Water Quality of the Lower Van Duzen River Basin
October 2006 to April 2008

Prepared for the Van Duzen Watershed Project

By
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Introduction

Water quality sampling was conducted in the lower Van Duzen River Basin in order to characterize water quality conditions. Field measurements were completed monthly or bi-monthly from October 2006 to April 2008 and included high-flow and low-flow conditions. Sampling sites were located on the Van Duzen River, at river mile 11 (RM 11), river mile 18 (RM 18), and the following five tributaries: Grizzly Creek, Hely Creek, Cummings Creek, Yager Creek, and Wolverton Gulch. Field measurements included pH, temperature, dissolved oxygen, and conductivity. Water samples were collected and analyzed for turbidity and total suspended solids at the Humboldt State University Wastewater Laboratory, Arcata, California.

Methods

Temperature:
Water temperature was measured *in situ* using Yellow Springs Instruments (YSI) Dissolved Oxygen Meter, Model 55 (Digital) with a precision of +/- 0.5 degrees. Continuous temperature monitoring was conducted from June 6, 2007 to September 21, 2007, using thermographs (Hobo Data Loggers). Thermographs were placed in run or riffle-type habitat and recorded temperature hourly.

pH
pH was measured *in situ* using a Hanna Instruments HI 98127 Waterproof pH Meter (accuracy +/- 0.1 pH). The meter was calibrated with 7.00 and 4.00 buffer solutions prior to sampling.

Specific Conductance
Specific conductance was measured *in situ* using a Hanna Instruments HI 8033 Portable Conductivity Meter. The accuracy of the HI 8033 is 0.1 μS/cm.

Dissolved Oxygen
Dissolved oxygen was measured *in situ* using Yellow Springs Instruments (YSI) Dissolved Oxygen Meter, Model 55 (Digital) with a precision of +/- 0.3 mg/L.

Discharge
Discharge rate was measured with a Global Water Flow Probe when conditions were safe for wading in streams.

Turbidity and Total Suspended Solids
Grab samples were collected in 500 mL Nalgene bottles, stored on ice and transported to the Wastewater Laboratory at Humboldt State University. Water samples were refrigerated at 4^{o}C when processing could not be completed promptly. Turbidity measurements were taken within 48 hours of collection with a Hach 2100 P Turbidimeter, calibrated according to manufacturer's

specifications. Total suspended solids were measured within 7 days of collection following Standard Method 2540 D (APHA, 1998).

Data Analysis

Data was summarized using descriptive statistics, box-and-whisker plots, and ANOVA. Microsoft Excel was used to generate descriptive statistics including range, mean, and standard deviations of water-quality parameters. Box-and-whisker plots were created using Number Cruncher Statistical Software to graphically display the 25^{th} and 75^{th} percentiles, indicated by the upper and lower edges of the box, the median, designated by a line within the box, and the whiskers representing the 5^{th} and 95^{th} percentile. ANOVA in Microsoft Excel was used to determine if there was a significant difference between the seven sampling locations and the parameters measured. Statistical significance was determined using a 95 percent confidence level (alpha=0.05). It should be noted that a true comparison of the seven sampling sites is difficult due to vast differences amongst the sites. A true comparison could only be made if the sites were similar in terms of stream size, orientation, discharge rate, riparian canopy, and habitat.

Results and Discussion

Temperature

Monthly water temperatures varied throughout the lower Van Duzen River Basin during the time of sampling. While all sites had similar low temperatures, the Van Duzen River and Yager Creek had the highest water temperatures overall, see Figure l. Table 1 and Figure 2 indicate that Wolverton Gulch, Cummings Creek and Hely Creek had the lowest temperature fluctuations during the period of sampling with ranges of 10.4^{o}C, 10.7^{o}C and 8.5^{o}C, respectively. Yager Creek and the two sites on the Van Duzen River (RM 11 and RM 18) had the highest fluctuations in temperature with ranges of 17.5^{o}C, 16.2^{o}C and 17.5^{o}C, respectively. The lowest water temperature measured was 4.7 on January 28, 2007, at Grizzly Creek. The highest water temperature measured was 23.7 on July 15, 2007, at the Van Duzen River (RM 18).

Water temperature data collected daily from 6/7/07 to 9/21/07, determined that Hely Creek had the coolest daily average water temperatures and the Van Duzen River (RM 18) had the highest daily average water temperatures, see Figure 3. Maximum weekly average temperatures (MWAT) were calculated using a seven-day moving average of daily average temperatures. Water quality criteria developed by the Environmental Protection Agency recommends that the MWAT threshold should not exceed 18^{o}C (64.4^{o}F) during the summer months for coho salmon and 19^{o}C (66.2^{o}F) for steelhead/rainbow trout (EPA 1986). The Van Duzen River had MWAT's that exceeded the recommended 18^{o}C threshold for all 15 weeks of data collection and Yager Creek exceeded the MWAT threshold for 14 weeks. Grizzly Creek, Hely Creek, Cummings Creek, and Wolverton Gulch did not exceed the recommended MWAT threshold at any time during data collection, see Figure 4. The Van Duzen River (RM 18) had the highest MWAT at 22.8^{o}C, see Figure 5.

The high summer water temperatures recorded in Van Duzen River and Yager Creek are due to these streams having wide stream channels that cannot be effectively shaded by riparian canopy thereby increasing the amount of solar radiation. Other factors possibly influencing water temperatures are groundwater inputs, stream depth, and flow. Wolverton Gulch, Hely Creek, Cummings Creek, and Grizzly Creek have narrow stream channels with sufficient riparian

canopy covering the channel which minimizes solar radiation thus maintaining cooler water temperatures during the warm summer and early fall months. These tributaries to the Van Duzen River offer cold-water refuges for salmonid species and other aquatic organisms that require cooler water temperatures during the summer. High water temperatures occurring during the summer months in the Van Duzen River and Yager Creek can cause strenuous conditions for salmonid species. Efforts to maintain cool water in tributaries should be a priority in order to protect aquatic species in the lower Van Duzen River.

Comparison of the monthly and continuous water temperature data from the seven sampling sites verified that there was a significant difference in temperatures between the sites (*p*-value=0.005 and <0.001). Water temperatures in Yager Creek and the Van Duzen River were significantly different from temperatures in Wolverton Gulch, Cummings Creek, Hely Creek and Grizzly Creek. The significant difference in temperatures between the seven sampling locations was due to the high summer temperatures occurring in the Van Duzen River and Yager Creek.

