The Role of Lakes and Reservoirs in the World Hydrological Cycle

Gronskaya T. Lemeshko N.

State Hydrological Institute July 2009

Hydrological Cycle

The hydrologic cycle is the continual recycling of water between the oceans, land surface, underground aquifers, rivers and the atmosphere.



The drivers of water cycle are energy factors.

- Water vapour is continually evaporating from the oceans, freshwater sources and soils and through transpiration from plants forming clouds and eventually precipitating as rain or snow.
- This precipitation (about 1030 mm for the Earth) often returns quickly to oceans and rivers as surface runoff but water remains for some time as soil moisture, groundwater, ice, snow, or as lakes water.

water at the Earth

Main reservoirs of water on the Planet are as follows:

- oceans,
- glaciers,
- underground aquifers
 And much smaller:
 lakes&reservoirs,
 soils, atmosphere, rivers and
 biosphere.

Reservoir	Volume (mln cubic km)	Percent of Total		
Oceans	1370	97.25		
Ice Caps and Glaciers	29	2.05		
Groundwater	9.5	0.68		
Lakes	0.175	0.01		
Soils	0.065	0.005		
Atmosphere	0.013	0.001		
Rivers	0.0017	0.0001		
Biosphere	0.0006	0.00004		

Water is continually cycled between these various reservoirs. The velocity of transfer of different forms of water differ significantly and time for their discharge and renewal is also different.

- The residence times of water in the major reservoirs fluctuates in wide limits: from a few hours for biological water to several thousands of years in glaciers and underground layers.
- Water in the atmosphere is completely replaced once every 8 days.
- Water is renewed in rivers once every 16 days at the average.
- Replacement of water in lakes vary from one year for small volumes up to several hundreds for the large deep lakes.
- Complete renewal of the water in Lake Baikal takes 380 years.
- The annual volume of lake water renewed is not more than 2% of the volume of the lakes.

Periods of renewal for reserves of water on the Earth.

kinds of water	Period of renewal
World ocean	2500 years
Glaciers	1600 - 9700 years
Groundwater	1400 years
Soil Moisture	1 year
Lakes	17 years
Rivers	16 days
Atmospheric moisture	8 days

Fresh water of hydrosphere constitutes about 2,5% of total global water



Although the blue color of Earth suggests the availability of large quantities of water, nearly all of it is in the oceans, unsuitable for most human needs.

None of natural resources had historically and has today such a profound material effect upon life as has the water...

- The alternative sources of energy and daylight have been discovered during the social life. But there is no substitute for fresh water for mankind.
- Volume of freshwater in ice cover and underground aquifers are by order of magnitude greater (98,9%) than in rivers, lakes and reservoirs (0,3%) but

more than 90% of liquid water contains in natural and artificial lakes

which are one of the most important source of water available for human and economic use.

The estimated area of all lakes in the world is about 2,1 mln km³- its about 1,4% of the total land area.

The total water volume in the 145 largest lakes throughout the world amounts to 167,100 km3 and 86,500 km3 of them - fresh water. The total water volume involved in the hydrologic cycle of the world largest lakes is equal to nearly 1% of their total secular storage.

Data on water reserves in the largest lakes by continents

Continent	Lakes with water	Surface area,	Water reserves, km³		
	surface larger 100 km²	10 ³ km²	fresh	salt	
Europe	34	430.4	2,027	78,000	
Asia	43	159.2	27,782	2,220	
Africa	21	196.8	30,00 0	203	
N.America	30	392.9	25,623	19	
S.America	6	27.8	913	2	
Australia & New Zealand	11	41.7	154	174	

20 of the world's lakes are considered extremely deep (more than 400 m in depth), containing a significant portion of our planet's freshwater.

Lake Baikal contains about 16%, while the Great Lakes of North America (Superior, Michigan, Huron, Erie, Ontario) constitute the greatest continuous mass of freshwater on earth, containing about 20% of all the liquid freshwater on the earth's surface. Lakes Victoria, Tanganyika and Malawi in Africa are also among the largest and deepest lakes in the world.

The Caspian Sea is the largest inland lake (78648 km3).

