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Hydrology and hydraulics of treatment wetlands constructed on drained peatlands

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ABSTRACT

Treatment wetlands are considered best management practice as they can remove nitrogen, phosphorus and suspended solids from peat extraction or forestry runoff. Treatment wetlands are established on intact or formerly drained peatlands after restoration of the site hydrology by ditch blocking or other methods. However, drainage changes the physical properties of peat, so the hydraulic and hydrological conditions in peatlands may change. Consequently, treatment wetlands constructed on drained areas may have short residence times, resulting in poor purification results. This study determined the hydrological and hydraulic characteristics of treatment wetlands constructed on drained peatlands by studying peat hydraulic conductivity and water distribution in 20 different wetlands in Finland. Four wetlands were studied in more detail using tracer tests, water balance and continuous groundwater measurements. More than 50% of the drained treatment wetlands studied had a lower active flow depth layer (only 10 or 20 cm) with higher hydraulic conductivity (*K*) than normally found in pristine peatlands. At 25% of the sites, *K* was high at all depths investigated (down to 60–70 cm). At several sites, the water was unequally distributed across the wetland surface, indicating that only part of the wetland was being used for purification. The residence time, as determined by tracer tests, varied significantly between sites. These results indicate that past drainage still influences the hydraulics of treatment wetlands.

1. Introduction

Treatment wetlands established on intact mire surfaces have been extensively used in the past to treat runoff from drained peatlands in Finland (Heikkinen et al., 1995; Nieminen et al., 2005; Ronkanen and Kløve, 2009). On these sites, the average removal of suspended solids can be 60–90%, nitrogen 20–50% and phosphorus 20–60% (Kløve et al., 2012). In some cases, however, due to intensive drainage activities intact peat sites are no longer available and treatment wetlands must be established on formerly drained sites. This is in particularly the case in Finland, where unproductive nutrient poor forestry sites, drained in the 1960s–1970s (Fig. 1a), are converted to peat extraction areas (Fig. 1b), instead of using pristine sites with higher ecological values.

The complex flow patterns in wetlands can be studied by different methods such as hydraulic conductivity measurements and tracer tests. The hydraulic conductivity of peat has been measured in many different ways in the laboratory, e.g., by mini-disc permeameter (Grover and Baldock, 2013) or constant head permeameter test (Beckwith et al., 2003; Lewis et al., 2012; Quinton et al., 2008). In field conditions, hydraulic conductivity has been measured e.g., by mini-disc tension infiltrometers (Wallage and Holden, 2011), tracer tests (Quinton et al., 2008), and piezometers (Chason and Siegel, 1986; Price, 2003; Ronkanen and Kløve, 2005). While hydraulic conductivity provides some information on local flow pathways in the peat profile, spatial studies are also needed to obtain a full understanding of wetland hydraulics. In previous studies, the water residence time in wetlands have been measured e.g., by using bromide as a tracer (Lin et al., 2003; Ronkanen and Kløve, 2007; Williams and Nelson, 2011), but this method has been reported to be slightly non-conservative, probably due to plant uptake (Whitmer et al., 2000). Other tracers used include rhodamine WT (Lin et al., 2003; Williams and Nelson, 2011) and iodide (Ronkanen and Kløve, 2007, 2008). Stable isotopes have also proven to be a good way to quantify flow patterns (Ronkanen and Kløve, 2008).

Drainage typically alters peat properties (Burke, 1978; Holden et al., 2004; Minkkinen, 1999; Vasander et al., 2003), such as degree of humification, subsidence of peat, porosity, hydraulic conductivity, water content and geochemical features. Hydrological properties such as runoff amount during flow peak may

