ASSESSMENT OF BASINWISE WATER RESOURCES POTENTIAL IN INDIA

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Synopsis

Assessment of Water Resources Availability and Utilization in the country is the corner stone of planning process as evident from the number of studies undertaken in the past for the purpose. Starting from the First Irrigation Commission study in early 1900 to the report of National Commission for Integrated Water Resources Development (NCIWRD-1999) different methodologies / approach have been followed to assess the available water resources in the country.

During the reassessment studies carried out by CWC in 1993, the entire country was divided into 20 river basins comprising 12 major basins and 8 composite river basins. The flow data observed by CWC in various terminal sites and the utilization data were used to assess the average annual water resources potential in the river basins of the country.

One of the major limitations of the study done in 1993 was non-availability of utilization data for various sectors uniformly in all river basins which meant that assumptions had to be made depending upon the type of data that could be obtained for the abstractions. The above limitation exists even today which prompted an attempt of assessing utilisation in the recent pilot studies taken up jointly by CWC and NRSC through water balance approach using technological tools such as GIS and Remote Sensing applications.

National assessment of water availability and utilization of water resources in the river basins of such a vast and diversified country like India, has to be a long term strategy. International case examples in USA and Australia indicate that these countries have formulated legal and institutional framework for assessment of availability and utilization of water in the country. In India also there may be a need for development of a National Water Availability and Utilization Assessment (NWAUA) Structure as a part of the long term strategy.

1.0 Introduction

Water being a precious resource without which no life can be sustained on Earth, the level of its availability and development influences quality of life to a considerable extent. The source of all fresh water on the land is precipitation. But all the precipitation that occurs on land is not directly available for use by human beings. Major part of precipitation returns back to the atmosphere by evaporation &evapo-transpiration. Rest of the water becomes available either as surface water in natural lakes, streams and rivers, or as ground water. Although all the water ultimately flows back into oceans or is lost to the atmosphere by way of evapo-transpiration, during the land phase of hydrologic cycle, water can be exploited and put to beneficial use.

Apart from basic need of drinking for sustaining human life, water is also used for other beneficial purposes such as irrigation for increasing crop productivity, industrial processing, etc. In our country with monsoonic type of climate which causes rainfall to occur mainly in three to four months of a year with large variations from year to year, exploitation of the resource to make it available when it is needed and where it is needed has been a major developmental activity.

Although irrigation is major consumer of water in the country, water requirement for other purposes such as industrial processing is also increasing day by day due to increasing economic activities. Because of increasing use of water for varied purposes, water is already scarce in some regions of the country.The assessment of country's water potential is thus an essential pre-requisite for efficient planning and management of the resources. River basin is basic hydrologic unit for planning and development of water resources. It therefore follows that assessment of water resources has to be necessarily basinwise.

2.0 ASSESSMENT OF WATER RESOURCES POTENTIAL IN INDIA DONE SO FAR

2.1 First Irrigation Commission (1901-03)

First ever assessment of the average annual flow of all river systems in India was attempted by the Irrigation Commission (1901-1903). The major constraint at that time was that while records in respect of rainfall were available, data in respect of river flows were not available even for many of the most important river systems. The Commission, therefore, resorted to estimation of river flows by adopting coefficients of runoff. The average annual flow of all river systems in India was assessed as 1443 BCM.

2.2 Dr.A.N. Khosla (1949)

Dr. A.N Khosla developed an empirical relationship between mean temperature (as an expression for mean evaporation loss) and mean runoff based on his studies on the flows of Sutlej, Mahanadi and other river systems. While applying these relationships Dr. Khosla divided the entire country into six regions, viz (i) Rivers falling into Arabian Sea excluding Indus, (ii) Indus Basin within India, (iii) Rivers falling into Bay of Bengal other than Ganga-Brahmaputra system, (iv) the Ganga, (v) the Brahmaputra, and (vi) Rajputana. According to these studies, total annual flow of all the systems worked out to 1673 BCM.

2.3 Central Water and Power Commission(1954-66)

The study was mostly based on the statistical analysis of flow data wherever available and rainfall-runoff relationships wherever data was meagre. The country was divided into 23 sub-basins / basins. Ganga was divided into as many as ten sub-systems. Other major peninsular river basins like Narmada, Tapi, Godavari, Krishna, Pennar and Cauvery were considered separately. Other river systems were combined together suitably into a few composite systems. According to these studies, water resources of various basins amounted to 1881 BCM.

2.4 National Commission on Agriculture (1976)

NCA estimated total annual water resources of the country as 1850 BCM based on water balance approach taking into account rainfall, percolation of water in soils, evaporation and evapo-transpiration.

