Appendix E—Streamflow, Seasonal Variation, and Flow Tiers

This appendix is a Technical Support Document (TSD) that provides additional analysis of streamflow in Rainbow Creek. This TSD examines rainfall patterns, daily streamflow rates and their frequency of occurrence, and flow-based tiers and their associated flow volumes.

Overview

In the semi-arid climate of Southern California there are two seasons—dry weather occurs during most of the year and intermittent wet weather events occur typically between November and March. This two-season climate creates significant differences in freshwater flow through the creeks and streams. In general, storm events yield both high flow rates and high flow volumes; the vast majority of flow volume occurs during the months of January, February, and March. Nonetheless, some storms occur in other months of the year.

The Regional Board has evaluated the merits of developing TMDLs for each pollutant (or group of pollutants) by using the seasonal variation approach (i.e., loading determined for wet versus dry weather seasons) and by using a flow-based approach. The flow-based approach divides stream flow into ranges or tiers. This method incorporates high flows that may occur outside of the wet season as well as low flows that happen in between rain events. Thus the applicable loading capacity and total allocation for a given pollutant does not depend on the time of year, but on the actual stream flow.

The following discussion concentrates on establishing flow tiers for Rainbow Creek. The flow-based approach is applied to total nitrogen and total phosphorus TMDLs in Section 5.0 Loading Capacity and Linkage Analysis. Three flow tiers have been identified: low flows, moderate to high flows, and very high flows. The flow data used in this analysis is from U.S. Geological Service (USGS) records (1989 – 2000) for Rainbow Creek near sampling station Willow Glen-4 (Gage No. 11044250).

Annual Precipitation

Precipitation during a water year (defined from July 1 to June 30) will influence the total flow volume within each freshwater system. Average annual rainfall is approximately 15 inches annually for inland North County (Escondido). During water year 1998, 29.86 inches of rain fell (El Nino conditions), whereas in 1999, 8.57 inches of rain fell. Table E-1 summarizes rainfall records at Escondido from 1980 to 2002.

Table E-1. Annual Precipitation Records at Escondido 2 (42863)

Water Year*	Annual Rainfall (inches)	Water Year*	Annual Rainfall (inches)	Comment
1980	30.4	1994	14.08	
1981	10.96	1995	26	
1982	15.74	1996	9.84	
1983	24.63	1997	10.84	
1984	8.16	1998	29.86	
1985	13.14	1999	8.57	
1986	20.89	2000	7.76	
1987	12.98	2001	10.3	
1988	17.02	2002	5.89	
1989	8.15			
1990	9.83	Summary		
1991	15.24	1980--2002	15.27	Annual average
1992	11.54	2002	5.89	Minimum value
1993	29.31	1980	30.4	Maximum value

Source: Western Regional Climate Center (2003), Southern California Climate Summaries, Monthly Total Precipitation

*For example, the 1998 water year is defined from June 30, 1997 to July 1, 1998.

Annual Flow Volume

The Regional Board reviewed daily flow records from the USGS record for the period of November 11, 1989 to September 30, 2000 for Rainbow Creek. We selected daily flow records corresponding to water year records (USGS, 2002). For example, July 1, 1990 to June 30, 1991 is water year 1991. This approach yielded 8 water year records for Rainbow Creek. Incomplete USGS data for the period 1989/90, 1992-93, and 1993-94 were not used because only partial records were available for each year.

USGS reports the daily median flow rate for each day of the record. This information is used to determine the annual flow volume of Rainbow Creek. This is accomplished by calculating and summing the daily volume for each day of the record. Table E-2 shows the annual flow volume for each year of the reviewed record.

Table E-2. Annual Flow Volumes and Rainfall Totals for Rainbow Creek

Water Year	Avg. Flow Rate (cfs)	Annual Flow Volume (cubic feet)	Annual Rainfall (inches)
91	2.4	69,465,600	15.24
92	1.93	61,031,232	11.54
95	9.58	298,804,032	26
96	1.22	38,579,328	9.84
97	2.19	69,063,840	10.84
98	7.87	240,028,704	29.86
99	1	31,536,000	8.57
2000	0.68	21,503,232	7.76

As can be expected, total flow volumes are directly related to annual precipitation. For example, the total flow volumes recorded for Rainbow Creek were 240,028,704 ft^3 (5,510 acre-ft) in 1998 (due to El Niño conditions) and 31,536,000 ft^3 (724 acre-ft) in 1999 (due to slightly below normal annual rainfall).

