# Ambient Water Quality Objective Attainment for the Bonaparte River, 2001 and 2002.

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December, 2003

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## 1.0 Introduction

The Bonaparte River is located in the southern interior of British Columbia. It has a number of tributaries which flow into it, the main ones being Clinton Creek, Loon Creek, Hat Creek, and Cache Creek. The Rayfield River is also a large tributary of the Bonaparte but is on the Bonaparte Plateau, upstream of the first sample. At the north side of the Village of Ashcroft, the Bonaparte River empties into the Thompson River.

The Bonaparte Watershed is influenced primarily by forestry, urbanisation and, most importantly, agriculture. The water quality of this river is extremely important as it is used for drinking water, irrigation, recreation, and livestock watering, as well as providing spawning and rearing habitat for Chinook and Coho salmon, steelhead and rainbow trout. Some factors which affect the water quality include the presence of livestock, hay fields, sewage treatment plant discharges, landfills, urban and rural storm water runoff, and forestry operations (Brewer, 1997).

In 1986 an in-depth technical report and resulting water management report were prepared. The purpose of these documents was to establish water quality objectives for the Bonaparte River in order to monitor and protect the watershed for its many users. This report, prepared by L.G. Swain, describes the basis for determining water quality objectives and outlines the objectives which should be monitored in the Bonaparte River (Swain, 1986).

In 2001 and 2002, sampling was done at a variety of sampling locations along the Bonaparte River and its tributaries in order to check if the objectives were being met. The water quality objective attainment sampling results are discussed in the following pages.

## 2.0 Sampling Sites

In order to monitor the water quality of the Bonaparte River and its tributaries, eight monitoring sites were established at various points, so that areas susceptible to contamination could be monitored, and the integrity of the river's water quality could be examined. The eight sites include:

- the Bonaparte River upstream of Clinton Creek (BR U/S Clinton Creek)
- Clinton Creek upstream of the Village of Clinton's sewage lagoon outfall (Clinton Creek U/S Lagoons)
- Clinton Creek downstream of the Village of Clinton's sewage lagoon outfall (Clinton Creek D/S Lagoons)
- the Bonaparte River downstream of Loon Creek (BR D/S Loon Creek)
- the Bonaparte River downstream of Hat Creek (BR D/S Hat Creek)
- the Bonaparte River upstream of the Cache Creek Sewage Treatment Plant (STP) outfall (BR U/S Cache Creek STP)
- the Bonaparte River downstream of the Cache Creek STP outfall (BR D/S Cache Creek STP)
- the Bonaparte River near it's mouth (BR near mouth).

Two sites along Loon Creek (upstream and downstream of the fish hatchery) and three sites on Loon Lake (at the water intake, at the Provincial Park beach, and at the rock bluffs) were also included in the objectives documents. Only the Provincial Park beach and the deep site off the rock bluffs in Loon Lake were sampled in 2001 and 2002 due to the closure of the fish hatchery on Loon Creek. Figure 1 shows the Bonaparte River, its tributaries, and the ten locations sampled in 2001 and 2002.

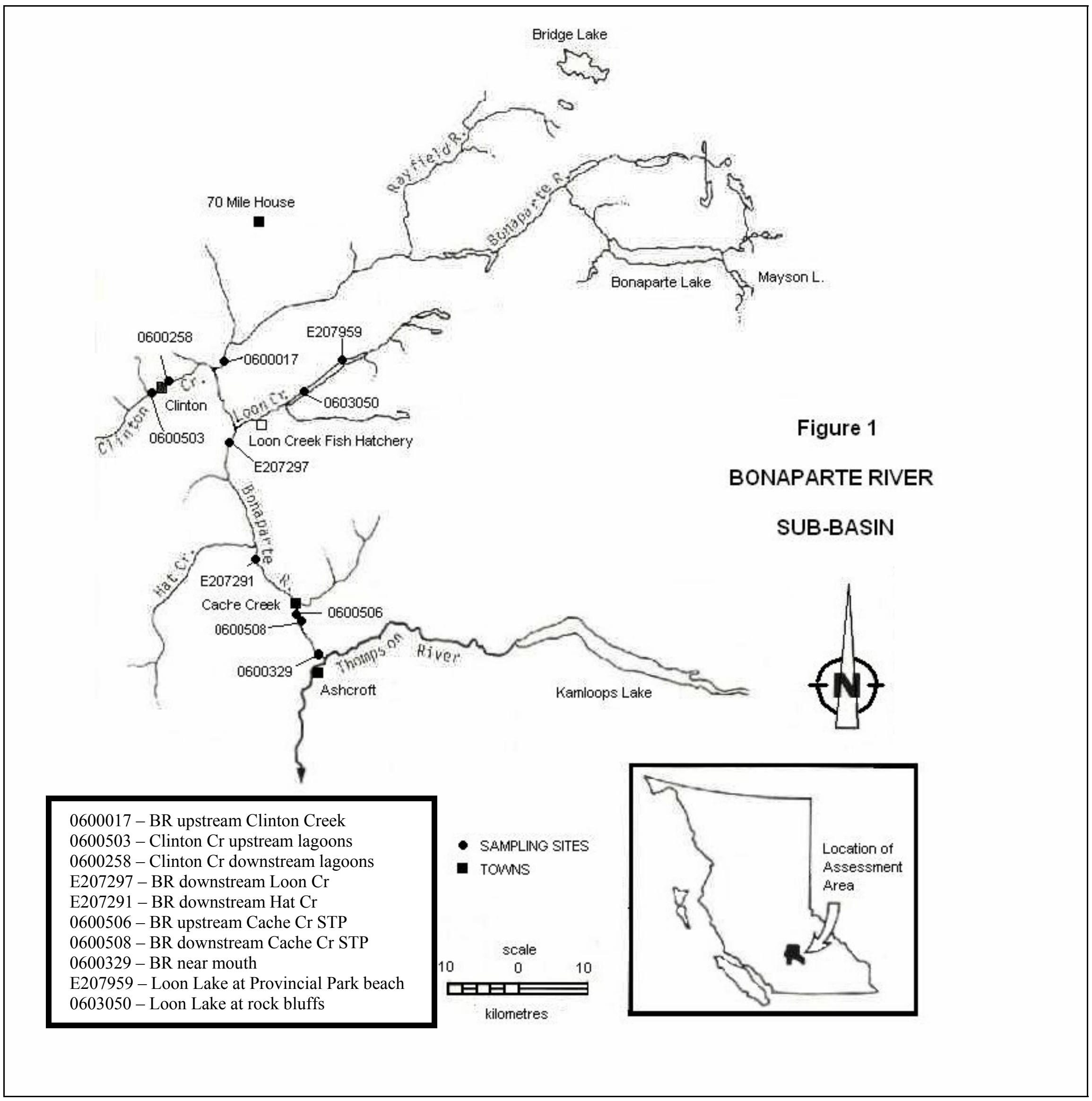


**Figure 1: Sampling locations along the Bonaparte River Sub-basin. (Modified from Swain, 1986.)**

The locations for each of the sampling sites reflect the impacts which are caused by various practices, either along the river itself, or which occur along its tributaries. For example, cattle grazing is one historical land use which is common along the river near many of these sites. Two sewage treatment facilities (one serving the Village of Clinton and another which serves Cache Creek) are also sources of contamination. Sample sites were established above and below these facilities in order to determine the change in water properties as a result of these operations. A summary of each tributary and the land uses along it can be found in L.G. Swain's report, *Ambient Water Quality Objectives for the Bonaparte River* (1986).

## 3.0 Sampling Results

Information on various water quality parameters from sampling locations along the Bonaparte River have been gathered for quite some time. In 2001 and 2002, only certain parameters at certain sites relevant to the water quality objectives for the river were sampled. The Loon Lake at water intake site was not sampled and only limited sampling was done at the Provincial Park beach. Results from water testing done over these two years has been summarized and discussed in the following pages.

### 3.1 Fecal Coliforms

Three different objectives were established for fecal coliform levels in the Bonaparte Watershed, based on the primary uses seen at the various sampling sites. Samples taken near water intakes should have a maximum fecal coliform [$90^{th}$ percentile] of ≤10MPN/100mL. (For the Bonaparte Watershed this objective only applies to the Loon Lake near water intake site.) Acceptable fecal coliform levels at bathing beaches (i.e. Loon Lake at the Provincial Park beach) are set at ≤200MPN/100mL, geometric mean ≤400MPN/100mL, $90^{th}$ percentile. The rest of the sampling sites in the Bonaparte Watershed are subject to the objective level of ≤100 MPN/100mL, $90^{th}$ percentile (Swain, 1986).

#### 2001 Results

For the majority of sampling sites along the Bonaparte River and its tributaries, the ≤100 MPN/100mL, $90^{th}$ percentile water quality objective for fecal coliforms applies. Figure 2 shows the coliform levels of each sampling location for 2001. Each bar shows the maximum, minimum, and $90^{th}$ percentile coliform levels found in each sampling location over the five week sampling period (the symbol is the $90^{th}$ percentile, the bar above the symbol is the maximum, and the bar below the symbol is the minimum).

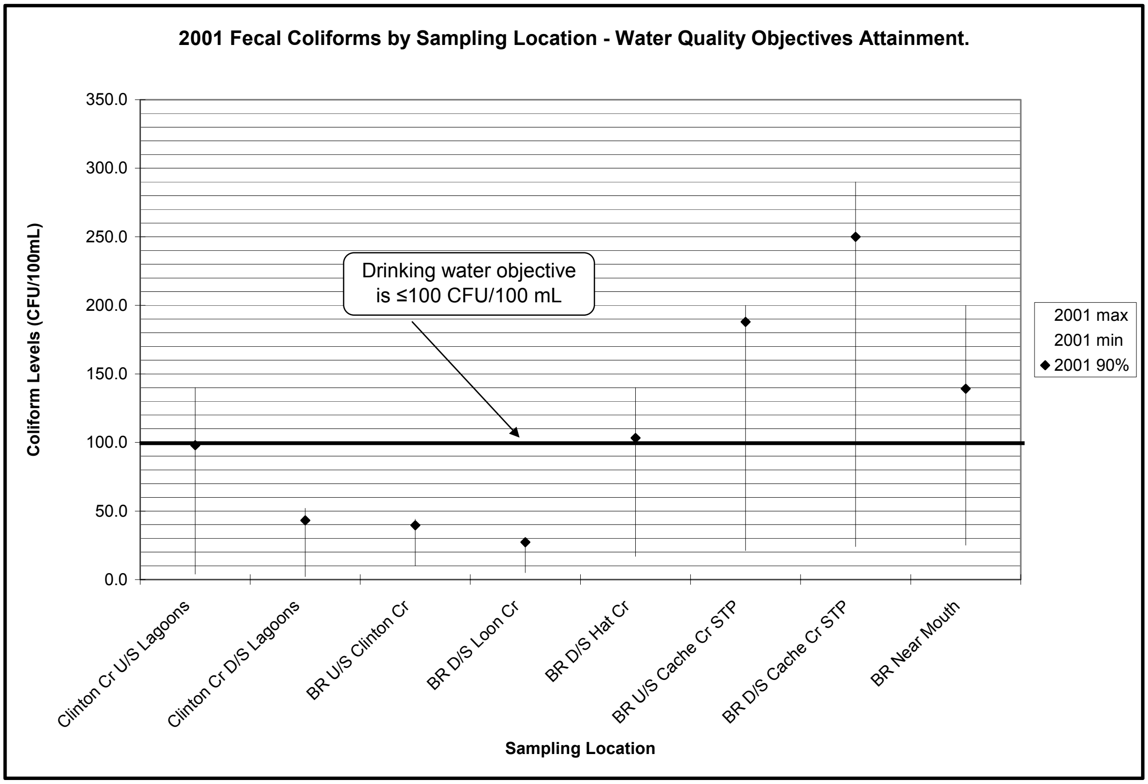


**Figure 2: A comparison of fecal coliform levels at sampling locations along the Bonaparte River in 2001.**

From this graph it is apparent that four sites were above the drinking water objective in 2001. The four sites which had levels above the objective are located along the lower portion of the Bonaparte River, downstream from Hat Creek. The elevated coliform levels downstream from the Cache Creek STP were possibly due to treated sewage entering the river. The sites are only a few hundred meters apart with no known surface runoff inputs between them. However, efficient disinfection of the sewage effluent should result in no major increase in the river, so this result is somewhat puzzling, unless there was an upset in the STP.

