EFFECTS OF STREAM RESTORATION ON POLLUTANT LOAD REDUCTIONS IN AN URBAN WATERSHED

RESEARCH PROPOSAL

A research proposal submitted in partial fulfillment of the requirements for the degree of Master of Science in Biosystems and Agricultural Engineering in the College of Engineering at the University of Kentucky

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Abstract

One of the major problems faced by streams with Urban Stream Syndrome is heavy nutrient loading caused by pollutants in runoff. If restoration projects can become focused on deliberately improving water quality in urban watersheds, the stream restoration industry may undergo a paradigm shift. The field of stream restoration is one that is just reaching its adolescence as a science and is constantly evolving in its practices and motivations. Urban streams have become a major focus in the field due to instability caused by infringement of their floodplains by urbanization. This causes dramatic changes in the hydrology of urban watersheds, and management practices in these watersheds are currently focused on mitigating these hydrologic disturbances. Previously, restoration projects focused on restoring hydraulics and hydrology to pre-disturbances conditions, with the expectation that this would improve the water quality and ecological health of the system. While this is true to some degree, the capacity of a stream to handle nutrient loading is still limited by the quality of its exchange (hyporheic) zone.

One project in Lexington, Kentucky was completed near Montessori Middle School of Kentucky and was designed to actively improve water quality. The exchange zone of this site was designed with an organic medium mixed into it in order to facilitate microbial processes that remove nitrogen based pollutants, as well as other pollutants. The project has a broad floodplain which vegetation has moved into causing it to behave like a linear wetland in high flow events. If data suggests that this method of restoration is effective at denitrification in head waters of urban streams, then it may mean a new direction for the industry.

Chapter 1: Introduction

The stream restoration at the unnamed tributary to South Elkhorn creek near Montessori Middle School of Kentucky was performed in 2013 to combat Urban Stream Syndrome. The typical stream restoration project does not usually enact measures to actively improve water quality. However, this restoration project, which is located adjacent to an industrial area, was designed with a filtration media in the hyporheic zone as well as within a biofiltration chamber. There is limited research on restoring streams with a focus on water quality, which means most restoration practices only focus on hydrology, hydraulics, and material transport.

Water quality is an important design consideration because heavy pollutant loads in urban watersheds often lead to water quality issues that extend well beyond the range of their infringing municipality. Urban Stream Syndrome is the name given to the impact of urbanization of watersheds leads to streams in developing and industrial areas often experiencing volatility in their behavior, ranging from unstable hydrographs, to nutrient loading, to destruction of habitats of sensitive native species. The removal of cover and buffer areas has impacted the chemistry of the water in these streams, reducing Dissolved Oxygen (DO), as well as increasing temperature and algae infestations [Biksey and Gross, 2001]. There can be a long distance downstream impact if the focus on water quality is not more emphasized in stream restoration projects. The connectivity of all of the national waterways has led to transportation of urban runoff based nutrients to the Mississippi River and eventually to the Gulf of Mexico. This has resulted in the eutrophication of the Gulf area and the exceedance of Maximum Contaminant Levels (MCLs) in Nitrogen of 10 mg/L [Daniluk et. al, 2013].

The final stream functions pyramid for stream restoration projects provides a hierarchy for the objectives in stream restoration projects and states that the first three functions are hydrology, hydraulics, and sediment & nutrient transport. These objectives are important for maintaining the continuity of the watershed and safe flow conditions. However, few stream restoration projects, especially those in urban areas have been designed to actively promote good water quality. These projects can do a decent job at removing some pollutants, but lack the fuel that drives the removal processes. The physiochemical properties of the stream fall on the fourth tier of the final stream functions pyramid. While some restoration measures improve the water quality of the stream, they are not designed for active filtration and management of environmentally threatening nutrients such as Nitrate or Phosphorus.

