Challenges and Opportunities in Integrated Water Resources Management

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Integrated Management of Water Resources in India: A Computational Approach

Optimizing for Sustainability and Planning

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Foreword

Water security is a critical challenge facing India, a nation with a vast and diverse population. Traditional siloed approaches to water management are no longer sufficient. This book, *Integrated Management of Water Resources in India: A Computational Approach*, offers a compelling and timely solution. By advocating for a computational approach to *Integrated Water Resources Management (IWRM)*, the authors break new ground. Leveraging the power of computational tools, they propose a comprehensive framework that considers the complex interplay between water quantity, quality, and the social and ecological systems it sustains.

This book is not merely a theoretical exploration. It presents a practical roadmap for implementing IWRM across India's diverse landscapes. The emphasis on stakeholder engagement ensures that the solutions developed are not only technically sound, but also meet the needs of the communities most impacted by water scarcity. *Integrated Management of Water Resources in India: A Computational Approach* is a valuable resource for water resource managers, policymakers, researchers, and anyone with a stake in India's water future. By embracing a holistic and data-driven approach, this book offers a path toward a more sustainable and equitable future for all. I congratulate the editors *Akhilesh Kumar Yadav, Kanchan Yadav, and Vijay P. Singh* for bringing out this thought-provoking work. I am sure this book will be useful to graduate students, faculty, and policymakers on environmental impact and public health.

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Preface

The motivation of this volume, entitled *Integrated Management of Water Resources in India: A Computational Approach*, is mainly to present techniques to protect water resources in India. Water is the lifeblood of our nation, sustaining not only our ecosystems, but also our very existence. However, India faces a growing challenge in managing its water resources. With a vast and diverse population, coupled with the effects of climate change, ensuring water security for present and future generations requires a holistic approach. This book, *Integrated Management of Water Resources in India: A Computational Approach*, proposes a paradigm shift in how we address this critical issue. It advocates for a framework that integrates various aspects of water management, moving beyond traditional siloed approaches. This framework takes advantage of the power of computational tools to analyze complex data, model water systems, and optimize decision making. This book is an important contribution for water professionals, policymakers, researchers, and students. It presents a comprehensive overview of the challenges and opportunities in Indian water management. By exploring the potential of computational approaches, the book equips readers with the knowledge and tools needed to develop and implement integrated water resource management strategies. Throughout the book, we emphasize the importance of stakeholder engagement. Sustainable water management requires the active participation of communities, government agencies, and private entities. By fostering collaboration and utilizing the power of computational tools, we can move toward a future where water resources are managed effectively and equitably for the benefit of all.

This book presents an overview of water resources in India. The book content has been categorized into four parts. Part I gives an overview of water resources fundamental and assessment with five chapters. Part II, consisting of eleven chapters, deals with water quality assessment, monitoring, and management, while Part III consists of six chapters under the title water resources management strategies and technologies; Part IV is devoted to the advanced optimization, and efficiency in water management of six chapters.

First, we thank the Almighty for His blessings throughout this project achievement, which envisioned us successfully exploring this challenging research domain with a technique perspective. We are also sincerely thankful to Springer Nature for allowing us to publish this monogram on a contemporary research domain of modeling and simulations.

Special thanks to all who contributed to making this volume a source of knowledge and reporting the latest findings in their areas. Against the title of the proposed chapter, the total number of abstracts received was 63, of which 48 were selected for a full chapter contribution. In this book, the project accommodated only **28** chapters according to the scope of the book, which were of better quality. The authors put a lot of effort during all phases of book production, starting from writing, revising based on the comments and Springer evaluation reports, and finally checking the proofs of the chapters. The project follows a review process in which the identities of the authors and reviewers are not disclosed to avoid bias decisions. We also thank and acknowledge the Springer Nature publication team for their quick responses and for providing a proper guideline on time. Finally, we acknowledge *Jaydeep Kumar (BCAS, New Delhi, India)* and *Advocate Dinesh Chandra Gupta (High Court, Allahabad, India)* for their continuous help and support during the execution of the project.

The editors would be happy to receive any comments to further improve future editions. Comments, feedback, and suggestions for further improvement or proposals for the new chapters for next editions are welcome and should be sent directly to the volume editors.

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Lucknow, India — Kanchan Yadav, Ph.D.
College Station, USA — Vijay P. Singh, Ph.D., D.Sc.