As the river flows down to the mouth, the fecal coliform bacteria appear to die off which is shown by the lower coliform levels found near the river mouth. Surface runoff is not thought to be a likely factor in causing this decline, but groundwater inputs could play a part. The most likely reason for this decline is that UV in sunlight could be responsible for killing the bacteria rather than dilution (Grace, 2003).
The elevated coliform levels found downstream from Hat creek could be caused by cattle grazing and congregation near the streams for water which historically has occurred along this stretch of the river and its tributaries (Swain, 1986).

It is interesting to note the difference in coliform levels between Clinton Creek sites upstream and downstream of the sewage lagoon outfall. The Village of Clinton uses a system of lagoons as a method of secondary treatment for domestic wastewater. (Swain, 1986). The data shows that in 2001 the lagoons did reduce the coliform in compliance with the drinking water quality objectives.

The Loon Lake at the Provincial Park beach site was well under the acceptable fecal coliform level in 2001: the measured coliform level was 2 CFU/100mL. Not only is this level safe for contact recreation, it is also safe for disinfected drinking water use (objective of 10 CFU/100mL).

## 2002 Results

Fecal coliform levels in 2002 differed substantially from 2001; Figure 3 shows the coliform levels at each site in 2002.

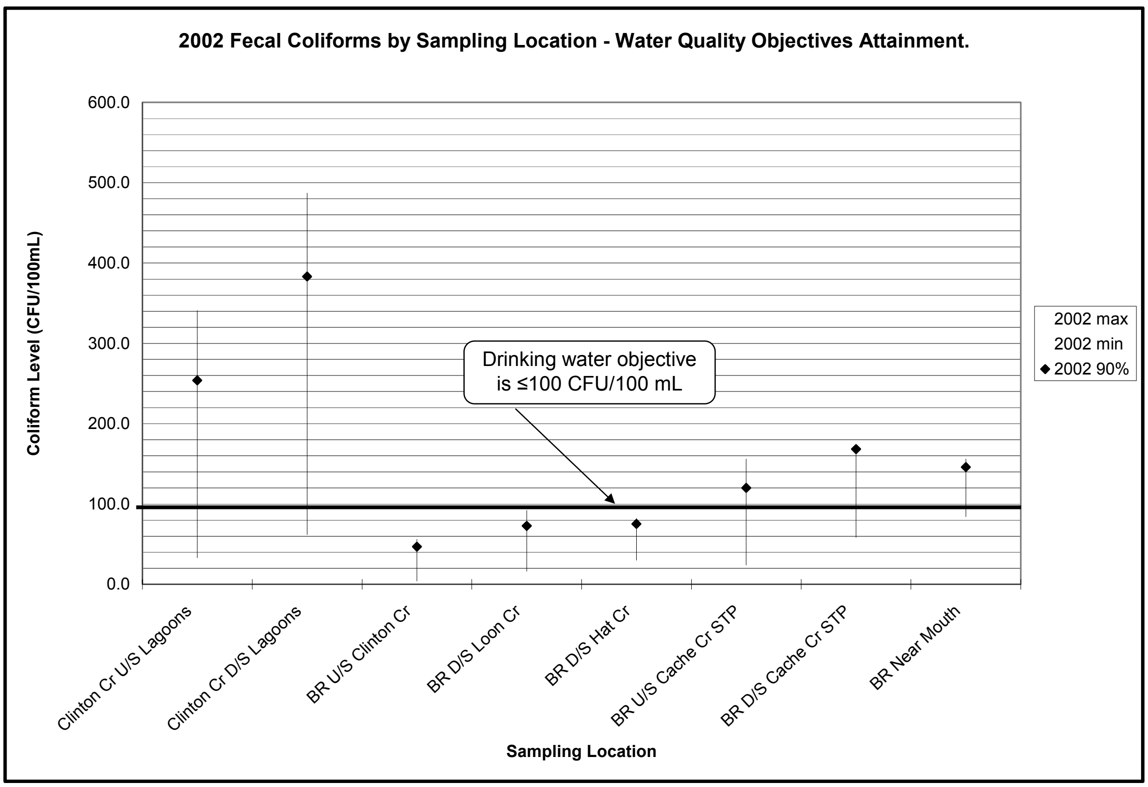


**Figure 3: A comparison of fecal coliform levels at sampling locations along the Bonaparte River in 2002.**

The samples taken in 2002 show that only three sites met the water quality objective for coliform levels. Both sites along Clinton Creek were above the acceptable limit, which differed from the 2001 results. Flow data for freshet in 2001 and 2002 (Figures 4 and 5) show that discharge levels were much higher in 2002 (Environment Canada, 2003).

Since 2002 was a high runoff year, the elevated fecal coliform levels may be due to increased erosion and runoff of manure and/or urban storm water into the creek. Even the upstream site is elevated, which indicates that the problem is more than just the STP outfall (Grace, 2003). Levels along the Bonaparte River from Hat Creek down were lower in 2002 than 2001; however, these levels (with the exception of the Hat Creek site) were still above the objective limit of 100 MPN/100mL.

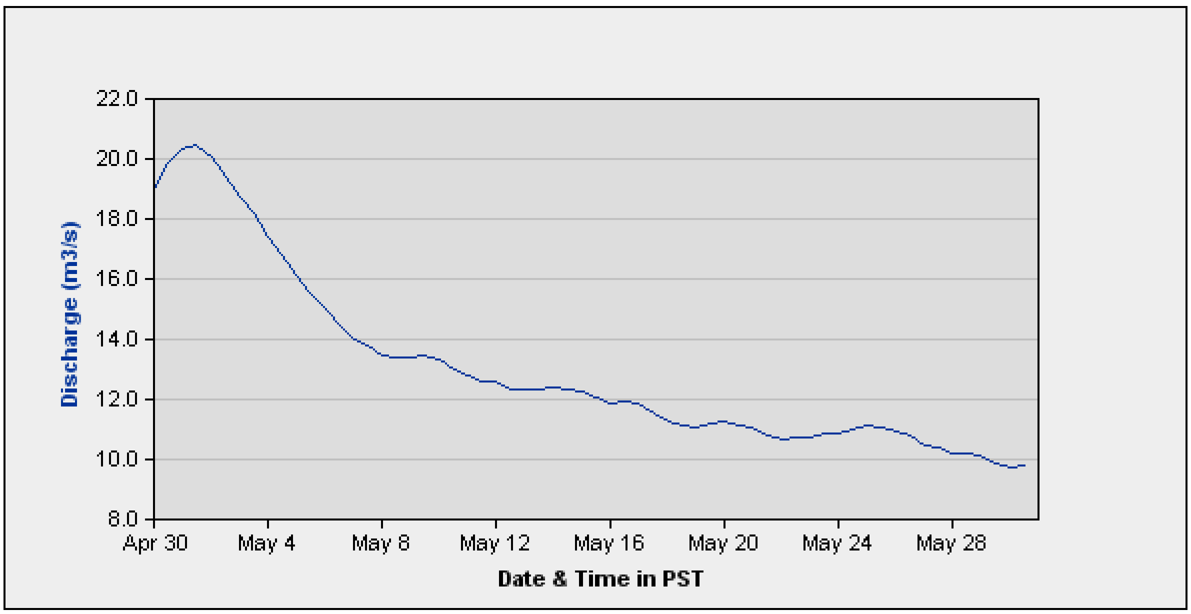


**Figure 4: Discharge levels at the Bonaparte River below Cache Creek Hydrometric Station from April 30th to May 28th, 2001. (From Environment Canada, 2003).**

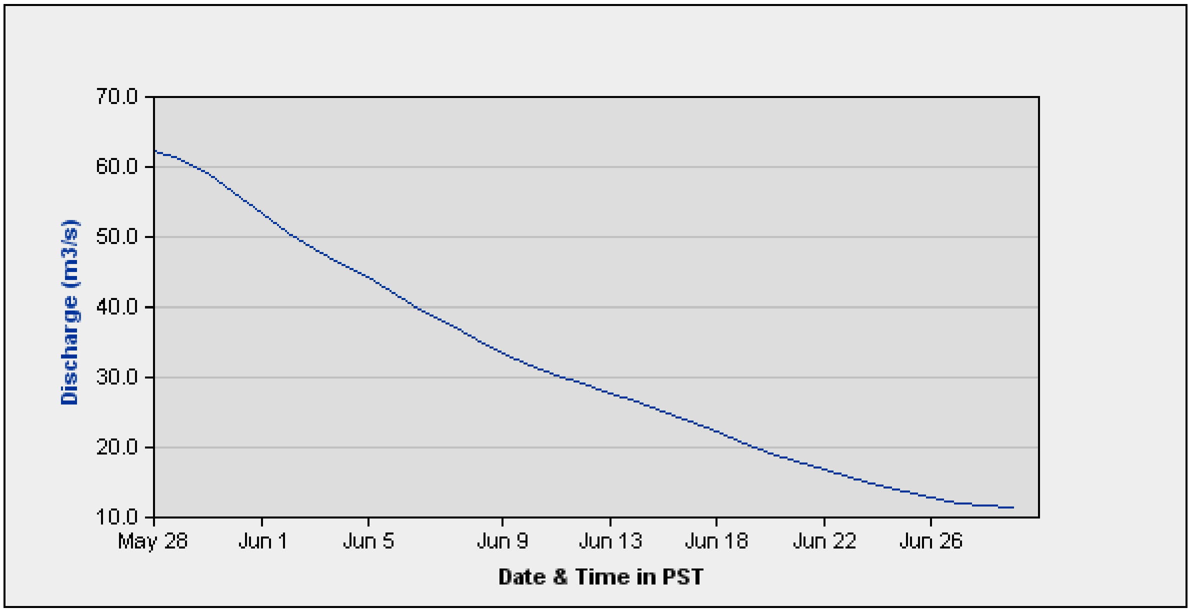


**Figure 5: Discharge levels at the Bonaparte River below Cache Creek Hydrometric Station from May 28th to June 26th, 2002. (From Environment Canada, 2003).**

The one sample taken at the Loon Lake Provincial Park beach site in 2002 was well under the contact recreation fecal coliform objective: 22 CFU/100mL versus a maximum of 200 CFU/100mL. For more detailed fecal coliform results see Appendix A.

### 3.2 pH

Two different water quality objectives have been established for pH levels: between 6.5 and 8.5 pH for sites along the Bonaparte River up to and including BR D/S Hat Creek, and between 6.5 and 9.0 pH for the BR U/S Cache Creek STP site to the river mouth. (pH objectives were not established for Loon Lake.) According to Health Canada there do not appear to be any human health problems directly related to pH. pH is, however, related to a number of other water parameters which means that indirect health effects may be seen. The two main problems resulting from pH levels being outside the acceptable range are the corrosion and incrustation of water supply systems; pH levels of 6.5 or lower can cause corrosion, and pH levels of 8.5 or higher may cause incrustation. Additionally, chlorine disinfection is more efficient at pH levels below 8.5 (Health Canada, 2003). pH levels can also be used to monitor for un-ionized ammonia and possible resulting toxicity (Swain, 1986).

pH levels can be problematic for aquatic life (Grace, 2003). According to the Canadian Water Quality Guidelines (1987), freshwater pH should be within the range of pH 6.5 – 9.0 for the protection of aquatic life. pH values below 6.5 can cause reproductive and emergence problems for fish and aquatic insects Harmful effects such as increased coughing, temporary loss of appetite, and mortality has been observed in some fish species at pH levels above 9.0 (CCREM, 1987). See Appendix C for a table summarizing the effects of pH on fish.

**2001 Results**

In 2001, all sampling locations met the drinking water quality guidelines for pH levels. Figure 6 shows the levels for each site.

