# The Nature Conservancy's Tensleep Preserve
# Beaver Monitoring Plan

Ucross High Plains Stewardship

Yale SCHOOL OF THE ENVIRONMENT

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# Section 1 - Introduction

## 1.1 - Purpose

The purpose of the Tensleep Beaver Monitoring Plan is to provide the information necessary to support the management of beavers at The Nature Conservancy's Tensleep Preserve in a way that allows for the coexistence of a healthy beaver population and local water users. The core questions that the methodologies in this protocol seek to address are:

1. What is the state and wellbeing of the Tensleep Preserve's beaver population?
2. What is the impact of the Tensleep Preserve's beaver population on the amount and timing of discharge in Canyon Creek?

While this protocol was written for TNC's Tensleep Preserve, it can be readily applied to answer the above questions at other protected areas or locations where there are concerns over the impact of beavers on water rights.

## 1.2 - Background

The Tensleep Beaver Monitoring Plan was developed in spring 2024 for The Nature Conservancy's Tensleep Preserve, in the western foothills of the Bighorn Mountains in northeast Wyoming. It was researched and written by Alex Wells—a Research Assistant at the Ucross High Plains Stewardship Initiative (UHPSI) and Master's of Environmental Management Candidate at Yale School of the Environment—with input from Trey Davis, Eastern Wyoming Stewardship Director at TNC Wyoming, and Michelle Downey, UHPSI Director. This monitoring plan is intended to complement and inform the Tensleep Preserve's existing Beaver Dam Management Plan (BDMP).

# Section 2 - Stream Discharge

## 2.1 - Why monitor streamflow?

The core function of a beaver dam is to impound water to create an area that offers a safe area for beavers to gather and store food and raise their young (Baker & Hill, 2003). However, actively altering their environment to suit their needs often puts beavers in conflict with humans. This is particularly contentious in the arid Intermountain West of the U.S., where predictable and sufficient flows of water are critical to irrigators' livelihoods. Few empirical studies have confronted this question, however one review of studies on beaver dam analogs—artificial structures built to mimic beaver dams—found their impact on streamflow to generally be negligible (Clancy & Wolf, 2022). Nonetheless, generalities are often insufficient for satisfying the concerns of downstream water rights holders who are interested in the specific potential impacts on their water rights. Measuring the impacts of beaver dams on streamflow is no small task, but if it is done sufficiently it can help to resolve some of the conflict between irrigators and beavers.

## 2.2 - Study design considerations

**Baseline data**

To assess the streamflow impact of beaver dams in Canyon Creek at The Nature Conservancy's Tensleep Preserve, it's critical to not just measure the change in discharge from above the beaver dams to below, but also to compare those measurements to an approximation of what discharge would be like without the dams (in other words, without beavers). The most defensible option by far would be to have collected concurrent baseline data for both the Canyon Creek beaver dam complex (BDC) before beavers arrived **and** an undammed reference stream with conditions as similar as possible to those at the BDC, **and then** continued those measurements after beavers built dams at the BDC (James Saiers, Yale School of the Environment, personal communication, 28 February 2024).

There is no baseline streamflow data available from before beavers arrived in Canyon Creek. Therefore, the next best option (though less experimentally defensible) is to compare streamflow data from post-beaver arrival to a similar reference stream without beavers. This will provide insight about streamflow impacts, and is elaborated on in this protocol. Another option would be to develop a stream-hydraulics model and evaluate a natural-system scenario against the actual (dammed) scenario (James Saiers, Yale School of the Environment, personal communication, 28 February 2024). This is beyond the scope of this monitoring plan, but it is an option that could be explored by TNC staff or other researchers in the future.

**Reductionist versus holistic approaches**

There are generally two approaches that can be used when investigating the change in something as it moves through a system. You can dive into the system and measure as many components and internal flows as possible to uncover all the important factors influencing what you're interested in. Or, you can treat the system as a black box and simply investigate the difference between what goes in and what comes out. In ecosystem science, these contrasting approaches are reductionism (looking at the system through its parts) and holism (looking at the system as a whole; Weathers et al., 2012).

In this context, the beaver dam complex can be treated as a black box where an amount of water goes in and another amount of water comes out. Or, instead, you can measure various factors inside the beaver dam complex (e.g., dam height, types of dams, amount of water impounded, groundwater level, etc.) to understand how they might impact streamflow. Both approaches are possible and can be used in tandem . As well,

Based on feedback from Trey Davis, Eastern Wyoming Stewardship Director, this protocol takes a holistic approach to measuring the impacts of beaver on streamflow.

## 2.3 – Protocol Overview

- **Choose one or more sections of stream from which to collect reference data**
  Find a reference stream section that approximates the conditions at Canyon Creek's BDC.
- **Collect stream data at Monitoring Points to build a rating curve**
  At Monitoring Points above and below both this section and the BDC, measure 1) the cross-sectional area, 2) the water level (aka stage), and 3) the velocity. By collecting these data at low, medium, and high flows (at a minimum), a rating curve can be created to approximate streamflow for each Monitoring Point using only stage.
- **Deploy data loggers** *(optional)*
  To collect data on how stage varies over the course of days, weeks, and seasons, deploy a water level data logger at each Monitoring Point (See Section 2.12).
- **Calculate change in streamflow**
  To understand how streamflow changes from above the BDC to below, calculate the difference between streamflow at the downstream and upstream Monitoring Points. To estimate how the beaver dams impact streamflow, compare the difference in streamflow in the BDC section to the difference in the reference section.

## 2.4 - Equipment needed

- **Stream Cross-Sectional Area**
  - Measuring tape / regularly marked rope
  - Means of attaching rope to banks (e.g. tent stakes)
  - Meter stick (or two-meter stick if the stream gets deeper than a meter)
  - Stream Discharge Datasheet
  - Pen / pencil

- **Stream velocity with the float protocol**
  - Cross-sectional area equipment
  - A 20-30 meter long rope (light enough to float)
  - A way to mark the start and end of the float distance (e.g., two ropes that can be tied taut across the stream)
  - Peeled orange
  - Timer / smartphone

- **Stream velocity with a flowmeter**
  - Cross-sectional area equipment
  - Flowmeter

- **Water level with a stream gauge**
  - Metal rod *at least* 5 ft long (e.g. rebar, iron pipe, etc.)
  - T-post pounder or metal mallet
  - Stream gauge (or waterproof, environmentally safe paint to mark the metal rod)
  - If using a stream gauge, a means of attaching it to the metal rod

- **Water level with loggers**
  - HOBO water level data loggers
  - Caps
  - Slotted PVC pipes
  - Securing cable
  - Cinderblock
  - Sawzall to cut into cinder block
  - Meter stick (or two-meter stick if there are sections of the creek deeper than a meter)
  - HOBOware software
  - HOBO Shuttle

## 2.5 - Site Selection

The first step in measuring the impacts of beaver dams on streamflow is to decide where you'll be taking your measurements.

**Selecting a reference stream**

As described in Section 2.2, it's critical to have **reference data** with which to compare the data gathered from the **beaver dam complex (BDC) section** of Canyon Creek. This should be from a section of stream that approximates as closely as possible what the BDC section would look like without beaver activity.

This can be from an entirely different stream or from Canyon Creek itself. One straightforward option would be to use the section of Canyon Creek immediately above the BDC section,which would also save on costs and equipment since the downstream Monitoring Point for the reference section would double as the upstream site for the BDC section. However, this section of stream might be more likely to also be impacted by beaver dams in the next few years, which would eliminate its usefulness as a reference site (though this would allow pre-beaver and post-beaver data to be collected there).

Another option for a reference site could be just below the confluence of Cooks Creek with Canyon Creek, approximately 1.2 miles upriver of the BDC section, which should have a similar discharge, bedrock geology, and relatively wide canyon bottom. If beavers were to colonize a new site upriver of the BDC section, it would likely be here, presenting a similar challenge and advantage to monitoring immediately upstream of the BDC (Trey, Davis, personal communication, May 1st, 2024).

If there is more than one stream section that could work as reference stream sections, the best option would be to measure at multiple reference sites and use an average to compare to Canyon Creek. This would help to ensure that even if data from one site is lost (e.g., the data logger is swept away, beavers colonize the site, etc.), data from other locations would still be available for comparison. The obvious downside is that this will require more equipment and time from staff or volunteers.

Take the following into account when selecting a reference section. They can be measured in detail or estimated if needed..

