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Research Article

Impact of Drainage Ditch Construction and Subsequent Use on a Treed Bog Adjacent to a Peat Harvesting Operation, Southwestern Manitoba, Canada

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Abstract

Manitoba has the most peatland by provincial area of any province in Canada and contributes ~11% of Canada's horticultural peatland production. Peat harvesting requires the lowering of the water table; this water is usually channeled to a fluvial system (e.g. a river) but in some cases must be actively pumped. The South Julius bog in Manitoba is an example where the pumped discharge was through an adjacent treed bog. The trees in the bog on one side of the drainage ditch were dead, but the trees on the other side were alive after nearly 10 years since the ditch was created. This study investigated possible hydrological causes by instrumenting three transects of wells that ran perpendicular to the drainage ditch and extended 20 and 50 m into the bog on the dead and live side, respectively. Average water tables on the live side were 15 cm lower than the dead side. The dead side water levels were similar to a natural fen located adjacent to the treed bog. Construction of the drainage ditch yielded a >20 cm high berm that ran alongside the live side, functionally isolating the live side from the surplus water in the drainage ditch. The berm helped with maintaining the lower water table treed bog vegetation requires. We recommend that future drainage ditches be constructed in such a way that berms on both sides are made, functionally creating a canal to the fen, where the excess water is less detrimental to the fen vegetation which is adapted to wetter average conditions.

Keywords: Peat Harvesting, Peatlands, Hydrology, Disturbance, Drainage

1 Introduction

Wetlands cover ~43% of Manitoba's land area with the majority of those being organic wetlands, commonly known as peatlands[1]. Within Manitoba, peatlands can be found across the province except for the southwest corner where part of the prairie pothole region (marshes and shallow open water wetlands) of North America is found[2]. Globally, peatlands represent a significant storage (16–33%) of the soil carbon (C) pool, despite covering only 3% of the Earth's surface[3]. Within North America, wetlands store 220 Pg C, most of which is in peat[4].

Peatlands are divided into two main categories: bogs and fens (some swamps are peatlands, but these are the minority in Canada)[5]. Bogs are ombrogenous (a water source from precipitation only), meaning that they are isolated from regional groundwater or surface flows. However, fens can receive water from various sources such as groundwater discharge or surface water (e.g. streams) inflows. Bogs typically have lower water tables (up to ~50 cm below the surface), whereas fens can have flooded conditions most of the year and act as conveyors of water in the landscape[6].

Bogs have a diplotelmic (two layer) soil structure[7]: the acrotelm and the catotelm. The acrotelm is the upper ~50 cm of alive and poorly decomposed *Sphagnum* mosses, which have very large pores and high hydraulic conductivity. These properties allow water to flow quickly and easily off of the bog in times of high water tables, such as spring melt or heavy rain. The catotelm is below the acrotelm and is typified by highly decomposed *Sphagnum* mosses (called peat), which has small pores and low hydraulic conductivity, which limits the lateral runoff of water from a bog. The catotelm varies in thickness, but 1-3 m is common in this area (unpublished data). Combined, these two layers allow the bog to remain wet (catotelm) but not too wet (acrotelm); permanently flooded conditions are detrimental to most bog vegetation[8].

Canada is one of the world's largest producers of horticultural peat[9] with ~11% of Canada's total coming from Manitoba peatlands. Bogs are the main peatland type used for peat extraction due to the presence of *Sphagnum* peat. Preparing a bog for peat extraction requires lowering the water table. This is achieved by digging ditches spaced 30 m apart to allow the catotelmic peat to drain more efficiently[10]. These drainage channels are connected in rectangular style drainage networks and, when possible, drained by gravity to a nearby fluvial system such as a stream or river. However, due to the low relief typical in peatland systems, sometimes the drainage water must be actively pumped into a nearby fluvial system because gravity drainage alone is insufficient.

At the South Julius bog in South Eastern Manitoba, drainage water is actively pumped through an adjacent bog from the harvested fields into a nearby fen. A drainage ditch was constructed through the bog to facilitate the drainage. A site visit in May 2015 revealed that all of the trees on one side of the ditch were dead, whereas on the other side the trees were alive. A bog with dead vegetation is no longer a carbon sink, nor would offer suitable habitat for various species. Thus understanding the cause of the death may lead to recommendations for prevention for future developments.

