D-8290
RES-1.10

MEMORANDUM

To:	Don Phillips, Manager, Curecanti Field Division, Montrose, Colorado, CCI-100.
From:	Doug Craft, Research Chemist, Fisheries Application Research Group, D-8290
Subject:	Chemical Analyses results for Crystal Reservoir samples collected on April 23, 2002 Technical Memorandum: D-8290-2002-02

Introduction

This report summarizes chemical analyses performed on water samples collected from Crystal Reservoir on April 23, 2002. Samples were analyzed by the Denver Environmental Chemistry Laboratory, D-8290, (the Denver Lab) for major ions (calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, and chloride), nutrients (nitrogen and phosphorus forms), chlorophyll, and algal species identification and enumeration. The purpose of this sampling was to perform an initial reconnaissance evaluation of the water chemistry at Crystal Reservoir in light of concern regarding algal blooms seen in past years. This investigation was performed at the request of your office and was coordinated with the assistance of Laurie Jones and John Milles. Draft data and a preliminary evaluation were emailed to you on May 7, 2002.

Methodology

Water samples were collected from two stations in Crystal Reservoir, and from the outflow downstream of the dam:

Site 1	River inflow zone of Crystal Reservoir (Figure 1)
Site 2	Crystal Reservoir, 500 m behind dam, N 38°30'24.6", W 107°37'20.4" (Figure 2)
Site 3	Outflow below dam at power plant

Field Sampling Procedures: Raw surface water samples for major ions, nutrients (nitrogen and phosphorus), chlorophyll, and algal analysis were collected according to established procedures (EPA, 1982) as near surface grab samples from the boat using a Kemmerer sampler (Wildco Supply, Inc.). Water samples were then transferred to labeled, pre-cleaned polyethylene sample bottles (Environmental Sampling Supply, Inc.) which were then placed on ice in a cooler. Samples were filtered within 6 hours of sampling. Chlorophyll samples were filtered within 6 hours of sampling through a 47-mm 1.0-µm pore-size glass fiber filters (Whatman GF/C). Chlorophyll filter disks were placed in labeled envelopes that were then sealed in ziploc plastic bags and packed in ice. Nutrient samples for dissolved constituents were filtered within 6 hours of sampling through 47-mm 0.45-µm pore-size (Millipore) polycarbonate membranes. Samples were delivered to the Denver Lab within 36 hours of sample collection and were sub sampled for individual analyses and preserved on receipt. A surface sample from inflow Site 1 was preserved with Lugol's solution and shipped by overnight courier to Aquatic Analysts, Inc., Wilsonville, Oregon, for algal identification analysis. Latitude and longitude were measured at the sampling site with a Garmin Etrex Vista model using the WGS-84 Datum. Because of the canyon walls, the GPS unit was only able to collect a location reading at Site 2 behind the dam.

Figure 1 Site 1 near the inflow of Crystal Reservoir. Note the green color of the water.

Figure 2 Crystal Reservoir at Site 2 near the dam.

Water column data profiles for temperature (T), pH, dissolved oxygen (DO), and conductivity (EC) were measured at each lake sampling station using a Hydrolab Datasonde 4a multi-probe with the Surveyor 4 data logger. The Datasonde probes were calibrated 36 hours prior to the sampling. EC was calibrated using a certified standard reference solution (ERA, Inc., Arvada, Colorado), pH was calibrated using a 2-buffer (VWR Scientific) calibration, and DO was calibrated using saturated air at the measured barometric pressure. Multiprobe profile data, Secchi disk depth, and sample notes were recorded in a field notebook.

