East Gallatin Nutrient Monitoring Project:

Summary Report, 2017 Data Collection and 'Site H' Algal Spike

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Project Background

The Gallatin Local Water Quality District (GLWQD) led water quality data collection for a modeling effort by the City of Bozeman (the City) from 2014-2016. The purpose of the model is to understand the potential implications of Montana Department of Environmental Quality's (DEQ) Total Maximum Daily Load assessment on the City's Montana Pollutant Discharge Elimination System permit for their water reclamation facility (WRF) that discharges to the East Gallatin River, just north of Bozeman, Montana.

Modeling (by HDR of Missoula) has provided insight into nutrient processing within the river system and its potential responses to nutrient management activities. The modeling process employs the river and stream water quality model QUAL2K, which couples nutrient data with light, weather, topography, and other inputs to predict algal growth in reaches along the river continuum.

A project progress report by City of Bozeman staff at the GLWQD Board of Directors May 4, 2017 meeting included results that indicated a spike in algal density at 'Site H', a site on the main stem of the East Gallatin River approximately 13 miles downstream of the WRF **(Figure 1)**. Chlorophyll-*a* is a photosynthetic pigment that is isolated from algae samples and used to quantify algal density.

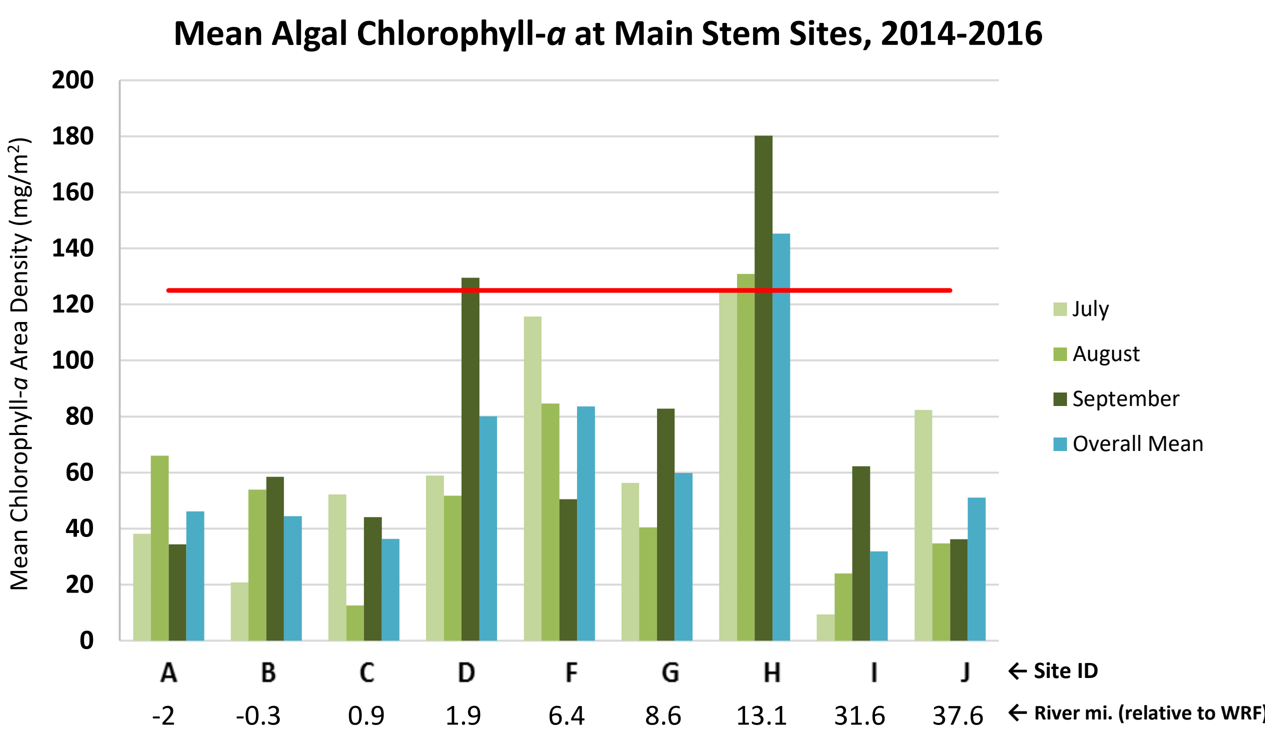

Figure 1. Mean monthly algal chlorophyll-*a* area densities are shown in green for the nine main stem sites (n≤3). The overall mean for the project period is shown in blue. The DEQ-recommended threshold value for chlorophyll-*a* density (125 mg/m²) is shown in red. This threshold is based on aesthetics, not health concerns. See Table 1 for sample collection schedule.

