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The hydrological function of upland swamps in eastern Australia: The role of geomorphic condition in regulating water storage and discharge

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ABSTRACT

Temperate Highland Peat Swamps on Sandstone (THPSS) are a type of wetland found in low-order streams on the plateaus of eastern Australia. They are sediment and organic matter accumulation zones, which combined with a climate of high rainfall and low evaporation function as water storage systems. Changes to the geomorphic structure of these systems via incision and channelisation can have profound impacts on their hydrological function. The aim of this study was to develop an understanding of how changes to the geomorphic structure of these systems alter their hydrological function, measured as changes and variability in swamp water table levels and discharge. We monitored the water table levels and discharges of three intact and three channelised THPSS in the Blue Mountains between March 2015 and June 2016. We found that water levels in intact swamps were largely stable over the monitoring period. Water levels rose only in high rainfall events, returned quickly to antecedent levels after rain, and drawdown during dry periods was not significant. In contrast, the water table levels in channelised THPSS were highly variable. Water levels rose quickly after almost all rainfall events and declined significantly during dry periods. Discharge also showed marked differences with the channelised THPSS discharging 13 times more water than intact swamps, even during dry periods. Channelised THPSS also had flashier storm hydrographs than intact swamps. These results have profound implications for the capacity of these swamps to act as water storage reservoirs in the headwaters of catchments and for their ability to maintain base flow to downstream catchments during dry times. Changes to geomorphic structure and hydrological function also have important implications for a range of other swamp functions such as carbon storage, emission and exports, contaminant sorption, downstream water quality and biodiversity, as well as the overall fate of these swamps under a changing climate.

1. Introduction

Geomorphic structure provides a basis for the hydrological function of any fluvial system (Poole et al., 2006; Brierley et al., 1999; Bellmore and Baxter, 2014). Changes to the physical structure of fluvial systems can result in profound changes to hydrological function that has flow on effects for water quality and habitat (Ballard et al., 2011; Luscombe et al., 2016; Fryirs et al., 2014b).

Anthropogenic landscape alterations such as urbanisation can have irreversible consequences, particularly for wetlands and swamps (Mackintosh et al., 2015; Fryirs et al., 2016; Stander and Ehrenfeld, 2009; Ehrenfeld, 2000). High volume runoff and concentrated flows from impervious surfaces and stormwater drains may have led to channelisation of many urban swamps and wetlands, increasing downstream discharges and compromising their ability to act as water storage reservoirs or 'sponges' that regulate the base flow of downstream receiving streams (Stander and Ehrenfeld, 2009; Bailey and Bedford, 2003; Fryirs et al., 2016). These effects are particularly noticeable in catchments where these headwater swamps form an important part of the water supply chain to towns and cities.

Temperate Highland Peat Swamps on Sandstone (THPSS) are located at the headwaters of low-order streams on low relief plateaus of eastern Australia. Similar to northern hemisphere fens, they are valley bottom swamps set within elongate catchments on relatively steep slopes and are fed through a combination of precipitation, overland flow, and shallow groundwater inflows from the surrounding bedrock aquifer (Evans and Warburton, 2007; Almendinger and Leete, 1998). Preliminary work on the water sources of THPSS in eastern Australia indicate that many Blue Mountains' swamps do source water from the surrounding porous sandstone aquifers while also being rainwater fed (Cowley, 2017). They were formed during the Holocene when sediment accumulated as a result of lowered transport capacity of streams post-Last Glacial Maximum, producing a valley fill (Fryirs et al., 2014a). Increased rainfall and temperatures throughout the Holocene led to organic matter preservation within the valley fill sediment, providing the basis for their permanently high water tables. All the water within intact THPSS is contained within the valley fill; usually there is no