Chemical Analyses: Samples were analyzed by the Denver Environmental Chemistry Laboratory, D-8220, for major ions, chlorophyll, nutrients (nitrogen and phosphorus), and a qualitative trace element scan following EPA methods (EPA 1983, EPA 1986) or APHA-AWWA-WEF *20th Edition Standard Methods* (American Public Heath Association, 1998) consensus methods. Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) alkalinity were analyzed following EPA method 310.1 using automated electrometric titration with a Brinkmann/Metrohm model 716 DMS Titrino auto titrator. Calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) were analyzed following EPA method 200.7 using inductively coupled plasma emission spectrometry with a Thermo-Jarrel Ash model ICP-61E spectrometer. Chloride (Cl-) and sulfate ($S0_4^{2-}$) were analyzed following EPA method 300 with a Dionex model DX-500 ion chromatograph. Ammonia (NH_3), was analyzed following EPA method 350.1, nitrate+nitrite (NO_2+NO_3) following EPA method 352.1, total Kjeldahl nitrogen (TKN) following EPA method 351.1, total-phosphorus (total-P) following EPA method 365.2, and ortho-phosphorus (ortho-P, or PO_4^{3-}) following EPA method 365.1. All nutrient species were analyzed using colorimetric methods on a Perstorp model Flow 4 automated flow-injection analyzer. Chlorophyll was determined colorimetrically following *Standard Methods* 10200H using a Beckman DU-600 UV/VIS spectrophotometer.

The Denver Lab operates under a formal ANSI-ASQC-Q2 (American National Standards Institute, 1991) quality assurance (QA) plan. This quality plan included provisions for standard operating procedures, instrument calibration verification, duplicates, spikes, laboratory control samples, and defined corrective actions for each instrument run. All data deliverable packages included QC reports that allowed evaluation and validation of data quality. All analyses were completed within recommended holding times and no chemical data from this study required special qualification.

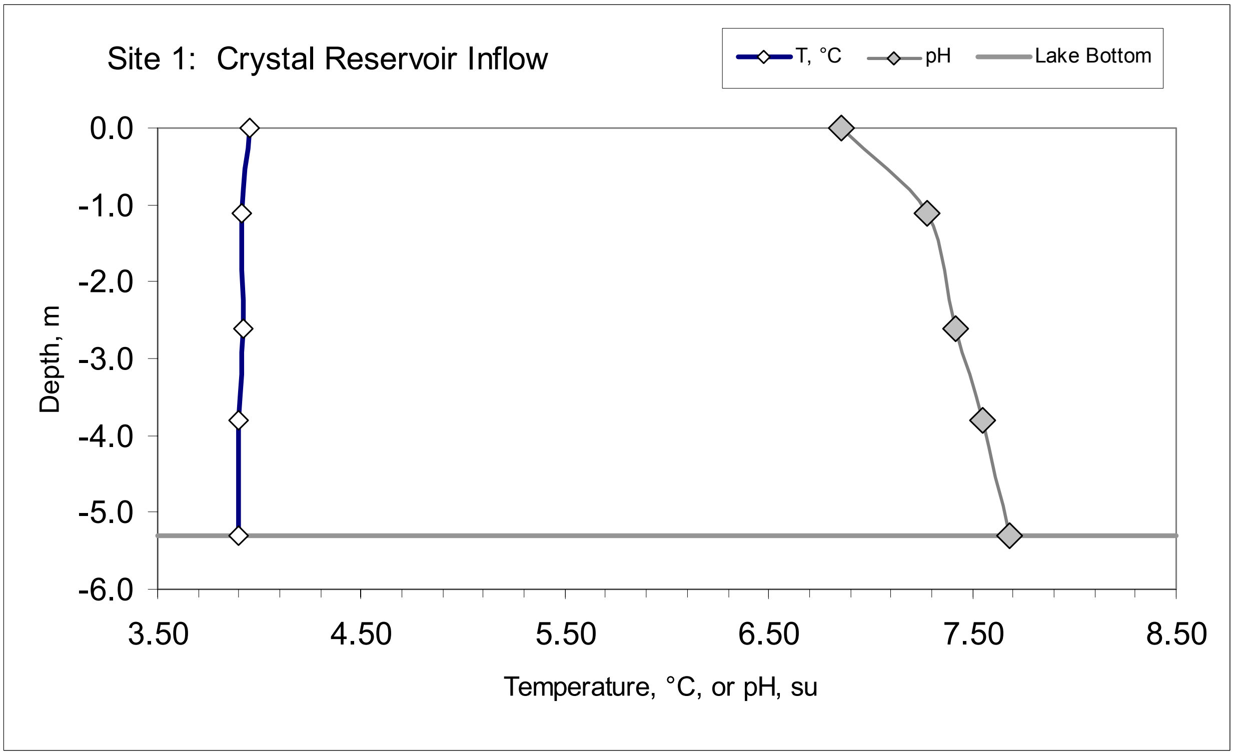
Results and Discussion:

