Creation of Land Cover and Wetland Inventory Datasets for the Bow River Basin

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Report Prepared by: Shari Clare and Shantel Koenig

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1.0 Introduction

Accurate and up-to-date wetland mapping data is essential for improving management outcomes for existing wetland habitats, as well as for identifying locations of historical loss and wetlands that have been previously impacted and are candidates for restoration. In Alberta, there are several wetland datasets that are publicly available; however, these datasets have several issues that limit their effectiveness for local and regional land use and conservation planning. This includes issues around spatial coverage, vintage, resolution, and accuracy (Miistakis Institute 2020).

As part of an initiative to improve access to wetlands data in the Bow River Basin, Miistakis Institute engaged with their partners to secure funding for the development of new regional wetland datasets. The primary intent behind this initiative is to create consistent spatial information that can be used by a wide range of organizations across the region for land use planning, as well as for a range of other wetland monitoring, conservation, and restoration initiatives.

Miistakis Institute retained Fiera Biological Consulting to create the new spatial datasets for the Bow River Basin. As part of this work, our team created four new spatial datasets, including a current Land Cover Inventory, Wetland Inventory, Restoration Wetland Inventory, and Historical Wetland Inventory.

This report outlines the methods used to create each of these datasets. Additionally, the report outlines considerations for the appropriate use of the data, along with suggestions for how the data sets can be used to assist with land use and conservation planning at local and regional scales.

2.0 Study Area

The study area is expansive, spanning 35,787 km^2 across southern Alberta, which is approximately 5% of the province. The study area was focused on the portions of the Bow River HUC 4 watershed that are located outside of the mountain parks. Because municipalities were identified as a primary end-user of the datasets, the study area was expanded to include all portions of the following rural municipalities that intersect the Bow River basin: M.D. of Bighorn, Kananaskis I.D, Rocky View County, Foothills County, Wheatland County, Vulcan County, and the County of Newell (Figure 1).

The study area has an extensive hydrological network that flows across a highly variable landscape that includes the Rocky Mountain, Foothills, Parkland, and Grassland Natural Regions (Figure 2). Climate, soils, vegetation cover, and land use is diverse throughout the study area. Mountains and forests dominate in the west, with grasslands and wetlands dominating the central and eastern portions of the study area.

Land use in the study area is diverse, with the most dominant land uses being forestry, urban development (including the large metropolitan centre of Calgary), and agriculture (both intensive cropping and ranching). Historically, a large proportion of natural cover (predominantly grasslands and wetlands) has been converted to other land uses, particularly with the central and eastern portions of the study area.

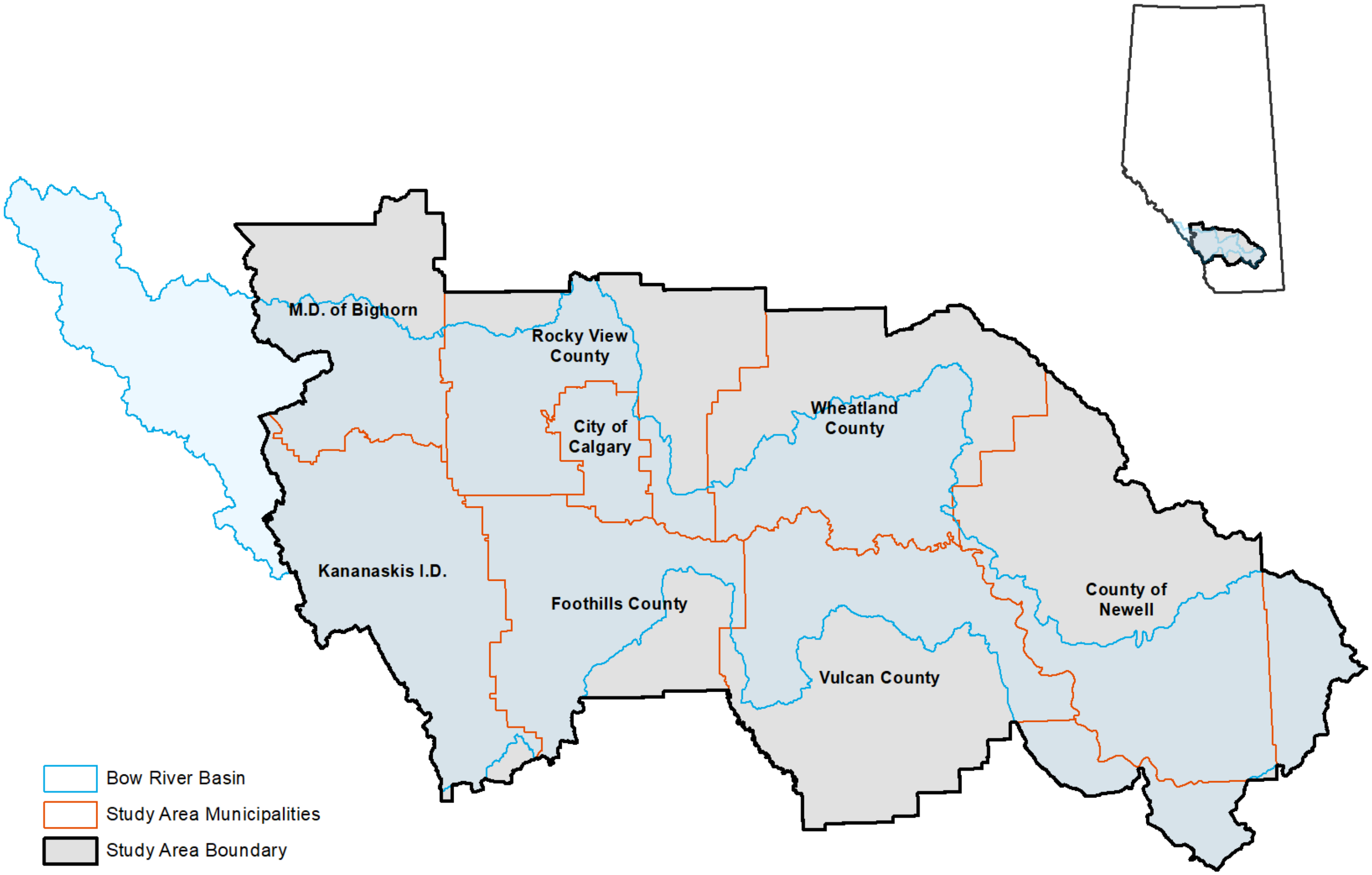


Figure 1. Study area extent in relation to the Bow River HUC 4 watershed and municipal boundaries that make up the study area.

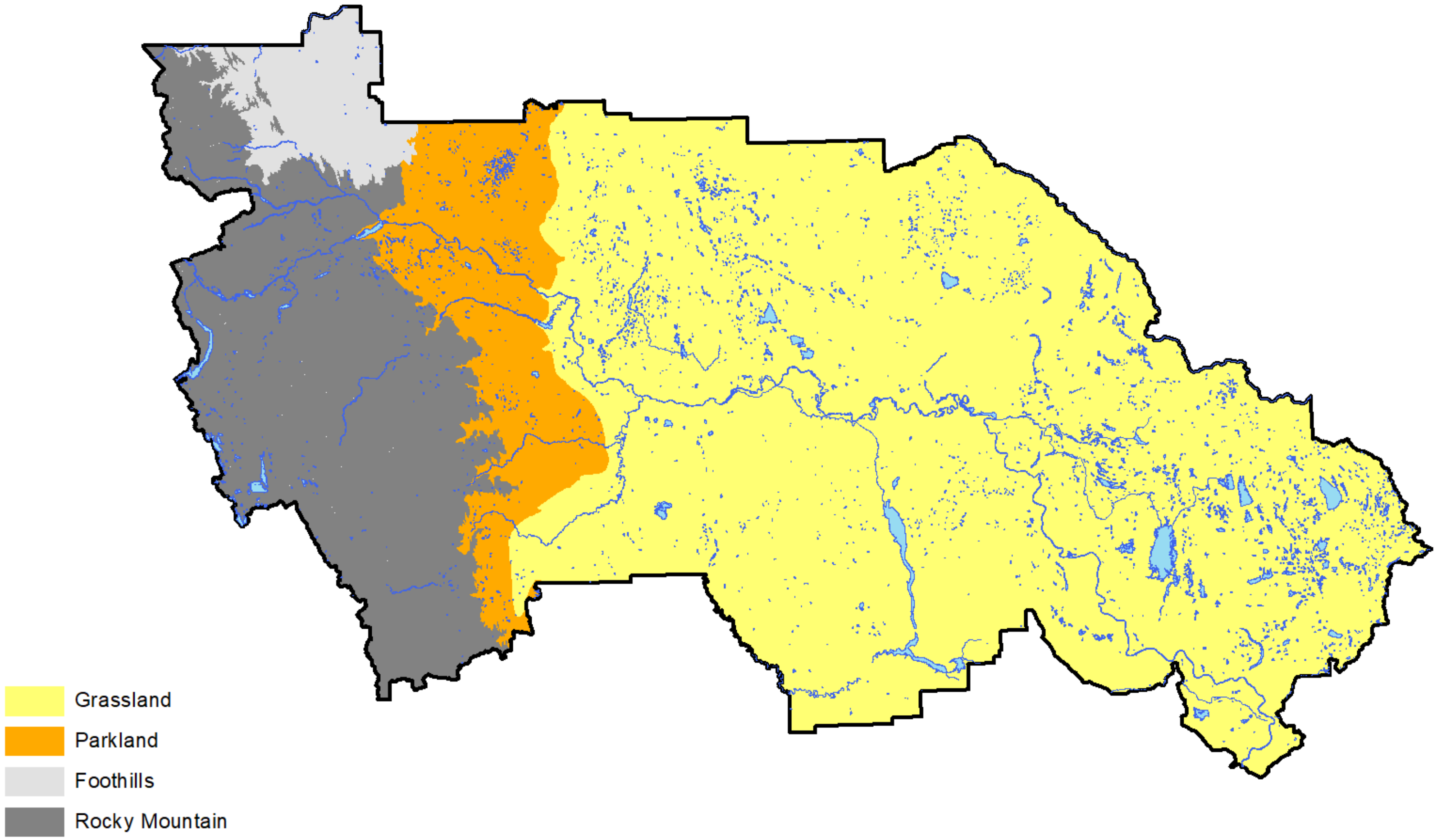


Figure 2. Natural Regions and major hydrologic features (rivers and lakes) located within the study area.

3.0 Land Cover

3.1. Overview

One of the first tasks in creating any land cover classification is to clearly define the primary purpose and user(s) of the data. This is an important consideration because it influences both the thematic resolution (i.e., number of land cover classes) and the spatial resolution (i.e., the minimum mapping unit) of the land cover data. Notably, the thematic and spatial resolution of the land cover is also influenced by more practical considerations, including the spatial and spectral resolution of the input datasets, and trade-offs related to the size of the study area and the associated budget/timeline available for producing the data.

For this land cover dataset, the primary purpose for its creation was to use the data as an input into the creation of a wetland inventory. A secondary purpose for the creation of the land cover data is to make it available to municipalities for landscape-level land use planning.

To create a dataset that serves both purposes, a hierarchical land cover classification with two levels was developed. Level 1 includes 10 broad land cover classes, while Level 2 has a much higher thematic resolution with 18 classes that nest within the broader Level 1 classes (Table 1). Because the primary purpose of the land cover was to use it as an input into the creation of a wetland inventory, the land cover includes very detailed “Lowland” classes at Level 2 that are not typically found in other, more basic land cover classifications. These classes were necessary to allow for the assignment of a wetland class as per the Alberta Wetland Classification System (AESRD 2015).

The spatial resolution of any land cover classification is primarily driven by the resolution of the input datasets, and in particular, the imagery used as the basis for the classification. The resolution of the imagery dictates the minimum mapping unit (MMU), which defines the smallest feature that is resolvable in a land cover classification. The lower limit of MMU size is determined by the pixel size of the imagery used to create the land cover, and for this project, we are working with SPOT 6/7 imagery with a pixel size of 6 m x 6 m (0.0036 ha). For reference, 0.0036 ha is approximately the size of a single-car garage. The upper limit of MMU is a choice determined by several factors, including the purpose of the classification, acceptable detection limits of the smallest landscape features of interest, size of the overall coverage area, and desired smoothness and homogeneity of the features in the land cover map. While a smaller MMU makes it possible to detect and map small features, it often yields a “noisy” classification (i.e., highly speckled) in appearance, and the time and effort required to clean-up and validate a classification at this resolution is extensive and costly, particularly over large geographic areas.

One of the intended uses of this dataset is to use it to support a wide range of municipal land use planning and mapping objectives. Considering the large size of the study area, and the more generalized land use planning applications, an MMU of 0.022 ha was selected. This mapping unit strikes a reasonable balance between resolution and accuracy.

Table 1. Land cover classes that were used to derive the land cover classification for the Bow River Basin study area.

Category	Level 1 Classification	Level 2 Classification	Class Definition
Open Water	Open Water	Open Water	Any deep or shallow open ponded (lakes, permanent wetlands, standing water) or flowing water. Includes artificial waterbodies (e.g., dugouts, stormwater ponds, and reservoirs).
Upland	Forest	Coniferous	Areas covered by coniferous (needle-leaf) trees.
		Deciduous	Areas covered by broadleaf trees.
		Shrub	Areas covered by shrubs (<2 m height). Includes shrubs in riparian areas.
	Natural Grassland	Natural Grassland	Areas dominated by native graminoids and forbs. Includes grasses in riparian areas.
	Natural Bare Ground	Natural Bare Ground	Naturally occurring areas of rock, bare soil, sand, sediment.
	Snow/Ice	Snow/Ice	Areas permanently or seasonally covered by snow or ice, including glaciers.
	Agriculture	Pasture	Agricultural areas used primarily as pasture or hayland.
		Cropland	Agricultural areas used primarily as cereal crop. Tilled most years.
	Disturbed Vegetation	Disturbed Vegetation	Non-agricultural human-impacted or managed non-woody vegetation. pipeline right of ways, wider seismic lines, vegetation in settled areas, golf courses, vegetation around industrial buildings, well sites, and cut blocks.
	Built Up/Exposed	Human Built	Human built features and human-caused exposed/bare areas.
		Roads	Paved and unpaved roads, as well as major railways.
Lowland	Natural Depression	Lowland Mineral Woody	Depressional or low-lying areas dominated by mineral soils and coniferous/deciduous tree or shrub cover.
		Lowland Mineral Graminoid	Depressional or low-lying areas dominated by mineral soils and emergent or graminoid vegetation cover.
		Lowland Mineral Saline	Depressional areas that are highly saline. This can include saline waters and/or saline mudflats.
		Lowland Peat Woody	Depressional areas dominated by coniferous/deciduous tree or shrub cover where surface water flow is apparent.
		Lowland Peat Graminoid	Depressional or low-lying areas dominated by emergent or graminoid vegetation and depressional areas adjacent to streams/creeks and lakes where surface water flow is apparent.
	Agricultural Depression	Lowland Mineral Disturbed	Low-lying depressional areas that are likely wetland basins but that have been impacted or altered by agricultural activity. In croplands these depressions are typically ephemeral, temporary, or seasonal marshes that are cultivated annually and/or drained basins that do not appear to have intact natural vegetation in most years. In pasture lands, these low-lying areas may be drained and/or utilized for agricultural purposes such as providing water for cattle.

3.2. Land Cover Classification Methods

A pixel-based Random Forest model was used to create the land cover layer for the Bow River Basin using multi-source datasets (Figure 3). Random Forest is a supervised machine learning classification algorithm that is commonly used to create land cover classifications. This approach builds a set of decision trees that are derived through a repeated selection of random subsets of training data, taking the majority vote for classification (Ho 1995).

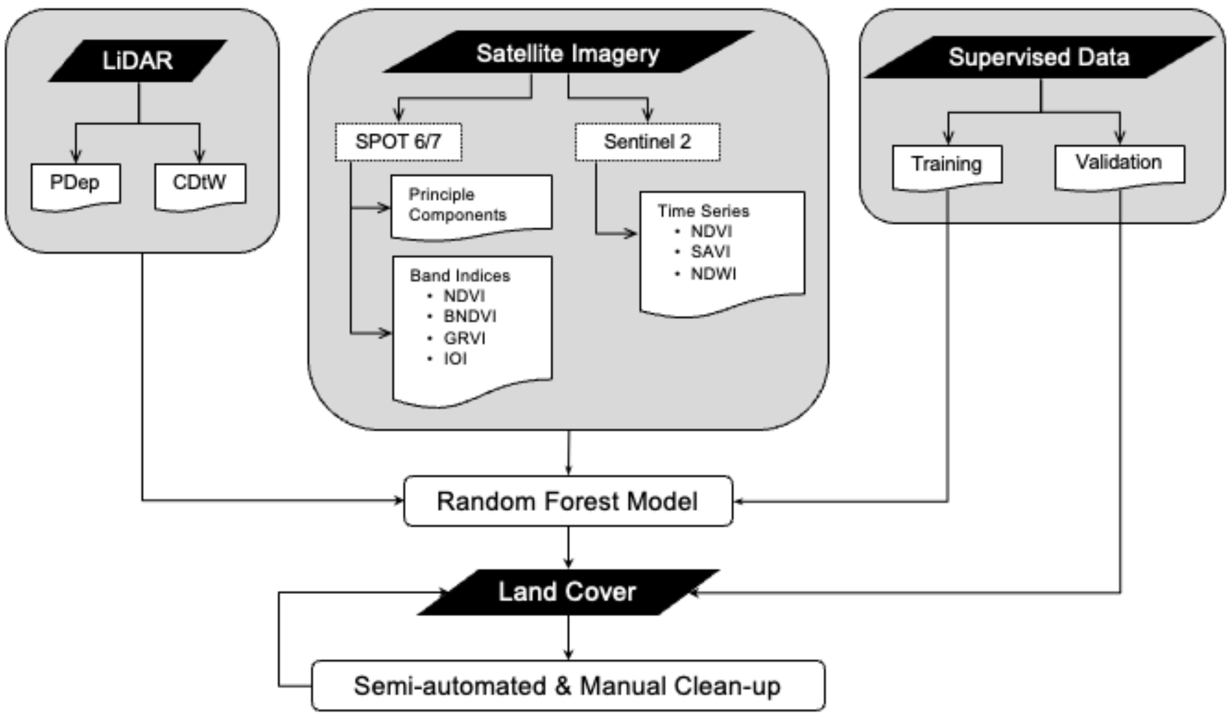


Figure 3. Overview of the primary steps used to create the Bow River Basin land cover dataset.

