



**BIG THOMPSON
WATERSHED FORUM**

THE FUTURE OF WATER QUALITY IS IN OUR HANDS

**High Plains Environmental Center
2006 Annual Water Quality Report**

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Introduction

Equalizer Lake and Houts Reservoir are two lakes located within the Centerra community in Loveland, Colorado. These lakes are owned/operated by the Greeley-Loveland Irrigation Company and incorporated into the High Plains Environmental Center's (HPEC's) trail system. Equalizer Lake has about 95 surface acres with a maximum storage capacity of about 600 acre-feet and Houts Reservoir has about 76 surface acres with a storage capacity of about 500 acre-feet. Both Lakes have been monitored through the Big Thompson Watershed Forum since June, 2002.

The mission of HPEC is to explore the connections between sustainable living and ecological processes. The HPEC monitoring program relates to this mission by establishing baseline water quality conditions in Houts Reservoir and Equalizer Lake and assessing any water quality changes in these water bodies as the Centerra community builds out.

A sampling site in the center of Houts and Equalizer has been maintained since 2002. In 2006, the center of Houts (site 880) was sampled 13 times and the center of Equalizer (site 881) was sampled 8 times. The parameters collected at each site and the general sampling schedule are listed in the Sampling and Analysis Plan in the Appendix.

Physical Data

Temperature

Houts and Equalizer are both shallow water bodies that do not exceed 2.5 meters in depth. Because of their shallow depth, Houts and Equalizer do not exhibit thermal stratification, or the vertical separation of layers of water. Instead, Houts and Equalizer exist mainly as well-mixed, shallow water bodies.

This phenomenon is evident when temperature data are contrasted with depth. Figure 1 summarizes the mean water temperature at Houts Reservoir at depths of 0.5 meter increments. The data were broken into three seasons to simplify assessment. Season one is March through May; season two is June through August and season three is September through November.

	Season 1					Season 2					Season 3				
	0.5m	1.0m	1.5m	2.0m	2.5m	0.5m	1.0m	1.5m	2.0m	2.5m	0.5m	1.0m	1.5m	2.0m	2.5m
2002	n/a	n/a	n/a	n/a	n/a	22.9	22.5	22.3	22.3	22.1	19.5	19.5	19.5	19.4	19.5
2003	14.5	14.4	14.0	n/a	n/a	23.4	23.1	22.8	22.3	23.2	19.0	17.8	17.3	17.0	16.7
2004	12.6	12.5	12.4	12.0	n/a	22.3	21.5	21.1	21.2	20.1	13.7	13.5	13.4	13.2	n/a
2005	11.7	11.6	11.6	11.2	n/a	22.9	22.0	21.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2006	14.6	14.2	14.1	13.9	n/a	21.1	23.6	23.3	23.3	n/a	14.3	13.9	13.4	13.3	n/a

Figure 1. Summary table of mean water temperatures (C°) at Houts Reservoir based on season, depth and year.

In 2006, water temperatures, on average, varied less than 1 C° from the surface to the bottom of Houts Reservoir. This pattern is fairly consistent throughout the five years Houts has been sampled. In addition, most seasonal temperatures have been consistent from year to year. In 2006 however, season one temperatures increased 2-3 degrees at each depth. This could be due to later season sampling when the Greeley-Loveland Canal delivered warmer Big Thompson River water. In 2004, season three average water temperatures decreased 4-5 degrees at each depth. Shallow water bodies can cool or

warm much quicker than deep water bodies, therefore, cool nights preceding 2004 season three sampling could have led to lower water temperatures.

Figure 2 lists the mean water temperatures at Equalizer Lake from 2002-2006. 2006 had the highest mean water temperatures during season two since 2005. Season three mean temperatures were the highest since 2004. These increased temperatures could be due to an increase in air temperature associated with the weeks Equalizer was sampled and/or a decrease in lake depth and temperature buffering capacity.

	Season 1					Season 2					Season 3				
	0.5m	1.0m	1.5m	2.0m	2.5m	0.5m	1.0m	1.5m	2.0m	2.5m	0.5m	1.0m	1.5m	2.0m	2.5m
2002	n/a	n/a	n/a	n/a	n/a	22.4	21.9	21.8	22.3	20.9	n/a	n/a	n/a	n/a	n/a
2003	n/a	n/a	n/a	n/a	n/a	17.7	17.0	17.3	16.7	n/a	19.3	18.1	17.3	16.7	n/a
2004	12.6	12.5	12.3	n/a	n/a	20.5	19.9	19.4	18.9	19.1	13.1	13.0	12.7	n/a	n/a
2005	11.7	11.2	10.7	13.5	13.4	21.7	21.1	20.9	20.0	19.1	n/a	n/a	n/a	n/a	n/a
2006	n/a	n/a	n/a	n/a	n/a	22.2	21.8	22.1	22.4	21.2	14.5	14.3	13.9	13.4	17.2

Figure 2. Summary table of mean water temperatures (C°) at Equalizer Lake based on season, depth and year.