Figure 1 shows the typical green color of the Site 1 inflow sampling station water, thought to be caused by algae attached to fine particulates and free-floating plankton. The Secchi depth at Site 1 was around 3.7 meters, fairly good visibility and comparable to Secchi data observed at Ridgway Reservoir (Craft and Miller, 2001). No algae blooms were observed during the sampling trip.

Figure 3 shows depth profiles for temperature and pH measured at Sites 1 (top graph) and Site 2 (bottom graph) using the Hydrolab multiprobe. These results suggest complete lake mixing at the inflow and only minor stratification in deeper reaches of the lake. Only a 1.5° C difference between surface and bottom and a 17-percent increase in EC (from around 30-m depth to the bottom) was observed at Site 2 . This is expected behavior for temperate-climate lakes after spring turnover. DO readings are not reported here because of problems with the probe; however, DO depletion is not thought to be a problem given the water temperature and lack of stratification.

Table 1 summarizes the results of major ions chemical analyses. The water in Crystal Reservoir is a low dissolved solids, calcium-bicarbonate dominant water with sulfate presence likely caused by contact with sulfide minerals (like pyrites) in the watershed. The surface water pH ranged from 6.86 to 7.93 and total ions from 76 to 84 mg/L. These are good quality waters typical of the watershed elevation, and consistent with those reported previously for Blue Mesa Reservoir (Cudlip and French, 1985; Johnson and Stockwell, 1998). The T, pH and EC in the Site 3 outflow sample were similar to the water from Site 2 at 21-m depth, suggesting that the dam releases waters from a depth of around 60 - 70 ft.

Figure 3 Temperature and pH vs. depth for the two Crystal Reservoir sampling sites. Site 1 near the inflow is at the top, Site 2 near the dam is below.



