Ecological Restoration in the LaPlatte Headwaters Town Forest: Understanding impacts and developing management strategies related to Beavers

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Author Biographies

Kerry Brosnan is a senior in the Rubenstein School at the University of Vermont majoring in Natural Resource Planning and minoring in Global Studies. Her contributions to this paper include researching and writing about beaver behavior and beaver related restoration and she contributed to the section on beaver management suggestions and helped summarize the current community relationship with beavers in the discussion section. She also conducted 3 field surveys, a stakeholder interview with two other group members, and reached out to two landowners for interviews alongside being a main point of contact for communications with our partners Pat Mainer and Jon Trefry.

Alexis Cady is an environmental science major in the Rubenstien school at the University of Vermont. Her contributions in this paper include the writing and research for the introduction, vegetation section, current beaver location section, and the acknowledgements. In addition she conducted 3 field surveys, a stakeholder interview and bridged the connection to UVM Professor Eric Roy.

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Connor Stack is an Environmental Science major in the Rubenstein school at the University of Vermont. His contributions to this paper include performing the GIS analysis of the land, and writing the property infrastructure and vulnerability section. He also conducted 3 field surveys as well as a stakeholder interview.

Introduction

This management report was completed by a group of UVM NR 206 students for the Hinesburg Town Forest Committee (HTFC). The group was tasked with working with the HTFC to explore and assess the impacts of beavers in the LaPlatte Headwaters Town Forest (LHTF) and it's surrounding private properties. During the spring of 2021 extensive research on beavers and the LHTF area was compiled, interviews with landowners surrounding the LHTF were held, and a handful of site visits were completed for this document.

This document reviews key factors that are important in understanding the current landscape of the LHTF including vegetation and restoration, and topography and infrastructure., The main purpose of this document, however, is to understand where the beavers are currently located on the land and how they may impact the land in the future. There is a strong focus on the relations between current adjacent landowners and the beavers, and what future management may be needed to reduce human-beaver conflict. In the end, this document proposes a variety of management actions that the HTFC may consider implementing in the future to help keep human-beaver conflict to a minimum.

The document's order is arranged in its current state to have background information lead into management suggestions specific for LHTF. First, vegetation and restoration in LHTF and then topography and hydrology are discussed. This is followed by some background information on beavers including beaver behavior, and the potential beaver impact on LHTF restoration. Next, the document gets into information gathered for this project including; beavers current locations in LHTF, property infrastructure/flooding vulnerability, and community relationship with beavers. Lastly, the suggested management for the LHTF are discussed and the document wraps up with a conclusion and an appendix that contains a pamphlet for landowners.

Overview of Goals

- Understand where the beavers are currently located on the land
- Determine how beavers may impact the land in the future in terms of
    - Future restoration efforts
    - Vulnerable flooding areas
    - Property owner conflict
- Determine what future management may be needed to support beaver populations while reducing future human-beaver conflict
    - Interview surrounding landowners
    - Compose a list of management actions

Vegetation and Restoration in LHTF

The LaPlatte Headwaters Town Forest (LHTF) consists of 301 acres in the town of Hinesburg, Vermont. The LHTF has seen a lot of restoration in the recent past with tree plantings and invasive removal, along with current ongoing projects for both. The goal of these restoration projects is to restore the floodplain and wetland ecology in the area with the potential to minimize nutrient loading in Lake Champlain further downstream. However, these current and upcoming restoration projects may need to take into account a species that is now present - the beaver. Beavers in many studies have been found to aid floodplain restoration and thus could benefit the LHTF. On the other hand, a major worry with their appearance on the land is what adjacent landowners will think and do in regards to potential flooding caused by beaver dams, tree cutting, and other potential landscape changes/damages they might cause.

A deeper look into past management of the area shows how the area has transformed to its current state. In 2007 tree planting and ditch plugging occurred with very limited success for the planted trees: ⅓ of trees failed, ⅓ were severely stunted by deer browsing above plastic sleeves, and ⅓ thrived (Pat Mainer, personal communication, March 24 2021). In 2017-2019 more trees were planted and by 2019-2020 most of the current invasive shrub honeysuckle, japanese barberry and common buckthorn were removed from the wooded portion of the LHTF (Pat Mainer, personal communication, March 24 2021). Additionally, in 2020 The Nature Conservancy planted elms, some with deer protective sleeves and some within deer exclosure fencing, with the current plan being to plant 2000 more in the coming years (Pat Mainer, personal communication, March 24 2021).

Current practices on the land include a project by The Nature Conservancy involving tree planting with sleeves, and deer exclosures. There is also a project by the U.S. Fish and Wildlife Service and Vt Fish and Wildlife Department that focuses on plots looking at three variables to control reed canary grass and create conditions amenable to direct seeding: haying, plowing and herbicide (Town of Hinesburg, 2020). A hope with the direct seeding trials is that this may allow for restoration densities much greater than with tradition shrub and tree plantings and thus would overwhelm the beaver and deer browsing (Annalise Carington, personal communication, May 4 2021). Monitoring of the wetland restoration and observations will focus on proper functioning of ditch plugs and depressions, condition of plantings, control of invasives, and progress of restoration (Town of Hinesburg, 2009). One goal of this reportis to look at how beavers may impact the current and future restoration efforts in the LHTF.

Topography and Hydrology

Geology/Topography

Geologically speaking Hinesburg has two very different areas that are considered two separate coregions, i.e. the Champlain Valley in the East and the Northern Green Mountains in the West. The western part of town is mostly characterized by an area of limestone bedrock and upper soils of clay and sand. The east side of Hinesburg contains the foothills of the Green Mountains where you can find metamorphosed bedrock (Bedrock Geological Map, 2011). The Hinesburg thrust runs north-south through the town and separates these geological zones. Due to the different geological zones, different areas of Hinesburg have been home to different types of industry. The lowland west side that is part of the LaPlatte river valley has been used for farming because of its rich soils, while the east side supported a large milling industry and is now mostly residential and town forest area.

The area that is now the LaPlatte Headwaters Town Forest (LHTF) consists of three main knolls, or oblong hills that run north to south under layers of loamy soil. The forested Owl's Knoll lies in the eastern half of Hinesburg (in the Eastern Valley) and on the southern end of the LHTF area (Town of Hinesburg, 2009). Bedrock lies just below the Knoll's western side (Town of Hinesburg, 2020). Some small wetland areas exist amongst the Knoll, including a cattail marsh (Town of Hinesburg, 2020).

On the northern end of the LHTF area lies the open River Parcel, formerly a wetland but drained for agriculture (Town of Hinesburg, 2009). Prior to agriculture, limerick soils covered the area with riverine floodplain forests, alluvial shrubs, and alder swamps (Town of Hinesburg, 2020). Part of a Red Maple-Green Ash swamp also extends into the River Parcel and onto adjacent landowner property (Town of Hinesburg, 2020).

Hydrology

The LaPlatte River runs approximately North-South through the LHTF area. The headwaters of the river itself start at the south end of LHTF near Owl's Knoll and drain those low hills in a network of small streams and gullies, eventually meeting the main stem of the LaPlatte River at the River Parcel (Figure 1), then flowing north and reaching Shelburne Bay 14 miles to the West before finally draining into Lake Champlain (Town of Hinesburg, 2020).

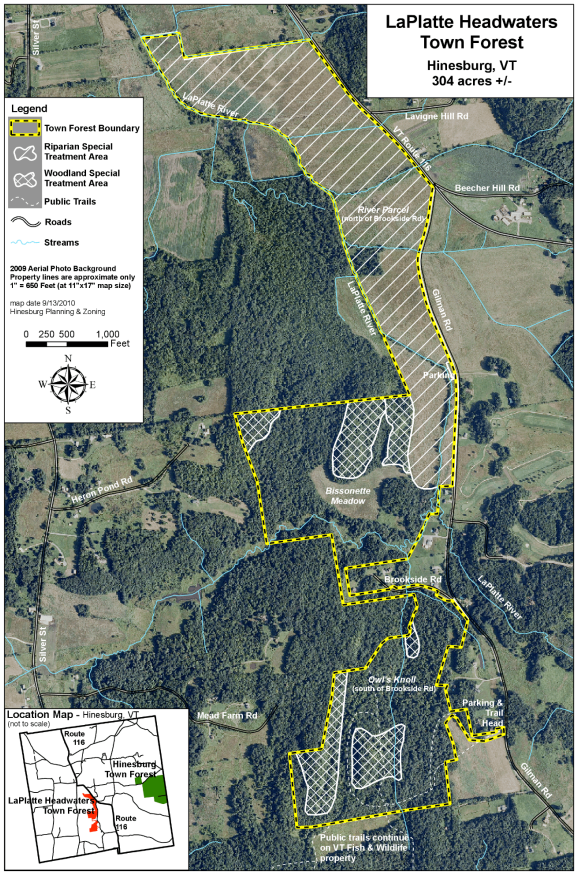


Figure 1: Map of LaPlatte Headwaters Town Forest

Naturally, the river meanders in across the LHTF area and allows a number of smaller tributaries as offshoots to meander and criss-cross the flat land as well, creating a floodplain in the Southern Owl's Knoll area but most noticeably and widespread in the northern River Parcel (Town of Hinesburg, 2020). Past agricultural activity, however, has channelized the river: the streams were ditched and straightened into a more linear direction, the channel itself was deepened so as to eliminate the floodplain and make way for fields and pastures, and the channel was then was regularly dredged to prevent any further potential flooding on the farmland (Town of Hinesburg, 2020, Hinesburg Forest Packet). Farmers were encouraged to plant reed canary grass along the banks which ended up dominating and eliminating much of the native vegetation (Town of Hinesburg, 2020).

Agricultural clearing has caused an almost recursive channelization effect of the river. Its initial deep incision increased the velocity of its waters and eroded the banks of the riparian area, making the river disconnect from the floodplain (Town of Hinesburg, 2020, Hinesburg Forest Packet). This "hazardous" erosion increased the sediment concentration in the river and deepened the river even further, causing the waters to speed up, further eroding the banks, and deepening the river over and over again over time (Town of Hinesburg, 2020). The increased load of sediments that

sped up with the river were not able to be captured in this disconnected, channelized system, subsequently leading to water quality problems downstream (United Stated 1978).

Currently the LaPlatte is a "low-grade" stream running almost completely straightened through an unconfined valley setting, with ongoing erosion occurring upstream at the headwaters in Owl's Knoll. Gullies on the eastern side of the Knoll have also deepened and elongated (Town of Hinesburg, 2020).

Class II Wetland

Currently, several areas of the LHTF are classified as Class II wetlands or Presumptive Class II wetlands (Vermont ANR, 2021). In Vermont, Class II wetlands are required to have a 50 foot buffer zone contiguous to the edge of the wetland (Vermont Wetland Rules, 2020). Allowed uses include, "Activities within existing lawns, including mowing, the placement of barbecue pits, sand boxes, bird houses, and other similar activities incidental to ordinary residential use" (Vermont Wetland Rules, 2020). It is interesting to note that there is no specific approval of fertilizer, pesticide, or herbicide application, all of which have severely detrimental effects to the health of wetland flora and fauna, and contribute to the eutrophication that we see downstream in Shelburne Bay. The current and future expansion of the LHTF wetlands due to beaver activity will reduce the buffer distance between the wetland and proximate properties, which may have an impact on the property owners (i.e. permits may be required for certain activities, while other activities may be prohibited). There is a grandfather clause for existing buildings and activities, but it seems that it would not exempt the properties at 734 and 846 Gilman Road, due to their original proximity to the wetland area. Throughout the course of our interviews with landowners, it became apparent that some of their current activities are clearly prohibited (such as unauthorized dam removal) while others require permitted approval (such as fertilizer and pesticide use). With the expansion of the LHTF wetland area, it is possible that some locations may be eligible for classification as Class I wetlands, which have a larger buffer zone. According to the VT ANR Wetland Rules, "Any person may petition the Panel to classify any wetland as a Class I wetland, or to reclassify any Class I wetland to a lower classification, in accordance with the Vermont Administrative Procedures Act, 3 V.S.A. §§ 800-849, these rules and the Natural Resources Board Rules of Procedure." (Vermont Wetland Rules, 2020).