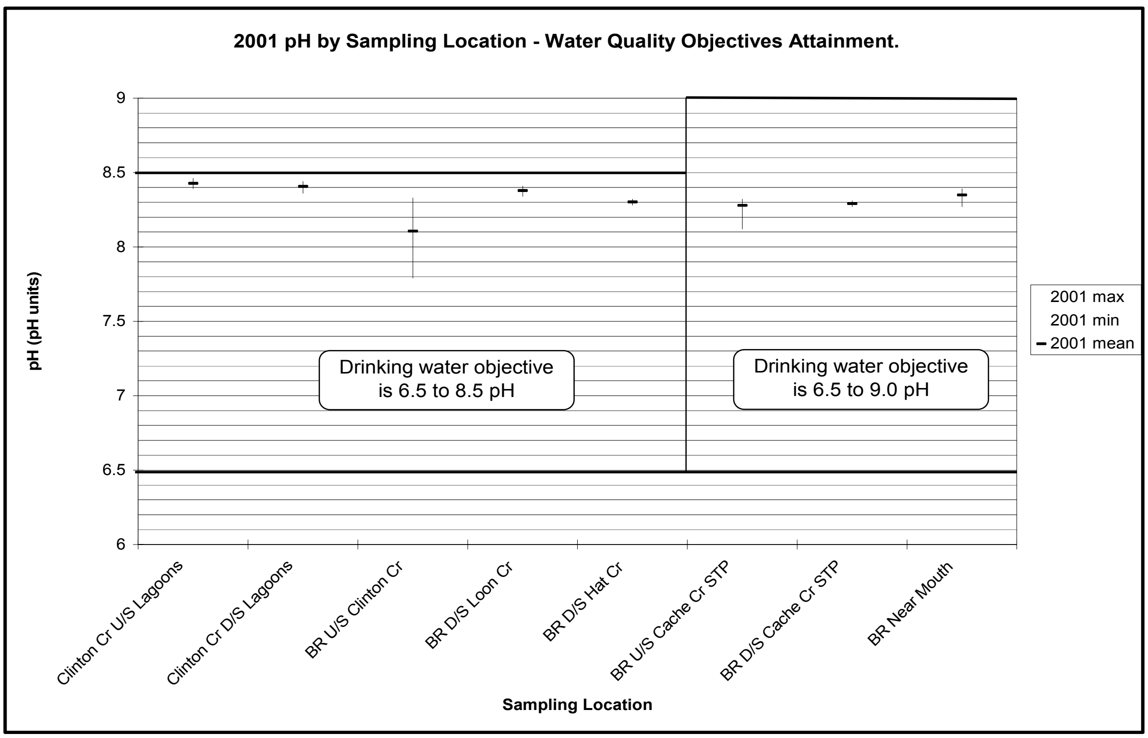


**Figure 6: A comparison of pH levels at sampling locations along the Bonaparte River in 2001.**

The greatest variation in pH was seen at the BR U/S Clinton Creek site. This site is where the river drops down from the high elevation plateau onto the low elevation, heavily developed, valley. The river receives substantial dissolved solids in the valley due to the high evaporation rate that increases the saltiness of the soil. This increased buffering capacity would result in less variation in pH (Grace, 2003). The BR U/S Clinton Creek site also had the lowest pH value of all the 2001 pH readings. This upper site has a lower pH due to its location; its proximity to the high elevation plateau area means that it receives more precipitation and less evaporation than the other sites. These two factors cause greater flushing of the alkaline materials over time which results in less alkaline material in the runoff (Grace, 2003).

**2002 Results**

pH levels in 2002 were all within the drinking water objective range. These results were similar to 2001. Figure 7 shows the pH levels for 2002.

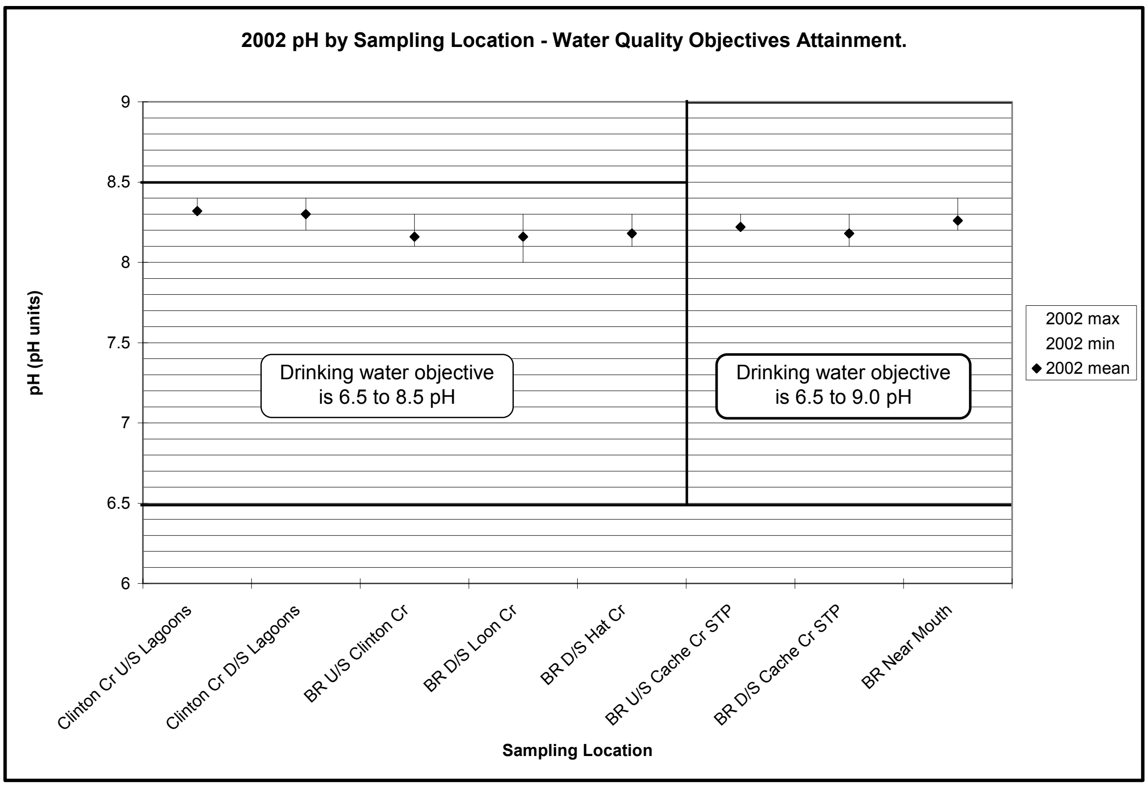


**Figure 7: A comparison of pH levels at sampling locations along the Bonaparte River in 2002.**

The largest range in pH in 2002 was seen at the BR D/S Loon Cr site. This site also had the overall lowest pH value. Overall, pH levels did not change substantially between sampling location from 2001 to 2002. See Appendix A for more detailed pH results.

## 3.3 Un-ionized Ammonia

Un-ionized ammonia can cause toxicity to aquatic life and is a concern for water users downstream from sewage treatment facilities (Swain, 1986). The drinking water quality objective limit for un-ionized ammonia is ≤0.007 mg/L average, or 0.03 mg/L max. (There are no objectives for un-ionized ammonia at Loon Lake sites.) According to the sampling results, all objectives for this parameter were met for all sampling sites in both 2001 and 2002. All 2001 total ammonia values were minimal, and all 2002 values were undetectable (<0.005/100ml). Since un-ionized ammonia is only a small fraction of total ammonia, and the detection limits were much lower than the water quality objectives, graphs for this parameter were not produced. See Appendix A for detailed un-ionized ammonia values.

## 3.4 Turbidity

Turbidity is the amount of suspended particles (such as sand, silt, clay, organic material, and microorganisms) that is present in the water. High levels may occur as a result of increased runoff, which often occurs during freshet. Large amounts of suspended particulate can inhibit the removal of microorganisms during disinfection processes. Additionally, high turbidity levels may stimulate bacteria growth which results in larger amounts of chlorine needed for effective water disinfection (Environmental Laboratory, 1982).

Water quality objectives for turbidity are in place for sites along the Bonaparte River and its tributaries, but not for the Loon Lake sites. The objective allows a maximum increase of 5 NTU when the upstream site is ≤50 NTU, and a 10% maximum increase when the upstream site is >50 NTU.

In past years, turbidity data has been analyzed by comparing each sampling site to the control site upstream. To analyze 2001 and 2002 data, BR U/S Clinton Creek is used as the control site for the rest of the sites along the Bonaparte River, and Clinton Creek U/S Lagoons site is used as the control for the Clinton Creek D/S Lagoons site. Since all of the downstream sites were compared to one upstream site rather than to the preceding site, turbidity objectives were rarely met.

Since all turbidity values recorded at both control sites were less than 50 NTU, the increase in turbidity allowed by the water quality objectives is 5 NTU. Therefore, each sampling site had to be within 5 NTU of the turbidity values measured at either BR U/S Clinton Creek or Clinton Creek U/S Lagoons for each sampling date. Graphs were prepared for each sampling site which show the turbidity values of the control site and sampling site, as well as the difference, by sampling date. All difference values above the 5 NTU line indicate that the acceptable turbidity limits were exceeded and the turbidity objective was not met for that site and date.

**2001 Results**

The 2001 data showed that none of the sampling locations along the Bonaparte River met the water quality objectives for turbidity. The BR D/S Loon Creek site was only above the acceptable turbidity level on April 30th, and was below the limit for the other four sampling dates. Turbidity levels at all sites dropped substantially from April 30th to May 7th. This drop is likely a result of the observed decline in discharge between these dates (refer to Figure 4). On May 22nd, only the BR D/S Cache Creek STP did not meet the turbidity objective. Figure 8 illustrates the changes in turbidity levels between the control site and the BR D/S Loon Creek site during freshet in 2001.

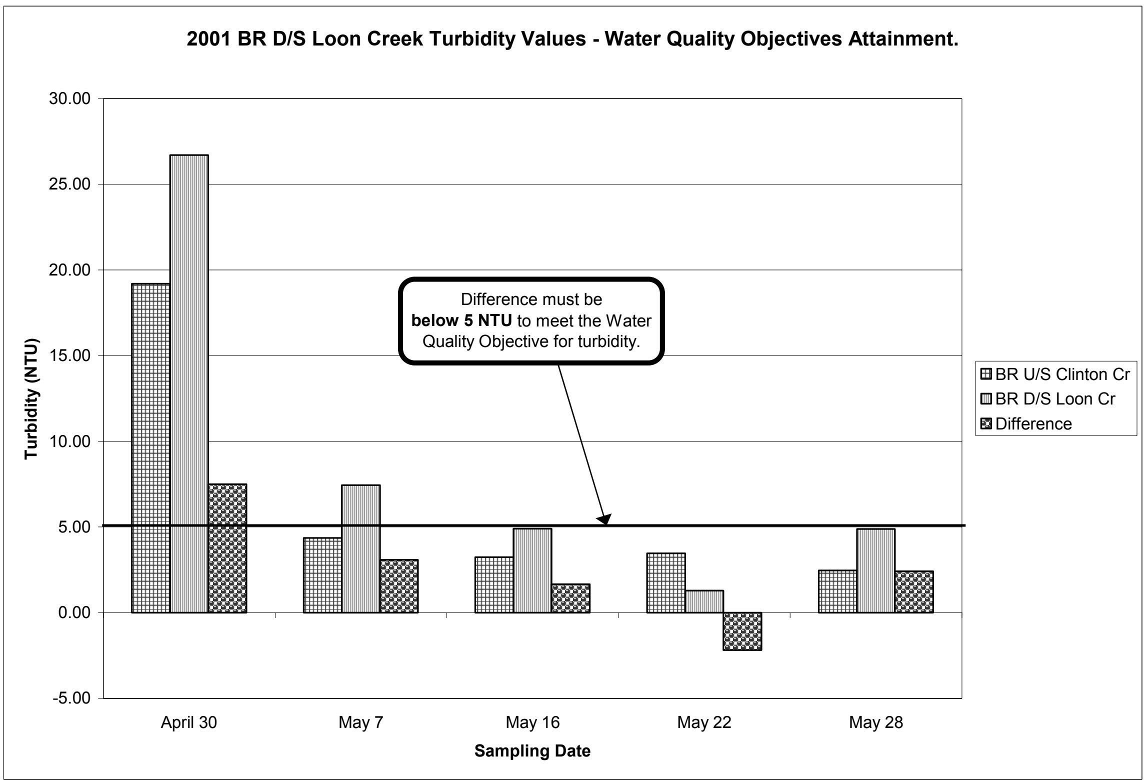


**Figure 8: A comparison of turbidity levels by date between the control site (BR U/S Clinton Creek) and BR D/S Loon Creek in 2001.**

In 2001, all sites exhibited a U-shaped trend, with large decreases in turbidity levels between April 30th and May 7th. (Note: BR D/S Loon Creek is not included in this discussion). This trend in turbidity largely reflects the discharge trend (refer to Figure 4). There was an increase in discharge from May 22nd to May 25th which is likely the cause for the turbidity levels increasing slightly at all sites on May 28th. All sites were above the acceptable turbidity levels for all sampling dates with the exception of May 22nd which saw three sites meeting the water quality objective (only BR D/S Cache Creek did not meet the objective on this sampling date). Clinton Creek D/S Lagoons showed the same U-shaped trend, although all of the turbidity values were well below the acceptable limits.

