Acquisition of airborne optical and thermal infrared (TIR) imagery

Restigouche River watershed, year 2

Preliminary report, February 2013

1. Mandate

Following the acquisition of aerial imagery of the Québec portion of the Restigouche River watershed in 2011, the Centre Eau Terre Environnement of the Institut National de la recherche scientifique was mandated with the acquisition of an inventory of optical and thermal infrared (TIR) imagery of the New Brunswick portion of the watershed. This work was carried out under the auspices of a contract with the Restigouche River Watershed Management Council / Conseil de Gestion du Bassin Versant de la Rivière Restigouche, Inc.

As in 2011, data acquisition for the mandated work was conducted in two major stages. The first consisted of the deployment and installation of a number of temperature loggers (referred to hereafter as thermographs) in the rivers that were to be surveyed in 2012. The second was the acquisition by helicopter of optical and thermal imagery of the following rivers:

- A section of the Restigouche River upstream from its confluence with the Patapédia and downstream from its confluence with the Kedgewick.
- Little Main Restigouche River
- Kedgewick River
- Upsalquitch River and its tributaries the Upsalquitch north-west branch and the Upsalquitch south-east branch

Additionally, owing to high precipitation in summer of 2011 which stopped the aerial photography season before all scheduled surveys could be completed, the following rivers from the Québec portion of the watershed were added to the mandate for 2012:

- Milnikek River
- Patapédia River

2. Temperature data

2.1. Protocol

As in 2011, it was necessary to deploy thermographs within the surveyed rivers in order to validate relative temperatures acquired with the thermal infrared camera with kinetic water temperatures recorded *in situ*. For each surveyed river, a range of thermographs were installed in the turbulent mixing zone, to ensure that logged water temperatures were representative of the true channel temperature. HOBO type UA-002-64 loggers were used. The logging frequency was 15 minutes.

A total of 17 thermographs were deployed throughout the New Brunswick portion of the Restigouche River watershed, the majority during the last two weeks of June 2012 (although some were installed at a later date owing to river levels). The majority were collected approximately one month later, after the aerial imagery had been acquired, although several remained in the water for a longer period until discharge levels facilitated their safe removal. The thermograph installation process is illustrated in figures 1 and 2.

Figure 1 : Deployment of a thermograph in the Patapédia River

Figure 2 : Thermograph fixed in a UPVC tube (to protect from overheating and collisions with bedload), then anchored to a jute sack filled with rocks.

2.2. <u>Data</u>

Temperature data from all thermographs has now been downloaded, and will be supplied at a later date along with the aerial photography.

3. Acquisition of optical and thermal imagery

3.1. <u>Acquisition system</u>

The image acquisition system used in 2012 was the same as that of 2011. The system (called 'Therminator') was developed by the INRS-ETE, and allows for the simultaneous capture of optical and thermal images from two cameras mounted in tandem on a pan-tilt head. GPS positioning data during the time of flight is also recorded. The cameras and pan-tilt system are fixed inside a helicopter luggage pod (helipod), which is then attached to the foot and hull of a

Robinson R44 helicopter. The system is operated by two people, the first is charged with ensuring the quality of data capture (camera triggering, altitude, airspeed), the second controls the pan-tilt (ie. camera) direction using a joystick, in order to better follow the river channel and reduce the incidence of repeat passes.

For the 2012 survey period, several modifications were made in order to streamline the efficiency of the acquisition system. These comprised: a second video screen allowing the pilot to see the TIR image feed, allowing him/her to better follow the river channel, several changes to the GPS capture code in order to increase positioning accuracy and reduce the number of errors and an updated hardware triggering system for the two cameras, enhancing the overall reliability of the system.

The table below gives specifications of the various components of the image acquisition system. The mount and installation of the system are shown in figures 3-6.

