Analyses of regional wetland distribution using predictive ecosystem mapping data sets for west-central Yukon and east-central Alaska

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Abstract

Predictive ecosystem mapping (PEM) in west-central Yukon and east-central Alaska effectively defines the location of larger, contiguous wetlands; however, it does not provide an accurate estimate of wetland. A quality control comparison between detailed mapping in the Indian River drainage and a regional PEM data set indicates that wetland area is underestimated by approximately two thirds within the PEM data set. Despite this, the PEM is useful at locating areas of wetland abundance from a regional perspective. Within the Tr'ondëk Hwëch'in Traditional Territory, the Ogilvie Mountains and Tintina Trench contain the largest concentrations of wetlands, whereas the Klondike Plateau has approximately 50% less wetland density due to topographic characteristics. When analyzing wetland distribution for the Klondike Plateau ecoregion that spans the border between Yukon and Alaska, the largest wetlands are located distal to the Yukon River in valleys that have not been affected by Pleistocene base level change. Overall average wetland coverage, for all study areas, is estimated to be upwards of 10% of the landscape. Their abundance is attributed to a combination of suitable terrain, Pleistocene aeolian sedimentation, periglacial processes and a climate supporting extensive discontinuous permafrost. Understanding regional wetland distribution through PEM can help frame significance when considering land management decisions that weight the placer mining economy and environment.

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Introduction

The distribution and character of wetlands in west-central Yukon, and in particular the Indian River drainage, has become a topic of interest in recent years. This was initiated by increasing awareness of placer mining activities in the drainage and concern that with wetland loss, an important part of the environment and its function could not be recovered. Best management practices for placer mining in wetlands continue to evolve, although fundamental differences in opinion remain regarding landscape transformation. This paper sets out to analyze the distribution and abundance of wetlands from the greater landscape perspective. The goal is to help frame the significance of landscape transformation in the Indian River drainage and advise land use planning decisions as they attempt to balance the environment and economy. Previously published predictive ecosystem mapping (PEM) and detailed mapping data sets are utilized to both identify the location of large wetland complexes and quantify their spatial significance within a variety of political and ecological boundaries in west-central Yukon and east-central Alaska.

Background

Location of Study Areas

Analysis of wetlands in west-central Yukon can be assessed from a number of regional perspectives. Politically, there are two important regional boundaries in which to analyze spatial data: the Dawson Land Use Planning area and the Tr'ondëk Hwëch'in Traditional Territory (Fig. 1). A second perspective is by ecoregion boundary, which defines a region based on similar physiography, ecology and climate (Fig. 1). For the purposes of this study, wetland distribution in west-central Yukon will be assessed according to the Tr'ondëk Hwëch'in Traditional Territory (63 983 km^2) and the Klondike Plateau ecoregion (102 490 km^2) that spans the border between Yukon and Alaska.

The distribution of wetlands will also be assessed within the Indian River drainage (2257 km^2), both as a means to evaluate the accuracy of regional data sets and to understand Indian River wetland area within the context of other wetland complexes in the region (Fig. 1).

Placer Mining in the Klondike Plateau and Indian River

Placer mining within the study areas, and in particular the Klondike Plateau, has been on-going since the 1880s. Robert Henderson prospected the Indian River drainage prior to the Klondike gold rush and focused on the tributary Quartz Creek before discovering gold in the Hunker Creek drainage. His efforts and communication with other prospectors led to the discovery of gold in nearby Bonanza Creek that kick-started the Klondike gold rush of 1897–98. During the ensuing years, all of the major gold-bearing creeks in the Klondike district were discovered and partially prospected or mined by hand. This included a number of tributaries to the Indian River including, Dominion, Gold Run, Sulphur, Eureka and Quartz creeks. The main stem of the Indian River was prospected during these early years, but was considered too low grade for early hand-mining methods. Following the hand-mining era, came a period of dredging that lasted from 1901–1966. The modern era of placer gold mining ensued with the introduction of bulldozer and excavator methods. In the late 1970s, prospecting was initiated along the Indian River floodplain. It was realized during this time that while placer gold distribution was erratic, high-grade patches were present that enabled economic production, especially with the rising gold price. In the early 1980s, placer mining along the main stem of the Indian River was initiated below the mouth of Quartz Creek marking the beginning of development in some of the larger wetland complexes in the valley (Debicki, 1983).

Total placer gold production from the Indian River drainage is estimated at more than 2 million crude ounces. Half of this production has occurred since excavator mining was initiated in the early 1980s. This equates to a modern economic value of more than $2.5 billion. To this day, miners in the Indian River drainage cumulatively produce more than 50% of the Yukon's placer gold every year. Approximately 250 people are directly employed by placer mining in the drainage and from an economic perspective, it is the most important placer gold producing watershed in Yukon.

More regionally, creeks and rivers of the Klondike Plateau ecoregion in Yukon such as the Klondike, Bonanza, Hunker, Sixtymile, Blackhills, and Henderson have historically produced more than 13 million crude ounces. Little to no production has been documented north of the Tintina Trench in the study area.

Physiography and Surficial Geology

Environments of west-central Yukon and east-central Alaska include a number of physiographic subdivisions including Klondike Plateau, Tintina Trench, and the southern and northern Ogilvie Mountains (Fig. 1; Smith *et al.*, 2004). The surficial geology is broadly subdivided

