The Best Dam Team

Gonzaga University School of Engineering and Applied Science

502 E Boone Ave

Spokane, WA 99258

December 2nd, 2020

Toni Boggan,

Assistant for CEDE

Gonzaga School of Engineering and Applied Science

Paccar 210,

Spokane, WA 99258

Mrs. Boggan,

The following document presents a project status report for the design of a beaver dam analog complex on Thompson Creek at Newman Lake, Washington. This report provides a summary on the work that has been completed up to date. Lastly, we will provide an update on our hours and the timeline for our project.

The main focus so far has been the development of our monitoring plan to determine the effectiveness of the proposed beaver dam analog (BDA) complex in storing water and sediment and reducing phosphorous entering Newman Lake. The Best Dam Team has identified three hypothesis that will assist in determining the effectiveness of the implementation of BDAs. The methods for the testing procedure were researched through our literature review of studies that have examined the effectiveness of both natural beaver dams and beaver dam analogs. The Best Dam Team has also synthesized the results of the evaluation of reach-scale processes in Thompson Creek that were prepared with the help of the CENG 426 class. The results of the evaluation of the reach-scale processes in Thompson Creek will help in the design of the BDA complex. This document also provides an update on the hours and the schedule of our project. These can be seen in the project management section.

The Best Dam Team is excited about the progress of the project, and we are looking forward to continuing the design process. Our team would also like to thank our Clients, the Lands Council and Spokane County Department of Ecology, for their help in this process. If any questions arise please contact Nick Whittlesey at nwhittlesey@zagmail.gonzaga.edu.

Sincerely,

Connor Denning

Project Manager

Nick Whittlesey

Client Liaison

Gonzaga University

School of Engineering and Applied Science

Center for Design and Entrepreneurship

ENSC 24- Design and Evaluation of Beaver Dam Analogues

Status Report

Prepared by:

Connor Denning

Nick Whittlesey

Reviewed by:

Dr. Sue Niezgoda

Gonzaga University

Academic Advisor

THOMPSON CREEK BEAVER DAM ANALOG STREAM RESTORATION

PROJECT STATUS REPORT

PREPARED FOR

Spokane County Environmental Program

DECEMBER 2, 2020

The Best Dam Team

Executive Summary

The dredging of Thompson Creek for agricultural purposes has resulted in many negative side effects on the surrounding watershed. It has resulted in a straight channel with faster flows that continues to incise. This has caused the separation of Thompson Creek from its surrounding watershed, allowing for invasive plant species to take over. The dredging has also resulted in an increase of sediment and pollutant transport downstream. The increase of the amount of phosphorus in Newman Lake has caused problems with summer algae blooms. The Washington Department of Ecology has placed the lake on its Total Maximum Daily Load (TMDL) 303d list for total phosphorus, indicating an unhealthy amount of phosphorus in the lake. Through the studies done in the TMDL, Thompson Creek has been found to be a large contributor of this Phosphorus. Thompson Creek itself contributes 43% of the total phosphorus into Newman Lake. With guidance from The Lands Council and Spokane County, The Best Dam Team is aiming to reduce phosphorous loads entering Newman Lake from Thompson Creek and also reconnect Thompson Creek to its surrounding floodplain. So far, we have completed our monitoring plan, and begun our baseline characterization of Thompson Creek's watershed, reach scale, and water quality processes. The monitoring plan lays out the three hypothesis that our group is testing: increase in water storage, increase in sediment storage, and reduction in phosphorus loading. The monitoring plan document also lays out the testing procedures that will be applied over the next three years to test the hypotheses. We have also completed our reach scale processes examination of Thompson Creek with the help of CENG 426, which included an examination of riparian processes, fluvial processes, habitat and water quality, and channel-floodplain connection. Summaries of the evaluation of these processes are provided in this document. After our summary of the watershed processes our team will begin to focus on design. Our design will ensure that the beaver dam analogues meet both hydraulic and structural requirements. The Best Dam Team will design the series of beaver dam analogs, ensuring that the project is both effective and cost efficient. Our project is ahead of schedule with the monitoring plan being fully completed. Currently TBDT has used approximately 31% of the projected hours and consulting fee. 31% is a reasonable amount of time considering we are three months into an eight-month project (37.5%). We will be giving a presentation summarizing this document on December 9th, an additional presentation will update the clients about our progress on February 24th, with a goal of 70% completion at that time. Lastly a final presentation will be given on April 28th, presenting our completed design and monitoring plan.

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1.0 Background and Introduction

Thompson Creek is located Northeast of Spokane, Washington. It flows into Newman Lake, on the north side. The location of Newman Lake, as well as Thompson Creek can be seen in Figures 1 and 2. Thompson Creek once meandered through the lower watershed but was straightened in order to help drain the land and prevent flooding for agriculture. However, this change has had a significant impact on the watershed and reach scale processes of the creek.

Figure 1: The map of Spokane County and location of Newman Lake (Google Maps 2010)

By straightening the channel, the velocity of the water increased heavily. This caused continued bank erosion and channel incision. This also resulted in more sediment and pollutants being transported downstream into Newman Lake. The incision of the creek has caused a disconnection between the creek and its surrounding floodplains, which has allowed for the dominance of Reed Canary Grass in the area, limiting the benefits that vegetation diversity can provide for the stream.

Figure 2: Aerial View of Thompson Creek (Google Maps 2010)

In the last 20-30 years, there has been an increase of algae in Newman Lake during the summer months, concerning many of the local residents. When this was looked into further, it was discovered that there was a phosphorus problem in Newman Lake. The Washington Department of Ecology released a total maximum daily load (TMDL) report of Newman Lake and identified Thompson Creek as one of the main contributors of phosphorus into the lake (WDOE 2007). This report found that Newman Lake has an annual external total phosphorus load of 1480 kilograms. Of this, 636.4 kg come from Thompson Creek. For Newman Lake, the goal is a reduction of 42 percent for a total of 903 kg per year. For Thompson Creek this report has set a goal of 365 kg total phosphorus entering Newman Lake from Thompson Creek reducing the total phosphorus from the creek by 42%. Finally, the TMDL report further suggested that activities should be completed that can act to restore Thompson Creek's degraded natural riparian corridors that have been dredged or straightened.

The Newman Lake TMDL report used Liberty Creek at Liberty Lake as a reference creek when examining total phosphorous loads. This creek is located east of Spokane, and South of Newman Lake. The location of Liberty Lake can be shown in Figure 3 with Liberty Creek seen in Figure 4. The Best Dam team will also do phosphorus testing on Liberty Creek to compare to Thompson Creek. This is because the land use and drainage areas for the two creeks are similar. Liberty Creek also has slowly degrading natural beaver dams which will provide good reference to see what kind of impact the insertion of beaver dam analogs can provide for Thompson Creek and Newman Lake.

Figure 4: Vicinity Map of Liberty Creek (Google Maps 2010)

Figure 3: Aerial View of Liberty Creek (Google Maps 2010)

Overall, the current conditions of Thompson Creek have contributed significantly to higher phosphorus levels in Newman Lake, and this has been identified as a primary cause of the summer algae blooms. The straightening of Thompson Creek has also created a floodplain that is now rarely flooded and has been overtaken by invasive plant species. These conditions need to be improved for the lake to be better used by locals, as well as to provide a healthier and cleaner creek.

Beaver dam analogs (BDAs) provide one possible solution to the phosphorous loading issues in Newman Lake from Thompson Creek. These man-made beaver dams, that are made of wooden posts and woven together with vegetation, have similar effects as natural beaver dams on creeks. The implementation of a series of beaver dam analogs, will slow velocities down resulting in longer times for sediment and pollutants to settle. The BDAs will also result in bringing the water level of Thompson Creek up and help to reconnect it to its floodplain. This will allow more natural vegetation and create a healthier ecosystem.

2.0 Project Goals and Objectives

2.1 Project Goals

There are two goals to our project, and they are to:

1. Complete a hydraulic and structural design for a series of beaver dam analogs (BDAs) to simulate a beaver meadow in the downstream reach of Thompson Creek to help control and reduce the sediment and phosphorus entering Newman Lake. Provide the Lands Council and Spokane County with a final design that is ready for implementation.

2. Design and begin to implement a controlled monitoring experiment to improve understanding of the impacts of a beaver dam analog complex on water, sediment, and phosphorus storage within Thompson Creek.

