THE YUKON'S CLIMATE BLIND SPOT

How mining in peatlands could amplify our carbon footprint.

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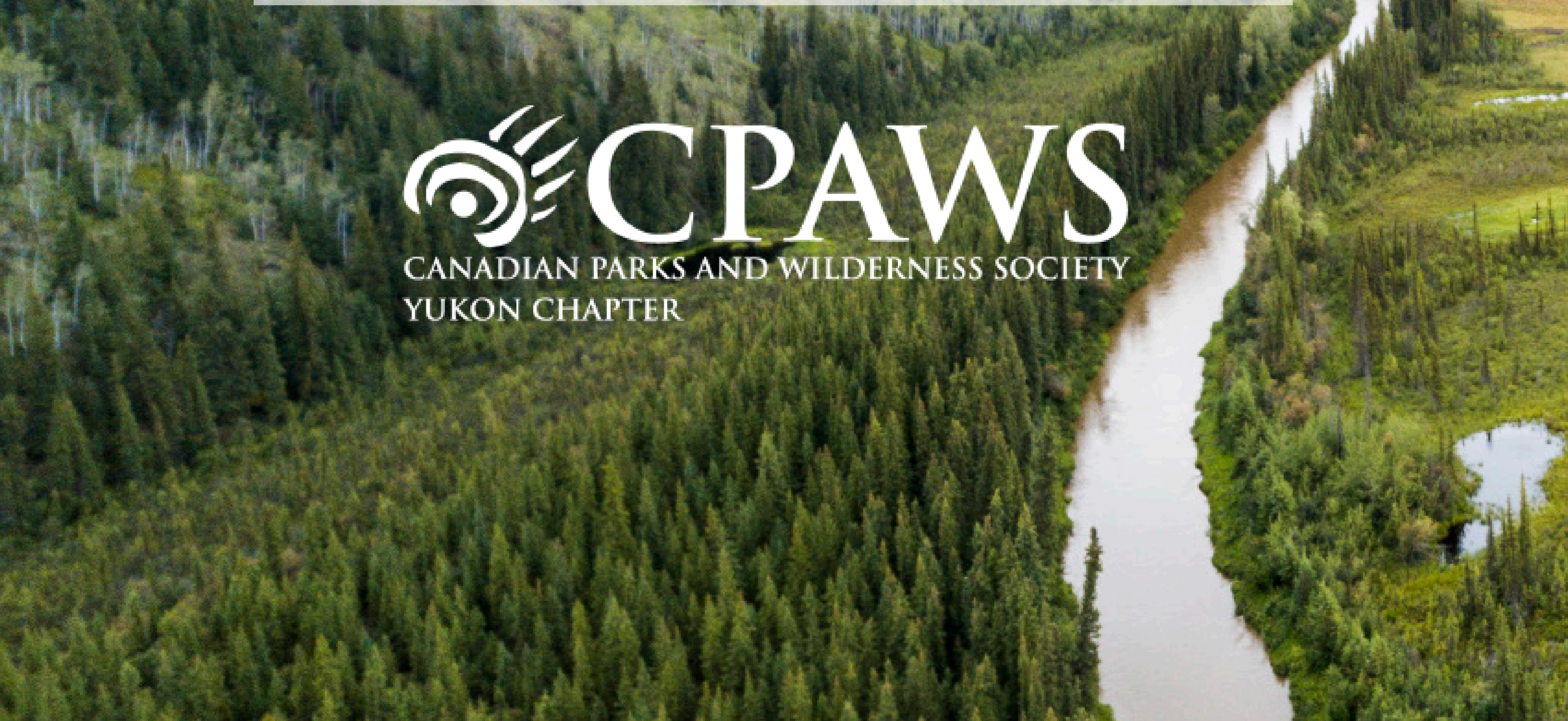

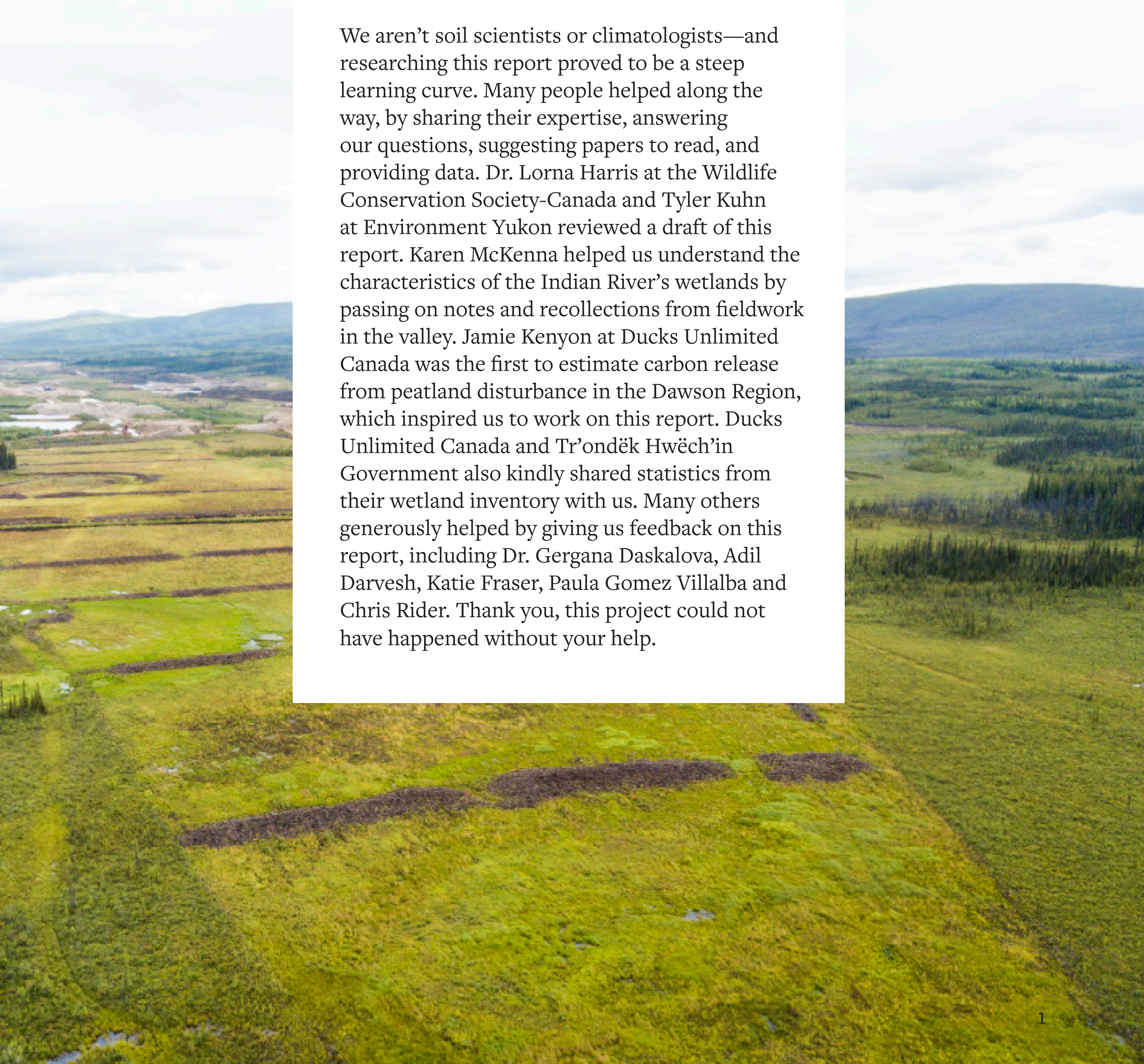

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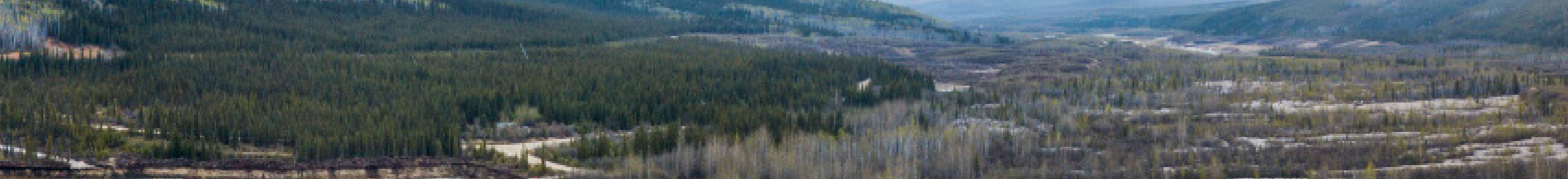
Executive summary

Centuries of burning fossil fuels and degrading nature has brought the world into a climate crisis. Across the Yukon, warming temperatures have triggered major changes to the lands people rely on for their livelihoods and lifestyles. In 2019 the Yukon Legislative Assembly unanimously declared a climate change emergency, and resolved to “apply the lens of climate change to all government decision-making.[1]” That following year, the Yukon released *Our Clean Future,* and pledged to cut the territory’s emissions 45% by the end of the decade.[2,3] But this climate change strategy, like many climate policies across the country and globe, is missing a key element. The Yukon has no plan to safeguard the carbon that is stored in peatlands.