- These factors should be as similar as possible between the reference section and BDC section:
  - Upstream watershed size
  - Stream order
  - Annual snowpack
  - Short-term weather impacts
  - Soil type
  - Bedrock formation
  - Slope of stream
  - Amount of sunlight received (e.g., steep canyon walls that block light from the south, stream runs north-south versus east-west, etc.)
  - Shape of stream (e.g., a bend in the stream or straight)
- These factors impact streamflow but are **also** impacted by beavers. Ideally, look for a reference section where these factors approximate what the BDC section would look like without beavers (based on site history and local knowledge).
  - Amount and composition of vegetation present
  - Streambed substrate
  - Groundwater level

**Selecting Monitoring Points**

With at least one reference section selected in addition to the BDC section, you now need to select **Monitoring Points** at the upstream and downstream ends of each stream section. These points can be thought of as lines running perpendicular to the direction of streamflow from one streambank to the other where you will measure stream cross-sectional area, stage, and velocity. **As a general rule, they should be as simple to measure as possible.**

Take the following factors into account when selecting Monitoring Points (Gore, 2006):

- Flow should be as uniform as possible across the channel width
- No large objects (e.g., logs, boulders) breaking the surface or, ideally, below the surface
- No overhanging vegetation in the stream
- Straight, rather than curving
- For the Monitoring Points above and below the BDC, place them 10 to 15 meters above or below the point where water is no longer slowed or impounded by a beaver dam.
- **Use a consistent distance between the upstream and downstream points between the different stream sections**. If one section is 150 meters, the other section(s) should be between 140 and 160 meters (i.e., a difference of less than 10 meters).
  - Measure this as the distance traveled by walking through the middle of the stream.

## 2.6 - Stream Cross-Sectional Area

At each of the Monitoring Points selected in Section 2.5 (above and below each monitored stream section) measure the cross-sectional area using the midsection method, a commonly used method recommended by the USGS (Gore, 2006). Measuring the dimensions of the stream section is the first step in calculating the volume of water passing through it. The methods below are drawn from *Methods in Stream Ecology*. Use the **Stream Discharge Datasheet** to keep track of your measurements as you go (also used for Sections 2.7 and 2.8).

1. Stretch a measuring tape perpendicular across the stream and stake it down on either side so that the first 1-meter mark is exactly where the water begins on one side (the "original side").
   - Instead of a measuring tape, you can also use a rope marked in regular increments.
2. Place some kind of permanent mark at each end (e.g., putting in a t-post or stake), so that you can repeat the following measurements in the exact same locations in the future.
3. Following the line between those marks, measure the width of the stream
   - I.e., from the water's edge on one streambank to the water's edge on the opposite bank.
4. Divide that width into at least 5 easy-to-measure **segments** of the same length.
   - **Don't worry about these segments adding up to the total width of the stream**. Instead make them a length that will be easy to measure.
     - For example, if the stream is 5.75 meters wide, use 1 meter as your segment length, because 5 of these fit into the total width, with a final 0.75 meter segment added on.
   - The segments should never be longer than 3 meters.
   - You should have chosen Monitoring Points that are as easy to measure as possible (Section 2.5), but if there are abnormalities in the stream, start a new segment at the point where more uniform conditions resume.
5. Measure the depth of the stream exactly one segment-length away from the original streambank.
   - You may want to collect stream velocity data at the same time! **See Section 2.8 for that.**
6. Measure the depth of the stream exactly two segments away from the original bank.

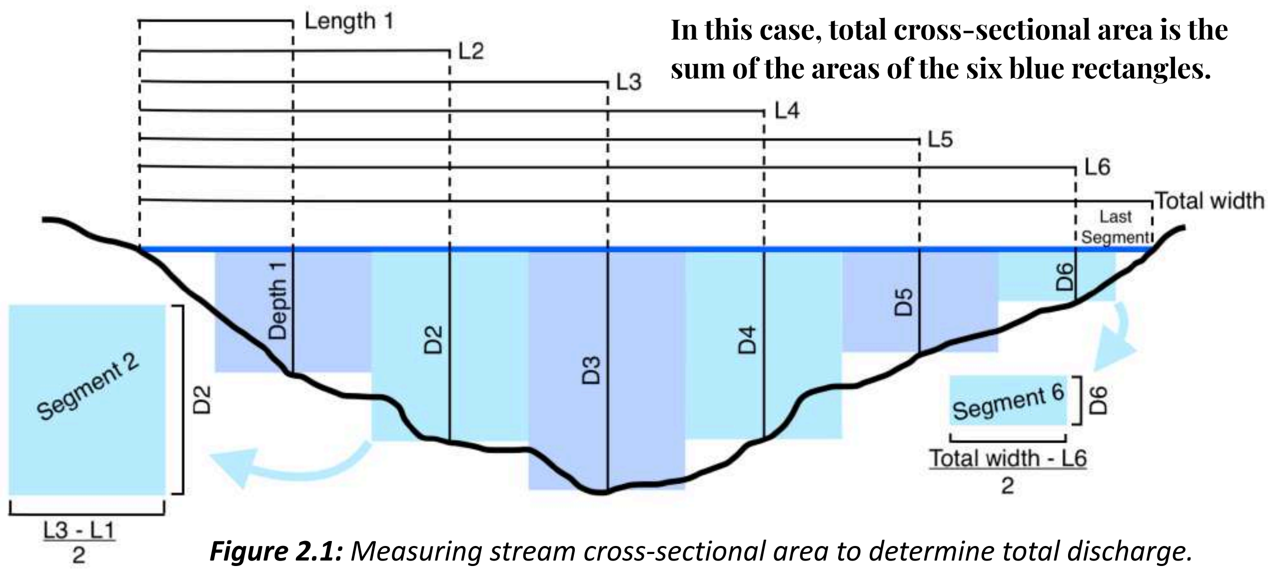


***Figure 2.1:*** *Measuring stream cross-sectional area to determine total discharge.*

7. Repeat this process until the next depth measurement would be on land on the opposite bank.

8. Estimate the cross-sectional area of each section of the stream's width using the formula below.

$$Segment\ Depth \times \left(\frac{NEXT\ segment's\ distance\ from\ original\ side - PREVIOUS\ segment's\ distance\ from\ original\ side}{2}\right)$$

   - For example, if your segments are 1.5 meters long, then the width of Segment 4 would be (7.5 – 4.5) / 2, which is 1.5.
   - **For Segment 1,** the **previous segment** will be 0 meters from the original side
   - **For the last segment**, the **next segment** distance from the original side will equal the total width.
   - The Discharge Calculator can help with this equation. Just plug in the data from the datasheet and it will calculate total stream discharge for you!

9. To get the total cross-sectional area of the stream, simply add up all of the segment areas.

## 2.7 - Manually measuring stage

At the same time that you measure cross-sectional area and velocity at a Monitoring Point, you should also measure stage (the height of the stream). This is similar to the segment depths measured in Section 2.6, but will provide an easy way to quickly and consistently update those depths at different flow levels as you construct a rating curve. A **stream gauge** can be used to measure stage. A water level data logger can also provide this information, but requires much more effort and money (see Section 2.12). For the initial phase of constructing a rating curve, deploying a stream gauge to measure stage makes more sense.

This video by the Stroud Water Research Center provides excellent, detailed instructions for installing a stream gauge (SWRC, 2019).

1. Assemble a stream gauge using the method and equipment used in the video linked above.
2. For each Monitoring Point, find a spot in the stream that is:
   1) As close as possible to the perpendicular line along which cross-sectional area is measured.
   2) Deep enough that the gauge's base will still be in water even when the stream is at its lowest.
   3) Stable substrate! You should NOT be able to push the metal rod deep into the substrate by hand.
   4) Ideally, readable from the streambank.

3. Pound the metal rod at least two feet into the ground at this spot
   - If you can easily twist the rod in place by hand after pounding it in, find a more stable location.
4. Slide the gauge down the rod until it is resting on the streambed. Tighten it in place as much as possible.
   - If the stream is particularly deep here, you may need to attach a second metal rod to the first along with a second stream gauge, which should lie flush atop the first.
5. Read the gauge by reading what number the stream level is at. Record this in the **Stream Stage** field on the **Stream Discharge Datasheet**.
   - This provides a consistent measurement that can be compared against any other time you visit this Monitoring Point.
   - With a stream gauge established, you no longer need to re-measure stream depth in each segment when you visit a Monitoring Point.

## 2.8 – Stream velocity

There are two methods explored below for calculating stream velocity, which is critical for estimating discharge.

The **Float Protocol** is cheap and easy, but it isn't as reliable. Using a **flowmeter** to calculate velocity will provide a more accurate measurement, however flowmeters can be fairly expensive. See the Section 2 Appendix for notes on different flowmeters. For either option, use the **Stream Discharge Datasheet** to keep track of your measurements. Both protocols are drawn from Chapter 3 in *Methods in Stream Ecology* (Gore, 2006).

