# APPENDIX E – HYALITE CREEK NUTRIENT LISTING HISTORY AND TMDL DEVELOPMENT

## TABLE OF CONTENTS



## LIST OF TABLES

# E1.0 Introduction

Hyalite Creek is located in the Lower Gallatin TMDL planning area in southwest Montana. The creek flows 36.8 miles from the headwaters in the Gallatin Range to the mouth at the East Gallatin River northeast of Belgrade, MT and drains an area of 108.38 square miles. The Creek contains the Middle Creek (Hyalite) Reservoir in the upper portion of the waterbody.

The purpose of this appendix is to outline the impairment listing history to date and the reasoning and support behind the decision to address a nutrient impairment on the lower segment of Hyalite Creek only. This document will provide a summary of existing conditions on Hyalite Creek and how impairment determinations were made using the best available and most recent water quality data.

# E2.0 Listing History – Nutrient Impairments

Prior to the 2010 303(d) List, Hyalite Creek was dived into 2 assessment units. The downstream boundary of the upper segment and start of the lower segments split being the location the city of Bozeman water supply diversion ditch.

Upper Hyalite Creek was first listed for nutrient impairments in 2006 with the 303(d) List identifying Total Kjeldahl Nitrogen, Total Phosphorous and chlorophyll-*a* as impairing contact recreation, coldwater fishery and aquatic life uses. The listing was based on water quality, macroinvertebrate and chlorophyll-*a* data collected in 2004. Impairment sources were identified as grazing, unpaved roads and silviculture/harvesting activities. For nutrient impairments, numeric criteria are used to interpret the narrative standard. The numeric criteria used in the assessment was 0.30 mg/L TKN and 0.03 mg/L TP. Impairment determinations did not change for either segment on the 2008 303(d) List except for chlorophyll-*a* which was delisted from the upper segment.

For the 2010 303(d) List, the upper segment of Hyalite Creek was split into the segment above Hyalite Reservoir (Upper) and the segment downstream of the Reservoir to the city of Bozeman waters supply diversion ditch (Middle). The segment was split because it was thought that the reservoir might be the source of the elevated TKN and TP concentrations in Hyalite Creek below the reservoir outlet. The lower segment of Hyalite Creek was not changed.

# E3.0 2011 Assessment of Hyalite Creek

In the summer of 2011, Hyalite Creek in its entirety (upper, middle, and lower segments) was re-assessed using data collected from 2008 to 2011 for water quality, macroinvertebrates and chlorophyll-*a*. In 2011, draft numeric criteria for the Absaroka-Gallatin-Volcanic Level IV ecoregion for Total Nitrogen and Total Phosphorous were developed based on extensive research and sampling by personnel in the Water Quality Standards Section of the Water Quality Planning Bureau at Montana DEQ (**Table E-1**). Target values in the Hyalite Creek drainage increased from 0.030 mg/L TP to 0.130 mg/L TP and TN targets decreased from 0.300 mg/L TN to 0.250 mg/L. The TN target value was lowered to reflect that N becomes the most limiting nutrient in a P-rich system such as the Absaroka-Gallatin-Volcanic level IV ecoregion.

**Table E-1. Nutrient Targets* in the Lower Gallatin Project Area per Ecoregion**

| Parameter | Target values | |
|---|---|---|
| | **Middle Rockies (Level III)** | **Absaroka-Gallatin Volcanic Ecoregion (Level IV, within Middle Rockies)** |
| Nitrate+Nitrite ($NO_3$+$NO_2$) | ≤ 0.100 mg/L | ≤ 0.100 mg/L |
| Total Nitrogen (TN) | ≤ 0.300 mg/L | ≤ 0.250 mg/L |
| Total Phosphorous (TP) | ≤ 0.030 mg/L | ≤ 0.105 mg/L |
| Chlorophyll-*a* | ≤ 125 mg/m² (≤35 g AFDW/m$^2$) | ≤ 125 mg/m² (≤35 g AFDW/m$^2$) |

*see **Section 6.4** for the adaptive management strategy for nutrient targets
AFDW = ash-free dry weight

Although only the upper segment of Hyalite Creek is within the Absaroka-Gallatin-Volcanic Level IV ecoregion, all three segments were assessed using the Absaroka-Gallatin-Volcanic target criteria for TN and TP. Hyalite Creek is a gaining stream until it hits the Bozeman Fan in the Gallatin valley where is dominantly a losing stream recharging the shallow, alluvial aquifer. Given the hydrology of Hyalite Creek, Absaroka-Gallatin-Volcanic target criteria were applied to all three reaches.