The vast majority of our easily accessible water resources, however, are contained in the numerous lakes of much smaller size and volume, usually less than

20 meters deep.

(Copyright 2003 International Lake Environment Committee Foundation and United Nations Environment Programme) The largest concentration of lakes is in areas of early and contemporary glaciation, large tectonic fractures of the Earth's crust, and in areas of internal run-off

- many lakes are in Finland where they occupy 9,4% of total country area
- in Sweden lakes surface cover 8,6 % of country
- The large lake complex is the Great Lakes of North America.

Russia is one of the most "lake" country in the world

with 2,76 mln. lakes

35 163 lakes with water surface larger than 1 sq. km.

The ratio between a lake's surface area and the whole area of a

lake district



The northwestern part of European Russia where the "lakeness" is about 5,4% without largest European Lakes Ladoga and Onega and rises up to 12,6% if include large Lakes.



Water-surface lake area (km²)

31722

17872 9693



- The annually renewable fresh-water lakes' resources are distributed among the continents as follows:
- 585 km³ in N.America
- 296 km³ in Africa
- 162 km³ in Europe
- 89 km³ in Asia
- 45 km³ in S. America
- ~5 km³ in Australia and Oceania (0,4%)
- The annual average figures hide large seasonal, inter-annual, and longterm variations.



Water balance components ratio

 Fresh-water lakes as well as salty ones are mainly fed with surface inflow (I) and precipitation (P). The income part of water balance is spent in different ways: in exorheic lakes - it is river outflow (O), and to a lesser degree evaporation (E);

• in endorheic lakes – evaporation only.

Continent	<i>inent</i> Characteristic of lake		Income (In)		Outcome (Out)		
		I /In, %	<i>P/In,</i> %	<i>0/0ut,</i> %	E/Out, %		
Europe	Exorheic	84	16	88	12		
Caspian Sea	Endorheic	76	24	0	100		
Asia	Exorheic	80	20	78	22		
	Endorheic	83	17	0	100		
Africa	Exorheic	30	70	13	87		
Chad, Rudolf	Endorheic	80	20	0	100		
N.America	Exorheic	64	36	71	29		
Great Salt Lake	Endorheic	74	26	0	100		
S.America	Exorheic	60	40	11	89		
Australia &Oceania	Exorheic	74	26	87	13		
Lakes Eyre,Torrens	Endorheic	66	34	0	Dried up		

World man-made lakes

Humans throughout history have constructed artificial lakes, also called reservoirs, primarily for addressing problems of water supply, or alternatively for providing flood or drought protection.

In modern times, they also are used for such purposes as hydropower generation, sports and commercial fisheries and water-based recreation.

Nearly all the world's major river systems have reservoirs in their drainage basins, and 800,000 reservoirs are now in operation worldwide.

Approximately 1,700 more large reservoirs are currently under construction, particularly in developing countries.

(Copyright 2003 International Lake Environment Committee Foundation and United Nations Environment Programme)

World man-made lakes



The Krasnoyarsk Reservoir Dam

There are about 60, 000 large reservoirs (>15m dam height) worldwide. In accordance with SHI assessments the total reservoirs volume in the world is 6370 km³ (14,9% from world renewable water resources) with water surface (without flooded lakes) - 356400 km² (by Shiklomanov&Balonishnikova).

Over the Russia territory there are 29,300 man-made water bodies: 1937 - reservoirs with volume 1-10 mln.cub.m 363 reservoirs - more than 10 mln. cub.m The volume of all these reservoirs equals to 790 KM³

In contrast to natural origin of lake, reservoirs are man-made water-bodies, usually formed by constructing a dam across a flowing rivers.

A dam also may sometimes be constructed on the outlet channel of a natural lake as a means of providing better control of the lake's water-level (examples being Lake Victoria (Africa), Lake Baikal (Russian Federation). However, these latter water-bodies usually remain their natural lake' characteristics. A number of river systems: Columbia, Dnieper, Volga, Angara, Parana, Missouri have cascades of reservoirs within their basins.

