Shared water resources in the western Asia region: An inventory of shared aquifers and aquifer systems

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ABSTRACT

Shared water basins play a significant role in linking populations and cultures, and creating hydrological, social and economic interdependencies between riparian ESCWA member states as well as neighbouring non-ESCWA countries. Enhancing cooperation between riparian member states on shared water issues is one of the main objectives of the ESCWA-BGR Water Project. Presently, all available information is being compiled in an inventory which will be the first systematic effort to comprehensively "map" shared groundwater systems and surface water basins in Western Asia, including second- and third-order sub-basins with emphasis on hydrology, hydrogeology, water resources development and use, as well as the status of cooperation and water resource management.

The regional inventory of shared waters is comprised of basin-level chapters and is enriched by in-depth analysis of issues relevant to shared waters in Western Asia (thematic chapters). It targets a wide range of stakeholders including decision-makers and non-technical government representatives responsible for water resource management and related sectors, the general public, media and international organizations. The inventory aims at: (1) activating and creating awareness among decision-makers and a broader audience; (2) improving the knowledge base and facilitating access to information on shared water resources; (3) establishing a link between this knowledge base and the management practices at both the national and inter-state levels; and (4) supporting regional processes towards improved dialogue and cooperation on shared water resources. The main findings of the inventory are to be disseminated through expert group meetings and a comprehensive report, which is to be reviewed and discussed with member states before being published.

This paper deals only with shared aquifers / aquifer systems. It describes the work process through which the inventory of these systems is being achieved in a systematic manner so as to provide regional information on the extent of the resources, their uses, as well as the status of cooperation and management of the resource. It also describes the structure of the report and specific information obtained on each aquifer system, and identifies some of the most common groundwater issues prevailing in the different aquifer systems. Most importantly, the paper outlines how the aquifer systems are classified into different groups, the criteria used for this purpose, the problems encountered in delineating the boundaries of some of these systems, the discrepancies in the available data/information, and some of the terminology used to describe the different aquifer systems.
Key words: shared aquifers; riparian; cooperation; inventory; Western Asia

1. INTRODUCTION

The United Nations Economic and Social Commission for Western Asia[1] (ESCWA) has been actively engaged in research, capacity development of national institutions and initiatives for cooperation on shared water resources in Western Asia for more than 20 years. Interest in shared water issues in Western Asia has grown tremendously since ESCWA's first attempt to compile a preliminary

[1] Western Asia in this paper refers to the region comprised of Member States of the United Nations Economic and Social Commission for Western Asia (ESCWA) which lies entirely within the Arabian Plate, geologically speaking, and have common geo-tectonic setting, physiography, and climatic conditions that contributed to the development of aquifer systems extending across political boundaries.

water resources database in the region, which identified about 25 major water basins shared between at least two riparian countries (UN-ESCWA, 1992). These shared water basins play a significant role in linking populations and cultures, and creating hydrological, social and economic interdependencies between riparian ESCWA member states as well as neighbouring non-ESCWA countries.

Enhancing cooperation between member countries on shared water issues is one of the main objectives of the on-going cooperation between ESCWA and the Federal Institute for Geosciences and Natural Resources of Germany (BGR). Presently, the project is compiling available information in an inventory which will be the first systematic effort to comprehensively "map" both shared groundwater systems and surface water basins in Western Asia. The approach, objectives, scope, structure and work process of the inventory are outlined in section 2 below.

The focus of this paper is placed on shared aquifers and aquifer systems[2] in the Western Asia region, many of which extend not only across political borders but also beyond the boundaries of major geo-tectonic plates. Most of them belong to the Arabian Sedimentary Basin and occur in the extremely arid Arabian Peninsula covering most of the Arabian Plate, which lie to the east of the Arabian Shield, to constitute shared aquifers between Saudi Arabia and neighbouring countries. Those that occur along the relatively unstable northern boundaries of the Arabian Plate, however, have been developing under different geological and climatic conditions. These aquifers / aquifer systems are much smaller in size but more complex, compared with those that develop further south, and often extend to non-ESCWA countries, namely Israel, Iran, and Turkey.

