
WEST FORK NITROGEN MONITORING PROJECT

Sampling and Analysis Plan (SAP)

Prepared for:

BLUE WATER TASK FORCE, INC.
P.O. BOX 160513
BIG SKY, MONTANA 59716

AND

MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY
P.O. BOX 200901
HELENA, MONTANA 59620-0901

Prepared by:

KRISTIN GARDNER
P.O. BOX 160584
BIG SKY, MONTANA 59716

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APPROVAL SHEET

Mark Kelly
Water Quality Specialist
Montana Department of Environmental Quality

Date

Mindy McCarthy
Quality Assurance Officer
Montana Department of Environmental Quality

Date

Kristin Gardner
Executive Director
Blue Water Task Force

Date

1.0 Introduction

The purpose of the *West Fork Nitrogen Monitoring Project* is to implement a monitoring program to identify nitrogen sources to the Upper West Fork of the Gallatin (“Upper West Fork”). The Upper Gallatin Total Maximum Daily Load (TMDL) assessments conducted between 2005-2008 documented increased streamwater nitrate concentrations, loads, and algal growth in the Upper West Fork as it travels two kilometers through the Big Sky Golf Course and Big Sky Meadow Village [MT DEQ, 2010]. A study conducted after the TMDL nutrient assessment but prior to the Nutrient TMDL being finalized, confirmed results from the TMDL and in addition, revealed steady increases in nitrate concentrations in the eastern half of the Big Sky Golf Course and small tributaries with very high levels of nitrate [Songline, 2009a].

The data from both the TMDL and the Songline study were insufficient to define nitrogen source areas so that management decisions could be made that would reduce nitrogen loading to the Upper West Fork. Consequently, the West Fork Gallatin TMDL recommended additional investigation to more precisely determine the location of the nitrogen source areas and the timing of nitrogen loading to the Upper West Fork. The information on nitrogen source areas collected through the *West Fork Nitrogen Monitoring Project* will be used to work with local landowners and land managers to develop restoration strategies that minimize nitrogen loading to the Upper West Fork.

1.1 Montana Standards

Waters in Montana are protected from excessive nutrient concentrations by narrative standards, which stipulate: “State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will create conditions which produce undesirable aquatic life” [ARM 17.30.637 (1)(e)].

Montana has recently developed draft numeric nutrient and benthic algae criteria, which are presented in **Table 1-1** for the Middle Rockies Level III Ecoregion in which the West Fork Gallatin River watershed is located [Suplee et al. 2009; Suplee and Sada de Suplee, 2010]. These criteria are applicable between July 1st and September 30th.

Table 1-1. Recommended Numeric Nitrogen and Benthic Algae Criteria for the Middle Rockies Ecoregion.

Parameter	Criteria
Total nitrogen	0.320 mg/L
Nitrate+nitrite nitrogen	0.100 mg/L
Benthic algae	150 mg/m ²

2.0 Objectives and Design

The objectives of this assessment are to:

- Quantify nitrate+nitrite, chlorophyll *a*, potassium, and $\delta^{15}\text{N}$ isotope of nitrate levels within the Upper West Fork Gallatin River and its tributaries.
- Quantify nitrate+nitrite, chlorophyll *a*, potassium, and $\delta^{15}\text{N}$ isotope of nitrate levels within the shallow groundwater of the Big Sky Golf Course.
- Identify sources and timing of nitrogen loading to the Upper West Fork Gallatin River.

The Upper Gallatin TMDL assessments found nitrate and chlorophyll *a* levels in the Upper West Fork West Fork Gallatin River to be above target levels [Montana DEQ, 2010]. A review of the existing data followed by an examination of potential sources is provided below. This section concludes with a description of the selected monitoring locations and a rationale for these site selections.

2.1 Existing Data Review

The majority of historical data collected from the Upper West Fork can be found in the Upper Gallatin TMDL [MTDEQ, 2010] and the individual studies that informed the Upper Gallatin TMDL [PBS&J, 2006; PBS&J 2008; Gardner and McGlynn, 2009; Gardner et al., in review] and a subsequent study conducted the following summer [Songline, 2009] (**Tables 2-1 and 2-2**). Here is a summary of the results from these assessments:

- Maximum nitrate concentrations in the Upper West Fork occurred during winter when biotic demand for nutrients (plants, algae, microbes) and stream flows were at a minimum [Gardner and McGlynn, 2009].
- Minimum nitrate concentrations in the Upper West Fork occurred during spring runoff when high stream flows diluted concentrations or later in the summer when potential for biologic activity in terrestrial and aquatic ecosystems was at a maximum [Gardner and McGlynn, 2009].
- The nitrate+nitrite load in the Upper West Fork increased notably between the Bunker site and the Little Coyote site (**Figure 2-1**) [PBS&J, 2008; Gardner and McGlynn, 2009; Songline, 2009a; Gardner et al., in press].
- Phosphate [PBS&J, 2008; Gardner, unpublished data], ammonium, and nitrite concentrations [PBS&J, 2008; Gardner and McGlynn, 2009] at all sites were close to or below the analytical detection level.
- Although nitrate concentrations in the West Fork were slightly above target values (between 0.06 and 0.08 mg/L) during the growing season, excess algal growth was observed [PBS&J, 2008; Songline, 2009a; Gardner, visual interpretation].
- Nitrate isotopes ($\delta^{15}\text{N}$ and $\delta^{18}\text{O}$) just upstream of Little Coyote suggest wastewater influence to streamwater nitrate concentrations during both winter and summer time periods [Gardner unpublished data].
- Algae growth within the West Fork Gallatin River increased in a downstream direction along the Big Sky Golf Course and the wastewater treatment ponds, with generally homogenous growth across the entire streambed at the sites just upstream of the confluence with the South Fork [PBS&J, 2008].

- During the summer months of 2009, nitrate+nitrite concentrations in the Upper West Fork consistently increased between the Two Moons and Little Coyote sites (**Figure 2-1**) [Songline, 2009a].
- From July to October 2009, nitrate+nitrite concentration above the Big Sky Golf Course was relatively static (except for a small jump after the 1st hard freeze), while the concentration below the course increased dramatically as the summer progressed [Songline, 2009a].
- Although unnamed tributaries to the Upper West Fork had consistently significantly higher nitrate+nitrite concentrations than the main-stem (~ 40 times MT DEQ target levels), they do not account for the increased concentrations along the lower reaches of the golf course. This observation suggests that the many gaining reaches in this area contribute a significant nitrogen load [Songline, 2009a].
- Nitrate isotopes ($\delta^{15}\text{N}$ and $\delta^{18}\text{O}$) collected during the summer just upstream of the Little Coyote site at the eastern edge (downstream end) of the Big Sky Golf Course suggest significant wastewater contribution, while nitrate isotopes collected in the unnamed tributaries with high nitrate+nitrite concentrations and at the Upper West Fork site upstream of Golf Course did not suggest wastewater contribution [Songline, 2009a].
- Qualitatively (determined by photographs) algal growth increased in the Upper West Fork with the documented downstream increase in nitrate+nitrite [Songline, 2009a].
- In general, groundwater sampling was too inconsistent to discern clear spatial or seasonal patterns. Groundwater wells within the Big Sky Golf Course did have nitrate+nitrite concentrations that suggest human impact, $>2 \text{ mg L}^{-1}$ [Mueller and Helsel, 1996]. Mueller and Helsel 1996, have suggested 2 mg/L-N as a conservative estimate to represent human impacts, although typical groundwater nitrate in the Big Sky area without human influence typically is $\ll 1 \text{ mg L}^{-1}$ [MBMG, unpublished data].
- Nitrate isotopes suggested wastewater contamination of groundwater at one well and fertilizer contamination of groundwater in two wells [MBMG, unpublished data]. Only three groundwater wells were tested for nitrate isotopes.

Table 2-1: Historical surface water monitoring sites for nitrate, chlorophyll a, and nitrate isotopes. For site locations, see **Figure 2-1**.

