each year (Smith et al., 2004).

5 Sediment Discharge

Sporadic bedload and suspended load measurements have been recorded in Garrapata and Joshua Creeks since 2001. The techniques are described in Smith et al. (2005). We use the combination of spot sediment discharge rates (g/s) and complementary water discharge measurements to regress a relationship between water flow and sediment flow. That relationship is then used to determine the volume of sediment annually leaving the watershed. We also use other sediment parameters to assess changes in the condition of the stream beds and the slopes feeding sediment to them. No bedload samples were taken from 9/20/05 to 12/1/05 because there was only a trace of bedload motion visible by diving mask. Our trials using the Helley-Smith bedload sampler in such low-flow conditions on a sand bed have shown that the orifice “vacuums” the bedload into the sampler at a rate far exceeding ambient bedload transport rate. On the days when no bedload samples were taken, it was because the amount of sand inadvertently “vacuumed” by the Helley-Smith sampler would produce egregious errors in calculating long term sediment transport values.

5.1 Garrapata Data

Spot data from the sediment transport monitoring of Garrapata Creek above Joshua Creek are in Table 7. Figures 12 and 13 show the relationships between flow and sediment transport in Garrapata Creek. Figures 14 and 15 show the functions relating sediment transport to gauge depth and discharge. The data from 9/20/05, 10/20/05, and 12/1/05 were excluded from the calculations and plots (Figs. 14 and 15). These data represent days when there was only trace sediment transport occurring. Their use in the equation would produce biased results by weighting the data set with a disproportionate number of low-flow data.

Table 7: Bedload and suspended load measurements for Garrapata Creek

	Garrapata					
Date	staff (ft)	gauge (ft)	Discharge (cfs)	Bedload (g/s)	Suspended (g/s)	Total (g/s)
10/27/2001	0.647	0.946	0.96	--	0.33	--
11/3/2001	0.659	1.018	1.30	0.76	0.44	
2/9/2002	0.800	1.342	5.22	3.00	1.63	4.63
3/10/2002	0.840	1.254	5.21	2.03	3.87	5.90
4/29/2002	0.800	1.238	3.74	2.28	--	--
9/9/2002	0.570	0.902	1.57	--	0.91	0.91
2/15/2004	0.815	1.283	3.14	1.81	0.56	2.37
2/19/2004	1.005	1.617	8.17	2.96	4.16	7.12
2/26/2004	1.310	2.310	25.61	20.45	39.07	59.52
3/23/2004	0.850	1.330	4.39	1.80	1.05	2.85
3/24/2004	0.840	1.340	4.86	9.61	1.05	10.66
4/25/2004	0.720	1.122	2.43	1.46	1.62	3.08
10/7/2004	0.420	0.557	0.34	0.00	0.07	0.07
3/11/2005	1.240	1.800	25.60	39.54	6.04	45.58
4/8/2005	1.4	2.409	27.11	90.91	16.03	106.94
5/13/2005	1.1	1.890	11.05	6.60	4.05	10.65
9/20/2005	0.690	1.056	1.78	trace	trace	trace
10/20/2005	0.690	--	1.55	trace	trace	trace
12/1/2005	0.700	--	1.55	trace	trace	trace
1/5/2006	1.1		10.42	21.8	16.15	37.95

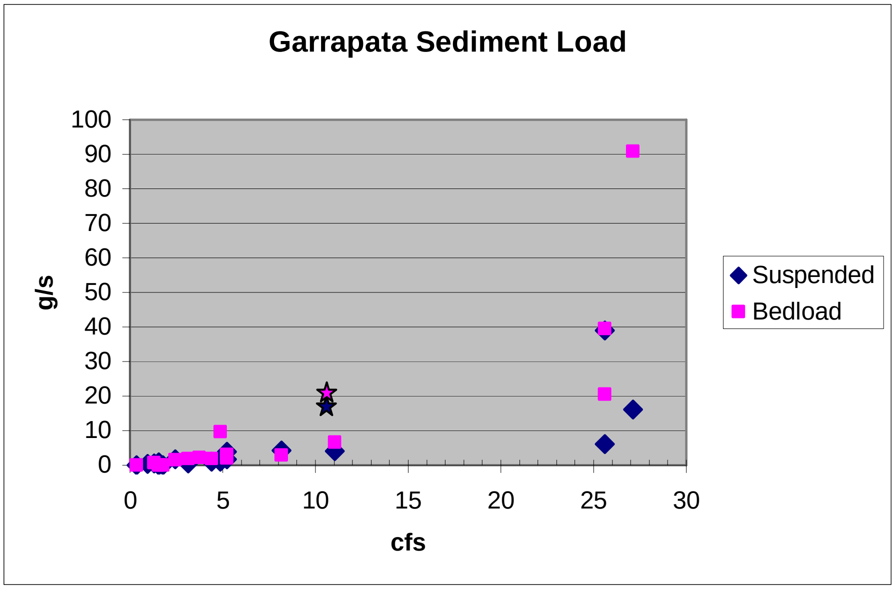

Figure 12: Scatter plot of Garrapata instantaneous sediment transport rates and water discharge. Star shows data from January 5, 2006.

