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by William M. Lewis, Jr.

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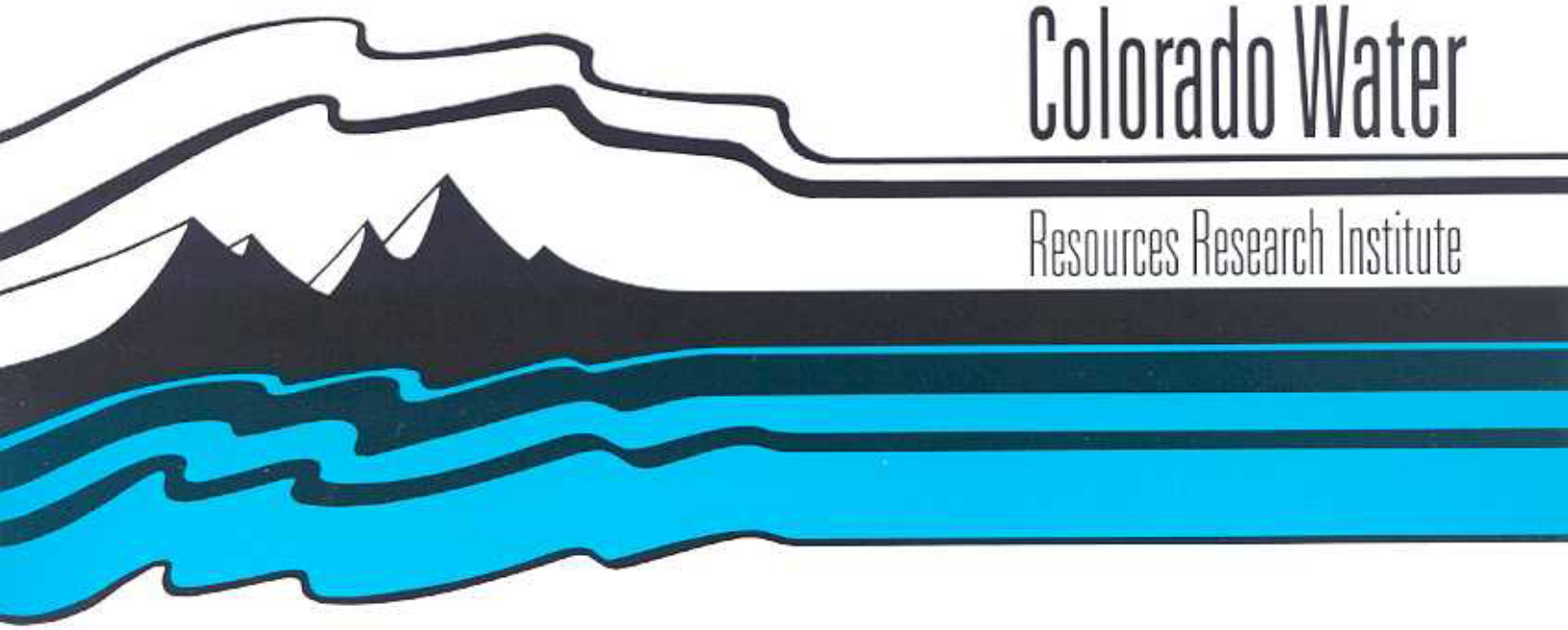
Completion Report 201



Colorado State University

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Completion Report No. 201

Colorado Water Resources Research Institute
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Robert C. Ward, Director

Introduction

The purpose of this project was to collect field data on streams in the foothills and montane parts of Colorado in support of the State of Colorado's attempt to develop nutrient criteria in preparation for producing nutrient standards for Colorado waters. The state has identified high elevations as the highest priority, which explains the focus on streams of the mountains and foothills. The study was instituted to provide sufficient data on nutrients and potential ecological indicators of nutrient enrichment to establish thresholds of ecological change associated with nutrient enrichment. On this basis, thresholds for enrichments relevant to Colorado waters could be established for the state.

Methods

Nutrients of interest for this study include nitrogen and phosphorus, which are considered by the USEPA, the State of Colorado, and the research community to be the factors most likely to limit potential growth of autotrophs (algae and aquatic vascular plants) in aquatic ecosystems. Total phosphorus was analyzed, as were phosphorus fractions (soluble reactive phosphorus, total soluble phosphorus, particulate phosphorus). Dissolved inorganic nitrogen (nitrate, ammonia) was analyzed, but total nitrogen, which is considered to contain large amounts of unavailable forms of nitrogen, was not analyzed.

Response variables for the current study included biomass of attached algae (periphyton) measured as chlorophyll *a* per unit area, which is a conventional method for evaluating biomass of algae on illuminated surfaces. In addition, community composition of attached algae was considered a potential response variable, as was

composition of the benthic fauna (bottom fauna) living in the streams. The present report deals only with the chlorophyll data because the counting and identification of organisms necessary for the community composition studies of periphyton and benthos are still in progress. Response variables were sampled once (in fall).