2.2 Project Objectives

The specific objectives of this project are to:

1. Working with the CENG426 class, research and analyze the existing degraded condition of Thompson Creek and the downstream impact it has on Newman Lake. This will include 1) conducting a literature review to determine the research work that has been completed as part of previous TMDL studies and 2) conducting a watershed and rapid geomorphic assessment of Thompson Creek to better understand watershed scale and reach-scale processes that are currently occurring.
2. Conduct a literature review to research the design, implementation, and monitoring effectiveness of using beaver dams and BDAs to trap stream sediment and nutrients. This literature review will focus on two specific areas: 1) identifying specific characteristics of natural beaver dam complexes to help with the design of the BDA complex to maximize sediment and nutrient retention, and 2) identifying monitoring efforts that can be applied to test the effectiveness of the BDA complex at reducing sediment and phosphorous loads downstream.
3. Using the results of the literature review and working with the CENG426 class, complete the hydraulic and structural design of a BDA complex to be implemented in Thompson Creek. This complex will best simulate a beaver meadow while also considering and accounting for the potential increased flooding risk to adjacent lands (e.g., FEMA) and infrastructure. The final design will include plans and drawings that show the location, spacing, and extent of BDAs and the structural details necessary to build the BDA complex.
4. Using the results of the literature review and past senior design team efforts, develop a long-term (3-5 year) controlled monitoring plan for examining and testing the hypothesis that a BDA complex will retain water and sediment and reduce phosphorus loads entering Newman Lake from Thompson Creek. The monitoring plan will include identifying specific hypotheses to be tested, monitoring parameters to be collected, monitoring methods (e.g. repeat cross section surveys, soil probing, aerial photogrammetry using drone captured photos, water quality sampling and testing, etc.), monitoring context (e.g., where, when, and who), monitoring data analysis methods, and monitoring costs. This will require discussions with Gonzaga Civil and Environmental Engineering, Biology, and Chemistry faculty to develop all aspects of the monitoring plan related to better understanding BDA sediment and nutrient retention.
5. Collect, analyze, and synthesize the results of the first year (i.e., before implementation) monitoring activities that will characterize baseline morphology, ecology, and water quality (sediment and nutrient loads) in Thompson Creek to compare to all future monitoring activities.

3.0 Project Requirements

3.1 Client Requirements

The client has requested that The Best Dam Team meet the following requirements:

- Project Management
    - Provide regular communication and give project updates as the project progresses.
    - Keep project on track and provide reports or presentations on the following dates:
        - Project Plan presentation (October 21)

        - Project Status report and presentation (December 2 and 9 respectively)
        - Status Presentation (February 24)
        - Final Project Report (April 21)
    - Flexibility for meetings in a timely manner
- Creation of a monitoring plan
    - Examine phosphorus and other water quality elements before and after insertion of BDAs
    - Take baseline data
- Design a series of BDAs
    - Not raising water levels above FEMA flood requirements
    - Create residence time to get sediment to settle
    - Not to back flood bridge to where it fails Washington Department of Fish and Wildlife regulations
    - Connect the stream to its floodplain
    - Create a healthier riparian zone.
    - Follow all codes and regulations that apply
- Evaluate Sustainability of the project

3.2 Constraints

The constraints of concern regarding this project include:

- NW Newman Lake Rd. Bridge.
    - This bridge may limit the BDA design because there are codes that restrict how close to the bottom chord of the bridge the water may reach. The back water from the BDA's may raise the water level close to this point.
- Data collection
    - If adverse weather or flow conditions cause data collection to be implausible or too dangerous, data collection at Thompson Creek will have to be performed at a different time than planned.
- COVID-19
    - Another spike or outbreak in COVID-19 could lead to exclusively remote learning again. This would mean that students being able to collect field data and access resources on campus could not be counted on due to the likelihood that they will no longer be in Spokane.
- Local property owners
    - If the water level is too high, it may encroach onto some privately-owned property, in which we would have to check with the owners. This can limit us on how high we can raise the water level.
- Budget
    - We may be restricted by how many BDAs we can add by the budget that is set out by The Lands Council and Spokane County.
    - We may also be restricted by budget in our monitoring plan, as we may not be able to collect all the data that we need.
- Conceptual Design
    - A variety of conceptual designs will be delivered to TBDT by the CENG 426 class. If none of these fit as a basis for design, we may need to create an additional conceptual design.

3.3 Codes and Regulations

The area of stream restoration has no applicable standards, as it is a fairly new field. However, the team will reference a variety of developed guidance documents to help guide the design process. Some of these documents that will be referenced in this project are:

- FEMA flood mapping (FEMA 2010)
- Washington Department of Fish and Wildlife Water Crossing design guidelines (WDFW 2013)
- Beaver Restoration Guidebook (Pollock et al. 2017)
- Low- Tech Process-Based Restoration of Riverscapes Design Manual (Wheaton et al. 2019)
- Stream and Watershed Restoration (Roni and Beechie 2013)

4 Work Completed

4.1 Baseline Characterization of Thompson Creek

4.1.1 Site Visits

TBDT and colleagues in the CENG426 class have performed multiple site visits since the beginning of the project. These have included both trips to Thompson Creek and nearby Liberty Lake. During these visits, baseline data measurements as well as channel characteristics have been examined. Liberty Lake has a creek entering it (Liberty Creek) that has a set of abandoned natural beaver dams that have been examined and will be used as a reference site in our monitoring plan. It is expected that there will be many more necessary site visits that will be laid out in future documents.

The site visits completed to date are listed below, along with pictures provided in Appendix A:

- **September 24th, 2020**: Site walkdown including marking cross sections, establishing data collection objectives and locations, and collection of the first of 12 water samples for baseline data collection
- **September 26th, 2020**: TBDT and the CENG 426 class collected field data that included longitudinal and horizontal cross-section profile surveys, streambed sediment analyses, and macroinvertebrate samples
- **October 1st, 2020**: TBDT and the CENG 426 Class performed a riparian and habitat assessment
- **October 8th, 2020:** TBDT and the CENG 426 class visited Liberty Lake to observe and take measurements of natural beaver dams. Riparian and water quality assessments were also performed.
- **October 31st and November 1st, 2020:** Visits to Thompson Creek and Liberty Lake to collect the second round of water quality samples.
- **November 9th, 2020:** TBDT examined the accuracy of the Spokane County rating curve by measuring the flow and examining staff gage depth.
- **November 19th, 2020:** TBDT and the CENG 426 Class visited a BDA complexes at Rattler Run Creek and California Creek to observe what they look like and how they function.

4.1.2 Assessment of Reach-Scale Processes

In conjunction with CENG 426, TBDT has assessed the reach scale processes of the Thompson Creek. Longitudinal and cross section surveys were performed on the stream, and quantitative and qualitative data was collected at each cross section. This data was used in CENG 426 to evaluated riparian processes, in-stream biological processes (habitat and water quality), fluvial processes, and channel and floodplain dynamics. TBDT then compiled this information to synthesize current reach-scale processes driving form and function in the Creek. The following sections summarize the results of the evaluation of each reach-scale process.

4.1.2.1 Riparian Processes

Definition of Processes: Riparian processes, are how the vegetation impacts the stream health by providing shade, bank stabilization, and filtration of pollutants. These processes can be examined by looking at the variety and type of vegetation present.
Methods: The class went to the creek and examined the species at 6 different cross sections. This was done by looking at the vegetation in a 1 ft range of the measuring tape used across the stream. With this information, the Shannon-Weiner diversity index was used to determine the diversity of vegetation in each reach and the reach as a whole. The Simpson's Index of dominance was also used to determine the dominance of different species in both the cross sections and the reach.
Results: The riparian processes report found that the stream is fairly unhealthy with regards to the vegetation. It was found that according to both indexes that the creeks is in the moderate health range. However, when it is looked into further, the riparian zone is dominated by invasive species. As a result, the species limit the streams health as they do not help in providing shade or stable banks. By raising the stream bed, it will allow for a bigger variety of native species to grow in the area.