3.2.1. Image Selection

The land cover classification (hereafter "wall to wall land cover") was created using 6 m resolution multi-band SPOT 6/7 imagery that was provided for use by the Government of Alberta (GOA). To select the best images for classification, imagery was requested from different years (2017 through 2020) and seasons (i.e., spring, summer, fall). Given the large spatial extent of the study area, the first step in the creation of the land cover was to review and select the most appropriate and consistent set of images for the classification. Images were selected based on quality (e.g., minimal cloud cover), and year/month of acquisition, with the goal of selecting a set of images that balanced the ability to accurately identify the classes of interest with temporal consistency across the entire study area. To ensure the land cover would be as current as possible, nearly all images were chosen from 2020, and cloud-free/low-cloud images were only available in the months of June, July, and August. Images from 2017, 2018, and 2019 had to be used to classify small areas where no cloud free images from 2020 were available. In total, 16 SPOT images were required to cover the study area (Figure 4; Table 2).

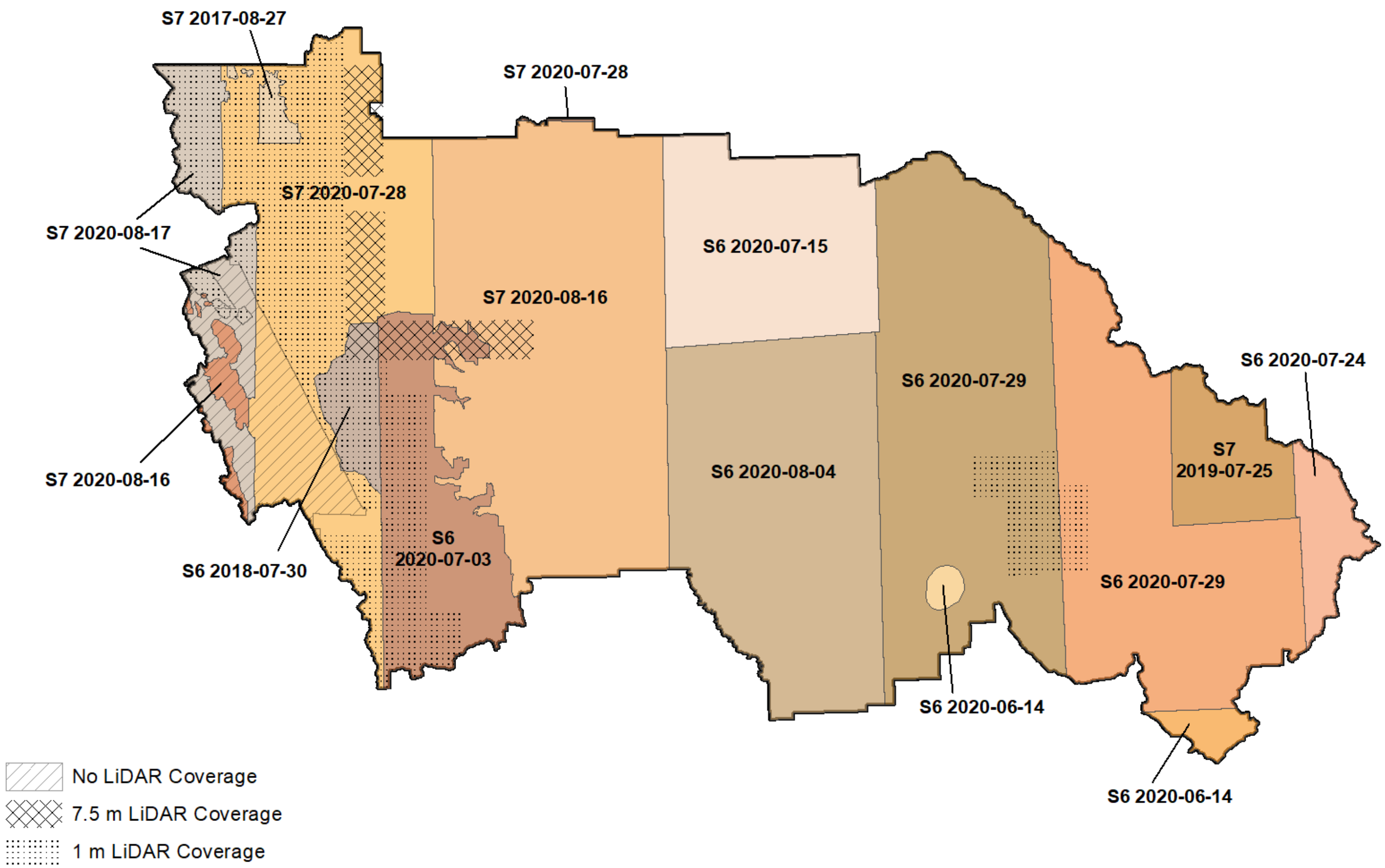


Figure 4. Coverage and vintage (year-month-day) of the SPOT images and coverage and resolution of the LiDAR data used to create the land cover for this project. Areas outside of the 1 m, 7.5 m, and no LiDAR coverage were covered by 15 m LiDAR.

Table 2. Year and month of SPOT images used to create the land cover products.

Year	Month			Number of Tiles
	June	July	August	
2017	-	-	1	1
2018	-	1	-	1
2019	-	1	-	1
2020	2	7	4	13
	2	9	5	16

In addition to the 6 m multispectral SPOT images that were used to run the land cover classification, we used pan-sharpened 1.5 m SPOT composite mosaic images from 2020 to select training and validation data. High-resolution imagery from Google Earth and ArcGIS base maps were used to assist with the interpretation of the 6 m SPOT imagery. The 1.5 m SPOT imagery was also used as a reference image during the quality assurance and quality control (QA/QC) check of the classification outputs.

A standard approach to producing a land cover classification for a large area (i.e., spanning multiple image tiles) is to merge all image tiles together into a unified mosaic, select training data across the entire project area, and run a single classification model. This approach is feasible if all image tiles have been calibrated in a known and standardized way; however, this is not the case with the GOA SPOT data. Instead, our approach was to train and run a unique classification model for each of the 16 SPOT tiles, which increased the overall data management workload, but produced a higher level of overall quality and classification accuracy.

3.2.2. Layer Stack Creation

Multiple sources were used to create derived data products (the “layer stack”) that were used in the Random Forest classifier. The SPOT 6/7 imagery was used to generate layers for Normalized Difference Vegetation Index (NDVI), Blue Normalized Difference Vegetation Index (BNDVI), Green Ratio Vegetation Index (GRVI), and Iron Oxide Index (IOI) (Table 3). Principal components analysis was used to derive layers for the first four components of the 4-band SPOT imagery. Additionally, Sentinel 2 satellite imagery (10 m resolution) was used to perform a time series analysis to generate mean and standard deviation maps of NDVI, Soil Adjusted Vegetation Index (SAVI), and Normalize Difference Water Index (NDWI). This historical image analysis was performed in Google Earth Engine and included the months of May through September for the years 2013 through 2020.

Elevation data was used to derive secondary terrain layers that included Probability of Depression (PDep) and Cost Distance to Water (CDtW). These layers were primary created using a 15 m Digital Elevation Model (DEM) that was derived using LiDAR data. The resolution and quality of the LiDAR data varied, and coverage was not complete across the study area (Figure 13). Where coverage was lacking, the 20 m Provincial DEM was used to derive the secondary terrain products.

All the derived layers were resampled to 6m and combined into a layer stack that was used to run the Random Forest model for each SPOT tile in R (Version 4.0.3).

Table 3. Description of the spatial data obtained or derived for use in the creation of the land cover.

Data Layer	Year	Source	Usage
SPOT 6/7 Satellite Imagery	2017-2020	Government of Alberta.	Used to create band ratio datasets (NDVI, BNDVI, GRVI, IOI) and Principal Components data for Random Forest Model.
Normalized Difference Vegetation Index (NDVI)	2017-2020	Fiera Biological. Layer created using SPOT 6/7 satellite data provided by the Government of Alberta.	Indicator of vegetation vigour and used to classify dominant vegetation types.
Mean and Standard Deviation of NDVI	2013-2020 (May-Sept)	Fiera Biological. Layers created using a time series of Sentinel 2 imagery.	Indicator of mean vegetation vigour and change in vigour over the growing season and used to classify dominant vegetation types.
Mean & Standard Deviation of Soil Adjusted Vegetation Index (SAVI)	2013-2020 (May-Sept)	Fiera Biological. Layers created using a time series of Sentinel 2 imagery.	Used to correct NDVI for the influence of soil brightness in areas where vegetative cover is low.
Blue Normalized Difference Vegetation Index (BNDVI)	2017-2020	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta.	Indicator of vegetation vigour and used to classify dominant vegetation types.
Green Ratio Vegetation Index (GRVI)	2017-2020	Fiera Biological. Layer created using SPOT 6/7 satellite data provided by the Government of Alberta.	Indicator of vegetation vigour used to classify dominant vegetation types.
Iron Oxide Index (IOI)	2017-2020	Fiera Biological. Layer created using SPOT 6/7 satellite data provided by the Government of Alberta.	Indicator of open (non-vegetated) areas.
Mean & Standard Deviation of Normalized Difference Water Index (NDWI)	2013-2020 (May-Sept)	Fiera Biological. Layers created using a time series of Sentinel 2 imagery.	Indicator of open water or areas with saturated soils and change in wetness or moisture over the growing season.
Principal Components 1-4	2017-2020	Fiera Biological. Layer created using SPOT 6/7 satellite data provided by the Government of Alberta.	Dimensionality reduction method to simplify spectral dataset to improve Random Forest Model prediction.
15 m DEM	n/d	Government of Alberta.	Used to create terrain layers (PDep, CDtW) for Random Forest Model.
Probability of Depression (PDep)	n/d	Fiera Biological. Layer created using LiDAR DEM data provided by the Government of Alberta.	Indicator of low-lying (depressional) areas.
Cost Distance to Water (CDtW)	n/d	Fiera Biological. Layer created using LiDAR DEM data provided by the Government of Alberta.	Indicator of soil moisture and areas where surface water flow is highly probable.
Roads	2019	Alberta Base Features.	Used to identify location of roads.
ABMI Human Footprint	2018/2019	Alberta Biodiversity Monitoring Institute.	Used to identify locations where human development and settlement have replaced natural land cover types.

3.2.3. Training Data Selection

The training data used to run the classifier was selected using manual and semi-automated methods. Where feasible, a semi-automated approach was used to extract training data from existing datasets (e.g., ABMI human footprint; Alberta Base Features) and personnel highly trained in image interpretation quality checked these data. Additional training data points were selected manually using the SPOT 6/7 1.5 m imagery and high resolution orthophotos. Training/validation data were manually selected for each SPOT scene for the following classes: Coniferous; Deciduous; Shrub; Lowland Graminoid Mineral, Lowland Woody Mineral, Lowland Graminoid Peat, Lowland Woody Peat, Open Water; Pasture; Cropland; Human Built; Natural Bare Ground; Snow/Ice. In total, 11,675 training data points were selected across the study area. For the classification of each SPOT tile, the training data overlapping the tile was extracted and 70% of the training data was used to train the classifier and the remaining 30% of the data was held back to validate the results.

Following the first stage of the classification, automated decision rules and manual editing were used to fix general classification errors. During this stage, the Natural Grassland class was added to account for areas of natural, non-woody low cover vegetation, and the Disturbed Vegetation class was added to account for non-agricultural human impacted low vegetation cover and areas with managed or manicured vegetation. The Lowland Graminoid Disturbed class was added to account for disturbed/modified wetland areas in agricultural fields, and the Lowland Mineral Saline class was added to account for saline/bare ground wetland areas. The Alberta Base features “Roads” layer was used to add in a Road class to complete the Level 2 land cover classification. Once the general classification errors were corrected, the land cover was ready for a manual quality assurance and quality control check (QA/QC).

3.2.4. Wall-to-Wall Land Cover QA/QC

The results of the random forest classification produced 16 individual land cover classifications. Each classification contained inconsistencies resulting from differences in the base SPOT imagery (e.g., season of image capture, cloud cover, shadow effects) and/or differences in quality and resolution of the elevation data used to derive terrain layers. To create a unified and consistent wall-to-wall land cover, we performed a rigorous review of each classified SPOT tile to assess and correct any systematic classification errors and to ensure consistent adherence to our class definition hierarchy across the entire study area.

The general method for this review and QA/QC process was to have trained photo interpreters review each scene using a grid-sweep approach at a pre-defined zoom level to ensure that an assessment of classification accuracy was performed thoroughly and at a consistent level of detail. We applied a standardized colour scheme to the land cover results so that the interpreters developed a consistent association between colour, class, and observed image features. Our photo interpreters worked on dual-monitor workstations, where one screen displayed the land cover results at 60-70% transparency overlain on the original SPOT 6 m or SPOT 1.5 m imagery, and an adjacent screen displayed a synchronized view of high-resolution Google Earth imagery to provide aid in feature interpretation. Any problems observed in the land cover layer were directly corrected by either re-assigning a class label and/or modifying land cover feature boundaries.

Our approach was to perform this QA/QC review in three stages. The first stage was performed at a coarse scale, during which reviewers assessed the general ecological accuracy of the distribution of classes within a tile, and identified and manually re-assigned class labels for large features that may have been frequently misclassified in a particular tile (e.g., darker agricultural vegetation frequently misclassified as one of the woody vegetation classes, freshly cultivated agricultural fields misclassified as human built). At this stage, errors addressed included those caused by patchy cloud cover, dark shadows, and solar glare. Tiles that had areas of cloud cover required manual digitization of the land cover features. In these areas, features were digitized at a scale of 1:20,000 and ArcGIS base maps were used as reference.

The second stage review was performed at a slightly finer scale with more attention to detail and with more time spent correcting misclassifications that were observed and noted during the first-round review. Given that the land cover was to be used to develop a wetland inventory, this review was primarily focussed on correcting upland versus lowland errors, and errors in lowland classes (i.e., Lowland Mineral Graminoid, Lowland Peat Graminoid, Lowland Mineral Woody, Lowland Peat Woody, Lowland Mineral Disturbed, Lowland Mineral Saline, Open Water). In particular, the Lowland Mineral Disturbed and Lowland Mineral Saline classes were added to account for disturbed (e.g., drained, cropped through, hydrologically modified/enhanced) and saline wetlands, respectively. At this stage, all lowland mineral graminoid features within agricultural fields (cropland, pasture) that were smaller than 600 m^2 were reassigned to the lowland mineral disturbed class to expedite the editing. Once this stage of review was complete, the 16 tiles were merged and the seams between tiles were reviewed to ensure consistency and accuracy.

The third and final stage of the QA/QC occurred after the development of the Current Wetland Inventory. During this final stage, the Identity function in ArcGIS was used to update the land cover with the Current Wetland Inventory. This step ensured that any edits to classes or boundaries in the wetland inventory were integrated into the land cover. Importantly, this step did not alter the classes of lowland polygons that were not included in the wetland inventory. A priority was placed on ensuring that class assignments were highly accurate at Level 1 of our class hierarchy, and that confusion between natural vs. anthropogenic features that are similar in appearance would be minimized (e.g., Natural Bare Ground areas misclassified as Human Built, Natural Grassland misclassified as Pasture). However, for some classes, there was an unavoidably high level of ambiguity between classes, and thus, it was difficult to differentiate and label these land cover classes with certainty. For example, in open grassland areas and valley and coulee areas of the Central and Eastern half of the study area, deciding whether the cover should be labelled as Natural Grassland or Pasture was often challenging. In these cases, the ABMI Human Footprint layer was used to help determine whether the cover was natural or agricultural, unless there was an obvious disagreement with the Human Footprint layer. This final stage of review was conducted to ensure classification consistency between a tile and its neighbors, as well as across ecological regions.

Once the QA/QC was complete, the land cover was converted back to a 6 m resolution raster to produce the final 2020 wall to wall land cover layer (Figure 5).