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About the Editors

Akhilesh Kumar Yadav Ph.D., MIE, earned a Bachelor of Technology (B.Tech.) in Electronics and Communication Engineering from Chaudhary Charan Singh University in Meerut, India. He then obtained a Master of Technology (M.Tech.) in Environmental Engineering from Madan Mohan Malaviya Engineering College in Gorakhpur, India (affiliated with Dr. A. P. J. Abdul Kalam Technical University, Lucknow). His doctoral degree, with a research focus on air pollution, was awarded by the Indian Institute of Technology (BHU), Varanasi, India.

Dr. Yadav has served at various institutions, including the Indian Institute of Technology (Banaras Hindu University), Varanasi, India; the Indian Institute of Technology Bombay, Mumbai, India; the Bhabha Atomic Research Centre in Mumbai, India (as a research collaborator); and Chaoyang University of Technology in Taichung, Taiwan. He has authored/co-authored several research and review articles, book chapters, and edited/authored books and holds a patent.

Dr. Yadav received the Young Engineer Award from the Institution of Engineers (India) and the Young Scientist Award from VDGOOD Technology Factory, Kolkata. His research interests include air, water, and soil pollution; climate change; vulnerability; human health risk assessments; and GIS applications in environmental pollution and management. He is an active member of several reputed international professional bodies, including the IEI (Kolkata), ECI (New Delhi), AEACI (Mumbai), MSI (New Delhi), and IASTA (Mumbai).

Kanchan Yadav Ph.D., possesses expertise in research writing, data analysis, study design, and methodology. She currently holds the position of the program coordinator at Progressive Foundation, where she is responsible for overseeing and executing programs in the fields of Public Health and Education. Prior to this, she served as a research associate specializing in the utilization of microwave technology for the management of hospital waste and the purification of water while retaining precious minerals. Furthermore, she has served as the research director for a project in collaboration with the Government of India, focusing on the adherence of tuberculosis medications. She has authored numerous research pieces that have been published in peer-reviewed journals and international conference proceedings.

Vijay P. Singh Ph.D., D.Sc., D.Eng. (Hon.), Ph.D. (Hon.), P.E., P.H., Hon.D.WRE, Dist.M. ASCE, Dist.Hon. M. IWRA, Dist.F. AGGS, Hon. Member AWRA, NAE, holds Caroline and William N. Lehrer distinguished chair in Water Engineering and is the distinguished professor and the regents professor, Department of Biological and Agricultural Engineering and Zachry Department of Civil and Environmental Engineering at Texas A&M University, USA. He has been recognized for four decades of leadership in research, teaching, and service to the hydrologic and water resources engineering profession. His contribution to the state of the art has been significant in many different specialty areas, including hydrologic science and engineering, hydraulic engineering, water resources engineering, environmental engineering, irrigation science, soil and water conservation engineering, entropy-based modeling, copula-based modeling, and mathematical modeling. His extensive publications in these areas include 32 textbooks, 1425 refereed journal articles, 115 book chapters, 330 conference proceedings papers, and 72 technical reports.

For his seminal contributions, he has been honored with more than 105 national/international awards from professional organizations. As a sample, he is a recipient of the Arid Land Hydraulic Engineering Award, Ven Te Chow Award, Torrens Award, Norma Medal, Lifetime Achievement Award, and OPAL Award, all given by ASCE. He was awarded the Ray K. Linsley Award for outstanding contributions to surface water hydrology and the Founders Award of AIH. He has been awarded three honorary doctorates. He is a fellow of ASCE, AWRA, IE, ISAE, IWRS, IASWC, and IAH; and a member of AGU, IAHR, IAHS, and WASER. He is a member/fellow of 12 engineering/science academies. He is licensed as the professional engineer (PE), the professional hydrologist (PH), and the honorary diplomate, AAWRE.

