FINAL REPORT

NEIWPCC Job Cost Code:	0365-003-001
Project Code:	LS-BIL-2022-105
Contractor:	SUNY Plattsburgh
Prepared By:	Luke Briccetti
Contract Execution Date:	02/03/2023
Contract End Date:	07/31/2025
Date Submitted:	03/06/2025
Date Approved:	04/15/2025

ASSESSING THE MANAGEMENT AND IMPACT OF PRIVATE ROAD CROSSINGS IN THE LAKE CHAMPLAIN BASIN

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This is a U. S. Environmental Protection Agency funded project.

This is a project funded by the Bipartisan Infrastructure Investment and Jobs Act through an agreement awarded by the U.S. Environmental Protection Agency to NEIWPCC in partnership with the Lake Champlain Basin Program (LCBP).

Although the information in this document may have been funded wholly or in part by the United States Environmental Protection Agency (under agreement BIL 4N0A001022-4) it has not undergone the Agency's publications review process and therefore, may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

PROJECT SUMMARY

This project focused on locating and assessing the impact of privately owned road-stream crossings across the Lake Champlain Basin, as well as on understanding the factors influencing behavior and decision-making of landowners around road crossing best management practices (BMPs) – with the goal of reducing threats to aquatic connectivity, water quality, and hazard risk to infrastructure. Over 1,500 crossings were identified and digitized using high-resolution LiDAR. A subset of these crossings were then assessed for aquatic passage, fish community, and stream habitat impacts. Lastly, landowners were surveyed and interviewed to better understand their perspectives on crossing BMPs, which were then synthesized and distributed in community outreach events and to the academic community.

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1. PROJECT INTRODUCTION

The Lake Champlain Basin is 66% forested, with around 80% of that land held in private ownership (Troy et al., 2007). Of this private, forested land, a variety of management types require private roads, including managed forest for timber, maple sugaring, and recreation, and for access of residential land. There are over 600 miles of residential driveways in the Missisquoi sub-basin alone, with many more miles of other private road types such as farm roads, sugaring roads, and logging roads currently unmeasured (VTRANS 2018). Therefore, there is a need for understanding how private road management in the watershed is impacting stream systems.

While consideration has been given to the impact of private roads on water quality – such as LCBP-funded work to inventory and implement private road erosion projects in the Lake Carmi watershed - there is not yet work on the impact of private roads on aquatic habitat connectivity (LCBP 2019). This lack of data is especially troubling in forested alpine areas, such as headwater sections of Lake Champlain sub-watersheds like the Missisquoi and Ausable. These forested areas often feature both high priority habitat for native species such as Brook Trout as well as road crossings that prevent aquatic organism passage (AOP) because of the structural design complications posed by steep stream slopes and flashy flow regimes (Bates & Kirn, 2009). Robust data is needed to identify the locations of private road-stream crossings and explore their AOP impact. These data will allow planners to identify, prioritize, and implement projects to replace impassable crossings.

The Missisquoi Basin is of particular interest for an assessment of the aquatic habitat connectivity impact of private roads because the watershed features more maple sugar production than any other in the state of Vermont, requiring large road networks for the transportation of equipment into areas that often coincide with otherwise pristine alpine stream habitat (CHC, 2019; Moore, 2019). In New York, the Ausable River basin is entirely contained within the Adirondacks, and crosses a combination of parkland, timber, maple sugar, and residential land (Tucker et al., 2016). Thus, an assessment of private crossings in both basins would offer an opportunity to collect important information about areas that are particularly vulnerable to private roads impacting stream systems. The methods used in this study to identify private road crossings could be applied throughout the Lake Champlain Basin in the future if they are successful.

Therefore, we received this funding to assess the impact of private road crossings on aquatic habitat connectivity in the Missisquoi Basin and Ausable Basin, specifically in the context of cold-water habitat in forested areas. We took a three-phased approach to this research project. Since there is no record of studies in which roads were remotely identified in areas without public access, Phase 1 involved piloting a novel approach to identifying private stream crossings. This approach used LIDAR imagery to identify topography changes that may indicate road-stream crossings, and then digitized these crossings. In Phase 2, we conducted field assessments of identified private barriers. In Phase 3, we conducted surveys and semi-structured landowner interviews to better understand landowner perspectives. These project phases – as well as other tasks, including our landowner outreach process – are outlined in detail below. The project team for this work consisted of project manager Luke Briccetti (former M.S. student at

SUNY Plattsburgh, current PhD student at University of Vermont), SUNY Plattsburgh faculty Dr. Tim Mihuc, and UVM faculty Drs. Kimberly Coleman and Elizabeth Doran. Project PIs have an array of expertise from stream ecology (Dr. Mihuc, Luke Briccetti) to environmental planning/literacy (Drs Coleman and Doran, Luke Briccetti). Project partners include the Ausable Freshwater Center, Clinton County Soil and Water District, Cold Hollow to Canada, US Fish and Wildlife Service, and Vermont Fish and Wildlife Department.

2. TASKS COMPLETED

Table 1 - Project tasks, deliverables, and timelines.

Task (or subtask)	Task Title	Task Objective	Deliverable and/or Output	Completed
1.	**Site identification**			
1a	Identification of study area (parcels)	Use GIS methods to identify privately owned parcels in each basin that co-occur with streams (perennial streams)	GIS Layer of private Parcels that Co-Occur with Streams	June 2023
1b	Identification of road crossings	Extract road crossings from study area using LiDAR data	Private road crossings GIS map layer	June 2023
1c	Prioritization of parcels for assessment	Prioritize parcels for road crossing assessment based on Brook Trout habitat quality indicators	List of priority parcels (top 25% or no more than 50)	October 2023
2.	**Outreach to landowners**			
2a	Landowner surveys	Mail landowner surveys on their perspectives and attitudes toward road crossings to parcels with identified road crossings	Survey response data	November 2023
2b	Outreach to landowners	Contact landowners of priority parcels to inform them of the research and our desire to conduct field assessments and anonymous interviews	List showing landowner consent for field assessments and interviews In-person engagement programs completed	July 2024
3	**Field assessments**	Conduct field assessments (AOP and biological) at road crossings of consenting landowners	Brief memo describing scope of collected field assessment data and initial observed trends	June 2024
4	**Landowner interviews**	Conduct semi-structured interviews of willing landowners	Brief memo describing scope of collected landowner	October 2024