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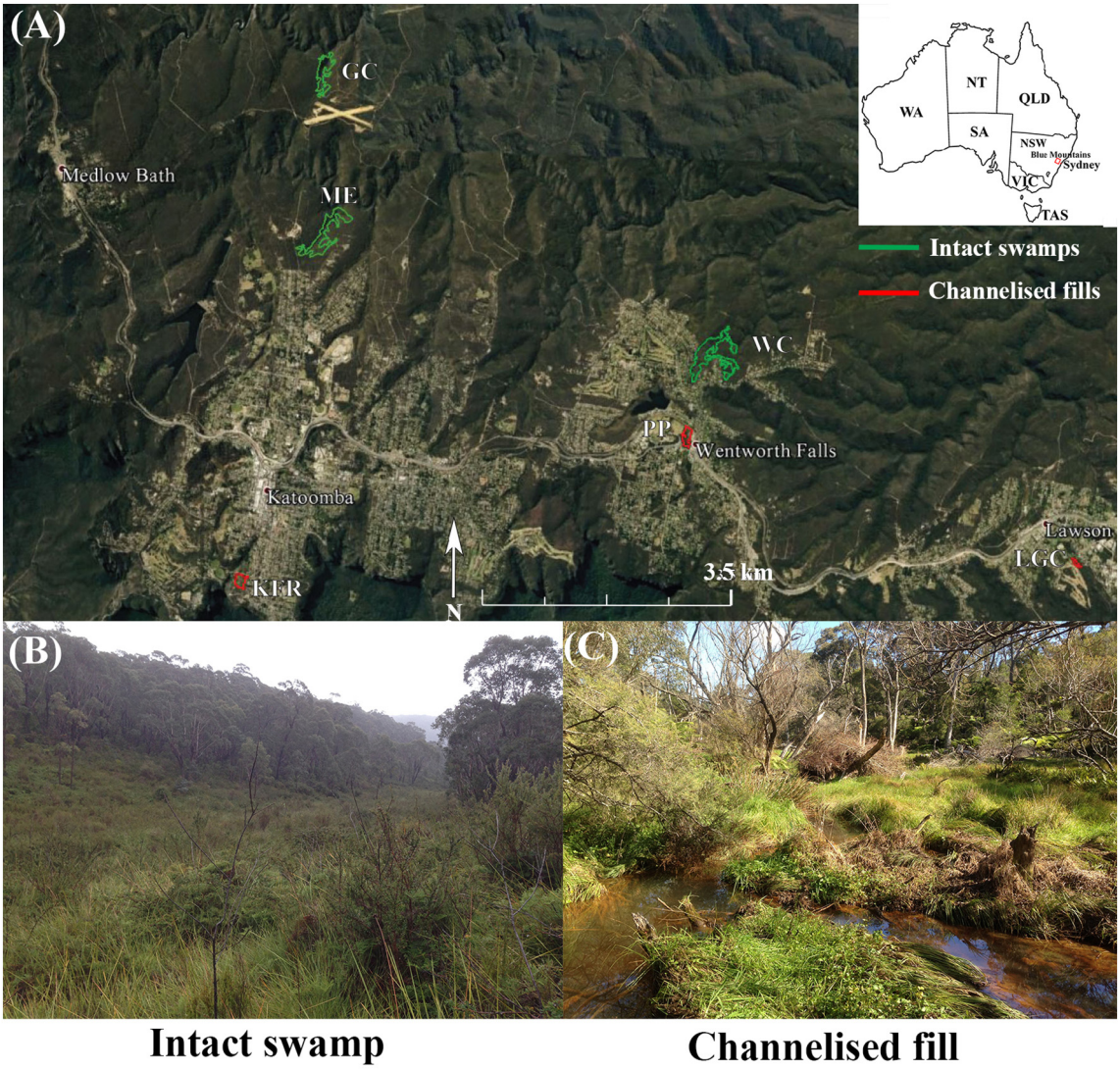

Fig. 1. (A). Location map of study region and study swamps, (B) example of an intact swamp, (C) example of a channelised fill.

surface water except after heavy rainfall. They are thought to act as effective water storage features that regulate base flow to downstream catchments and streams, providing a continuous water supply even in times of drought (Fryirs et al., 2014b; Bourgault et al., 2017).

Like northern hemisphere peatlands, THPSS have been subjected to urbanisation, mining, and agricultural disturbance (Fryirs et al., 2016; Freidman and Fryirs, 2015). This disturbance has resulted in significant alterations to biotic and abiotic structure and function of affected swamps (Cowley et al., 2016; Benson and Baird, 2012; Gorissen et al., 2016). THPSS are listed as Endangered Ecological Communities (EECs) under state and federal legislation. Approximately 26% of THPSS in the Blue Mountains, west of Sydney, have experienced incision and gullying and are now channelised (Fryirs et al., 2016). Holden et al. (2006) found that blanket peatlands that have been drained had flashier storm hydrographs and shorter lag times after rainfall, and throughflow was more significant than overland flow. This hydrological regime indicates that water table levels may be lower and more variable in drained (channelised) peatlands relative to intact (unchannelised) peatlands. Water table lowering (drawdown) after rainfall and reduced water residence times have been documented for northern hemisphere peatlands that have been subject to channelisation (Wilson et al., 2010; Holden et al., 2006). Wilson et al. (2010) found that water retention and water table levels increased after channel blocking, producing lower discharge rates and greater water table stability.

Changes to the water storage function of THPSS (and wetlands generally) have secondary consequences for other swamp functions such as carbon storage, water quality, biodiversity, and microbial activity (Wilson et al., 2010; Strack et al., 2006). Channelised THPSS (henceforth called channelised fills) in the Blue Mountains export up

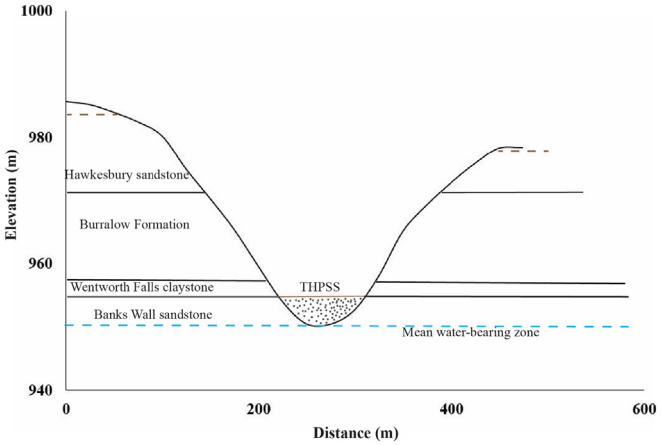

Fig. 2. THPSS position within Blue Mountains' geologic units.