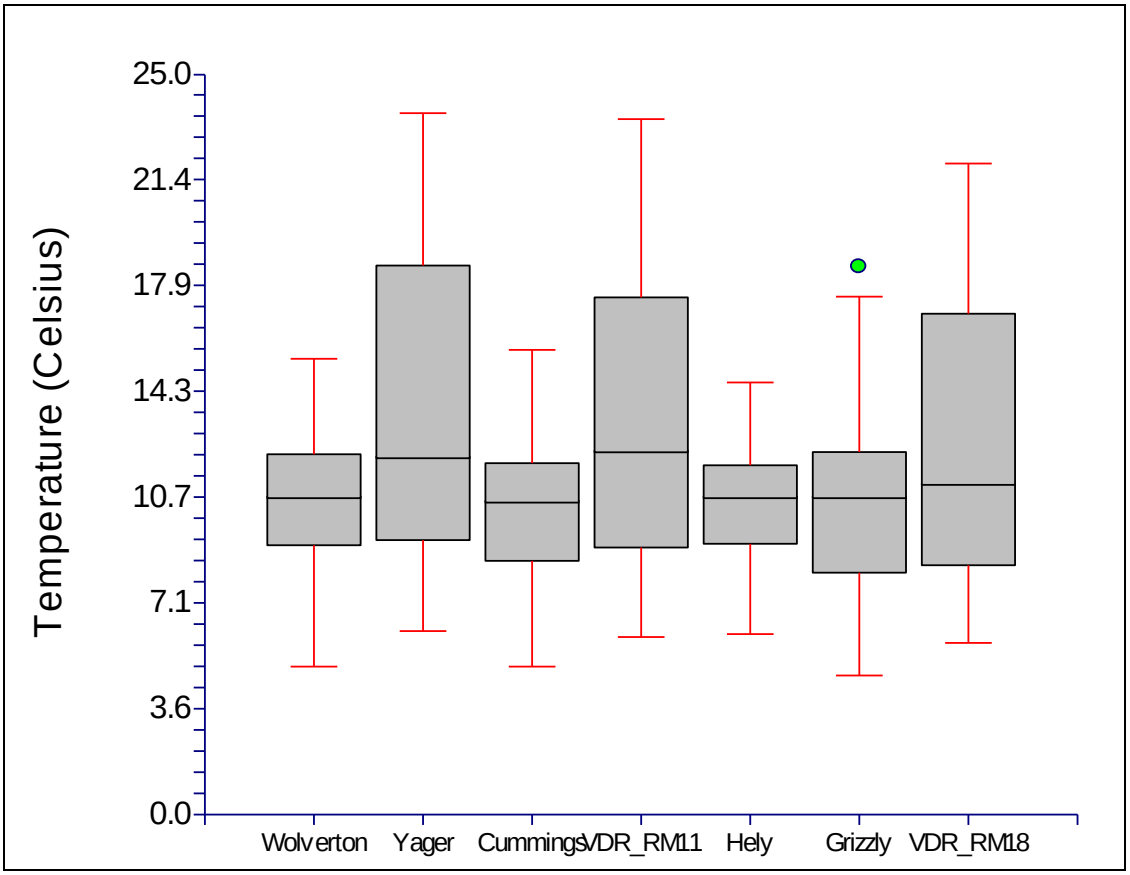

Figure 1. Box plot of monthly water temperature data collected in the lower Van Duzen River (VDR) Basin from October 2006 to April 2008. Boxes represent 50% of the data, the horizontal line is the median and vertical lines represent the 5th and 95th percentiles. Green dots correspond to mild outliers.

Table 1. Descriptive statistics for monthly water temperature data (^{o}C) collected in the lower Van Duzen River Basin during the time period of October 2006 to April 2008 (N=32).

Site	Minimum	Maximum	Range	Mean	St. Dev.
	Date	Date			
Van Duzen River at Weares (river mile 11)	6.0	23.5	17.5	13.2	5.38
	1/28/07	7/15/07			
Van Duzen River at Rainbow Br. (river mile 18)	5.8	22.0	16.2	12.5	5.09
	12/22/07	7/15/07			
Wolverton Gulch	5.0	15.4	10.4	10.9	2.45
	1/28/07	7/15/07			
Yager Creek	6.2	23.7	17.5	13.5	5.44
	1/28/07	7/15/07			
Cummings Creek	5.0	15.7	10.7	10.64	2.55
	1/28/07	7/15/07			
Hely Creek	6.1	14.6	8.5	10.65	2.2
	1/28/07	7/15/07			
Grizzly Creek	4.7	18.5	13.8	10.8	3.46
	1/28/07	8/10/07			

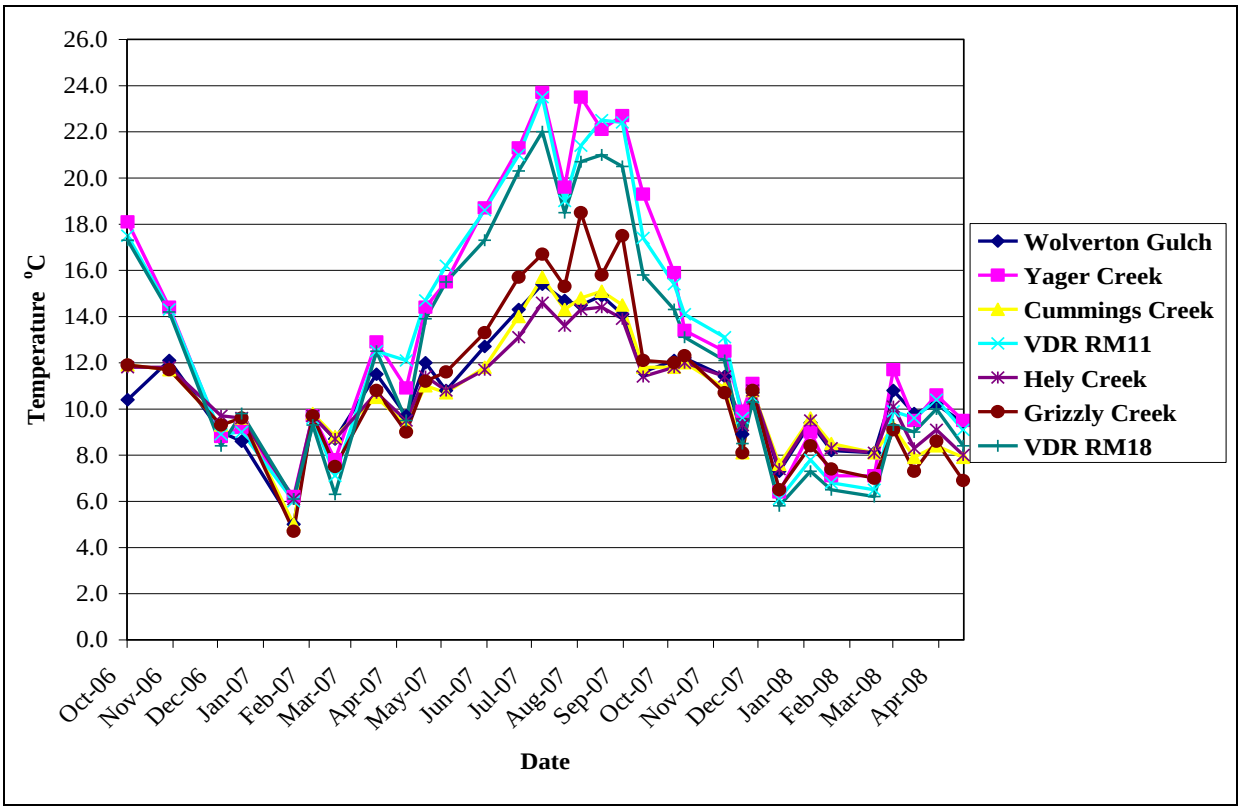

Figure 2. Monthly temperature results for the lower Van Duzen River (VDR) Basin for the time period of October 2006 to April 2008.

