# A Model to Gauge Natural Habitat in the FEMA Special Flood Hazard Area of Middlebury, Vermont

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Introduction: Conservation planners can create and improve upon models of land cover to display the estimated extent of natural habitat in a given region. The Special Flood Hazard Area (hereafter SFHA) for Middlebury is an example of a map which concerns the risk that natural flood regimes carry for damaging human property (FEMA 2023, 2020). Conservationists can convey the benefits of areas such as the SFHA by focusing upon the habitat which exists within the area and the wildlife adapted to its conditions (Professor Howarth, personal communication, 3/9/2023). The Middlebury Planning Commission should thus receive information about land cover in the SFHA to prioritize the protection of said habitat. In order to support increased understanding of flood zone habitat in Middlebury, this report models all patches of habitat in the SFHA and quantifies and visualizes their protected status.

Background: Much of the southwestern area of Middlebury falls under the SFHA, with sections of the overlay meeting the Cornwall and Salisbury borders (Figure 1). A thin section of the SFHA which extends into the town center follows Otter Creek and includes the land directly adjacent to the river (Figure 2); similarly, the SFHA also follows the Middlebury River into East Middlebury (Figure 3). The overlay specifically details the area predicted to flood in the event of a 100-year flood (FEMA 2020). As a flood-related product of the Federal Emergency Management Agency, SFHAs represent the provision of flood risk data to communities, which ostensibly interpret the layer in the context of its built environment to mitigate property damage (FEMA 2023). However, the layer necessarily projects aquatic habitat and includes any habitat near the aforementioned rivers; in addition, Olsen (2006) and Diehl et al. (2021) imply that SFHAs represent floodplain area. Sorensen et al. (2015) report that river and riparian habitat benefits biodiversity in Vermont and suggest that protection of existing natural habitat in these areas is paramount. Ward et al. (1999) also state that floodplains have high biodiversity, and Fischer et al. (2019) add that they contain many types of habitat; the work of Nislow et al. (2002) on the Upper Connecticut River indicates that floodplain habitats in the Northeast can include forested areas and meadows.

While the above sources suggest the importance of modeling existing habitat and protected habitat within the Middlebury SFHA, extremely small areas of natural land cover may nevertheless be somewhat irrelevant in view of their size relative to larger blocks. This report

therefore aims to reduce unwanted noise through filtering images. Andreatta et al. (2022) and Pazur et al. (2021) use this general method in GIS analyses to improve land cover images.

Methods: A Google Earth Engine script entitled "surface-waters.js" served as a base for a modified workflow (Howarth 2023c). The workflow (Figure 1) isolated those areas of the SFHA which contain land cover class values corresponding to forested land (core and edge forest), grass/shrubland, and water, together representing natural habitat, and created a binary image with the .remap function. The workflow excludes bare ground and agricultural land due to their perceived status as human-altered areas (Prof. Howarth, personal communication, 2/16/2023). The .reduceToVectors function transformed binary images of SFHA habitat and collated protected land (sourced from "parcels-with-protections.js"; Howarth 2023b) into separate feature collections (FCs). An FC for the SFHA existed in the source script (Howarth 2023c). A function then restricted the extent of the protected lands FC to the SFHA and aggregated the area of each feature in each of the three FCs to produce total area values. The script next converted area values to acres and calculated the percentage of SFHA area with natural habitat (using the SFHA habitat and SFHA area FCs) and the percentage of SFHA habitat under protection (using the protected land and SFHA habitat FCs). Repeated trials of this basic workflow tested whether changes in variables impacted these percentages (Table 1). In certain tests, the workflow included a filter with a circular kernel and a reducer of mode; the radius value of the kernel and the position of the .reduceNeighborhood function relative to the .remap function also varied (Figure 1). The value for the scale argument of the vectorization function represented another independent variable (Table 1).

