

Volume Preface

A watershed depicts a geographic boundary where the precipitation falling within the bounded land area flows to streams, rivers, and lakes or seeps into the subsurface water system situated within the watershed. Thus, in a watershed, a strong dynamic interaction exists between land and natural water systems, which can significantly impact water availability and water quality for various human uses and ecosystem health. Water resource managers and researchers have deployed the watershed concept in water assessment studies since the 1960s. However, recent advances in geospatial analysis, satellite imagery, electronics, computer software, and wireless and Internet technologies have facilitated a revolutionary change from limited (spatially and temporally) manual and discrete methods of assessment to real-time and broad-spatial-coverage-capable methods of assessment. Research and development in these new technologies provide tremendous and exciting opportunities for watershed assessment, sustainable management of land and water resources, and ecosystem preservation around the world.

This volume presents a discussion of concepts, methods, and case studies of innovative and evolving technologies in the arena of watershed assessment. Themes discussed in this volume include (1) development and applications of geospatial, satellite imagery, and remote sensing technologies for land monitoring, (2) development and applications of satellite imagery for monitoring inland water quality, (3) development and applications of water sensor technologies for real-time monitoring of water quantity and water quality, and (4) advances in biological monitoring and microbial source tracking (MST) technologies.

This volume contains ten chapters. The chapter “Land Use/Land Cover Monitoring and Geospatial Technologies: An Overview” discusses remote sensing, its technological evolution, and remote sensing applications in land use and land cover mapping and monitoring. The chapter “Using Remote Sensing to Map and Monitor Water Resources in Arid and Semiarid Regions” provides an overview of satellite and airborne remote sensing technologies and applications to management of water resources and drought monitoring in arid and semiarid regions. The chapter “Imaging Spectrometry of Inland Water Quality in Italy Using MIVIS: An Overview”

presents examples of applications of using Multispectral Infrared and Visible Imaging Spectrometer (MIVIS) imagery for monitoring inland water quality parameters and detecting submerged vegetation, cyanobacteria blooms, and floating materials of terrestrial origin (e.g., oil). The chapter “Using Remote Sensing to Assess the Impact of Human Activities on Water Quality: Case Study of Lake Taihu, China” demonstrates the potential of remote sensing for detecting harmful algal blooms and using the technology for integrated assessment of watershed dynamics. The chapter “Remote Sensing for Regional Lake Water Quality Assessment: Capabilities and Limitations of Current and Upcoming Satellite Systems” discusses satellite imagery advances and limitations for regional scale measurements of lake water characteristics.

The chapter “Interactive Geospatial Analysis Tool for Estimating Watershed-Scale Consumptive Use: Potomac River Basin Case Study,” presents a basin-wide analysis and mapping tool that incorporates water use data from multiple political jurisdictions and estimates consumptive water use for effective management of water resources. The chapter “Advances in Water Sensor Technologies and Real-Time Water Monitoring” is an overview of state-of-the-art technologies in water sensor technologies for water quantity and water quality measurements, data collection, and transport platforms. The chapter “Instrumenting Caves to Collect Hydrologic and Geochemical Data: Case Study from James Cave, Virginia” presents information about the instrumentation, data collection, processing, and management and makes recommendations for hydrologic and geochemical monitoring of cave systems in karst environments. The chapter “Principles for the Development of Contemporary Bioassessment Indices for Freshwater Ecosystems” discusses bioassessment, the use of ecological assemblages, primarily fish, macroinvertebrates, and algae, as indicators of anthropogenic impairment in aquatic systems, and focuses on analytical approaches for improving the effectiveness of bioassessment indices for detecting anthropogenic impairment in freshwater ecosystems. The chapter “Microbial Source Tracking—Advances in Research and a Guide to Application” discusses the main drivers of MST and the evolving MST research development and technology and presents a guideline for decision-making on where, when, and how to deploy MST.