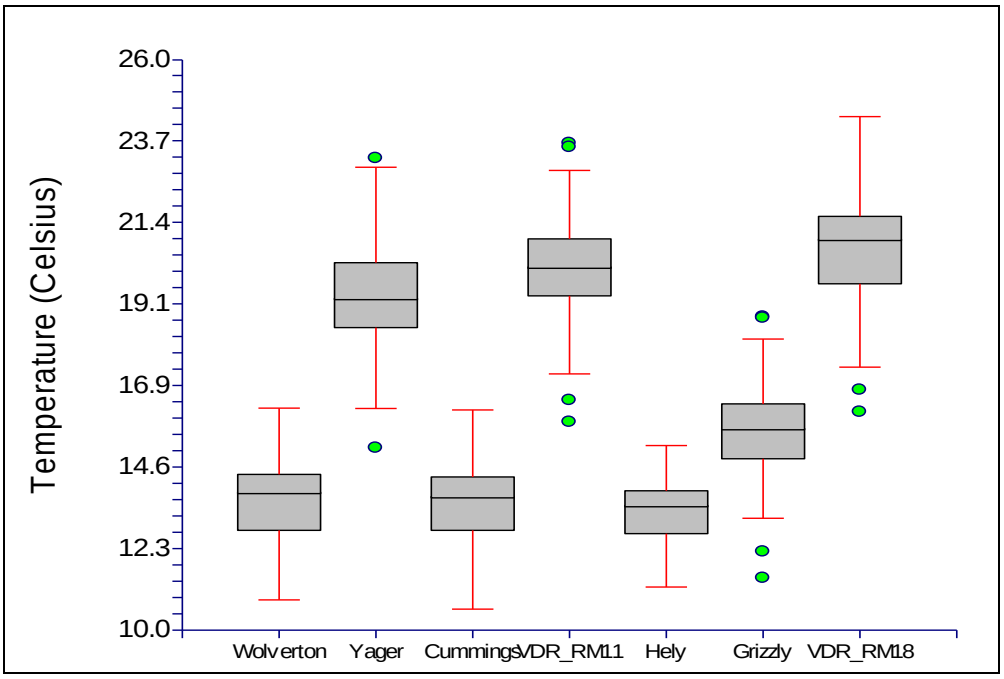

Figure 3. Box plot of daily average water temperature data collected in the lower Van Duzen River (VDR) Basin from 06/07/07 to 9/21/07. Boxes represent 50% of the data, the horizontal line is the median and vertical lines represent the 5th and 95th percentiles. Green dots correspond to mild outliers.

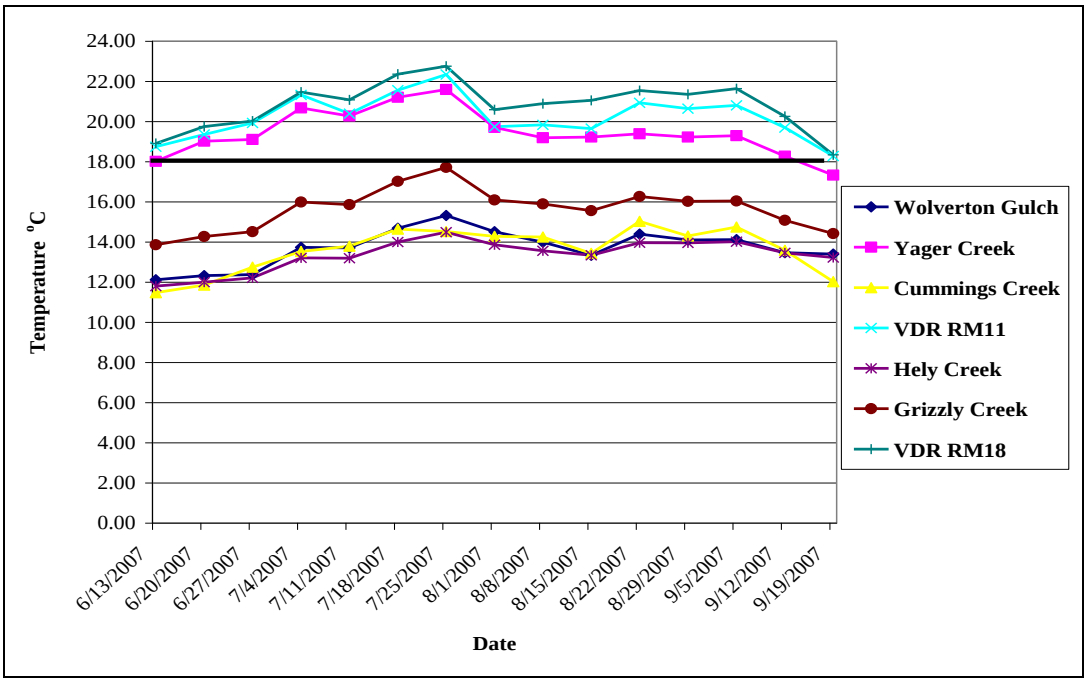

Figure 4. Maximum weekly average temperatures for the lower Van Duzen River (VDR) Basin during the period of 6/7/07 to 9/21/07. The thick, black line represents the MWAT threshold of 18°C for coho salmon.

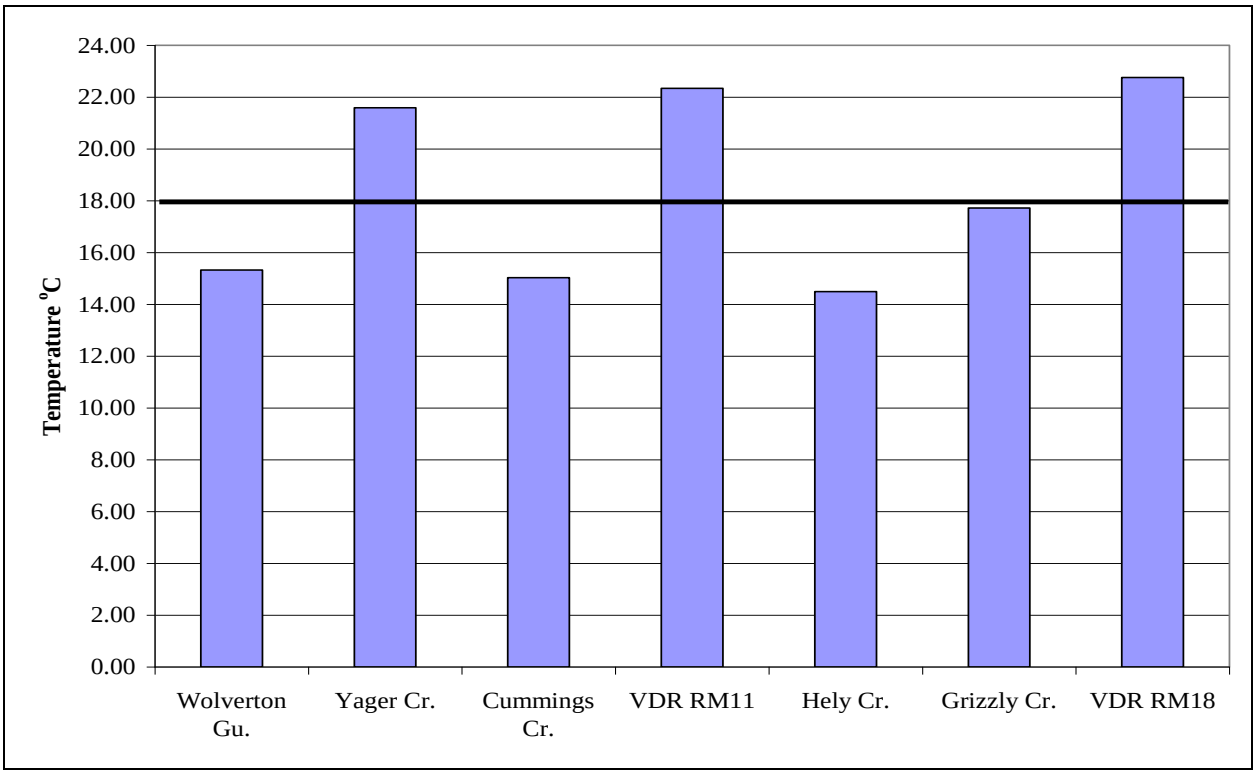

Figure 5. Highest maximum weekly average temperature (MWAT) for sampling sites in the lower Van Duzen River (VDR) Basin for the time period of 6/6/07 to 9/21/07 (15 weeks). The thick, black line indicates the MWAT threshold of 18°C for coho salmon.