Part III
Water Resources Management Strategies and Technologies

Chapter 19
Challenges and Opportunities in Integrated Water Resources Management

Krishna Neeti, Reena Singh, Shaz Ahmad, Sakshi, and Abhishek Kumar

Abstract Integrated Water Resources Management (IWRM) is a process that harmonizes the utilization of water, land, and associated resources to enhance economic and social well-being while ensuring ecosystem sustainability. It is crucial to global water resource development and addressing conflicting demands. This chapter analyzes urban challenges, such as water, wastewater, solid waste, and climate change, and assesses the gaps in achieving the SDGs, especially SDG 6 (clean water and sanitation) and SDG 11 (sustainable cities and communities). It provides solution pathways for IWRM, which have many benefits, such as coordinated resource development, environmental protection, economic growth, sustainable agriculture, democratic governance, and human health. It also faces challenges, such as water shortages, quality deterioration, and flood impacts, which are worsened by climate variability and change, urbanization, and consumption and production patterns. It proposes to improve IWRM planning by aligning it with local to national priorities and employing a learning-by-doing approach to innovate and adjust water resources management strategies, tools, and technologies.

Keywords Integrated water resource management · Sustainable development goals · Urban challenges · Water governance · Climate change adaptation

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19.1 Introduction

Water is vital for life, health, food, energy, environment, and development. Water resources face challenges such as demand, pollution, scarcity, variability, and conflicts. These are exacerbated by climate change, population growth, urbanization, and socioeconomic inequalities (Yadav et al. 2014; Kumar et al. 2024). We need a holistic approach and IWRM to address these challenges. It should consider the multiple dimensions and interdependencies of water and balance the diverse needs and interests of different stakeholders (Hameed et al. 2019; Brennan et al. 2021).

IWRM is a strategy that coordinates the planning and use of water, land, and associated resources. It aims to equitably optimize economic and social well-being while safeguarding the sustainability of vital ecosystems. IWRM is grounded in three principles: (1) water is a finite and vulnerable resource that requires integrated management; (2) water management should be participatory and sensitive to gender issues; and (3) water management should be informed by robust knowledge and information. IWRM also comprises three components: (1) a supportive framework of policies, laws, and institutions; (2) the institutional roles of various actors and organizations; and (3) management tools and techniques (Arfan et al. 2020; Kulwant et al. 2024).

Water governance involves the decision making and execution of plans concerning water resources and services. It influences the accessibility, utilization, and administration of water. It is a fundamental aspect of IWRM, determining the allocation, timing and methods of water distribution, as well as the rights and advantages associated with water and its services (Meran et al. 2021). It also influences the effectiveness, efficiency, equity, accountability, and transparency of water management. Improving water governance is a key challenge and opportunity to achieve IWRM.

The Sustainable Development Goals (SDG) are a set of 17 global objectives and 169 targets designed to eradicate poverty, protect the environment, and promote peace and prosperity by 2030 (Halkos and Gkampoura 2021). They are relevant for IWRM, as they recognize the interlinkages and synergies among water, food, energy, health, the environment, and development. SDG 6 and SDG 11 are related to the challenges and opportunities of IWRM in urban settings. Achieving these goals requires implementing IWRM at different scales and sectors, and addressing the trade-offs and cobenefits among water-related objectives and targets. IWRM practices and initiatives are found at various levels and sectors. However, more assessments, solutions, and innovations are needed for IWRM and its links and contributions to the SDGs. They should address the complex and dynamic challenges of water resource management and enhance the resilience and sustainability of water systems (Nagata et al. 2022).

This chapter provides an overview of IWRM and water governance and their linkages with the SDGs, especially SDG 6 and SDG 11. It presents examples and case studies of IWRM implementation in different regions and countries. Explore IWRM and its intersection with the SDGs and the opportunities, challenges, and solutions in water resource management. It prepares the reader for understanding the complex dynamics of sustainable water and urban development.

19.2 IWRM: An Overview

IWRM is a process that emerged in the late twentieth century to address the challenges and complexities of water resource development and management (Arfan et al. 2020). It was introduced by the Dublin Conference in 1992 and endorsed by the Rio and Johannesburg Conferences in 1992 and 2002, respectively (Meran et al. 2021). IWRM is a way to manage water, land, and related resources together to help everyone in a community, without hurting the environment. It is based on the idea that water is really important and that we have to use it carefully because it is limited. It considers the interdependencies and trade-offs between different sectors, stakeholders, and environmental objectives. IWRM integrates the technical, social, economic, and environmental aspects of water issues to achieve efficient, equitable, and sustainable development and management.