Secchi Depth

Secchi depth is the maximum depth at which a secchi disk is visible. This simple procedure measures the transparency of lake water and can vary throughout seasons based on algal blooms and suspended sediments. Lakes that become muddy or rich with algae will experience reduced transparency and secchi depths.

Figure 3 illustrates Houts Reservoir secchi depths from June 2002-October 2006. Every secchi depth recorded since 2002 ranged from 0.1 to 1 meter in depth. Compared to most lakes and reservoirs, this range is very small. The consistently shallow secchi depth and small range in secchi depths is explained by the shallow maximum depth of the center of Houts Reservoir, just 2.5 meters.

There does not appear to be an annual secchi depth trend in Houts Reservoir. Since 2002, Houts appears to have fairly consistent secchi depth patterns from year to year, with secchi depths at their deepest April through early June and decreasing from late June through October.

Figure 4 illustrates Equalizer Lake secchi depths from June 2002 to October 2006. Secchi depth ranged from 0.24 to over 2 meters in depth. A slight increasing trend is reflected, suggesting that secchi depths are getting deeper from year to year. However, the increase is slight and may not be statistically significant.

In 2006, secchi depths were deepest in August and most shallow in September. This September and October decline in secchi depth was apparent from 2002-2004. Secchi depths were not calculated for Equalizer Lake in 2005.

Dissolved Oxygen

Oxygen is necessary for both plant and animal respiration and therefore important to aquatic habitat and species composition. Since HPEC is interested in the ecology of Houts Reservoir and Equalizer

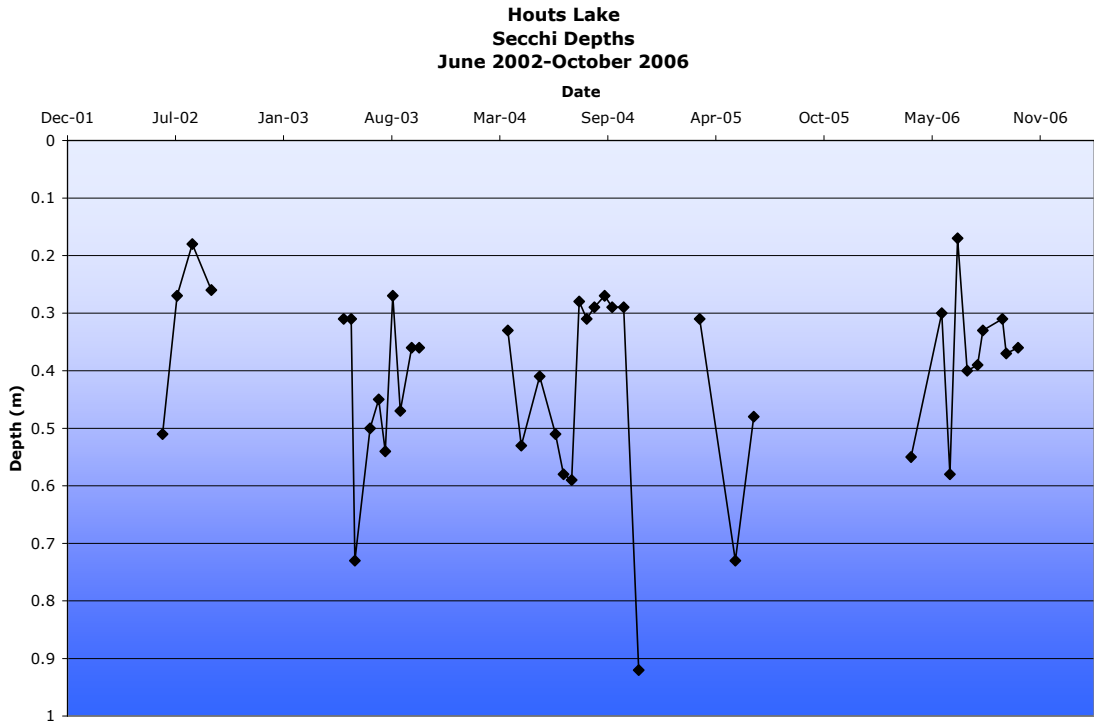


Figure 3. Houts Reservoir secchi depth.