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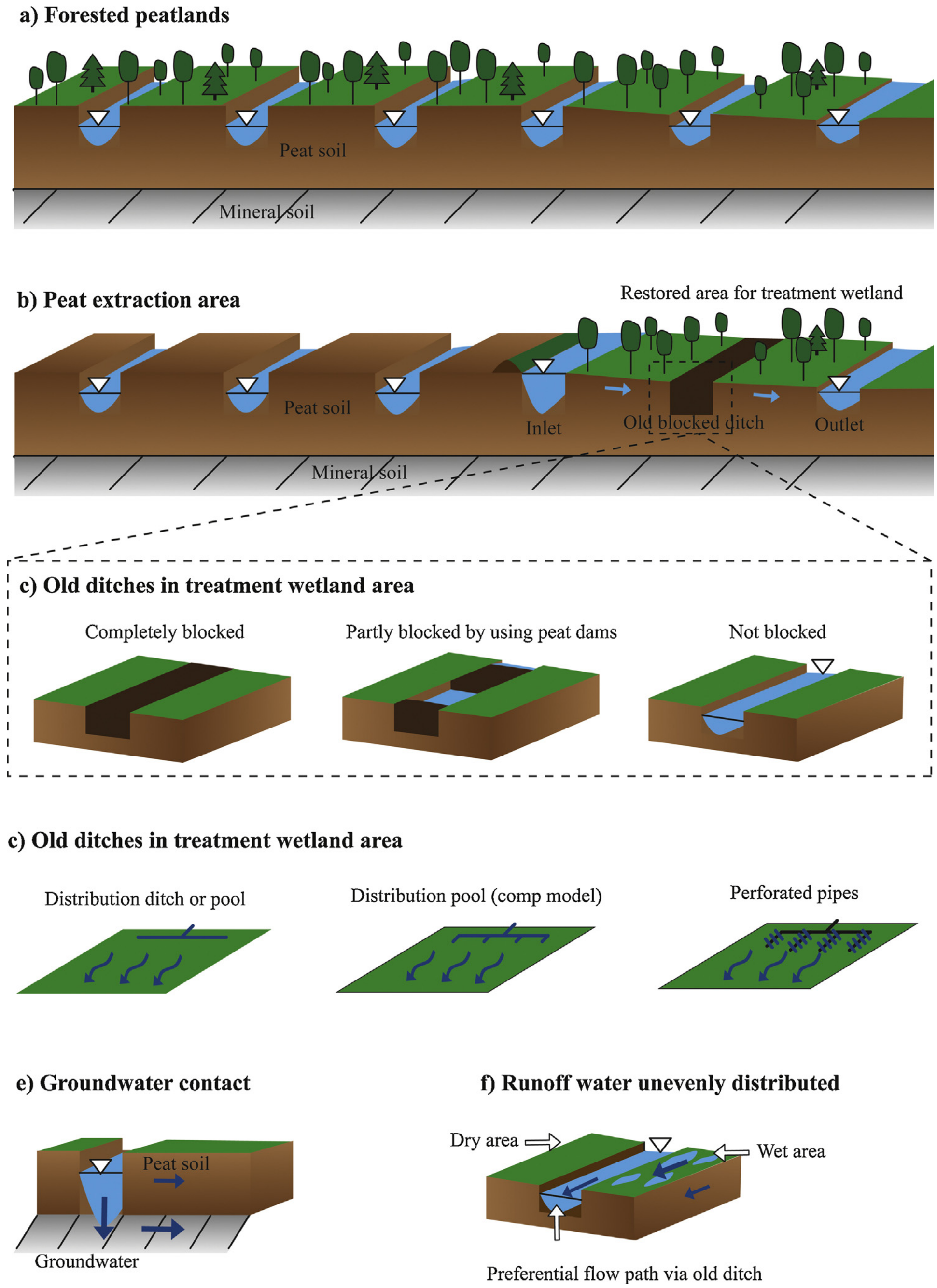

Fig. 1. (a) Forestry drained peatlands and (b) forestry drained site is converted to peat extraction area (no vegetation, only peat cover). Part of the drained area is restored to treat runoff using different (c) ditch blocking techniques and (d) different wetland inflow distribution systems. Hydraulic contact between the (e) wetland and groundwater result in water loss to below aquifers and (f) old ditch can result in short residence time with poor contact between treated water and the peat filter.

also change (Holden et al., 2004). When a treatment wetland is established on a previously drained site, the old ditches can create shortcut flow paths and prevent uniform distribution of water. This decreases residence times and affects pollutant removal. The water flow in peat soils occurs partly as matrix flow within the peat soil and partly as overland flow. The flow on drained areas can also interact with the underlying mineral soil.

In Finland, there are large areas of unproductive forested peatlands with no conservation value (Working Group on a National Strategy for Mires and Peatlands, 2011). These sites are currently more often used for peat extraction. At such sites, intact peatlands to treat runoff are not typically available. Thus treatment wetlands need to be established on formerly drained areas, which may influence the treatment process (Nieminen et al., 2005; Postila et al., 2014). A key question is when and whether such drained sites can be restored to service as treatment wetlands. The starting hypotheses in the present study were: (1) hydraulic conductivity and active flow depth are lower in drained peatland used as a treatment wetland than in corresponding pristine sites; (2) runoff water is unequally distributed to the whole wetland area in drained sites; (3) in drained treatment wetlands, water residence time is shorter compared to pristine peatlands. To test these hypothesis, the hydrology and hydraulic characteristics of treatment wetlands constructed on drained peatlands were determined e.g., using soil hydraulic field measurements and tracer tests.