19.2.1 The IWRM Paradigm and Its Evolution

The IWRM paradigm emerged in the 1970s to address the interconnected issues of water quantity, quality, and allocation. In the 1980s and 1990s, it gained prominence due to the global water crisis and the environmental and social repercussions of water projects (Godinez-Madrigal et al. 2019; Arfan et al. 2020). The IWRM paradigm was shaped by environmental movements, human rights and gender perspectives, and international conferences and declarations, such as the Dublin Principles and the Rio Declaration. They highlighted the need for a holistic, participatory and sustainable water management approach. The IWRM paradigm was supported and promoted by the international community and various organizations in the 2000s as a key means to achieve the Millennium Development Goals and the World Water Vision (Godinez-Madrigal et al. 2019). The IWRM paradigm has also integrated novel dimensions and challenges, including adaptation to climate change, the water-food-energy nexus, and transboundary water cooperation. The IWRM paradigm is comprehensive, flexible, and reflects widely accepted principles and values. It can provide multiple benefits and solutions to water problems. However, it is ambiguous, complex and lacks clear definition, operationalization, implementation, and evaluation. It also faces practical and institutional barriers and requires balancing interests, values, and conflicts.

19.2.2 A General Framework of IWRM and Its Components

IWRM is a way to achieve sustainable development and management of water resources, endorsed by various international organizations, such as the GWP, the UN and the WWC (Challies and Newig 2022). Figure 19.1 shows the general framework of IWRM, comprising three interrelated components: the Enabling Environment, the Institutional Framework, and the Management Instruments.

i. Enabling environment: This component provides the foundation and direction for water management. It includes policies, laws, and plans at different levels (Jiménez et al. 2019).
ii. Institutional framework: This component defines the organizations and arrangements for water management and service delivery. It includes roles and responsibilities, water rights and permits, and coordination and collaboration among stakeholders. It also includes capacity-building and training (Van Hofwegen and Jaspers 2020).
iii. Management instruments: This component employs various tools and methods to assess and monitor water resources, allocate and distribute water, regulate water use, and resolve conflicts and disputes. It includes data and information systems, water resource assessment and accounting, water demand management,

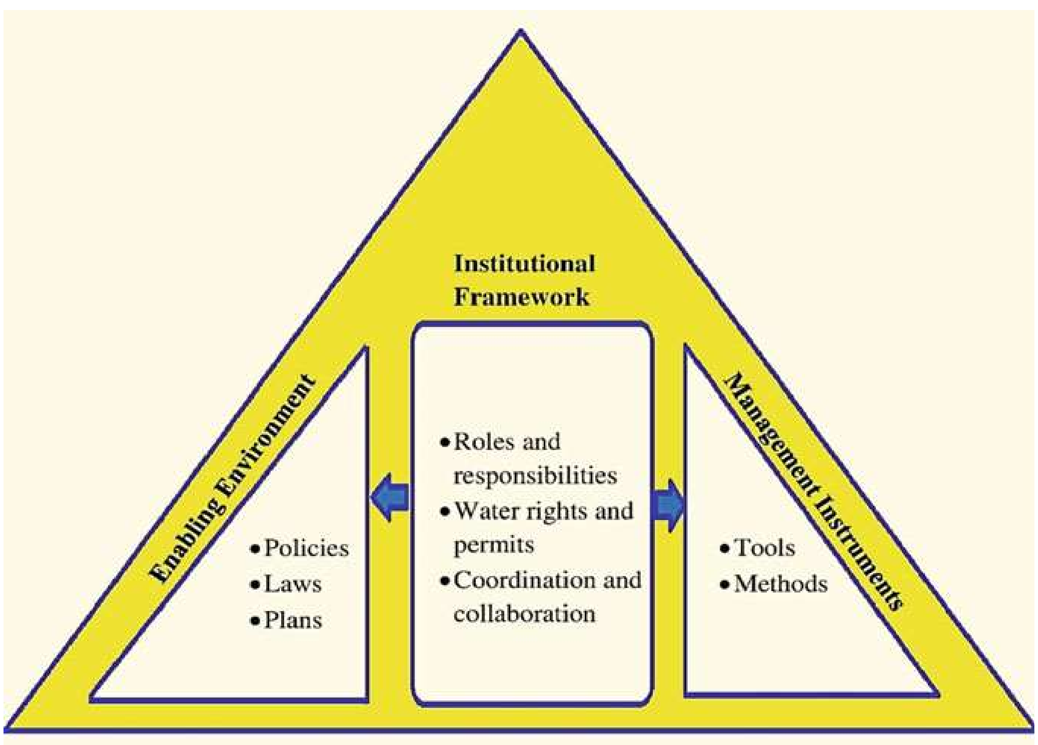

Fig. 19.1 Framework of IWRM and its components

water quality management, water pricing, cost recovery, and conflict resolution mechanisms (Dirwai et al. 2021).