4.1.2.2 Fish Habitat and Water Quality Assessment

Definition of Processes: Habitat processes, in this case, is the relationship between a stream and the fish that inhabit it, as habitat is defined as the type of environment that groups of organisms inhabit.
Methods: The Oregon Habitat Assessment Criteria was used to assess instream habitat. Assessment criteria included channel condition, percent pool habitat, shelter rating, off-channel habitat, percent embeddedness, percent shade and canopy, percent stable bank, riparian width and condition, and macroinvertebrate quantity and diversity. A macroinvertebrate analysis was performed to get a qualitative understanding of the water quality in Thompson Creek as certain species of macroinvertebrates indicate good or bad stream health. Fish passage flows and criteria for migration were analyzed for the stream to determine the likelihood of fish passage and migration in the stream.
Results: The habitat and water quality report found that the stream needs to have a slower velocity and more depth in order to accommodate for the fish passage of both rainbow and brown trout during the time of year when they would look to migrate. This would require a streambed with larger rocks allowing for better spawning. BDAs can provide a reduction in velocity and an increase in stream depth when implemented, both being advantageous for fish passage. When looking at the three methods for analyzing the macroinvertebrates, there were varying results indicating the stream health to be anywhere from poor to excellent. The phosphorus load does indicate poor stream health and is the main problem in the stream. Samples have detected a loading of 50 ug/L which is double the 25 ug/L laid out in the TMDL report.

4.1.2.3 Fluvial Processes

Definition of Processes: Fluvial processes is the interaction between flow in a stream and the stream channel itself, specifically the available sediment. Analyzing fluvial processes includes incipient motion, fluvial hydraulics, and stream stability. Fluvial processes govern whether a stream will erode or aggrade.

Methods: Manning's N values, longitudinal slope, cross section hydraulics, and an analysis of sediment incipient motion were used to perform the analysis. Said data was used to evaluate the fluvial processes using Shield's Diagram and subsequent equations.
Results: The fluvial processes report determined that Thompson Creek is a somewhat stable creek, citing the fact that the 2-year peak flow (42 cfs) is approximately equal to the bankfull flows in the majority of the cross sections. Variation in vegetation type showed no correlation with decreased erosion potential. Although data indicates that the creek is somewhat stable, erosion is expected at each cross section as the shear stress ratios are greater than one for all cross sections. With erosion being probable, TBDT expects that there will be significant sediment build up behind each BDA.

4.1.2.4 Channel and Floodplain Dynamics

Definition of Processes: The relationship between the channel and the floodplain is a very important indicator of the stream health, as more connectivity can help in limiting shear stress. This group also looked at a variety of classifications that can help those in the field understand the processes better.
Methods: The group used a variety of methods to find the flows. This included looking at Andrews Creek near Mazama WA, which has similar watershed characteristics to Thompson Creek and would lend itself to a comparison of flows by watershed area. This group also used Streamstats to find what flow data was calculated using this resource. After this, the group looked at the data to determine what values to use for the flows by comparing them to historical data. Using StreamMetrics the team calculated the flows needed to go over the banks and reach the floodplain. By comparing the 2-, 10-, 50- and 100-year flows and the flows needed to reach the flood plain it was determined how often the Thompson creek is able to reach the floodplain. This report also focused on classifications using both the Rosgen Classification system (Rosgen 2019) and Cluer and Thorne Stream Evolution Model (Cluer & Thorne 2013). These required the calculations for entrenchment ratio, width to depth ratio, slope and sinuosity in order to determine the Rosgen Classification. The Cluer and Thorne Stream Evolution Model was selected by observing the processes happening in the creek.
Results: The channel-floodplain processes report found that the lower interval of the Streamstats evaluation provided the best estimation of the flows in Thompson Creek. This is because the values found in this were more similar to historical values and what was seen in the field. The table showing the 2-, 10-, 50-, and 100-year flows can be seen below in Table 1. By comparing this to the flows needed to reach the floodplain it was found that the creek reaches the floodplain about once every four years. The goal for this would be 1-2 years meaning that the creek bed needs to be raised. This report classified Thompson Creek as an E3 in the Rosgen Classification and a stage 3 according Cluer and Thorne Stream Evolution Model. Both of these represent relatively unhealthy streams.

Table 1: Return Period Flows from Lower Interval Streamstats Peak Flow Estimates

Return Period	Flows (cfs)
Q2	42
Q10	111
Q50	154
Q100	165

These reports all indicate that the addition of beaver dam analogues will be beneficial to the reach-scale processes of the stream. For riparian processes, raising the stream will allow for a wider variety of vegetation to grow in the reach and have more stable banks. For habitat, the insertion of beaver dam analogues will allow for slower velocities and deeper streams which are more beneficial for fish. BDAs will also allow for slower velocities and more sediment buildup. Lastly, by raising the water level, beaver dam analogues will allow for the stream to connect to the floodplain more often.

4.2 BDA Effectiveness Monitoring Plan Development

4.2.1 Literature Review of Monitoring Techniques for Phosphorus Removal by Natural Beaver Dams

TBDT has conducted a study on published literature to determine the best practice for collecting and evaluating data regarding stream health, with an emphasis on phosphorus monitoring. The study also included a review on the impacts that natural beaver dams and BDAs have on monitoring efforts. Methods from our literature review were included in our monitoring plan. The literature review aided in establishing the effectiveness, efficiency, and confidence of the monitoring plan. Consulted literature will continue to serve as a reference when needed throughout the duration of the project and a summary of reviewed literature is provided below.

Title: Influence of beaver ponds on the Phosphorus concentration of stream water
Summary: This study was done in New York on 5 separate natural beaver ponds, all varying in age and size. The ponds were monitored for 1 year and water quality was tested twice a month upstream and downstream of the dams.
Findings of Note:

- Wetland sediments retain phosphorus by chemical precipitation and adsorption reactions and by incorporation into biomass. However, processes that lead to the release of phosphorus from sediments also occur in wetlands simultaneously with retention. While wetlands may initially remove large amounts of phosphorus, this would be followed by large exports of phosphorus in a few years.
    - Phosphorous can be trapped and released by wetlands at the same time and an inundation of phosphorous can occur after initial removal.
- (Black Warrior pond froze over during the winter) Perhaps the combination of high H_2S and anaerobic conditions led to phosphorus release under ice cover at Black Warrior. Some research suggests that storage and release of phosphorus by sediment bacteria are redox-dependent processes, with anaerobic conditions leading to rapid release of phosphorus from living cells.
- Stream sediments do not provide a limitless sink for phosphorus, and therefore, renewal of sorption sites is important. This renewal is accomplished by storm events that wash out streambed sediments and bring in new material from the stream banks

Title: Does the Morphology of beaver ponds alter downstream ecosystems?
Summary: This article elaborates on the fact that beaver pond morphology (size and shape of a beaver dam) changes the way that nutrients are transported in a stream. It also has insight on how the intensity of the water year and overall hydrology also effects the phosphorus concentration downstream of a given beaver dam. There is also discussion of nutrient limitation with Phosphorus and Nitrogen. The results are not conclusive but more research into limitation may be needed.
Findings of Note:

- Soluble reactive phosphorus (SRP) increased downstream of high hydraulic-head dams and decreased downstream of low-head dams, but also only during baseflow conditions.

- After a sustained period of baseflow conditions (as in 2007) small surface area ponds with high head dams (high morphology ratios) have greater hydraulic head gradients driving upwelling into downstream reaches relative to larger surface area ponds with low-head dams.

Title: The effect of beaver (Castor canadensis) dam removal on total phosphorus concentration in Taylor Creek and Wetland, South Lake Tahoe, California
Summary: This thesis project examined how the yearly removal of natural beaver dams around Lake Tahoe impacted the water quality, specifically the phosphorus entering the lake. This study took samples before and after the dam removal and then used statistical analysis to compare the phosphorus amount downstream before and after the dam removal.
Findings of Note: This study found that there was an increase of over 100 μg/l of phosphorus in the water downstream after the dams were removed. It is important to find another similar stream so a before-after, control-impact test (BACI) can be performed much like how this analysis was performed. The statistical analysis that is described in this study can also be used in this study.