Seventy-Five percent of the Resource Conservation and Recovery Act (RCRA) or Comprehensive Environmental Response Compensation and Liability Act (CERCLA) sites in the US are within 2 miles of a water body that is vital to its watershed. Hazards from these sites, as well as from urban environments can cause contamination of the water supply [Karanasios et al., 2010]. The primary natural mechanism for counteracting contamination is the buffer zone and an effective hyporheic zone located beneath the surface surrounding the stream bed. The health of this area can directly promote biodiversity [Harman et al., 2012]. However, in urban environments, the size of these areas has dramatically decreased. This means urban waterways are more susceptible to contaminant loading and that conventional buffer zones might not be effective enough. Sharpley and Weld (2003) discussed the harmful effects of eutrophication and nutrient loading in US waterways similar to the those described by urban stream syndrome.

One potential solution for managing pollutant and nutrient loading is the installation of instream biofiltration reactors. Greenan (2006) studied bioreactors extensively and concluded that instream reactors are more effective at treating a polluted water source by running it through a piped filtration chamber than by constructing wetlands for such purpose [Greenan et al., 2006]. Additionally, in Greenan (2009), it was stated that several factors needed to be considered in order to understand the effectiveness of biofiltration, several factors must be examined. These include pH level, flow rate, concentration of pollutants, and concentration of filtering media [Greenan, 2009].

Biofiltration chambers have been installed along the right side of the study stream and the entire stream valley was designed with the same filtration media as the chambers. Pre-restoration water quality measurements were taken by a research team from the University of Louisville. The site is directly adjacent a commercial business park with a high percentage of impervious surface.

Rassam (2013) stated that the selection of optimal locations for riparian buffer selection is dependent on the availability of a fuel source for the microbial invertebrates that perform denitrification. It is also stated that the hyporheic zone limits the transport of Nitrogen depending on the vegetation and root systems occupying the exchange zone. This indicates that the microbes prefer a source such as carbon, not oxygen, in the denitrification process. Thus areas with ample full, may see decreased levels of dissolved oxygen in the water. Rivett (2008) states that organic carbon is the primary source donor of the electrons necessary for denitrification. Consequently, these bacteria may also contribute to organic pollutant loading in a stream as a byproduct of denitrification.

According to Read and Wevill (2008), the selection of the plants for nutrient neutralization in the exchange zone can be optimized depending on the pollutants present. They state that each area has a set of native flora that vary in their ability to remove harmful materials. This means that the design of the buffer zone can be critical in removing nitrogen based contaminants. It shows that each stream restoration project must consider unique designs to manage these pollutants and that no plant is perfect for the removal of all contaminants.

Rivett (2008) observed that some agricultural crops have the ability to increase the absorption of nitrogen based chemicals, such as fertilizers. Rivett noted that seasonal changes in rainfall can impact the amount of nutrient transport, especially in areas with poor infiltration. It was also noted that treatments, such as Nitrapyrin, could be used to improve the uptake of Nitrogen. While farm crops do not make a very good riparian zone, these principals can be applied to areas of high percentage of impervious surface that encounter high runoff volumes and nutrient transport. It is also possible to treat the hyporheic zone and buffer zones for increased uptake of Nitrogen.

Campana (1996) observe the mechanics of the exchange zone. Campana noted that factors such as flow speed and settling velocity, as well as hydraulic conductivity, as factors that impact nutrient retention and exchange. It was also noted that dissolve oxygen decreased with residency time for water. This indicates that flow retarding factors, such as channel vegetation, improve the exchange rate. Daniluk (2013) analyzed the impacts of designed structures on improved hyporheic zone exchange. Daniluk stated that some structures that do immediately improve exchange, tend to deteriorate. Upon deterioration, the structures can begin to impact the ability of the hyporheic zone to exchange nutrients. Thus the only exchange is occurring laterally within the stream, leading to downstream excessive nutrient loading.

Greenan (2006) studied the impact of various substrate combinations which included varieties of wood chips in combination with oils, sugars, and alcohols. All of these methods have the possibility to increase denitrification. The conclusion of the research indicated that woodchips on their own remove the most nitrogen. Corn stalks were also deemed effective, but produced high ammonia byproduct volumes.