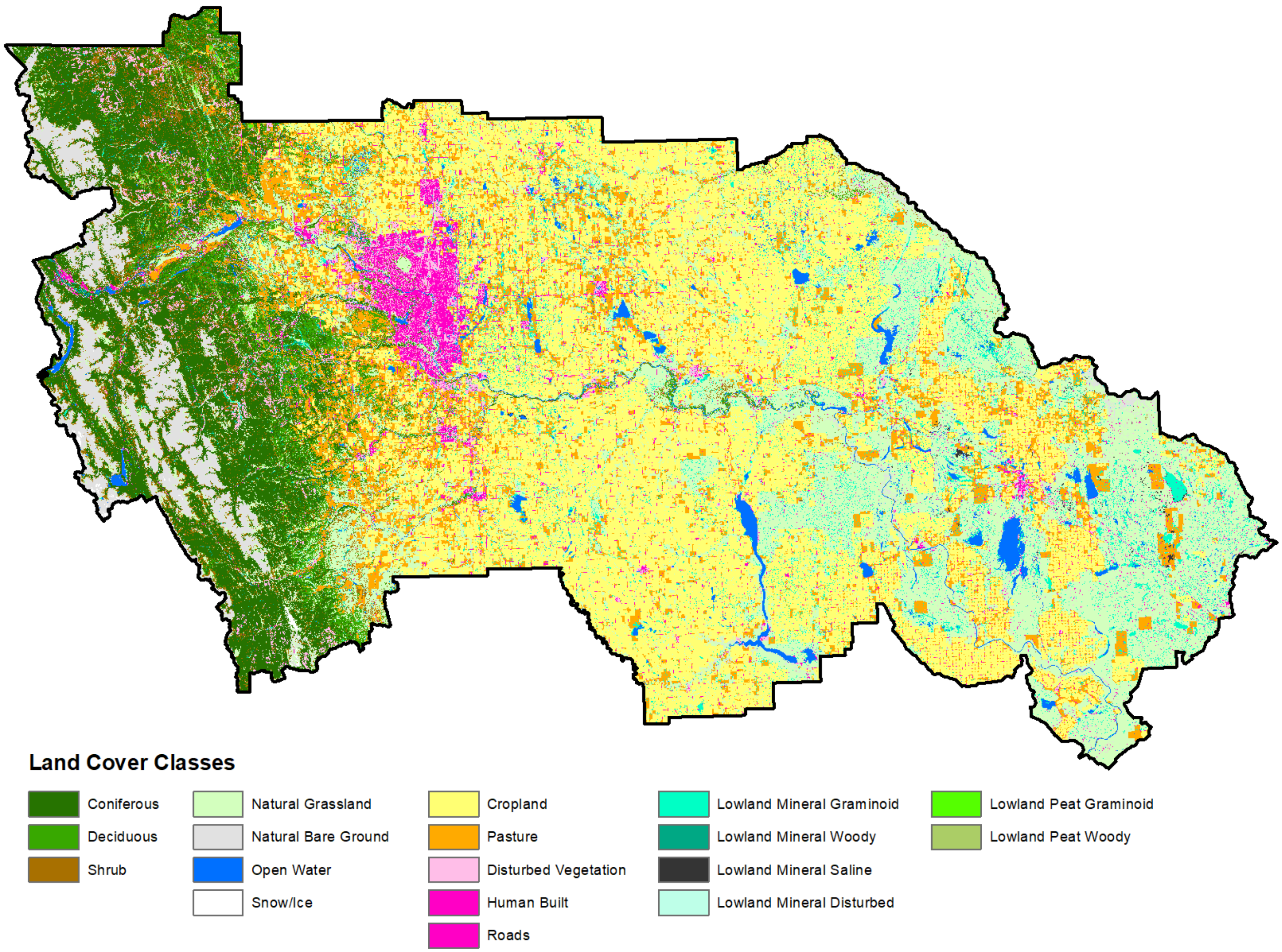


Figure 5. The final 18 class 6 m resolution wall to wall land cover for the study area created using SPOT 6/7 imagery from 2020.

4.0 Wetland Inventory

4.1. Overview

Wetlands are unique habitats that are ecologically distinct from dry terrestrial (upland) habitats and permanently flooded deepwater aquatic habitats (e.g., rivers, lakes). There are three primary ecological and hydrologic characteristics that are most often used to distinguish a wetland from other habitats (Mitsch and Gosselink 2007):

1) Water is present at or near the ground surface. When surface water is present on the ground surface, it is typically less than 2 m in depth.
2) Unique soil conditions that are influenced by the presence of water and differ from adjacent uplands.
3) Vegetation that is specially adapted to growing in wet soil conditions.

In Alberta, there are five major classes of wetlands: Bogs, Fens, Swamps, Marshes, and Shallow Open Water (AESRD 2015). These classes are primarily differentiated by the type of soil and vegetation found within the wetland. Within each class, wetlands are further subdivided into form based on the dominant vegetation (e.g., graminoids, shrubs, tress), as well as by the amount and duration of time that surface water is present. For this inventory, and as per the Alberta wetland mapping standards (GOA:AEP 2020), wetlands were identified to the class level only.

The class, size, and location of wetlands is influenced by climate and geology. Because wetlands generally form in depressions, they are most typically found in topographically low areas in the landscape. Often, wetlands are found in association with deepwater aquatic habitats. These “fringe” wetlands are usually located along the margins of lakes, rivers, and streams. Wetlands also occur at very high densities in areas characterized by past glacial activity. Most of these “pothole” wetlands receive water inputs exclusively from rain or snow. As a result, there can be considerable seasonal and annual variation in the amount of surface water present within a wetland. Under these conditions, some wetlands may be permanently flooded, while others only contain surface water for a period of days or weeks in the spring or after a significant rainfall event.

While certain wetland characteristics are generally predictable (e.g., they are typically found in a depression), the ecological and hydrologic diversity of wetlands makes them notoriously difficult to accurately map using GIS and remote sensing techniques. In particular, many of the marsh wetlands in southern Alberta are very small and have shallow basins. As a result, these wetlands can only be reliably detected using high resolution imagery or elevation data. To further complicate the task of wetland mapping, many wetlands and other aquatic features, such as lakes and streams, have been highly altered by human activities (e.g., draining, channel re-alignment, damming, etc.). In some cases, these modifications have fundamentally changed the natural hydrology across large areas, making it difficult to accurately predict the location of wetlands on these highly altered landscapes. Further, decisions about how to classify wetland basins that are still intact, but have been impacted by human activity (e.g., a seasonal marsh that is cultivated annually) are not straightforward and require considerable thought as to whether these features should be classified as wetlands or some other land cover type.

There are many different methods for creating a wetland inventory, including both pixel-based and object-based classifications (see Mahdianpari et al. 2020 for an overview). To create the wetland inventory for this study, we used the pixel-based land cover classification as the primary data input (Figure 6). The provincial guidelines for mapping wetlands in the Prairie/Parkland zones of Alberta (GOA 2020) were also considered when creating the wetland inventory. Specifically, this inventory uses the Alberta Wetland Classification System (AESRD 2015) to assign a wetland class to each wetland, and the inventory meets the minimum mapping unit (MMU) standard of 0.04 ha specified in the provincial guideline. A detailed description of the approach to creating the wetland inventory is provided in Section 4.2.

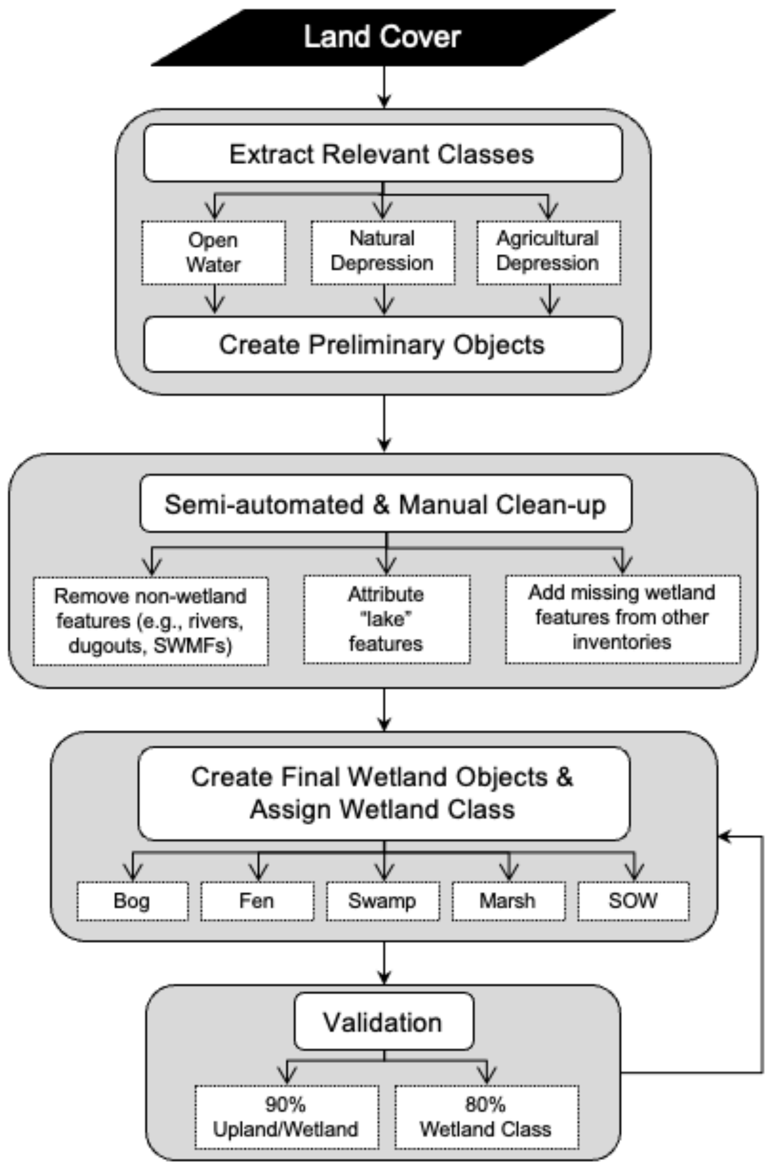


Figure 6. Overview of the primary steps used to create the Bow River Basin Wetland Inventory dataset.

4.2. Wetland Inventory Methods

4.2.1. Extraction of Land Cover Classes & Editing of Preliminary Objects

The first step in the creation of the wetland inventory was to extract "wetland relevant" classes from the land cover. This included all features associated with the Level 1 Open Water, Natural Depression, and Agricultural Depression classes. These extracted features were dissolved and merged to create outer boundaries that represented potential wetland objects. At this point, the preliminary objects contained all open water features (e.g., rivers, lakes, dugouts, open water wetlands), as well as all types of lowland vegetation (e.g., wetlands, vegetation along stream channels, stormpond vegetation, inundated ditches, etc.). Because many of the extracted features were not wetlands, the next step included cleaning-up and removing non-wetland features from the preliminary object layer.

Non-wetland features were removed using an iterative, semi-automated workflow. First, flowing deepwater aquatic habitats (rivers and streams) were removed by overlying the Base Features hydropoly and hydroline layer and deleting intersecting features. Exceptions included locations where potential wetland areas extended out from the channel, or where a feature was isolated from the channel (e.g., oxbows). In cases where it was not clear if the channel widening was wetland, existing inventories, including the Alberta Merged Wetland Inventory (AMWI) and the Alberta Biodiversity Monitoring Institute (ABMI) wetland inventory, were cross-referenced alongside terrain and hydrology information to decide whether to include the feature as a fringe wetland. Next, lakes and man-made open water features were removed using existing wetland inventories, the Alberta Base Features hydropoly layer, and the ABMI Human Footprint Sublayers (Borrowpits/Dugouts, Reservoirs). The accuracy of these layers in distinguishing wetlands from deepwater lentic habitats (lakes) or man-made reservoirs was not sufficient to automatically remove features, so all intersecting features were cross-checked manually before deletion. Many of the unnamed "permanent" lakes and reservoirs in the Base Features hydropoly layer, as well as "reservoirs" in the ABMI reservoir layer, appeared to be large wetlands (i.e., open water areas less than 2 m in depth) and not deepwater habitats. Because there is no existing spatial data in Alberta that includes water depth as an attribute, these features could not be definitively classified as wetland or non-wetland (deepwater aquatic habitats). In these cases, the features were retained and attributed with the feature type from the cross-referenced layers (Base Features or ABMI layers) in later steps.

To ensure that the best available wetland mapping data was considered in the creation of this inventory, we identified regions within the study area that were mapped in the Alberta Merged Wetland Inventory using manual digitization of high-resolution air photos (AWH - Arrowwood / Wintering Hills, EID - Eastern Irrigation District, ROC - Rocky View, SUL - Sullivan Lake). A secondary layer was created that consisted of AMWI polygons >0.04 ha that did not intersect objects in the preliminary wetland inventory and these missing features were reviewed at a 1:15,000 scale to determine whether they should be added to the inventory.

A final 1:15,000 sweep of the study area was performed to make final edits to land cover class categories and wetland boundaries within the preliminary object layer.

4.2.2. Creation of Wetland Objects & Wetland Class Assignment

The preliminary object layer was dissolved by land cover class to remove any extra inner boundaries from editing, and this layer was dissolved to create the final wetland object layer. A spatial join was used to link the class layer to the object layer and land cover class proportions were calculated for each wetland object. The land cover proportions were used to assign a wetland class based on the Alberta Wetland Classification System (AWCS; AESRD 2015). The AWCS "Classification Key to Wetland Classes and Forms" was adapted to assign a wetland class to each object in an automated way using the following hierarchical rules:

1) **Fen (Woody)**: >25% cover of the Lowland Peat Woody class
2) **Fen (Graminoid)**: >25% cover of the Lowland Peat Graminoid class
3) **Swamp**: >25% cover of the Lowland Mineral Woody class
4) **Marsh**: >25% cover of the Lowland Mineral Graminoid and/or Lowland Mineral Disturbed class
5) **Shallow Open Water**: >25% cover of the Open Water and/or Lowland Mineral Saline class

After application of the rules, the class assignments were QA/QC'd at a coarse scale. At this point, it was noted that some larger open water wetlands were being misclassified as Marshes due to the inability to identify a permanent open water zone using simple GIS rules. Therefore, all objects greater than 8,000 m^2 that had been assigned to the Marsh class, but that had more than 50% Open Water/Lowland Mineral Saline cover, were reassigned to the Shallow Open Water Class.

Wetlands were further attributed using the "Lowland Mineral Disturbed" class by adding a "Disturbed" field. If the wetland had any percentage cover of Lowland Mineral Disturbed, it was attributed with "Yes". This field provides an indication of wetlands that have been impacted by various agricultural activities (e.g., drainage, cultivation, modified with a dugout).

Wetlands were also attributed with a "SubFeature" field. This field was added because of the ambiguity in determining whether a feature was a wetland or a deepwater habitat (i.e., lake). In these cases, we did not want to automatically delete features based on attributes in the layers being used to "clean" the inventory. For example, in the Alberta Base Features hydropoly layer, many named and unnamed features are identified as "Lakes", but are instead large, shallow wetlands (i.e., <2 m in depth). In cases where there was ambiguity as to whether the feature was a lake or wetland, this field was populated with the Feature Type from the ancillary data layers that were used to remove non-wetland features from the inventory. For example, Lost Lake is identified in the provincial Base Features hydropoly as "Lake-Recur" (recurring lake); however, this feature appears to be less than 2 m in depth and is therefore considered a wetland as per the ecological/hydrological criteria we used to guide the creation of the inventory. Consequently, this feature was retained in the inventory and was attributed with the information from the Base Features layer. This gives the user ultimate control over whether to include or exclude these ambiguous features from their analysis based on their data needs and preferences. The SubFeature field includes the following attributes:

- Named features from the hydropolys layer (Feature Name/Feature Type)
- Unnamed features of type "Lake-Per" (perennial lake) from the hydropolys layer (Unnamed Lake/Lake-Per)
- Reservoirs from the ABMI human footprint reservoirs that had a wetland appearance or visible wetland characteristics (e.g., shallow water, substantial graminoid vegetation) (Reservoir)
- Reservoirs from the base features update layer that had a wetland appearance that were not identified by the ABMI layer (Reservoir (BFUpdate))

The final Wetland Inventory is shown in Figure 7. Inset maps show examples of the inventory in different geographical regions of the study area.

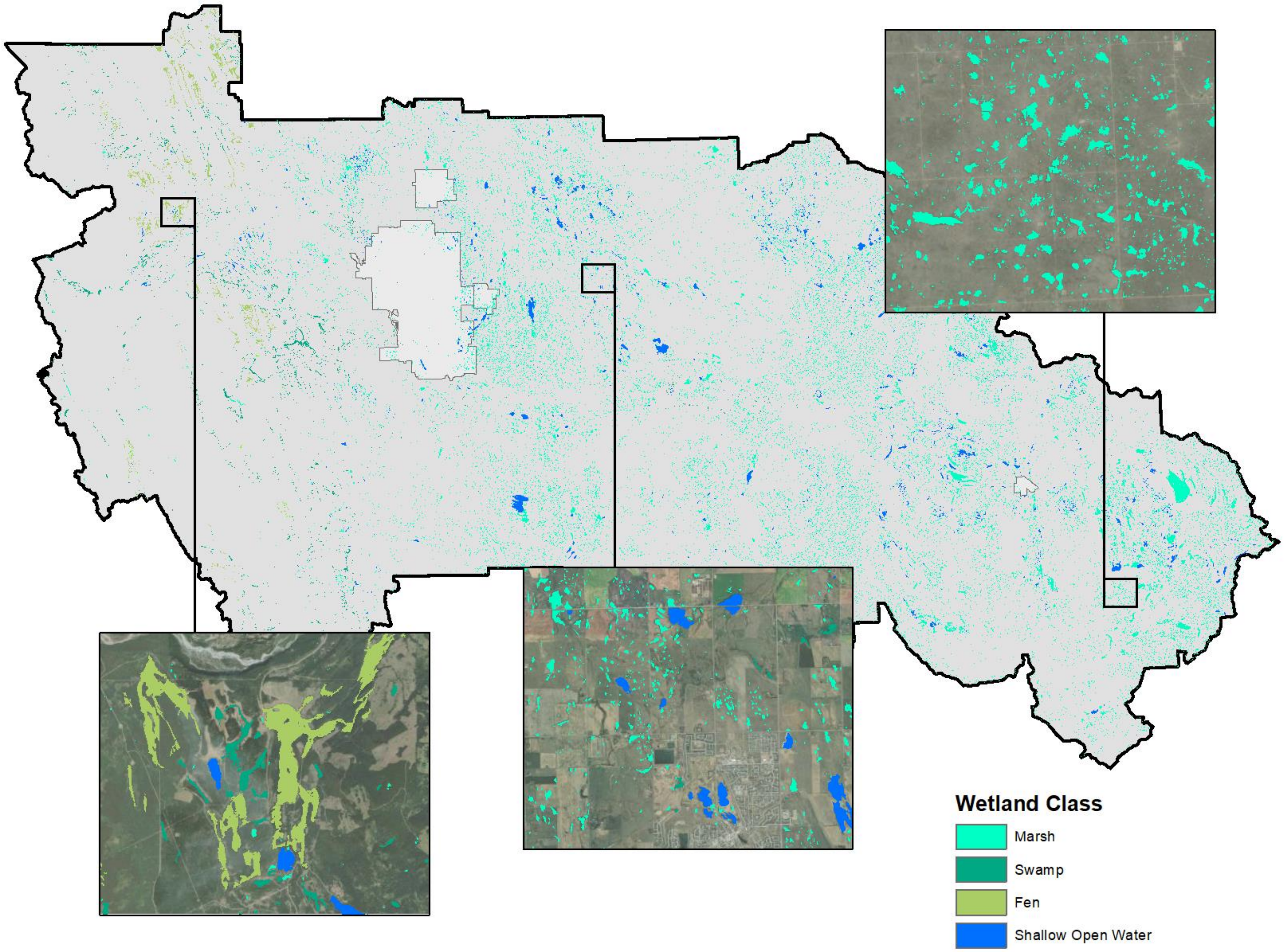


Figure 7. The final Wetland Inventory derived from the land cover that was created using SPOT 6/7 imagery from 2020.