Title: Meta-analysis of environmental effects of beaver in relation to artificial dams
Summary: This article compared the performance of artificial dams and beaver dams, with a strong background into the methods that they used to compare data. This study was done by compiling data from a large number of literature articles. Different stream characteristics were analyzed using a method from Osenberg 1997 which uses the equation:

$$\triangle r=\ln(XD/XU)$$

In this equation the r is response rate, and the X represents the mean stream value, where D is downstream, and U is upstream.
Findings of Note: When this equation was used for phosphorus as a whole, the response rate was near zero, meaning that there was little phosphorus retention in dams as a whole. However, when this is broken up into beaver dams and manmade dams there is a significant difference. Four different categories of dams were examined in the study: old artificial, old beaver, new artificial, and new beaver. This study found that the response rate for both categories using artificial dams were below 0.5. These values are lower than those of natural beaver dams. This study also shows the increase of phosphorus retention over time with natural beaver dams being compared to artificial ones.

4.2.2 Development Monitoring Plan Hypothesis

With the information gathered from the literature review, Dr. Kyle Shimabuku, Dr. Dave Cleary and past senior design efforts, TBDT hypothesizes that implementation of a proper BDA complex on Thompson Creek will result in reduced sediment and phosphorus transport, and an increase in water storage. The final set of hypotheses to be tested over the next three years include:

- Hypothesis 1 - The implementation of BDAs in Thompson Creek will increase water storage (volume) within the landscape.
- Hypothesis 2 - The ponds formed by the BDAs implemented in Thompson Creek will increase sediment storage in excess of local channel storage.
- Hypothesis 3 - The addition of BDAs in Thompson Creek will reduce the phosphorus levels entering Newman Lake to less than 25 mg/L as laid out in the Washington Department of Ecology TMDL report.

4.2.3 Design Monitoring Plan

TBDT has developed a three-year monitoring plan to test the hypotheses proposed above. This monitoring plan includes a description of the methods, frequency of testing, and personnel needed for examining each of the three hypotheses. The methods developed in our monitoring plan include:

- capturing aerial photo footage using an unmanned aerial vehicle (i.e., drone) and measuring surface water areas shown in the photos (Puttock et al 2015)
- measuring BDA pond water depths and sediment depths using on-the-ground surveying and soil probing techniques (Puttock et al 2018),
- collecting water samples in both Thompson Creek and the nearby Liberty Creek reference reach and testing for total suspended solids and total phosphorous (USEPA 2007, USEPA 1978).

These methods will assist in determining the volume of water and sediment that has been collected by the BDAs, as well as tracking the suspended sediment and total phosphorus levels in the creek. The methods will be applied over a three-year time frame to allow time for the river to adjust to the implemented BDAs. Methods will be applied by Gonzaga civil engineering students under the direct supervision of Dr. Sue Niezgoda, Dr. Kyle Shimabuku, and Dr. Dave Cleary. The complete monitoring plan describing these methods is provided in Appendix B.

4.2.4 Develop QA/QC Plan for Monitoring Activities

In order to ensure that the data collected throughout the monitoring plan is accurate, it is important to consider a quality assurance and quality control protocol. Using the literature review as well as conversations with professionals in the respective fields, TBDT has developed procedures that ensure that data collection efforts are accurate. Our team has laid out procedures that will limit the chance of error. When looking at taking sediment samples and measuring water depth, using a gridded system will allow for the results to be averaged out over the area. This ensures that even if a few samples provide inaccurate data, it will be averaged out over the total area. For the drone footage, TBDT will ensure the accuracy of the photo scan program by doing hand calculations to find the area. Site observations will also be done each time a sample is taken to ensure that values are reasonable. Lastly when taking water samples, triplicates will be done in order to use an average. The complete QA/QC plan is provided in Appendix B.

4.2.5 Ongoing Baseline Data Collection Stream Gauge Analysis Design.

TBDT is continuing to collect and analyze data related to the characterization of watershed and reach scale processes in Thompson Creek that might go beyond the work being completed by CENG 426 and described in the monitoring plan. TBDT questioned the accuracy of the existing flow rating curve (Figure 5) at Thompson Creek that was established prior to the construction of NW Newman Lake Rd. Bridge on the upstream end of the reach. The accuracy of the staff gauge (Figure 6) and accompanying rating curve is in doubt because there has been significant sediment build up on the stream gauge upstream of the bridge (~1.8 ft of sediment). TBDT performed a site visit to measure stream flow and depth where the stream gauge is located to compare to the rating curve. The results said the streamflow measurement found a flow of 1.8 cfs with a thalweg depth of 1.4 feet. When using the staff gauge on the same day, the depth was read as 2.4 feet correlating with a flow from the rating curve of almost 20 cfs. It is evident that the stream staff gauge is providing inaccurate readings and cannot be used currently to evaluate flow in Thompson Creek. Upon further discussion with colleagues from Spokane County Department of Ecology, it is assumed that the stream staff gauge and rating curve were accurate prior to the construction of the new bridge; however, it is hypothesized that the bridge widened the channel and caused sediment to aggrade and build up on the staff gage. As a result, the stream staff gauge cannot be used to measure flows, and TBDT will need to measure flow manually if a flow measurement is of necessity.

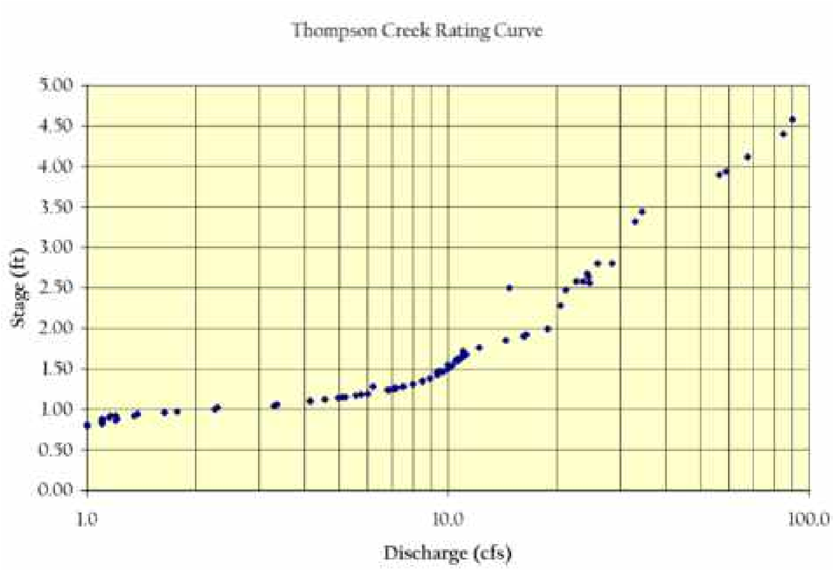

Figure 5: Thompson Creek Rating Curve (Spokane Department of Ecology)

Figure 6: Thompson Creek Stream Staff Gauge

5 Future Work

5.1 Assessment of Watershed Processes

In conjunction with CENG 426, data regarding the watershed processes was collected and analyzed. By using wikiwatershed's Model my Watershed (Stroud Water Research Center 2017), an online watershed delineation and modeling tool, we examined the terrain, land use, climate, biota and water quality in the watershed. This allowed us to identify the current watershed processes related to hydrology, sediment delivery, and nutrient delivery and identify the causes of the poor water quality in the creek. This has helped to show the problems that Thompson Creek currently faces, and how beaver dam analogues are a viable solution. The reports from the class have just been received and are currently in the process of being summarized. A full summary of the watershed processes will be provided in the final report.

5.2 Ongoing Baseline Data Collection and Analysis for Monitoring and Design

In particular, TBDT will continue to conduct site visits to collect data and observe flow patterns during the high water of Spring flooding. This data and observation will be useful in understanding reach scale processes during high flows. Understanding what is happening in the river during the Spring runoff will be useful to the design of the BDA complex and its possible impacts of the Bridge at the upstream end of the reach. In addition, TBDT will continue to collect the samples that are listed in the monitoring plan. These include monthly water samples from Thompson Creek and Liberty Lake to be tested by Dave Cleary and the Gonzaga Chemistry Department in order to quantify the total phosphorous in Thompson Creek. Baseline sample collection and testing began in September 2020 and ends in August 2021. The objective is to establish baseline data throughout the year in Thompson Creek prior to BDA implementation. These results will help to understand our hypothesis and provide values to compare future data against.

5.3 Conceptual Design of BDA Complex

Using the information from the Watershed and Reach-Scale Processes Assessment, TBDT and the CENG 426 class will develop a conceptual design for a series of BDAs that will aim to improve the water quality and overall stream health of Thompson Creek. The conceptual BDA design will serve as a base concept for the final BDA design and the results of a literature review will be used to assist in making design decisions. The type, number, and locations of the beaver dams will then be proposed to implement on Thompson Creek. The design will promote aggradation and floodplain reconnection, while limiting steep gradient drops.