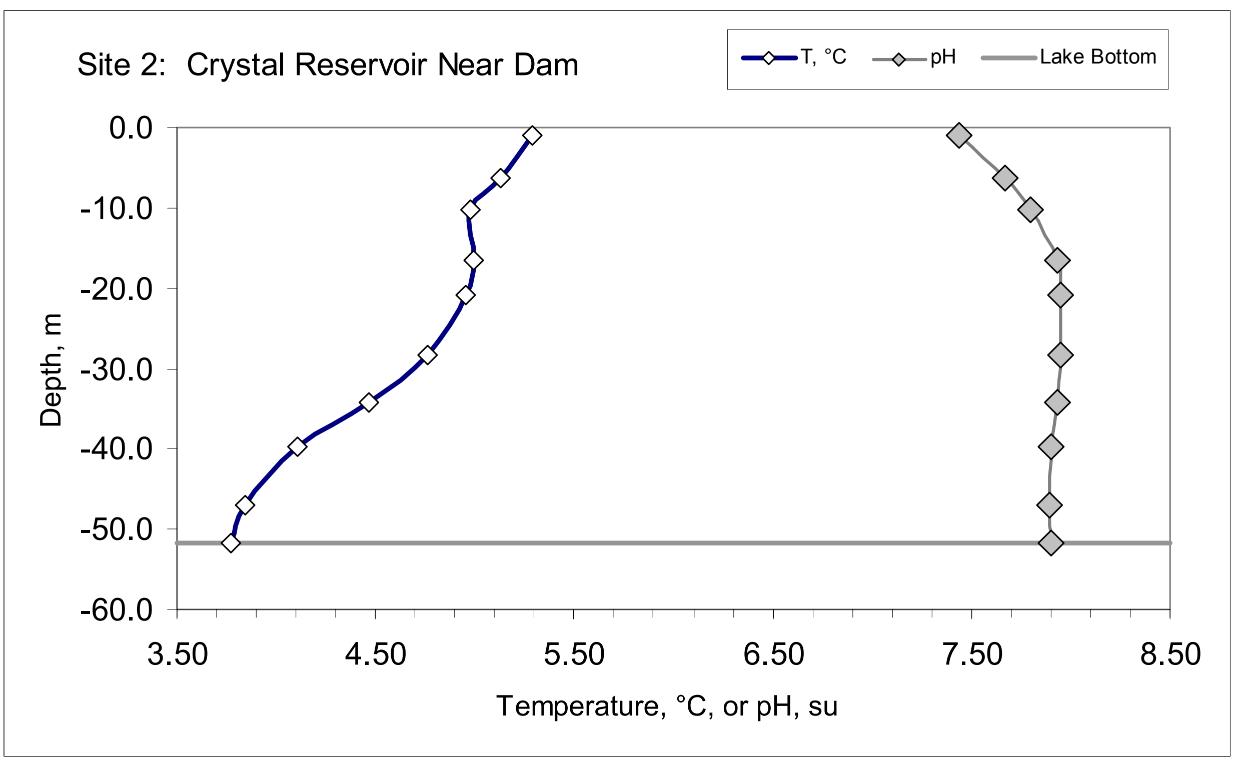


Table 1 Major ions data for water samples collected from Crystal Reservoir on April 23, 2002.

Lab Number	Sample ID	Field T, °C.	Field pH	Lab EC µS/cm	Sum mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	HCO_3 mg/L	CO_3 mg/L	SO_4 mg/L	Cl mg/L
K5721-1	Crystal Reservoir Inflow	3.93	6.86	183	78.0	26.8	5.39	4.95	0.500	102	0.00	18.0	1.24
K5721-2	Crystal Reservoir Lake	5.29	7.44	187	84.0	27.2	5.52	5.10	1.07	104	0.00	18.5	1.25
K5721-3	Crystal Reservoir Outflow	4.95	7.93	189	76.0	27.3	5.59	5.24	0.500	104	0.00	19.2	1.31

Table 2 Nutrient data for water samples collected from Crystal Reservoir on April 23, 2002.

Laboratory Number	Sample ID	Chlorophyll A mg/m³	Chlorophyll B mg/m³	Chlorophyll C mg/m³	Total Kjeldahl Nitrogen (TKN) unfiltered, mg/L	Ammonia NH_3, filtered, mg/L	Nitrate+ Nitrite, NO_3+NO_2, filtered, mg/L	Calculated Organic Nitrogen, mg/L	Total-P, unfiltered, mg/L	Dissolved Ortho-P, filtered, mg/L	Total N to Total P Ratio
K5721-4/7	Crystal Reservoir Inflow	2.4	0.35	0.91	0.310	0.0230	0.0390	0.287	0.0180	0.007	19.4
K5721-5/8	Crystal Reservoir Lake	2.3	0.13	0.62	0.210	0.0140	0.0450	0.196	0.0200	0.008	12.8
K5721-6/9	Crystal Reservoir Outflow	2.1	0.32	0.93	0.260	0.0190	0.0470	0.241	0.0200	0.008	15.4

A qualitative scan for trace metals (provided at no cost) revealed no toxic metals (cadmium, lead, zinc, copper) above instrument detection limits. Comparison of all data reported here with National Drinking Water Standards (U.S. Code of Federal Regulations, 2000a and 2000b) and State of Colorado Table Value Standards (State of Colorado, 1999) for water quality revealed no exceedances. The EPA (EPA, 2002) classifies water from Crystal Reservoir and its watershed (Upper Gunnison, hydrologic unit code 14020002) as level 1 (best).

Table 2 summarizes the nutrient analysis data. Total-P ranged from 0.018 to 0.020 mg/L. Dissolved ortho-P, the form of P most readily available to phytoplankton, was also fairly low, around 0.007 mg/L. The P data suggest that about half of the P is associated with suspended phytoplankton, and that Crystal Reservoir is phosphorus-limited. There appears to be sufficient available P to stimulate algal blooms; however, I would be surprised if blooms are dense or long lasting. Most of the N appears to be organic, also suggesting association with phytoplankton (or the dissolved proteins and organic compounds associated with plant and animal decay). Ammonia, which is indicative of animal waste and biological decay processes (Stumm and Morgan, 1996) is also low, although the inflow site shows higher concentration than the Site 2 sample.

