STATISTICAL COMMISSION and
ECONOMIC COMMISSION FOR EUROPE

CONFERENCE OF EUROPEAN STATISTICIANS

COMMISSION OF THE
EUROPEAN COMMUNITIES

EUROSTAT

Joint ECE/Eurostat Work Session on Methodological Issues of Environment Statistics
(Ottawa, Canada, 1-4 October 2001)

WORKING PAPER No. 25

ORIGINAL: ENGLISH

STATISTICS ON WATER RESOURCES BY COUNTRY IN FAO'S AQUASTAT PROGRAMME

Paper submitted by FAO's AQUASTAT Programme[1]

Summary: In order to provide a rational basis for the discussion on increasing water scarcity and the role of irrigation in the world water balance, FAO's AQUASTAT program compiles existing information on water resources, water use and irrigation. In this framework, a major effort was put on developing a rational base of comparison between regions and countries.

Today, a standardised data sets and indicators on water resources is available for 150 countries surveyed by AQUASTAT (mostly developing countries) and is currently completed for the rest of the world. All this information is currently being assembled in a document to be published by the end of 2001. Once completed, this data set, based on information emanating from national and international sources, should constitute a reference document for FAO.

In order to enhance comparability of statistics at a regional level, a framework of data entry and computation of the water resources has been developed within the AQUASTAT program. The major focus is put on reducing the risks of double counting in internal water resources that may occur when assessing separately surface and groundwater, or external resources when accounting for border or frontier water resources. The approach and key findings are presented in this paper.

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Introduction

Water has been a main issue on the international agenda for the last 30 years, i.e. Mar del Plata in 1977, Dublin and Rio in 1992. During the 2nd World Water Forum in The Hague in 2000 the UN system committed itself to produce a bi-annual assessment of the state of the world's freshwater resources in the form of the World Resources Development Report (WWDR). In view of both the critical roles of water for food production and of the importance of agriculture in global water withdrawal, FAO play a major role in the preparation of this report.

In order to provide a rational basis for the discussion on increasing water scarcity and the potential for irrigation expansion in the world, FAO undertook in 1993 to compile existing information on the water resources in the framework of his AQUASTAT programme. This program is the core of FAO's information capacity with regards to water and agriculture.

The AQUASTAT program

AQUASTAT is the UN's Food and Agricultural Organisation's global information system on water and agriculture with a focus on irrigation, developed since 1993 by the Land and Water Development Division of FAO.

The main purpose of the AQUASTAT program is to systematically select the most reliable information on water resources and water uses in countries and make it available, in a standard format, to users interested in global or regional perspectives. The objectives of AQUASTAT are:

- To provide users with comprehensive information on the state of agricultural water management across the world, with emphasis on developing countries and countries in transition, featuring major characteristics, trends, constraints and prospective changes.
- To help support continental and regional analyses by providing systematic, up-to-date and reliable information on water in agriculture and to serve as a tool for large-scale planning and predictive studies.

AQUASTAT collected its information through national surveys. They follow a standard methodology, which relies to a great extent on national capacities and expertise:

- Country-based reviews of literature and existing information, i.e. national statistics and yearbooks, water resources and irrigation master plans, reports from FAO and other international agencies etc.
- Data gathering through a detailed questionnaire
- Standardisation of available data
- Data processing and critical analysis of the information, including quality check.
- Preparation of country tables and country profiles which is submitted to national authorities for comments and possible corrections.

After eight years of existence, AQUASTAT has produced a range of products on water in agriculture with focus on irrigation to the users. Identified users are primarily international and national organisations, e.g. FAO, World Bank, World Resource Institute, decision-makers and universities. Today five regional overviews are available (Africa, the Near East region, the countries of the former Soviet Union, Asia and Latin America and the Caribbean). It represents 150 country profiles. As the focus was put on developing countries and countries in transition, part of the world has not been covered, i.e. Europe, North America, Australia and the Pacific.

The Regional overviews and the Country profiles are available on the web and as published reports. For specific information by country the user can query two online databases on a) water and agricultural data and b) regional and national institutions. In addition, a CD-ROM "Atlas of water resources and irrigation in Africa" containing geographical information by river basin and country has recently been produced.

The AQUASTAT information system consists of:	
Regional overviews	key features of water, and irrigation in 5 regions of the world, summary tables and maps.
Country profiles	key features of water and irrigation at a national level, graphs and summary tables.
Data on water and agriculture	online database by country for 150 countries
Institutions	online database of national and regional institutions
Atlas of water resources and irrigation	geographical information by river basin and country in Africa
Glossary	definition of variables

Please see our web site for further information and feedback :
http://www.fao.org/ag/agl/aglw/aquastat/aquastat.htm.

Work on Water statistics in AQUASTAT

In the framework of the AQUASTAT program, a major effort was done to have a rational base of comparison between regions and countries. Today, a standardised data sets and indicators on water resources is available for the 150 countries surveyed by AQUASTAT and is currently completed for the rest of the world. Information is emanating from countries and regional organisations. FAO is currently working on a reference document that should provide statistics on water resources for all the countries of the world. It will present a compilation and critical review of available information. It is part of a larger effort to improve the assessment of water resources and use potential for irrigation.

In order to enhance comparability at a regional level, a framework of data entry and computation of water resources data has been developed within the AQUASTAT program. The major focus was put on reducing the risks of double-counting for :

- internal water resources, occurring when assessing separately surface and groundwater,
- trans-boundary waters (or border rivers.

The method used to assess water resources follows four steps:

1. compilation of sources to select the best set of country data from multiple sources -national or international- for each country, **(Annex 1)** ;
2. assessment of internal resources with estimate “overlap” for internal water resources **(Box 4)**, and of actual resources;
3. assessment of “actual” flows for external waters and exchange flows among the countries **(Box7 & Annex 3) ;**
4. computation of natural and actual water resources in a standard way **(Box 2 & Annex 4).**

The main elements of AQUASTAT approach to assess natural and actual water resources, including the concepts of overlap are presented thereafter.

Information sources and data gathering

This is the most difficult task of the AQUASTAT program as it is time and resource consuming.

Global information

Very little information exists at present on water resources on a regional basis at country level. The only systematic country based study was conducted in the 1970s, and led to a publication of a book entitled “World water resources and their future”(L vovitch, 1974) which is still today used as a reference in that field . Based on a water balance approach and on large amount of information on stream flow gathered around the world, it proposed a table of water resources by country, including water resources generated in the country, as well as flows from neighbouring countries. The works of Korzun et al (1974) and later of Shiklomanov since 1990, based on a water balance approach, are the most frequently quoted and the most up to date source of information on water resources at regional and continental level. Other useful works of compilation are those of Gleick (2000), and the World Resources Institute. The later provides the most recent systematic information about water resources at country level. It is mainly a compilation of existing information, including figures taken from AQUASTAT.

National sources

To acquire the current AQUASTAT data and information (all subjects), extensive surveys have been carried out for Africa in 1995, the Near East in 1996, the countries of the former Soviet Union in 1997, Asia in 1998 and Latin America and the Caribbean in 1999. On this base, country profiles with detailed data sets were prepared.