Discussion by the GLWQD board following the City's update led to a decision to collect additional data in 2017, focused on the reach immediately downstream of the WRF outfall and on sites bracketing Site H. These areas were chosen in order to provide additional data for model calibration. This report will briefly summarize relevant project data, discuss potential drivers indicated by the data, and suggest next steps to correct or further study the increased algal growth within the Site H reach.

2017 Data Collection

Data collection occurred monthly at two main stem sites bracketing Site H in June through October of 2017 **(Figure 2)**. Because the 2017 data was intended for model calibration, no additional data was collected at Site H in 2017. The sampling methods used were a subset of those used in previous project seasons, and included water chemistry sampling (total alkalinity, bicarbonate, carbonate, and carbonaceous biochemical oxygen demand), nutrient sampling (total nitrogen, nitrate, nitrite, organic nitrogen, total Kjeldahl nitrogen, ammonia, orthophosphate, total phosphorus, polyphosphate, and organic phosphorus), in-situ conditions via meter (water temperature, pH, specific conductance, dissolved oxygen, dissolved oxygen saturation), and streamflow. Data collection at the mouth of Trout Creek was also planned for the 2017 season, but site access could not be secured.

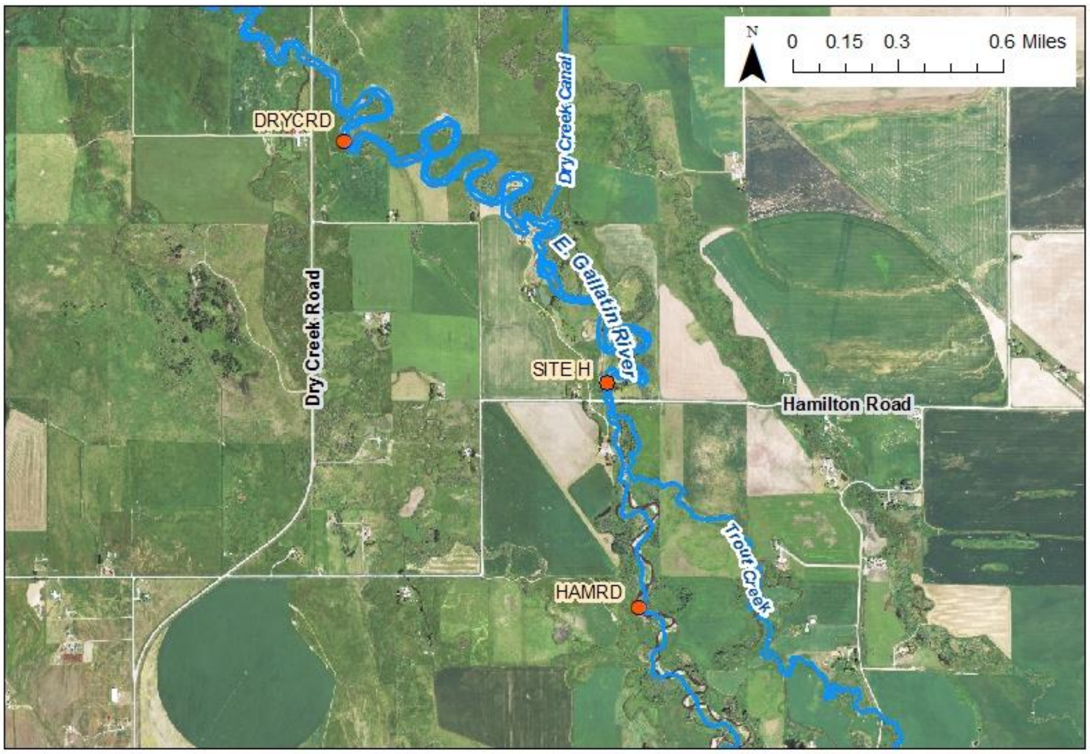

Figure 2. Map of 2017 study area. Data was collected at two sites (DRYCRD and HAMRD) bracketing Site H. No data was collected at Site H in 2017. Site access could not be secured for Trout Creek.

Results

It is important to note that data collection was not consistent at all sites for all years of the project. This means that any differences seen between sites could be influenced by confounding annual differences (intensity and timing of peak flow, water temperature, etc.). **Table 1** provides a summary of the project data collection schedule.

Table 1. Summary of project data collection schedule. X's indicate collection of nutrient grab and chlorophyll-*a* composite samples.

SITE	2014			2015			2016			2017		
	July	August	September	July	August	September	July	August	September	July	August	September
A				x	x	x		x				
B		x	x	x	x	x						
C		x	x	x	x	x						
D		x	x	x	x	x		x				
F		x	x	x	x	x						
G		x	x	x	x	x		x				
HAMRD										x	x	x
H		x	x	x	x	x		x				
DRYCRD										x	x	x
I		x	x	x	x	x		x				
J		x	x	x	x	x		x				
Tributaries								x	x			

2014-2016 data indicated that the area of increased algal growth was localized within the Site H reach **(Figure 1)**. 2017 data, collected at sites that more closely bracket Site H, appear to confirm the localized nature of the spike within Site H **(Figure 3)**.

