Book review: Estimating Groundwater Recharge, by Richard W Healy (Cambridge University Press, 2010)

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Estimating Groundwater Recharge by Richard W. Healy (Healy 2010, with contributions from Bridget R. Scanlon) is an excellent addition to the growing knowledge base of groundwater science and technology. Understanding groundwater recharge is a prerequisite for the meaningful simulation of groundwater flow and transport, and, hence, successful management of renewable water resources. By placing an emphasis on method, this book provides clear concepts of the recharge process and associated methods that stem from more than 800 peer-reviewed references.

Estimating Groundwater Recharge is organized into nine relatively concise chapters. It begins with descriptions of the conceptual framework of groundwater recharge and ends with an example of the USA to illustrate how the conceptual models are applied in reality. Chapters 2 through 8 deal with various methods. Theoretical models are combined with cases studies, drawn largely from the research projects undertaken in developed countries. Chapter 2 discusses water-budget methods, a foundation of following methods. Chapter 3 is about the modeling approach, while chapter 4 introduces the methods related to surface-water data. The physical, chemical and heat-tracer methods form chapters 5 through 8, which acknowledge the differences between applications for both the unsaturated and saturated zones. For instance, chapter 5 is dedicated to the physical methods as applied in the unsaturated zone, whereas chapter 6 discusses the same methods but in the saturated context.

The organization of chapters in the book does, in some respects, resemble Groundwater Recharge in a Desert Environment: The Southwestern United States edited by Hogan et al. (2004). Perhaps due to the common authorship, some similarities exist. However, Healy's book offers a comprehensive yet focused treatment in both theoretical and practical aspects through a wealth of cited references. The approach helps to reinforce theoretical concepts and therefore gives it a more modern feel.

Introduction of recharge terminology in section 1.2 of the book is helpful, not only for its use as an academic text but also for practical clarity for those who are not necessarily groundwater practitioners. 'Recharge' is defined in the book as the downward flow of water reaching the water table, adding to groundwater storage. In fact, adding storage should be seen as an innate part of water arrival at the water table. Depending on the rate of groundwater discharge, the buildup of the groundwater storage due to recharge may not necessarily be observed as this storage is conditioned by other factors apart from recharge. Healy rightly points out that the

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definition excludes water flow to an aquifer from an adjoining groundwater system, which is referred to as interaquifer flow or groundwater underflow. Another interesting term that is expanded upon is 'base flow', which is sometimes understood differently between groundwater and surface-water professionals. The groundwater camp would insist that base flow is water that has been discharged from the saturated zone. This is the stated definition in many groundwater books, including this one. In the opposing camp, base flow may be regarded as all stream flow that is not derived directly from surface runoff. Without proper clarification of the terminology used, confusion may arise as has been experienced during the assessment of the role of base flow in the in stream flow requirements required by the national Water Act in South Africa. The conceptual clarification of base flow made in section 4.1.2 of this book is practically valuable for multi-disciplinary research. Like many other hydrogeological phenomena, recharge varies both spatially and temporally, dependent upon the combination of influencing factors such as climate, soils, geology, geomorphology, hydrology, vegetation and land use. Based on the source of data, its availability and the nature of the parameters considered, etc., the book comprehensively documents some 40 methods that can be applied for estimating groundwater recharge in a range of hydrogeological scenarios. A distinction is made between point and integrated values of recharge estimation. Diffuse and focused recharges are also highlighted throughout the text for the readers' consideration. The concepts used are consistent with those given by popular books, most notably Freeze and Cherry (1979) and Learner et al. (1990).

In addition to the theoretical description of various methods that can potentially be employed, 40 examples, inserted in various chapters, are used to illustrate how the methods are applied in a real world setting under typical climatic conditions ranging from arid and semi-arid to subhumid and humid conditions. In many cases, the estimates given in the examples are in terms of drainage flux, recharge rate or base flow volume. It occurs to this author that the water-table fluctuation method appears attractive because groundwater-level data can easily be made available in many developing regions, especially those in arid and semi-arid areas. Though the assumptions and complexity associated with the determination of the water level and specific yield are thoroughly discussed in chapter 6, the book fails to adequately discuss field examples from those regions.

Recharge estimations are often constrained by a suite of non-scientific factors such as deadlines (how quick to deliver a result), funding (ownership of project) and purpose (what the result is used for). In reality not all the proposed methods would be applied as recommended. Some methods may be highly preferred to the others due to cost-effectiveness and technical feasibility consideration in a particular project. It is inevitable that the uncertainty associated with the formulated methods must be dealt with. In this regard, the book takes up the challenge through the case of water-budget method, as seen in section 2.2.1. To put it differently, uncertainty, often reflected in differing recharge estimates obtained through multi-methods, can arise from the inaccuracy of measurements (or imprecision) and the use of suboptimal models (bias). The combination of these two factors, bias and precision, gives rise to four scenarios. Neither the high bias nor low precision would generate a realistic estimate. An ideal scenario of the low bias and high precision is hardly achieved in practice. Perhaps a

combination of the low bias and low precision approach is pragmatically acceptable. This could be achieved through the adaptation of multi-methods whose results can be cross-checked, guided by realistic conceptual models for the aquifers of interest.

One of the best things about this book is that the development of a conceptual model of recharge processes, which is highlighted up-front in chapter 1, is consequently contextualized in the case of the USA in the concluding ninth chapter. Healy repeatedly cautions the readers that initially conceived models should be revised and adjusted as additional data and analyses provide new insights to the hydrologic system. In fact a conceptual model for estimating groundwater recharge is a working model or hypothesis, which is always subject to new information and knowledge to be acquired in due course.

The book does not offer any generalised information in the form of an appendix, which both water-related students and stakeholders might look for, e.g., regional comparisons of recharge estimates, ranges of recharge values, and recharge maps under typical climatic zones. Yet, in its concise form, the book does provide well- summarised insights into the recharge estimation framework.

Perhaps for the first time, both theoretical and practical aspects are considered within the conceptual framework. It makes the book an excellent reference for both students and practicing hydrogeologists to consult in their endeavour to better understand recharge estimation.

References

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