Discussion: Different decisions on the controlled variables affected the output values for percentage of natural habitat in the SFHA (hereafter "percent habitat") and percentage of natural habitat in the SFHA with protections (hereafter "percent protected habitat"). These measured variables occupied ranges of approximately 49.5-51% and 35-36%, respectively (Table 2). Percent habitat values often decreased as scale increased in tests with the same radius value, which matched decreases in estimated total area of habitat (see Tests 2-9 through 2-11). In contrast, percent protected habitat values for tests with the same kernel radius often increased as scale increased (see Tests 2-6 through 2-9) and sometimes peaked at a 5 -meter scale (see Tests

2-9 through 2-11). Smaller radius values exerted a lesser influence on results, but values changed in tests with a radius of 10 meters (see Tests 1-4, 2-5, 2-8, 3-5, and 3-8 compared to Tests 2-11 and 3-11). Values differ slightly with respect to where the workflow applied the kernel, implying that this decision wielded somewhat low influence over results (Table 2).

**Table 1.** A presentation of the variables used throughout the different instances of the script. Minimum values for radius and scale were set at 2.5 meters after Howarth (2023a). Zoom level was set at 13.

| Fixed variables | Controlled variables | Measured variables |
|---|---|---|
| Region (Special Flood Hazard Area; SFHA) | Use of a kernel filter (.reduceNeighborhood) | % of SFHA with habitat (SFHA area and habitat FCs) |
| Land cover base image ("LCU", based on LCP) | Radius of kernel filter (2.5, 4, 5, or 10 m) | % of habitat under protection (protected land and habitat FCs) |
| Definition of habitat (core forest, edge forest, grass/shrub, water) | Position of kernel filter code (before or after remapping the land cover image) | Area of habitat (SFHA habitat FC) |
| | Vectorization scale value (.reduceToVectors: scale argument; 2.5, 4, 5, or 10 m) | Area of protected habitat (protected land and habitat FCs) |

The tests caused differences in the appearance of the land cover layer, corresponding to kernel radius, and the habitat and protected land FCs, corresponding to scale. A kernel radius of 10 meters erased small streams (or ditches; Professor Howarth, personal communication, 4/4/2023) (Figure 4a). Though these aquatic features are small in width, a workflow intended to document the extent of habitat should not erase them before community members investigate their characteristics in the field; Sorensen et al. (2015) include small organisms such as invertebrates in their description of aquatic biodiversity in Vermont, and Painter (1999) suggests that macroinvertebrates can use even ditches as habitat. A radius of 4 meters maintained these small streams or ditches (Figure 4b) and appeared to marginally reduce noise, which manifests as particularly small areas of forest or grass/shrub in the midst of non-habitat (Figure 5). Other layers contextualize decreases in percent habitat and the two variables which estimate area (Table 2) in that the habitat FC in tests with higher scales appears less accurate at covering the extent of

the land cover image (Figure 6a-b). These observations suggest that Tests 2-2 and 3-2 represent a medium between noise reduction and vector accuracy; however, Test 2-2 better visualizes different types of land cover.

**Table 2**. These tests incorporated different values or states for controlled variables (Table 1). The placement of filter code refers to where the workflow evaluated the ".reduceNeighborhood" function, which applied a filter over the land cover image. "N/A" corresponds to a test with no filter. Scale refers to the "scale" argument of the ".reduceToVectors" function. This report does not analyze all possible combinations of radius and scale due to brevity, and the table shows these variables in meters. The table presents values rounded to two decimal places.