Beaver Behavior

General

Beavers are native to North America and are North America's largest rodent. Throughout Vermont beavers can be found along wooded streams, marshes, lakes, and ponds. They seek areas where water is flowing consistently or near still waters with consistent water levels. An abundance of desirable trees for food and construction of their lodges and dams is also important (VT Fish & Wildlife, n.d.). Beavers preferably feed on the inner bark of trees in the willow family including willows, poplars, aspens, and cottonwoods (Wessels, 1997). At these locations, beavers will begin constructing dams and lodges from surrounding sticks, rocks, and mud. The most obvious signs of beavers are the distinctive "pencil points" of gnawed tree trunks and the lodges and dams they build (Figure 2). Beavers and humans are similar in our ability to construct and greatly alter our habitats to suit our own needs.

Figure 2: Images of the distinctive "pencil points" (top right), a beaver dam (top left), a beaver lodge (bottom left), and beaver tracks (bottom right). Top right and left are images taken at LHTF.

Beavers build dams to create deep ponds that do not freeze at the bottom in winter. Within or beside these constructed ponds, they build "lodges" to provide protection for their young in summer and for the entire colony in winter. There are two main types of lodges, the conical lodge and the bank lodge. The conical lodge is completely surrounded by water. The walls of the conical

lodge are very strong due to layers of mud and sticks, and are extremely insulated; even with sub zero outside temperatures it will not drop below freezing inside the lodge due to retained body heat from the family of beavers (Beaver Solutions, n.d.). The second type of lodge is the bank lodge which is excavated into the bank of a large stream, river, or lake where the water is too deep or too fast moving to build the classic conical lodge. Beavers build dams to surround their lodge with water for protection from predators, as well as to access food more easily without having to move too far from the water (VT Fish & Wildlife, n.d.). Beavers are slow moving on land, especially in snow, making them easy prey for large predators in Vermont such as bobcats, coyotes, and foxes. Therefore, beavers tend not to stray more than a few hundred feet of the pond margin (Wessels, 1997). The creation of dams also result in ponds that offer beavers their summertime food supply; aquatic plants like water lilies, pickerelweed, and cattails (Wessels, 1997). Though beavers build dams for their own survival purposes, the dams they create have a large beneficial impact on the surrounding floodplains.

Beavers play an important part in the maintenance of a healthy wetland habitat, making them a keystone species for this distinct, important ecosystem. By building dams and flooding a woodland area, trees will die off and new ponds are created. The dead trees provide nesting sites for Great Blue Herons, Wood Ducks, Tree Swallows, and other birds while the new ponds become homes to amphibians, turtles, fish, otters, muskrats, and other animals (Mass Audubon, n.d.). Beaver-created wetlands also enhance human habitat by storing and slowly releasing floodwater, which controls downstream flooding, trapping silt, binding and removing toxic chemicals, and removing sediment (Mass Audubon, n.d.). Flooded areas also recharge and maintain groundwater levels which can benefit agricultural areas (Seventh Generation Institute, n.d.).

The role of beavers as keystone species of wetlands is particularly important today. Wetland restoration is a conservation effort of serious importance as over 35% of Vermont wetlands have disappeared since European settlement in North America (VT Department of Environmental Conservation, 2019). Beaver-related restoration is a strategy that seeks to address a wide-range of ecological objectives by reestablishing dam building in degraded stream systems, particularly low order, intermittent and ephemeral headwater streams in order to recreate a reconnected wetland (Nash et. al, 2021). In the following paragraphs, the impact of beavers on restoration efforts will be outlined.

Beaver-related Restoration

When beavers build dams, they flood woodland swamps and other nearby ecosystems, which starts the process of restoring lost wetlands. Over 50% of wetlands have disappeared since the European settlement in North America. This means that over 50% of the critical ecosystem that provides food and habitat for an array of biodiverse species has also disappeared. The two driving causes were that beavers were hunted to near extinction in the Northern hemisphere and most of

their wetland habitats were drained to make land viable for agriculture. Humans have since built over or dammed these wetland ecosystems, meaning that when beavers move in and try to revert these landscapes back to their wetland state, humans do everything in their capacity to prevent this to protect their anthropocentrically centered landscapes. Humans tend to see beavers as a nuisance and not a critical player in the wetland ecosystem (Brazier et al. 2020).

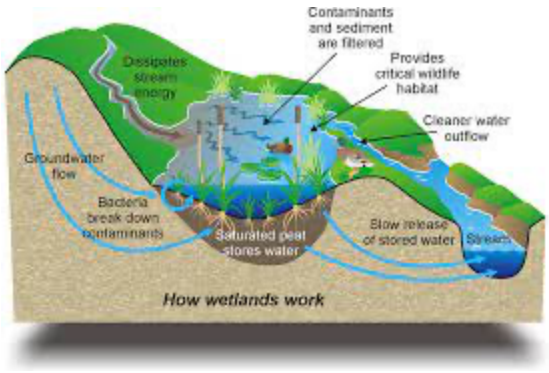


Figure 3: How wetlands work by soaking in water to the ground table and reducing flood impacts (Kusler et al. 2011)

However, this idea of beavers as a nuisance to human existence is a false narrative – beavers provide a number of ecosystem services which benefit human habitation. With the increasing threat of severe weather storms from climate change, people are experiencing increased flooding and damage to their properties. In some landscapes this is due to the lack of wetlands that act as a buffer to flooding, absorbing water and releasing it slowly in the event of increased flooding. When wetlands are not present, the lack of vegetation and this sponge dynamic allows erosion and wash out events to occur because the land does not absorb the water as effectively. Contrary to public concern about rising water levels and ever-expanding wetlands, beavers carefully maintain their dams to keep the water at a very specific level. Beavers require about three to four feet of water in order to store food and live in their lodge when the ice freezes over in the winter months. When the water level rises above 3-4 feet, beavers will normally perforate the dam or let the water flow over the top to maintain this level.

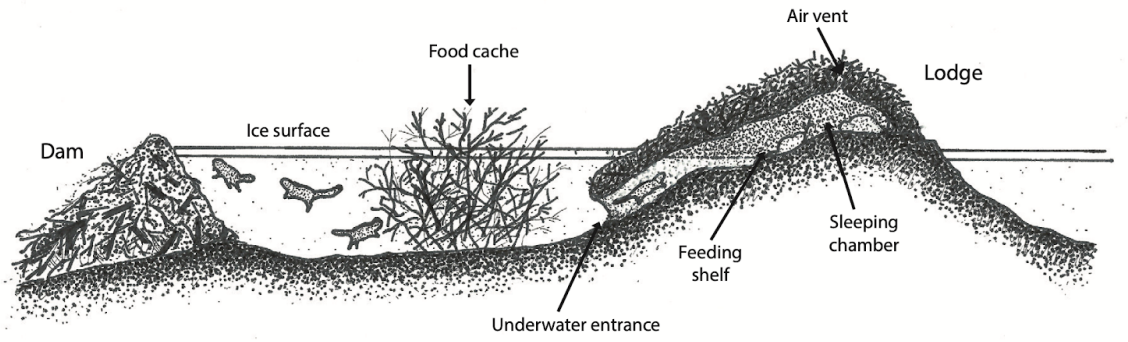


Figure 4: Beaver dam diagram with water level (three meters) and lodge infrastructure (Kastro et al. 2015).

Wetlands can act as a carbon sink, as plants photosynthesize and turn CO2 into O2 and the sponge quality of the wetland traps litter, organic soils, peat, and sediment that have built up over the years. The U.S. Global Change Research Program has estimated that wetlands store approximately 13.5 billion tons of carbon in the continental United States. However, wetlands can also release CH4, creating a net effect for carbon sequestration (Kusler et. al 2011).

Beavers also reduce the impact of drought by building dams that store water, which absorbs into the edges of the pond and into the surrounding ecosystem. This reduces peak flows downstream and stores and slowly releases the water in a drought. They also excavate canals laterally across the floodplain, which enhances ecosystem connectivity and helps the beavers access resources and transport food. In addition, beavers create a crucial habitat for insects, birds, amphibians, and bats by coppicing trees that produce deadwood and allowing sunlight to reach the understory (Brazier et al. 2020).

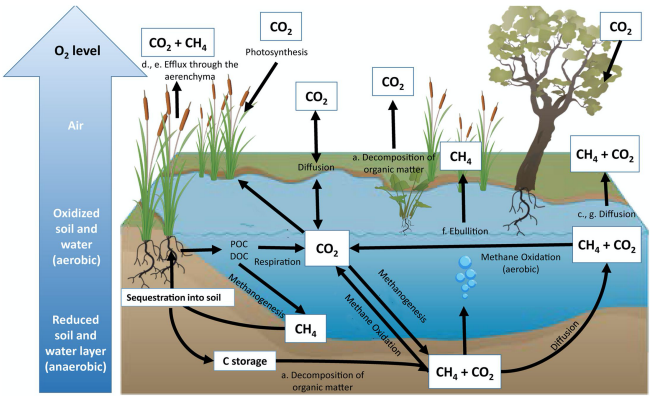


Figure 5: Beaver pond creating a wetland carbon sink dynamic. (Brazier et al. 2020).

Do we need beavers to achieve the benefits of beaver activity? Some have tried to recreate beaver habitats without beavers. Artificial dams created by humans have been implemented to restore wetland habitats without introduction or presence of beavers. It is rarely the beavers alone that are desired but the outcomes they bring to the landscape - namely, the changing hydrogeomorphic and ecological conditions (Nash et al, 2021). Human constructed beaver dams are known as Beaver Dam Analog (BDA) and have been extremely successful in (1) mimicking the form and function of a natural beaver dam, (2) creating immediate deep water habitat that reduces the risk of predation for translocated beavers, and (3) offering a cost-effective, non-intrusive approach to stream restoration that influences hydraulic, geomorphic and hydrologic processes in order to achieve restoration goals (Anabranch Solutions, n.d.). It is important to note, however, that these human-made structures do not perfectly mimic beaver ecosystems. In a study done in Sweden, it was found that beaver wetlands had a much higher site richness with a larger plant species pool overall compared to non-beaver wetlands (Willby et al, 2018). There are also small scale disturbances unique to beaver ponds which enhance habitat complexity (Willby et al, 2018). This study concluded that

beavers can be regarded as agents of within-habitat heterogeneity as well as ecosystem engineers (Willby et al, 2018).