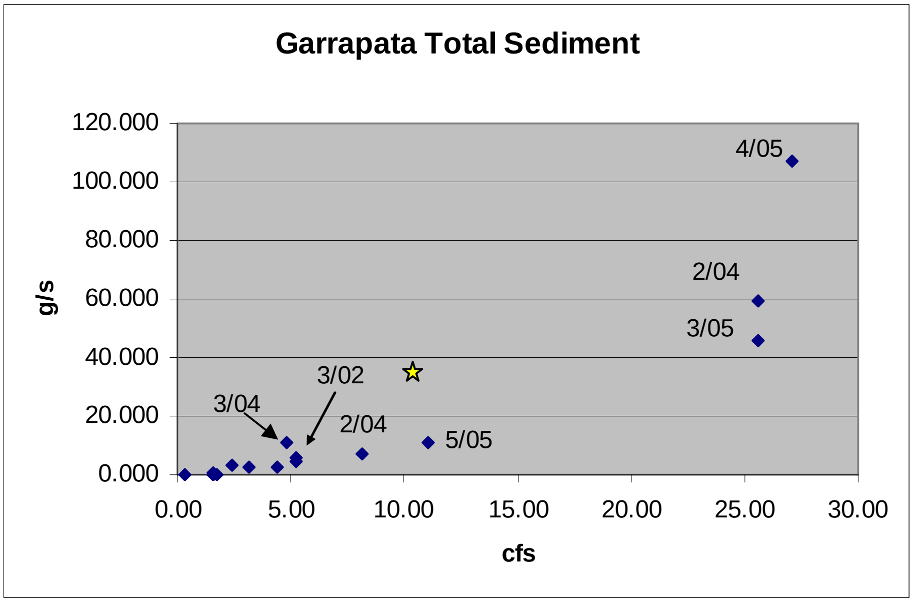

Figure 13: Scatter plot of Garrapata instantaneous total sediment transport rates (bedload + suspended load) and water discharge. Dates of select measurements are shown. Star is sample from January 5, 2006.

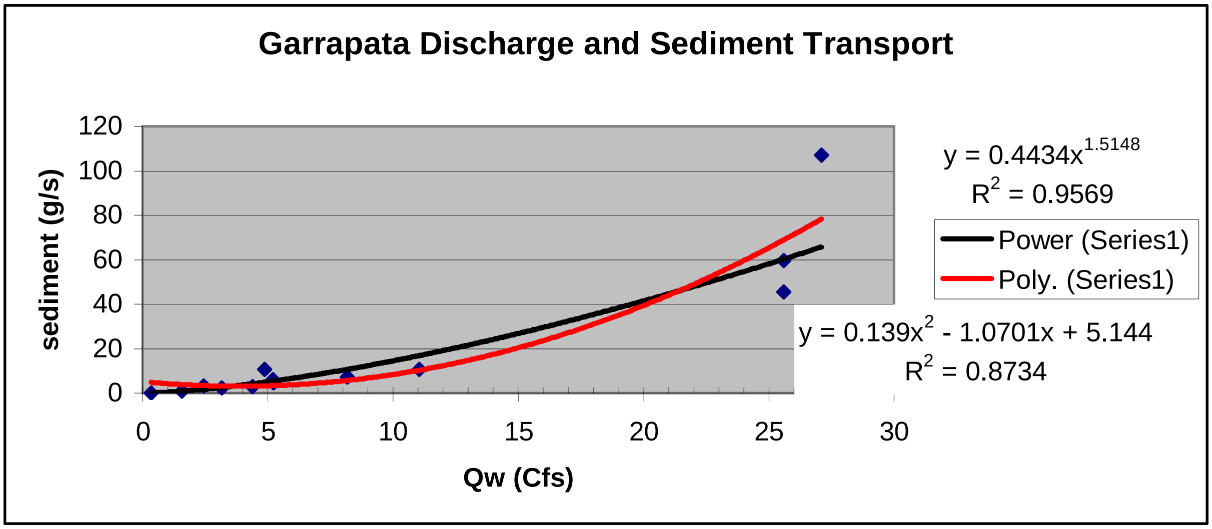

Figure 14: Scatter plot of Garrapata Creek discharge and combined bedload and suspended load transport rate. Power function and polynomial relationships are shown. Graph excludes certain low-flow data (see text).