Deliverables: A conceptual design plan for a BDA complex at Thompson Creek

Responsible: Nick Whittlesey

5.4 BDA Complex Design for Thompson Creek

5.4.1 Literature Review on Natural Beaver Dam Configurations

TBDT will conduct a study on published literature and existing beaver dams to become familiar with how beaver dams are constructed naturally. Using the information gathered, TBDT will emulate natural beaver dam characteristics in the BDA complex design. Attributes like dam height, width, and frequency in the stream will be key to a proper BDA design.

Deliverables: Documentation of design requirements used during the design process

Responsible: Nick Whittlesey

5.4.2 Hydraulic Design of BDA Complex

5.4.2.1 Hydraulic Analysis of Existing Flow Conditions

TBDT will utilize HEC-RAS to generate a hydraulic model which will be used to analyze the existing flow/hydraulic conditions in Thompson Creek and the existing hydraulic capacity of the Thompson Creek Bridge. TBDT will decide whether HEC-RAS 1D or 2D is more appropriate for the hydraulic model as a greater understanding of flow conditions is established. Observing Thompson Creek under higher flows over the winter will help with deciding if flow is more one- or two-dimensional in nature. Peak design flows for use in hydraulic modeling will be determined by TBDT through the application of a flood frequency analysis to existing flow data records for Thompson Creek. Channel geometry will be established by TBDT through an analysis of Lidar data (Washington Dept of Natural Resources Lidar Portal) and cross section geometry surveyed by the CENG426 class. TBDT will determine Manning's roughness coefficients based on field observations of roughness characteristics in the main channel and floodplains. The resulting existing conditions hydraulic model will be calibrated to mimic existing FEMA studies. The existing conditions model will set the baseline hydraulic conditions that the proposed BDA design must attempt to maintain.

Deliverables: A report of existing hydraulic stream conditions

Responsible: Nick Whittlesey

5.4.2.2 Determination of Design Requirements

Using the established baseline characteristics and the existing conditions hydraulic analysis of Thompson Creek, TBDT will set hydraulic design requirements and constraints. These requirements will be referenced when making design decisions. As of now the most prominent constraint is the NW Newman Lake Road Bridge which cannot be inundated as that would violate FEMA flood guidelines. All design decisions will be made in compliance with FEMA.

Deliverables: Documentation of design requirements used during the design process

Responsible: Nick Whittlesey

5.4.2.3 Hydraulic Design of Proposed BDA Complex

TBDT will develop multiple BDA design alternatives to provide design diversity and promote the optimal design for the BDA complex. Alternatives will primarily focus on the impact that the BDAs have on stream morphology and backwater from flood flows. Alternative designs will also look into the possibility of dry beaver dam analogs which will only be active during flood flows as they will provide several benefits to floodplain flows. For all alternatives, the BDAs will be modeled in HEC-RAS as inline weirs, to demonstrate their impact on the various flow regimes in the creek. Although beaver dams do pass flows through their structure, as the BDAs mature, they become more impermeable due to sediment build up on the upstream face of the dam. Thus, modeling the BDAs as inline weirs with no gates (solid structures) will capture the hydraulic nature of the BDA structures. TBDT will complete a hydraulic analysis of all BDA alternatives by implementing different configurations of BDAs into HEC-RAS, analyzing the hydraulic impacts that results, and selecting the configuration that maximizes a depositional environment. Ultimately, the final BDA design configuration will be one that promotes a depositional environment to trap sediment and phosphorous but does not cause inundation to extend onto NW Newman Lake Road Bridge or increase flooding beyond existing FEMA flooding extents.

Deliverables: A report summarizing the alternatives analysis and the final proposed BDA design

Responsible: Nick Whittlesey

5.4.2.4 Proposed BDA Complex Hydraulic Assessment and Alternatives Analysis

TBDT will develop multiple BDA design alternatives to provide design diversity and promote the optimal design for the BDA complex. Alternatives will primarily focus on the impact that the BDAs have on stream morphology and backwater from flood flows. Alternative designs will also look into the possibility of dry beaver dam analogs which will only be active during flood flows as they will provide several benefits to flood plain flows. Multiple iterations of the design hydraulic model will be necessary for proper design selection, and all design models will mimic FEMA studies and will be consistent with FEMA flood guidelines. Selection of the final design will be based on a weighted matrix allocating scores to certain design criteria, e.g. bridge freeboard or material cost and the highest scoring design will be chosen.

Deliverables: A hydraulic assessment report and an alternatives analysis of the hydraulic design

Responsible: Nick Whittlesey

5.4.3 Structural Design of BDA Complex

5.4.3.1 Determination of Design Factors of Safety for Structural Failure Modes

After the final hydraulic design of the BDA complex is complete, TBDT will perform a structural design of each of the BDAs. BDA structural design and construction requires understanding factors of safety related to vertical movement, post breakage, and post overturning that can occur in BDA structures. TBDT will determine an appropriate factor of safety for structural design which will consider the cost associated with a larger factor of safety size and its implication on design efficiency. It is presumed that the factors of safety will be greater than 1.2.

Deliverables: Documentation of the factor of safety used in design

Responsible: Connor Denning

5.4.3.2 Structural Design of BDAs and Structural Design Tools

After the final hydraulic design of the BDA complex is complete, TBDT will perform a structural design of each of the BDAs. BDA structural design and construction requires understanding factors of safety related to vertical movement, post breakage, and post overturning that can occur in BDA structures. TBDT will determine an appropriate factor of safety for structural design which will consider the cost associated with a larger factor of safety size and its implication on design efficiency. It is presumed that the factors of safety will be greater than 1.2.

Deliverables: Documentation of the factor of safety used in design

Responsible: Connor Denning

5.4.4 BDA Complex Construction Cost Estimate

TBDT will formulate an estimate for the cost of the BDA complex using available data and research. Past BDA complex design and industry professionals will serve as the primary source for bid documents as there is no standard for BDA cost estimation.

Deliverables: Construction Cost Estimation

Responsible: Connor Denning

5.4.5 Plans and Drawings for Implementation

TBDT will develop a thorough drawing set for design implementation and construction as part of the final design and report. The design plans will include guidelines and instructions for BDA construction to assure proper implementation. Drawing sets for BDA design will be developed using AutoCad Civil 3D.

Deliverables: BDA complex Plan and Drawing set

Responsible: Nick Whittlesey

5.5 Project Sustainability Evaluation

With input from The Lands Council and Spokane County Environmental Programs, TBDT will develop a sustainability analysis considering the social, environmental, and economic benefits provided by the BDA complex at Thompson Creek. TBDT's sustainability efforts will continue throughout the duration of the project as it is a goal to improve upon the sustainability of this project given any opportunity to. It is initially expected that the BDA complex will provide environmental benefits including a reduction in phosphorus and sediment transport, reduced stream velocity, and improved floodplain connectivity. Economically, reducing the phosphorus loading in Thompson Creek will result in improved water quality in Newman Lake thus reducing the need for water quality treatment. Improved Newman Lake water quality will also benefit the community surrounding Newman Lake as it will reduce negative impacts such as algae blooms and poor fish habitat. A quantitative sustainability evaluation will be conducted by using Envision, a sustainability infrastructure rating system which focuses on Quality of Life, Leadership, Resource Allocation, Natural World, & Climate and Risk.

Deliverable: A sustainability summary in the final BDA Complex report

Responsible: Connor Denning

6 Project Management

6.1 Schedule of Design Work

Below is a Figure 7, a project Gantt chart summarizing the expected project timeline. Our project is ahead of planned with both the monitoring plan and QA/QC section of the monitoring plan completed early.