			interview data and initial observed trends	
5	**Reporting**			
5a	Reporting results to the scientific community and local stakeholders	Share results with the scientific community via peer-reviewed literature and conference attendance. Distribute reports to municipalities and other local stakeholder organizations.	Draft manuscript(s) for submittal to peer-reviewed scientific journals Short (1 page) report(s) on information relevant to local stakeholder organizations and surveyed municipalities	July 2024
5b	Quarterly Progress Reporting	Provide clear, consistent reports on project status	Approved quarterly reports	January 2025
5c	Final Reporting	Describe fulfillment of project goals and positive impact in depth.	Approved final report Data submitted Project metrics submitted	March 2025

Table 2: Summary of analyses, methods, and quality assurance procedures.

Analysis	Methodology	Completeness	Quality Control	Corrective Action
Identifying stream-road crossings	Remote GIS analysis following methods described in Briccetti, 2023	Analysis is undertaken for 100% of private parcels in the study area	Field verification of at least 25 sites per watershed (50 sites total)	Analysis will be repeated with alternate methods if >15% of crossings are not present, or the mean predicted vs. actual crossing location is > 35 m
Written survey to private landowners	Survey design: methods described in Briccetti, 2023	Survey is distributed to at least 80% of identified landowners	Non-response surveys comprising 10% of the not responded population	An additional survey will be distributed if non-response bias is identified
Aquatic organism passage (AOP) field assessment	NACCC assessment in NY (Jackson & Abbott, 2019); VT F&W assessment in VT (Bates and Kirn, 2009)	A minimum of 25 sites per watershed (50 total)	QA officer reviews all field assessment notes	AOP assessment will be repeated at any site where QA officer notes inconsistencies
Stream physical characteristics (velocity, width, and depth)	(Hauer & Lamberti, 2017)	A minimum of 5 sites per watershed (10 total)	QA officer reviews all field assessment notes	Repeated sampling if mistakes are noted on field notes

Fish abundance	(Hauer & Lamberti, 2017; Zippin, 1958)	A minimum of 5 sites per watershed (10 total)	QA officer reviews all field assessment notes	Repeated sampling if mistakes are noted on field notes
Landowner interviews	LCBP Project LS-BIL-2022-105 Workplan, Briccetti et al. (2023)	A minimum of 15 interviews conducted	Project members Coleman and Doran will review all interview memos	Any interviews containing biased data will be removed from analysis

1. Site identification

1a. Identification of study area (parcels)

Prior to data collection, forest road crossing sites and corresponding landowners were identified remotely using GIS. This process is not a well-defined one for researchers and has historically been an impediment for managers intent on addressing private road culvert issues, as private road GIS layers often do not exist or are limited in scope and completeness. The GIS pre-processing workflow that we used is outlined in Figure 1 below.

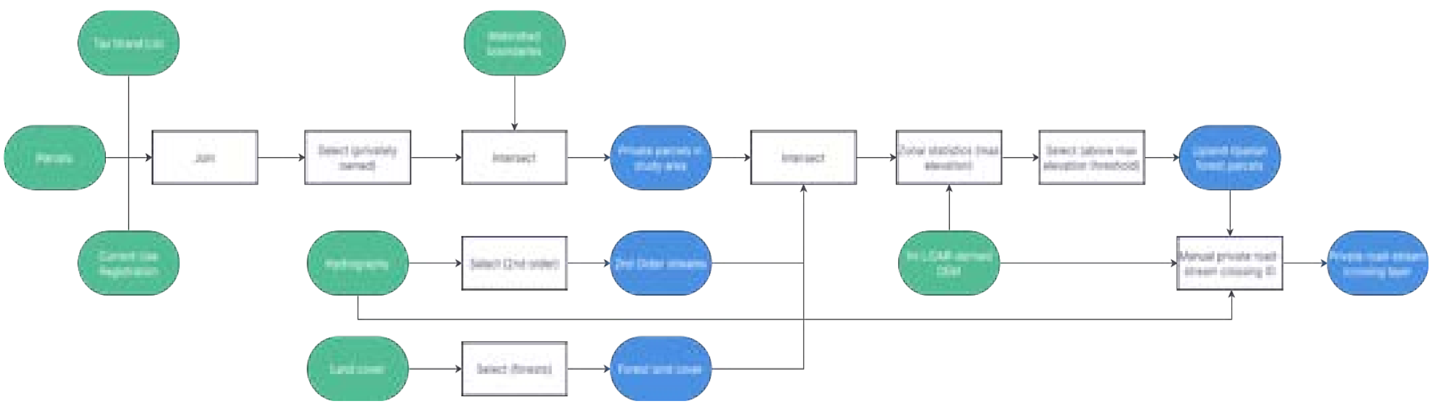


***Fig. 1. A graphical depiction of the GIS pre-processing workflow used in this project**. White rectangles represent processing steps, while green ovals represent input data and blue ovals represent intermediate data / outputs.*

Methodologically, the first component of study site identification was to locate privately owned forest parcels. Parcels in our study areas (the Ausable and Missisquoi River basins) were identified using publicly available Vermont and New York parcel shapefiles, which were joined to tax grand list data in order to determine land ownership, from which privately owned parcels were selected. Parcel ownership status was determined by selecting out common public landowners (state agencies, the National Park Service, municipalities, etc.), and then manually examining the parcel data to identify and remove remaining public landowners. The private parcels layer was then intersected with streamlines derived from a 1m resolution LiDAR-derived Digital Elevation Model (DEM) and with all forest land cover types identified in the National Land Cover Database (NLCD) land cover layer. Parcels intersecting small, likely intermittent streams were not selected, which was accomplished by only selecting streams designated as 2nd order using the Strahler stream order tool in ArcGIS. Although this action likely resulted in the exclusion of some smaller perennial streams, it was also necessary for limiting the scope of the stream layer (and therefore the number of identified parcels) to a manageable quantity and for limiting the number of surveys sent to landowners that did not own a road-stream crossing. Finally, parcels with a maximum elevation below 500 ft MSL were selected out of the private parcels layer, as past surveying has shown Lake Champlain basin streams below this elevation are usually more characteristic of a warm-water lowland fish assemblage (Kirn, 2017). The result was a private parcels layer from which private roads were extracted.