5.0 Historical Wetland Inventory

5.1. Overview

To better understand change in wetland cover in the study area, a historical wetland inventory (circa 1950) was created using object-based image analysis (Figure 8). The freely available ABMI Historical Orthophotos of Alberta data product was used as the input for the inventory. This data product is a mosaic of black and white orthophotos that were captured between 1949 and 1951 (ABMI 2015).

The historical imagery was very challenging to work with due to its age and low quality, resolution, and positional accuracy. While our intention was to create a historical wetland inventory for the entire study area, the western portion had to be excluded because of poor image quality in this area (Figure 9). Additionally, river valleys were excluded from the historical inventory because of image quality issues (i.e., warping) resulting from georectification. For the remaining portion of the study area, an object-based image analysis was performed to create a historical inventory with a minimum mapping unit of 0.04 (Figure 8).

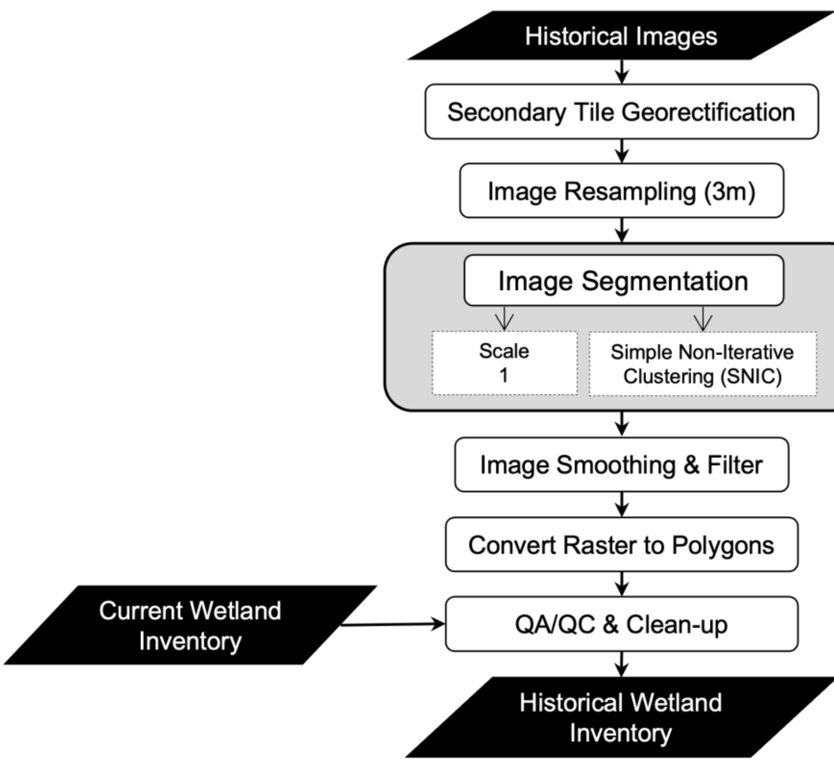


Figure 8. Overview of the primary steps used to create the Bow River Basin Historical Wetland Inventory dataset.

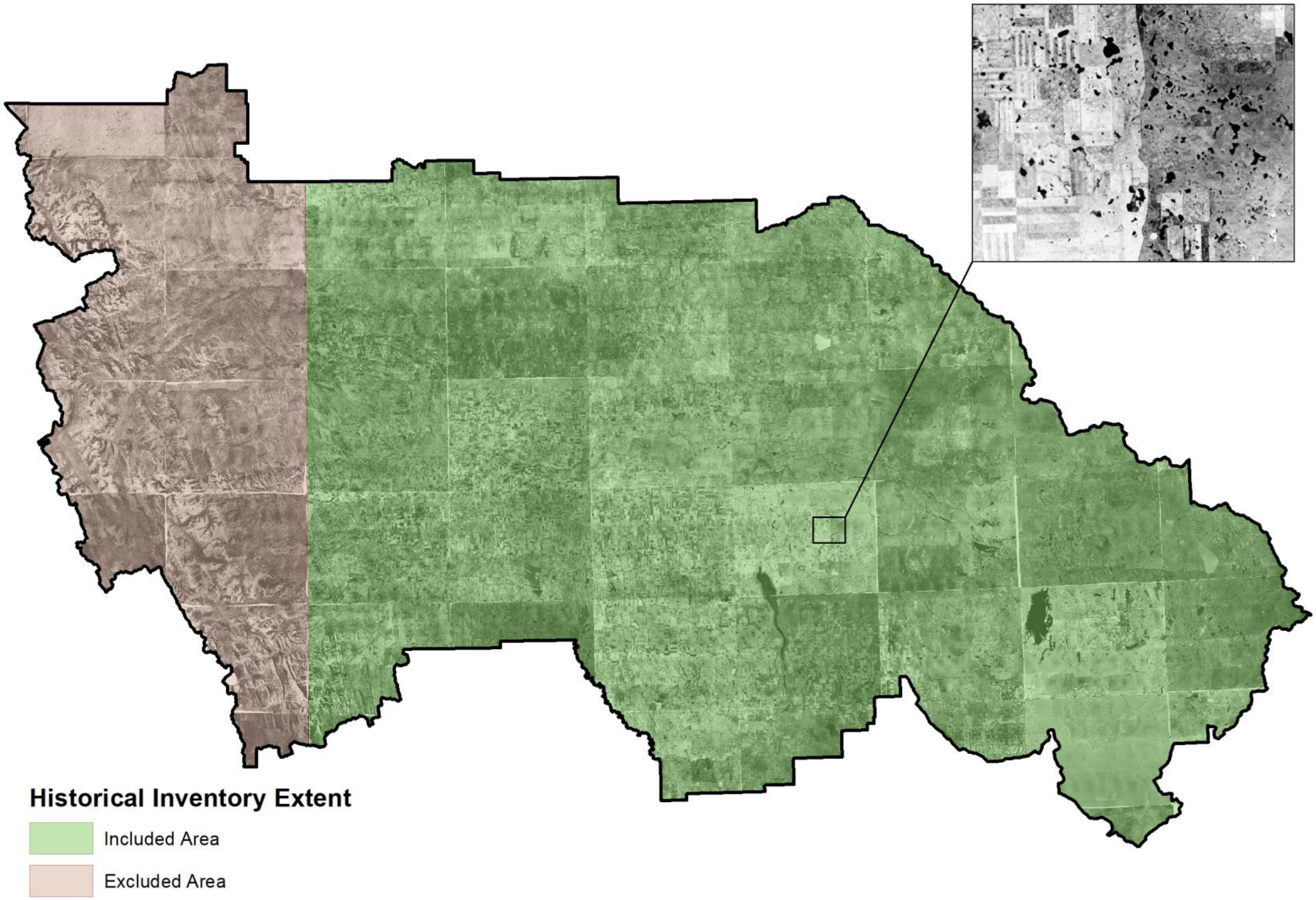


Figure 9. ABMI historical orthophotos (circa 1950) within the study area. Air photos in green were included in the creation of the Historical Wetland Inventory. Areas in red were excluded due to an inability to extract wetland features. Inset map shows an example of variation in individual historical orthophoto quality and differences in the image contrast within a single image tile.

5.2. Historical Wetland Inventory Methods

5.2.1. Secondary Image Georectification

The ABMI historical orthophoto imagery has a reported positional horizontal accuracy of 206 m at a 95% confidence level (ABMI 2015). While this level of horizontal accuracy is sufficient for many purposes, it was unacceptably large for this study, where positional accuracy is needed to identify wetland losses between the historical and current time-steps. To reduce the horizontal offset between the ABMI orthophoto imagery and the SPOT imagery used to create the Wetland Inventory, we chose to perform a secondary georectification on each of the 52 image tiles covering the study area. The georectification was done using a variety of high-resolution imagery, including 1.5 m SPOT imagery and ArcGIS base maps. For each historical image tile, over 100 tie points were selected at identifiable locations (e.g., highway intersections, buildings, permanent natural features) that were visible in both the current and historical imagery. Tie points were well distributed throughout the image tile, and all tie point root-mean-square error (RMSE) values were assessed. Any tie point with a large RMSE were inspected and removed, if necessary. Historical imagery was then georeferenced using a third order polynomial transformation.

Following this second georectification process, the average horizontal offset between the current and the historical imagery was reduced to an average of less than 20 meters; however, large offsets remained in areas with more complex terrain (e.g., coulees, hilly areas). This high spatial offset between the historical and the current imagery makes it very difficult to make accurate comparisons of wetland area and location between the two timesteps.

5.2.2. Object Based Image Analysis

Object-based image analysis was used to group pixels with similar spectral characteristics into segments. These segments generally correspond to the boundary of wetlands within the historical imagery, reducing the need to manually delineate wetland boundaries.

To reduce file size and processing time, the historical black and white orthophotos were resampled to 3 m resolution. Image segmentation was performed in Google Earth Engine (GEE) using the simple non-iterative clustering (SNIC) segmentation method, which is an image segmentation method based around simplifying an image into small clusters of connected pixels called superpixels (Achanta and Susstrunk 2017). This method is computationally efficient and provides the option to create segments at different scales, depending on the objects of interest. Different scales were explored to determine the most appropriate segmentation scale. Ultimately, a scale of 01 was applied to each image tile (52 tiles) and a segmentation raster was exported from GEE.

A majority filter was applied to each raw segmentation raster in ArcGIS to remove overly small segments and individual pixels and to make wetland boundaries smoother. This step was also applied to decrease the number of individual objects in each image created by the SNIC algorithm. The raster files were then converted to polygon files for editing and QA/QC.

5.2.3. QA/QC & Clean-up

Digital number (DN) values can often be used to perform an automated clean-up by applying a threshold value that removes non-wetland objects. A DN value is a raw digital value that is directly proportional to the radiance or reflectance at each pixel (i.e., the value is an expression of how dark or light each pixel is). The 52 image tiles used to create the historical inventory are a compilation of many smaller air photographs. When these air photos were originally compiled by the ABMI into larger image tiles (which are based on NTS tiles), the DN values associated with each air photo were not standardized. This resulted in high variability in the tonal contrast within a single image tile (i.e., some parts of an image tile are very bright, while others are very dark), with the result being that features of interest (wetlands) did not have similar DN values across or between image tiles. Consequently, a DN threshold could not be applied to remove non-wetland objects in a standardized and automated way. Instead, each tile was assessed and iteratively edited manually at a scale of 1:10,000. As part of the manual editing, the Wetland Inventory was referenced, as well as Google Earth time series images, SPOT images, existing historical inventories (e.g., Ducks Unlimited historical inventory for Rocky View County), and terrain information (e.g., Probability of Depression) to determine whether to delete or add wetland objects. The inventory of potential wetland objects was then dissolved to remove boundaries between adjacent objects, which gave the preliminary historical inventory.

The preliminary inventory was then reviewed a second time. This final QA/QC involved manually reviewing wetlands at a 1:15,000 scale to solve some technical errors (i.e., holes, major boundary errors, non-wetland objects), and to manually edit in missed wetland features. Due to the low quality of the historical image and the size of the study area, it was not possible to assign wetland class to objects in the historical wetland inventory.

The Historical Wetland Inventory is illustrated in Figure 10. A comparison between the Historical Wetland Inventory and the Wetland Inventory is shown in Figure 11.

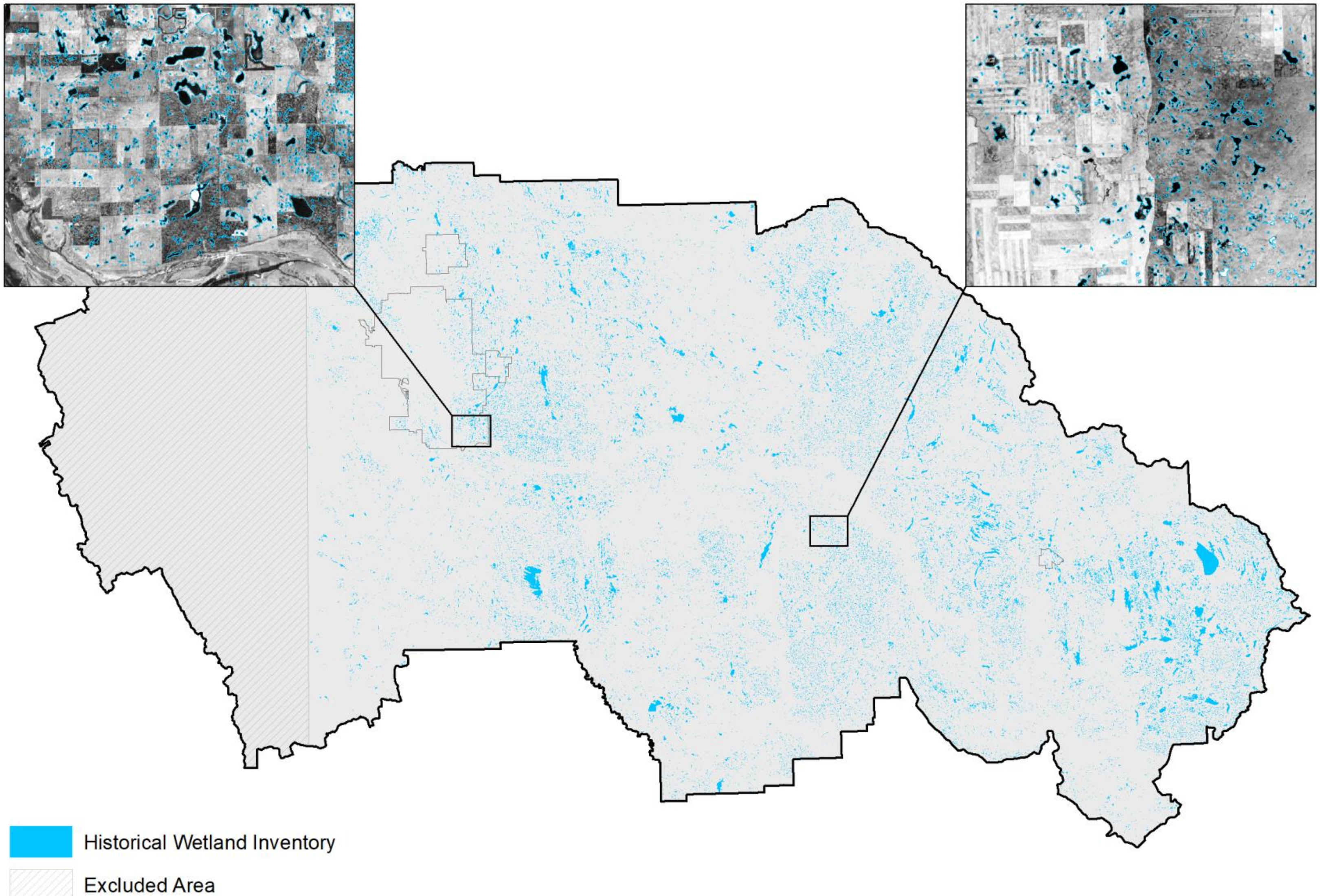


Figure 10. Historical Wetland Inventory (c. 1950) for the study area.