Algal Growth: 2017 algal chlorophyll-*a* results from EGHAMRD and EGDRYCRD were well below the DEQ-recommended threshold value of 125 mg/m^2, and within the range seen at other main stem sites (except Site H) in other years **(Figure 3)**. There are no clear patterns in algal densities by month, but results were generally lower in 2015. With the exception of Site C (~0.9 river miles below WRF), the range of results seen at a single site across multiple years was generally lower above the WRF (Sites A-B) and at sites more than 30 river miles below the WRF (Sites I and J) than at sites immediately below the WRF (Sites D-H).

Single factor analysis of variance of all project algal chlorophyll-*a* data **(Figure 3)** indicates that one or more sites has a significantly different mean, and two-sample t-Tests ($\alpha = 0.05$) performed against Site A (used as a reference site/control) found only Site H to have significantly different algal density.

A 2016 DEQ report discussing the sample collection method, which entails collection of 11 subsamples that are composited for analysis based on the substrate present at the subsample location, lists an 80% confidence level that the measured value is within 30% of the true mean (Suplee and Sada de Suplee, 2016). The relative percent difference of means for all samples from Site A and Site H was 96.19%, indicating algal densities are probably higher at Site H, despite the 30% uncertainty inherent in the method. However, differences should be considered in light of the method's 80% confidence interval, which attempts to strike a balance between precision and the time and expense associated with sample collection.

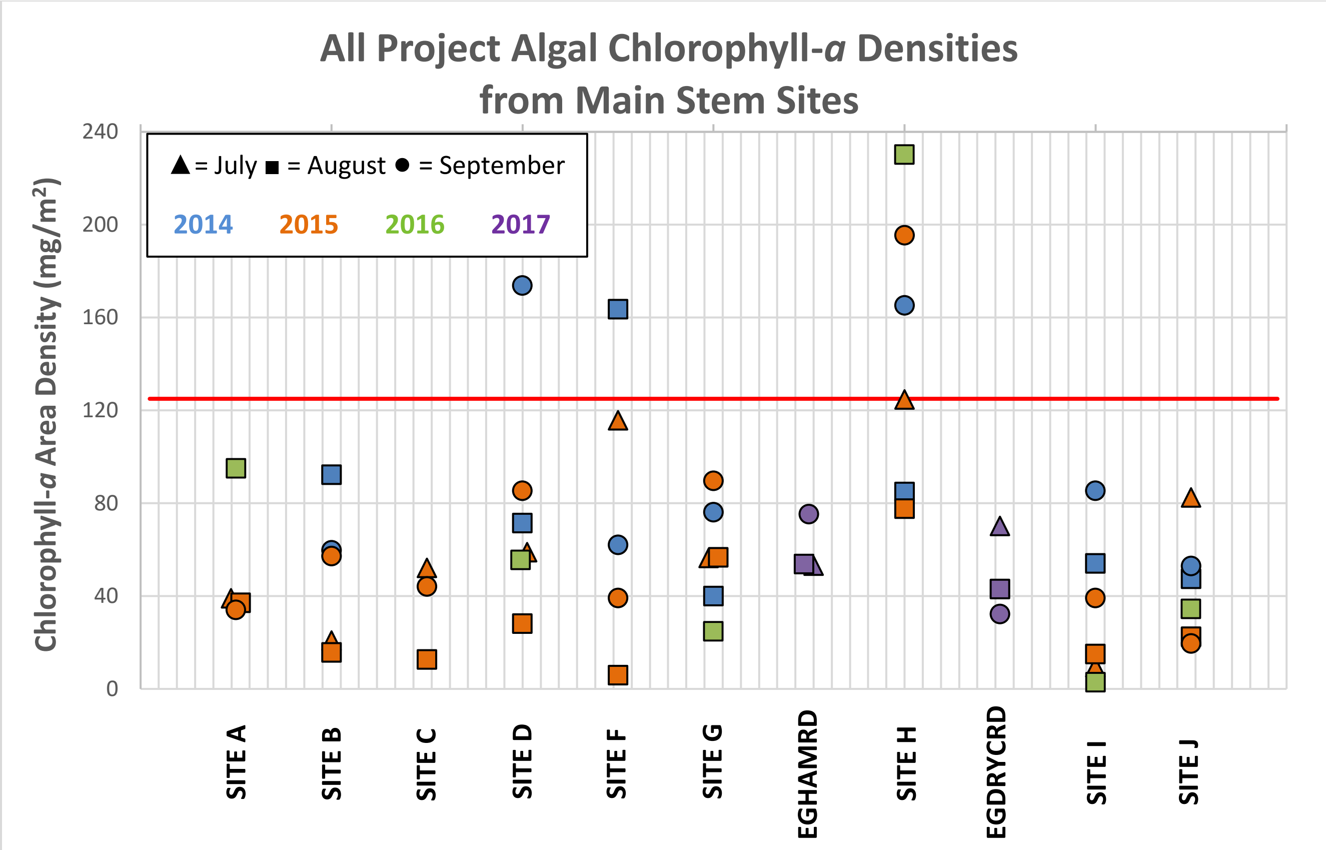

Figure 3. All project algal chlorophyll-*a* area densities for main stem sites. The DEQ-recommended threshold value for chlorophyll-*a* density (125 mg/m^2) is shown in red.