It is important to note the limitations of this approach. First, there are locations within the Lake Champlain Basin – such as the New Haven River in Addison County, VT or Furnace Brook in Rutland County, VT – where cold-water fish predominate below 500 ft MSL. However, these locations are limited in the Ausable Basin (where elevations rise above 500 MSL very quickly, and this process removed very few parcels) and are nearly non-existent in the Missisquoi Basin (which has significant stretches of slow-moving, warmwater tributaries flowing through largely agricultural land); especially within streams small enough to host privately owned, impassable crossings. Second, it is important to note that warmwater fish passage is important to preserve and protect. While looking at warmwater streams (particularly within the Missisquoi Basin) would have incurred a volume of field surveys and digitization that would have been outside the capacity of our Project Team, future funding directed toward projects that prioritize warmwater fish passage would be worthwhile, and perhaps yield different results than our study. If future studies were to occur, it is important to note that (1) more time would need to be dedicated to fish assessments, as any fish assessments we conducted in warmwater streams took considerably longer than in coldwater streams because of dense cyprinid populations, and that (2) a protocol would need to be developed for assessing farm-road crossings, which are often somewhat informal, and therefore more difficult to remotely identify.

This process resulted in the identification of 1,353 eligible parcels in the Ausable watershed and 1,577 in the Missisquoi watershed. Although the Missisquoi basin is significantly larger in area than the Ausable basin, it also has a greater proportion of low-relief, agricultural land – resulting in a similar amount of identified eligible parcels.

1b. Identification of road crossings –

Private road segments were manually identified using "Hillshades" derived from 1m Digital Elevation Model (DEM) LiDAR topography data and intersected with hydrography polylines to identify road crossing locations on the private parcels layer (Koch 2016). Hillshade (also known as shaded relief) layers apply shading differences to areas of varied elevation and are widely available for download in our study areas through the VT LiDAR finder and the NYS LiDAR FTP server. Using 1m LiDAR-derived DEM Hillshade layers to manually identify forest roads has been validated by White et al. (2010) and was shown to be accurate regardless of road slope. Orthoimagery was also used as a supplemental tool to assist in making these determinations in situations where tree cover was thin. Lastly, crossings were designated as likely culvert, likely bridge, likely low-water crossing (also known as a ford), likely road-dam crossing, or unknown depending on the shape of the crossing on the Hillshade layer (Fig. 2). Generally, culverts appeared on the Hillshade layer as continuous road across the course of the stream, while a bridge appeared as a road that terminates on one side of the stream and resumes on the other, with steep drop-offs at the location of abutments. This topography differs from a low-water crossing, in which the road also is not visible within the stream, but there are no steep drop-offs present. A road-dam crossing is easiest to distinguish, as the road generally courses along the downstream side of a ponded area of the stream. Crossing type predictions are useful both for selecting field visits as a part of future projects, and for management professionals who may use these data to approach landowners about replacement funding. The most likely crossings to be missed were bridges that were not supported by abutments, as the steep drop-offs associated with abutments were not present for these bridges. In cases where tree cover was thin, orthoimagery was used to assist in the identification of these structures. Future research could seek to improve remote field identification of structures by field verifying structures that are difficult to discern, and attempting to identify the characteristics that made it difficult to discern (such as bridges not supported by abutments). It is important to note that this identification process began prior to the recent AI boom; supervised AI training for structure ID could also be a helpful tool.