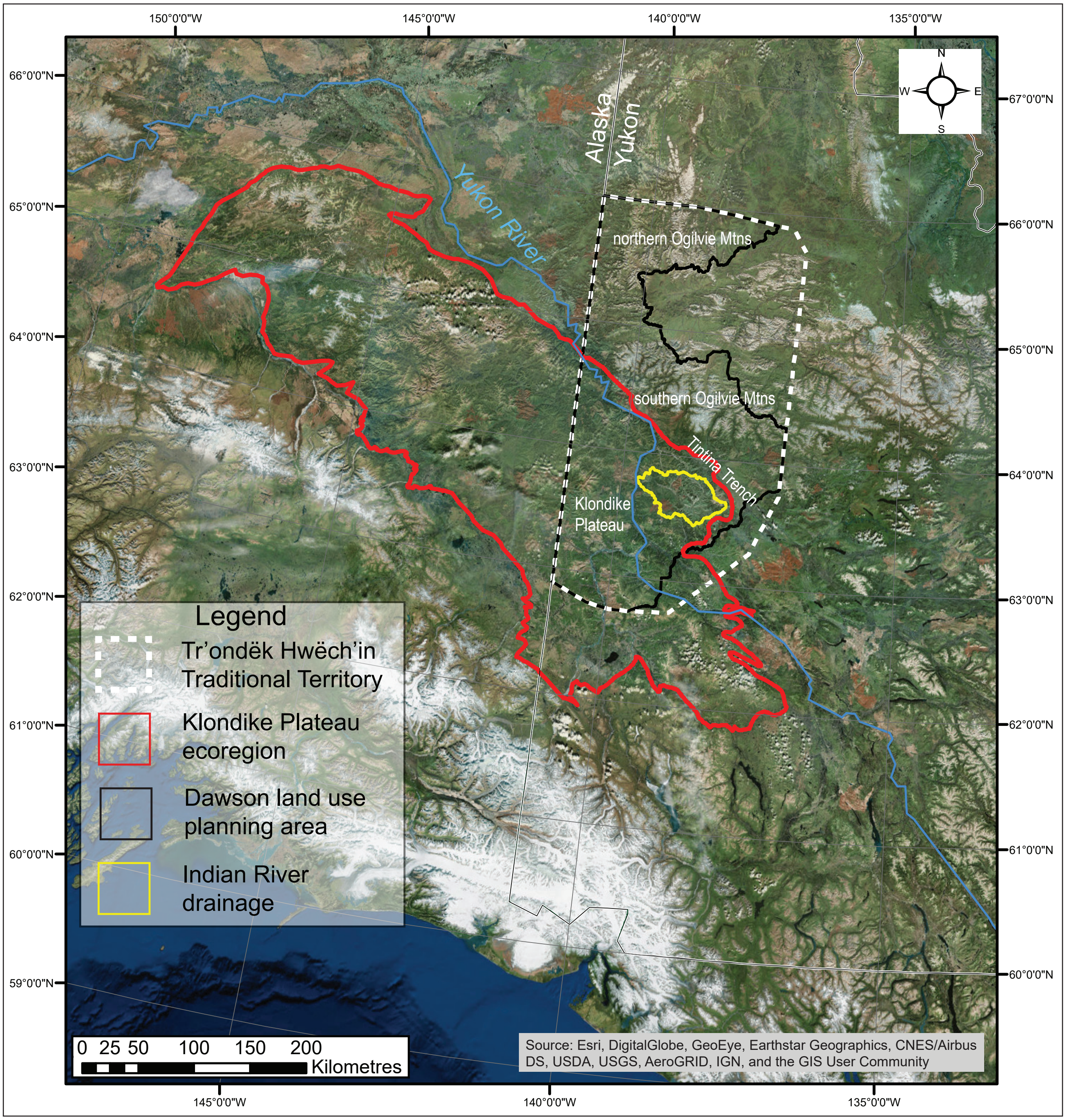

***Figure 1.** Location of the study areas located in Yukon and Alaska.*

by the physiography and glacial history of the region. Isolated ice caps formed repeatedly in the Ogilvie Mountains and Tanana Uplands in the Pleistocene and the Cordilleran Ice Sheet flowed into the area from the east along the Stewart River valley and Tintina Trench (Fig. 2). In these glaciated areas, valley bottoms are filled with mixed glacial debris and fluvial sediments. On steeper landscape positions the slopes are overlain by a variable cover of colluviated weathered bedrock and till. Outside of the glacial limits in the Ogilvie Mountains, the surficial deposits consist of colluviated weathered bedrock and fluvial deposits. Silt-rich loess deposits are incorporated into soils. The north slope of the southern Ogilvie Mountains, is a region of more subdued unglaciated foothills and a peneplain that encompasses the headwaters of the Ogilvie River.

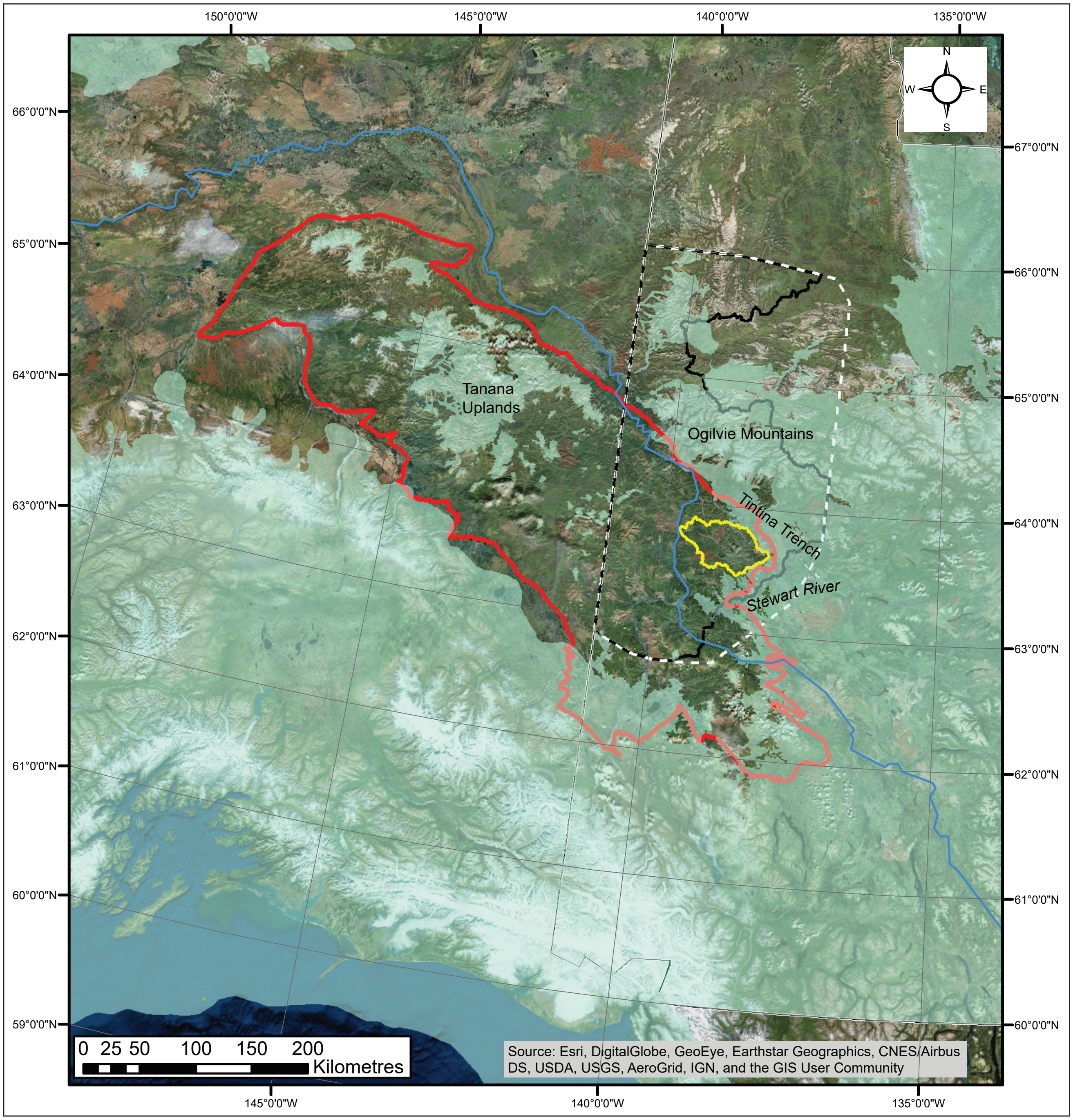

Figure 2. *The all-time limit of glaciation to affect the study areas (Duk-Rodkin, 1999; Manley and Kaufman, 2002).*

The Tintina Trench is a major strike slip fault with a physiographic expression that is characterized by a wide northwest trending valley. Within the study area the trench separates the Ogilvie Mountains from the Klondike Plateau ecoregions (Smith et *al*., 2004). The trench was a conduit for ice during glaciation that formed low relief and rolling topography. Sediments within the trench consist of dissected, unconsolidated glacial and fluvial sediments originating largely from the Ogilvie Mountains to the north (Duk-Rodkin, 1996).

The Klondike Plateau ecoregion in the southern part of the study areas extends northwest into Alaska and differs from the rugged mountainous terrain to the north (Fig. 1). The dissected plateau exhibits mature landscape characteristics with more subdued topography. With the exception of the Stewart River and Tanana Uplands in Alaska, most of the Klondike Plateau escaped glaciation (Fig. 2). Upland slopes are gentle, however cliff faces form where fluvial processes and base-level change have caused erosion against valley sides. Slopes are covered by weathered-bedrock colluvium. Fluvial deposits are widespread in the valley bottoms and include Pliocene and Pleistocene fluvial terraces that developed in response to early Pleistocene base-level change along the Yukon River.

