Application of the Resource Allocation Framework to the International Waters Focal Area of the GEF

Transboundary Aquifers

Background

UNESCO-IHP was entrusted by the Global Environmental Facility (GEF) with the development of an indicators approach paper for possible application of the Resource Allocation Framework (RAF) to Transboundary Groundwater Aquifers (TBAs) in the International Waters (IW) Focal Area. The GEF Terms of Reference (TOR) describe the scope of work required for an Indicators Approach Paper. A Transboundary Aquifers Expert Group (TBAEG) was established by UNESCO (list attached), which is composed of international senior experts in the field of groundwater resources management.

Two meetings of the TBAEG were held at UNESCO facilities in Paris on 29-30 September and 20-21 October 2008. Both meetings were financed by UNESCO-IHP.

The work of the UNESCO TBAEG has concentrated on the tasks formulated in the GEF TOR, and in particular on:

- the analysis of alternative ways to determine the GEF Benefits Index[1] (GBI) - a measure of the *potential to generate global environmental benefits* that can be accrued through the International Waters focal area action on the groundwater resources contained in transboundary aquifers.
- answering the key question: how to establish priorities for GEF support to interventions among the many transboundary aquifers in the world, and among different types of transboundary aquifers with renewable and non-renewable groundwater resources.

The proposed approach is focused on the relevance of the indicators and the feasibility of their calculation. The feasibility depends on the availability on a global scale of the data required as a basis for the calculating the indicators. The proposed approach can be conducted as a desk study, avoiding delay and additional funds.

The GEF Focal Area Strategy for the 4th Cycle provides a definition of the global environmental benefits to be accrued in the IW focal area[2].

Most of the data currently available on transboundary aquifers result from the studies conducted by the UNESCO International Hydrological Programme (IHP 6th phase 2002-2007) jointly with its partners in particular in the framework of the ISARM and WHYMAP projects with the support of the IGRAC center (UNESCO-WMO). The TBAEG considered the limited availability of globally consistent datasets for transboundary aquifers as a major determinant upon the structure to determine GEF resources allocations framework (RAF). While the first global inventory of transboundary aquifers initiated by the beginning of 2002 by the UNESCO IHP (IHP-ISARM project) is almost completed, however aquifers detailed delineation and comprehensive data sets are not yet available. Furthermore at national and regional level available data are not aggregated over

[1] The GBI has to be informed by the best available science and independent expert advice to arrive at a score, which takes account of the key targets for which outcomes are expected as a result of GEF funded interventions.

[2] The Global Environmental Benefits (GEB) identified for the International Waters (June 2007) can be summarized as follows:
IW GEB 1 - *Established/improved multi-state, international cooperation on priority water concerns*.
Accruing benefits under this category would bring about political commitments to improved multi-country cooperation supporting sustainable economic development opportunities, stability, and water-related security in transboundary water systems.
IW GEB 2 - *Transboundary action addressing water concerns catalyzed/accelerated*.
Global benefits are accrued as participating states demonstrate the ability to take effective action to reduce overexploitation of fish stocks, reduce land-based coastal pollution, and balance competing water uses in basins and aquifers.
Additional guidance from the GEF recommends *focus on aquifers requiring urgent action because of high degradation due to pollution and /or over-exploitation, high vulnerability (e.g. aquifers still in good conditions but highly vulnerable like karst aquifers, or freshwater lenses in SIDS), non-replaceability (e.g. arid areas where groundwater provides most of water, including for drinking).*

transboundary aquifers. Existing Data bases contain mainly information aggregated over administrative units on country level and are not arranged by aquifers. In many countries information on groundwater resources are scarce and when available it is difficult to extrapolate those by aquifers.

Groundwater occurrence and aquifer characteristics

Groundwater is a vast resource and its occurrence, flow and storage depend upon climate and the prevailing geological conditions. In transmissive unconsolidated sands and gravels, sandstones and limestones as well as fractured volcanic and crystalline rocks, groundwater forms **aquifers and aquifer systems.** In the set of articles on the Law of Transboundary Aquifers prepared by the UN International Law Commission with the scientific support of the UNESCO IHP (UNILC report 2008) an aquifer is defined as ; "*a permeable water-bearing geological formation underlain by a less permeable layer and the water contained in the saturated zone of the formation"* and an aquifer system is defined as; *" a series of two or more aquifers that are hydraulically connected"..* Another useful definition is given by the UNESCO – WMO Glossary (1992) where aquifer is defined as: "*a permeable water-bearing formation capable of yielding exploitable quantities of water".*

Groundwater occurs within the broad context of the hydrological cycle and being part of the environment, is in complex interrelations with it. Groundwater is a significant component of watersheds and river basins. In nature, groundwater is a key element in many geological and hydrogeochemical processes, and geotechnical factor conditioning soil and rock behaviour. Groundwater also has ecological functions, sustaining spring discharges, river base-flow, lakes and wetlands. The use of groundwater has increased significantly in recent decades due to its widespread occurrence, mostly good quality, reliability during droughts and other natural disasters and generally modest development costs. Groundwater represents 97 % of the world's freshwater resources and is the main drinking water source for more than a third of world's population. Global groundwater resources withdrawals are estimated of the average from 600 to 800 Km3/year (800 Km3 by J.Margat, BRGM-UNESCO 2008, 1000 km3 by Tushar Shah, IWMI 2004 and 600 – 700 km^3/year by Zektser and Everett, UNESCO 2004). As such groundwater is the world's subsurface most extracted raw material. In the rural areas of developing countries, in arid and semi arid regions and on islands, groundwater is the most important and safest source of drinking water. Agriculture and particularly irrigation systems in many parts of the world depend on groundwater resources.

Groundwater resources are mostly **renewable** and the renewal period range from days and weeks (in karstic rocks) to years or thousand of years in sedimentary basins. However, if present-day replenishment is very limited compared to the stored volume the groundwater resources can be considered **non-renewable**. In case that groundwater recharge relates to past Pleistocene geological period millennia ago and groundwater is stored since that time, is called **fossil** (Foster and Loucks, UNESCO-World Bank 2006).

Uncontrolled aquifers exploitation and pollution reflect in **groundwater resources degradation in terms of both, quantity and quality**. Excessive groundwater abstraction affects groundwater piezometric levels and storage in the aquifer, springs, rivers base-flow, vegetation, productivity of crops, the surface water-groundwater interface, wetlands and can also induced land subsidence. Groundwater quality can be affected by discharge of pollutants from point and diffuse pollution sources, saltwater intrusion into coastal aquifers, downward and upward influx of low water quality into exploited aquifers or by irrigation return flow. Groundwater quality can be also affected by natural hazards, particularly coastal aquifers can be very vulnerable to floods, tsunamis and typhoons. Groundwater lenses in small islands represent also a very fragile hydrological system of high vulnerability to human and natural impacts. Groundwater vulnerability to depletion and pollution is recognized as a serious social, economic, and ecological problem which in case of transboundary aquifers may generate conflicts.

The global 'loss of aquifer storage' combined with the risks to aquifer functions & to ecosystems dependent on them, needs urgent quantification. Because economic losses, translated through environmental and livelihood losses, will be difficult to reverse. The decline in resilience of ecosystems that link closely with aquifers and groundwater in the lower income countries, may reach a 'tipping point' beyond which they cannot be revived. Aquifer resources should be considered as an undeniable component of 'ecosystems', thus invoking the so called 'ecosystems approach'. Once this is accepted then the framework for the Millennium Ecosystem Assessment can be used to address both national and transboundary aquifers, thus neatly putting a value on the ecosystems services that aquifers provide.

Transboundary Aquifers

Until 2002 no regional or global estimation existed for transboundary aquifers. The Intergovernmental Council of the UNESCO International Hydrological Programme (IHP) responded to this knowledge gap at its fourteenth session (23–25 June 2000) and adopted a resolution to launch a worldwide inventory and assessment project (UNESCO ISARM). The UNESCO International Shared Aquifer Resources Management (ISARM) project objectives are to identify the transboundary aquifers in each continent, support countries in the assessment of these aquifers and formulate recommendations on their management. ISARM is a multidisciplinary project with five focal areas. The ISARM studies consider the scientific-hydrogeological, socio-economic, environmental, legal and institutional aspects related to the management of transboundary aquifers (S. Puri, UNESCO 2001).

The UNESCO ISARM is operating in response to the Member States' needs and in close coordination with different intergovernmental, governmental and international partners. The number of transboundary aquifers inventoried since 2002 is comparable to the one of international water basins (A Wolf 2002) although this number will increase in the future years due to more detailed investigations that will be conducted (IHP VII ISARM 2008-2013) in Asia and Africa: 68 transboundary aquifers have been identified in the Americas, (29 in South America, 18 in Central America, 17 in North America and four in the Caribbean), 89 in Europe, 65 in South Eastern Europe, and 39 in Africa. The ISARM Asia inventory is currently in its initial phase and 12 transboundary aquifers have been identified in Asia so far.

The preliminary study and assessment of TBAs has not yet been carried out everywhere with uniform intensity and not always according to the same methodological approach. It is foreseen that the Global Groundwater Information System (GGIS; at www.igrac.nl) established by the UNESCO and WMO International Groundwater Resources Assessment Centre, (IGRAC) should collect and compile the necessary data to provide more detailed additional information. The World Hydrological Map (WHYMAP) project, lead by UNESCO and BGR, is providing an essential contribution with its mapping programme presenting an overview of the global groundwater resources and thus a visualization of most of the inventoried transboundary aquifer systems.

Inventories, maps and data sets compiled in the framework of ISARM show that TBAs are widespread over the entire globe and some of them extend over distances of several hundred kilometers (J.Margat). These systems have a crucial role in supporting livelihoods by the provision of drinking water, water for irrigation, terrestrial and coastal ecosystems, and for socio-economic development of many regions of the world. TBAs underlie an important percentage (> 15 %) of the earth's total land surface. A provisional breakdown by continent of the percentage of land area covered by transboundary aquifer systems is as follows: North America: less than 10 %, South and Central America: 25 %, Europe: 10%, Africa: 30%, Asia: 6 %, and Australia / Oceania: 0%.