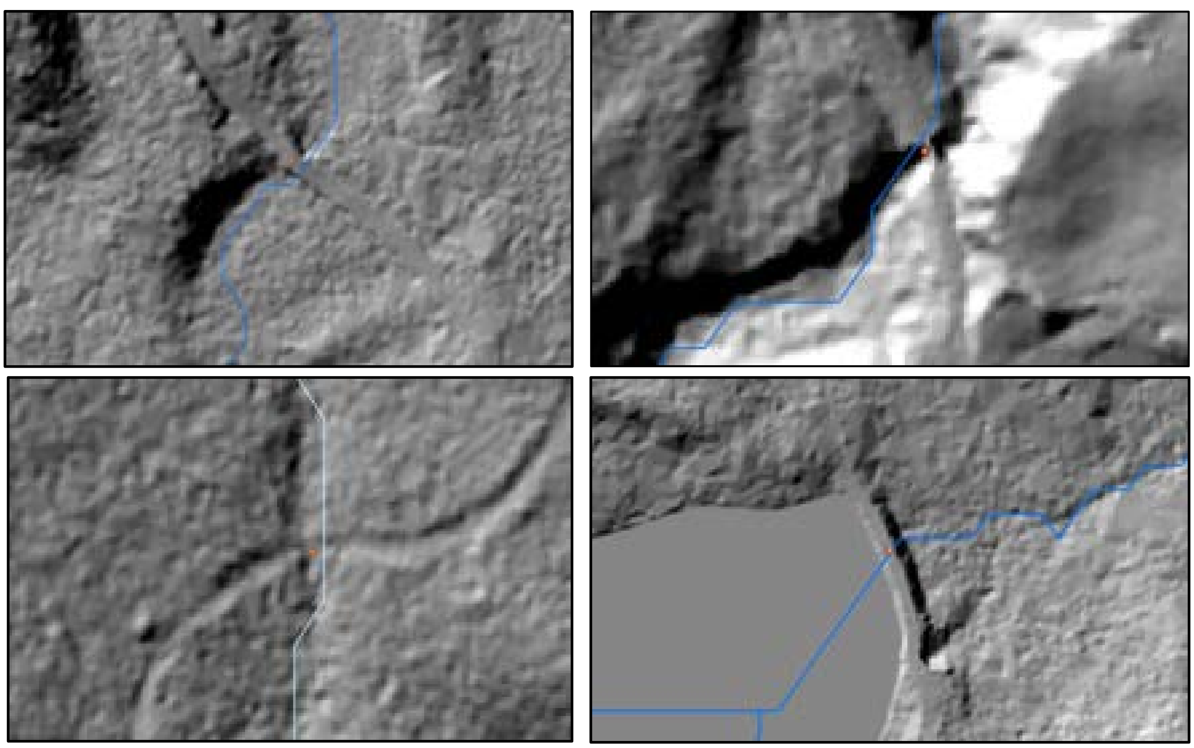


***Fig 2*. Examples of the appearance of road-stream crossing types in a 1m resolution LiDAR-derived Hillshade layer.** *Streams are represented by blue lines. The orange point represents the centerline of the road-stream intersection point. Clockwise from top left: culvert, bridge, road-dam crossing, low-water crossing (ford).*

This task resulted in the identification of 545 road-stream crossings in the Ausable watershed and 585 crossings in the Missisquoi watershed. Of the crossings in the Ausable watershed, 356 were remotely identified as likely culverts, 28 as bridges, 13 as low-water crossings, and 11 as dam crossings, with 137 crossings where we were unable to predict structure type. In the Missisquoi watershed, 237 sites were identified as likely culverts, 58 as bridges, 43 as low-water crossings, and 11 as dam crossings, with 235 crossings where we were unable to predict structure type. Although crossing types were not all field-verified, these predictions could be useful to project planners in the future and are included in our data layers. To disseminate these data, these remotely identified crossing point layers are publicly available on the Forest Ecosystem Monitoring Cooperative (FEMC) data repository at this link.

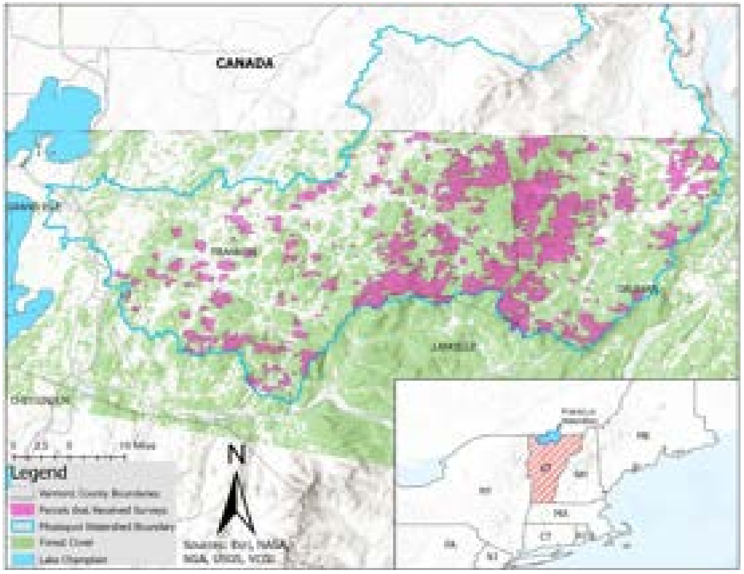
1c. Prioritization of parcels for assessment –

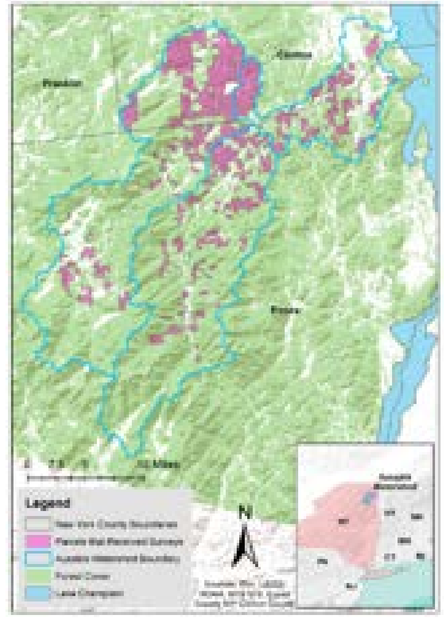
Parcels were prioritized for field assessments in order to select crossings obstructing stream reaches that were likely to hold priority conservation habitat (e.g., cold-water streams large enough to hold fish). To select these areas, we simply ranked crossings owned by survey respondents based on (1) the mileage of the stream network upstream of the crossing and (2) the crossing point's elevation. We then summed these rankings and considered the lowest values to be the highest priority structures. Parcel owners were then contacted for field visits in the order of these rankings.

2. Outreach to landowners

2a. Landowner surveys –

Identified crossing sites were also used as the basis for the mail surveys that occurred during Task 2a. Crossing points were intersected with the parcels layer, and all parcels within 10 m of a crossing point (in order to account for parcel border inaccuracies) were sent mail surveys. Clear duplicate landowners were removed, so as to only send individuals who owned multiple parcels one survey mailing, if possible. This resulted in 417 sent mailings in the Ausable basin, and 425 in the Missisquoi basin. Additional surveys were sent to 421 landowners in the Lamoille basin during pilot research not funded by this project. These surveys, in which all the methods used are the same, are relevant because these responses were included in survey analysis. These parcels are mapped in Fig. 3 below.