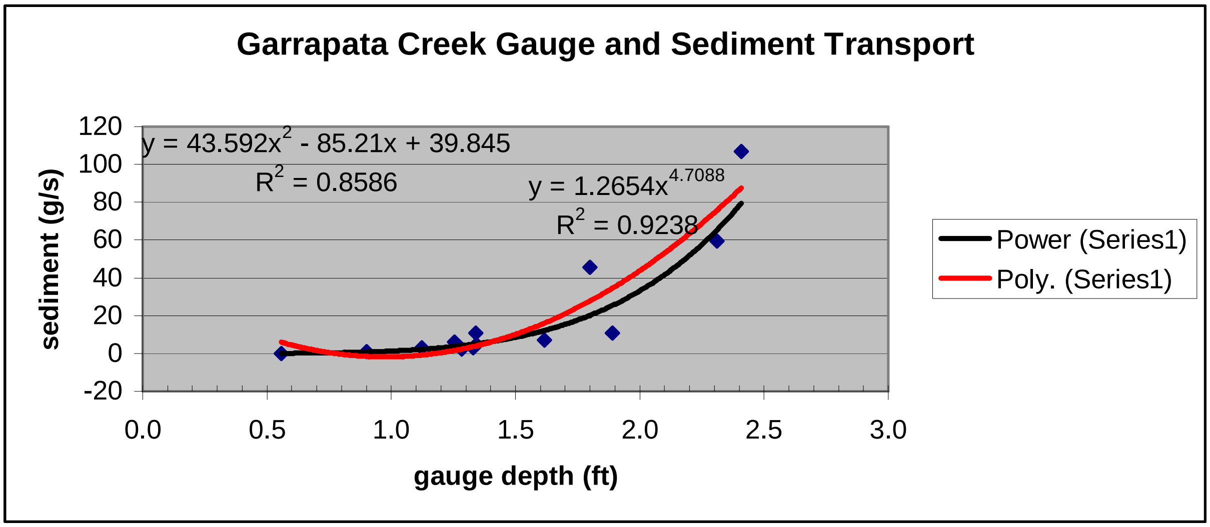

Figure 15: Scatter plot of Garrapata Creek gage depth and combined bedload and suspended load transport rate. Power function and polynomial relationships shown. Graph excludes certain low-flow data (see text).

5.2 Joshua Creek Data

Spot data from the sediment transport monitoring of Joshua Creek are in Table 8. We note that errors present in Joshua Creek data table of Smith et al. (2005) have been corrected in Table 7. Figures 16 and17 show the relationships between flow and sediment transport in Garrapata Creek. Figure 18 shows the functions relating sediment transport to stream discharge for all available data. Figure 19 shows the sediment transport relations for data collected between February 2002 and October 2004, while Figure 20 shows the data collected thereafter up until December 1, 2005, before the first heavy rains of the 2005-2006 season. Three low-flow readings are averaged in Figure 19 to reduce bias in the data distribution. Figure 21 combines those two plots to better illustrate the differences in those two time periods.

Table 8: Bedload and suspended load measurements for Joshua Creek

	Joshua					
Date	**staff**	gauge (ft)	Discharge (cfs)	Bedload (g/s)	Suspended (g/s)	Total (g/s)
10/27/2001	na	na	0.862	--	0.47	--
11/3/2001	na	na	0.181	--	--	--
2/9/2002	na	na	1.480	25.80	3.01	28.81
3/10/2002	na	na	0.862	13.15	2.35	15.50
4/29/2002	na	na	0.396	3.53	--	--
9/9/2002	na	na	0.104	0.61	0.03	0.63
2/15/2004	na	na	0.950	1.50	0.15	1.65
2/19/2004	na	na	1.797	43.85	9.69	53.54
2/26/2004	na	na	7.520	84.42	104.27	188.69
3/23/2004	na	na	0.658	1.08	0.18	1.26
3/24/2004	na	na	0.511	2.29	0.07	2.36
4/25/2004	na	na	0.727	--	--	--
10/7/2004	na	na	0.074	0.00	0.03	0.03
3/11/2005	0.610	0.75	4.500	2.50	3.00	5.50
4/8/2005	0.62	0.72	6.216	115.32	4.73	120.05
5/13/2005	0.47	0.556	2.088	0.00	0.86	0.87
9/20/2005	0.250	0.30	0.230	0.00	0.00	0.00
10/20/2005	0.240	0.27	0.160	0.00	0.00	0.00
12/1/2005	0.240	0.30	0.240	0.00	0.00	0.00
1/5/2006	.49		1.74	9.20	8.65	17.85

