DESIGN OF A SUBSURFACE BIOREACTOR SYSTEM TO TREAT GROVE GULCH
NITRATES AND HEAVY METALS
A Proposal to the Butte Natural Resources Damage Restoration (BNRC)

Raja Nagisetty, Ph.D., P.E., Assistant Professor,
William Drury, Ph.D., P.E., Professor,
Department of Environmental Engineering
Montana Tech of the University of Montana, Butte, MT.

A) Grove Gulch before the confluence with the Blacktail Creek
B) Grove Gulch downstream of Copper Mountain Recreation Complex
C) In-stream detention pond upstream of Copper Mountain Recreation Complex (photo taken on 10/15/2015)
D) Grove Gulch near Little Basin Creek Road
A. Contact Information

Raja Nagisetty, Ph.D., P.E.
Assistant Professor,
RNagisetty@mtech.edu,
406-496-4448
Department of Environmental Engineering
Montana Tech of the University of Montana, Butte, MT.

William Drury, Ph.D., P.E.
Professor,
BDrury@mtech.edu,
406-496-4203
Department of Environmental Engineering
Montana Tech of the University of Montana, Butte, MT.

Authorized Official
Beverly K. Hartline, Ph.D.
Vice Chancellor for Research
grants@mtech.edu
406-496-4456
Montana Tech of the University of Montana, Butte, MT.

B. Project summary and map

TITLE: DESIGN OF A SUBSURFACE BIOREACTOR SYSTEM TO TREAT GROVE GULCH NITRATES AND HEAVY METALS
SPONSOR: Butte Natural Resources Damages Program
Location: Grove Gulch, at the southeast corner of I-15/90 and Lexington Avenue (Figure 1)
Total Dollar Amount: $23,478 (BNRDP = $19,832; Match = $3,646)
Principal Investigator: Raja Nagisetty, Ph.D., P.E.
Beginning Date: March 1, 2014, or whenever the grant funding is available to the investigators.

We propose to do a preliminary study for a passive system that would remove nitrates and heavy metals from a portion of the storm water runoff in Grove Gulch. Preliminary sampling has indicated that contaminant concentrations in Grove Gulch are above water quality standards. The proposal covers sampling and analysis of Grove Gulch water, a survey of the site where the system will be placed, and a 30% conceptual design of the system.
B.2 Background

Silver Bow Creek (Blacktail Creek to Warm Springs Creek) is listed as impaired for arsenic, cadmium, copper, lead, mercury, nitrates, total nitrogen, total phosphorus and siltation in the Montana 2014 303(d) list (Montana DEQ, 2014a). Blacktail Creek, a head water to Silver Bow Creek, has significantly elevated concentrations of nutrients (Montana DEQ, 2014b). To meet the target concentrations, Blacktail Creek and Silver Bow Creek require an average reduction of 91% and 93% of total nitrogen and total phosphorus respectively (Montana DEQ, 2014b). Grove Gulch flows approximately 6 miles before joining the Blacktail Creek east of Lexington Avenue. It drains primarily open range, a historic metal milling site (Timber Butte zinc mill) and a reclaimed mine waste repository (Copper Mountain Recreation Complex). Mine waste in the Grove Gulch watershed has led to significant inputs of metals into the stream, particularly zinc, copper, lead, arsenic, and iron. A Blacktail Creek preliminary nutrient study (Reedy, 2015) noted that Grove Gulch may be a major contributor of nutrients to Blacktail Creek and suggested further detailed investigation. Blacktail Creek stream characterization study by Montana Bureau of Mines and Geology (MBMG) stated that the sources of Cu and Zn to the Blacktail Creek may be from bed sediments or nearby streambank sediment loading from historic Grove Gulch discharges (Tucci, 2014). Preliminary water quality sampling and laboratory analysis for Grove Gulch was performed by Garrett Craig (Montana Tech Environmental Engineering graduate student) in the summer of 2015. From the data analysis, it appears that nitrates (during runoff) and metal concentrations (during base flow and runoff) are significantly elevated downstream of the abandoned metal milling and metal tailings repository sites.
Treatment of Nitrates