Location	Site ID	Sample Type	Collected By	Time Frame
Upper West Fork	WF_B4G	nitrate, nitrate isotopes ⁵ , nitrite, ammonium, DON	MSU	2005 - 2008 ¹
Upper West Fork	Two Moons	nitrate+nitrite, chlorophyll <i>a</i>	PBS&J	2006 - 2008 ²
Upper West Fork	WF-10	nitrate+nitrite, nitrate isotopes ⁴	Songline	Summer 2009
Upper West Fork	Golf 3	nitrate, nitrate isotopes ⁶ , nitrite, ammonium, DON	MSU	2005-2008 ¹
Upper West Fork	WF-9	nitrate+nitrite	Songline	Summer 2009
Upper West Fork	Golf 2	nitrate, nitrate isotopes ⁶ , nitrite, ammonium, DON	MSU	2005 - 2008 ¹
Upper West Fork	WF-8	nitrate+nitrite	Songline	Summer 2009
Upper West Fork	Bunker	nitrate+nitrite, chlorophyll <i>a</i>	PBS&J	Summer 2008
Upper West Fork	WF-6	nitrate+nitrite	Songline	Summer 2009
Upper West Fork	Golf 1	nitrate, nitrate isotopes ⁶ , nitrite, ammonium, DON	MSU	2005 - 2008 ¹
Upper West Fork	WF-5	nitrate+nitrite	Songline	Summer 2009
Upper West Fork	WF-4	nitrate+nitrite	Songline	Summer 2009
Upper West Fork	Golf 4	nitrate, nitrate isotopes ⁵ , nitrite, ammonium, DON	MSU	2005 - 2008 ¹
Upper West Fork	WF-3	nitrate+nitrite	Songline	Summer 2009
Upper West Fork	WF-2	nitrate+nitrite	Songline	Summer 2009
Upper West Fork	Golf 5	nitrate, nitrate isotopes ⁵ , nitrite, ammonium, DON	MSU	2005 - 2008 ¹
Upper West Fork	Little Coyote	nitrate+nitrite, chlorophyll <i>a</i>	PBS&J	2006 - 2008 ²
UWF Tributary	TR-1	nitrate+nitrite, nitrate isotopes ⁴	Songline	Summer 2009
UWF Tributary	TR-1A	nitrate+nitrite, nitrate isotopes ⁴	Songline	Summer 2009
UWF Tributary	TR-2	nitrate+nitrite, nitrate isotopes ⁴	Songline	Summer 2009
UWF Tributary	TR-3	nitrate+nitrite	Songline	Summer 2009
UWF Tributary	TR-4	nitrate+nitrite	Songline	Summer 2009
UWF Tributary	TR-5	nitrate+nitrite	Songline	Summer 2009
UWF Tributary	TR-6	nitrate+nitrite	Songline	Summer 2009
UWF Tributary	TR-7	nitrate+nitrite	Songline	Summer 2009

¹ Sampling occurred September 10, 2005, February 12, 2006, June 11, 2006, October 16, 2006, March 25, 2007, and August 7 2007.

² Sampling dates were August 18, 2006, November 17, 2006, March 1, 2007, and June 4, 2007

³ Sampling occurred July 1, July 24, September 1, September 15, and October 12.

⁴ Nitrate isotopes were measured in September 1, 2009

⁵ Nitrate isotopes were measured February 12, 2006 and August 7, 2007

⁶ Nitrate isotopes were measured in August 7, 2007

Table 2-2: Historical groundwater monitoring sites for nitrate and the $\delta^{15}\text{N}$ value of nitrate. For site locations, see **Figure 2-1**.

Location	Site ID	Sample Type	Collected By	Time Frame
Big Sky Golf Course	236778	nitrate, $\delta^{15}\text{N}$ of nitrate ⁵	MBMG	2008-2010 ¹
Big Sky Golf Course	165687	nitrate	MBMG	2008-2010 ²
Big Sky Golf Course	165688	nitrate	MBMG	2008-2010 ²
Big Sky Golf Course	165689	nitrate	MBMG	2008-2010 ³
Big Sky Golf Course	165690	nitrate	MBMG	2008-2010 ²
Big Sky Golf Course	165685	nitrate, $\delta^{15}\text{N}$ of nitrate ⁶	MBMG	2008-2010 ⁴
Big Sky Golf Course	165686	nitrate	MBMG	2008-2010 ³
Big Sky Golf Course	255834	nitrate, $\delta^{15}\text{N}$ of nitrate	MBMG	May 10, 2010

¹ Sample occurred in May 2010, October 2009, August 2009, May 2009, October 2008, and July 2008.

