

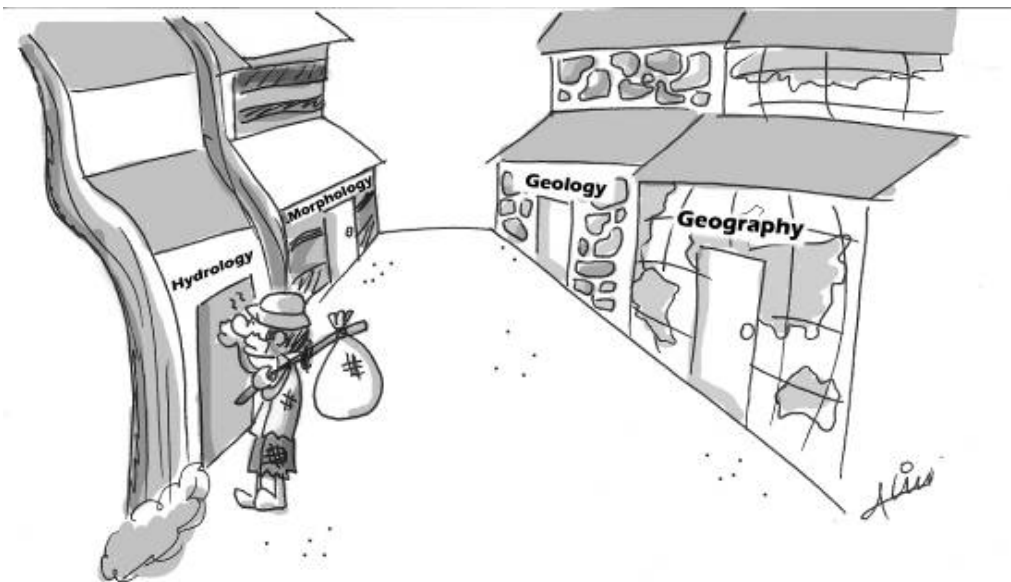
Chapter 37

Hydromorphologic Scientific and Engineering Challenges for 2050

Richard M. Vogel

ABSTRACT

By the year 2050, the hydrologic cycle will be influenced by changes in climate, water use, land use, and water infrastructure at nearly all spatial and temporal scales. It may be impossible to find a “research” watershed subject only to natural or virgin hydrologic conditions. Nearly every hydrologic method introduced prior to 2050 will have been adapted to account for the increased uncertainty and nonstationarity which have become the central challenges of our profession. A new subfield of hydrology termed hydromorphology will emerge to describe the structure, evolution and dynamic morphology of watershed systems over time (e.g., years, decades and centuries). The need for this new field will arise due to the enormous societal challenges and demands resulting from human impacts on environmental and water resource systems. The science of hydromorphology will develop a conceptual basis for improving our understanding of the impact of humans on the hydrosphere. Hydromorphologic engineers will introduce methods for the detection, attribution, design, management and prediction of water resources in a hydrosphere which by 2050 will be dominated by multiple and interacting sources of uncertainty and nonstationarity.



“Hydromorphology - trying to find a home.”

HYDROMORPHOLOGY: THE EVOLUTION AND STRUCTURE OF HYDROLOGIC SYSTEMS

In the 21st century, it became apparent that a wide range of environmental damages are linked to urbanization including, but not limited to: decreases in biodiversity, increased flooding, degradation of human health, decreases in evapotranspiration and decreased quality of air, water and soil resources. The hydrologic effects of urbanization are primarily a result of both continuous and abrupt land-use and infrastructure changes that lead to changes in the land and the atmospheric component of the hydrologic cycle as well as changes in the water use cycle. Urbanization leads to the construction of water distribution systems, as well as an infrastructure to accommodate storm water and sewage. All of these modifications to the landscape result in changes to the hydrologic cycle and watershed processes. There has been a wide range of initiatives relating to watershed management to ameliorate past damages and/or prevent future environmental damages resulting from the urbanization of watersheds. Regardless, watershed systems evolve due to changes in land-use, climate, and an array of other anthropogenic influences. The evolution of a watershed system in response to such influences at the scale of years to centuries is termed its hydromorphological response (Dressler et al. 2006).

Traditional hydrologic approaches assume stationarity (Milly et al. 2008) and such approaches omit the influence of humans on the structure and evolution of hydrologic processes. By the year 2050, traditional approaches which focus primarily upon natural physical hydrologic processes will become obsolete. Humans and hydrologic processes are coupled and models and methods which do not account for that coupling will lead to unrealistic results, and thus become outdated.

By the year 2050 the science of hydrology will merge with many other fields outside the realm of traditional science. During the late twentieth century, hydrology merged with several traditional scientific fields resulting in the fields of ecohydrology, geohydrology and hydrometeorology. During the first half of the 21st century, hydrology will merge with a variety of other fields in the social sciences and the medical sciences. In due course, the need for hydromorphology will arise as described below.

Geomorphology is to Geology as Hydromorphology is to Hydrology

Geology is that branch of science dealing with the study of the Earth, the materials of which it is made, the structure of those materials, and the processes upon them. *Hydrology* is that branch of science dealing with the study of water on earth, including its occurrence, distribution, movement, and its relationship to all aspects of the environment with which it interacts.

Geomorphology is that subfield of Geology dealing with the structure and evolution of the surface of the earth, including the origin and dynamic morphology (changing structure and form) of the earth's land surfaces.

By analogy: *Hydromorphology* is a subfield of Hydrology dealing with the structure, evolution, origins and dynamic morphology of the earth's water resources. Although geomorphology deals primarily with the dynamic morphology of the virgin earth system, hydromorphology addresses the dynamic morphology of water resource systems due to both natural and anthropogenic influences.