These surveys are principally based on information emanating from countries or regional organisations. The main sources of information used were:

- National water resources and irrigation master plans;
- National yearbooks, statistics and reports;
- Reports from FAO or other organisations;
- International surveys;
- Results from surveys made by national or international research centres.

Comments on information sources

The option taken was to rely in priority on country information. This option is based on the assumption that no regional information can be more accurate than studies carried out at country level.

However, there are a number of difficulties, when dealing with national sources:

- Information sources for water resources' information are various but rarely complete. In most cases, a critical analysis of the information was necessary to ensure consistency between the different data collected for a country and a river basin.
- Gathering data from different sources highlights both similarities between the different sources, contradictions, and mistakes for the same data. It is illustrated by the example in **Annex 1** where some references indicate different figures, that should be explained by the country experts.
- In arid and semi-arid climate, abundant literature exists as water plays a determinant role for economic development. However access to information on water resources is still sometimes restricted for reasons related to the sensitivity at regional level.
- Another kind of problem originated from the creation of new independent states for which no breakdown of information was previously available.
- The accuracy and reliability of the information vary greatly between regions, countries and categories of information, as does the year in which the information was gathered.

Due to the difficulty in collecting the information, the AQUASTAT surveys refer mostly to long term yearly averages, with only rarely consideration of variability, when possible. No consistency can be ensured at regional level on the duration and dates of the period of reference.

Taking this problem into account, the selection of the most reliable information was based on several criteria including the source of information, the conceptual approach used to assess water resources and the accuracy of the data.

- When possible cross checking of information between countries was used to improve assessment in countries where information was limited.
- When several sources gave different or contradictory figures, preference was always given to information collected at national or sub-national level and, unless proved wrong, to official rather than unofficial sources.
- In the case of shared water resources, a comparison between countries was made to ensure consistency at river basin level, most notably with regard to information on trans-boundary river flows.

New approach with data

To improve comparability at regional and global levels, AQUASTAT has also been working on global GIS based data sets and modelling for some issues, i.e. for rainfall data. A water balance model has been developed and implemented on Africa to improve the data comparability. The results are presented in the CD-ROM "Atlas of water resources and irrigation in Africa" cited before.

Water resource assessment : AQUASTAT approach

AQUASTAT work only considers *renewable*[2] *water resources*. It is a key information for who wishes to analyse the situation of irrigation and its potential for development. Its objective is to assess not only the 1) the natural situation with the **natural renewable resources,** but also the current situation with two information levels 2) the **actual water resources**, 3) the **manageable water resources.**

Key concepts

The computation of *total renewable water resources* requires the assessment of **water flowing from neighbouring countries** (*natural or actual inflows*) and **water produced internally** (*internal water resources*). By definition, total water resources computed by countries are not additive at regional level. The definition implies that unused water, accounted for as a resource in upstream countries, is also considered a resource in downstream countries. Therefore when working at global or regional level, it is important to check the balance and therefore the *exchanges flows* among the countries.

Water resources are computed in terms of annual flow. The AQUASTAT review concentrated only on **long-term averages** and did not consider inter-annual or seasonal variations. However, it should be stressed that the review is based on information available from a multiple sources and that no consistency in the choice of reference period can be expected.

The following definitions are used in AQUASTAT:

- *Potential yield or natural renewable resources* is defined as the total amount of water resources, be it surface water or groundwater, which is generated by the hydrological cycle on a yearly basis. When divided by the number of inhabitant, the potential yield is used as the indicator to assess water resources by country.
- *Actual water resources* is defined as the sum of internal and external renewable water resources, taking into consideration the quantity of flow reserved to upstream and downstream countries through formal or informal agreements or treaties and reduction of flow due to upstream withdrawal.
- *"Manageable water resources, available water resources or water development potential"* consider other factors such as the economic feasibility of storing flood water behind dams or extracting groundwater, the physical possibility of catching water which naturally flows out to the sea, the minimum flow requirement for navigation, the environment, aquatic life, etc.

Box 1: manageable water resources in Lebanon

The case of Lebanon shows the difference between potential yield and water development potential. A large part of the country's potential yield estimated by various authors is hardly manageable.
The groundwater losses to the sea which are accounted for in the assessment of potential yield, estimated around 0.7 km3/year, are coming out as submarine springs and can hardly be mobilised since the karstic channels in which water is flowing are subject to mixing with saline water. Similarly the floods running from small watersheds of the coastal mountains are lost in the sea with little possibility to be put into beneficial use. Thus, out of a potential yield of about 4.8 km3/year, manageable water resources represent probably about 2.2 to 2.5 km3/year.

In computing water resources on a country basis, a distinction is to be made between renewable and non-renewable water resources and between internal and total water resources.

- *Renewable water resources* are the natural resources that, after exploitation, can return to their previous stock levels by natural processes of growth or replenishment.

[2] The term *renewable* is used in opposition to fossil waters which have a negligible rate of recharge on the human scale and can thus be considered *non-renewable*. Non-renewable resources are usually expressed either in terms of volumes or extractable flow, while renewable resources are always a measure of annual flow.

- *Non renewable water resources* are not replenished at all or, for a very long time by nature. Generally, they are aquifer sources, which have a negligible rate of recharge on the human scale (<1%) and thus can be considered non-renewable. In practice, this essentially concerns aquifers with large stocking capacity in relation to the average annual volume being discharged, of which a large proportion is said to be "fossil".

Key Rules adopted for water resources computation

AQUASTAT program adopted a number of rules to work on national data sets in order to improve the comparability and quality of regional data sets.

Assessing Internal water resources

Internal renewable water resources (IRWR) is that part of the water resources (surface water and groundwater) generated from endogenous precipitation. It is computed by adding up average annual surface runoff and groundwater recharge occurring within the countries' borders. Special care is taken to avoid double counting of their common part (overlap) as shown thereafter. The internal renewable water resources figures are the only water resources figures that can be added up for regional assessment and they have been used for this purpose.

Surface and groundwater interdependency: Although they are linked through the hydrological cycle, surface water and groundwater resources are often computed separately. One of the major risks in assessing surface water and groundwater separately lies in the possible double counting of part of the resource.

- *Surface water resources* are usually computed by measuring or assessing total river flow occurring in a country on a yearly basis.
- *Groundwater resources* are expressed as a measure of aquifer recharge through infiltration. Computation of groundwater can be performed into two distinct ways, which depend mostly on the climatic conditions of the area. In arid areas, the most classical way of computing groundwater is to estimate recharge from rainfall, while in humid areas, where aquifers are connected to the river system, it is usually associated with the base flow of the river system. The first method tends to over-estimate the ground water resource while the other usually gives a conservative measure of groundwater potential.

Although many countries fall into one of the two categories, most of them show important spatial variations of climates and may require different methods for estimating groundwater. At the country level, this results in a mixed situation where part of the groundwater constitutes the base flow of the rivers while another part is estimated from recharge.

Overlap: They are two sorts of exchange between aquifers and watercourses that may create overlap:

- Contribution of aquifer to the surface flow, it constitutes the "base flow". This type of exchange dominates or is exclusive in humid climatic zone (temperate or tropical) except in the special case of the karstic domain.