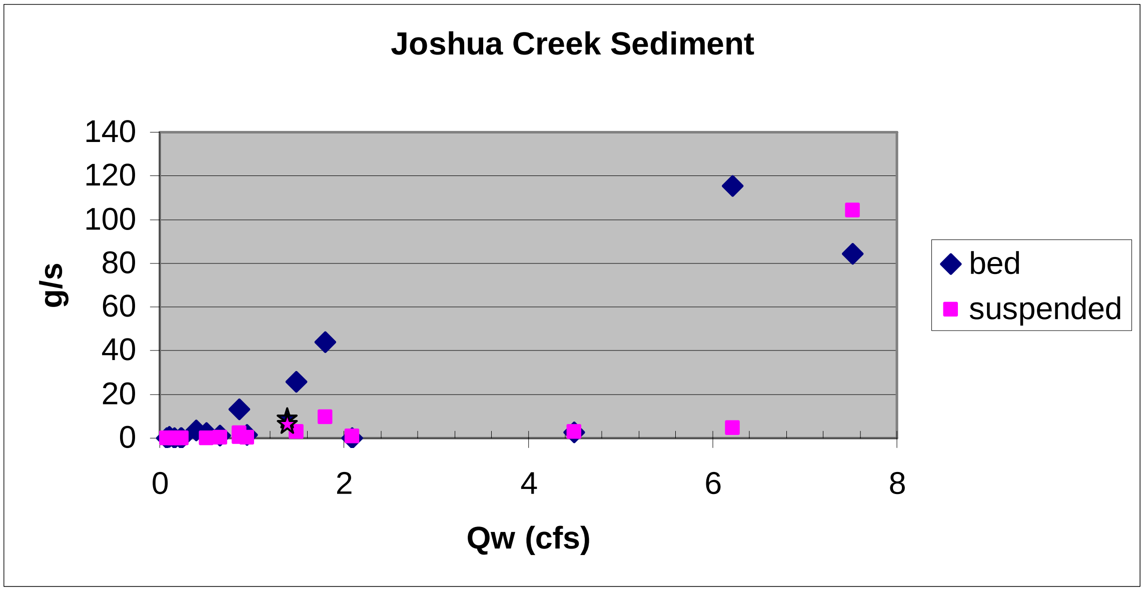

Figure 16: Scatter plot of Joshua Creek instantaneous sediment transport rates and water discharge. Star symbols are data from 1/5/2006.

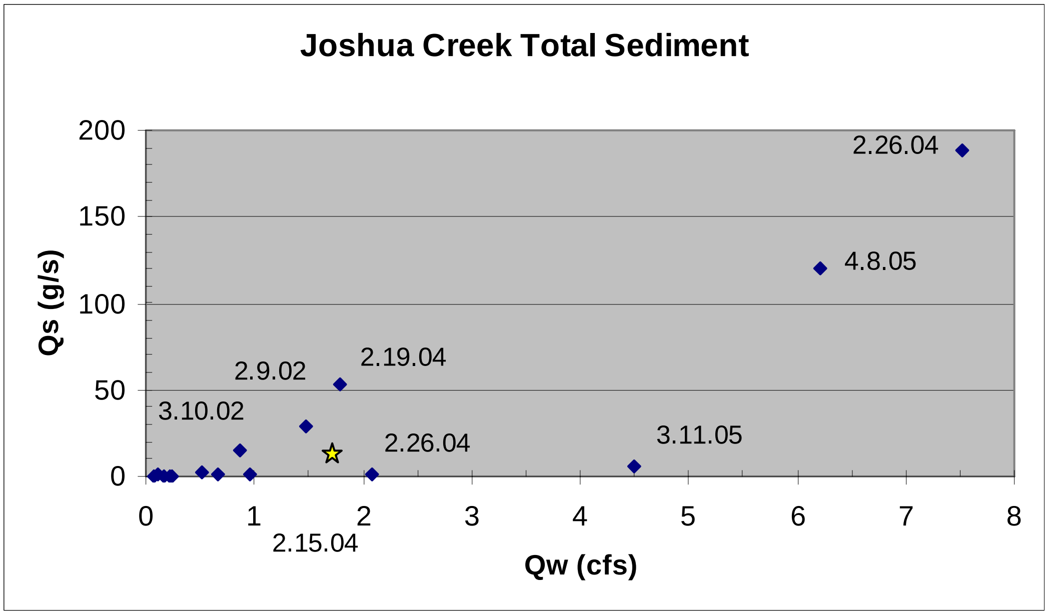

Figure 17: Scatter plot of Joshua Creek instantaneous total sediment transport rates (bedload + suspended load) and water discharge. Dates of select measurements are shown. Star represents data from 1/6/2006.