TBAs coverage represents an average of 40% of the land surface in the Middle-East and North Africa. In arid zones TBAs can play a strategic role in supporting fragile ecosystems and providing drinking water supply. In some of these arid zones GEF IW has recently initiated studies of TBAs (f.e. Iullemeden Aquifer System, Nubian Sandstone Aquifer System). Further, projects are ongoing at different locations spread over the world, e.g. the GEF IW Guaraní aquifer project, the Heilongjiang-Amur groundwater system, and others. The information for each of these aquifers has not been fully inventoried yet but may add more detail to the referenced global and regional information sources.

The scientific principles involved in the sound management of transboundary aquifers are well known and understood by groundwater specialists. These include an appreciation of the full system, i.e. from sources of recharge, to the regions of discharge, as well as the quantity and quality issues along the flow path. Usually the system is well described by the use of conceptual models through which groundwater specialists from across national boundaries can communicate well. However, sustainable management of transboundary aquifers goes well beyond developing consistent conceptual models. It needs in addition, harmonisation of *legislation*, and *institutional structures* and consistency in *socio-economics* drivers and also a coherent application of the *environmental protection* criteria.

Until the year 2002 there was no legal instrument available to comprehensively deal with TBAs by addressing its specific characteristics at the global level. In order remedy this gap the UN International Law Commission (UNILC), which is in charge of the codification and progressive development of international law, has included in its program of work the topic of Shared Natural Resources, divided into three sub-topics: transboundary groundwaters, oil and gas. The UNILC decided to start by the topic of 'transboundary groundwaters'. Since the year 2003 UNESCO IHP and UNILC have cooperated in the preparation of an international legal instrument for the management and use of transboundary aquifers that resulted in a complete set of articles on The Law of Transboundary Aquifers (UNILC report July 2008) that was presented in October 2008 at the UN General Assembly. The Un General Assembly (UNGA) may adopt a Resolution on the articles in the near future. This allows expecting an increased consideration of TBAs by Member States and improved recognition at regional and international level. The articles represent a milestone in the international recognition of the crucial function of transboundary aquifers for humans and the environment.

The articles provide clear guidance and a reference to member states and national regional and international organizations on the use and management of shared aquifer resources. The articles define a transboundary aquifer (TBAs) as "*an aquifer and/or aquifer system that exists in more than one state"(UNICL, 2008*). TBAs may receive the majority of its recharge in one country whereas the majority of its discharge may occur in another country or countries (Fig. 1). The articles recommend the setting up of a conceptual model of a aquifer system as an important initial stage in defining the transboundary aquifer behavior and provide the basis for the determination of further data requirements needed for the evaluation of groundwater resources in terms of quantity and quality and assessment of their vulnerability.

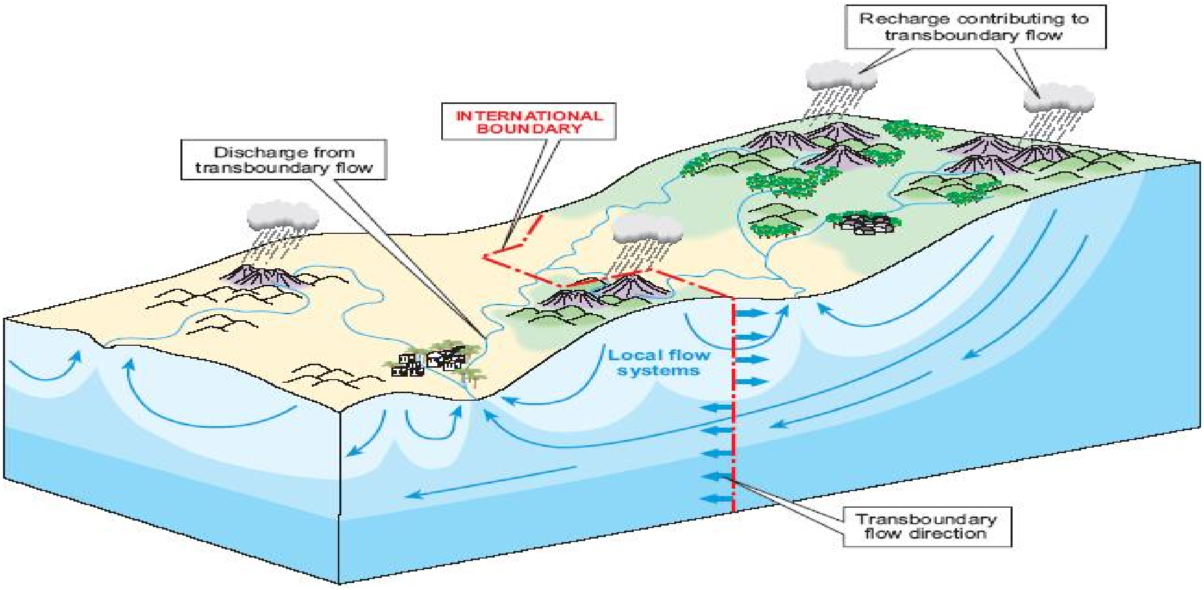


Figure 1 Schematic illustration of a transboundary aquifer (UNESCO ISARM Framework Document, S. Puri modified, UNESCO 2001)

Global Groundwater Resources Maps and related datasets

The development of a GBI index, and related set of indicators requires 1/knowledge of basic characteristics of TBAs groundwater system and its vulnerability, 2/ accessibility of reliable groundwater and other relevant data, and 3/ availability of suitable maps depicting groundwater resources quantity, quality and vulnerability. The work of the TBAEG was based – inter alia - on the results of the studies conducted by the UNESCO IHP in its 6th phase (2002-2007). This includes the ISARM, WHYMAP and IGRAC datasets as well as the publication on *Groundwater resources sustainability indicators* (UNESCO IHP Series on Groundwater No 14, 2007).

The analysis of the available datasets referring to transboundary aquifers identified the following data sources on TBAs organized at the global/regional level:

1. The ISARM Project, UNESCO IHP: Some 273 transboundary aquifers have been identified so far. Approaches followed include many similarities, but there are substantial differences in the degree of aggregating subsurface hydrogeological units into the transboundary aquifer systems. Moreover, horizontal transboundary aquifer system limits are available for not more than one-third of the mentioned number of aquifers.
2. UNESCO's WHYMAP, (2006 and 2008) provides a global picture on the location, characteristics and lateral extent of 98 main transboundary aquifers or groups of aquifers. Other UNESCO-IHP regional maps and databases complement WHYMAP's synoptic global maps with more detailed information, including maps, organized at the regional level.
3. AQUASTAT, FAO's information system on water and agriculture and FAO's atlas of water resources used for irrigation at river basin and country scales provide sufficient information for the development of groundwater resources abstraction indicators.
4. IGRAC (UNESCO-WMO groundwater center) has produced global groundwater indicator maps (groundwater abstraction as a percentage of average groundwater recharge, total exploitable non-renewable groundwater resources / annual abstraction on non-renewable groundwater resources, dependence of agricultural population on groundwater) for the UNWWAP and the UNESCO IHP project on development of groundwater resources sustainability indicators. Furthermore, IGRAC's

Global GIS includes world-wide coverage of many variables and indicators of potential relevance for the GBI.

5. Many useful global groundwater related data sets and maps are available in the recently published book "Les eaux souterraines dans le monde" (Margat, UNESCO-BRGM 2008).

6. In many countries hydrogeological and vulnerability maps are published showing an overall picture of aquifers in areas closely to the boundaries of riparian countries.

7. Groundwater data collected by various satellite remote sensing programmes (e.g. GRACE, ESA) are spatially and temporally coherent and provide a consistent, political boundary-free view of several groundwater elements useful for formulation of TBAs indicators.

It has been concluded that these data and maps represent a valuable basis for the characterization of many TBAs in the world, although the process of calculating the GBI for groundwater may be feasible only for those aquifer systems that have been clearly delineated.

Table 1 lists maps and other documents that allow characterizing the TBAs to some extent and that may help defining indicator values.

#	Name of map or atlas/report/publication	Author and year	Other bibliographic information	General description and/or remarks
A	Global documents			
A-1	WHYMAP – Groundwater Resources of the World - Transboundary Aquifer Systems, scale 1: 50 M. Special Edition for the 4th World Water Forum, Mexico City, March 2006.	W. Struckmeier, A. Richts et al., 2006	Prepared by BGR-led WHYMAP team, under the auspices of UNESCO-IHP, UNESCO-IGCP, BGR, CGMW, IAEA and IAH.	World-wide compilation of selected important TBAs known by 2005. Location symbolically indicated, without strict delineation of lateral boundaries.
A-2	WHYMAP – Map of Groundwater Resources of the World, scale 1: 25 M.	W. Struckmeier, A. Richts et al., 2008	Prepared by BGR-led WHYMAP team, under the auspices of UNESCO-IHP, UNESCO-IGCP, BGR, CGMW, IAEA and IAH.	Global picture of groundwater resources, focusing on the world's groundwater reservoirs with their storage and recharge.
A-3	Les eaux souterraines dans le monde.	Jean Margat, 2008	BRGM Editions, Printed by UNESCO, © UNESCO, BRGM, 2008.	Geographically focused description of the world's groundwater and its use (contains many world maps)
A-4	World Map of the Köppen-Geiger Climate Classification updated.	Kottek, Grieser, Beck, Rudolf & Rubel, 2006	Meteorologische Zeitschrift, Vol 15, no 3, pp. 259-263, Gebrüder Borntraeger.	Map can be downloaded in different formats from http://koeppen-geiger.vu-wien.ac.at. Resolution 0.5 o latitude/longitude.
A-5	World Land Use Map	Anonymous	Downloadable from a website of HowStuffWorks, owned by Discovery Communications LLC: http://maps.howstuffworks.com/	Map without references to authors, year or methodologies followed, but making clear distinction between agricultural zones of different nature and intensity (commercial agriculture/ dairying/livestock ranching/nomadic herding/ subsistence agriculture/ primarily forestland/limited agricultural activity).
A-6	List of Ramsar sites in the World	The Secretariat of the Ramsar Convention on Wetlands, Gland, Switzerland; 31 October 2008	Downloadable at http://www.ramsar.org/sitelist.doc	Ramsar sites are listed by country and identified by name and geographic coordinated (rounded to degrees).
A-7	Map of Ramsar sites in the World	Wetlands International, 2005	To be accessed at http://www.wetlands.org/reports/rammap/mapper.cfm	