Box 2: Surface water and groundwater base flow in Morocco

In Morocco, the total groundwater flow equivalent to the aquifer recharge is estimated at 10 km3/year, out of which 3 km3/year corresponds to the base flow of rivers.

- Recharge of aquifer by surface runoff. This type of exchange dominates in arid and semi-arid zones, or in karstic areas.

Box 3: recharge of aquifer by floods in Iran

In Iran, the contribution of surface water (floods) to aquifer recharge is estimated at 12.7 km3/year, out of the total internal renewable water resources of 128.75 km3/year.

It is the sum of these exchange flows that constitutes the "overlap". Overlap distribution is guided by the climatic as well as hydro-geological conditions. In both cases, the need to correctly assess water resources has made it necessary to estimate that part of the water resources which is common to both surface water and groundwater sub-systems and subtract it from their sum.

- **Box 4** describes the basic rules, adopted by AQUASTAT, to estimate the overlap, especially in arid and semi arid climate. In humid areas, the very complex interrelation between surface water and groundwater makes it difficult to assess their common part. Although in such cases most of the groundwater recharge is expected to be drained as base flow in the rivers. In extreme cases of complexity, groundwater resources in one country may come from infiltration of runoff generated in an upstream country, making it difficult to make the distinction between internal and external water resources.

Box 4: Basic rules adopted to estimate overlap

Concept

The objective of "overlap estimation" is to avoid the double counting that results from summing up surface water and groundwater in the computation of water resources.

There are two sorts of exchange between the surface and groundwater that create overlap**:**

- **Contribution of groundwater to the internal surface water flow (surface runoff)**; it constitutes the "base flow". This type of exchange dominates or is exclusive in humid climatic zone (temperate or tropical) except in the special case of the karstic domains. There, the base flow of the rivers originates from groundwater through springs and ex-filtration in the riverbed. In those areas, the surface water estimates thus include a part of the resources, which can also be considered as groundwater and could be developed through wells. Where possible - i.e. where data are available - the groundwater resources in humid areas have been considered as equivalent to the base flow of the rivers.
- **Contribution of the surface runoff to the recharge of aquifers, through infiltration in the river bed or losses**. This type of exchange dominates in arid and semi-arid zones, or in karstic areas. There, most of the groundwater recharge occurs through infiltration of short-lived surface flow (flash floods) in the plains. In those areas, the groundwater resources is estimated either by assessing the groundwater recharge from rainfall or runoff infiltration estimates or from the characteristics of the aquifers and piezometric levels. The surface water resources are estimated through few flash flood discharge measurements and extrapolation to nearby rivers. In this case, it happens frequently that both flood estimates and groundwater resources resulting from infiltration of the same floods are summed up for assessing the total water resources, thus leading to an over-estimation of these resources. In arid areas, where rainfall contributes little to the groundwater recharge, the whole groundwater flow is considered as overlap. In areas, where rainfall may significantly contribute to groundwater recharge in addition to flood seepage, only part of the groundwater resources may be considered as overlap. However, in semi-arid countries, data on the origin of groundwater recharge is seldom available and in most case groundwater flow as a whole was considered as overlap in this study.

Estimation methods:

There are different ways to estimate overlap. AQUASTAT used a simplified approach on the base of the d**irect calculation of the groundwater flow received** (drained) by the watercourses. This flow is estimated by the analysis of the hydrograms of these watercourses and estimation of the base water flow assimilated to the "groundwater flow". In a simplified default approach, the surface water low flow can be considered to be this base flow. In that case all groundwater resources overlap with surface water.

Assessing External water resources

External water resources are that part of the country's renewable water resources shared with neighbouring countries. It is the sum of the external groundwater and external surface water inflow. External flow consists most of the time of river runoff, but in arid regions, it can also consist of groundwater transfer between countries. However, groundwater transfers are rarely known and their assessment requires a good knowledge of the general behaviour of the aquifers. The only known case in AQUASTAT refers to transfer of groundwater from Sudan to Egypt.

Natural and actual incoming flows

In assessing the *external flow to a country*, it is usual practice to distinguish *Natural incoming flow* and *Actual incoming flow.*

- *Natural incoming flow* is the average annual amount of water, which would flow into the country in natural conditions, i.e. without human influence.
- *Actual incoming flow* is the average annual quantity of water entering the country, taking into account extraction taking place in upstream countries. It also takes into account the part of the flow which is secured through treaties or agreements.

The *natural incoming flow* could theoretically be estimated by adding the *actual incoming flow* to the net water consumption from the same corresponding basins in the upstream countries. These figures are not available and the values of trans-boundary flow collected from the available documentation, usually refer to actual flow affected by upstream consumption and not to compute natural flow.

Actual external flow takes into account the quantity of flow reserved by upstream (incoming flow) and/or downstream (outflow) countries through formal or informal agreements or treaties, and reduction of flow due to upstream consumption. This figure may vary with time. It may be negative when the flow reserved to downstream countries is more than the incoming flow. Exchanges between countries are further complicated when a river crosses several times the same border. Part of the incoming water flow may thus originate from the same country in which it enters, making it necessary to calculate a “net” inflow to avoid double counting of the resources. Rules have to be set for the computation of incoming water resources.

Actual flows in humid countries are likely to be close to natural flows because of the low water consumption in these countries. Oppositely, in the arid and semi-arid countries, the actual flows are much lower than natural flows, because of high water consumption rates.

The rules described in **Box 5** are neither absolute nor universal. They have been selected to represent all the situations in the most realistic way possible. In summary, in the case of trans-boundary rivers, the mean annual flow at the border is considered as an external resource for the receiving country. In the case of bordering rivers or lakes, an arbitrary 50% rule is applied to distribute the water between the two countries (it should be stressed that these rules have been set for the purpose of this exercise, and that they do not imply any consideration of judgement on possible or effective ways to share the resources).
The difficulties encountered in setting these computation rules also show the arbitrary aspects of computation of total water resources for bordering water bodies, as compared to the indisputable measure of internal resources.

Box 5: Rules used in AQUASTAT for computing incoming water resources

Trans-boundary rivers

The mean annual flow measured or estimated at the border is accounted for as an external resource for the downstream country. It is not deducted from the resources of the donor country, except in the case of an agreed apportionment between the countries. While internally produced water resources are a quantity which should not vary with time, incoming flow may decrease with an increasing use by the upstream country. The bi- and multi-lateral agreements and the situations resulting from the actual water consumption in the countries located upstream, have made it necessary to differentiate two categories of external resources for each of the "receiving" countries:
Natural flow corresponding to long term average flow not affected or before being affected by upstream consumption; natural flow was not considered in this survey due to the lack of data
Actual flow corresponding to a given period which takes into account water abstraction from upstream, be it through an agreement or from a factual situation, and/or agreed or accepted commitments towards downstream countries.

A particular case is the situation where part of the runoff entering the country originates in the country itself, after having flowed into another country. In such a case, and when the information is available, this flow is deducted from the incoming flow to avoid double counting. As an example, the Pripyat river originates in Ukraine but flows to Belarus where it joins the Dniepr before it enters Ukraine: in this case the flow of Pripyat from Ukraine to Belarus (5.8 km^3/yr) is deducted from the flow of Dniepr to Ukraine (32 - 5,8 km^3/yr).