Peatlands are a major carbon storehouse, holding carbon that has accumulated over thousands of years.[4] When people damage peatlands, carbon is lost to the atmosphere, adding even more fuel to the climate crisis.[5] National peatland maps don’t provide a fine scale picture of peatlands in the Yukon, and local mapping of peat has only happened in a few pockets of the territory. That means decision makers don’t have a good frame of reference for how much carbon the Yukon’s peatlands hold, and how much of this carbon is vulnerable. This report attempts to fill some of these gaps by looking at a small but important part of the Yukon: the Indian River Watershed.

The Indian River is the epicentre of the Yukon’s placer mining industry, and peatlands are being steadily lost as the footprint of mining expands. We worked with publicly available surface maps of peatlands to approximate the amount of carbon they store. From there, we estimated the carbon losses that could result from future mining disturbances in this landscape, based on the amount of development permitted under the Recommended Dawson Land Use Plan.[6] We estimated that over the next century, almost 600 kilotonnes of CO_2 could be released into the atmosphere because of placer mining in the Indian River’s peatlands alone. That’s the same amount of carbon as the annual tailpipe emissions from 125,000 cars—or running Whitehorse’s LNG plant around the clock, every day, for a decade.

The emissions from many peatland disturbances aren’t counted towards territorial, provincial and federal climate targets.[7] Unfortunately, these emissions have the same impact on the earth’s climate, regardless of whether or not they’re factored into our carbon accounting systems. Protecting peatlands and other natural carbon stores needs to be a pillar of the Yukon’s climate action plan. The Yukon is a small player in the fight against climate change, but home to peatlands that span thousands of square kilometres. Keeping the carbon stored in peatlands safely underground could be one of the Yukon’s biggest contributions to global efforts to control climate change.



Key messages

Peat is carbon-rich soil that can be thousands of years old. Around the world, peatlands hold more carbon than all the carbon humans have burned since the Industrial Revolution. Peat builds up in wetlands, like those along the Indian River, south of Dawson City.

Industrial developments in wetlands can unlock the carbon stored in peat, and release it to the atmosphere. We estimated that mining a hectare of fens would release about 70 tonnes of CO_2. Placer mining around the Indian River Watershed could release 574 kilotonnes of CO_2 over the next century—as much carbon as flying a fully loaded jet the circumference of the earth 425 times.

Mining is one of many threats to peatlands. Peatland disturbance is a major source of greenhouse gases, and the Yukon doesn't have a plan to limit these emissions—or even track them. It's time for the Yukon to take action to protect peatland ecosystems, and the carbon they hold.

Introduction

A string of extreme weather events over recent years has brought the climate crisis into sharp focus. Floods, wildfires and heat waves are striking with increasing regularity and severity. Each of the last four decades has set a new global heat record.[8] The planet has already heated up by over 1°C[8], and Northern Canada has warmed by 2.3°C.[9] Without steep cuts in carbon emissions, average global temperatures are very likely to rise by more than 2°C this century.[8]

Much of the world's attention has focused on the urgency of transitioning off fossil fuels. But there is another major factor in the climate crisis that is often forgotten—the impacts from people degrading nature. This report focuses on one key natural storehouse of carbon: peatlands. Peats are ancient, carbon-rich soils, made from partially decayed plants. Peatlands are found across the northern boreal region, as well as in the tropics.[10,11] Peat forms in wet areas, where the shortage of oxygen in waterlogged soils slows down the decomposition of vegetation.[12] Over thousands of years, layers of organic matter build into peat.[12] Disturbing peat can expose it to oxygen, which causes peat to decay and release carbon.

Peat is one of the earth's largest carbon reservoirs.[13] The world's peatlands hold over five hundred gigatonnes of carbon, more than all the carbon that humans have burned since the beginning of the Industrial Revolution.[14,15] Unfortunately, disturbing these peatlands can transform them from carbon stores to carbon emitters.[16,5] Industrial development from mining, logging and agriculture can unlock carbon that has been stored away for millennia, with serious implications for the climate crisis.

The carbon that is lost from peat is essentially irrecoverable.[17] Unlike logged forests, which may recapture carbon over a span of six or seven decades if allowed to regenerate,[17] peatlands take millenia to form. That means it would take peatlands thousands of years to recover lost carbon.[17] Global emissions from disturbed peatlands could account for between 10% to 40% of the world's remaining carbon budget—the amount of carbon that can be released without pushing the planet beyond 2°C of warming.[5] The decisions the world makes about peatlands could be the difference between meeting our climate goals, or the planet heating beyond the point of no return.

A note about carbon. Carbon takes many forms. Organic carbon molecules are stored in peatlands as soil carbon, which get transformed and released as carbon dioxide gas (CO_2) when peatlands are disturbed. In this report we state when we are referring to a specific type of carbon—but also use the word more broadly, as in the Yukon's efforts to cut its carbon emissions, or peatlands being key carbon stores. This report measures both soil carbon and CO_2 in kilotonnes, which is one thousand metric tonnes.

Yukon peatlands are in danger

Canada houses the world's largest peatland carbon store, with some of the most extensive distribution of peatlands found in the Hudson Bay Lowlands and Mackenzie River Basin.[18,19] Peat is found broadly, if patchily, across the Yukon: from the Old Crow and the coastal plain in the north, to MacMillan Pass in the east, to the Kluane Plateau and the Southern Lakes.[20–23] These peatlands come in many forms, like fens, bogs and swamps. Peat is often frozen as permafrost, or underlain by frozen ground. National-scale maps generally show limited peat deposits across the Yukon—but these maps may be less accurate for the Yukon where peat has not been thoroughly mapped in most places.[24] Local-scale mapping can reveal peatlands to be more common than previously thought, as was the case in the Indian River Watershed. There, environmental professionals "largely assumed" that wetlands were not prevalent in the area until extensive field surveying showed otherwise.[25]

Peatlands in places like the Klondike Goldfields are at risk from placer mining development. Because gold settles at the bottom of water courses, placer mining development is concentrated around rivers, creeks and wetlands. These habitats are often peatlands, and mine operators must remove entire peat deposits to access gold in the gravels beneath. Placer mining has already led to the widespread losses of peatlands in the Indian River.[26] Placer operators are required to reclaim mines, but these sites are very different from the original peatlands. The Yukon Environmental and Socioeconomic Assessment Board (YESAB) acknowledges that the loss of peatlands to placer mining development in the Indian River is "irreversible.[25]"

As with many jurisdictions around the world, the Yukon's climate change strategy does not address the climate impacts of developing peatlands. The Yukon does not include emissions from disturbances

The different types of peatlands

Fens, bogs and swamps are all peatlands, but differ in vegetation, hydrology and mineral balances. Fens are characterized by sedges and brown moss, while bogs are rich in Sphagnum moss.[27] Fens and swamps are fed by both groundwater and surface water, and the water table changes over the course of the year as water passes through the landscape. Bogs are cut off from groundwater, and are fed only by rainfall, snow melt and condensation. Swamps are often forested, and contain woody peat matter that is often shallower than in bogs and fens.[27,28] Swamps can occur on both mineral and organic soils. This report uses a shallow estimate for peat accumulation in swamps, to compensate for some swamps in the Indian River containing little peat.

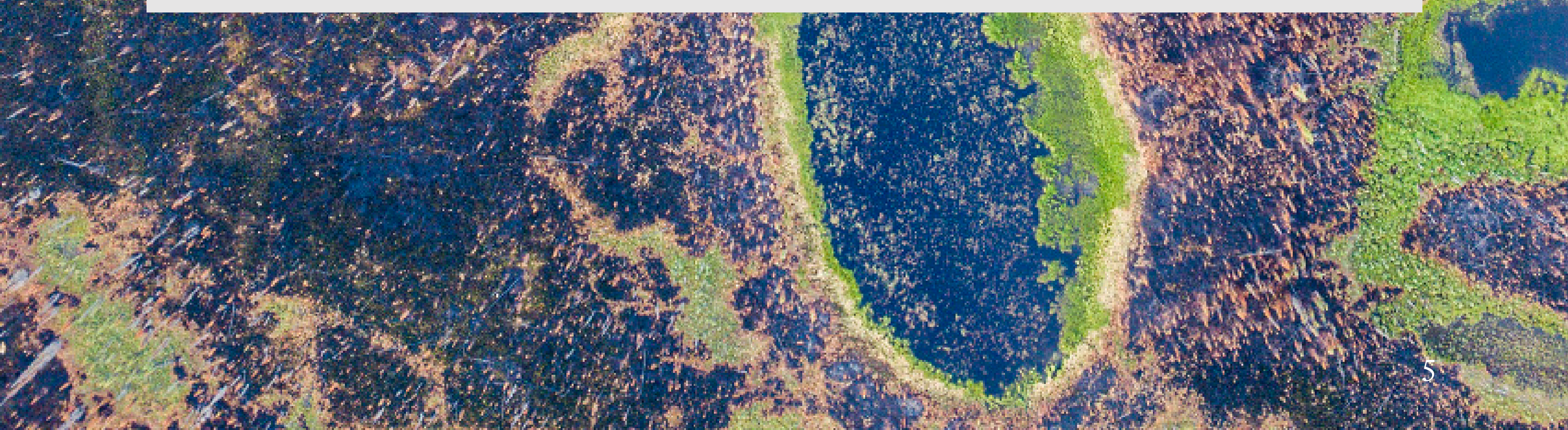
Other risks to peatland carbon stores

This report focuses on the impacts of peat from placer mining, but this is only one of many threats to peatlands in the Yukon. Developments like roads and ditches can indirectly impact peatlands, by interrupting the way water flows through landscapes. Water can accumulate on the upstream side of roads, while the water table downstream can drop, causing peat to dry out and decompose.[29] Wildfires are another major threat to peatlands. Peat that catches fire can smoulder for months or even years, and can result in rapid carbon releases.[16] Peatlands that have dried out as a result of previous disturbances are highly vulnerable to wildfires.[16]