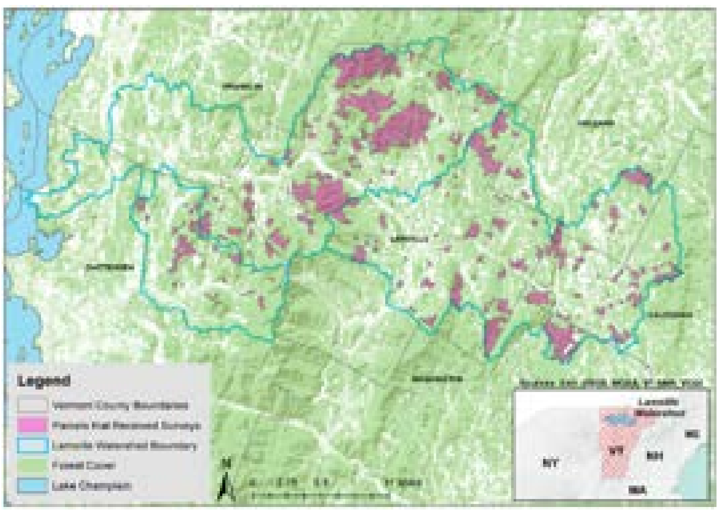


Fig. 3. Maps of parcels that received surveys in (clockwise from top left) the Ausable, Missisquoi, and Lamoille watersheds. *Parcels mailed surveys were generally concentrated in forested headwaters, with the exception of the Ausable basin in which the headwater areas are largely publicly owned (Adirondack Park). Lamoille river basin surveys were conducted as a pilot, and were not funded by this project.*

Surveys were structured based on Theory of Planned Behavior (Ajzen, 1991), a behavioral change theory common in environmental social science work. This theory contends that decision-making is influenced by attitudes, perceived norms, and perceived behavioral control (e.g., perceived barriers to action). Accordingly, the survey was structured to ask questions which assess these concepts in the context of participant willingness to implement road crossing BMPs. We also assessed which impacts were the most salient motivators for participants: impacts to wildlife movement, impacts to water quality, or the access / damage risk to them or their neighbors. These surveys were approved by UVM’s Institutional Review Board in June of 2023. We received 174 responses, of which 157 were complete and usable for quantitative analysis. Survey response rate was 17.18% in New York and 12.99% in Vermont.

Our results showed a few general trends, including distinct differences between Vermont and New York landowners. In Vermont, those concerned about water quality are more aware of the impacts of road stream-crossings on water resources – and likely to believe that there are impacts when not aware – whereas this correlation is not present in New York. These results, as well as other differences documented between responses from different drainage basins, may indicate greater awareness about water quality issues in Vermont than the Adirondacks – which is unsurprising given Vermont's higher phosphorous load, and corresponding higher investment in water quality action through the federal Clean Water Act and Vermont Act 64. In Vermont, we also found that active management (logging, sugaring, etc.) was tied to low behavioral control, e.g., individuals who actively manage their land felt greater autonomy and ability to follow road crossing best management practices if needed. This finding can inform outreach strategies for extension agents or watershed groups, as it indicates that forest residents who do not actively manage their land are better suited to messaging on the "how" of crossing improvement, while reinforcing the "why" could be more important to those who actively manage their land. This tailored approach can enhance compliance with BMPs and Vermont water quality Acceptable Management Practices (AMPs), ultimately supporting Clean Water Act goals for Lake Champlain.

2b. Outreach to landowners –

Outreach to landowners was accomplished in two forms – first, by reaching out to landowners ranked in Task 1c, and second via in-person outreach events.

Outreach to survey respondents who were ranked in Task 1c involved reaching out to email addresses or phone numbers that were provided on survey responses. The relationships formed from this initial outreach were the basis of field assessment (task 3) permissions. Through this process, 28 landowners in the Ausable basin and 20 landowners in the Missisquoi basin were contacted, many of whom owned multiple structures. Although some landowners did not respond, only one declined to allow access for field assessments. While some of the landowners contacted here simply gave permission to conduct field assessments on their property and did not seek out further information or conversations, others did seek out further information about this project or best management practices. Each of these individuals were provided with resources, or connected to someone who could help them. For example, multiple landowners in Vermont wanted to know more about assistance with beaver management, and were correspondingly connected with Vermont F&W. These individuals were also provided with a resource guide created by L. Briccetti (Appendix 3), which focuses on both education and funding opportunities for crossing BMPs.

The most significant challenge associated with this component of the project was tracking permissions for field visits, as some gave conditional permission or specific instructions for accessing the property. Detailed notes on conversations with these landowners helped with keeping track of these intricacies, but it was still a major challenge for this type of private lands work.

As part of this subtask, we also conducted in-person outreach events in both the Missisquoi and Ausable basins. In Vermont, these events were embedded in meetings of the existing Woodlots Program through Cold Hollow to Canada (CHC). This program is a peer-to-peer learning program intended to engage forest landowners in a community focused on sustainable forest management practices, including practices that may impact water quality. Project manager L. Briccetti attended meetings for the four woodlots groups (by community: Belvidere-Waterville, Enosburgh-Richford, Montgomery, and Bakersfield-Fletcher) in April of 2024, accompanied by Vermont River Scientist Staci Pomeroy for two of these events. During these 3-hour meetings, he conducted a walkthrough of a host landowner's road system and road crossings to share knowledge about crossing BMPs, led a group discussion (focus group) over lunch regarding barriers to following these BMPs, and distributed the resource guide in Appendix 3. These events were each attended by between 12 and 20 forest landowners (Table 3).

Additionally, we conducted one in-person outreach event in the Ausable basin with the Ausable Freshwater Center (AFC), a watershed organization in Wilmington, NY. Unlike the CHC events in Vermont, this event was not within a group of forest landowners with existing relationships, as such a group does not exist in the Ausable watershed. Therefore, this event necessitated planning and publicization from both the project team and AFC (the community partner). As a result of the greater planning load, we only conducted one in-person outreach event in the Ausable watershed. This event was similar in structure to the events in Vermont, except the walkthrough was replaced by a drive-through of sites that AFC had conducted culvert replacements, in addition to a tour of a generous landowner's property with crossings that did not follow BMPs as an example of how AFC's replacements looked prior to their work. This event had a robust turnout (for a new public event) of 15 individuals.

Table 3. In-Person Outreach Event Attendees.