Border rivers
As a general rule, 50% of the river flow is assigned to each of the bordering countries. Several situations exist:

- The river exclusively borders the countries without entering into any of the riparian countries nor coming from them (this is the case of Prut between Romania and Moldavia). In such a case, the incoming resources are estimated on the basis of the runoff of the river in the upstream part of the border section. When the runoff increases substantially from upstream to downstream, the downstream figure is used after subtraction of the part of the runoff generated by the country itself.
- If the source of the river is in one of the two countries, the rule applies only for the other country. For the originating country, 50% of the contribution from the other country could similarly be considered as external resources when known. This is the case of the Samur river, which originates in the Russian Federation before being the border between the Russian Federation and Azerbaijan.

If, on the contrary, the river enters one of the two countries after having divided the two countries, it is considered a transboundary river for the receiving country, in which case all the runoff at the entry point in the country is considered external resources. The 50% rule applies for the other country. If a treaty exists between the countries riparian of a river system, the rules applied are those defined in the treaty.

Dependency of a country to external water
To compare countries dependency to external waters, we can use the following indicator:
The *dependency ratio* of a country (dr) is an indicator expressing the part of the water resources originating outside the country. It is computed as follows:

$dr = \dfrac{Ia}{IRWR + Ia} \times 100$	IRWR is the internal renewable water resources, Ia is the actual amount of water flowing in from neighbouring countries.

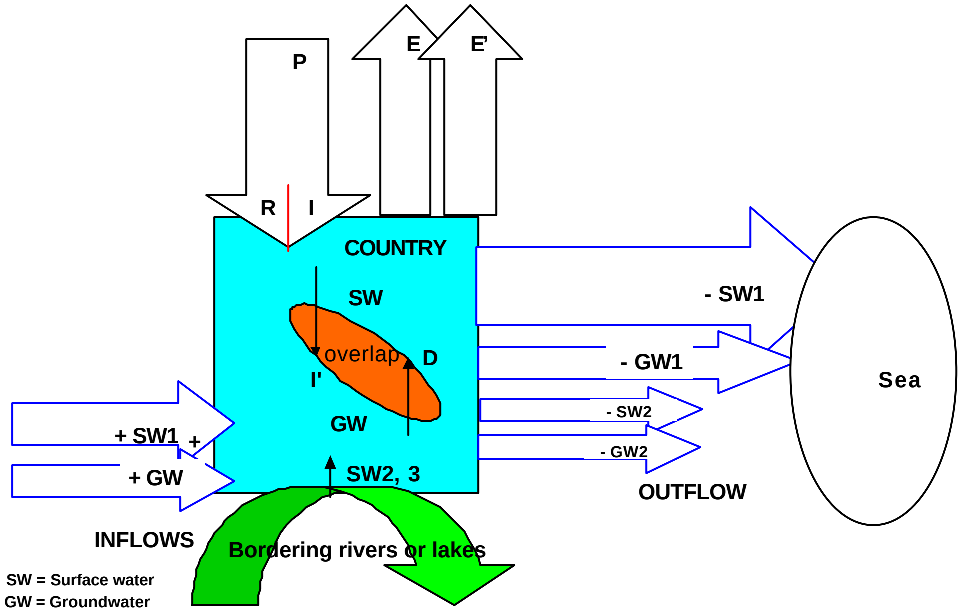
This indicator may theoretically vary between 0% and 100%. When dr = 0%, the country does not receive water from neighbouring countries. A country with dr = 100% receives all its water from outside without producing any. This indicator does not consider the possible allocation of water to downstream countries.

Computation of water resources

To assess **natural and actual water resources**, AQUASTAT developed a standard framework for input and computing water resources data for each country. It implements the concepts and detailed review of both *internal and external waters* described before,. The methodology applied is presented thereafter, with an example a national level and of results at regional level, and comments.

An example of a water resources computation sheet, with an explanatory graph, is shown in **Annex 4** (general) and **Box 6** (for Syria).

- The section related to internal renewable water resources (IRWR) indicates the surface water and the groundwater resources and the overlap, which is then deducted from the sum of the water resources estimated separately in order to obtain IRWR (66.3 km^3 in this case). The methodology for assessing overlap is detailed in **Box 4,** with an explanatory graph.
- The section related to external renewable water resources shows the various components of the incoming and outgoing surface water and groundwater flows. Further computational details are shown in the footnotes.



INFLOW	OUTFLOW
P = precipitation	E = actual Evapotranspiration from land
R= internal runoff	E ' = Actual evapotranspiration of water courses lakes , swamps of wetlands, and of groundwater in aric
I = groundwater recharge	*to sea*
+ SW1 surface water inflow	- SW1 surface water outflow
+ SW2 inflow part of boundary river (potential)	- GW1 groundwater outflow
+ SW3 inflow part of boundaries lakes (potential)	*To other countries*
+ GW groundwater potential	- SW2 surface water outflow
	- GW2 groundwater outflow

Assessment of overlap

I' Surface water to groundwater (infiltration losses of river)

D groundwater drained by river = base flow

I '+ D = overlap

Internal water Balance

P = E + R + I

Total water balance

R + I + SW1 + GW - SW1 - SW2 - GW1, 2, 3 - E ' = 0

(inequilibrium conditions, with no storage variations)

GRAPH : Simplified water balance

The content of the shaded cells is purely informative and is not taken into account in the computation.

- The *part submitted to treaties* refers to that part of the water entering or leaving the country, which is subject to treaty. Treaties are not always expressed in terms of annual flows and interpretation might be needed for the sake of the water balance computation (in the case of the Aral Sea basin the allocation of flow to single countries are expressed in percentage of actual resources of the basin and may therefore vary from year to year).
- The *inflow secured through treaties* refers to that part of the *flow submitted to treaties*, which is reserved for the country. The *flow to be reserved by treaties* refers to that part of the *outflow submitted to treaties* which has to be reserved for the downstream countries; it has therefore to be subtracted from the country's balance.
- In all cases the *part accounted for in the country's balance* is computed according to the rules described in Box 5.

