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Humans Transforming the Global Water System

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Fresh water figures prominently in the machinery of the Earth system and is key to understanding the full scope of global change. Greenhouse warming with a potentially accelerated hydrologic cycle is already a well-articulated science issue, with strong policy implications. A broad array of other anthropogenic factors—widespread land cover change, engineering of river channels, irrigation and other consumptive losses, aquatic habitat disappearance, and pollution—also influences the water system in direct and important ways. A rich history of site-specific research demonstrates the clear impact of such factors on local environments. Evidence now shows that humans are rapidly intervening in the basic character of the water cycle over much broader domains. The collective significance of these many transformations on both the Earth system and human society remains fundamentally unknown [*Framing Committee of the GWSP*, 2004].

The Notion of a Global Water System

Diminutive by ocean standards and representing but a small fraction of the planet's hydrosphere (< 3% of total volume [*Shiklomanov and Rodda*, 2003]), fresh water nonetheless serves as an essential building block of the Earth system. Fresh water is intertwined with energy exchange, atmospheric teleconnections, and feedbacks linking the climate system. Water movement constitutes the largest flow of any material through the biosphere, and serves as the primary vehicle for erosion and dissolution of the continents. The importance of fresh water, which strongly regulates productivity and supports ecosystems and biodiversity, is evident throughout the biosphere.

Fresh water is also critical to human society. It underpins global food production by providing the fundamental resource upon which irrigation, livestock production, fisheries, and aquaculture depend. Domestic, industrial, hydropower, and recreational water use is crucial to a large and growing population that aspires to long-term improvements in well-being. Providing basic sanitation and clean drinking water services remains a major public health challenge. More than 1 billion people are without access to clean drinking water, 2.5 billion are without sanitation, and over 5,000 people, mostly children, die each day from water-related diarrheal diseases [*World Water Assessment Programme*, 2003].

Key manifestations of variability in the terrestrial water cycle continue to shape human history and are a costly source of vulnerability. In the United States, annual drought damage averages $6 billion, with the 1988 drought alone costing over $60 billion in 2002 dollars [*Ross and Lott*, 2003]. Annual damages from flooding and other extreme weather involving the global water cycle are even more costly. Initial estimates in press reports put losses from the 2004 hurricane season in the tens of billions of dollars.

In the context of water's many roles in the Earth system, the concept of a Global Water System (GWS) provides a useful organizing framework. The GWS is defined by a series of interacting components (Figure 1): (1) water in all its forms, as part of the physical hydrologic cycle; (2) biological systems, as integral transformers of water and constituent fluxes that determine biogeochemical cycling and water quality; and (3) human beings and their institutions, as agents of environmental change, and as entities that experience and respond to ongoing transformations of the GWS.

A systematic assessment of how each of these components and their interactions define the evolving state of the GWS is a fundamental challenge confronting the Earth and human-dimensions science communities.

The Global Water System Project

A new international research effort constituted as an Earth System Science Partnership (ESSP) project of the Global Environmental Change Programmes (DIVERSITAS, International Geosphere-Biosphere Programme [IGBP], International Human Dimensions Programme on Global Environmental Change [IHDP], and World Climate Research Programme [WCRP]) has been launched to study these complex issues. The primary aim of the Global Water System Project (GWSP) is to promote improved understanding of fresh water in the Earth system through integrated study of its interactions, feedbacks, and thresholds. The GWSP science agenda emerged from a broad consensus of the water science and assessment community, with more than 200 contributors to interdisciplinary planning meetings starting in 2002, science planning documents, and a recent Open Science Conference (October 2003; Portsmouth, New Hampshire). A peer-reviewed framework and implementation plan consolidates these deliberations [*Framing Committee of the GWSP*, 2004]. This article presents the scientific rationale for the GWSP, the project's key research questions, and an emerging agenda for the decade-long effort.

In the crowded landscape of acronyms representing projects, programs, and institutions that deal with water, a strong justification must accompany any new international initiative. Several characteristics distinguish the GWSP from other international water-related programs. The GWSP is designed to be the following:

(1) *Science driven but policy-informing*. GWSP considers fundamental questions about water and global change. Owing to the central role of water in human society, the questions bear high relevance to environmental management and sustainable development.

(2) *Global in its perspective*. GWSP will help determine the importance of pandemic local changes to the hydrologic cycle on the behavior of the Global Water System as a whole. While new world water models and databases are envisioned, the project will draw heavily from a rich history of case studies and regional analysis.

(3) *Integrative and interdisciplinary*. From its inception, GWSP has sought to unite socioeconomic, physical, and ecological perspectives.

(4) *Multitemporal*. GWSP focuses on a century time frame starting in the mid-20th century, a time of rapid change and growing human influence on many of the planet's physical and biogeochemical cycles. For broader context, it will draw on historical and paleo perspectives and scenario-based visions of the future.

Global Change and the Global Water System

The freshwater cycle is under rapid transformation (Figure 1). Climate change has clear ramifications for global hydrology, with major concerns surrounding the links of progressive

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