The components of IWRM interact and complement each other and can be applied at different scales and sectors, depending on the context and needs (Badham et al. 2019). The enabling environment gives vision and guidance, the institutional framework implements and enforces policies and laws, the management instruments optimize the use and protection of water resources, and the financing ensures the availability and sustainability of funds. IWRM principles can be effectively implemented on different scales, including local, national, regional, and global levels. These principles span a wide range of water-related domains, encompassing agriculture, industry, energy, health, and environmental contexts.

19.2.3 Approaches and Methods for IWRM Implementation

Various approaches and methods can implement IWRM in different contexts and scales. Some of the main ones are the following:

(a) River basin management: This approach manages water resources within a natural hydrological unit, the river basin. Integrates quantity and quality, surface and groundwater, and upstream and downstream uses and impacts. It can facilitate transboundary cooperation (van den Brandeler et al. 2019).
(b) Adaptive management: This method monitors and evaluates water resource management actions and outcomes, and adjusts plans and strategies based on feedback and learning. It recognizes the uncertainty and complexity of water resources systems and the need to cope with change and challenge. It can improve resilience, flexibility, innovation, and learning (Karthe et al. 2021).
(c) Ecosystem approach: This approach considers the water resource system as part of a larger ecosystem, including the biotic and abiotic components and their interactions. It aims to maintain or restore the structure and function, and the provision of ecosystem services. It can promote conservation and restoration of natural capital and restoration, and environmental and social values (Hülsmann et al. 2019).
(d) Stakeholder participation: This method involves stakeholders in the water resource management process, from planning and decision-making to implementation and evaluation. Stakeholders are individuals or groups that have a stake in the water resource system. Participation can improve legitimacy, transparency, accountability, and ownership and foster social learning and conflict resolution (Sigalla et al. 2021).
(e) Water accounting and auditing: This method measures and reports the status and performance, using physical and monetary indicators. It can provide information on water availability, use, allocation, and productivity, and the costs and benefits of water management interventions. It can support evidence-based planning and

management and efficiency, effectiveness, and equity evaluation (Delavar et al. 2020).

These approaches and methods have advantages and disadvantages and depend on various criteria and conditions, such as the context, data, capacity, and objectives of water resource management.

19.2.4 Application of the Components of IWRM at Different Scales and Sectors

19.2.4.1 IWRM on Different Scale

IWRM can be applied at different scales, such as local, national, regional, and global, with different challenges and opportunities for water management.

(a) Local scale: IWRM can empower communities, protect ecosystems, and improve water efficiency and security. This can be done through integrated urban water management. These involve participation, planning, implementation, and monitoring of water activities and integration of water supply, wastewater, stormwater, and reuse. Challenges include lack of capacity and resources, conflicts among water users and stakeholders, and inadequate institutions and laws (Cacal and Taboada 2022).

(b) National scale: IWRM can provide data, framework, regulation, and pollution control for water resources. This can be done through the evaluation of water resources, the national the policy and strategy, water allocation and licensing, and water quality. These involve the evaluation, allocation, regulation and protection of water resources among different sectors and users, including surface, ground, and rainwater. The challenges include political instability and corruption, weak governance and enforcement, and divergent interests and priorities between sectors and regions (Cacal and Taboada 2022).

(c) Regional scale: IWRM can promote cooperation, harmonization, coordination, and integration of water resources within a basin. This can be done through transboundary water cooperation, regional water agreements and institutions, and basin-wide planning and management. These involve the negotiation, establishment, and implementation of water sharing agreements and joint institutions for water management between different countries and users within a region or river basin. Challenges include cultural, social, economic, political, legal, and environmental barriers to cooperation, power imbalances between countries or actors in a basin, and uncertainty due to impacts of climate change (Cacal and Taboada 2022).