## 2002 Results

In 2002, the differences in turbidity levels between the control site and the BR D/S Loon Creek site rose as freshet continued. This differed from 2001 data which showed that the differences decreased over the first four weeks and then increased on the last sampling date. (It must be remembered that the locations were sampled weekly, which means that there may be fluctuations between these sampling days.) Figure 9 illustrates these changes in turbidity.

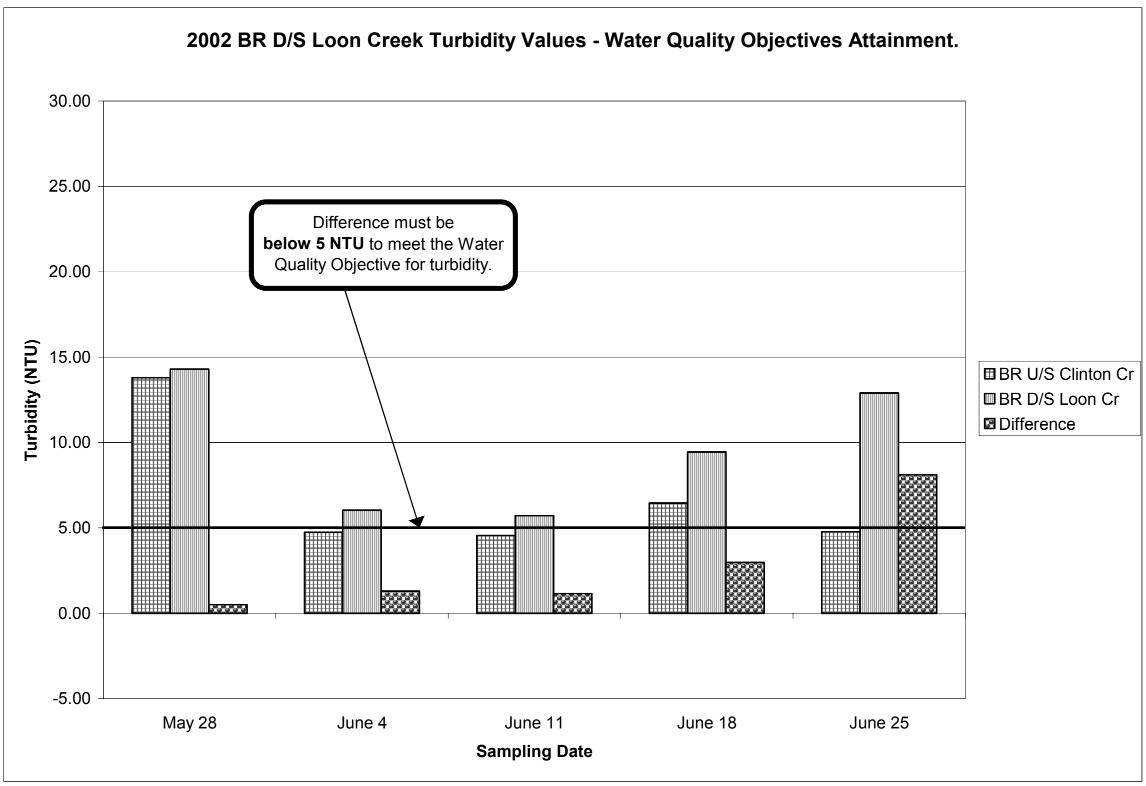


**Figure 9: A comparison of turbidity levels by date between the control site (BR U/S Clinton Creek) and BR D/S Loon Creek in 2002.**

In 2002, all sites (except BR U/S Cache Creek) showed a distinct downward trend in turbidity levels, which mirrored the continuous downward trend in discharge (refer to Figure 5). Overall, the BR U/S Cache Creek site also exhibited this same downward turbidity trend, with the exception of June 4th which had a slightly lower turbidity value than June 11th. All sites along the Bonaparte River were above the acceptable objective limit in 2002. The Clinton Creek D/S Lagoons site showed an overall increasing trend in turbidity levels (which is opposite to the sites along the Bonaparte River), but levels were all within the acceptable objectives limit.

Detailed turbidity values can be seen in Appendix A. Also, similar graphs for each sampling location can be seen in Appendix B, in addition to summary graphs comparing turbidity levels of all sampling sites by sampling date.

## 4.0 Conclusion

Monitoring water quality in rivers is very important, especially in rivers which have multiple users and stakeholders. The water from the Bonaparte River watershed is an important resource which is used by many for numerous purposes including irrigation, livestock watering, contact recreation, drinking water, wildlife, and aquatic biota. At several sites, the water quality objectives were not met for several parameters which would limit the use of the Bonaparte River water or impact aquatic life. The possible impacts of two sewage treatment facilities, a large-scale landfill, cattle grazing, riparian vegetation destruction, and forestry on this watershed could be increasingly harmful if care is not taken. Continued efforts should be made to improve water quality in the Bonaparte River. Yearly monitoring of the Bonaparte River should continue in order to make certain that no detrimental contaminants or changes to water quality occur which would negatively impact the users of this valuable resource.

## 5.0 References


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## APPENDIX A

## Water Quality Objectives Tables

**Table 1: Fecal coliform results for the Bonaparte River and its tributaries.**

Variable and Objective:

| **Fecal coliforms: ≤100 MPN/100mL, 90th percentile (drinking water objective)** |
|---|

| SITE | n | RESULTS RANGE | | OBJECTIVES | |
|---|---|---|---|---|---|
| | | 2001 | 2002 | 2001 | 2002 |
| **BR U/S Clinton Cr 0600017** | 5 | 10 - 44/100mL np = 39.6/100mL | 4 - 56/100mL np = 46.8/100mL | met | met |
| **Clinton Cr U/S Lagoons 0600503** | 5 | 4 - 140/100mL np = 98/100mL | 33 - 341/100mL np = 253.8/100mL | met | not met |
| **Clinton Cr D/S Lagoons 0600258** | 5 in 2001 4 in 2002 | 2 - 52/100mL np = 43.2/100mL | 62 - 487/100mL np = 383.2/100mL | met | not met |
| **BR D/S Loon Cr E207297** | 5 | 5 - 30/100mL np = 27.2/100mL | 16 - 92/100mL np = 72.8/100mL | met | met |
| **BR D/S Hat Cr E207291** | 5 | 17 - 140/100mL np = 103.2/100mL | 30 - 82/100mL np = 75.2/100mL | not met | met |
| **BR U/S Cache Cr STP 0600506** | 5 | 21 - 200/100mL np = 188/100mL | 24 - 156/100mL np = 120/100mL | not met | not met |
| **BR D/S Cache Cr STP 0600508** | 5 | 24 - 290/100mL np = 250/100mL | 58 - 174/100mL np = 168.4/100mL | not met | not met |
| **BR Near Mouth 0600329** | 5 | 25 - 200/100mL np = 139.2/100mL | 84 - 156/100mL np = 146/100mL | not met | not met |

**Table 2: Fecal coliform results for Loon Lake.**

Variable and Objective:

| |
|---|
| **Fecal coliforms: ≤200 MPN/100mL, geometric mean; ≤400 MPN/100mL, 90th percentile (bathing beaches objective)** |

| SITE | n | RESULT | | OBJECTIVES | |
|---|---|---|---|---|---|
| | | 2001 | 2002 | 2001 | 2002 |
| **Loon Lake, Provincial Park beach E207959** | 1 | 2 CFU/100mL | 22 CFU/100mL | met | met |

**Table 3: pH results for the Bonaparte River and its tributaries.**

Variable and Objective:

| |
|---|
| **pH: 6.5 to 8.5, 6.5 to 9.0** |

| | SITE | n | RESULTS RANGE | | OBJECTIVES | |
|---|---|---|---|---|---|---|
| | | | 2001 | 2002 | 2001 | 2002 |
| **pH** 6.5 to 8.5 | **BR U/S Clinton Cr 0600017** | 5 | 7.79 - 8.33 | 8.1 - 8.3 | met | met |
| | **Clinton Cr U/S Lagoons 0600503** | 5 | 8.39 - 8.46 | 8.3 - 8.4 | met | met |
| | **Clinton Cr D/S Lagoons 0600258** | 5 | 8.36 - 8.44 | 8.2 - 8.4 | met | met |
| | **BR D/S Loon Cr E207297** | 5 | 8.34 - 8.41 | 8.0 - 8.3 | met | met |
| | **BR D/S Hat Cr E207291** | 5 | 8.28 - 8.32 | 8.1 - 8.3 | met | met |
| 6.5 to 9.0 | **BR U/S Cache Cr STP 0600506** | 5 | 8.12 - 8.32 | 8.2 - 8.3 | met | met |
| | **BR D/S Cache Cr STP 0600508** | 5 | 8.27 - 8.31 | 8.1 - 8.3 | met | met |
| | **BR Near Mouth 0600329** | 5 | 8.27 - 8.39 | 8.2 - 8.4 | met | met |

**Table 4: Un-ionized ammonia results for the Bonaparte River and its tributaries.**

Variable and Objective:

| Un-ionized ammonia: ≤0.007 mg/L average, 0.03 mg/L max. |
|---|

| SITE | n | RESULTS RANGE | | OBJECTIVES | |
|---|---|---|---|---|---|
| | | 2001 | 2002 | 2001 | 2002 |
| BR U/S Clinton Cr 0600017 | 5 | <.000119 - .000350 mg/L | <0.005 mg/L | met | met |
| Clinton Cr U/S Lagoons 0600503 | 5 | NA | <0.005 mg/L | NA | met |
| Clinton Cr D/S Lagoons 0600258 | 5 | .000385 – .000943 mg/L | 0.0003 – 0.0021 mg/L | met | met |
| BR D/S Loon Cr E207297 | 5 | .000264 – .000402 mg/L | <0.005 mg/L | met | met |
| BR D/S Hat Cr E207291 | 5 | <.000184 - .000981 mg/L | <0.005 mg/L | met | met |
| BR U/S Cache Cr STP 0600506 | 5 | <.000251 - .000739 mg/L | <0.005 mg/L | met | met |
| BR D/S Cache Cr STP 0600508 | 5 | .000465 – .000720 mg/L | <0.005 mg/L | met | met |
| BR Near Mouth 0600329 | 5 | <.000257 - .000744 mg/L | <0.005 mg/L | met | met |

**Table 5: Turbidity**

Variable and Objective:

| |
|---|
| **Turbidity: 5 NTU max increase when upstream is ≤50 NTU. 10% max increase when upstream is >50 NTU.** |

| SITE | n | RESULTS RANGE | RANGE IN DIFFERENCE FROM CONTROL SITE | RESULTS RANGE | RANGE IN DIFFERENCE FROM CONTROL SITE | OBJECTIVES | |
|---|---|---|---|---|---|---|---|
| | | 2001 | 2001 | 2002 | 2002 | 2001 | 2002 |
| **Clinton Cr U/S Lagoons 0600503** | 5 | 1.25 - 1.88 NTU | NA | 1.56 - 3.85 NTU | NA | control site | control site |
| **Clinton Cr D/S Lagoons 0600258** | 5 | 0.94 - 2.89 NTU | -0.52 - 1.64 NTU | 2.02 - 4.43 NTU | -0.83 - 0.83 NTU | met | met |
| **BR U/S Clinton Cr 0600017** | 5 | 2.46 - 19.2 NTU | NA | 4.55 - 13.8 NTU | NA | control site | control site |
| **BR D/S Loon Cr E207297** | 5 | 1.29 - 26.7 NTU | -2.18 - 7.5 NTU | 5.71 - 14.3NTU | 0.5 - 8.12 NTU | not met | not met |
| **BR D/S Hat Cr E207291** | 5 | 6.42 - 65.1 NTU | 2.95 - 45.9 NTU | 11.6 - 50.2 NTU | 6.82 - 36.4 NTU | not met | not met |
| **BR U/S Cache Cr STP 0600506** | 5 | 5.27 - 71.4 NTU | 1.8 - 52.2 NTU | 15.9 - 78.6 NTU | 11.12 - 64.8 NTU | not met | not met |
| **BR D/S Cache Cr STP 0600508** | 5 | 11.8 - 72.9 NTU | 8.33 - 53.7 NTU | 20.5 - 79.8 NTU | 15.72 - 66.0 NTU | not met | not met |
| **BR Near Mouth 0600329** | 5 | 5.82 - 91.8 NTU | 2.35 - 72.6 NTU | 20.8 - 102 NTU | 16.02 - 88.2 NTU | not met | not met |