Dissolved Oxygen Concentration

Dissolved oxygen concentrations ranged from a low of 8.23 milligrams O_2 per liter (mg/L) at the Van Duzen River (RM 18) site to a high of 13.23 mg O_2/L at the Van Duzen River (RM 18) site (Table 2). Fluctuations in dissolved oxygen throughout the sampling period were greatest at the Van Duzen River sites and Yager Creek, see Figure 6. Cummings Creek and Hely Creek had the least amount of fluctuation in dissolved oxygen concentration. Because water temperatures directly affect dissolved oxygen concentration, the warmer sites had the lowest dissolved oxygen measurements. The highest concentrations of dissolved oxygen occurred during the high-flows when colder water and more turbulent discharge allow for a greater amount of oxygen to enter the water column. Dissolved oxygen concentrations decrease during low-flows when warmer water temperatures hold less oxygen and lack of turbulent conditions results in a reduction of oxygen replenishment.

The North Coast Regional Water Quality Control Board (NCRWQCB) has determined that dissolved oxygen concentrations in the Van Duzen River Basin should be greater than 10.0 mg O_2/L for 50% of samples, and no samples should be less than 7.0 mg O_2/L (NCRWQCB 2007). Table 2 and Figure 6 show that there were no occurrences of dissolved oxygen concentrations that were less than 7.0 mg O_2/L at any of the sampling sites in the lower Van Duzen River Basin. Figure 7 shows that 50% of the dissolved oxygen data from each sampling site were above 10 mg O_2/L. All monitored locations in the Van Duzen River Basin met the NCRWQCB dissolved oxygen objectives for good water quality. Comparison of the dissolved oxygen data between the seven sampling locations found that there was no significant difference (*p*-value =0.78) and all sites had similar concentrations of dissolved oxygen (Figure 8).

Table 2. Dissolved oxygen concentrations (mg O_2/L) for sampling sites in the lower Van Duzen River Basin during the time period of October 2006 to April 2008 (N=32).

Site	Minimum Date	Maximum Date	Range	Mean	St. Dev.
Van Duzen River at Weares (river mile 11)	8.53 7/15/07	12.90 12/22/07	4.37	10.86	1.17
Van Duzen River at Rainbow Br. (river mile 18)	8.23 10/8/06	13.23 4/24/08	5.00	10.83	1.51
Wolverton Gulch	8.38 11/25/07	12.49 4/24/08	4.11	10.61	1.29
Yager Creek	8.52 7/15/07	12.84 12/22/07	4.32	10.77	1.24
Cummings Creek	9.53 9/21/07	12.75 1/28/07	3.22	11.02	1.04
Hely Creek	9.31 8/10/07	12.62 4/24/07	3.3	10.87	0.99
Grizzly Creek	9.02 10/8/06	13.21 4/24/08	4.10	11.09	1.20

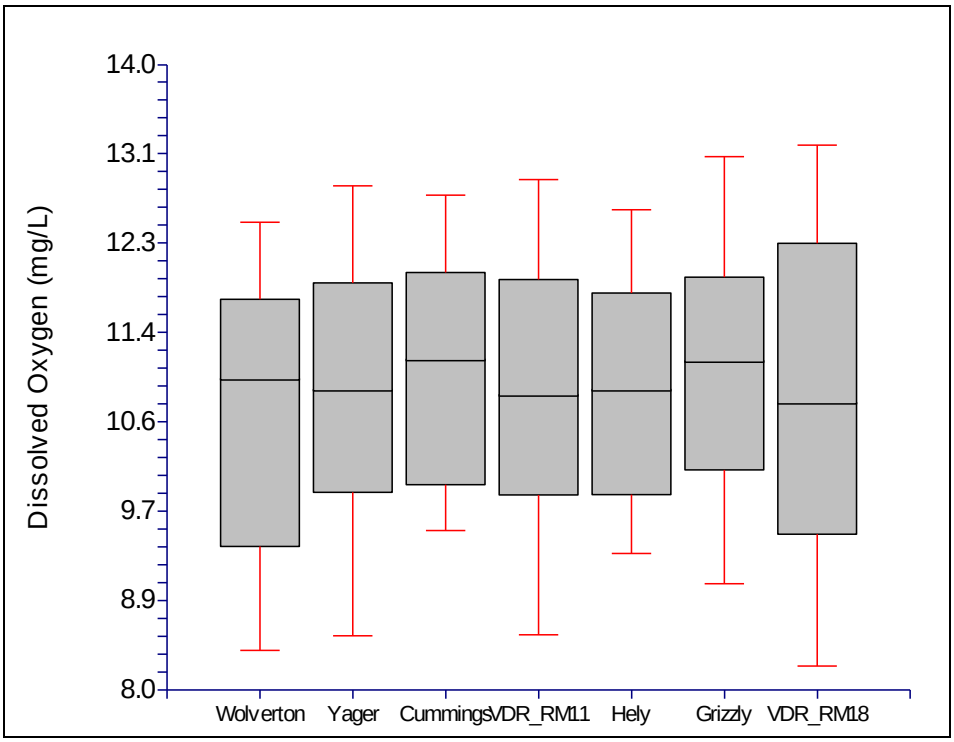

Figure 6. Box plot of dissolved oxygen data (mg O_2/L) collected in the lower Van Duzen River (VDR) Basin from October 2006 to April 2008. Boxes represent 50% of the data, the horizontal line is the median and vertical lines represent the 5th and 95th percentiles. Green dots correspond to mild outliers.

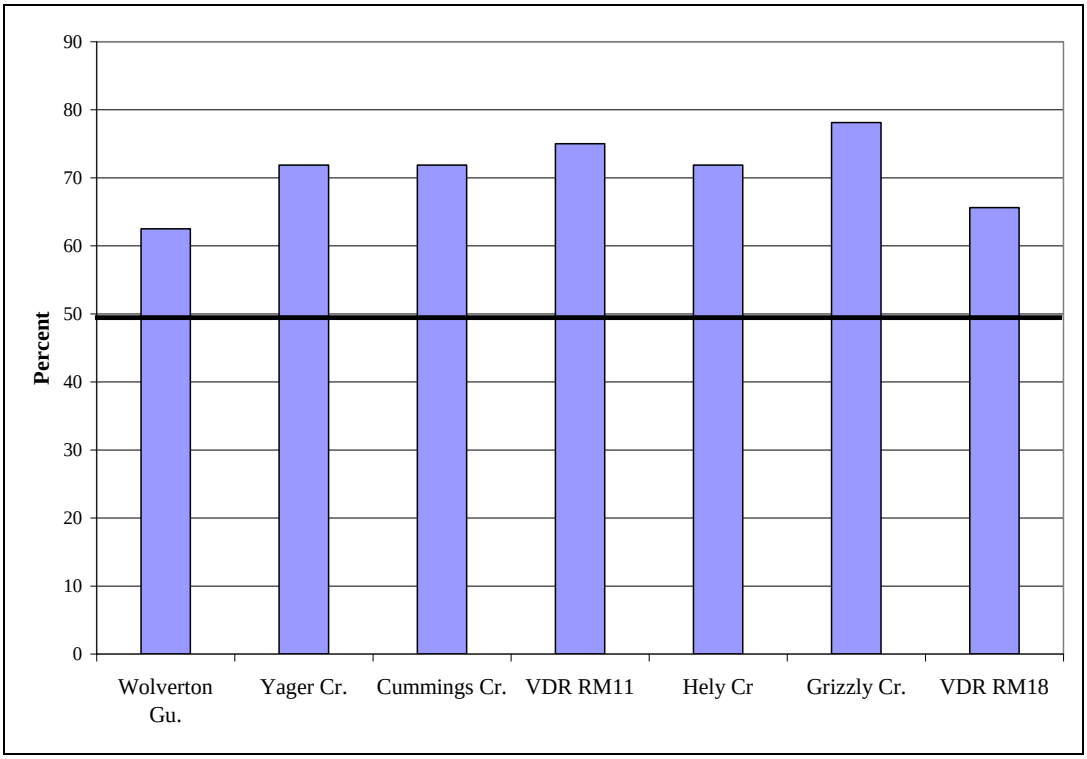

Figure 7. Percent of dissolved oxygen concentrations in the lower Van Duzen River (VDR) Basin above 10 mg O_2/L. The thick, black line at 50% signifies the water quality objective for samples above 10 mg O_2/L.