Chapter 2: Objectives

The stream restoration of an unnamed tributary to South Elkhorn Creek at Montessori Middle School of Kentucky will quantify the effectiveness of designing the hyporheic zone to actively improve water quality. The study will attempt to see if restoring streams for active water quality demonstrates a notable improvement in water quality in urban streams. It will assess the capacity of restoring streams hyporheic zones with a denitrification facilitating media will effectively reduce the levels of pollutant being transported through the watershed.

Several properties of chemical properties will be used to determine the effectiveness of this restoration project for water quality. The project determine the influent and effluent quantities of PO_4-P, NO_3-N, NO_2-N, NH_3-N, Cl, SO_4, TOC (total organic carbon), DOC, and E.coli. The design parameters, which include the hyporheic zone design and the channel dimensions, will be compare to pre-restoration data to assess their impact on filtration. These design parameters will be analyzed for their ability to neutralize urban runoff nutrient loads. The tests will determine if the filtration media, 30% wood chips blended with rock, is effective at denitrifying pollutants. The instream biofiltration chambers will be assessed to determine if they are effective at removing the pollutants over a short section of the reach. Once the parameters are established, the data can be used to compare the effectiveness of the MMSK UT to South Elkhorn Creek restoration project to restoration methods that do not actively design for water quality improvement.

The objectives of the project are:

- To analyze the design parameters of the stream for water quality in relation to the pre-restoration water quality report from UofL.
- To determine the effectiveness of the design filtration media at removing harmful chemicals such as nitrogen or phosphorus
- To determine the influent and effluent concentrations of chemicals within the filtration chambers

Chapter 3: Methods

The first step in assessing this restoration technique is to gain an understanding of the flows in the stream as well in the exchange zones beside the stream. Well screens were installed at six different transects along the length of the stream. They will be positioned to determine spatial variation in the concentration of chemicals at the entrance, at a point representative of the center of the restored reach, and at the end of the reach. Six screens will be installed across the floodplain at each longitudinal station for a total of 36 monitoring wells. The wells will then be used to measure flow in the near stream areas using HOBO data logger level gages (Onset). The YSI 556 multi-probe system will be used to determine the pH, DO, EC, and the temperature.

Water elevations will also be measured and recorded for three previously installed trapezoidal flumes that are located at upstream, midstream, and downstream locations. These will also be performed using the HOBO gages.

At each of the well transect locations the water quality will also be tested for PO_4-P, NO_3-N, NO_2-N, NH_3-N, Cl- , SO_4 , TOC, DOC, E.coli (stream only), TSS, and turbidity. The tests will be performed in a lab on UK's campus (equipment has not yet arrived at UK so I am not sure of the procedure we will use) and the samples will be collected with standard grab sampling techniques. The wells and transects will also be monitored once a week for temperature, pH, and dissolve oxygen (DO). The equipment for testing these parameters is the YSI multiprobe system. All of the data collected will be analyzed using a 2nd order autoregression method because it is effective when a current variable such as accumulated flow depends on the previous values of that variable. The data will also undergo a statistical analysis to determine the importance of each variable being tested in relation to the filtration media.