Section 3 of this paper defines groundwater provinces in which the shared aquifers / aquifer systems in the region develop, and categorize such systems into different groups. We hope to stimulate discussion on the proposed approach and the overall activity being undertaken by ESCWA-BGR to ensure that it constitutes an added value towards a better understanding of shared water systems in the region.

2. APPROACH OF THE INVENTORY

2.1. Scope and objective

The inventory the first systematic effort to comprehensively "map", compile and explore shared groundwater systems and surface water basins in Western Asia, including second- or third-order sub-basins with emphasis on hydrology, hydrogeology, water resources development and use, as well as status of cooperation and management. In providing a regional inventory of shared waters, enriched by in-depth analysis of issues relevant to shared waters in Western Asia (thematic chapters), the study targets a wide range of stakeholders including decision makers and non-technical government representatives from water and other sectors, the general public, media, donors and international organizations.

The inventory thereby aims at (1) activating and creating awareness among decision makers and a broader audience; (2) improving the knowledge base and facilitate access to information on shared water resources; (3) establishing a link between this knowledge base and the management practices at both the national and inter-state levels; and (4) supporting regional processes towards improved dialogue and cooperation on shared water resources.

[2] An aquifer system *"means a series of two or more aquifers that are hydraulically connected"* (United Nations, 2009)

2.2. Structure of the inventory

The inventory builds on two major pillars: the actual inventory of shared waters in Western Asia, consisting of mostly descriptive chapters on each of the shared water basins, and an analytical part consisting of 4-6 thematic chapters that shed light on various issues of shared water resources in Western Asia such as in the context of groundwater, the issue of shared coastal aquifers.

For the part of the inventory dealing with shared aquifers, an introductory chapter with an overview map of shared aquifers / aquifer systems in Western Asia will introduce the approach used to compile relevant information. This is followed by basin chapters on the identified groundwater systems/units. Each basin chapter will consist of a map introducing the groundwater system, a table of basic facts & figures (see Table 1), a brief summary text and a more detailed, illustrated description of the basin covering the following issues:

Table 1: Basic information to be collected on each aquifer /aquifer system

Basin introduction	*Riparian countries, areal extent, boundaries, climate, population.*
Hydrogeology	*Aquifer geometry, outcrop areas, subsurface extent, litho-stratigraphy, thickness, depth, recharge/discharge, flow regime, confined/unconfined, etc.*
Groundwater use and development	*timeline of development, areas and sector of use, abstraction, changes in storage, return flows, impact on quality, trends, demand issues, future supply plans, etc.*
Agreements and cooperation	*Agreements, existing cooperation mechanisms, timeline of cooperation, issues of conflict.*

2.3. Methodology and work process

The inventory is originally a desk study that gains added value through a comprehensive review and validation process. Information for the basin chapters is first collected and summarized from ESCWA reports, regional literature, scientific publications, country papers, media reports and other secondary literature. After an internal review, information in the basin chapters will be discussed, validated and/or reconciled with the experts from respective member countries. This consultation process is considered crucial to enhance ownership of the compilation process and stimulate discussion on shared water resources among member countries, concerned expert circles and academia.

3. SHARED AQUIFERS / AQUIFER SYSTEMS IN WESTERN ASIA

3.1. Delineation of groundwater provinces

The sedimentary provinces containing the main aquifers across Western Asia are controlled by the major geological structures of the Arabian Plate, including those that are still actively developing in its northern and north-eastern edges where the Arabian Plate is subducting beneath the Turkish (Anatolian) and Iranian plates. For the purpose of this paper, four different *groundwater provinces* with shared aquifers / aquifer systems are differentiated within the sedimentary provinces: A mega-basin spreading across the main Arabian Plate with extensive regional aquifer systems (the *Arabian Peninsula Groundwater Province*) and three smaller basins along the northern periphery of the Plate with localized (the *Euphrates-Tigris Groundwater Province*) and complex aquifer systems (the *Mashrek-Sinai Groundwater Province* and the *Taurus-Zagros Groundwater Province*).