Collections of all organisms at each site were made by standard methods, which involve taking multiple samples over the stream cross-section in order to compensate for spatial irregularities in the distribution of organisms. Sites were chosen so as to represent a range of elevations, and also to be located where an historical record was available for nutrient concentrations. Thus, the study did not rely entirely on nutrient samples taken at the time of sampling, but rather on a longer-term record that reflects more accurately the nutrient history of growth of the organisms at a particular site.

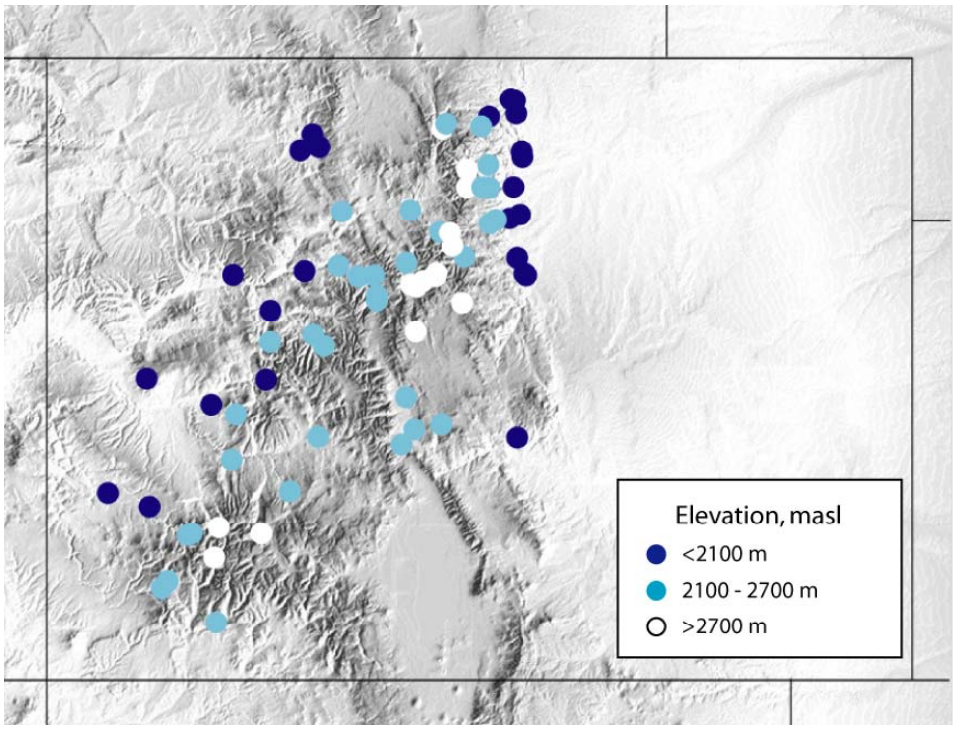

Figure 1. Map of sites sampled for this project.

Approximately 75 sites were sampled at locations for which multi-year records were available for concentrations of total phosphorus (Figure 1). Most of these sites lacked adequate information on phosphorus fractions and on nitrogen fractions. Therefore, a subset of the sites, totaling approximately 20, were analyzed with respect to these nutrient fractions.

Results

It was suspected at the beginning of the study that growth of attached algae would depend in part on elevation. The sites were grouped for convenience into three elevation categories: high (greater than 2700 m), low (less than 2100 m), and intermediate (2100-2700 m).

Figure 2 shows the relationship between total phosphorus and chlorophyll *a* at the time of the fall sampling. It is clear that sites from any elevation and for any annual mean phosphorus concentration can produce a high chlorophyll in fall. Sites with higher total P, however, show consistently high chlorophyll. Therefore, the main distinction between the sites is the range in chlorophyll concentrations that can be expected in fall: enriched sites (greater than 25 μg/L total P) have consistently high chlorophyll, whereas unenriched sites or minimally enriched sites (below 25 μg/L) shown a range of chlorophyll concentrations, including some very low amounts and some high amounts.

Figure 3 shows the relationship between chlorophyll *a* in the fall and the nitrogen and phosphorus fractions. The general pattern is very similar to the pattern for total P. Basically, total P and the nutrient fractions give redundant information with respect to the

response of biomass as represented by fall sampling. Therefore, total P can be used as the key nutrient indicator.