## APPENDIX B

# Water Quality Objectives Graphs

## Figures 1 – 12: Turbidity Graphs by Sampling Locations.

### BR D/S Loon Creek:

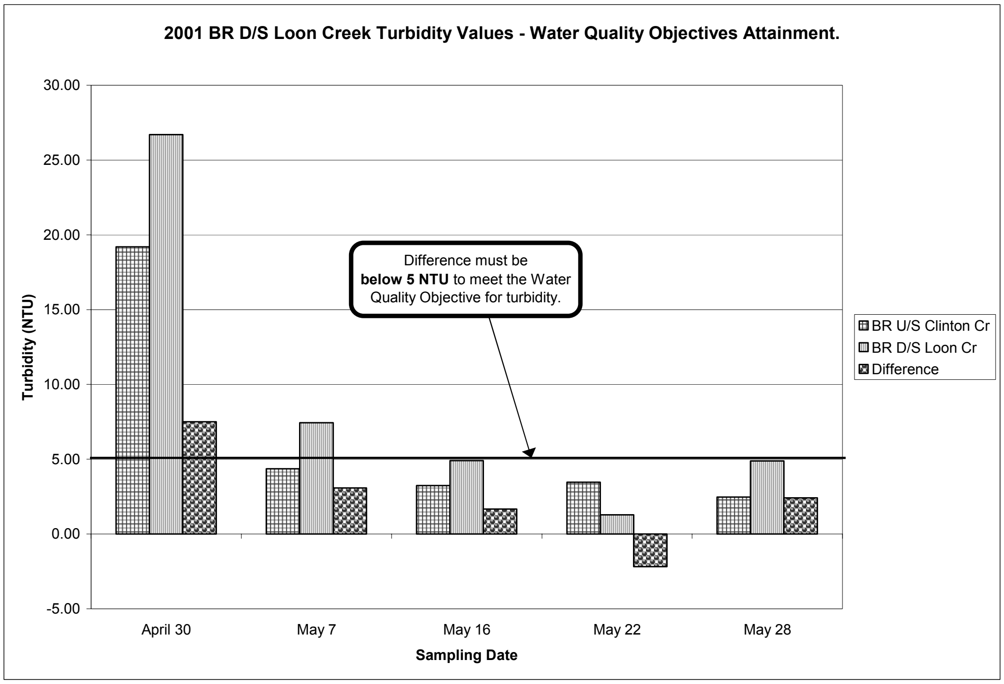



**Figure 1**

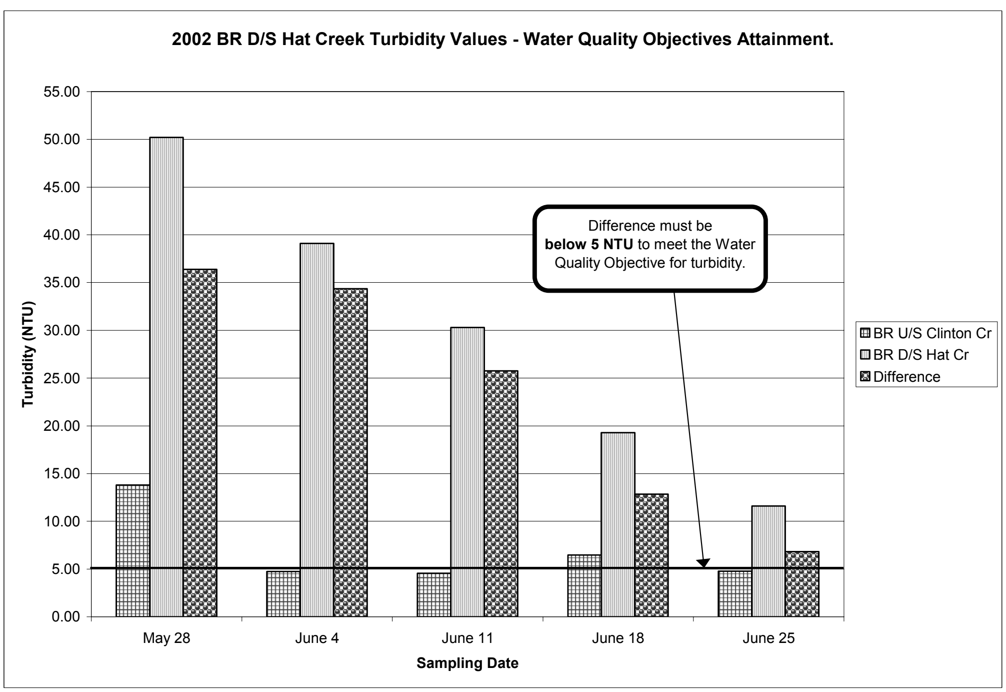



**Figure 2**

## BR D/S Hat Creek:

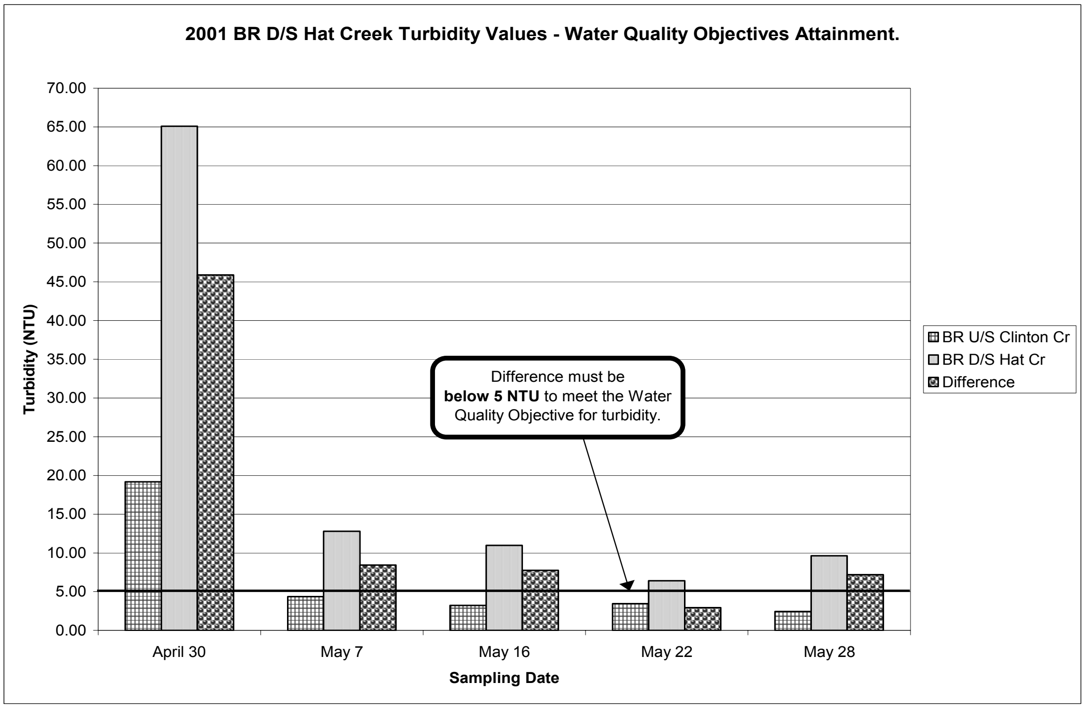



**Figure 3**

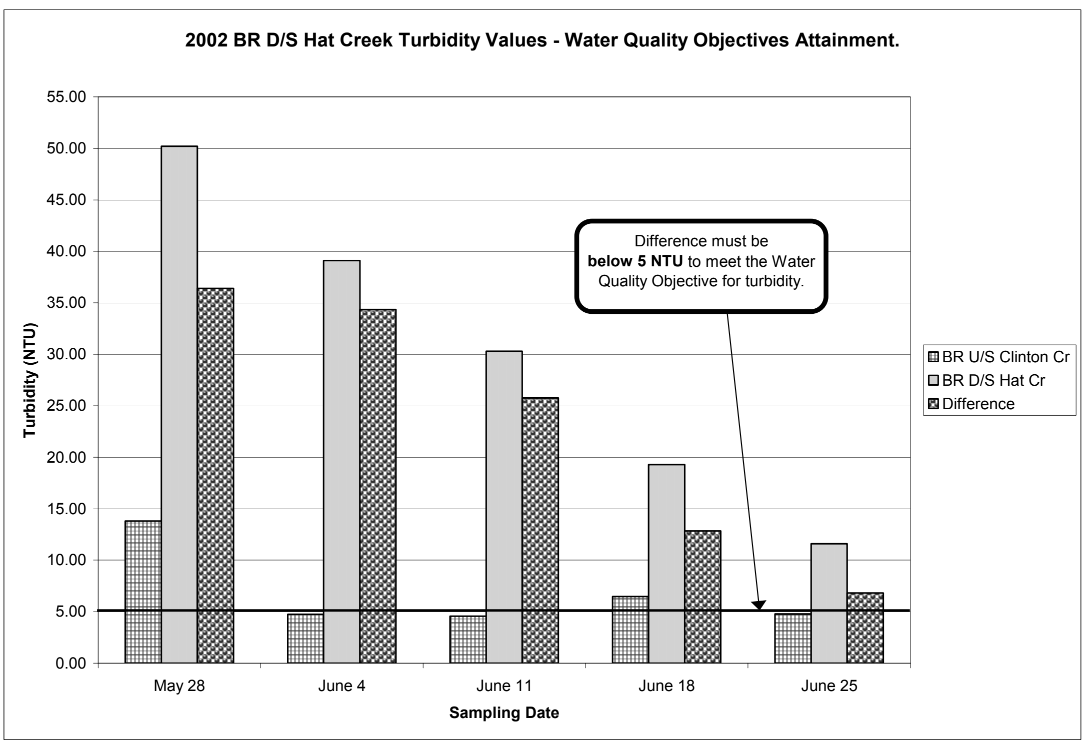



**Figure 4**

## BR U/S Cache Creek STP:

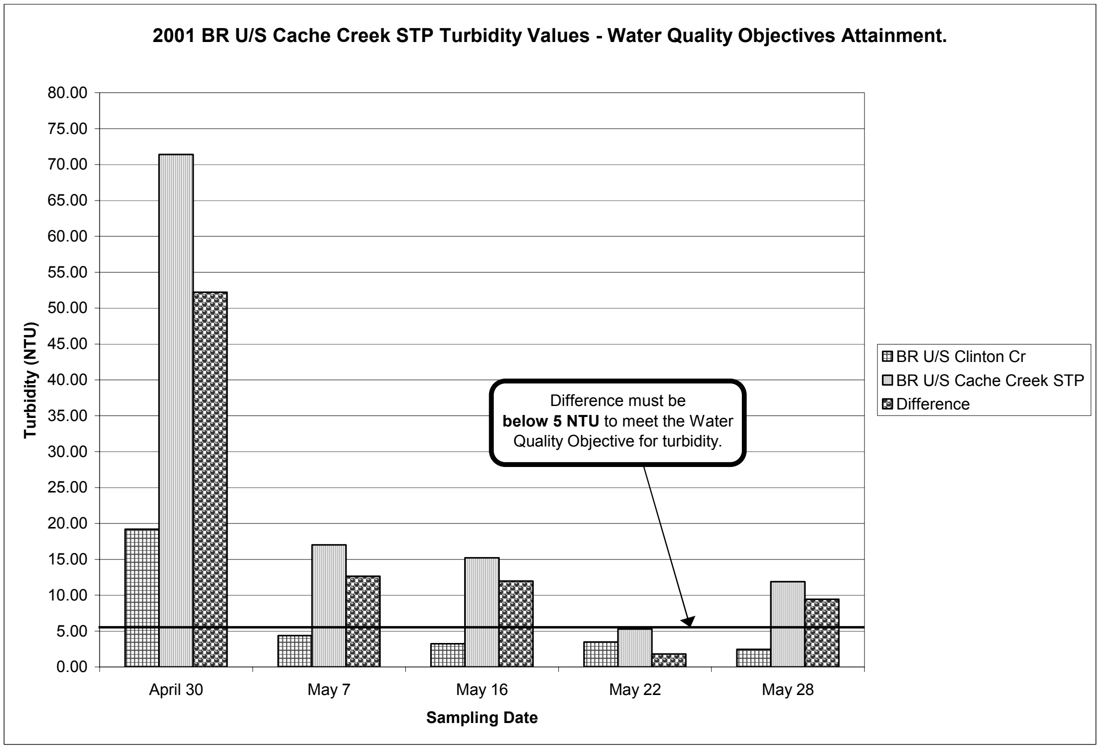



**Figure 5**

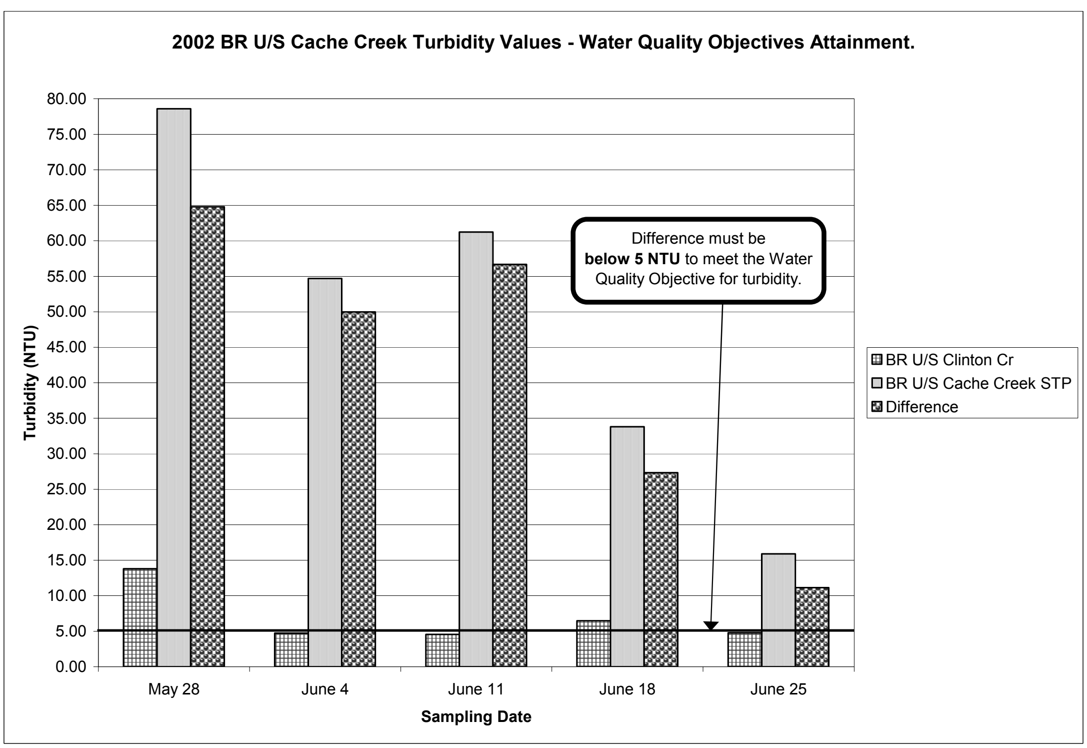



**Figure 6**

## BR D/S Cache Creek STP:

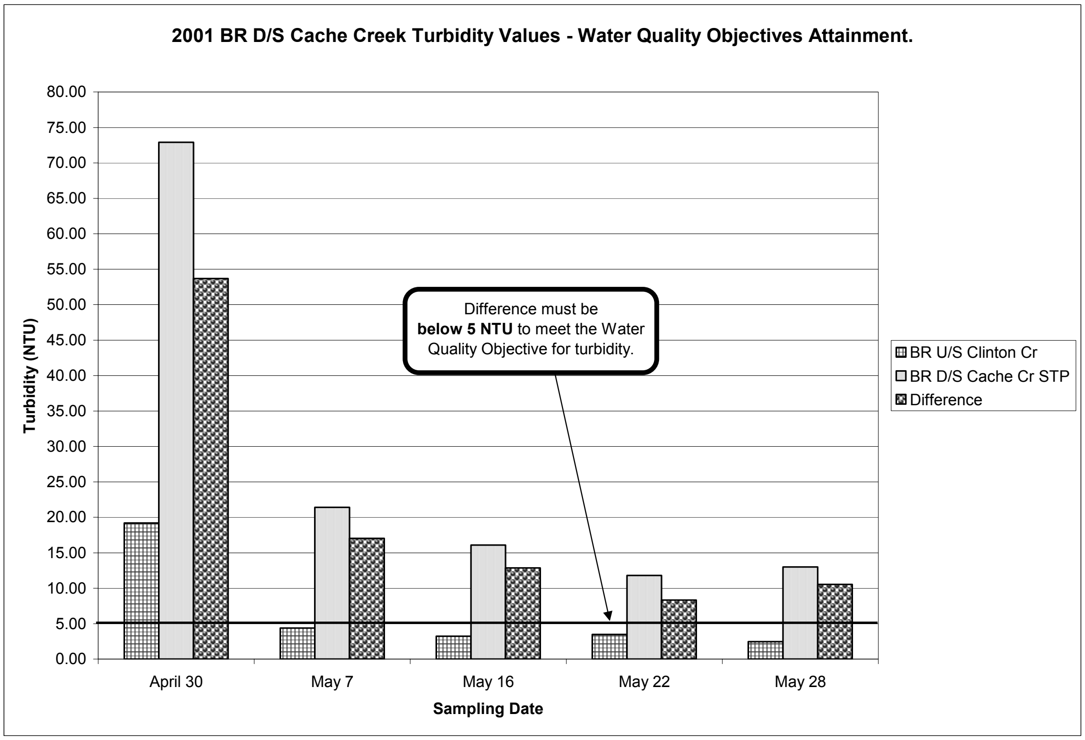



**Figure 7**

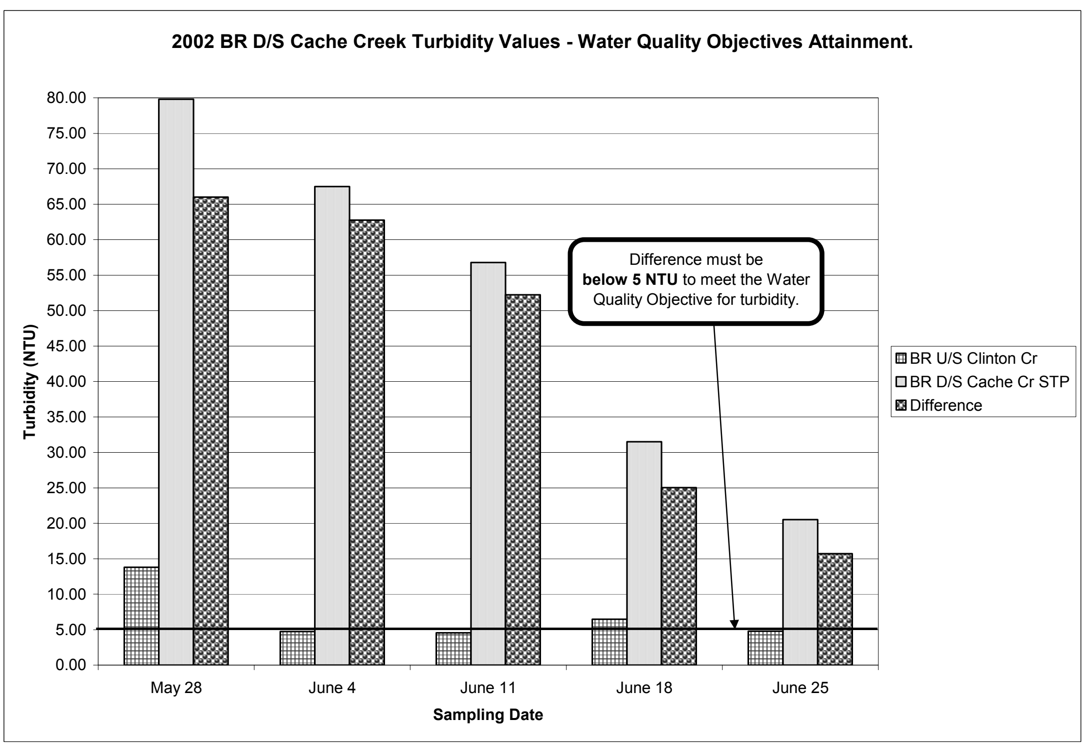



**Figure 8**

## BR Near Mouth:

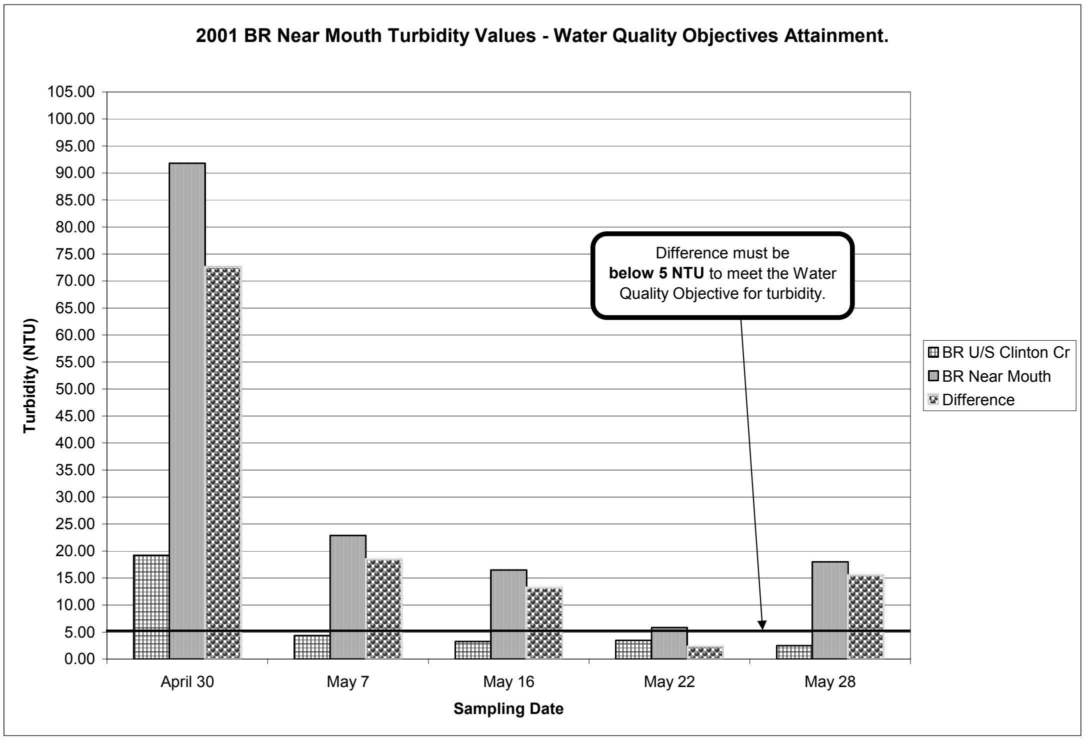



**Figure 9**

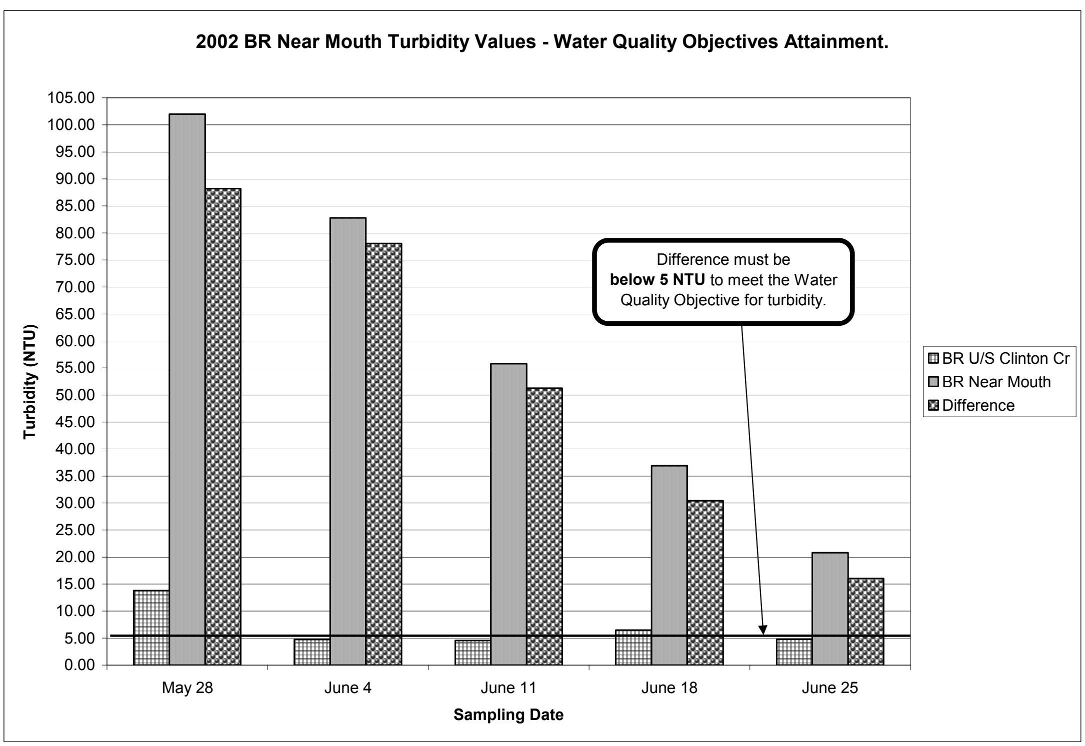



**Figure 10**

# BR D/S Clinton Creek Lagoons:

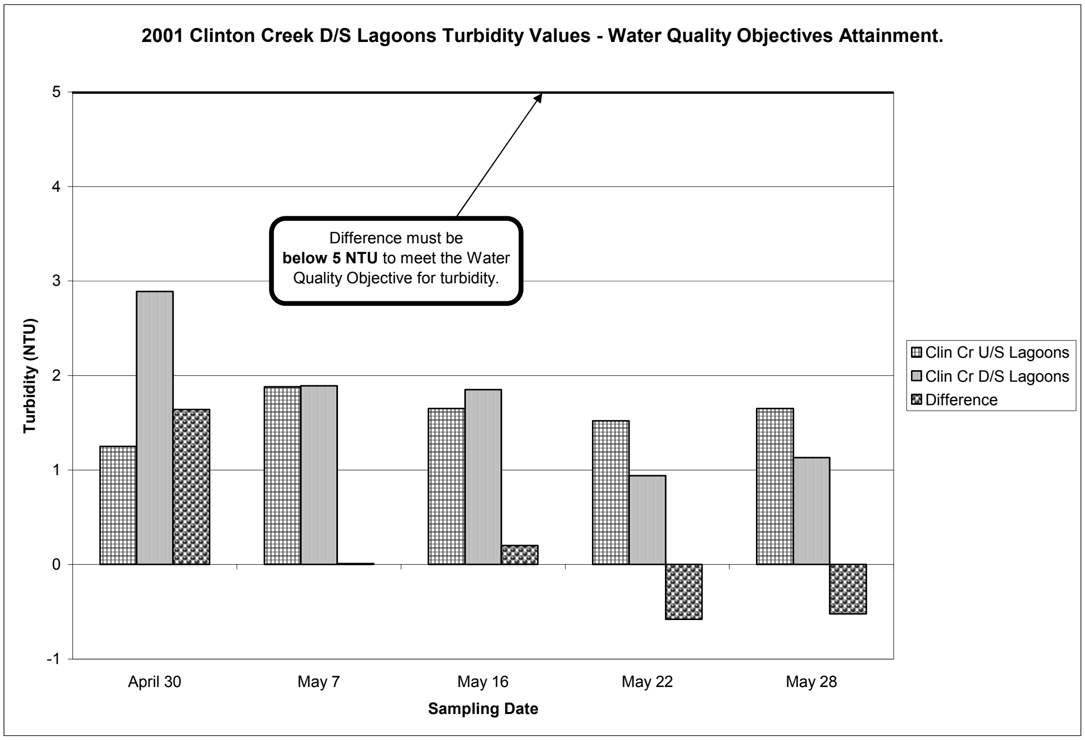



**Figure 11**

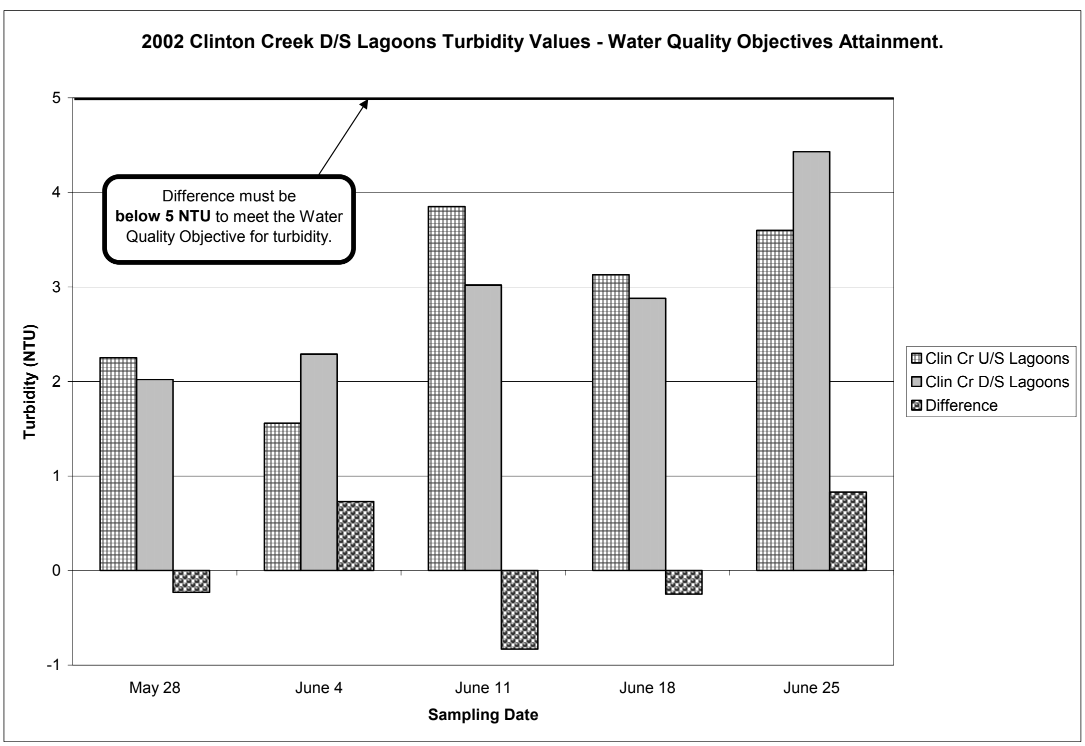



**Figure 12**

## Figures 13 - 14: Turbidity Graphs by Sampling Date (all Bonaparte River sites)

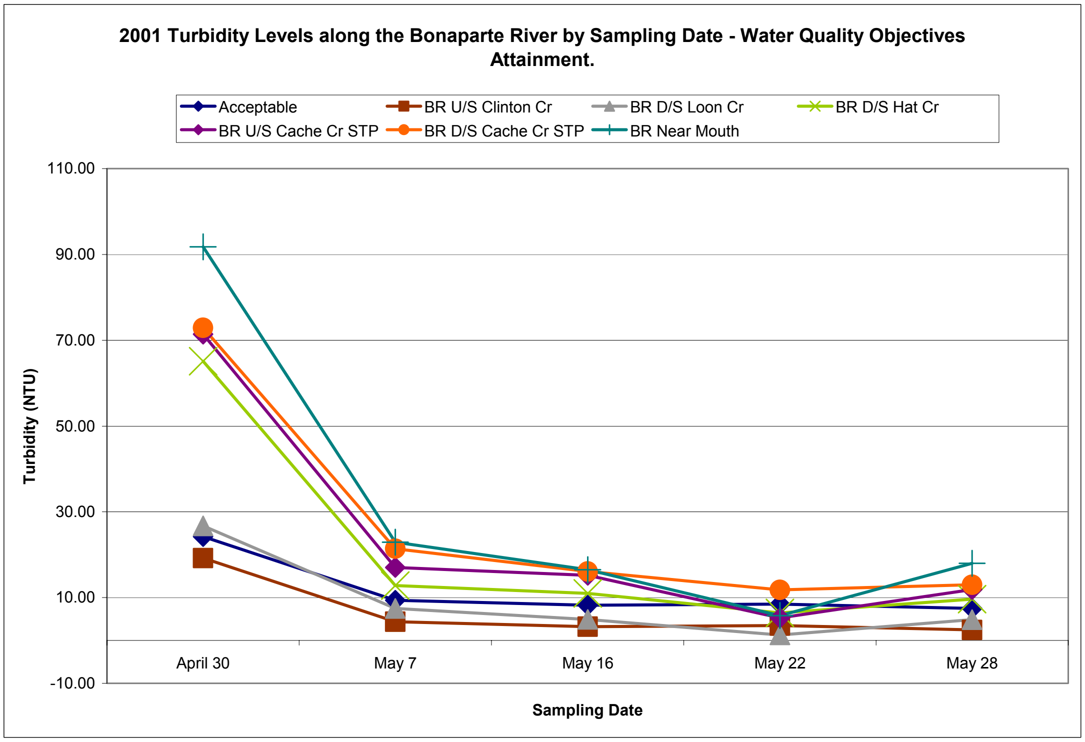