Climate change is also a driver of peatland carbon emissions, especially among peat that is frozen as permafrost. On a micro scale, thawing permafrost stimulates microbial activity in peat, which in turn accelerates decomposition and the release of carbon into the atmosphere.[30,31] On a macro scale, thawing permafrost can drive dramatic landscape changes: collapsed hillsides and slumping river banks, new lakes forming in some places, while other lakes drain away.[32] These events can speed up the rate of permafrost thaw, or transform a landscape's hydrological regime—upending the natural cycles of water, fire and carbon in peat ecosystems.[31-33]

A note about methane. Methane (CH_4) is an important factor in the carbon fluxes of wetlands. Methane is a highly potent greenhouse gas, released as bacteria decompose organic matter in waterlogged conditions. Reclaimed placer mines are interspersed with shallow, open-water ponds, which are likely a source of methane.[34] Peatlands are another methane source, but overall, the sequestration and storage of carbon in peatlands outweighs the climate-warming impacts of methane release.[35] That means that over the past millennia peatlands have had an overall cooling effect on the earth's climate.[35] Human-driven disturbances that drain peatlands can reduce methane emissions from these ecosystems, which could offset some of the corresponding releases of CO_2 when peatlands are developed.[36] Looking closely at the relationship between methane, peatlands and placer mining was beyond the scope of the report, but nonetheless important for policymakers to examine.

Image: Scorched peatlands near Stewart Crossing, burned by a wildfire in 2022.



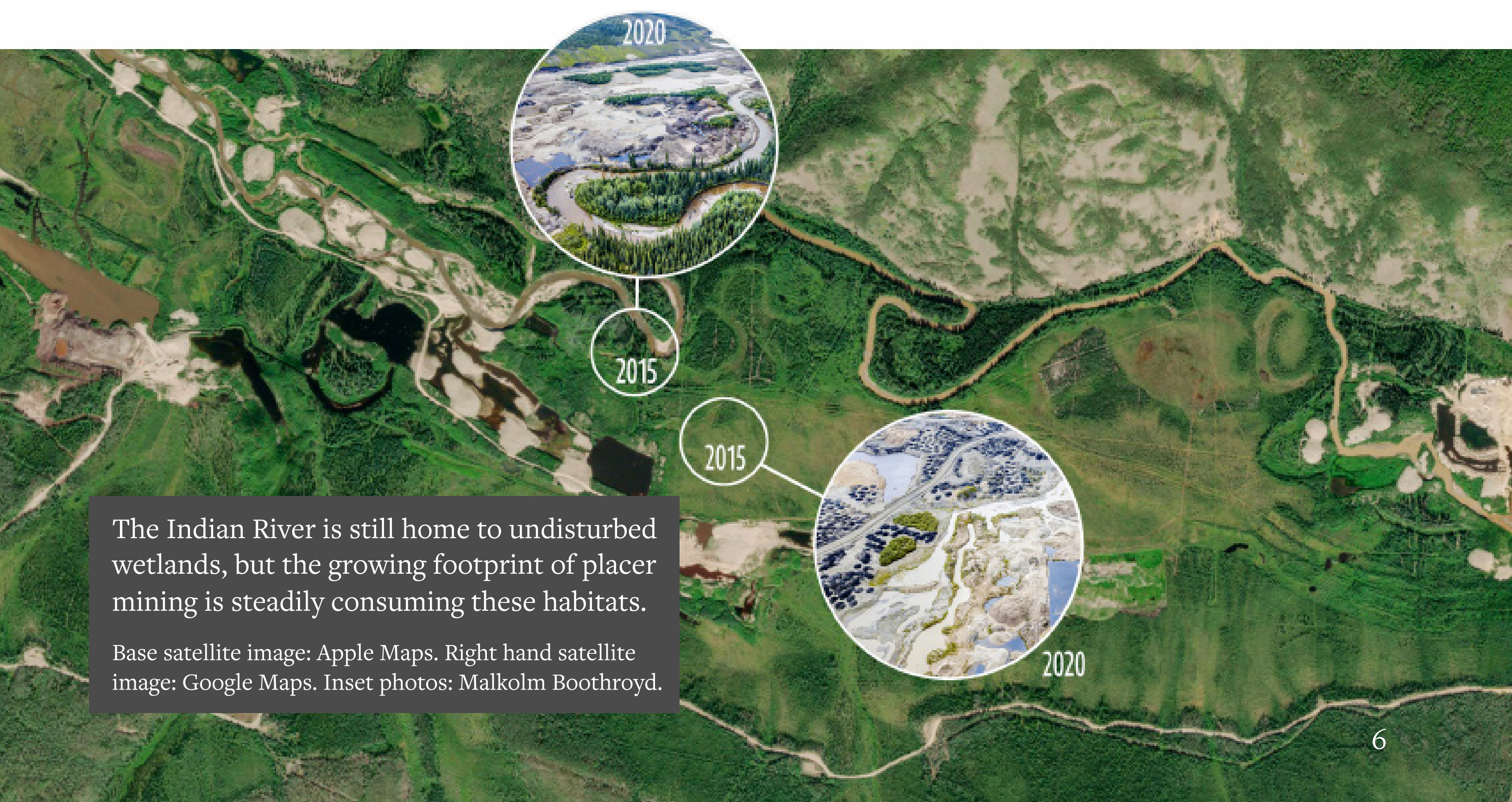
to peatlands or other natural carbon stores in its carbon reduction targets, and lacks a comprehensive inventory of where peatlands are and how much carbon is stored within them.[32] (The Northwest Territories has begun mapping the carbon stored in peat, soils and permafrost with the aim of making more informed decisions about developments in peatlands).[37] YESAB, the Yukon's project assessment system, doesn't account for the climate implications of mining and other developments in peatlands. The Yukon is not alone in these shortcomings. Canada, like most countries, does not count peatland emissions in its international carbon emissions reporting either.[38] However, at the COP 26 United Nations Climate Change Summit in 2021, Chile, Peru, Indonesia and the Democratic Republic of Congo announced they would include peatland emissions and restoration in their carbon reporting.[39]

This report only looked at one kind of development in a small part of the Yukon. Other types of development can degrade peatlands too, like hardrock mining, road construction and agricultural drainage of peatlands. Unless the Yukon takes bold action to safeguard peatlands across the territory, we risk triggering massive releases of greenhouse gases. On paper this carbon is invisible, while in real life it steadily accumulates in the earth's atmosphere.

A case study of carbon release from Yukon peatlands

Placer mining could trigger significant releases of stored carbon from peatlands across the Klondike Goldfields. We estimated the amount of carbon that could be lost from one small area: the Indian River Watershed, south of Dawson City. The Indian River is one of the few places in the Yukon where peatlands have been thoroughly mapped, which made this project possible. We estimated that the Indian River's peatlands store 1,681 kilotonnes of soil carbon—equivalent to almost 6,200 kilotonnes of atmospheric CO_2. Mining within these peatlands could release nearly 600 kilotonnes of CO_2 over the next century.

The Indian River Watershed is the epicentre of the Yukon's placer mining industry. The watershed lies within the territories of the Tr'ondëk Hwëch'in and the First Nation of Na-cho Nyäk Dun, about fifty kilometres south of Dawson City. The Indian River meanders through a wide valley dominated by fens and swamps.[40] The wetland complexes along the Indian River are important First Nation hunting and fishing



The Indian River is still home to undisturbed wetlands, but the growing footprint of placer mining is steadily consuming these habitats.

