Westlands Ranch

White River Headwaters Algae Dataset Evaluation, 2016

ORIGINAL

Andrew Z. Skibo, PhD

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WESTLANDS RANCH WHITE RIVER HEADWATERS ALGAE DATASET EVALUATION, 2016

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REVIEWS AND APPROVALS

AUTHOR:

09JAN18

Andrew Z. Skibo, PhD., President, Amaruq Environmental Services Date

APPROVALS:

Owner, Westlands Ranch Date

General Manager, Westlands Ranch Date

PREFACE OR ACKNOWLEDGEMENTS

The author wishes to thank several individuals and organizations associated with this study. Notably, Pat Krause of Westlands Ranch who contracted Amaruq Environmental Services to conduct this study for Westlands Ranch and provided logistics in order to attend the WRTAG Meeting in Meeker, CO; John Haney also of Westlands Ranch who provided information on day to day operations and history of Westlands Ranch. All due thanks to the members of the WRTAG and the members and organizations responsible for conducting the initial and preceding data collections which made this study possible.

EXECUTIVE SUMMARY

Nuisance algae blooms have been increasingly common along the upper stretches of the White River, from Meeker to the headwaters of the North Fork. These nuisance filamentous algae blooms have primarily comprised of *Cladophora glomerata*, a reticulated filamentous *Ulvophyceae* (green algae); However, several secondary species such as *Didymo* spp. and *Ulothroix* spp. have also been detected during peak active blooms. Colorado Parks & Wildlife (CPW) has been actively monitoring the situation and continued water quality data collection in 2016 directly and through a network of entities to ascertain the extent of these nuisance algae blooms and begin to determine root causal factors. CPW subsequently issued a report citing decreased river water flows and increased nitrogen concentration as primary factors and suggested several possible nutrient loading sources within the rivershed. Independent analysis of the same dataset confirmed that reduced river flows, particularly in the North Fork, and an adequate nutrient concentration were driving the nuisance algae blooms. This analysis confirmed lack of a specific point source of either nitrogen or phosphorous within the rivershed and highlighted the need for further and more comprehensive water quality parameter sampling before conclusions as to likely sources or practices were drawn. As such, this report reviews known conditions within the White River watershed with particular emphasis on the North Fork and provides a preliminary outline for work scope to determine both primary causal factors as well as likely areas of potential point source contributions.

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LIST OF ABBREVIATIONS

$(PO4)_3^-$	orthophosphate
°C	degrees Celsius
°F	degrees Fahrenheit
A2	square acres
AES	Amaruq Environmental Services
A-ft	acre feet
CDPHE	Colorado Department of Health and Environment
cfs	cubic feet per second
CIRES	Center for Limnology at The University of Colorado
CPW	Colorado Parks & Wildlife
DON	dissolved organic nitrogen
EPA	United States Environmental Protection Agency
FRP	free reactive phosphorus
highµ	average high temperature
km2	square kilometers
LDO	liquid dissolved oxygen
LOEC	Lowest Observable Effect Concentration
lowµ	average low temperature
MCL	maximum contaminant level
mg/L	micrograms per liter
mg/ml	milligrams per milliliter
mi2	square miles
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
ppb	part-per-billion (equivalent to µg/L)
SNOTEL	Snow Telemetry
TI	trophic index
TP	total phosphorus
USFS	United States Forest Service
USGS	United States Geologic Service
WRAG	White River Algae Group
WRTAG	White River Technical Advisory Group

1.0 Introduction

Image 1.1. North Fork White River Headwaters to Gooseberry Creek Drainage Area; approximately 258.19mi^2

The White River proper forms at the confluence of the North and South Forks of the White River, whose headwaters lie within the Flat Tops Wilderness Area in the White River National Forest. The White River is a tributary of the Green River which is a tributary of the Colorado River itself. The White River Rivershed drainage Basin covers some 5,120 square miles (13, 261 km^2) and sees an average flow at the confluence with the Green River of 689 cubic feet per second (cfs). The White River Technical Advisory Group limits its immediate concerns to the Rivershed drainage area from the town of Meeker to the headwaters of both the North and South Forks of the White River. This drainage system covers approximately 1042 mi^2 and has a USGS Waterwatch[1] historical monitoring record spanning some 56 years. The North Fork of the White River has a drainage area of some 259 mi^2 while

Image 1.2: Tributaries and source waters of the North Fork of the White River; *tributary confluence locations are approximate*

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[1] https://waterwatch.usgs.gov/?m=real&r=co

the South Fork of the White River has a drainage area encompassing approximately 177 mi^2. This portion of the White River Rivershed is monitored through 4 permanently installed USGS stream gauge monitoring stations: 09303000, 09304000, 09304200 and 09304800 (**Appendix B**). These stream gauge stations record discharge (cfm) and in some cases temperature (°F).

Image 1.3: Westlands Ranch, Buford, Colorado

Image 1.4: Golf Course Pond, Westlands Ranch, Buford, Colorado

Waterbody Name: Golf Course Pond
Mean Depth (ft): 3
Size (ac): 0.13
Perimeter (ft): 405.84
Max Depth (ft): 3
Volume (ac ft): 0.17
Water Uses:
Fishing
Potable
Irrigation
Recreation

Retention/Flood Control

Image 1.5: Main Pond, Westlands Ranch, Buford, Colorado

Waterbody Name: Main Pond
Mean Depth (ft): 10
Size (ac): 1.43
Perimeter (ft): 867.12
Max Depth (ft): 12
Volume (ac ft): 14.3
Water Uses:
Potable
Irrigation
Recreation

Fishing
Retention/Flood Control

The North Fork is fed by 17 tributaries[2] (**image 1.2**) as well as the outfall of Trappers Lake (301 A^2, 9,729 Acre-feet), though some of these source waters may be ephemeral in nature and only active during spring runoff conditions or during heavy rainfall events. Westlands Ranch (39°59'56.42"N 107°35'20.08"W), encompasses some 5,000 acres, maintains an approximate 17,850 feet of river frontage[3] (**image 1.3**) and has two ponds onsite that circulate water on an "as needed" basis to maintain volume. These ponds (**images 1.4, 1.5**) comprise some 1.67 surface acres and retain an average 15.37 A-ft of water at full pool volume. The primary function of these ponds is to provide flood retention and irrigation water. The Main Pond is maintained as a cold-water fishery, primarily for rainbow trout (*Oncorhynchus mykiss*) although populations of Brook trout (*Salvelinus fontinalis*) and Brown trout (*Salmo trutta*) are likely to exists onsite as well.