<u>Nutrients</u>: Total nitrogen concentrations were higher at EGDRYCRD (below Trout Creek) than they were above the tributary at EGHAMRD **(Figure 4)**. However, mean total nitrogen data from the entire East Gallatin River continuum indicate notably lower concentrations at the EGHAMRD site, likely due to an influx of water with concentrations below the standard from Hyalite Creek **(Figure 5)**.

Total phosphorus concentrations were consistently highest in September, and generally decreased upstream to downstream **(Figure 6)**. This decreasing trend appears to be the case along the entire East Gallatin River continuum, except at sites immediately downstream of inputs of water with relatively higher concentrations from tributaries **(Figure 7)**.

However, nutrient concentrations do not appear to correlate with chlorophyll-*a* densities along the main stem of the East Gallatin River **(Figures 8 & 9)**.

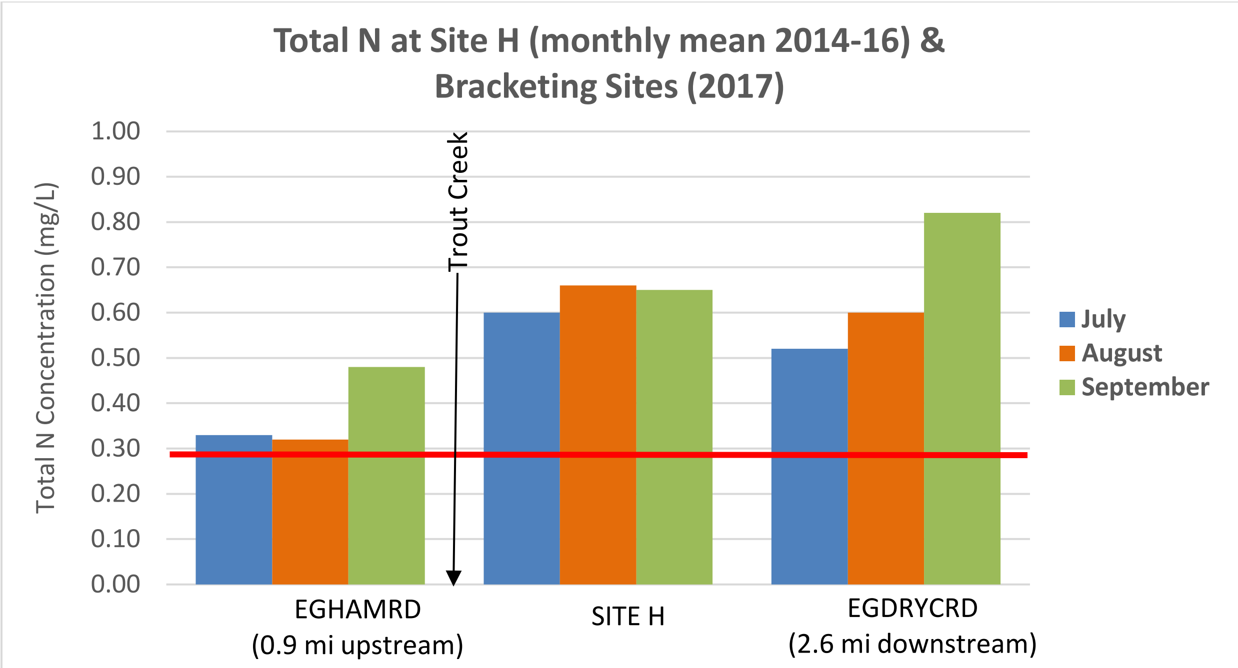

Figure 4. Monthly mean total nitrogen concentrations for July – September are shown for Site H and the 2017 sites bracketing it. The reach-specific DEQ numeric nutrient criteria (0.29 mg/L) is shown in red. Trout Creek enters the East Gallatin between EGHAMRD and Site H.

