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HYDROLOGICAL CONNECTIVITY OF HEADWATERS TO DOWNSTREAM WATERS: INTRODUCTION TO THE FEATURED COLLECTION[1]

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BACKGROUND

In January 2001, the U.S. Supreme Court issued a ruling in the case of *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, 531 U.S. 159 (2001) (SWANCC). The *SWANCC* case presented the Court with two issues: (1) whether an isolated water could be considered part of the "waters of the United States," protected under the Clean Water Act (CWA) – and thus subject to the U.S. Army Corps of Engineers' (Corps) regulatory authority under Section 404 of the CWA – solely based on its use by migratory birds; and, if so, (2) whether Congress had the constitutional authority under the Commerce Clause to include these as waters of the United States. In particular, the Court considered the Corps' Migratory Bird Rule – which deemed waters of the United States to include isolated intrastate waters that provide habitat for migratory birds. In a 5-4 decision, the Court found that the Migratory Bird Rule exceeded the Corps' authority under the CWA [531 U.S., 159 (2001)], and held that the CWA is not intended to protect isolated, intrastate, non-navigable waters based solely on their use by migratory birds. While the Court's decision did not create a bright line test for what Congress intended to regulate under the CWA, the Court's reasoning implies that the CWA intended some "connection" to navigability, and that isolated waters need a "significant nexus" to navigable waters to be jurisdictional.

The *SWANCC* decision has had profound implications on the legal status of so-called isolated waters – those lacking a surface water connection to other bodies of water. Furthermore, that decision affects all CWA programs – including Section 303 water quality standards, Section 311 oil spill prevention and cleanup, Section 401 water quality certification, and Section 402 pollution discharge permits – not just Section 404, which regulates the discharge of dredged or fill material into waters of the U.S, including wetlands. Initially following the *SWANCC* decision, much of the regulatory debate was focused on so-called isolated wetlands, while the debate in the courts focused on the jurisdictional status of tributaries, including headwater, intermittent and ephemeral streams. These case law and regulatory debates made apparent that the emerging issue is "what is the extent of the tributary system," with a focus on headwater, intermittent and ephemeral streams and the connectivity, or "significant nexus," of these waters to navigable waters. The Corps and the U.S. Environmental Protection Agency issued guidance in January 2003 indicating that field staff were to continue to assert jurisdiction over tributaries and their adjacent wetlands, and that formal headquarters approval should be obtained prior to asserting jurisdiction over isolated waters based solely on links to interstate commerce [68 Fed. Reg. 1995, 1998 (January 15, 2003)]. During that same time period, a significant majority of courts, including 17 appellate court decisions, concluded that *SWANCC* was narrowly focused

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on isolated waters, and did not change the jurisdictional status of tributaries or adjacent wetlands.

In October 2005, the U.S. Supreme Court agreed to review two cases related to *SWANCC*, the *John A. Rapanos et al. v. United States* (U.S., No. 04-1034, 2005) and *June Carabell et al. v. United States Army Corps of Engineers and the United States Environmental Protection Agency* (U.S., No. 04-1384, 2005) decisions from the Sixth Circuit. By granting review of these appellate court decisions, the Supreme Court increased uncertainty about the extent to which the CWA protected tributaries, and the jurisdictional status of headwater, ephemeral and intermittent streams. The consolidated cases were heard on February 21, 2006. The petitioners argued that CWA jurisdiction extends only to wetlands that actually abut navigable-in-fact waters, and that if the CWA extends to any other wetlands, Congress has exceeded its Commerce Clause authority. The petitioners also argued that CWA jurisdiction does not extend to non-navigable tributaries. As this JAWRA featured collection was under review, the Supreme Court handed down its judgment in these consolidated cases in five separate opinions, none of which had a majority of five votes, 126 S. Ct. 2008 (2006) (*Rapanos*). The 4-1-4 decision is extremely complex, and has left many questions, some highly technical in nature, regarding CWA jurisdiction over headwater, intermittent, and ephemeral streams.

Given the debate over non-navigable waters and the regulatory turmoil caused by the *SWANCC* and *Rapanos* decisions, as well as the scientific, legal, and political complexities of CWA jurisdiction, now is an opportune time to review the state of our scientific understanding of the contributions of headwater, intermittent and ephemeral streams to the integrity of downstream waters. This featured collection of the Journal of the American Water Resources Association provides such a review. One motivation for this featured collection is that scientific information will be useful for on-going policymaking, at the federal, state, and local level. Another primary motivation for the featured collection is the need to address the more basic questions of hydrological and ecological connectivity of headwaters, how such connectivity contributes to the integrity of downstream waters, and to assess our knowledge of the processes that occur in these waters and the impacts they have on the larger aquatic ecosystem.

This featured collection is based on an invited special session exploring the roles played by headwaters in maintaining the physical, chemical, and biological integrity of waters in lower watershed positions, held at the American Water Resources Association Annual Conference in Seattle, Washington in November, 2005. Participants were asked to address several key topics in preparing their presentations, and subsequent manuscripts, focused on the roles played by headwater streams in maintaining the physical, chemical, and biological integrity of downstream waters, the roles played by headwater streams in maintaining the integrity of the larger stream network, the spatial and temporal scales over which this hydrological connectivity is relevant, and the relative roles of surface water and ground-water flow paths.