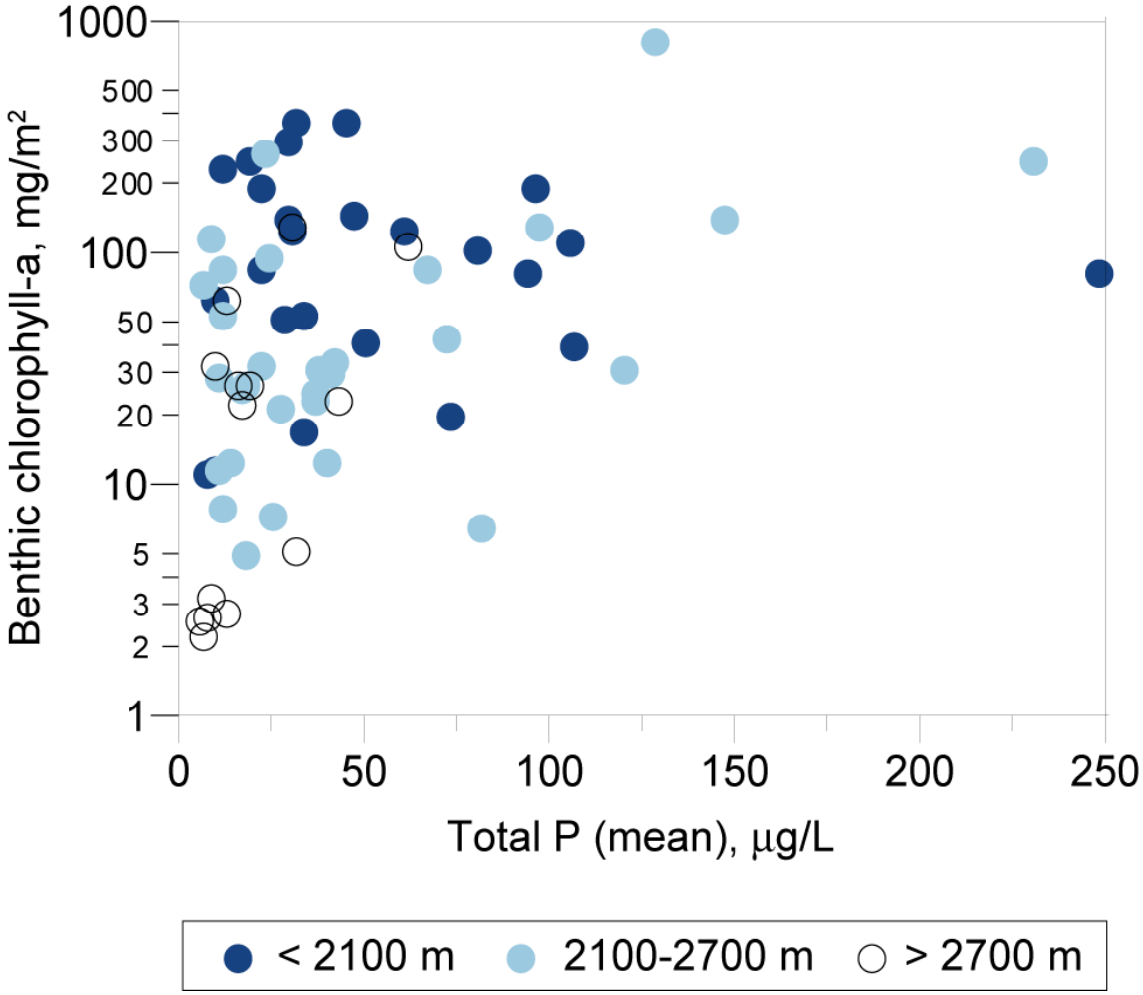

Figure 2. Benthic (periphyton) chlorophyll *a* in relation to mean total P for all dates. Open circles = high sites, Dark circles = low site, intermediate circles = intermediate sites.

Interpretation and Application of Results

The information on total phosphorus and chlorophyll suggest a threshold at about 25 µg/L total P separating a wide range of chlorophyll concentrations (below the