Potential beaver impacts on LHTF restoration

The presence of beavers in the LaPlatte Headwaters Town Forest has the potential to restore native vegetation and establish a floodplain forest and/or wetland vegetation. The current state of the LaPlatte headwaters area is of former agricultural fields dominated by invasive reed canary grass. Beavers have a high potential to alter their landscape - they are the only animal in North America besides humans that can fell mature trees (Johston & Naiman, 1990). However, beaver foraging is usually concentrated within a small area, nearest to their damming locations. The majority of wood used by beavers is harvested in the first few years of their occupancy. Beavers do have a "distinct hierarchy" among the species of trees they harvest (Wessels, 1997). Beavers preferably feed on the inner bark of trees in the willow family including willows, poplars, aspens, and cottonwoods. Next, beavers will also feed on available oaks, ashes, sugar maples, cherries, and apple trees. Lower on the beaver's food preferences include members of the birch family, red maple, and hop hornbeam. Conifers like pine and hemlock are at the bottom of a beaver's food preference and are usually only consumed when preferred tree species are already fully consumed, indicating the beavers will abandon their pond within a year (Wessels, 1997). In some cases, herbivory by beavers can actually stimulate sprouting of new stems, but this sprouting can be offset by an increase of browsing by other mammals, such as deer (Johston & Naiman, 1990). Aspens, however, have unique regeneration and can maintain productivity through their root suckering behavior even if most of the mature trees are removed - the relationship between beavers and willows is mutualistic (Johnston & Naiman, 1990).

Beaver herbivory is of concern in the LaPlatte headwaters area due to the impact they may have on revegetation projects. There are a few considerations when predicting the impact beavers may have on planted trees. For example, beavers typically concentrate their felling efforts closest to water, and choose trees of specific sizes. Typically, medium-sized trees are preferred, usually felling trees with trunks that are 11-300mm (11-12 inches) in diameter at breast height (larger trees may be girdled instead of felled) (Crisler & Russell, 2010). Given these factors, future plantings should take into consideration the species and location preferences of beavers, to maximize the success of plantings for combating reed canary grass and re-establishing the floodplain. Additionally, beaver flooding may benefit efforts to combat reed canary grass (current efforts being shading and herbicide) by increasing the water table and flooding these grasses out.

Establishment of beavers at the LaPlatte headwaters offers several potential benefits for both the upstream and downstream areas of the watershed. For example, beaver ponds act as sinks for several nutrients of interests, such as nitrites and sulfates (Cirmo & Driscoll, 1993). By acting as sinks for solutes, these ponds decrease watershed acidification by raising the pH of the soil and water (Margolis et al., 2001). By establishing a freshwater wetland upstream, beavers improve water quality downstream. The benefits and mechanisms depend on wetland type, but generally include: sedimentation, vegetation growth, litter decomposition, flood buffering, and microbial nutrient cycling (Johnston, 1991). These are of special importance in Lake Champlain, where excess nitrogen

and phosphorus runoff create algal blooms. In terms of the LaPlatte headwaters, the purification capacity of a stream with beaver dams is several times higher than similar streams without beaver dams. This is a result of sedimentation - pollutants and nutrients attach to the sediment, which is accumulated behind the dam instead of flowing downstream. Re-establishing the floodplain and wetlands will also protect downstream infrastructure from flood damage. In an assessment of the value of flood mitigation by the Otter Creek floodplains and wetlands in Middlebury, VT during Tropical Storm Irene and other floods, the avoided flood damages exceeded $126,000 per year, and were potentially as high as $450,000 per year. Moreover, it was found that wetlands and floodplains reduce flood damages by 54-78% (Watson et al., 2016). Specifically, wetlands are most effective at reducing small, frequent floods, and floodplains at reducing downstream peak flows in more severe events (Watson et al., 2016). Although these benefits would take time and succession to accrue, with extreme rain events becoming more common due to climate change, all possible mitigation strategies should be considered and implemented. For the LHTF, this includes re-establishing the floodplain and wetlands over the next several years, which beavers can help facilitate. In addition to the nutrient-storage benefits, establishing beavers has also been found to be a viable climate change adaptation strategy, such as through carbon storage and the slowing of snowmelt (Bird et al., 2011).

Beavers Current Locations in LHTF

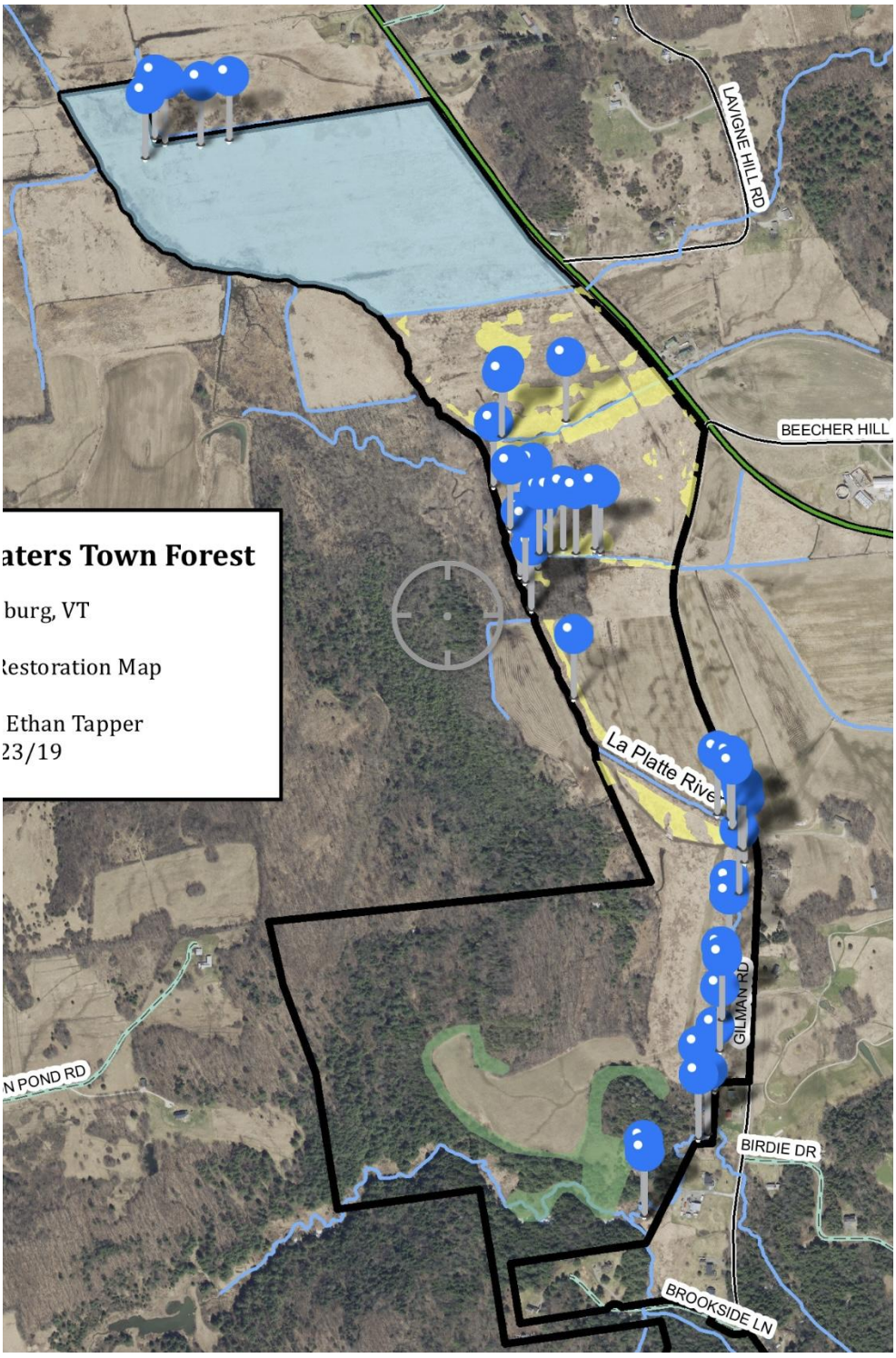


Figure 5: Avenza Map with current points observed during site visit survey (can be exported to another avenza map).

Upon visiting the site and conducting site surveys an understanding of current areas in habitat by beavers was determined. Due to timing the site surveys were split up into sections: south, south central, central and north (Figure 6).

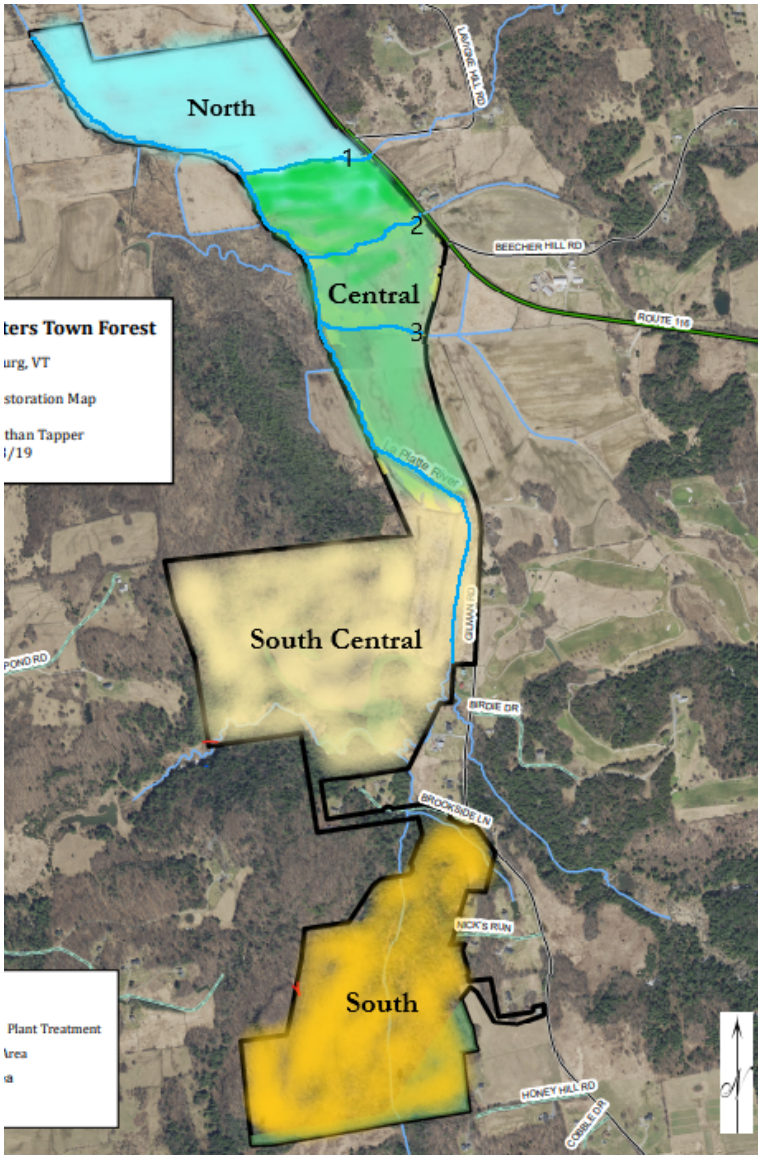


Figure 6: Avenza map with color blocking depicting site survey locations

South

In the southern-most part of the LHTF, preliminary site surveys showed no signs of beaver activity. The river in this area is located in an incised valley and does not offer the habitat the beavers prefer. This area is of minimal concern when it comes to beavers due to the lack of preferred habitat and its distance from any adjacent landowners or infrastructure (i.e., roads).

South central

In the southern region of the riparian area of the LHTF there is a high intensity of beaver activity behind the properties of 734 and 846 Gilman road. As shown in Figure 7 , there are multiple points of dams already built and what appears to be new dams in the process of being built. Recent tree chewings on maple and Alder were also present. In addition, one or two lodges appear to be in this area. This activity in this area is of high concern due to the proximity of it to the land of the properties of 734 and 846 Gilman road and the potential for flooding from the LHTF onto their properties.