2.0 Experimental Procedure

Data collection was conducted by numerous White River Watershed stakeholders; namely Colorado River Watch[4], Colorado Parks & Wildlife (CPW)[5] and the USGS National Water Information System (NWIS)[6], as well as concerned citizens and vested public/ private entities. Sample analysis was conducted by several independent entities, namely the Metro Wastewater & Reclamation District[7], Colorado River Watch, The Center for Limnology at University of Colorado (CIRES)[8] and Timberline Aquatics[9].Collected 2016 historical water quality data was provided to Amaruq Environmental Services[10] through the White River Algae Group (WRAG[11]) as a participating member of the White River Technical Advisory Group (WRTAG) and a representative of Westlands Ranch. The majority of the data analyzed in this report was

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[2] Trappers Lake, Skinny Fish Creek, Big Fish Creek, Lynx Creek, Picket Pin Creek, Bear Creek, Ripple Creek, Mirror Creek, Snell Creek, Missouri Creek, Long park Creek, Lost Creek, Marvine Creek, Ute Creek, Crooks Creek, Cattle Creek, Schneider Creek and Gooseberry Creek

[3] Information provided by Westlands Ranch Management; 20DEC17

[4] http://coloradoriverwatch.org/

[5] http://cpw.state.co.us/

[6] https://waterdata.usgs.gov/nwis

[7] http://www.metrowastewater.com/Pages/default.aspx

[8] http://cires.colorado.edu/limnology/welcome

[9] http://timberlineaquatics.com/

[10] info@amaruqenvironmental.com

[11] www.whiterivercd.com/white-river-algae-working-group.html

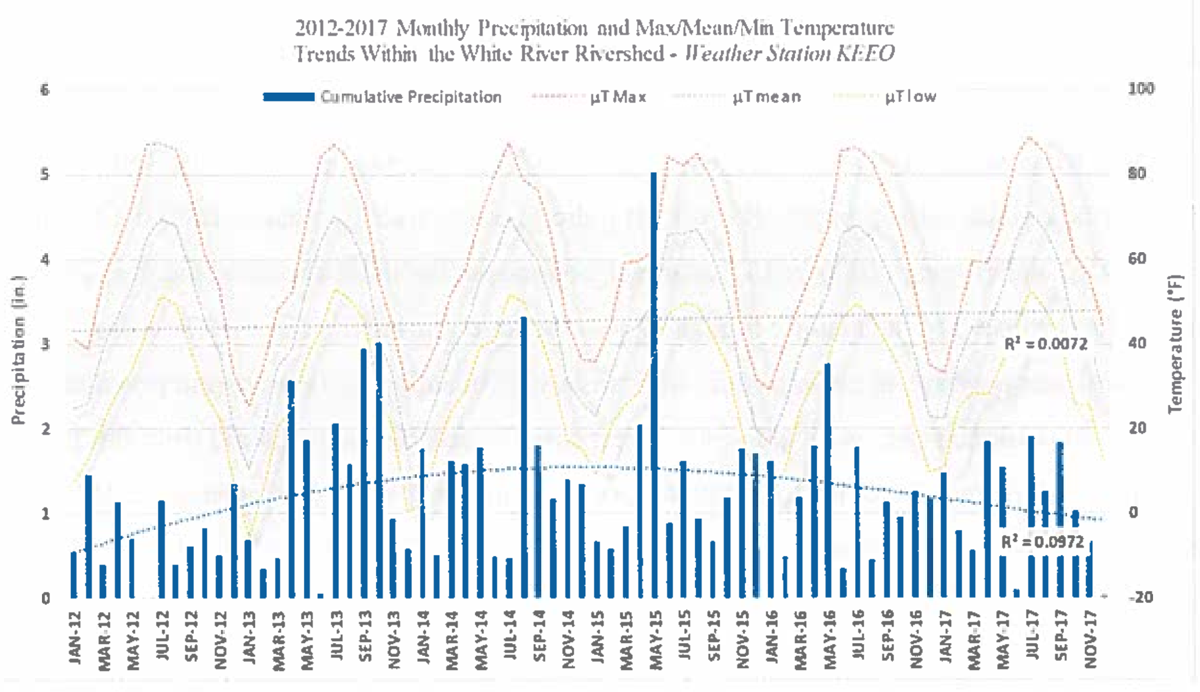
generated by two independent entities; River Watch and Metro. Within duplicated water quality parameters (-NO_2/-NO_3; mg/ml) and Total Phosphorus (TP; mg/ml) significant discrepancies were noted despite identical collection times (**Figure 3.1**). As such, the mathematical mean between individual data points was calculated as a representative value of true concentrations, *in situ*. As actual values likely varied within the constraints of the reported value plus/minus some degree of unreported error, the mathematical mean was determined to be a "best fit" in examining this data series.

3.0 Results & Discussion

3.1 Meteorological conditions

Historical meteorological conditions (2013-17DEC2017) for the Meeker area (**Figure 3.1**) indicate a minor, statistically significant decline in annual precipitation from 2015 levels to levels similar to those seen in 2013. Relative timing of these events was not evaluated; However, Natural resource Conservation Service (NRCS) Snow Telemetry (SNOTEL) data[12]

Figure 3.1



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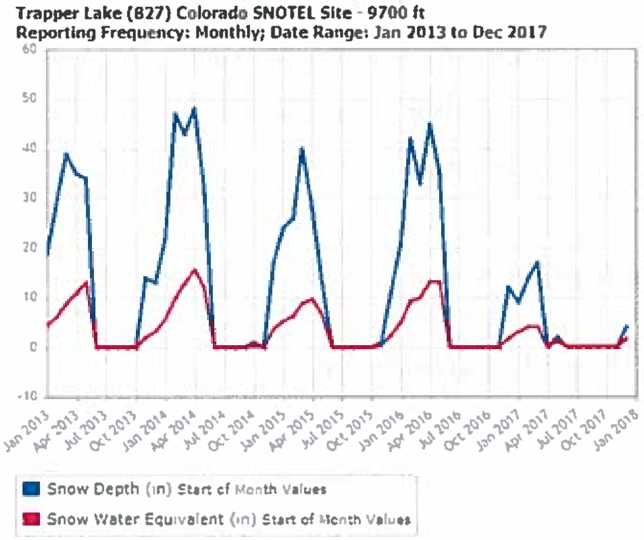
[12] https://www.wcc.nrcs.usda.gov/snow/

for the North Fork White River Headwaters (NRCS SNOTEL Station 827; **image 3.1**) indicate a linear decline in averaged annual accumulation, corroborating data represented in **figure 3.2**.

Figure 3.2

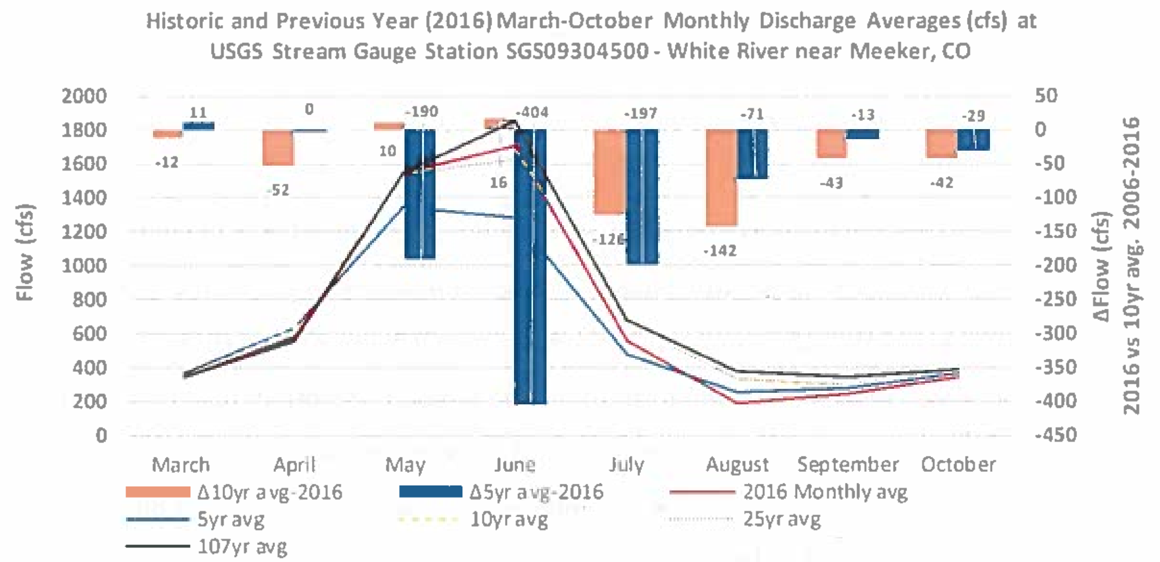


Average annual temperatures for the 2013-2016 period demonstrated a linear increase in low, mean and high averaged temperatures and further highlighted 2016 and 2017 as the warmest years of the series. During the period of CPW data collection, 2016, mean high temperatures were 84.5°F with mean lows of 43.5°F. Temperatures for the year prior were statistically equivalent while 2014 was slightly cooler during the period of record (high$_{\mu}$:79.5°F, low$_{\mu}$:45.5°F).