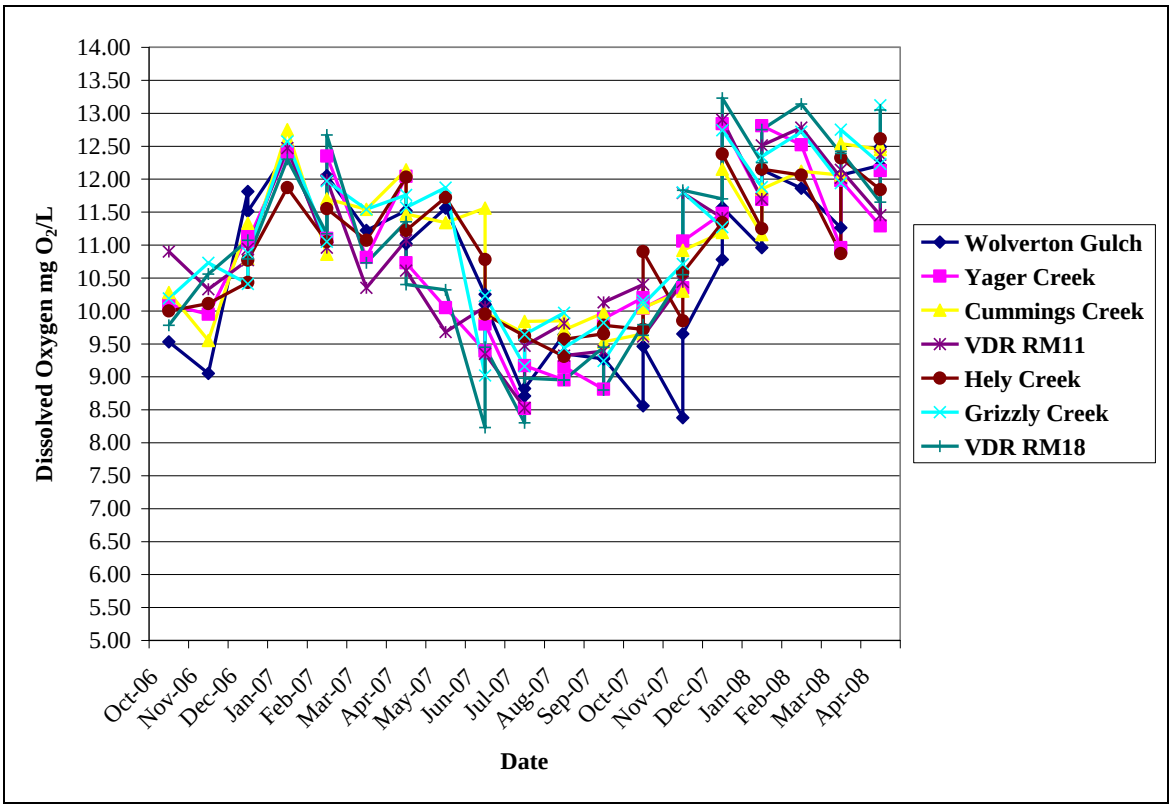

Figure 8. Dissolved oxygen concentrations (mg O_2/L) in the lower Van Duzen River (VDR) Basin during the time period of October 2006 to April 2008.

pH

The pH of water is a measure of its hydrogen-ion activity. The pH of rivers and streams typically ranges from 6.5 to 8.0 standard units (Hem 1985). The pH values in the lower Van Duzen River Basin ranged from a low of 6.0 at Yager Creek to a high of 8.4 at the Van Duzen River (RM 11). The NCRWQCB water quality objective for pH is a range of 6.5 to 8.5 for the Van Duzen River Basin. There were no occurrences of pH values greater than 8.5 at any of the seven sampling locations (Figure 9). However, most sites, with the exception of Cummings Creek, had at least one pH value of less than 6.5 (Table 3 and Figure10). The low pH values occurred following significant storm events which produced increased discharge that diluted the concentration of base minerals causing a lower pH. The highest pH values occurred during the summer and fall months when discharge rates are low and there is a greater concentration of base minerals resulting in increased pH values (MacDonald et al. 1991).

Overall the pH values for all the sites were within the range of 6.0-8.5 that salmonid species and most aquatic organisms require for survival. Comparison of pH values between the seven sampling locations indicated that all sites had similar ranges of pH values and were not significantly different (*p*-value=0.57).

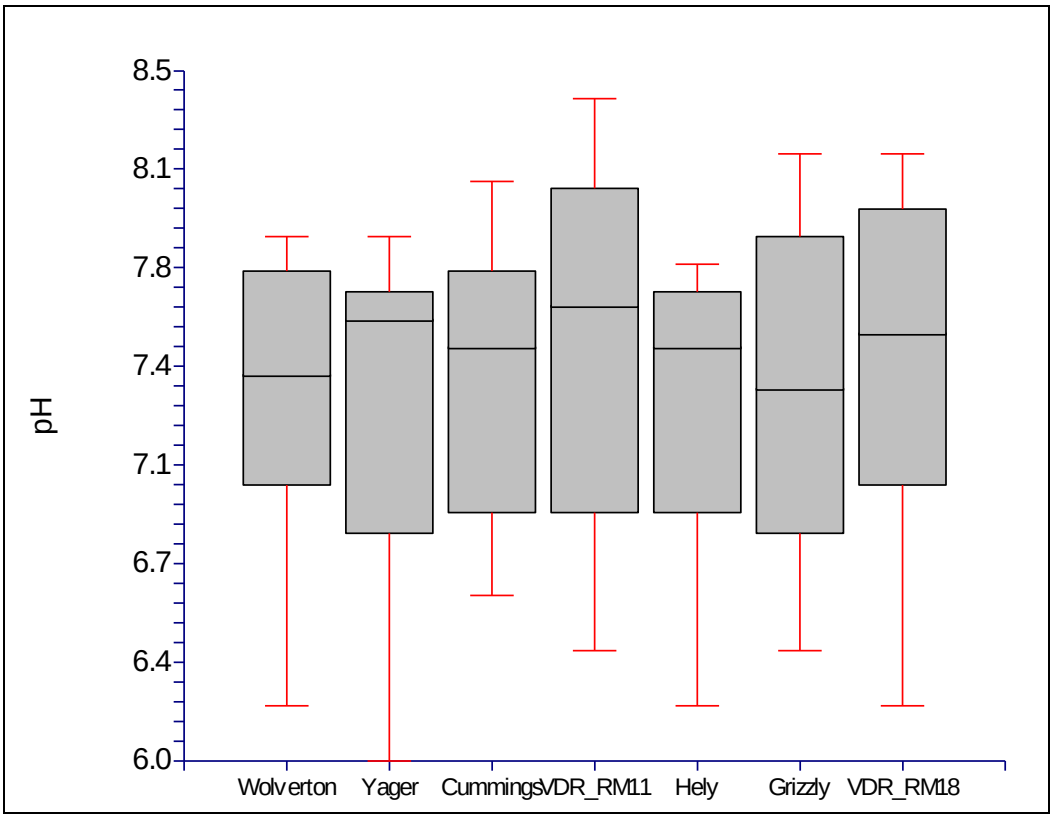

Figure 9. Box plot of pH data collected in the lower Van Duzen River (VDR) Basin from October 2006 to April 2008. Boxes represent 50% of the data, the horizontal line is the median and vertical lines represent the 5th and 95th percentiles.