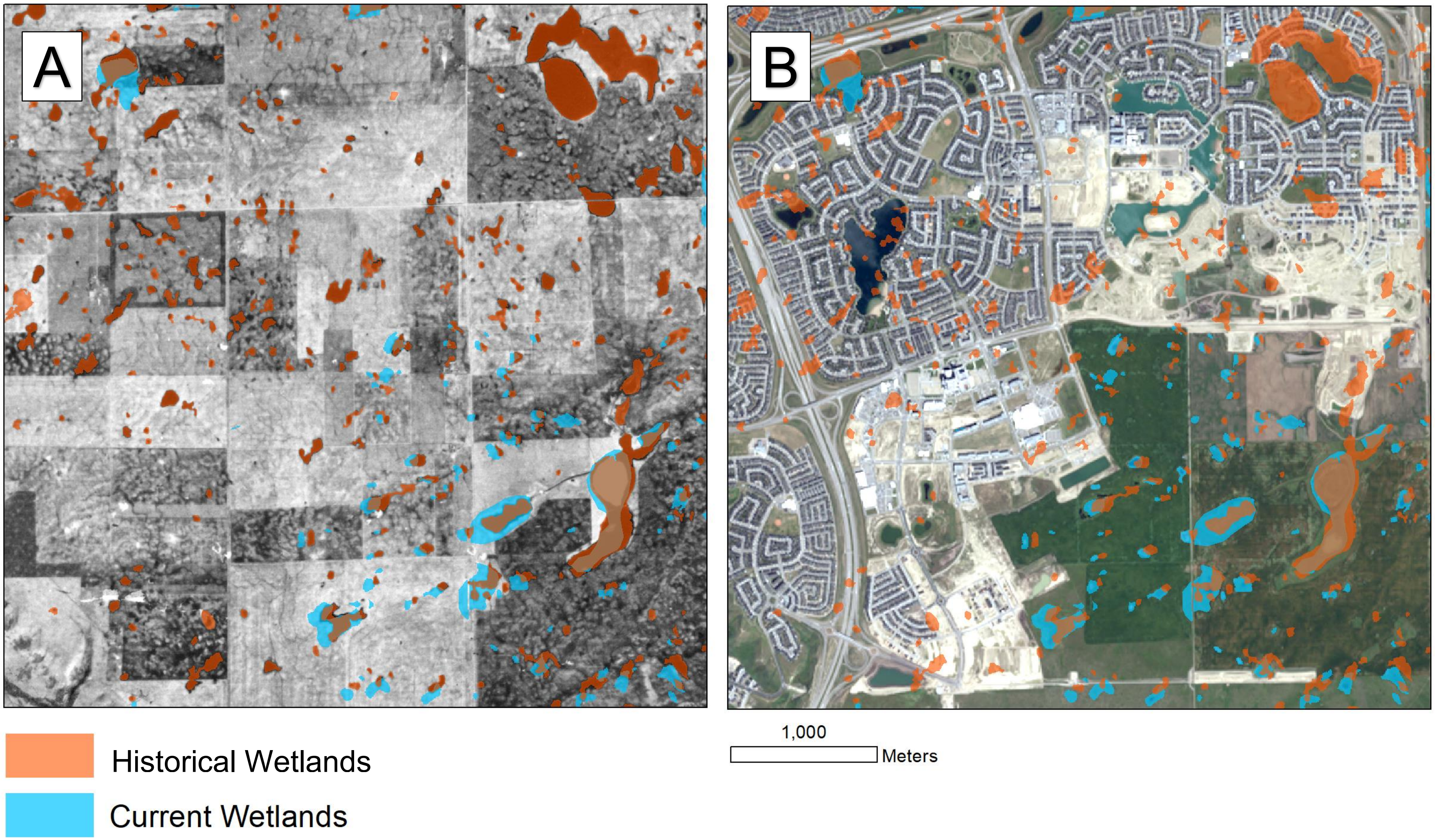


Figure 11. Comparison between the Historical Wetland Inventory and the Wetland Inventory in the southeast part of the City of Calgary, as overlaid on top of historical (A) and current (B) imagery.

6.0 Restorable Wetland Inventory

6.1. Overview

The goal of the Alberta Wetland Policy is to “conserve, restore, protect, and manage Alberta’s wetlands to sustain the benefits they provide to the environment, society, and economy” (GOA 2013, pg. 2). The mitigation hierarchy is a foundational principal of the provincial wetland policy, where impacts to wetlands should first be avoided, then minimized, and as a last resort, unavoidable impacts should be compensated through habitat replacement. Based on the permitting provisions of the *Water Act*, the Alberta Wetland Policy prohibits the unauthorized drainage or disturbance of wetlands, and any activity that will permanently impact a wetland must first be authorized by the provincial government. Through this approval process, permitees are required to replace lost wetland habitat either through undertaking a wetland replacement project or through the payment of an in-lieu wetland replacement fee that is collected by the provincial government. Revenue from these fees is used to fund wetland habitat replacement through the Wetland Replacement Program (WRP), which is administered by Alberta Environment and Protected Areas (AEPA).

The mandate of the WRP is to “facilitate the replacement of wetlands within all municipalities and watersheds across Alberta” (GOA 2023). Priority is given to habitat replacement within watersheds that have had the greatest wetland loss since 2015, as well as areas with the highest rates of historical loss. Wetland replacement fees can only be used to fund wetland construction or restoration activities. Wetland construction includes creating a new wetland on a site that did not historically contain a wetland, while wetland restoration includes “returning natural/historical area and hydrological functions to a drained, partially drained, or filled-in wetland” (GOA 2023). Wetland enhancement activities, such as improving an existing but degraded wetland, are not eligible for funding under the WRP.

Notably, WRP has identified municipalities and non-profit organizations as priority partners for the delivery of wetland restoration projects. These organizations can participate in the program by signing a Memorandum of Understanding (MOU) with the provincial government. Under the MOU, a proposal for a wetland replacement project is submitted for approval by AEPA, and once approved, WRP funds are released to offset the costs of the restoration project.

An important step in the wetland replacement process is identifying wetlands that are eligible for WRP funding. Specifically, to be eligible for restoration funding, wetlands must have been historically drained or filled, and the restoration of the wetland must result in the creation of new wetland acres. Given this requirement, the objective of this Restorable Wetland Inventory was to identify wetlands that have a high likelihood of qualifying for WRP funding. Specifically, this inventory focused on identifying wetlands that have been historically drained or partially drained, as these are the wetlands that are eligible for restoration funding under WRP.

6.2. Restorable Wetland Inventory Methods

The restorable wetland inventory was created through a combination of manual and semi-automated procedures. The first step in the creation of the inventory was the manual interpretation of high resolution ESRI (ArcGIS) Basemap and Google Earth imagery to identify wetlands connected to a surface drainage feature. This interpretation was conducted by experienced wetland ecologists who were trained in air photo interpretation. The study area was systematically reviewed using a grid-sweep approach at a pre-defined scale of 1:10,000. This scale provided a visible extent of 3x3 quarter sections and provided a zoom level that allowed for the identification of obvious drainage features, while balancing the amount of time required to manually review the entire study area. Personnel worked on dual-monitor workstations with one screen displaying ESRI Basemap imagery and the adjacent screen displaying a synchronized view of high-resolution imagery in Google Earth Pro. Where required, the historical imagery available in Google Earth Pro was reviewed to aid in feature interpretation. The ABMI historical orthophoto imagery was also used as a reference layer.

Wetland basins that appeared to be impacted by a drainage feature were identified in ArcGIS by placing a point near the center of the wetland basin. Drainage features that were flagged included ditches that appeared to be human created. These features often appear as relatively straight channels that enter and/or exist a wetland basin. Drainage channels can also be more natural in appearance (i.e., more meandering), and are located in areas where ditches are not excavated, but rather, the field is recontoured to help facilitate more rapid runoff of surface water. In instances where the drainage appeared more natural, but the analyst determined that there was likely some enhancement of drainage that resulted from human activity, the wetland was flagged as being impacted by drainage. Often, wetlands are “consolidated”, meaning that multiple wetlands are drained via a series of ditches into a single wetland that receives the drainage water. Where this was observed, points were placed on both the drained and consolidated wetlands. Wetlands that were modified (e.g., excavated to create a dugout) or otherwise impacted by human activity (e.g., cultivated) but did not have a drainage ditch associate with them were not identified as restorable basins, as these wetlands would not be eligible for restoration through WRP. This first review of the study area yielded a preliminary restorable inventory that then underwent a QA/QC review.

The first step in the QA/QC process included a comparison of the preliminary restorable wetland points to wetlands greater than 2000 m^2 in the Current Wetland Inventory that were attributed as “Disturbed” (i.e., wetlands that contained any amount of the "Lowland Mineral Disturbed" class). Disturbed wetlands that did not intersect a point in the preliminary restorable inventory were manually reviewed at a scale of 1:15,000, and a point was added where obvious drainage features had been missed during the first pass. Ancillary terrain layers (Probability of Depression, Deviation from Mean Elevation) were also used to assist with decision making. As a final QA/QC step, the Wetland inventory and Probability of Depression layers were used to remove points that had been placed in areas where the likelihood of a wetland occurring was low. This step removed all points that were >20 m from a wetland feature in the Wetland Inventory or points that were >20 m from a “probable wetland feature” (i.e., features >220 m^2 in size with a Probability of Depression value of >80%). This distance was selected based on a review of the datasets and captured points that were not likely to be associated with a wetland feature.

The final Restorable Wetland Inventory is shown in Figure 12. This inventory can be used to estimate locations where there is a high likelihood that a wetland has been impacted by drainage activity, and where the wetland may be eligible for restoration under the provincial Wetland Restoration Program.

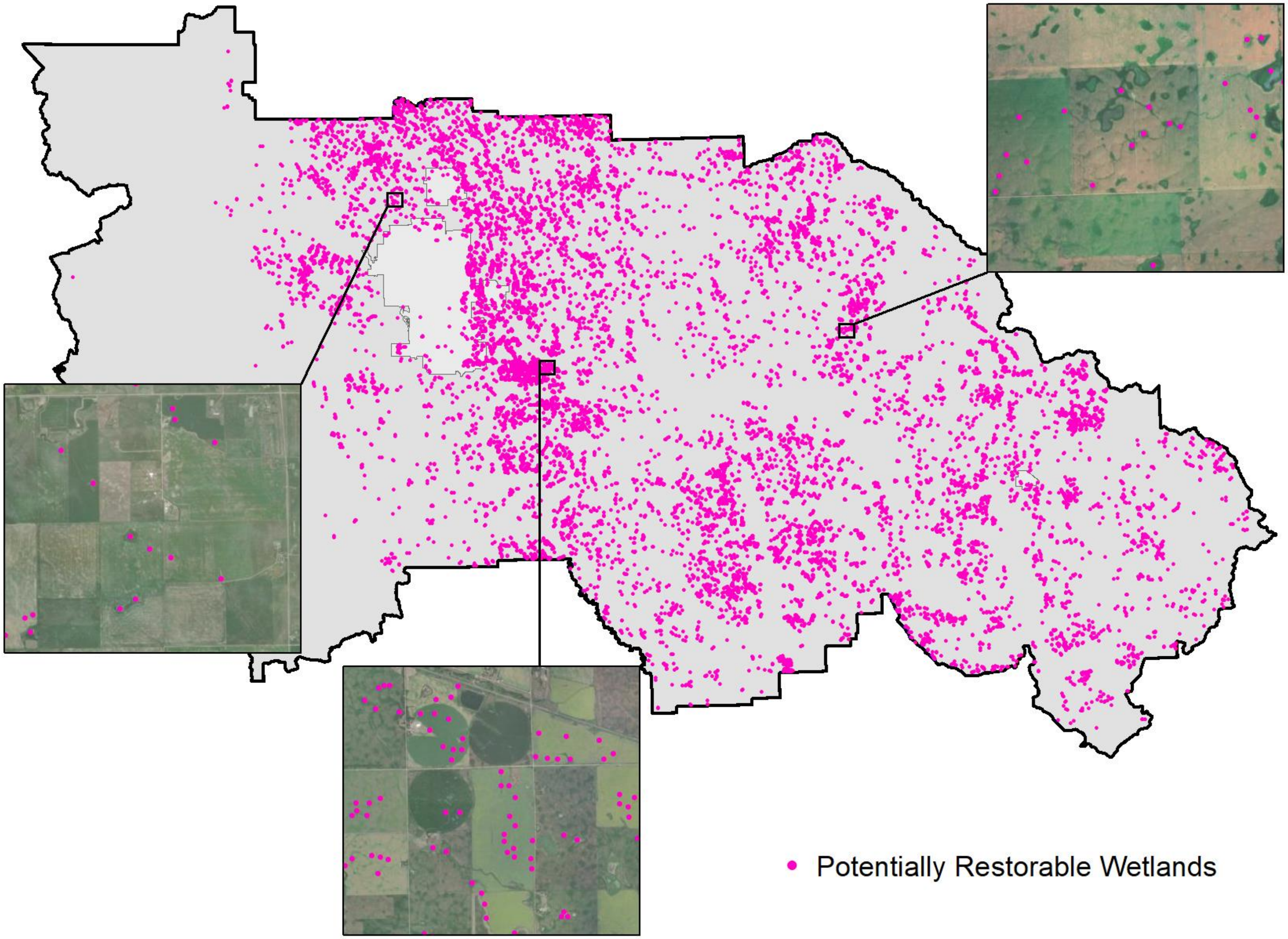


Figure 12. The Restorable Wetland Inventory for the study area, showing point locations where it is estimated that there are wetlands that may be eligible for restoration under the provincial Wetland Restoration Program.

7.0 Accuracy Assessment

7.1. Land Cover

Accuracy of the land cover products was assessed using traditional remote sensing techniques. This provides a measure of accuracy for each land cover class, as well as an overall accuracy for all classes combined. The wall-to-wall land cover layer accuracy was assessed at Level 1 and Level 2 using a stratified validation dataset that was a combination of held back training data points (samples collected at the same time as training data was selected but were not used to train the random forest model) and randomly selected points that were validated by a trained photo interpreter.

A total of 732 samples were used to assess accuracy, with a minimum number of 25 samples for each Level 2 class. Overall accuracy at Level 1 (10 thematic classes) was 95.4% with a Kappa statistic of 0.95 (Table 4). Class accuracies were above 80% for all classes except Agricultural Depression. Agricultural Depression tended to be confused with Cropland or Natural Depression, which is understandable given that the Agricultural Depression class was assigned manually to lowland features during editing and clean up. Some subjectivity is involved with assigning the Agricultural Depression class, especially in deciding whether there is intact lowland vegetation present or not.

Overall accuracy at Level 2 (18 thematic classes) was 92.5% with a Kappa statistic of 0.92 (Table 5). Class accuracies were above 80% for 15 of 18 classes. Lower performing classes were primarily confused with closely related classes within the same Level 1 grouping (e.g., confusion among Natural Depression classes; Pasture and Cropland; Shrub and Deciduous). Confusion between Pasture and Natural Grassland can be attributed to the subjectivity in determining the difference between Pasture and Natural Grassland. Many areas used as pasture within the Eastern areas of the study area exist along a gradient of “tame” (highly managed) pasture to “rough” (low-intensely grazing areas) pasture. While tame pasture is much easier to differentiate from natural grassland, rough pasture often appears natural in the 6 m SPOT imagery.

Table 4. Accuracy assessment results for the Level 1 land cover classes in the Study Area.

	Agriculture	Built Up/ Exposed	Agricultural Depression	Disturbed Vegetation	Forest	Natural Bare Ground	Natural Grassland	Open Water	Snow/ Ice	Natural Depression	User's Accuracy
Agriculture	209	0	3	0	1	0	3	0	0	0	97%
Built Up/Exposed	0	50	0	1	0	1	0	0	0	0	96%
Agricultural Depression	1	0	17	0	0	0	0	0	0	0	94%
Disturbed Vegetation	1	0	0	24	0	0	0	0	0	0	96%
Forest	0	0	0	0	104	0	0	0	0	3	97%
Natural Bare Ground	0	0	0	0	0	24	0	0	1	2	89%
Natural Grassland	7	0	0	0	0	0	105	0	0	0	94%
Open Water	0	0	0	0	0	0	0	25	0	3	89%
Snow/Ice	0	0	0	0	0	0	0	0	24	0	100%
Natural Depression	0	0	6	0	1	0	0	0	0	117	94%
Producer's Accuracy	96%	100%	68%	96%	98%	96%	97%	100%	96%	94%	95%

Table 5. Accuracy assessment results for the Level 2 land cover classes in the Study Area.

	Coniferous	Cropland	Deciduous	Disturbed Vegetation	Human Built	Lowland Mineral Saline	Lowland Mineral Disturbed	Lowland Mineral Graminoid	Lowland Peat Graminoid	Lowland Mineral Graminoid	Lowland Peat Woody	Natural Bare Ground	Natural Grassland	Open Water	Pasture	Roads	Shrub	Snow/Ice	User's Accuracy
Coniferous	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100%
Cropland	0	165	0	0	0	0	3	0	0	0	0	0	0	0	6	0	0	0	95%
Deciduous	1	0	22	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	85%
Disturbed Vegetation	0	0	0	24	0	0	0	0	0	0	0	0	0	0	1	0	0	0	96%
Human Built	0	0	0	1	25	0	0	0	0	0	0	1	0	0	0	1	0	0	89%
Lowland Mineral Saline	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	100%
Lowland Mineral Disturbed	0	1	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	94%
Lowland Mineral Graminoid	0	0	0	0	0	1	5	25	2	2	0	0	0	0	0	0	0	0	71%
Lowland Peat Graminoid	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	100%
Lowland Mineral Woody	0	0	1	0	0	0	0	0	0	21	1	0	0	0	0	0	0	0	91%
Lowland Peat Woody	0	0	0	0	0	0	0	0	3	0	23	0	0	0	0	0	0	0	89%
Natural Bare Ground	0	0	0	0	0	2	0	0	0	0	0	24	0	0	0	0	0	1	89%
Natural Grassland	0	0	0	0	0	0	0	0	0	0	0	0	105	0	7	0	0	0	94%
Open Water	0	0	0	0	0	3	0	0	0	0	0	0	0	25	0	0	0	0	89%
Pasture	0	1	1	0	0	0	0	0	0	0	0	0	3	0	37	0	0	0	88%
Roads	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	100%
Shrub	1	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	23	0	85%
Snow/Ice	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	100%
Producer's Accuracy	96%	99%	88%	96%	100%	76%	68%	100%	84%	80%	92%	96%	97%	100%	73%	96%	92%	96%	92%

NOTE: Producer's accuracy measures errors of omission, which is a measure of how well real-world land cover types can be classified. User's accuracy measures errors of commission, which represents the likelihood of a classified pixel matching the land cover type of its corresponding real-world location.