(d) Global scale: IWRM can recognize and protect the global water commons, promote collaboration and knowledge sharing, and monitor and evaluate progress toward sustainable water management. This can be done through international water conventions and protocols, global water partnerships and networks, and water-related SDGs and indicators. These involve the adoption, implementation, and monitoring of global frameworks and standards for water management, including protection and sustainable use of transboundary water resources. They also involve collaboration of different stakeholders, including governments, civil society, and the private sector, to address water challenges at the global level (Burlacu et al. 2020; Cacal and Taboada 2022).

19.3 Examining IWRM Implementation Across Regions and Projects

19.3.1 Regional Perspectives: IWRM in Different Countries

IWRM has been implemented in different regions and countries, with different success and challenges. Some examples are as follows:

A. South Africa

The 1998 National Water Act created a legal framework for water management, based on IWRM principles. It recognized water as a scarce and public resource and introduced authorizations for water use, water pricing, catchment management agencies, and stakeholder participation (Burlacu et al. 2020). It aimed to ensure an equitable allocation of water for human needs, environment, and development. The challenges included lack of capacity, complex authorization process, resistance from water users, and interbasin and transboundary issues.

B. Brazil

The 1997 National Water Resources Policy and the 2000 National Water Resources Management System established a decentralized and participatory model for water management, engaging various levels of government, water users and civil society (Kratzert et al. 2019). The model introduced water resource planning, information and financing. It embraced the principles of IWRM, including river basin management, integration of quantity and quality aspects, recognition of water as an economic asset, and active participation in social participation and conflict resolution. The results included river basin committees, water resource plans, water charges, and water monitoring and information systems. Challenges included coordination among government levels, land and water integration, enforcement of water rights and regulations, and climate change adaptation.

Table 19.1 summarizes the key aspects of IWRM in South Africa and Brazil. It shows the legal framework, stakeholder participation, challenges, and outcomes of IWRM in these contexts. The analysis compares the variations and commonalities in IWRM approaches and their success and challenges.

Table 19.1 A comparative analysis of the operationalization of IWRM in three diverse regions: South Africa and Brazil

Region	Legal framework	Stakeholder participation	Challenges	Outcomes
South Africa	The National Water Act of 1998	Water use authorizations, water pricing, catchment management agencies	Lack of capacity, complex authorization process, resistance from water users, inter-basin and transboundary issues	Equitable water allocation for human needs, environment, and development
Brazil	The National Water Resources Policy of 1997 and the National Water Resources Management System of 2000	Different levels of government, water users, and civil society	Coordination among government levels, land and water integration, water rights and regulations enforcement, climate change adaptation	River basin committees, water resources plans, water charges, water monitoring and information systems

19.3.2 Project-Level Insights: IWRM Approaches and Methods

IWRM approaches and methods have been integrated in different case studies and projects around the world. Some examples are:

A. Nile Basin Initiative (NBI)

NBI is a regional partnership of 10 countries that share the Nile River, the longest and most complex river system in the world. It was launched in 1999 to foster cooperation and development in the Nile basin, using river basin management and stakeholder participation (Sintayehu 2020). The NBI has implemented various projects and programs that address the basin's challenges and opportunities, such as water security, hydropower, irrigation, navigation, fisheries, wetlands, climate change, and transboundary governance (Bukhari and Brown 2022). The achievements include: strengthening trust and dialogue, knowledge and information generation, improving water management and infrastructure improvement, and creating benefits and opportunities. Challenges include political tensions and disputes over water allocation, lack of a comprehensive and binding legal framework, insufficient funding and capacity, and population growth, urbanization, and climate change impacts.

B. Water Evaluation and Planning (WEAP) system

WEAP is a software tool designed to facilitate the integrated analysis and planning of water resources. It employs adaptive management, water accounting, and auditing techniques to simulate current and future water supply and demand, as well as the potential impacts of various scenarios and policies (Agarwal et al. 2019). It uses indicators and criteria, such as water availability, quality, efficiency, environmental flows, costs, benefits, equity, and adaptation to climate change. It also facilitates