Loess deposits are widespread on the Klondike Plateau in Yukon and Alaska and are an important soil component for wetlands. Loess was produced largely during glacial climates when interior Yukon and Alaska were drier and less vegetated. Floodplains during these periods were more active and therefore had less vegetation to stabilize surface sediment, making them susceptible to wind erosion. Repeated glacial climates during the Pleistocene have resulted in significant loess accumulations on the landscape. Reworking of loess deposits off hillsides and into valley bottoms by sheetwash and solifluction processes is ongoing. The result is poorly drained, silt-rich, surficial accumulations that are geomorphologically important for establishing terrain characteristics ideal for hosting wetland soils (Figs. 3 and 4).

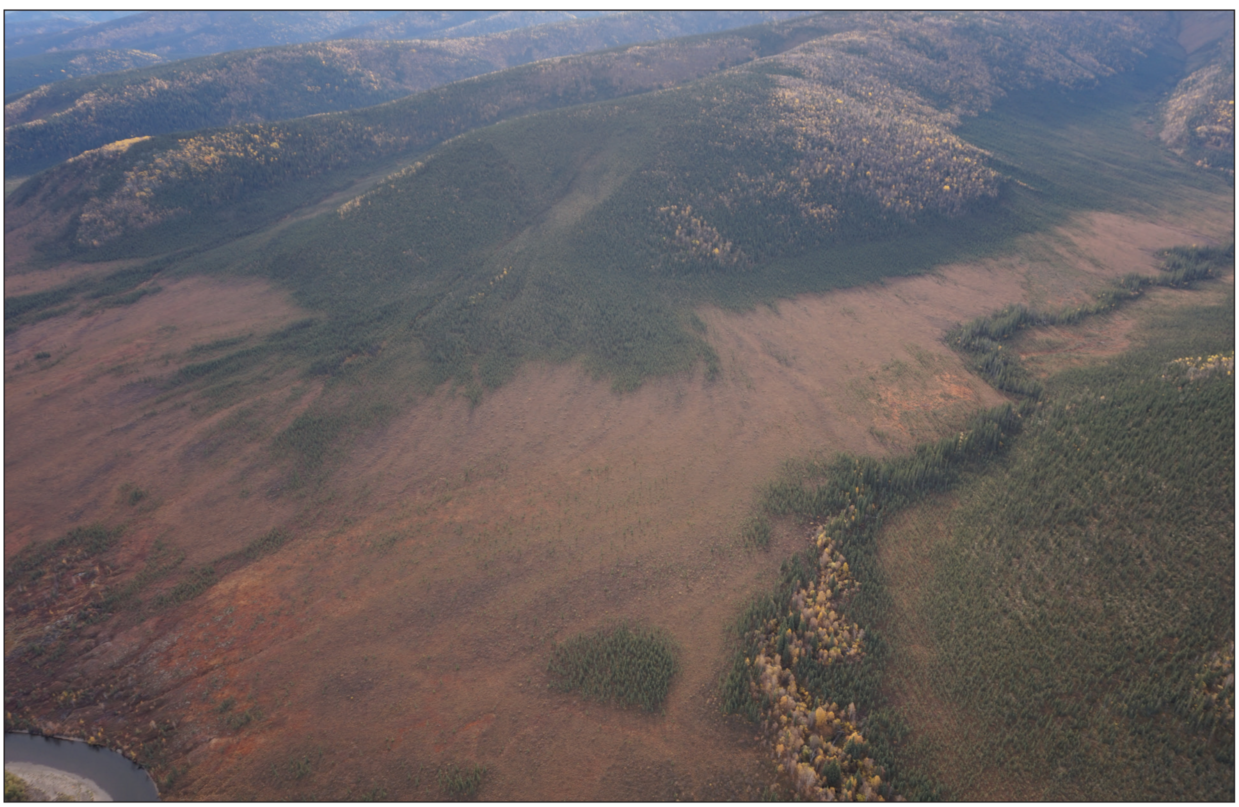

Figure 3. *An example of terrain modified by sheetwash processes in the Klondike Plateau ecoregion near Dip Creek. Subtle lines or streaks within the light-red coloured vegetation highlight the flow of water and sediment (loess) across this landform. This process creates a smooth apron underlain by fine sediment and permafrost. This landform would be considered a fen wetland.*

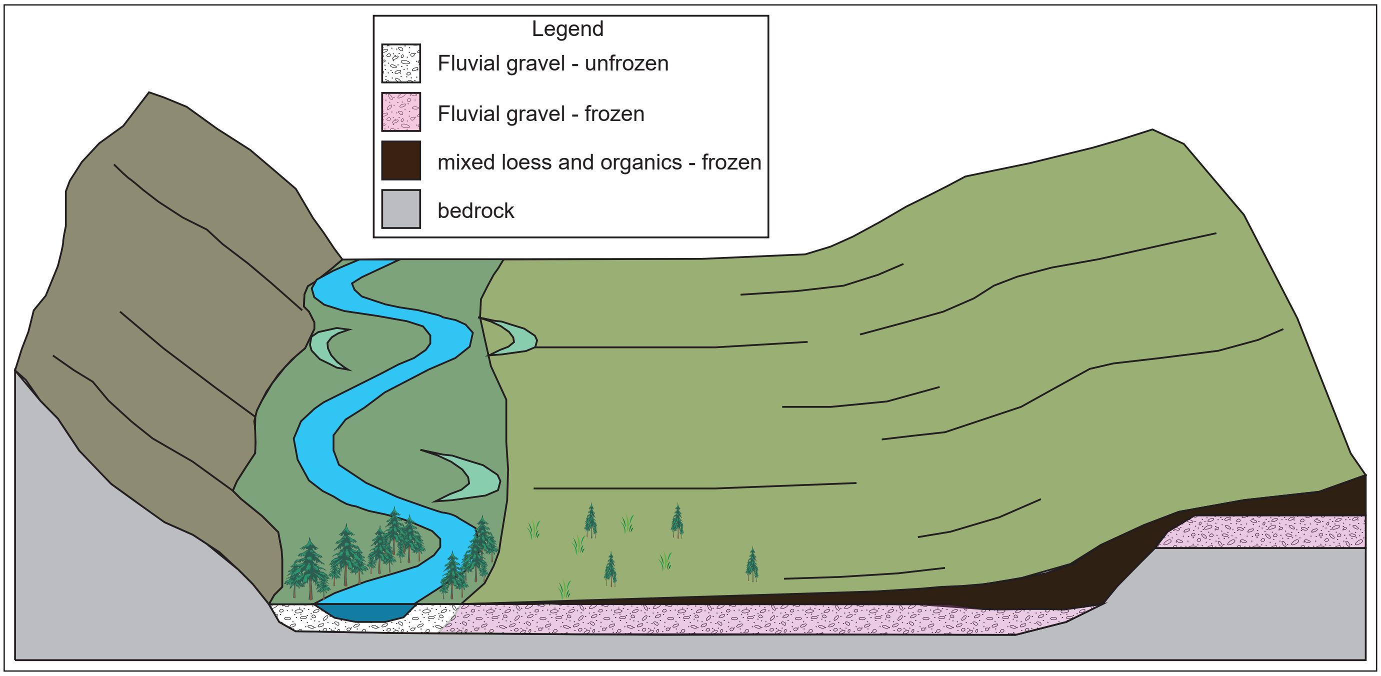

Figure 4. *A block diagram depicting typical sediment stratigraphy in an unglaciated valley in the study areas. Note the mixed loess and organic unit forms a wedge of sediment across the floodplain. This unit traps moisture and provides insulation, which promotes permafrost development.*

Permafrost

The study areas span the zones of extensive discontinuous and continuous permafrost. Its presence and characteristics are further controlled by site topographic position, aspect and surficial geology. Disseminated to massive ice may be present and ice wedge polygons are common, particularly in poorly drained valley bottoms (Fig. 5). Permafrost is an important controlling factor in most wetlands within the study areas.