The objective of this research paper was to determine what might be causing the tree death on one side of the drainage ditch, but not the other. We hypothesise that excess water from the pump would be too much water for the acrotelm to effectively shed, raising the water table too high for healthy bog vegetation growth.

2 Methods

2.1 Study Site

The South Julius bog (49.937778°N, -96.235249°W) is located ~20 km west of the town of Whitemouth, Manitoba (Fig. 1). The peat extraction area is ~250 ha and drains towards the middle of the east edge of the site. To the north/east of the site is the remaining treed bog that was not harvested, and north of that is a fen system that flows north west. Black spruce and tamarack contained in the bog make it heavily treed with a ground cover of *Sphagnum* hummocks and various *Ericaceous* shrubs.

The drainage ditch was constructed in 2007 (Tim North, personal communication) it runs ~500 m in a northeast direction and is ~2 m wide. During construction of the ditch, the extracted material was placed on the east side, forming a small berm (more details in the results) that runs along the length of the ditch. The north/west side of the ditch is called the "dead" side and the south/east side is called the "live" side.

Beausejour, ~22 km northwest of South Julius, is the closest Environment Canada weather station with 1981-2010 climate normals data. Mean January and July temperatures are -16.9°C and 19.2 °C respectively, with a mean annual temperature for the area of 2.8°C. Annual precipitation is 570.3 mm, with snow accounting for 20% of this total[11].

2.2 Methods

To determine the elevation profile across the ditch, a topographic survey using a differential global positioning system

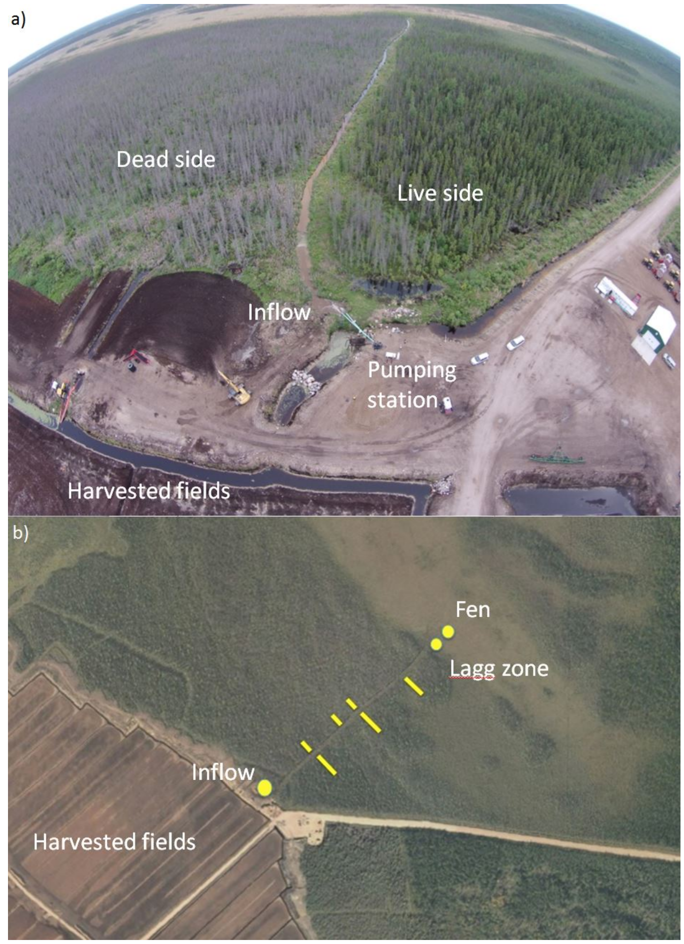

Figure 1: *Oblique air photo (drone) of the site looking northeast (a) and Google Earth satellite image of the surrounding landscape, showing the approximate locations of the transects and well locations (b). Distance from Inflow to Fen point in the lower figure is ~500 m.*

(DGPS) was conducted in June 2015 by KGS Group Consulting Engineers. They surveyed three transects (~80 m long) that ran perpendicular to the ditch at approximately 50, 200, and 350 m from the start of the ditch. The transects went into the bog on both the live and dead side (Fig. 1).