² Sampling occurred in July 2008, October 2008, and May 2009

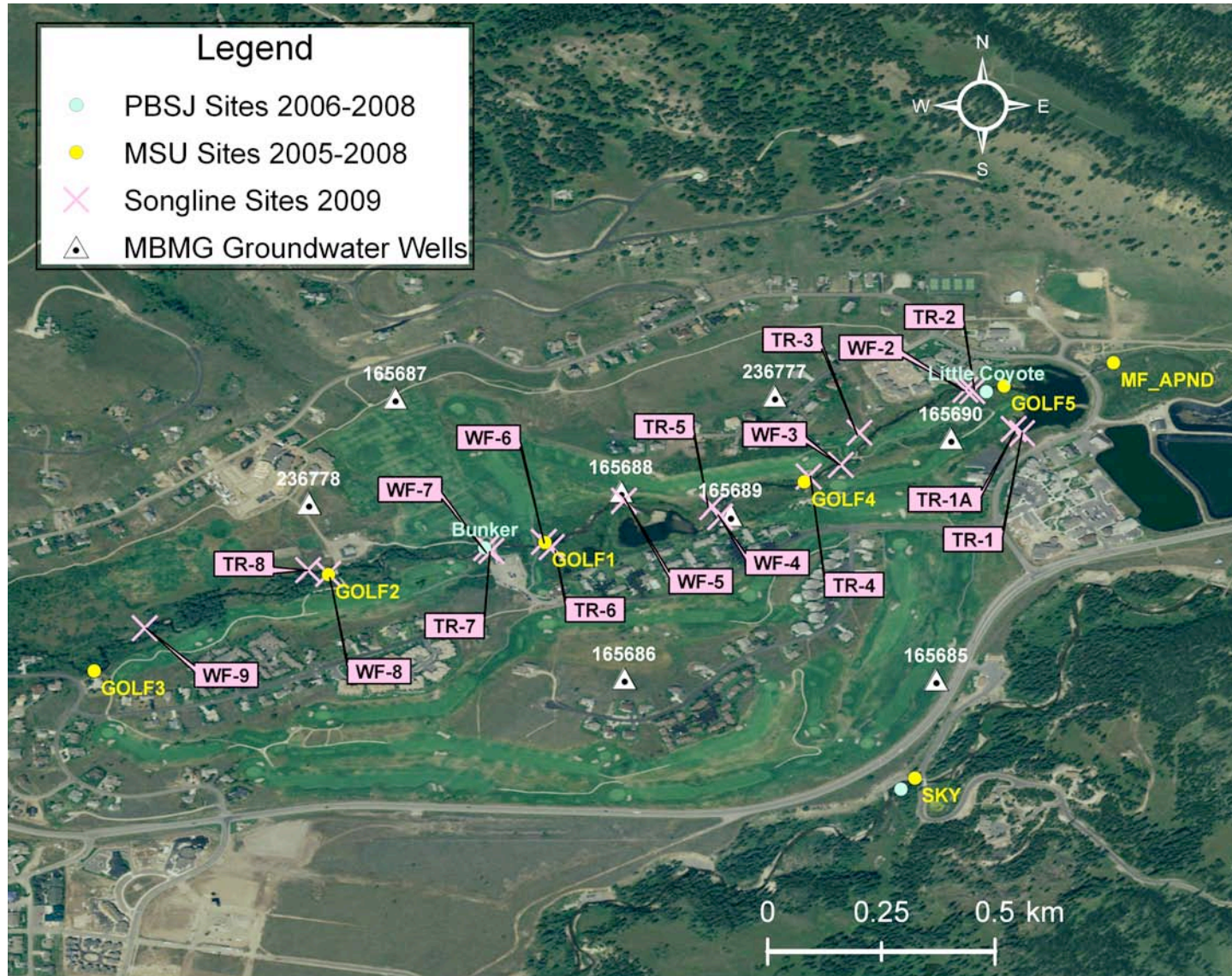
³ Sampling occurred in July 2008, October 2008, May 2009, and August 2009.

⁴ July 2008, October 2008, May 2009, August 2009, May 2010

⁵ $\delta^{15}\text{N}$ of nitrate was assessed in October 2009 and May 2010

⁶ $\delta^{15}\text{N}$ of nitrate was assessed in October 2009 and June 2010

Figure 2-1: Historical monitoring sites on the Big Sky Golf Course



2.2 Potential Sources of Nitrogen

Potential sources of nitrogen to the Upper West Fork include natural sources such as soils and geology natural, nitrogen fixation, vegetative decay, wet and dry airborne deposition, and wild animal waste. Background concentrations resulting from natural sources of nitrogen have been estimated at $<0.037 \text{ mg L}^{-1}$ nitrate+nitrite⁻ based on reference data [MTDEQ, 2010].

Anthropogenic sources of nitrogen within this reach are believed to consist of a variety of sources and include nitrogen derived from: 1) upstream sources (Middle Fork West Fork Gallatin River, North Fork West Fork Gallatin River), 2) residential and commercial lawn and landscape management, 3) wastewater effluent land-applied to the Big Sky Golf Course, and 4) wastewater originating from sewer or service line failures or leaks.