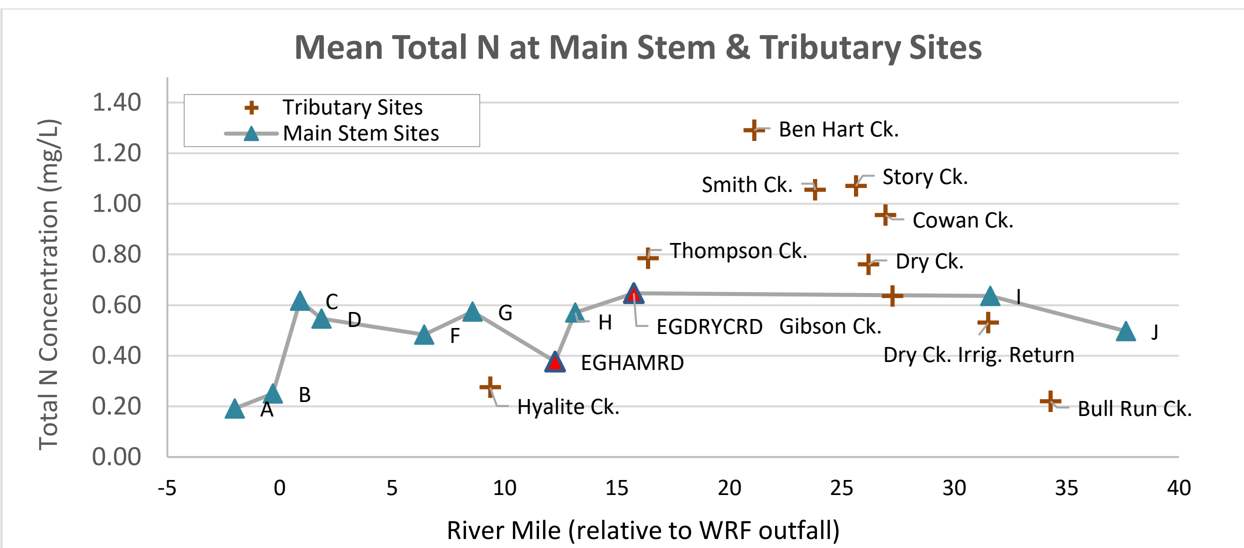

Figure 5. Mean total nitrogen concentrations for July - September data from all project sites. With the exception of Hyalite and Bull Run Creeks, Total N means for all sites below the WRF outfall (at River Mile 0) exceed their reach-specific DEQ numeric nutrient criteria (which range from 0.29 to 0.30 mg/L – not shown). See Table 1 for sampling schedule.

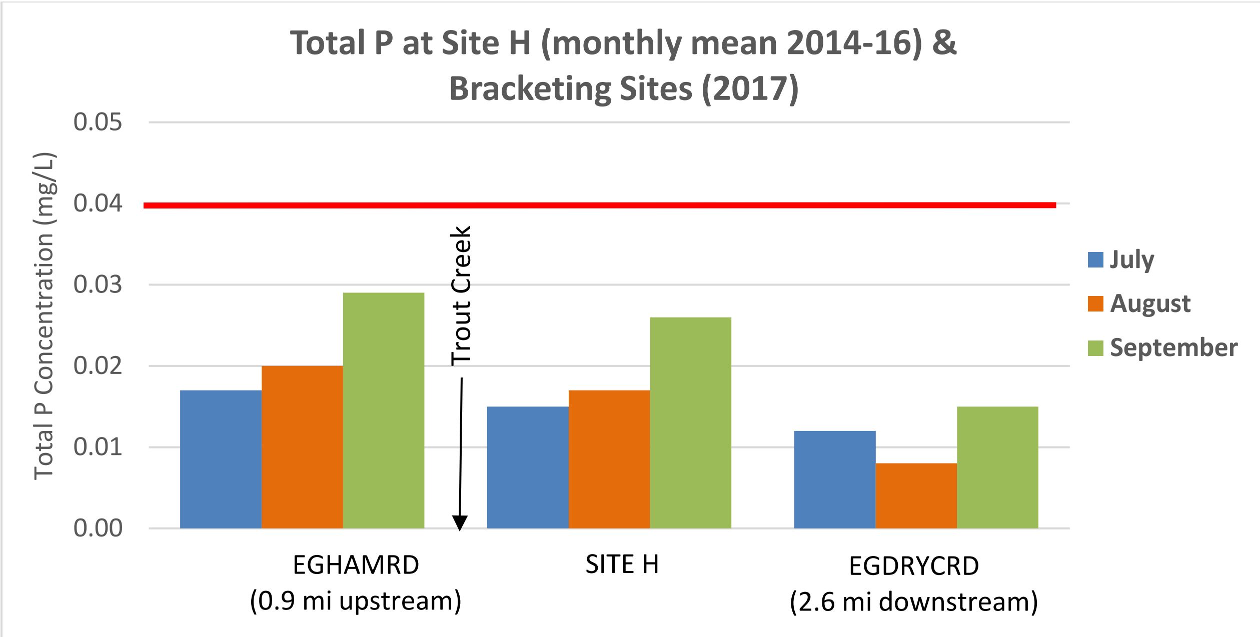

Figure 6. Monthly total phosphorus concentrations for July – September are shown for Site H and the 2017 sites bracketing it. The reach-specific DEQ numeric nutrient criteria (0.04 mg/L) is shown in red. Trout Creek enters the East Gallatin River between EGHAMRD and Site H.