AQUASTAT
Computation of water resources by country (in km3/year, average)

Country: Syria

	Natural	Actual			Notes
INTERNAL RENEWABLE WATER RESOURCES					
Surface water produced internally	4.800				
Groundwater produced internally	4.200				
Overlap			2.000		
Total internal renewable water resources (IRWR)	9.000		- 2.000	= 7.000	
EXTERNAL RENEWABLE WATER RESOURCES	Natural	Actual	Ref year	1995	
External surface water					
Surface water entering the country	28.730				Euphrates (26.29) Affluents Euphrates (1.62)
Part not under agreements		1.930			Afrine (0.19) Sajour (0.12); Orontes 0.51 [0.43]
Part under agreements		26.800			Euphrates + Orontes
Part secured through agreements		16.180			Euphrates 15.75; Orontes 0.43
S.T: Part accounted for in the country's balance	28.730	18.110			
Flow of border rivers					
Total	18.000	18.000			Tigris (Hasbani not counted)
Part accounted for in the country's balance	9.000	9.000			
Shared lakes					
Part accounted for in the country's balance	0.000	0.000			
Surface water leaving the country	31.975				Orontes (N1.2;A0.012)Afrine (N0.25) Euphrates (N30;A9(58%)) Yarmouk (N 0.4;A0.2) Baniyas (N0.125)
Part not under agreements		1.575			
Part under agreements		30.400			
Part to be substracted from the country's balance			9.200		
Total external surface water (natural)	37.730			= 37.730	
Total external surface water (actual)		27.110	- 9.200	= 17.910	
External groundwater					
Groundwater entering the country					
Part accounted for in the country's balance	1.350	1.350			Turkey (Khabour, 1.2) Lebanon 0.15
Groundwater leaving the country	0.250	0.250			Dan
Total external groundwater (natural)	1.350			= 1.350	
Total external groundwater (actual)		1.350		= 1.350	
Total external water resources (natural)				39.080	
Total external water resources (actual)				19.260	

TOTAL RENEWABLE WATER RESOURCES (GRWR)

SUMMARY	Internal	External		Total	
		Natural	Actual	Natural	Actual
Surface water resources	4.800	37.730	17.910	42.530	22.710
Groundwater resources	4.200	1.350	1.350	5.550	5.550
Overlap	2.000			2.000	2.000
Total	7.000	39.080	19.260	46.080	26.260

Dependency ratio

80.259

Results on a regional level

The results obtained from this spread sheet give the total natural resources and the actual renewable water resources (ARWR).

The *natural resources* are a useful reference for global studies but do not represent the available water resources for a given country. Each country has to face natural, socio-economic, or environmental constraints and political limitations and therefore not all the natural resource is available.

The *actual renewable water resources* (ARWR) indicate what has to be reserved under agreements. It is the maximum theoretical amount of water actually available for a country. While assessing the ARWR, the unused water flowing out of a country and accounted for as a resource for that country, is also considered as a resource for the downstream countries. As a consequence, the total water resources of a set of countries sharing river basins are not additive.

Summary of water resources in a region

The results of the global water resources review are still in process. They will be presented as shown in table in the **Annex 2**, where the results for the former Soviet Union region are displayed.

- Surface water and groundwater have been presented in a non-additive way, that is to say their common part appears in both columns. The reason for this choice is that in most cases this is how the resources are presented in the country studies, and there is no objective reason to subtract the common part either from one or the other category. To make the computation of internal renewable water resources possible, a third column was added where the common part between surface water and groundwater (overlap) was indicated. Internally produced water resources is computed by removing this overlap from the sum of surface water and groundwater.
- External renewable water resources are also presented in the Annexe 2 and have been computed following the rules described in the previous section.
- Resources available on a dry year have also been presented in order to show the variability of resources.
- Manageable water resources have also been presented in order to show, when data are available the major differences that can be found between “natural” and “manageable” resources.

Cross-checking external flow at a regional level

When working at a regional level (group of countries). It is necessary to complete the water resources computation sheets by a cross- checking of exchanges between the countries. A matrix is used to compare inflow and outflows in the group of countries.

Annex 3 presents the matrix of exchange between countries of the Central Asia sub-region.

- The rows of the matrix correspond to the outflow from the countries listed in the first column. The last column to the right shows the total outflow from each country.
- The columns of the matrix correspond to the inflow to the countries listed in the first row. The bottom row shows the total inflow to each country.
- The inflows and outflows indicated in the matrix correspond to the sum of the actual inflows or outflows not submitted to treaties and the inflows or outflows secured or reserved through treaties. Contrarily to what is indicated in the Surface Water Resources table of **Annex 3**, the inflows presented in the matrix are the real inflows without deduction of that part of the upstream flow coming from the same country. This way of displaying the data allows for a more precise representation of the flow exchange between the countries. It also leads to some discrepancies between the data on water resources and the data on flow exchange. **Box 7** provides concrete examples of the differences that may arise between the water resources estimates and the flow exchange.

Box 7: Example of differences between water resources estimates and flow exchange: Case of Ukraine

- The **Pripyat** river supplies 12.7 km^3 /yr. of water to the Dnepr at its entry point to Ukraine from Belarus; however, part of this flow (5.8 km^3/yr) is generated in Ukraine in the upstream river basin and has to be deducted from 12.7 km^3/yr. to represent the water resources of Ukraine, since 5.8 km^3/yr is already accounted for as internal resource. In the matrix of Eastern European Countries, the flow from Belarus to Ukraine is indicated as 12.7 km^3/yr and the flow from Ukraine to Belarus is indicated as 5.8 km^3/yr.
- The **Dnestr** river supplies 9.84 km^3/yr from Moldova to Ukraine, out of which 9.2 originate from Ukraine itself and has to be deducted to represent the water resources of Ukraine (being 9.2 already accounted for as internal resource). In the matrix of Eastern European Countries, the flow from Moldova to Ukraine is indicated as 9.84 (+0.11 from other rivers) but the 9.2 km^3/yr are indicated as flow from Ukraine to Moldova.
- The **Danube** is a border river with Romania which receives the flow of two tributaries originating in Ukraine where 6.5 and 2.9 km^3/yr are generated, respectively within the Cisa and Prut basins. As total Danube flow is accounted for half of its actual flow, i.e. 126/2=63 km^3/yr (border river, see box 2), half of the flow generated in Ukraine (9.4/2) is deducted to represent the water resources of Ukraine but is presented as outflow from Ukraine to Hungary for the Cisa and from Ukraine to Moldavia and Romania for the Prut.
- **Total: as** a whole, according to the matrix of exchange, Ukraine receives 106.150 km^3/yr while only 86.450 (see table of Annex 1) can be considered as water resources.

Examples of some difficulties found when computing external water resources

Surface water: An analysis of the surface water resources at river basin level and by country brings the following remarks.

- The figures under the column "inflow" are provided by national document ; they may correspond either to actual inflow affected by upstream consumption or to theoritical inflow secured through treaties. Therefore, it may happen in certain countries that the actual inflow is different from the inflow secured by treaties indicated on the table.
- Another difficulty related to the inflows or outflows secured by treaties is due to fact that in most cases the treaties fix the exchanges between countries in term of percentage of basin water resources which obviously vary from year to year.
- For the flows, which are not subject to formal treaties or agreements, the value indicated in the computing table should correspond to average annual actual flows over the last years. It should be mentioned however, that, due to the difficulty to collect data the flow average was not systematically done over the same period. The figures indicated should therefore be considered as the best possible estimate.

Total resources: As shown in **Annex 1**, it is difficult to select the necessary data set for water resources computation. In the available sources, there are slight or big differences between the figures. It is not clear whether the differences are due to better estimation of resources (improved knowledge, better measurement network...), or changes in the method of estimation and calculation, or a change in the definition of the various variables used in the calculation. In some cases, it appears that the change were simply due to typing errors!