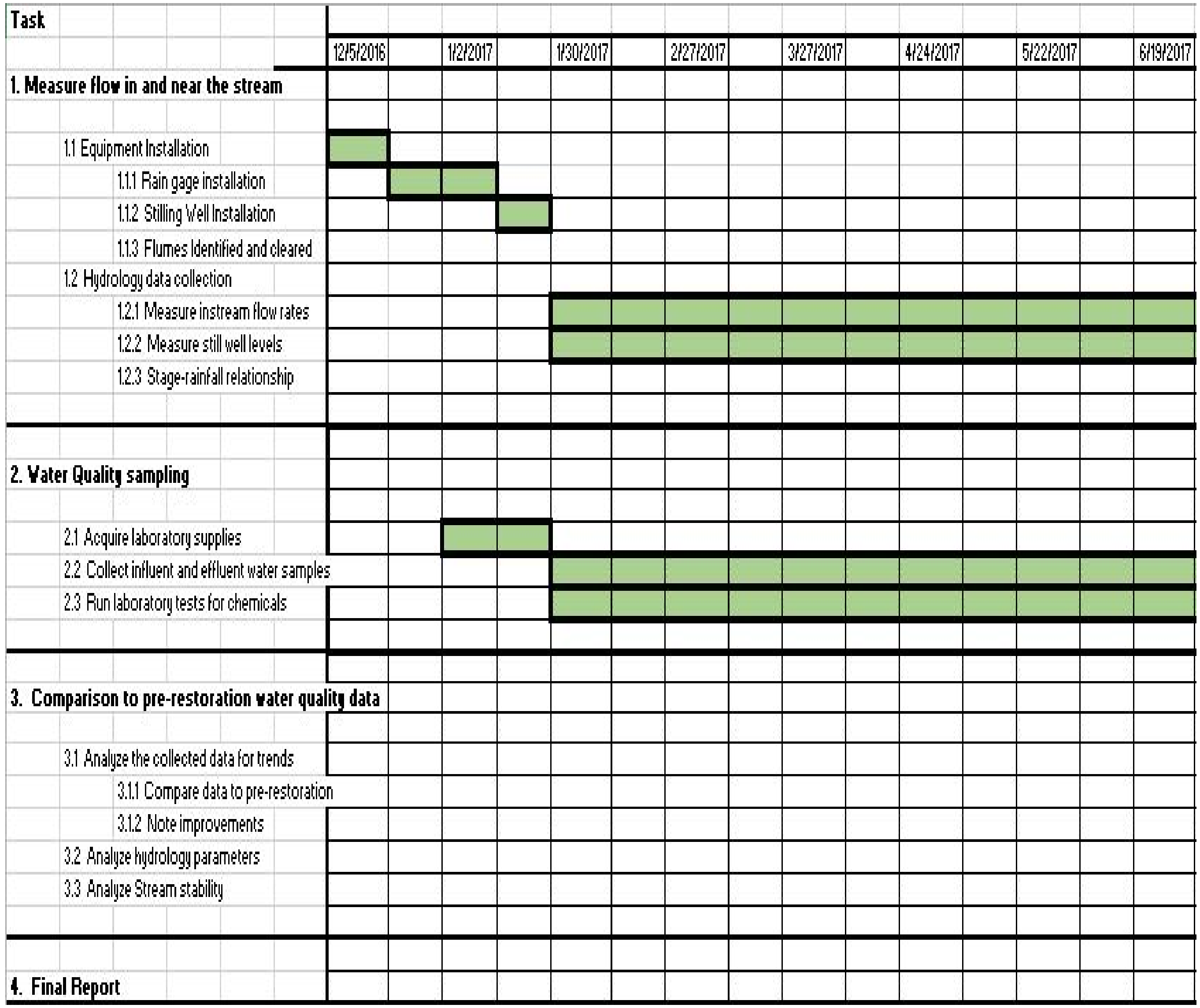
The project will also assess the effectiveness of the biofiltration chambers installed during the restoration. The first step is to adjust the flow control mechanisms within the existing chambers such that the flow rate through them is known. The intake port for the chamber will be used to inject a known quantity of a selected contaminant and the outlet port will be used to assess the filtration effectiveness.

