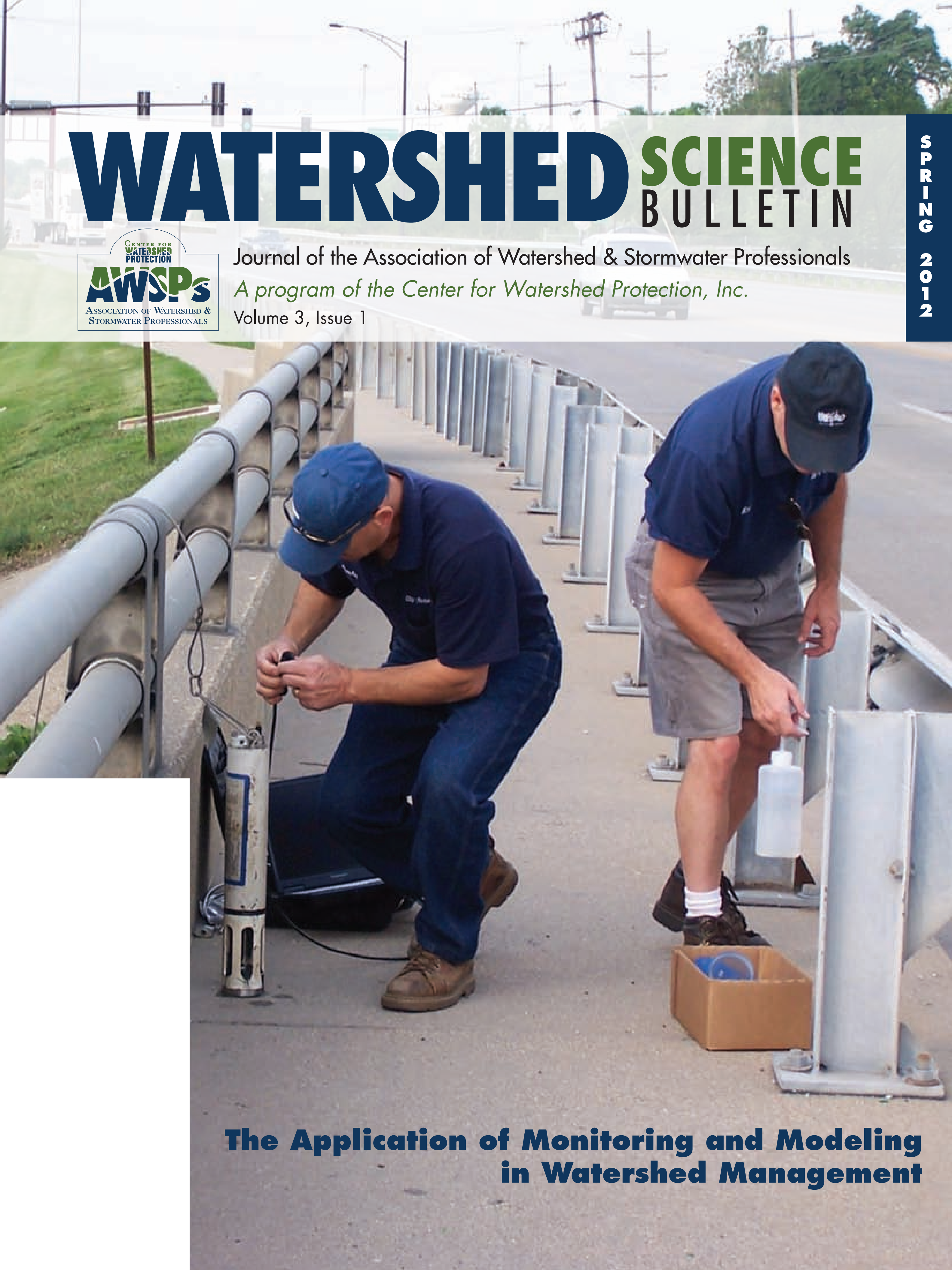

WATERSHED SCIENCE BULLETIN

Journal of the Association of Watershed & Stormwater Professionals
A program of the Center for Watershed Protection, Inc.
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The Application of Monitoring and Modeling in Watershed Management