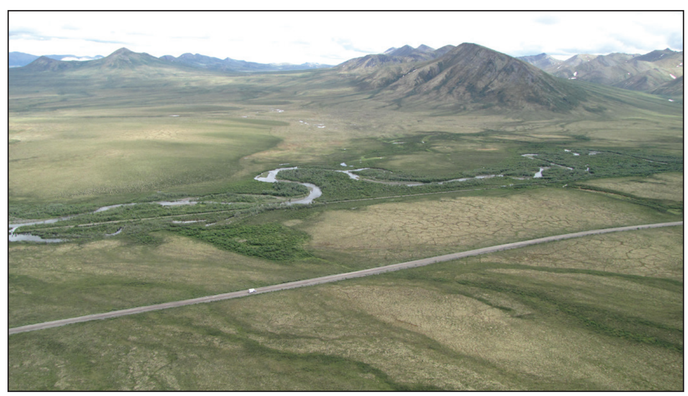

Figure 5. *Ice wedge polygons are visible in the flat-lying terrain near the Dempster Highway in the southern Ogilvie Mountains.*

Wetlands

Detailed wetland classification in the study areas has not occurred outside of the Indian River valley. Therefore, the major classes of wetlands in the Indian River area are assumed to be found across the greater study areas. According to McKenna (2018) the major classes include fens, bogs, marshes, swamps and open water ponds. Fens are by far the most common wetland class, largely due to the prevalence of permafrost-rich sloping terrain (Figs. 6 and 7).

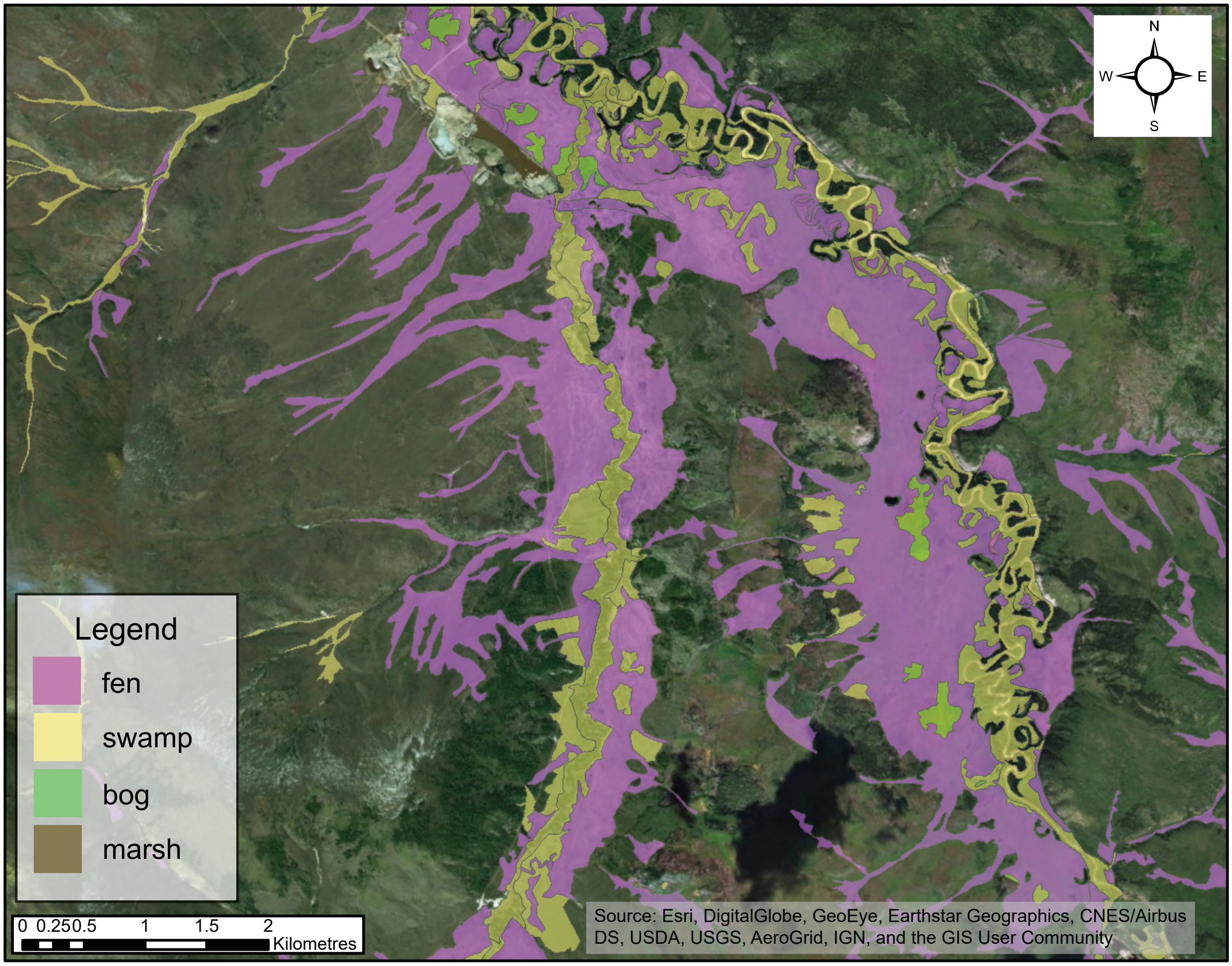

Figure 6. *An excerpt of the mapping completed by McKenna (2018) in the Indian River drainage near the mouth of Montana Creek. Fen wetlands account for the majority of the wetlands in the valley bottom.*

Figure 7. *An aerial view over a typical fen wetland near a placer mine in the Indian River valley. The sparsely treed fen wetland is underlain by a layer of reworked loess that is interbedded with organics that accumulated over the last 6,000 years. Permafrost is prevalent. The relatively flat surface is dipping gently towards the foreground allowing surface waters to drain slowly across that landform.*

Methods

Predictive Ecosystem Mapping (PEM) Data Sets

Two predictive ecosystem mapping data sets were used to evaluate the regional distribution of wetlands within the study areas. For west-central Yukon, the broad ecosystem spatial data was used, and in Alaska, the National Land Cover Database was analyzed (Grods et *al*., 2012a; Homer et *al*., 2015). PEM modeling uses a series of data inputs such as spectral land cover, surficial geology and topography, along with knowledge of ecosystems, to predict ecosystem distribution over large areas (Grods et *al*., 2012b). The final product is a raster data set with a best-fit classification for each cell.

The west-central Yukon broad ecosystem spatial data set established 44 different possible ecosystem phases from 11 broad ecosystem types (Grods et *al*., 2012b; Fig. 8). The modelling generated a raster map with 25 by 25 m resolution of the ecosystem phases. For this study, wetland distribution and abundance analyses included the phases: Wetland–Herb Bryoid (311), Wetland–Shrub (312) and Wetland–Treed (315). Phases excluded from the analyses that may have wetland characteristics, included floodplain ecosystems and wet drainage and depression phases. By only including the “most obvious” wetland phases it allowed spatial identification of the more significant wetland complexes. As a result, the area calculations are considered a minimum, which is discussed further in the Data Accuracy section below. Within Alaska, a similar PEM data set was used that classified the land cover into 20 different units and applied the modeling to a 30 by 30 m resolution raster (Fig. 9; Homer et *al*., 2015). For analyses of wetlands using this data set, the Woody Wetlands (90) and Emergent Herbaceous Wetlands (95) units were utilized. In addition to analyzing the wetland phases, the anthropogenic disturbances are also quantified for discussion purposes.

