PROVINCE OF NEW BRUNSWICK

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FINAL REPORT: Project No.: 140156

Visualizing Hydrographical Relationships between Wetlands and Urban Structures using LiDAR based Wet Areas Mapping (WAM)

Report submitted on behalf of CNBA (Cities of New Brunswick Association)

by

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Marc h 1, 2015

Summary

The Cities of New Brunswick Association (CNBA) partnered with the University of New Brunswick to undergo a research and development project to determine best method practices of using LiDAR-based wet-areas mapping (LiDAR WAM) to identify and position (map) wetlands within areas subject to current development interests. For this purpose, wetland-focused areas in four cities (Fredericton, Moncton, Miramichi), Bathurst) were selected for direct comparisons between LiDAR-based WAM versus actual wetland delineations (Figure 1). The aim of the Project is to generate LiDAR-based wetland delineations with an accuracy that is acceptable for development planning in general, and would also be useful within the context of the Watercourse and Wetland Alteration Regulation (WAWA) permitting requirements.

The LiDAR based wetland delineation refers to inferring soil wetness from 1 m bare-ground digital elevation models (DEMs) through the recognition of elevational change and related consequences in terms of flow direction, and flow accumulation in flat areas. In

most, cases, wetlands are confined to occur in DEM-determined depressions and along flat areas up to hydrologically significant changes in elevation that may be abrupt or gradual. Actual wetland delineation discerns wetland borders by recognizing transitions away from hydro-obligatory vegetation which also signal a transition away from hydromorphic soil conditions. For the most part, the two methods correspond to one another quite closely, as to be expected, and as documented below. Exceptions occur where:

(i) the wet-area soil is well drained, and is therefore not hydromorphic, e.g., generally along outwash plains and upper terrace alluvial sand and silt deposits;
(ii) the soil is wet but receives well-aerated seepage from adjacent upslope area: under natural conditions, such areas are generally forested
(iii) the soils have been artificially drained.

Within built-up areas, on-the-ground wetland delineations is further complicated by noting changes in wetland conditions and developments on account of past to present soil disturbances. New areas with hydromorphic vegetation may appear where soil drainage was/is restricted because of increased soil compaction or flow blockage, and the reverse is true as well: portions of wetlands may transit into forest conditions on account of accelerated drainage. Filling-in through local earthwork obliterates targeted wetlands or wetland portions altogether.

From a hydro-functional perspective, any changes in wetland and related wetland drainage configurations should consider the following DEM- and WAM-derivable wetland attributes:

(i) extent of wetlands and associated areas that are subject to periodic flooding
(ii) extent to the upslope water-contributing area
(iii) amount of water flowing towards and through the wetlands for flood-event scenarios, this includes estimating the wetland effect on water retention and flow rates
(iv) location of the wetlands within the already built-up area and its connection with local hydrological infrastructure and their specific drainage places within floodplains if present.

DEMs can be used to ascertain potential extent of wet-area and wetland flooding through the DEM-based high-resolution delineations

(i) of local depressions
(ii) of wet areas next to open-water surface features (all DEM-derived streams, lakes, shores)
(iii) of all small to large floodplains.

These delineations can now be done across the province with DEMs are 10 m resolution, and locally at 1m resolution using the LIDAR DEMs. The latter tend to reflect neighbourhood flood-relevant extent as defined by the elevational contouring of roads and housing developments as they were in place at the time of the LiDAR DEM scans.

Procedures

(i) Wetland-containing areas subject to development considerations within Fredericton, Moncton, Miramichi), Bathurst were selected with approval through contacting city interested representatives and developers.
(ii) City-wide hydrological infrastructure datalayers were obtained.
(iii) DEMs (LiDAR 1 m resolution) were obtained from NBELG, and were used to develop the pertinent wet-areas mapping (WAM) layers for each city (flow direction, flow accumulation, flow channels, cartographic depth-to-water; with and without flow channels corrected by hydrological infrastructure layer; these were used to determine the LiDAR derived wetland borders .
(iv) Wetland areas were delineated using professional wetland delineators, who used the abbreviated wetland ground-truthing method prepared by DELG for 2013 10. UNB will compare these boundaries with the ground-truthed data.
(v) Several meetings were held to review the process, and interim project results were discussed with the project contacts for Fredericton.
(vi) Final project presentations/workshops will be made for each Project area in March/April 2015, with city representatives and other interested parties attending.
(vii) Project deliverables (datalayers in ArcMap and pdf format) will be made available to project partners at the workshop meetings.

(viii) Feedback from these workshops will be used to engage CNBA membership to make recommendations to DELG regarding implementing the project methodology on a broader basis, specifically to to guide activity/development reconnaissance, planning and WAWA permitting.

Progress made

To date, all pertinent LIDAR-WAM data layers have been generated for the select project areas, and can be directly compared with the ground-truthed wetland delineations. There is generally good conformance. Where there are differences, these differences are related to local changes in flat soil drainage and soil water and conditions as these may vary from aerated to non-aerated, with the latter indicating the presence of hydro-morphic vegetation. Considerable progress has been made in terms of situating wetlands within their local topographic and hydrological contexts as defined by natural engineered inflows and outflows. City-based project evaluations will follow the project based workshops in March/April 2015.

Acknowledgements

Special thanks to the University of New Brunswick, Dr. Paul Arp for the resources necessary to complete the project; to Cities of New Brunswick Association, especially to Dennis Roussel or Project facilitation, and to Department of Environment, especially to Mark Miller, for his interest and support for this project. Derrick Mitchell served as ground-truthing delineator for the designated wetlands in Fredericton, Moncton and Bathurst and for preparing detailed reports for each site. Thanks also fo to the field and technical assistance by Tanner Sagouspe, Michael Dekouchay and Friedrich Wütrich. Mark Castonguay and Jae Ogilvie were instrumental in terms of GIS and GPS assistance in general, and in terms of the ArcMap mapping procedures in particular.

Appendix 1: Wetland delineation details

Section 1: Fredericton

All of the LiDAR-DEM for Fredericton was used for wet-areas mapping, with and without DEM enforcement of the local hydrological infrastructure data layers (Figs 1.1, 1.2 1.3). Of special priority interest were the development interests for the Heron Road extension north of the Saint John River.