**Float Protocol**

1. Complete steps 1, 2, and 3 of Section 2.6 (Stream Cross-Sectional Area) for the Monitoring Point.
2. Use the floating rope to measure a length of the stream at least 20 meters long (**the float distance**), with the Monitoring Point in the middle. Mark the start and end of this length in a way that will make it obvious when a floating object goes past them.
    - Be sure that the units you're using to measure length match what you used to calculate cross-sectional area (e.g., if you used meters, velocity should be in meters per second).
    - One way to mark this length is to stretch two ropes across the stream, which can serve as a starting line and a finish line.
3. For **each** segment of the stream measured for area in Section 2.6, do two to three time trials measuring how long it takes for a peeled orange to travel the float distance.
    - Set the orange into the water a little above the starting point, so that it is moving at the speed of the stream by the time it hits the start of the length.
    - Use the floating rope to line up each trial with the middle of each segment.
    - The float does not have to be an orange. To quote from *Methods in Stream Ecology*, "Choose a float that is only slightly buoyant. This will allow the object to move smoothly with the main vector of flow and minimize the influence of air currents. An orange (peeled oranges float lower in the water), a chunk of ice, a half-filled fishing float or bobber (or tennis ball), or waterlogged branch is ideal."
4. The surface velocity within a given segment is calculated as the average of the trials in that segment.
5. Account for streambed roughness by multiplying this average by a value between 0.8 and 0.9, which will give the **velocity** for each segment.
    - 0.85 is typically used unless the stream bed is very rough (0.8) or very smooth (0.9).

**Flowmeter Protocol**

1. Complete steps 1, 2, and 3 of Section 2.6 (Stream Cross-Sectional Area) for the Monitoring Point you are measuring velocity data at.
2. At the same spot where you measured stream depth for each segment, hold the flowmeter vertically in the stream, with the turbine facing directly upstream.
    - Be sure that you're standing downstream of the flowmeter and that the eddies around your legs don't disturb it.
3. If the water is less than 60 cm deep, record your velocity measurement at 40% of the depth (40 cm above the streambed if the water is 1 meter deep). If the water is more than 60 cm deep, record one measurement at 20%, another at 80%, and then average the two for velocity.
    - Be sure that the length units you're using match what you used to calculate cross-sectional area.
        - For example, if you used meters, velocity should be in meters per second.

- If the water is too fast or strong to keep the flowmeter vertical at that depth, measure at the surface.
- If the water in the segment is disturbed by large submerged objects (e.g., logs, boulders) or overhanging vegetation, take measurements at 20%, 40%, and 80% of depth. Calculate the average as $(V_{20\%} + V_{40\%} + V_{80\%}) * 0.25$.

4. Account for streambed roughness by multiplying this average by a value between 0.8 and 0.9, which will give the velocity for each segment.
   - 0.85 is typically used unless the stream bed is highly rough (0.8) or highly smooth (0.9).

### 2.9 - Calculating discharge

With a measurement of the cross-sectional area (Section 2.6) and velocity (Section 2.8) for the Monitoring Point, you can now calculate an estimate of the total volume of water flowing through that point at the time of your measurements.

1. For each segment making up the Monitoring Point, multiply the cross-sectional area by the velocity.
2. Add up these segment discharges to get the **total discharge** at this Monitoring Point at the time of your measurements.
   - The units of this should be in cubic feet per second or cubic meters per second.

### 2.10 - Creating a rating curve

Of course, that discharge measurement took a great deal of effort to obtain and only produced an estimate of streamflow for one point in time. However, by taking these measurements at different water levels, you can create a **rating curve** for each Monitoring Point, allowing you to estimate total discharge using only stage (i.e., water level). A rating curve is an equation that approximates the relationship between stage and discharge.

1. Calculate the discharge at the Monitoring Point under **at the very least** low flow, median flow, and high flow conditions.
   - More samples will make for a more accurate rating curve, but it is not uncommon to just use these three flow levels (Gore, 2006).
   - It is important to re-measure velocity under each different flow level (**repeat Section 2.8**).
   - Don't re-measure the water depth for each segment at each flow level. Instead, just take a reading of the stage using the gauge (Section 2.7). The difference between stage and the individual segment depths should be constant, so just adjust each depth based on the stage to get the new cross-sectional area.

2. Plug your data into the Rating Curve Calculator to produce an equation that can be used to estimate discharge with only stage.
   - This rating curve calculator takes the natural logarithm of the input stream depth and discharge data and then finds the best-fit linear model for those converted values, which provides the coefficients needed for the power law equation used to determine the relationship between stage and discharge in a given stream.
   - This video provides a detailed walk-through of creating a rating curve (NCSSM, 2019).
3. More data can be added to the Rating Curve Calculator over time to make this equation more accurate.

## 2.11 – Estimating the impact of beaver dams

With rating curves for each and every Monitoring Point, it is now simple math to understand how streamflow changes as it passes through each monitoring stream section.

1. Take a reading of the stage at each Monitoring Point.
   - Since these readings will be used to compare from one site to the next, take them all as close in time as possible.
   - If you're using data loggers to collect stage data, this is easily accomplished by aligning the start time and monitoring interval between the loggers.
2. Use each Monitoring Point's rating curve to turn that stage measurement into a discharge estimate.
3. For each stream section, subtract the upstream site's discharge from the downstream site's discharge to get the difference between the two. **This is the change in streamflow for a given section of stream at that point in time**.
4. **To estimate the impact of the beaver dams**, find the difference between the beaver dam complex section and the reference section(s).
   - If you are measuring multiple reference sections, calculate their mean change in streamflow.
5. Data loggers are the easiest way to **estimate the streamflow impacts of the beaver dams over time**. This is functionally no different from steps 1 through 4, with the only difference being the number of measurements the data loggers are able to take.
   - This involves synchronizing the time that each logger measures stage and using the rating curves to estimate discharge for all of those measurements.

## 2.12 – Water level data loggers

With established rating curves, it is easy to estimate streamflow in each section of stream knowing only the water level. However, you still have to go into the field and take a manual reading of the stream gauge anytime you want to estimate streamflow. By deploying an **Onset HOBO U20L Water Level Logger** at each stream monitoring site, you can automatically record this information at any desired frequency. This can provide incredibly detailed information about how streamflow changes over the course of each storm event, day, season, or year. The downside of these loggers is that they are expensive (around $450 per logger; see **Water Level Logger Equipment Purchasing** in the Section 2 Appendix for more information on equipment costs). It also takes a fair amount of effort to deploy them and process their data compared to just reading a stream gauge.

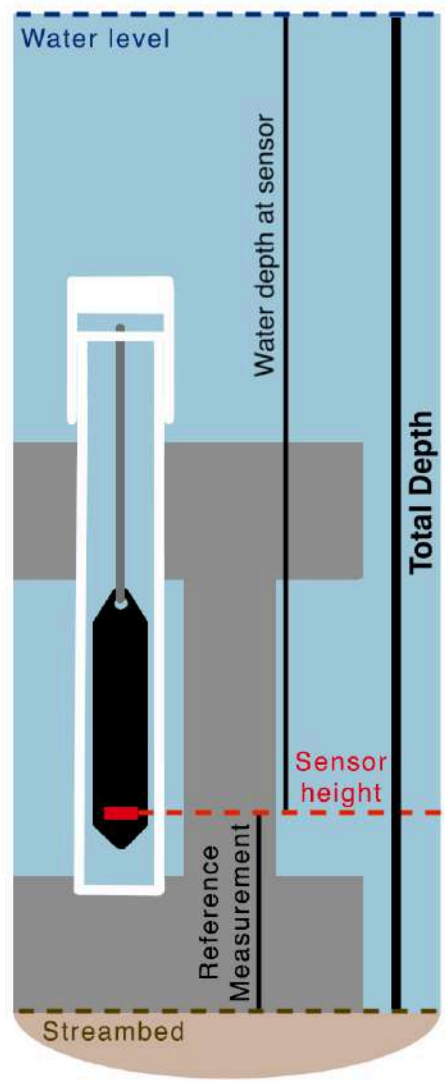


***Figure 2.2**: The Reference Measurement should be measured whenever the data logger is moved to account for sensor drift over time of potential changes in the height of the logger.*

Here are basic steps for setting up these loggers at Tensleep:

1. Gather equipment and download HOBOware Pro
2. Configure and launch each logger using HOBOware Pro

3. Deploy a logger at each Monitoring Point by placing each in a stilling well that is firmly attached in place and will not be washed away
4. Once deployed, take a Reference Measurement of the gap between the logger's sensor and the streambed
5. Periodically download the data from the logger and then put it back in the stilling well for more measurements
    - Be sure to take Reference Measurements at the before and after this step.
6. Obtain concurrent barometric pressure data from an additional data logger or from the nearest weather station for the time period.
7. Obtain water level measurements in HOBOware Pro using the logger data, the weather station data, and your Reference Measurements.