The total-N to total-P ratio ranged from 12 to 19, and ratios of this magnitude are usually associated with productive systems that range from eutrophic (highly productive) to mesotrophic (less productive) lake classifications (Downing and McCauley,1992). However, total-P is not greatly elevated in Crystal Reservoir and the Secchi depth of 3.7 m (at Site 1) suggests fairly transparent water. The chlorophyll concentrations are also fairly low and do not suggest high productivity, and no algal blooms were observed at the time of sampling.

The algal analysis of the inflow sample at Site 1, is detailed in Table 3. The summary from Aquatic Analysts reports:

> "The dominant algal species <*with respect to number of organisms - dc*> was *Rhodomonas minuta*, which is a widespread, flagellate, small cryptophyte that occurs under a wide range of ecological conditions. *Tabellaria fenestrata* was also abundant; it is a colonial, planktonic diatom more often found in oligotrophic lakes. *Cryptomonas erosa* was common; it is another cryptophyte that is also widespread, and is more common in eutrophic lakes. There were a fair number of periphytic (attached) diatoms, indicating some influence from inflowing water (*Cymbella minuta*, *Fragilaria vaucheria*, *Nitzschia* species, *Navicula* species, *Amphora*, *Rhoicosphenia*, and *Hannaea*). *Fragilaria crotonensis*, although not abundant (2.3%), indicates eutrophic waters. The total algal abundance indicates this lake to be at the higher end of mesotrophy. The trophic state index based upon total algal biovolume was 43.8 (mesotrophy range about 35-50)." (Sweet, 1986)

The pie diagram in figure 4 shows the relative abundances of the different algal species based on biovolume. This chart shows that despite greater numbers of *Rhodamonas minuta*, the dominant species with respect to biovolume is *Tabellaria fenestrata*. This species, associated with oligotrophic systems, suggests that the trophic classification index by Sweet may be overstating mesotrophy. Also inflow sample algal results are likely not applicable to deeper parts of the lake.

The observed periphytic diatoms are likely being encouraged by turbid inflows from the Cimarron River, which enters the Gunnison River just below Morrow Point Dam (figure 5) . Figure 5, photographed from the river access park at Morrow Point Dam, shows that inflow from Morrow Point Dam is considerably clearer compared to the Cimarron River, which is probably responsible for most of the suspended materials in Crystal Reservoir. Figure 6 graphs average daily streamflow and 2002 discharge for April and May from the USGS gage station on the Cimarron River at Cimarron, Colorado. Note that flows for May 2002 are well below historical average values.

Table 3 Algal species and numbers observed in the April 23, 2002 water sample from Site 1 near the inflow zone of Crystal Reservoir.

	Species	Density cells/mL	Density percent	Biovolume $\mu m^3/mL$	Biovolume Percent
1	*Rhodomonas minuta*	132	33	2,600	0.60
2	*Tabellaria fenestrata*	64	16	260,000	60
3	*Cryptomonas erosa*	36	9.1	19,000	4.4
4	*Cymbella minuta*	32	8.0	13,000	3.0
5	*Fragilaria vaucheria*	18	4.5	6,300	1.5
6	*Melosira ambigua*	14	3.4	56,000	13
7	*Asterionella formosa*	9	2.3	4,000	0.90
8	*Fragilaria crotonensis*	9	2.3	27,000	6.2
9	*Synedra ulna*	9	2.3	18,000	4.2
10	*Nitzschia paleacea*	9	2.3	890	0.20
11	*Navicula tripunctata*	9	2.3	10,000	2.4
12	*Nitzschia frustulum*	5	1.1	550	0.10
13	*Chrysococcus rufescens*	5	1.1	390	0.10
14	*Nitzschia palea*	5	1.1	820	0.20
15	*Navicula cryptocephala*	5	1.1	840	0.20
16	*Chroomonas sp.*	5	1.1	300	0.10
17	*Amphora perpusilla*	5	1.1	760	0.20
18	*Unidentified flagellate*	5	1.1	91	0.00
19	*Navicula gregaria*	5	1.1	800	0.20
20	*Rhoicosphenia curvata*	5	1.1	530	0.10
21	*Navicula cryptocephala veneta*	5	1.1	430	0.10
22	*Hannaea arcus*	5	1.1	8,000	1.8
23	*Chlamydomonas sp.*	5	1.1	1,500	0.30
24	*Navicula minuscula*	5	1.1	210	0.00
	sum	***406***	***100***	***433,000***	***100***