| *Test number* | Placement of filter code in workflow | Kernel radius | Scale | % of SFHA with natural habitat | % of SFHA natural habitat with protections | Area of habitat in SFHA (acres) | Area of protected habitat in SFHA (acres) |
|---|---|---|---|---|---|---|---|
| *1-1* | N/A | 0 | 2.5 | 51.55 | 36.18 | 1474.53 | 533.51 |
| *1-2* | N/A | 0 | 4 | 51.01 | 36.24 | 1459.03 | 528.89 |
| *1-3* | N/A | 0 | 5 | 50.98 | 36.29 | 1458.03 | 529.14 |
| *1-4* | N/A | 0 | 10 | 50.14 | 36.26 | 1434.00 | 520.00 |
| *2-1* | Before remap | 2.5 | 2.5 | 51.82 | 36.04 | 1482.17 | 534.30 |
| *2-2* | Before remap | 4 | 2.5 | 51.73 | 35.96 | 1479.86 | 532.14 |
| *2-3* | Before remap | 4 | 4 | 51.37 | 35.97 | 1469.33 | 528.57 |
| *2-4* | Before remap | 4 | 5 | 50.97 | 36.29 | 1458.03 | 529.14 |
| *2-5* | Before remap | 4 | 10 | 50.14 | 36.26 | 1434.00 | 520.00 |
| *2-6* | Before remap | 5 | 4 | 51.37 | 35.97 | 1469.33 | 528.57 |
| *2-7* | Before remap | 5 | 5 | 51.34 | 36.00 | 1468.66 | 528.70 |
| *2-8* | Before remap | 5 | 10 | 50.14 | 36.26 | 1434.00 | 520.00 |
| *2-9* | Before remap | 10 | 4 | 51.42 | 35.66 | 1470.93 | 524.55 |
| *2-10* | Before remap | 10 | 5 | 51.32 | 35.77 | 1467.82 | 525.06 |
| *2-11* | Before remap | 10 | 10 | 51.13 | 35.74 | 1462.57 | 522.74 |
| *3-1* | After remap | 2.5 | 2.5 | 51.41 | 36.17 | 1470.43 | 531.84 |
| *3-2* | After remap | 4 | 2.5 | 51.41 | 36.17 | 1470.43 | 531.84 |
| *3-3* | After remap | 4 | 4 | 50.64 | 36.22 | 1448.53 | 524.73 |
| *3-4* | After remap | 4 | 5 | 50.97 | 36.29 | 1458.03 | 529.14 |
| *3-5* | After remap | 4 | 10 | 50.14 | 36.26 | 1434.00 | 520.00 |
| *3-6* | After remap | 5 | 4 | 50.64 | 36.22 | 1448.53 | 524.73 |
| *3-7* | After remap | 5 | 5 | 50.57 | 36.25 | 1446.42 | 524.38 |
| *3-8* | After remap | 5 | 10 | 50.14 | 36.26 | 1434.00 | 520.00 |
| *3-9* | After remap | 10 | 4 | 50.24 | 36.19 | 1437.21 | 520.18 |
| *3-10* | After remap | 10 | 5 | 50.28 | 36.22 | 1438.07 | 520.90 |
| *3-11* | After remap | 10 | 10 | 49.54 | 36.30 | 1416.96 | 514.39 |

For types and location of habitat, the land cover layers show that grass/shrubland and/or forest are consistently present in the areas adjacent to Otter Creek and the Middlebury River in addition to the aquatic habitat provided by the streams themselves (Figure 7a). Whether forested habitat near the river represents floodplain forest (Nislow et al. 2002) may depend upon seasonal flooding regimes (Anderson et al. 2010). The layer also indicates that there are certain larger patches of habitat with sections located further from the stream channels. These areas appear mostly forested with grass/shrubland often around their edges; Morse Road separates two of them, while one is located off Creek Road and 3 Mile Bridge Road. This latter area appears largely protected but has unprotected areas of forest within, while the areas near Morse Road remain nearly entirely unprotected (Figure 7b, 8a-b). The land cover layer also displays extensive protections for land around Middlebury River in the center of the SFHA (Figure 7b).

The percent protected habitat values for the SFHA may already be somewhat promising to planners who view 30 percent protection of an area such as the town or state by 2030 as a conservation goal ("30x30"; Professor Howarth, personal communication, 3/7/2023). After Moravek et al. (2023), who propose that planners prioritize freshwater areas at a watershed scale for 30x30, the Planning Commission could focus on the potential for protecting more land adjacent to Otter Creek near Creek Road and Middlebury River near 3 Mile Bridge Road, as well as the rivers themselves (Figure 9a-b). Middlebury College also represents an important party for future discussion of increasing protections; the College owns a large part of an aforementioned forested area north of Morse Road, yet little or none of this area shows as protected (Figure 10).