7.2. Wetland Inventory

Accuracy of the Wetland Inventory was assessed by generating an equally stratified validation dataset of randomly selected polygons that was validated by a trained photo interpreter specializing in wetland ecology. Seventy-five (75) samples were used to assess the accuracy in each group, with samples being located at least 500 m apart. The accuracy assessment focussed on the assigned class for the wetland objects (Marsh, Shallow Open Water, Swamp, Fen) alongside an equal number of samples for Upland areas (e.g., forest, disturbed vegetation, grasslands, built up areas, agricultural areas) and non-wetland open water features (e.g., lakes, rivers, dugouts, reservoirs).

Accuracy was first tested to assess the accuracy for Wetland vs Non-Wetland assignment. The wetland class included the four wetland types (Fen, Marsh, Swamp, and Shallow Open Water) and the Non-Wetland class included the Upland and Open Water (Non-Wetland) features. Overall accuracy for Wetland vs Non-Wetland assignment was 96.4% with a Kappa statistic of 0.92.

Class accuracy was then tested. Overall accuracy at the class level (including upland and non-wetland open water classes) was 85.1% with a Kappa statistic of 0.82 (Table 7). Class accuracies were close to or above 80% except for the User's Accuracy for Swamp, due to mixing between the Swamp and Fen classes, as well as some over-classification of Swamp as Marsh. The per-class F1-scores were Fen = 0.84, Marsh = 0.79, Swamp = 0.62, Shallow Open Water = 0.89, Upland = 0.94, and Open Water (Non-Wetland) = 0.96. The misclassification between Swamp and Fen wetlands is very common given the difficulty in determining soil type (mineral versus peat) from remote sensing datasets. Marshes were classified as Swamps in some cases where a Marsh is bordered by a woody fringe that consists of lowland and upland areas, and this entire woody area was classified as lowland woody.

Table 6. Accuracy assessment results for Non-Wetland versus Wetland assignment.

	Non-Wetland	Wetland	User's Accuracy
Non-Wetland	146	4	97%
Wetland	12	288	96%
Producer's Accuracy	92%	99%	96%

Table 7. Accuracy assessment results at the class level for the Bow River Basin wetland inventory.

	Fen	Marsh	Swamp	Shallow Open Water	Upland	Open Water (Non-Wetland)	User's Accuracy
Fen	73	0	2	0	0	0	97%
Marsh	2	61	0	7	4	1	81%
Swamp	22	11	35	1	4	2	47%
Shallow Open Water	0	6	0	68	0	1	91%
Upland	0	1	1	0	73	0	97%
Open Water (Non-Wetland)	0	1	0	1	0	73	97%
Producer's Accuracy	75%	76%	92%	88%	90%	95%	85%

8.0 Considerations for Data Use

8.1. How is this Data Different?

The datasets created as part of this project were designed to provide freely available spatial data that is consistent across a large area for a wide variety of users. Previously available land cover datasets have either had lower spatial resolution (e.g., 30 m Agriculture and Agri-Food Canada (AAFC) land cover) or are out of date (e.g., 10 m ABMI 2010 land cover). The land cover created in this project is relatively current (2020), has high spatial resolution (6 m), high thematic resolution (18 classes), and extensive coverage (5% of the province). Specifically, there is fully spatial coverage of the City of Calgary, six rural municipalities, and the Kananaskis I.D., thereby creating a consistent data product that can be used by these jurisdictions for intermunicipal planning purposes. The Historical and Restorable Wetland Inventories are new and one-of-a-kind datasets that have never been previously available across the study area.

While there are existing wetland inventories for the study area, including the Alberta Merged Wetland Inventory (AMWI) and the ABMI Wetland Inventory, the Wetland Inventory created as part of this project has several key differences (Table 8). Most notably, the Wetland Inventory was derived from a land cover classification that was created using consistent methods and data applied across the entire study area. Additionally, the land cover classification and the resulting wetland inventory were subject to several rounds of intensive manual clean-up and QA/QC reviews to ensure a high-quality data product. The result is an inventory that includes wetlands that were mapped at a consistent scale and level of detail across the entire study area. The inventory was also created following the Provincial Wetland Mapping Standards (GOA: AEP 2020) and uses the Alberta Wetland Classification System (AESRD 2015) to assign wetland class.

Table 8. Comparison of the key features of the major wetland inventories that cover the study area, including the Bow River Basin Current Wetland Inventory created as part of this project.

	Alberta Merged Wetland Inventory (AMWI)	**Alberta Biodiversity Monitoring Institute (ABMI) Wetland Inventory**	**Current Wetland Inventory**
Imagery Type & Resolution	SPOT 4 (20 m) SPOT 5 (10 m) 1:15,000 to 1:30,000 scale air photographs	Sentinel-1 & Sentinel-2 (10 m)	SPOT 6/7 (6 m)
Image Dates	1998 to 2015	2017-2020	2017-2020
Minimum Mapping Unit	0.04 to 0.2 ha	0.04 to 0.1 ha	0.04 ha
Wetland Classification System	Canadian Wetland Classification System	Canadian Wetland Classification System	Alberta Wetland Classification System

By comparison, AMWI is a mosaic of many different wetland inventories that were created between 1998 and 2015 using different classification techniques applied to image sources of varying resolution. Where AMWI overlaps the study area, it was largely derived from moderate resolution (10 m SPOT 5- and 20-meter SPOT 4 imagery) or 1:15,000 to 1:30,000 scale air photographs. Coverage in the Rocky Mountain Natural Region within the study area is minimal. Due to the variability in image resolution, the minimum mapping unit ranges between 0.04 ha for areas mapped using high resolution air photographs and 0.2 ha for areas mapped using SPOT imagery. Boundary and locational accuracy are also variable, ranging from 5 to 50 m. Wetlands are classified using the Canadian Wetland Classification System, which includes five classes: Bog, Fen, Marsh, Swamp, and Open Water.

The ABMI Wetland Inventory is a combination of three different project areas: Boreal and Foothills, Prairie, and Rocky Mountain. These areas are mapped using Sentinel-1 and Sentinel-2 satellite imagery (10 m resolution) collected between 2017 and 2020. Like AMWI, wetlands are organized into five classes: Bog, Fen, Marsh, Swamp, and Open Water. The MMU approaches 0.04 ha in the Prairie project region and 0.1 ha in the Boreal/Foothills and Rocky Mountain project areas. Accuracy varies by project region. The Boreal/Foothills region has an 85% overall accuracy (kappa = 0.58) and wetland class accuracies ranging from 20% to 84%. In the Prairie region, overall accuracy is 90% (kappa = 0.80), and wetland class accuracies range from 59% to 87%. In the Rocky Mountain region, overall accuracy is 84.5% (kappa = 0.69), and wetland class accuracies range from 58% to 90%.

Both existing wetland datasets provide information about the location and area of wetlands in the study area; however, these inventories differ from the Wetland Inventory created as part of this project in the following major ways:

1) **Method for assigning wetland class**: The Wetland Inventory uses the Alberta Wetland Classification System (AWCS) to assign a class to each wetland. As per the AWCS, wetland class is assigned primary based on soil type (mineral versus peat), and secondarily based on the proportion of the wetland area that is covered by woody vegetation (trees/shrubs), graminoid vegetation, and/or open water <2m in depth (AESRD 2015). Because the Wetland Inventory was created using the land cover classification as the primary input, each wetland has land cover information that was used to assign a wetland class based on cover proportions specified in the AWCS. This means that wetlands with multiple cover types only receive a single wetland class (e.g., a wetland with 75% graminoid and 25% open water cover is assigned the Marsh class). The AMWI and ABMI inventories do not assign wetland class based on the proportional cover of different land cover types within a wetland boundary. Instead, a single wetland with multiple cover types (e.g., 75% graminoid and 25% open water cover) is assigned multiple wetland classes (e.g., Marsh, Open Water). Put another way, within a single wetland, each individual class type (marsh, swamp, open water, etc.) is treated as a distinct wetland, despite those classes being part of a single wetland.
2) **Deep water and anthropogenic features**: The AMWI and ABMI inventories include many non-wetland features that are classified as “Open Water” wetlands. This includes deepwater habitats such as rivers and lakes, as well as anthropogenic features such as dugouts, reservoirs, and stormponds. As part of the creation of the Wetland Inventory, non-wetland features were removed to the extent possible using semi-automated and manual clean-up. Where there was uncertainty about whether a feature was a lake, reservoir, or wetland, we included additional attribute information in the inventory. This was done to allow users to ultimately decide whether to include or exclude these ambiguous features in their application of the data. The removal of deepwater and anthropogenic features from the Wetland Inventory provides a more accurate overall description of wetland abundance and extent in the study area.

3) **Disturbed wetland attribute**: Many of the small wetlands located on agricultural lands within the study area have been extensively modified or impacted by various activities (e.g., drainage, cultivation). While many of these areas do not appear in imagery as a “typical” wetland because the cover within the basin has been highly modified, these areas still give a wetland “signal” in the classification outputs (i.e., located within a depression, high soil moisture). Further, many of these areas would likely be classified as either ephemeral or temporary marsh wetlands if surveyed in the field. While these types of wetland features are relatively abundant in the study area, the approach to the management of these features is likely to vary relative to more permanent wetland features. Because of this, the Wetland Inventory has a “Disturbed” attribute that identifies features that have all or a portion of their basin covered by the “Lowland Mineral Disturbed” land cover class. This allows users to identify wetland features that have been disturbed or modified in some way, and that may be eligible for habitat enhancement. Neither the AMWI nor the ABMI inventories have a similar attribute identifying these unique types of wetlands.

These differences in how the Wetland Inventory was created and how the wetland features are attributed sets it apart from the other existing inventories. In addition to creating an inventory that is accurate and current, this inventory was also designed to be flexible and practical. Ultimately, the aim was to create an inventory that was useful to a wide range of users, and for a wide range of applications.

8.2. Data Quality, Limitations & Appropriate Use

While every effort was made to create accurate and reliable datasets for the study area, all spatial data products have data quality issues and/or limitations that should be considered by users. Major considerations for the use of the various datasets are detailed below, along with specific recommendations for limitations on the use of the data, if applicable.

8.2.1. Land Cover Inventory

The accuracy assessment in Section 7 provides an assessment of the accuracy of the land cover inventory across the entire study area. However, the classification was performed on individual SPOT tiles acquired on different dates, and as such, were subject to different atmospheric conditions and types of spectral interference. As a result, classification accuracy for each tile may be better or worse than the accuracy reported across the study area. The amount and extent of human modification at more localized scales also impacts the accuracy of both the land cover and the wetland inventory. An overview of each SPOT tile and a description of issues and limitations from a remote sensing and classification perspective that users should consider when using the land cover data associated with a particular SPOT tile is provided in (Table 9).

Table 9. Description of SPOT 6/7 tiles and associated issues with the imagery that impacted the classification results at a tile-scale. Locations for tiles is illustrated in Figure 13.

SPOT Tile	Date	Imagery Issues	Tile Quality
S7 2017-08-27	Aug 08, 2017	Small patches of thin cloud cover; used to fix cloudy patches in S7 2020-07-28 1.	Good
S6 2018-07-30	July 30, 2018	Small patches of thick cloud cover and associated cloud shadow; used to fix cloudy patches in S7 2020-07-28 1.	Good
S7 2019-07-25	July 25, 2019	Solar glare on waterbodies and bare soil; used to fix cloudy patches in S6 2020-07-29 2.	Good
S6 2020-06-14 1	June 14, 2020	Solar glare on waterbodies and bare soil.	Good
S6 2020-06-14 2	June 14, 2020	Image appears to be underexposed with poor balance between bands; used to fix cloudy patches in S6 2020-07-29 1.	Moderate
S6 2020-07-03	July 03, 2020	Small patches of thick cloud cover and associated cloud shadow; some bands of haze throughout image.	Moderate
S6 2020-07-15	July 15, 2020	Cloud and cloud shadow patches obscure northeast corner of image; some small thin cloud patches elsewhere.	Moderate
S6 2020-07-24	July 24, 2020	Solar glare on waterbodies and bare soil.	Good
S7 2020-07-28 1	July 28, 2020	Large patches of thick cloud and associated cloud shadow in various parts of tile; hazy cloud in several other parts of tile. Substantial portion missing LiDAR data.	Poor
S7 2020-07-28 2	July 28, 2020	No issues.	Good
S6 2020-07-29 1	July 29, 2020	Solar glare on waterbodies and bare soil; some small patches of cloud cover.	Good
S6 2020-07-29 2	July 29, 2020	Small patches of thick cloud cover and associated cloud shadow; image appears to be slightly underexposed with poor balance between bands.	Moderate
S6 2020-08-04	Aug 04, 2020	Small patches of cloud cover; solar glare on waterbodies and bare soil.	Good
S7 2020-08-16 1	Aug 16, 2020	Some solar glare on waterbodies in southeast portion of tile.	Good
S7 2020-08-16 2	Aug 16, 2020	Image is dark; used to fix cloudy patches in S6 2020-08-17. No LiDAR data available.	Moderate
S6 2020-08-17	Aug 17, 2020	Image is dark; large patches of thick cloud and associated cloud cover in south portion of tile. Large area missing LiDAR data.	Moderate

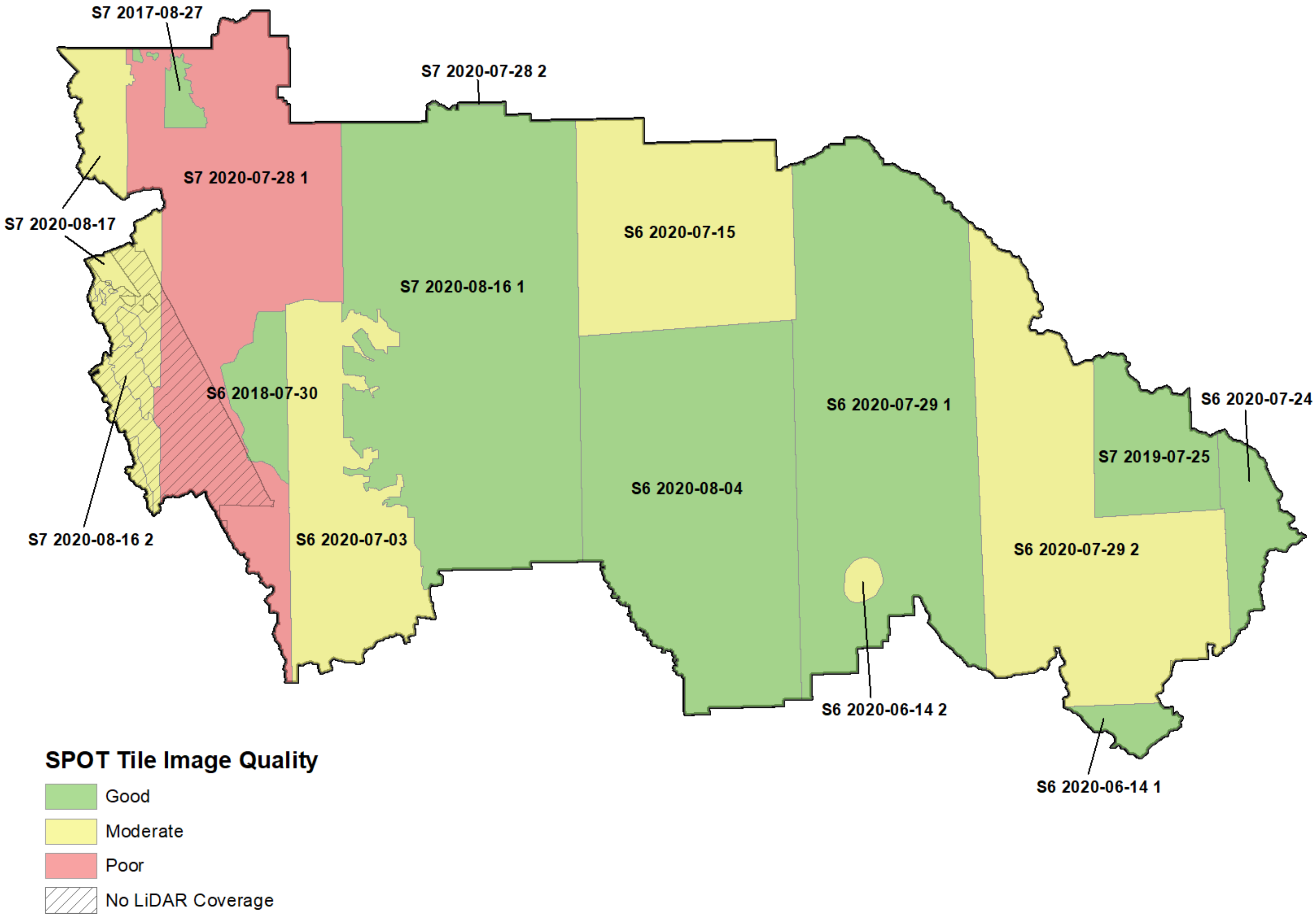


Figure 13. Reference map illustrating SPOT tile quality and areas where no 15 m (or higher resolution) LiDAR coverage was available for use in the classifications.

8.2.2. Wetland Inventory

The Wetland Inventory was created from the Land Cover Inventory, and as such, the Wetland Inventory is subject to the same limitations regarding the quality of SPOT imagery outlined in Section 8.2.1. Additionally, as part of our methodology, the prediction of lowland (i.e., wetland) features is highly dependent on terrain information, and the availability and resolution of LiDAR data was variable across the study area (Figure 4). Furthermore, the ability to detect and accurately map wetlands becomes increasingly challenging where terrain and hydrology have been modified by human activities. Notably, there are areas within the central and eastern portion of the study area where there have been significant and landscape-scale modifications to terrain and hydrology. As a result, the accuracies reported in Section 7 for the Wetland Inventory may be better or worse in some regions of the study area based on one or more of the factors outline above.