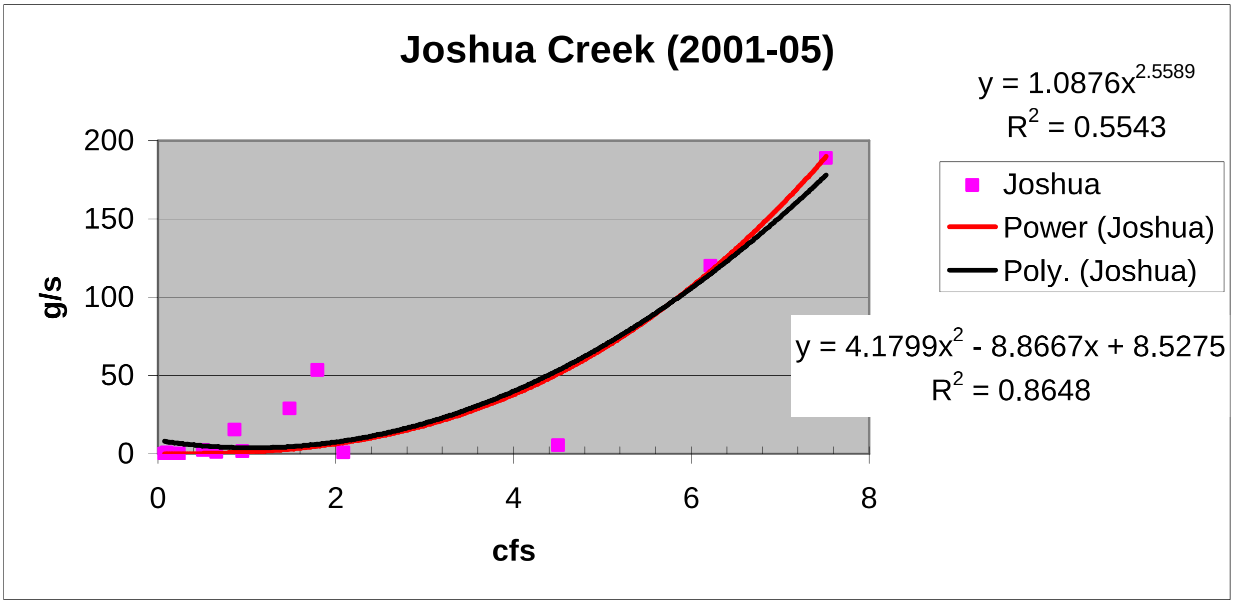

Figure 18: Scatter plot of Joshua Creek discharge and total sediment transport rates (bedload + suspended load). Power function and polynomial relationships shown. Plot uses all available data.

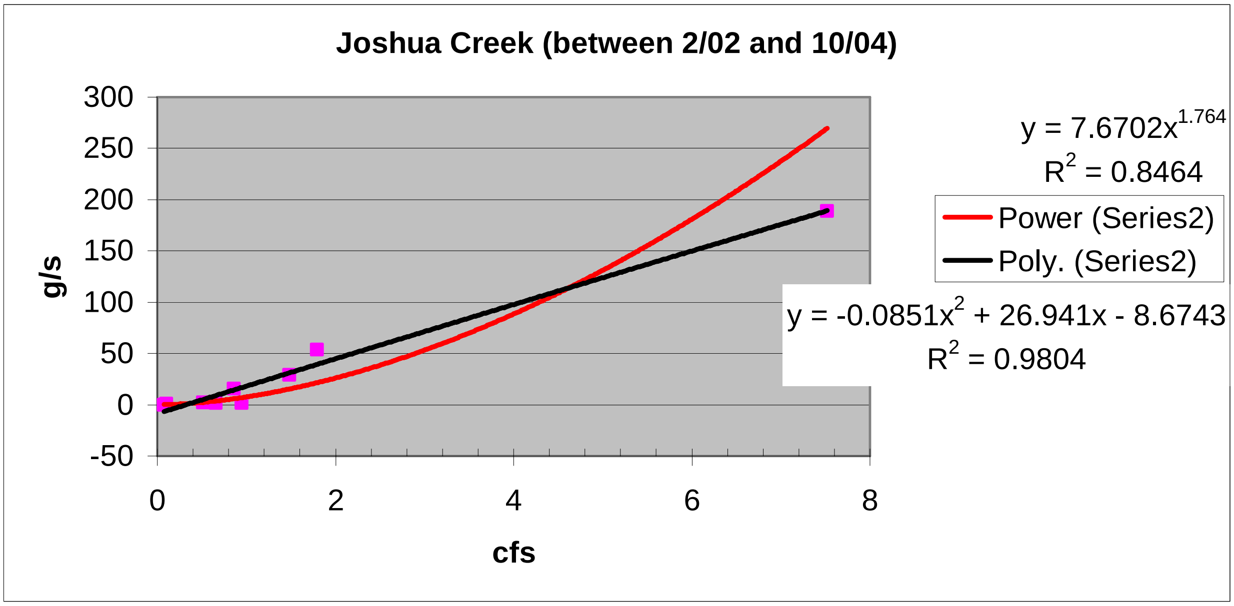

Figure 19: Scatter plot of Joshua Creek discharge and total sediment transport rates (bedload + suspended load). Power function and polynomial relationships shown. Plot uses data collected between February 2002 and October 2004.