Nitrogen entering streams may potentially be removed and/or transformed into other forms by denitrification, immobilization into microbial biomass, dissimilatory NO$_3^-$ reduction to NH$_4^+$, and anaerobic NH$_4^+$ oxidation [Schipper et al., 2010]. Denitrification is an anoxic process, where facultative heterotrophic bacteria reduce nitrogen oxides (NO$_3^-$ and NO$_2^-$) to the gaseous nitrogen forms (NO, N$_2$O, N$_2$). Microorganisms responsible for denitrification are heterotrophic (organisms that use organic materials for energy and growth), facultative (can use either dissolved oxygen or oxygen obtained from molecules such as nitrate or sulfate ions) and generally ubiquitous in aquatic environments [USEPA, 1993; Kadlec, 2010]. Research results support that high rates of denitrification are favored by conditions which include low dissolved oxygen, a good carbon source, and an adequate supply of nitrate. Woodchip bioreactors are one of the newest passive technologies being used for nitrogen removal through the denitrification process (Schipper et al., 2010; Christianson et al., 2012). Both Schipper et al., (2010) and Christianson et al., (2012), who have reviewed various wood chip bioreactors that have been constructed concluded that denitrifying bioreactors are cost effective (Schipper et al., 2010) and promising technology (Christianson et al., 2012).

Treatment of Metals

Bioreactors can also be used to precipitate most of the metals of concern (for example: Zn, Cu, Cd, Pb) as a metal sulfide (Reisman et al., 2009; Butler et al., 2011). Hydrogen sulfide can be easily produced by the activity of sulfate reducing bacteria (SRB) as long as the SRB are fed (have an electron donor) and the water is kept in an anaerobic environment for a long enough time. In order for sulfate reduction to proceed, dissolved oxygen, nitrate, and ferric iron must be depleted from the water. Two such reactors were built in the early 2000’s southwest of Helena, MT, one at the Luttrell Repository and one at the Upper Ten Mile Creek Mining District (Peerless Jenny and Peerless King mines) to treat mine influenced water (Butler et al., 2011). Metal removals range from 99% (iron) to over 99.9% (cadmium, copper, and zinc) by the Luttrell Repository anaerobic bioreactor, and from 94% (zinc) to over 99.9% (iron) by the Peerless Jenny King treatment system.

C. Project Goals and Objectives

To treat Grove Gulch nitrates and metals of concern, a sub-surface woodchip bioreactor will be designed (for location, please refer to figure 1). The goal of this project is to prepare a 30 percent conceptual remediation design, which will be included in a conceptual report to be submitted to BNRC at the end of this project.

To meet this goal, we will (a) assess the nitrate and metal concentrations in Grove Gulch, (b) survey the study area and (c) prepare the 30 % conceptual plan

D. Project Benefits

The major beneficiary of this project will be the Blacktail Creek and Silver Bow Creek. Treatment of Grove Gulch nitrates and metals will significantly increase water quality of Blacktail Creek
and Silver Bow Creek. Treatment of pollutants in headwater streams (like Grove Gulch) is more feasible and efficient than treatment in the higher order streams (like Silver Bow Creek).

The additional benefits include:

- Understanding of nitrate and metals concentrations in Grove Gulch
- Support graduate and undergraduate students at Montana Tech
- The technique that will be developed in this study will be useful to the other similar streams impacted by mining and/or mills.

E. Project Implementation

E.1. Sample collection and laboratory analysis

The purpose of this sampling is to assess the concentrations and loads of nitrates and metals in Grove Gulch. Samples will be collected during base flow and storm events. The samples will be analyzed for nitrates and metals in the Montana Tech Environmental Engineering Laboratory. Montana Tech department of Environmental Engineering will provide the instruments and chemicals required for this analysis. Grove Gulch flow rates will be measured using a weir or flow meters.

E.2 Surveying of the study area

Knowledge of the ground surface profile is required for the design of the treatment system. Montana Tech Environmental Engineering has LiDAR data (courtesy to Montana Bureau of Mines and Geology) for this area. While LiDAR data is a great asset, our previous experience suggests that additional field surveying is required. The light used while collecting LiDAR data does not penetrate water and does not penetrate thick vegetation well. These areas will be surveyed using the Montana Tech total station GPS system.

E.3 Design parameters

A literature review of the existing wood chip bioreactor systems will be conducted to obtain the typical values for various design parameters like hydraulic conductivity, residence times required, wetland volume, and subsurface system volume.

E.4 Conceptual design

As part of this 30% conceptual plan development, plan view and typical cross section drawings will be developed for the treatment system.

E.5 Report preparation

The results of this study, including the 30% conceptual design plan, will be summarized and submitted to the BNRC in a report.
F. Project Schedule

Most of the project work will be performed during the summer of 2016. The report will be delivered before July 1st 2017.

G. Monitoring activities

There will be no monitoring activities associated with this project.

H. Project Budget

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References:


