Sustainable Civil Infrastructures

Hany Shehata
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Advanced Numerical Methods in Foundation Engineering

Proceedings of the 3rd GeoMEast International Congress and Exhibition, Egypt 2019 on Sustainable Civil Infrastructures – The Official International Congress of the Soil-Structure Interaction Group in Egypt (SSIGE)

Springer

Sustainable Civil Infrastructures

Sustainable Infrastructure impacts our well-being and day-to-day lives. The infrastructures we are building today will shape our lives tomorrow. The complex and diverse nature of the impacts due to weather extremes on transportation and civil infrastructures can be seen in our roadways, bridges, and buildings. Extreme summer temperatures, droughts, flash floods, and rising numbers of freeze-thaw cycles pose challenges for civil infrastructure and can endanger public safety. We constantly hear how civil infrastructures need constant attention, preservation, and upgrading. Such improvements and developments would obviously benefit from our desired book series that provide sustainable engineering materials and designs. The economic impact is huge and much research has been conducted worldwide. The future holds many opportunities, not only for researchers in a given country, but also for the worldwide field engineers who apply and implement these technologies. We believe that no approach can succeed if it does not unite the efforts of various engineering disciplines from all over the world under one umbrella to offer a beacon of modern solutions to the global infrastructure. Experts from the various engineering disciplines around the globe will participate in this series, including: Geotechnical, Geological, Geoscience, Petroleum, Structural, Transportation, Bridge, Infrastructure, Energy, Architectural, Chemical and Materials, and other related Engineering disciplines.

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About the Editors

Hany Shehata is the founder and CEO of the Soil-Structure Interaction Group in Egypt "SSIGE." He is a partner and vice-president of EHE-Consulting Group in the Middle East, and managing editor of the "Innovative Infrastructure Solutions" journal, published by Springer. He worked in the field of civil engineering early, while studying, with Bechtel Egypt Contracting & PM Company, LLC. His professional experience includes working in culverts, small tunnels, pipe installation, earth reinforcement, soil stabilization, and small bridges. He also has been involved in teaching, research, and consulting. His areas of specialization include static and dynamic soil-structure interactions involving buildings, roads, water structures, retaining walls, earth reinforcement, and bridges, as well as, different disciplines of project management and contract administration. He is the author of an Arabic practical book titled "Practical Solutions for Different Geotechnical Works: The Practical Engineers' Guidelines." He is currently working on a new book titled "Soil-Foundation-Superstructure Interaction: Structural Integration." He is the contributor of more than 50 publications in national and international conferences and journals. He served as a co-chair of the GeoChina 2016 International Conference in Shandong, China. He serves also as a co-chair and secretary general of the GeoMEast 2017 International Conference in Sharm El-Sheikh, Egypt. He received the Outstanding Reviewer Award for 2016 of the ASCE as selected by the Editorial Board of International Journal of Geomechanics.

Professor Braja Das is the Dean Emeritus of the College of Engineering and Computer Science, California State University, USA. He is a geotechnical engineering by profession and received his Ph.D. degree in 1972 from the University of Wisconsin, Madison, USA. For more than three decades, Professor Das has worked as a faculty member and in academic administration in several universities. He is a Fellow and Life Member of the American Society of Civil Engineers; Life Member of the American Society for Engineering Education; and Emeritus Member of TRB's AFS-80 Committee on Stabilization of Geomaterials and Stabilized Materials.

As a teacher, he has received many teaching awards including the Distinguished Achievement Award for Teaching Excellence, University of Texas at El Paso (1983); AMOCO Foundation Award for Outstanding Teaching, University of Texas at El Paso (1983); Western Electric Fund Award, ASEE (1984); and Ralph R. Teetor Educational Award, Society of Automotive Engineers Inc. (1985).

Professor Das has published more than 300 papers in various journals and peer-reviewed conference proceedings. They are mostly in the areas of shallow foundations, earth anchors, and geosynthetics. He published some of the early founding studies on the bearing capacity of shallow foundations on geogrid-reinforced sand. His past editorial activities in geotechnical engineering journals include Editorial Board Member of Journal of Geotechnical Engineering, ASCE (1988–1992); Lowland Technology International, Japan (1999–2007); Geotextiles and Geomembranes, Elsevier, UK (2008–present). He was the Associate Editor of the International Journal of Offshore and Polar Engineering (1995–1998); and Co-Editor of Geotechnical and Geological Engineering, Springer (2001–2006). He is Founder and Editor-in-Chief of the International Journal of Geotechnical Engineering (Taylor and Francis, UK) from 2007 up to the present.

Dr. Das has been a very popular keynote/or invited speaker in many conferences and special meetings in various countries. These countries include Mexico,

Dominican Republic, Costa Rica, El Salvador, Peru, Colombia, Ecuador, India, University of Birmingham, UK, Korea, Bolivia, Venezuela, Turkey, Turkish Republic of North Cyprus, and Tunisia. He has been named as the first Eulalio Juárez Badillo Lecturer by the Mexican Society of Geotechnical Engineers (November 2016).

Professor Das is the author/co-author of several texts and reference books in the area of geotechnical engineering, probably having written more than any other individual in geotechnical engineering. His textbooks have been translated into several languages and are used throughout the world. His clear, concise, and singularly unique style of presentation is very much admired, thereby attracting many students over the last 25 years who might not have considered geotechnical engineering as a profession.

This is truly his most outstanding achievement which has endeared him to many young geotechnical engineers around the world. This is his legacy—now and for years to come.

A. P. S. Selvadurai is currently William Scott Professor and Distinguished James McGill Professor in the Department of Civil Engineering and Applied Mechanics, McGill University, Montréal, Canada. He obtained his PhD degree in Theoretical Mechanics from the University of Nottingham, under the tutelage of the world-renowned continuum mechanicist, the late A. J. M. Spencer. In 1986, the University of Nottingham awarded him its first-ever research DSc in Theoretical Mechanics. He was Professor and Chair of the Department of Civil Engineering at Carleton University, Ottawa, 1982 to 1991, and from 1993 to 1997, the Chair of the Department of Civil Engineering and Applied Mechanics at McGill University.

Dr. Selvadurai was awarded the Humboldt Senior Scientist Award and in 2000 (re-invitation Award, 2019) and the first civil engineer to be awarded the Killam Research Fellowship (Canada Council for the Arts). In 2003, he received the prestigious Max Planck Research Prize in the Engineering Sciences. In 2007, he

received the Killam Prize for Engineering, awarded by the Canada Council for the Arts and the CANCAM Gold Medal, awarded by the Central Committee for Canadian Congresses of Applied Mechanics. In 2008, he received the IACMAG Medal for Outstanding Accomplishments in Theoretical, Computational, and Experimental Geomechanics, and in 2010, he received the ALERT Medal awarded by Alliance of Laboratories in Europe for Research and Technology. In 2012, he was awarded the degree of Docteur Honoris Causa by the Institut Polytechnique de Grenoble, France. In 2013, he was awarded the Eric Reissner Medal of the ICCES and The Maurice A. Biot Medal of the ASCE. In 2017, he received the Chandrakant S. Desai Medal from the International Association for Computer Methods and Advances in Geomechanics.

His research includes the mechanics of elastic media undergoing large deformations, fracture mechanics, micromechanics of inclusions and defects, poroelasticity, coupled thermo-hydro-mechanical processes in deformable media, mechanics of inhomogeneous media, interfaces in geomechanics, fragmentation of brittle geomaterials, transport in porous media, and mechanics of geosynthetics subjected to chemical exposure. He is the author or co-author of texts devoted to Elastic Analysis of Soil-Foundation Interaction (Elsevier, 1979), Elasticity and Geomechanics (with R. O. Davis) (Cambridge University Press, 1996), Partial Differential Equations in Mechanics Vols. 1 & 2 (Springer-Verlag, 2000); Plasticity and Geomechanics (with R. O. Davis) (Cambridge University Press, 2002), Transport in Porous Media (with Y. Ichikawa) (Springer-Verlag, 2012), and Thermo-Poroelasticity and Geomechanics (with A. P. Suvorov) (Cambridge University Press, 2016). He serves on the Editorial Boards of nine leading International Journals devoted to Geomechanics, Applied Mechanics, Computational Mechanics, and Engineering Mathematics. He is a Fellow of several Academies and Learned Societies.

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- Main research areas of interest: soil-structure interaction, deep foundations, excavation support systems, ground improvement and subsurface characterization.
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- Geotechnical consultant of more than 20 years of professional practice.
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Groundwater Numerical Modelling of Amman-Zarqa Basin-Jordan

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Abstract. Amman Zarqa Basin (AZB) is the most developed groundwater basin in the arid region of Jordan and faces water shortage and declining water table due to overexploitation to meet irrigation and domestic water demands. Therefore, groundwater flow modeling for this watershed is a necessary tool for proper management of groundwater resources to protect AZB from depletion. MODFLOW was calibrated and used to simulate the behavior of the flow system under different pumping rates scenarios. The conceptual model for Amman-Wadi Sir (B2/A7) aquifer system was formulated by one layer unconfined type overlaid by impervious layer (A1/6 aquitard) and calibrated for steady state condition by matching observed and simulated initial head contour lines. Drawdown data for the period 1985–1995 was also used for calibration of the transient model by matching simulated drawdowns with observed ones, and then validated by using drawdown data for the period 1996–2002. The results of the calibrated model showed that the horizontal hydraulic conductivity of the B2/A7 aquifer ranges between 0.007 to 45 m/d. Calibrated specific yield ranges from 0.001 to 0.15.

Three scenarios were conducted to predict the B2/A7 aquifer system response under different conditions during the period 2020–2030. The first scenario assumed that the pumping rates of year 2005 (110.4 MCM/year) are constant for 15, and 25 years. The maximum drawdowns where found reached about 99.9 and 104.9 m in the years 2020, and 2030, respectively. The second scenario assumed that the present abstraction rates (110.4 MCM/year) is reduced to 80 MCM/year. The maximum drawdowns were reduced to about 90, and 94.8 m in the years 2020 and 2030, respectively. The third scenario assumed an abstraction rate of only 65 MCM/year. The maximum drawdowns in this case will be decreased to only 76.8, and 72.5 m for the years 2020 and 2030, respectively; this scenario (abstraction rate of 65 MCM/year) has been found to provide a safe recovery and stability in the drawdown and therefore, could be considered as the safe yield of AZB.

Keywords: MODFLOW · Amman-Zarqa Basin · Groundwater modeling · Calibration · Validation

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1 Introduction

Jordan is an arid country with very limited water resources. Groundwater contributes a significant portion of the water supply in Jordan. Increased dependence on groundwater needs improved aquifer management with respect to understanding recharge and discharge issues (Tompson et al. 1999). Amman-Zarqa aquifer is located in the northern part of Jordan and is a major source of drinking water for Amman, Zarqa and Jerash cities. Furthermore, due to the increasing demand, the withdrawal from most of the Jordan's aquifers is almost double that of the safe yield. This will eventually lead to the depletion of water resources and deterioration in the water quality according to the National Water Master Plan of Jordan (NWMP 2001). Groundwater modeling is an effective tool to understand the nature of groundwater flow and for aquifer management. Groundwater modeling begins with the development of conceptual model after enough knowledge of the hydrogeology of the system, followed by the mathematical model, which consists of differential equations for hydraulic head with specification of system geometry, and boundary conditions. Many numerical methods are used to solve these differential equations; however the most common methods are finite difference and finite element method.

The present study is oriented toward finding simple methodology tool for predicting, with reasonable accuracy, the hydrological behaviour of Amman-Zarqa Basin (AZB) using appropriate and adjusted models such as MODFLOW. The study may, in future, help decision makers and planners in selecting optimum groundwater management scenarios suitable for arid and semiarid regions. This report presents the results of the groundwater modelling for AZB-Jordan the numerical groundwater modelling of the AZB aims at

1. Simulating the hydrological behaviour of AZB using the MODFLOW
2. Carrying out different management scenarios for AZB (local climate effects such as successive droughts hydrological years, groundwater pumping…)

2 Materials and Methods

2.1 Study Area

The study area lies in the north of Jordan as shown in Fig. 1. The Amman-Zarqa Basin (AZB) covers 3739 km^2 of area, 415 km^2 of which are in Syria. The basin is bordered by the Yarmouk Basin in the North, the Azraq Basin in the East and South, the Dead Sea Basin in the southwest, and by the Rift Sides Basin in the West. The drainage pattern is primarily towards west into the Jordan Valley area. The Zarqa River is the main drainage course and originates from the Amman area conveying As-Samra Treatment Plant effluent via Wadi Dhuleil where meets Zarqa River near Sukhnah Town and flowing into the King Talal Reservoir (KTR) (Fig. 2).