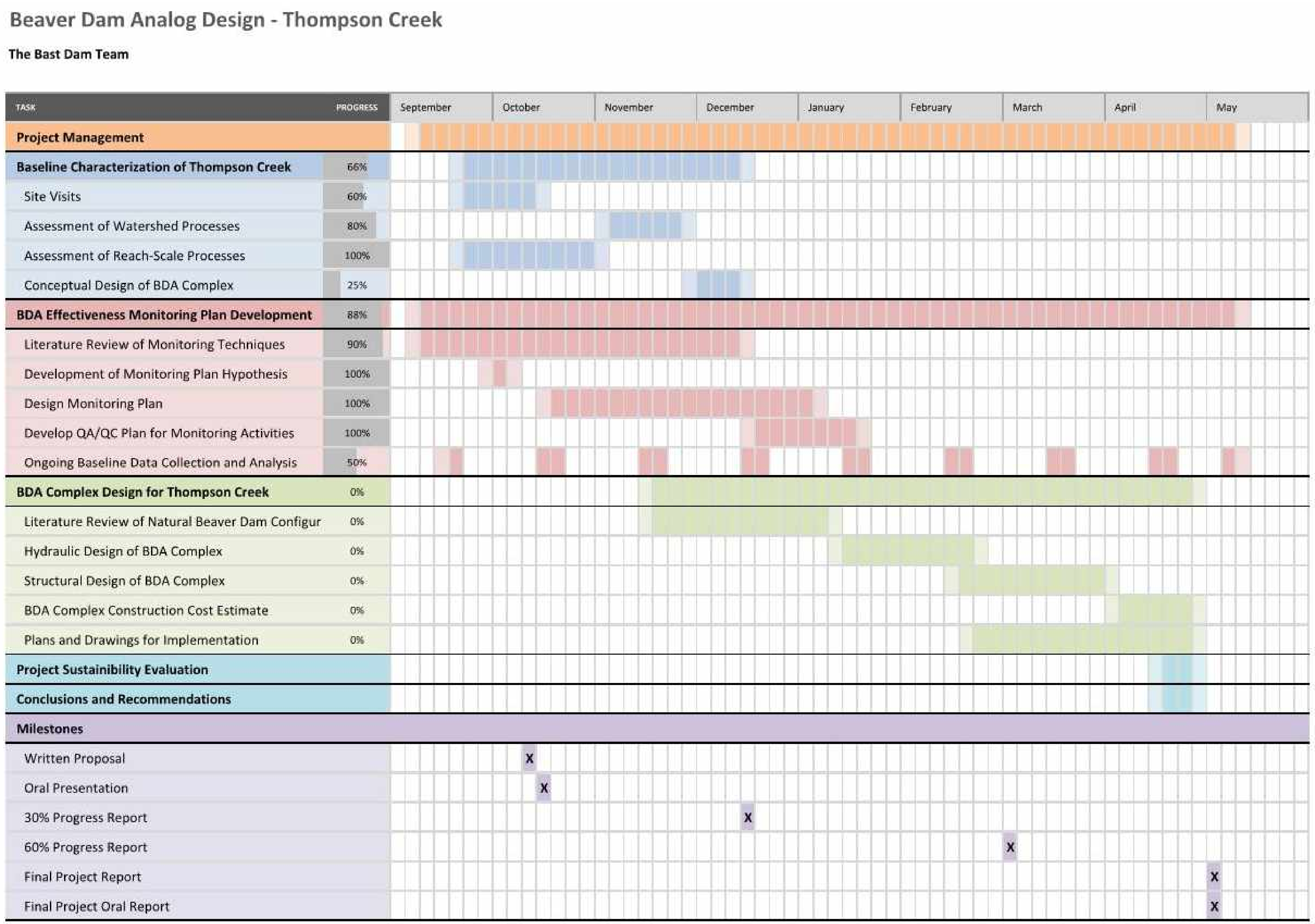

Figure 7: Project Schedule

6.2 Consulting Fee

Below is Table 2, a summary of the expected project consulting fee. Table 3 below lays out the hours worked to date. Overall, our team has worked 31% of what we were estimated, which is slightly less than what we were expecting for this status report. We projected that the second phase of our project (January – May) would be about 60 % of our total work. When we look into the different sections that our team has worked on so far, it shows that we may have been overestimating our hours on the project plan. We expect our Project Management section to come in below what we were expecting. Our team also overestimated the number of hours that it would take for us to develop our monitoring plan, with our original estimate being 168 hours total and our team only having worked a total of 91 hours. There is still baseline data collection and analysis that needs to be done, but we still estimate that our team will come in about 20-30 hours short of what we were expecting. We are expecting that our projected hours for Baseline Characterization, BDA Complex Design, Sustainability Evaluation and Conclusions are still accurate. Therefore, because of our overestimations in a few sections, we expect that our project will come in underbudget due to these overestimations of hours.

Table 2: Project Consulting Fee

Task	Project Manager: Connor Denning	Project Engineer: Nick Whittlesey
Project Management	**50**	**30**
Baseline Characterization of Thompson Creek	**72**	**80**
Site Visits	24	24
Assessment of Watershed Processes	15	18
Assessment of Reach-Scale Processes	15	18
Conceptual Design of BDA Complex	18	20
BDA Effectiveness Monitoring Plan Development	**84**	**84**
Literature Review of Monitoring Techniques	20	20
Development of Monitoring Plan Hypothesis	4	4
Design Monitoring Plan	10	15
Develop QA/QC Plan for Monitoring Activities	15	10
Ongoing Baseline Data Collection and Analysis	35	35
BDA Complex Design for Thompson Creek	**82**	**89**
Literature Review of Natural Beaver Dam Configurations	12	12
Hydraulic Design of BDA Complex	25	30
Structural Design of BDA Complex	25	30
BDA Complex Construction Cost Estimate	5	5
Plans and Drawings for Implementation	15	12
Project Sustainability Evaluation	4	4
Conclusions and Recommendations	6	6
Total Hours	**298**	**293**
Rate ($/hr)	125	110
Design Fee	**$ 37,250**	**$ 32,230**
Report Copies (500 pgs x $0.25/pg)	$ 125.00	
Travel Expenses (600 miles x $0.50/mi)	$ 300.00	
Total Consulting Cost	**$ 69,905.00**	

Table 3: Hours worked to Date

Task	Hours to Date Project Manager: Connor Denning		Project Engineer: Nick Whittlesey	
Project Management		**18**		**12**
Baseline Characterization of Thompson Creek		**27.5**		**34.5**
Site Visits		**14.5**		**14.5**
Assessment of Watershed Processes		**4**		**8**
Assessment of Reach-Scale Processes		**9**		**12**
Conceptual Design of BDA Complex		**0**		**0**
BDA Effectiveness Monitoring Plan Development		**48**		**43**
Literature Review of Monitoring Techniques		**15**		**12**
Development of Monitoring Plan Hypothesis		**7**		**4**
Design Monitoring Plan		**12**		**11**
Develop QA/QC Plan for Monitoring Activities		**6**		**5**
Ongoing Baseline Data Collection and Analysis		**8**		**11**
BDA Complex Design for Thompson Creek		**0**		**0**
Literature Review of Natural Beaver Dam Configurations		**0**		**0**
Hydraulic Design of BDA Complex		**0**		**0**
Structural Design of BDA Complex		**0**		**0**
BDA Complex Construction Cost Estimate		**0**		**0**
Plans and Drawings for Implementation		**0**		**0**
Project Sustainability Evaluation		**0**		**0**
Conclusions and Recommendations		**0**		**0**
Total Hours to Date		**93.5**		**89.5**
Rate ($/hr)		125		110
Design Fee	**$**	**11,688**	**$**	**9,845**
Report Copies (500 pgs x $0.25/pg)		$	125.00	
Travel Expenses (600 miles x $0.50/mi)		$	300.00	
Total Consulting Cost		**$**	**21,957.50**	

6.3 Contingency Plan

TBDT has set up a contingency plan to ensure that our project will be completed if it is necessary for Gonzaga to go fully remote in the Spring Semester due to COVID-19. Our team has ensured that we have access to the programs that will be needed to perform our design. Our communication plan has also been built so we have the flexibility of working over zoom if the possibility of in person meetings are not possible. The only aspect of this project that could be completely halted by a remote Spring Semester is baseline testing. TBDT would attempt to collect baseline data per what is laid out in the monitoring plan. While baseline testing is very important to our project, the project as a whole can go on without establishing baseline phosphorus and suspended sediment measurements. Baseline testing is an important factor for our monitoring plan, but it is not necessary for our BDA complex design. The TMDL results for phosphorus would serve as the baseline data rather than what is being collected currently.