Outreach Event Name	Location	Date	Number of Attendees
Cold Hollow to Canada (CHC) Woodlots – Belvidere-Waterville Group Meeting	Waterville, VT	04/20/2024	16
CHC Woodlots – Enosburgh-Richford Group Meeting	Richford, VT	04/20/2024	12
CHC Woodlots – Montgomery Group Meeting	Montgomery, VT	04/27/2024	20
CHC Woodlots – Bakersfield-Fletcher Group Meeting	Bakersfield, VT	04/27/2024	14
"Stream Stewardship Symposium" with Ausable Freshwater Center (AFC)	Jay, NY	07/25/2025	15

Fig. 4. Photos from In-Person Public Events. *Clockwise from top left: talking about culvert sizing with Belvidere-Waterville Woodlots Group, Staci Pomeroy discussing beaver impoundment with Montgomery Woodlots Group, walking with Belvidere-Waterville Woodlots Group, and Talking about "Climate-Ready" Culverts with AFC in Jay, NY.*

<u>3. Field assessments</u> –

Field assessments were conducted at 56 road-stream crossing sites in New York and Vermont. Landowners willing to allow assessments of their crossing sites were recruited via mailed survey responses (task 2a), in which one question asked if respondents would be willing to allow student researchers access to their property for field assessments (Appendix 1). These landowners were then contacted via email or phone to confirm their consent for field visits. Site visits were conducted using equipment and research assistants housed at SUNY Plattsburgh's Lake Champlain Research Institute, directed by T. Mihuc.

In total, we assessed 64 structures at 56 different road-stream crossing sites throughout the Lake Champlain watershed. In the Ausable watershed, we assessed 36 structures at 30 individual road-stream crossing sites during the summer of 2023. These assessments followed the NAACC protocol described in the project QAPP, which focuses mainly on measuring structure parameters, measuring connectivity parameters, and qualitative assessments of stream habitat impacts. This exceeded the goals of the QAPP by 5 assessments. In the Missisquoi watershed, assessments followed the VTFW stream crossing assessment protocol described in the QAPP, which is similar to the NAACC protocol. Additional data that is part of the NAACC protocol was also collected to maintain analysis compatibility with the NY sites. Different methods were used in NY v. VT mainly to comply with each state's crossing inventory database to ensure that data could be uploaded for public use. We assessed 28 structures at 26 individual road-stream crossing sites in this watershed during the fall of 2023 and summer of 2024. This exceeded the goals of the QAPP by 1 assessment. This crossing data is now available publicly on the NAACC portal in NY or on the VTFW stream crossing layer within the VT ANR Atlas.

We also collected fish data and stream physical data on a subset of these crossing structures. Stream physical data encompassed basic parameters such as width, depth, substrate details, and periphyton cover to provide context for fish data. Fish sampling was done using backpack electroshocking equipment and using a 3-pass Zippin Method above and below barriers. Both of these assessments occurred over 30-meter reach segments. Culvert plunge/scour pools were cordoned off from the downstream reach segment for fish assessments and assessed separately, as these pools were often the deepest in the reach, which could skew passage results. In total, we conducted these assessments at 12 sites, exceeding our stated goal of 10 total assessments. In the Ausable watershed, we assessed stream physical data and fish populations for 9 sites, exceeding the QAPP goals by 4 assessments. In the Missisquoi watershed, we assessed stream physical data and fish populations for 3 sites, which was 2 sites short of QAPP goals. This was due to a combination of factors, but mainly that we were unable to assess fish populations at more sites that we visited for crossing assessments than expected. Streams were often too small to hold fish populations, too wide or physically challenging (due to vegetation, muddy substrate, depth, etc.) to be sampled effectively, or we were unable to secure sampling permission from adjacent landowners. Our combined biological sampling between VT and NY watersheds still exceeded our goal of 10 sites.

Trends that we observed through these assessments are that 59% (33/56) of crossing sites assessed were severely constricted, while 50% (28/56) of crossing sites were assessed to have severe barriers to aquatic organism passage (AOP). These results were expected and highlight the challenges posed by privately owned structures toward resilience to extreme weather (in terms of both failure risk and sediment loading) and toward AOP on small streams throughout the basin. Additionally, fish sampling documented 9 different species, including two salmonids (brook and brown trout), sculpin, and a mix of cyprinids and catostomids. This community was rather indicative of a sample of healthy alpine streams in the Champlain basin. As expected, fish populations were greater and more diverse below barriers, which is likely both reflective of barriers limiting upstream fish populations, and erosion from undersized culverts leading to deeper pools and incised banks that attract fish to these specific reaches. These habitat differences were partially accounted for by separate sampling of plunge pools, which were separated from the rest of the downstream reach during sampling with a blocking net.

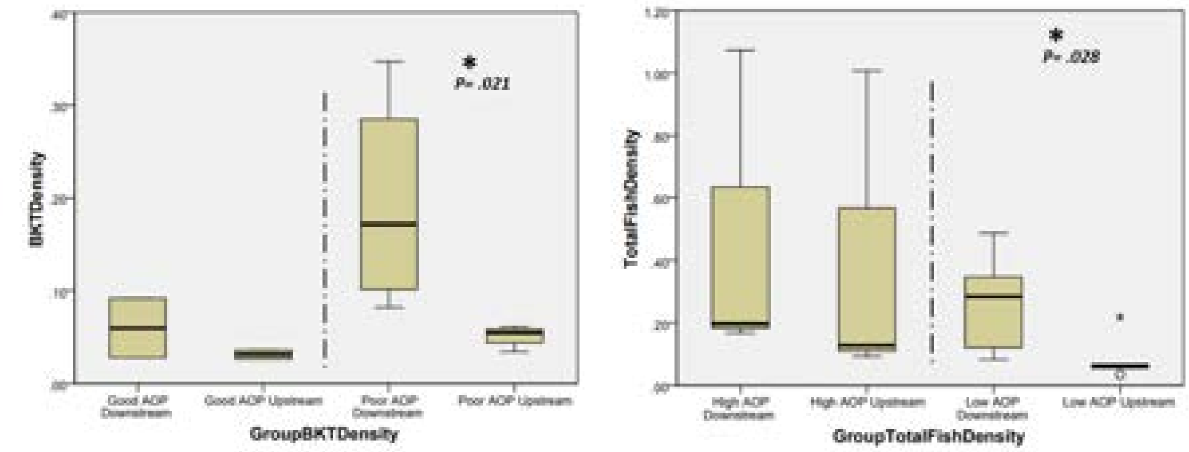


Fig 5 and 6, left to right*: Density (fish per sq. m.) of native Brook Trout* (Salvelinus fontinalis) *and of total fish, respectively, both above and below passable and impassable crossings. Density difference comparison of means (Mann-Whitney U Test) P values displayed between site types. Error bars represent standard deviations between sampled stream reaches.*