The Amman-Zarqa basin is the most developed watershed in Jordan. It is the fastest growing region both industrially and in terms of population. Amman-Zarqa basin comprises the Greater Amman, Dhuleil, upper Zarqa, Baqa'a and Jerash areas.

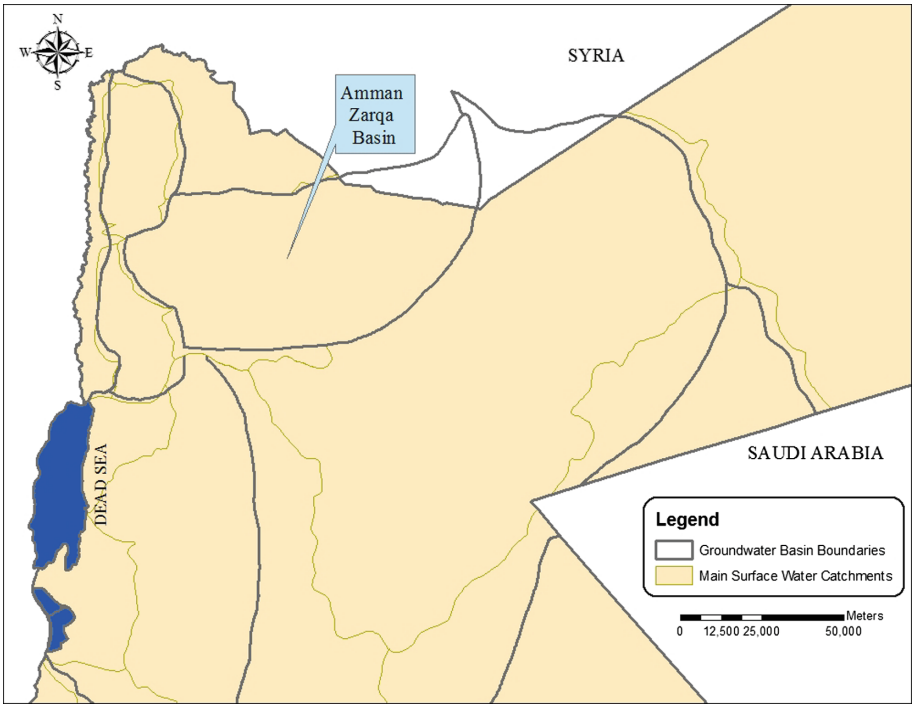

Fig. 1. Study area location (MWI 2006)

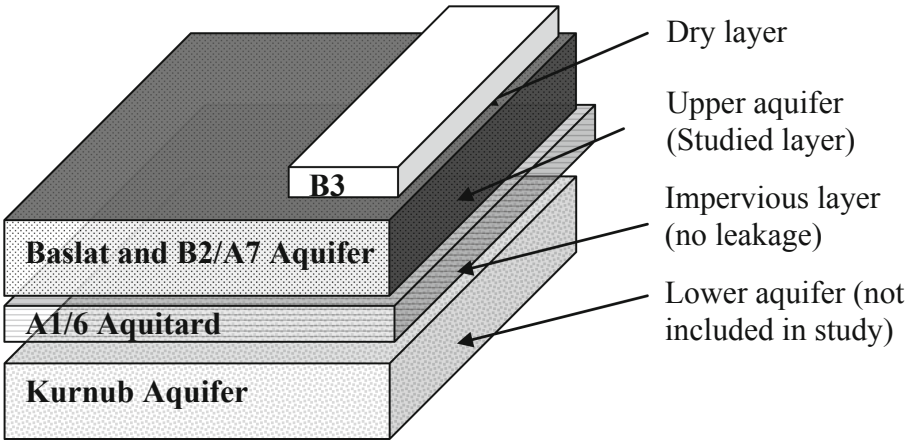

Fig. 2. Conceptual model of the study area

Groundwater resources in most of these areas are highly developed and over exploited. Groundwater potential in the basin is mostly utilized for irrigation in the areas of upper Zarqa, Baqa'a, Dhuleil and Jerash.