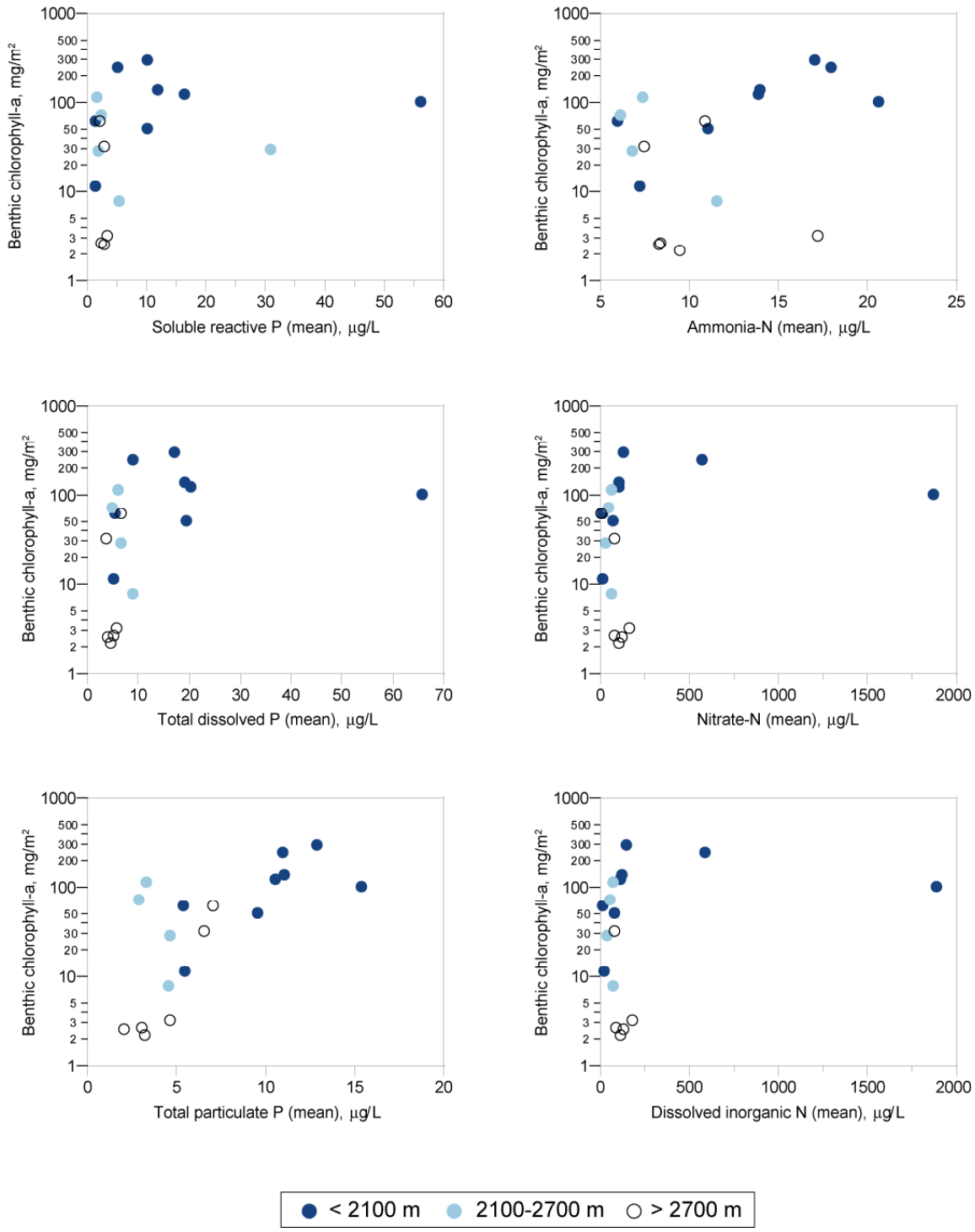

Figure 3. Benthic (periphyton) chlorophyll *a* in a relation to mean concentration of nutrients. Site coding same as for Figure 2.

threshold) from consistently very high concentrations above the threshold. This threshold could be used as the basis for nutrient criteria in Colorado. In terms of SRP (the soluble inorganic portion of phosphorus) the threshold falls at about 15 mg/L.

Additional sampling is underway through EPA support that will build on the observations made in this study. In addition, the studies of community composition may show that the threshold is verified or superseded by thresholds represented through community composition.