2.3 Nitrogen Monitoring Sites

Nitrogen monitoring sites for the *West Fork Nitrate Monitoring Project* are presented in **Table 2-3** and **Figure 2-2**. The sites include:

- 7 sites on the Upper West Fork Gallatin River
- 7 sites on unnamed tributaries of the Upper West Fork Gallatin River
- 5 shallow groundwater of the Big Sky Golf Course
- Wastewater irrigation water and untreated wastewater

2.3.1 Upper West Fork Gallatin River

Monitoring at 7 sites on the Upper West Fork is designed to pinpoint the increase in nitrate concentrations on the Upper West Fork and to determine whether the increase in nitrate concentrations is influenced by wastewater and/or fertilizer contributions. $\delta^{15}\text{N}$ of nitrate will be monitored to assess wastewater contamination, while potassium will assess fertilizer contamination. Chlorophyll *a* and biomass measurements will provide information on whether nitrate concentrations may be being influenced by biological uptake of nitrate.

2.3.2 Unnamed Tributaries to the Upper West Fork Gallatin

The unnamed tributaries to the Upper West Fork identified by Songline, 2009 will be monitored summer 2011 to fill in data gaps. Like the Upper West Fork, the tributaries will be monitored for nitrate+nitrite, $\delta^{15}\text{N}$ of nitrate, chlorophyll *a*, biomass, and potassium (**Table 2-1 and Figure 2-1**). Although these tributaries do not directly contribute to increased nitrate loads between the Bunker and Little Coyote sites, the high nitrate concentrations suggest that shallow groundwater from the golf course may be elevated in nitrate. Similarly, shallow groundwater could be contributing to the steady rise in nitrate seen between the Bunker and Little Coyote sites.

2.3.3 Shallow Groundwater Big Sky Golf Course

Nitrate+nitrite and $\delta^{15}\text{N}$ of nitrate will be monitored at 5 sites on the Big Sky Golf Course to fill in historical data gaps. In addition, potassium will be measured to assess fertilizer contamination.

2.3.4 Wastewater

Two samples of wastewater irrigation water from the Big Sky Golf Course and untreated wastewater from Big Sky Water and Sewer District will be collected and analyzed for nitrate+nitrite, $\delta^{15}\text{N}$ of nitrate, and potassium.

Table 2-3: Proposed monitoring sites for the *Upper West Fork Nitrate Monitoring Project*

Location	Site ID	Type	Parameters to Be Analyzed
Upper West Fork	WF-1	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Upper West Fork	WF-2	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Upper West Fork	WF-2a	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Upper West Fork	WF-3	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Upper West Fork	WF-4	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Upper West Fork	WF-5	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Upper West Fork	WF-6	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
UWF Tributary	TR-1	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
UWF Tributary	TR-1a	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
UWF Tributary	TR-2	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
UWF Tributary	TR-3*	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
UWF Tributary	TR-4*	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
UWF Tributary	TR-5	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
UWF Tributary	TR-6*	Stream	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Big Sky Golf Course	BSGC-1	Groundwater	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Big Sky Golf Course	BSGC-2	Groundwater	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Big Sky Golf Course	BSGC-3	Groundwater	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Big Sky Golf Course	BSGC-4	Groundwater	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium
Big Sky Golf Course	BSGC-5	Groundwater	nitrate+nitrite, δ^{15} of nitrate, chlorophyll <i>a</i> , biomass, potassium

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*Intermittent stream/spring – in 2009 measurable streamflow ceased by August.

Figure 2-2: Proposed monitoring sites on the Big Sky Golf Course.



3.0 Monitoring Parameters and Methodology

Monitoring parameters will include nitrate+nitrite, $\delta^{15}\text{N}$ of nitrate, and potassium from the water column, streamflow, biomass, and chlorophyll *a*. Samples collected from surface and ground waters will be rinsed three times with native water prior to sampling. Groundwater samples will be taken after the well is purged three times the well volume of water. All samples will be immediately set on ice and chilled to 4°C or less. Additional protocols for individual sampling parameters are discussed below.

3.1 Nitrate+Nitrite Nitrogen

The nitrate was the form of nitrogen responsible for nutrient impairments in the Upper West Fork. Since nitrite measurements were shown to be negligible [Gardner and McGlynn, 2009] nitrate+nitrite will be assumed to be primarily nitrate. Samples will be acidified to a pH of less than 2 by adding concentrated sulfuric acid (H₂SO₄). A field blank will be performed during each sampling event.

3.2 Chlorophyll *a*

The TMDL assessments demonstrated considerable increases in chlorophyll *a* concentrations as the Upper West Fork traveled through the Big Sky Golf Course [PBS&J, 2008; MTDEQ, 2010]. Chlorophyll *a* concentrations at the downstream end of the Big Sky Golf Course failed to meet state water quality targets. In addition to assessing adherence to state water quality standards, another reason for sampling chlorophyll *a* in the Upper West Fork is to determine whether biotic uptake may be masking nutrient loading in the summer by removing nitrate from the water column [Gardner and McGlynn, 2009; McNamara, 2010].