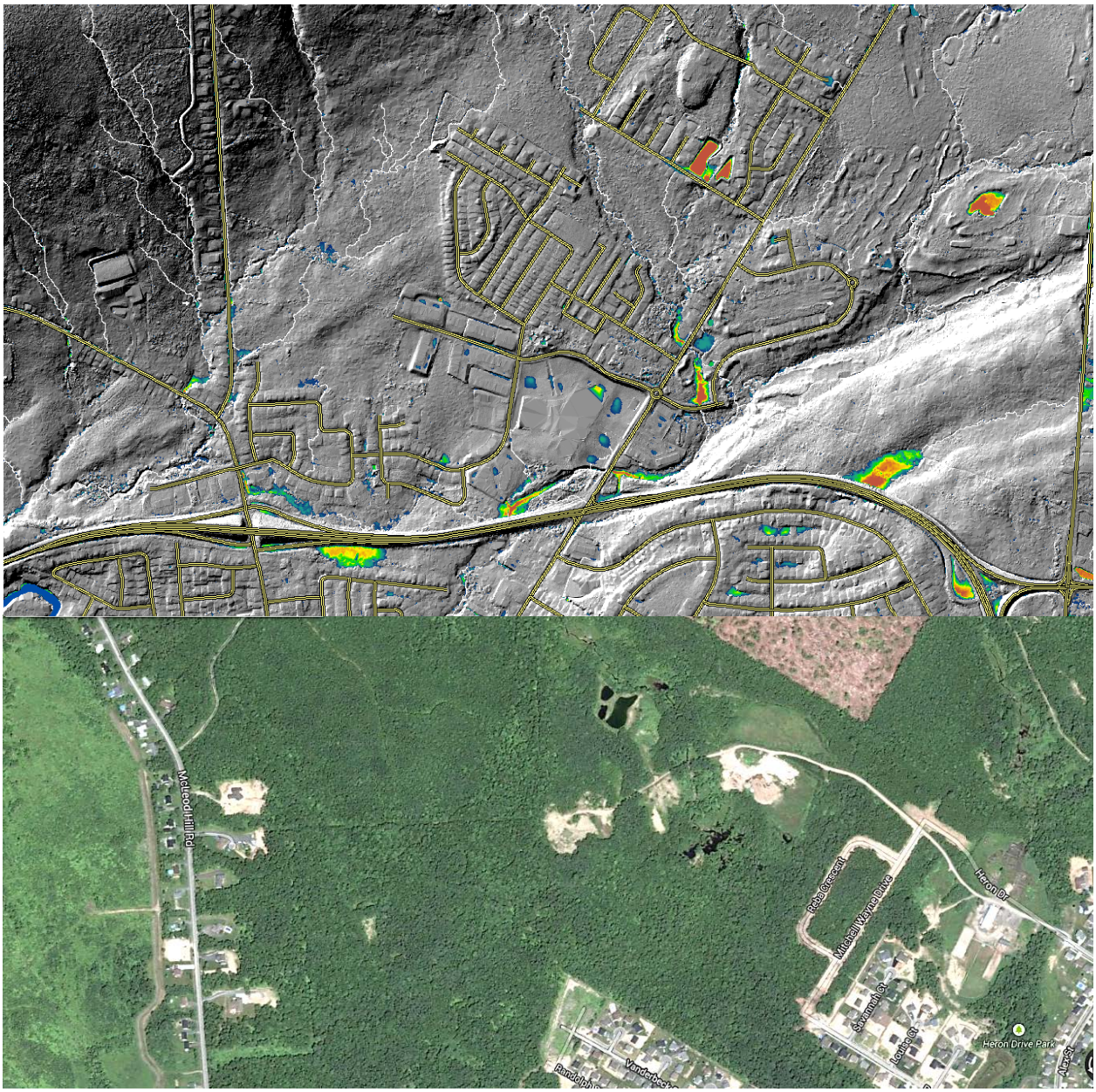


Fig. 1.1. Hill-shaded LiDAR-DEM for Fredericton, focused on Heron Road developments in the northwest portion of this map. Colored patches represent local depressions. White lines: LiDAR-derived flow channels. Bottom: Googlearth image.

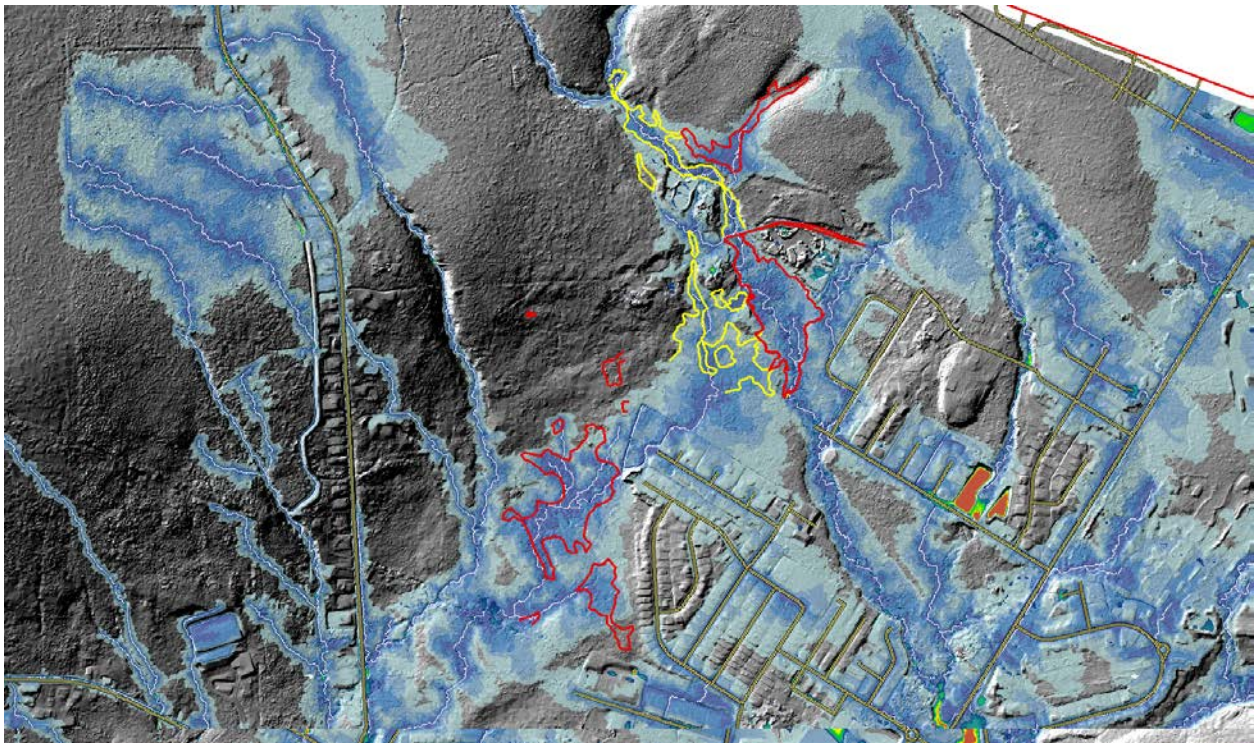


Fig. 1.2. Wetland delineations along and around the Heron Road developments, showing a complex patterns in part owing to topographically restricted flow conditions, as depicted by the blue shaded wet-areas from shallow (dark blue) to 1 m deep (light blue).

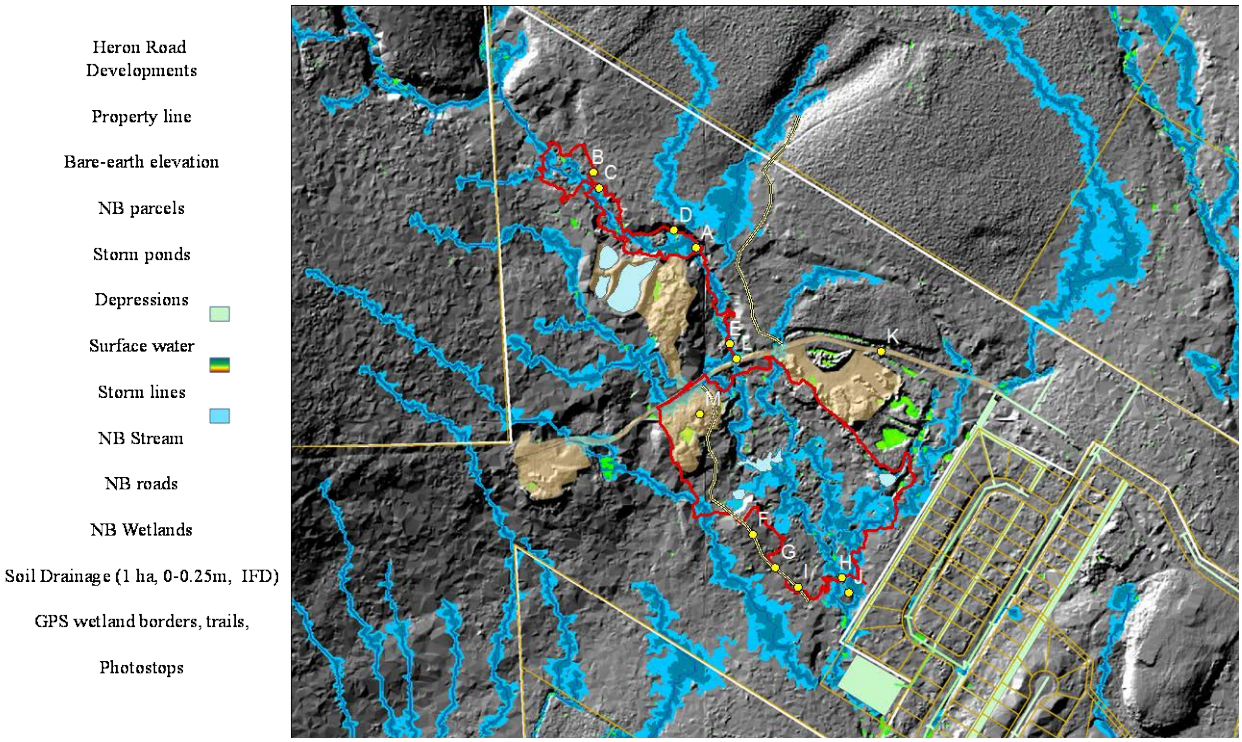


Fig. 1.3. Enforcing hydrological infrastructure drainage on LiDAR-derived wet-areas mapping, with depth-to-water restricted to a depth 0f 25 cm.

Some of the wetland delineations for the Heron Road areas (Figs. 1.4, 1.5) were rendered difficult by way of a series of land-use changes over several decades, starting with a conversion of the land from general forest conditions to a homestead. Part of this land was bought by an asphalt company, which then built the settlement ponds on its property and used the land for storing and processing sand and rocks. Continued bulldozing and recent beaver dam activities further changed the area through flooding and scattering of debris, thereby changing the local elevation and soil drainage conditions, and also changing the preceding geoNB wetland delineation for this particular area. Soil drainage conditions would also be changed on account of soil compaction, fill-in, un-filled sinks, and flow-channel blocking along bulldozed areas.