Additionally, following the river north from the properties of 734 and 846 Gilman road (north of Birdie drive) there is high activity of beavers. While no lodges were spotted, extensive tree chewings and multiple dams were present as well as the startings of dams. Due to the current level of the water to the river banks, beaver activity here currently poses no threat to the road. One hazard to be aware of is the beavers proximity to a culvert on the 453 Gilman Rd driveway that cuts into the fields of the LHTF. They have the start of multiple dams and extensive tree chewing before and after the culvert. At the moment there is not an immediate danger but if the water levels were to rise drastically due to the dams then issues with the culvert will occur.

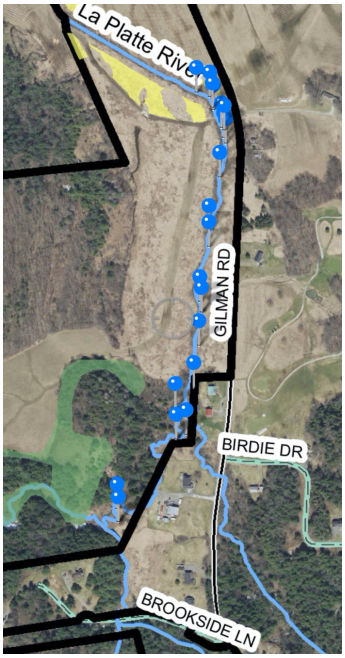


Figure 7: South central, Blue Pins represent beaver activity in the area behind 734 and 846 Gilman Rd. Beaver activity includes dams, lodges, and chewed trees.

Central

On the Central portion of the property, beaver activity is evidenced by a couple dams on a part in a stream (Figure. 6, stream 2) running adjacent to the western boundary and cutting east across the land, separating the upper part of the Central portion from the rest.

Moving south there are at least 2-3 dams bordering the western edge, though this area was not thoroughly surveyed and this number could use return visits to see if this number is an underestimation.

Below that section, another stream (Figure 6, stream 3) curves from the western boundary to cut east across the property. This part of the river is *heavily* populated by beaver dams and fallen trees along the banks. As of the last visit two thick, freshly downed trees can be found near the bend. This appears especially vulnerable to potential flooding from beaver activity.

Following the river further south along the western boundary a few points of beaver activity can be found, with the beginnings of a dam and some tree chewings present. This area is right along the property boundary of 1067 Silver St. If activity here were to increase then some management strategies would need to be used to minimize flooding onto the property of 1067 Silver St.

The river bends one last time from the western boundary east across LHTF on the lower edge of the Central portion, creating a line between the central and south central survey sections. (Figure 8) There are almost no signs of beavers in this part of the stream.

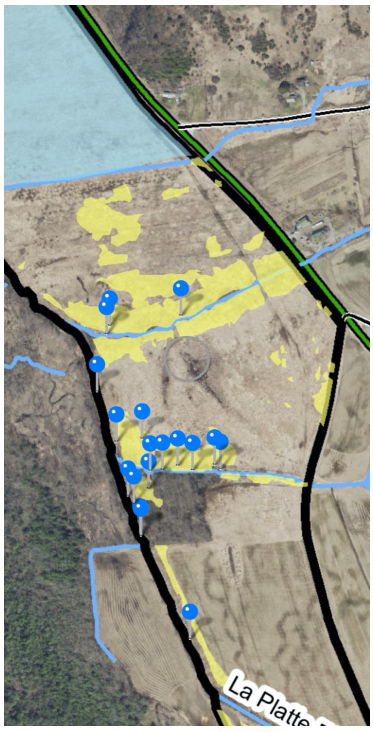


Figure 8: Central, Blue Pins represent beaver activity. Beaver activity includes dams, lodges, and chewed trees.

<u>North</u>

The northern boundary of the LHTF has minimal observed beaver activity. The markers on the Avenza map indicate the presence of recently beaver-chewed branches and logs. There was a suspected active lodge but due to impassable conditions it could not be confirmed. A complete survey was not possible due to these conditions, so the presence of active beavers may be much more than what is illustrated in Figure 9. The species composition of this area indicates a healthy floodplain with a mixture of ash, silver maple, dogwood, poplar, and wetland plant species. The river in this section of the LHTF was minimally channelized. The property at 11532 Route 116 adjacent

to the northeast corner of the northern boundary could potentially be impacted by beaver activity due to its proximity to a tributary of the La Platte. Culverts connect streams on opposite sides of Route 116 in the northeast corner of the northern boundary and on the boundary of the northern and central sections (see Figure 6). If beavers begin to build structures in or around culverts, installing culvert protection structures would be recommended. If flooding from the large floodplain south of the boundary begins to present problems for the landowner or the road, flex pipes or other water control devices would be recommended.

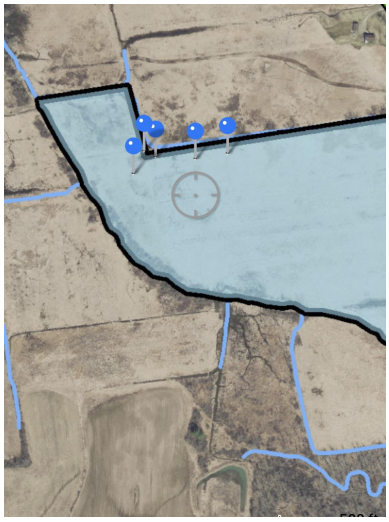


Figure 9: North section, Blue Pins represent beaver activity. Beaver activity includes dams, lodges, and chewed trees.

Potential Current and Future locations:

Due to time constraints of this project one area of the LHTF was missed and may need to be considered in the future management plans. The main location we are suggesting further monitoring is in the northern section. In the northern section, only the very upper edge and very lower edge were able to be surveyed. The western edge of the northern section, as seen in figure 9, had extreme swampy conditions and made it impossible to go through to conduct the survey. The western edge of the Central portion was partially but not thoroughly surveyed as well due to the same weather conditions, and could use return visits.

Property Infrastructure and Flooding Vulnerability

Recently the LaPlatte River appears to be widening and re-balancing back to its natural floodplain state in light of abandoned agricultural activity and development of the land (Town of Hinesburg, 2020). Even more, the 2009 LaPlatte Headwaters Town Forest Management Plan actively pushed concerted efforts to *facilitate* flooding of the area and return it back to its natural floodplain state, suggesting management practices to achieve this end. These practices include excavating shallow ditches and ponds, installing ditch plugs in the tributary channels, and planting hundreds of native trees and vegetation in the riparian corridor to create habitats that will restore the early successional shrubland habitat and native wetland communities which formerly dominated the area (Town of Hinesburg, 2009). The River Parcel in particular is set to become an area that floods often once more.

Suggested management practices of the 2009 Management Plan also includes a section stating to "Allow beavers and other native wetland species to recolonize and influence the areas along and around the LaPlatte" (Town of Hinesburg, 2009). Management goals for beavers in relation to floodplain restoration includes both allowing beavers to make homes and flood public land wherever possible, and working with landowners and town road crews to resolve any human-beaver conflicts. Conflicts should be resolved in a way that allows beavers to remain active and create dams on the LHTF land wherever possible while also mitigating any conflicts with the purpose of the land's conservation easement, town roads or culverts, or neighboring properties (Town of Hinesburg, 2009). The challenge is to balance those objectives or increasing beaver activity and flooding of the area's waters, while making sure the flooding doesn't become so much that it affects landowners and community members.

There are multiple property owners surrounding the boundaries of the LHTF area, extending east on the other side of Gilman Road and west into the more wooded areas, to north around the River Parcel where Gilman Road meets Route 116 and south along Gilman Road until about the area it intersects with Cobble Drive (Figure 10). Overall, the land most obviously at risk of flooding is that along the LaPlatte River and the land in the North surrounding the River Parcel - especially given the town's plans to increase flooding and tributaries off the river and to turn the lower end of the River Parcel back into a floodplain (Figure 11). The other main targeted area for floodplain restoration is the riverbanks in the section cutting horizontally across Owl's Knoll.

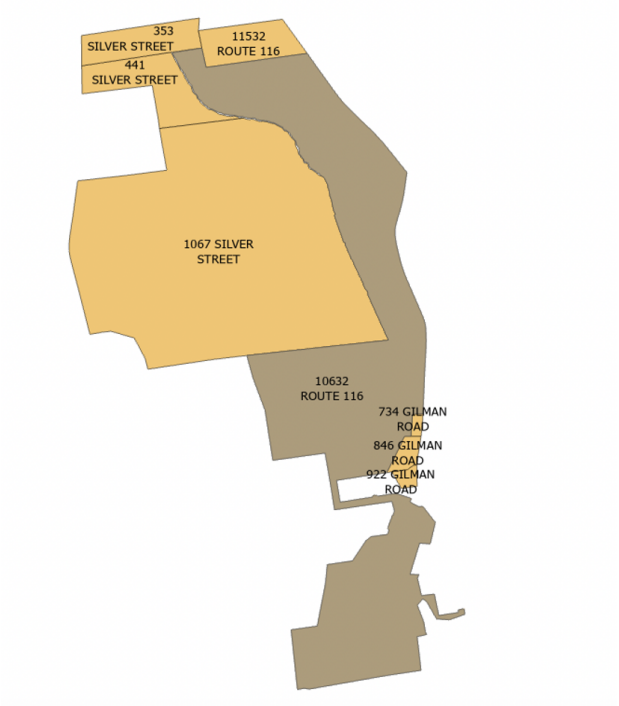


Figure 10: Map of properties

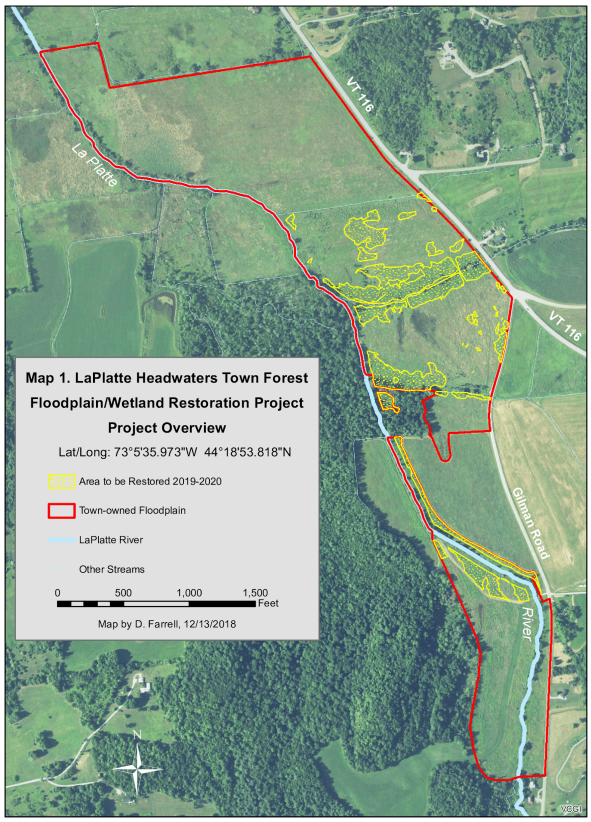


Figure 11: Floodplain restoration area

Terrain Assessment with ARC GIS

To assess risk of flooding, ESRI's ARC GIS Pro 2.6.2 was used (ESRI, 2020). . Digital elevation model (DEM), imagery, roads, parcel boundaries, and building data were collected from the Vermont Open Geodata Portal. This data was then synthesized. The trend tool and raster calculator were used to level the slope of the DEM based on the river system. This allowed an analysis to be performed showing height above the stream and assess at-risk property. The DEM was symbolized to visually show areas at risk of flooding. Overall, no structures or roads are threatened by a 1m increase in water level. This increase would be extreme and nowhere is expected to flood by this much. 1m was however chosen in some scenarios due to it being easiest to clearly see the extent of flooding. Areas of concern arehighlighted below.