Daily Flow Records

The Regional Board's review of the daily flow records for Rainbow Creek revealed a wide range of flow rates. In dry weather, low flows are less than 3 cubic feet per second (cfs) and can occur year around. Flows of 3 cfs and above occur with less frequency by comparison and appear to be related to rainfall. However, it is reasonable to assume that some of the flows can be attributed to irrigation. Flows of 40 cfs or greater occur during the months with the highest rainfall and occur less than five days a year (averaged over 8 years). These very high flows are considered to be due to extreme weather conditions.

Figure E-1 presents the frequency of occurrence of flow rates in Rainbow Creek for the 8-water years evaluated. This figure also illustrates the month of the year that the flows occur. Figure E-2 provides another graphical representation of the frequency of occurrence.

Figure E-1 Annual Distribution of Flow Rate Frequency of Occurrence

Flow Rate (cfs)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	No. Days (in 8 yrs)
0.04 - 0.09							●	●					141
0.1					●	●	●	●	●	●	●	●	386
0.2	●				●	●	●	●	●	●	●	●	205
0.3	●	●	●	●	●	●	●	●	●	●	●	●	228
0.4	●	●	●	●	●	●	●	●	●	●	●	●	261
0.5	●	●	●	●	●	●	●	●	●	●	●	●	268
0.6	●	●	●	●	●	●	●	●	●	●	●	●	164
0.7	●	●	●	●	●	●	●	●	●	●	●	●	120
0.8	●	●	●	●	●	●	●	●	●	●	●	●	122
0.9	●	●	●	●	●	●	●		●	●	●	●	103
1	●	●	●	●	●	●	●	●	●	●	●	●	355
2	●	●	●	●	●	●			●		●	●	122
3	●	●	●	●	●	●			●		●		58
4	●	●	●	●	●	●				●	●	●	45
5	●	●	●	●	●						●	●	42
6	●	●	●	●					●			●	34
7	●	●	●	●	●							●	19
8		●	●								●	●	18
9	●	●	●	●	●							●	18
10	●		●	●									7
11	●	●	●	●							●	●	13
12	●	●	●	●									10
13	●	●	●	●									14
14	●	●	●	●									7
15	●	●	●	●									11
16	●		●	●									6
17	●	●	●	●									9
18	●	●	●	●									4
19	●		●										6
20	●	●	●	●	●						●		28
30	●	●	●	●	●							●	16
40	●	●	●										10
50		●	●										4
60	●	●	●								●	●	5
70		●											1
90		●	●										2
100		●	●										2
120	●		●										2
130	●	●											2
140	●												1
150		●											1
180	●												1
220			●										1
242		●											1
293		●	●										2
333		●											1
442			●										1