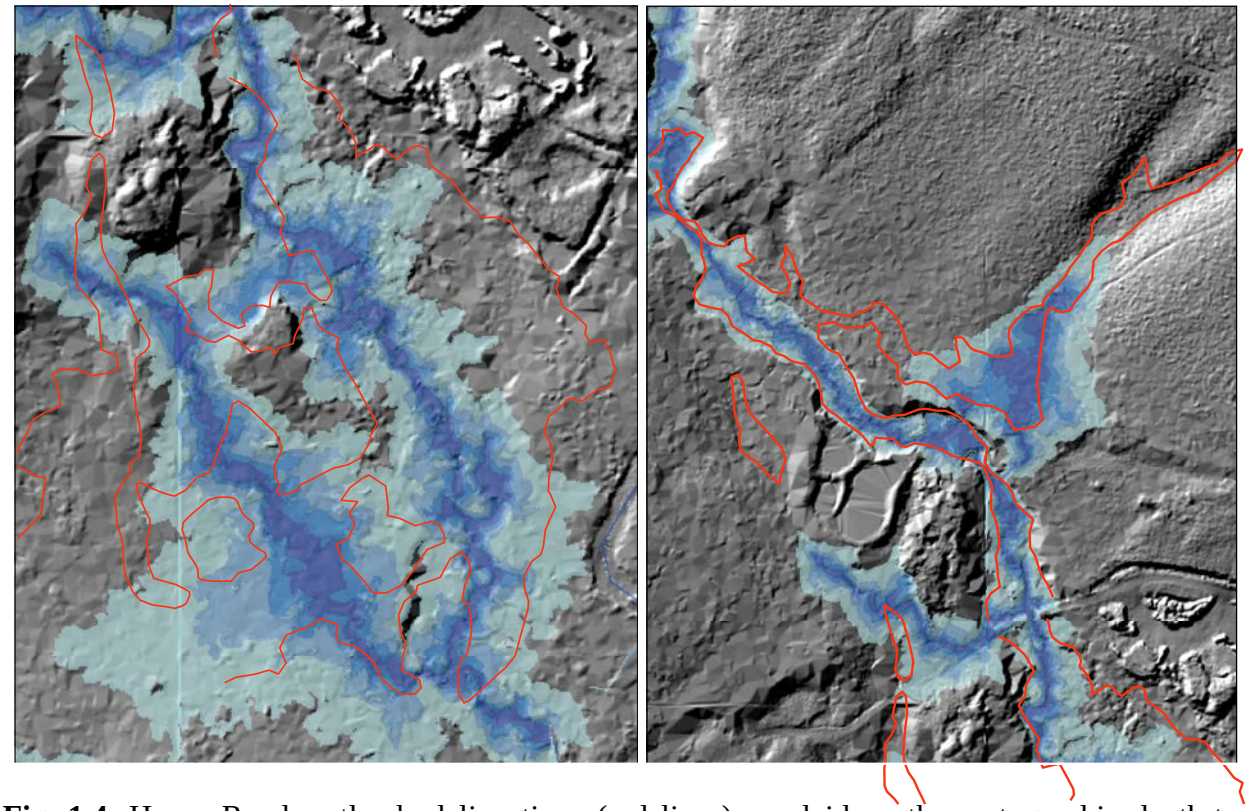


Fig. 1.4. Heron Road wetlands delineations (red lines) overlaid on the cartographic depth-to-water delineations (DTW 0 to 1 m shared dark to light blue, respectively) as derived from LIDAR-DEM (hill-shaded background), using flow channels with 4ha flow initiation areas as zero depth-to-water reference. **Left:** Flow channel, wetland and wet soil conditions are rapidly changing due to continued earthwork. **Right:** Wet-areas mapping using flow channels with is more conservative with 4ha flow initiation channels is too conservative for the wetland delineation purpose. Generally, wet areas mapping with 1ha flow initiation channels is better, with wetlands confined o DTW<0.5 m.



Fig. 1.5 Features within the wetland delineated Heron Road area. A pond; rutted ATV trails, and frost exposed drain channel at stream-trail crossing.

The network of ATV trails running through the Heron Road wetland area is depicted in Fig. 1.6, along with the extent of the LiDAR-clipped wet areas after polygonising the $0 < DTW < 0.5$ m wet area / wetland delineations.

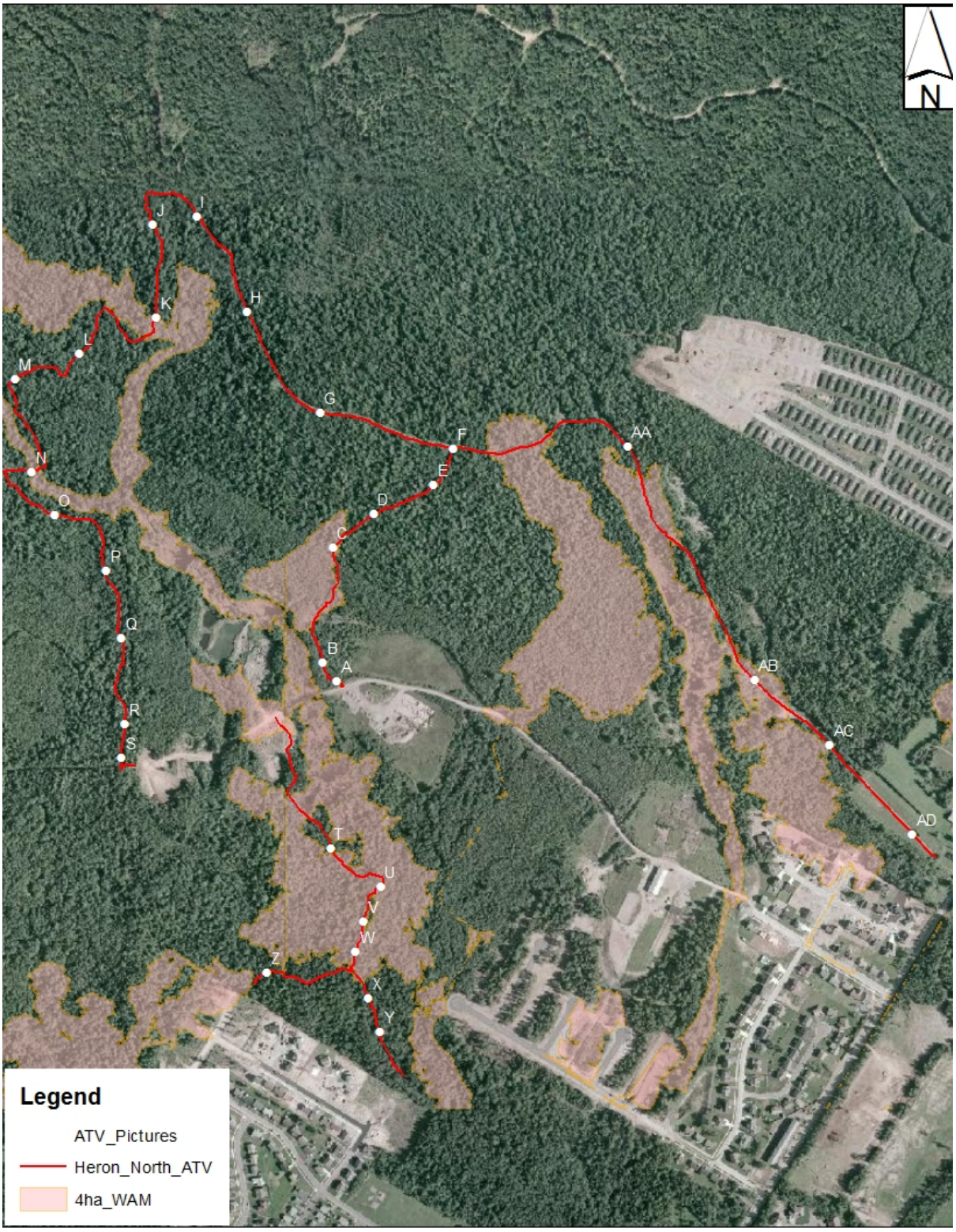


Fig. 1.6. Heron wetlands displaying ATV trails and LiDAR-derived wet-area / wetland delineations

Fig. 1.7 shows a direct comparison between a geoNB wetland southeast of the Heron Road development areas, the on-the-ground wetland delineation, and the LiDAR-DEM derived wet area extent. Since the on-the-ground delineation is in part restricted to noticing the presence of wetland obligatory vegetation, it would miss areas that have recently been disturbed.