Northern River Parcel Properties

GIS analysis shows that the northern boundary is extremely flat, putting it at risk for widespread flooding with very little water level rise (Figure 12). Overall fields around the Northern boundary are reverting back to wetland. In this area however, no structures, or developed areas

appear to be seriously threatened. Aerial imagery does show hay fields threatened by flooding, but that this may not be as much of an issue with the reduction in agricultural activity in the area over the past several years. A landowner on the northern boundary also corroborated the GIS assessment of the Northern boundary and reported that in 2017 and 2019 large floods occurred, and flooded approximately the extent shown in the GIS assessment. The landowner reported that 2.71 and 3.94 inches of rain fell in each year respectively.

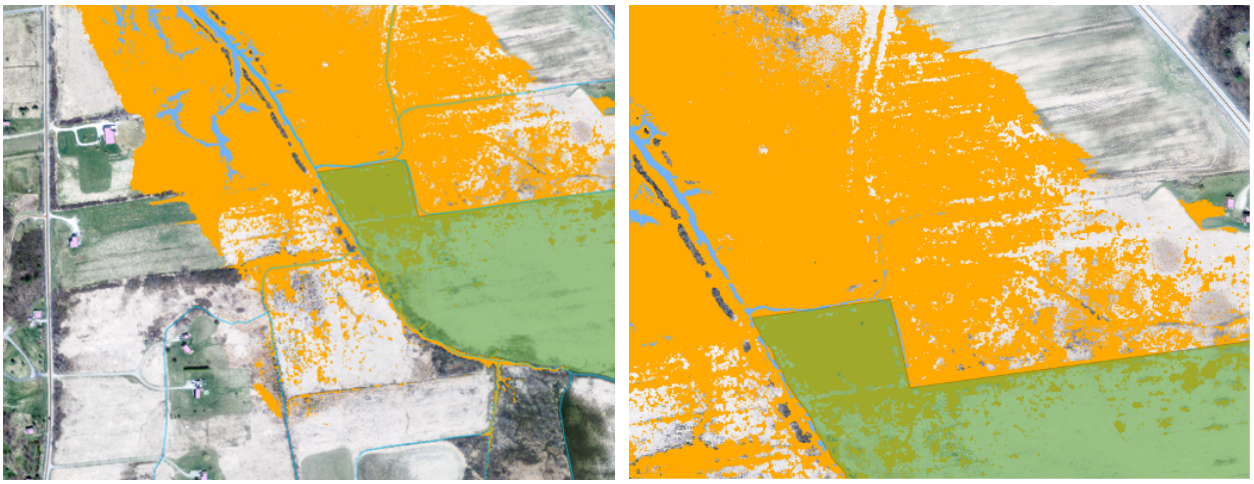


Figure 12: Northern Boundary of LaPlatte Headwaters Town Forest with blue representing current river extent, and orange representing a .25m increase in river height.

Western Boundary Properties

Moving southward, another area of concern is the Western boundary. The area on the west side of the river is privately owned and is currently dry due to a levee. The land is at the same elevation as the river (Figure 13). This property has experienced much flooding and damage in the past due to beaver activity. Properties further north are swampy but not as close to the river and therefore not as in danger of damaging floods. Those further south running adjacent to the river, however, are much closer to beaver activity and are likely to have their land reverting back to wetland. This is especially given their proximity to the areas in LHTF being targeted for wetland restoration by the town.

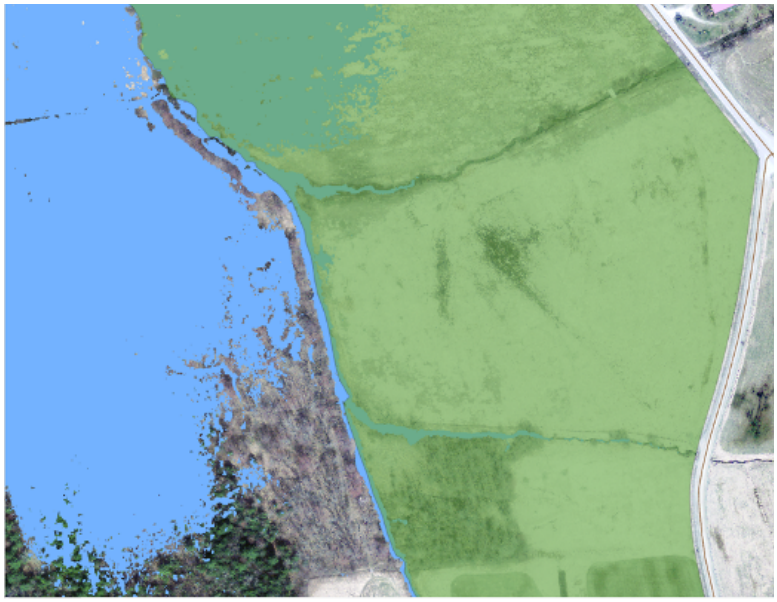


Figure 13: Western Boundary of LaPlatte Headwaters Town Forest. Blue represents the elevation of the river and shows that the land to the west is at the same elevation. The green polygon is the boundary of LHTF. Currently, there is a levee between the river and this floodplain (left side of figure, outside of LHTF boundary.)

Eastern Boundary Properties

Another concern was rising water levels impacting Gilman road to the east of the forest. A 1m increase in water level will not come near the road, but will create a significant amount of wetland (Figure 14). One meter is an extreme scenario, and water levels are not expected to rise to this extent. As stated in the LHTF management plan, "The Town Forest Committee wanted to allow flooding only insofar as it would not threaten roads, culverts, or neighboring properties" (Town of Hinesburg, 2009, 2020). Gilman road is not threatened by these restoration efforts.

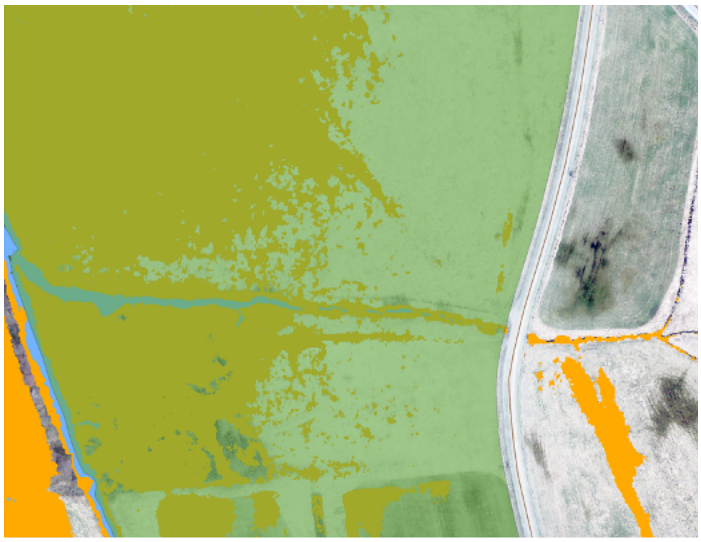


Figure 14: Stream in LaPlatte that crosses under Gilman Rd. Blue represents the stream and orange represents a 1m increase in water level.

The Southernmost area of concern identified was behind 734 and 846 Gilman road as shown in Figure 15. These properties are at risk of flooding with small increases in water level, since the property boundaries go right to the edge of the stream. However, existing buildings and structures are not threatened even with a 1m rise in water level, which is a very extreme, highly unlikely scenario.

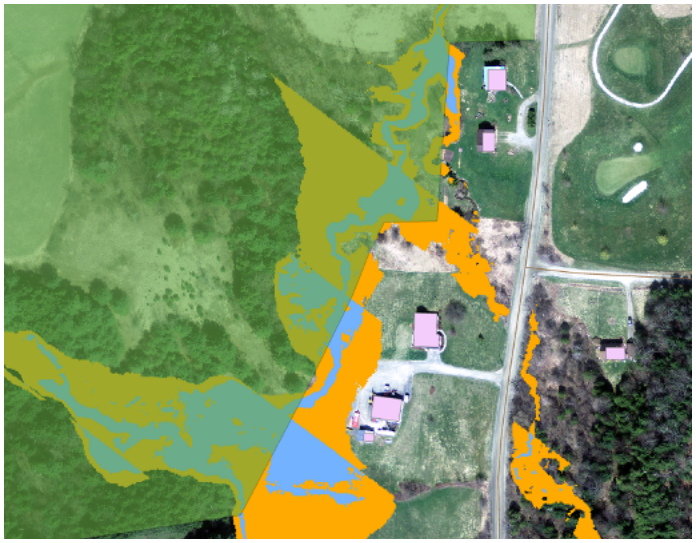


Figure 15: The boundary of LaPlatte Headwaters Town Forest behind 734 and 846 Gilman road. Blue represents current river extent, and orange represents a 1m increase in water level.

Community Relationship with Beavers

This section looks into LHTF adjacent property owners' specific relationships, actions and opinions in regards to beavers on the landscape. Below we have compiled information from interviews that were conducted with each property owner. At the end of this section there is discussion on the key relations and concerns for property owners. Discussed in the next section are ways to further interact with the landowners and options for how to include them in the management plans regarding beavers. The involvement of the community will be paramount moving forward with management of LHTF in terms of beaverimpacts and activity on the landscape.

Property Owner #1:

The current property owners have over 200 acres of land with about half mile of the back and the majority of the east side of their property being impacted by the laplatte river. They are both extremely involved in different conservation organizations like Ruffed Grouse Organization and more. Their property is used for their own recreational hunting and use, including timber harvest and some farming. They closely manage their land to foster an upland forest for certain game birds.

In the past they have encountered beaver damage including the flooding of a large section of their timber part of their property. When this damage was occurring they took action in the form of trapping or killing until the beavers moved off of the landscape near their property. Thus, their current overall reaction to beavers is one of negativity. Both understand the importance of beavers and their place on the landscape but on their property they want to make sure any beaver activity will yield minimal damage. Their largest concern with the beavers is flooding and damage to their timber zones. In their view, the only way to move forward and co-exist on the landscape with beavers is to control them in a way that significantly minimizes impact and damage to their land. They would have a problem with any water level rise if it damaged their timber. In addition, they are concerned about how the beavers have taken down small trees and left the spikes which changes the composition of the understory, an important habitat for game birds.

However, when asked about coexisting with the beavers, the owners didn't think it was impossible. They believe they can coexist as long as the beavers and their impact is under control and minimized. One of the owners says, "We can coexist with them as long as they play by our rules." When asked about positive and negative impacts of beavers that they were aware of, the owners mentioned how the beavers play a huge role in destruction of timber as a negative but *also* how their presence might bring in more waterfowl for hunting. It is important for them to have control of managing the land and finding balance with the beavers.

Another important point they discussed is the need for any intervention by the town to show extreme respect for the tax paying landowners and involve them from the start - ask for

permission first not forgiveness later. They want to keep control of their property and would have a problem with municipalities getting involved with flooding in terms of outside entities controlling their property.

734 Gilman Rd, Hinesburg, VT

The current property owner lives on the western side of Gilman Rd. His property is the furthest north of all the private properties abutting the eastern edge of the LHTF that are in contact with the wetland area and riparian buffer. Currently there is an active dam and lodge behind his property.