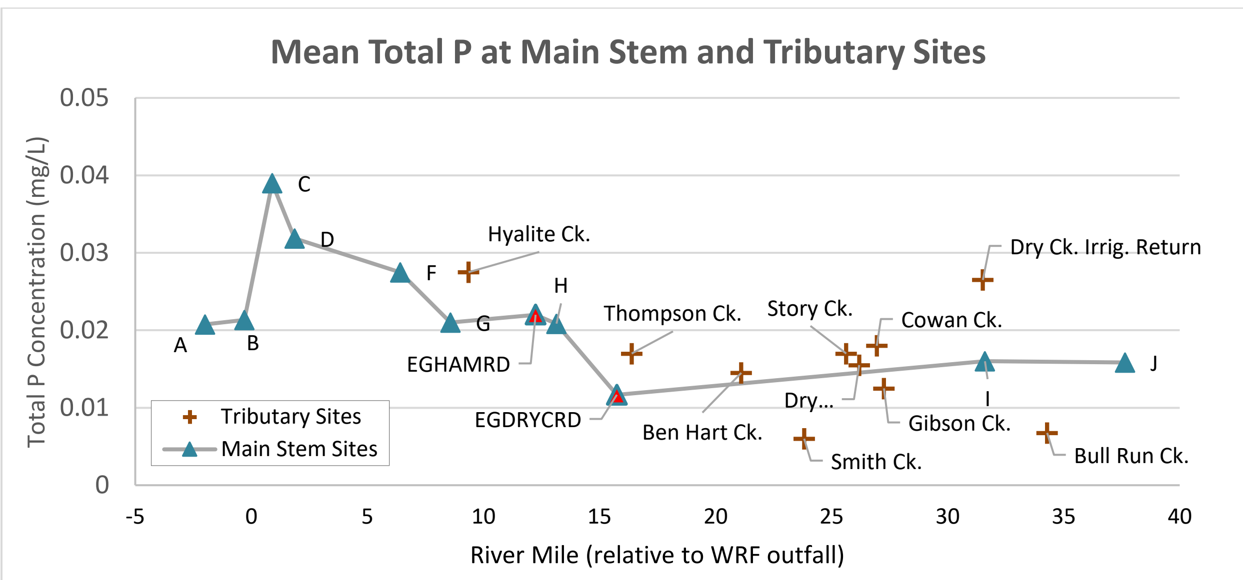

Figure 7. Mean total phosphorus concentrations for July - September data from all project sites. Total P means from all sites are below their respective reach-specific DEQ numeric nutrient criteria (which range from 0.03 to 0.06 mg/L – not shown). See Table 1 for sample collection schedule.

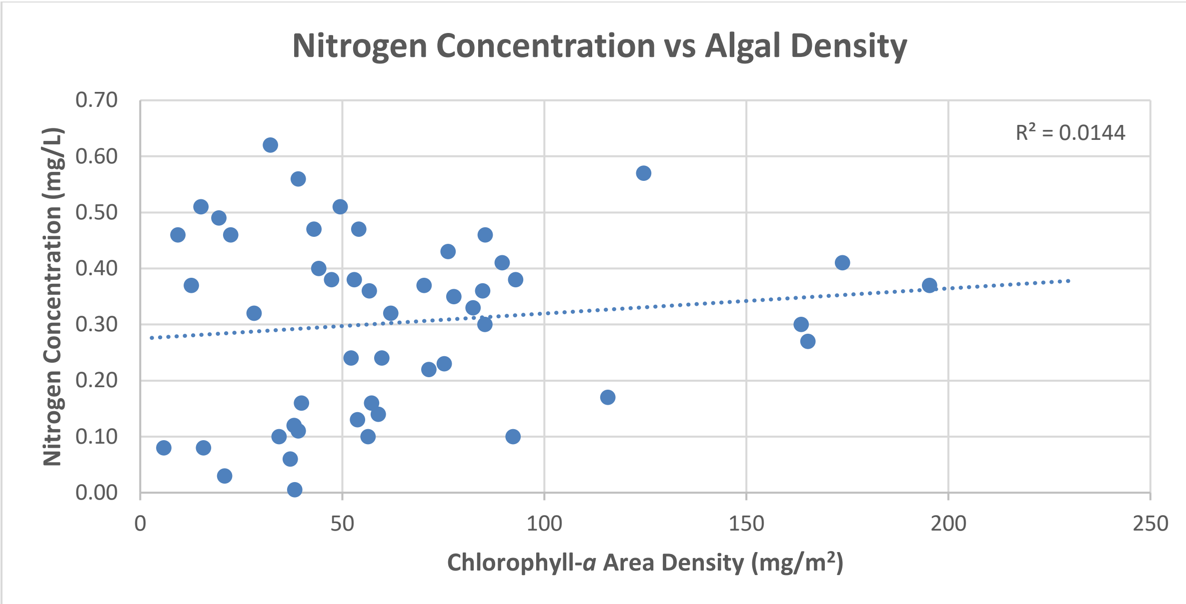

Figure 8. Total nitrogen concentrations and corresponding Chlorophyll-*a* area densities for all project data from main stem sites.