The distribution and abundance of wetlands within the study areas was assessed using ArcMap software. With the two PEM data sets loaded into ArcMap, various political or physiographic boundaries were used to clip the raster data sets. After the clipping process, the attribute table for the newly created raster data set was extracted to Excel to multiply the attribute “count” field by the area of the raster cells (625 m^2–Yukon data; 900 m^2–Alaska data). The spatial abundance of a particular land cover attribute can then be quantified within the respective study boundary. Identification of concentrated and relatively abundant wetland cells was completed visually by toggling off non-wetland attributes in ArcMap.

The boundaries used for clipping and analyzing the PEM raster data sets included the Tr’ondëk Hwëch’in Traditional Territory (TT), Klondike Plateau ecoregion and the Indian River watershed. Where large wetland complexes were identified (e.g., >30 km^2), an arbitrary shapefile polygon was created around the specific complex and used to clip the PEM raster data to extract the statistics.

Data Accuracy

The accuracy of the PEM data sets was assessed by comparing it to detailed 1:10 000-scale wetland mapping by McKenna (2018) and 1:50 000-scale surficial geology mapping of organic units by Jackson (2005) within the Indian River drainage. Both of these detailed data sets included ground-truthing. While it is recognized that PEM will not be as accurate as manual airphoto and field-based mapping, the comparison was useful to assess and quantify spatial differences and accuracy.

A visual comparison revealed that the PEM data are reasonably effective at identifying the major valley-bottom wetland complexes that occur on relatively flat to gently-sloping surfaces in the Indian River valley bottom and its tributaries (Fig. 10). The PEM method is less accurate at identifying wetlands on sloped topographic positions and in narrow valley bottoms (Fig. 10). In addition, some areas that were identified as ‘floodplain’ on the PEM classification were mapped as a wetland class in the detailed mapping by McKenna. Table 1 summarizes the wetland area for the Indian River according to the different methodologies. It should be noted that wetland mapping completed by McKenna (2018) did not include most of Dominion Creek, which accounts for 19.4% of the drainage. Approximately 1818 km^2 of the Indian River drainage was mapped during the McKenna study and this value is used when calculating percentage of wetlands as land cover.

Group		Type *	Phase *
DRY	UPLAND Ecosystems (100)	Rock (700)	Not applicable
		Ridge (110)	Ridge – Herb-Bryoid (111) Ridge – Shrub (112) Ridge – Deciduous (113) Ridge – Mixed wood (114) Ridge – Coniferous (115)
		Steep South-Facing Slope (120)	Steep South-Facing Slope – Herb-Bryoid (121) Steep South-Facing Slope – Shrub (122) Steep South-Facing Slope – Deciduous (123) Steep South-Facing Slope – Mixed wood (124) Steep South-Facing Slope – Coniferous (125)
		Upper Slope (130)	Upper Slope – Herb-Bryoid (131) Upper Slope – Shrub (132) Upper Slope – Deciduous (133) Upper Slope – Mixed wood (134) Upper Slope – Coniferous (135)
MOIST		Gentle Slope and Plain (140)	Gentle Slope – Herb-Bryoid (141) Gentle Slope – Shrub (142) Gentle Slope – Deciduous (143) Gentle Slope – Mixed wood (144) Gentle Slope – Coniferous (145)
		Steep North-Facing Slope (150)	Steep North-Facing Slope – Herb-Bryoid (151) Steep North-Facing Slope – Shrub (152) Steep North-Facing Slope – Deciduous (153) Steep North-Facing Slope – Mixed wood (154) Steep North-Facing Slope – Coniferous (155)
WET	WETLAND Ecosystems (300)	Drainage and Depression (160)	Drainage and Depression – Herb-Bryoid (161) Drainage and Depression – Shrub (162) Drainage and Depression – Deciduous (163) Drainage and Depression – Mixed wood (164) Drainage and Depression – Coniferous (165)
		Wetland (310)	**Wetland – Herb-Bryoid 311)** **Wetland – Shrub (312)** **Wetland – Treed (315)**
		Floodplain (370/380/390)	High Flood Frequency (370): • Floodplain – Gravel Bar-Herb-Bryoid (371) • Floodplain – Shrub (372) Moderate Flood Frequency (380): • Floodplain – Deciduous (383) • Floodplain – Mixed wood (384) Low Flood Frequency (390): • Floodplain – Coniferous (395)
	WATER and ICE (400)		Water (401) Ice (Glacier) (403)
OTHER	**DISTURBANCE (500)**		Natural Disturbances (501) Anthropogenic Disturbances (502) Mine site Disturbances (503)

Figure 8. *The ecosystem phases identified by Grods et al. (2012b) and utilized to produce the west-central Yukon predictive ecosystem map.*

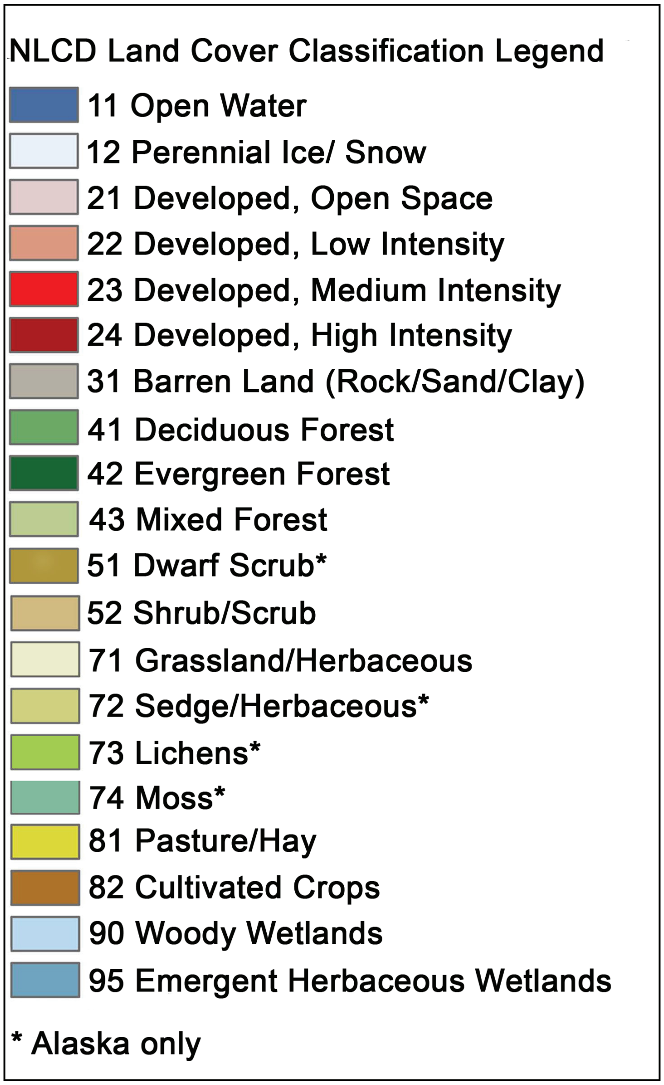

Figure 9. *The land cover classification used to produce the Alaska predictive ecosystem map (Homer, 2015). NLCD = National Land Cover Database.*

The data accuracy results indicate that the west-central Yukon PEM mapping identified areas of contiguous wetlands but does not classify the sloped wetlands and wetlands proximal to the active floodplain environment. The PEM methods mapped 29% of the wetlands that were mapped by McKenna and 19% of the organics mapped by Jackson. For purposes of this study, since the PEM under-estimates the amount of wetlands by about ⅓, a multiplier of 3 is applied to more accurately estimate the true area of wetlands identified using the PEM. The multiplier is not applied to anthropogenic disturbance calculations since these features are spectrally easier to identify. Similarly, a multiplier was not applied to the Alaskan land cover data set because a local case study comparison was not available to evaluate that data set.