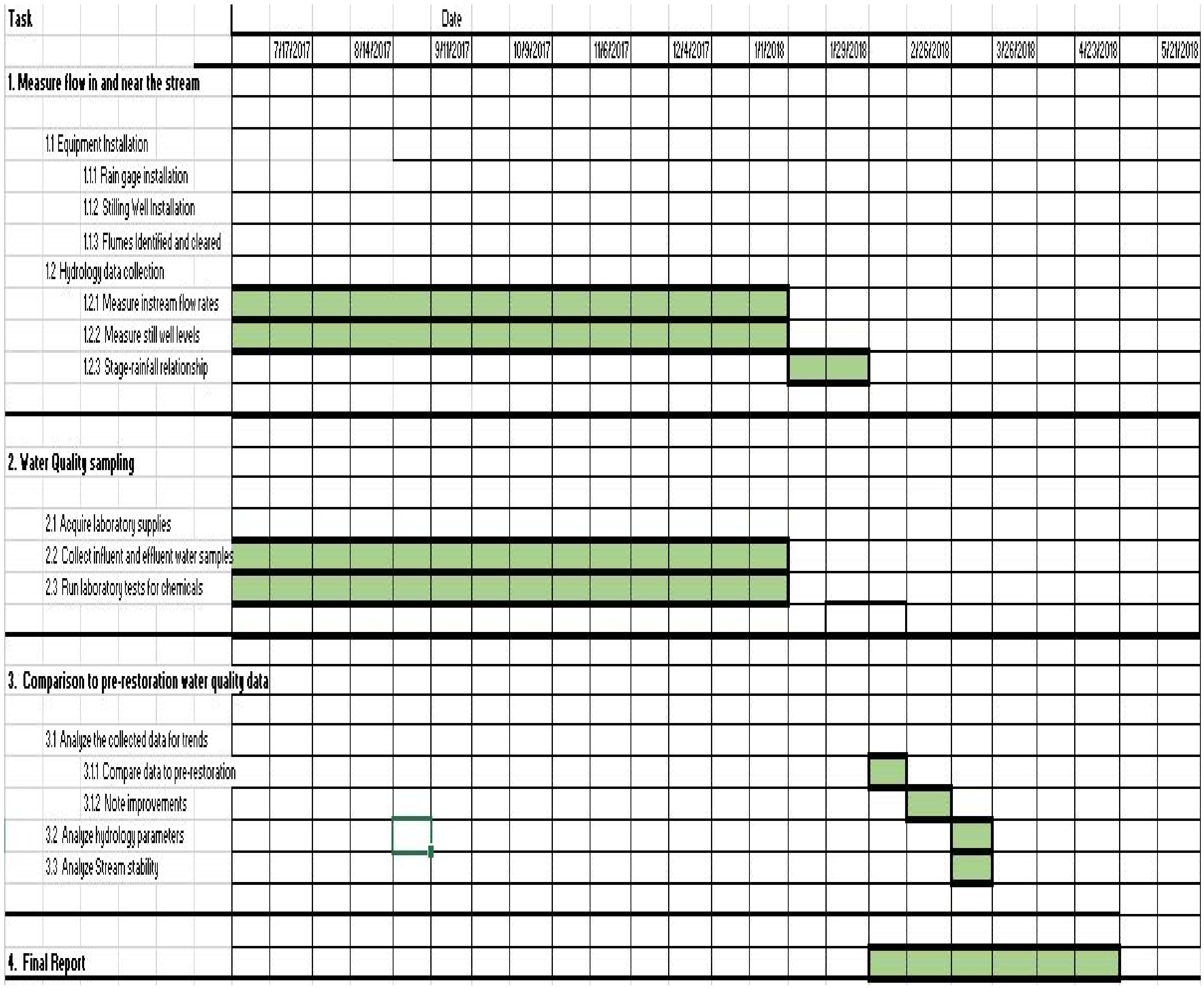
Appendix 1: Budget

1. Direct Costs	Year 1	Year 2	Total
A. Salaries and Wages			
(1) You	$16,000.00	$16,000.00	
(2) Your advisor	$13,175.00	$13,504.38	
(3) Others as appropriate	$1,295.56	$1,327.95	
Total Salaries and Wages	**$30,470.56**	**$30,832.32**	**$61,302.88**
B. Fringe Benefits			
(1) You	$1,416.00	$1,416.00	
(2) Advisor	$2,799.69	$2,869.68	
(3) Others as appropriate	$278.55	$285.51	
Total Fringe Benefits	**$4,494.23**	**$4,571.19**	**$9,065.42**
C. Travel			
(1) ASABE meeting	$1,518.00		
(2) Sample collection	$500.00	$ 500.00	
Total Travel	**$2,018.00**	**$ 500.00**	**$ 2,518.00**
D. Materials and Supplies			
(1) Chemical reagents	$2,625.00		
(2) IDEXX supplies	$1,800.00		
(3) Others	$1,000.00		
Total Materials and Supplies	**$5,425.00**		**$5,425.00**
E. Equipment			
(1) Other			
Total Equipment	**$0.00**		
F. Other Direct Costs			
(1) Publication costs		$1,000.00	
(2) Tuition and fees	$28,380.00	$29,000.00	
(3) Other	$1,000.00	$1,000.00	
Total Other Direct Costs	**$16,400.00**	**$31,000.00**	**$47,400.00**
G. Modified Total Direct Costs	**$125,711.31**		
2. Indirect Costs	**$49,884.52**		
3. Total Costs	**$175,595.83**		

1. Direct Costs
   A. Salaries and Wages
      (1) Based on current departmental stipend of $16000/year for a first-year MS Research Assistant.
      (2) Estimated 10% contribution from advisor at a salary of $105,400/year.
      (3) Estimated 2% contribution from laboratory supervisor at a salary of $64,778/year.
   B. Fringe Benefits
      (1) Current University of Kentucky fringe benefit rate for graduate students is 8.85%.
      (2) Current University of Kentucky fringe benefit rate for faculty is 21.25%.
      (3) Current University of Kentucky fringe benefit rate for staff is 21.55%.
   C. Travel
      (1) Attendance at 2017 International Meeting of ASABE. Air fare estimated as $703 round trip ,three days' lodging and per diem at $99 per day, meeting registration of $518.00
