A BRIEF SUMMARY OF A REPORT BY THE NATIONAL RESEARCH COUNCIL ON THE HYDROLOGIC IMPACTS OF FOREST MANAGEMENT

Peter F. Ffolliott[1]

There are close connections among forests, water, and people. Forests cycle water from precipitation inputs through the soil and deliver it as streamflow to supply nearly two-thirds of the clean water to the people of the United States. Changes in the character of forested headwater areas that include tributary streams impact on the quantity and quality of the water resources available to people. In this way, forests, water, and people are closely intertwined. At the request of the U.S. Bureau of Reclamation and the U.S. Forest Service, the Water Science and Technology Board of the National Research Council convened a committee to study and then report on the present status of forest hydrology science, connections between forest management, the attendant hydrologic effects, and the consequent impacts on people; and future research and management needs to sustain water resources from forests. This study has been completed and the report of the study, entitled "Hydrologic Effects of a Changing Forest Landscape," was published by the National Academy of Sciences late last year. This paper presents a brief summary of the report.

STATE OF FOREST HYDROLOGIC SCIENCE

Forest hydrology science draws on hydrological sciences, water resources engineering, and forestry to address primary questions about forests and water. Among the questions frequently asked are:

- What are the flowpaths and storage reservoirs of water in forests and forested watersheds?
- How do modifications of forests impact water flowpaths and storage?
- How do changes in forests affect water quantity and quality?

Researchers seeking answers to these kinds of questions have obtained much of their source data and information from plot studies, paired watershed investigations, and hydrologic simulation models. All of these approaches are important elements of forest hydrology. However, plot studies and pair watershed investigations have generally been conducted on relatively small, homogeneous areas and span short time periods. While there are a large number of hydrologic simulation models available, not all are suitable for applications on forested watersheds because of the complex nature of forests cycling precipitation inputs through the soil and deliver it downstream as streamflow.

FUTURE RESEARCH AND MANAGEMENT NEEDS

Forest hydrology science has led to a better understanding of the principles of water movement through forests. These principles focus mostly on general hydrologic responses to changes in forests on small areas for short periods of time. Many interacting factors affect forests including climate change, forest disturbances, forest species composition and structure, and land development and ownership. These factors tend to "break up" forests into smaller, noncontiguous parts. However, today's forest and water managers need forest hydrology science that helps them to understand and predict how the factors will affect water quantity and quality across large areas and over long time scales.

One of the more important unresolved issue in forest hydrology science is how to "scale up" finding from the principles of forest hydrology that were largely developed on small, homogeneous watersheds to improve the predictions of hydrologic responses across large, heterogeneous watersheds and landscapes. A landscape perspective allows for the analysis of forest and water connections over large areas to use the principles of forest hydrology to make predictions about forests and water that address current and anticipated future issues such as cumulative watershed effects, climate change, and forest management practices.

Cumulative Watershed Effects

Cumulative watershed effects are the hydrologic effects resulting from multiple land-use activities over time on watershed landscapes. Extreme precipitation events often reveal cumulative watershed effects and, in doing so, spur public interest in obtaining better

1 School of Natural Resources, University of Arizona, Tucson, Arizona

understanding on how land uses on forested watersheds are related to downstream flooding and other detrimental effects. Assessing cumulative watershed effects required a knowledge of the physical, chemical, and biological processes that route water, sediment, nutrients including pollutants, and other materials from watershed hillslopes and headwater streams to downstream areas. Future research on this issue should strive to elucidate the relationships among forests, water pathways and quality, and watershed land-use activities over large spatial and long temporal scales.

Climate Change

Effects of climate change on forests and water are becoming increasingly evident and future impacts of continuing climate change are likely to have "major effects" on forest hydrology. Direct effects of climate warming such as increases in frequency of wildfires and changes in the magnitude and timing of snowmelt-runoff contributions to streamflow are already being observed. However, more research is needed to improve predictions of the indirect effects of climate change including evaluations of how changes in forests and forest management influence hydrologic responses.