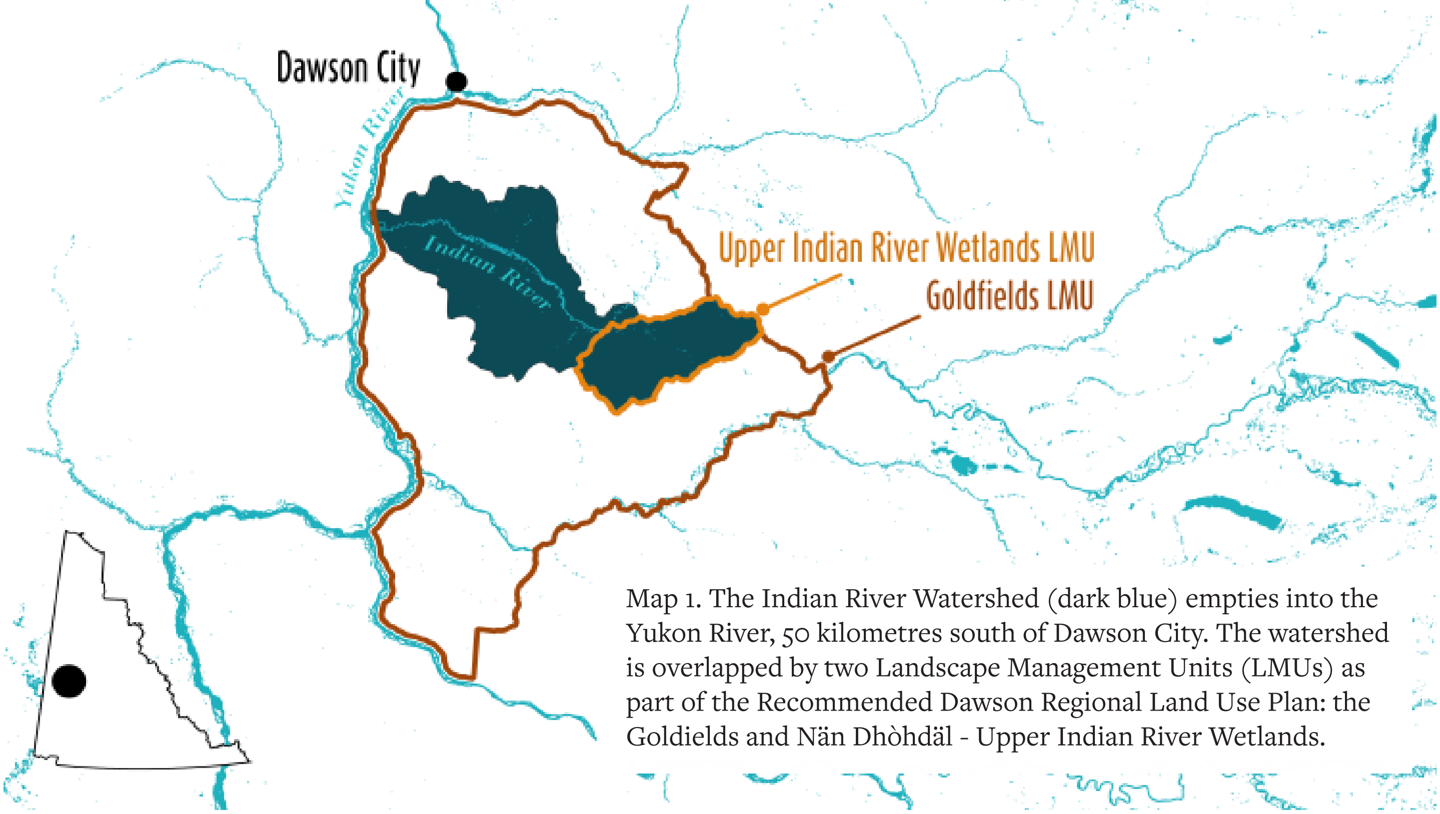
Base satellite image: Apple Maps. Right hand satellite image: Google Maps. Inset photos: Malkolm Boothroyd.

grounds, but placer mining has transformed the watershed. As one Tr'ondëk Hwëch'in citizen described, the watershed "is much different from the broad, sweeping wetland habitat it used to be. With the increase in activity levels and lack of reclamation and destroyed habitat, I don't feel as comfortable with harvesting down there anymore... I find it depressing.[6]"

Around 2 million ounces of gold have been mined from the Indian River Watershed since the 1880s.[41] Today, the Indian River accounts for roughly half of the Yukon's placer gold production.[41] Placer mining is a way of extracting gold that has settled in gravels along water courses. In the Yukon, gold bearing 'pay gravels' often lie beneath layers of vegetation, topsoil, peat, mineral soils and gravel, which can be metres deep.[42] The ground is often frozen as permafrost. In order to access these gold deposits, placer miners use excavators and bulldozers to strip away vegetation and unfrozen soils, then let the exposed permafrost thaw.[42,43] Some operators use hydraulic monitoring to accelerate thaw—blasting frozen ground with pressurized water.[44] Once soils have been stripped away and pay gravels exposed, placer operators run gravel through sluices to separate out gold. While mining for horticultural peat only cuts away upper layers of peat, placer mining strips the entire peat column to access the gold bearing gravels below. Peat and other soils are stored in overburden heaps, similar to the process used during bitumen mining in northern Alberta. These soils are later spread out over tailings during the reclamation process.

Peat decays when it dries out and is exposed to oxygen. Peat decomposition can happen at many stages of placer mining—during initial permafrost thaw, through the time peat spends sitting in overburden piles, and across the post-reclamation period when peat soils have been spread out over tailings, but no longer remain saturated in water. Placer operators are required to undertake reclamation efforts, but reclaimed placer mines are very different from the habitats that were there before.[45] Post-mining landscapes are defined by shallow ponds and hummocks of old tailings, whereas the Indian River's undisturbed wetlands are flat and meandering, with deep layers of organic materials and permafrost.[26] YESAB writes that "fens and bogs subject to placer mining cannot be restored for all practical purposes.[25]" The Klondike Placer Miners Association's wetland reclamation guide acknowledges that peatlands are essentially unrestorable.[46] Peatland habitats along the Indian River have formed over the past six thousand years,[41] but can be lost in just a few seasons of mining.

The placer mining disturbances that surround the Indian River and its tributaries are clearly visible on satellite images.



Map 1. The Indian River Watershed (dark blue) empties into the Yukon River, 50 kilometres south of Dawson City. The watershed is overlapped by two Landscape Management Units (LMUs) as part of the Recommended Dawson Regional Land Use Plan: the Goldields and Nän Dhòhdäl - Upper Indian River Wetlands.

The future of the Indian River's peatlands will be shaped by the Dawson Regional Land Use Plan. The Recommended Plan divides the region into 21 different Landscape Management Units (LMUs), each with a different set of land use designations, management directions, and disturbance limits.[6] The Indian River Watershed is overlapped by two LMUs: the Goldfields and Nän Dhòhdäl - Upper Indian River Wetlands (Map 1). The Goldfields are designated for the highest levels of development as an Integrated Stewardship Area IV. Here, disturbances could consume up to 4% of the area's landmass: up to 246 km^2 of disturbance. The Upper Indian River Wetlands are designated for moderate levels of development as an Integrated Stewardship Area II. There, placer mining could disturb 1% of the landmass, just under 5 km^2 of habitat.

While the Recommended Dawson Land Use Plan sets limits on surface disturbances, these thresholds average out disturbances across the entirety of each LMU.[6] Because gold settles at the bottom of water courses, placer mining development is concentrated around rivers, creeks and wetlands. Existing placer disturbances in the Goldfields cover about 2% of the landscape as a whole, but consume 20% of the lands within a kilometre of the Indian River. The disturbance thresholds in the Recommended Dawson Land Use Plan would allow for substantial amounts of new placer mining along the Indian River and its tributaries—much of which could occur within carbon-rich peatlands. We created a scenario for what future development in the Indian River could look like, then estimated how much carbon could be released if this scenario were realized.

Methods

Estimating carbon storage in peatlands

In an ideal world, we could have accessed soil core data from the Indian River, and used precise values for the depth, density and carbon content of peat in our calculations. Unfortunately, Yukon-specific data was not available. Instead we used published measurements from fens, bogs and swamps from other locations with similar environmental conditions. This challenge is not unique to us. Even many peer-review studies on peatland carbon storage use measurements for peat characteristics drawn from literature, rather than field sampling.[47–49] Future peat sampling in the Indian River Watershed would support more refined estimates for peatland carbon storage.

We began by estimating the volume of soil carbon stored within the Indian River's peatlands. Many studies have estimated the amount of carbon stored in peatlands, from local scales all the way up to global scales.[47,49,50] These studies use a version of the formula: $PEATC_{total} = PEAT_{area} \times PEAT_{depth} \times BD \times C_{con}$, where $PEATC_{total}$ is the total soil carbon, $PEAT_{area}$ is the peatland surface area (m^2), $PEAT_{depth}$ is the depth of peat (cm), BD is the bulk density or dry weight of peat in g/cm^3, and C_{con} is the percentage of the dry weight of peat that is carbon. We used this equation in our study. The surface area of peatlands are well mapped in the Indian River, and we were also able to view some peat depth measurements from the area. We had to make rougher estimates of the remaining peat parameters. Even small changes to the equation's inputs could have a large impact on overall carbon storage estimates, and our results should be interpreted as ballpark figures.