Some of the major causes of differences among countries and within countries are:

- Differences in the reference period used to calculate averages;
- Differences in the way water resources are estimated on a catchment level from extrapolation of measured results;

- Over-estimation of resources when there is double–counting. It is the case when summing up surface water and groundwater, that have been estimated independently and that are not additive; or the summing of flows originating from sources and the groundwater actually feeding the sources.
- Differences in the methods to estimate incoming flows and trans- boundary rivers flows between the respective countries.
- Mis-summing up when adding stocks (as potential groundwater in fossil aquifers, so non renewable resources) to the flows of renewable resources; or when adding to renewable resources, secondary resources such as waste water discharged that may be reused (more particularly drained water from irrigation perimeters).
- Change in estimates, often rising, due to improvement of knowledge (better methods or better measurement network. For example, for the three Maghreb countries (Tunisia, Algeria, and Morocco) the average total flow increased of 20% in 20 years, going from 38 km3/year in 1970 to 48 km3/year in 1990.

Therefore, in the attempt to compile water resources statistics, we have to be conscious of these differences and the necessary caution when using these data for comparison.

Conclusion

This paper presented the approach used within the AQUASTAT program to assess natural and actual water resources. It deals with renewable resources and concentrates mainly on the physical assessment of internal and external resources. It is part of a larger effort to assess the water resources and use of the countries of the world.

When national data are absent or not reliable, estimates may need to be obtained from model and satellite imagery. However, modelled data can help but will never replace local measurements.

The comments on the drawbacks of water resources statistics show that the path is still long to get good statistics on water resources, and particularly standardised data sets. The methodology used by AQUASTAT to computer water resources is therefore voluntarily simple, and follows transparent rules. There is certainly still a lot of work to be done on water resources assessment and accounting.

We hope that the work presented here provides a good starting block for structuring data collection at national level and improving global data sets and computation methods.

Glossary of main terms used in AQUASTAT water resources survey

Average precipitation: (mm/year and km3/year) Double average over space and time of water falling on the country in a year.
Dependency ratio: (%) That part of the total renewable water resources originating outside the country.
External groundwater inflow : (km3/yr) Average quantity of groundwater annually entering the country (usually restricted to large aquifers shared by several arid countries).
External groundwater outflow (km3/yr): Average quantity of groundwater annually leaving the country either to the sea or to other countries (usually restricted to large aquifers shared by several arid countries).
External renewable water resources: (km3/year). Part of the country's renewable water resources shared with neighbouring countries.
External surface water / outflow not submitted to agreements or treaties (km3/yr): Average quantity of water leaving the country (including to the sea) and not submitted to treaties.
External surface water /flow of bordering rivers (not submitted to agreements or treaties) (km3/yr): Average quantity of water annually reaching the country through bordering rivers.
External surface water /outflow to be reserved through agreements or treaties (km3/yr) : Average quantity of water to be reserved by treaty for a downstream country.
External surface water/ inflow secured through agreements or treaties (km3/yr): Average quantity of water entering the country which is secured through treaties.
External surface water/inflow not submitted to agreements or treaties (km3/yr): Average quantity of water annually entering the country through trans- boundary flow (rivers, canals, pipes). This figure concerns only the flows which are not submitted to a formal agreements or treaties.
Internal renewable water resources: (km3/year) Average annual flow of rivers and recharge of groundwater generated from endogenous precipitation.
Manageable water resources: (km3/year) Part of the water resources which is considered to be available for development under specific economic conditions. This figure considers factors such as the dependability of the flow, extractable groundwater, minimum flow required for non consumptive use, etc. Also called water development potential.
Natural flow: (km3/year) The amount of water which would flow in natural conditions, i.e. Without human influence.
Overlap: (km3/year) That part of the water resources which is common to both surface water and groundwater.
Potential yield: (km3/year) Total amount of water resources, be it surface water or groundwater, generated by the hydrological cycle on a yearly basis. It is a physical concept.
Total actual outflow ;(km3/yr) actual outflow of river and groundwater into the sea plus actual outflow into neighbouring countries
T**otal actual renewable water resources**: (km3/year) The sum of internal renewable water resources and incoming flow originating outside the country, taking into consideration the quantity of flows reserved to upstream and downstream countries through formal or informal agreements or treaties. This gives the maximum theoretical amount of water actually available for the country.
Total natural renewable water resources: (km3/year) The sum of internal renewable water resources and natural incoming flow originating outside the country.
Total outflow (GW & SW) going to sea and neighbouring countries : (km3/yr) annual outflow of surface and ground waters from a country into the sea or a neighbouring country.

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Annexes

ANNEX 1 : comparison of various information sources for USA

ANNEX 2 : Summary table of water resources for former Soviet Union countries

ANNEX 3 : Matrix of exchange between the Central Asian countries and the former Soviet Union.

ANNEX 4 : Computation of renewable water resources by country

ANNEX 1 : comparison of various information sources for USA

Country : USA Data in km3/yr

	source and date of reference	1 annual average precipitation	internal natural renewable water resources (annual average)				6 internal water resources in a dry year on a 10 yr frequency	7 external renewable resources (a)	8 total natural resources	actual renewable resources (contemporary annual average)		exploitable resources c)				
			2 average surface water flow	3 groundwater	4 overlap	5 total (2+3-4)			5+7	9 actual external resources (b)	10 total actual resources 5+9	renewable (annual average)				15 non renewable
												11 regular surface water	12 irregular surface water	13 groundwater (d)	14 total 11+12+13	(n years)
	US WRO, 1968	5800 (usa1)				2478										
1	FAO/AQUASTAT															
2	Shiklomanov, 1997					2810		146	2856							
3	Shiklomanov, 1998															
4	Shiklomanov, 2000					2930		148	3078							
5	IWMI 1998					2478										
6	IWMI 2000								3048						1829	
7	Raskin 1997								2478							
8	Gleik, 1993					2478										
9	Gleik, 1998								2478 (usa1)							
10	WRI 2000					2460		18	2478							
13	OCDE					2460		18	2478							
	UNECE, 81					1890 (usa1)	1100 (usa1)	18.9	2008.9					106 (usa 1)		
	UNECE, 77	7116				2460		-						130 (usa 1)		
	L'V, 74	6398	1685 (usa 2)	660	-	2345 (usa3)		-								
	USGS, 77 ; USWRC					2478	1030 (usa1)									
	USGS 1983		3610	1300	1150	3760		20	3780 (usa4)							
	USWSC 77 + ICID 83	5800 (usa 1)				3110	930 (20 yrs. avg.)	22.5								

NOTES:
col1 the data "average annual volume of precipitation allows to assess the green water volume= rainfall- IRWR (as a first estimation) ; it is equivalent to the resource for dry agriculture.
col 7 a) surface and groundwater including the agreed part of border river
col 9 b) under existing upstream geopolitical constraints (de facto or by agreement)
col 11-14 c) according to criteria specific to each country (they can be techno-economic, geopolitical, environmental...)
col 13 (d) including under constraint of reservation of sources and water courses.
NOTES ON DATA SETS:
USA 1 : USA only
USA2 : including Alaska representing 432 Km3/year
USA3 : including Alaska representing 610 km3/year
USA4 : including Alaska representing 1346 km3/year

REFERENCES (USA ones); the others are international references:
WRC 1968, "the nations water resources, US water resources council, Washington DC
We find for the sum of natural runoff the figure 2478 km3/year for the sum of USA.
WRC 1978, "the Nations's water resources 1975-2000"Second National water assessment US WRC, Washington DC 1978
Cf. Vol2, fig N2 "average daily water budget" that indicate the following sub surface flow out to the sea: 25 bgd to the pacific, 75 bgd to Atlantic so it is a sum of 100 bgd= 138.15 km3/year
1 bgd = billion gallons/day = 1.3815 km3/year
USGS1983, national water summary 1983, hydrological events and issues, United States Geological Survey, water supply paper 2250. Jan. 1984 Washington DC.
It is indicated in this ref. that the sum of groundwater recharge (conterminous USA) is around 880 bgd = 1215 km3/year.
The overlap was calculated by taking the differences between GW recharge (around 1300 km3/year to account also for Alaska etc.) according to the data thereafter.
For the "conterminous USA" overlap would be more exactly: 2003-138 = 1865 km3/year
However these estimations certainly need to be updated.