Results

The total area of wetlands and anthropogenic disturbance within the respective study area boundaries are presented in Table 2. For the Klondike Plateau ecoregion this includes both Yukon and Alaska data sets. A portion of the Klondike Plateau ecoregion in Yukon was not mapped by the west-central Yukon PEM and therefore the area values are considered minimums.

Within the Tr'ondëk Hwëch'in Traditional Territory the PEM determined there are 2367 km^2 of wetland and possibly as much as 7101 km^2 when considering sloping wetlands and the error adjustment. A number of sizeable wetland complexes were identified during the PEM modeling within the TT (Fig. 11 and Table 3). In the Ogilvie Mountains, extensive wetland complexes are present in the upper Ogilvie River area and along the Blackstone River. Farther south in the Tintina Trench, a considerable wetland area is present northeast of the Indian River drainage. Within the Klondike Plateau portion of the traditional territory, wetland complexes are found in the Indian River, Ladue River, Scottie Creek, and adjacent to the floodplains of the Yukon, White and Stewart rivers. The areas of anthropogenic disturbance include all municipal, transportation and mine-related activities. PEM suggests that 0.29% of the Tr'ondëk Hwëch'in Traditional Territory has been modified by humans.

In the Klondike Plateau, the combined Alaska and Yukon PEM data sets determined that there are >5131 km^2 of wetland covering >5% of the landscape (Fig. 12). These values do not take into account any potential adjustment error. Large wetland complexes are located on the southwestern side of the plateau, in particular, in the upper reaches of the Fortymile River and in the Scottie Creek drainage (Table 4; Fig. 12). On the south side of the Dawson Range, the Dip Creek area, a tributary to the Donjek River also contains a large wetland complex.

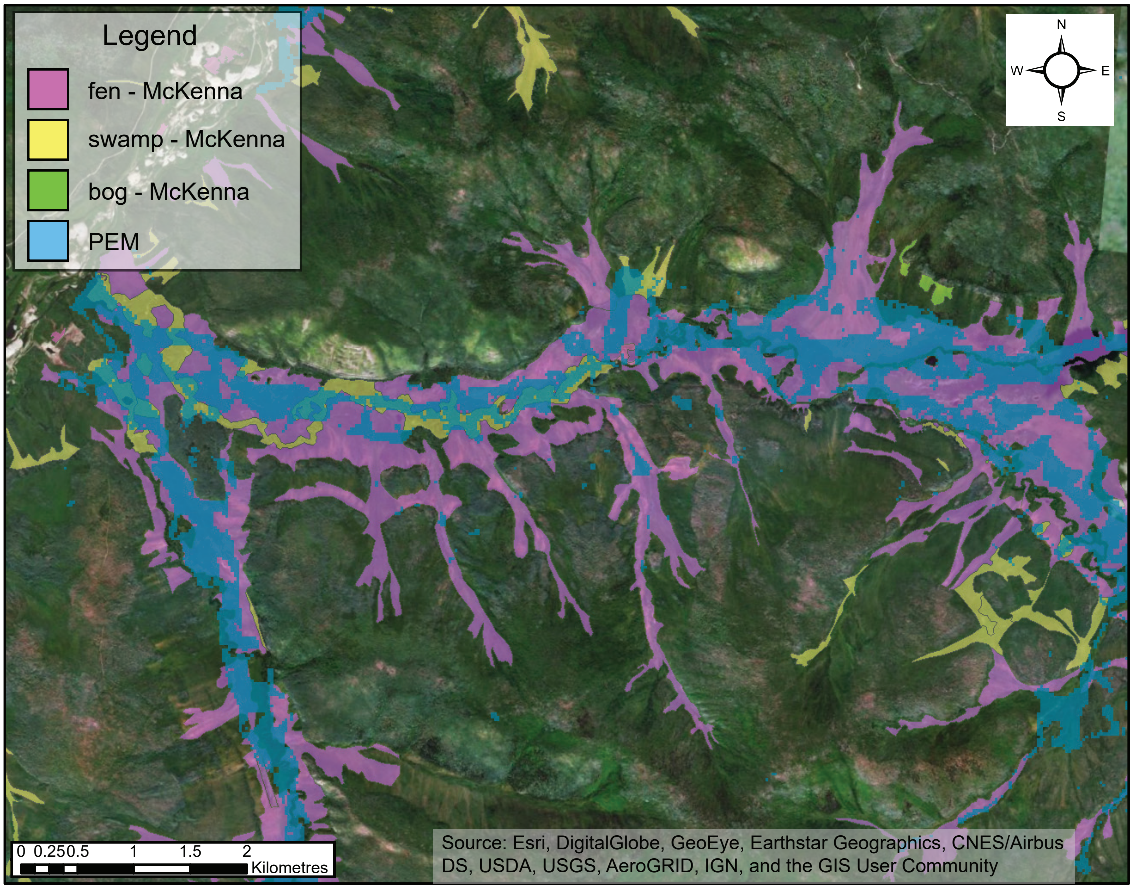

Figure 10. *A comparison of the predictive ecosystem mapping (blue) to detailed mapping completed by McKenna (2018, pink and yellow). PEM identifies wetlands in the flat to gently sloping terrain of the valley bottom but does not map wetlands up the valley slopes.*

Table 1. *Comparison of predictive ecosystem mapping to detailed mapping in the Indian River.*

Wetland Mapping Method	Area (km²)	Percent wetlands as land cover in drainage
PEM (wetlands)	53	2.3
PEM wetlands + floodplain	69	3.0
McKenna	143 (minimum)	7.9 (undisturbed wetlands)
Jackson organic units	278	12

Table 2. *Total area of PEM wetlands and anthropogenic disturbance within study areas.*

Assessment boundary (various)	Phase	Area (km²)	% of land cover	Area with 3× error adjustment (km²)	Adjusted % of land cover
Tr'ondëk Hwëch'in TT	W	2367	3.94	7101	11
Tr'ondëk Hwëch'in TT	A	171	0.29	n/a	n/a
Klondike Plateau	W	>5131	5	n/a	n/a
Klondike Plateau	A	274	0.27	n/a	n/a
Indian River	W	53	2.3	159	7.4
Indian River	A	63	2.8	n/a	n/a

W = wetland, A = anthropogenic disturbance, % of land cover refers to the percent of wetlands relative to the total area within the assessment boundary.