Peat area

The wetlands of the Indian River were mapped and classified in 2018.[40] We used the peatland surface area measurements from these maps. Since these maps do not include Sulphur Creek and Dominion Creek, two tributaries of the Indian River, our project did not encompass the entirety of the watershed. For simplicity, we still refer to our project area as the Indian River Watershed throughout the report. Our project area contains 60.1 km^2 of fens, 49.7 km^2 of swamps, and 3.3 km^2 of bogs.[51] We did not include bogs in our disturbance scenarios, since the Recommended Dawson Land Use Plan would prevent development in bogs.

Peat depth

In our calculations, we estimated peat depths to be 35 cm for fens, 20 cm for swamps and 50 cm for bogs. We based this on published descriptions of peat characteristics in the Indian River Watershed, and personal communication with Karen McKenna, who has surveyed wetlands in the area.[40,52] Our depth estimates are below the Canadian definition of peatlands as wetlands with at least 40 centimetres of peat accumulation.[27] Peat is slow building in the Yukon, and depths vary dramatically between wetlands. Peat depths can exceed two metres in old oxbow channels along the Indian River, but elsewhere may be less than 5 or 10 centimetres.[52] Even though some of the fens and swamps mapped in the Indian River would not meet the Canadian peatland criteria, they should be considered in carbon mapping projects to avoid underestimating carbon storage.

Bulk density

Each peatland class is associated with a different type of peat: herbaceous peats in fens, woody peat in swamps and Sphagnum moss-based peat in bogs.[53] The bulk density of peat is affected by peat type, as well as other factors like peat depth and state of decomposition.[47,54] We searched literature for references to the bulk density of different types of peat,[47,49,53,55,56] and calculated average values for each type: 0.095 g/cm^3 fens, 0.067 g/cm^3 for bogs, and 0.123 g/cm^3 swamps (Table 1).

Table 1. Bulk Density (g/cm^3) across peatland class and type.

Reference	Fen	Herbaceous	Bog	Sphagnum	Swamp	Woody
Redding & Devito, 2011	0.05, 0.09		0.02, 0.05		0.11	
Loisel et. al., 2014	0.095*	0.118	0.078*	0.076		0.108
Tarnocal, 1968		0.11		0.07		0.15
Bielman et. al., 2008	0.091, 0.099*		0.075*			
Packalen et. al., 2016	0.108**		0.104**			

* Values were originally presented as Organic Matter Density, but were converted to Bulk Density by dividing by corresponding means for organic matter content reported by Loisel et. al., 2014.

** Values converted from kg/m^3 to g/cm^3

Carbon content

We used carbon content values reported by Loisel et. al., (2014): 50.5% for herbaceous peat, 46.0% for Sphagnum peat and 50.9% for woody peat.[49] We assigned the herbaceous peat value to fens, the Sphagnum peat value to bogs and the woody peat value to swamps, based on the dominant peat type in each wetland.

Carbon storage in the Indian River's peatlands

Based on these measurements and assumptions, we estimated that a hectare of fens in the Indian River Watershed contains 167.9 tonnes of soil carbon, a hectare of swamps holds 125.2 tonnes of soil carbon, and a hectare of bogs contain 154.1 tonnes of soil carbon. This may be a conservative estimate, as we did not account for the tendency of carbon densities to be higher in permafrost peatlands than in unfrozen peatlands.[57] We estimated the total volume of carbon stored in Indian River peatlands by first calculating the carbon stored in each wetland type, and then adding these values together (Table 2).

Projecting future disturbances in the Indian River

We considered two approaches to estimating future peatland disturbances in the Indian River Watershed. The simplest approach would be to guess what percentage of fens and swamps—or the overall area of these habitats—that could be mined (Figure 1). This approach would be fitting if the Recommended Dawson Land Use Plan included a concrete threshold for the amount of wetland that could be mined. One could simply have taken the wetland disturbance threshold, applied it to the area of peatlands in the watershed, and then calculated the carbon releases should that area of wetland be developed. Apart from one policy unique to the Upper Indian River Wetlands LMU, the Recommended Plan does not set limits on wetland disturbance. Instead we used a second approach, based on the plan's surface disturbance thresholds. We built a scenario that illustrated what developments in the Indian River Watershed resemble decades into the future, if disturbances reached the highest levels permitted. We then calculated the area of fens and swamps that fell within this future disturbance scenario.

Table 2. Estimated carbon storage across the Indian River's peatlands

Peatland type	Area	Depth	Bulk Density	Carbon Content	Total soil carbon	CO_2 equivalent
Fen	60.10 km²	0.35 metres	.095 g/cm³	50.5%	1,009 kilotonnes	3,700 kilotonnes
Bog	3.24 km²	0.5 metres	.067 g/cm³	46.0%	50 kilotonnes	183 kilotonnes
Swamp	49.70 km²	0.2 metres	.123 g/cm³	50.9%	622 kilotonnes	2,281 kilotonnes

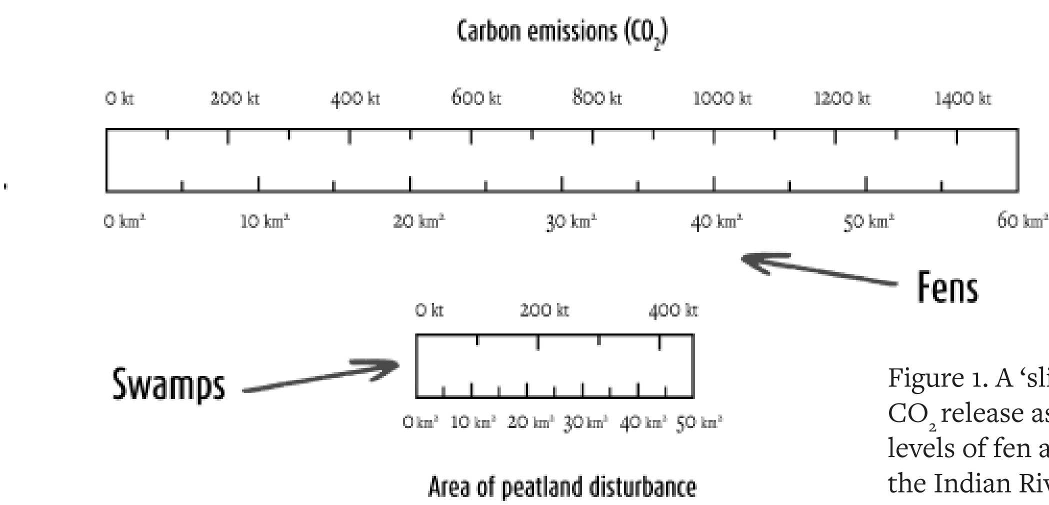
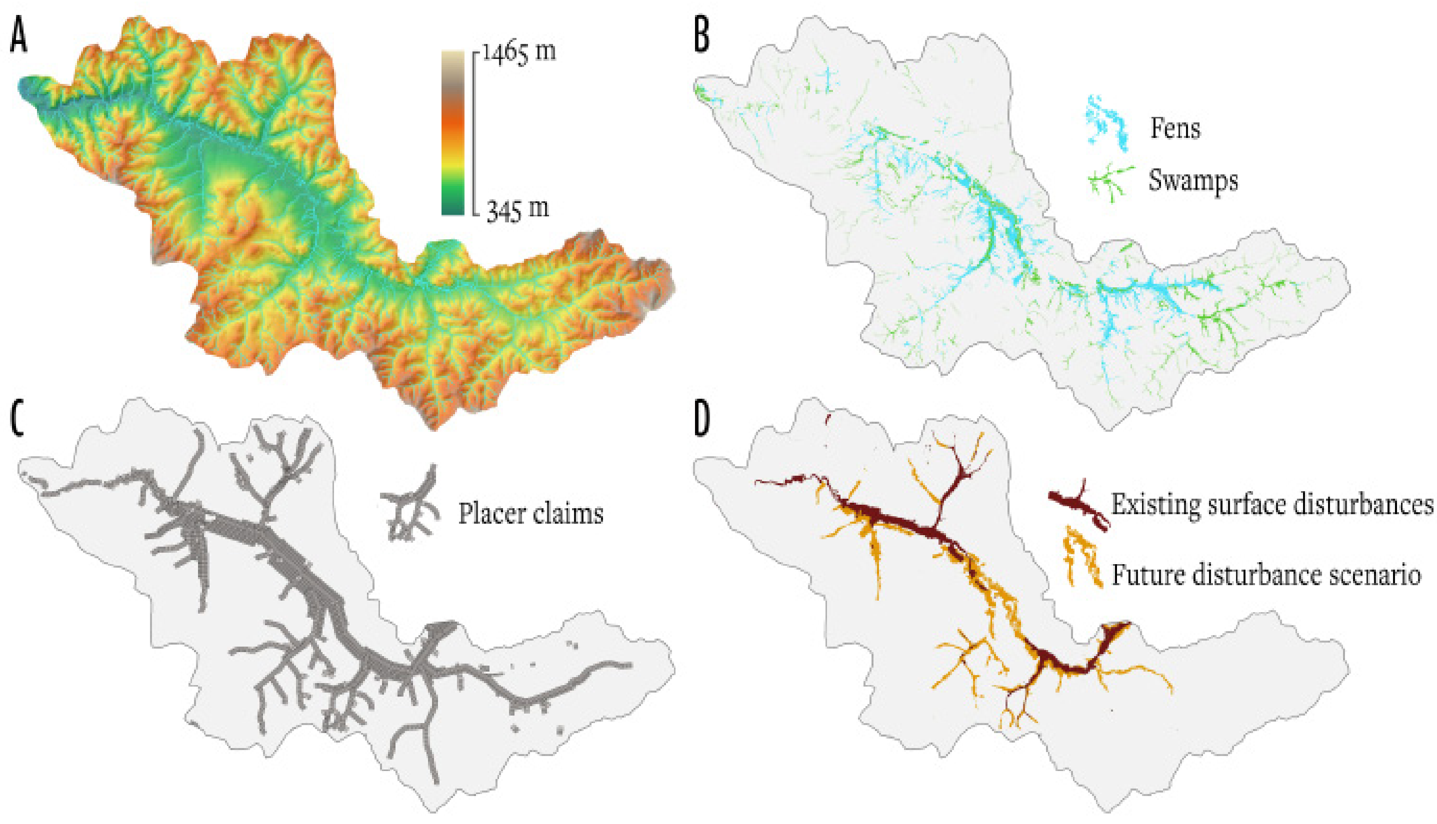