3.2 White River Discharge at Station 09304500 'White River near Meeker, CO'

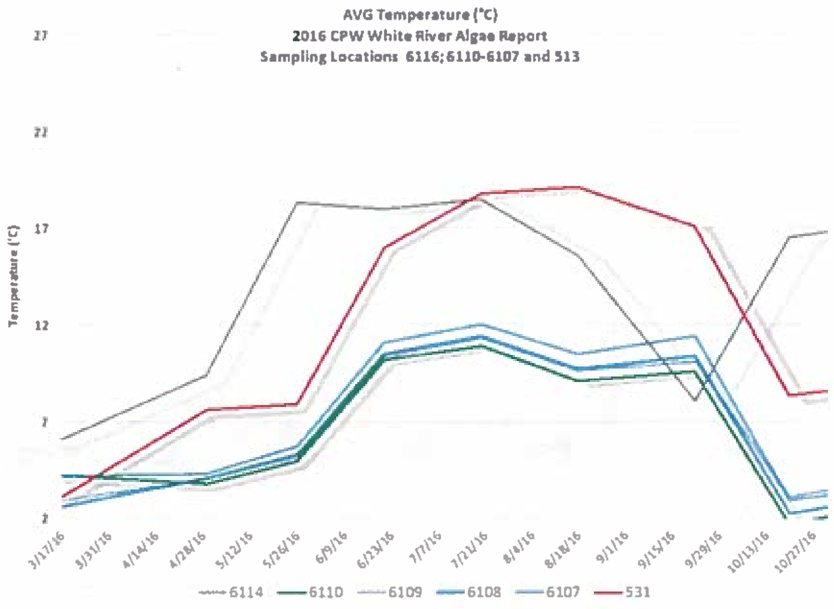
White River water discharges, as measured at USGS stream gauge station 09304500 for the CPW period of data collection (MAR-OCT16) indicate a negative divergence from the 5-year (2013-2016) and 10-year (2006-2016) historical averages in the latter period of the year (AUG-OCT). As compared to the historic 5- and 10-year averages during the JUL-OCT record, flow differential was negative in every month; indicating significantly less flow than in previous seasons. Of particular note is the previous 5-year average divergence (-404cfs) from the 107 year historical average June flow of 1850cfs. As compared to the 107-year average, 2016 June, July, August and September flows were all significantly off at -146, -123, -190 and -99 respectively.

Figure 3.2-1



3.3 North Fork White River Nutrient & Water Quality Quantitation

Figure 3.3-1



Data points for water transiting CPW stream sample stations[13] 6110, 6109, 6108, and 6107 was examined for any locality effect that Westlands Ranch may have on North Fork water quality. Coal Creek, a downstream White River tributary, was included as

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[13] White River Algae Report on 2016 Data; 2017. May, M. and C. Noble.

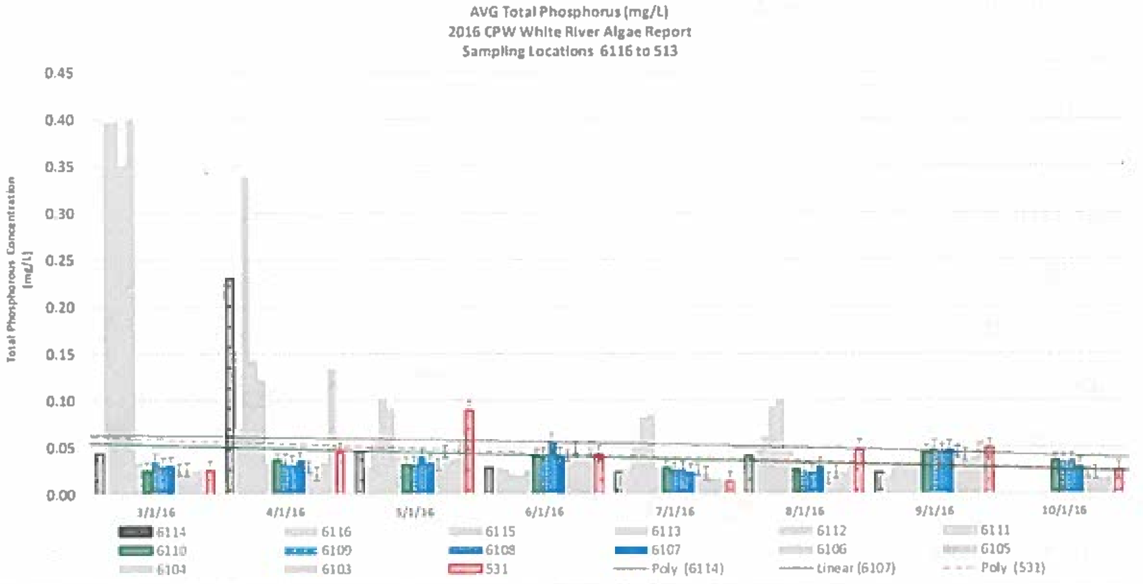
WRTAG sample location 6114 (Coal Creek at Lumney Ranch), while a "positive check" at WRTAG sample location 531 (White River at 5th Street, Meeker) was examined as the most downstream sample point available in the CPW dataset.

3.3.1 PHOSPHOROUS (-PO_4) CONCENTRATIONS

Phosphorus (P) is one of the key elements necessary for growth of plants and animals. Phosphorus in elemental form is very toxic and is subject to bioaccumulation (Kumar & Puri, 2012). Phosphorus exists in the environment in three forms: Orthophosphate $(PO_4)^{3-}$ or soluble phosphorus, mineralized phosphate in the form of apatite which is generally unavailable to plants and animals, and organically bound phosphate which is in constant flux through $(PO_4)^{3-}$ and the phosphorus cycle. The following criteria for total phosphorus were recommended but not codified into law by the US EPA (1986):

1. no more than 0.1 mg/L for streams which do not empty into reservoirs,
2. no more than 0.05 mg/L for streams discharging into reservoirs, and
3. no more than 0.025 mg/L for reservoirs.

Figure 3.3-2



Surface waters that are maintained at .01 to .03 mg/l of total phosphorus tend to remain uncontaminated by algal blooms. The State of Colorado criteria maintains a maximum concentration in drinking water reservoirs at 0.035mg/L. As a measure of impairment, the US EPA utilizes Carlson's (Carlson, 1977) Trophic State Index (TSI), which utilizes three independent variables (chlorophyll$_a$, total P and Secchi depth) as they tend to correlate in water. Waters are considered eutrophic (Carlson, 1996) with a trophic index (TI) of 50-70 (TP 24-96 µg/L) and are thus capable of supporting algal blooms. This trophic index is also generally considered the point at which fish die offs may occur as a result of dissolved oxygen fluctuations concomitant with seasonal algal bloom collapse.