      (2) Estimated costs for 100 round trips to MMSK at 10 miles per trip using a department vehicle.
   D. Materials and Supplies
      (1) Estimated costs to perform the laboratory analysis for the samples.
      (2) Colilert-18 200-pack, quanti-trays, bottles with sodium thiosulfate, and foaming agent for testing grab samples.
      (3) Well screens, caps, risers, and supplies to install gages.
   E. Equipment
      (1) All equipment is already owned by the department.
   F. Other Direct Costs
      (1) Estimated 10-page article to be published in the *Transactions of the ASABE* at $100/page.
      (2) Tuition and Fees for 2 years of MS degree.

Appendix 2: Research Plan


Task
12/5/2016
1/2/2017
1/30/2017
2/27/2017
3/27/2017
4/24/2017
5/22/2017
6/19/2017
1. Measure flow in and near the stream
1.1 Equipment Installation
1.1.1 Rain gage installation
1.1.2 Stilling Well Installation
1.1.3 Flumes Identified and cleared
1.2 Hydrology data collection
1.2.1 Measure instream flow rates
1.2.2 Measure still well levels
1.2.3 Stage-rainfall relationship
2. Water Quality sampling
2.1 Acquire laboratory supplies
2.2 Collect influent and effluent water samples
2.3 Run laboratory tests for chemicals
3. Comparison to pre-restoration water quality data
3.1 Analyze the collected data for trends
3.1.1 Compare data to pre-restoration
3.1.2 Note improvements
3.2 Analyze hydrology parameters
3.3 Analyze Stream stability
4. Final Report


Task
Date
7/17/2017
8/14/2017
9/11/2017
10/9/2017
11/6/2017
12/4/2017
1/1/2018
1/29/2018
2/26/2018
3/26/2018
4/23/2018
5/21/2018
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Milestones

1/30/17 – All Equipment Installed onsite at MMSK

1/1/18 – Full data collection

3/19/18 – Data Analysis Complete

5/1/18 – Thesis completed

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