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The give and take (but mostly take) of forested boreal plains hummocks: Are they hydrologic sources or sinks?

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A widely accepted approach in both conceptual and numerical models of groundwater flow is to assume that the water table (WT) is a subdued replica of topography, where groundwater recharges at topographic highs and discharges at topographic lows. However, WTs in low-relief, water-limited environments are generally not topographically controlled, therefore traditional paradigms where forested hummocks are sources of water to both adjacent local wetland-pond systems and catchment-scale runoff do not usually hold true. Local groundwater flow systems (flow in which the recharge area is directly adjacent to its discharge area) are necessary to link forested hummocks with adjacent peatlands or ponds. However, the development of the groundwater mounds beneath topographic highs required to generate local groundwater flow systems is both spatially and temporally infrequent in low-recharge settings like the Boreal Plains. Thus, identifying the spatiotemporal controls on groundwater mounding is crucial to understanding the climatic and geological conditions required for landscape connectivity and runoff generation at larger, regional scales. This insight is becoming increasingly important as water security, ecosystem sustainability, and environmental quality become the focus of land management and reclamation efforts.

The Canadian Boreal Plains are dominated by aspen mixedwood forests, shallow lakes, and peatlands, and has a sub-humid climate that causes large interannual variability in runoff generation and hydrological connectivity at the landscape scale. Through a combination of field observations and numerical modelling, this study identifies the role of aspen forested hummocks in the generation (or loss) of groundwater and hydrologic connectivity to adjacent peatlands and lakes. WT elevations and climate data (precipitation (P) and potential evapotranspiration (PET)) collected over the last 20 years at nine fine-textured forested hummocks were examined for frequency and magnitude of groundwater mounding and/or depressions relative to their adjacent peatlands. It was evident that no simple metric (e.g., annual P, multiyear cumulative P-PET, etc.) was a good predictor for WT position. Through a combination of 1D and 2D, variably saturated numerical modelling, we identify the relative spatiotemporal controls that hummock morphometry, texture, and climate have on groundwater recharge and WT position. Multiple scales of climate forcings (seasonal, interannual; P, PET), substrate texture, hummock height, and rooting parameters all affect groundwater recharge (both positive and negative). Groundwater recharge is most dependent on timing and magnitude of snow melt; however, during periods of

large interannual moisture surplus, when available subsurface storage is low, large summer and fall storms can also contribute to recharge. Otherwise, the overwhelming majority of scenarios result in hummocks storing and transpiring water and receiving inputs of groundwater from neighboring peatlands, therefore acting as a net sink of water to the larger landscape.

We show that groundwater mounds, and therfore the development of local topographic flow systems, under forested hummocks are spatiotemporally rare in sub-humid, low-relief regions, resulting in these hummocks being net sinks of water. Not only does this study emphasize the role of peatlands in the generation of landscape-scale runoff, it encourages a reconceptualiztion of the overall hydrologic function of forestlands and peatlands in catchment hydrology.