Figure 4 Pie chart showing relative biovolume percentages of algae species observed in the Site 1 inflow zone sample from Crystal Reservoir.

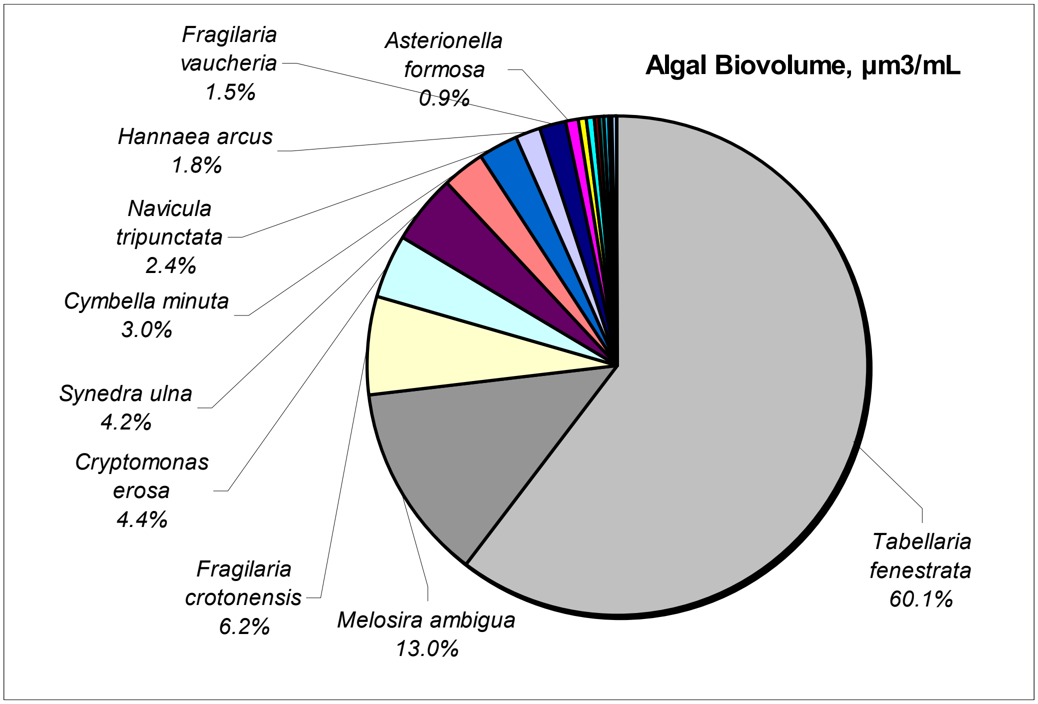
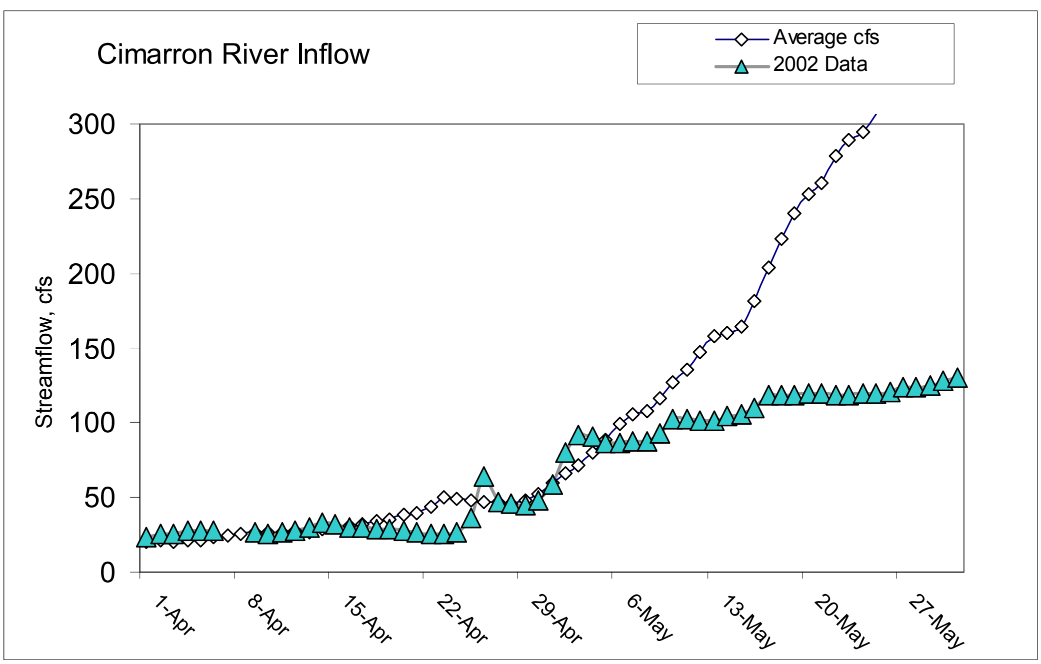