The owner has 275 feet of property on the stream edge, and over the years the brook has moved further into his property. He doesn't want it to get any closer to his house and is frustrated with the amount of land he has lost to it, including 4 mature apple trees to the beavers. In the past, a couple neighboring houses have had their basements flooded due to beaver activity, and that is a concern for this property owner as well. Overall, he wouldn't mind the beavers if they didn't pose any threat to his land, though that may not be a realistic expectation. In the past, he has taken matters into his own hands and torn down parts of their dams. However, he is interested in preventative management measures to protect his trees (e.g. cages, sand paint). His preference for management would be to remove the beavers entirely with relocation programs, but he is open to trying beaver baffles/flex pipes/etc. to manage water levels. The negative impacts of beavers are more important to him than the positive impacts, and he is most concerned about how beaver dams could lead to road washouts.

11532 Route 116, Hinesburg, VT

The current property owners live on an east-west facing property of ~18 acres (3 acres by 6 acres) on Route 116. There are two feeder streams on either side of the property converging into one stream. Infrastructure on the property includes one house and a detached garage. There is a lot of wildlife activity on and around the property, which has been increasing in recent years. Some species include ducks and geese, wild turkey, red fox, white-tailed deer, coyotes, hawks, lots of birds, and spring peepers. Although there haven't been beaver sightings on the property, there has been some beaver damage in the form of small downed trees.

In the 27 years of owning the property, only two floods have occurred, both within the last 4 years. The first in 2017 with about 2.71 inches of flooding, and the second in October of 2019 with 3.94 inches of flooding. Both of these floods occurred at the same time as major rainstorms. There is concern that flooding events will occur more regularly, but there is uncertainty if this increase in flooding is due to beaver activity, to changing weather patterns associated with climate change (ie

more severe rain events), or even if some of their ditches need to be more cleared of hay. However there is a 3 foot drop at the back of the property which typically accumulates water, and the homeowner thinks it would take a lot of flooding for this to be overcome by water. There have also been observable increases in groundwater levels.

Previously the landowners have been interested in a state program for managing property for wetlands, but they didn't want to lose control over how they could use their property.

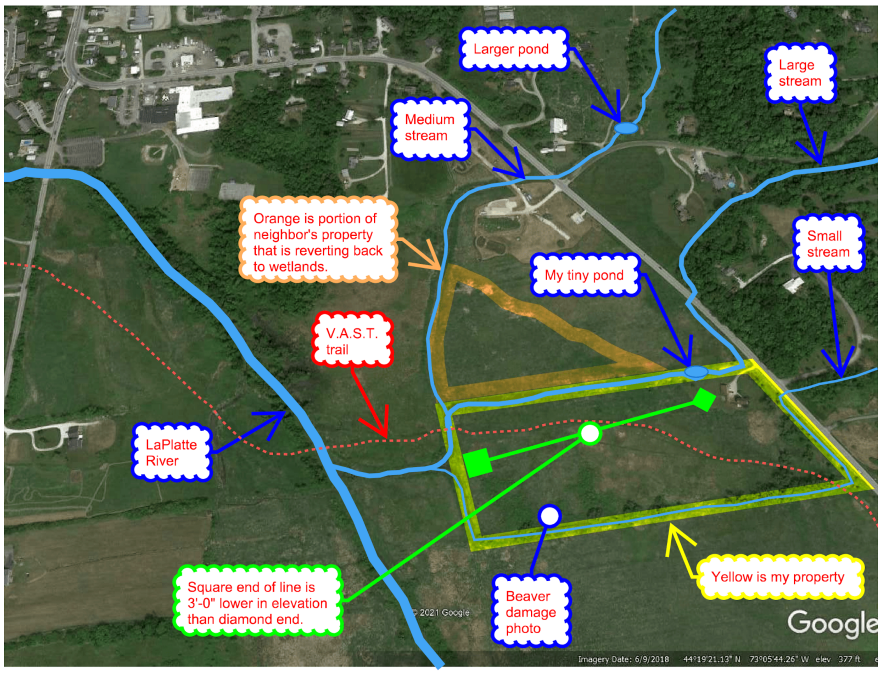


Figure 16: Image of the property provided by Dale

Overall, the landowners' views on beavers are positive as they enjoy the presence of wildlife. They don't mind much if their yard or even their basement floods, but are however concerned about the flooding of their home due to the inconvenience it would cause. They are interested in learning more about beaver behavior, especially damming behavior and beaver management practices that promote coexistence. Since farming has dropped off in the basin area they live in, they think it would be a good idea for property owners not to mow their lawns quite as much and let the areas return to a natural floodplain. If beavers become a problem they would prefer to coexist with the beavers rather than kill them, and would contact the state before taking matters into their own hands. There are no current direct conflicts with the beavers, aside from some minor tree damage. Several tree species on their property are favored by beavers, such as black willow, poplar, and red maple. They have been letting black willow grow along the stream to increase shading, and are interested in more trees or vegetation that may be beneficial to beavers. In terms of wetland restoration, the owners see the value of wetlands for absorbing water and acting as buffers, and see that this can ultimately help prevent flooding on their own property.

441 Silver Street, Hinesburg, VT

The current property owners have a residence on Silver Street, on a section of the western boundary of the LaPlatte headwater area. The corner of the property matches up with another property on Route 116. The swamp in the back of their property used to be a walkable snowmobile trail, but due to beaver activity is now swampy and inaccessible. Overall, only 2 acres out of the 26 acres on his land would be considered a wetland. There is no farming equipment, planting, or other structures on the property. On the whole they are not against beavers and are in favor of a mutual, sustainable balance between beaver and human cohabitation - where beavers and humans actually mutually interact rather simply living alongside each other - but as of now it is difficult to maintain this balance. The owners are a bit unsure if beavers have helped or harmed their situation over the past 25 years, but are not concerned that beavers will immediately negatively impact their land - it would take a lot of flooding of other areas first to do so. The land has always been a wet area that was transformed with the reed canary grass for farming, so minor flooding occurs with bigger floods on other properties after heavy rainstorms when the river swells. The owners believe managing beavers nowadays will be easier than in the past as a result of the cessation of active agriculture and the increase in Land Trust property in the area. If activities were to resume beavers would be more of a problem, but without these development activities beavers can "get away with more." Although the owners do not foresee beavers being a significant problem for their property, if beavers were to create problems they would like to see management strategies with VT Fish & Wildlife and the Town Forest Committee that prioritize a balance between beaver persistence and human well-being. Potential solutions they would support include translocation of beavers from the area if necessary (though this strategy is intensive in both time and cost, as beavers migrate into the LHTF annually and removal would be a recurring cost). There hasn't been any beaver damage to trees on the property immediately surrounding their house, but they predict there has been damage on the southern edge, which is not a big issue to them. They are interested in the impact beavers will have on the flow of the river and potential erosion, and would be interested in educational material on beaver behavior, ecosystem services, and management strategies.

Discussion

Overall, landowners surrounding the LaPlatte Headwaters town forest are concerned about flooding on their private property from beaver activity. Though there are some positive attitudes towards beavers and wildlife, there are serious concerns about property damage and the loss of land and trees due to flooding and other beaver activity. Some property owners have taken matters into their own hands with trapping, shooting, and dam removal or reduction. Despite this, many of the landowners said they were interested in educational material on beavers and beaver management practices.

The word cloud below visually represents what words were used most during the landowner interviews and helps gauge their overall feelings on beavers (Figure 17). This visual shows there was more focus on negative impacts rather than benefits of beavers. For example, loss, hate, destroyed, damage, and flooding are amongst the most frequently used words. However, some positive to neutral attitudes towards beavers exist, with words like coexist, birds, and habitat as some of the recurring themes. It is clear that there is a lot of concern about flooding and damage with a huge emphasis on the need to control the beaver population and their activity.

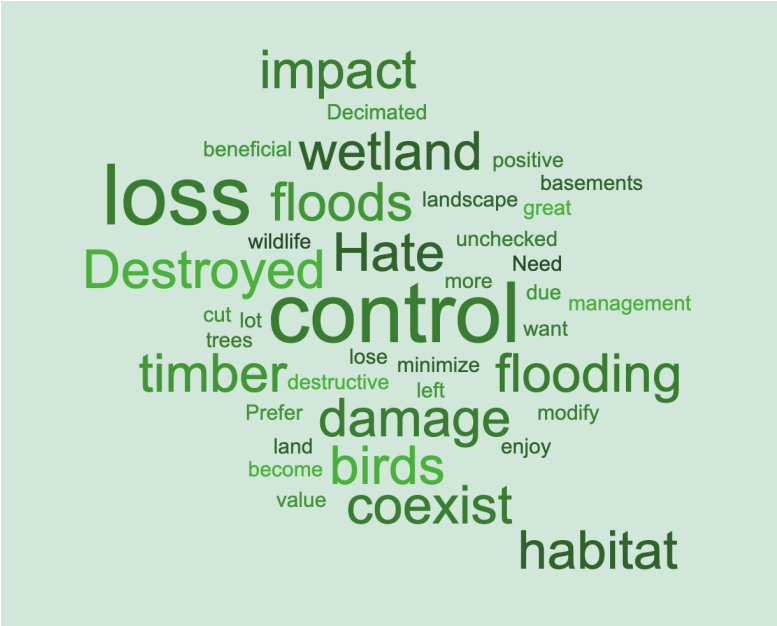


Figure 17: Word cloud representing the most common themes brought up by adjacent landowners during interviews about beavers in the LHTF.

Though these interviews demonstrated that many of the landowners are open to trying some preventative management measures, there are concerns about cost. When asked about implementing new management strategies, one landowner asked "at whose time and expense?" These interviews also showed that the landowners' attitudes towards beavers are associated with how at-risk their property is for flooding and damage. Overall, it was found that adjacent landowners have a willingness to work with the HTFC, are interested in learning more about beaver behavior and management strategies, and desire to be included in the decision-making process. Ultimately, specific management practices should promote coexistence, with the concerns and voices of the surrounding landowners playing a key role in decision making.

Beaver Management Recommendations

The aim of the Hinesburg Town Forest Committee should be to maintain a healthy beaver population for their ecosystem services while avoiding property damage and nuisance for nearby landowners. The recommendations below serve this aim. Healthy beaver populations can play a valuable role in restoration efforts, specifically floodplain restoration. As such, removing or killing beavers should be avoided. Ecological studies have shown that non-lethal management strategies are more effective and significantly less costly than lethal strategies, such as trapping or hunting (Animal Alliance, 2015). While lethal strategies may immediately remove beavers, they almost ensure that new beavers will come to fill an empty habitat niche. In fact, a decade-long survey conducted by Beaver Solutions found that trapping was ineffective in 84% of cases in permanently removing beavers from a site (Aberth, 2020). For this reason, preventative measures and responsible reactive strategies are necessary to properly manage beaver populations.

If beaver dams are causing flooding or are likely to cause flooding in the future, it is recommended to install a flex pipe water control device, often referred to as beaver baffles. These devices allow water to pass through a beaver dam without breaching it, thus reducing the risk and/or severity of flooding (Vermont Fish and Wildlife, 2002). Flex pipes are a popular beaver management solution and are very cost-effective. These devices would be especially useful in the areas prone to flooding, namely the northern and central western boundaries, and the area adjacent to 734 and 846 Gilman Road.