The Colorado Department of Public Health and Environment (CDPHE) lists Total Phosphorous (TP) at the state level lists the White-Yampa watershed as having a median TP concentration (mg/L) of 0.000001-0.080000 (1-80,000 parts-per-billion; ppb)[14]. This suggests the White River as being oligotrophic (TP$\leq$12µg/L) and the data collected by CPW (**Figure 3.3-1**) shows maximum detected TP levels at 0.5mg/L for all sample stations in 2016. With regards to waters of the North Fork, which transit Westlands Ranch (CPW stations 6109 and 6108), no significant difference with regards to TP was seen at any specific sample event nor was a significant difference seen when analyzing across all sampling periods. Coal Creek (CPW station 6114) tested several orders of magnitude higher in TP concentration during most sampling events while White River waters transiting through the town of Meeker (downstream from Westlands Ranch) were, in many cases, significantly higher in TP concentration as well. With regards to samples taken from Coal Creek, the White River in Meeker (CPW Station 531) and just below Westlands Ranch (CPW station 6107), a declining trend was seen in TP concentrations throughout the season (**Figure 3.3-1**).

3.3.2 NITRATE/ NITRITE ($-NO_2$/$-NO_3$) CONCENTRATIONS

Nitrogen is typically present in wastewater effluents as either dissolved inorganic nitrogen (DIN), i.e. ammonia ($-NH_3$), ammonium ($-NH4^+$), nitrite ($-NO_2$) and nitrate ($-NO_3$), or as dissolved organic nitrogen (DON), i.e. urea ($CO(NH_2)_2$ (Ross *et al*, 2017). Nitrite ($-NO_2$) is an intermediate-stage anion formed in the oxidation process of ammonia ($-NH_4$) to Nitrate ($-NO_3$), (Lewis & Morris, 1986). Both anions are found naturally in surface waters of the US; However, while nitrate does occur naturally in groundwater, concentrations greater than 3 mg/L generally

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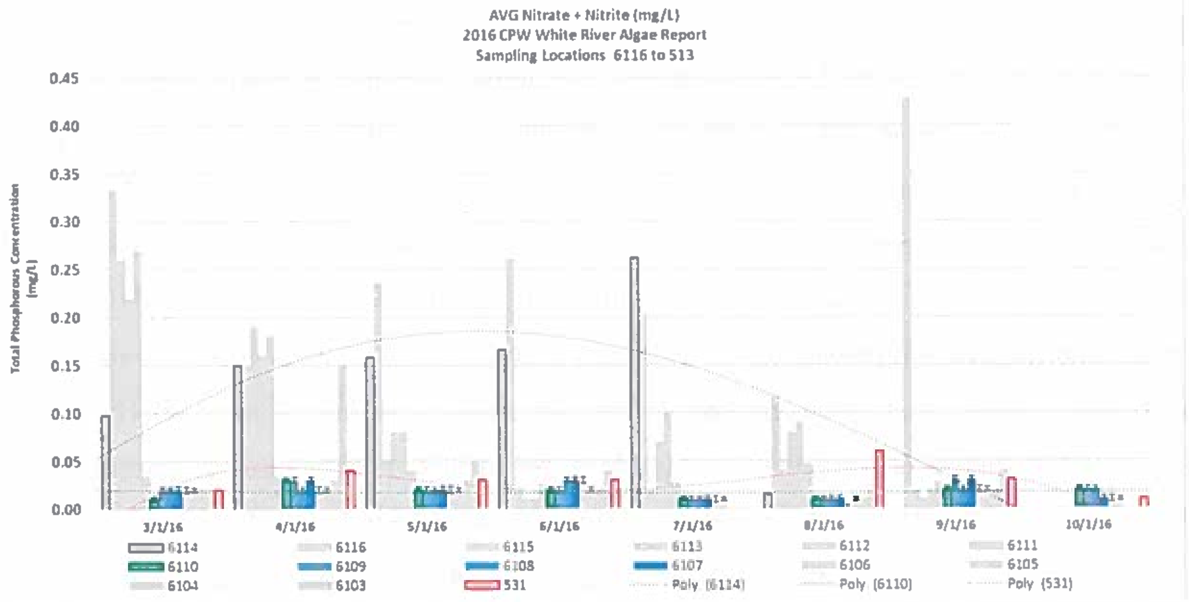
[14] https://www.colorado.gov/pacific/cdphe/clean-water-rivers-lakes-and-streams

indicate contamination (Madison and Brunett, 1985), and a more recent nationwide study found that concentrations over 1 mg/L nitrate indicate human activity (Dubrovsky et al. 2010). EPA's maximum contaminant level (MCL) for nitrate set to protect against blue-baby syndrome is 10 mg/L. The US EPA found that only an estimated 4% of the surface area of the State of Colorado has groundwater nitrate levels >5mg/L, or 50% of the US EPA Maximum Concentration Level (MCL).

Figure 3.3-3



Nitrate concentrations are directly correlated to the predominant land use of the basin and nitrogen applied to the land surface over a span of decades will impact the condition of the underlying aquifer. As a result, nitrite/ nitrate levels are typically measured in private and municipal wells, at points of spring discharge, and in the baseflow of trout streams as a safety precaution (Watkins, 2011). Concentrations of nitrate in the surface waters of the mid-west U. S. are a concern because they fall within ranges that are harmful to aquatic organisms. Fifty-three rivers sampled by the USGS in 1994 and 1995 in the 9 mid-western states (Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio and Wisconsin) indicated that 88% had concentrations in excess of 2mg/L -NO_3, while 43% had concentrations in exces of 6 mg/L -NO_3.

Although low amounts of nitrite (<0.005mg/L) occur naturally in running waters, it can reach high concentrations through the introduction of nitrogen-rich agricultural and industrial waste water (Borchardt 1992). Other studies have revealed that the toxicity of nitrite to fish is dependent on other water parameters, such as the pH-value and the chloride, bicarbonate, calcium, phosphate and sulfate concentrations (Bath and Eddy 1980; Russo et al. 1981). Of these factors, chloride seems to have the most deciding influence. It is believed that nitrite is actively taken up by fish mainly through the chloride cells of their gills. This would explain the moderating effect that higher chloride concentrations have on nitrite toxicity; chloride competes with nitrite for the carriers on the gill epithelia (Bath & Eddy 1980; Huey *et al.* 1982; Gaino *et al.* 1984). However, the "chloride effect" is inversely effective with regards to fish sensitivity; thus, Salmonids will have a much lower tolerance to nitrite even in the presence of elevated chloride concentrations (Lewis & Morris, 1986) as they are among the most sensitive species to in-water nitrite concentrations. Typical indicator species such as Fathead Minnow (*Pimephales promelas*) and Black bullhead (*Ictalurus melas*) are less sensitive to nitrate concentration and Largemouth Bass (*Micropterus salmoides*) may be the least sensitive as this species does not accumulate nitrite (Lewis & Morris, 1986). Despite increased nitrite sensitivity, the lowest observable effect concentration (LOEC) was 12.5 mg/L NO_3 for mortality in domestic brook trout embryos and 100 mg/L NO_3 for biomass reduction.