Appendix I: Data Record

Site name	Total P, ug/L	Soluble reactive P, ug/L	Total dissolved P, ug/L	Total particulate P, ug/L	Ammonia-N, ug/L	Nitrate-N, ug/L	Dissolved inorganic N, ug/L	Benthic chlorophyll-a (average), mg/m2	Benthic chlorophyll-a (rep-1), mg/m2	Benthic chlorophyll-a (rep-2), mg/m2
Anthracite Creek above Erickson Springs CG	45.91	.	.	.	.	.	.	360.2	341.0	379.4
BOULDER CK @ EBEN FINE PARK	23.33	.	.	.	.	.	.	188.4	187.2	189.7
BOULDER CK DOWNSTREAM HYDROELECTRIC PLANT (@ ORODELL GAGE)	23.33	.	.	.	.	.	.	82.7	83.3	82.0
BOULDER CREEK UPSTREAM BOULDER WWTP @ 61ST	33.33	.	.	.	.	.	.	361.5	382.0	341.0
Bear Creek at Bear Creek Reservoir	81.52	56.48	66.05	15.46	20.70	1877.0	1897.7	103.8	125.6	82.0
Big Thompson in Loveland	30.35	10.32	17.30	12.93	17.14	139.1	156.2	293.6	292.3	294.8
Buckhorn Creek	.	.	.	.	.	.	.	59.0	.	59.0
CLEAR CREEK ABOVE GOLDEN	51.93	.	.	.	.	.	.	40.2	40.2	.
CRYSTAL RIVER NEAR MOUTH	48.57	.	.	.	.	.	.	142.3	156.4	128.2
EAGLE RIVER AT GYPSUM	97.80	.	.	.	.	.	.	188.4	187.2	189.7
EAST ELK CREEK NORTH OF NEWCASTLE @ GRAY EAGLE RANCH	13.18	.	.	.	.	.	.	232.0	246.1	217.9
FOURMILE CREEK AT GARDEN PARK	108.33	.	.	.	.	.	.	38.5	38.5	38.5
KANNAH CR. ABOVE DOW FISHING AREA	107.14	.	.	.	.	.	.	111.5	120.5	102.6
MAD CR. @ CHRISTINA SWA	8.63	.	.	.	.	.	.	10.9	11.5	10.3
MUDDY CR.	249.00	.	.	.	.	.	.	82.0	84.6	79.5
NATURITA CREEK AT NATURITA	74.62	.	.	.	.	.	.	19.9	19.9	.
North Fk Poudre at Livermore	29.33	10.49	19.68	9.65	11.17	78.8	91.0	51.9	47.4	56.4
Pine Creek at mouth	30.55	12.06	19.39	11.16	14.00	113.8	128.4	138.4	171.8	105.1
Poudre abv North Fork	11.34	1.65	5.80	5.47	6.03	17.3	23.0	62.8	60.2	65.4
Poudre abv South Fork	10.95	1.61	5.43	5.52	7.29	22.5	29.8	11.5	12.8	10.3
SAN MIGUEL NEAR NORWOOD	35.00	.	.	.	.	.	.	16.5	16.5	.
SMITH FK BLW CRAWFORD	34.42	.	.	.	.	.	.	53.8	53.8	53.8
St Vrain Creek belowt Lyons at gage	31.89	16.73	20.42	10.63	13.97	110.8	123.8	123.1	133.3	112.8
TROUT CR. NR. MOUTH	95.83	.	.	.	.	.	.	82.0	76.9	87.2
Turkey Creek at Bear Creek Res	20.21	5.43	9.21	11.00	18.07	576.0	594.0	242.3	246.1	238.4
YAMPA R. @ 5TH ST. BRIDGE IN STEAMBOAT	62.31	.	.	.	.	.	.	125.6	115.4	135.9
ARKANSAS R. above Buena Vista	19.13	.	.	.	.	.	.	26.9	24.4	29.5
ARKANSAS R. at Salida	23.00	.	.	.	.	.	.	32.0	30.8	33.3
BEAVER CR. @ AVON	26.00	.	.	.	.	.	.	93.6	82.0	105.1
BIG THOMPSON RIVER BELOW ESTES PARK	130.00	.	.	.	.	.	.	807.6	1102.4	512.8
BOULDER CK BELOW BARKER DAM @ MILE MARKER 29	98.33	.	.	.	.	.	.	126.9	148.7	105.1
BRUSH CR @ MOUTH NR. SNOWMASS	232.14	.	.	.	.	.	.	247.4	133.3	361.5
Boulder Creek below Boulder Falls	.	.	.	.	.	.	.	255.1	294.8	215.4
CEBOLLA CR. @ USGS GAGE	121.67	.	.	.	.	.	.	31.4	26.9	35.9
CIMARRON RIVER BLW. LITTLE CIMARRON	148.18	.	.	.	.	.	.	140.5	136.7	144.3
COLORADO RIVER NEAR HOT SULFUR SPRINGS	68.46	.	.	.	.	.	.	83.3	74.4	92.3
CRYSTAL RIVER NR. MARBLE	13.00	.	.	.	.	.	.	84.6	107.7	61.5
DOLORES R. BLW RICO	19.35	.	.	.	.	.	.	4.9	4.7	5.1