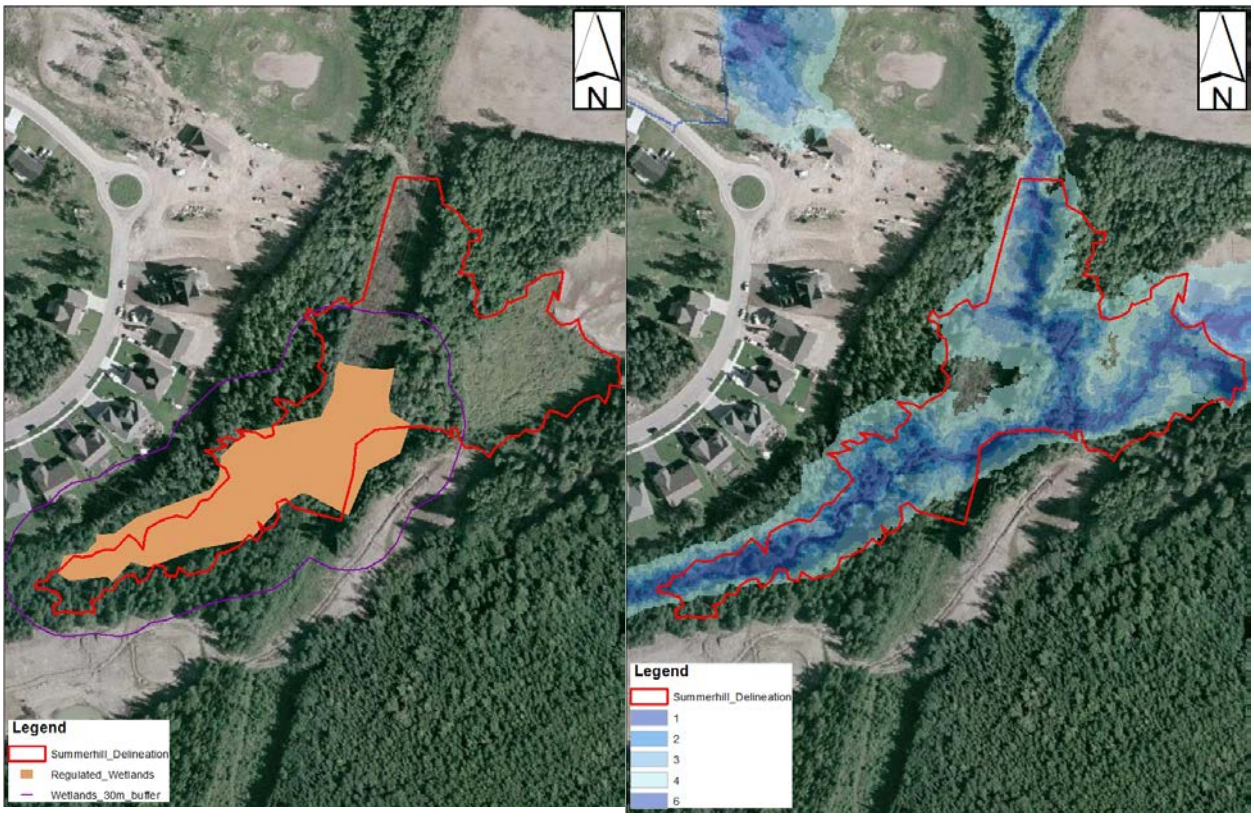


Fig. 1.7. Comparison between a geoNB wetland and the corresponding on-the-ground wetland, and LiDAR-DEM derived wet area delineations east of the Heron Road wetland areas (Summerhill Road).

Section 2: Moncton

Wetland delineation and wet-areas mapping in Moncton was done for a wet area complex located along and south of the Humphrey Brook Trail and east of Fairview Knoll (Fig. 2.1). While the areas available for on-the ground delineation were in part restricted, wet-areas mapping was done for the combined shaded areas in Fig. 2.1 and beyond across the entire LiDAR-DEM coverage for Moncton.

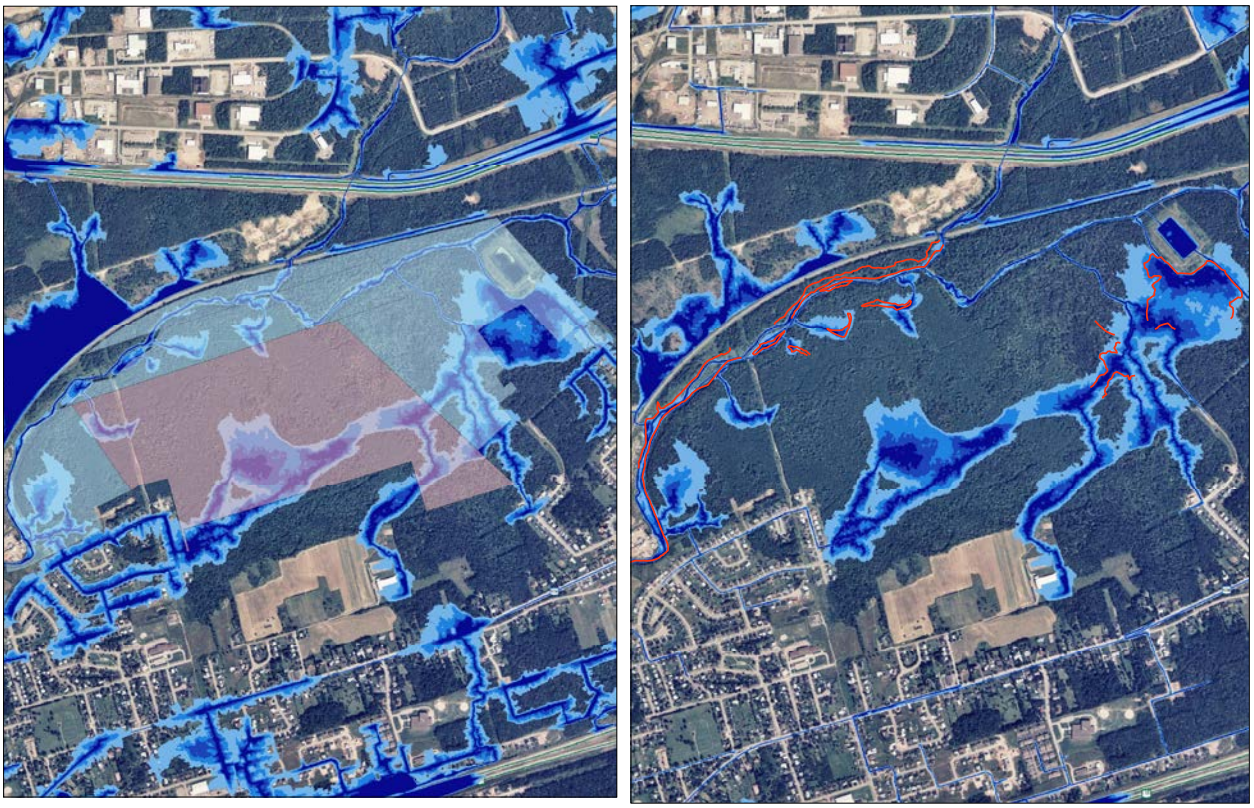


Fig. 2.1. Wet area and wetland delineation south of the Humphrey Brook Trail and east of Fairview Knoll in Moncton, also showing areas available and not available for on-the-ground wetland delineation.

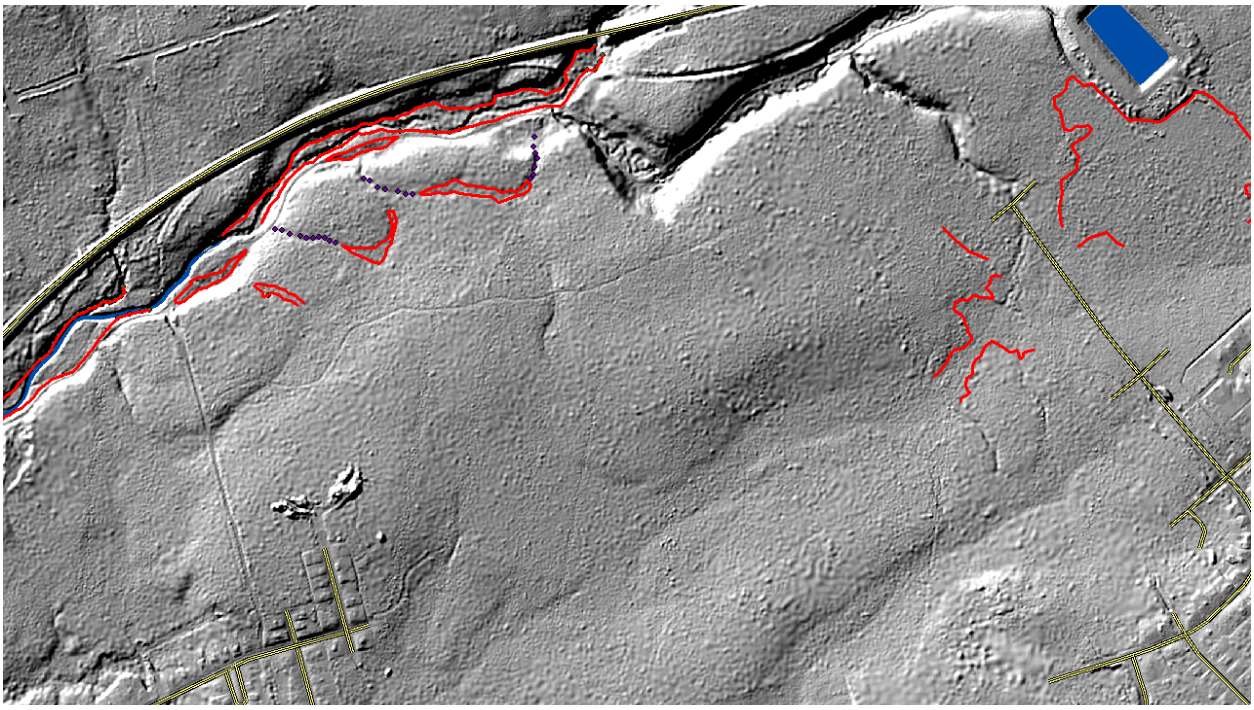


Fig. 2.2. Hill-shaded LiDAR DEM for a section of the Humphrey Brook Trail area in Moncton, with wetland delineations overlaid.