Chlorophyll *a* sampling will occur at the most upstream site on the Upper West Fork and at each site where algae growth is determined by visual estimation to be greater than the upstream site. For sites that are determined not to have algal growth greater than the upstream site, at least two pictures will be taken showing substrate (i.e. low chlorophyll *a*) conditions at the site. . For each sampling site that chlorophyll *a* is collected, a picture will be taken at a minimum of one transect. Additionally, if substrate at the site dominated by small boulders, cobble, and gravel, three representative rocks will be collected from the site and photographed at close range. Field sampling methods for chlorophyll *a* will follow the established DEQ protocols outlined in: http://deq.mt.gov/wqinfo/QAProgram/PDF/SOP%20WQPBWQM-011v4_final.pdf

3.3 Biomass (Ash-free Dry Weight)

For the TMDL assessments, algal biomass was critical in interpreting algal trends in the West Fork. While chlorophyll-a concentrations were witnessed to decrease over time, algal biomass, as measured by ash-free dry weight (g/m²) remained very high (>200 g/m²) throughout the study period. The high biomass indicated that substantial algae was present, yet had begun to die off (senesce) thereby reducing its chlorophyll-a content. All chlorophyll *a* samples will also be measured for biomass following methods discussed in section 3.2.

3.4 $\delta^{15}\text{N}$ isotope of Nitrate

Isotopic analysis of $\delta^{15}\text{N}$ of NO_3^- can be used successfully to identify N sources and determine their relative contributions to streamwater NO_3^- when the isotopic signatures of primary sources of NO_3^- are sufficiently distinct [Kendall and McDonnell, 1998]. Research has shown that $\delta^{15}\text{N}$ of NO_3^- alone can distinguish a domestic wastewater signature from other NO_3^- sources [Aravena, 1993; Kaushal et al., 2006] because wastewater is enriched in $\delta^{15}\text{N}$ relative to other N sources (soil, precipitation, mineral weathering). Typically, $\delta^{15}\text{N}$ of NO_3^- values of wastewater (+10 to +20‰) are higher than other N sources.

Since streamwater at the eastern edge of the Big Sky Golf Course suggested wastewater contribution, all water samples collected over study period will be measured for the $\delta^{15}\text{N}$ value of nitrate to discern the source of wastewater inputs. Isotope samples will be filtered and immediately frozen and shipped overnight for analysis. A field blank will be performed during each sampling event and measured for nitrate.

3.5 Potassium

Potassium concentrations will be monitored to assess contamination by fertilizer. Golf Course fertilizer consists of 10% soluble Potash (K_2O). Application of fertilizer has been shown to increase groundwater potassium concentrations [Hamilton and Helsel, 1995; Rajmohan and Elango, 2005]. A field blank will be performed during each sampling event.

3.6 Streamflow

Streamflow will be measured at each site for nitrate load calculation. Stream discharge will be measured with a Marsh McBirney Flo-Mate 2000™ current velocity meter and standard USGS area-velocity. Continuous stage data collected on the Upper West Fork downstream of the Big Sky Golf Course [Songline, 2009b] will be used to calculate area-scaled discharge at all Upper West Fork sites during spring runoff. Stream discharge at this downstream site will be calculated from stage-discharge rating curves developed from measurements over the full range of discharge. The relationship between watershed area and stream discharge measured at four locations in the West Fork watershed has been shown to be strongly correlated ($R^2=0.99$) and significant ($p<0.05$).

3.7 Monitoring Schedule

Monitoring events for nitrate+nitrite, $\delta^{15}\text{N}$ of nitrate, and potassium will occur in February, early May just prior to Golf Course irrigation/fertilization, mid-August after the Golf Course has undergone significant irrigation, and mid-October once irrigation and fertilization has commenced and biological uptake is waning. Chlorophyll *a* monitoring at surface water sites will occur once mid-summer (end of July/ early August, when chlorophyll *a* concentrations are at a peak [PBS&J, 2008]). Data assessment and reporting will be completed once all the laboratory analysis has been received.

It should be noted that winter conditions might limit monitoring sites and parameters. While it is anticipated that water column measurements can be performed during the winter months, heavy snows and/or ice may prevent stream flow measurements from occurring at some sites. If this is the case, then stream flows will be estimated by watershed area-scaled discharge.