A-8	Global Overview in IGRAC's GGIS	IGRAC, 2005	To be accessed at http://www.igrac.nl	Global Overview is one of the modules of IGRAC's Global Groundwater Information System (GGIS). It presents for countries and fro Global Groundwater Regions standard set of attributes (variables and indicators) relevant to groundwater. Incorporates statistics originating from AQUASTAT, EUROSTAT, WRI and many other global, regional and national data sources.
B	Regional documents			
B-1	Sistemas acuíferos transfronterizos en las Américas: Evaluación preliminar UNESCO-OAS,.ISARM AMERICAS	Nelson da Franca, Michela Miletto, Maria Concepción Donoso et al., 2007	Programa UNESCO/OEA – ISARM Americas. PHI-VI/Serie ISARM Americas No 1, Montevideo/Washington DC, 2007.	Atlas presenting brief descriptions of 68 identified TBAs and containing maps showing their lateral boundaries.
B-2	Marco legal e Institucional en la Gestión de los Sistemas acuíferos transfronterizos en las Américas. UNESCO-OAS, ISARM AMERICAS	Nelson da Franca, Raya Marina Stephan, Maria Concepción Donoso et al., 2008	Programa UNESCO/OEA – ISARM Americas. PHI-VII/Serie ISARM Americas No 2, Montevideo/Washington DC, 2008.	Report presenting a summary of the legal and institutional setting relevant for the management of transboundary aquifers in the Americas.
B-3	Inventory of Transboundary Groundwaters	A. Almássy & Zs. Buzás, 1999	UN/ECE Task Force on Monitoring and Assessment, Working Programme 1996/1999, Volume 1, Lelystad, 1999.	Report with location maps and attributes of 89 TBAs in Europe. No aquifer delineations given. Only 25 out of 37 countries have responded.
B-4	Transboundary aquifers' data base and maps of South Eastern Europe. UNESCO ISARM Balkans	Jacques Ganoulis, UNESCO Chair, Thessaloniki; continuously updated	To be consulted via the Internet: http://www.inwg.gr	Data base and interactive maps of 65 TBAs in SE Europe and the Eastern Mediterranean. No aquifer delineations given.
B-5	Our waters: Joining hands across borders. First assessment of transboundary rivers, lakes and groundwaters.	UNECE, 2007 with UNESCO Chair INWEB TABS	Prepared under the auspices of the Working Group Monitoring and Assessment of the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes.	Includes the inventory of 51 transboundary aquifers in South-Eastern Europe, and 18 in the region Caucasus and Central Asia. UNESCO chair INWEB TBAs for the ISARM Balkans

B-6	Managing shared aquifer resources in Africa. UNESCO ISARM Africa	B. Appelgren, (editor), 2004	Proceedings of the Tripoli Workshop 2002, held within the framework of the IHP-ISARM Programme. IHP-VI Series no 8. Published by UNESCO, Paris, 2004.	Well documented proceedings, identifying and characterizinmg 38 TBAs, including eight large ones in N. Africa. For these large ones lateral boundaries are delineated.
B-7	UNESCO ISARM-SADC Inventory of Transboundary aquifers of and information flow	Vasak, L, 2008	Draft report IGRAC, 2008.	Shows 21 TBAs, six of which have been delineated.
B-8	Transboundary aquifers in Asia with special emphasis to China. UNESCO ISARM Asia	Zaisheng, Wang Hao & Chai Rui;	China Geological Survey & China University of Geosciences, 2006.	Shows 12 TBAs, with their approximate locations indicated by ellipses.

Table 1: Relevant global and regional maps or other documents containing transboundary aquifer location maps or characterizing such aquifers

The WHYMAP (Item # A-1, Table 1, WHYMAP, 2006) provides a global picture of transboundary aquifers. The map, due to scale limitation it is presenting only some of the aquifers inventoried by the ISARM project (only 98 aquifers or groups of aquifers if they are too small to be individually shown at the scale of the map) and does not present the detail available in the regional documents, in particular the accurate delineation of aquifers.

The Regional documents listed in Table 1 (Table 1, items # B-1 through # B-8) contain the available information on the presence, location and lateral extent of transboundary aquifers in each of the respective regions. Some of the maps, reports and data bases are providing important contextual information that may be of interest for defining indicator values. Even in the most up-to-date regional publications (item 2 # 4 through 8), the exact delineation of the aquifers is shown for only one-third of the identified transboundary aquifers: those in the Americas, and part of those in South East Europe and Africa.

Many countries have published maps showing an overall picture of their main aquifers and groundwater resources quantity and quality. Such maps may serve for more precise delineation of transboundary aquifers particularly in areas close to international boundaries. A global information system that may assist in this respect is WHYMAP's Web Mapping Application that contains a large number of national and regional hydrogeological maps.(http://www.whymap.org/cln_092/nn_354296/whymap/EN/Web__Mapping/web__mapping__node__en.html?__nnn=true).

Within the framework of the UNESCO IHP VII phase, BGR/WHYMAP and IGRAC are presently preparing an updated version of the world map of transboundary aquifers, to be presented at the 5th World Water Forum at Istanbul, in March 2009. The preparation of such a map it is a time-consuming and expensive activity and requires the participation of experts from different regions and from the UNESCO network.

Data sets for SIDS follow the same methodology as outlined below for transboundary aquifers. Information is available through UNESCO's Sustainable Living in Small Island Developing States Programme and is available via the UNESCO Portal
(http://portal.unesco.org/fr/ev.php-URL_ID=12123&URL_DO=DO_TOPIC&URL_SECTION=201.html)

Analytical approach to identifying possible indicators relevant to TBAs from global databases and information systems.

Identification and formulation of possible TBAs indicators is the first step toward the development of a GBI which is a measure of the potential of each participating country to: 1/ generate global environmental benefits in a relevant GEF IW focal area and 2/ address more urgent and vulnerable situation. Transboundary aquifer related benefits will be evaluated with the view that GEF funding is cost-effective and directed to high benefit groundwater bodies and countries.

The proposed set of groundwater related indicators for TBAs reflects the present status in groundwater data reliability and availability, which is somewhat restricted due to the fact that national groundwater monitoring networks have not yet been established in many countries. Reliability and mutual comparability of existing groundwater data is often low, because groundwater monitoring methods, sampling procedures and data reporting are not standardized at the international level.

The development of more sophisticated indicators will depend on countries' capabilities to cope with these challenges related to data collection and management.

It was agreed that the potential benefits to be achieved in the case of TBAs depend on three sets of variables[3]:

a) Value and functions of the transboundary aquifer considered

b) Its current importance for human, social, ecological and environmental services

c) Its vulnerability to anthropogenic and natural stresses, considering probability, magnitude and risk of such stresses

Based on these variables, and on the available global/regional datasets and maps the following three TBAs sub-indexes have been considered feasible and relevant, each of them depending on a series of relevant indicators:

1/ TBAs intrinsic value and functions (I_{IV}).

2/ Human and environmental dependency on TBAs (I_{HE}).

3/ TBAs Vulnerability to stress (I_{RS}).

Both indicators and sub-indexes are shown in Figure 2 and Table 2, together with an indication of the information source recommended for each.

1/ TBAs intrinsic value and functions sub-index

The sub-index is is based on four indicators

a- Mean annual rate of current groundwater recharge,
b- Potential storage capacity (inclusive of renewable, non-renewable and fossil aquifers)
c- Intrinsic vulnerability
d- Natural Quality (based on electric conductivity EC , chloride Cl, pH standards for drinking water)

Those indicate:

- Aquifer recharge that is here considering mean annual precipitation, climatic conditions and geographical characteristics. Groundwater recharge is the replenishment of an aquifer with water from the land surface. It is usually expressed as an average rate of millimetres of water per year, similar to precipitation.

- Quantitative value considering the amount of stored groundwater resources

- Qualitative (natural groundwater quality evaluated on widely available data – e.g. electric conductivity, chloride, pH or on more complex groundwater analysis if accessible).

- Intrinsic vulnerability (Guidebook on mapping groundwater vulnerability –UNESCO-IAH Volume 16 , Heise 1994). This is defined solely as a function of hydrogeological factors due to the natural characteristics of an aquifer, the rocks that form the system and of the overlying soil and geological material. It is mainly based on the

[3] The assumption here is that institutional-legal-political and socio-economic aspects affecting the achievement of benefits will be included in the next phase of GEF indicators development in separate GEF Performance Index (confer to Annex 2 and 3).

natural chemical physical properties of an aquifer and its position in the subsurface. These characteristics are well known and descriptions are widely available in literature. TBAs data can be extrapolate from global (IGRAC, WHYMAP 2008, ISARM) regional and national documents and data sets. Simple variables based on available data will be used for aquifer intrinsic vulnerability assessment (aquifer type – small islands aquifers, shallow water table, coastal, karstic, deep unconfined, confined, non-renewable, fossil, and – rate of recharge).

- Quantity and quality indicate the value of aquifer for drinking or other purposes. Classification of the proposed indicators gives basic notion about the importance of TBAs groundwater resources for human, social and economic development and their ecological and environmental functions.