Table 2 - Groundwater Provinces in Western Asia region as defined in this paper

Arabian Peninsula *Groundwater Province*	This mega-basin extends across the Peninsula from the Indian Ocean to the Jordan Uplift, the Palmyride Mountains, and Rutba Highs along the northern Arabian Plate. The existence of structurally-positive land masses along the Red Sea and the Gulf of Aden rifts (Basement Massifs), which have been amazingly stable since Precambrian time (Powers et al., 1966), and the extension of a 400 km-wide gentle plain along their periphery (Interior Homocline) provided the perfect setting for the deposition of extensive sedimentary strata from the Paleozoic to the Neogene eras. These strata extend from Saudi Arabia to neighboring countries along its boundaries to the north, east and south across some of the most arid desert areas in the world: the *Rub' al Khali* in the south and southeast, and the *Nafud-Hamad* in the north.
Mashrek-Sinai *Groundwater Province*	Comprises the region between the Levant (Dead Sea) rift and the Mediterranean sea, which constitutes a subplate (Sinai Peninsula-Levant subplate) sandwiched between the Arabian and Nubian plates (Mahmoud et al., 2005). The northern part (Mashrak) is characterized by high precipitation falling on extremely well exposed karstic carbonate rocks of Early Jurassic to Late Cenozoic (Walley, 1998), extending mainly along the boundaries of Lebanon with neighboring countries to constitute shared aquifers in several zones. Many springs issue from these rocks, which rise up to about 3 000 meters in Lebanon to sustain important river systems, some of which flow across political boundaries. The southern (Sinai) part is a much more arid land through which important groundwater systems flow across political boundaries to the Mediterranean Sea.
Euphrates-Tigris *Groundwater Province*	Essentially comprises the Mesopotamian Foreland Basin extending across the Euphrates-Tigris Rivers, and is bounded by two major faults (Euphrates Boundary Fault and Kirkuk Fault) that belong to the Najd Fault System. It is characterized by Mio-Pliocene formations overlain by Quaternary fluvial sediments, which extend from the Euphrates-Tigris alluvial plains to the foothill areas further north.
Taurus-Zagros *Groundwater Province*	Lies within the High Folded and Suture Zones and follows the Iraq frontier with turkey in the north and with Iran in the northeast. It comprises elevated areas built by karstified Tertiary and older carbonates with many springs discharging good-quality water, and younger clastics which form isolated to semi-isolated aquifer systems (Krasny et al., 2006).

3.2. Categorization of shared aquifers / aquifer systems

From the management point of view, and for the purpose of this paper, the aquifer systems can be categorized on the basis of:

(1) Whether or not they receive significant[3] recharge,

[3] In this paper, we consider recharge to be significant if it is observed in rising groundwater levels and insignificant if it is deduced from isotopic signatures only.

- *Renewable:* Localized and/or complex aquifers / aquifer systems receiving significant present-day recharge, i.e. those that may not be vulnerable to mining if used wisely,
- *Non-renewable:* Regional aquifers / aquifer systems receiving no significant present-day recharge, i.e. those that are vulnerable to mining regardless of how they are used;

(2) How water is retained within them (i.e. in inter-granular spaces, or in fissures, or a combination of both),

- *Porous:* Aquifer systems dominated by primary voids (pores); these are mainly alluvial sediments along river/wadi channels and foothill areas,
- *Fractured/karstic:* Aquifer systems dominated by secondary fractures and karstic features; these are mainly carbonate rocks occurring in mountain areas along the northern zone,
- *Mixed:* Aquifer systems of mixed pores and fissures; different types of rocks occurring in relatively unstable areas in which sedimentation is interrupted by magmatic activities and/or volcanic events, and

(3) The groundwater province in which they develop (see Section 3.1. above).

Applying these criteria, twenty one shared aquifers / aquifer systems are identified in the Region as shown in Table 3.