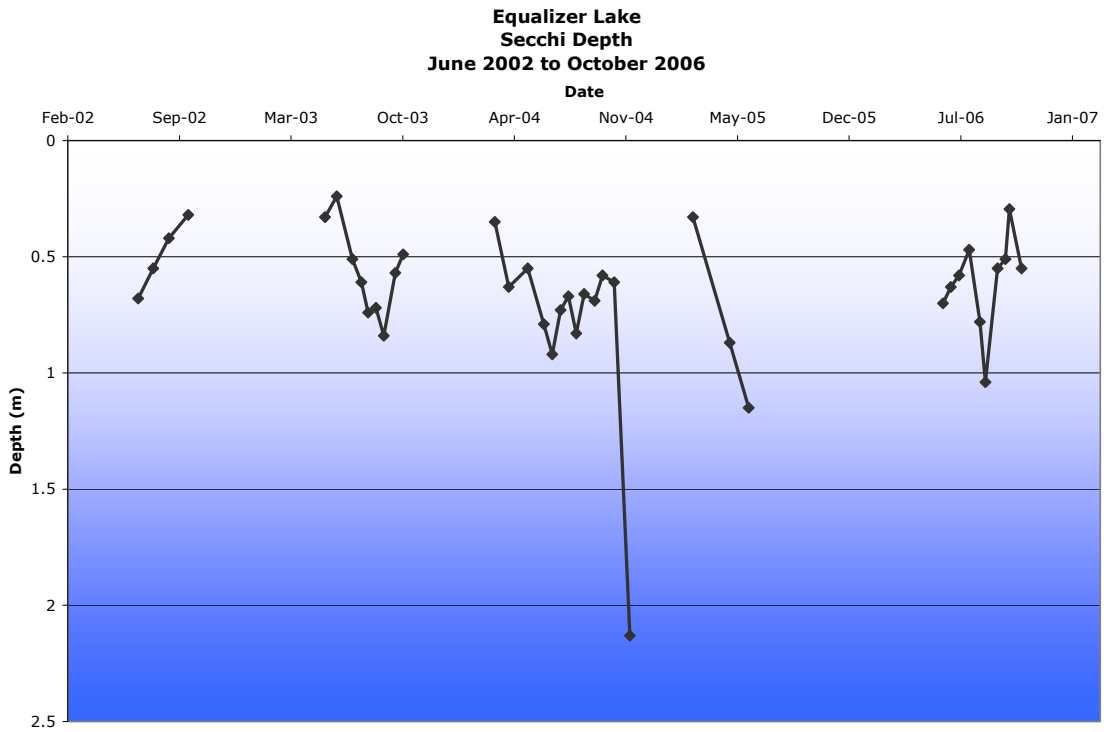


Figure 4. Equalizer Lake secchi depth.

Lake, dissolved oxygen is an important water quality parameter. Photosynthesis and atmospheric deposition are the two main sources of additional oxygen and respiration and decomposition are the two main sources of oxygen depletion.

Percent saturation of dissolved oxygen is the ratio of actual dissolved oxygen concentration to the potential dissolved oxygen concentration. This calculation indicates the percentage of the dissolved oxygen that is possible given the altitude of the site and the temperature of the water.

Figure 5 illustrates percent saturation curves for Houts Reservoir in 2006. Deeper lakes tend to have decreasing oxygen levels at increasing depths, due to the dead and decomposing matter that sink to the bottom. Since Houts is very shallow, it does not exhibit typical temperature stratification and therefore, there is not a substantial change in the percent saturation of dissolved oxygen throughout the vertical water column.

In Houts Reservoir, most samples were between 80-100% saturated, regardless of depth. September samples indicated supersaturation (saturation level above 100%) at the 0.5 and 1 meter depth. These results indicate that oxygen production exceeded diffusion out of the lake at these depths.

Equalizer Lake also showed consistent dissolved oxygen, percent saturation values (Figure 6). Most samples were between 90-100% saturated and percent saturation did not vary considerably by depth. The lowest readings were calculated at 2.5 meters in early August and early September. By late September, Equalizer Lake became supersaturated from the 0.5-2 meter depths.

pH

PH is the measure of hydrogen activity in a solution. The toxicity of compounds often varies with pH and most plants and animals tolerate pH values that range between 6.5 and 9.0. Any values outside this range can reduce fitness of aquatic organisms or lead to mortality.

All pH values collected from 2002 – 2006 have ranged from 7.9 - 9.2 (Figure 7). The median 2006 Houts pH value was the second highest median pH value (8.58) of the of the five year period of record. 2006 also had the highest maximum pH value during the five year period of record.

The median pH of Equalizer Lake was also higher compared to previous years. Figure 8 shows that median, minimum and maximum pH values increased almost ½ a standard pH unit from 2005 to 2006. PH is measured on a logarithmic scale; an increase in pH by just 0.5 standard units translates to a pH value that is five times higher than the previous value. Since 2003, the pH of Equalizer Lake has increased, making the water more basic or alkaline. While aquatic biota can sustain chronic pH values over 9.0, optimal conditions for the fish species that inhabit Equalizer Lake are between 6.5 and 8.0.

Specific Conductivity

Specific conductivity indicates a solution's ability to conduct an electric current. Electric currents are transmitted through ions, so specific conductance indirectly measures the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron and is a good general indicator of water pollution.

The median specific conductivity values for Houts Reservoir vary considerably. In 2006, the median value was 765.0 uS/cm (Figure 9). This was the second lowest annual value, next to the 2003 annual