Table 19.2 Comparative summary of IWRM approaches in case studies and projects

Case study	Main focus and objectives	Methodologies and tools	Achievements	Challenges
Nile Basin Initiative (NBI)	Regional cooperation, basin management, stakeholder participation	Shared Vision Program (SVP), Subsidiary Action Program (SAP)	Trust-building, knowledge generation, improved infrastructure	Political tensions, legal framework gaps, funding issues
WEAP system	Integrated analysis and planning of water resources	Adaptive management, water accounting, auditing methods	Scenario simulation, stakeholder involvement, decision support	Trade-offs among water uses, climate change vulnerability
PES scheme	Market-based instrument for rewarding ecosystem services	Ecosystem approach, water accounting, auditing methods	Improved water quality and quantity, livelihood generation	Implementation costs, scalability, stakeholder cooperation

stakeholder participation. It has a user-friendly interface, a transparent and flexible modeling framework, and a scenario-based approach. It has been applied in various regions and countries to support the decision making and planning of water resource management. The outcomes include: trade-offs and synergies identification, alternative options and strategies evaluation, vulnerability and resilience assessment, and dialogue and consensus promotion.

C. Payment for Ecosystem Services (PES) scheme

The PES scheme is a market-based instrument that rewards ecosystem services, such as water quality and quantity, for their conservation and restoration efforts. It uses the ecosystem approach and water accounting and auditing methods. It is based on the principle that the beneficiaries of ecosystem services should pay for them and the providers should be compensated. It can create incentives and mechanisms, promote sustainable and fair management of water resources, and recognize and value the environmental and social benefits of water (Bleeker and Vos 2020).

Table 19.2 compares three IWRM approaches in different case studies and projects. They are NBI, WEAP system, and PES scheme. It summarizes their focus, methods, results, and challenges.

19.4 Role of IWRM in Achieving SDG 6 and SDG 11

The SDGs are 17 global goals for 2030 to end poverty, protect the planet, and ensure peace and prosperity. SDG 6 and SDG 11 are about water resources and management. SDG 6 is for clean water and sanitation, and SDG 11 is for sustainable cities and communities. IWRM can help achieve SDG 6 and SDG 11 (Halkos and Gkampoura 2021).

19.4.1 The Role of IWRM in Achieving SDG 6 (Clean Water and Sanitation)

SDG 6 is a global goal for sustainable development. It aims to ensure universal access to water and sanitation while promoting sustainable management. The scope includes water resources and essential services, which include drinking water, sanitation, hygiene, and wastewater treatment. It also covers water quality, efficiency, IWRM, transboundary cooperation, and ecosystems (Benson et al. 2020). IWRM can help achieve this goal by using an inclusive approach that considers the whole system and involves everyone. It can improve access to water and sanitation, especially for the poor, marginalized, and vulnerable groups. It can respect their human rights and empower them in decision-making.

19.4.2 The Role of IWRM in Achieving SDG 11 (Sustainable Cities and Communities)

SDG 11 is a global goal for sustainable development. It wants to make cities better for everyone. It covers many things that affect urban life. IWRM can improve water supply and sanitation services in cities by building and improving facilities and systems, making them affordable and accessible to all. IWRM can also improve water quality and reduce water pollution in cities by treating, recycling, and reusing wastewater, managing stormwater and pollution, and using green and nature-based solutions. These can clean water and benefit the urban environment and well-being. IWRM can also increase water efficiency and reduce water stress in cities by encouraging rational and fair water use and diversifying water sources. This can meet the water demand of urban people and activities and deal with water scarcity and variability (Benson et al. 2020). IWRM can also improve water governance and management in cities by creating and carrying out policies, plans and strategies that treat water as part of the city system, a natural resource, and an economic and social good.

19.5 Opportunities of IWRM

IWRM has many benefits and opportunities for various sectors and stakeholders. Some of them are as follows:

(a) Coordinated resource development and management: IWRM coordinates water, land, and related resources for equitable and sustainable welfare. It overcomes the fragmented water management approach. It adopts a holistic and cross-sectoral policy. Encourage participation and collaboration. This improves water governance and management.
(b) Environmental protection and ecosystem sustainability: IWRM implements measures to protect and restore water and biodiversity. These improve the resilience and adaptation.
(c) Economic growth and social welfare: IWRM optimizes and maintains water use for various purposes. It improves water supply and services, which are vital for human development and the reduction of poverty. It also supports the creation of employment, income, and livelihoods. Encourages water-related development and innovation.
(d) Economic growth and social welfare: IWRM optimizes and maintains water use for various purposes. It improves water supply and services, which are vital for human development and the reduction of poverty. It also supports the creation of employment, income, and livelihoods. Encourages water-related development and innovation.
(e) Democratic Governance and human rights: IWRM supports democratic governance and human rights to water resources and services. It ensures participation, representation, and empowerment of all water users and stakeholders. Respects and protects the human right to water and sanitation. It resolves and prevents water conflicts and disputes.
(f) Human health and well-being: IWRM improves health and well-being by improving water resources and services, which are vital for survival, hygiene, and sanitation. It prevents and reduces waterborne and water-related diseases by improving safe drinking water and sanitation coverage, and implementing hygiene education and behavior change.