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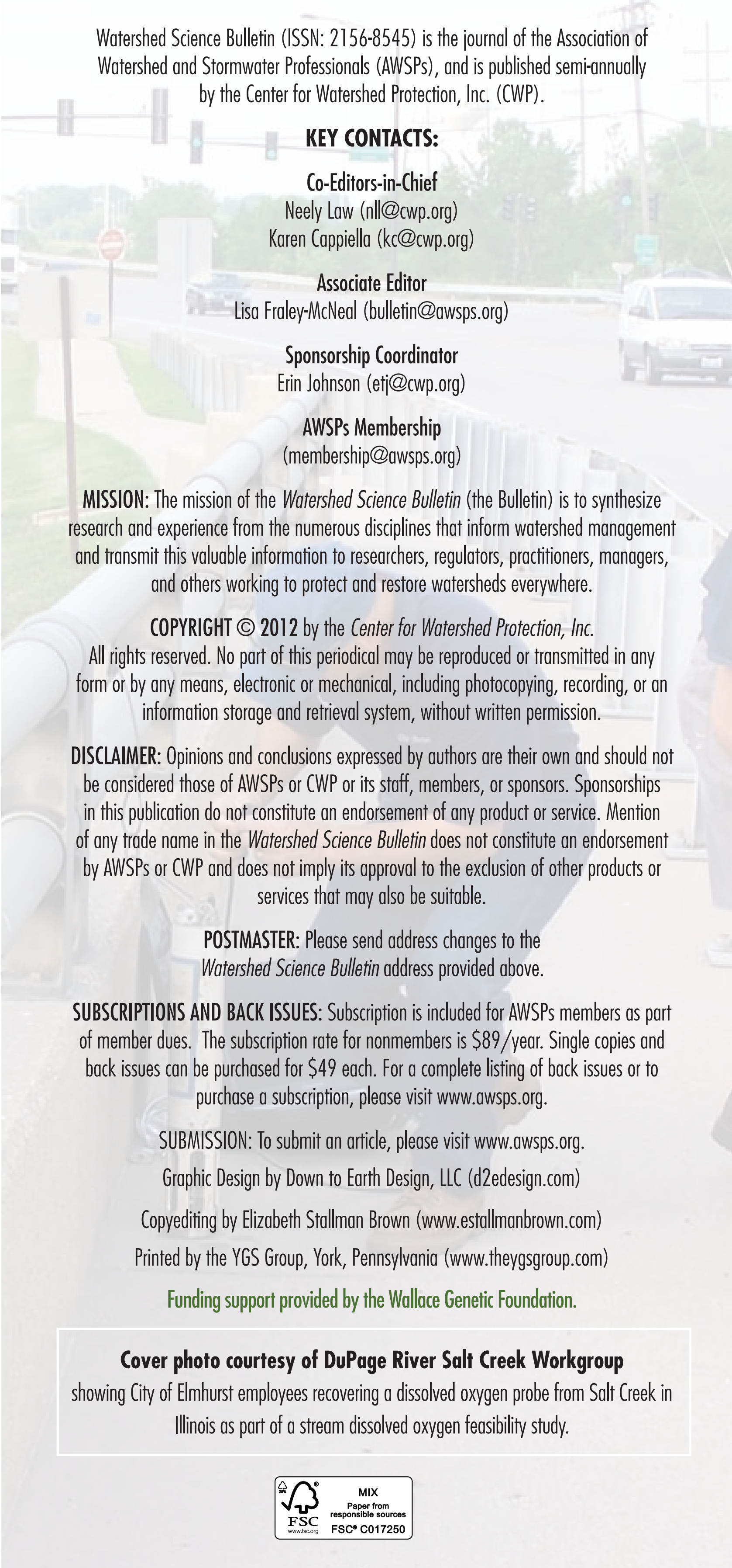

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Local Monitoring Data Used To Support Watershed-Based Hydrologic Modeling of Downscaled Climate Model Output

Maintaining a safe and abundant water supply is a primary concern of water system managers. The traditional approach for maintaining an adequate water supply has been to design the system based on the worst-case scenario from the area's recorded history. This approach has worked well in the modern era of development. However, given our current uncertainty about the effects of climate change and of the continued land use changes brought about by an ever-expanding population, it is not clear how much longer we can continue to rely on the historical hydrologic record to inform future water supply.

> *…it is not clear how much longer we can continue to rely on the historical record to inform future water supply.*

Researchers at Virginia Tech's Department of Civil and Environmental Engineering are studying the effects of climate and land use change on water resources within the Occoquan Reservoir watershed. The Occoquan watershed, which encompasses 1,500 km^2 in northern Virginia, lies in the Middle Potomac River basin (Figure 1).