Figure 1. A 'sliding scale' for estimating CO_2 release associated with different levels of fen and swamp disturbance in the Indian River Watershed.

The Indian River is accessible by roads along two of its main tributaries: Sulphur Creek and Quartz Creek. Placer disturbances radiate out from these two access points, but there are still stretches of undisturbed habitat between Sulphur and Quartz Creek. The Recommended Dawson Land Use Plan would permit significant amounts of new development within the Indian River Watershed, much of which would occur within wetlands that today remain intact. Our disturbance scenario imagines a future where the footprint of placer disturbances extends uninterrupted between Sulphur and Quartz Creek, and reaches upwards along other tributaries of the river.

We used the spatial mapping program QGIS to create our future disturbance scenario. Using QGIS's 'Add Polygon Feature' tool, we drew out a series of hypothetical developments, all of which fell within placer claims, and followed historical patterns of placer development (Map 2). We constrained this future disturbance scenario to align with parameters set out in the Recommended Dawson Land Use Plan. For example, the Recommended Plan would allow up to 246 km^2 of disturbances in the Goldfields LMU, or 4% of the landscape. We calculated that 43% of existing disturbances in the Goldfields fall within the Indian River Watershed, and allocated the same percentage of future disturbances to our project area.

We aligned our disturbance scenario with other aspects of the Recommended Plan, such as protections for bogs and marshes, and the directive that no more than 50% of the fens within any given claim block within the Upper Indian River Wetlands LMU may be disturbed[6]. Beyond the Upper Indian River Wetlands LMU, the Recommended Plan states that "limited development in wetlands is acceptable and the allowable disturbance allocated is measured at the scale of a permit area or claim block.[6]" The plan does not set thresholds for "allowable disturbance". Within the Goldfields LMU, our disturbance scenario overlaps with 60% of the area of fens that fall within placer claims. We did not set out with the intention of creating a scenario that overlapped with any specific percentage of wetlands. Coincidentally, 60% is also the amount



Map 2. Gold, like water, settles at the lowest point in a landscape. The bottoms of valleys in the Indian River Watershed (A) are where peatlands (B), placer mining claims (C) and disturbances (D) are all clustered.

of development in undisturbed wetlands that the Government of Yukon permits in its interim guidelines for placer operators in the Indian River.[58] If the Final Dawson Land Use Plan sets a lower wetland disturbance limit at the claim block level, then future peatland disturbance would likely be less than in our development scenario. In comments on the Draft Dawson Land Use Plan the Government of Yukon wrote that no more than 50% of fens should be protected,[59] while the Klondike Placer Miners' Association advocated for placing no limits on fen disturbance.[60]

In total our future disturbance scenario included 105 km^2 of new and existing surface disturbances in the Goldfields LMU, and additional 4.6 km^2 of disturbance within the Upper Indian River Wetlands LMU. The future disturbance scenario we created is a plausible outcome if the footprint of placer mining continues to expand. Still, it is a rough approximation of where developments could occur, and which wetlands are at risk to development. Not all wetlands within a given mine site would be directly disturbed, but making a more refined disturbance scenario is not possible without knowing the subsurface geology of specific sites. One way or another, allowing significant levels of new placer disturbances within the Indian River Watershed would lead to substantial losses of peatlands, unless there are explicit policies to protect these wetlands.

Estimating carbon losses from peatlands

Our final step was to estimate the amount of carbon that could be released if the peatlands overlapped by our future development scenario were mined. We calculated the area of peatland disturbance by overlaying our future development scenario onto maps of fens and swamps in the Indian River. In total, 19.2 km^2 of fens and 10.5 km^2 of swamps fell within our future disturbance scenario. This amounts to 32% of fen area and 21% of swampland area within the Indian River Watershed. We did not include bogs in this development scenario since the Recommended Dawson Land Use Plan proposes protecting these wetlands.

We estimated the amount of soil carbon held within peatlands at risk of development, and then estimated the volume of carbon that could be lost from the soil if peatlands were replaced by reclaimed soils. We used 100 t C/ha as a rough estimate for the volume of carbon in reclaimed soils. This is the midpoint for the carbon content in reclaimed bitumen mines, based on Alberta reclamation standards reported by Rooney et. al. (2014).[48] Our estimate for carbon storage in reclaimed soils is a rough approximation. Reclaimed placer mines are a mix of upland soils and shallow ponds, and as far as we know, soil carbon has not been measured in these different types of reclaimed habitat. We then estimated carbon losses in developed peatlands by subtracting the carbon volume of reclaimed soils from the carbon volume of intact peatlands. We multiplied this number by 3.667—the molecular weight differential between soil carbon and carbon dioxide gas to convert soil carbon to the equivalent amount of CO_2.[61] We estimated that mining a hectare of fens would release 249 tonnes of CO_2, while mining a hectare of swamps would release 97 tonnes of CO_2. These losses are only a portion of the total carbon these peatlands store, because we presumed some carbon would be retained in soil following reclamation. Our estimates amount to 40% carbon losses from disturbed fens and 20% losses from disturbed swamps, though these may be underestimates.

The methods in this report are simplifications, and we erred towards being conservative in our estimates. For example, we only considered the immediate footprint of development. If half of a fen were to be excavated, then our methods would only address the carbon losses from that part of the fen—even if water drained from the remainder of the fen, causing peat to dry out and decompose. We also did not include the carbon values of other soils in our analysis, such as the carbon contained within mineral soils that often underlay peat. Johnson et al. (2011) reported 109 tonnes C/ha for 0.5 m deep mineral soils within wooded wetlands in the Intermontane Boreal region of Alaska.[62] However, carbon held in mineral soils is more resistant to decomposition than carbon held in organic soils such as peat.[63] As a result, the disturbance of mineral soils would likely be a lesser source of CO_2 emissions when compared to peat disturbance.

Time scales for carbon releases from disturbed peatlands

The developments in our future disturbance scenario would happen across many decades, not all at once. As of 2016, there were 49 km^2 of existing surface disturbances in the Indian River Watershed, the vast majority of which have occurred since the mid 1980s.[64,65] At this rate of development, it would take until the 2040s or 2050s to reach the level of development in our future disturbance scenario.

Once distrubed, peatlands do not release all of the carbon they store instantly. Carbon is released at different rates peat decomposes, and decomposition rates are influenced by factors such as the depth, age, temperature and chemical composition of peat.[66,67] We do not know of Yukon-specific research on peat decomposition, but it's possible to get a rough idea by looking at decomposition rates from elsewhere. The most rapid carbon release would likely occur during the years immediately following disturbance, after which peat decomposition rates slow.[67] Lab measurements of CO_2 release from drained peat cores showed 5-10% decomposition over one year.[66] Another study estimated that over 10% annual decomposition occurred immediately following peatland disturbance, after which decomposition rates dropped off rapidly.[67]

While some carbon release would likely continue across decades-long time scales, there could be rapid carbon losses in other circumstances. Some of the peat in the goldfields is frozen as permafrost, but placer operators deliberately thaw permafrost in order to access the gold deposits beneath. This can be done passively, by removing insulating vegetation and letting the summer heat thaw the soil, or blasting permafrost with pressurized water to accelerate thaw. Peat that has been previously frozen as permafrost is more vulnerable to decomposition than non-permafrost peat.[68] Newly-thawed peat could release more carbon, and at a faster rate than unfrozen peat. Thawed peat could also flow into rivers as runoff, and stored carbon could be released through being dissolved into water.