Table 3. Descriptive statistics for pH values from sampling sites in the lower Van Duzen River Basin for the time period of October 2006 to April 2008 (N=32).

Site	Minimum Date	Maximum Date	Range	Mean	St. Dev
Van Duzen River at Weares (river mile 11)	6.4 12/10/2006	8.4 8/10/07	2.0	7.5	0.62
Van Duzen River at Rainbow Br. (river mile 18)	6.2 12/10/06	8.2 10/12/07	2.0	7.5	0.57
Wolverton Gulch	6.2 2/10/07	7.9 7/30/07	1.7	7.3	0.46
Yager Creek	6.0 2/10/07	7.9 8/10/07	1.9	7.3	0.52
Cummings Creek	6.6 2/10/07	8.1 7/30/07	1.5	7.4	0.46
Hely Creek	6.2 11/15/07	7.8 11/15/07	1.6	7.3	0.48
Grizzly Creek	6.4 12/10/07	8.2 8/10/07	1.8	7.3	0.55

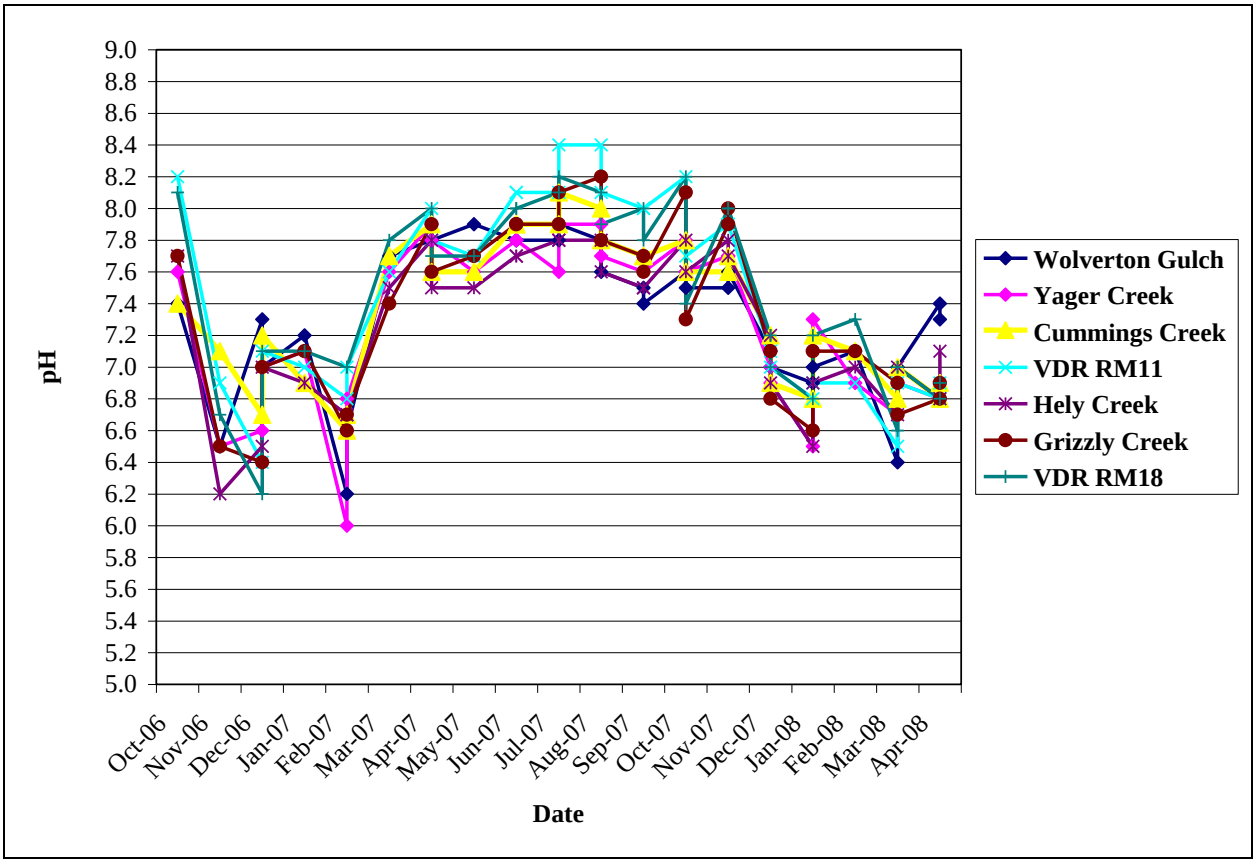

Figure 10. pH values in the lower Van Duzen River (VDR) Basin from October 2006 to April 2008.

Conductivity

Conductivity is a measure of the ability of water to conduct an electrical current and is an indication of the number of dissolved ions in the water. As the concentration of ions decreases or increases, so does the electrical conductance of water. The water quality objectives for conductivity in the Van Duzen River are as follows: 50% of recorded values should not exceed 175 microsiemens per centimeter (µS/cm) and 90% of values should not exceed 375 µS/cm (NCRWQCB 2007). Most sites, with the exception of Wolverton Gulch and Hely Creek, had 50% of values less than 175 µS/cm. Conductivity levels in Wolverton Gulch and Hely Creek exceeded 175 µS/cm for 90% and 43% of samples, respectively. The high conductivity readings in Wolverton Gulch and Hely Creek could be due to the geology of these watersheds, contributing to the leachates dissolved in the water column, and are not necessarily an indication of poor water quality. Conductivity levels at all sites were highest during low-flows and lowest during high-flows, see Table 4 and Figure 11. Low summer/fall baseflows typically have a higher concentration of ions and therefore a higher electrical conductance. High winter/spring flows have a lower concentration of dissolved ions and a corresponding low electrical conductance (MacDonald et al. 1991). None of the monitoring sites had conductivity levels greater than 375 µS/cm.

A comparison of conductivity data from the seven sampling sites determined that there was a significant difference between sites (*p*-value <0.001). The variance was due to the conductivity in Wolverton Gulch which was distinctly different than the other sampling locations, see Figure 11 and Figure 12.

Table 4. Descriptive statistics for conductivity values (µS/cm) for the lower Van Duzen River Basin for the time period of December 2006 to April 2008 (N=30).

Site	Minimum	Maximum	Range	Mean	St. Dev.
	Date	Date			
Van Duzen River at Weares (RM 11)	86.1	280.1	194	157.7	72.2
	12/4/07	9/21/07			
Van Duzen River at Rainbow Bridge (RM 18)	72.8	238.8	166	141.7	58.7
	2/25/07	8/24/07			
Wolverton Gulch	112.2	364.9	252.7	269.6	64.1
	2/24/07	11/15/07			
Yager Creek	57.6	263.8	206.2	145.6	71.3
	2/24/07	8/10/07			
Cummings Creek	74.8	283.4	208.6	151.3	63.4
	12/10/06	4/24/08			
Hely Creek	84.8	296.0	211.2	191.9	65.9
	2/25/07	9/21/07			
Grizzly Creek	64.3	278.0	213.7	150.1	74.1
	2/25/07	9/7/07			