Table 1: Major components of 'Therminator' image acquisition system

Component	Model	Notes
TIR camera	FLIR SC660	640x480 pixels @ ±1°C
Optical camera	Canon EOS 550D	5184 x 3456 pixels (17.9 MP)
Pan-tilt system	Directed Perception PTU-D48	Permits 10° freedom of movement for cameras
GPS system	Garmin GPS76 CSx	Accuracy ~2m

Figure 3 : Helipod showing cameras in image capture position

Figure 4 : Optical camera (Canon) on left; TIR camera (FLIR) on right

Figure 6 : Helipod attached to R44

Figure 5 : Pan-tilt control panel

3.2. Image acquisition

It is necessary to account for a number of important hydrometeorological conditions when acquiring both optical and thermal aerial imagery of a river channel. For optical imagery, good lighting and reduced haze are optimal. Although high altitude clouds are acceptable, low level clouds can cause diffuse reflections which reduces the ability to discriminate features below the water surface. Optimal image conditions therefore generally coincide with warm, sunny days.
For thermal imagery, it is necessary to perform image acquisition when river discharge is stable, generally within the 'trough' of the hydrograph. This avoids the 'dilution' of the river's temperature signal, a phenomenon which often occurs following periods of intense rainfall. For both the optical and thermal imagery, peak acquisition time generally occurs between the hours of 11:00 and 16:00, when river temperatures are at their warmest and the high sun position limits blurring within optical imagery.

The surveys scheduled for 2012 were conducted between 20th and 23rd July 2012 by a group of three people (2 researchers from INRS-ETE, one pilot) based in Matapédia, Québec. In contrast with 2011, weather was optimal with no significant precipitation or cloud cover, and all scheduled surveys (including those remaining from 2011; Milnikek, Patapédia) were carried out within a four day period with no breaks in between.

In total, c. 342 km of river were surveyed, comprising 9979 optical and 9979 thermal images (not including images disregarded in preprocessing). Initial data processing indicates that in excess of 1000 thermal refuges were identified from the surveyed rivers, although this number includes 'warm' thermal anomalies, and is likely to be revised downwards during the validation process. Details of each of the surveys is given in table 2.

In addition to the rivers surveyed under the 2012 mandate, there was sufficient time to conduct three further short surveys, the details of which are not given in table 2. Imagery was acquired of a large logjam on the Little Main Restigouche with the aim of aiding the RRWMC / CGBVRR in their efforts to remove it. Imagery was also acquired of a ~8km strip of the shoreline of the Restigouche River estuary between Tide Head and Campbellton with a view to identifying interesting features, such as thermal outfall or illegal fishing. Finally, a repeat survey was conducted of the Thomas Ferguson tributary of the Restigouche River, with a view to comparing the size of thermal refuges present with those identified from 2011 imagery. These images have not yet been processed, but it is hoped that they will aid our understanding of how the size of thermal refuges, particularly those created by groundwater seeps, vary inter-annually.

Table 2: Details of surveyed rivers.

River	Date	Survey length (km)	No. optical images	No. TIR images	Approx. no. thermal refuges
Kedgewick	2012-07-23	63.62	1794	1794	198
Little Main Restigouche	2012-07-22	21.34	740	740	109
Milnikek	2012-07-20	33.13	1085	1085	72
Patapédia	2012-07-20	60.77	1710	1710	243
Restigouche (NB portion)	2012-07-22	35.73	989	989	120
Upsalquitch	2012-07-21	41.13	993	993	149
Upsalquitch NW	2012-07-21	61.72	1937	1937	168
Upsalquitch SE	2012-07-21	24.52	731	731	54
Total		**341.96**	**9979**	**9979**	**1113**

3.3. Data

Imagery and associated data will be supplied at a later date when processing is complete.