Forest Management Practices

Forest management practices evolved over time. Forces that modify forests today are triggering forest managers to initiate novel and contemporary practices. Many of these new practices such as thinning for fuel reduction and best management practices to manage riparian buffers for species protection have not been fully assessed for their attendant hydrologic effects. It is important, therefore, that the hydrologic effects of these newer forest management practices be understood over long temporal and large spatial scales.

ACTIONS FOR RESEARCHERS, MANAGERS, AND CITIZENS TO TAKE

Researches who study forest hydrology, forest and water managers, and citizens each have a role in sustaining water resources from forests. Through individual and collective actions, they can apply the current understanding of forest hydrology science, explore research gaps and informational needs, and pursue the following recommended actions.

Researchers

Researchers are poised to advance forest hydrology science to address critical water issues. New research approaches should be pursued and many of the current research agendas should be maintained or expanded. Researchers should:

- Continue current small watershed experiments and re-establish small watershed experiments where research has been discontinued.
- Catalogue historical and modern climatic and hydrologic records.
- Use the "whole body" of paired watershed experiments as a "meta experiment" to better understand hydrologic responses to forest disturbance over large spatial and temporal scales and across a range of forest types.
- Expand the capacity for visualization and prediction of hydrologic response on large watersheds and river basins through geographic information systems, remote sensing technologies, sensor networks, and advanced simulation models.
- Work with economists and other social scientists to improve understanding of the value of sustaining water resources from forests.

Managers

Forests, forest management, and the climate and social contexts of forests are dynamic. Therefore, best management practices should be updated continually through an adaptive management approach. Best management practices for forests can mitigate the negative consequences of forest management activities, but their "effectiveness" might be mostly site- and storm-specific and, as a result, difficult to quantify. Managers should assess best management practices and modify the current suite of these practices to increase their effectiveness. To do this, management should:

- Catalogue individual or agency best management practices at the national level and make this information available to the public.
- Monitor best management practices for effectiveness and analyze monitoring data for use in adaptive management frameworks.
- Design adaptive management approaches that

coordinate research, management, monitoring, and modeling efforts.

Citizens

Citizens and communities can influence forest and water management at the local, regional, or watershed level. Cumulative watershed effects, changes in land ownership and management, changing population and development patterns, and water supply concerns have spurred activity to protect watersheds and water quality from the "grass-root" community level. Watershed councils and other locally-led citizen groups should work within communities and with state and federal agencies to:

- Use councils and other citizen groups as vehicles to meet multiple goals of integrated watershed management at the community level.
- Participate in watershed councils and other citizen groups and help them grow in number and influence on watershed uses at the community level.

CONCLUDING COMMENTS

Much of the content of this paper has been extracted from a "Report in Brief" of the National Academies entitled "Hydrologic Effects of a Changing Forest Landscape," dated July 2008. The complete report on the study, also entitled "Hydrologic Effects of a Changing Forest Landscape," is available from the National Academies Press, Washington, DC. The committee preparing this report consisted of Paul K. Barten (Chair), University of Massachusetts; Julia A. Jones (Vice-Chair), Oregon State University; Gail L. Achterman, Oregon State University; Kenneth N. Brooks, University of Minnesota; Irena F. Creed, University of Western Ontario; Peter F. Ffolliott, University of Arizona; Anne Hairston-Strang, Maryland Department of Natural Resources; Michael C. Kavanaugh, Malcolm Pirnie, Inc.; Lee Macdonald, Colorado State University; Ronald C. Smith, Tuskegee University; Daniel B. Tinker, University of Wyoming; Suzanne B. Walker, Azimuth Forest Services; Beverley C. Wemple, University of Vermont; George H. Weyerhaeuser, Jr., Weyerhaeuser Company; and Lauren Alexander (Study Director)and Ellen de Guzman (Research Association), National Research Council.