Effects of Urbanization on Groundwater

An Engineering Case-Based Approach for Sustainable Development

Edited by Ni-Bin Chang

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EFFECTS OF URBANIZATION ON GROUNDWATER

AN ENGINEERING CASE-BASED APPROACH FOR SUSTAINABLE DEVELOPMENT

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Urbanization Effects on Groundwater Task Committee
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Foreword

For the past 50 years the population of the world has increased from 3 billion to 6.5 billion, and it is likely to rise by 2 billion by 2025 and by 3 billion by 2050. Following the current trends it is safe to say that the increasing number of people will dwell in cities. This will imply rapid urbanization, accelerating land use change, depleting groundwater resources, pollution of surface streams and rivers at an alarming rate, and decaying infrastructure at the same time. Water demand in urban regions would rise correspondingly or even more.

To make matters worse, there is the specter of climate change hanging over our heads. During the last one hundred years the temperature has arisen by nearly 0.6 degree C, and it is expected to rise by 2 degree C during the next 100 years. This would translate into the intensification of hydrologic cycle, rising sea levels, more variable patterns of rainfall (more intense rainfall, more extremes), more variable patterns of runoff (more frequently occurring floods and droughts), shorter snowfall season, spring snowmelt season starting earlier, increasing evaporation, deterioration in water quality, changing of ecosystems, migration of species, changes in the way plants grow, trees reacting to downpours, drying up of biomass during droughts, and quicker growing and then wilting of crops.

The impact on water management would entail serious ramifications. Larger floods would overwhelm existing control structures, reservoirs would not have enough water to store for people and plants during droughts, global warming would melt glaciers and cause snow to fall as rain, regimes of snow and ice, which are natural regulators-storing water in winter and releasing in summer, would undergo change, and there would be more swings between floods and droughts. It is likely that dams, after three decades of lull, might witness a come back.

Current patterns of use and abuse of water resources result in the amount being withdrawn dangerously close to the limit and even beyond; an alarming number of rivers no longer reach the sea: The Indus, the Rio Grande, the Colorado, the Murray-Darling, the Yellow River-the arteries of main grain growing areas in many parts of the world; freshwater fish populations are in precipitous decline: Fish stocks have fallen by 30% (WWF for Nature), larger than fall in populations of animals in any ecosystem; 50% of world's wetlands have been drained, damaged or destroyed in the 20th century; in addition to fall in volume of freshwater in rivers, invasion of saltwater in delta, and changing in balance between freshwater and salt water.

As compared to the global water resources situation, local water shortages are even multiplying; Australia has suffered a decade long drought; Brazil and South America which depend on hydroelectric power have suffered repeated brownouts-not enough water to drive turbines; excess pumping of water from rivers feeding led to an almost collapse of Aral Sea in Central Asia in 1980; global water crisis impinges on the supplies of food and other goods.

Water resources situation in the U.S. is facing the same trend with decaying infrastructure built 50 to 100 years ago, i.e., where 17% of treated water is lost due to leaky pipes. In Texas, there is ongoing drought; ranchers have already lost nearly 1 billion; worst hit are Central Texas and the Hill Country; December 2008-February 2009 has been the driest on record; 60% of the state's beef cows are in counties with severe to exceptional drought; in 2006, drought related

crop and livestock losses were the worst for a single year, totaling 4.1 billions; effects are long-term.

The book "Effects of Urbanization on Groundwater: An Engineering Case-Based Approach to Sustainable Development," edited by Ni-Bin Chang is timely and addresses a number of key questions gravitating around the interactions amongst energy, environment, ecology, and socio-economic paradigms. The subject matter of the book will help promote sustainable management, with due consideration to linkages between regional economic development, population growth, and terrestrial hydrologic systems. It states challenges of and opportunities for science, technology and policy related to sustainable management of water.

Introducing sustainable development in urban regions in Chapter 1, the subject matter of the book is organized into four parts encompassing the remaining 13 chapters, each part corresponding to a specific theme. The theme of Part I is water supply and pollution prevention. Storm water management with regional infiltration technologies is the theme of Part II. Wastewater treatment and disposal with nutrient removal is the theme of Part III, and low impact development with landscape architecture technologies is covered in Part IV. These thematic areas cover the aspects from the fundamental theory to physical, chemical, and biological processes to the coupled human and natural environment, and to the representation of simulated evolutionary pathways. The linkage between these themes is thus becoming ever more important. Models of differing complexity have been used to study a wealth of well formulated engineering and management issues with risk assessment implications. Various real world applications in each chapter explore different impacts with varying degrees of sophistication.

The book will help improve our understanding of the sensitivity of key water quantity and quality management targets to urban development. The book is therefore timely and makes a strong case for sustainable development and management. The book is well written and well organized. Dr. Chang deserves a lot of applause to assemble an excellent array of chapters written by established professionals known for their technical contributions.

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Preface

During the last few decades, fast urbanization has altered such hydrologic cycle and related watershed processes that affect water resources and a range of potential consequences of urban development. This urbanization combined with economic growth and improving living standards in cities led to an addition to the quantity and complexity of generated wastewater effluents and stormwater runoff, which interrupt the hydrologic cycle and endanger the structure, function, and services provided by aquatic ecosystems. The negative feedbacks thus actuate an acute need to enhance fundamental understanding of the complex interactions within and among natural and human systems due to fast urbanization and its relevant countermeasures. These countermeasures that may lead to significant impacts on regional-scale hydrologic processes are basically linked with several disciplinary areas from water supply, to stormwater management, to wastewater treatment, and to groundwater conservation.

It is recognized that sustainable management is necessary at all phases of impact from the interactions among energy, environment, ecology and socioeconomic paradigms in human society. To promote the concept of sustainable management, this unique publication may be capable of presenting and applying sustainable systems engineering technologies to improve the overall understanding of the sensitivity of key water quantity and quality management targets to the types of human perturbations due to urban development. Hence, this book aims to address the following research topics in the context of the urbanization effects on groundwater:

- What are the potential impacts of water supply on groundwater aquifer and groundwater recharge rates, and how will these changes affect groundwater quality and/or quantity in both inland and coastal areas?
- What are the regional differences in stormwater and wastewater management technologies to urbanization?
- How can wetland extent and function be incorporated as an integral part of urban infrastructure systems, including effects on groundwater level?
- How will green infrastructure design philosophy influence the availability of suitable stormwater reuse and recharge for groundwater recovery?
- How can process-level models be improved to better represent the sensitivity of key water quality or quantity management targets to urbanization?
- How will changes in the low impact development strategies impact the hydrologic cycle in terms of both water quantity and quality in the nexus of stormwater management and groundwater conservation?

While focusing on the regional and urban watershed issues necessary for dealing with groundwater usage and quality endpoints, this book tries to answer all of the above questions as much as possible that capture important linkages between regional economic development, population growth, and terrestrial hydrologic systems.

Ni-Bin Chang, Editor
Orlando, Florida, March 25, 2009

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