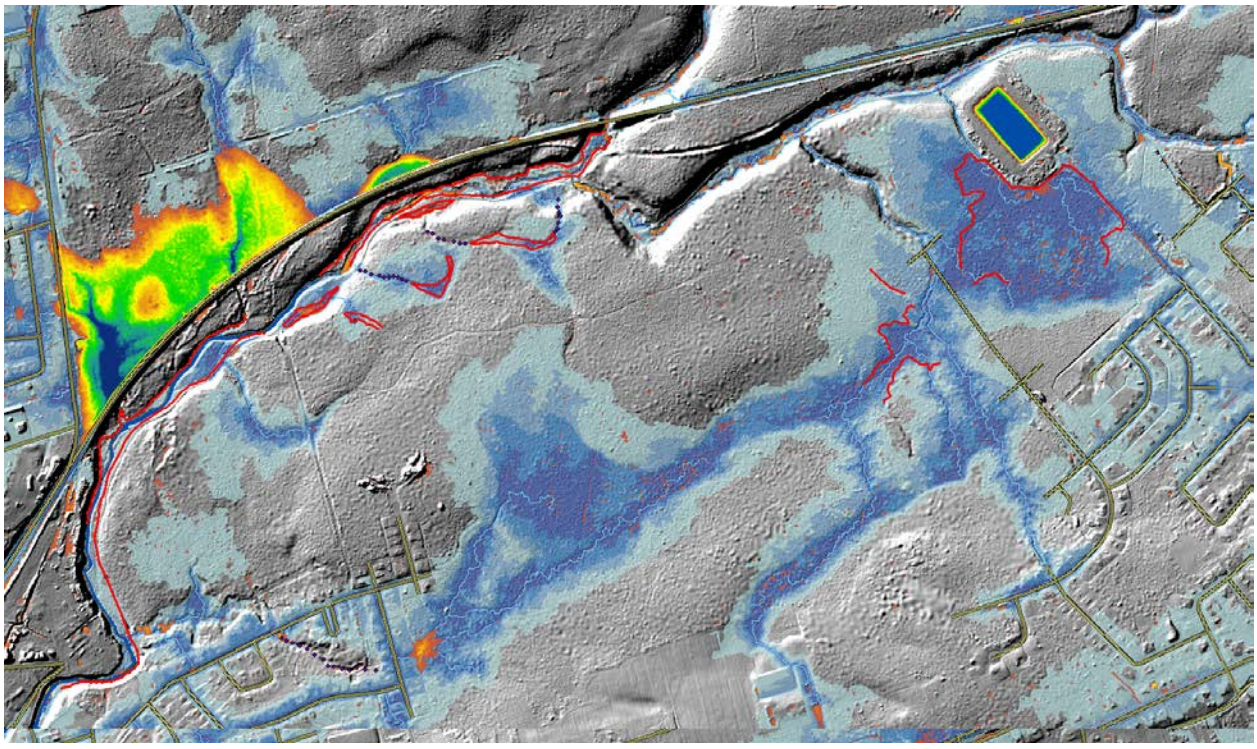


Fig. 2.3. Same as in Fig. 2.2., also showing the blue-shaded wet-areas mapping detail, indicating that the wetlands selected for delineation generally coincide with the LiDAR-DEM derived depth-to-water < 0.5 m areas.

Section 3: Miramichi

The Miramichi on-the-ground and LiDAR-DEM derived wetland and wet area delineations (Fig. 3.1, 3.2) address seven wetlands ("Miramichi Wetland Assessment", Overdale Environmental Inc. 2014; wetland delineators: Theo Popma and Harry Collins). These wetlands include Freshwater Marshes, a Shrub Swamp, a Forested Wetland, a Fen, and a Coastal Wetland. (Fig. 3.3).

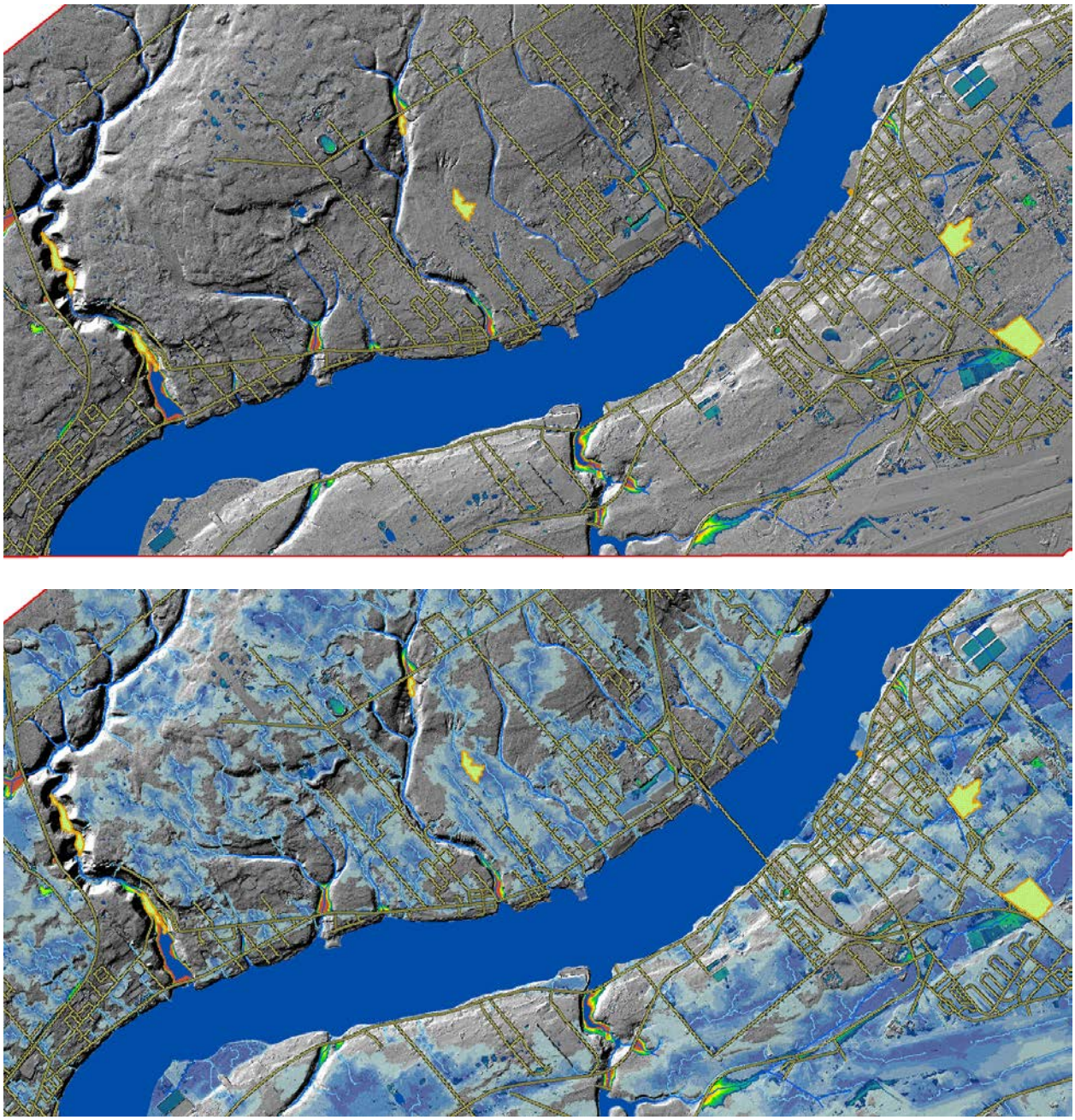


Fig. 3.1. On-the-ground and LiDAR-DEM derived wetland and wet area delineations for the Miramichi area.