Houts Reservoir 2006
Dissolved Oxygen, Percent Saturation

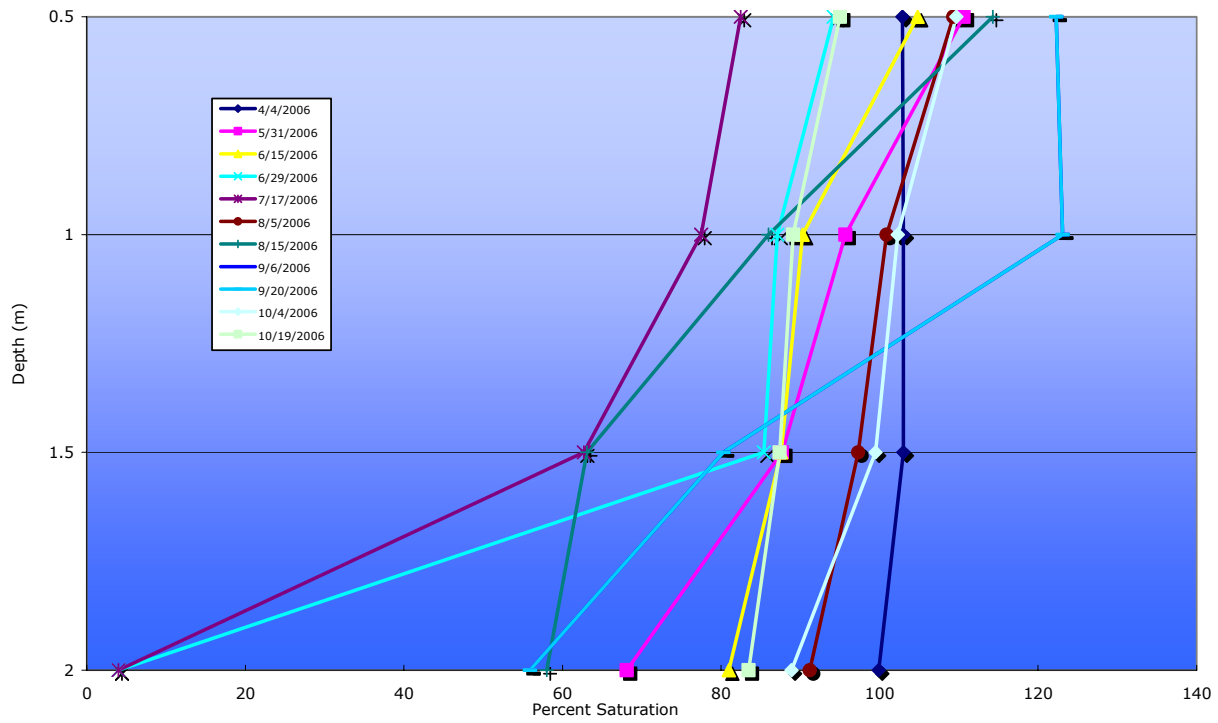


Figure 5. Houts Reservoir dissolved oxygen, percent saturation.

Equalizer Lake 2006
Dissolved Oxygen, Percent Saturation

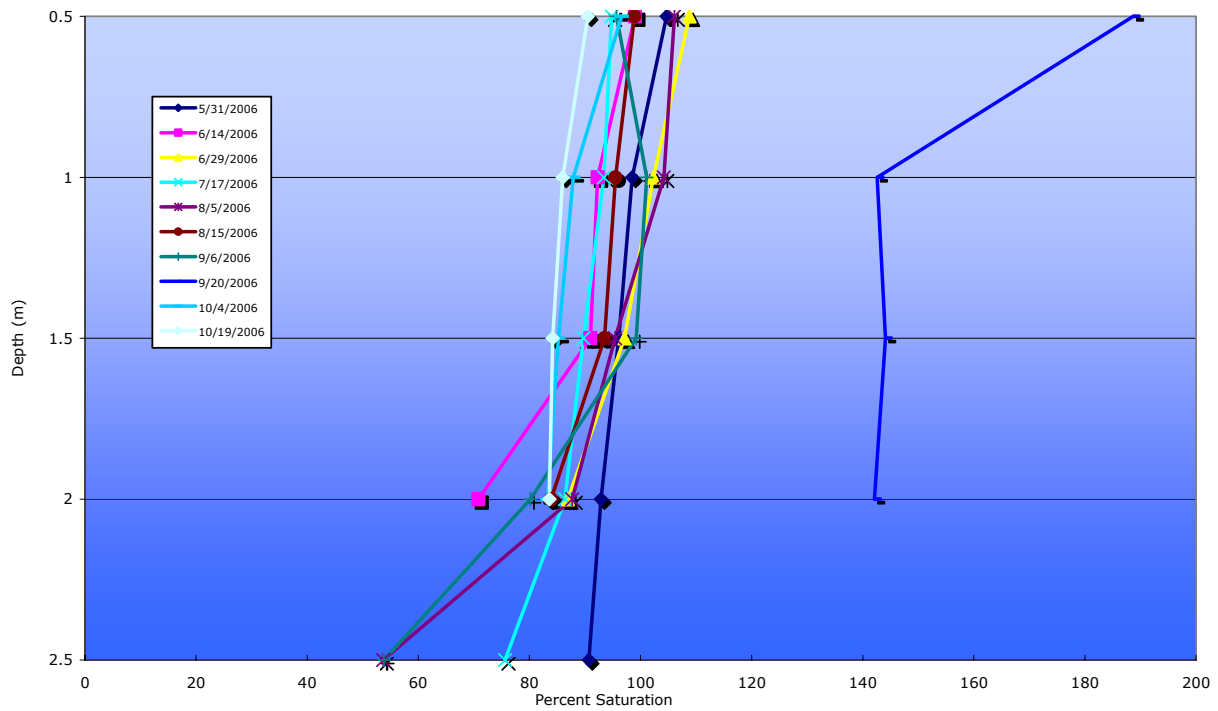


Figure 6. Equalizer Lake dissolved oxygen, percent saturation.