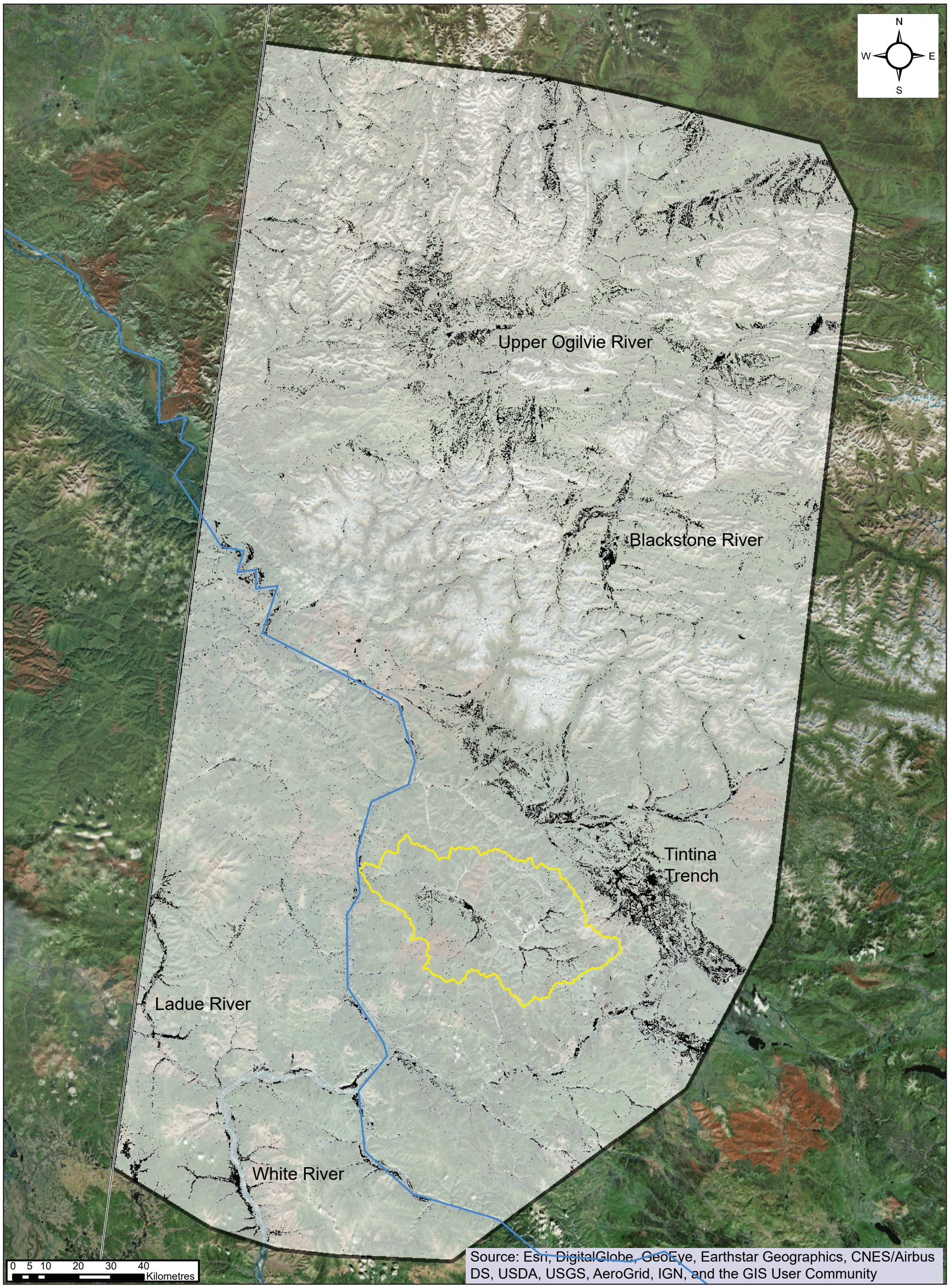

Figure 11. *Wetland distribution map of the Tr'ondëk Hwëch'in Traditional Territory (white shade) from the west-central Yukon PEM (Grods et al., 2012a). Black-coloured pixels correspond to wetlands modeled by Grods, et al., 2012. For reference, the Indian River drainage is highlighted in yellow. Wetland concentration is greater north of the Indian River and Klondike Plateau in the Tintina Trench and Ogilvie Mountains. The Ladue River wetland is the largest wetland in the Klondike Plateau portion of the Traditional Territory.*

***Table 3.** Large PEM wetland complexes in the Tr'ondëk Hwëch'in Traditional Territory.*

Wetland Name	**Area (km^2)**	**% of land cover**	**3× error adjustment (km^2)**	**Adjusted % of land cover**
Upper Ogilvie River	811	1.3	2433	3.8
Blackstone River	91	0.14	273	0.42
Tintina Trench	491	0.77	1473	2.3
Ladue-White River	73	0.11	219	0.33
Indian River	53	0.08	159	0.25
Sixtymile River	38	0.05	114	0.18

% of land cover refers to the percent of each wetland area relative to the entire Tr'ondëk Hwëch'in Traditional Territory.

***Table 4.** Large PEM wetland complexes in the Klondike Plateau ecoregion.*

Wetland Name	**Area (km^2)**	**% of land cover**	**3× error adjustment (km^2)**	**Adjusted % of land cover**
Dip Creek	107	0.1	321	0.31
Scottie Creek	204	0.2	612	0.6
Upper Fortymile River	592	0.58	n/a	n/a
Ladue-White River	73	0.07	219	0.21
Indian River	53	0.05	159	0.16
Sixtymile River	38	0.04	114	0.11

% of land cover refers to the percent of each wetland area relative to the entire Klondike Plateau ecoregion.

Discussion

Predictive ecosystem mapping was useful for identifying the location and distribution of large contiguous wetlands within the study areas. However, accurate quantification of wetland areas was problematic and a comparison with detailed mapping in the Indian River drainage suggests PEM captured ~29% of wetlands when analyzing the main wetland phases. In general, PEM does a good job of identifying wetlands on more gently sloping to flat topographic sites, whereas it does not predict wetlands found on moderately sloping topography. Spatial analysis estimates that wetlands cover between 4 and 10% of the total landscape in the study areas. Detailed mapping by McKenna (2018) determined that ~8% of the Indian River drainage contains undisturbed wetlands and 2.8% of the drainage has been modified by humans. Anthropogenically disturbed areas account for 0.29% of the landscape from the regional perspective. Updated disturbance mapping by the Department of Environment, Government of Yukon, indicate that disturbance is closer to 244 km^2 within the Traditional Territory, which amounts to 0.38% of the region (Heynen, *pers. comm.*, 2018).

Wetlands can be found throughout the Tr'ondëk Hwëch'in Traditional Territory largely due to permafrost conditions and the abundance of silt-rich soils. Overall, wetland density is greater north of the Klondike Plateau. The highest concentration of wetlands are found in the Tintina Trench near the Klondike River and in the headwaters of the Ogilvie River (Fig. 11). In the Klondike Plateau portion of the Traditional Territory the largest wetland complexes are found near the valleys of the White, Ladue and Indian rivers (Fig. 11). PEM spatial analysis estimates that the ratio of wetland density in the Ogilvie Mountains and Tintina Trench versus the Klondike Plateau is 2:1. In terms of overall volume inventory within the Tr'ondëk Hwëch'in