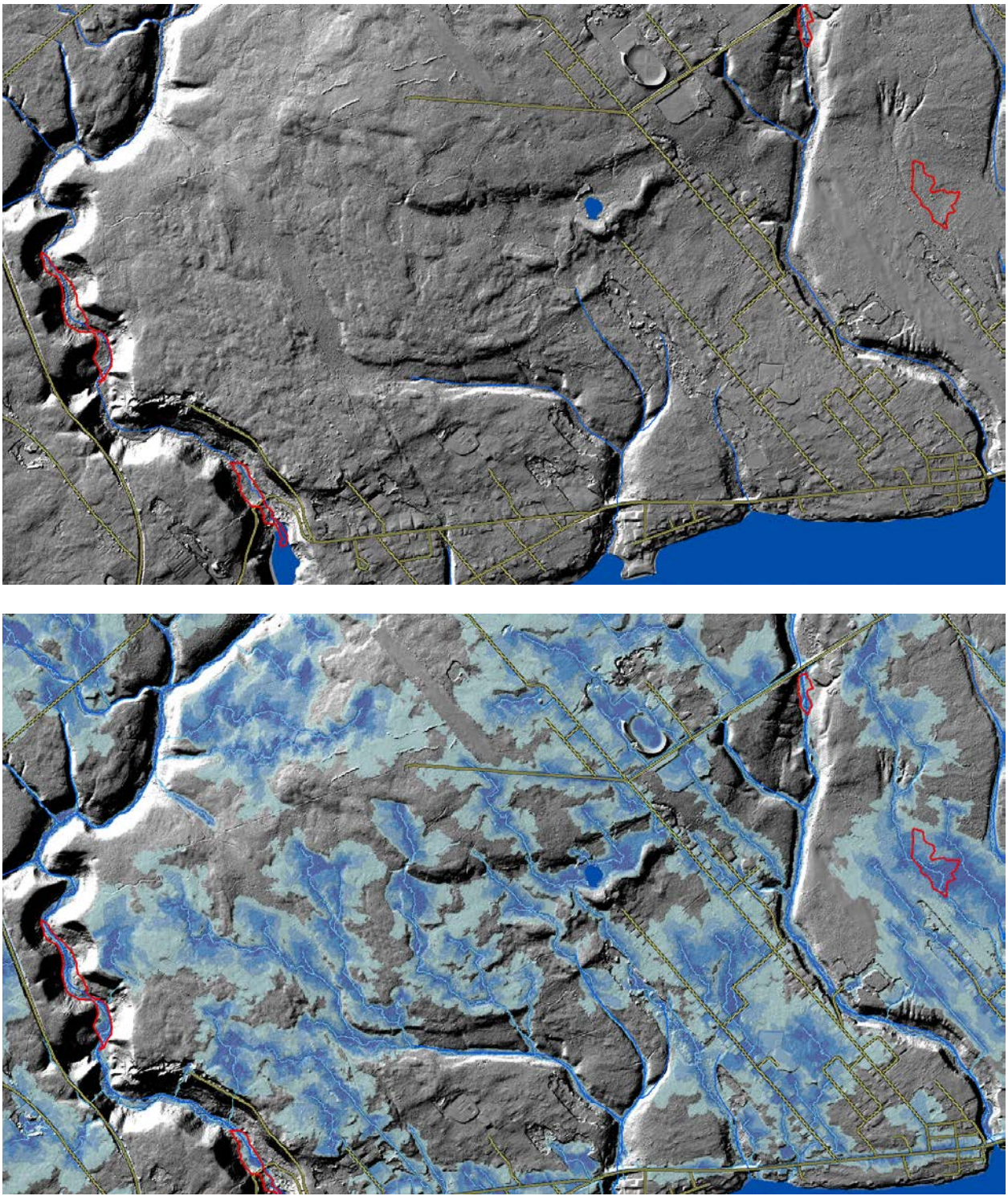


Fig. 3.2. Close-up of Fig. 3.1 for the wetland delineations north of the Miramichi River. These include the Freshwater Marshes (left), the Shrub Swamp (top right), and the Fen (right) in Fig, 3.2, all bordered by red lines.



Fig. 3.3. Miramichi wetland types.

Figs. 3.4 show details concerning the on-the-ground wetland delineations and the LiDAR-DEM derived wet-area derivations for the forested wetlands south of the Miramichi River. Also shown are the corresponding geoNB outlines. In both cases, the geoNB outlines are the most restricted. The LiDAR-DEM derived wet-areas show were the soil would currently be wet, and how the originally delineated wetland would have been modified by recent to current developments, as exemplified in Fig. 3.3 by the curved border to the north, and the trail-induced soil wetness through the middle of the wetland.

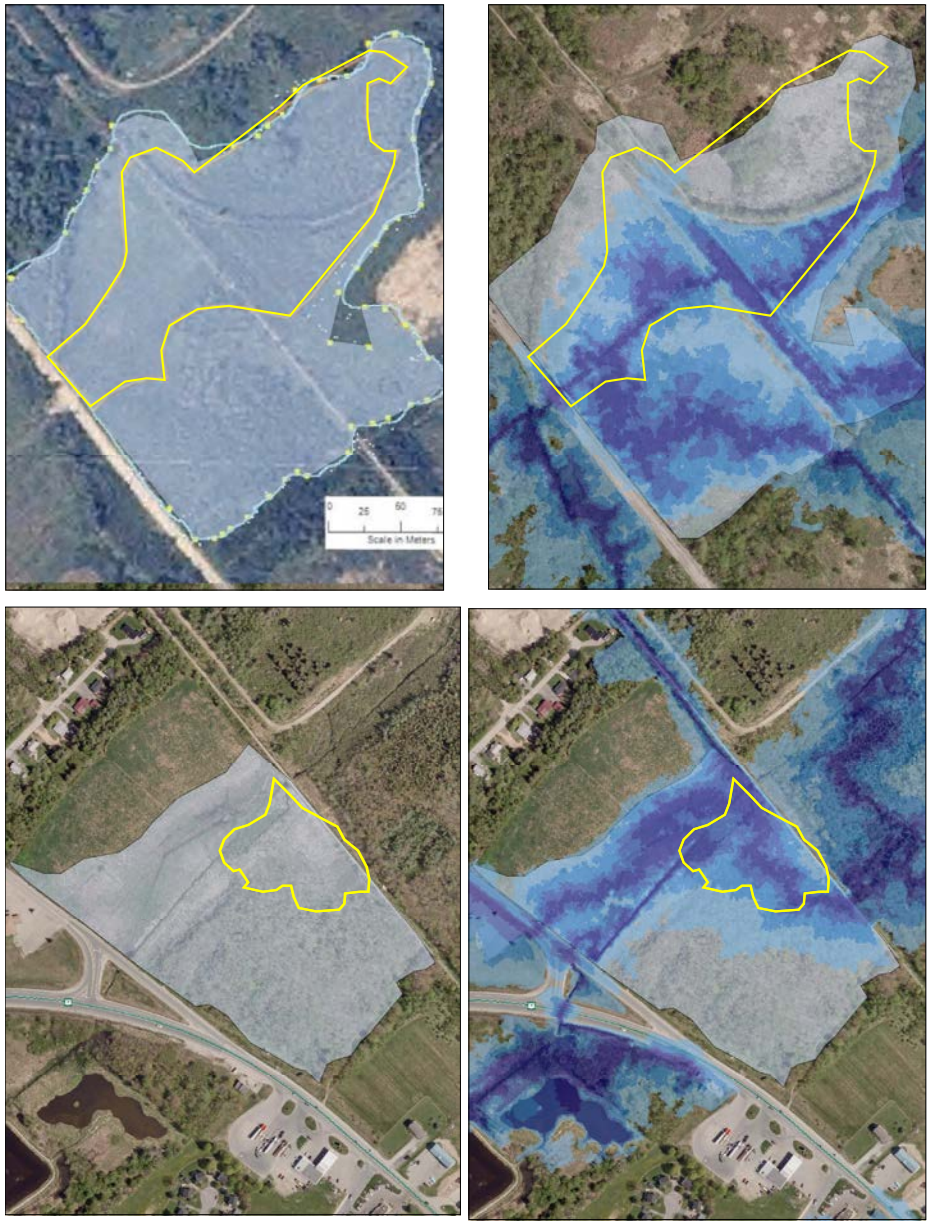


Fig. 3.4. On-the-ground, geoNB and LiDAR-DEM derived wetland and wet area (4 ha flow initation) delineations for the two forest wetlands south of the Miramichi River.