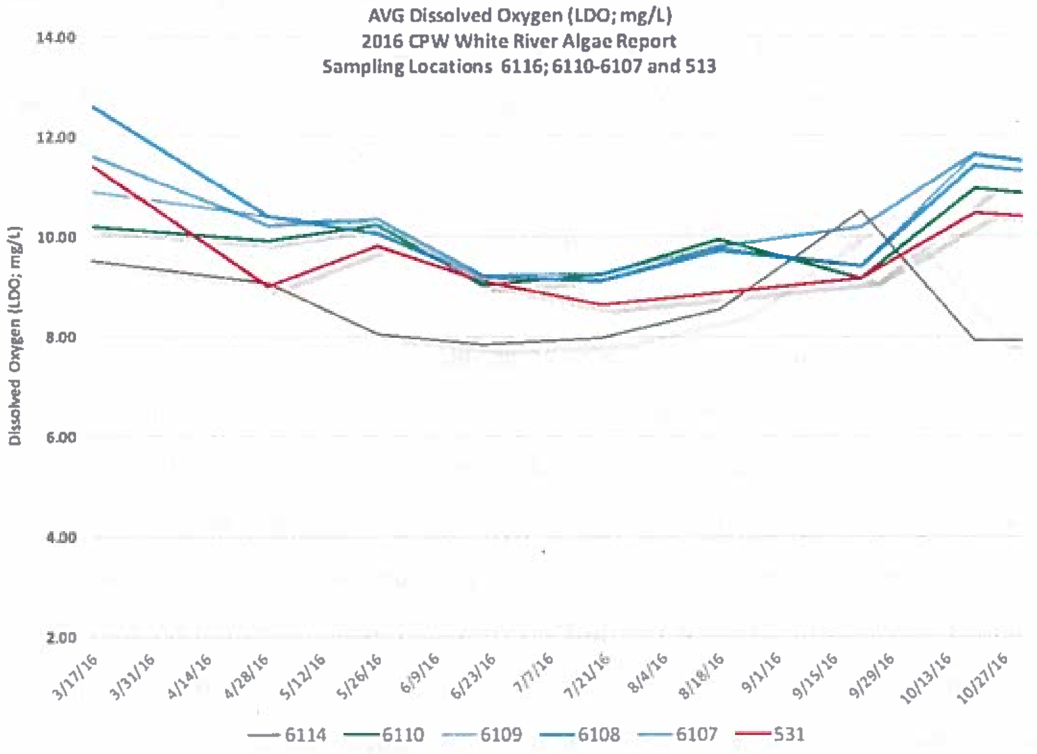
3.3.3 Liquid Dissolved Oxygen (LDO; O_2) concentrations

There are three main sources of oxygen in an aquatic environment: 1) direct diffusion from the atmosphere; 2) air–water gas exchange as a result of mechanical incorporation through turbulence; and 3) photosynthesis. Predictable changes in dissolved oxygen (DO) occurring within a 24-hour period are called the diurnal oxygen cycle. This cycle is affected by many factors, including ambient temperature, atmospheric pressure, and ion activity (ionic strength of the water body). Sources of DO in water include atmospheric aeration and photosynthetic activities of aquatic plants. Sinks of DO in water include respiration, aerobic decomposition processes, ammonia nitrification, and other chemical/biological reactions. Many chemical and biological reactions in groundwater and surface water depend directly or indirectly on the amount of available oxygen. The presence of DO in aquatic systems is necessary for the survival and growth of many aquatic organisms and is used as an indicator of the health and geochemical quality of surface-water and groundwater systems.[15] EPA criteria for no impairment of salmonid production (USEPA 1987):

Embryo and larval stages: 11 mg/l
Other life stages: 8 mg/l
Normal activity: > 5 - 6 mg/l dissolved oxygen (Baker et al. 1993)
Spawning season: > 7.0 mg/l (necessary for egg survival)

From a species perspective, Rainbow trout are more tolerant of low dissolved oxygen levels while brook trout are particularly sensitive to low dissolved oxygen levels (Camp Dresser and McKee 1981).

Figure 3.3.3-1



In rivers containing very little aquatic vegetation, the relative contribution to the diurnal oxygen cycle may be quite small. During adverse events such as nuisance algae blooms, the effect upon diurnal oxygen cycle may be quite large and may occur only during times of algae

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[15] https://water.usgs.gov/owq/FieldManual/Chapter6/6.2_ver3.pdf

growth or as a result of algal colony collapse following senescence or seasonal changes. As such, measuring DO flux within a rivershed requires extensive temporal data collection as simple spot-grabs only serve to provide immediate DO concentration values and will miss greater effects that diurnal cycling or plant biomass loading may have locally.

Within DO-impaired water bodies, typically ponds and lakes, mechanical aeration will increase DO concentrations such that adverse events associated with aquatic plant or algal biomass decay may be temporarily mitigated, thereby preventing potential impact to sensitive species such as Salmonids. Dissolved oxygen deficits are not typically an issue in alpine streams and will likely have DO readings from 7 to 15 mg/L, depending on the water temperature and air pressure. In their lower reaches, rivers and streams can have DO readings between 2 and 11 mg/L. One reason for this is the occurrence of rapids in shallow rivers. Rapids are located at debris fans associated with tributary inputs in areas of bedrock fractures (Dolan et al. 1978). While transiting rapids, water turbulence increases to the point where the water surface breaks and air bubbles are advected into the flow, greatly increasing gas transfer velocity (Wilhelms and Gulliver 2005). The extreme turbulence in rapids and subsequent bubble formation is likely to drive gas transfer velocity (up to 7700 cm hr^{-1}) which greatly exceeds estimates for virtually all other types of aquatic ecosystems. Gas exchange can be highly spatially variable within a river, and the random spatial distribution of natural features may increase variability from one sampling point to another.

DO values as reported through the CPW 2016 dataset show Coal Creek as generally having lower DO concentrations (min: 8.64 mg/ml, 04AUG16; max: 11.4 17MAR16) than the White River at Meeker (min: 7.82 mg/ml, 23JUN16; max: 10.5 29SEP16) for the same time periods **(Figure 3.3-3-1)**. As averaged across the 2016 monitoring period, Coal Creek had an average DO concentration of 8.66 mg/ml versus the White River at Meeker at 9.55 mg/ml. Looking at Stations 6110, 6109, 61008 and 6107, no significant difference in DO concentration was noted between any station nor across these four stations save for the 17MAR16 measurements. These data points indicated an increasing DO concentration as water transited from Station 6110 (N. Fk. White R. @ CR 14) downstream (10.20 mg/ml) to Station 6108 (N. Fk. White R. @ Westlands) (12.60 mg/ml). Interestingly, the relative DO concentration at the next monitoring point downstream (Station 6107; N. Fk. White R. @ Bel Aire) noted a declining DO concentration to 11.60 mg/ml. However, this trend did not continue through the season and at subsequent monitoring intervals.

3.3.4 Cladophora glomerata biology in macronutrient polluted waters

The genus *Cladophora* are a group of Chlorophytic macroalgae of which both marine and freshwater species are found. In fresh waters, large blooms of *Cladophora* are typically reflections of nutrient enrichment often resulting in local fouling of streams, rivers and waterfront properties (Hiriart-Baer *et al*, 2007). Nuisance growth of *Cladophora* has often been associated with urban areas, specifically, their proximity to nutrient sources such as water and sewage treatment plant effluent pipes or river mouths (e.g. Herbst 1969, Neil and Owen 1964, Painter and Kamaitis 1987). Gubelit (2009) posited that large-scale growth of *C. glomerata* is directly correlated to intensive eutrophication in and along studied shorelines.