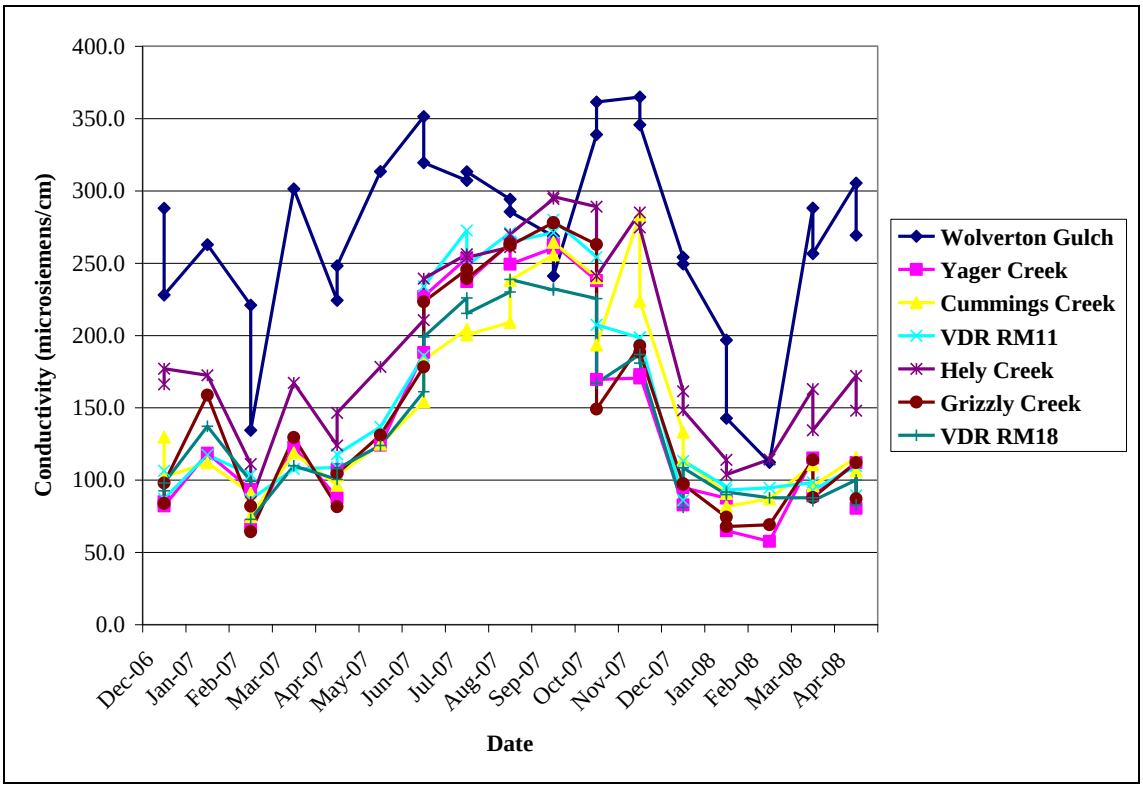

Figure 11. Conductivity results for the lower Van Duzen River (VDR) Basin during the time period of October 2006 to April 2008.

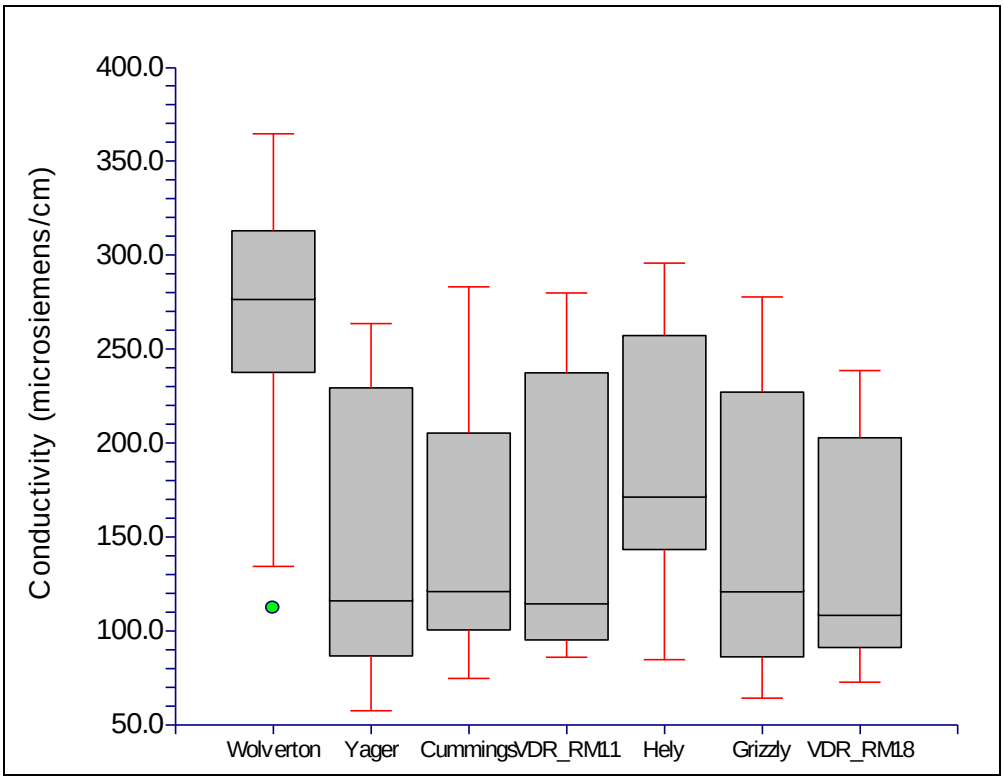

Figure 12. Box plot of conductivity data collected in the lower Van Duzen River (VDR) Basin from October 2006 to April 2008. Boxes represent 50% of the data, the horizontal line is the median and vertical lines represent the 5th and 95th percentiles. Green dots correspond to mild outliers.

Turbidity and Total Suspended Solids

In the lower Van Duzen River Basin turbidity values ranged from 1 NTU at all sites to a high of 600 NTU at the Van Duzen River sites (Table 5). Turbidity levels were high following winter storm events but levels decreased to less than 30 NTU between storm events. Furthermore, turbidity levels were less than 10 NTU during the dry summer and fall months. Wolverton Gulch had the highest turbidity values overall and Cummings Creek had the lowest turbidity values (Figure 13). The NCRWQCB has determined that turbidity in the Van Duzen River should not exceed 20% of background levels. However, natural background levels have not been established for the Van Duzen River and therefore it is not possible to determine if levels exceeded 20% of background levels. The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment for California State Water Resources Control Board expects turbidity levels to be between 20-1000 NTU for creeks and rivers in California (CWT 2004).

Levels of total suspended solids (TSS) in the lower Van Duzen River Basin ranged from <5 mg/L at all sites to a high of 948 mg/L at the Van Duzen River (RM 11) (Table 6). Yager Creek and the Van Duzen River at RM 18 had the highest level of TSS. Cummings Creek had the lowest levels of TSS (Figure 14). No water quality objectives were provided by the NCRWQCB for TSS in the Van Duzen River. Research has shown that levels greater than 400 mg TSS/L can be deleterious to salmonid species when they are exposed to these levels for an extended period of time (Caux et al. 1997). All sampling sites had TSS results that were greater than 400 mg/L. High levels of TSS occurred following large storm events. It is not possible to determine from the data the amount of time that TSS levels exceeded 400 mg/L. Future studies in the lower Van Duzen River Basin should evaluate the number of hours that suspended sediment levels exceed 400 mg/L and determine if high levels of sediment are affecting salmonids and other aquatic organisms.

Table 5. Turbidity in the lower Van Duzen River Basin from December 2006 to April 2008 (N=18).