Year	Median	Minimum	Maximum
2002	8.36	8.11	8.55
2003	8.69	7.94	9.16
2004	8.47	7.95	8.86
2005	8.29	8.17	8.65
2006	8.58	8.24	9.17

Figure 7. Median, minimum and maximum annual pH values for Houts Reservoir.

Year	Median	Minimum	Maximum
2002	8.02	8.33	8.63
2003	7.26	8.45	9.02
2004	7.55	8.35	8.67
2005	7.96	8.32	8.76
2006	8.43	8.64	9.22

Figure 8. Median, minimum and maximum annual pH values for Equalizer Lake.

value. The median specific conductivity for Equalizer Lake in 2006 (263.5 uS/cm) was considerably lower compared to Houts Reservoir (Figure 10). This value was also the lowest specific conductivity annual median for the entire Equalizer Lake period of record.

Equalizer Lake is flushed with water from the Greeley-Loveland Canal, which may help dilute the build-up of free ions. Houts Reservoir is fed through a dam from Equalizer Lake and may not receive new water as frequently as Equalizer Lake. The difference in source water and inflow frequency may explain the specific conductivity differences between the two water bodies.

Year	Median	Minimum	Maximum
2002	836.0	804.0	894.0
2003	691.0	602.0	1027.0
2004	804.0	603.0	926.0
2005	847.0	801.0	856.0
2006	765.0	635.0	949.0

Figure 9. Median, minimum and maximum annual specific conductivity (uS/cm) for Houts Reservoir.

Year	Median	Minimum	Maximum
2002	616.0	488.0	719.0
2003	363.0	124.0	866.0
2004	256.5	150.0	649.0
2005	481.0	314.0	532.0
2006	263.5	165.0	479.0

Figure 10. Median, minimum and maximum annual specific conductivity (uS/cm) for Equalizer Lake.

Total Suspended Solids

Total suspended solids (TSS) reflects the organic and inorganic matter in water. Organic matter can be harmful to aquatic organisms both in the suspended form and when sediments settle to the bottom of the water body. Suspended solids can affect prey detection and collect in the epithelium of fish gills, hindering respiration. Suspended solids can also reduce light penetration and affect the photic zone of water bodies, minimizing areas where plants can grow. These solids also absorb heat from atmosphere and result in increased water temperatures. Solids that settle to the floor of water bodies can harm aquatic habitat by filling in nesting areas and smothering fish eggs.

Figure 11 shows the annual median TSS concentration for Houts Reservoir. The concentration of TSS increased from 15.00 mg/L in 2005 to 20.45 mg/L in 2006. Of the five years TSS has been analyzed at Houts, 2006 had the third lowest annual median.

In 2006, the median TSS concentration for Equalizer Lake (12.15 mg/L) was approximately ½ the 2006 median concentration for Houts Reservoir. Except for 2005, the median TSS concentration for Equalizer Lake was consistently lower than the median TSS concentration for Houts Reservoir.

Figure 12 indicates that the 2006 median TSS concentration of Equalizer Lake doubled from 2005 to 2006, but was lower than every other annual median. In 2005, TSS data were collected in March, May and June, before and during early irrigation deliveries from the Big Thompson River. 2006 TSS data were collected near the end of the sampling season, in September and October. Only 3-6 records per year and sampling schedules varying from year to year do not provide data sufficient to draw comparisons between Houts or Equalizer annual TSS concentrations.

Year	Median	Minimum	Maximum
2002	28.50	14.00	57.00
2003	14.00	9.00	33.00
2004	26.00	16.00	50.00
2005	15.00	7.00	25.00
2006	20.45	17.90	36.00

Figure 11. Total suspended solids (mg/L) for Houts Reservoir.

Year	Median	Minimum	Maximum
2002	14.00	5.00	16.00
2003	22.00	8.00	36.00
2004	13.50	10.00	31.00
2005	6.00	5.00	16.00
2006	12.15	11.20	19.20

Figure 12. Total suspended solids (mg/L) for Equalizer Lake.

Nutrient Data

Nutrients are chemical elements and compounds that occur naturally in the environment. Plants and animals require these nutrients to survive and grow. However, and overabundance of nutrients can result in an overabundance of algae and eutrophication related phenomena.

Phosphorus

Phosphorus is scarce in a normal aquatic environment and many of the sampling results in the Big Thompson Watershed have been censored because they were lower than detection limits. This element is also one of the limiting agents to growth of phytoplankton and attached algae. Keeping phosphorus and nitrogen ratios in check and reducing the availability of these elements sustains a healthy aquatic environment and reduces the likelihood of algae blooms.

Figure 13 lists the median, minimum and maximum values for total phosphorus at Houts Reservoir since 2002. These data indicate that total phosphorus concentrations of Houts Reservoir varied throughout the period of record. However, the maximum concentration levels in 2005 and 2006 were lower than the maximum concentration levels in the preceding 3 years. This could indicate that nutrient loads have lowered recently.