Additionally, users of the Wetland Inventory should consider the following qualitative observations made by analysts while developing this dataset:

- The Provincial DEM, which has a resolution of 20 m, was used to create the terrain layers that were used to derive the land cover and wetland inventories for the portion of the study area that did not have LiDAR coverage (Figure 4). The coarse resolution of the terrain data limited the ability to detect small wetland features and accurately predict wetland boundary locations. Manual interpretation was used extensively in this area to improve the classification outputs; however, the lack of high-quality terrain data in this area likely impacted the accuracy of the Wetland Inventory.
- Wetlands dominated by woody vegetation (i.e., Swamp, Bog, Fen) are notoriously difficult to classify without field sampling. This is because of the need to differentiate between mineral and peat soils to accurately differentiate Swamps (mineral soils) from Fens (peat soils). High resolution soils data do not exist for the study area, and we did not have access to validation data that was collected in the field. Consequently, accurately differentiating between Swamps and Fens in our classification was difficult, and there is likely to be confusion between Swamp and Fen classes in the inventory, especially in the Rocky Mountain and Foothills region.
- Several areas within the southeastern portion of the study area have been highly modified by human activities. This includes development of canals, redirecting and altering watercourses, filling in or leveling natural topography, and filling or draining wetlands. These kinds of human alterations affect the ability to accurately predict and identify wetlands on the landscape. As a result, the accuracy of the Wetland Inventory in these areas is likely lower as compared to less modified areas.
- In and around many urban areas or towns, wetlands have been replaced with or have been modified into stormwater management facilities (SWMF). Older SWMF can be readily differentiated from wetlands, as these facilities have a distinct visual appearance (e.g., deep water, uniform shorelines, minimal or manicured vegetation). Newer SWMF are more difficult to differentiate from wetlands, and in some cases, modifications to wetlands are minimal and the wetland continues to perform many of its natural functions. As part of the creation of the Wetland Inventory, features that appeared as obvious SWMF were removed. Wetlands that have been integrated into a stormwater management facility, but appeared to retain its original boundary may have been retained. This scenario occurred most in the newly developed and outlying areas of the City of Calgary. All efforts were made to remove or retain features in a consistent way; however, the decision to retain or remove was ultimately up to the discretion of the analyst. Some users may not agree with these decisions.

- The “Disturbed” identifies wetlands that appear to have been impacted by various agricultural activities (e.g., drainage, cultivation, modified with a dugout). This label was assigned to wetlands using the “Lowland Mineral Disturbed” land cover class. There is some inherent subjectivity associated with this label and different people may have higher or lower tolerance for what warrants labelling a wetland as disturbed. For example, a wetland may appear as cultivated in the SPOT image that was for the classification, but it may be avoided in other years. Additionally, some wetlands that have been disturbed by cultivation or have been modified in some way may have been missed. Ultimately, this “Disturbed” attribute is meant to alert users that there is a high likelihood the wetland has been disturbed or altered in some way, but it may not be accurate in all cases.
- An automated approach was used to assign wetland class based on land cover proportions (see Section 4.2.2). This hierarchical decision tree is an adaptation of the AWCS “Classification Key to Wetland Classes and Forms” (AESRD 2015); however, it is solely based on proportions of land cover classes and does not account for spatial configuration of different cover classes or traits such as water depth or temporality. Thus, woody wetlands (Swamp, Fen) are likely to be overclassified, and confusion between Marsh and Shallow Open Water can occur. Ultimately, users should keep in mind that the wetland class assigned to features in this inventory are the *predicted* class, and these classes should be verified in the field.

8.2.3. Historical Wetland Inventory

The historical images of the study area provide important context about the condition of the landscape during the mid-1900s. Particularly for wetlands, where historical loss of habitat has been extensive, this past view allows for a better understanding of the location and extent of landscape change. While the Historical Wetland Inventory was created to provide users with a better understanding of changes in the extent of wetland habitat in the study area, the age, resolution, and quality of the historical imagery presented significant challenges that impacted the accuracy of the inventory. We discuss some of the key issues below:

1) Each individual historical image tile (based on NTS tiles) is a compilation of many smaller air photos (ABMI 2015). To create a single image tile, each individual air photo was georeferenced separately, and all the air photos that made up a single image tile were compiled together. While our team performed secondary georectification on each of the image tiles that were used to create the Historical Wetland Inventory, we were not able to perform a secondary georeferencing on the individual air photos that made up each of the larger tiles. As a result, any georeferencing errors associated with individual air photos reduced the accuracy of our inventory. Examples of common issues related to image georectification are described below:
    a. In many instances, the georectification error for a single air photo was high, resulting in poor alignment between adjoining air photos that created a “duplication” of areas along the margins of air photos (Figure 14). While an effort was made to manually correct these duplication errors, this issue affected large portions of the study area and likely contributed to error in the inventory.
    b. In many locations across the study area, adjacent image tiles do not match up, resulting in gaps between the tiles (Figure 15 and Figure 16). As a result, the historical image coverage of the study area is not seamless. This resulted in areas within the Historical Wetland Inventory where there is no data.
    c. In areas where there is varying topography, image tiles are often warped and stretched (Figure 17). This changes the size and shape of features, such that the wetland boundary is not a true reflection of the actual boundary. This makes wetlands

hard to identify in the historical image, as well as makes it difficult to directly compare size and shape of wetlands between the Historical and Current inventories.

2) When the individual air photos were initially compiled by the ABMI into larger image tiles, the digital number (DN) values were not standardized across photos in any way. Consequently, there is high variability in tonal contrast (dark and bright areas) across and between image tiles (Figure 15 and Figure 18) that resulted in inconsistent segmentation results that required extensive clean-up. Specifically, where image contrast was poor, the segmentation algorithm was not able to accurately identify wetlands or generate smooth boundaries (Figure 16 and Figure 18). The lack of DN value standardization also made the QA/QC more difficult, as features of interest could not be automatically identified using DN threshold values. As a result, our team had to rely on manual clean-up of the segmentation results, which was very time consuming and difficult due to the resolution and quality of the imagery.

Despite these challenges, as many wetlands as possible were identified from the historical imagery. Many users of this data will be tempted to directly compare the location, number, and extent of wetlands between the Historical and Current Wetland Inventories; however, we strongly caution against this approach.

Direct spatial comparisons between the two inventories, especially at smaller spatial extents, is not appropriate due to the issues outlined above. Additionally, despite multiple rounds of secondary georeferencing of the historical image tiles, the spatial offset between wetlands in the Historical and Current inventories (especially for small wetlands) in certain areas remain quite large (Figure 15 and Figure 18). Because of this, directly associating a wetland in the Historical Inventory with the same wetland in the Current Inventory is difficult, which makes direct comparisons of area loss/gain impossible at the scale of an individual wetland, as well as at larger spatial extents. We also caution against making direct comparisons of the number of wetlands identified in each inventory at any spatial extent given the known errors in the Historical Wetland Inventory dataset.

While this inventory has its limitations, it can be used as a visual reference to generally compare changes in wetland distribution across the study area. This includes identifying locations or regions where a change in wetland area is most evident, including both loss and gain of wetland area. For example, in many locations, many small wetlands have been drained (area loss) and consolidated into one large wetland (area gain). This highlights areas where surface water flows have been substantially altered, which may be helpful in identifying the root cause of larger surface water management issues, such as flooding or water quality concerns.

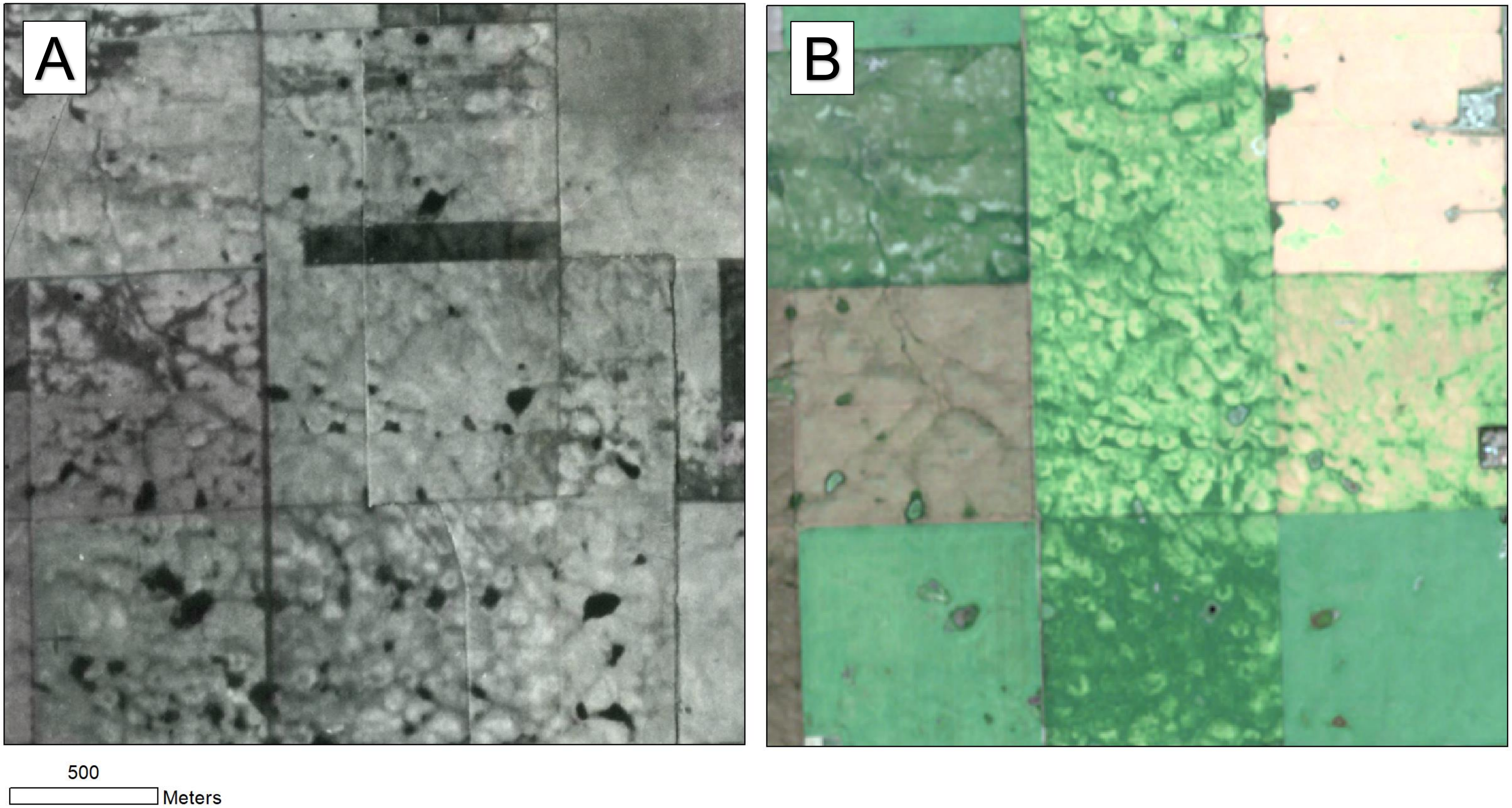


Figure 14. Example of poor georectification of adjoining air photos in the historical image tiles (A), with current imagery (B) for comparison. These types of georeferencing errors resulted in the "duplication" of areas along the margins of air photos, which could not be resolved by our team.

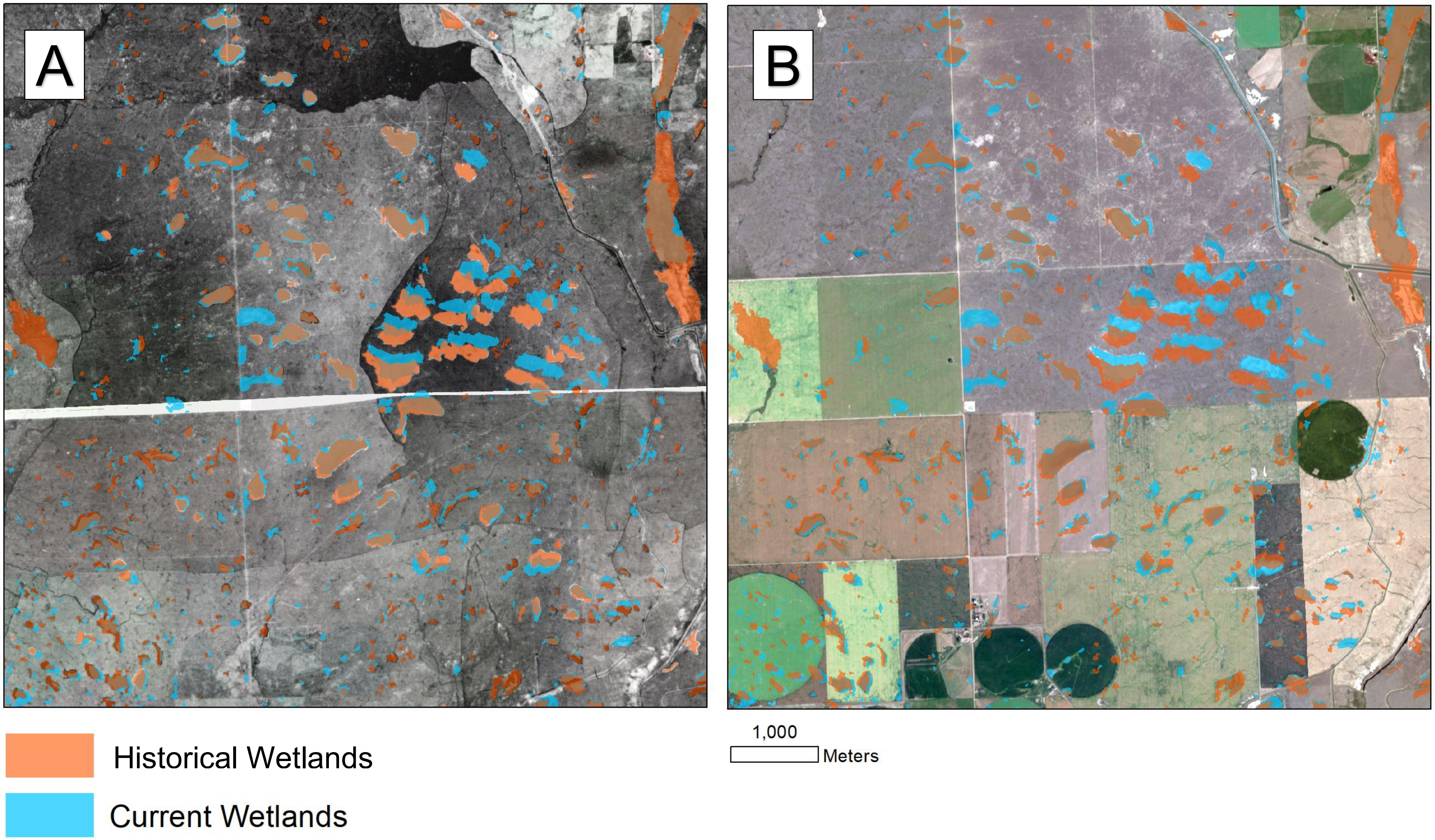


Figure 15. Example of georeferencing errors and variation in spatial offset between the Historical and Current Wetland Inventories, as overlaid on historical (A) and current (B) imagery. Features are generally aligned well throughout the image area; however, the offset is much higher in the central part of the image. The differences in contrast and Digital Number (DN) balancing are also apparent in the historical image, as is the gap between air photo tiles.

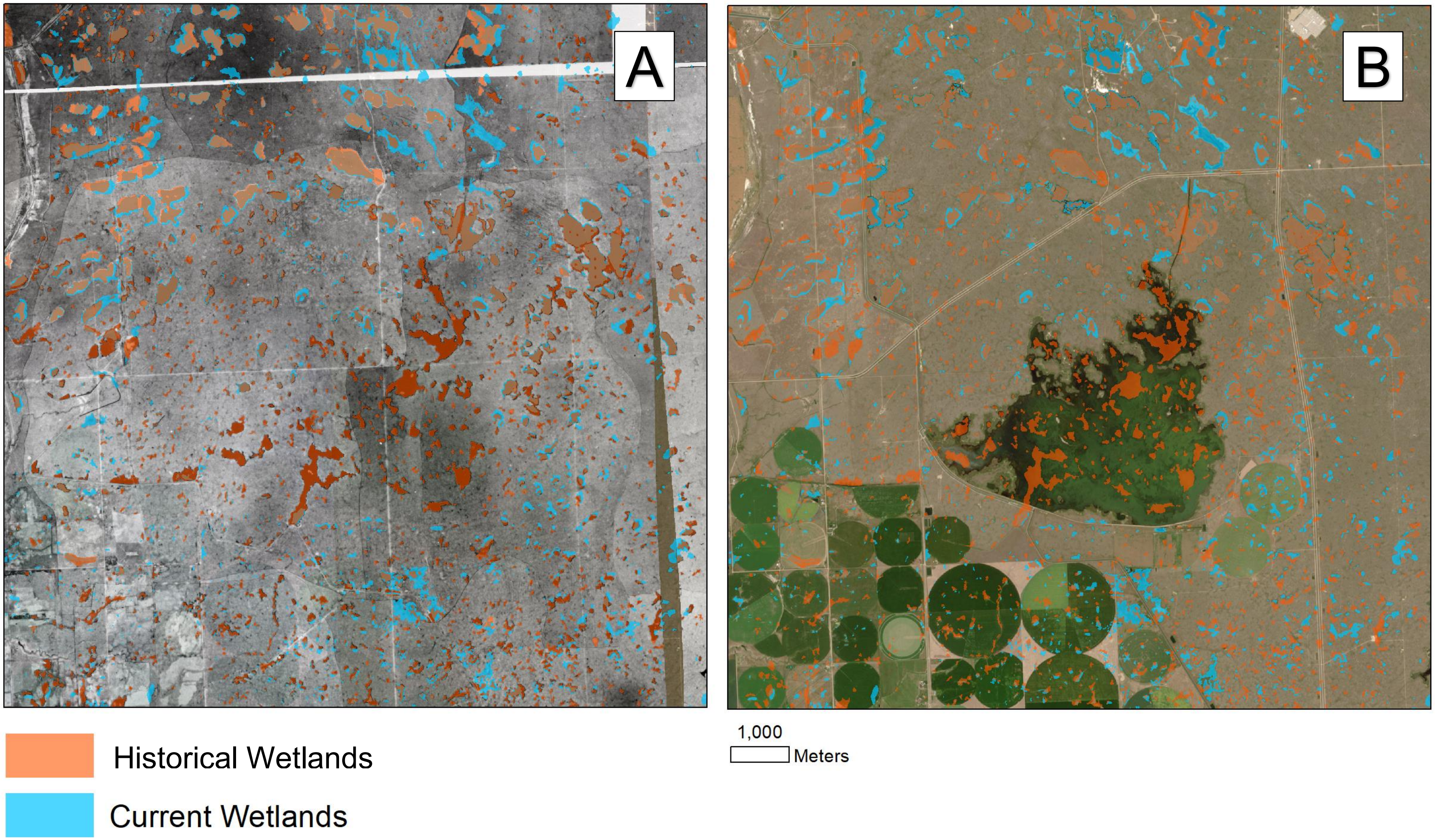


Figure 16. Example of the gaps between image tiles and poor contrast in the historical air photos (A). The segmentation algorithm was able to identify larger wetlands quite well; however, where the contrast in the black and white imagery was low (e.g., lower right portion of image A), the segmentation did not capture small wetlands.