## E3.1 Upper Hyalite Creek

The upper segment of Hyalite Creek is listed on the 2012 303(d) List for Total Nitrogen and Total Phosphorous nutrient impairments. Upper Hyalite Creek is located in the Absaroka-Gallatin-Volcanic Level IV ecoregion and flows 7.0 miles from the Headwaters in the Gallatin National Forest to the top of Hyalite Reservoir. This ecoregion in the Level III Middle Rockies has documented natural sources of phosphorous and therefore has target values for TN and TP different than other Level IV ecoregions within the Middle Rockies (**Table E-1**).

The original segment of Hyalite Creek (MT41H003_131) from the headwaters to the Bozeman water supply diversion ditch was first listed in 2006 for nutrient impairments based on nutrient, chlorophyll-*a* and macroinvertebrate sampling in 2004. In the 2010 303(d) List, Hyalite Creek was split into 2 segments (MT41H003_131 split into MT41H003_129 and MT41H003_130) and the TKN and TP nutrient impairments were assigned to both segments.

Extensive water quality sampling was conducted in the summer of 2012 in order to complete a full assessment. In examining **Tables E-2 and E-3**, there were no exceedances of the target values for $NO_3$+$NO_2$, TN or TP and all chlorophyll-*a* and AFDW data point were below the target criteria. Macroinvertebrate samples (*n*=2) were collected in 2004 and 2007. Both have HBI scores much less than 4. This complete assessment determined that the upper segment of Hyalite Creek is not impaired by nutrients.

**Table E-2. Nutrient Data Summary for Upper Hyalite Creek**

| Nutrient Parameter | Sample Timeframe | n | min | max | mean | 80$^{th}$ percentile |
|---|---|---|---|---|---|---|
| Nitrate+Nitrite | 2004-2012 | 14 | <0.05 | 0.09 | <0.05 | <0.05 |
| TN | 2004-2012 | 13 | <0.01 | 0.04 | <0.01 | <0.01 |
| TP | 2004-2012 | 14 | 0.03 | 0.055 | 0.045 | 0.052 |
| Chlorophyll-*a* | 2004, 2012 | 5* | NA | NA | 0.1 | NA |
| AFDW | 2012 | 5** | NA | NA | NA | NA |
| Macroinvertebrate HBI | 2004-2007 | 2 | 1.669 | 1.691 | NA | NA |

*4 of 5 chl *a* samples were visual assessments; **all AFDW were visual assessments and were <35

**Table E-3. Assessment Method Evaluation Results for Upper Hyalite Creek**

| Nutrient Parameter | n | Target Value (mg/l) | Target Exceedances | Binomial Test Result | T-test Result | Chl-*a* Test Result | Indicates Impairment? |
|---|---|---|---|---|---|---|---|
| Nitrate+Nitrite | 14 | 0.100 | 0 | PASS | PASS | PASS | NO |
| TN | 13 | 0.250 | 0 | PASS | PASS | PASS | NO |
| TP | 14 | 0.130 | 0 | PASS | PASS | PASS | NO |

## E3.2 MIDDLE HYALITE CREEK

The middle segment of Hyalite Creek is listed on the 2012 303(d) List for Total Nitrogen and Total Phosphorous nutrient impairments. The middle segment of Hyalite Creek is located in the Absaroka-Gallatin-Volcanic Level IV ecoregion and flows 8.8 miles from the Hyalite Reservoir outlet to the Bozeman water supply diversion ditch. This ecoregion in the Level III Middle Rockies has documented natural sources of phosphorous and therefore has target values for TN and TP different than other Level IV ecoregions within the Middle Rockies ecoregion (**Table E-1**).