4.0 Laboratory Analytical Methods

Nitrate+nitrite nitrogen, potassium, chlorophyll *a*, and biomass samples will be processed by the Montana Department of Health and Human Service Environmental Laboratory (DPHHS) in Helena. The DPHHS lab utilizes the ion chromatography method for assessing nitrate+nitrite, the High Performance Liquid Chromatography with Visible Wavelength Detection method for chlorophyll *a*, ash-free dry-weight method for biomass, and Inductively Coupled Plasma-Atomic Spectrometry method for potassium (**Table 4-1**). $\delta^{15}\text{N}$ value of nitrate will be analyzed at the UC Davis Stable Isotopic Laboratory (<http://stableisotopefacility.ucdavis.edu/>) using the bacteria denitrification method [Sigman et al., 2001].

Table 4-1. Requirements for sample collection and analysis.

Analyte	Sample Volume	Container	Preservation	Holding Time	Analysis Method	Detection Limit
Nitrate + nitrite nitrogen	250 ml	acid-washed polyethylene	Add H ₂ SO ₄ to pH<2.0, cool to 4°C	28 days	EPA 300.0	0.01 mg/L
Chlorophyll a	na	50 cc centrifuge tube	Covered in aluminum foil in ziplock on ice	Ship immed.	EPA 447	0.01 mg/m ²
Biomass	na	50 cc centrifuge tube	Covered in aluminum foil in ziplock on ice	Ship immed.	SM 10300C	0.1g/m ²
$\delta^{15}\text{N}$ of nitrate	30 – 60mL	acid-washed polyethylene	Filter, freeze immediately until analysis	No limit	Sigman et al., 2001	1 μM NO ₃
Potassium	1 L	acid-washed polyethylene	Add HNO ₃ to pH<2.0, cool to 4°C	6 months	EPA 200.7	0.2 mg/L

5.0 Quality Assurance and Quality Control Requirements

All quality assurance and quality control (QA/QC) requirements followed by Montana DEQ will be instituted for this project. The QA/QC requirements are described in *Quality Assurance Project Plan (QAPP) Sampling and Water Quality Assessment of Streams and Rivers in Montana, 2005*, which is available on the internet at <http://www.deq.state.mt.us/wqinfo/QAProgram/WQPBQAP-02.pdf>.

6.0 Data Analysis, Record Keeping and Reporting Requirements

Data generated during the Upper West Fork nitrate Monitoring project will be stored in field notes, on field forms, and in spreadsheets obtained from the laboratories. Written field notes and measurements will be entered into a spreadsheet by Kristin Gardner following QA/QC procedures to screen for data entry errors. Kristin Gardner will submit all monitoring data to the Montana Department of Environmental Quality (DEQ) in a SIM-compatible format in an Excel spreadsheet that will provide for minimum data and metadata requirements for import into the MTDEQ MT-eWQX database. All data generated during this project will be stored at BWTF's Big Sky office, and will be made available to the public via a data storage device or data download from the BWTF website (www.bluewatertaskforce.org).

7.0 Schedule for Completion

Nitrate, $\delta^{15}\text{N}$ of nitrate, chlorophyll *a*, biomass $\delta^{15}\text{N}$ of nitrate, and potassium monitoring described within this Sampling and Analysis Plan is scheduled to be performed in 2011. Additional monitoring may be undertaken once the initial data has been reviewed and an evaluation has been performed.

8.0 Project Team Responsibilities

This project is a partnership between the Blue Water Task Force (BWTF), Montana Department of Environmental Quality (MTDEQ), Big Sky Resort, and Big Sky Water and Sewer District (BSWSD). Personnel involved in this project are presented in **Table 8-1**.

Table 8-1: Project Personnel Roles.

Name/ Group	Organization	Position	Project Responsibilities
Kristin Gardner	BWTF	Executive Director	Project management Project implementation
Jon Holtzman	BWTF	Board Chair	Project oversight
Mark Kelly	MTDEQ	Watershed Specialist	Project manager, MTDEQ
Taylor Middleton	Big Sky Resort	General Manager	Primary stakeholder
Ron Edwards	BSWSD	General Manager	Primary stakeholder
Mindy McCarthy	MTDEQ	QA Officer	QAQC

Kristin Gardner is Executive Director for BWTF and a hydrologist specializing in water quality. Kristin is responsible for contract oversight, project management, and implementation. Kristin has expertise in nutrient dynamics in the West Fork watershed; her doctorate research directly informed the Upper Gallatin Nutrient TMDL. Kristin will collect and compile data according to the Sampling and Analysis Plan, perform data analysis and reporting. Kristin will ensure that measurement quality objectives and quality control requirements are met.