The Environmental Protection Agency (EPA) recommends that the abundance of nuisance algae can be reduced in small lakes in the Plains Ecoregion when total phosphorus levels are kept below 0.15 mg/L. The median total phosphorus concentration of Houts Reservoir was below this threshold in all years while the maximum concentration met or exceeded this threshold in 2002 and 2004.

Year	Median	Minimum	Maximum
2002	0.01	0.01	0.16
2003	0.05	0.01	0.08
2004	0.05	0.01	0.31
2005	0.01	0.01	0.02
2006	0.02	0.01	0.05

Figure 13. Total Phosphorus (mg/L) for Houts Reservoir.

Figure 14 lists the median, minimum and maximum values for total phosphorus at Equalizer Lake since 2002. These data are similar to the Houts data. The maximum total phosphorus concentration was recorded in 2004 and since then, phosphorus concentrations have decreased. Based on EPA's recommendations, nuisance algae over abundance would have been most likely in 2004.

Year	Median	Minimum	Maximum
2002	0.04	0.01	0.08
2003	0.05	0.01	0.07
2004	0.03	0.01	0.25
2005	0.01	0.01	0.02
2006	0.03	0.02	0.03

Figure 14. Total phosphorus (mg/L) for Equalizer Lake.

Nitrogen

Nitrogen is a fundamental nutrient required by all plants and animals to build proteins. Generally, nitrogen is found in higher concentrations than phosphorus in ambient water. A nitrogen phosphorus ratio of 10:1 is common. Most of the nitrogen in aquatic ecosystems is in the form of nitrogen gas, nitrate, ammonia, nitrite or urea. The most biologically active form of nitrogen is nitrate and thus nitrate is an important compound to consider when researching productivity levels of lakes and reservoirs.

Nitrite is generally present in trace amounts but is often analyzed in conjunction with nitrate in labs. Figure 15 lists the nitrate plus nitrite concentration of Houts Reservoir. Nitrite plus nitrate concentrations were low throughout the period of record and many values did not exceed detection limits. Values below detection limits were recalculated at 1/2 the detection limit for this report. Because these values were consistently low, it is difficult to draw any conclusions from the resulting data other than nitrite plus nitrate levels have not varied considerably throughout the period of record.

Figure 16 lists the nitrite plus nitrate concentrations of Equalizer Lake. This limited data set also included many non-detects. Only six records from 2005 and 2006 were available for this report and five of them were non-detects. Therefore, this data set should be reviewed with caution and only the general conclusion that nitrite plus nitrate concentrations remained low throughout the period of record should be drawn.

Year	Median	Minimum	Maximum
2002	0.02	0.01	0.03
2003	0.01	0.01	0.03
2004	0.01	0.01	0.01
2005	0.01	0.01	0.12
2006	0.01	0.01	0.03

Figure 15. Nitrite plus nitrate concentration (mg/L) of Houts Reservoir.

Year	Median	Minimum	Maximum
2002	0.02	0.01	0.06
2003	0.01	0.01	0.06
2004	0.03	0.02	0.10
2005	0.10	0.10	0.10
2006	0.01	0.01	0.09

Figure 16. Nitrite plus nitrate concentration (mg/L) of Equalizer Lake.

Biological Data

Algae Density

Algae compose the foundation of a small lakes' dynamic food web and help indicate productivity levels. A preponderance of algae is a symptom of a eutrophic water body and can result in other physical and chemical changes including severe variation and depression in oxygen saturation and decreased light penetration and transparency. These factors can affect more complex organisms including fish and aquatic invertebrates.

Figure 17 illustrates total algae density at Houts Reservoir from sampling events between June 2002 and July 2006. Algae density decreased in 2005 and 2006. Prior to 2005, algae density was highest late in the sampling season, particularly in August and September. Algae densities tend to decline in the early and middle of the summer (May and June).