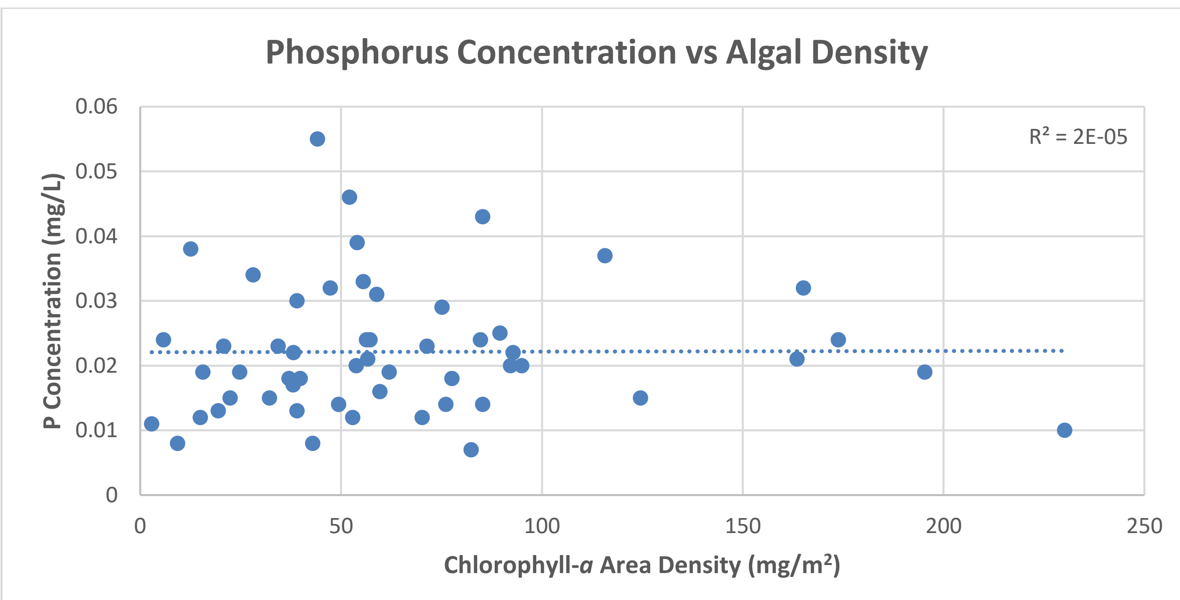

Figure 9. Total phosphorus concentrations and corresponding Chlorophyll-*a* area densities for all project data from main stem sites.

<u>Temperature</u>: Mean monthly water temperatures at Site H fall within the range measured at main stem sites **(Figure 10)**. However, mean July water temperature at Site H is lower than the means for other months at the site. This is only seen at Site H.

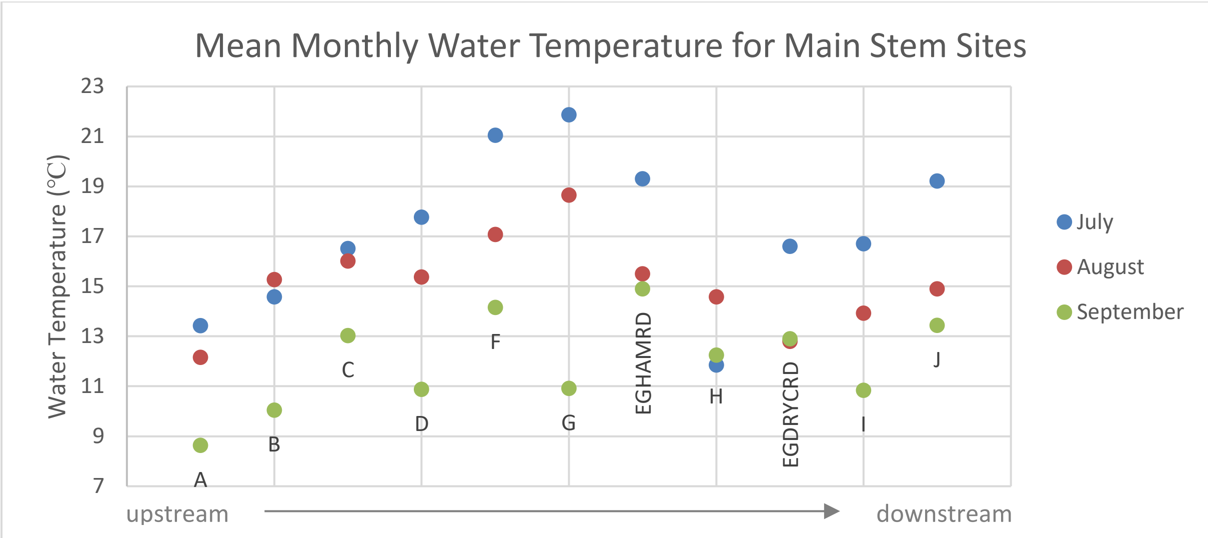

Figure 10. Mean monthly water temperature for all main stem sites.