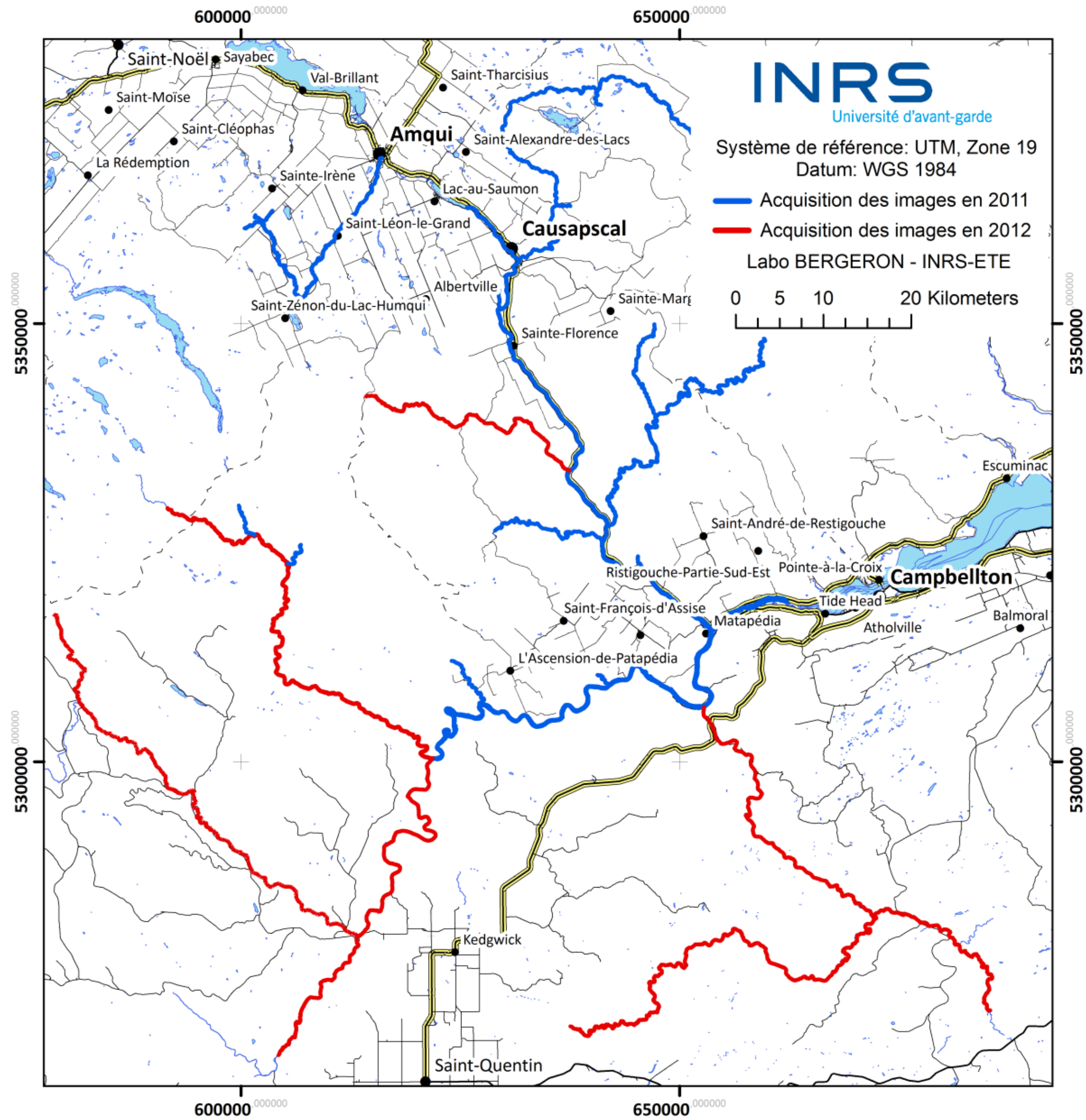


Figure 7: Map showing image acquisition during 2011 (blue) and 2012 (red) surveys

4. Long profiles and identification of thermal refuges

Following data acquisition, INRS-ETE was also mandated to analyse the optical and thermal images in order to extract both surface water temperature data (used to form temperature long profiles for each river) and the location and classification of all thermal refuges identified

The image analysis process started in early 2013, and is still being undertaken, although initial impressions suggest that the New Brunswick portion of the watershed is at least if not more rich in terms of thermal refuges than that of Québec. Several modifications were made to the data extraction system in comparison to that used in 2011, so the process is both faster and more accurate in terms of the localisation of each thermal refuge.

For each river, the processing methodology establishes a river kilometre system (PK), whereby each image is assigned a metric coordinate relative to its distance upstream. The average river surface temperature from each image (achieved by extracted five temperature values from the channel thalweg), is then attributed to the PK, resulting in a longitudinal profile of river temperature. At the same time, the optical and thermal images are scrutinised for the presence of thermal refuges. If found, the thermal refuge is classified into one of a series of process-based categories. These categories are given in the appendix. A screenshot of the graphical user interface (GUI) used for data extraction and analysis is given below (figure 9).