2.5 Specific Studies

Studies were reportedon various instancesfor specific purposes in respect of some of the river basins. Godavari basin by Krishna-Godavari Commission (1962); Cauvery basin by Cauvery Fact Finding Committee (1972); Krishna basin by Krishna Water Dispute Tribunal(1973); Narmada basin by Narmada Water Dispute Tribunal (1979); Mahanadi, Subernarekha, Sabarmati and Tapi basins by Central Water Commission; Ganga basin by Ganga Brahmaputra Water Studies Organisation (GBWS); Brahmaputra basin by Brahmaputra Board (1987); Indus basin by Indus Commission(1960); etc.

2.6 Central Water Commission (1988)

Central Water Commission during 1987-88 made corrections on the average annual flows on the basis of observed river flows in consideration of the significant increase in ground water extraction over the years and additional evapo-transpiration.

The Irrigation Commission (1972) estimated the ground water draft for the year 1967-68 as about 58 BCM. District-wise estimate of total ground water draft for the year 1983-84 estimated by Central Ground Water Board for the country was about 100 BCM.Assuming linear variation, the yearly ground water draftswerecomputed. Consumptive use of ground water was assumed as 70% of the withdrawal.Average annual water resources potential of the country was worked out as 1880 BCM.

2.7 Reassessment of Average Annual Water Resources Potential (1993)

A study on Reassessment of Water Resources Potential of India was published in 1993 by Central Water Commission. The country was divided into 20 river basins comprising 12 major and 8 composite river basins.

The twelve major basins are: (1) Indus; (2) Ganga-Brahmaputra-Meghna; (3) Godavari; (4) Krishna; (5) Cauvery; (6) Mahanadi; (7) Pennar; (8) Brahmani-Baitarni; (9) Sabarmati; (10) Mahi; (11) Narmada; and (12) Tapi.

The eight composite river basins are: (1) Subernarekha – combining Subernarekha and other small rivers between Subernarekha and Baitarni; (2) East flowing rivers between Mahanadi and Pennar; (3) East flowing rivers between Pennar and Kanyakumari; (4) Area of Inland Drainage in Rajasthan Desert; (5) West flowing rivers of Kutch and Saurashtra including Luni; (6) West flowing rivers from Tapi to Tadri; (7) West flowing rivers from Tadri to Kanyakumari; and (8) Minor rivers draining into Myanmar (Burma) and Bangladesh

Natural (virgin) flow in a river basin is reckoned as water resources of basin. The mean annual flow was obtained on pro-rata basis from the mean annual flow at terminal site of the basin. Natural flow at any location on a river was obtained by summing up the observed flow, upstream utilization for irrigation, domestic and industrial uses both from surface and ground water sources, increase in storage of reservoirs (both surface and sub-surface) and evaporation losses in reservoirs, and deducting return flows from different uses from surface and ground water.

Therefore,following equation was adopted.

$$R_N = R_O + R_{IR} + R_D + R_{GW} - R_{RI} - R_{RD} - R_{RG} + S + E$$

R_N is the natural flow
R_O is the observed flow
R_{IR} is the withdrawal for irrigation
R_D is the withdrawal for domestic and industrial requirement
R_{GW} is the ground water withdrawal
R_{RI} is the return flow from irrigated areas
R_{RD} is the return flow from domestic and industrial withdrawal
R_{RG} is the return flow from ground water withdrawal
S is the increase in storage of the reservoirs in the basin
E is the net evaporation from the reservoirs

2.7.4 Results of the Study

Based on the above methodology, CWC assessed average annual water resources potential of the country as 1869 BCM against an earlier assessment of 1880 BCM. Basin-wise water resource potential is given in Table 1.

2.7.3 Limitations of the Study

(1) For working out upstream abstractions, for various uses, assumptions were made depending upon the type of data that could be obtained for the abstractions. Uniform procedure could not naturally be adopted for all river basins. Particularly for estimating withdrawals for irrigation which is major consumer of water varying assumptions had to be made. In many cases while diversions from major and medium irrigation projects were available, those from minor schemes were seldom available.

(2) In most of the cases year-wise withdrawal from ground water had been estimated approximately assuming linear variation between state-wise draft estimated by the Irrigation Commission (1972) for year 1967-68 and by the Central Ground Water Board for year 1983-84.

(3) Return flows have been assumed to be 10% in case of irrigation (major and medium) and 80% in case of domestic and industrial supplies which were only approximate.