The project manager for the Montana Department of Environmental Quality is Mark Kelly. Mark is a watershed and water quality specialist in the Water Quality Planning Bureau and is responsible for contract oversight and review of all project deliverables.

Two primary stakeholders will be critical in implementation of the Upper West Fork Monitoring project. Taylor Middleton, the General Manager of Big Sky Resort, who owns and manages the Big Sky Golf Course will provide information on all of Big Sky Golf Course irrigation and fertilizing practices. Ron Edwards, the General Manager of Big Sky Water and Sewer District will provide maps of sewer lines, wastewater samples, and wastewater loads and concentrations.

Mindy McCarthy of the Montana Department of Environmental Quality Water Quality Planning Bureau is the state water quality monitoring quality assurance officer.

9.0 References

Aravena, R.M., M.L. Evans, and J.A. Cherry (1993). Stable isotopes of oxygen and nitrogen in source identification of nitrate from septic systems. *Ground Water*, 31: 180-186.

- Gardner, K.K., B.L. McGlynn (in review). Quantifying watershed sensitivity to spatially variable nitrogen loading and the relative importance of nitrogen retention mechanisms. *Water Resources Research*.
- Gardner, K. K., and B. L. McGlynn (2009). Seasonality in spatial variability and influence of land use/land cover and watershed characteristics on stream water nitrate concentrations in a developing watershed in the Rocky Mountain West, *Water Resources Research*, doi:10.1029/2008WR007029.
- Hamilton, P.A. and D.R. Helsel (1995). Effects of agriculture on groundwater quality in five regions of the United States. *Groundwater*, 33(2): 217-226.
- Kaushal, S.S., W.M. Lewis, and J.H. McCutchan (2006). Land use change and nitrogen enrichment of a Rocky Mountain Watershed. *Ecological Applications*, 16(1):299-312.
- Kendall, C and J.J. McDonnell (1998). *Isotope Tracers in Catchment Hydrology*. Elsevier, New York.
- McNamara, R.A. Stream nitrogen uptake dynamics from ambient to saturation across development gradients, stream network position, and seasons. Master Thesis, Montana State University, Bozeman, Montana.
- Meuller, D.K., and D.R. Helsel (1996). Nutrients in the nations waters –too much of a good thing? U.S. Geological Survey Circular 1136.
- Montana Department of Environmental Quality (MTDEQ) (2010). *The West Fork Gallatin River Watershed Total Maximum Daily Loads (TMDLs) and Framework Watershed Water Quality Improvement Plan*. Final Report.
- PBS&J (2006). *2005 Biological Monitoring chlorophyll A Data Summary, Upper Gallatin River Water Quality Restoration Planning Area*. Prepared for Blue Water Task Force, Inc., Big Sky, Montana, and Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.
- PBS&J (2008). *Upper Gallatin Pathogen Monitoring 2006-2007*. Prepared for Blue Water Task Force, Inc., Big Sky, Montana, and Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.
- PBS&J (2009). *Upper Gallatin Water Quality Monitoring Report*. Prepared for Blue Water Task Force, Inc., Big Sky, Montana, and Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.
- Rajmohan, N. and E. Elango (2005). Nutrient chemistry of groundwater in an intensely irrigated region of southern India. *Environmental Geology*, 47: 820-830.
- Sigman, D.M., K. L. Casciotti, M. Andreani, C. Barford, M. Galanter, and J. K. Böhlke. 2001. A Bacterial Method for the Nitrogen Isotopic Analysis of nitrate in Seawater and Freshwater. *Anal. Chem.* 73: 4145 -4153
- Songline (2009a). Upper West Fork Gallatin River nitrate Monitoring Project. Prepared for Blue Water Task Force, Inc., Big Sky Montana.
- Songline (2009b). Upper West Fork Gallatin River nitrate Monitoring Project. Prepared for Blue Water Task Force, Inc., Big Sky Montana.

Suplee, M., and R. Sada de Suplee (2010). *Guidance Document: Assessment Methodology for Determining Wadeable Stream Impairment Due to Excess Nutrients (Nitrogen and Phosphorous)*. Draft. Montana Department of Environmental Quality, Water Quality Planning Bureau.

Suplee, M., V. Watson, V. Watson, M. Teply and H. McKee (2009). How Green is too Green? Public Opinion of what constitutes undesirable algae levels in streams. *Journal of the American Water Resources Association (JAWRA)*, 45(1):123-140.