Conclusion: A Google Earth Engine workflow with multiple trials estimated that approximately 50% of the Middlebury SFHA represents natural habitat, from water to grass/shrubland to forest, and that protections cover approximately 36% of this habitat. Test 2-2 performed best and incorporated limited noise removal while maintaining some vector accuracy. These tests provide a model for field visits which assess the accuracy of estimated habitat area as compared to current field conditions. Planning Commission members or others should communicate with owners of those parcels which contain unprotected natural habitat, including Middlebury College. The Planning Commission and students should also consider restricting the area of habitat features to prioritize particularly relevant areas (after Sorensen and Osborne (2014)).


**Figure 1**. The extent of the Special Flood Hazard Area in Middlebury (shown with Test 2-2; Table 2).


**Figure 2**. Close-up of the SFHA showing its extent in the center of town (shown with Test 2-2; Table 2).


**Figure 3**. Close-up of the SFHA showing its extent in East Middlebury (shown with Test 2-1; Table 2).

a. b.

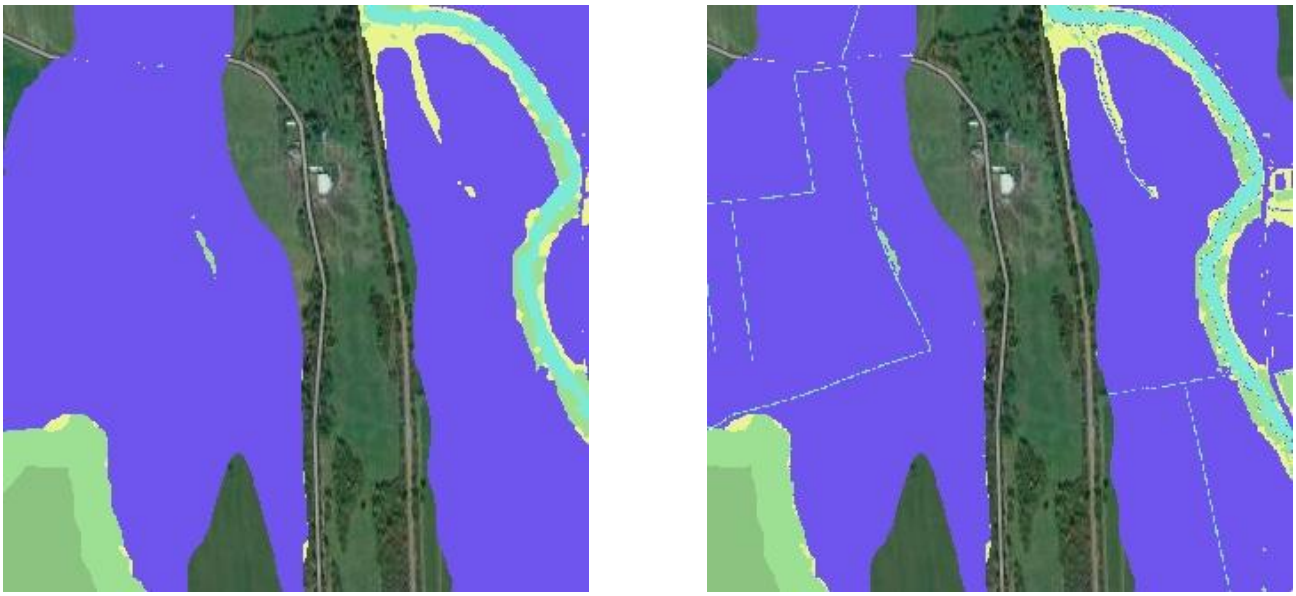


**Figure 4a-b**. Comparison of Tests 2-11 (**a**) and 2-2 (**b**) (Table 2) near Otter Creek (left) and South Street Extension (center). Note the lack of small light-blue channels in a, whose associated test has a 10-meter kernel radius. Purple represents the SFHA, while any other pixel displayed with a solid color is natural habitat. The model shows this result in multiple areas of the SFHA including this close-up.