Discussion

Nutrients (nitrogen and phosphorus) are known drivers of algal growth. Increased nitrogen concentrations at sites immediately below Trout Creek **(Figure 4)** point to the tributary as a possible source. However, chlorophyll-*a* and nutrient data were not collected at Site H in 2017 so year-to-year differences could be contributing to the differences between Site H and the bracketing sites. Additional data from Site H, the bracketing sites (EGHAMRD and EGDRYCRD), and Trout Creek, collected during the same time period, would provide temporal consistency and potentially more concrete evidence of Trout Creek's influence. When examined on a multi-reach scale, it appears that the upstream bracketing site (EGHAMRD) sits within a reach with relatively lower nitrate, possibly due to an influx of low-N water from Hyalite Creek **(Figure 5)**.

The absence of a correlation between nutrient concentrations from grab samples and aquatic algal densities from the entire project dataset **(Figures 8 & 9)** is not surprising. In addition to the year-to-year differences mentioned above, nutrient concentrations can be influenced by a variety of confounding factors in natural systems, such as ongoing metabolism by algae and macrophytes, diel influences on metabolism rates (Nimick et. al 2011), and variable short-term loading from irrigation return flows (Pellerin et. al 2009). Therefore, additional nutrient data via monthly grab sampling is unlikely to provide insight on nutrient concentrations as a driver of algal growth in this dynamic system.

Algal growth can also be affected by water temperature. The temperature range for optimum growth of *Cladophora glomerata* (typically abundant in Montana streams) is 10-24 Celsius (Bahls, 1976). With the exception of a single late-season measurement at Site A, all temperature data fall within this optimal range **(Figure 10)**. The notably lower mean July temperature at Site H might indicate upwelling of groundwater within this reach, which could be a source of nutrients not captured by grab sampling for the reasons discussed above. Shallow groundwater nutrient sampling and groundwater level monitoring from throughout the study area could be used to test this hypothesis.

The 2017 East Gallatin River Channel Migration Mapping report (Thatcher and Boyd, 2017) indicates that Site H is located within a reach that has the largest 60-year channel migration distance, as well as the highest avulsion density within the East Gallatin River continuum. Suplee (2004) theorized that the unstable stream bottoms associated with this type of active channel morphology could discourage benthic plant development, and that available (nutrient) resources may shift to algal species. Further, an active channel, combined with grazing pressure, has the potential to limit the establishment of willows, cottonwoods and other shade-creating riparian vegetation that might discourage algal growth.

Summary and Next Steps

While the complexities of diel effects and other confounding factors make it difficult to determine if nutrient concentrations are having an exceptional effect on algal growth in the Site H reach, physical characteristics (i.e. an actively migrating channel and absence of shade) seem likely to be bigger drivers than water quality when nutrient concentrations are considered on the river scale **(Figures 5 & 7)**.

The area characterized by the spike appears to be highly localized **(Figures 1 & 3)**, and is therefore not of great concern in the context of stream health at the reach scale. Since neither on-the-ground observations during data collection, nor review of site photos during the writing of this report, led staff to document visual differences in the algae/macrophyte community within the Site H reach as a whole, it is reasonable to assume physical conditions might happen to favor algal growth only in the immediate area of sample collection.

Therefore, appropriate steps for the District to address this issue might include:

- Educating landowners along the East Gallatin River (and within the Site H reach in particular) on the effects of grazing on the recruitment of shade-producing riparian vegetation, and the effects of riparian shade on algal growth.
- Connecting landowners with organizations (like the Greater Gallatin Watershed Council) that conduct willow planting (or similar) events once/if grazing pressure can be reduced.

In addition to promoting activities that could shade and stabilize the Site H reach, further data collection could serve to enhance understanding of the role of nutrients at Site H.

- Data from Trout Creek would provide insight into this tributary as an immediately upstream source. A recent Natural Resource and Conservation Service restoration project slightly upstream of the mouth of Trout Creek has made us aware of landowners that might provide access for this work. Hopefully, the restoration efforts made at this property will help reduce any nutrient inputs from Trout Creek.
- Characterizing the quantity and quality of shallow groundwater inputs would enhance understanding of groundwater as a source of nutrients within the Site H reach.

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