**Figure 13**

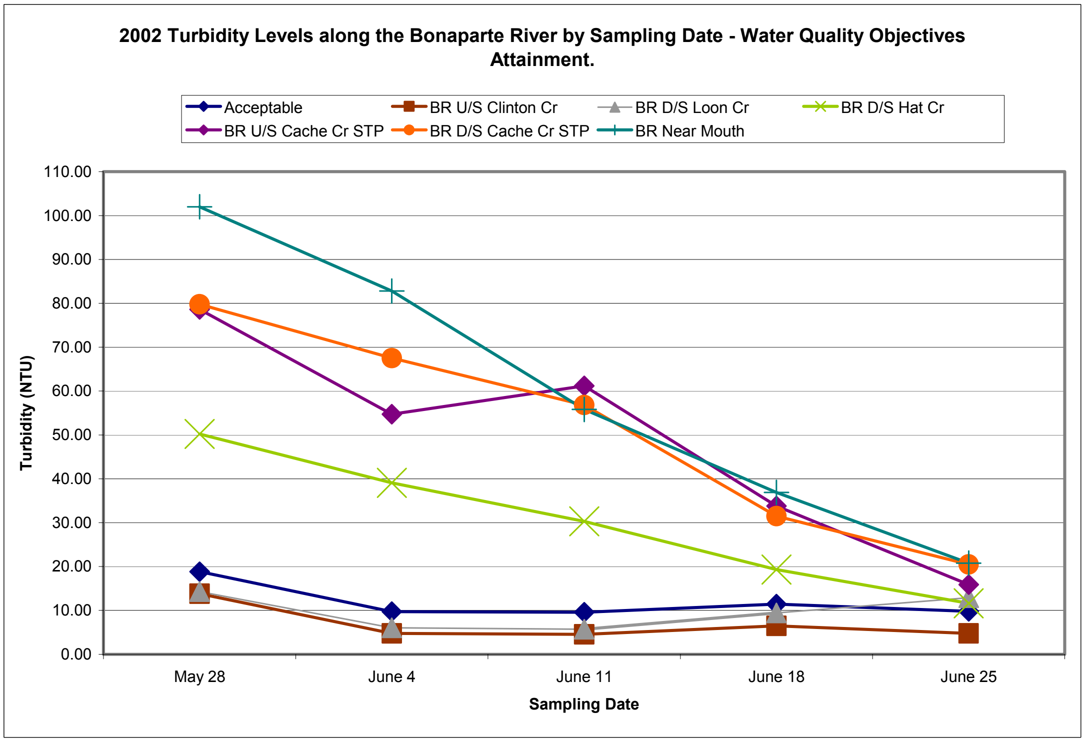



**Figure 14**

## Figures 15 - 16: Turbidity Graphs by Sampling Location (all Bonaparte River sites)

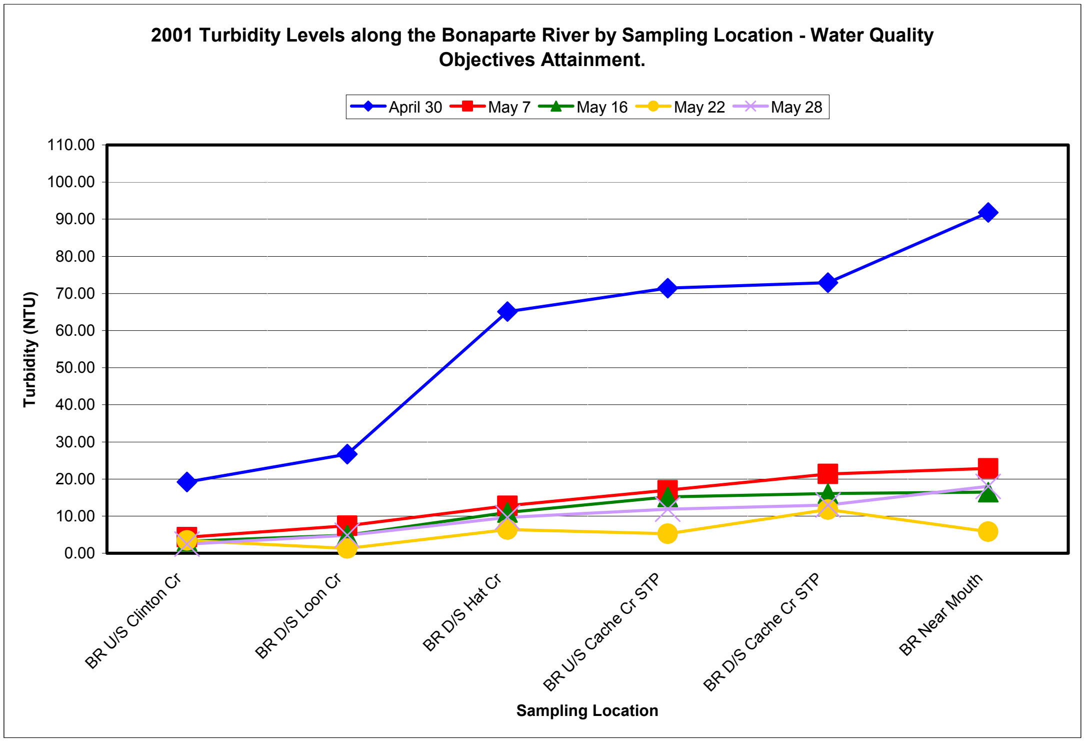



**Figure 15**

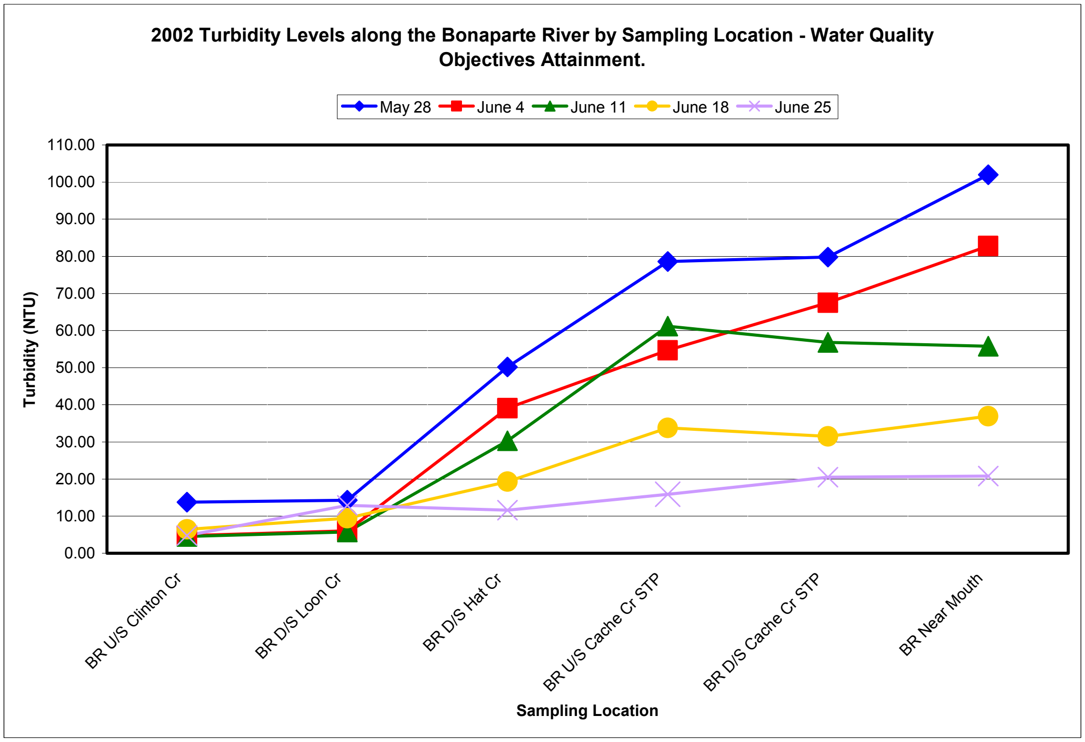



**Figure 16**

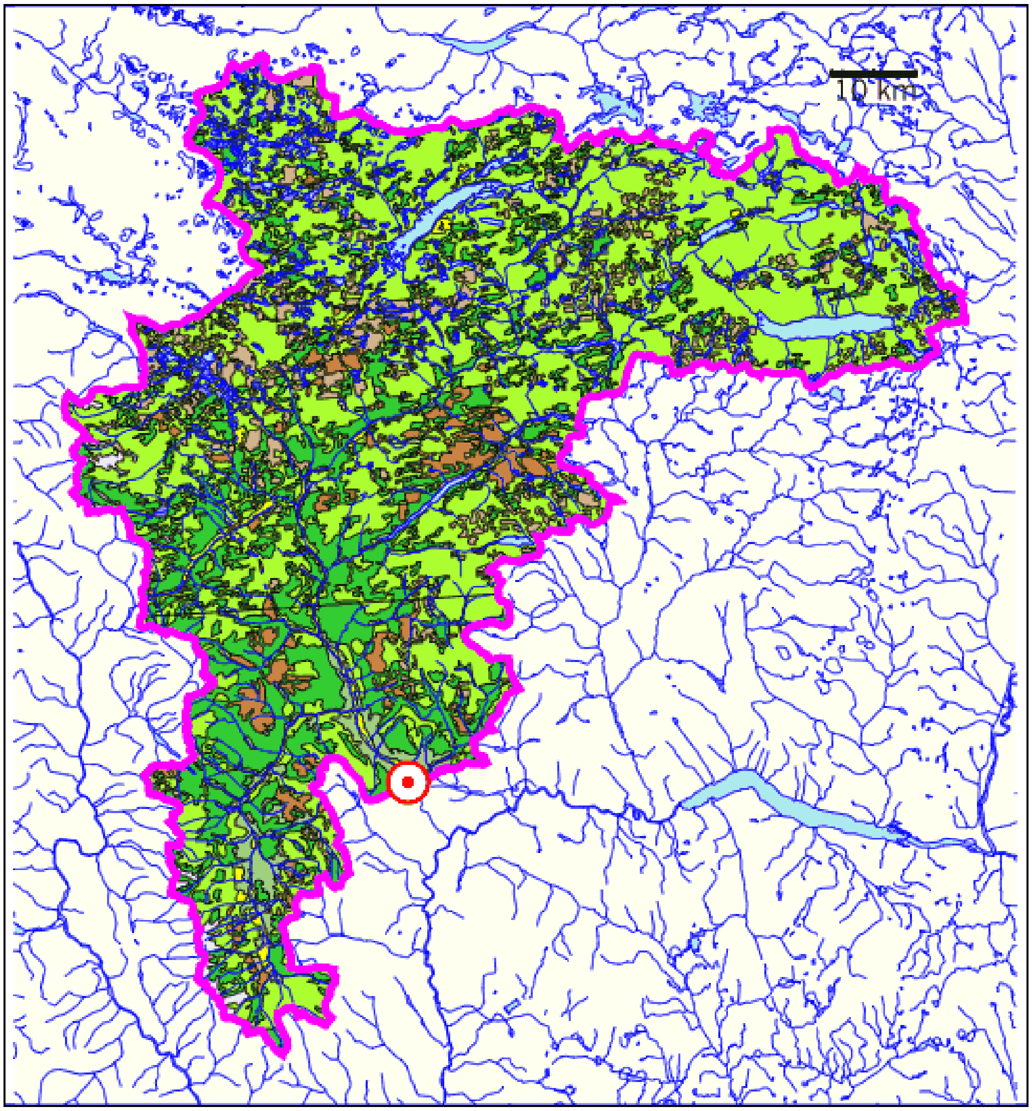
# APPENDIX C

## Additional Information

### Summary of the Effects of pH on Fish (Modified from CCREM, 1987)

| pH range | Effect |
|---|---|
| 3.0-3.5 | Unlikely that any fish can survive for more than a few hours in this range, although some plants and invertebrates can be found at pH values lower than this. |
| 3.5-4.0 | This range is lethal to salmonids. There is evidence that roach, tench, perch and pike can survive in this range, presumably after a period of acclimation to slightly higher, nonlethal levels, but the lower end of this range may still be lethal for roach. |
| 4.0-4.5 | Likely to be harmful to salmonids, tench, bream, roach, goldfish and common carp which have not previously been acclimated to low pH values, although the resistance to this pH