Figure 5. Close-up of the area of the SFHA near the intersection of South Street Extension and Morse Road (shown with Test 2-1; Table 2). Note the many small groups of pixels in the center of the image, which correspond to modeled natural habitat separate from a larger portion of habitat such as the area in the bottom left corner.

a. b.

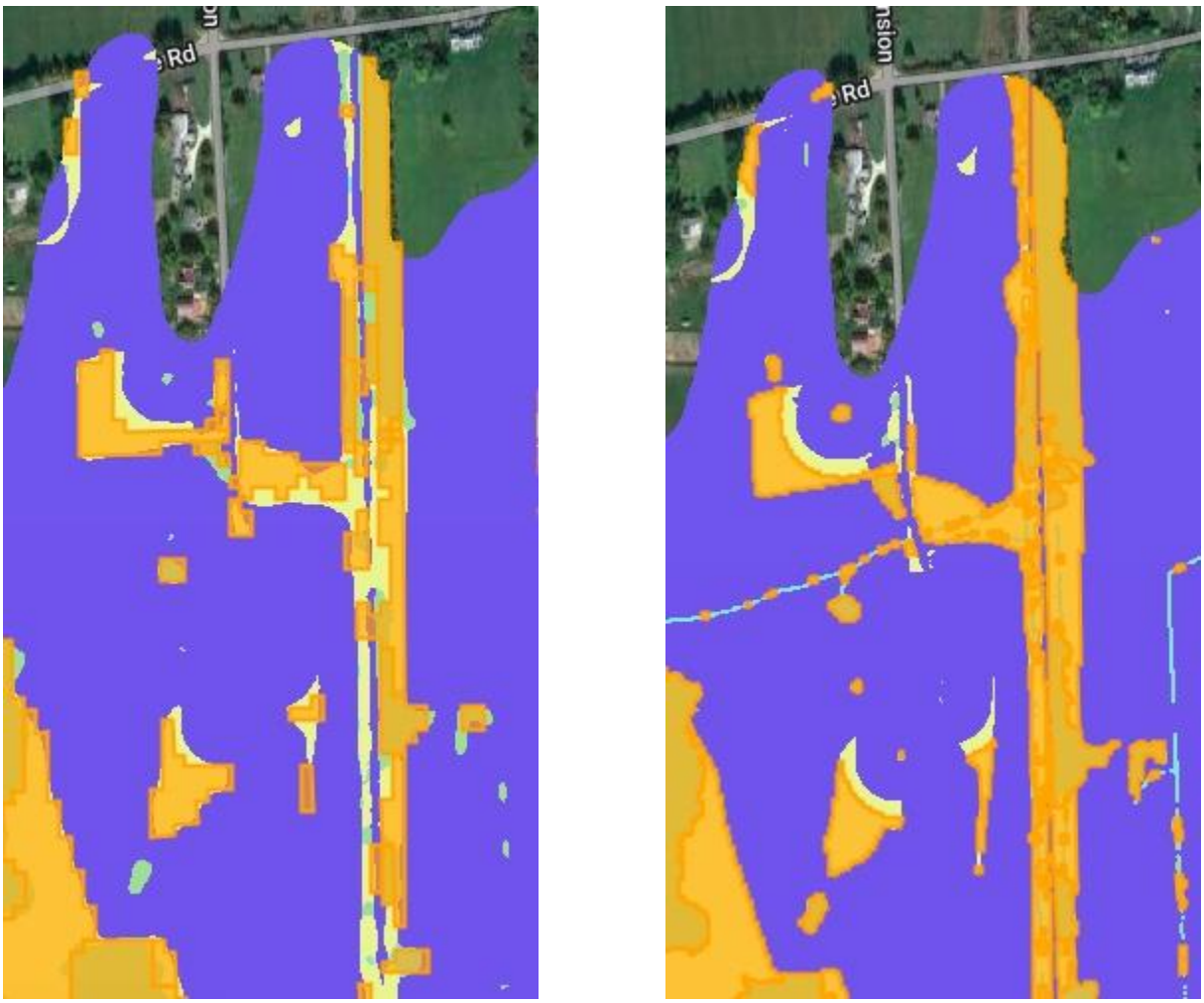


**Figure 6a-b.** Comparison of Tests 2-11 (**a**) and 2-2 (**b**) (Table 2) near the intersection of South Street Extension and Morse Road. Purple represents the SFHA, while any other pixel displayed with a solid color is natural habitat. The orange overlay represents the habitat feature collection which the workflow created through vectorization of the land cover image. Note that the test which included a smaller scale (**b**) seems to cover the modeled habitat more completely. The model shows this result in multiple areas of the SFHA including this close-up.

a. b.