To determine meteorological inputs (rain) to the site, a simple weather station was installed (as part of another project at the South Julius site) approximately 500 m southwest of the start of the drainage ditch. The weather station consisted of a Campbell Scientific CR1000 data logger with a Texas Instrument (TE525) tipping bucket rain gauge and a Rotronic Instrument Corp (HC-S3) air temperature and relative humidity probe. The logger measured the instruments every minute, but recorded the total rain and average temperature every 30 minutes.

To determine water table positions on either side of the ditch, three transects of wells that ran perpendicular to the drainage ditch were installed approximately equidistance

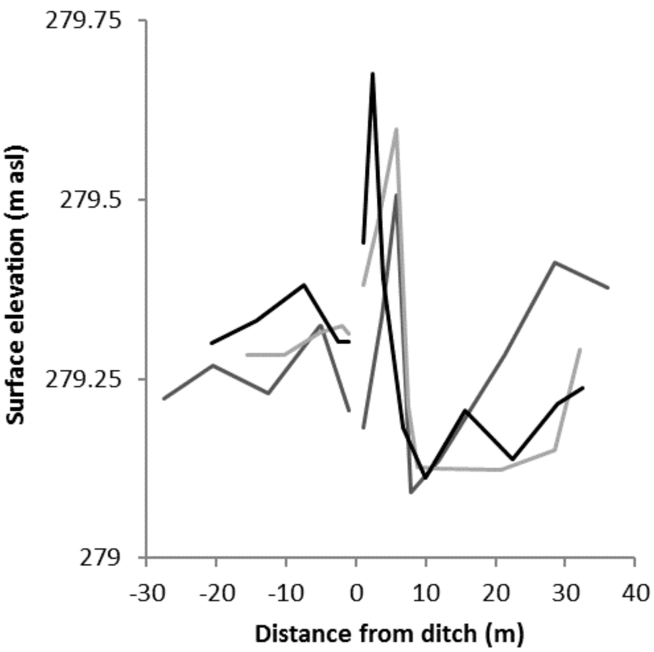

Figure 2: *Surface elevation of the three DGPS transects. Distances are reported from the end of the ditch, assuming a 2 m wide ditch (hence -1 and 1 m on the x-axis). The live side are the positive values. The distances from the start for the light grey, black, and dark grey lines were 50, 200, and 350 m, respectively.*

along the length of the drainage ditch (100, 200, and 300 m from the start of the ditch; except on the Dead side where the final transect was closer, due to the incredibly difficult walking conditions). Wells within each transect were located on the live side at 2, 5, 20, and 50 m intervals from the ditch edge. On the dead side, wells were located at 0, 5, and 20 m (Fig. 1). Wells were also installed at the inflow (south end of the ditch), in the lagg (transition between bog and fen) zone, and in the fen proper. Within the bog on the live side, the wells were typically installed in the hollow (low lying areas between the hummocks) as they represent a more consistent eleveation. Due to the flooded conditions, this was not possible on the Dead side (could not see the hollows). These 28 wells were measured bi-weekly in July and August. Wells were constructed from 2.54 cm diameter PVC pipe with 0.75 cm holes every 10-15 cm along the length of the pipe. The pipes were covered in a nylon stocking to prevent peat from entering the pipe and clogging the holes. An auger with a diameter slightly smaller than the pipe was used to pre-auger the hole to ensure a snug fit. Wells were measured using a calibrated blow stick to measure the water depth relative to the surface and were measured five times (roughly every other week) from late June to early September, 2015. Pumping rates for the water pumped into the ditch were obtained from SunGro Horticulture staff as the amount of time the pump was on. If the pump was on, it would be pumping at a rate of 200 imperial gallons per minute (909.2 L/min).

3 Results

The seasonal (May to September) precipitation was 199 mm higher than the 30-year climate normal[11]. Temperatures were generally slightly warmer with May to September average temperatures being +0.7, +0.7, +1.2, -0.1, and +3.6 °C compared to the 30-year average for that respective month.

The topographic survey revealed that construction of the drainage ditch yielded a small raised berm on the live side of the ditch (Fig. 2). Of the transects surveyed, the berm height ranged from 22 cm to 33 cm, but visual observations obtained by walking the entire length would suggest that the range was actually larger, with some areas of berm being > 60 cm higher than the surrounding landscape. The width of the berm also varied, but was typically between 6 and 8 m wide. Ground surface elevations on the dead side appeared to be ~15 cm higher than that on the live side immediately adjacent to the ditch. These differences became less pronounced by 25m away from the berm, where the dead and live sides were similar in elevation.