EAGLE R. @ REDCLIFF	12.92	.	.	.	.	.	.	53.8	48.7	59.0
EAGLE R. ABOVE GORE CR.	28.93	.	.	.	.	.	.	21.2	21.8	20.5
East River at Almont	.	.	.	.	.	.	.	67.9	66.7	69.2
FLORIDA RIVER BELOW LEMON RESERVOIR	73.08	.	.	.	.	.	.	42.7	42.7	.
GOLD CR. ABOVE OHIO	15.00	.	.	.	.	.	.	12.2	14.1	10.3
GORE CR. AB. WWTF	24.46	.	.	.	.	.	.	262.8	262.8	262.8
HOMESTAKE CR. @ GAGE	12.14	.	.	.	.	.	.	11.5	10.3	12.8
N St Vrain above Buttonrock Res	13.39	5.70	9.06	4.60	11.62	69.2	81.0	7.9	.	.
North Fork St Vrain at RMHRC lab	8.05	2.71	5.12	2.92	6.20	54.3	60.5	73.1	73.1	.
Poudre abv Joe Wright	9.74	1.84	6.37	3.37	7.49	75.0	82.4	113.4	107.7	119.2
ROARING FORK RIVER ABV. ASPEN	39.18	.	.	.	.	.	.	30.8	28.2	33.3
ROARING FORKS CREEK	.	.	.	.	.	.	.	6.8	9.0	4.7
ROCK CR. @ SWA NR. TOPONAS	42.50	31.19	.	.	.	.	.	29.5	25.6	33.3
ROCK CR. NR SILVERTHORNE	18.06	.	.	.	.	.	.	25.6	28.2	23.1
SAN MIGUEL RIVER AT SOCIETY TURN	40.74	.	.	.	.	.	.	12.4	12.0	12.8
SMITH FORK ABOVE SMITH FK C.G.	43.50	.	.	.	.	.	.	33.3	35.9	30.8
SOUTH ARKANSAS RIVER NEAR MAYSVILLE	37.73	.	.	.	.	.	.	23.1	23.1	23.1
SOUTH FORK SAN MIGUEL RIVER NEAR MOUTH	26.25	.	.	.	.	.	.	7.3	6.0	8.5
ST. LOUIS CR. ABV. FRASER AT THE ST LOUIS CR. CAMPGROUND	38.25	.	.	.	.	.	.	25.0	26.9	23.1
South Fork CLP	11.63	2.21	6.90	4.73	6.85	36.0	42.9	28.2	28.2	.
WEST FORK CLEAR CREEK BELOW EMPIRE	83.25	.	.	.	.	.	.	6.4	6.4	.
Animas River near Siverton	43.40	.	.	.	.	.	.	0.9	1.7	0.0
BLUE R. ABV DILLON RESERVOIR	44.60	.	.	.	.	.	.	23.1	23.1	.
Chambers Release	14.00	2.31	6.89	7.11	10.95	11.3	22.3	61.5	57.7	65.4
FRASER RIVER AT WINTER PARK SKI RESORT	63.07	.	.	.	.	.	.	105.1	105.1	.
Fraser River at Robbers Roost	18.00	.	.	.	.	.	.	21.8	17.9	25.6
LAKE FK. GUNNISON RIVER ABOVE LAKE SAN CRISTOBAL	17.00	.	.	.	.	.	.	26.5	25.6	27.3
MOSQUITO CR. U/S MIDDLE FORK S PLATTE R. NR. ALMA	31.73	.	.	.	.	.	.	128.2	123.1	133.3
N Fork Snake R near A-Basin Ski Area	10.16	3.68	5.87	4.72	17.27	168.6	183.6	3.3	.	.
N Fork Snake River near Loveland Pass	6.59	3.08	4.28	2.10	8.39	130.7	138.1	2.6	2.6	.
N St Vrain below Thunder Lake	8.23	.	4.89	3.28	9.56	112.6	122.1	2.2	.	.
N St Vrain near Mt Alice	8.49	2.61	5.35	3.11	8.45	89.5	98.0	2.7	.	.
N.F. SOUTH PLATTE ABOVE ROBERTS TUNNEL	32.62	.	.	.	.	.	.	5.1	7.7	2.6
SNAKE RIVER BELOW KEYSTONE	10.50	3.23	3.88	6.63	7.57	83.5	86.4	32.0	33.3	30.8
TEN MILE CREEK AT FRISCO	20.70	.	.	.	.	.	.	26.9	28.2	25.6
UNCOMPAHGRE R. @ RED MOUNTAIN CR. @ HWY 550	14.29	.	.	.	.	.	.	2.8	3.4	2.1

	Site name	Site code	Latitude	Longitude	Elevation, ft	Elevation, m	Elevational zone	Samling date
Anthracite Creek above Erickson Springs CG		ACCG	38.9567	-107.2667	6750	2057	Low <2100	10/27/2004
BOULDER CK @ EBEN FINE PARK		BCEF	40.0135	-105.2947	5600	1707	Low <2100	10/20/2004
BOULDER CK DOWNSTREAM HYDROELECTRIC PLANT (@ ORODELL GAGE)		BCAO	39.2493	-106.8838	5826	1776	Low <2100	10/20/2004