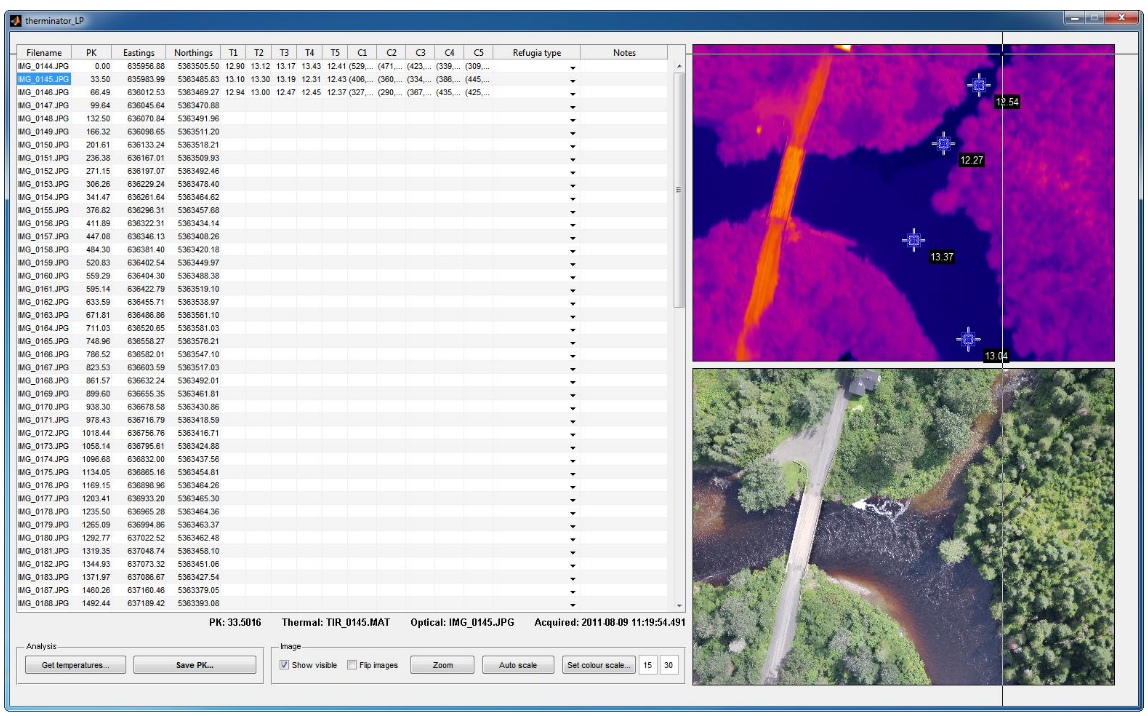


Figure 9: GUI (graphical user interface) used for the extraction of temperature measurements and the classification of thermal refuges from optical and thermal infrared images.

An example of a preliminary long profile, extracted from the Upsalquitch NW branch, is given in figure 9 (below). Here, it is noted that a cool tributary at around 38km upstream from the confluence with main stem Upsalquitch River contributes a considerable amount of cool water to the main channel, decreasing the water temperature to such an extent that the entire river channel downstream of this feature is cooled by approximately 2 °C. This cool tributary input is visible in figures 9 and 10 as optical and thermal images.