Water table depths were statistically significantly different between the dead and live sides of the ditch (Fig. 3, Table 1). Median water table depth (relative to the surface; positive being above and negative being below the surface) on the dead side ranged between 13 and 16.8 cm depending on the distance from the ditch. On the live side, these values ranged between -5.8 and 2.6 cm, with the 5, 20, and 50 m distances being within 1 cm of each other (3.4, 3.6, and 2.6 cm for 5, 20, and 50 m, respectively). Within the Lagg and Fen locations, median water tables were 21 and 13.4 cm, respectively, and not statistically significantly different (at 99%, but were at 95%) from each other, nor any of the Dead side locations (Fig. 3, Table 1).

From May to September the pump ran between 24 to 168 hours per week (i.e. never off), with monthly total discharge ranging from 6541 m^3 (May) to 30,526 m^3 (August). Total discharge for the May to September period was 88,669 m^3. With a surface area of the dead side of 0.6 km^2, the pumped water represented 153 mm of "runoff" (volume of water pumped / surface area of the bog) on the dead side.

4 Discussion and Conclusion

It is well documented that bogs and fens have different hydrology[2, 5]. Bogs are seen as storage features in the landscape, discharging water rapidly through the acrotelm in the spring when water tables are high, or after heavy rain events. Fens, however, are seen as conveyors of water, or the "rivers" of

Table 1: *Wilcoxon Rank Sum test p-values of water table depths between the Dead (D) and Live (L) sides for their given distance (m) from the ditch. For example, the wells located 20 m from the ditch on the dead (D20m) and live (L20m) sides were significantly different, but the D20m was not different from the Lagg, Fen, or the other Dead side locations.*

p-value	D20m	D5m	D0m	L2m	L5m	L20m	L50m	Lagg	Fen
D20m	-	0.14	0.53	<0.01	<0.01	<0.01	<0.01	0.12	0.76
D5m		-	0.49	<0.01	<0.01	<0.01	<0.01	0.54	0.76
D0m			-	<0.01	<0.01	<0.01	<0.01	0.22	0.23
L2m				-	<0.01	<0.01	<0.01	<0.01	<0.01
L5m					-	0.83	0.22	<0.01	<0.01
L20m						-	0.21	<0.01	<0.01
L50m							-	<0.01	<0.01
Lagg								-	0.015
Fen									-

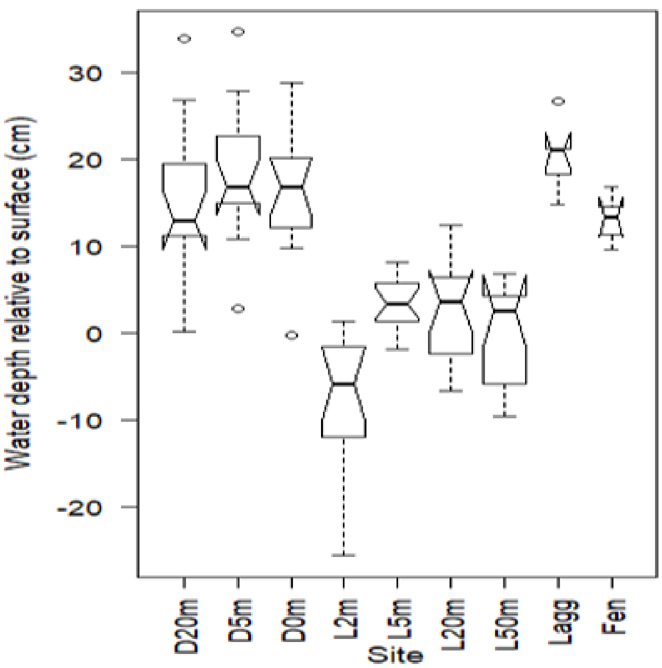

Figure 3: *Boxplots of median water table elevations relative to the surface (positive being above, or flooded, and negative being below the surface) on the dead (D) and live (L) sides. Distances follow the letter (e.g. D20m means 20 m from the ditch on the dead side). The notches (triangular indent) above and below the median (black line) can be used as a way to visualize statistically significant differences: where the notches (or the base of a triangle that would fill the notch) do not overlap on the y-axes they are significantly different at α = 0.05, but where they do overlap, they are not significantly different[12]. For example, L50m has top and bottom notches at ~6 cm and -1 cm, and Lagg has top and bottom notches at ~22 cm and 18 cm. L50m's notch range of -1 to 5 cm does not overlap with Lagg's notch range of 18 to 22 cm, and thus they are statistically significantly different. However, L20m's notches are ~6 cm and 0 cm, and 0 to 6 cm overlaps with -1 to 5 cm (L50m), and thus they are not statistically significantly different. See also Table 1.*

peatland systems, and thus often have water tables at or above the surface. As such, vegetation indicative of each environment has adapted to the average water table conditions.