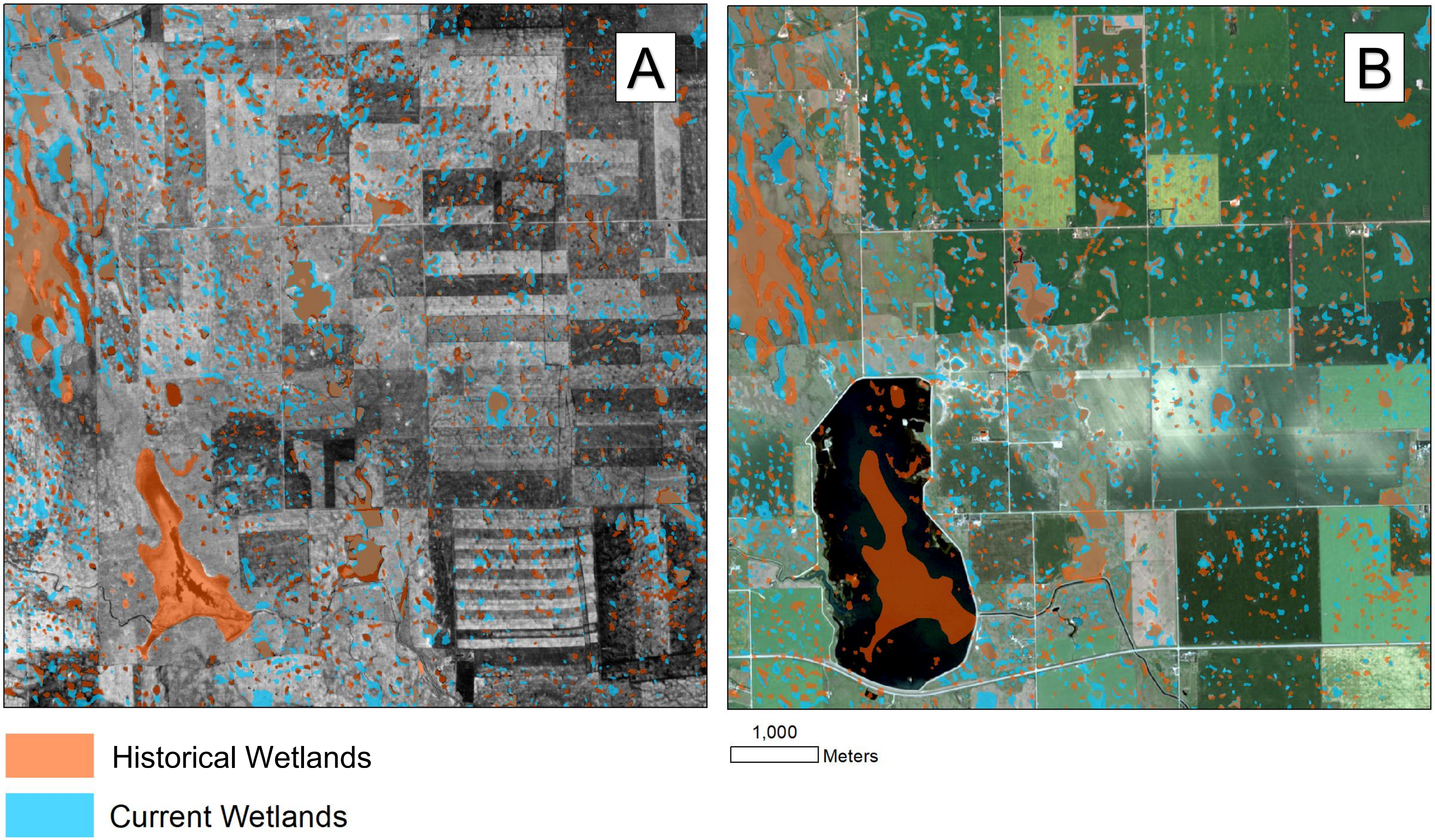


Figure 17. Example of georeferencing errors and variation in spatial offset between the Historical Wetland Inventory and the Wetland Inventory, as overlaid on historical (A) and current (B) imagery. Warping of the historical image (A) is particularly notable in the agricultural fields.

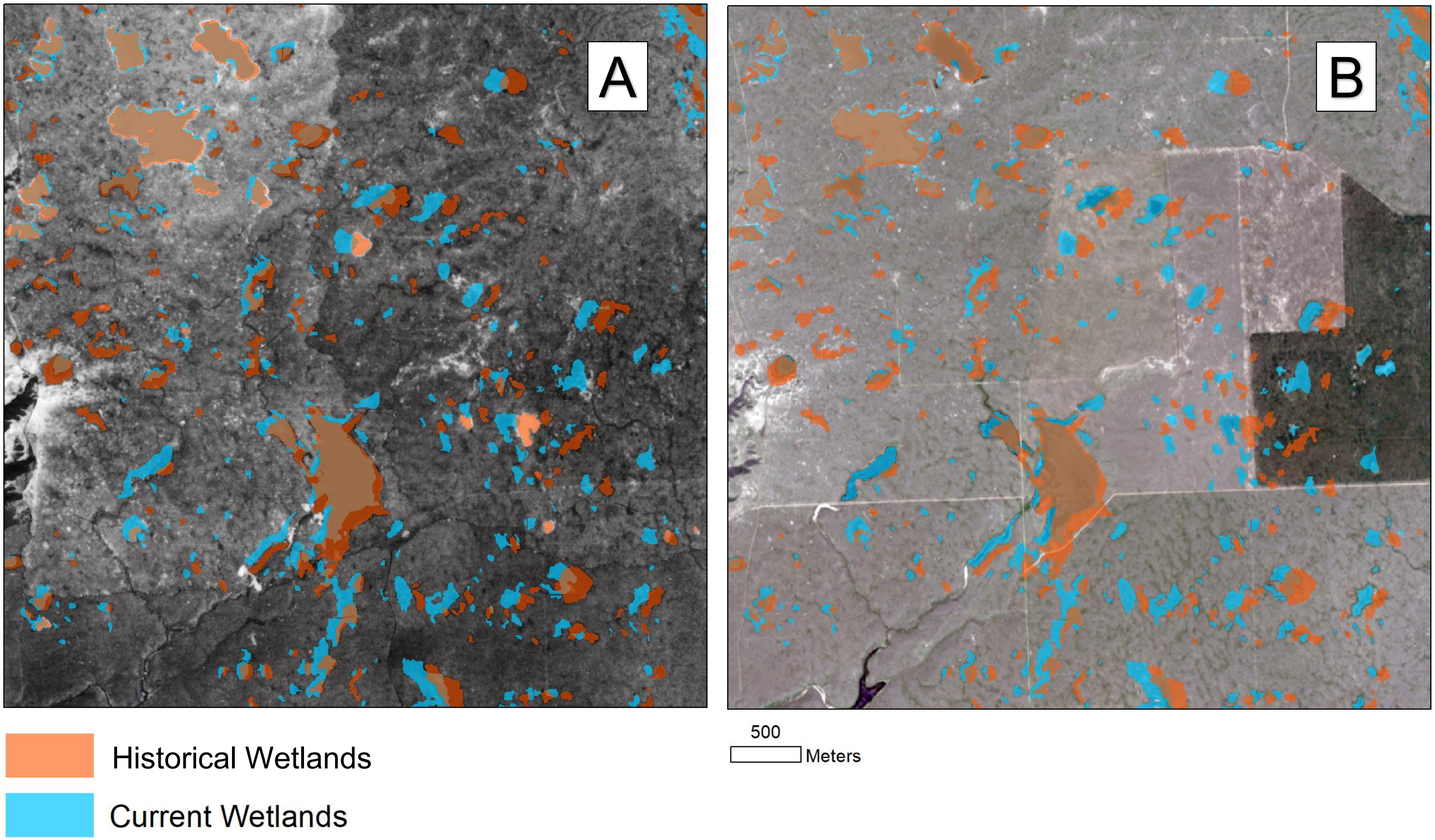


Figure 18. Example of georeferencing errors and variation in spatial offset between the Historical and Current Wetland Inventories, as overlaid on historical (A) and current (B) imagery. Features are generally aligned well in the upper left of the image area; however, the offset is much higher in the right side of the image. The differences in contrast and DN balancing are also apparent in the historical image.

8.2.4. Restorable Wetland Inventory

The Restorable Wetland Inventory was derived from manual interpretation of high-resolution air photo images (ESRI Basemaps) and satellite images (Google Earth) available across the study area. These features were detected at a moderate zoom scale of 1:10,000 with restrictions on “zooming in” to spend extra time evaluating features in detail. In some cases, determining whether a wetland is associated with a drainage feature came down to weight of visual evidence, and because of this, there may be points placed in basins where there is no drainage ditch.

When the points from the restorable inventory are compared to the Wetland Inventory, there may be instances where the point does not intersect a wetland. This can occur for a variety of reasons:

- The point is a short distance from the delineated wetland (within 20 m).
- A wetland and/or obvious drainage features were visually detected in the base map imagery but was not detected as part of the land cover classification algorithm. The classification algorithm depends extensively on terrain modelling and prediction of wetland basins from the LiDAR data. Consequently, wetland may not have been identified in areas where the terrain has been extensively altered due to drainage activities, or in areas where there the terrain features do not provide a strong wetland “signal” (e.g., shallow basins associated with ephemeral or temporary wetlands). Notably, natural hydrology has been extensively modified in many portions of the study area (particularly the eastern portions). This includes earth moving and construction of canals, berms, reservoirs, dugouts, and drainage ditches to re-direct, retain, or eliminate surface water. In these highly modified areas, it can be challenging to understand where the historical wetland basins are located, and thus, it is difficult to know where to place the “point” to locate the restorable basin.
- In instances where the analyst identified drainage, but could not clearly identify a basin, a point was located on the drainage feature. In some cases, these may be locations of tile drainage, and in these instances, there is no overlap with a wetland in the Wetland Inventory.
- A point is associated with a drainage feature that is connected to a dugout, borrow pit, or reservoir that was removed as part of the editing and QA/QC step that eliminated anthropogenic features from the inventory.
- A point may have been erroneously assigned to a feature that is associated with a natural drainage course (i.e., ephemeral stream), rather than an anthropogenic drainage feature.
- A point may have been erroneously assigned to a feature that is not a wetland.
- More than one point may be assigned to a single wetland in the Wetland Inventory. This may have occurred in instances where multiple wetlands have been drained and have been consolidated into what is now a single, large basin.

Assessing the accuracy of the Restorable Wetland Inventory was not possible, as there are no existing datasets to complete this task, and field verification was not undertaken given the size of the study area. As such, this data can be used to identify locations where there is a high probably of a restorable basin being present; however, all locations should be verified in the field prior to making management or restoration decisions based on the data.

8.3. Primary Users & Applications

Wetlands and other natural habitats are essential components of the landscape that provide important ecosystem services to people. Some of the most well-recognized ecosystem services provided by wetlands include water filtration and treatment, amelioration of floods and droughts, and modulation of local, regional, and global climate systems. Wetlands also provide many other less recognized regulating, provisioning, and cultural services that significantly contribute to human well-being, such as nutrient cycling modulation, erosion control, pollination, and aesthetic appreciation.

There has been extensive loss and/or conversion of wetlands and other natural habitats in Alberta over the last century. This has resulted in the loss of important ecosystem services that have negatively impacted communities. Because of this, there is increasing recognition of the need to conserve and restore natural habitats. To do this, more effective and coordinated land use planning is needed at both local and regional scales. These new datasets can contribute to more effective and coordinated local and regional land use planning in southern Alberta. Specifically, these datasets can be used by municipalities, watershed groups, stewardship groups, friends-of groups, land trusts, industrial operators, agricultural producers, and provincial government departments to undertake a wide range of different analyses, monitoring, or planning initiatives. Some examples of how these datasets can be applied by users is provided below. Note that this is not an exhaustive list of potential uses, but rather, serves to illustrate the diverse range of applications for the datasets.

- The **Land Cover** and **Current Wetland Inventory** provide a benchmark for the current extent of natural habitats in the study area. This serves to provide a measure against which any future habitat losses can be assessed, including understanding rates of conversion/loss over time.
- The **Land Cover** and **Current Wetland Inventory** can be used by municipalities to assist with landscape level planning (e.g., Intermunicipal Development Plans, Area Structure Plans). These datasets can also be used by municipalities to create a Natural Asset Inventory such as the one that was recently completed by the Town of Okotoks (Fiera Biological 2020). Additionally, these datasets can be used to carry out a wide range of local and regional assessments, such as assessing the contribution of natural assets to flood mitigation (e.g., Clare et al. 2021), carbon storage and sequestration, or other ecosystem services of interest.
- The **Land Cover** can be used for a wide range of habitat assessment, monitoring, and modelling applications, such as connectivity analysis, habitat modelling, and conservation planning.
- The **Current Wetland Inventory** and **Restorable Wetland Inventory** can be used together to identity wetland restoration opportunities in the study area. Municipalities and other organizations who wish to access provincial Wetland Restoration Program funds can use these datasets to identify potential locations for restoration projects.
- The **Land Cover**, **Historical Wetland Inventory** and the **Restorable Wetland Inventory** may be useful in identifying watersheds that may be at risk. Local watersheds with a high density of drained wetlands, or where there has been a large change in wetland cover may be susceptible to water management issues such as flooding or poor water quality. This analysis may be particularly useful for municipalities who may be experiencing water management issues, as this allows for an exploration of land use and wetland cover in watersheds located upstream.
- The **Current Wetland Inventory** can be used to identify wetlands that may be candidates for habitat enhancement. This can be done using the “Disturbed” attribute, which identifies wetlands that may be eligible for inclusion in habitat enhancement or stewardship programs, such as those offered by organizations like ALUS, Agriculture Woodlot Extension Society, and others.

9.0 Conclusion

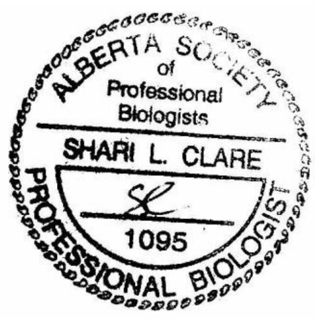
Effective land use and conservation planning requires reliable, consistent, and accessible datasets. To expand the capabilities and potential for conservation planning within the Bow River Basin, this project created four new spatial data products, including a Land Cover Inventory, Wetland Inventory, Restorable Wetland Inventory, and Historical Wetland Inventory.

The datasets were created with the intent of making them useful and accessible to a broad range of organizations and for a wide range of applications. In particular, these datasets provide useful information about the current location, extent, and class of wetlands that can be used to inform local and regional land use planning. Additionally, the datasets can be used to identify areas where historical loss of wetlands has been high, as well as wetlands that may be eligible for restoration through the provincial Wetland Restoration Program. Combined, these datasets can be used to improve the conservation of remaining wetlands, while also identifying opportunities to restore lost or degraded wetlands and their associated ecosystem services. The Land Cover inventory can also be used alongside the wetland datasets to support a large number of conservation planning initiatives that range from watershed planning to natural asset inventories.

Notably, while these datasets provide an opportunity to undertake a wide range of planning, monitoring, and restoration initiatives, users should be aware of the limitations of the datasets. In particular, prior to using the data, users should be aware of the minimum mapping unit that was applied to each dataset. This will ensure that the user understands the size of features that may have been missed in the mapping. Further, to ensure the highest level of mapping accuracy, these datasets should be used alongside a field or other verification process.

9.1. Closure

This report was written by:



Shari Clare, PhD, PBiol
Director, Sr. Biologist

Shantel Koenig, MGIS, PhD
Sr. Landscape Ecologist and GIS Specialist

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FIERA
Biological Consulting

301, 10359-82 Avenue | Edmonton, Alberta | T6E 1Z9 | 780.466.6554
w: fieraconsulting.ca | e: info@fieraconsulting.ca | t: @FieraBiological