Particularly hard and alkaline waters are the chemical environments generally occupied by *Cladophora* (Neil and Owen 1964, Whitton 1970). In terms of alkalinity, *Cladophora* are typically restricted to waters with a pH between 7 and 9 (Bellis 1968b, Whitton 1970). It is still unclear what the physiological reasons are for this pH restriction but it may be related to the form of inorganic carbon available at different pHs (Sheath and Burkholder 1985). The typical naturally occurring hard substrate used by *Cladophora* spp. ranges from coarse gravel, to boulders and bedrock (Neil and Owen, 1964); these being the prevalent conditions across the White River study area.

With respect to carbon availability, the main species of dissolved carbon between pH 7 and 9 is bicarbonate (HCO3-). While *Cladophora* can utilize HCO_3- through the activity of carbonic anhydrase, not all aquatic plants can and many require carbon as dissolved CO_2 for carbon fixation (Raven et al. 1982, Sikes 1978). The lower physiological pH limit of *Cladophora* could be a manifestation of competition with other macroalgae and macrophytes while the higher physiological pH limit of *Cladophora* may be related to the Ca requirements of this macroalgae. At higher pH, Ca readily precipitates as $CaCO_3$ and may become biologically unavailable. Moreover, as for all other organisms, high pH in the surrounding environment can lead to ammonium (NH4+) toxicity (Robinson and Hawkes 1986). The requirement for calcium (Ca) and possibly magnesium (Mg) may be the main reason for the restriction to hard waters. While the Ca and Mg requirements for survival (1.2 mg/L Ca and 0.7 mg/L Mg) of *Cladophora* *glomerata* are below levels found in most freshwater environments (ca. 5 mg/L), the needs for growth (i.e. branching) and sporulation are much higher (64.0 mg/L Ca and 108.5 mg/L Mg) (Bellis 1968b).

It has been suggested that while seasonal differences in *Cladophora* productivity are likely related to variations in temperature and perhaps light availability, productivity within and between water bodies during the growing season are likely related to different nutrient levels (Adams and Stone 1973). Some studies have demonstrated nitrogen limitation of growth in both marine and freshwater *Cladophora*, at least temporarily during the growing season (Mason 1965, Peckol et al. 1994, Planas et al. 1996). However, most studies have identified phosphorus as the first rate-limiting nutrient for *Cladophora* growth in freshwater ecosystems (e.g. Auer and Canale 1980, Herbst 1969, Painter and Kamaitis 1987, Wong and Clark 1976).

Wong & Clark (1976) evaluated the critical phosphorus concentration as 0.060 mg P1-1, whilst Herbst (1969) supported the suggestion of 0.030mg P l-l, results from this study generally support these estimates. Pitcairn & Hawkes (1973), however, found that rivers containing less than 1.0 mg P1 -a supported only modest growths of *Cladophora*, and Robinson (1983) found biomass significantly less in a simulated stream ecosystem with mean monthly phosphate concentrations of 0.5-0.7 mg P 1-1 than in similar streams with phosphate concentrations of 1.9-3.1 and 3.0-3.8 mg P 1-1. (Robinson & Hawkes, 1981).

Temperature tolerances and optimum requirements for survival, growth and/or reproduction are thought to be some of the most important variables limiting the geographical distribution of *Cladophora* sp. (Breeman et al. 2002). However, on average, *Cladophora* sp. demonstrate good growth between 15 and 25°C (e.g. Bellis 1968a, Hoffman and Graham 1984, Wong et al. 1978). During the summer months there is typically a rapid reduction in *Cladophora* biomass (die-off) which is commonly thought to be directly associated with increases in temperature (Graham et al. 1982, Whitton 1970). In temperate climates, *Cladophora* frequently has two annual peaks in biomass, the first occurring in the spring (May/June) and a second often reduced peak in the fall (September/October) (Bellis and McLarty 1967, Wong et al. 1978). During the summer months, there is typically a rapid reduction in *Cladophora* biomass which is commonly thought to be directly associated with increases in temperature (Graham et al. 1982, Whitton 1970), although some evidence disputes the involvement of temperature in the summer die-offs in Lakes Erie (Mantai 1987) and Michigan (Lester et al. 1988). *Cladophora* sp. are obligate photoautotrophs, and they cannot maintain vegetative stands without light. It is likely that the minimum light requirement for *Cladophora* spp. is near 30 μmol/m/s, a conclusion based on the field study conducted by Lorenz et al. (1991). It has been suggested that while seasonal differences in *Cladophora* productivity are likely related to variations in temperature and perhaps light availability, productivity within and between water bodies during the growing season are likely related to different nutrient levels (Adams and Stone 1973). Thus, four essential environmental conditions are needed for *Cladophora* sp. to flourish (Hiriart-Baer *et al.*, 2007): hard substrate; water temperatures in the range of 10-25°C; adequate light; and nutrients, particularly phosphorus (V. Harris, 2004).

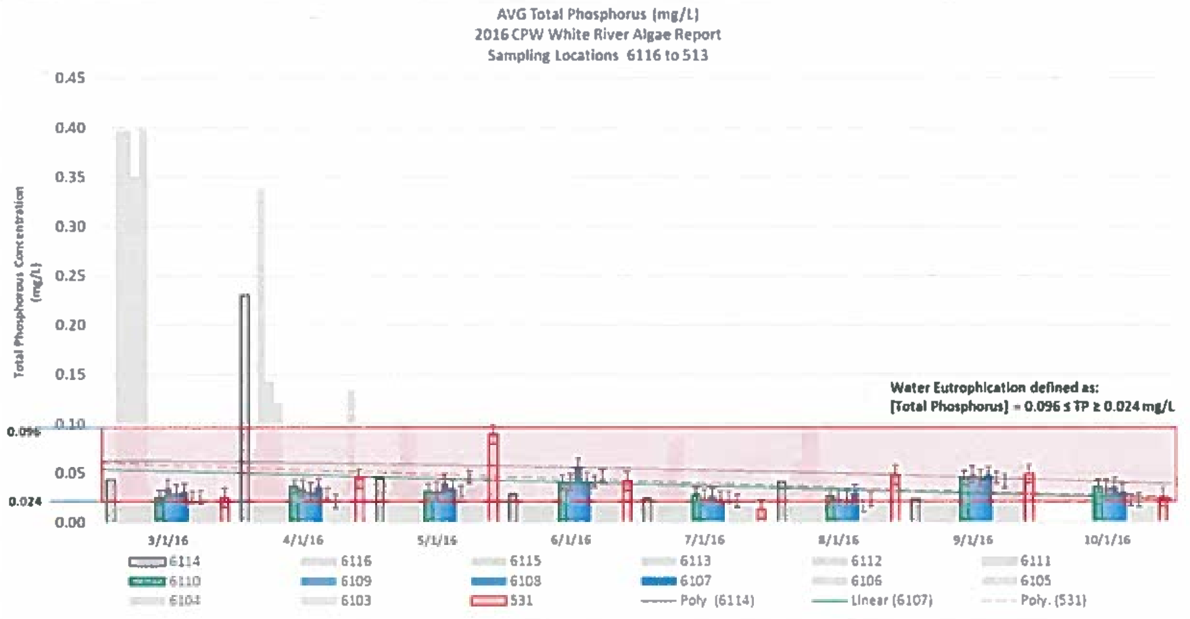
4.0 Conclusions

High rates of agricultural runoff can cause large quantities of nitrates and phosphates to enter river systems, and these nutrients can create a large proliferation of algae which is harmful to water quality. The blooms deplete oxygen levels in aquatic ecosystems and thus have a detrimental effect on the organisms within the system. Both nitrates and phosphates have positive effects on algal growth. However, these variables affect algal growth independently of each other and there is no interaction between the two (Fried *et al*, 2003). The implication of which is that both nitrates and phosphates are limiting nutrients to algal proliferation (Fried *et al*, 2003).