In “Land Use/Land Cover Monitoring and Geospatial Technologies: An Overview,” Parece and Campbell state that the availability of multispectral satellite data beginning in 1972 has significantly advanced the ability of researchers to systematically monitor and evaluate land use/land cover changes and their impacts on water quality and quantity. In that context, practitioners have developed classification schemes specifically tailored for use with remotely sensed imagery and for systematic assessment of land use change. Land observation technologies in the twenty-first century include the use of lasers for 3D analyses and unmanned aerial systems. Such technologies have enabled land use assessment to contribute not only to its original focus in urban and regional planning but to a broad range of environmental and social issues.

In “Using Remote Sensing to Map and Monitor Water Resources in Arid and Semiarid Regions,” Klemas and Pieterse state that in arid environments, the exploration and monitoring of water resources is a prerequisite for water

accessibility and rational use and management. Authors argue that conventional land-based techniques must be complemented by using satellite and airborne remote sensors. Authors describe using various technology applications: multispectral and radar sensors for mapping surface water systems, microwave radiometers for sensing soil moisture in the unsaturated zone, multispectral cameras for mapping freshwater wetlands, thermal infrared radiometers for detecting freshwater springs, and satellite remote sensors and satellite gravitational surveys with ancillary data analysis to infer groundwater behavior from surface expressions and to estimate groundwater aquifer storage.

In "Imaging Spectrometry of Inland Water Quality in Italy Using MIVIS: An Overview," Giardino, Bresciani, Matta, and Brando state that airborne imaging spectrometry is a powerful tool to investigate key biophysical parameters in inland waters. Authors present examples of applications using airborne MIVIS imagery of Italian inland waters acquired at a spatial resolution varying from 3 to 5 m. Examples include the retrieval of water quality parameters (i.e., chlorophyll-*a*, suspended particulate matter, and colored dissolved organic matter), the detection and monitoring of submerged vegetation, the observation of cyanobacteria bloom in productive lakes, and the signal reflected by floating materials of terrestrial origin (i.e., pollens and oil).

In "Using Remote Sensing to Assess the Impact of Human Activities on Water Quality: Case Study of Lake Taihu, China," Villa, Duan, and Loisel state that the capacity of remote sensing to deliver spatial and temporal information about fundamental environmental dynamics makes it an ideal tool for performing an integrated assessment of water quality stressors and the causes of water quality deterioration at watershed scale. Authors focus on harmful algal blooms in Lake Taihu, as a case study. The temporal and spatial variabilities of the conditions in Lake Taihu and its watershed were derived from satellite data to produce a monthly time series of algal bloom coverage, aquatic vegetation extent, and land cover. Environmental features related to nutrient loading, climate conditions, and agricultural practices were also used to analyze the driving forces of algal blooms.

In "Remote Sensing for Regional Lake Water Quality Assessment: Capabilities and Limitations of Current and Upcoming Satellite Systems," Olmanson, Brezonik, and Bauer state that remote, satellite-based, sensing is a cost-effective way to gather information needed for regional water quality assessments in lake-rich areas. For example, in the Midwest United States, historic and recent Landsat water clarity assessments have been conducted on >20,000 lakes to investigate spatial and temporal patterns and explore factors that affect lake water quality. Advances over the past decade have enabled the use of satellite imagery for regional scale measurement of lake characteristics, such as clarity and chlorophyll. The spatial characteristics of Landsat imagery allow for the assessment of all lakes greater than ~4 ha, but the broad nature and placement of its spectral bands have assessments limited largely to water clarity. Improvements of the recently launched Landsat-8 and the upcoming ESA Sentinel-2 and Sentinel-3 satellites will expand capabilities further and enable assessment of other optically related water quality characteristics, such as colored dissolved organic matter and mineral-suspended solids.

In “Interactive Geospatial Analysis Tool for Estimating Watershed-Scale Consumptive Use: Potomac River Basin Case Study,” Ducnuigeen, Ahmed, Bencala, Moltz, Nagel, and Schultz state that temporal and spatial watershed-scale information is needed on both the total amount of water withdrawal and the portion of withdrawn water which is not returned to the source for effective water resource management decisions. Authors present a case study of consumptive water use model developed for the Potomac River Basin in the United States. The model and associated tools consist of a basin-wide analysis and mapping tool that incorporates monthly water use data from multiple political jurisdictions, estimates consumptive water use, displays raw and summary information in an interactive geospatial format, and shares information with stakeholders via an interactive web-based mapping tool.