Annex 2 : SUMMARY TABLE OF WATER RESOURCES FOR FORMER SOVIET UNION COUNTRIES

(all figures in km3/year)

No	Country	Population	Internal Renewable Water Resources (IRWR)					External Renewable Water Resources		Total Actual Renewable Water Resources (ARWR)		Dependency ratio	Country
			Surface water	Ground-water	Overlap	Total	IRWR per inhabitant	Surface water	Ground-water	Actual	ARWR per inhabitant		
		inhabitants				=(2+3-4)	in m ^{3}	Actual	Actual	=(5+8+10)	in m ^{3}	%	
		(1)	(2)	(3)	(4)	(5)	(6)	(8)	(10)	(12)	(13)	(14)	
1	Armenia	3 638 000	6.271	4.200	1.400	9.071	2 493	1.458		10.529	2 894	13.8	Armenia
2	Azerbaijan	7 594 000	5.955	6.510	4.350	8.115	1 069	22.160		30.275	3 987	73.2	Azerbaijan
3	Belarus	10 348 000	37.200	18.000	18.000	37.200	3 595	20.800		58.000	5 605	35.9	Belarus
4	Estonia	1 471 000	11.712	4.000	3.000	12.712	8 642	0.096		12.808	8 707	0.7	Estonia
5	Georgia	5 442 000	56.900	17.230	16.000	58.130	10 682	5.200		63.330	11 637	8.2	Georgia
6	Kazakhstan	16 820 000	69.320	35.870	29.770	75.420	4 484	34.190		109.610	6 517	31.2	Kazakhstan
7	Kyrgyz Republic	4 469 000	44.050	13.600	11.200	46.450	10 394	-25.870		20.580	4 605	0.0	Kyrgyz Republic
8	Latvia	2 504 000	16.540	2.200	2.000	16.740	6 685	18.709		35.449	14 157	52.8	Latvia
9	Lithuania	3 728 000	15.360	1.200	1.000	15.560	4 174	9.340		24.900	6 679	37.5	Lithuania
10	Moldova	4 444 000	1.000	0.400	0.400	1.000	225	10.650		11.650	2 622	91.4	Moldova
11	Russian Feder.	148 126 000	4 036.700	788.000	512.000	4 312.700	29 115	185.540		4 498.240	30 368	4.1	Russian Feder.
12	Tajikistan	5 935 000	63.300	6.000	3.000	66.300	11 171	-50.320		15.980	2 693	16.7	Tajikistan
13	Turkmenistan	4 155 000	1.000	3.360	3.000	1.360	327	23.360		24.720	5 949	97.1	Turkmenistan
14	Ukraine	51 608 000	50.1000	20.000	17.000	53.100	1 029	86.450		139.550	2 704	61.9	Ukraine
15	Uzbekistan	23 209 000	9.540	19.680	12.880	16.340	704	34.070		50.410	2 172	77.4	Uzbekistan
	TOTAL	**293 491 000**				**4 730.198**	**16 117**						

Findings on the Former Soviet Union region

For the purpose of AQUASTAT, the 15 countries of the Former Soviet Union have been grouped in five regions,, based primarily on geographic conditions and, as far as possible, on hydro-climatic homogeneity, although the Russian Federation is, due to its size, subject to a wide variation of geographic and hydro-climatic conditions. The regions are here referred to as: Russian Federation, Central Asia, Eastern Europe, Caucasus and Baltic States.

While the FSU covers 17% of the area of the world, its annual renewable water resources are 12% of the renewable water resources of the world. However, as the FSU contains only 5% of the population of the world, the annual internal renewable water resources per inhabitant, over 16 000 m3, are more than twice the mean internal renewable water resources per habitant for the world as a whole. There is a wide variation by region, Eastern Europe with the highest population density having only 1 375 m3/year per inhabitant of internal renewable water resources and the Russian Federation with the lowest population density having over 29 000 m3/year per inhabitant.

Although, as a whole, FSU is well endowed in terms of water resources related to the population (over 16 000 m3/yr/inhabitant), their distribution is still uneven, from 227 m3/yr/inh.) for the Moldova to 190 000 m3/yr/inh.) for the Far Eastern par of the Rusian Federation. In those areas with the lowest Internal Renewable Water Resources, the surface water system partly offsets these handicaps and brings the total water resources per inhabitant to an acceptable level.

Water ressources are distributed among the former FSU and surrounding countries through an extensive surface water network crossing borders or occasionally acting as borders between countries. While this situation was simply governed through master plans at the time of the Soviet Union, today, treaties had to be enacted in order to fix the shares of each riparian country in a river system. Situations prevailing now in the FSU region are very diverse: transboundary or border rivers not submitted to treaties, transboundary or border rivers submitted to treaties. It requires detailled research for each country.

Annexe 3 : MATRIX OF EXCHANGE BETWEEN THE CENTRAL ASIAN COUNTRIES OF THE FORMER SOVIET UNION

		receiving										
	COUNTRIES	KAZAKHSTAN	KYRGYZ REP.	TAJIKISTAN	TURKMENISTAN *	UZBEKISTAN	RUSSIAN FED.	AFGHANISTAN	CHINA	IRAN	MONGOLIA	TOTAL
emitting	KAZAKHSTAN		0.000		0.000	0.000	Tobol 1.000 Ishim 1.800 Irtysh 36.000		0.000			
			0.000		0.000	0.000	38.800		0.000			38.800
	KYRGYZ REP.	Chu (treaty) 1.240 Talas (treaty) 0.790 Charyn 0.360		Amu Darya (treaty) 1.510		Syr Darya (treaty) 22.330			Tarim 6.180			
		2.390		1.510		22.330			6.180			32.410
	TAJIKISTAN		0.000		Amu Darya (actual) 49.000	Syr Darya (treaty) 11.540 Zeravshan (actual) 3.090		0.000	x ?			
			0.000		49.000	14.630		0.000	0.000			63.630
	TURKMENISTAN	0.000				Amu Darya ** (treaty) 18.910		0.000		0.000		
		0.000				18.910		0.000		0.000		18.910
	UZBEKISTAN	Syr Darya (treaty) 10.000	0.000	Syr Darya (treaty) 11.800	to Amu Darya (south-east) 3.900			0.000				
		10.000	0.000	11.800	3.900			0.000				25.700
	RUSSIAN FED.	Tobol 0.800 Ural 5.000 Caspian Sea 0.500							0.000		0.000	
		6.300							0.000		0.000	6.300
	AFGHANISTAN			0.000	Murghab 1.250 Amu Darya 4.180	0.000			0.000			
				0.000	5.430	0.000			0.000			5.430
	CHINA	Irtysh 9.200 Emel 0.300 Ili 6.000	0.000	0.000			Amur (net) 100.000	0.000			0.000	
		15.500	0.000	0.000			100.000	0.000			0.000	115.500
	IRAN				Tedzhen (1.07) treaty: 0.750 Atrek (0.10) treaty: 0.040							
					0.790							0.790
	MONGOLIA						Yenisey 25.000		x ?			
							25.000		0.000			25.000
	TOTAL	**34.190**	**0.000**	**13.310**	**59.120**	**55.870**	**163.800**	**0.000**	**6.180**	**0.000**	**0.000**	