2.8 Assessment by National Commission for Integrated Water Resources Development (1999)

National Commission for Water Resources Development (NCIWRD) while assessing water resource potential, agreed with the estimates of CWC publication entitled "Reassessment of Water Resources Potential of India (1993)" except in case of Brahmaputra and Krishna basins. In Brahmaputra basin, NCIWRD assessment included additional contribution of 91.81 BCM of estimated flow of 9 tributaries joining Brahmaputra downstream of Joghighopa site. In Krishna basin, NCIWRD adopted mean flow of the yield series that is accepted by the KWDT Award. With these two variations, the estimation of NCIWRD yielded that average annual water resources potential of the country as 1953 BCM.

3.0 REASSESSMENT OF BASINWISE WATER SITUATION - STRATEGY UNDER NATIONAL WATER MISSION

One of the strategies identified for implementation under Comprehensive Mission Document of National Water Mission is "Reassessment of basin wise water situation" under present scenario including water quality by using latest techniques, which inter-alia may include:

- development or adoption of comprehensive water balance based model,
- fitting models to basin using current data, and
- assessment of likely future situation with changes in demands, land use, precipitation and evaporation.

The steps for implementation of the strategy envisaged coordination with National Remote Sensing Centre (NRSC), ISRO for assessment of national water resources using Remote Sensing, GIS based modelling.

NRSC, ISRO, Hyderabad initiated a R&D project on "Assessment of National Water Resources using Space Inputs" under EOAM funding for integrating space technology, geographical information tools, hydro-meteorological data and hydrological models. A brain-storming session on Water Resources Assessment was organized by NRSC at Hyderabad on 24th March, 2009 where IITs, IISc, RRSSC, CWC, NRSC participated.The need for re-assessment of water resources at national level, methods, models, time scale, spatial scale, input data, quality of data, impact of climate change on water resources, and other key aspects were discussed thoroughly in the session. Subsequently a technical document (guide) for research and practice on water resources assessment in the country was brought out.

3.1 Pilot Study for Godavari and Brahmani-Baitarni River Basins by CWC and NRSC using Remote Sensing and Geospatial Technology

The methodology for carrying out the pilot studies on experimental basis in two selected river basins of Godavari and Brahmani-Baitarani was worked outthrough discussions held among the officers of CWC, NRSC, CGWB and NIH. The highlights of the methodology include:

- Water balance approach;
- Precipitation as primary resource (spatial interpolation);
- New technology tools i.e. satellite derived spatial data (land use, land cover, elevation, soil), GIS;
- Semi-Distributed modelling approach;
- Concept of Hydrologic Response Unit (HRU) for water balance computation;
- Calibration and validation using CWC observed discharge observations.

The study indirectly estimates the utilization of water by various sectors. The study is jointly executed by CWC and NRSC officers.

3.2 Methodology of the Pilot Studies

The water balance technique using Thornthwaite and Mather(1957) has been adopted to carry out the pilot studies.

Estimation of Annual Water Resources:

Annual water balance of a basin can be represented as follows.

$P = I + AET + R$ ---------- (1)

P= Precipitation

I = Interception by the vegetation which can be ignored when the water balance is computed at monthly time step as the intercepted water reaches the ground or gets evaporated in the given monthly time step.

AET = Actual evapotranspiration from all landuse classes (forest, rain-fed agriculture, irrigated agriculture, other vegetation, water bodies, barren, scrubland, settlements, etc.)

$AET = AET_{iag} + AET_{rag} + AET_{o}$

AET_{iag} = AET from irrigated agriculture area (canals and well irrigated)
AET_{rag} = AET from rain-fed agriculture area
AET_{o} = AET from other landuse classes(forest, other vegetation, water bodies, and other landuse classes)

R = Balance after evapotranspiration from various landuse classes

Hence, the equation (1) becomes;

$P = AET + R$ ---------- (2)

For calculating AET, the Potential Evapotranspiration (PET) was calculated by Thronthwaite method;soil moisture in each month was calculated based on water holding capacity and accumulated water loss in the month; andchange in soil moisture of a month to its previous month.

AET is evaluated for various landuses for computing value of R.

R comprises of the components as given under:

$R = Ro + \Delta GWS + \Delta SWS + UDI$ ---- (3)

Ro = Observed flow at CWC terminal site
ΔGWS = Change in Groundwater in a hydrological year
ΔSWS =Change in reservoir storage in a hydrological year
UDI = Effective consumptive use for domestic and industry.

Change in groundwater and surface water storages at annual time step is aggregated at basin level. Domestic and industrial use is calculated based on demographic data and other norms.

The model is calibrated and validated using observed flow measured by CWC.

The water resources potential of the river basin is being computed based on the average values for 20 years. Average annual water resources availability of the basin comprises of sum of flow in the river at final outlet, upstream consumptive utilisations for irrigation, domestic and Industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs.