2/ Human and environmental dependency sub-index

The sub-index is based on social and ecological indicators. Data about population dependency on groundwater supplies on country level are available in national drinking-water related statistics and can be derived on aquifer level. Data scarcity however, limits in many cases the possibility of implementing an indicator related to the dependency upon groundwater for agricultural and other uses. The Ramsar database will be used to identify aquatic ecosystems sensitive to groundwater depletion (groundwater level decline) and/or quality degradation (pollution). Evaluation of ecosystems dependency on groundwater and formulation of relevant indicator will be based on their position in the aquifer (recharge or discharge area, flow conditions and direction).

3/ Vulnerability to stress sub-index

The sub-index is based on indicators expressing current human and natural stresses on aquifers and their groundwater resources. Vulnerability to stress (i.e. specific vulnerability, Guidebook on Mapping Groundwater Vulnerability, 1994) is assessed in terms of the degree of the susceptibility of the groundwater system to human stresses (pollution, depletion) and natural (climate variability and natural disasters) impacts and climate change which may prove to be detrimental in space and time to the present and future uses of groundwater resources. This is reflecting undesired potential changes of the groundwater system as a result of stresses.

- The indicator of groundwater vulnerability to depletion in principle can be based on groundwater recharge and aquifer potential storage capacity and can be coupled with groundwater-level measurements if such data are available.
- The indicator of groundwater vulnerability to pollution is focused specifically on groundwater diffuse pollution produced by spatially extended intensive agricultural activities.

Evaluation of both vulnerability to depletion and pollution related indicators have to consider distance of the impacted groundwater from country borders. Development of an indicator expressing TBAs vulnerability to climate variability and change and natural disasters (e.g floods, droughts, tsunamis, storms) can be evaluated with respect of aquifers type (e.g. shallow, coastal, karstic) and location (semi arid and arid zones, coastal areas, SIDS).

A Low 1, Moderate 2 and High 3 scoring will be applied for each indicator. In some cases a simpler 1-2 scoring system will be utilized. The sum of the indicators scores will rate of sub- indexes I_{IV}, I_{HE}, and I_{VS}. The Global Benefit Index (GBI) will be a function (weighted sum, product or other type of function) of these sub-indexes:

$$GBI = f\,(I_{IV}, I_{HE}, I_{VS},)$$

As an example, should the TBAs intrinsic value and functions be considered as the most important sub-index (in case that amount of stored water in aquifer is not significant or its quality is low, aquifer scoring will be low regardless of other sub-indexes) and assuming GBI to be calculated as a weighted sum, then I_{IV} sub-index may be weighted multiplied by 2 and the GBI is then expressed as follows:

$$GBI = 2 \times I_{IV} + I_{HE} + I_{VS}$$

The proposed analytical approach for the identification of indicators, sub-indexes and GEB – Index relevant to transboundary aquifers based on present status of global databases and information systems and global and regional groundwater resources maps has been tested on transboundary aquifers in South America (Annex 1).

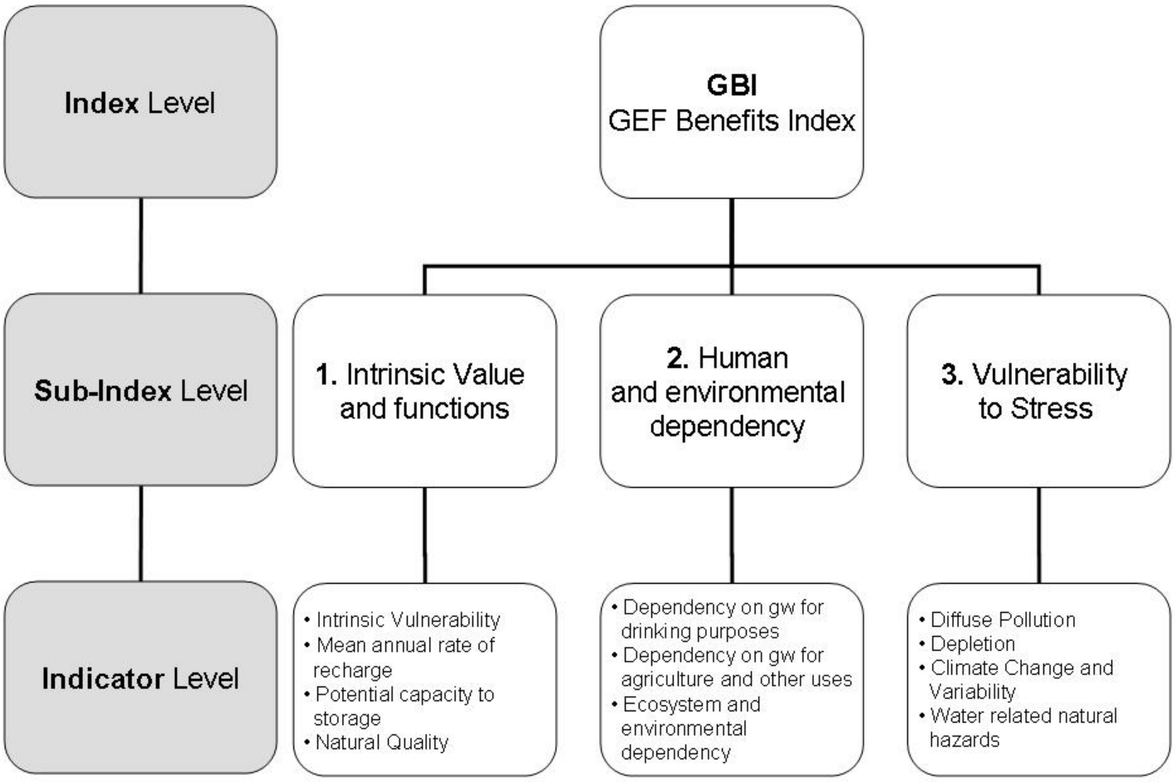


Figure 2: Conceptual relation between the GEF Benefits Index (GBI), Sub-Indices and indicators

Sub-Index	Indicator	Classification		Proxies (Indexes according to the Table .1)
1. Intrinsic Value and functions	• Mean annual rate of current groundwater recharge	1	Low < 20 mm/year	A – 2, A – 1, A – 3, A - 8
		2	Medium 20 – 100 mm/year	
		3	High > 100 mm/year	
	• Potential storage capacity (inclusive of non-renewable and fossil aquifers)	1	Low (areas with local and shallow aquifers)	A – 2, A – 3, A - 8 B-1 – B-8
		2	Medium (areas with complex hydrogeological . structures)	
		3	High (major groundwater basins)	
	• Intrinsic vulnerability	1	Low (deep confined aquifers)	A – 2, A – 3, A - 8 B-1 – B-8
		2	Moderate (confined aquifers and deep unconfined aquifers)	
		3	High (shallow, coastal, karstic aquifers, aquifer lens in small islands)	
	• Natural quality (based on electric conductivity EC , chloride Cl, pH standards for drinking water)	1	Low quality	A – 2, A – 3, A - 8 B-1 – B-8
		2	good quality (EC, Cl, pH fulfil drink. Wat. stand.	
2. Range of human and environmental dependency	• Dependency on groundwater for drinking water proxy (as percentage of total drinking water use)	1	Low (< 20%)	A - 8 B-1 – B-8, WWAP, WWDRs, FAO- Aquastat, national statistics
		2	Medium (20-50%)	
		3	High (> 50%)	
	• Dependency on groundwater for agriculture and other uses (as percentage of total water use)	1	Low (< 20%)	A – 5, A - 8 B-1 – B-8 FAO-Aquastat, national statistics,
		2	Medium (20-50%)	
		3	High (> 50%)	
	• Ecosystem dependency on groundwater	1	no dependency	A – 2, A – 6, A- 7
		2	dependency	
3. Vulnerability to stresses[4]	• Vulnerability to diffuse pollution risk (as percentage of total aquifer area)	1	low (spatial extent of intensive agricultural activities < 20%)	A – 3, A – 5, A - 8 FAO world map on intensive agriculture areas, B-1 – B-8
		2	Moderate (spatial extent of intensive agricultural activities 20-50%)	
		3	High (spatial extent of intensive agricultural activities > 50%)	
	• Vulnerability to depletion (based on groundwater recharge and aquifer potential storage capacity, coupled with	1	Low (recharge > 100 mm/year, high gw. Storage, seasonal gw. table fluctuation)	A – 2, A – 3, A – 8 B-1 – B-8

[4] Probability of occurrence and magnitude of stresses will need separate indicators to be defined yet, e.g. likely occurrence of stresses of pollution (pollution sources), depletion (very high demands for groundwater) and climate change (predicted change). In order to define an indicator of risk (risk=stress x vulnerability).

	groundwater table measurements data (if available) and rate of water withdraw if known	2	Moderate (recharge < 100 mm/year, limited gw. storage)	
		3	High (recharge < 20 mm/year, low gw. Storage, long term gw. table decline)	
	o Groundwater climate variability and change risk	1	Low (other aquifers in different climate zones)	A – 2, A – 3, A – 4, A – 8, B-1 – B-8 G-WADI
		2	Moderate (aquifers in semi arid zone- recharge < 20 mm/year)	
		3	High (coastal and SIDS aquifers, shallow water table aquifers, aquifers in arid zones-recharge < 2 mm/year)	

Table 2: The table displays the three sub-indices, which form the GEF Benefits Index (GBI). Each sub-index is based of a set of indicators. For each indicator, different classes are assigned; higher numbers indicate priority to be given in terms of GEF support. The proxies indicate the data source as a basis for decision. Table reflects the current work progress and will be further more elaborated. (Note: For the viability test reported in Annex 1 some modifications were made in the set of the indicators and their calculation. This was mainly done for pragmatic reasons, in response to data availability).