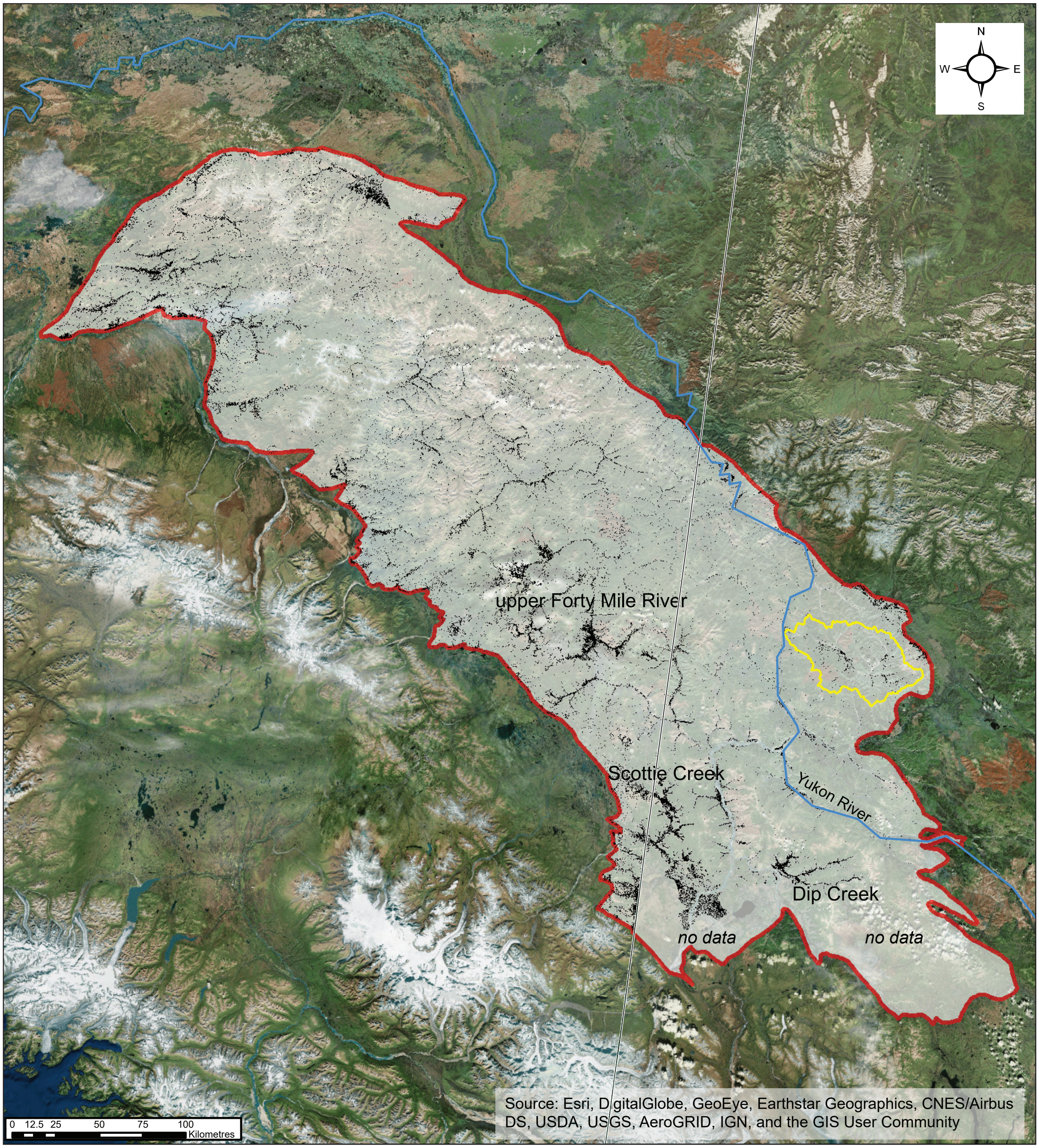

***Figure 12.** Distribution of wetlands across the Klondike Plateau ecoregion (white shade) that spans the border between Yukon and Alaska. Black-coloured pixels correspond to wetlands modeled by Grods, et al., 2012 and Homer, et al., 2015. The majority of the wetlands are concentrated in drainage reaches that are distal to the Yukon River such as the upper Fortymile River and Scottie Creek wetlands.*

Traditional Territory, 78% of the wetlands are located in the Ogilvie Mountains and Tintina Trench and the remaining 22% are located in the Klondike Plateau portion of the territory. Conversely, nearly 100% of the placer gold is produced from the Klondike Plateau ecoregion within the Traditional Territory.

A distinct spatial pattern of wetlands was observed in the Klondike Plateau. Drainages proximal to the Yukon River tend to contain fewer contiguous wetlands compared to drainages distal to the Yukon River (Fig. 12). This pattern is caused by the effects of base level change that was initiated when the Yukon River reversal occurred 2.8 million years ago (Hidy et *al.*, 2013 and 2018). The ensuing fluvial erosion had a ripple effect in tributary drainages causing stream incision and creation of a more complex (and less flat) topography in valley bottoms (Fig. 13). On the south side of the Klondike Plateau, drainages are generally more distal to the Yukon River, and as a result contain some of the largest wetland complexes in the ecoregion (Fig. 12). This includes the poorly drained valleys at the headwaters of the Fortymile River in Alaska and tributaries to the Tanana River such as Scottie Creek in Yukon.

Some of the largest placer gold deposits in Yukon remain in the Indian River drainage. This includes the Eureka bench, remaining deposits in Dominion Creek and Indian River, and the largely unexplored prospects of Australia, Wounded Moose and Montana creeks. In addition, opportunities still exist within, or adjacent to, previously mined areas (van Loon, 2017). Finding a balance between placer mining and wetland protection is challenging but possible. To effectively strike this balance, decision makers can benefit from considering both placer and wetland distribution from a more regional perspective. The Klondike Plateau, particularly in vicinity of the Yukon River, is an important placer gold resource area, whereas according to predictive ecosystem mapping, the Tintina Trench, upper Ogilvie River, upper Fortymile River, Ladue River and Scottie Creek have the largest wetland complexes.

While this assessment does not consider specific biological or cultural significance of the various wetlands, it does provide a perspective on the regional inventory and provides context for the Indian River wetlands. Continued improvements in reclamation practices by the placer mining industry are important in wetland environments. The structure of wetlands in the Indian River valley, and across the study areas are governed by geological factors such as permafrost, soil moisture holding capacity and landform. Understanding the natural connectivity and geology of these environments is beneficial for guiding mine planning and reclamation goals.

Conclusions

Wetlands in west-central Yukon and eastern Alaska are largely controlled by loess distribution, topographic position and permafrost. The impermeable soil conditions created by loess, or reworked loess, raises soil moisture conditions and promotes permafrost development, which further compounds water retention. The topography and geomorphology of the study areas varies, which influences the regional distribution of wetlands. Predictive ecosystem mapping is particularly good at identifying large, contiguous wetlands, such as those found on near-level surfaces. PEM is less accurate at predicting the location of sloping wetlands and therefore under estimates total wetland area by approximately two thirds.

Within the Tr’ondëk Hwëch’in Traditional Territory, wetland density is higher in the Tintina Trench and Ogilvie Mountain ecoregions compared with the Klondike Plateau ecoregion. This is largely due to the quantity of flat lying to gently sloping terrain. The Tintina Trench is a sediment-filled fault valley with relatively low-relief terrain and the Ogilvie Mountains have broad valleys and peneplains that are particularly suitable for wetland formation. In the Klondike Plateau ecoregion, the largest wetland complexes are located distally to the Yukon River in drainages that have been less affected by base-level changes. Predictive ecosystem mapping suggests the total volume of wetlands within the various study areas covers between 4 and 10% of the landscape.

In the Indian River drainage, detailed mapping indicates that 8% of the drainage is currently covered by undisturbed wetlands (McKenna, 2018). The total amount of anthropogenic landscape modification due to mining and road building in the drainage is estimated at

Figure 13. *Proximity to the Yukon River has influenced valley bottom morphology in the Klondike Plateau. The upper photo illustrates drainages that are distal to the Yukon River have yet to experience significant base level change and contain broad, relatively flat valley bottoms, which host large wetland complexes. Conversely, the lower photo illustrates drainages that are proximal to the Yukon River have responded to base level change by undergoing a period of incision and terrace development. This creates a more topographically complex landscape in the valley bottom that is less conducive to large wetlands.*

2.8%, with the majority of this located in valley bottoms where wetland and riparian phases are located. From this land area, approximately 2.1 million crude ounces of placer gold have been produced since the gold rush.

Balancing of environmental and economic interests in the Indian River drainage needs to take into account landscape attributes from a regional context. This includes both wetland and placer gold-related attributes. Predictive ecosystem mapping is good at providing a regional inventory of landscape cover, and can help frame significance for local-scale management decisions.

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