In an effort to maintain a healthy water system and to minimize algal growth, the United States Environmental Protection Agency (USEPA) recommends that phosphate levels be kept below 0.1mg/l (USGS 1996-1998). In systems with low algal growth, there is a shortage of either nitrogen or phosphorus which limits the algal growth. The cause of this shortage varies between different water systems. Phosphate depletion most likely occurs because the phosphates are lost from the water column through sedimentation and because they do not have a gas phase (An and Park 2002).

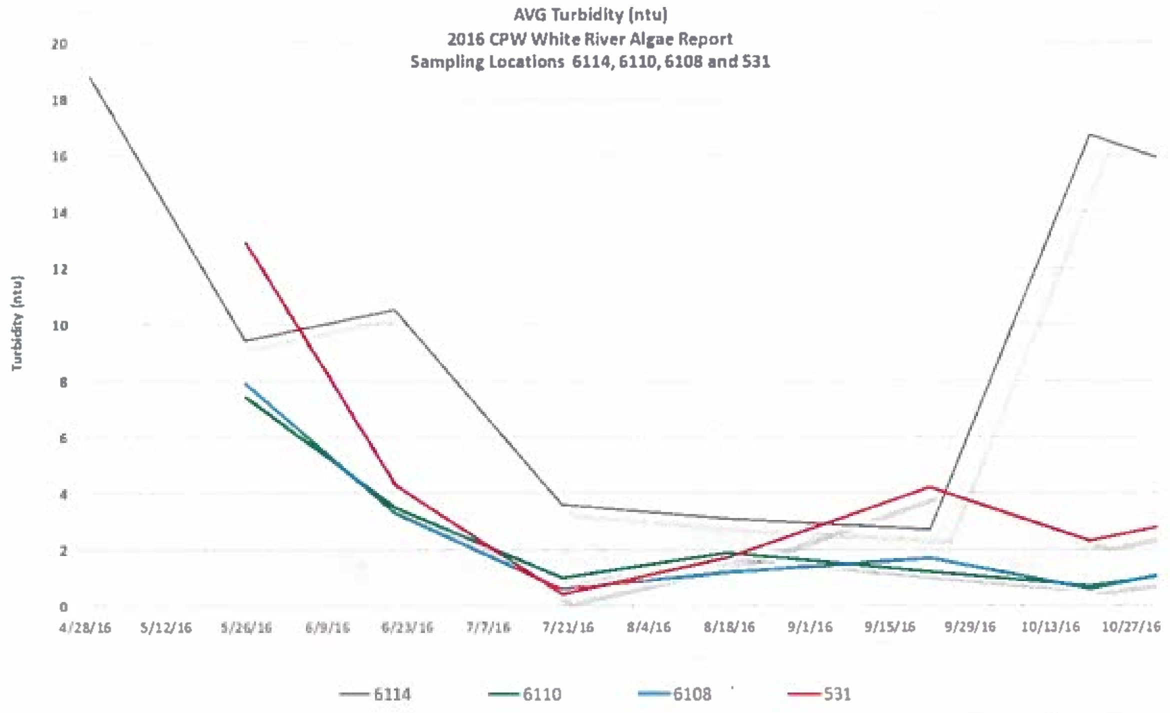
Total phosphorus concentrations for all sampled locations within the White River above the town of Meeker approached or exceeded the minimum eutrophic threshold of 0.024ug/L TP concentration at all sampling intervals, 2016 (Figure 4.1.1.1). Several stations reported TP concentrations in excess of 0.10 ug/L. Coal Creek samples returned significantly higher TP concentrations during earlier sampling intervals (MAR, APR) which may have been a result of entrained sediment in sampled waters following early season run off. This hypothesis is supported by collected turbidity data (**Figure 4.1.1.2**) for the period of record noting significant periods of river water turbidity in Coal Creek April-early June 2016. The phenomenon of increased light penetration as a result of increased water clarity in the presence of biologically-available phosphorus driving increased growth of benthic algae is well documented (Lowe and Pillsbury, 1995; Skubinna and others, 1995). Entrained sediment totals, as respective to the White River versus Coal Creek may also serve to explain the relative lack of nuisance algae blooms in the former in that turbid water may not permit adequate light penetration through the water column to support algae growth.

Figure 4.1.1.1



Available seasonal flow data for the White River upstream of Meeker indicates that the 5-year average (MAR-OCT) was significantly drier than the 107-year historical record. 2016 itself saw less flow than this historical average, particularly towards the mid-point and end of the reporting season (**Figure 3.2-1**). Nutrient-rich, shallower waters with minimal suspended solids such as have been recorded in this dataset may very well be the trigger that resulted in nuisance *Cladophora* blooms 2016 as well as in previous seasons. With regards to nutrient runoff, fisheries practices and nuisance algae bloom management at Westlands Ranch, the reported values in this dataset do not indicate a significant effect with regards to waters that transit the site (CPW stations 6109, 6108) as compared to any sampling location upstream in the rivershed. The occurrence of nuisance algae blooms cannot be attributed, at this stage, to any specific factor within this report other than elevated nutrient levels (-NO_2/-NO_3 and -PO_4) detected across the entirety of the rivershed system. Localized effect through increased sunlight penetration as a result of decreased flows and thus decreased levels of suspended sediments can only be inferred at this stage. The evolution of land use patterns from traditional agricultural practices such as grazing cattle and forage crop production to one of recreational use may have some responsibility yet to be determined.

Figure 4.1.1.2



5.0 Recommendations

Amaruq Environmental Services proposes to greatly expand water quality data collection both spatially and temporally within a monitoring season and to expand upon the water quality parameter set collected as compared to previous historical efforts. This increased focus is intended to capture intra-seasonal fluctuations in White River water quality, particular focus on the headwaters (the North ands South Forks of the White River, respectively). The expansion of water quality parameters is intended to better capture drivers, both biotic and abiotic, of the nuisance algae blooms as a symptom of decreased water quality within the rivershed as well as to begin the framework for a point-source determination (if possible) of the nutrient loading. The scope of work below should, at a minimum, allow for nonpoint-source determination on an inter-tributary basis with subsequent work to then move into point-source determination. Expansion of the monitoring period into a full water season; from spring runoff to fall draw down, should allow for a more in-depth determination of potential interactions between individual parameters and yield a more comprehensive assessment of changes in water quality and subsequent algae blooms.