Concluding remarks

The proposed indicators provide a coherent analytical approach to a GBI for TBAs. The composition of the indicators reflects present status in availability of groundwater data which in case of transboundary aquifers are scare. Lack of data have resulted in unsatisfactory knowledge of many transboundary aquifers and are also a serious limitation in the formulation of more sophisticated indicators. The need for groundwater monitoring and internationally coordinated effort to collect and evaluate groundwater data and data exchange between countries sharing transboundary aquifers is therefore stressed. Nevertheless proposed indicators are based on observable and measurable data and their implementation can provide reasonable information about the present state of transboundary aquifers and human and natural stresses on their functions. The proposed indicators can support GEF IW Resources Allocation Framework (groundwater) based on cost-effective use of GEF funding with the scope to produce high priority transboundary benefits. However, we are still in a process of learning and gradual adjustment and it is expected that new international programmes attention to TBAs should improve and the proposed set of groundwater indicators and sub-indexes could then be more elaborated and precise .

Examples of GEF – IW – Groundwater socio economic indicators and legal indicators are given in the Annexes 2 and 3. Formulation of such indicators is possible only in limited number of transboundary aquifers because relevant economic and legal data are not widely available and mostly on country, not aquifer, level. Example of formulation of climate change factor within an integrated GBI IW TBAs indicator at the national scale is attached in the Annex 4.

Annex 1: Indicators, sub-indexes and GBI to be used for resources allocation: Summary of methodology and an example of application for individual TBAs – South America

Purpose and methodology

The purpose of this annex is to report on testing the viability of calculating the GBI-index on the basis of three sub-indices that – in turn – each are based on a number of indicators. The index GBI for any transboundary aquifer is calculated simply as a linear combination of values of the three sub-indices:

$$GBI = (a.I_{iv} + b.\ I_{dep} + c.I_{risk})/(a+b+c)$$

in which:
a, b and c are weighting factors
I_{iv} = sub-index expressing intrinsic value of the aquifer
I_{dep} = sub-index expressing human and ecosystem dependency on the aquifer
I_{dep} = sub-index expressing the risks related to the aquifer

In a similar way, each sub-index is computed as a linear combination of values of a number of indicators:

$$I_x = (d.x_1 + e.x_2 + \ldots\ldots + f.x_n)/(d+e+ \ldots.+f))$$

in which:
d, e and f are weighting factors
x_1 , x_2 , ……. x_n are values of indicators related to sub-indicator I_x.

The viability of evaluating the proposed indicators was tested on the basis of the 29 transboundary aquifers identified in South America. For simplicity and transparency, each indicator may have a score 1, 2 or 3. The derived sub-indices and the GBI were also defined in such a way that their scores range on the 1.0 to 3.0 interval.
During this testing process a few of the initially proposed indicators were deleted. A proposed vulnerability indicator (under the intrinsic aquifer value index) was deleted because vulnerability is already addressed under the subindex expressing the risks related to the aquifer (avoidance of double-cunting). Two other indicators (‘dependency on groundwater for drinking water’ and ‘dependency on drinking water for agriculture, etc.’) were deleted because of difficulties in locating adequate information for their calculation, while a new one was introduced (‘human dependency on groundwater) to replace the two deleted ones. Table A1-1 shows the indicators adopted and how they are evaluated.

Results of the test

The results of the test are shown in Table A1-2. Note that subjective values of the weighting factors were chosen. They can be adjusted according to the user’s views. The GBI ratings for the 29 transboundary aquifers range from 1.2 to 2.5 (on a scale ranging from 1.0 to 3.0). Although the methodology is very simple there is confidence that the ranking reflects properly the main criteria adopted for prioritizing. Furthermore, the scores of the sub-indices help understanding which main factor causes a low or high GBI score.

Conclusions

In order to make evaluation possible on the basis of easily available global or regional data sources, both the indicators and the calculation of their scores had to be set on a rather simple footing. Using the resulting simple methodology summarized in this annex, it appeared to be viable to determine credible scores for a set of indicators for each of the 29 transboundary aquifers in South-America. It is expected that this viability will apply for other regions in the world as well, even there where lateral boundaries of transboundary are not accurately known. Modifications of the methodology, e.g. adding additional indicators, can easily be introduced.

Table A1-1 – Adopted indicators and their scores determined

No	Indicator	Score	Criteria for scores	Information sources used
Related to I_{iv} (sub-index expressing intrinsic value of the aquifer)				
1	Groundwater recharge	1	Low: 0-20 mm/a	WHYMAP 2008
		2	Medium: 20-100 mm/a	WHYMAP 2008
		3	High: > 100 mm/a	WHYMAP 2008
2	Groundwater storage capacity	1	Low: mainly local/shallow aquifers (brown)	WHYMAP 2008
		2	Medium: complex hydrogeological structure (green)	WHYMAP 2008
		3	High: major gw basins (blue)	WHYMAP 2008
3	Natural groundwater quality	1	Low: if info sources mention limitations	WHYMAP 2008; PHI/ISARM-Americas 2008
		2	Moderate: some restrictions	WHYMAP 2008; PHI/ISARM-Americas 2008
		3	High: default	WHYMAP 2008; PHI/ISARM-Americas 2008
Related to I_{dep} (sub-index expressing human and ecosystem dependency on the aquifer)				
4	Human dependency on groundwater	1	Low: Groundwater abstraction < 20 % of total water abstraction	IGRAC's GGIS
		2	Medium: Groundwater abstraction < 20 % of total water abstraction	IGRAC's GGIS
		3	High: Groundwater abstraction < 20 % of total water abstraction	IGRAC's GGIS
5	Ecosystem/environment dependency	1	Low: default	
		2	Medium: coastal lowlands	Topographic map
		3	High: ecological Ramsar site included	Ramsar database
Related to I_{risk} (sub-index expressing aquifer risks)				
6	Groundwater pollution risk	1	Low: subsistence agriculture, forestry, herding etc.	World land use map
		2	Medium: livestock ranching	World land use map
		3	High: commercial agriculture, dairy farming	World land use map
7	Groundwater depletion risk	1	Low: humid climates	World climate map (Köppen-Geiger updated)
		2	Medium: temperate (semi-)arid climates (Cw, Cs)	World climate map (Köppen-Geiger updated)
		3	High: Arid climates (BW, BS)	World climate map (Köppen-Geiger updated)
8	Climate change risk	1	Low: Default	
		2	Medium: (semi-)arid or coastal lowland	World climate map and topographic map
		3	High: (semi-)arid and coastal lowland	World climate map and topographic map

Annex 1 SUMMARY OF INDICATORS, SUB-INDICES AND GEB-INDEX to be used for Resources Allocation Framework GEF-IW (Groundwater)

NOTE: This summary is based on the estimates of indicator values as shown and explained under the subsequent workbook sheets. For simplicity, GEB index is calculated as a weigthed sum of the sub-indices

				SUB-INDICES			INDICATORS									
			GBI-INDEX	**INTRINSIC VALUE**	**DEPENDENCY**	**RISK**	Recharge	Storage capacity	Natural GWater quality	Dependency for drinking	Dependency for agric etc	Human dependency on gw	Ecol/envir. dependency	Pollution risk	Depletion risk	Climate change risk
		Range:	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3
				Weighting factors for incorporation into next higher index:												
Scores for indivividual TBA's - South America				**1**	**2**	**3**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**1**	**1**	**1**
Countries	*ID*	*Name*														
CO-PA	1S	Choco-Darién	**1,2**	2,0	1,0	1,0	3	1	2	2	2	1	1	1	1	1
CO-VE	2S	Táchira-Pamplonita	**1,4**	2,3	1,0	1,3	2	2	3	2	2	1	1	2	1	1
CO-VE	3S	La Guajira	**2,2**	2,3	1,5	2,7	2	3	2	2	2	1	2	3	2	3
BR-GY-VE	4S	Grupo Roraima	**1,2**	2,0	1,0	1,0	2	1	3	2	2	1	1	1	1	1
BR-GY	5S	Boa Vista-Serra do Tucano-North Savanna	**1,3**	2,0	1,0	1,3	2	1	3	2	2	1	1	2	1	1
GY-SU	6S	Zanderij	**1,3**	2,0	1,5	1,0	2	1	3	2	2	1	2	1	1	1
GY-SU	7S	Coesewijne	**1,5**	2,0	1,5	1,3	2	1	3	2	2	1	2	1	1	2
GY-SU	8S	A-Sand/B-Sand	**1,4**	1,7	1,5	1,3	2	1	2	2	2	1	2	1	1	2
BR-GF	9S	Costeiro	**1,7**	2,3	1,5	1,7	3	1	3	2	2	1	2	2	1	2
CO-EC	10S	Tulcán-Ipiales	**1,2**	2,3	1,0	1,0	3	1	3	2	2	1	1	1	1	1
EC-PE	11S	Zarumilla	**1,9**	1,7	1,5	2,3	1	1	3	2	2	1	2	1	3	3
EC-PE	12S	Puyango-Tumbes-Catamayo-Chira	**1,6**	1,7	1,0	2,0	1	1	3	2	2	1	1	1	3	2
BO-BR-CO-EC-PE-VE	13S	Amazonas	**2,0**	3,0	3,0	1,0	3	3	3	2	2	3	3	1	1	1
BO-PE	14S	Titicaca	**2,5**	2,0	3,0	2,3	1	2	3	2	2	3	3	3	2	2