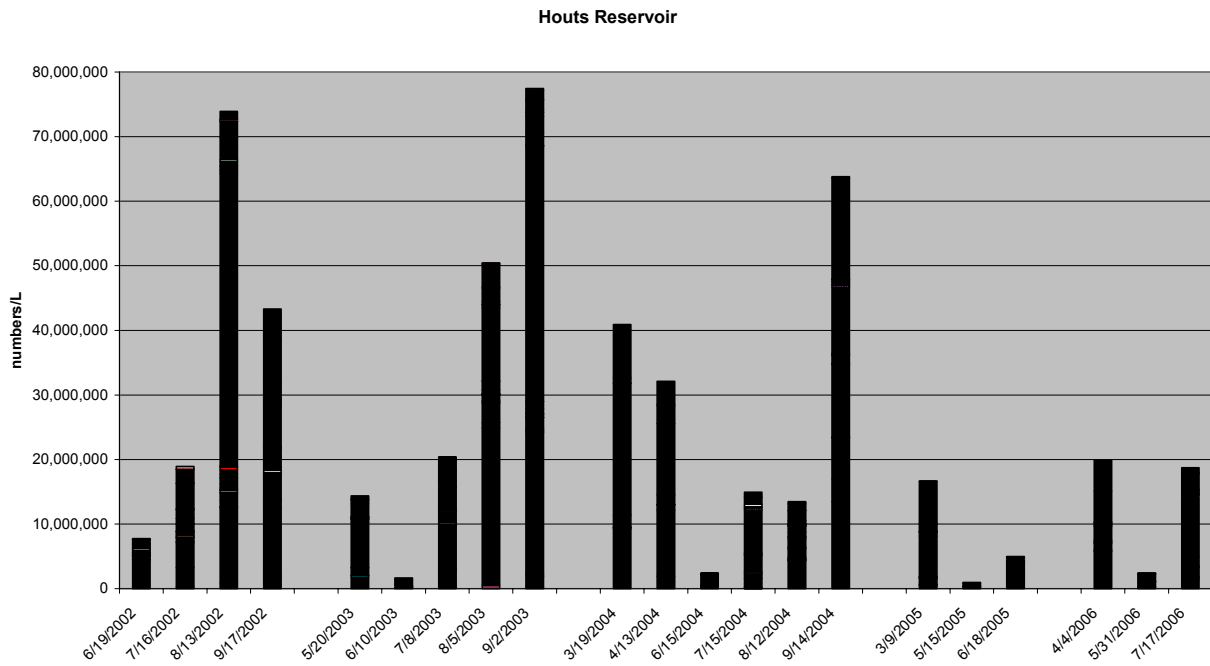


Figure 17. Algae species density (numbers/L) for Houts Reservoir.

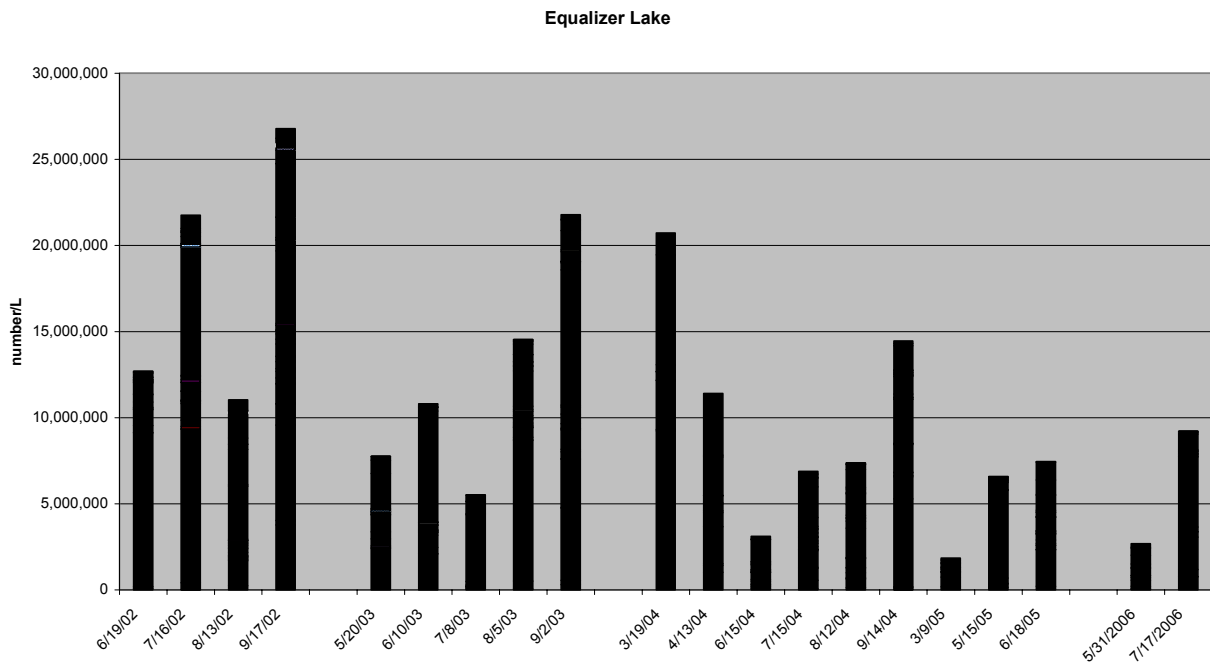


Figure 18. Algae species density (numbers/L) for Equalizer Lake.

Maximum algae density levels are lower in Equalizer Lake (Figure 18), compared to Houts Reservoir, while minimum levels are higher in Equalizer Lake. This indicates that Equalizer Lake has more consistent algae density levels than Houts.

The results from two 2006 Equalizer sampling events were available for this report. These results were both less than 10,000,000 numbers/L and fairly consistent with other samples collected in May and June in previous years. Historically, algae density levels are highest in Equalizer Lake during September. However, Figure 14 indicates that algae levels can rise throughout the year, including in March, July and August.

Major Conclusions and Summary

Because both Houts and Equalizer have consistently shallow depths throughout the year, they do not exhibit behavior typical of most lakes and reservoirs along the Front Range. Temperature and dissolved oxygen do not vary considerably throughout the vertical water column of Houts and Equalizer and secchi depth does not vary considerably from year to year.