Cascade of the Volga River reservoirs with total storage 193 km³ - 80,5% from the river annual run-off



Dynamics of reservoir construction in Russian Federation

Dynamics of Reservoir construction in Russia shown here is much similar to those in Europe and N.America: the periods of massive construction of reservoirs on continents began in the middle of last century and continued up to 1985-1990, increasing the cumulative full volume of water stored in about 10 times.



Total water storage > 10 mln.cub m

Total water storage 1- 10 mln.cub m

Volumes and water areas of reservoirs by continents according to SHI Database

(by Shiklomanov&Balonishnikova)

Continent	All reservoirs			Included:						
	number volume km ³	water area	with volumes >1km ³		with volumes >0.1km ³			with volumes <0.1km ³		
			(without lakes) km ²	number	volume km ³	number	volume km ³	area km²	number	volume km ³
EUROPE	134	516	45520	75	488	126	515	45480	8	0.40
NORTH AMERICA	234	1407	86280	183	1374	231	1406	86260	3	0.14
AFRICA	57	910	40970	43	903	56	910	40960	1	0.04
ASIA	245	1683	68550	170	1645	231	1681	67870	14	0.50
SOUTH AMERICA	111	902	52160	82	885	106	902	52150	5	0.25
AUSTRALIA AND OCEANIA	30	72.6	3708	21	67.7	29	72.5	5.0	1	0.10
THE WORLD (raunded)	811	5491	297200	574	5363	779	5489	292700	32	1.43

Increment of the total and active volumes of reservoirs by continents

for different periods:

up to 1940, 1941-1960, 1961-1980, 1981-2000 (Shiklomanov&Balonishnikova).

Volume,km3



The data come from the latest reviews by SHI based on a database holding information on all reservoirs in the world with storage volumes of more than 0,1 cub.km

Increment of the total area of reservoirs by continents for different periods : up to 1940, 1941-1960, 1961-1980, 1981-2000 (Shiklomanov&Balonishnikova).



The countries with largest total volume of reservoirs

(Shiklomanov&Balonishnikova).



The distribution of reservoirs by countries is extremely uneven. For 20 countries – 6 countries have the largest volumes, Russia-950 km³ of full volume, less- Canada& USA -800 km³ but USA has the larger than Russia active volume of reservoirs –about 700 km³

The largest reservoirs in the world are:

by volume

- the lake reservoir of Owen Falls (Lake Victoria, Nile basin, Uganda) -205 cub.km
- Bratsk (Angara River, Russia) -169 cub.km

by surface

the Volta (Ghana) -8500 sq.km

Kuybyshev Res. (Russia) -6500 sq. km



- Water of Lakes and reservoirs, which involve in local water cycles within river watersheds, intensify the water cycle over the continents because of their water resources are considerable both in absolute and relative volumes.
- ***** What is most important for lakes as a part of water cycle?
- First of all evaporation from the lakes are larger than from the land surface. Increased evaporation from the man-made and natural lakes decrease total water resources.
- Secondly- exorheic and man-made lakes regulate river run-off.

Natural & man-made lakes are one of the most important source of water that are available for human and economic use.

- Fresh water spends some time in lakes and reservoirs, so they are very sensitive to any anthropogenic influence and pollutions.
- Lakes and reservoirs influence significantly on the quantity and the quality of the fresh water.

As a conclusion

• No dough that lakes are very important object not only from scientific point of view but as the world's easily-accessible water resources, and as sources of food and economic development.

Lakes also are among the most vulnerable aquatic ecosystems.

Based on these , the World Lake Vision Committee prepared the document

"World Lake Vision : A Call to Action".

- The preparation and production of this report was supported and promoted by the International Lake Committee Foundation (ILEC), Shiga Prefectural Government, and United Nations Environment Programme-International Environmental Technology Centre (UNEP-IETC).
- Many organizations and individuals contributed in the development of the World Lake Vision, but only one person from Russia-from Baikal Information Center.
- To join this initiative should be **for the common good**
 - both for SHI and HYDROLARE



Although the blue color of Earth suggests the availability of large quantities of water, nearly all of it is in the oceans, unsuitable for most human needs.