BO-BR-PY	15S	Pantanal	**2,0**	2,0	3,0	1,3	2	1	3	2	2	3	3	2	1	1
BO-PY	16S	Agua Dulce	**1,8**	1,7	2,0	1,7	1	1	3	2	2	3	1	1	2	2
BO-CL	17S	Ollagüe-Pastos Grandes	**2,0**	2,0	2,0	2,0	1	2	3	2	2	3	1	1	3	2
CL-PE	18S	Concordia/Escritos-Caplina	**2,0**	2,0	1,5	2,3	1	2	3	2	2	1	2	1	3	3
BR-PY	19S	Aquidauana-Aquidabán	**1,4**	2,7	1,0	1,3	2	3	3	2	2	1	1	2	1	1
BR-PY	20S	Caiuá/Bauru-Acaray	**1,3**	2,7	1,0	1,0	2	3	3	2	2	1	1	1	1	1
AR-BR-PY-UY	21S	Guaraní	**1,7**	2,3	2,0	1,3	2	3	2	2	2	1	3	2	1	1
AR-BR-PY-UY	22S	Serra Geral	**1,4**	2,7	1,0	1,3	2	3	3	2	2	1	1	2	1	1
BR-UY	23S	Litoráneo-Chuy	**1,7**	2,0	1,5	1,7	2	1	3	2	2	1	2	2	1	2
BR-UY	24S	Permo-Carbonífero	**1,3**	2,0	1,0	1,3	2	1	3	2	2	1	1	2	1	1
AR-UY	25S	Litoral Cretácico	**1,3**	2,0	1,0	1,3	2	1	3	2	2	1	1	2	1	1
AR-UY	26S	Salto-Salto Chico	**1,4**	2,3	1,0	1,3	3	1	3	2	2	1	1	2	1	1
AR-BO	27S	Puneños	**1,8**	2,0	2,0	1,7	1	2	3	2	2	3	1	1	2	2
AR-BO-PY	28S	Yrendá-Toba-Tarijeño	**1,7**	1,3	2,0	1,7	1	1	2	2	2	3	1	1	2	2
AR-CL	29S	Cóndor-Cañadón del Cóndor	**1,7**	2,3	1,5	1,7	1	3	3	2	2	1	2	2	1	2

<u>Annex 2 : GEF-IW/groundwater. A socio-economic indicator on other options for GBI scoring/ranking.</u>

The opportunity is to introduce a supplementary socio-economic "other options (OO)" indicator on available alternative options and then the potential for change of the current state to meet social and economic needs and reduce (a) <u>Dependency</u> and (b) <u>Risk and uncertainty</u>, in transboundary aquifers, and at individual country level. Other Options, focused on quantity are exemplified, with indicated proxies in Table 1., including other technically feasible options for alternative water supplies, water conservation, water efficiency and policy and legal/institutional reform.

The challenge for the introduction of a socio-economic indicator is the availability of directly targeted global databases. However a range of authoritative global, mainly country based water use and development data bases, maps and assessments including FAO AquaStat, the bi-annual UNDP Development Report with the HDI, OECD economic data for all countries, The World Poverty Index, and IFAD regional assessments of Rural Poverty etc. are available to support information/proxies for scoring of the OO indicators
The OO indicator is based on the relationships:

$$\frac{\textbf{Estimated annual other-alternative water resources x 100\%}}{\text{Total annual use of water}}$$

For the GBI the Dependency and the Risk Sub-Indices are <u>adjusted</u> for the <u>added</u>[5] OO indicator as :

$$\text{S-I}_{\text{dependence, adjusted}} = \text{S-I}_{\text{dependence}} + \text{OO indicator}$$
$$\text{S-I}_{\text{risk, adjusted}} = \text{S-I}_{\text{risk}} + \text{OO indicator}$$

The OO indicator is tested for GBI scoring transboundary aquifers in the Cases Studies, and for scoring at individual riparian country level, in the Appendix.

The OO indicator measures the outlook for introducing change from the current state for reduced environmental pressures consistent with the two objectives of the GEF-IW focal area, at <u>the level of transboundary aquifers,</u> *to foster international, multi-state cooperation on transboundary water concerns*, and, at <u>the country level,</u> "*to play a catalytic role in addressing those transboundary water-related concerns by assisting cooperating countries to institute the full range of technical assistance, economic, financial, regulatory, and institutional reforms that are needed*."

Table. Other Options (OO) for reduced (a) Dependency; (b) Risk

[5] The OO indicator, adds to the dependency and risk sub-indices and score, the GBI for TB aquifers –as an indicator of the potential for alternative action for multi-country cooperation and catalyses addressing TB concerns in line with the GEF-IW objectives, and of scope for alternative change also at the individual country level, in harmony with national strategies and plans.

I. State/ Social Capacity	Data sources/Proxies
Socio-economic capacity water scarcity index: (country level, aggregated for TB aquifers) Options for supply management: surface water, non-traditional supplies (desalinisation, re-use..)	Country water scarcity data; HDI, bi-annual UNDP Development Report 1964- 2007. National water resources strategies & development plans; FAO AQUASTAT
II. Socio-economic Drivers (country level) i. equity: improved rural income; ii. structural change: for water efficiency, e.g. from agriculture to tourism, or other services iii. finance: government resources (tax, charges, reduced subsidies); iv. social: access to drinking water supply and sanitation; v. direct/ indirect water subsidies: agricultural pricing, food security, agricultural exports.	World Bank poverty index/map; OECD; CIA Millennium Data; National development strategies/development plans;
III. Water conservation; (country level) i. use sector water efficiency: agricultural water productivity, crop management, par capita water supply use; ii. scheme water efficiency: modern irrigation, transfer and network losses, water-saving and efficient irrigation; equipment; iii. watershed management; managed aquifer recharge, iv. local incentives/subsidies: v. non-polluting, ecological agriculture	National water resources strategies & development plans;
III. Structured cooperation (country level) i. regional socio-economic institutions ; regional economic communities, trade; ii. country economic policy, sector plans and investments, international and micro-trade; iii. community water management and use, watershed management, common resource and public trust resource management; iv. private sector and NGOs; v. sustainable financing; at regional, national, community level.	National water resources strategies & development plans;
IV.Legal/Institutional/Governance: (TB aquifer/domestic country level) i.members of international and regional MEAs. ii. international issues (harm, equitable use…..) **iii. modern domestic gw legislation; provisions for water rights, abstractions, quality /environmental standards, implementation /enforcement mechanisms .** **iv. gw protection areas, land use regulations.** v. administrative & coordination capacity. vi. local regulations; water user associations	

Appendix:
1. Application/test on GBI indicators, including socio-economic Other Options socio-economic indicator at, (a) transboundary aquifer and (b) individual country level, on
- Iullemeden Aquifer System, Mali, Niger, Nigeria (GEF –UNEP MSP)
- North Western Sahara Aquifer system, Algeria, Libya, Tunisia (GEF-UNEP MSP),

2. Discussion: a GBI for the Disi / Saq aquifer system, Jordan, Saudi Arabia

Reference;

GEF; *Progress on the development of RAF indicators for the focal areas not yet under the RAP;* GEF Council, November 11-13, 2008.

Annex 3: Legal Indicators

In the GEF Benefits Index, the legal indicators are meant to evaluate the ability, capacity and will of a country to engage in cooperation on transboundary aquifers for reaching joint management, and also to manage sustainably, in a sound manner the transboundary aquifer. Therefore the legal indicators have to address two levels: the transboundary level, or cooperation which is the aquifer level, and the national level of each of the riparian countries, which is the legal and institutional framework within a country for groundwater management. The transboundary level is meant not only at the level of the transboundary aquifer, but also all transboundary cooperation over waters the country has engaged, or is participating in. The transboundary level indicators will give therefore an idea of the existence or not of any agreement on transboundary aquifers, or on transboundary waters in general, and the capacity of a country in entering into a negotiation process with its neighbor(s).

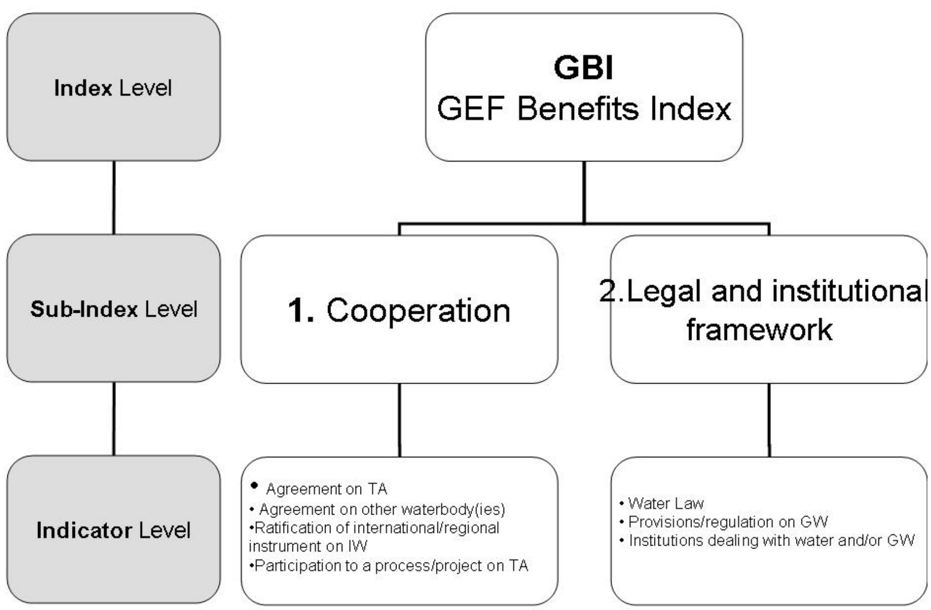
Every transboundary water body, including groundwater, is managed at the level of the country through national laws and regulations, implemented by national institutions. Therefore the legal indicators will also include an evaluation of national legal and institutional settings for the management of groundwater.

The identified indicators are conceptualized in Figure 1 and presented in Table 1.

If for certain indicators the rating or scoring system is very clear, in some cases it is not easy to have a clear cut score, some nuances need to be introduced. The indicators are scored from high, good, medium, low and non existent. At the level of the aquifer, the high score indicates that at the aquifer level an agreement exists demonstrating some level of cooperation, while the non existent is when nothing is happening. At the level of the country, high means that the country has a good legal and institutional framework for the management of groundwaters, while non existent means that this is not the case.