The original segment of Hyalite Creek (MT41H003_131) from the headwaters to the Bozeman water supply diversion ditch was first listed in 2006 for nutrient impairments based on nutrient, chlorophyll-*a* and macroinvertebrate sampling in 2004. In the 2010 303(d) List, Hyalite Creek was split into 2 segments (MT41H003_131 split into MT41H003_129 and MT41H003_130) and the TKN (now TN) and TP nutrient impairments were assigned to both segments.

Nutrient sampling on the middle segment was conducted between 2004 and 2011 (**Table E-4**). Sixteen samples were analyzed for TN and 17 for TP and for $NO_3$+$NO_2$. There were no exceedances of target values for TN or TP and only a single exceedance for $NO_3$+$NO_2$. Macroinvertebrate HBI ($n$=4) scores were <4. There were no AFDW data available for this segment. Of the 3 chlorophyll-*a* samples, one exceeded the criteria (>120 mg/$m^2$) (**Table E-5**).

In light of the well documented natural sources of phosphorous in the Absaroka-Gallatin-Volcanic Level IV ecoregion, a TP TMDL was deemed not necessary as detections were significantly below the target value. Natural phosphorous loads to the segment would imply that exceedances in the chlorophyll-*a* samples would be attributed to excess nitrogen as nitrogen would be the most limiting nutrient to primary production in this system. Further research determined that Hyalite Reservoir is a source of inorganic nitrogen to Hyalite Creek. For reasons that will be explained in the **Section E4.0**, the inorganic nitrogen concentrations in Hyalite Creek are considered to be naturally occurring according to state law regarding the ‘reasonable operation’ of dams built prior to 1971.

**Table E-4. Nutrient Data Summary for Middle Hyalite Creek**

| Nutrient Parameter | Sample Timeframe | n | min | max | mean | $80^{th}$ percentile |
|---|---|---|---|---|---|---|
| Nitrate+Nitrite | 2004-2011 | 17 | 0.005 | 0.104 | 0.026 | 0.028 |
| TN | 2004-2011 | 16 | 0.050 | 0.200 | 0.124 | 0.170 |
| TP | 2004-2011 | 17 | 0.042 | 0.086 | 0.062 | 0.071 |
| Chlorophyll-*a* | 2004-2008 | 3* | 0.4 | 175.0 | NA | NA |
| AFDW | NA | 0 | NA | NA | NA | NA |
| Macroinvertebrate HBI | 2004-2011 | 4 | 3.203 | 3.506 | 3.358 | 3.469 |

* The third observation was a visual estimate of < 50 mg/$m^2$ and was not included in the summary statistics.

**Table E-5. Assessment Method Evaluation Results for Middle Hyalite Creek**

| Nutrient Parameter | n | Target Value (mg/l) | Target Exceedances | Binomial Test Result | T-test Result | Chl-*a* Test Result | Indicates Impairment? |
|---|---|---|---|---|---|---|---|
| Nitrate+Nitrite | 17 | 0.100 | 1 | PASS | PASS | FAIL | NO |
| TN | 16 | 0.250 | 0 | PASS | PASS | FAIL | NO |
| TP | 17 | 0.130 | 0 | PASS | PASS | FAIL | NO |

## E3.3 Lower Hyalite Creek

The lower segment of Hyalite Creek is not listed on the 2010 303(d) List for nutrient impairment but is included in this review because data collected to assist with TMDL development for the Lower Gallatin watershed indicated elevated nutrient concentrations. The lower segment extends 21.0 miles from the Bozeman water supply diversion ditch to the mouth (East Gallatin River). The middle and upper segments of Hyalite Creek are located in the Absaroka-Gallatin-Volcanic Level IV ecoregion which has documented natural sources of phosphorous and therefore has target values for TN and TP different than other Level IV ecoregions within the Middle Rockies ecoregion (**Section 6**, **Table 6-2**). The lower segment does not fall within the Absaroka-Gallatin-Volcanic ecoregion but reflects targets for TN (0.260 mg/L) and TP (0.090 mg/L) due to the influence of natural sources of phosphorus from the upper drainage (**Section 6, Table 6-3**).