6.4 Project Meetings and Communications

A communication plan is laid out in Appendix C. This document outlines the people who we will be in communication with and the frequency in which we will reach out to them. It also provides the contact information for these people.

6.5 Project Data

Our documents will all be on a Microsoft Teams group along that all members of The Best Dam Team have access to. These documents will also be kept in a hardcopy in a project folder, that will be used for organization and group meetings.

6.6 Project QA/QC

Due to the fact that The Best Dam Team consists of just two student engineers, all work will be completed by both team members to ensure that correct methods and calculations are made. Our proposal laid out a plan to partner with a different team and work with them to check each others work. This partnership did not prove very beneficial for our team, and therefore was changed. Our team now reviews our own work multiple times, before passing it to the other teammate. After this check, documents will be passed off to our Faculty Advisor to revise. After multiple rounds of editing and revision by TBDT and our Faculty Advisor, we send documents to Design Advisory Board members to ensure that our work is both correct and up to professional engineering standards.

7 References

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Appendix A – Site Visit Photos

Figure 8: A View upstream at Thompson Creek from our visit on September 24th

Figure 9: A look into our day surveying with our CENG 426 Class on September 26th

Figure 10: A picture of a natural beaver dam at Liberty Lake taken during our October 8th visit

Figure 11: A BDA at California Creek taken during our visit on November 19th

Appendix B- Monitoring Plan

Thompson Creek BDA Complex Monitoring Plan

Hypotheses:

1. The implementation of BDAs in Thompson Creek will increase water storage (volume) within the landscape.
2. The ponds formed by the BDAs implemented in Thompson Creek will increase sediment storage in excess of local channel storage.
3. The addition of BDAs in Thompson Creek will reduce the phosphorus levels entering Newman Lake to less than 25 mg/L as laid out in the Washington Department of Ecology TMDL report.

Hypothesis 1: The implementation of BDAs in Thompson Creek will increase water storage (volume) within the landscape

Monitoring Methods

Drone Aerial Imagery: Following the procedure outlined by Puttock et al. (2016), a combination of drone aerial imagery and subsurface profiling will be used to determine water storage volumes within the BDA reach. A drone will be used to fly over Thompson Creek and capture aerial imagery of the entire study reach and each BDA and pond that is formed. Using Agisoft Metashape software, an orthomosaic photo of the entire reach and all ponds will be created. Agisoft Metahsape will also be used determine pond and stream surface areas from the orthomosaic photo for calculating water storage within the reach. The result will be the wetted surface area of Thompson Creek at the time of survey.

Subsurface Profiling: Water depth in each BDA pond, immediately upstream of each BDA, will be measured at every node on a 1 x 1-yard grid using a ranging rod (marked with tenths of an inch increments). At each node, the rod is to be inserted into the water until the tip of the rod reaches the top of sediment, then that depth on the ranging rod is to be recorded as water depth*. Recording depth at each node will establish a topographic profile for each BDA pond, which will then be used with wetted surface area to calculate total pond water storage (Puttock et al. 2016, Puttock et al, 2018).

> *Note: This method will also be used to measure sediment depths at each node for hypothesis 2

Frequency:

- Prior to implementation of the BDA complex, existing water storage will be calculated once from pre-established cross section surveys that were completed as part of the baseline characterization. The surveyed cross sections will be input into StreamMetrics to calculate maximum cross-sectional area in at least six locations along the reach. The maximum area will be defined as the cross-sectional area if water levels were at the top of bank (just about to break out into the floodplain). The average cross-sectional area will be determined from the six-representative surveyed cross sections. Aerial imagery from Google Earth will then be used to measure stream length which will be combined with the surveyed average maximum cross-sectional area to calculate the existing (pre-BDA) maximum water storage volume within the stream.

- After BDA implementation, drone and subsurface surveys will be completed biannually in the late spring and fall to capture high and low flow impacts on water storage, respectively.

Equipment:

- Ranging rod (soil probe)
- Waders
- Measuring Tape
- Drone and Agisoft Metashape software
- StreamMetrics Excel Worksheet

Procedure:

Drone Aerial Imagery:

1. Using Pix4D Capture, set a grid pattern flight path and set the camera to take photos with at least 70% overlap
2. Process the images in Agisoft Metashape software to create the orthomosaic photo to help in calculating areas of ponds

Subsurface Profiling:

1. Measure the area of the pond using a tape measure and getting values for length (upstream direction) and width of the ponds upstream of each BDA.
2. Setup a grid and begin data collection on the left side closest to the BDA.
3. Insert the rod until you hit the top of the sediment at the bottom of the pond. Record this as water depth 1 (WD1).
4. Push the probe down as far as you can. Record this new value as total depth 1 (TD1).
5. Move to the right into the next grid section and record values for WD2 and TD2.
6. Once the right bank is reached move upstream into the next gridded section and start moving leftward.
7. Average the WD values over the area.
8. Multiply the average depth by the surface area measured from orthomosaic to find water volume.
9. Repeat steps for all BDAs.

Hypothesis 2: The ponds formed by the BDAs implemented in Thompson Creek will increase sediment storage in excess of local channel storage.

Monitoring Methods

Soil Probing: Following the methods outlined in Puttock et al (2018), the sediment volume trapped behind each pond will be determined from a combination of soil probing within the ponds and surface area measurements from drone imagery. In conjunction with subsurface profiling in hypothesis 1, once water depth at a given node is measured, the ranging rod is to be gently pushed through the unconsolidated sediment until a compact layer of sediment is reached and that is to be recorded as sediment depth. Similar to establishing water storage, the sediment depth at each node and the surface area determined from the drone aerial imagery for each pond will be used to calculate a trapped sediment volume behind each BDA.

Suspended Sediment: Three water samples will be collected upstream and downstream of the BDA complex, totaling six samples. Using a bottle grabber, water should be collected at 40% depth (maximum stream velocity). Samples are to be labeled "upstream" or "downstream" prior to sampling and each bottle must be rinsed twice with stream water prior to sampling. In the Gonzaga Environmental Engineering Laboratory, these samples will be tested for Total Suspended Solids using Standard Method 2540B (Standard Method 2017). Prior to the implementation of BDAs, baseline suspended sediment will be measured upstream and downstream of the study reach using the same methodology.

Frequency:

- Soil Probing: Annually in the fall as low flows allow for easier surveying and any higher frequency would be redundant given the slow response for sediment build up (BINC Final Report, 2017)
- Suspended Sediment: Quarterly, alongside sample collection for monitoring phosphorus

Equipment:

- Ranging rod (soil probe)
- Waders
- Measuring Tape
- Drone Agisoft Metashape software
- Sampling bottles (at least 250 mg)
- Bottle grabber
- Items per Standard Method 2540B

Procedure:

Soil Probing:

1. Follow steps 1-6 laid out in the subsurface profiling procedure.
2. Calculate the soil depth by taking TD-WD for each location
3. Average out the soil depth values.

4. Multiply this by the area to find the total soil volume accumulated.
5. Repeat steps for all BDAs

Suspended Sediment:

1. Collect three water samples upstream and downstream of the BDA complex, totaling in six samples. Make sure to rinse the bottles with stream water prior to sampling and use the grabber to lower the bottle into the stream.
2. Label the bottles US or DS depending on whether they're from upstream or downstream, respectively.
3. In the Gonzaga Environmental Engineering Lab, perform Standard Method 2540B to measure suspended sediment in each sample. A summary of that procedure is listed below:
    1. Weigh your circular sediment filters prior to filtering each sample. This weight will be used later to calculate sediment weight.
    2. Transfer each sample into a flask in order to get a volume of water for each sample.
    3. Using one sediment filter for each sample, filter each sample completely. There should be some sediment left on the paper after the bottle is emptied through the filter.
    4. Place the filters with the sediment on them into a drying oven until the filters are completely dried.
    5. Once dried, weigh the filters again. Subtract the originally measured filter weight from the weight of the dried filter with sediment. The result is the weight of sediment that was present in the sample. Sediment weight divided by the volume of water sampled will yield a concentration of suspended sediment.

Hypothesis 3: The addition of BDAs beaver dam analogues in Thompson Creek will reduce the phosphorus levels entering Newman Lake to less than 25 mg/L as laid out in the Washington Department of Ecology TMDL report.