The legal indicators represent an important support for developing a GEF Benefit Indicators because they are the expression and the tools of the countries to implement a policy. In water related issues, the legal indicators express the existence of sound management of a transboundary aquifer whether among the riparian countries or at least at the level of the country itself. If a country has entered into agreement with its neighbors on the transboundary aquifer, it means that consultations exist and decisions are taken jointly, which in the best cases should ensure a better use and protection of the aquifer. When a country regulates in its territory the use of water and groundwaters in particular, it is also the indicator of the existence of a rules for ensuring a sustainable use and a protection of the aquifer.

Figure 1 Conceptual relation between the GEF Benefits Index (GBI), Sub-Indices and indicators, applied to the legal and institutional indicators.



Sub-Index	Indicator	Description	Score
1.Cooperation	Existence of agreement on TBA among riparian countries, with a joint mechanism for cooperation	Cooperation exists and is formalized in an agreement	High
	Agreement on other water body(ies), including or not a joint mechanism for cooperation	Two aspects should be differentiated here: 1. The agreement is among all riparian countries of an aquifer: the countries already cooperate. If a mechanism of cooperation is already established, it might be possible to extend its scope to include TBA. 2. The agreement is between one or more country(ies) of the TBA and other countries : The country(ies) is (are) used to negotiate and cooperate over transboundary waters. Some mechanisms may exist within the country or at the level of the transboundary water body. This will make easier to start cooperation and negotiations over a transboundary aquifer.	High Medium
	Ratification of international or regional framework convention on international/transboundary waters, such as the UN Watercourse Convention (1997) (not yet in force, but its core principles are part of international customary law); UN ECE Water Convention (1992), or Revised Protocol SADC (2000)	The Conventions mentioned here offer a framework for cooperation over transboundary waters (international watercourses in the case of the UN Watercourse Convention and SADC Protocol). If the countries have signed one of these Conventions, this might reflect the expression of their interest, concern and ***awareness*** about transboundary waters issues. The framework of the conventions might be of inspiration when negotiating an agreement on transboundary waters. Ex Lebanon and Syria have both signed the UN Watercourse Convention, based on this Convention they have signed an agreement on the El Kebir international watercourse. It seems that a TBA is related to this International Watercourse. The existence of this agreement can foster the cooperation on th TBA. Unfortunately the political situation is not permitting.	Medium
	Participation to a process or project on transboundary aquifers (examples with the results could be added)	Usually the participants to these processes or projects are technical people from the national institution in charge of water resources. Their involvement in projects on TA is at various level, depending on the requirements of the project, and in their countries decision. These projects create some awareness and can be a start for some confidence building, which is a very important factor in transboundary cooperation.	Low

	No activity at all on transboundary waters	Such a situation can be the reflection of the absence of political will and/or institutional capacity	Low

2.Legal and institutional framework	Water law	The adoption of a water law by a country indicates the existence in this country of a legal framework for water management. This law translates into legal rules and tools the water policy of the country. It is a good indicator of the structure of a country and how it manages its waters	Medium
	Provisions on Groundwater or regulation on Groundwater	Same comment, but more dedicated to groundwaters. The part of transboundary aquifers in a country is managed according to the groundwater provisions or regulations. This is an indicator of how GW is managed in a country, which is important to know when the resource is shared with another country.	High
	Absence of legal framework on water resources or groundwater resources	This situation is the indicator of the lack of a national policy on water and groundwater resources.	Low
	Institutions: Dealing with water Dealing with Groundwater Coordination/cooperation mechanism	This indicator would be to identify the existing institutions in charge of water resources, and of groundwaters in particular when existing and the definition of their scope of competences and responsibilities. Institutions are very important for decision making and implementation of legislation. In case of efficient institutions with clear responsibilities, and a good cooperation mechanism among the various insitutions the rate would be high or good. This last indicator is difficult to identify without a proper knowledge of the situation in each country.	Various situations : from high to low

Table 2 The table displays the two sub-indices, which form the GEF Benefits Index (GBI) for the legal and institutional indicators. Each sub-index is based on a set of indicators. For each indicator, a score is identified.

These legal and institutional water related indicators, whether at the country or transboundary level, give a first picture of the legal situation in a country.

However, to have a complete picture, and to deeper the analysis, it would be necessary to know about the implementation, as in some countries the legislative framework transboundary and domestic is not implemented or is far to be implemented. This question could only be answered after the detailed study of the specific case of each country.

It should be noted also that the legal indicators are presented here for the GEF Benefits Index. But they could also be used for the GEF Performance Index, and one of the aims of a GEF project on a transboundary aquifer could be improving the legal tools within a country for the management of its groundwaters, as well as developing cooperation among Aquifer States. Another instrument worth mentioning in the case as part of the GPI would be the draft articles on the law of transboundary aquifers, currently under study at the UN General Assembly. It is expected that the UN GA adopts the draft articles as an annex in a Resolution, which ill give them the status of guidelines for countries to refer to in drafting any agreement on Transboundary Aquifers.

References

Burchi S. & Mechlem K, Groundwater in International Law, UNESCO, FAO 2005

FAOLEX, database of national legislation and international agreements concerning food and agriculture (including fisheries, forestry and **water**). The database offers direct access to the abstracts and indexing information about each text, as well as to the full text of most legislation contained in the database. http://faolex.fao.org/faolex/index.htm

Water Law and Standards database : A joint project by FAO and WHO, the database contains country level systematic analyses of the water resources legislation of approximately 50 countries, with plans for expansion and regular update, and to add information on water quality standards. www.waterlawandstandards.org

Marco legal e institucional en la gestion de los sistemas acuiferos transfronterizos en las Americas, PHI, Programa UNSECO/OEA ISARM Ameritas, 2008. http://unesdoc.unesco.org/images/0015/001589/158963s.pdf The book includes a comprehensive assessment of the legal and institutional situation of the 22 countries in the Americas regarding transboundary aquifers, at both transboundary and domestic level. An English translation is on the way.

Annex 4 Proposed climate change factor (f_{cc}) within an integrated $GBI_{IW\text{-}TBA}$ indicator at the national scale

Increases in global mean air temperature as a result of climate change are predicted to intensify the global hydrological system (Trenberth *et al.*, 2003; Wentz *et al.*, 2007). This intensification will involve not only a net transfer of water out of long-term storage from icesheets and glaciers to more dynamic reservoirs but also higher saturation pressures for water vapour as warmer air is able to hold more moisture (Clausius-Clapeyron relation). Of critical importance, however, is how a warmer atmosphere will influence the distribution in precipitation around the globe. Consensus among projections of the General Circulation Models (GCMs) considered in the 4th Assessment Report (AR4) of the Inter-governmental Panel on Climate Change (IPCC), is that precipitation will increase in high latitude areas of Eurasia and North America and equatorial east Africa but decrease in southern Africa and southern Europe over the 21st century (Kundzewicz *et al.*, 2007). Numerous studies (*e.g.,* Alcamo *et al.*, 2003; Arnell, 2003; Milly *et al.*, 2005; Oki and Kanae, 2006) have attempted to assess the global impact of climate change on mean annual river runoff and water scarcity. Global assessments of the impact of climate change on groundwater resources are still in their infancy (*e.g.,* Döll and Florke, 2005). A baseline estimate of mean annual recharge at national and continental scales has, however, recently computed over the period 1961-1990 by Döll and Fiedler (2008) using the WaterGAP Global Hydrology Model (WGHM) (Döll *et al.*, 2003).

Climate change is expected to influence both the availability of freshwater from transboundary aquifers (TBAs) and freshwater demand. As a result, it is critical that climate change be considered explicitly as a factor (f_{cc}) in the calculation of the $GBI_{IW\text{-}TBA}$ (eq. 1). In the estimation of f_{cc}, diffuse, direct recharge is considered to represent internally renewable groundwater resources. Although this assumption may underestimate recharge in some semi-arid and arid environments where indirect recharge can occur via riverflow and wadi flow, a globally consistent dataset of estimates indirect recharge does not presently exist. For areas where climate change leads to a decrease in diffuse groundwater recharge, it is assumed that global environmental benefits will increase as a result of improved cooperation over, and management of, TBAs. For TBAs in northern Europe and tropical Africa where groundwater recharge may increase, it assumed that the global environmental benefits that may result from improved management of, and international cooperation over, TBAs, will reduce. These assumptions explain the negative sign placed in front of change in diffuse recharge (ΔR_i^z) in equation 2. In the f_{cc}, the magnitude of changes in recharge are calculated relative to the baseline estimate of diffuse recharge for the period 1961-1990 (R_i). Equation 2 assumes that global environmental benefits increase linearly with decreases in recharge and vice versa. In reality, thresholds will occur. For TBAs around the Mediterranean and in Southern Africa that receive rainfall-fed recharge episodically (*e.g.* a few events per decade), recharge may effectively cease as a result of climate change.

Climate change will also affect demand for groundwater. Current predictions (*e.g.,* Allen and Ingram, 2002; Trenberth *et al.,* 2003) indicate that under a warmer atmosphere, precipitation will occur in fewer but more intense events. This increase in the variability of precipitation will lead to more variable supplies of freshwater from surface waters (rivers, lakes, wetlands) and more variable soil moisture. The former will increase dependence upon freshwater stores such as groundwater whereas the latter will increase demand upon groundwater for irrigation. Continental-scale estimates of how climate change will affect freshwater demand in agricultural, domestic and industrial sectors are available from Alcamo *et al.* (2007) and Shen *et al.* (2008). *It is presently unclear whether national estimates are available.* In the present calculation of f_{cc}, it is not considered feasible to include a simple, globally consistent representation of national changes in freshwater demand placed upon TBAs as a result of climate change.