Suggested 2018 Work Scope

1) Historical analysis of data – Completed in AES-2017-0003, Revision 0
2) Seasonal reconnaissance sampling (field parameters, nutrients, major ions, suspended sediment, pesticides, and isotopes)
3) Continuous monitoring (water temperature, dissolved oxygen, $-NO_2/-NO_3$)
4) Algal biomass and identification
5) Streambed disturbance (particle-size, potential bed-material transport)

Seasonal Reconnaissance Sampling (Scope of Work Element 1)

- Seasonal Reconnaissance Sampling (APR-SEP)
- Continuous Monitoring (data logger)
    a. Field Parameters: water temperature, DO, and $-NO_2/-NO_3$
- Streambed disturbance (particle-size, potential bed-material transport)

Continuous monitoring (Scope of Work Element 2)

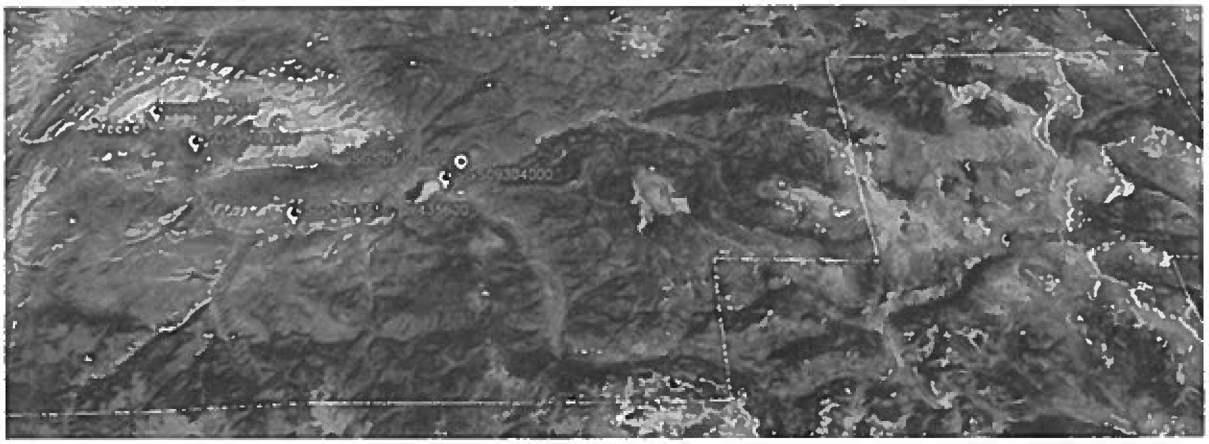
- Field Parameters: pH, alkalinity, conductivity, hardness (mg/ml CaCO3), Dissolved Oxygen (DO), turbidity, total phosphorous (TP), free reactive phosphorous (FRP), chlorophyll_a, nitrite/ nitrate ($-NO_2/-NO_3$), Total Nitrogen (TN), algal identification and count, microbial bacteria (*E. coli* and total fecal coliform)
- Description: Reconnaissance Stream Sampling (30-day cycle; APR-SEP). 18 stations total (all public land accessible);
    - 5 USGS gauge stations (09304500, 09304200, -5600, 0930300 and 0930400)
    - 6 North Fork White River Stations: Ute Creek to Trappers Lake Outfall

  - 7 South Fork White River Stations: Buckeye Creek to South Fork White River terminus
- Importance: Loading, spatial, temporal, sources; apportion source contributions to various input streams and perhaps diffuse groundwater inputs to specific reaches

Sampling program

- 5 USGS gauge stations (09304500, 09304200, -5600, 0930300 and 0930400)

USGS Gauge Station Sampling Locations



- 13 additional Tributary/White River sites (limited to streamflow and nitrate probe measurements)
  - 6 North Fork White River Stations: Ute Creek to Trappers Lake Outfall
  - 7 South Fork White River Stations: Buckeye Creek to South Fork White River terminus
- 13 streambed thalweg substrate sample points for sediment phosphorous (mineral: available) fractioning (APR, SEP)

South Fork Sampling Locations

North Fork Sampling Locations

Work Scope Justification

Work Plan Element 1

- Description: Continuous measurement of streamflow (Q), water temperature, and dissolved oxygen and $-NO_2$/$-NO_3$
- Importance: The continuous data will facilitate better analysis of short-term changes to water quality and fill in information gaps between discrete water-quality sampling events, and characterize temporo-spatial hydrologic and water-quality conditions.

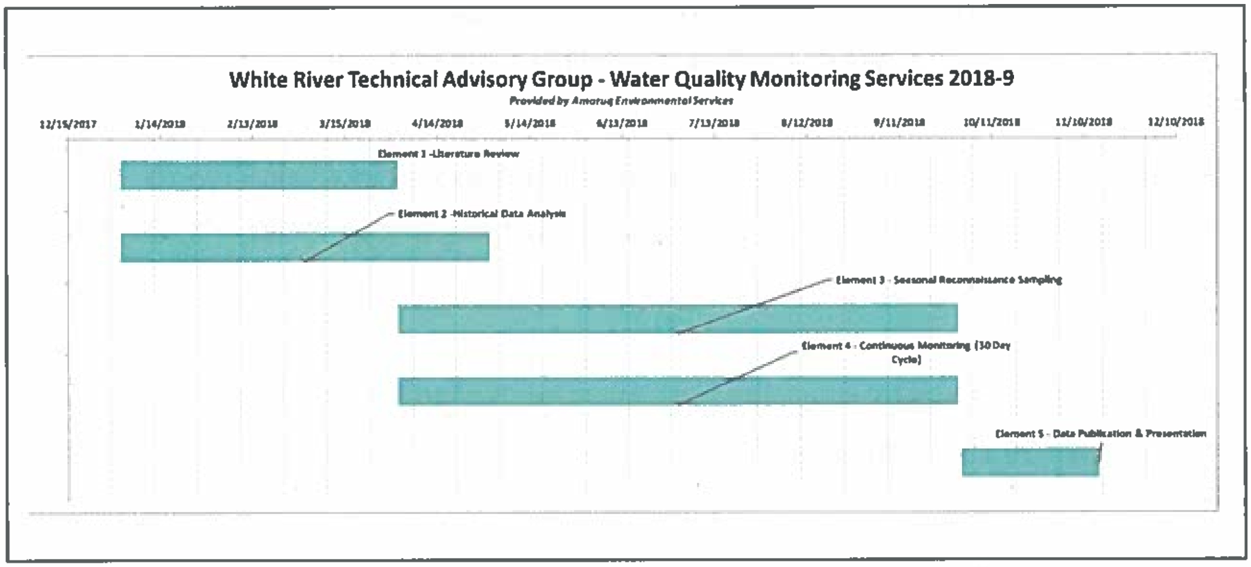
Work Plan Element 2

- Description: Reconnaissance Stream Sampling (30-day cycle; APR-SEP). 18 stations total (all public land accessible);
    - 5 USGS gauge stations (09304500, 09304200, -5600, 0930300 and 0930400)
    - 6 North Fork White River Stations: Ute Creek to Trappers Lake Outfall
    - 7 South Fork White River Stations: Buckeye Creek to South Fork White River terminus
- Importance: Nutrient loading (temporo-spatial) and point-sources (if extant); apportion source contributions to various input streams and surface inputs to specific reaches

Deliverables

- Analysis of (available) White River Area Historic Streamflow data
    - Publicly available data for all work plan elements and interpretive analysis
- USGS Scientific Investigations Report
- Presentation & Publication to White River Group

Timeline:


White River Technical Advisory Group - Water Quality Monitoring Services 2018-9
Provided by Amaruq Environmental Services
12/15/2017
1/14/2018
2/13/2018
3/15/2018
4/14/2018
5/14/2018
6/13/2018
7/13/2018
8/12/2018
9/11/2018
10/11/2018
11/10/2018
12/10/2018
Element 1 -Literature Review
Element 2 -Historical Data Analysis
Element 3 - Seasonal Reconnaissance Sampling
Element 4 - Continuous Monitoring (30 Day Cycle)
Element 5 - Data Publication & Presentation

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Distribution:

PKRAUSE@WESTLANDSRANCH.COM
JHANEY1@EARTHLINK.NET
ANDREW.SKIBO@AMARUQENVIRONMENTAL.COM

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