Nutrient data was collected each year from 2008 to 2011. Summary nutrient data statistics and assessment method evaluation results for the lower segment of the East Gallatin River are provided in **Tables E-6** and **E-7**, respectively. Nineteen samples were collected for TN, and 20 TP and $NO_3$+$NO_2$. TN had 12 exceedances and $NO_3$+$NO_2$ had 13 exceedances out of 20 samples and TP had 5 exceedances of the target. There is no AFDW data available for the segment. There were 2 chlorophyll-*a* samples collected and 4 macroinvertebrate samples collected in 2004-2011. None of the chlorophyll-*a* samples exceeded the target criteria but 2 of the 4 macroinvertebrate samples had an HBI score > 4. Both AFDW samples were below thresholds for impairment.

**Table E-6. Nutrient Data Summary for Lower Hyalite Creek**

| Nutrient Parameter | Sample Timeframe | n | min | max | mean | 80th percentile |
|---|---|---|---|---|---|---|
| Nitrate+Nitrite | 2004-2012 | 20 | <0.01 | 0.55 | 0.178 | 0.29 |
| TN | 2004-2012 | 19 | <0.05 | 1.91 | 0.452 | 0.598 |
| TP | 2008-2012 | 20 | 0.012 | 0.14 | 0.064 | 0.091 |
| Chlorophyll-*a* | 2008, 2012 | 4* | 15.8 | 83.6 | 41.2 | 59.9 |
| AFDW | 2008, 2012 | 2 | 24.2 | 37.1 | NA | NA |
| Macroinvertebrate HBI | 2009-2011 | 4 | 2.618 | 4.695 | 3.672 | 4.537 |

*The fourth sample was a visual estimate of <50.

**Table E-7. Assessment Method Evaluation Results for Lower Hyalite Creek**

| Nutrient Parameter | n | Target Value (mg/l) | Target Exceedances | Binomial Test Result | T-test Result | Chl-*a* Test Result | Indicates Impairment? |
|---|---|---|---|---|---|---|---|
| Nitrate+Nitrite | 20 | 0.100 | 13 | FAIL | FAIL | PASS | YES |
| TN | 19 | 0.260 | 12 | FAIL | FAIL | PASS | YES |
| TP | 20 | 0.090 | 5 | PASS | PASS | PASS | NO |

# E.4 MIDDLE CREEK (HYALITE) RESERVOIR

## E4.1 INTRODUCTION

The Middle Creek Reservoir Dam is an earthen dam with concrete panels on the downstream side. It is located 15 miles south of Bozeman on the Gallatin National Forest and is owned and managed by the Montana Department of Natural Resources (DNRC) under special permit with the United States Forest Service (USFS). Completed in 1951, the dam is 125 feet high from the downstream channel toe and 1,900 feet long. It has a storage capacity of 10,130 acre-feet at normal full pool covering 490 surface acres. The reservoir provides irrigation water for 73 farms and ranches and 1/3 of the drinking water supply to the city of Bozeman. The reservoir drains an area of 27.8 $mi^2$.

In 1991-1992, the principle spillway crest elevation was raised 8.2 feet which increased storage capacity from 8,393 to 10,130 acre feet. The reservoir is drained via a 5 foot diameter, steel-lined concrete conduit cast in place. The outlet is 600 feet long and drops 6.5 feet (slope = 0.01%). The inverted conduit discharge is 83 feet below the dam crest and is a bottom draw outlet.