4. Landowner interviews –

Landowners were recruited for semi-structured interviews using mailed surveys (task 2a) via a question asking if they would be willing to discuss their survey responses further in an interview. An interview guide was approved by UVM Institutional Review Board in July 2024 (Appendix 2), and interviews occurred July-September 2024. In total 19 individuals were interviewed (11 in New York and 8 in Vermont) exceeding our stated goal of 7-8 interviews per watershed. Interviews used Diffusion of Innovations Theory (Rogers, 2003) as a theoretical framework, were between 45-90 minutes in length, and covered a variety of topics, but were mainly focused on perspectives and attitudes toward road crossing management. We also asked interviewees about changes they've observed during their land tenure, and how they perceive those changes to be influencing their behavior. Interviews were designed and executed by project team members L. Briccetti, K. Coleman, and E. Doran.

Our primary takeaways from these interviews were that there is a high rate of caring about wildlife passage through culverts among our population of respondents. Compared to hazard risk or water quality impacts of undersized structures, habitat connectivity seems to be the impact of culverts that people are most familiar with, or at least most easily able to grasp. This subgroup of interviewees, who tend to generally be conservation / wildlife-minded, seem attentive to making their culverts passable. Additionally, the impact of beavers came up often (usually unsolicited); beavers were generally regarded as nuisances that impact road crossing structures, regardless of a landowner's general orientation towards conservation.

Another main takeaway is that – while landowners may have experienced outreach from practitioners (for example, regarding riparian buffers, forest management plans, carbon credits, etc.) – no interviewee mentioned ever receiving outreach about road crossings. This finding – which was shared by quantitative surveys – shows that there is a significant educational gap that could be filled by practitioners.

Lastly, and perhaps most consequential, were individuals' perception of broader environmental and societal changes, and the way that these changes impact their thinking and management of road crossings, writ large. In terms of these social-environmental changes, individuals perceived the following: warmer temperatures, wetter weather, more traffic on surrounding roads, increased use of road salt, more sediment in their stream, loss of community (i.e., less church attendance, loss of working lands), changing norms for "self-reliance" with land management, and a decreased workforce, especially in terms of contractors. Self-reliance and contractor availability are particularly relevant here, as both elderly interviewees and interviewees with a shorter land tenure felt reliant on a perceived-to-be dwindling (and more expensive) supply of contractors to manage road crossings. More culvert replacements being performed by professionals is likely to increase the proportion of road crossings that follow BMPs over time. However, reliance on a dwindling contractor supply decreases community resilience in the face of extreme weather – potentially resulting in more culvert blow-outs and people isolated from their homes for longer. Lastly, this finding indicates that contractors are driving norms that influence habitat connectivity, water quality, wildlife, and general extreme weather resilience. There is a clear opportunity for policies and education directed at contractors (a relatively small, identifiable population) that can improve adherence to road crossing best management practices.

5. Reporting –

5a. Reporting results to the scientific community and local stakeholders –

Results were distributed to the scientific community via conference presentations and written publications. L. Briccetti has presented about this project at a variety of academic conferences. Specifically, he presented the project proposal at two conferences (the "Lake Champlain Research Conference" in Burlington, VT, and the "Conference on Society and Natural Resources" in San Jose, Costa Rica) in May and June 2022, preliminary results at the "International Conference on Ecology and Transportation" in Burlington, VT in June 2023, and a more complete presentation of findings at the "Forest Livelihoods, Assessment, Research, and Engagement" Conference in Rome, Italy in October 2024. Additionally, a manuscript using data collected under this grant was accepted as a peer reviewed book chapter for a book volume entitled "The Clean Water Act in the Lake Champlain Basin: 50 years of Environmental Stewardship". This book is set to be published by SUNY Press in 2025. Lastly, a minimum of one peer-reviewed journal article manuscript will be prepared using the interview data that was collected during the summer and fall of 2024.

Reporting information to local stakeholders was completed via road crossing resource sheets that were distributed during in-person outreach events (Task 2b). This information has also been distributed to interviewees that were sampled as a part of Task 4.

5b. Quarterly Progress Reporting –

Quarterly progress reports were completed according to QAPP guidelines. A total of 7 quarterly reports were completed over the course of this grant agreement.

3. Quality Assurance Tasks Completed

The QAPP was approved on 06/20/2023. All activities were completed in accordance with the QAPP. Quality assurance tasks are listed in Table 2 above. Specifically:

Identifying stream-road crossings – the designated quality control method for this form of analysis was field verification of a minimum of 25 road-stream crossing sites per watershed. As part of our completion of workplan task #3, we field verified the existence of 30 sites in the Ausable watershed and 26 sites in the Missisquoi watershed (exceeding our minimum by 6 sites). If >15% of road crossings that were remotely identified were not present, corrective action would have been taken; however, of these assessments, 0 field visits resulted in road crossings that were not present, demonstrating high quality in our remote crossing identification process.

Written survey to private landowners – Non-response bias was examined using a desktop assessment of geographic variance in responses (by county) and whether a respondent's mailing address matched their local property address. This method was used to make sure responses weren't skewed toward a particular area in the watershed, and to make sure that second home-owners/business weren't a disproportionate component of the sample. Cumulatively, this assessment showed negligible differences between responders and non-responders regarding these factors.

Aquatic organism passage (AOP) field assessment – For AOP surveys, the QA officer (T. Mihuc) reviewed the data and provided approval that repeated mistakes did not occur as a part of this sampling.

Stream physical characteristics (velocity, width, and depth) - For stream physical surveys, the QA officer (T. Mihuc) reviewed the data and provided approval that repeated mistakes did not occur as a part of this sampling.