For the purposes of this report, we assumed that carbon losses would take place over the next 100 years. This is a crude estimate, only intended to convey that the carbon releases found in this report would occur incrementally over many decades, not all at once.

Placer mining along a bend of the Indian River.

Results and discussion

Implications for the Yukon's climate plans

Developing peatlands could lead to substantial losses of CO_2 to the atmosphere. We estimated that future placer mining developments along the Indian River Watershed alone could lead to the release of 574 kilotonnes of CO_2 over the next century. That is almost a year's worth of all the CO_2 emissions in the Yukon—or flying a loaded jet plane around the earth's circumference 425 times.

The Yukon aims to cut its CO_2 emissions 45% from 2010 levels by 2030. That means bringing the territory's annual emissions down to about 345 kilonnes a year. This target doesn't include emissions from peatland disturbance, or mining more generally. A full accounting of the Yukon's emissions would find the Yukon's emissions to be higher, and the challenge of cutting them back even greater. The scale of carbon emissions released by peatland degradation across the Yukon is unknown, as our analysis was limited to the impacts of one industry in one watershed. Reaching the Yukon's 2030 climate targets may come down to very fine margins. Adding any new emissions to the territory's carbon ledger could prevent the Yukon from meeting its target.

Climate targets can also be thought of as carbon budgets, with jurisdictions only able to release a limited, and ever diminishing amount of CO_2 each year. Global efforts to avert 1.5°C or 2°C of warming are only as good as the progress made by individual provinces, territories and countries to stick to their carbon budgets. Any jurisdiction that fails to achieve its target means that others will have to pick up the slack, or risk making the climate breakdown even more severe. Every time the Government of Yukon approves another development in a peatland, it commits the territory to decades of incremental carbon releases.

The price of carbon and the price of gold

Gold is synonymous with wealth and prestige. The premise of gold mining is to extract this wealth from the ground, but the carbon that can be released as a side effect of the process can be costly. One way many countries have tried to address climate change is putting a price on carbon—assigning an economic cost to pollution. By 2030, Canada's carbon tax will be 150$/tonne. The World Bank estimates that an ounce of gold will be worth the Canadian equivalent of $2,095 in 2030.

We estimated that mining a hectare of fens would recover an average of 113 refined ounces of gold,[69] but release close to 70 tonnes of CO_2 into the atmosphere. In dollar figures that is $236,000 of gold, and $37,000 worth of carbon. Put another way—about 15% of the value of gold could be cancelled out by the cost of CO_2 lost during extraction. In 2015 the Yukon placer industry operated at roughly a 15% profit margin, expending $60.5 million and extracting $70.4 million worth of gold.[44,70] This estimate only includes the CO_2 released from peatland disturbance, not other carbon emissions from placer mining. A 'polluter pays' system that accounted for the full carbon footprint of placer mining could erase the industry's profit margin—at least for mining in fens. Not requiring placer operators to pay for the carbon costs of their practices is what economists refer to as an externality—a cost passed on to society and the planet in the form of carbon pollution.


Land disturbances are a major source of carbon emissions worldwide, and the Intergovernmental Panel of Climate Change (IPCC) encourages countries to report these emissions. Since not all landscape emissions are human driven, the IPCC recommends tracking emissions only on “managed lands,” where human activities are the principal driver of changing carbon balances. Canada has further divided managed lands into three types: forests, grasslands and wetlands. Canada defines managed wetlands as ecosystems where human activities have altered water tables, but currently addresses only two types of disturbances: horticultural peat extraction, and flooding from hydroelectric projects.[71] Mining in peatlands isn’t captured by this framework—in spite of the IPCC and Government of Canada’s general intent to track carbon emissions from human-driven landscape changes. The Government of Yukon isn’t currently required to track emissions from peatland disturbances, but that could change. Either way the Yukon should be proactive, and make a plan to monitor and reduce emissions from peatland destruction.

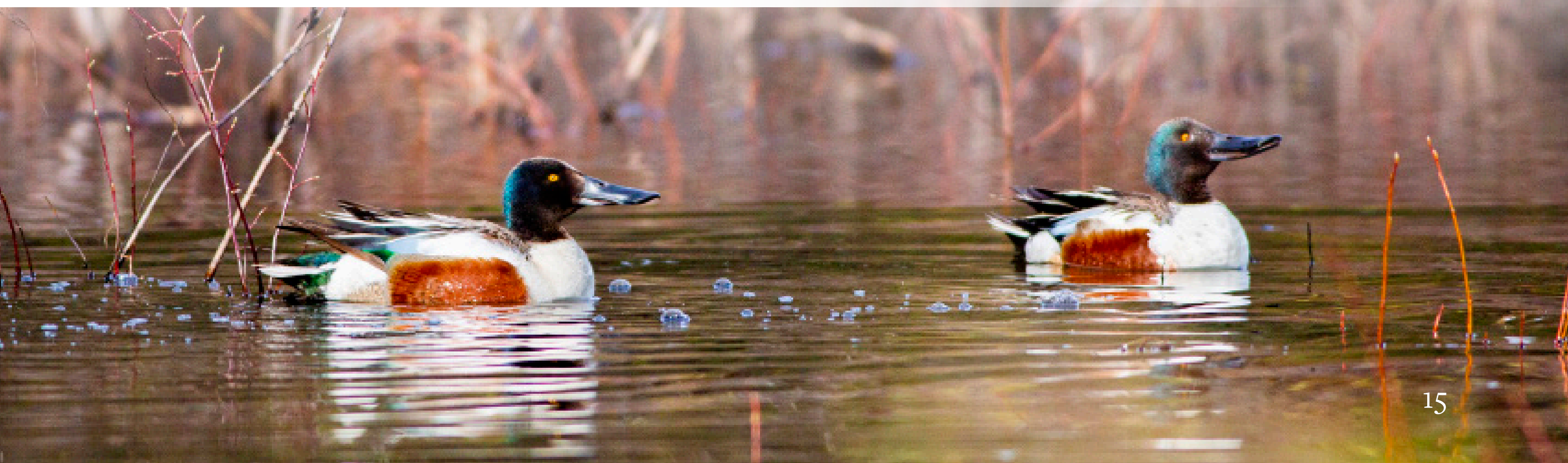
Beyond the Indian River

This report looked only at the Indian River Watershed, but peatlands in other areas are vulnerable to placer development too. 275 km^2 of fens and swamps are overlapped by placer claims in other parts of the Dawson Region.[72] That’s three and half times the area of peatlands that are staked for placer mining in the Indian River Watershed. The carbon footprint of placer mining in peatlands elsewhere in the Dawson Region could be even greater than what we have reported for the Indian River.

This report only addressed carbon releases from direct disturbance of peatlands, in a tiny fraction of the Yukon. The Indian River Watershed covers less than 1700 km^2, only 0.3% of the territory. This watershed is experiencing a high rate of peatland disturbance, but isn’t the only place in the Yukon where peat is vulnerable. This report didn’t look at the impacts to peatlands from other industrial developments, like roads that can interrupt the way water flows through landscapes, or hard-rock mining that can depress water tables in the surrounding areas. [73] To date, nobody has analyzed the emissions from peatland disturbance on a Yukon-wide scale. Not knowing the magnitude of these emissions is a massive blind spot for the Government of Yukon.

We hope this report sheds light on the carbon footprint, and helps to illustrate the magnitude of emissions that could be released from placer mining in peatlands. We also hope this report prompts more detailed studies in the near future—to give us a better picture of the Yukon’s peatlands, and the climate implications of disturbing them. In the meantime, uncertainty around the exact scale of CO_2 loss from peatlands shouldn’t be a reason to delay the protection of these natural carbon stores. Approving more developments in peatlands will commit the Yukon to decades of CO_2 release, at a time when it is critical to keep carbon in the ground.

Northern Shovelers in the Klondike River valley.



Solutions and recommendations

The major carbon emissions reported here depict a future scenario where widespread destruction of peatlands continues throughout the Indian River Watershed. This is a foreseeable scenario, but not a foregone conclusion. It's not too late to protect peatlands, and the carbon they store.

The Yukon should take bold action to safeguard the carbon stored in peatlands—and that means halting developments that destroy peatlands. This would require a major shift in the Government of Yukon's approach to placer mining in wetlands. We are not the first to call for such action. Tr'ondëk Hwëch'in Government has strongly opposed placer developments in undisturbed wetlands in their Traditional Territory for the last several years due to an overall lack of understanding on wetland function. Tr'ondëk Hwëch'in has also repeatedly advocated for developing a robust legal framework for wetland management before further wetland loss occurs.[74] The Yukon Environmental and Socioeconomic Assessment Board has consistently recommended against mining in undisturbed wetlands in the Indian River Watershed, which the Government of Yukon repeatedly overrules in decision documents.[26,74,75] The Yukon Water Board has also declined to licence placer mining in undisturbed wetlands.[76]

This report has focused on the impacts to peatlands from one industry in a small part of the Yukon, but these issues are not confined to the Indian River. This report's findings go to the heart of the Yukon's climate strategy. The Yukon has pledged to make steep cuts in carbon emissions, but these reductions do not apply to all emissions. Mining emissions will be covered by a soft intensity target, instead of the absolute emissions reductions required of other sectors. Emissions from peatland disturbance aren't considered at all. Not including these emissions in the Yukon's climate budget means that we are only addressing part of the problem. The same problem exists at a national level, where major categories of peatland disturbances are not factored into the federal government's emissions calculations or carbon reduction commitments.[19]

Conserving the carbon that is stored in peatlands will require leadership from many places. Governments need to factor peatlands into their climate plans, and environmental assessors need to look more closely at the climate implications of developments in areas rich in peat. Researchers should investigate the characteristics of bogs, fens and swamps in understudied areas, and mining companies should concentrate on keeping peatlands intact.