Climate change will induce a rise in sea level exacerbating sea-water intrusion of coastal aquifers by inducing an inward shift of the freshwater–seawater interface approximated by the Ghyben-Herzberg relation. The magnitude of the predicted rise in sea level rise varies according to the applied model but is predicted to range from 0.2 to 0.6 m for the SRES A1b scenario (Bindoff *et al.*, 2007). The A1b scenario represents a similar but more integrated future world than that represented by the A2 scenario recommended for changes in recharge (ΔR_i^z) above. The magnitude of increasing salinity associated with the intrusion of seawater into coastal aquifer systems as a result of sea-level rise will depend strongly upon localized conditions of current and historical abstraction of groundwater from these aquifers. The impact of sea-level rise associated with climate change on estimation of f_{cc} for coastal TBAs is, for simplicity, considered to be uniform globally. As a result, if a TBA is coastal, it is assumed in the estimation of f_{cc} to be affected by sea-level rise. If the TBA is not coastal, the impact of sea-level rise is excluded from the calculation of f_{cc}.

$$GBI_{IW\text{-}TBA} = (\ldots.)\cdot f_{cc} \qquad \textit{(eq. 1)}$$

$$f_{cc} = x_R \cdot \left(\frac{-\Delta R_i^z}{R_i} \right) + y_X \cdot X_i \qquad \textit{(eq. 2)}$$

x_R - *weighting factor for relative changes in internally renewable groundwater resources*

ΔR_i^z - *change in diffuse (direct) recharge (km^3·a^{-1}) as a result of climate change scenario (z) for a country (i)*

R_i - *per capita internally renewable groundwater resources as defined by the long-term (1961-1990) mean annual recharge (km^3·person^{-1}·a^{-1}) for the population of country (i) in 2000*

y_X - *weighting factor for the impacts of sea-level rise due to climate change on coastal, transboundary aquifers*

X_i - *if country (i) has a transboundary coastal aquifer, X = 1; if not, X = 0*

Data sources

ΔR_i^z Döll and Florke (2005) provide gridded (0.5°x0.5°) estimates of predicted changes in diffuse, direct (rainfall-fed) recharge around the world under two climate projections (*z*): SRES (Special Report on Emissions Scenarios) A2 and B2 (Nakicenovic and Swart, 2000) from experiments using two GCMs included in the IPCC AR4, HadCM3 and ECHAM4. *It is presently unclear whether gridded datasets have been grouped by country (i).* Due to the coarse grid dimensions relative to the size of some Small Island States (SIDS), national statistics for SIDS remain unavailable. The SRES A2 scenario represents 'business-as-usual' conditions with greenhouse gas emissions rising from 11 Gt C (CO_2 equivalent)·year^{-1} in 1990 to 25 Gt C·year^{-1} in 2050. Under B2, greenhouse gas emissions rise more slowly from 11 Gt C (CO_2 equivalent)·year^{-1} in 1990 to 16 Gt C·year^{-1} in 2050. It is recommended that calculation of f_{cc} employs the more probable, SRES A2 scenario and the more widely used HadCM3 GCM. It is very important to note that the output from the global recharge model in WHGM be taken as indicative not only because climate projections are highly uncertain but because the global recharge model has not undergone a rigorous validation exercise. The model does, however, provide a globally consistent method of predicting future recharge. Biases in model output may exist as a function of model formulation. For instance, the current global recharge model indicates that recharge in the humid tropics will decrease as the frequency of heavy precipitations increases under a warmer atmosphere. Field evidence in tropical Africa (*e.g.,* Taylor and Howard, 1996; 1999) suggests the reverse is true.

R_i Döll and Fiedler (2008) provide estimates of mean, annual diffuse, direct (rainfall-fed) recharge over the period 1961-1990 for all countries larger than 10 000 km^2 around the world. As a result, this database excludes SIDS (as above). Although an attempt has been made to tune the global recharge model using estimates of groundwater recharge in semi-arid regions and a few select countries (*e.g.* Germany), the model has not been subject to a rigorous validation exercise (as highlighted above) so recharge estimates should be considered indicative (*i.e.,* order of magnitude) rather than definitive.

X_i Struckmeier et al. (2006) have produced a global transboundary aquifer map that can be consulted to ascertain whether a TBA is coastal or not. An updated global transboundary aquifer map is currently in production and expected to be ready in the first quarter of 2009.

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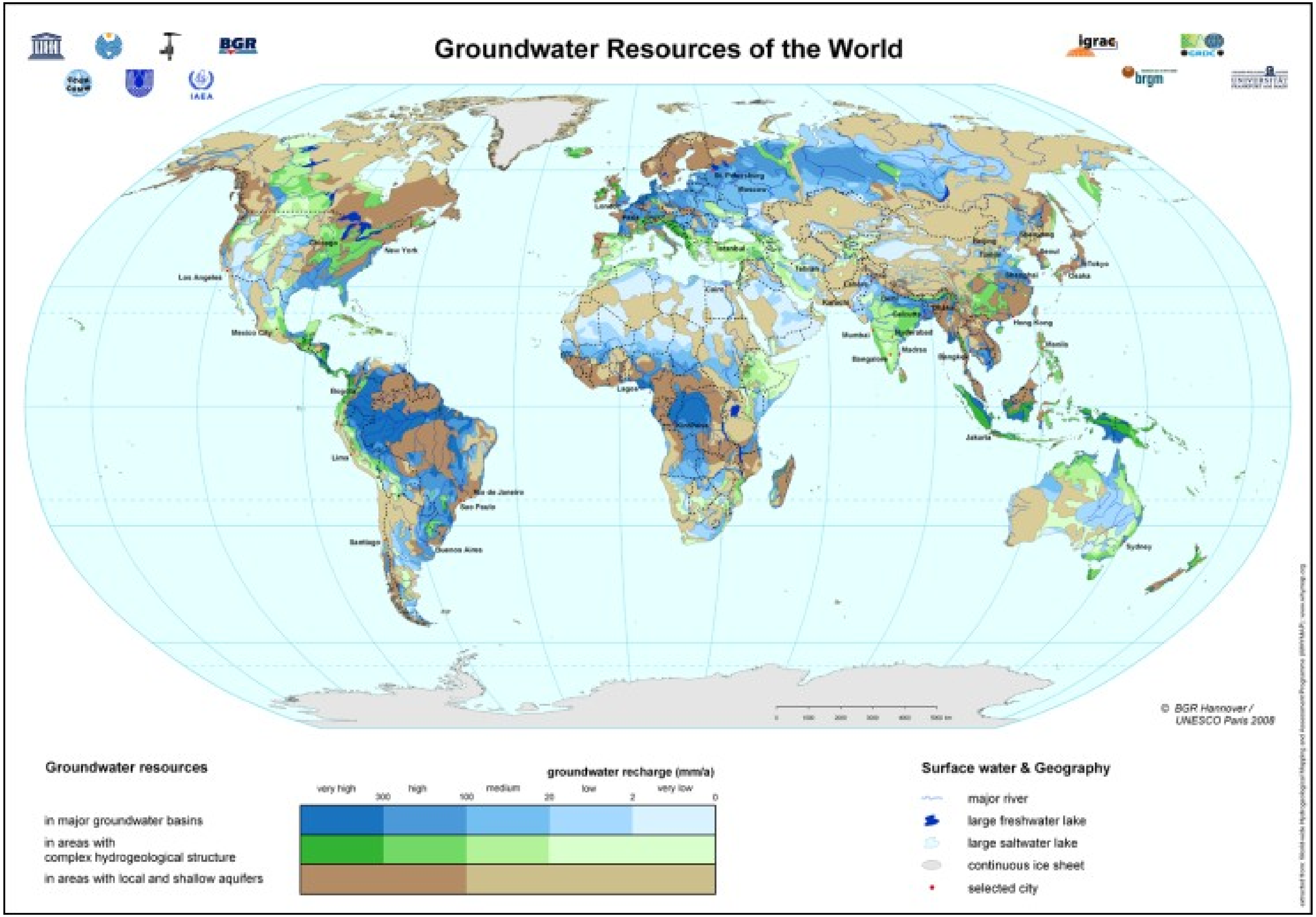
IMAGE v2.3 global land-cover dataset: Van Vuuren, D., Lucas, P.L. & Hilderink, H. (2006) Downscaling drivers of global environmental change: enabling use of global SRES scenarios at the national and grid levels. Global Environmental Change 17, 114-130.

Global recharge dataset, gridded 0.5 x 0.5 degree and country level: Döll, P. and K. Fiedler, 2008. Hydrol. Earth Syst. Sci., 12, 863-885.

Annex 5: Groundwater Resources of the World Map of WHYMAP (UNESCO/BGR)



About 35% of the area of the continents (excluding the Antarctic) is underlain by relatively homogeneous aquifers, 18% is endowed with groundwater, some of which are extensive, in geologically complex regions. Nearly half of the continental areas contain generally minor occurrences of groundwater that are restricted to the near-surface unconsolidated rocks, where groundwater resources are usually sufficient for small to medium-sized population centres.
Source: BGR & UNESCO

Annex 6: General References Data sets

http://www.unesco.org/water/

http://www.whymap.org/

http://www.igrac.nl/

UNESCO IHP Groundwater Indicators for Environmental Sustainability , UNESCO IHP 2007 Series on Groundwater N 14- http://unesdoc.unesco.org/images/0014/001497/149754e.pdf

Annex 7: Composition of the UNESCO-led expert group

Ms Alice Aureli	UNESCO-IHP, responsible for groundwater activities
Mr Andrea Merla	Former Deputy Chief GEF IW
Mr Jaroslav Vrba	International Association of Hydrogeologists (IAH)
Mr Bo Appelgren	UNESCO Senior Consultant
Mr Richard Taylor	University College London
Mr Willi Struckmeier	WHYMAP (UNESCO-BGR), Germany
Mr Jac van der Gun	International Groundwater resources Assessment Centre (IGRAC)
Ms Raya Stephan	UNESCO Senior Consultant, UNILC Advisor
Mr Jean Margat	BRGM, France
Mr Holger Treidel	UNESCO-IHP