If there is evidence of beaver populations plugging culverts, installing exclusion fences is a common and effective preventative solution. Culverts are very attractive damming locations for beavers. Culverts plugged by beaver debris can cause flooding and put local infrastructure at risk. Exclusion fences are simply a fence built around the inlet of a culvert to prevent beavers from accessing the culvert and plugging it (Vermont Fish and Wildlife, 2002). For sites that have a high water table near a culvert, exclusion fences can be made even more effective by adding a flex pipe to ensure that enough water passes through the fence, especially if the fence gets dammed. Several culverts run under Route 116, Gilman Road, and other roads in proximity to the Town Forest. They should be checked and cleared of debris regularly to avoid flooding.

While exclusion fences are perhaps the most common and most universally effective culvert protector, several other structures can be installed. Sometimes starting your own dam 10-15 feet upstream of a culvert will be enough to convince beavers to stay away from culverts, but this method is less effective than the aforementioned structures. These man-made dams are called diversion dams, and they can be made from a variety of materials i.e. sticks, fencing, rocks, etc. (Aberth, 2020). If beavers in and around the Town Forest have a proclivity for damming culverts, diversion dams could be used as a preventative measure. Additionally, putting a mesh wire fence on a culvert opening can prevent plugging, but in many instances, more complex devices are required. The Clemson Beaver Pond Leveler, for example, is a more complex water control structure that can be

used to ensure adequate water flow through a culvert. These devices can be used instead of the aforementioned flex pipes as well. Contact VT Fish and Wildlife to see what device is best for each specific situation.

Private contractors can be hired to build and install flex pipe structures and exclusion fences. Skip Lisle of Beaver Deceivers International has been hired in the past to build these structures throughout Vermont. You can contact Skip Lisle by phone at (802) 843-1017 or by email at skip@beaverdeceivers.com. Also, VT Fish and Wildlife has a long-standing program to assist landowners and municipalities in resolving beaver/human conflicts. This assistance might include the installation of tree cages, water control devices, and advice on beaver population management (*How to deal*, n.d.). Contact VT Fish and Wildlife before approving or installing any water control structures.

It is important to note that beaver activity can be used as a tool for restoration projects alongside revegetation projects. Though beavers can impact trees planted through revegetation projects, beaver eating habits are well documented and relatively predictable. For example, beavers typically concentrate their felling efforts closest to water, not straying farther than a few hundred feet from the waters edge, and choose trees of specific sizes. Typically, medium-sized trees are preferred, usually felling trees with trunks that are 4-6 inches in diameter (Wessels, 1997). Given these factors, future plantings should take into consideration the species and location preferences of beavers, to maximize the success of plantings for combating reed canary grass and re-establishing the floodplain. For example, in areas where erosion control via tree roots is the top priority, species that beavers avoid, like conifers, can be planted. In areas where beaver activity is encouraged, plantings of the willow family, oaks, ashes, sugar maples, cherries, and apple trees would attract beaver activity. Additionally, beaver flooding may benefit efforts to combat reed canary grass (current efforts being shading and herbicide) by increasing the water table and flooding these grasses out.

Several landowners have already had beavers cut down trees on their properties, and other landowners have expressed concern regarding this issue. If the committee and/or landowners are concerned about beavers damaging specific trees, there are two effective and inexpensive strategies to mitigate this issue. The use of abrasive tree paint at the base of a tree has proven effective at preventing beaver damage. The paint is a mixture of latex paint and mason sand and is relatively cheap (Vermont Fish and Wildlife, 2002). Another effective strategy for tree damage prevention is the use of tree cages. A firmly anchored wire cage installed around the base of trees will offer protection from beaver damage (*Tips*, 2015). In determining which trees are at risk, it's helpful to remember that beavers typically concentrate their felling efforts closest to water, and choose trees with trunks that are 11-300mm (11-12 inches) in diameter (Crisler & Russell, 2010). Given these factors, future plantings should take into consideration the species and location preferences of beavers, to maximize the success of plantings for combating reed canary grass and re-establishing the floodplain.

Table 1: Primary Recommendations for Beaver/Human Conflict Management

Solutions	Purpose	Cost	Materials	Installation
Flex pipes	Beaver dams can create large ponds which can cause flooding. Flex pipes are installed overtop of dams to increase water flow downstream, thus reducing and preventing flooding.	Cost varies depending on location. Previous projects done by private contractors have ranged from $1,000-$4,500*. If interested in DIY, materials cost approx. $250-$350**	Go to VT Fish and Wildlife's online document titled "Best Management Practices for Resolving Human/Beaver Conflicts" for more information on the materials needed.	Go to VT Fish and Wildlife's online document titled "Best Management Practices for Resolving Human/Beaver Conflicts" for more information on the installation process.
Exclusion fences	Culverts are very attractive damming locations for beavers. Exclusion fences are used to prevent beavers from plugging culverts. Flex pipes can be added to increase effectiveness in high water areas.	Cost varies depending on location. Previous projects done by private contractors have ranged from $2,400-$2,900*. If interested in DIY, materials cost approx. $300-400**	- 6' cedar posts or metal T posts - 4' tall utility panels - spruce 2x4s - 1-1/2" galvanized fence post staples or heavy gage wire for T posts - 3" framing nails or exterior screws	Go to VT Fish and Wildlife's online document titled "Best Management Practices for Resolving Human/Beaver Conflicts" for more information on the installation process.
Abrasive tree paint	Trees in proximity to beaver dams are at risk of being cut down. Abrasive paint is used to deter beavers from chewing on trees.	Cost dependent on quantity. 1 quart of paint mixed with sand costs approx. $25. 1 gallon costs approx. $50.	- exterior latex paint - mason sand	Mix 5 ounces of sand per quart of paint or 20 ounces of sand per gallon of paint. Apply to bottom 3-4' of tree.
Tree cages	Trees in proximity to beaver dams are at risk of being cut down. Tree cages are used to prevent beavers from chewing on trees.	Cost dependent on quantity. Materials for tree cages cost approx. $60-$100, which will cover 10-25 trees.	- 4' tall woven wire fencing, hog wire, or hardware cloth. - optional: stakes to keep beavers from pushing cages against trees	Go to the link "lakebarcroft.org/community/environmental-quality/beaver-damage-tips" for more information on the installation process.

*Skip Lisle is a private contractor who specializes in water control structures. Contact Skip by phone at (802) 843-1017 or by email at skip@beaverdeceivers.com.

**Contact VT Fish and Wildlife before installing any water control structures. You can reach them by phone at 802-828-1000 or by email at fwinformation@vermont.gov.

Interviews with abutting property owners have made it clear that community involvement is vital to the success of beaver repopulation. The majority of landowners interviewed had serious

concerns about increased beaver activity in and around LHTF. The loss of land, trees, and purposefully managed habitat due to flooding and beaver activity is an understandable concern for property owners. Some property owners have taken matters into their own hands with trapping, shooting, and dam removal or reduction. Despite all of this, the landowners are interested in receiving educational material on beavers and beaver management practices, and are willing to invest in protecting trees on their own property. Landowners emphasized a strong desire for transparency from the town forest in all aspects of beaver and wetland management. It is our recommendation to offer educational material to concerned landowners, such as our provided communication brochure. This brochure shows management strategies and their cost and required materials, as well as beaver vegetation preferences, impact on landscape (including flooding facts and biodiversity increase), beaver behavior, and how to identify beaver signs (see appendix A). We suggest personally inviting them to town meetings, answering their questions, and emphasizing a desire to work with them. The health and longevity of beavers in the town forest will have the most success with involvement from abutting property owners included in the management process.

Conclusion

The LHTF offers a promising opportunity for developing an environmentally sustainable relationship between humans, forest, and beavers. With the projections for beaver impacts we have developed and the relevant, practical management strategies to work with, we hope to establish a coexistence-based approach for beaver restoration in the area. Management of flooding or other damage caused by beavers will have to be considered on a case-by-case basis, to ensure the involvement of all relevant stakeholders, such as Hinesburg community members, agencies such as VT Fish and Wildlife and the Nature Conservancy conducting revegetation projects, and the beavers themselves.

We have adopted this coexistence-based framework because of the variety of benefits beavers offer for the floodplain forest ecosystem, and the ecosystem services they provide to both the Hinesburg community and Lake Champlain, such as the facilitation of nutrient cycling and sequestration, and promotion of wildlife and vegetative biodiversity.

Overall, this document is meant to display where current beaver activity is taking place in the LHTF, where potential beaver activity may occur, and the benefits and the consequences that those could entail. Throughout this paper we have outlined multiple management strategies that when implemented will allow both the beaver population and the Hinesburg community to coexist and thrive.

References

Aberth, J. (2020). *Management strategy for beavers*. Protect Our Wildlife Vermont. https://cc3411ed-8eb8-49d7-a73a-a71a42282c49.filesusr.com/ugd/5073cd_6c177c44715D47cd943c363d7dc1b3a4.pdf

Agency of Natural Resources. (n.d.). *Beaver*. Vermont Fish & Wildlife Department. https://vtfishandwildlife.com/learn-more/vermont-critters/mammals/beaver#:~:text=Diet,roots%20and%20other%20aquatic%20plants.

Anabranch Solutions. (n.d.). *Beaver Dam Analogs*. https://www.anabranchsolutions.com/beaver-dam-analogs.html.

Animal Alliance of Canada. (2015, June). *Techniques for mitigating human/beaver conflicts in urban and suburban environments*. https://www.beaverinstitute.org/wp-content/uploads/2017/08/AnimalAllianceBeaverManual2015.pdf

Beaver Behavior and Biology. (n.d.). Beaver Solutions. https://www.beaversolutions.com/beaver-facts-education/beaver-behavior-and-biology/

Bedrock Geologic Map of Vermont, 2011. Retrieved from https://dec.vermont.gov/geological-survey/publication-gis/VTrock

Bird, Bryan, Mary O'brien, & Mike Peterson. (2011). Beaver and Climate Change Adaptation in North America. *Wild Earth Guardians* & *Grand Canyon Trust*. Retrieved 12 April 2021

Brazier R., Puttock A., Graham H., Auster R., Davies K., Brown C. (2020). Beaver: Nature's ecosystem engineers. *Wires Water*. *https://doi.org/10.1002/wat2.1494*

Building Riparian Resilience through Beaver Restoration. (n.d.). Seventh Generation Institute. https://www.seventh-generation.org/beaver-resilience

Bushnell, Mark. (2020, June 28). Then Again: Geologic events long ago shaped more than Vermont's landscape. Retrieved from https://vtdigger.org/2020/06/28/then-again-geologic-events-long-ago-shaped-more-than-vermonts-landscape/

Cirmo, C. P., & Driscoll, C. T. (1993). Beaver pond biogeochemistry: Acid neutralizing capacity generation in a headwater wetland. *Wetlands*, *13*(4), 277–292.

Crisler, J. D., & Leland Russell, F. (2010). Patterns in Beaver Herbivory in South-Central Kansas Riparian Woodlands. *Transactions of the Kansas Academyof Science, 113*, 161–176.

ESRI. (2020). ArcGIS Pro: Version 2.6.2. Redlands, CA: Environmental Systems Research Institute

Fugro EarthData, Inc. (2013). *VTORTHO_0_15M_CLRIR_2013* [Data File]. Retrieved from https://maps.vcgi.vermont.gov/OrthoFinder/

Hinesburg Forest Packet. Ahead of the Storm: Stormwater Resilience Demonstration Site. https://static1.squarespace.com/static/57d1b980d482e9f1f107981b/t/58ac79b7db29d6ca0cf3b505/1487698379083/HinsburgForest_Packet-2016-11-03%2C+SM.pdf

How to deal with problem beaver in Vermont. (n.d.). Wildlife Help. Retrieved May 4, 2021, from https://wildlifehelp.org/animals/vermont/beaver

Johnston, C. A. (1991). Sediment and nutrient retention by freshwater wetlands: Effects on surface water quality. *Critical Reviews in Environmental Control*, *21*(5–6), 491–565.