The 2015 field season was much wetter than average, with 199 mm of surplus precipitation in only 5 months (recall average annual precipitation is only 570.3 mm, with 374.1 mm for the same 5 months). As such, the discussion of the results must be considered with a wetter than normal field season for data.

We believe that the berm, being > 22 cm high, isolated the live side from the surplus water of the pump. The pump's "runoff" (volume of water pumped / surface area of the bog) was 153 mm of water, or 15.3 cm, which is below the height of the berm. Combined with the surplus precipitation, 352 mm of extra water needed to be shed from the bog, which likely exceeded the bog's ability to remove the water. The dead side water tables were 15 cm (150 mm) higher than the live side, suggesting that the flood waters remained well past the spring melt, as the pump acted as surrogate for continuous "heavy rain" that the bog was unable to shed in a timely fashion.

Complicating matters further, we were informed after our field season that there was a second, even larger pump that discharged water into the middle of the dead side for periods of the summer. We do not have the data for this pump, but would argue that its impact would exacerbate the problem of the main pump and not change the interpretation of our results.

Interestingly, there was no difference in water table between the Lagg and Fen locations and the dead side (Fig. 3, non-overlapping notches), suggesting that the fen would be more than capable of handling the surplus water of the pump. In fact, due to the increased area of the fen, the pumped water from the 2015 field season would be ~43 mm of water (rather than the 153 mm reported above).

It is likely that the difference in water levels reported here between the dead and live sides is actually much less (i.e. we have under-represented how flooded the dead side is) due to the location of the wells. As noted in the Methods, wells in peatland studies are often installed in the hollows as the hollows have a much more consistent elevation within the landscape, despite hollows only covering roughly a third to a quarter of the area. On the live side, wells were installed in the hollows. If we considered the depth below the average hummock height (not measured, but a reasonable estimate would be 30 cm obtained from a nearby bog), water tables would drop a further 30 cm. The flooded conditions on the dead side meant that locating hollows was nearly impossible as we could not see the surface when the wells were installed. Visual observations of the live side would suggest that hummocks accounted for 75% of the surface area, thus is it quite likely that wells installed in the dead side were installed in hummocks. Installing a well in a hummock would automatically increase the depth to water table (or lessen the flooded depths found here) as hummocks rise up above the hollow surface. Thus, based on our well locations the live side would have had an average lower water table than reported here, and the dead side a higher average water table. This highlights just how much more standing water there is on the dead side than the live side.

Lowering of the water table in harvested peat fields is a necessary component of peat extraction, and, when possible, peat companies would much rather discharge to a natural fluvial systems (e.g. a river) as it can be done passively, without the costs of running and maintaining a pump. Given that river watershed areas are significantly larger than the peatlands noted here, the volume of water can easily be absorbed by the system with no “flooding” impact downstream. However, when no such natural fluvial system exists, pumps must be used. Discharging to a fen makes a lot of sense, given their higher water tables and natural “river” role in the landscape, and their ubiquity of being located next to bogs[13]. However, when discharging through a bog, we would strongly recommend that berms be constructed on both sides of the ditch so that the water may flow directly to the fen, bypassing the bog. This would allow the bog to remain as a carbon accumulating ecosystem with important habitat for various flora and fauna. As bogs are ombrogenous, the ditch with berms would have little impact to the hydrology of the bog, as evidenced by normal water tables and the healthy, live vegetation immediately adjacent to the ditch.

We acknowledge that this study represents only one field season at one field site and that the flooded conditions of this field season alone did not contribute to the death of the trees on the dead side (as they were dead when we arrived in May). However, it is very likely the surplus water discharged into the bog every summer from 2007 to the current study year continually raised the water level to maintain flooded conditions not conducive to continued bog vegetation growth, and hence their death.

5 Acknowledgements

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