Fig. 3.5 shows how soil wetness for one of the forest wetland s in Fig. 3.4 would change once the flow channels fill up with water at 1 ha flow initiation. In this case, the area marked by the on-the-ground wetland delineations would also become wet as the depth to water rises to within 1 m of soil depth

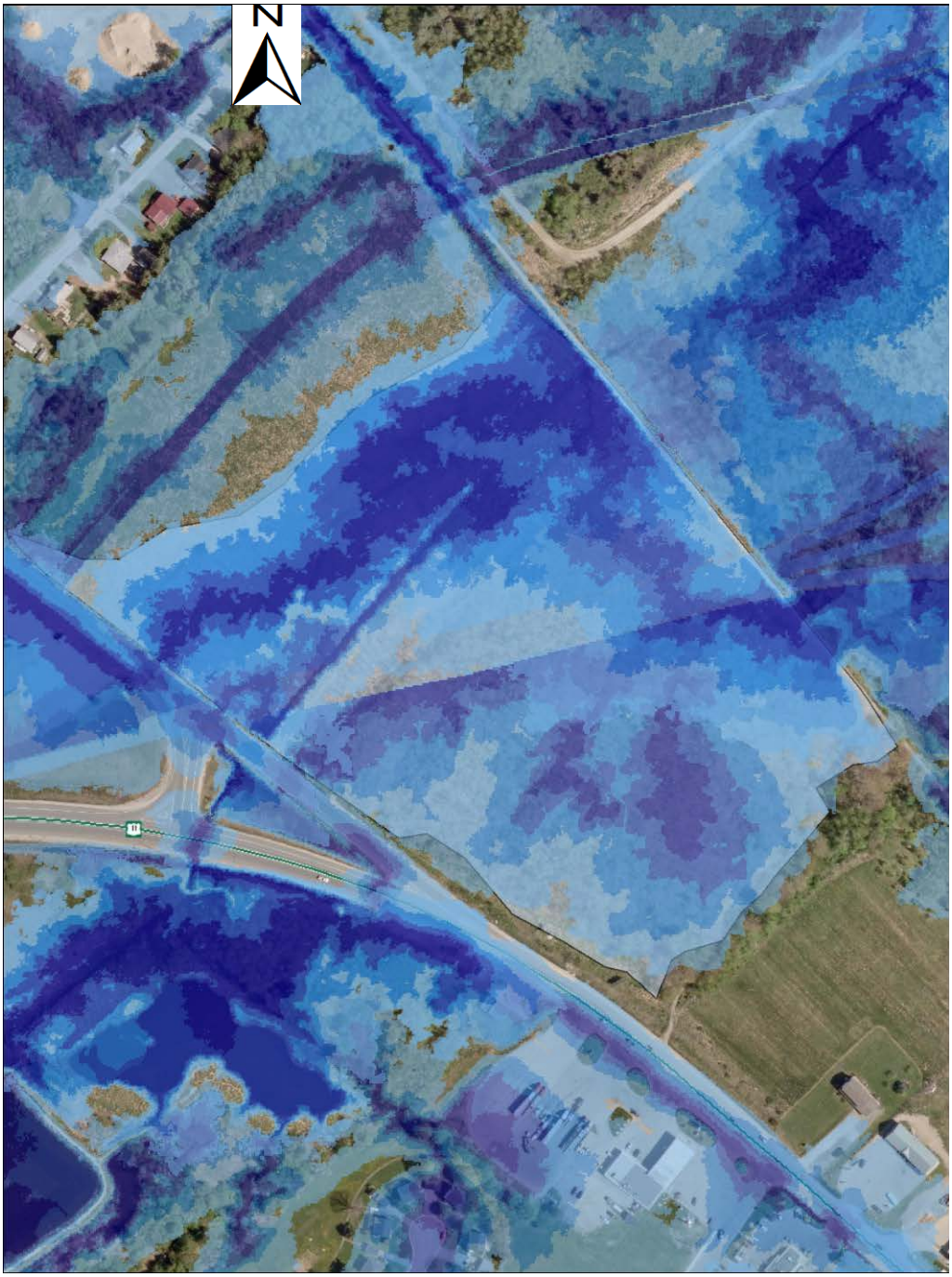


Fig. 3.5. LiDAR-DEM derived wet area (1 ha flow initiation) delineations for one of the two forest wetlands south of the Miramichi River.

Section 4: Bathurst

The Bathurst wetland delineations include two areas (Fig. 4.1). The northern component shows a tidal coastal swamp, and the southern wetlands are basin swamps (Fig. 4.2)

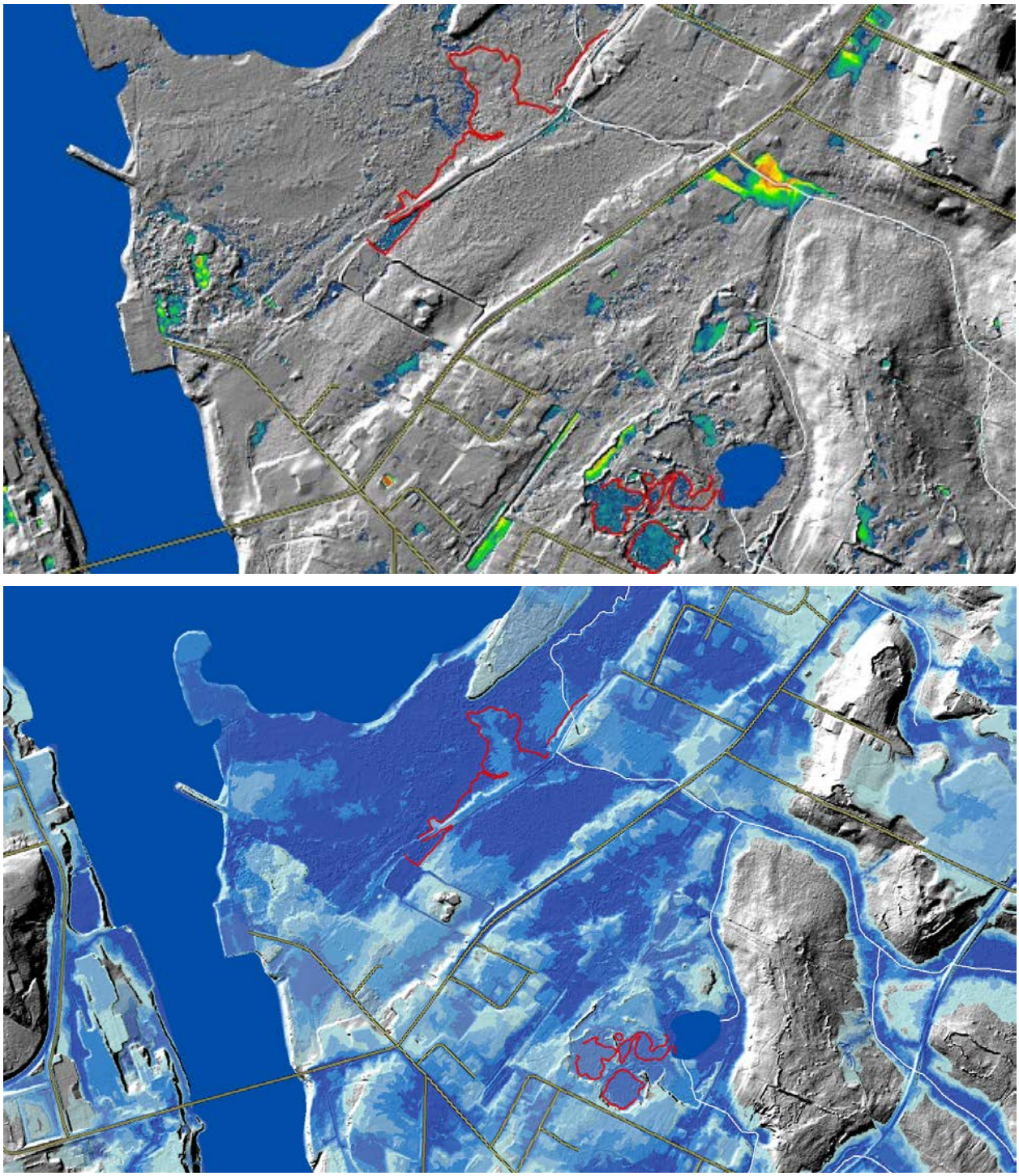


Fig. 4.1. Hill-shade DEM with on-the-ground wetland and LiDAR-DEM derived wet area (1 ha flow initiation) delineations.



Fig. 4.2. Google images of the two wetland areas in Fig. 4.1. Left: Tidal Freshwater Swamp. Right: Basin Swamps.

The coastal wetland was in part dominated by white spruce (*Picea glauca*) and eastern white cedar, corresponding to fresh water habitats; and in part dominated by graminoid and reeds corresponding to brackish and/or saline conditions (Fig. 4.3).