These steps are described in detail in the **HOBO U20L Water Level Logger (U20L-0x) User's Manual**. Rather than repeating those instructions below, this document instead provides clarifications and suggestions specific to monitoring water level in headwater streams (particularly at TNC's Tensleep Preserve in Wyoming). Underlined titles refer to sections of the User Manual.

**Launching the logger**

- Using the HOBOware software, you will set the logger to begin collecting data at a certain time and at a certain frequency.
    - Consider setting a **delayed start time** of 12 am the day *after* you plan to deploy the logger. By doing so, you have the flexibility of the entire day to set up the logger before it begins collecting data. If you are not able to get the logger set up on this day, you can set a different start time in the evening.
    - Consider setting a **logging interval** between 15 minutes and one hour, the typical range for automated stream height measurements by the USGS (EPA, 2017).
    - **Use consistent start times and logging intervals for all deployed loggers so that they will take simultaneous measurements.**
        - This will be helpful for calculating the difference in streamflow within and between stream sections.

**Deploying the logger**

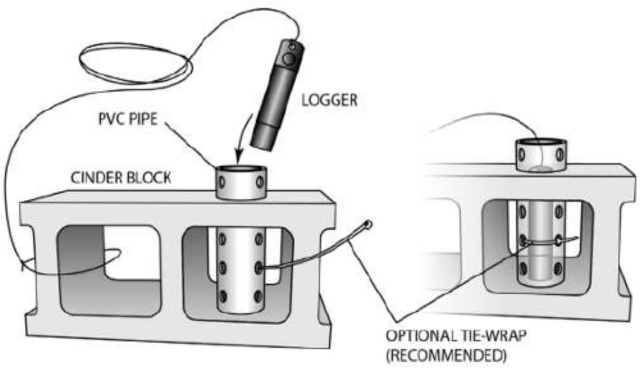

***Figure 2.3:*** *A potential configuration for securing the logger in place in the stream ("Monitoring Wetlands with Data Loggers: A Best Practices Guide", Onset)*

- Given that the loggers will be deployed in flowing streams, a stilling well will be needed to protect them from sediment, debris, and water currents. These in-stream stilling wells are typically constructed using 2" diameter slotted PVC pipe. Onset sells well caps for this diameter of PVC pipe that a U20L logger can be easily attached to using no-stretch wire.
    - Onset provides instructions for installing this cap onto the PVC pipe and attaching the logger.
    - If you don't want to buy a well cap, Onset suggests hanging the wire (with the logger dangling from it) from a ¼" bolt drilled through the PVC pipe near its top.

- Secure your loggers to avoid them being washed out by high flows in the spring or after storms.
    - One method suggested by Onset is to mount the PVC pipe within a cinder block. This entails drilling a hole slightly larger than 2” through the concrete which the PVC pipe can fit snugly into. Then, directly attach the PVC to the cinder block using zip ties, metal wire, etc. Place the cinder block with its holes parallel to the direction of flow so that water will pass through it more easily.
    - Rocks can be placed on or around the cinder block to help keep it in place, so long as you are still able to remove the logger and take a Reference Measurement of the gap between the logger’s sensor and the streambed.
    - Consider securing the cinder block to the stream gauge to further ensure that it stays in place. Alternatively, if you feel very confident in the stream gauge not being washed away, you could attach the PVC pipe directly to the gauge without a cinder block or other heavy object.
- Another benefit to putting the logger in the same location as the stream gauge is that there will be no need to account for the difference between the manual stage measurements with the gauge and the automated stage measurements with the logger.
- If it is easier to have the logger be sideways or diagonal (rather than vertical), that is completely fine. The pressure transducer is not based on facing a certain direction. What is most important is that the height of the logger’s sensor in the water column does not change during deployment or while it’s monitoring.
- Adding a weight is not necessary if the logger is in the stilling well (according to Onset Tech Support).
- Keep in mind that you will need to be able to return the logger to the same location / height in the stream each time you remove it to download its data. With this in mind, consider placing the cinderblock directly on the streambed.
- When you deploy the logger, you will need to take a Reference Measurement of the distance between the logger’s sensor and the streambed. Doing this allows you to account for the drift of the pressure sensor over time. Be sure that the housing protecting the logger (PVC pipe, cinder block, etc.) doesn’t prevent you from taking this Reference Measurement.
    - This measurement should be recorded as a positive number.
    - This measurement also needs to be taken **right before** pulling the logger out of the stilling well to download its data **and right after** putting the logger back after downloading its data.
    - You can use this datasheet to record these measurements over time and keep track of when you deploy and download the data from each logger.

**Reading out the logger**

- The most convenient tool for downloading data from U20L data loggers at Tensleep will likely be the HOBO Waterproof Shuttle. An alternative is the HOBO Optic USB Base Station. While cheaper, the base station is not waterproof and has no onboard memory, meaning that you will need a computer on hand to download data from each logger.
- If any one of the loggers is lost or damaged you will lose all of the data collected since your last download. Download the data more frequently to reduce what can potentially be lost.
    - Be sure to download the data prior to the spring runoff, as this is likely the time when there’s the highest risk that the logger will be washed downstream.
- When downloading data, don’t forget to take a Reference Measurement of the distance between the logger’s sensor and the streambed **before you remove it from the stilling well and after you put it back**!

**Barometric pressure from other sources**

- Because the loggers measure absolute pressure, barometric pressure data is needed to accurately convert those measurements to water depth. This can be achieved through either of two different options, but at the Tensleep Preserve, only the first is feasible.
    1) Purchase another U20L data logger and deploy it somewhere where it will experience the same weather conditions and be at the same elevation as the in-stream loggers.
        - Be sure that this logger is both exposed to the atmosphere and within 10 miles and at a similar elevation to all Monitoring Points.
        - Temperatures at the Tensleep Preserve often fall below freezing, outside of the factory calibrated operation range of these loggers (32° to 104°F). To overcome this challenge, Onset recommends placing the loggers several feet below ground in an observation well. This can be constructed with PVC pipe, similarly to an instream stilling well.
            - An added challenge will be ensuring that snow doesn't build up on top of the observation well and block the logger's reading of atmospheric pressure.
        - This method would likely be more accurate than relying on weather station data, given the topography / elevational differences.
    2) Obtain barometric pressure data from your monitoring period from a weather station within ~10 miles of the monitoring sites. Then reformat that data to be in the format described by the Import Text Files Requirements' section of the HOBOware User Manual.
        - **When selecting a weather station, choose whichever will best approximate the weather conditions at the monitoring sites. Keep in mind that pressure varies due to altitude and local weather conditions that can be heavily influenced by topography.**
        - Historic, high-frequency weather data for many weather stations is available from Weather Underground, including the local weather station in Ten Sleep.
        - A challenge with this method is that there is no easy way to download these pressure measurements from Weather Underground. One workaround is to use a script to automatically download the data as a csv file. Examples can be found here and here.

**More sources of information**

- Insider Tips for Successful Water Level Logger Deployment
- More information from Onset on field deployment of loggers
- Suggestions from Onset on constructing a stilling well
- Onset webinar: "HOBO Water Logger Deployment Considerations: Ask the Experts!"
- HOBOware® Pro Barometric Compensation Assistant User's Guide
- A python script for scraping high-resolution weather data from Weather Underground
- Scraping 5-min weather data from Weather Underground

## Section 2 Appendix

**Additional Resources**

- **Stream Discharge Datasheet** – Record data for stream cross-sectional area, stage, and velocity for each Monitoring Point.
- **Discharge Calculator** – Plug in the velocity and length data written on the **Stream Discharge Datasheet** and get the discharge for that Monitoring Point at that time. It does all the math for you if you just plug in the numbers!
- **Rating Curve Calculator** – Plug in the discharge data for different flow level at a Monitoring Point and a rating curve will be calculated for them. There are four sheets currently, one for above and below each stream section.