Date	Wolverton Gulch	Yager Creek	Cummings Creek	Van Duzen R. (RM 11)	Hely Creek	Grizzly Creek	Van Duzen R. (RM 18)
12/10/2006	397	345	148	252	130	138	184
12/24/2006	14	14	10	30	13	18	29
1/28/2007	5	2	2	1	5	2	2
2/10/2007	403	308	284	254	440	403	314
2/25/2007	416	427	227	386	241	198	274
3/25/2007	7	7	7	7	8	5	6
4/14/2007	262	52	41	20	90	101	77
4/27/2007	12	9	9	8	13	9	7
5/11/2007	9	3	4	3	7	4	3
6/29/2007	2	1	1	1	2	1	1
8/24/2007	10	2	1	3	3	1	2
10/19/2007	291	166	29	22	82	300	104
11/15/2007	3	5	4	10	2	2	5
12/22/2007	16	31	21	37	23	32	29
1/12/2008	40	105	39	144	56	119	181
1/26/2008	500	600	209	600	290	416	600

Table 5. continued

Date	Wolverton Gulch	Yager Creek	Cummings Creek	Van Duzen R. (RM 11)	Hely Creek	Grizzly Creek	Van Duzen R. (RM 18)
3/8/2008	13	11	10	8	11	9	8
4/24/2008	23	29	15	46	19	34	42

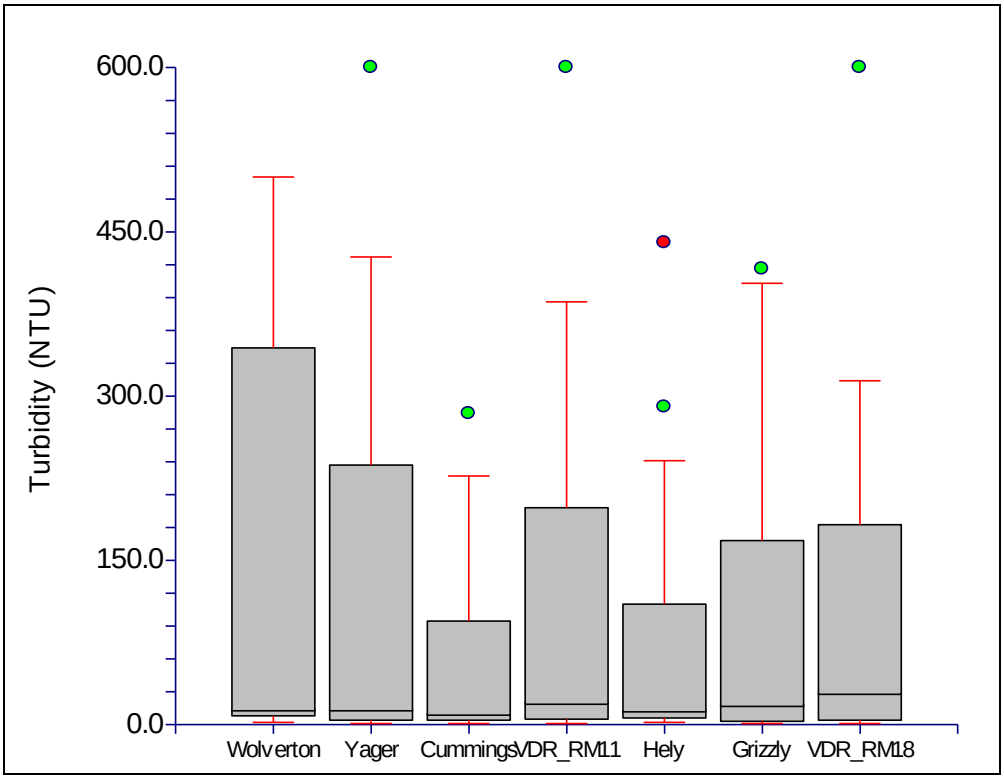

Figure 13. Box plot of turbidity values measured in the lower Van Duzen River (VDR) Basin from December 2006 to March 2008. Boxes represent 50% of the data, the horizontal line is the median and vertical lines represent the 5th and 95th percentiles. Green dots correspond to mild outliers and red dots are extreme outliers.

Table 6. Total suspended solids (mg/L) for the lower Van Duzen River Basin measured during storm events from November 2006 to April 2008 (N=13).

Date	Wolverton Gulch	Yager Creek	Cummings Creek	Van Duzen R. (RM 11)	Hely Creek	Grizzly Creek	Van Duzen R. (RM 18)
11/5/2006	50	50	<5	50	<5	<5	50
12/10/2006	600	700	100	300	100	100	200
12/24/2006	<5	<5	<5	40	<5	<5	40
2/10/2007	750	700	572	300	900	550	600
2/25/2007	500	346	250	440	300	200	320
4/14/2007	200	36	18	18	80	276	145
5/11/2007	80	40	40	38	38	55	36
10/19/2007	175	234	24	19	90	290	84
1/12/2008	52	92	29	157	46	84	146

Table 6. continued

Date	Wolverton Gulch	Yager Creek	Cummings Creek	Van Duzen R. (RM 11)	Hely Creek	Grizzly Creek	Van Duzen R. (RM 18)
2/24/2008	476	708	207	537	394	731	799
3/22/2008	14	14	18	21	15	15	30
4/24/2008	17	30	13	48	15	26	37

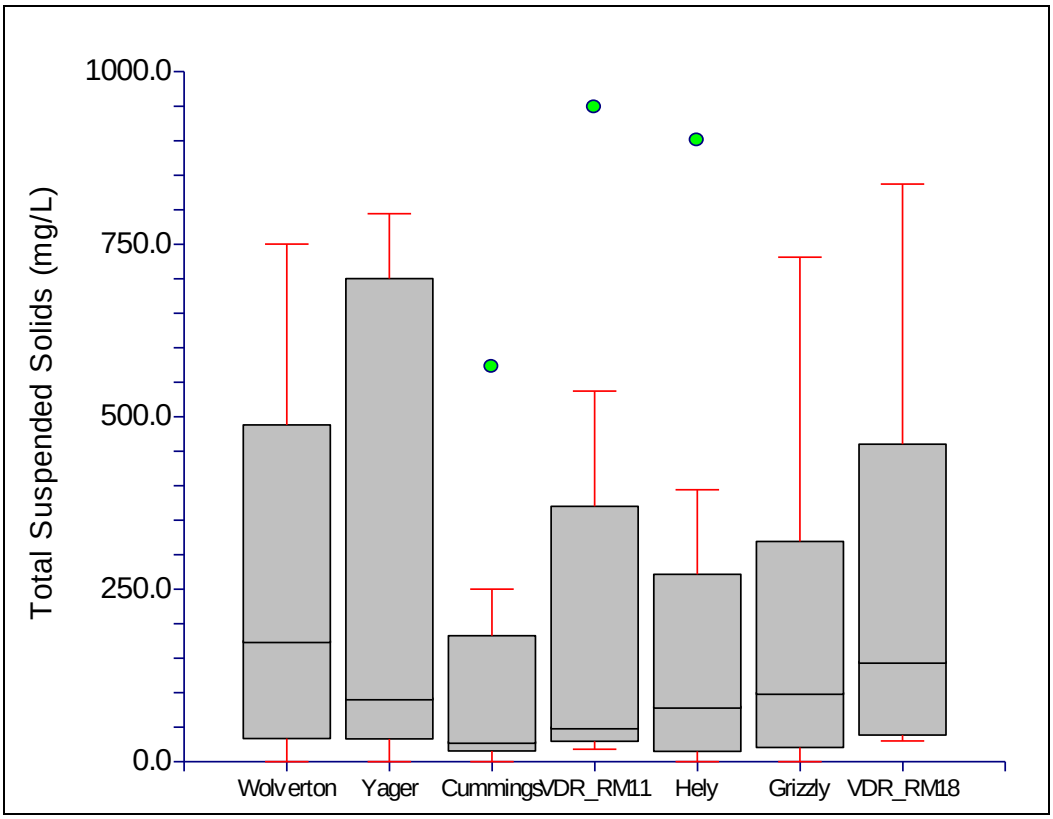

Figure 14. Box plot of total suspended solids (mg/L) collected in the lower Van Duzen River (VDR) Basin during the time period of November 2006 to April 2008. Boxes represent 50% of the data and the horizontal line is the median. The vertical lines represent the 5th and 95th percentiles and green dots correspond to mild outliers.

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