Fish abundance - For fish abundance surveys, the QA officer (T. Mihuc) reviewed the data and provided approval that repeated mistakes did not occur as a part of this sampling.

Landowner interviews – For landowner interviews, project members K. Coleman and E. Doran reviewed interview memos to assess data bias, and did not find issues warranting the removal of an interview from analysis.

4. Deliverables Submitted

Information on timelines and content of project deliverables is below. More information is included in the task description section (Section #2) above. All deliverables were submitted over email to project officer C. Miller.

1a. GIS Layer of private Parcels that Co-Occur with Streams – These GIS layers were completed by June of 2023, resulting in a shapefile of 1,353 eligible parcels in the Ausable watershed and a shapefile of 1,577 in the Missisquoi watershed.

1b. Private road crossings GIS map layer – GIS layers of private road crossings were also completed in June of 2023 after the completion of task 1a. The result is a shapefile of 545 identified road-stream crossing layers on private land in the Ausable watershed, and a shapefile of 585 of these points in the Missisquoi watershed.

1c. List of priority parcels (top 25% or no more than 50) – Parcel prioritization was completed in October of 2023. The deliverable for this task was two excel spreadsheets (one for each watershed) which exhibit our rankings of parcel by priority for assessment, as well as rankings for factors (elevation and upstream network) used to arrive at this overall ranking. This spreadsheet was used to determine order of contact for field assessments.

2a. Survey response data; List showing landowner consent for field assessments and interviews – Survey responses were closed in November of 2023. We received 174 total responses, of which 157 were complete and usable for quantitative analysis. These surveys were submitted as a .csv file to our project officer; this .csv has some identifying information removed in compliance with our IRB protocol through UVM's Institutional Review Board. Within this spreadsheet, a column notes landowner consent for field assessments or interviews (categorized as yes, no, or "I am not sure, but willing to be contacted further").

2b. In-person engagement programs completed – In-person outreach was completed through partnerships with the non-profit groups Cold Hollow to Canada (Vermont) and the Ausable Freshwater Center (New York). Engagement programs were completed in July of 2024.

3. Brief memo describing scope of collected field assessment data and initial observed trends – Field assessments were completed in June of 2024. A memo describing the scope of the data collected (AOP assessments and fish community assessments with stream physical parameters) and initial trends was submitted to our project officer.

4. Brief memo describing scope of collected landowner interview data and initial observed trends – Landowner interviews were completed in September of 2024. 19 individuals were interviewed in a semi-structured format for 45-90 minutes, depending on the interviewee. A memo describing some of the initial trends has been prepared and submitted to our project officer.

5. Draft manuscript(s) for submittal to peer-reviewed scientific journals; Short (1 page) report(s) on information relevant to local stakeholder organizations and surveyed municipalities – A manuscript comprised of data from the survey portion of this project has been prepared and accepted as a peer-reviewed book chapter (accepted January 2025). A short resource inventory report was prepared and distributed to local stakeholder organizations, attendees of in-person events, and interviewees by September 2024.

5. Project Metrics

Table 4. Project metrics, based on LCBP guidelines.

Metric	**Final value**
Undergraduate students supported by this grant	***1*** undergraduate student supported across ***2*** part-time summer internships
Graduate students supported by this grant	***1*** full-time equivalent graduate student funded for ***1.5 years***
Research fellows supported by this grant	***4 total weeks*** of academic year salary for ***1*** UVM faculty member
Stream crossing/culvert assessments completed	***56***
Culvert replacement/retrofit/removal projects identified	***29***
Dam removal projects identified	***1***
Projects identified	***30***
Landowners reached	*# of landowners* - ***174*** streamside landowners in the Ausable and Missisquoi watershed engaged in survey portion of this project, ***38*** of these landowners engagement in the field assessments portion of the project, and ***19*** engaged in the interview portion of the project.
Grant-funded events held	*# of events* - 5
People who attended grant-funded events	*# of people* - *77* residents of the Ausable and Missisquoi watersheds (recruited from surveys, public event outreach, and existing peer-to-peer learning groups) engaged in in-person events.

6. Conclusions

This project took an integrated approach to addressing a specific problem within the social-ecological system of the Lake Champlain watershed. We used a variety of methods (spatial analysis, mixed methods social science, ecological monitoring, and education/outreach) to address this problem both in research and in practice. The GIS component of this project advanced our social science research, ecological monitoring, and landowner outreach efforts, while also generating an important dataset that can be used by area researchers and transportation/water quality planners well into the future. The social science component of this project has resulted in one incoming publication, as well as additional data that will certainly be used in the preparation of future manuscripts, and the PhD dissertation of L. Briccetti. AOP monitoring has greatly increased the privately-owned structures in NY and VT road-stream crossing databases, which is a critical step to reducing AOP barriers, P inputs, and resilience to extreme weather in the Lake Champlain basin. Additionally, when there is landowner buy-in, these structures often present fewer hurdles to project completion than structures on public land, making their presence in online databases for planners critical. Planners at federal agencies, state agencies, natural resource conservation districts, and non-profits have contacted project team members about potential projects discovered through this monitoring data, and some of these projects are being actively pursued. Fish community assessments have resulted in valuable data that will also certainly contribute to future research publications. Lastly, and perhaps most importantly, this project resulted in fruitful outreach to streamside landowners that has educated some individuals about road crossing BMPs; one landowner has even contacted the project team to let us know that they replaced their undersized crossing with a larger, at-grade structure after considering our educational materials. Additionally, multiple landowners were connected to helpful services, such as beaver management consultations through Vermont F&W. Lastly, in-person events resulted in the distribution of educational and financial resource information verbally and as a document to 77 people. Therefore, by addressing a variety of different data gaps regarding road-stream crossings on private land in the Lake Champlain basin, we are confident that this work has had a multifaceted positive impact on the area's aquatic connectivity, water quality, and resilience to extreme weather – and that the data and education generated by this funding can continue to have a positive impact for years to come.

7. References

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8. APPENDICES

Submitted separately.