**Glossary**

Hydrological terms

- **Flowmeter** – A device used to measure the velocity of water in a stream. There are various types of flowmeters, including mechanical, doppler, and electromagnetic. Also known as a current meter.
- **Rating Curve** – A mathematical relationship between stage and discharge that allows discharge to be predicted at stages other than those measured. It can be produced with a discharge measurement at low, medium, and high flow (Gore, 2006).
- **Stage** – The height of the water in a stream relative to an arbitrary point; equivalent to stream height or stream level (Gore, 2006).
- **Stream Gauge** – An instrument used to measure the stage of a stream. Often, it is a simple staff gauge, which is a length with measured increments used to track stream height (Gore, 2006).
- **Water Level Data Logger** – A device that automatically collects data on stage at set time intervals. In this protocol, it specifically refers to Onset's U20L-04 HOBO Water Level Data Logger.

Specific to this protocol

- **BDC** – Beaver Dam Complex; referring to the area of a stream where stream height and streamwater velocity are impacted by beaver dams.
- **Monitoring Point** – A cross-section of one point along a stream located at the top or bottom of a stream section (see below) where stream discharge data is collected.
- **Section** – A section of stream where the change in discharge is measured from one end to the other through data collection at Monitoring Points. Each section is either beaver-impacted (i.e., a BDC) or is a site reference for a BDC.

**Water Level Logger Equipment Purchasing**

- At *minimum* 3 U20L-04 HOBO Water Level Data Loggers – $375*3 = **$1125**
  - Two for above and below beaver complex. One to measure a control site (if that control site could be immediately above the beaver complex. If it wouldn't be, you need another).
  - This also assumes that there is a weather station collecting publicly available barometric pressure within 10 miles of Canyon Creek, which I'm pretty sure there is in Tensleep, right?
- HOBOware Pro software for data processing – **$75**
  - TNC might already have this though
- HOBO Shuttle for data collection – **$325**

- Housing for each logger
  - Onset sells an option, but it would likely be better for the loggers / more cost effective to purchase 5' of slotted 2" PVC pipe which could be chopped into a section for each logger– **$37**
  - Top well caps for those PVC pipes, which logger will hang from – $65 * 3 = **$195**
    - The Onset caps are convenient and easily reusable, but you could also purchase simple caps and rig up a connection for cheap.
  - Caps on the bottom of each PVC pipe will further help to protect loggers from sediment – **$13**
- Rebar or cinder block to hold the logger in place and keep the setup from washing out – **Negligible**
- Some means of attaching the PVC pipe to the rebar or cinder block – **Probably negligible**
- Stainless steel cable (ideally teflon-coated) to attach the PVC pipe to the cinder block and/or the cinder block to surrounding rocks. Onset sells 50' of 1/16" stainless steel cable, but there might be cheaper options – **$105**
  - Home Depot doesn't seem to sell *coated* stainless steel cable
- 4 crimps to crimp the ends of the wire after its looped through the well cap and the logger (2 for each end) – **$6**

  **Total of $1787**, with $440 more per additional logger

**Flowmeter Equipment Purchasing**

| Flowmeter Type | Product Name | Price | Notes |
|---|---|---|---|
| Mechanical | Flowwatch Flowmeter | $476 on Forestry Suppliers | There's a used version on ebay for $200. Returning it is a maybe. |
| Mechanical | General Oceanics Flowmeter | $668 | 1 yr warranty. On eBay for $300 |
| Mechanical | Swoffer flowmeter with 2.7' top setting rod | $2,070 | |
| Mechanical | Flinn Scientific flowmeter | $380 | Can return up to 180 days after purchase. |

## Section 2 Sources


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# Section 3 - Beaver Lodge Survey

## 3.1 - Why monitor the beavers?

If you wish to understand the state of a population, it is essential to monitor its trend over time. How many individuals are there? Is that number growing or shrinking? What's the survival rate and is it different for different age groups? Surveying the beaver population allows this to be assessed, providing a coarse understanding of the "wellbeing" of a beaver colony.

## 3.2 - Protocol Overview

A small group of surveyors will observe beavers from multiple vantage points around a beaver lodge for 2.5 hours at dusk or dawn. The goal is to obtain a minimum count of how many beavers of different age groups are living in the lodge and how that changes over time. Since individual beavers are very difficult to distinguish (especially in the dark), surveyors should focus on gauging size and keeping their eyes peeled for multiple beavers out at the same time.

This will be more effective if different surveyors are watching from different vantage points around the lodge, because data can be compared afterwards to determine if multiple beavers were observed in different locations at the same time.

In the figure to the right, surveyors at **Vantage Point A** can see everything covered by vertical yellow lines. Surveyors at **Vantage Point B** can see everything covered by horizontal blue lines. Individually, the surveyors at each point only see one beaver at this point in time. However, if they compare their notes afterwards, they'll find that there were two beavers visible!

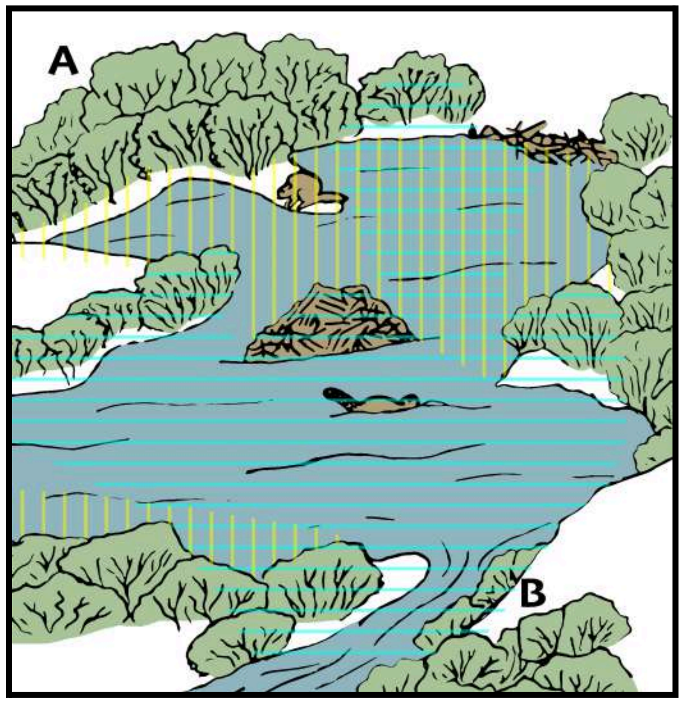


***Figure 3.1*** *- Multiple vantage points allow for a fuller view of the beaver pond*

## 3.3 - Equipment needed

- This protocol, for reference
- [Beaver Lodge Survey Datasheet]
- Pen / pencil
- Watch or phone
- GPS device or smartphone with a GPS app
- Compass or smartphone
- Dark clothing
- Whatever surveyors need to safely and comfortably watch for beavers for two hours in the dark (e.g. snacks, warm clothing, a camp chair, etc.)
- Headlamp or flashlight

### 3.4 - Preparing for the surveys ahead of time

1. **Find several vantage points that offer good, close-up views of the beaver lodge and food cache while still allowing surveyors to be comfortable and hidden from the bevers.**
    - At Canyon Creek, the canyon rim offers an excellent view of the beaver pond. Use it to get a good sense of the area and pick out potential vantage points.
    - These vantage points should be spread around the lodge so that as much of the area in the beaver dam complex as possible can be collectively observed.
    - Beavers have poor eyesight but excellent senses of smell and hearing (Long, 2000). Ideally, surveyors should be downwind of the beavers, so consider prevailing winds.

2. **Make a plan for when and how often surveys will happen (obviously you can adjust this later!)**
    - This protocol is best done with at least two surveyors.
    - Surveys should happen in the 2.5 hours before sunrise or the 2.5 hours after sunset. Either or both dawn and dusk surveys can be conducted, depending on surveyor preferences.
        - Though be sure that everyone is within shouting distance of each other for safety.
    - The annual window for surveys is the time of year when the beaver pond isn't covered with ice. Within this period, surveys can be conducted at whatever frequency works for surveyors.
    - Crossing Canyon Creek could be treacherous during the spring runoff in June.
    - **Keep the following things in mind with planning the timing of surveys:**
        - Kits are generally born between mid-May and mid-June, which is also when two-year-olds will leave the family in search of mates (Olsen, 1994). Consider beginning annual surveys during this period to try to catch the initial number of new kits.
        - Consider timing your surveys to be close to the full moon, so that a bright moon will be overhead during your survey period. For dawn surveys, the moon will be higher above the horizon in the days after the full moon. For dusk surveys it will be higher in the days before the full moon.
        - A beaver monitoring project in Colorado found beavers to be most active in the evening and in the **late summer and fall**, when beavers are busy preparing for the winter (EcoMetics, 2023). **If you only want to survey for a limited period in the year, consider focusing on this period!**

3. **Have all surveyors check out Section 4.6 on examples of beaver signs.**
    - Relevant signs for a lodge survey include beavers themselves, tail slaps, and cloudy water.
    - **Pay particular attention** to the difference between beavers, muskrats, and otters, all of which are nocturnal and can be easily confused with each other, especially in the dark.