## E4.2 LITERATURE REVIEW

***Marcus, M.D., 1989, Limnological Properties of a Rocky Mountain Headwater Reservoir, Water Resources Bulletin, American Water Resources Association, v.25, no. 1, pp. 15-25.***

In biweekly sampling of 3 equally spaced sites on Hyalite Reservoir from July through September 1976, the author observed total phosphorous concentrations averaged greater than twice the total nitrogen concentrations and the highest detections for both were in the near-bottom waters closest to the outlet. The author hypothesized that the enrichment of nitrogen concentrations in outflow over the inflow waters occurred from nitrogen fixation by *Aphanizomenon flos-aquae*.

Average concentrations of total phosphate in the deep-water measurements ranged from 0.54 – 0.78 mg/L. There were no significant differences by site or depth. Nitrate-N and nitrite-N averaged less than 0.06 mg/L in the bottom zone. In contrast, average ammonia-N in near-bottom waters near the outlet (0.36 mg $NH_3$-N /L) was approximately twice the concentrations for euphotic zone samples at the same location (0.16 mg $NH_3$-N /L). Nitrogen species increased in concentration with proximity to the outlet although only total nitrogen was significantly greater at the outlet ($P < 0.05$). Specific to the near-bottom sampling location near the outlet, slight trends in concentration of orthophosphate, total phosphate, ammonia, and total nitrogen were observed which peaked in the August 30$^{th}$ samples.

N:P ratios identified nitrogen as severely limiting primary production in Hyalite Reservoir. Algal bioassays conducted on Hyalite Creek downstream from the reservoir provided additional evidence of nitrogen limitation (Schillinger and Stuart, 1978).

The author proposed mechanisms to explain the elevated nutrients in reservoir outflows: (1) nitrogen fixation by blue-green algae; and (2) deep-water outlets continually discharge settling nutrients, elevating outflow over inflow concentrations. Nitrogen fixation by *Aphanizomenon flos-aquae* was suggested as the source of nitrogen enrichment in Canyon Ferry Reservoir (Rada, 1974, Rada and Wright, 1979). Blooms of *Aphanizomenon flos-aquae* were observed in Hyalite Reservoir. Decomposition of these algal blooms may be the principle source of N in reservoir outlet flow. Nitrogen and phosphorous species sample means were consistently the greatest at the sample location closest to the reservoir outlet.

Hyalite Reservoir is a mesotrophic, or naturally eutrophic lake. Nutrient enrichment in outflows are likely due to mineralization and leaching of nutrients from (1) sediments), (2) newly exposed shorelines, and/or (3) particles settled from the tophogenic zone.

***Marcus, M.D., 1980, Periphytic Community Response to Chronic Nutrient Enrichment by a Reservoir Discharge, Journal of Ecology, v. 61, no. 2, pp. 387-399***

*Abstract:* Periphytic communities were investigated using glass slide substrates at four sites downstream from the montane Hyalite Reservoir, Montana, USA. Comparison of the most upstream site with the three lower sites revealed that the discharges to Hyalite Creek stimulated periphytic productivity, increased periphytic proportions of chlorophyll-*a* in the organic accumulations, and increased diatom diversity and evenness. As nitrogen concentration was the only stream physiochemical parameter which correlated with periphytic variations, it is probable that ammonia-nitrogen discharged from the reservoir was the primary factor influencing periphyton growth.

***Marcus, M.d., J.E. Schillinger, and D.G. Stuart, 1978, Limnological Studies in Montana: Hyalite Reservoir and Responses of Lotic Periphyton to Deep-Water Discharges, Grazing and Logging, Report 92, Montana University Joint Water Resources Center, Bozeman, Montana.***