Table 3: Shared aquifers / aquifer systems occuring in the Western Asia region

Groundwater Province		**Mode of occurrence**		
		Porous	Fractured /karstic	Mixed
Arabian Peninsula	renewable	▪ Wadi Sirhan ▪ Al Hasa-AlDahira ▪ Asir-Nejran		
	non-renewable	▪ Sakaka-Rutba ▪ Mahra-Tawila/ Cretaceous Sands ▪ Biyadh-Wasia ▪ Saq-Ram ▪ Wajid	*Umm er Radhuma-Dammam:* ▪ Dibdiba ▪ Gulf ▪ Rub' al Khali-Nejd-Hadhramaut	▪ Central Hamad
Mashrek-Sinai	renewable	▪ Coastal Aquifer Basin	▪ Anti Lebanon ▪ Western Mountain Aquifer ▪ Western Galilee Basin	▪ Jebel Al Arab (Basalt aquifer)
Euphrates-Tigris		▪ Bai Hassan	▪ Jazira Tertiary Limestone	▪ Fatha/Injana (prev. L./U. Fars)
Taurus-Zagros			▪ Bekhme-Pila Spi	
Number of systems		5 renewable, 5 non-renewable	5 renewable, 3 non-renewable	3 renewable

3.3. Major constraints

A number of problems were encountered during the compilation of data/information and the literature review. Further issues emerged during the delineation and mapping of the aquifer systems. Important constraints include the following:

Limited accessibility of information: Most data/information relevant to understanding shared aquifers / aquifer systems in the region is either outdated, and in many cases obsolete, or in government files that are not accessible to the public and international organizations. Most ESCWA member states continue to update their knowledge on shared aquifers / aquifer systems without sharing it, sometimes even not among national organizations.

Data discrepancies: Since available data/information was not collected through coordinated efforts or comparable methodologies, there are often discrepancies that hinder the integration of information and interpretation beyond political boundaries. For example, recharge to the Wajid aquifer system inside Saudi Arabia was estimated at 114 MCM (British Arabian Advisory Company, 1980), 240 MCM (Ministry of Agriculture and Water, 1984), and 500 MCM (Prince Sultan Research Center for Environment, 2007). In contrast, estimates inside Yemen were 7.2 MCM (DHV, 1993), 10 MCM (Van der Gun, 1983) and 17.7 (Al Shami and Al-Dubby, 2004). As it is not known how the recharge intake areas were delineated in these different studies, and since recharge is not translated into a rate value per area unit, it s extremely difficult to reconcile the results reported in these studies.

Geographical basin VS geological formation: Shared aquifers / aquifer systems are often defined by geological formations that extend beyond geographical basins, and it is not usually known whether or not the aquifer units are hydraulically connected across such basins. This creates some discrepancy in terminology such that some studies refer to a groundwater basin[4]; others describe a specific aquifer unit as a shared aquifer. For example, ACSAD (1983) treated the Hamad plateau as one basin extending across the boundaries of four countries (Iraq, Jordan, Saudi Arabia, and Syria) although there are 6 hydrogeological regions within the plateau that constitute separate basins not extending to all the countries. In contrast, Al-Jawad et al. (2008) described individual Cretaceous formations along the south-western desert of Iraq as shared aquifers extending into Saudi Arabia.

Defining "effective" shared aquifers / aquifer systems in extensive sedimentary basins: Many non-renewable aquifer systems in the Arabian Peninsula Groundwater Province extend over thousands of kilometres inside one country before crossing its border into one or more neighbouring countries. Do we consider the entire system as shared or delineate 'effective' zone(s) within the system and, if so, how? What would this imply in terms of assessing the use (or right of use) of the different riparians and its impact on the resource? In some cases, an aquifer system is found to be too deep or too saline on one side of the political borders, which limits its present use by one or more riparian countries. Can it still be considered a shared system even if it is not really an 'effective' one?

