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Recharge modelling for the West Bank aquifers

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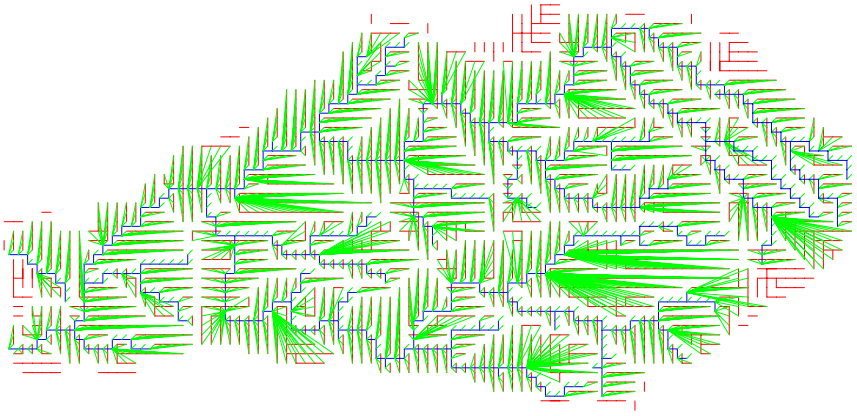

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Recharge modelling for the West Bank aquifers

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Foreword

The report has been prepared by British Geological Survey (BGS) for the Department for International Development (DFID) funded project “Sustainable Management of the West Bank and Gaza Aquifers” (SUSMAQ).

The primary aim of the SUSMAQ project is to support the Palestinian Water Authority (PWA) by improving the current understanding of the flow system of the aquifers of the West Bank and Gaza, and to assess the sustainability of the aquifers under a variety of economic, demographic and land use scenarios in terms of meeting the consequent water demand from aquifers. This is achieved through a set of management tools based on mathematical simulation of flow in the aquifers, a component of which is the recharge modelling.

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BGS staff members are also acknowledged for their contributions; Nick Robins and Denis Peach for their hydrogeological experience, Chris Jackson for his patient answering of object-oriented queries, Andrew Mckenzie, Brighid O Dochairtaigh and Helen Rutter for their prior knowledge of the West Bank and Roger Calow and Alan MacDonald for a glimpse into the softer side.

Executive Summary

Recharge can take two main forms, direct recharge from rainfall infiltrating the ground or indirect recharge from leakage from wadi beds. The recharge processes operating in the West Bank can be summarised as rainfall recharge, wadi recharge, urban recharge processes and irrigation losses. Rainfall recharge is the predominant form of recharge, whilst wadi recharge, urban and irrigation losses are only minor components. However, these minor components can be locally important.

The recharge processes operating in the Wadi Natuf catchment are varied and complex. The four main geological strata through which recharge takes place are:

- Jerusalam
- Upper Lower Beit Kahil
- Lower Beit Kahil
- Hebron

The main aquifer units are karstic which receive recharge once a wetting threshold is exceeded. This assumption is supported by field observations (Messerschmid, 2003) and a field experiment close to the study area (Lange et al., 2003). Other minor aquifers receive recharge and distribute water laterally to springs. Flow from springs, if not used for water supply or irrigation, can then be routed to other aquifer units or as loss from wadis.

High intensity rainfall can produce overland runoff and wadi flow. Flowing wadis loose water to all but the Yatta formation.

Recharge can, therefore, occur by two methods, direct infiltration from rainfall and from losses from wadi beds.

There are four main recharge processes operating in the aquifers of the West Bank;

1. Direct recharge from rainfall
2. Indirect recharge from wadi losses
3. Recharge from urban water supply and waste water proceses
4. Recharge from irrigation losses

The difference between rainfall and potential evaporation, known as effective rainfall, is the main control on direct recharge from rainfall. Rainfall is greatest in the north and west whereas potential evaporation is the highest in the south and east. The greatest potential for rainfall recharge is, therefore, in the north and west. Soil cover also controls the amount of rainfall recharge and is highly variable over the West Bank. In particular, the main soil types have patchy coverage, over only 30-50 % of the ground surface, the rest being bare rock. The patchiness of the soil means that soil moisture is not developed in the same way as for soils with uniform coverage.

To determine the rainfall recharge mechanisms operating in the West Bank, a combination of factors such as rainfall, potential evaporation, soil cover, land use, etc need to be assessed. Combining these factors mean that recharge processes based on soil moisture are most likely to be operating in the north-west of the West Bank. Elsewhere, direct recharge will be based on how the soil and rocks combined as single system respond to the balance between rainfall and evaporation (e.g. Lange et al., 2003).

Indirect recharge occurs due to wadi flows over the whole of the West Bank. Runoff from intense rainfall events will collect in valley bottoms and create surface water flows. Recharge from wadi beds will form the predominant source of recharge in the south and east of the West Bank, where the climate is more arid.

Urban recharge processes reflect leakage from pipes and sewers and increased runoff from paved surfaces, roofs, roads, etc. The enhanced runoff in the urban environment is routed to wadis and enhances flows after rainstorms. This can increase indirect recharge from wadi beds.

Losses from irrigation systems can enhance recharge. The main areas for irrigation are the north-west of the West Bank, in the vicinity of Jericho and the Upper Jordan Valley.

A significant amount of work has been undertaken on calculating recharge to the aquifers in the West Bank and in the Western Aquifer Basin by measuring discharge and abstraction as a surrogate for recharge. However, most of the estimates rely on empirical relationships between annual rainfall and recharge. Estimates undertaken using an empirical method are not physically based, but nonetheless can be used as a guide to determine whether the recharge calculated by the modelling are realistic. The estimates for the Western Aquifer Basin are around 350 $Mm^3 a^{-1}$ and 800 $Mm^3 a^{-1}$ for the West Bank as a whole.

To enable recharge to be calculated using a physical basis over aquifer outcrops, a distributed recharge model has been developed and tested. An existing object-oriented groundwater flow model has been adapted from an existing code. An object-oriented approach was chosen to enable a range of recharge mechanisms to be incorporated easily into the model. Recharge is calculated at a node, which is held on a grid and enables a distributed recharge estimate to be undertaken. Four types of recharge node can be specified; soil moisture balance method, wetting threshold, urban recharge process and irrigation losses. In addition to these mechanisms, runoff routing to wadis and subsequent infiltration is implemented.

1 Introduction

This report describes the application of a distributed recharge model to the aquifers of the West Bank. An analysis of recharge, i.e. the quantity of water that infiltrates from the land surface to the aquifer, is an essential input for simulation of flow in the aquifers. Recharge is a complex process, but quantification is critical in order to understand the total water availability from the West Bank aquifers. To aid the quantification of recharge, a distributed recharge model has been developed using object-oriented techniques. This recharge model has been adapted from an existing code to include the recharge mechanisms observed in the West Bank. The model has been applied to two areas, the Wadi Natuf catchment, as a pilot application, and the main outcrops of the aquifers underlying the West Bank.

This report builds on previous work (McKenzie et al., 2001), which summarises the recharge processes operating in the West Bank aquifer and the previous estimates of recharge and presents data collected during a visit to the project office in Ramallah. The work on the Wadi Natuf catchment is helped by various field visit reports undertaken by the SUSMAQ team (e.g. Messerschmid, 2003).

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