Connecting the dots: hydrologic connectivity between wetlands and other wetlands and waterbodies

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FEATURE

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Figure 1. Wetlands are embedded in landscapes connected by hydrological flowpaths from "ridge-to-reef." At any moment in time, there may be a diverse portfolio of wetland connections, the integration of which resulting in the proper functioning of downgradient wetlands and waterbodies.

Wetlands perform numerous ecosystem functions that in turn provide a multitude of services beneficial to humankind. These include flood water storage and release, nutrient transformations, carbon sequestration, and habitat for a diverse flora and fauna. Wetland effects on other wetlands, lakes, streams and estuaries depend critically on how they connect hydrologically to the rest of the landscape (Figure 1).

Wetland hydrologic connectivity broadly describes how, and how strongly, wetlands are linked to the rest of the landscape, especially other wetlands and waterbodies (e.g., streams, rivers, lakes). Most commonly, we discuss this in terms of the flowpaths that enable hydrologic connectivity, which may be across the land surface (i.e., surface flowpaths), over short distances just below the land surface (i.e., shallow subsurface flowpaths), over long distances far below the land surface (i.e., deep subsurface flowpaths), or combinations of all three. More broadly, wetland hydrologic connectivity includes atmospheric fluxes into (i.e., precipitation) and out of (i.e., evapotranspiration) wetlands. Together, these flowpaths connect wetlands to other wetlands and waterbodies in four dimensions – longitudinal, lateral, vertical and through time.

This four-dimensional hydrological connectivity, operating across spatial and temporal scales, is a foundational concept in freshwater science. Individual wetlands connect to other wetlands and waterbodies via numerous flowpaths that vary in both space and time (Figures 2 and 3). Together they act as a complex network wherein wetlands are nodes connected to the rest of the landscape by a web of flowpaths, or edges. Landscape networks differ from one another in terms of both their nodes (e.g., differences in wetland area, depth, and shape) and edges (e.g., differences in flowpath distance, gradient, roughness, or permeability), creating a unique and diverse portfolio of functions critical to healthy landscape function.

Indeed, the patterns of water flow in and across landscapes are fundamentally

Figure 2. Hydrological connections are often intermittent, occurring and observable only under specific circumstances. For example, western vernal pools and swales form the headward extent of tributary systems when the variable source areas from which runoff is generated expand seasonally and/or through the course of storms. On the left is a western vernal pool staging up and spilling toward the upper left; on the right is the western vernal swale immediately downgradient just prior to discharging to a larger stream. These flows play an important role in maintaining the chemical, physical and biological integrity of the larger stream, which in turn supports Chinook salmon and Steelhead trout.

Figure 3. Aeolian-transported snow can be an important mode of connectivity in northern climates. In south-central Alaska, snow blown off the uplands can be trapped in depressions, like the small ponds that form in ice-scour, kettle, and moraine depressional settings. As the trapped snow melts, it is then redirected into groundwater recharge. On the left is a small pond buried under snow blown off the adjacent uplands; on the right is the top of a two meter tall stage gage in that same small pond. This excess water will provide a surcharge of groundwater recharge when it melts in late spring and early summer.

controlled by the spatially and temporally varying structure of this network. At any moment, some wetlands might be connected by short, rapid, surface flowpaths, others might be connected by long, slow, deeper flowpaths and still others might be hydrologically disconnected. The combination of these conditions – including the temporary lack of connectivity – is reflected in downgradient wetlands and waterbodies, impacting the time-varying patterns of flow or chemical loads to other wetlands, lakes, streams and estuaries.

Human activities alter the hydrologic network via, for example, ditches and tile drains (which enhance connectivity) or levees and roadbeds (which diminish connectivity), with consequences for important landscape functions (Figure 4). In many cases, wetlands and their connections to other wetlands and waterbodies are difficult to map, limiting our ability to effectively protect them individually, or the resilience of the network to which they belong. Furthermore, detecting and predicting individual and cumulative effects of altered wetland connectivity requires resource intensive tools that may make implementation cost-prohibitive. As a result, information on where wetlands are located, how they are connected and the how their connectivity impacts landscape functioning is frequently inadequate. This has led to the incremental loss of wetland area and function, with important landscape implications. Now, wetlands – particularly small wetlands that connect only intermittently via surface flowpaths – are at risk of being lost *en masse* with the numerous and ongoing legal challenges to their protection. The impacts of selected removal of these small wetlands from the landscape are likely to be significant, but remain poorly understood.

In response to these challenges, researchers are actively seeking to quantify wetland functions and hydrologic connectivity, focusing in particular on these smaller wetlands that connect principally via deeper flowpaths and infrequently via obvious surface flowpaths. Using readily available data on climate, geology, relief and land cover, scientists are developing tools to predict – across all of North America including the United States, Canada and Mexico – how, when, and how strongly wetlands connect to other wetlands and waterbodies. At finer scales, there is also a clear and pressing need for new tools to inform management and regulatory decisions to optimize the protection of the wetland resources that remain. While much of this research is in its infancy, there are already promising new tools and concepts that will meet the urgent need to improve our understanding of wetland hydrologic connectivity. ■

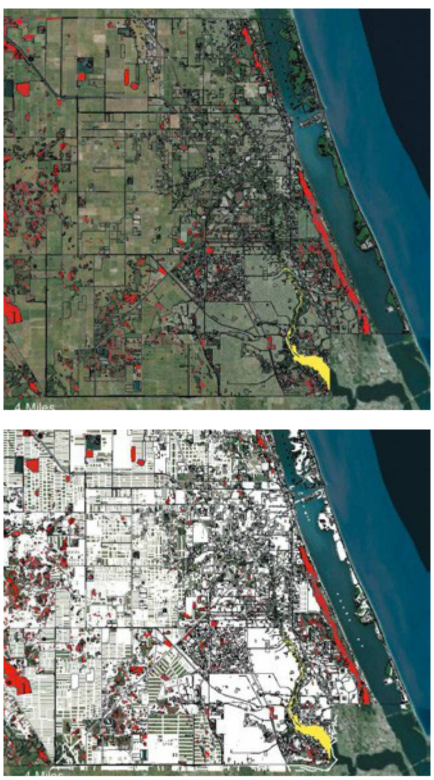

Figure 4. Ditching and draining have systematically changed hydrological connectivity, enhancing the connectivity between remote wetlands and downgradient wetlands and waterbodies. On the left are all of the depressional wetlands (red) and natural waterways and waterbodies (yellow) in St. Lucie County, Florida; on the right are the same two sets of features as well as the artificial waterways and waterbodies (white). The receiving waterbody is the Indian River Lagoon, which increasingly suffers from both chronic and episodic water-quality impacts.

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