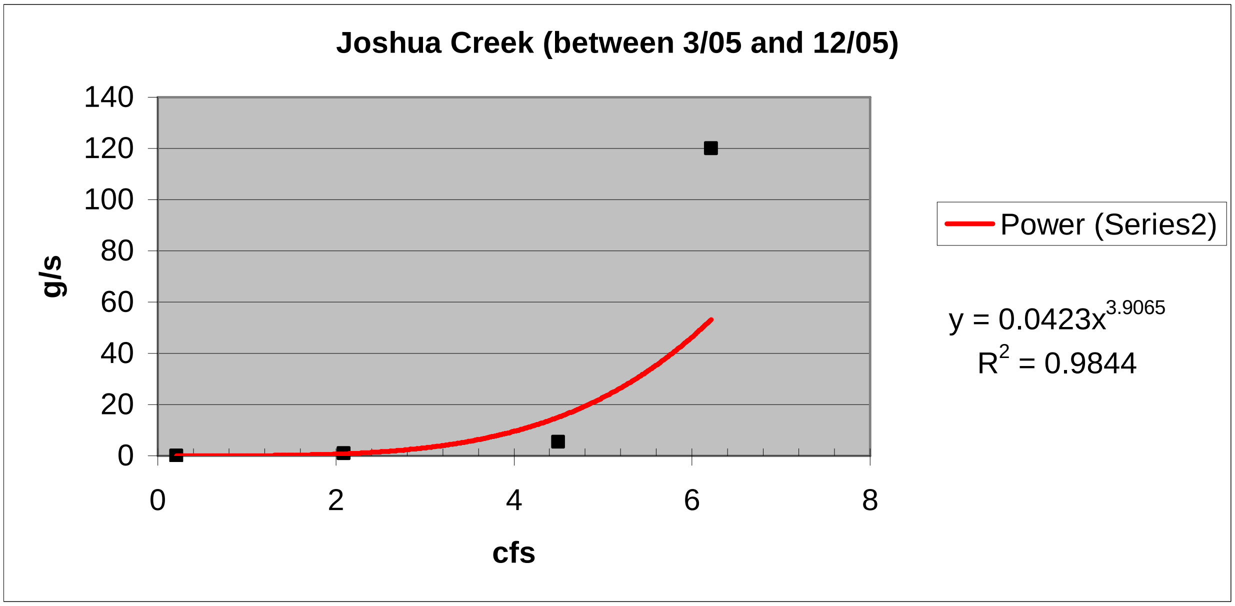

Figure 20: Scatter plot of Joshua Creek discharge and total sediment transport rates (bedload + suspended load). Power function relationship shown. Plot uses data collected between March 2005 and December 2005, with two low values averaged.