OVERVIEW OF FEATURED COLLECTION

The first paper in the collection, by Freeman *et al.* (this issue), defines hydrological connectivity and explores mechanisms by which the cumulative alteration of headwater streams may affect ecological function at larger scales. Using examples of coastal eutrophication, diminished riverine productivity, and lowered viability of river biota, the authors suggest that headwater alteration has the potential to reduce ecological integrity at large spatial scales, particularly where river systems are already affected by landscape changes and downstream modifications including dams, levees and flow regulation.

Next, two contributions examine the relationships between ground water and surface water. Noting that understanding the interactions of ground water and surface water is fundamental to understanding and managing the chemical and biological characteristics of streams throughout their length, Winter (this issue) examines how ground water affects the generation and maintenance of streamflow in selected hydrogeologic and climatic settings. The paper presents background information on some fundamentals of stream and ground-water interaction, then discusses small headwater streams in mountainous terrain, larger streams in different hydrogeologic terrain, and causes for loss of stream water that affect its ability to reach lower watershed positions. The author concludes that the effect of ground-water contribution to headwater streams on the volume of stream flow lower in a watershed is partly related to the volume of ground water contributed in the headwater area, and partly related to losses which deplete the flow in the stream. To maintain baseflow throughout the length of a stream, he notes, it is generally necessary to have ground-water discharge to the stream throughout much of its length. Izbicki (this issue) describes the physical and temporal isolation of mountain headwater streams in the western Mojave Desert, an internally drained basin. He summarizes the brief physical connection of selected mountain headwater streams to downstream hydrologic systems that may occur following precipitation events, the connection of water infiltrated from these streams through the unsaturated zone to the underlying ground-water system, and the longer timescale connection through the ground-water system to discharge areas farther downgradient. Despite the physical isolation of surface flow in these streams, the author concludes, they are an integral part of the hydrologic cycle.

Two articles follow which address water quality and chemistry. Alexander *et al.* (this issue) review current watershed research and apply the spatially explicit, mass-balance watershed model SPARROW to consider transport and transformations of water and nutrients throughout stream networks in the northeastern United States. Simulating fluxes of nitrogen, a primary nutrient that is a water-quality concern for acidification of streams and lakes and eutrophication of coastal waters, and refining the model structure to include observations of nitrogen removal in streams and lakes, they quantify nitrogen transport from headwaters to downstream navigable waters. Their results underscore the profound influence that headwater areas have on shaping downstream water quantity and water quality. Synthesizing several studies of dissolved inorganic nitrogen (DIN) transport in a headwater site of the Upper Mississippi River Basin, Triska *et al.* (this issue) developed basin scale conception of DIN transport and underlying controls using both new and existing data. These researchers examined DIN retention-transport through four hydrologically distinct zones: hillslope ground water, alluvial riparian ground water, hyporheic ground water, and stream surface water. Their results indicate that headwaters with intact hydrologic connectivity, especially through riparian and hyporheic zones, are critical in mitigating downstream DIN loading to navigable waterways.

Three papers then address aspects of ecological connectivity. Wipfli *et al.* (this issue) present conceptual models of energy and nutrient fluxes that outline small stream processes and pathways important to downstream communities. The models, based on empirical evidence and best professional judgment, suggest navigable waters are significantly influenced by headwater streams through hydrological and ecological connectivities, and land-use can dramatically influence these natural connectivities, impacting downstream riverine ecosystems. The authors emphasize that while headwater streams provide downstream habitats with a multitude of ecosystem services, including water, nutrients, food (e.g., organic matter and invertebrate prey), and woody debris, the quality and timing of delivery of these services to downstream communities remain poorly understood. Meyer *et al.* (this issue) examine the contribution of headwater streams to biodiversity in river networks. They review the diversity of organisms dependent on headwaters, discuss the ecological factors that make these habitats favorable for so many species, illustrate the ecological connectivity that exists between headwater and downstream ecosystems, and discuss the ways in which downstream biota depend on headwater ecosystems. They conclude that the cumulative impact of degraded headwaters contributes to the loss of ecological integrity in ecosystems downstream. From the Crown of the Continent Ecosystem (CCE) in the northern Rocky Mountains, water flowing to the west enters the Columbia River basin (Pacific Ocean), waters flowing to the northeast flow into the Saskatchewan River basin (Arctic Ocean), and water flowing southeast enters the Missouri River basin (Atlantic Ocean). A paper by Hauer *et al.* (this issue) describes the importance of water resources in the CCE to continental scale biodiversity, illustrates hydrogeomorphic, biogeochemical and organismal linkages between CCE alpine, subalpine and valley bottom headwater streams and their coupling to water quality and quantity and regional biocomplexity, and presents supporting studies that demonstrate the various sources and processes associated with both natural and man-caused disturbance and their effects within the CCE. These authors also discuss pending threats to headwaters that will likely affect the larger river systems that flow from this ecoregion, as well as direct impact to ecosystem integrity within the CCE itself.

The concluding synthesis paper (Nadeau and Rains, this issue) presents information on the geographic distribution of headwater streams and intermittent and ephemeral streams throughout the United States, and summarizes major findings from the contributed papers and the existing scientific literature in considering hydrological connectivity between headwater streams and downstream waters. It also relates the scientific information presented to policy issues surrounding the scope of waters protected under the CWA, including a postscript discussing the U.S. Supreme Court's recent decision in *Rapanos*.

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