Delineation of "individual" shared aquifers / aquifer systems in localized complex sedimentary basins: In localized basins, particularly those in folded and faulted zones such as the Anti Lebanon or the Taurus-Zagros, there are usually numerous small aquifers that exist as individual units within a political boundary in some areas, while merging with others in other areas to constitute a shared aquifer system. It becomes too difficult to delineate zones where these units act as aquifer systems and where they don't, or to define the boundaries between such systems.

[4] A groundwater basin is defined as *"physiographic unit containing one large or several connected or interrelated aquifers, whose waters are flowing to a common outlet, and which is delimited by a groundwater divide"* (UN-ESCWA and BGR, 2009)

4. BIBLIOGRAPHY

ACSAD. (1983). *Hamad Basin Studies/ Part 1: Natural and Human Resources - Annex 4 - Groundwater Resources*. Damascus.

Al-Jawad, S., Razaq, M. A., & Ahmad, A. (2008). *Transboundary Groundwater Aquifers between Iraq and Neighbouring Countries*. In Ministry of Water Resources (Ed.): Center of Groundwater Studies.

Al Shami, A. A., & Al-Dubby, S. A. (2004). *Yemen - Saudi Shared Aquifer (Wajid Sandstone)*. Sana'a: Federal Institute for Geosciences and Natural Resouces; United Nations.

American Meteorological Society. (2010). *Glossary of Meteorology* Retrieved August,25, 2010, from http://amsglossary.allenpress.com/glossary/browse?s=a&p=-25

British Arabian Advisory Company. (1980). *Water Resources of Saudi Arabia*. Ministry of Agriculture and Water. Riyadh.

DHV. (1993). *Groundwater Resources and Use in the Sa'dah Plain*. In NORADEP (Ed.): SSHARDA/UNPD.

Krasny, J., Alsam, S., & Jassim, S. Z. (2006). Hydrogeology. In S. Z. Jassim & J. C. Goff (Eds.), *Geology of Iraq*, Dolin, Prague and Moravian Museum. Prague.

Mahmoud, S., Reilinger, R., McClusky, S., Vernant, P., & Tealeb, A. (2005). GPS evidence for northward motion of the Sinai Block: Implications for E. Mediterranean tectonics. *Earth and Planetary Science Letters, 238*(1-2), 217-224.

Ministry of Agriculture and Water. (1984). *Water Atlas of Saudi Arabia; Water Resources Development*. Ministry of Agriculture and Water. Riyadh.

Powers, R. W., Ramirez, L. F., & Redmond, C. D. (1966). *Geology of the Arabian Peninsula*. U.S. Govt. Print. Off. Washington,.

Prince Sultan Research Center for Environment. (2007). *Space Images, Saudi Arabia*. In Space Image Atlas of Kingdom of Saudi Arabia (Ed.), (Vol. 38.6x28.5). Riyadh: King Fahd National Library Cataloging-in-Publication Data.

Struckmeier, W., & Richts, A. (Carographers). (2008). *Groundwater Resources of the World: scale 1:25,000,000*.

Struckmeier, W. F., Gilbrich, W. H., Gun, J. v. d., Maurer, T., Puri, S., Richts, A., Winter, P., & Zaepke, M. (Carographers). (2006). *WHYMAP and the World Map of Transboundary Aquifer Systems: Transboundary Aquifer Systems at the scale of 1:50,000,000*.

UN-ESCWA. (1992). *Water Resources Database in the ESCWA Region*. In UN (Ed.).

UN-ESCWA, & BGR. (2009). *Glossary of Shared Water Resources: Technical, Socio-economic and Legal Terminology (Unpublished, Draft Version)*: BGR, UN-ESCWA.

United Nations, Genereal Assembly. (2009). *Resolution adopted by the General Assembly: The Law of Transboundary aquifers*, 63/124 C.F.R.

Van der Gun, J. A. M. (1983). *Water Resources of the Sadah Area*. In YOMINCO/TNO (Ed.). Sana'a/Delft.

Walley, C. D. (1998). Some outstanding issues in the geology of Lebanon and their importance in the tectonic evolution of the Levantine region. *Tectonophysics, 298*(1-3), 37-62.