4. **Ensure that all surveyors have all the equipment listed in Section 3.3 and have read through, understand, and have a copy of this protocol and the [Beaver Lodge Survey Datasheet](#).**

### 3.5 - Survey Protocol

1. For a dawn survey, time your arrival so that you can start your survey about two hours before sunrise. For a dusk survey, plan to start surveying about 15 minutes before sunset.
2. Quietly spread the group out between the predetermined survey vantage points, ensuring that between everyone the whole beaver pond is within sight.
3. The surveyors at each vantage point should fill out **the Pre-Survey section** of the datasheet.
    - For **Viewpoint Location**, record your latitude and longitude or describe where you are (e.g., in clump of willows ~15 yards northeast of the Canyon Creek beaver lodge).
4. Fill out the **Survey Start section** of the datasheet and start your survey.
5. Survey the beaver dam complex for 2.5 hours, using your datasheet to record details about any beaver observations.
    - Pay particular attention to the area around the beaver lodge and the food cache.
        - See Section 4.6 for photos of a beaver lodge and cache.
    - Be observant about the size of what you're seeing, as this is the best and easiest way to distinguish between beaver kits, yearlings, and adults (see the figure below for approximate sizes of different beaver age groups compared to a labrador retriever).
    - Use the **Confidence in your ID** field to note how confident you are about whether or not you saw a beaver and how big it was.
    - Do your best to stay quiet. Beavers have poor eyesight, but excellent senses of smell and hearing (Long, 2000).
6. When the survey period has ended, get the whole group back together and leave the beaver dam complex.
7. Compare the observation times and ages of the beavers that you observed to determine the total number of beavers of different age groups observed.

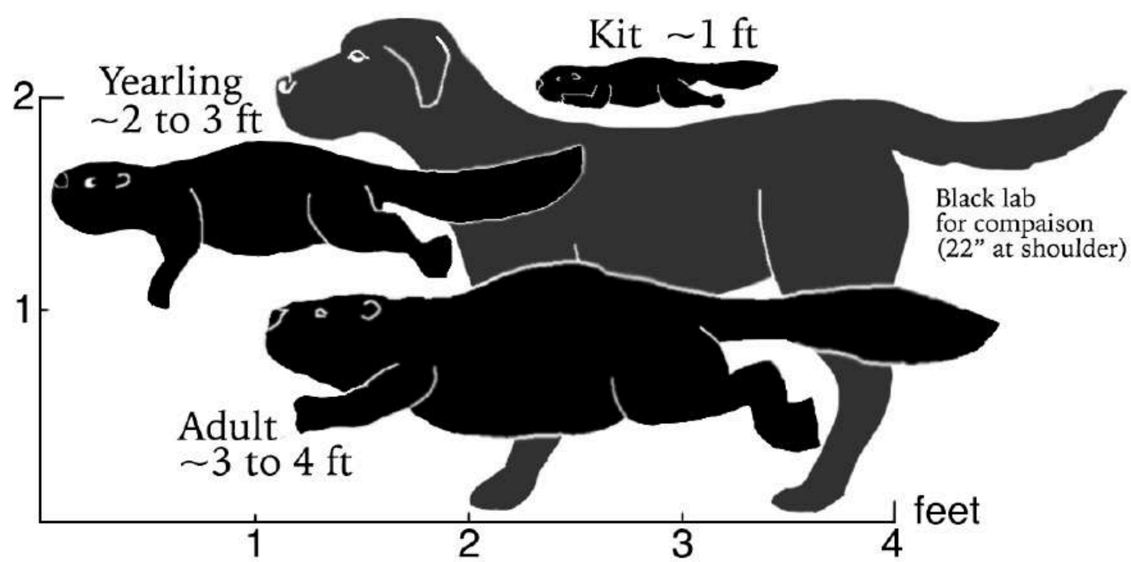


***Figure 3.2*** *- Size of an average beaver adult, one-year-old, and kit, in comparison to an average adult labrador retriever.*

## Section 3 Appendix

Additional Resources

- **Beaver Lodge Survey Datasheet** – Record data for each beaver lodge survey

Key background information from sources

- Cucumber Gulch 2022
    - More active in evening
    - “Identification of individual beavers is hard, so the best chance to estimate numbers of individuals is when multiple beavers are spotted at the same time. In 2022, we adjusted to have multiple observers at the most active locations.”
    - “In 2022, we continued biweekly seasonal beaver population surveys in locations where beavers were known to be active, and multiple observers simultaneously watched all neighboring ponds. By comparing the location and time of observations, it is possible to determine the minimum number of individual beavers present in the surveyed areas.
    - Periods of highest activity are in the late summer and fall. This pattern coincides with preparations for the upcoming winter.
- Hay 1958
    - “An average of 5 hours of ground observations was required before the highest count was recorded on any colony. Moreover, this count was not in all cases the population that was later revealed by trapping records. The error was usually concerned with the kits, which appeared for only short, infrequent periods.”
    - “dead-trapping is essential in obtaining reliable index values for average winter-colony numbers”
    - For this observing, they found downwind vantage points near the population center with good views
- Osmundsen & Buskirk 1993
    - “During observation periods, beavers were first observed within 0.5-2 (mean=0.83) hours. The number of beavers observed during an observation period was not correlated w duration of the observation period
    - Time required to observe all beavers believed to be at a colony was less w 2 observers watching than with 1.
- Easter-Pilcher 1990
    - Late Nov to early Dec “when beaver were active and readily observed around the nearly completed cache”
    - Infrared night vision goggles–150 minute survey period from 4:30 (sunsetish) to 7. Just one observer.
    - Observers were within 10m of cache and in camouflage, face netting, and dark clothes
    - They only counted as separate, beavers that could be positively IDed as different. So final counts were minimum estimates.

| Source | Time of Year | Time of Day | Survey Length | Number of Observers | Location | Other |
|---|---|---|---|---|---|---|
| Easter-Pilcher, 1990 | Late Nov-early Dec | Sunset to 7 | 150 min | 1 | Within 10m of cache | Infrared night vision + camo + face netting + dark clothes |
| Osmundsen & Buskirk, 1993 | Took place over many months? | Pre-dawn or post-dusk | 120 to 240 min | 1 or 2 (2 more effective) | Concealed site with good cache visibility | # of beavers observed did not correlate w survey length. Night vision |
| Hay, 1958 | Summer & fall | *Unknown* | 5 hours of surveying needed to get max beaver count | *Unknown* | downwind vantage points near pop. center + good views | Kits were hardest to observe |
| Cucumber Gulch monitoring protocol | Biweekly surveys from May to Sept. Late summer/fall saw most activity | Evening & morning. Evening best | *Unknown* | Multiple | *Unknown* | Recommended multiple to correlate observations and confirm multiple beavers |

***Table 3.1*** *- Basic information on other beaver lodge surveys.*

## Section 3 Sources


- Easter-Pilcher, A., 1990. Cache Size as an Index to Beaver Colony Size in Northwestern Montana. Wildlife Society Bulletin, 18: 110-113. https://www.jstor.org/stable/3782121
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# Section 4 - Beaver Sign Survey

## 4.1 - Why survey for new beaver colonies?

Generally, most beavers are driven away from their birth colonies at the age of two during the spring runoff. At this point, they disperse upstream or downstream in search of a mate and a location to form a new colony. As a beaver population grows, new colonies will form, each with their own family of beavers. The purpose of this survey is to monitor the formation of new beaver colonies within TNC's Tensleep Preserve.

It is useful to know about these new colonies for a few reasons. First, it shows if there is growth of the local beaver population and how much, providing data on the health of the beaver population. Second, one of the major challenges with measuring the impact of beavers on streamflow is the difficulty of collecting data prior to dam building. However, if the location or likely location of a new beaver colony is identified prior to dam construction, stream monitoring equipment could potentially be set up to capture both pre- and-post-dam data.

## 4.2 - Protocol Overview

Two to four surveyors will search for signs of beaver activity as they walk the length of a stream corridor. The goal is to identify the location of beavers and new beaver colonies beyond already established and known colonies. For The Nature Conservancy's Tensleep Preserve, this should entail volunteers surveying all stretches of Canyon Creek that are habitable for beavers and within the boundaries of the Preserve.