BOULDER CREEK UPSTREAM BOULDER WWTP @ 61ST	BC61	40.0387	-105.2113	5100	1554	Low <2100	10/20/2004
Bear Creek at Bear Creek Reservoir	BCIN	39.6521	-105.1749	5645	1721	Low <2100	10/21/2004
Big Thompson in Loveland	BT3	40.4173	-105.1920	4906	1495	Low <2100	9/16/2004
Buckhorn Creek	BUCK	40.4539	-105.1983	5200	1585	Low <2100	11/10/2004
CLEAR CREEK ABOVE GOLDEN	CCGA	39.7530	-105.2347	5735	1748	Low <2100	10/5/2004
CRYSTAL RIVER NEAR MOUTH	CRBA	39.4083	-107.2288	6120	1865	Low <2100	10/8/2004
EAGLE RIVER AT GYPSUM	EAGY	39.6663	-106.9518	6275	1913	Low <2100	9/30/2004
EAST ELK CREEK NORTH OF NEWCASTLE @ GRAY EAGLE RANCH	ECAN	39.6425	-107.5327	6800	2073	Low <2100	10/9/2004
FOURMILE CREEK AT GARDEN PARK	FCGP	38.5778	-105.2333	6100	1859	Low <2100	10/22/2004
KANNAH CR. ABOVE DOW FISHING AREA	KDOW	38.9617	-108.2297	6060	1847	Low <2100	10/28/2004
MAD CR. @ CHRISTINA SWA	MACS	40.5652	-106.8892	6800	2073	Low <2100	10/7/2004
MUDDY CR.	MCPR	38.9567	-107.2667	6800	2073	Low <2100	10/27/2004
NATURITA CREEK AT NATURITA	NATN	38.2175	-108.5450	5610	1710	Low <2100	9/23/2004
North Fk Poudre at Livermore	NFL	40.7880	-105.2526	5715	1742	Low <2100	10/19/2004
Pine Creek at mouth	PCM	40.7949	-105.2872	5900	1798	Low <2100	11/9/2004
Poudre abv North Fork	PNF	40.7014	-105.2414	5600	1707	Low <2100	11/2/2004
Poudre abv South Fork	PSF	40.6828	-105.4614	6850	2088	Low <2100	10/14/2004
SAN MIGUEL NEAR NORWOOD	SMNO	38.1260	-108.2077	6563	2000	Low <2100	9/23/2004
SMITH FK BLW CRAWFORD	SFBC	38.7913	-107.7102	6030	1838	Low <2100	10/27/2004
St Vrain Creek belowt Lyons at gage	LYON	40.2207	-105.2637	5292	1613	Low <2100	11/10/2004
TROUT CR. NR. MOUTH	TCAM	40.4602	-106.9885	6600	2012	Low <2100	10/7/2004
Turkey Creek at Bear Creek Res	TCIN	39.6394	-105.1610	5645	1721	Low <2100	11/11/2004
YAMPA R. @ 5TH ST. BRIDGE IN STEAMBOAT	YAST	40.4832	-106.8323	6695	2041	Low <2100	10/7/2004
ARKANSAS R. above Buena Vista	ARBV	38.8417	-106.1333	7920	2414	Mid 2100-2700	9/17/2004
ARKANSAS R. at Salida	ARNS	38.6333	-106.0667	7050	2149	Mid 2100-2700	9/17/2004
BEAVER CR. @ AVON	BCAV	39.6310	-106.5213	7453	2272	Mid 2100-2700	9/30/2004
BIG THOMPSON RIVER BELOW ESTES PARK	BTBE	40.3667	-105.4667	7500	2286	Mid 2100-2700	11/10/2004
BOULDER CK BELOW BARKER DAM @ MILE MARKER 29	BCBB	39.9790	-105.4555	8100	2469	Mid 2100-2700	11/9/2004
BRUSH CR @ MOUTH NR. SNOWMASS	BCNS	39.2493	-106.8838	7600	2316	Mid 2100-2700	9/25/2004
Boulder Creek below Boulder Falls	BCAF	40.0047	-105.4056	7050	2149	Mid 2100-2700	10/20/2004
CEBOLLA CR. @ USGS GAGE	CCAG	38.2275	-107.0727	8285	2525	Mid 2100-2700	9/20/2004
CIMARRON RIVER BLW. LITTLE CIMARRON	CRLC	38.4333	-107.5427	6930	2112	Mid 2100-2700	9/24/2004
COLORADO RIVER NEAR HOT SULFUR SPRINGS	CRHS	40.0667	-106.1000	7670	2338	Mid 2100-2700	10/8/2004
CRYSTAL RIVER NR. MARBLE	CRBM	39.2017	-107.2313	7920	2414	Mid 2100-2700	9/24/2004
DOLORES R. BLW RICO	DORI	37.6390	-108.0599	8422	2567	Mid 2100-2700	8/18/2004
EAGLE R. @ REDCLIFF	EARC	39.5093	-106.3667	8654	2638	Mid 2100-2700	9/30/2004
EAGLE R. ABOVE GORE CR.	ER	39.7042	-106.6783	7900	2408	Mid 2100-2700	9/15/2004
East River at Almont	ERAT	38.6644	-105.8475	8006	2440	Mid 2100-2700	9/18/2004
FLORIDA RIVER BELOW LEMON RESERVOIR	FBLR	37.3680	-107.6672	7772	2369	Mid 2100-2700	10/21/2004
GOLD CR. ABOVE OHIO	GCAO	38.5818	-106.8418	8700	2652	Mid 2100-2700	9/18/2004