A reclaimed placer mine (foreground) and active mining (background).

Recommendations for the Government of Yukon

- The Yukon should start counting and reporting emissions from peatland disturbances, as well as other emissions from land use disturbances.

- The Government of Yukon should develop a plan to cut back emissions from peatland disturbances and other land use changes. These emissions should be covered by the Yukon's 2030 greenhouse gas reduction targets under *Our Clean Future*.

- The Yukon should stop approving new mining developments in undisturbed peatlands. YESAB routinely recommends against placer mining in undisturbed wetlands[33], but the Government of Yukon consistently varies this recommendation to allow for continued development in wetlands.

- The Yukon's forthcoming Wetland Policy should include safeguards for peatlands. Peatlands cannot be restored on human time scales, so the Wetland Policy should emphasize the protection of these ecosystems over reclamation. One way to do this would be to classify known peatlands as "Wetlands of Special Importance," and protect them against future development.

- The Yukon Department of Environment should undertake a territory-wide inventory of peatlands. Most maps of Yukon wetlands are out of date, mapped at coarse resolutions, and do not distinguish between peatlands and other types of wetlands.[32] The Yukon's Draft Wetland Policy recognizes the need to develop territory-wide mapping and detailed local inventories. Such an inventory should include field sampling of peat to give the Yukon a better picture on the depths, densities, and carbon content of the territory's peatlands.

- The Yukon should provide research grants to promote further studies of Yukon peatlands. There are many important questions to investigate, such as the vulnerability of Yukon peatlands to climate change, and the rate of peat decomposition following disturbance.

- The Department of Environment should use the results of peatland and carbon storehouse inventories to identify hotbeds of carbon storage and work with First Nations to prioritize conservation in these areas.

Recommendations for Land Use Planners

- The Dawson Regional Planning Commission should recommend against development within fens. Doing so could prevent hundreds of kilotonnes of CO_2 from being released into the atmosphere—from the Indian River alone. The Government of Yukon could consider compensating placer operators who hold claims within peatlands.

- The Final Dawson Land Use Plan should restore protections to the Upper Indian River Wetlands LMU. In our estimates, developments in the Upper Indian River Wetlands accounted for 66 kilotonnes of CO_2 release. Previously, the Draft Dawson Land Use Plan had designated this area as a Special Management Area, which would have allowed for some mining on existing placer claims, but would have prevented development in fens, which accounted for most of carbon releases in our estimates.

- Upcoming land use plans for the Northern Tutchone, Teslin, Whitehorse and Kluane regions should put a heavy focus on climate change and carbon stores. For example, carbon emissions should be added as a cumulative effects indicator. That would mean setting a limit on the carbon emissions that could be released from future developments in each given landscape management unit, such as through disturbing peatlands and other carbon stores.

- Land use plans should undertake a conformity check with the Yukon's climate target, so that the development levels permitted with the land use plan are compatible with the territory's emission reduction commitments. Carbon emissions from land use change should be a key part of this analysis.

Recommendations for the Yukon Environmental and socio-economic Assessment Board (YESAB)

- YESAB should continue to recommend against mining within undisturbed wetlands.

- YESAB should assess the lifecycle carbon emissions of each project, including emissions associated with the disturbance of carbon stores.

- YESAB should recommend that projects that don't conform with the Yukon's carbon reduction targets not proceed.

Recommendations for industry

- Resource extraction companies should not focus their developments in places that are rich in peat or permafrost.

- Mining companies should report when they discover peat deposits during exploration work.

- Developers should take extra caution when operating in peatlands. For example, roads should be constructed so as not to interrupt the flow of water through peatlands. Mining and other development practices should seek to maintain above and below-ground hydrological connections.

- If operators can demonstrate a reclamation technique that can be relied upon to provide long-term protection of the carbon stored in peat, then the Yukon could consider a more lenient approach to regulating development in peatlands.

Conclusion

Peat began forming in the Indian River Watershed around six thousand years ago—at a time when woolly mammoths still persisted on Siberian islands, and fish had only recently returned to the lakes and rivers around Whitehorse following millennia of glaciation[4,1,77,78]. Ever since these peatlands have been slowly drawing carbon out of the atmosphere, building a massive carbon storehouse. Over the past century, a wave of industrial development has washed over parts of the Yukon. In the space of a few generations, these developments are unlocking carbon that has taken milennia to form.

Peatlands are one of the ecosystems at the biggest risk of development, which could transform them from carbon storehouses to carbon emitters. Many have called for protection of peatlands, but the Government of Yukon has continued to approve new developments in these ecosystems. Now the world faces a climate emergency. The decisions we make about development and conservation in peatlands will play an important role in determining whether the Yukon lives up to its climate commitments.

The swamps, bogs and fens in places like the Indian River are more than carbon reservoirs. These wetlands are home to moose, beavers and waterfowl, and a breadbasket for many First Nations citizens. Safeguarding peatlands is critical for their ecological and cultural importance—let alone for their importance to the climate crisis. The Yukon should rise to the urgency of the moment, and take leadership to conserve these peatland ecosystems.

Intact wetlands alongside the Indian River

Appendix 1. Specific calculations

Carbon content of fens per hectare:
$10{,}000\ m^2 \times 0.35\ m \times 0.095\ g/cm^3 \times 0.505\ C =$
167.91 t soil C/ha

Carbon content of swamps per hectare:
$10{,}000\ m^2 \times 0.20\ m \times 0.123\ g/cm^3 \times 0.509\ C =$
125.22 t soil C/ha

Carbon release per hectare of fen disturbance:
(167.91 t C - 100 t C) x 3.667 = 249.03 t CO_2

Carbon release per hectare of swamp disturbance:
(125.22 t C - 100 t C) x 3.667 = 92.48 t CO_2

Carbon release from fens within our future disturbance scenario:
1,916.2 ha x 249.03 t CO_2/ ha = 477,191 t CO_2

Carbon release from swamps within our future disturbance scenario:
1046.3 ha x 92.48 t CO_2/ ha = 96,762 t CO_2

Total estimated carbon release from peatlands in the Indian River study area: 573,953 t CO_2

Appendix 2. Research directions

It's difficult to find data on the Yukon's peatlands, as we learned many times in the process of researching and writing this report. Most regions of the Yukon lack comprehensive maps of peatland distribution and filling in these gaps should be a priority—especially in areas with high development pressures. This section describes several more areas in need of study. We hope this report will help to inspire more investigations of the Yukon's peatlands.

The estimates of carbon loss presented in this report are precisely that—estimates. Our work is limited by the shortage of data on the bulk densities, carbon content and depth of peat in the Indian River, and the Yukon more broadly. Without knowing these values precisely, further efforts to calculate carbon storage in the Indian River's peatlands will remain approximations. Drilling a series of peat cores would give a clear picture of carbon storage in the Indian River area, and would make peatland carbon estimates for comparable parts of the Yukon more accurate. The Government of Yukon should undertake this work directly, or fund researchers to sample peat in the Indian River.

In addition to sampling soils in intact peatlands, soil cores could be taken from reclaimed placer mines. Knowing the carbon content of post-disturbance soils would make it easier to calculate the carbon storage differentials between undisturbed peatlands and reclaimed placer mines. It would be informative to compare the carbon content of soils at recently reclaimed mines, to soils at mines that were developed longer ago. Comparing the carbon content of reclaimed soils over a time gradient may make it possible to approximate rates of carbon release from mine sites following disturbances. Sampling carbon content at reclaimed placer mines could also reveal if different reclamation techniques are more effective at retaining carbon.

We suspect that during the process of placer mining, some peat dissolves in water and flows away as runoff. Runoff would probably be highest among peat that was previously frozen as permafrost, and especially when placer operators blast permafrost with pressurized water to accelerate thaw. Researchers could sample water from the Indian River and similar rivers where placer mining does not occur, then compare levels of dissolved carbon. This could help determine how much carbon is being lost from peatlands due to runoff from placer mines.

Methane is a potent greenhouse gas and a key factor in understanding carbon fluxes across landscapes. Addressing the impacts of placer mining on methane fluxes was outside the scope of this report, but should be looked at in the future. Researchers could measure levels of methane release from intact peatlands as well as from reclaimed placer mines—especially areas that have been converted to shallow open water wetlands during the reclamation process.

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