In “Advances in Water Sensor Technologies and Real-Time Water Monitoring,” Younos and Heyer state that traditional discrete water quantity measurements and water quality sampling do not provide sufficient data to capture temporal and spatial changes that occur during episodic events. In recent decades, significant advances in water-monitoring technologies have occurred; sensors, remote monitoring, and data-transfer technologies allow real-time and continuous water monitoring and can capture temporal changes and provide broader spatial coverage of water quantity and quality in a watershed. Authors present and discuss various types of sensors for water quantity and water quality measurements, examples of commercially available water quantity and water quality monitoring devices, data collection and transport platforms, and data management and quality assurance/quality control for water monitoring. Authors conclude that water sensor technologies and associated computer hardware/software and telemetry technologies are evolving fields of research and technology development and discuss some of the limitations of existing technologies.

In “Instrumenting Caves to Collect Hydrologic and Geochemical Data: Case Study from James Cave, Virginia,” Schreiber, Schwartz, Orndorff, Doctor, Eagle, and Gerst state that karst aquifers are productive groundwater systems, supplying approximately 25 % of the world’s drinking water. Sustainable use of this critical water supply requires information about rates of recharge and quality in karst aquifers. Caves are an important feature in karst environments. Authors provide detailed information about the instrumentation, data processing, and data management and show examples of collected hydrologic and geochemical datasets for an instrumented cave study site in Virginia, United States. The cave has been instrumented for continuous measurement of the temperature and rate of precipitation; water temperature, specific conductance, and rate of epikarst dripwater; temperature of the cave air; and temperature, conductivity, and discharge of the cave stream. The chapter provides recommendations on instrumentation and methods of measurement for cave water.

In “Principles for the Development of Contemporary Bioassessment Indices for Freshwater Ecosystems,” Garey and Smock define “bioassessment” as the use of biota to assess the nature and magnitude of anthropogenic impacts to natural water systems. Authors particularly focus on an important and specific type of

bioassessment: the use of ecological assemblages, primarily fish, macroinvertebrates, and algae, as indicators of anthropogenic impairment in aquatic systems. Authors provide an introduction to the process of developing assemblage-level indices that provide quantitative estimates of the ecological integrity of freshwater ecosystems and discuss recent developments that have improved the effectiveness of bioassessment strategies. Authors conclude that developments, such as advanced predictive modeling techniques, coupled with emerging technologies and the development of large-scale bioassessment programs will continue to improve our understanding of how aquatic assemblages are affected by anthropogenic impairment.

In “Microbial Source Tracking—Advances in Research and a Guide to Application,” Badgley and Hagedorn state that MST is a still-new and developing discipline that allows users to discriminate among the many potential sources of fecal pollution in environmental waters. Authors further explain that the main area of research in MST focuses on the identification of source-specific genetic markers that can be used to detect contributions from different hosts such as humans, livestock, and wildlife. Authors discuss the main drivers of MST and how these have shaped the development of past and present methodological approaches, plus current research initiatives such as community analysis that could usher in yet another new and improved methodological basis for the entire field of MST. Finally, a tiered system is presented as a recommended means to navigate the multiple options for MST analyses that will assist the reader in how best to use MST within the context of more traditional approaches. This chapter can serve as a guide for decision-making on where, when, and how to deploy MST.

Chapters presented in this volume primarily focus on advanced methods of land and water monitoring in aquatic ecosystems. Except for limited application in “Interactive Geospatial Analysis Tool for Estimating Watershed-Scale Consumptive Use: Potomac River Basin Case Study,” this volume does not include watershed models, another avenue of important research relevant to watershed assessment and management. However, spatial and temporal land- and water-monitoring technologies and analysis discussed in this volume will significantly contribute to developing improved watershed models, model verification, and applications.

We hope this volume serves as a textbook and reference material for graduate students and researchers involved in watershed science and environmental studies. Equally, we hope this volume serves as a valuable guide to experts in governmental agencies who are concerned with water availability and water quality issues and engineers and other professionals involved with the design of land- and water-monitoring systems.

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