Johnston, C.A. & R.J. Naiman. (1990). Browse selection by beaver: effects on riparian forest composition. *Canadian Journal of Forest Research,20*, 1036-1043.

Kusler, J. and J. Christie. (2011). Wetlands and Carbon Storage and Carbon Sequestration. White Paper: Reducing Climate Change Impacts and Promoting Fish and Wildlife: Findings and Recommendations for Biological Carbon Storage and Sequestering. Association of Fish and Wildlife Agencies and the Association of State Wetland Managers. https://www.wildtrout.org/assets/img/shop/Brazier-Dec-2020.pdf

Massachusetts Audubon Society. (n.d.). *Beaver Dams*. Mass Audubon. https://www.massaudubon.org/learn/nature-wildlife/mammals/beavers/dams.

Massachusetts Audubon Society. (n.d.). *Beaver Situations & Solutions*. Mass Audubon. https://www.massaudubon.org/learn/nature-wildlife/mammals/beavers/situations-solutions.

Margolis, B. E., Castro, M., & Raesly, R. (2001). The impact of beaver impoundments on the water chemistry of two Appalachian streams. *Canadian Journal of Fisheries and Aquatic Sciences, 58*.

Nash, C. S., Grant, G. E., Charnley, S., et al. (2021). Great Expectations: Deconstructing the Process

Pathways Underlying Beaver-Related Restoration. *BioScience*, *71*(3), 249–267. https://doi.org/10.1093/biosci/biaa165

Pollock, M., Lewallen, G., Woodruff, K., Jordan, C., & Castro, J. 2015. *The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains*. Version 1.0. United States Fish and Wildlife Service, Portland, Oregon. 189 pp. Online at: http://www.fws.gov/oregonfwo/ToolsForLandowners/RiverScience/Beaver.asp

Tips for protecting your property from beaver damage. (2013, February 19). Lake Barcroft. https://lakebarcroft.org/community/environmental-quality/beaver-damage-tips

Town of Hinesburg. 2009. *LaPlatte Headwaters Town Forest Management Plan.* Hinesburg, Vermont.

Town of Hinesburg. 2020. *LaPlatte Headwaters Town Forest Management Plan.* Hinesburg, Vermont.

United States. Soil Conservation Service. (1978). Erosion and sedimentation nonpoint pollution sources and controls : LaPlatte River watershed. Vermont: New England River Basins Commission, 1978.

University of Vermont Spatial Analysis Laboratory. (2019). *LandLandcov_Buildings2016* [Data File]. Retrieved from https://geodata.vermont.gov/datasets/vt-data-2016-3d-building-roofprints?geometry=-80.351%2C42.477%2C-64.530%2C45.249

Vermont Agency of Natural Resources. (2021). *Wetlands Inventory Map.* https://anrmaps.vermont.gov/websites/WetlandProjects/default.html

Vermont Agency of Natural Resources. (February 7, 1990). *Vermont Wetland Rules.* https://dec.vermont.gov/sites/dec/files/documents/wsmd_VermontWetlandRules.pdf

Vermont Fish and Wildlife Department. (2002, August). *Best management practices for resolving human-beaver conflicts in Vermont*. Retrieved from https://vtfishandwildlife.com/sites/fishandwildlife/files/documents/Learn%20More/Library/REPORTS%20AND%20DOCUMENTS/FURBEARER%20AND%20TRAPPING/ BMP-FOR-BEAVER-HUMAN-CONFLICTS-2017.pdf

Vermont Center for Geographic Information. (2018). *ElevationDEM_DEMHF0p7M2017* [Data File].
Retrieved from https://geodata.vermont.gov/pages/elevation

Vermont Center for Geographic Information. (2018). *EmergencyE99_RDS* [Data File]. Retrieved from https://geodata.vermont.gov/datasets/vt-data-e911-road-centerlines?geometry=-

80.348%2C42.478%2C-64.527%2C45.249

Vermont Center for Geographic Information. (2019). *CadastralParcels_VTPARCELS* [Data File]. Retrieved from https://geodata.vermont.gov/datasets/vt-data-statewide-standardized-parcel-data-parcel-polygons?geometry=-80.352%2C42.478%2C-64.532%2C45.249

Vermont Center for Geographic Information. (2019). *WaterHydro_VHDCARTO* [Data File]. Retrieved from https://geodata.vermont.gov/datasets/vt-data-vt-hydrography-dataset-cartographic-extract-lines?geometry=-80.488%2C42.417%2C-64.668%2C45.191

Vermont Department of Environmental Conservation. (2019, September 25). *VT Wetland Program: Wetlands 101*. Vermont Wetlands. https://dec.vermont.gov/sites/dec/files/wsm/wetlands/docs/2014_Wetlands%20101.pdf

Watson, K. B., Ricketts, T., Galford, G., Polasky, S., & O'Niel-Dunne, J. (2016). Quantifying flood mitigation services: The economic value of Otter Creek wetlands and floodplains to Middlebury, VT. *Ecological Economics*, *130*, 16–24.

Wessels, T. (1997). *Reading the forested landscape: A natural history of New England* Woodstock, Vt: Countryman Press.

Willby, N. J., Law, A., Levanoni, O., Foster, G., & Ecke, F. (2018). Rewilding wetlands: beaver as agents of within-habitat heterogeneity and the responses of contrasting biota. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1761), 20170444. https://doi.org/10.1098/rstb.2017.0444

Appendices

Appendix A: Landowner Communication Brochure

(Front side)

Identifying beavers:

What do beavers look like?

- Broad (horizontally flattened) and almost hairless tail.
- Length is between 39 and 47 inches.
- They weigh between 35 and 50 pounds or more.
- Fur color appears reddish brown to black.
- Each foot has five digits
- The hind feet have webbing, but the front do not.

What do beaver signs look like?

- Girdled or felled trees, limbs with bark removed
- Dams and lodges made from limbs and mud
- Primary dam-building time is August through October
- Slides or slicked-down paths where they enter and leave water, 15 to 20 inches wide and at right angles to the shoreline
- Channels that lead to their ponds
- Coppiced trees with multiple branches stemming from the trunk.

Preferred Vegetation

WINTER:
Feed on inner bark of trees such as:
-Aspen
-Willow
-Birch
-Alder

-Beavers seek areas of flowing water where the volume of water is reliable or still waters where water levels are consistent. An abundance of desirable trees for food and construction of their lodges and dams is also important.

SUMMER:

- Bulrushes, sedges, pond lily roots and other aquatic plants
- Poplar
- Alder
- Paper birch
- Willow
- Gray birch
- Red oak
- Red maple
- Cherry
- Viburnum
- Tamarack

Vegetation they dislike

- Conifers
- Cascara
- Indian plum
- Sitka spruce
- Ninebark
- Elderberry
- Twinberry

BEAVERS

An informational guide for landowners

Created by UVM Natural Resources class of 21'
Distributed by the Town Forest Committee of Hinesburg

(Back side)

Can beavers be aggressive?

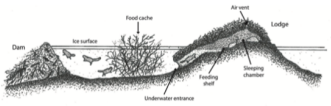
- Beavers are usually shy and timid creatures. They are also nocturnal so an encounter with one is pretty rare.
- However they can be territorial
- A beaver dam is their home/lodge and also acts as a food storage and protection from predators so they are quite territorial.
- piles of mud around their dams that are marked with their scent. If that pile of scent is disrupted by other scents (say dog urine) they can become aggressive.
- Once antagonized, they will slap their tails as a warning and if further antagonized they can bite.
- Beavers are also known to carry rabies, so keeping your distance while you cohabitate is important.

Facts about flooding

- Beavers plug leaks in dams to maintain water levels (to the 0.6m depth they prefer), so when the ponds and wetlands reach their storage capacity (dictated by the beaver dam height), any excess water can pass through a leaky dam or overtop it and carry on down the stream.
- Beavers may help reduce flooding IF they are able to build dams.
- Their ponds and wetlands can help reduce the flood peaks by slowing the flow of water. The scale of this effect depends on how much spare capacity is available in the ponds, the size of the flood, the number of dams and the extent to which a beaver dam can push water onto the floodplain.

Beaver Benefits!

-Beavers only need 3-4ft of water to store food and access their lodge in the winter. This means they won't purposefully raise the water table beyond this amount.



- Their dams also act as filters, catching sediment and runoff that could pollute Shelburne Bay and the La Platte Headwaters.
-When beavers create dams, it increases groundwater in the banks, creating a wetland ecosystem that absorbs and releases water slowly, reducing potential for drought and creating a buffer during storms that reduces the impacts of flooding.
-Wetlands increase biodiversity by 25% bringing in new species like:

-otters	-grebes
-Bald eagles	-frogs and toads
-turtles	-songbirds
-geese	-hawks
-owls	-mink
-ducks	-trout
-deer	-herons

Management solutions

It is important that humans and beavers find a healthy way to cohabitate, which can be tricky, but if successful, will benefit all while creating a beautiful ecosystem.

Devices	Purpose	Cost	Materials	Installation
Flex pipes	Beaver dams can create large ponds which can cause flooding. These devices are installed overtop of dams to increase water flow downstream, thus reducing and preventing flooding	private contractors have ranged from $1,000-$4,500*. If interested in doing this yourself, materials cost approx. $150-$250**	Go to VT Fish and Wildlife's online document titled "Best Management Practices for Resolving Human/ Beaver Conflicts"	Go to VT Fish and Wildlife's online document titled "Best Management Practices for Resolving Human/Beaver Conflicts"
Exclusion fences	Culverts are very attractive damming locations for beavers. Plugged culverts can put local infrastructure at risk. These devices are used to prevent beavers from plugging culverts.	private contractors have ranged from $2,400-$2,900*. If interested in doing this yourself, materials cost approx. $300-400**	6' cedar posts or metal T posts, 4' tall utility panels, spruce 2x4s, 1-1/2" galvanized fence post staples for cedar posts or heavy gage wire for T posts, 3" framing nails or exterior screws	Go to VT Fish and Wildlife's online document titled "Best Management Practices for Resolving Human/Beaver Conflicts"
Abrasive tree paint	Trees in proximity to beaver dams are at risk of being cut down. This paint is used to deter beavers from chewing on trees.	Cost dependent on quantity. Quart of paint + sand = approx. $25 Gallon of paint + sand = approx. $50	Exterior latex paint, mason sand	Mix 5 ounces of sand per quart of paint or 20 ounces of sand per gallon of paint. Apply to bottom 3-4' of tree.
Tree cages	Trees in proximity to beaver dams are at risk of being cut down. This paint is used to prevent beavers from chewing on trees.	Cost dependent on quantity. Typically $50-$70 for materials.	4' tall woven wire fencing, optional: stakes to keep beavers from pushing the cage against the tree	Go to the link "lakebarcroft.org/community/environmental-quality/beaver-damage-tips"

*Skip Lisle is a private contractor who specializes in water control structures. Contact Skip at (802) 843-1017 or skip@beaverdeceivers.com.
**CONTACT VERMONT FISH AND WILDLIFE BEFORE INSTALLING ANY WATER CONTROL STRUCTURES 802-828-1000 or fwinformation@vermont.gov.