## 4.3 - Equipment needed

- This protocol, for reference
- Beaver Sign Survey Datasheet
- Pen / pencil
- Camera / phone
- GPS device or smartphone with a GPS app
- Waders (or a willingness to get very wet from hiking through streams)

## 4.4 - Preparing for the surveys ahead of time

1. **Make a plan for when surveys will occur based on the information on beavers below, the site conditions at Tensleep, and the needs of volunteers.**
    - **The ideal goal is to identify the formation of beaver colonies *before* dam-building occurs. Surveying more frequently from the spring runoff through the fall (the beaver dispersal season) will be helpful for this.**
    - Two-year old beavers will generally disperse out of their birth colony during the spring runoff when streams are highest. Van Deelen & Pletscher found this to be between mid-April and June in one study in western Montana (Van Deelen & Pletscher, 1996).
    - Dispersing beavers will form a sub-population of transient juveniles during the summer months looking for mates and places to build a lodge of some kind (Van Deelen & Pletscher, 1996).
    - In one Ohio study, pair formation peaked for dispersing beavers between September and November (Svendsen, 1988).
    - While beavers are still active to some degree during the winter, always prioritize safety around icy water or during the spring runoff when young beavers begin to disperse.

2. **If possible, observe the Survey Area from a distance before conducting an actual survey from within the stream corridor.**
   - This will allow you to build an understanding of the survey area, including key areas of interest your survey should focus on, potential challenges posed by terrain or vegetation, and how much of the stream you may want to survey.
   - In the Tensleep Preserve, this can be accomplished by walking along the canyon rim of Canyon Creek and looking down at the stream below you.

3. **Based on your pre-survey observations from Step 1, make a plan for how far you will need to hike and how long it might take you to survey the sections of Canyon Creek most habitable for beavers.**

4. **Surveyors should check out the photos of different types of beaver sign in Section 4.6 below to better understand what they will be looking for.**

5. **Ensure that all surveyors have all the equipment listed in Section 4.3 and have read through, understand, and have a copy of this protocol, datasheet, and beaver sign photos.**

> **Survey Area**
> At the Tensleep Preserve, the "Survey Area" should ideally be…
> 1) The length of Canyon Creek from the western property boundary through the cottonwood gallery at the confluence of Cooks and Canyon Creeks.
> 2) Any water infrastructure adjacent to this area that could be dammed or otherwise impacted by beavers.

## 4.5 - Survey Protocol

1. **With a group of two to four surveyors, hike to either the top or bottom of the stretch of Canyon Creek that you will be surveying.**

2. **Fill out the Date, Observer Name(s), and Survey Start section of the Beaver Sign Survey Datasheet.**

3. **Survey the target section of Canyon Creek by hiking as a group through the riparian corridor, observing intently for signs of beaver presence.**
   - It will likely be easiest to just walk through Canyon Creek itself, but be sure to still watch out for signs of beaver presence in the vegetation surrounding the stream.
   - Surveyors should move as a group through the survey area, but also spread out to ensure that as much of the survey area is being observed as is possible.
     - At the very least, be sure to have a surveyor focused on each bank of the stream.
   - Keep a close watch for the following signs of beaver presence:
     - A beaver
     - Tail slap
     - Scat
     - Prints
     - Active Lodge / bank den
     - *Old lodge*
     - Active dam
     - *Old dam*
     - Food cache
     - Slide
     - Scent mounds
     - Freshly chewed stump / stem
     - Old chewed stump / stem
     - Cloudy water
   - **Check out Section 4.6 below for more info and photos of each sign listed above.**

4. **Once you have surveyed the whole length of the survey area (or need to stop for other reasons), end your survey by filling out the Survey End section of the datasheet.**

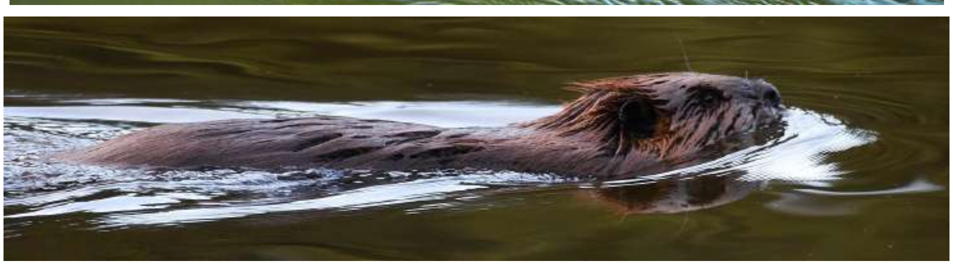
## 4.6 - Beaver Sign Examples

1. **A beaver**
    - See the Beaver Lodge Protocol for a figure showing beaver size. Adults are generally 3 to 4 feet long, including their tails, and average over 40 pounds.
    - Beavers are covered in dark brown fur and have a long, **flat** tail.
    - When a beaver swims, generally its whole body length (minus its tail) will be visible lying flat on the surface (Waugh, 2015).

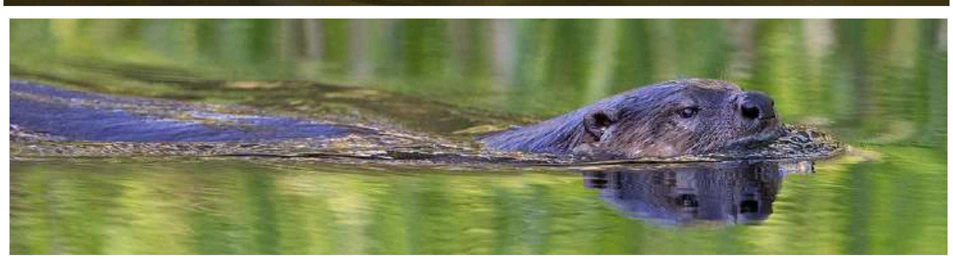
*Adult beaver. Photo by Cheryl Reynolds, Courtesy of Worth a Dam*

    - **The easiest animal to confuse with a beaver is a muskrat.**
        - **Muskrats are much smaller than beavers**, maxing out around 4 pounds and 2 feet long.
        - When a muskrat swims, it will expose much of its head and back above the water's surface and its **narrow tail** will likely be visible swishing back and forth (Mass Audubon).
        - The ears of a muskrat are generally more hidden in their fur than beaver ears.
        - Muskrats have been observed at the Tensleep Preserve.
    - **Another animal that can cause confusion is the river otter.**
        - Otters are around the same size as a beaver, but are much narrower.
        - Often **only the neck and head** of a swimming otter will be visible above the water.
        - Otters tend to behave much more energetically and swim faster than beavers.
    - Beavers, muskrats, and otters are all nocturnal, but will also be active at dawn and dusk.
    - [This page] offers excellent photos and advice for distinguishing beavers, muskrats, and otters (Waugh, 2015).

*A swimming muskrat.*
*Photo by Vince Pahkala*



*A swimming beaver.*
*Photo by Mary Lewandowski*



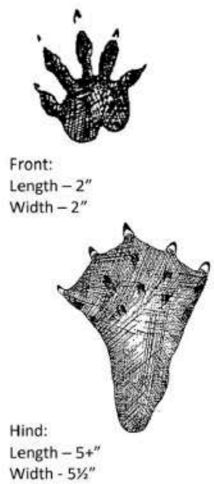
*A swimming otter.*
*Photo by Max Waugh*

2. **Tail slap**
    - When a beaver is alarmed, it will alert members of its colony to potential danger by slapping its tail on the water, creating a loud slapping sound (WDFW).

3. **Scat**
    - Beaver scat is uncommon to find since beavers spend the vast majority of their time in the water.
    - It is oval, about one inch wide, and filled with wood chips (Holland, 2022; NWFG).

*Beaver scat in Montana. Photo by Torrey Ritter, Montana Fish, Wildlife & Parks*

4. **Prints**
    - Beaver hind feet are webbed and over 5” long. Their front feet are not webbed and around 2”.



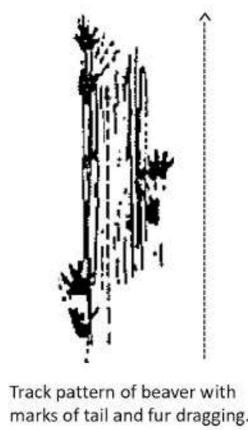




*Photo by Terry Kem. Photo & illustration from Illinois Department of Natural Resources.*

5. **Active Lodge / Bank den**
    - Depending on site conditions, beavers will construct a lodge in the water or dig a bank den, which provides a place to raise young, spend the winter, and shelter from predators.
        - Bank dens are likelier when the water level and stream banks are high (WDFW).