The Occoquan Watershed Monitoring Laboratory (OWML) at Virginia Tech has been collecting data within the watershed for almost 40 years. This study used local weather station data from OWML and from the National Climatic Data Center to calibrate the hydrologic model and to downscale climate model output. The downscaling methodology employed in this study uses statistical relationships to incorporate the climate signal generated by global-scale climate models while maintaining the observed local-scale weather phenomena. Drawing from three downscaled climate model projections, we used an ensemble average output of modeled local streamflow for the past century (1901–2000) and this century (2001–2100) to make a comparative (historical to future) analysis of water supply impacts from both climate and land use change. The three climate models chosen to make up the ensemble were (1) the Parallel Climate Model (NCPCM), developed in the United States by the National Center for Atmospheric Research, the Department of Energy, the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric Administration; (2) the Model for Interdisciplinary Research on Climate (MIMR), developed in Japan by the Center for Climate System Research, University of Tokyo, the National Institute for Environmental Studies, and the Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology; and (3) the ECHAM5 climate model, developed in Germany by the Max Planck Institute for Meteorology. In this study area, the NCPCM showed the greatest increase in precipitation, the MIMR showed the greatest decrease in precipitation, and the ECHAM5 modeled streamflow with the closest agreement to streamflow in the observed years 1981–2000.

This study used land use data assembled by the OWML from the Northern Virginia Regional Commission (from the years 1977, 1979, 1984, 1989, 1995, 2000, and 2006). Land use patterns in the Occoquan watershed from 1977 through 2006 show a steady increase in urban area with equivalent decreases in agricultural and forested land. The western half of the watershed is less urbanized, with large areas of agricultural lands, and the eastern half is predominantly urbanized, with small areas of agricultural lands. This study assumes that the trend of increased suburban and urban development will continue during this century, forming the basis of future land use projections.

This study evaluated the effects of climate and land use change on local streamflow using the Hydrological

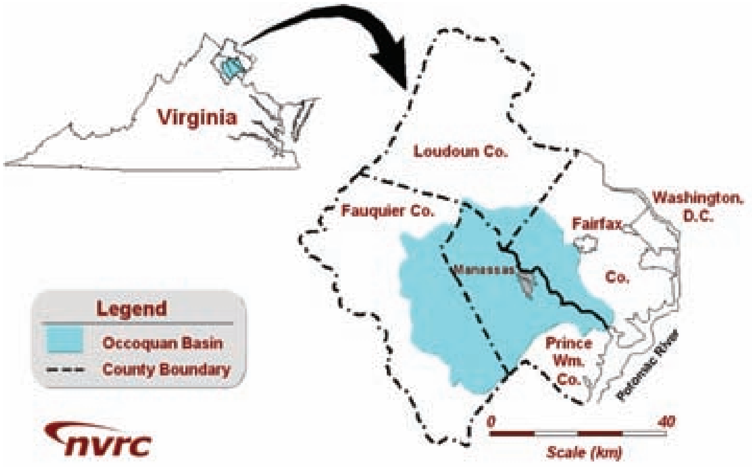


Figure 1. Location map of the Occoquan watershed. Source: Northern Virginia Regional Commission, "Occoquan," http://www.novaregion.org/index.aspx?NID=410 (used with permission).