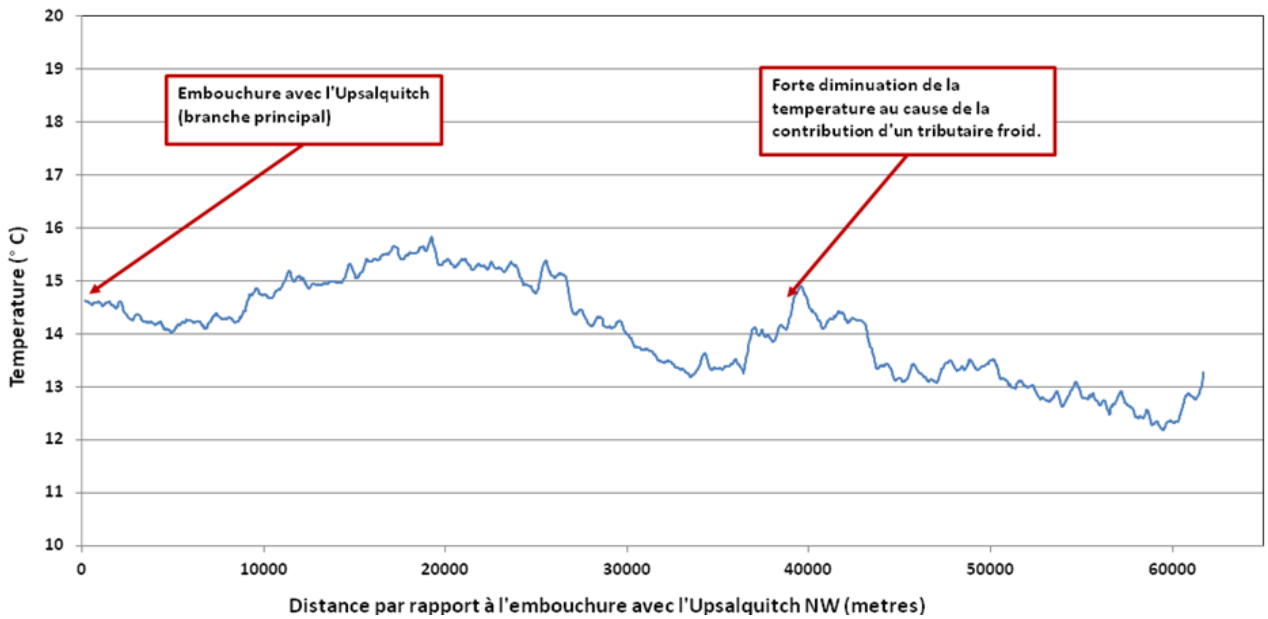


Figure 9: Long profile of surface water temperatures for the Upsalquitch NW branch (from confluence with the Upsalquitch River to a point ~60km upstream). Note that the temperature data are still relative and have not yet been validated using thermograph data.

Data such as this will aid greater understanding of the causes of longitudinal temperature patterns. Though the example given shows a cooling trend resulting from a cold tributary, cooling features such as this can often not be explained by single cold tributary inputs, and may be the function of several interrelated hydrological and geomorphological factors.