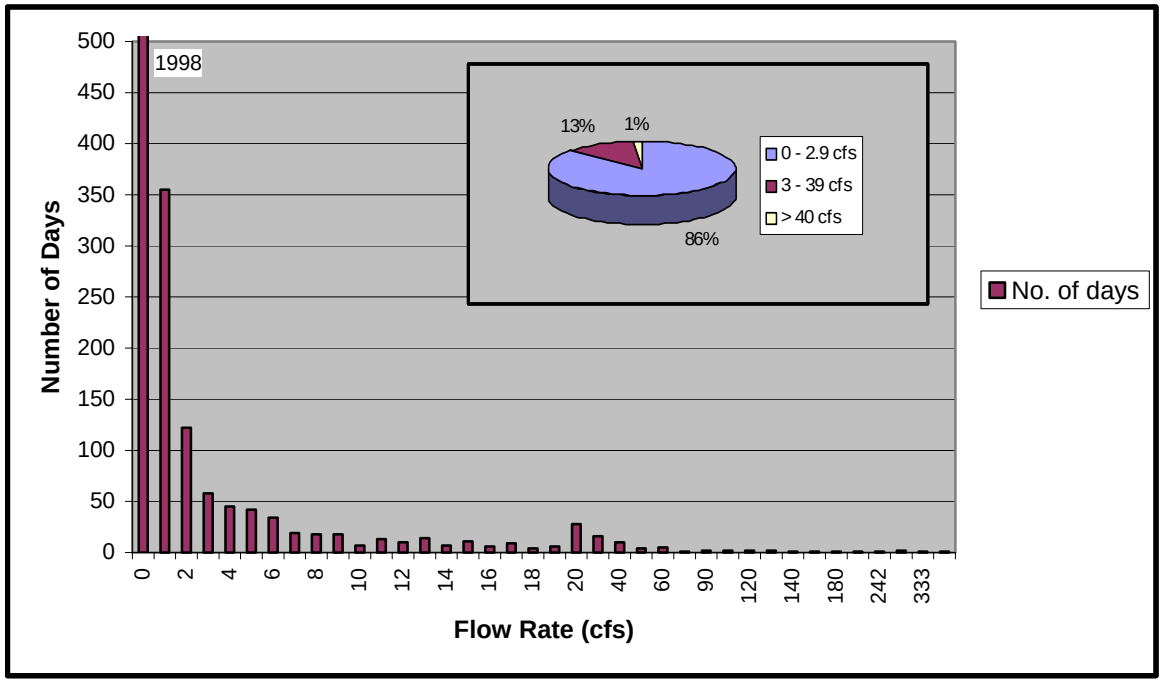

Figure E-2 Flow Rate Frequency of Occurrence During 8-Year Record

Flow Tiers for TN and TP TMDLs

Based on the flow data discussed above, flow tiers and their corresponding annual flow volumes are used to calculate the loading capacity for the total nitrogen and total phosphorus TMDLs in the Technical Report. Three flow tiers were defined for the complete range of flows (Table E-3). The three flow tiers are low flow (0 to 2.9 cfs), moderate to high flows (3 to 39 cfs), and very high flows (> 40 cfs). A comparison of the frequency of occurrences of flow rates and the distribution of the flows over the course of the eight years determined the flow tiers. To determine the total flow volume associated with each tier, the daily flow volume was calculated and summed for each tier.

$$\textbf{Total Flow Volume}_{(\text{tier 1, 2, 3})} = \Sigma_{(t=1,\,2,\,3)}\ \textbf{Daily Flow Volume}$$

Next the total flow volume is divided by the number of days in the flow tier to determine the mean daily flow volume.

$$\textbf{Mean Daily Flow}_{(\text{tier 1, 2, 3})} = \frac{\textbf{Total Flow Volume}_{(\text{tier 1, 2, 3})}}{\textbf{No. Days}_{(\text{tier 1, 2, 3})}}$$

Then the mean daily flow volume for each tier is annualized by multiplying by the percentage of days that the flow rate occurs during the eight years of data.

$$\textbf{Annual Flow Volume}_{(\text{tier 1, 2, 3})} = \textbf{Mean Daily Flow}_{(\text{tier 1, 2, 3})} * (\textbf{\% of Total Days}_{(\text{tier 1, 2, 3})} * 365\ \textbf{Days})$$

Table E-4 presents the annual flow volume for Rainbow Creek for a typical year.

Table E-3. Flow-based Tiers and Corresponding Mean Daily Flow Volume in Rainbow Creek

Flow Tier	Corresponding Flow Rate (cfs)	Total Flow Volume Associated with Tier (cubic feet)	Total No. days (for 8 yrs)	% of Total Days	Mean Daily Flow Volume for Tier (cfd)
Low flow	0 – 2.9	140,024,160	2475	86	56,575
Mod – High flows	3 – 39	321,399,360	365	12.7	880,546
Very High flows	> 40	368,928,000	37	1.3	9,971,027

Table E-4. Flow-based Tiers and Corresponding Annual Flow Volume in Rainbow Creek

Flow Tier	Corresponding Flow Rate (cfs)	Mean Daily Volume for Tier (cfd)	Avg. No. of Days for Year [#]	Annual Flow Volume (cubic feet)
Low flow	0 – 2.9	56,575	314	17,764,622
Mod – High flows	3 – 39	880,546	46	40,775,379
Very High flows	> 40	9,971,027	5	46,805,255

[#] Calculate by multiplying percentage of total days for each tier and 365 days

References

U.S. Geological Survey (USGS), 2002. Daily mean streamflow data for USGS 11044250 RAINBOW C NR FALLBROOK CA, November 7, 1989 through September 30, 2000. USGS National Water Information System, http://water.usgs.gov/realtime.html, queried on April 4, 2002.

Western Regional Climate Center (WRCC), 2003. Southern California Climate Summaries: Monthly Total Precipitation at Escondido 2, California, (042863). http://www.wrcc.dri.edu/cgi-bin/cliMONtpre.pl?caesc2, queried on April 16, 2003.