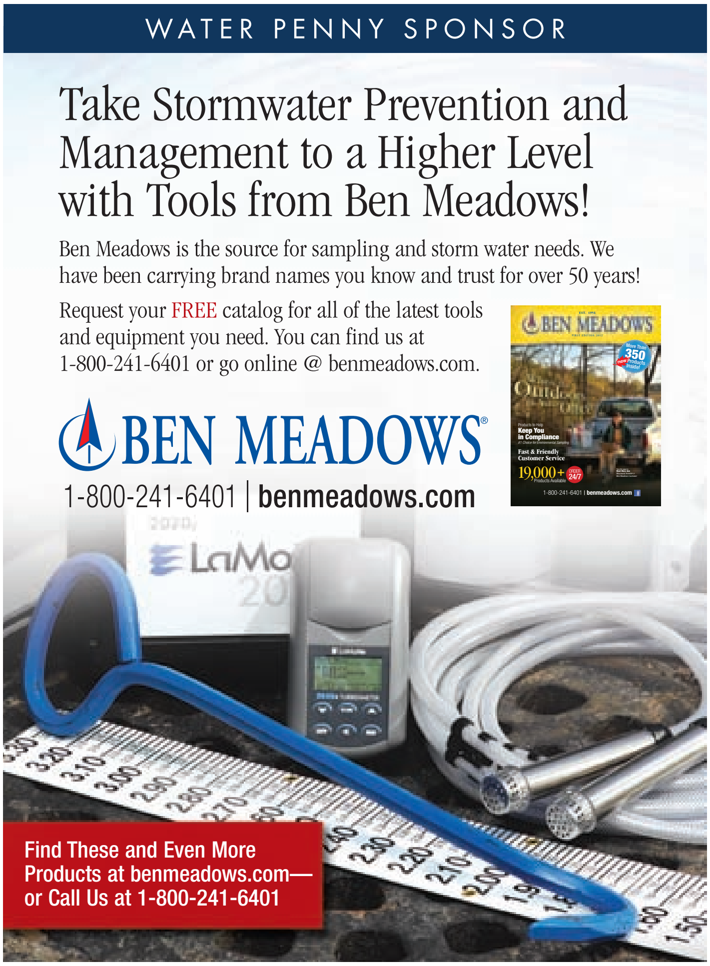
Simulation Program–FORTRAN (HSPF) watershed model. Researchers modeled three scenarios of future change to discern the effects of climate change (S1), land use/demand change (S2), and joint climate and land use/demand change (S3). We used these scenarios, along with multiple analysis metrics, to focus the assessment on low flows (drought conditions) within the watershed, which are of primary concern to water supply managers. In the initial results, the influence of reclaimed water return flows upstream of the Occoquan Reservoir on the drought sensitivity of the system stood out as an important variable to analyze. By modeling the system without accounting for expansion in the reclaimed water inflows, a clear picture of the growing reliance on this source became apparent within this century (2001–2100). This vignette is a summary of a more detailed analysis presented by Philip Maldonado (see List of Sources).

The ensemble analysis of three HSPF-modeled climate outputs, projected through the end of this century (2001–2100), produced the following outcomes:

- Scenario S1 (climate change alone) showed an increase in the winter and spring low flows through the end of this century. The summer and fall low flows decreased slightly compared to the historical ensemble model.
- Scenario S2 (land use/demand change alone) modeled the future hydrology based on the past century's climate (1901–2000) while using three projections of future land use, to the years 2040, 2070, and 2100. Each of the three future models showed increases in low flows for all seasons compared to both Scenario S1 and the historical ensemble model.
- Scenario S3 (joint climate and land use effects) modeled the future hydrology based on the downscaled projection of future climate (2001–2100) along with the three projections of future land use. As in Scenario S2, each of the three future models showed increases in low flows compared to Scenario S1 and the historical ensemble model. However, when compared to Scenario S2, the winter and spring low flows showed a larger increase, whereas the low-flow statistics for summer and fall showed a slight decrease.

To assess the importance of the reclaimed water supply stream, we repeated Scenarios S2 and S3 without accounting for expansion in reclaimed water return flows. The analysis employed a metric that incorporated the storage response curves used by operators to manage the reservoir. The response curves indicated a failure of the reservoir given a repeat of the drought of record, as influenced by climate change, and given the land use/demand projections for the latter part of this century (land use/demand years 2070 and 2100).

This study reinforces the established scientific contention that anthropogenic climate and land use change are likely to affect the timing and magnitude of runoff, changing the behavior of reservoirs managed for water supply. These changes are dampened by the expansion of reclaimed water inflows in the Occoquan watershed. The total volume of water increased for all scenarios, but when analyzed on a seasonal basis, the majority of increases occurred in the winter and spring, whereas the summer and fall showed little to no increase. With reclaimed water expansion, these increases maintained a supply sufficient to meet expanding demands; but without reclaimed expansion, demands outpaced supplies in the latter part of this century (land use/demand years 2070 and 2100). The increases in the Scenario S2 model projections beyond those of Scenario S1 show that increases in runoff due to increased



imperviousness (land use change) are large relative to those due to climate change when modeled through the end of this century. Based on this study, increased flows and drought resistance appear very likely to occur in the Occoquan Reservoir system.

Because of the uncertainty in these models and the statistical methods used, one should interpret these results only as an indication of the sensitivity of the current system to predicted future climate, not as a prediction of the specific effects of climate change. Regardless, place-specific studies such as this one are crucial for future water supply plans as our climate and landscape continue to evolve. As this study shows, the current management practices of the Occoquan watershed are well-positioned to absorb the impact from both climate and land use change. This type of study is possible only through a reliable and well-maintained watershed monitoring system, which forms the basis of a well-developed management plan. Such studies are useful tools through which planners and managers can gain insight into unforeseen impacts from future development and quantify system vulnerabilities to previously unassessed risks.

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