Figure 10: Optical image of cold water tributary on Upsalquitch NW branch

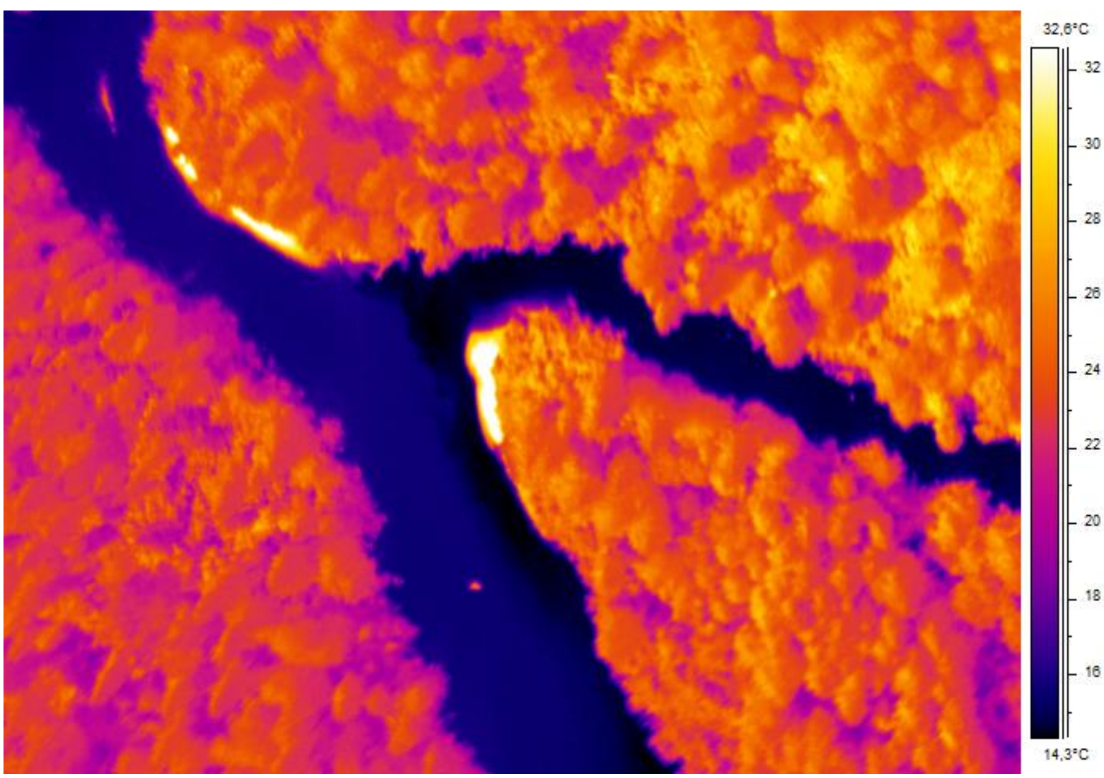
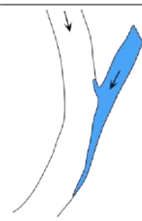
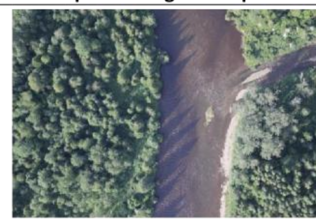
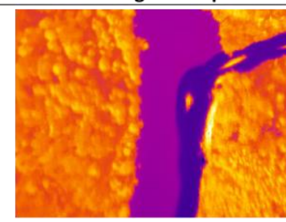
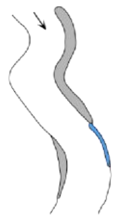
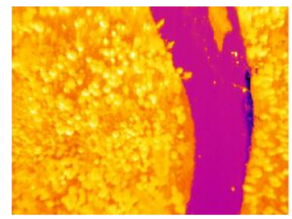
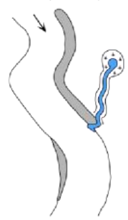
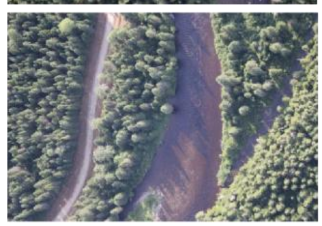
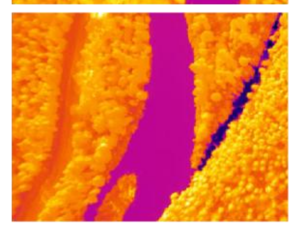
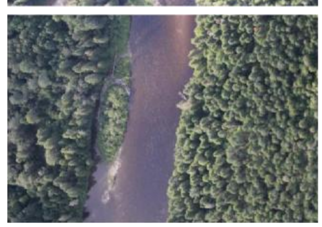
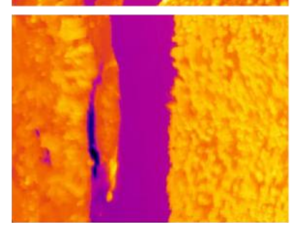
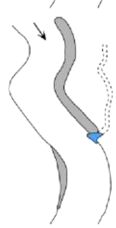
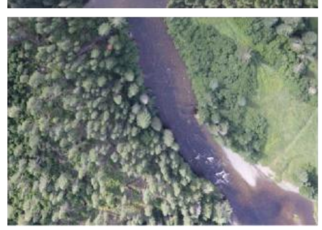
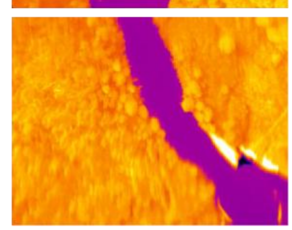
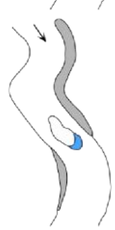
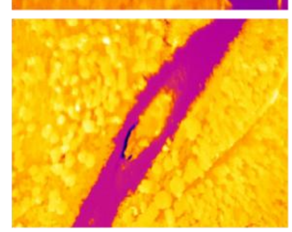
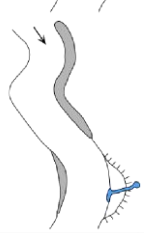
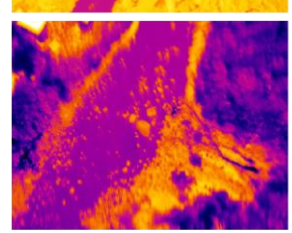


Figure 8: Thermal image of cold water tributary on Upsalquitch NW branch. Note that the tributary is approximately 3°C cooler than the main stem.

Appendix

Thermal refuge classification schema

Thermal refuge	Reference	Schematic	Optical image example	TIR image example
Tributary confluence plume	Torgersen et al., 2012			
Lateral seep	Bilby, 1984 Ebersole et al., 2003a			
Springbrook	Stanford and Ward, 1993 Ebersole et al., 2003a			
Cold side channel	Ebersole et al., 2003a Stevens and DuPont, 2011			
Cold alcove	Ozaki, 1988 Ebersole et al., 2003a			
Hyporheic upwelling	Brunke and Gonser, 1997 Poole and Berman, 2001 Burkholder et al., 2008			
Wall-base channel	Peterson and Reid, 1984 Torgersen et al., 2012			

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