Data indicate that productivity levels increase in both water bodies at the end summer. Total algae densities were typically highest in September. September dissolved oxygen levels also indicated that photosynthetic algae were producing more oxygen than the water bodies were diffusing. The decrease in secchi depth was also typical in late summer in both Houts and Equalizer. This relationship between increasing algae density and dissolved oxygen saturation and decreasing secchi depth is typical of water bodies that experience late season algae blooms.

Nutrient data were not sufficient to detect annual trends but did indicate low levels during most sampling events. The annual median total phosphorus concentrations were below EPA's recommended threshold for water bodies in the Plains Ecoregion. Nitrogen data were not sufficient to compare to EPA's recommendations, however, research in the Big Thompson Watershed indicates that most water bodies are not nitrogen limited and therefore, nitrogen may not be as important in limiting algae growth as phosphorus.

Total suspended solids concentrations affect the transparency of water and could affect prey detection and reproduction in fish. Data presented in this report indicate that the total suspended solids concentrations in both Houts and Equalizer increased in 2006. However, these median values were within the range of values observed since sampling began in 2002. This suggests that these water bodies are not getting more turbid.

pH levels in both Houts and Equalizer increased in 2006 and increasing pH levels have been observed annually in Equalizer. Median pH levels are at the higher end of the range that warm water fish can tolerate. A pH reading of 9.22 was observed on Equalizer Lake in 2006, this reading was the highest reading the Forum has observed on either of these lakes since sampling began in 2002.

Conductivity levels declined in both Houts and Equalizer Lakes in 2006. Conductivity is a good overall indicator of water quality and decreased conductivity levels is a positive sign. 2006 median conductivity levels on Equalizer Lake were lower than any other year sampled. On Houts Reservoir, median conductivity levels were lower than any other year, except 2003.

Generally, the water quality of Houts and Equalizer are similar and do not appear to vary considerably from year to year. Additional information on the delivery of water from the Greeley/Loveland Ditch to Equalizer Lake and the delivery of water from Equalizer to Houts may explain changes in water quality. The decline in algae density levels in 2005 and 2006 is positive, suggesting abundant nuisance algae may be unlikely if the current water quality conditions of this system are sustained. Additional samples need to be collected throughout 2007 to determine if these and other trends continue.



**Sampling and Analysis Plan
Houts and Equalizer Lakes 2006**

Objectives: To characterize basic physical water quality conditions and define the trophic status of Houts and Equalizer. To assess the degree of compliance with physical water quality standards and future nutrient standards.

Sampling Sites: 3 – Center of Houts (880) and Equalizer (881) and Inlet of Equalizer (882) (lat/longs needed)

Frequency of Sampling: Physical parameters sampled monthly during winter and fall months when lakes are not frozen over and bi-monthly throughout summer/early fall; Nutrient-related parameters and algae are sampled monthly when lakes are not frozen over.

Anticipated Sampling Events: Monthly March - April and October
Bi-monthly May - September

Parameters Sampled and Detection Limits for Sites 880 and 881

<u>Parameter</u>	<u>Frequency</u>	<u>Sampling Depth(s)</u>	<u>Units</u>	<u>Detection Limit</u>	<u>Lab</u>
Water Temperature	Each event	0.5 m increments to bottom	°C	na	Field
pH, Field	Each event	0.5 m increments to bottom	Standard Units	na	Field
Dissolved Oxygen	Each event	0.5 m increments to bottom	mg/L	na	Field
Dissolved Oxygen Level	Each event	0.5 m increments to bottom	Percent Saturation	na	Field
Secchi Depth	Each event	na	Meters	na	Field
Specific Conductance, Field	Each event	0.5 m increments to bottom	us/cm	na	Field
Total Suspended Solids	Monthly	1 m below surface	mg/L	5 mg/L	RiverWatch
Ammonia, Total	Monthly	1 m below surface	ug/L	50 ug/L	RiverWatch
Nitrate+Nitrite, Total	Monthly	1 m below surface	mg/L	0.02 mg/L	RiverWatch
Phosphorus, Total	Monthly	1 m below surface	mg/L	0.02 mg/L	RiverWatch
Phytoplankton Density	Monthly	1 m below surface	Numbers/L	n/a	Wellspring

Phytoplankton Biovolume	Monthly	1 m below surface	ug/L	n/a	Wellspring
Total Inorganic Nitrogen	Monthly	1 m below surface	ug/L	n/a	?
Chlorophyll-A	Monthly	1 m below surface	ug/L	n/a	?

Parameters Sampled and Detection Limits for Sites 882

<u>Parameter</u>	<u>Frequency</u>	<u>Sampling Depth(s)</u>	<u>Units</u>	<u>Detection Limit</u>	<u>Lab</u>
Water Temperature	Each event	0.5 m	°C	na	Field
pH, Field	Each event	0.5 m	Standard Units	na	Field
Dissolved Oxygen	Each event	0.5 m	mg/L	na	Field
Dissolved Oxygen Level	Each event	0.5 m	Percent Saturation	na	Field
Specific Conductance, Field	Each event	0.5 m	us/cm	na	Field