19.6 Challenges and Solutions of IWRM

IWRM faces many challenges in urban settings, where water demand is high, but resources are scarce and polluted. Urban areas have high population density, growth, industrialization, and consumption, which pressure water resources. We will discuss some challenges and solutions for IWRM.

(a) Water scarcity and demand management: Water scarcity occurs when water resources are not sufficient for water demand. A solution is to manage water demand, not increase supply. This involves reducing water losses, improving water efficiency, promoting water conservation, and implementing water pricing and allocation mechanisms.
(b) Water quality and pollution control: The quality is the characteristics of water for its use. Water quality can be affected by natural or human factors. Water pollution is the introduction of harmful substances or microorganisms into water

bodies. A solution is to implement integrated pollution prevention and control measures, or adopt the ‘polluter pays’ principle.

(c) Water supply and distribution systems: These collect, store, treat, and deliver water to users. They face challenges that can compromise water services, such as aging, deterioration, leakage, vandalism, inadequate maintenance, natural disasters, and human-induced threats. A solution is to invest in and modernize water infrastructure, and enhance its resilience and security.

(d) Wastewater collection and treatment: These collect, convey, and treat wastewater from different activities. They face challenges from insufficient coverage, capacity, or performance, water pollution and health risks, high costs, energy consumption, or greenhouse gas emissions. A solution is to adopt a circular economy approach or implement low-cost and low-energy wastewater treatment systems. These recover, reuse, or recycle wastewater and reduce the environmental footprint.

(e) Municipal solid waste management and resource recovery: These handle urban solid waste. They face challenges from the growing and complex waste stream and the environmental and social impacts of waste disposal. A solution is to apply the waste hierarchy principle or integrate waste management with the water and energy sectors, recovering and using water, nutrients, or energy from waste.

(f) Impacts of climate change and adaptation: The water sector is affected by climate changes. These are the impacts. The water sector also adapts its policies, practices, and infrastructure. These are the adaptations. However, both face challenges, such as climate uncertainty, variability, complexity, and hazards. A solution is to adopt a ‘no-regret’ or a ‘flexible’ approach.

Table 19.3 shows a summary of the main challenges and solutions for urban water management in the twenty-first century. The solutions are based on the principles of IWRM.

19.7 Conclusion

This chapter has provided a comprehensive analysis of IWRM and its pivotal role in achieving the UN Sustainable Development Goals (SDGs) 6 and 11. It has traced the evolution of IWRM from its origins to its current status and discussed its main components and implementation methods. It has also revealed the importance of IWRM in fostering sustainable water and urban development, especially in the face of the challenges posed by population growth, urbanization, climate change, and water scarcity and pollution. The chapter has also identified promising opportunities for IWRM to improve resource development, environmental protection, economic growth, and social welfare. It has proposed a variety of technical, institutional and behavioural measures to address the persistent challenges of water management, ensuring the efficiency and sustainability of water use and allocation. In addition, it has highlighted

Table 19.3 Challenges and solutions for urban water management based on IWRM principles

Challenge	Solution
Water scarcity and demand management	Reduce water losses, improve water efficiency, promote conservation, use water pricing reflecting true value
Water quality and pollution control	Enforce environmental regulations, monitor water quality, implement wastewater treatment, "polluter pays" principle
Water supply and distribution systems	Invest in infrastructure rehabilitation, enhance resilience and security with risk assessment
Wastewater collection and treatment	Adopt circular economy for wastewater recovery, use decentralised, low-cost treatment systems
Municipal solid waste management	Apply waste hierarchy principle, integrate waste management with water and energy sectors
Climate change impacts and adaptation	Implement 'no-regret' measures, Adopt a 'flexible' approach with adaptive management

the intersectoral and multiscale linkages and trade-offs of water management, and the need for integrated and adaptive solutions that can accommodate the diversity and complexity of water-related issues.

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