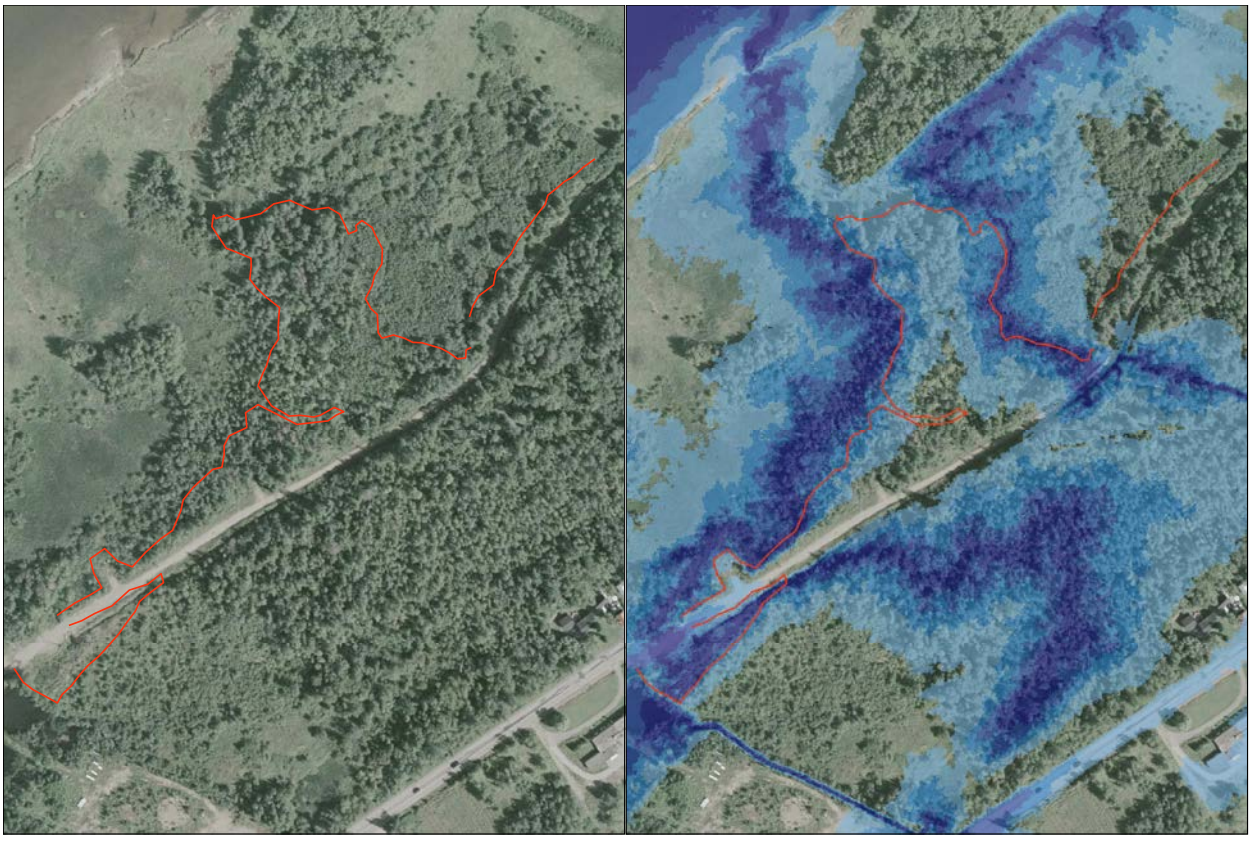


Fig. 4.3. Bathurst GeoNB basemap imagery of tidal freshwater swamp with delineation vs same image with 4ha WAM.

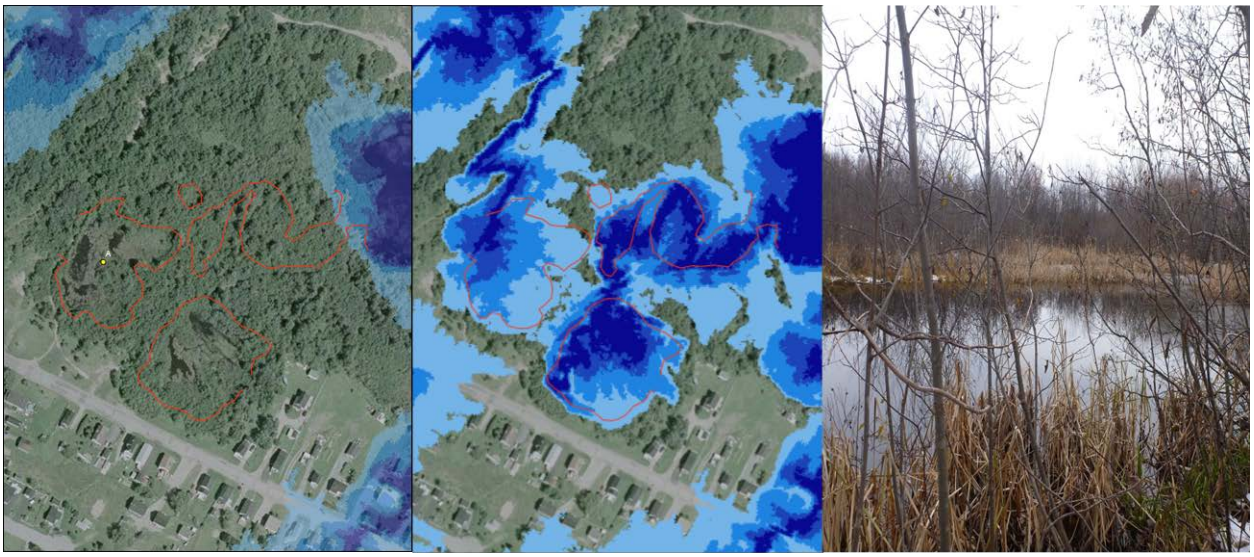


Fig. 4.4. Basin marshes with 4 (left) and 1 (middle) ha wet-areas mapping delineations. The 4 ha wet-area delineations generally correspond well with end-of summer soil wetness delineations; the 1 ha generally correspond well with soil wetness during wet seasons. Top right: water conditions in November, 2014.

Appendix 2: Frequently Asked Questions

What is LiDAR?

Light Detection and Ranging (LiDAR) is a form of remote sensing that utilizing short-bursts of pulsed laser to detect the range of elevations over a surface. LiDAR is often derived from an airborne laser (either on an airplane or helicopter). A sensor at the bottom of the aircraft measures the time taken to for the laser to reflect off the surface back to the aircraft to determine the topography of the ground. Each point is then calculated to have a longitudinal, latitudinal and height spatial coordinates.

The LiDAR typically used by the University of New Brunswick in their research is a 1 meter resolution and sometimes can be as precise as 50 centimeters. This is in comparison to provincial data which is around 10 meter resolution.

What is DEM?

A Digital Elevation Model (DEM) is a digitalized image of an elevation as derived from LiDAR. A DEM provides an image of how the topography looks over an area as well as the elevational changes across the location. Thus, this allows for a model to be created that visually displays the data gathered by the initial LiDAR.

What is WAM?

Wet Area Mapping (WAM) is the predicting of flow channels through DEMs. It can be used to determine areas where water is present either at the surface of subsurface. It is separated into three categories directly relate to varying flow seasons. With a 4 hectare WAM, it requires 4ha of land to accumulate enough water for the initiation of flow. This is most commonly seen during the summer months when the ground is the driest. A 1ha WAM is during the late fall into early winter months where more water is present and less hectares are required to initiate flow. Finally, a 0.25ha flow is during the melting season where rain and melt saturates the ground, resulting in minimal hectares required for flow initiation.

What is a wetland?

A wetland is an area where water is at or right below the surface either seasonally or year round. A typical wetland has several centimeters of standing water for a majority of the year and as such the plant and wildlife are adapted to wet environments. There are five major wetland types: marsh, swamp, bog, fen and shallow open waters.

What is wetland delineation?

Wetland delineation is the process of mapping wetlands by walking their borders. Since wetlands are protected, this is vital when planning on developing an area where a wetland may be present. The process of delineation is when a certified wetland delineator walks the boundary of areas that are either wet or predicted to be wet in a form of “ground-truthing”. Through this they are able to examine fauna, flora and soil composition, all of which aid in the determining of if an area should be considered a wetland.

Will LiDAR replace the need for a wetland delineator?

No, but LiDAR and WAM will reduce the time necessary for a wetland delineator to find a questionable wet area. With WAM, a delineator would be able to locate saturated areas faster and more effectively to begin their delineation, thus adding additional time to conduct the surveys. With WAM, a delineator knows what areas are prone to flooding and is able to focus their analysis there to determine if the fauna, flora and soil composition are conclusive with wetlands. Even with the best LiDAR and WAM, we would still recommend a delineator to “ground-truth” the location for additional variables that cannot be analyzed through LiDAR.

Appendix 3: Contact List

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