range increases with the size and age of the fish. Fish can become acclimated to these levels, but of perch, bream, roach and pike, only the last named may be able to breed. |
| 4.5-5.0 | Likely to be harmful to the eggs and fry of salmonids, and to adults particularly in soft water containing low concentrations of calcium, sodium and chloride. Can be harmful to common carp. |
| 5.0-6.0 | Unlikely to be harmful to any species unless either the concentration of free carbon dioxide is greater than 20 $mg \cdot L^{-1}$, or the water contains iron salts which are freshly precipitated as ferric hydroxide, the precise toxicity of which is not known. The lower end of this range may be harmful to nonacclimated salmonids if the calcium, sodium and chloride concentrations or the temperature of the water are low, and may be detrimental to roach production. |
| 6.0-6.5 | Unlikely to be harmful to fish unless free carbon dioxide is present in excess of 100 $mg \cdot L^{-1}$. |
| 6.5-9.0 | Harmless to fish, although the toxicity of other poisons may be affected by changes within this range. |
| 9.0-9.5 | Likely to be harmful to salmonids and perch if present for a considerable length of time. |
| 9.5-10.0 | Lethal to salmonids over a prolonged period of time, but can be withstood for short periods. May be harmful to developmental stages of some species. |
| 10.0-10.5 | Can be withstood by roach and salmonids for short periods but lethal over a prolonged period. |
| 10.5-11.0 | Rapidly lethal to salmonids. Prolonged exposure to the upper limit of this range is lethal to carp, tench, goldfish and pike |
| 11.0-11.5 | Rapidly lethal to all species of fish. |

## Map of Landuse Types surrounding the Bonaparte River below Cache Creek Hydrometric Station. (From Environment Canada, 2003).




| Landuse Zones Legend | | |
|---|---|---|
| Urban | Young Forest | Alpine |
| Recreation Activities | Old Forest | Glaciers and Snow |
| Agriculture | Recently Logged | Estuaries |
| Residential Agriculture Mixtures | Selectively Logged | Wetlands |
| Mining | Recently Burned | Fresh Water |
| Rangelands | Sub-alpine Avalanche Chutes | Salt Water |
| Shrubs | Barren Surfaces | |