Hydromorphology deals with problems relating to the structure, evolution and dynamic morphology of hydrologic systems over time.

HUMANS WILL HAVE TRANSFORMED THE HYDROSPHERE BY 2050

As predicted by numerous investigators (Röckström et al. 2009; Vörösmarty et al. 2010, and many others), by 2050, the hydrosphere will be almost completely transformed by humans. Approaches addressing the nonstationarity of hydrologic processes will become the norm and stationary approaches which were dominant during the twentieth century, will be generally outdated in 2050. In 2050 it will be difficult to find a hydrology or other water resource textbook which ignores human impacts due to urbanization, agriculture and other land use modifications.

As a result of the profound transformations of the hydrosphere, new scientific and engineering disciplines will arise to meet the societal challenges posed by those transformations. A science of hydromorphology will develop to improve our conceptual understanding of the impacts of the multiple interacting and pervasive human and natural influences on the behavior of hydrologic systems. An engineering discipline of hydromorphology will emerge to develop improved methods to operate, plan and manage our water resources to accommodate the increased uncertainty and nonstationarity which result from the multiple interacting and pervasive human and natural influences which have led to ecosystem degradation, biodiversity losses, and global climate change.

A Scientific View of Hydrologic Systems and Watershed Models in 2050

By 2050, the hydromorphological response of watersheds will be paramount to hydrologists, due to the then pervasive impacts of population growth, urbanization, ecosystem degradation, biodiversity losses, and global climate change. Those pervasive human influences combined with our improved awareness and ability to detect and attribute hydromorphological impacts will make the notion of a virgin watershed only a distant abstraction or vestige of the pre-industrial era. In 2010, we usually define a *scientific* or *research* watershed as a virgin watershed without human impacts. In 2050, *scientific* or *research* watersheds will exhibit a wide range of anthropogenic influences, ranging from forested and agricultural watersheds to highly urbanized watersheds and watersheds dominated by water infrastructure. Consequently, in the year 2050, nearly all scientific watershed models will by necessity, include mathematical or conceptual models of a wide range of human processes in addition to traditional natural hydrologic processes such as infiltration, evaporation, and groundwater outflow included in current models. At present, most

conceptual formulations of human influences such as residential and industrial water use, “best management practices,” and irrigation and stormwater systems were developed by engineers and incorporated in engineering models useful for design of infrastructure and operating complex water resource systems. In 2050, scientific hydrologists will be studying what is now, in 2010, under the purview of engineering hydrologists, because their focus will evolve to improving our understanding of the interactions among human and natural processes.

In 2050 nearly all scientific watershed models will include a wide range of human processes in addition to traditional natural hydrologic processes

An Engineering View of Hydrologic Systems and Watershed Models in 2050

Analogous to the developments in scientific watershed models described above, by 2050, engineering-oriented watershed models will also have evolved to meet the new and emerging challenges of hydromorphology. Concerns over watershed damages due to population growth, urbanization, ecosystem degradation, biodiversity losses, and global climate change will lead engineers to develop fully integrated and modular modeling systems. The new generation of hydrologic and watershed models described in the previous section will be routinely integrated with climatic, demographic, geographic, ecologic, economic and decision oriented systems models to solve a new class of engineering problems. Engineers will no longer be designing water resource infrastructure in isolation, such as an individual culvert, dam, well or recharge basin. Instead, such infrastructure will be designed using integrated systems models, so that for example, flood control objectives and water supply objectives are not in competition with one another, but rather, a recharge basin may be chosen because it serves to both reduce flood flows and increase groundwater supplies, while simultaneously improving water quality goals and ecosystem services. It will become common practice for engineers to use the type of generalized watershed management modeling systems envisioned by Zoltay et al. (2010) when they attempted to develop an integrated decision support system for selecting the optimal combination of management alternatives from a much wider class of land, ground and surface water, recycling, wastewater, and best management practices than had been considered previously.

CONCLUSIONS

By the year 2050, the field of hydromorphology will be a rich and fertile young discipline dealing with the myriad of scientific and engineering challenges created by the wide range of natural and anthropogenic influences which have literally “morphed” the hydrologic cycle at all spatial and temporal scales. Hydrologic or watershed systems will evolve due to a variety of both natural and anthropogenic influences such as changes in land use and water use due to urbanization, and agriculture, climate change, modifications to water infrastructure and water use and a variety of other factors. By 2050, a major transition will have occurred in the development, management, and use of our water resources on local, regional, and

global scales (Röckström et al. 2009; Vörösmarty et al. 2004, 2010). Hydrologic scientists and engineers have always been concerned with how to plan under nonstationary and uncertain conditions. What will be different in 2050, is that anthropogenic modifications to the hydrosphere will be so profound and pervasive that the central challenge facing hydrologists will be how to manage our water resources in an uncertain and nonstationary environment while simultaneously responding effectively to ecosystem degradation, biodiversity losses, and global climate change.

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AUTHOR INFORMATION

Richard M. Vogel has been a professor of civil and environmental engineering at Tufts University since 1984. He received a BS and MS degree from the University of Virginia in the areas of engineering science and environmental science, respectively, and a PhD in Water Resource Systems Engineering from Cornell University. He is the director of an interdisciplinary graduate program in Water: Systems, Science and Society. His research program focuses upon the areas of hydrologic and environmental statistics, water allocation, regional hydrology, regional water assessment, flood and drought management, climate change impacts, natural hazards as well as watershed modeling and management. He was awarded the 1995 Walter L. Huber Prize in Civil Engineering and the 2009 Julian Hinds Award, both from ASCE. He has published over 93 refereed journal articles. Email: Richard.vogel@tufts.edu