* *Turkmenistan receiving:* *By treaty, Turkmenistan 43.32 (Amu Darya) and not 49+3.9+4.18=57.08.*

** *Uzbekistan* *The treaty between the five Central Asian States allocates 22 km3/yr to Uzbekistan which have been, for computation purpose, divided into 3.09 km3/yr from Tajikistan to Uzbekistan through Zeravshan river and 18.91 km3/yr from Turkmenistan to Uzbekistan through the main stream of Amu Darya*

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Computation of renewable water resources by country (in km^3/year, average)

Country: **COUNTRY NAME**

INTERNAL RENEWABLE WATER RESOURCES

Rainfall average						
Surface water: produced internally	a					
Groundwater: produced internally	b					
Water resources: overlap (Internal SW - GW)					c	
Water resources: Total internal (IRWR)		0.000	-	0.000	=	**0.000**
		=a+b		=c		d=a+b-c

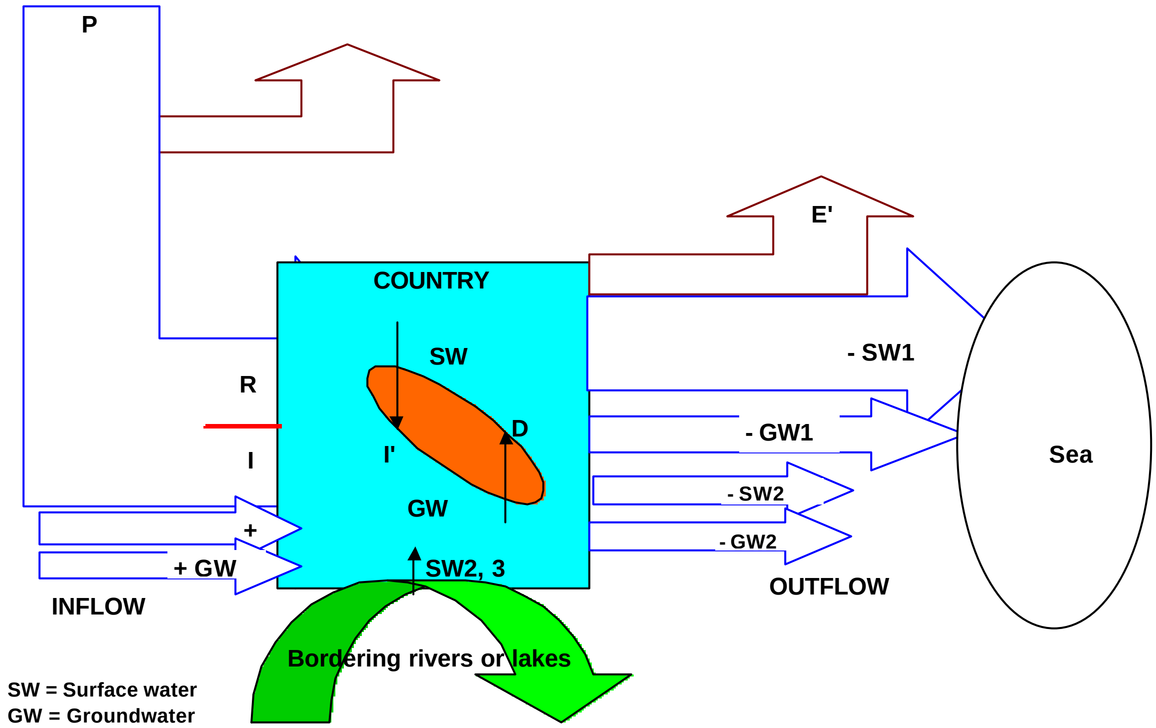
EXTERNAL RENEWABLE WATER RESOURCES

		Natural		Actual				
Surface water								
Surface water: inflow	e							
Inflow not sumitted to treaties					f			
Inflow submitted to treaties								
Inflow secured through treaties				0.000	g			
Accounted inflow		0.000		0.000				
		h=e		i=f+g				
Surface water:								
Total flow of border rivers								
Accounted flow of border rivers	j				k			
Surface water:								
Accounted part of shared lakes	l				m			
Surface water: outflow	n							
Outflow not submitted to treaties								
Outflow submitted to treaties								
Flow to be reserved by treaties							o	
Surface water: total external (natural)	p=h+l+j	0.000						
Surface water: total external (actual)			q=m+k+f+g	0.000	-	0.000	=	0.000
						r=o		a1=q-r
Groundwater								
Groundwater : total external	s							
								a2
Groundwater outflow	t				u			
Water resources								
Water resources: total external (natural)	v=p+s	0.000					w=v	0.000
Water resources: total external (actual)							x=a1+a2	**0.000**

TOTAL RENEWABLE WATER RESOURCES (TRWR)

		Total			
		Natural		Actual	
Surface water : total	y=a+p			0.000	aa=a+a1
Groundwater : total	z=b+s			0.000	bb=b+a2
Overlap	c			0.000	c
Water resources: total	wn=y+z-c			**0.000**	wa=aa+bb-c

Dependency ratio **#DIV/0!** **%** =100*(q+a2)/(q+a2+d)



INFLOW	OUTFLOW
P = precipitation	E = actual Evapotranspiration
R= internal runoff	E' = Actual evapotranspiration of water courses lakes , swamps of wetlands, and of groundwater in arid zones
I = groundwater recharge	*to sea*
SW1 surface water inflow	- SW1 surface water outflow
SW2 part of boundary river (potential)	- GW1 groundwater outflow
SW3 part of boundaries lakes (potential)	*To other countries*
GW groundwater potential	- SW2 surface water outflow
	- GW2 groundwater outflow

Assessment of overlap

I' Surface water to groundwater (infiltration losses of river)

D groundwater drained by river = base flow

I '+ D = overlap

Internal water Balance

P = E + R + I

Total water balance

R + I + SW1 + GW - SW1 - SW2 - GW1, 2, 3 - E ' = 0

(inequilibrium conditions, with no storage variations)

GRAPH : Simplified water balance