*Photo by Tony Hisgett*

    - A beaver lodge consists of a large mound of branches and logs, plastered together with mud.
    - Bank dens are dug into stream / pond banks and may be under a stump, log, or dock (WDFW).
    - A colony may have multiple lodges, though generally only one is used in the winter (WDFW).

6. **Active Dam**
    - Beaver dams are built on some streams to impound an area of water, providing a safe haven from predators.
    - They vary greatly in size and are generally constructed from mud, branches, and logs.

**"Active" dams and lodges**

As a beaver pond fills with sediment, eventually a beaver colony will abandon their lodge.

Determine if a lodge / dam is "active" by looking for…
- **Food cache** present
- **Fresh mud**, **fresh stems**, **recently peeled sticks** on the lodge or dam
- **Sufficient depth** in the pond for beavers to swim
- Dams may be leaky, but there are no large blowouts

*Fresh willow stems are visible on this dam near Lake Tahoe. Photo by Schmiebel*

7. **Food cache**
    - Each beaver colony will store food for the winter by creating a food cache near to their lodge, which looks like a messy raft of wood and mud.
    - Less desirable logs and stems may be placed on top of the raft and caked with mud to keep the more nutritious stems (often aspen and willow) submerged and accessible from underwater when the beaver pond freezes (Slough, 1978).
    - Beavers will begin constructing caches in the fall after the first heavy frost (Novak, 1987).

*A small food cache in Alberta composed primarily of willow Photo by Rick Bonar.*

*A beaver slide. Photo from the Mendocino County Resource Conservation District.*

8. **Slide**
    - A slide is a slicked down, muddy path made by a beaver as it enters and leaves the water.
    - They are generally 15 to 20 inches wide and are perpendicular to the shore line (ODFW).

*Beaver scent mound. Photo by Mary Holland*

*Freshly chewed willow stems.*
*Photo by the National Park Service*

9. **Scent mound**
    - To mark their territory for dispersing beavers, established beaver colonies will build scent mounds along stream or pond banks.
    - Each mound is a pile of mud, stems, and other pond debris and smeared with urine and smelly castoreum. Mounds can be up to 3 feet tall, but are typically much smaller (Holland, 2013).
    - Scent mounds can be very difficult to find, particularly in vegetation thickets (Hay, XXXX).

10. **Freshly chewed stump / stem**
    - Look for signs of beavers chewing through stems or tree trunks along the stream banks.
    - Beavers generally prefer to eat willow, cottonwood, and particularly aspen (Hay, 1958; Severud et al., 2013).

11. **Cloudy water**
    - A beaver that has just dived underwater (for instance, if it was frightened by a surveyor) will produce a cloud of sediment where it dove.
    - While this alone shouldn't be taken by itself as confirmation that a beaver is present, it can serve as a clue that a beaver is in the area and that other signs should be searched for.

## Section 4 Appendix

**Additional Resources**

- **Beaver Sign Survey Datasheet** – Record data for each survey for beaver sign.

## Section 4 Sources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# Section 5 - Future Directions

## 5.1 - Beaver surveys using wildlife camera traps

An alternative to conducting an in-person, dusk/dawn Beaver Lodge Survey to determine the number of beavers in a colony would be to set up a camera trap in the vicinity of the beaver lodge. In particular, combining this camera trap with the creation of a castor mound—a common technique used in beaver trapping—would significantly increase the likelihood of capturing photos of all the beavers in a colony by mimicking the territory marking scent mounds described in Section 2.6. The key component of a castor mound is castoreum, which can be readily purchased online. When constructing a castor mound, keep in mind that the smell of castoreum might draw in other animals, including predators of beaver. To avoid creating a point that might put beavers at risk of predation

Place the camera itself in a way that will provide a full shot of a beaver investigating the scent mound and allow for its size to be easily determined. One way to accomplish the latter is to put a small marker (e.g., a metal rod with reflective outdoor tape and flagging tape) near to the castor mound that can be used to gauge the size of the beaver. The camera should be attached to a t-post that is pounded into the ground in a location where it will not be at risk of being washed out in times of high flow.

Alternatively, the camera trap can be placed facing directly towards the ground to get a shot of each beaver's tail. Hinds et al. (2023) were 100% accurate when using the tails of deceased beavers to distinguish one individual from another. While this was in a laboratory setting with ideal photographs of the disembodied tails of Eurasian beavers, it suggests that a well-placed camera trap with a clear overhead view of a beaver's tail might produce photos from which one beaver can be distinguished from others.

The primary challenge with using camera traps is the processing of photos. A summer field season of camera trapping can produce tens, if not hundreds, of thousands of photos, which would need to be processed to not only identify individual beavers, but to determine if there is a beaver in the photo at all. One method for achieving this is through online citizen science platforms such as Zooniverse.org. The Colorado Corridors Project, an initiative to monitor wildlife abundance along the Interstate-70 corridor on East Vail Pass in Colorado, has used this platform to determine the number and species of wildlife in hundreds of thousands of photos. Accuracy is supported by requiring a certain number of people to produce the same number and species of animal for a given photo (CCP). This method also provides an opportunity to engage volunteers and members of the public in beaver monitoring and generate local interest in their conservation. Challenges with this method include a significant time investment to set up a user interface and training materials on Zooniverse before photos can be analyzed and the need to process photos before uploading.

Another option for the analysis of camera trap photos is the use of artificial intelligence to identify individual beavers in photos, or at least to determine which photos do or do not show a beaver or other animal. Vélez et al. (2022) found that the MegaDetector and MLWIC2 platforms were particularly effective at distinguishing blank photos from those containing an animal. As well, this is an area of active research and development, with more advanced software currently being developed to perform this identification.

### 5.2 - Spatial analysis using seasonal drone imagery

Given The Nature Conservancy Wyoming's access to staff and equipment capable of producing high-resolution, multi-spectral drone imagery, this presents another fruitful avenue for future investigation. Multi-spectral drone imagery collected during the period between deciduous trees losing their leaves and ice and snow forming on waterbodies can be used to determine their shape and surface area of beaver ponds. Collecting this image seasonally over time would allow for the change in these variables to be evaluated, providing a sense of beaver activity and a very rough estimate of the amount of water being impounded by beavers. Due to the fact that water strongly absorbs near-infrared light it is critical that this imagery contains a band in this range to accurately distinguish impounded areas from non-impounded areas.

Another use for high-resolution, multi-spectral drone imagery would be to assess the quantity and quality of beaver forage in the vicinity of Canyon Creek. Beavers generally prefer to eat willow, cottonwood, and particularly aspen (Hay, 1958; Severud et al., 2013). These deciduous trees and shrubs could be distinguished from coniferous species by comparing leaf-off and leaf-on multi-spectral imagery. By collecting this data over multiple years, it would also be possible to investigate the relationship between beaver activity and change in tree species composition around the Tensleep Preserve's beaver-dam complex.

### 5.3 - Expanding stream discharge monitoring

There are several ways that Section 2 - Stream Discharge of this Monitoring Plan could be expanded upon to more accurately and fully investigate the impacts of beavers on streamflow. First, groundwater monitoring could be conducted in the vicinity of the beaver-dam complex to understand the relationship between Canyon Creek's discharge, groundwater levels, and beaver activity. Using an array of mini-piezometers to measure groundwater levels, Dittbrenner et al. (2022) found that beaver dams raised water table elevations by as much as 0.33 meters and stored approximately 2.4 times as much groundwater as surface water at each beaver release site.

Alternative methodologies for estimating discharge to the midsection method and velocity measurements described in Section 2, include 1) measuring discharge at constructed weirs above and below the BDC and reference stream section(s) and 2) constructing a stream-hydraulics model for the Canyon Creek BDC and evaluating a non-beaver-impacted scenario against the current BDC (James Saiers, Yale School of the Environment, personal communication, 28 February 2024).

### 5.4 - Effect of beavers on vegetation and biodiversity

As ecosystem engineers, beavers impact their local environments in innumerable ways. By impounding water it is doubtless that beavers alter the species composition of other taxa, such as fish, plants, and invertebrates. One opportunity for future research would be to investigate these impacts through volunteer surveys and identification within the beaver dam complex. Multiple surveys could be conducted each field season, or if volunteer capacity does not allow for this, a single "bioblitz" event (a single day when a larger group of surveyors gather for an in-depth assessment of a given area) could be conducted each year, which could also serve as a way to engage and excite more member of the local community.

## Section 5 Sources


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