Monitoring Methods

Sample Collection: A total of six water samples will be taken at both Thompson Creek and at Liberty Lake. The six samples will be broken up into three upstream and three downstream of the dams. The locations of the sample sites for Liberty Lake are upstream of the walking bridge and downstream of the dam, where the path runs parallel to the creek. The sample sites at Thompson Creek should be above the most upstream BDA and below the most downstream BDA in a location where water is still flowing and not within the backwater of Newman Lake.

Phosphorus Testing: Total phosphorus for the samples will be determined in the Gonzaga Chemistry Lab using EPA Method 365.3. This method determines both hydrolysable phosphorus and orthophosphate, in order to calculate the total phosphate in the water sample.

Frequency: For baseline data and the first-year post BDA installation, samples will be taken and tested for total phosphate monthly. Sampling and testing frequency may be adjusted if patterns are noticed from the first two years of data.

Equipment:

- 12 sampling bottles per testing period. (At least 250 mg)
- Grabber
- Thermometer
- Items per USEPA method 365.3 (USEPA 1978)

Procedure:

1. Start at the upstream location. Place a thermometer just below the surface in the water for 30 seconds and read the temperature. Repeat this again to ensure the value from the first test is correct.
2. Label each sampling bottle with the temperature, either TC (Thompson Creek) or LL (Liberty Lake) as well as US or DS representing upstream and downstream, respectively.
3. Hold the grabber in the water for 30 seconds, washing off any phosphorus that may be on the grabber.
4. Remove the lid of the testing bottle and place in the grabber. Fill the bottle two times with stream water and dump out downstream of testing location.
5. Fill one more time about 4-6 inches below the water surface and close the cap on the bottle.
6. Repeat this bottle filling procedure for the other two samples at that location.
7. Repeat at the downstream location at that site
8. Deliver the water samples to the Gonzaga Chemistry Department for total phosphate testing per USEPA method 365.3

Summary of Monitoring Plan Methods, Frequency, and Personnel:

Table 1 below summarizes the methods, frequency, and personnel assigned to implement the monitoring plan described above.

Table B-1. Monitoring Plan Schedule – Gannt Chart

Activity	2020				2021												2021											
	S	O	N	D	J	F	Mar	Ap	May	Jn	Ju	Au	S	O	N	D	J	F	Mar	Ap	May	Jn	Ju	Au	S	O	N	D
	Fall			Winter			Spring			Summer			Fall			Winter			Spring			Summer			Fall			Winter
Phosphorus Sampling	US	US	US	US	US	US	US	US	US	US	US	US		US			US			US			US			US		
Drone Aerial Surveying								US/PI							US/PI						US/PI						US/PI	
Subsurface Profiling & Soil Probing								US							US						US						US	
Suspended Sediment					US			US			US				US			US			US			US			US	
US = Undergraduate Students																												
PI = Principle Investigator																												

Table B-1. Monitoring Plan Schedule – Gannt Chart

Activity	2022												2023											
	J	F	Mar	Ap	May	Jn	Ju	Au	S	O	N	D	J	F	Mar	Ap	May	Jn	Ju	Au	S	O	N	D
	Winter		Spring			Summer			Fall			Winter			Spring			Summer			Fall			
Phosphorus Sampling	US			US			US			US			US			US			US			US		
Drone Aerial Surveying					US/PI						US/PI						US/PI						US/PI	
Subsurface Profiling & Soil Probing					US						US						US						US	
Suspended Sediment		US			US			US			US			US			US			US			US	
US = Undergraduate Students																								
PI = Principle Investigator																								

Monitoring Plan Costs:

The Best Dam Team has access to all of the necessary materials needed with the exception of a probing rod. The materials needed are laid out in Table B-2 below.

Table B-2: Summary of Costs

Equipment	Number	Cost per	Total Cost
Ranging Rod	1	$25	$25
Waders	-	-	-
Measuring Tape	-	-	-
Drone	-	-	-
Sampling Bottles	-	-	-
Bottle Grabber	-	-	-
USEPA STD Method 2540 B	-	-	-
Thermometer	-	-	-
USEPA STD Method 365.3	-	-	-
Total Cost			$25

References:

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Appendix C- Communication Plan

Communication Plan – Senior Design Project ENSC 24 - Beaver Dam Analogs

Summary: Design a series of beaver dam analogs, and a monitoring plan to examine the impact of them on the channel.

Communication Goals:

- Provide weekly updates to advisor
- Keep all stakeholders informed (of project timeline, budget, needs, etc.)
- Establish patterns and preferred modes of communication for all members.
- Communicate with design advisory board in order to give them time to review documents and team to make changes before it is due.

Stakeholder Information:

Stakeholder:	Contact:	Role & Title:	Frequency:	Channel:	Notes:
Dr. Niezgoda	niezgoda@gonzaga.edu	Faculty Advisor	Weekly	Email	Weekly meetings for project and open contact at anytime
Kat Hall	khall@landscouncil.org	Client	As needed	Email	
Colleen Little	clittle@spokanecounty.org	Client	As needed	Email	
Dawson Matthews	dmatthews@spokanecounty.org	Client	As needed	Email	
Lindsay Gilbert	Lindsay.d.gilbert@gmail.com	Design Advisory Board	Before Major Milestones, As needed	Email	Contact before submittal dates of papers to review
Katie Larimer	Khal461@ecy.wa.gov	Design Advisory Board	Before Major Milestones, As needed	Email	Contact before submittal dates of papers to review
Toni Boggan	509-313-3913 boggan@gonzaga.edu	CEDE Academic Director	As needed	Email	
Megan Weed	509-313-5751 weed@gonzaga.edu	CEDE Program Assistant	As needed	Email	
Dr. Juliane Mora	mora@gonzaga.edu	Communication Studies Professor	As needed	Email	Contact Dr. Mora to set-up time to discuss project presentations/ get feedback

Team Information:

Role:	**Member:**	**Rotation:**	**Tasks:**
Project Manager	Connor Denning Nick Whittlesey	Connor first semester, Nick second	Coordinate meeting times, send out agenda, lead meetings, send post-meeting follow-up with tasks
Communication Liaison	Nick Whittlesey	Permanent role	Communicates with stakeholders, takes notes during meetings, works closely with team lead to keep documents updated

Communication Plan:

Type of Communication:	**Audience:**	**Goals:**	**Frequency:**	**Method:**	**Responsibility:**
Team Work Sessions	Team members	Work on project together and review the weeks work	Weekly	In-person or Zoom	Project Manager
Advisor Meeting	Team members and Sue Niezgoda	Review status, manage tasks, address issues	Weekly	In-person or Zoom	Entire Team
Project Review	Team members, Sue Niezgoda and Clients	Present project deliverables, gather feedback, and discuss next steps	At milestones	In-person or Zoom	Entire Team
Deliverable Review	DAB Members	Review deliverables and suggest changes before submittal to clients	Before Milestones	In-person or Zoom	Entire team
Status Report	Advisor, technical audience	Inform them about the progress of our project.		In-person or Zoom	Entire Team
Presentations	Advisor, DAB, technical & general audience	Inform them about the progress of our project.		First = 4-min. Video + Q&A Second = Team Presentation Third = 7-min. Video + Q&A Fourth = Team Presentation	Entire Team

Different Types of Communication Events require different information:

Weekly Check-in meetings

Weekly team meetings and/or team meetings with advisor to go over progress, ask questions, gather feedback, share updates on work completed, etc.

- Share:
    - What's been completed
    - What needs to be completed this week (in progress)
    - Any deliverables needing consensus or approval
    - Updates to be sent to stakeholders
    - Timeline and budget
    - Review upcoming deadlines

Major Milestone meetings

Meetings set-up in advance for delivery of major project milestones deliverables

- Share:
    - Agenda for meeting (2-3 days in advance)
    - Attendees needed for meeting
    - Materials needed by stakeholders (drafts of reports, data, schematics, plans, etc.)
- Meeting Format:
    - Agenda review (attendees may wish to add something to the agenda)
    - Presentation of deliverables (decide which team member(s) will present material)
    - Questions/ Discussion
    - Next steps
- Email (immediately after the meeting):
    - Meeting notes to all attendees (this helps all stakeholders stay on the same page)
    - Next steps and anything needed to complete those steps (equipment, samples, resources, etc.)
    - Materials requested by stakeholders (i.e., draft report or data, videos of testing, etc.)