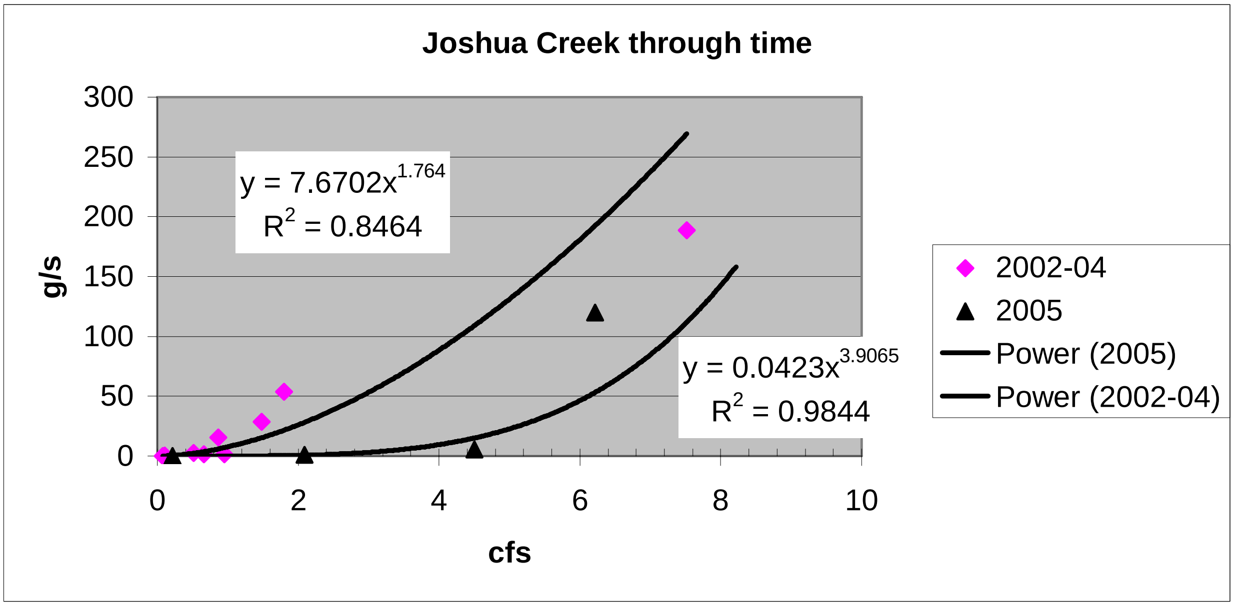

Figure 21: Same data as in Figures 19 and 20 plotted together for cmparison.

6 Discussion

Sediment transport rates from Joshua Creek have been disproportionately higher than Garrapata Creek since before our monitoring program began in 2001 (Fig. 22). The higher sediment transport rates stem from a high rate of sand input from impaired watershed terrain in the Joshua Creek subwatershed (Smith et al., 2005). As discussed below, the above average flow conditions of 2004-2005 have partially cleaned out the sand fraction from the creek. It is likely that flow conditions in 2005-2006 will determine whether or not the creek bed remains sand-free. High flows approximating the flows of 2004-2005 will probably keep the creek clean, whereas below average flows would add sediment o the pools without flushing them out.

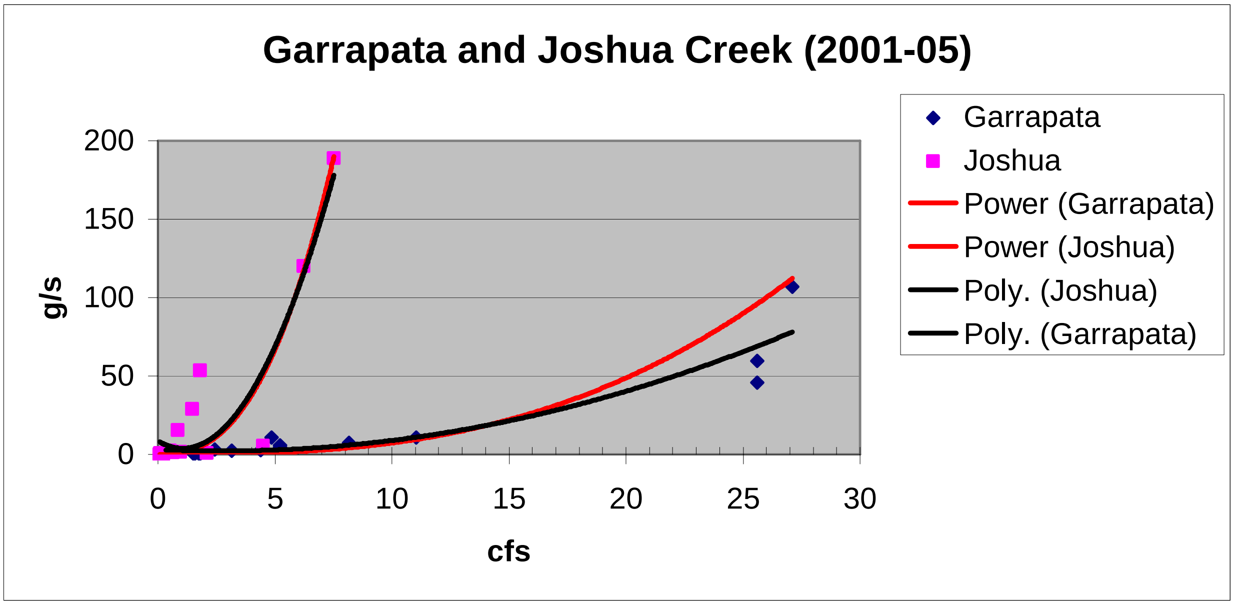

Figure 22: Scatter plot of all available discharge and sediment transport data for both Garrapata and Joshua Creek sampling sites. Power function and polynomial trend lines shown.