***The following is taken from the Montana Water Center Research Projects summaries:***

To develop limnological data for Hyalite Reservoir, a montane reservoir in Montana, physical, chemical and biological parameters were studied at three sites from 18 V to 16 X 76. During this period, physiochemical parameters and periphyton dynamics were also investigated at sites in Hyalite Creek, a tributary to Hyalite Creek, and Bozeman Creek to evaluate impacts from (1) deep-water reservoir discharges, (2) logging activities, and (3) cattle grazing. Highest mean nutrient concentrations in the reservoir occurred in the water mass nearest the outlet. Reservoir water-flow patterns were strongly influenced by wind action and the deep-water discharge. Highest chlorophyll-*a* concentrations and primary productivities occurred at the site nearest the dam. An *Aphanizomenon flos-aqae* bloom in the reservoir appeared to result from the combination of low nitrogen and low carbon-dioxide concentrations. Reservoir primary productivity was primarily nitrogen limited. Stream sites were also generally nitrogen limited. Reservoir discharges stimulated periphytic productivity, improved the physiological condition of the primary producers and increased diatom species diversity. These changes were primarily related to reservoir releases of nitrogen. Logging activities had no apparent impact on the periphyton. Cattle grazing increased periphytic productivity and decreased diatom diversity, compared to the control site. Periphyton growth can apparently be inhibited by possible toxins released from old growths on diatometers and low water temperatures.

## E4.3 Discussion of 'Naturally Occurring' Conditions

On the middle segment of Hyalite Creek, nutrient data collected between 2004 and 2011 yielded only a single target exceedance. The chlorophyll-*a* target of 125 mg/m$^2$ was exceeded in July 2004. There were no exceedances of TN, TP or $NO_3$+$NO_2$ using the draft numeric criteria for the Absaroka-Gallatin-Volcanic Level IV ecoregion. Macroinvertebrate HBI scores were less than the threshold and did not indicate a condition of impairment. A literature review implicated concentrations of ammonia-N from the outlet of

Hyalite Reservoir resulting in periphyton production immediately below the outlet. The system is characterized as being severely nitrogen limited. Inorganic forms of nitrogen such as Ammonia-N are readily available for uptake and in a P-rich system such as the Absaroka-Gallatin-Volcanic Level IV ecoregion even small additions of N propagate algal growth.

Hyalite Reservoir is operated for irrigation and for drinking water supply for the city of Bozeman. At full pool, it covers 490 surface acres and is drawn down throughout the summer and fall to meet demand in the valley. The dam is a deep bottom draw design. Total nitrogen near the outlet in deep water was significantly greater than total nitrogen in the eutrophic zone at the same location ($P < 0.05$). Based on data from Marcus, 1976, slight gains in nitrogen concentrations might be realized with a top draw design but this would elevate water temperature in the discharge by several degrees in late summer.

In examining the dam design and known operation and land management in the drainage area of the reservoir, the data analysis and literature review suggest that the dam is under reasonable operation and that changes to design and/or operation would significantly affect downstream water users to no or minimal benefit to water quality. Hyalite Reservoir was completed in 1951 and falls within the bounds of 17.30.602(19) which follows.

*From Administrative Rules of Montana 17.30.602(19) "Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil, and water conservation practices have been applied. Conditions resulting from the reasonable operation of dams in existence as of July 1, 1971, are natural.*

### E4.4 Research Conclusions

The middle segment of Hyalite Creek is listed on the 2012 303(d) List for Total Nitrogen and Total Phosphorous nutrient impairments. Data analysis and a literature review suggest that there is not a nutrient impairment and that the elevated chlorophyll-*a* observation from 2004 is a naturally occurring condition resulting from the reasonable operation of Hyalite Reservoir.

## E.5 Hyalite Creek Assessment Summary

The upper segment of Hyalite Creek was split prior to formalization of the 2010 303(d) List. When split, the nutrient impairments were assigned to each segment. In 2011, draft numeric criteria for the Absaroka-Gallatin-Volcanic Level IV ecoregion were used to assess all 3 segments of Hyalite Creek. There were no exceedances of target values for TN, TP or $NO_3$+$NO_2$ on the middle or upper segments of the creek. Combined with the understanding of the "naturally occurring" conditions caused by the reservoir, there was enough evidence to determine that the middle and upper segments are unimpaired by nutrients. A full assessment did indicate that the lower segment of Hyalite Creek is impaired for total nitrogen and a TN TMDL will be developed for this assessment unit.