Figure 5 Confluence of the Cimarron and Gunnison Rivers a short distance downstream from the outflow of Morrow Point Dam. Note the turbidity plume associated with the Cimarron River inflow.

Figure 6 Recent and average streamflow measured at the USGS gage on the Cimarron River at Cimarron, Colorado.



Conclusions:

While there was sufficient ortho-P available to stimulate algal blooms in Crystal Reservoir, the data from this sampling do not suggest that these blooms would pose a serious water quality problem. The nutrient data suggest that Crystal Reservoir is phosphorus-limited and chlorophyll concentrations do not suggest excessive productivity in the inflow zone or elsewhere in the reservoir. The data also suggest that water quality in Crystal Reservoir is very good and comparable to that observed in Blue Mesa Reservoir, though perhaps more similar to average June chemistry because of the drought conditions.

This sampling investigation represents a single snapshot of early spring conditions in Crystal Reservoir, so comments about the trophic state of the reservoir are tentative at best. The nutrient and algae data suggest that the inflow zone of the lake may be mesotrophic, but deeper sections of the reservoir may be more oligotrophic. In general, we don't have enough information to classify the trophic status of Crystal Reservoir. During late April 2002, the reservoir was well mixed and the low water temperatures associated with snowmelt runoff were not conducive to algal blooms.

If a better understanding of the algal dynamics in Crystal Reservoir is required, I recommend additional sampling events: one complete sampling (chemistry + algal analysis) later in summer when the reservoir is fully stratified, and algal samples each time an algae bloom occurs. Please let us know if you need our help with these services. To save money, the dam crew could collect algal samples when blooms occur. You will need to order the following items:

Lugol's Iodine Solution (a preservative for algal samples)

Available from: VWR Scientific at
http://www.vwrsp.com/catalog/product/?catalog_number=15204-126
Catalog Number 15204-126 Each $39.81
LUGOL IODINE CONC 16OZ EM SCIENCE
Iodine, Lugol's Concentrated, HARLECO.

Amber High Density Polyethylene Wide Mouth Sample Bottles - 500 mL

Available from: Environmental Sampling Supply at
http://www.essvial.com/products/nalgene.html
info@essvial.com 1-800-233-8425
Catalog Number 0500-1260, Case of 12 $17.52
UC Class, 16 oz./500 mL

Call me for instructions if you decide to have your personnel collect the algal bloom samples.
We appreciate the opportunity to provide technical services to your office. Please call me if you have any additional questions or need further assistance.

CC: D-8290 Technical Memo File
D-8290 (Craft)
CCI-460 (Laurie Jones)
CCI-430 (John Milles)

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