GORE CR. AB. WWTF	GCAW	39.6413	-106.3885	8150	2484	Mid 2100-2700	9/15/2004
HOMESTAKE CR. @ GAGE	HSAG	39.4733	-106.3680	8783	2677	Mid 2100-2700	9/30/2004
N St Vrain above Buttonrock Res	BTNR	40.2161	-105.4574	7500	2286	Mid 2100-2700	10/11/1995
North Fork St Vrain at RMHRC lab	RMHL	40.2167	-105.5167	8275	2522	Mid 2100-2700	9/10/2004
Poudre abv Joe Wright	PJW	40.6347	-105.8072	8600	2621	Mid 2100-2700	8/31/2004
ROARING FORK RIVER ABV. ASPEN	RFAA	39.1767	-106.7972	8014	2443	Mid 2100-2700	9/24/2004
ROARING FORKS CREEK	RFC	37.5916	-108.1083	8400	2560	Mid 2100-2700	8/18/2004
ROCK CR. @ SWA NR. TOPONAS	RCRC	40.0583	-106.6542	8600	2621	Mid 2100-2700	10/7/2004
ROCK CR. NR SILVERTHORNE	ROSI	39.7215	-106.1283	8502	2591	Mid 2100-2700	10/6/2004
SAN MIGUEL RIVER AT SOCIETY TURN	SMST	37.9497	-107.8685	8622	2628	Mid 2100-2700	8/17/2004
SMITH FORK ABOVE SMITH FK C.G.	SFCG	38.7280	-107.5068	7091	2161	Mid 2100-2700	10/27/2004
SOUTH ARKANSAS RIVER NEAR MAYSVILLE	SAMV	38.5343	-106.1685	8300	2530	Mid 2100-2700	10/22/2004
SOUTH FORK SAN MIGUEL RIVER NEAR MOUTH	SFSM	37.9397	-107.8985	8400	2560	Mid 2100-2700	8/17/2004
ST. LOUIS CR. ABV. FRASER AT THE ST LOUIS CR. CAMPGROUND	SLNT	39.9228	-105.8573	8850	2697	Mid 2100-2700	9/3/2004
South Fork CLP	SFM	40.6182	-105.5255	8100	2469	Mid 2100-2700	9/16/2004
WEST FORK CLEAR CREEK BELOW EMPIRE	WFCC	39.7592	-105.6602	8271	2521	Mid 2100-2700	9/10/2004
Animas River near Siverton	ANSV	37.7918	-107.6833	9200	2804	High >2700	8/17/2004
BLUE R. ABV DILLON RESERVOIR	BLBB	39.5667	-106.0491	9000	2743	High >2700	8/27/2004
Chambers Release	CHR	40.6008	-105.8369	9020	2749	High >2700	8/31/2004
FRASER RIVER AT WINTER PARK SKI RESORT	FRBW	39.9163	-105.7760	8900	2713	High >2700	9/10/2004
Fraser River at Robbers Roost	FRRR	39.8333	-105.7583	9820	2993	High >2700	9/3/2004
LAKE FK. GUNNISON RIVER ABOVE LAKE SAN CRISTOBAL	LFSC	37.9497	-107.3017	9056	2760	High >2700	9/20/2004
MOSQUITO CR. U/S MIDDLE FORK S PLATTE R. NR. ALMA	MOAL	39.2703	-106.0540	10220	3115	High >2700	9/17/2004
N Fork Snake R near A-Basin Ski Area	ABSN	39.6337	-105.8938	10550	3216	High >2700	9/15/1995
N Fork Snake River near Loveland Pass	LVPS	39.6533	-105.8875	11400	3475	High >2700	8/27/2004
N St Vrain below Thunder Lake	BTLK	40.2167	-105.6416	10340	3152	High >2700	8/9/1995
N St Vrain near Mt Alice	ALIC	40.3333	-105.6388	11170	3405	High >2700	8/8/1995
N.F. SOUTH PLATTE ABOVE ROBERTS TUNNEL	NFSP	39.4608	-105.6792	8900	2713	High >2700	10/5/2004
SNAKE RIVER BELOW KEYSTONE	SNBK	39.6018	-105.9960	9100	2774	High >2700	10/1/2004
TEN MILE CREEK AT FRISCO	TMCF	39.5793	-106.0922	9099	2773	High >2700	10/1/2004
UNCOMPAHGRE R. @ RED MOUNTAIN CR. @ HWY 550	UNRM	37.9897	-107.6475	9000	2743	High >2700	8/17/2004