6.1 Garrapata Creek

Garrapata Creek above Joshua Creek has had relatively low sediment transport rates since we began monitoring in 2001 (Smith et al., 2005). Those low rates are supported by subsequent data as well, but it is clear that sediment waves, with higher transport rates do pass by the monitoring site. Evidence for this occurring are the data collected in March 2005 (Fig. 13), which produced a data point lying above the previously calculated trend. A single sample taken on January 5, 2006 also shows elevated bedload, suspended load and total sediment loads relative to measurements from previous years (Figs. 12 and 13). Walking reconnaissance indicates that other sediment waves located higher in the watershed will also eventually move downstream to the monitoring site. There is also sediment trapped behind large wood barriers that will sporadically move downstream as logs are rearranged (Casagrande and Smith 2004). As more sediment waves are measured, we will develop a better appreciation of the true inter-annual and intra-annual variability in sediment transport. This knowledge is essential for meaningful assessment of change through time.

Variability in sediment concentration (grams/cubic foot) through time can be seen in Figure 23. The concentration value includes suspended and bedload combined. Both the absolute values of concentration and concentration variability are much higher in Joshua Creek than in Garrapata Creek. The last three measurements represent low flow conditions at the end of the 2004-2005 water year when both bedload and suspended load transport were very low. It is clear that impact assessment and assessment of gradual change will have to include measurements that are frequent enough to include variability. Biased results will be occur if sediment is measured too infrequently.

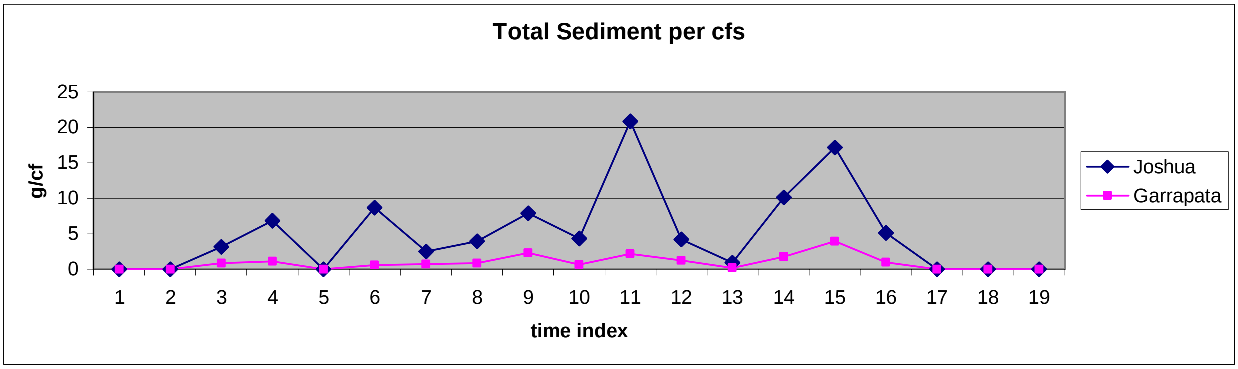

Figure 23: Plot of sediment concentration through time for Garrapata and Joshua Creeks. The time axis is an index of time, it is not scaled to true time.

6.2 Joshua Creek

Joshua Creek, like other steep coastal creeks of the Santa Lucia range has a step-pool bed with grade control provided by large boulders and buried tree trunks. In the absence of excess sand bedload, these creeks have deep clear pools that foster passage and spawning of Steelhead. Joshua Creek has been heavily impacted by excess sand-sized material since before our monitoring started in 2001 (Smith et al., 2005). Based upon air reconnaissance, Smith et al. (2005) hypothesized that the excess sediment is brought to the creek bed from eroding dirt roads and landslides located along the flanks of Joshua Creek. The high supply of sediment produced a steep sediment rating curve (Fig. 21).

Sediment transport rates decreased markedly in Joshua Creek following the peak December and January flows of the 2005-2004 season (Figs. 19 and 21). Following those heavy flows the amount of sand present in the creek bottom visibly decreased as well. Smith et al. (2005) estimated the volume of excess, pool-filling sediment in Joshua Creek to be 584 tonnes. Using the high sediment transport rates measured in the creek they suggested that the creek bed could be rapidly cleared if the sediment input were suddenly stopped. This report supports their contention, and demonstrates that the creek “cleanup” can be greatly accelerated by higher than average peak flows (Figs. 10 and 21). If the power-function sediment rating equation of Figure 19 is applied to the high flow year of 2004-2005, over 1000 tonnes of sediment would have been flushed from the creek, far in excess of the 584 tonnes estimated to have been present in 2004. The present clean condition may be short lived. A short reconnaissance walk above the sampling site on Joshua Creek in December 2005 revealed that more excess sediment is gradually moving toward the monitoring location. Early flows of the 2005-2006 season will either refill the cleaned pools of Joshua Creek, or, if they are strong enough, will flush the sediment to Garrapata Creek. Sediment transport measurements taken on Januray 6, 2006 support the idea that overall sediment yield has significantly diminished in the watershed for the present(Figs. 16 and 17).

7 References

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