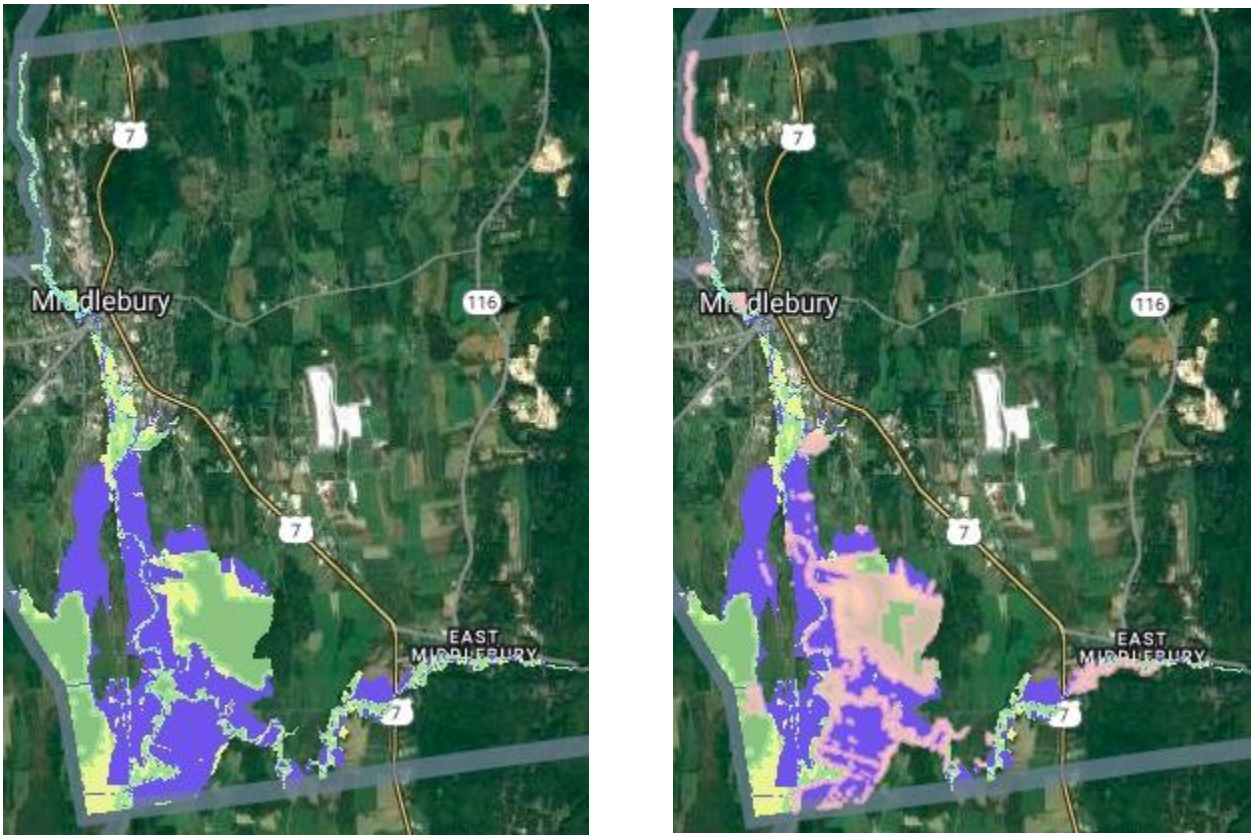



**Figure 7a-b.** (**a**) Modeled natural habitat in the SFHA (shown with Test 2-2; Table 2). Purple represents SFHA extent, light blue represents water, yellow represents grass/shrubland, and green (dark and light) represents forest cover. (**b**) Figure 7a with the protected lands feature collection shown in pink.

a.

b.

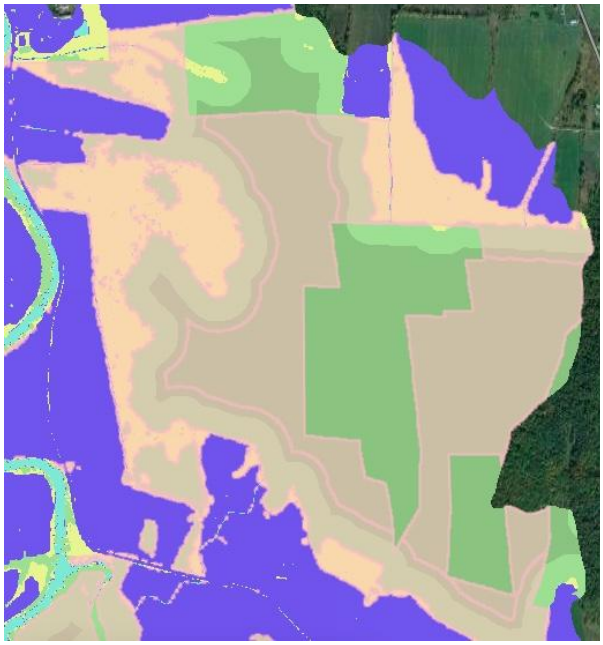
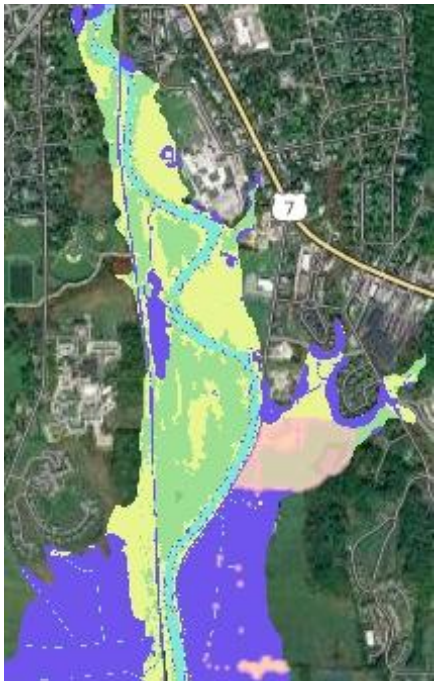


**Figure 8a-b**. (**a**) Two particularly large areas of natural habitat are separated by Morse Road. (**b**) A large area of natural habitat to the east of Otter Creek and located off Creek Road and 3 Mile Bridge Road (shown using Test 2-2; Table 2). See the caption of Figure 7a-b for legend.

a.




b.


**Figure 9a-b**. Close-up screen captures showing some sections of unprotected natural habitat near (**a**) Creek Road and Otter Creek and (**b**) 3 Mile Bridge Road and Middlebury River (shown using Test 2-2; Table 2). See the caption of Figure 7a-b for legend.

**Figure 10**. Close-up on the relatively large habitat north of Morse Road (shown using Test 2-2; Table 2). The legend is the same as detailed in the caption of Figure 7a-b with the addition of Middlebury College lands as a gold overlay. Protected lands owned by the college would have both the pink and gold feature collections overlaid, but this does not seem to occur in this area. The SFHA layer is removed to avoid confusion with the color produced by the overlap of said layer with the College lands FC.

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