3.3 Data used and analysis for the study

3.3.1 Meteorological Data:

- IMD daily Temperature data to compute Potential Evapotranspiration (PET) for 20 years.
- IMD Rainfall data for computation of water balance for 20 years

3.3.2 Topographic Data:

- Basin is divided into sub basins using DEM, Satellite data and other reference maps.
- Rainfall, temperature and PET values for all the sub basins are computed.
- NBSS-LUP soil map having 7 soil textural classes.
- Land use Land cover(LULC) maps
- HRU's are generated by overlaying LULC, Soil.
- Monthly Vegetation/Crop Coefficient factors which depend on type of land use/land cover/crop type are adopted for arriving at revised PET values.

3.3.3 Hydrological Data:

- Monthly discharge data of various CWC gauge stations
- Reservoirs flux data for 20 years
- Groundwater flux data of CGWB

3.3.4 Demographic data:

- Village level census data of 2001, state level growth rate data of Census Department for computing Domestic use

4.0 LONG TERM STRATEGY FOR ASSESSMENT OF AVAILABILITY AND UTILIZATION OF WATER RESOURCES

4.1 Legal and Institutional Framework of USA and Australia

USA in 2009 have formulated an Act titled ‘‘Omnibus Public Land Management Act of 2009’’. The section 9508 of the said Act at its page 353 provides for the establishment of a national assessment program to be known as the ‘‘National Water Availability and Use Assessment Program’’.

The Australian Parliament has enacted the Water Act 2007, which provides the legislative framework to make provision for the management of the water resources of the Murray-Darling Basin, and to make provision for other matters of national interest in relation to water and water information, and for related purposes. Under the Water Act 2007, the Bureau of Meteorology, Govt. of Australia has a legislative requirement to deliver an annual National Water Account and regular National Water Resource Assessments. A hydrologic workflow known as the Australian Water Resources Assessment system (AWRA) is currently under development within Commonwealth Scientific and Industrial Research Organisation (CSIRO), to underpin and support the Bureau’s reporting requirements. AWRA will consist of model components, data streams, pre- and post- processors and a workflow engine.

4.2 National Water Availability and Utilization Assessment (NWAUA)

In India, the entire country is divided into 20 river basins comprising 12 major basins and 8 composite river basins for the purpose of assessment of water resources. Evidently national assessment of water availability and utilization of water resources in the river basins may be a long term strategy.

A suitable institutional arrangement may, therefore, be necessary for carrying out such studies involving Central as well as State agencies. A well developed water information system having database on hydro-meteorology, topography, storage projects, water utilization, ecology, etc is necessary for carrying out the assessment studies. Various efforts are being undertaken for creation of information system by collecting data from the State Governments through Nodal Officers designated by the States, development of INDIA-WRIS, etc.

National Water Availability and Utilization Assessment (NWAUA) is not merely a creation of databank / information system but a synergy of data collection, trend analysis of information using latest statistical tools and methods, mathematical modelling techniques, application of latest technology tools like remote sensing and GIS. This requires substantial technical know-how and gradual built up of knowledge base. This is also apparent from case examples of USA and Australia.

Evidently the NWAUA may basically have three distinct aspects:

I. Data / Information collection in the desired format from various State agencies / Information System developed by the Central Government

II. Participation of specialized agencies for analysis of information using scientific methods, mathematical modelling techniques, application of latest technology tools like Remote Sensing and GIS

III. Reporting at specified time intervals

4.2.1 Objectives of NWAUA

The broad objectives of National Water Availability and Utilization Assessment could be:

I. Basin / sub-basin wise assessment of status of water resources availability periodically;

II. Assessment of utilization of water for various sectors such as agriculture, domestic, industry, energy production, ecology and other uses, etc periodically;

III. To assist in the studies related to predicting long-term trends of change in availability of water resources and utilization including the possible impacts of climate change

4.2.2 Elements of NWAUA

4.2.2.1 Water Utilization Assessment

Assessment of water utilization in hydrologic accounting units i.e basin / sub-basin and aquifer systems including:

i. Assessing water utilization for various purposes based on applied research / statistical estimation techniques incorporating the water use science principles;

ii. Integration of all possible dataset maintained by Central or State agency into the dataset maintained for the purpose of assessment of utilization of water resources from time to time (a vast number of agencies keeps record of water use in their own manner.)

iii. Basin / sub-basin wise maintenance of inventory of anthropogenic water resources utilization for various uses and linkages with INDIA-WRIS

iv. Predicting long-term trends in change of utilization of water resources for various sectors

4.2.2.2 Water Resources Availability Assessment

Assessment of water resources availability in basin/sub-basin including:

i. Analysis of meteorological (rainfall, temperature, evapotranspiration), hydrological (stream flow and surface water storage measures including lakes, reservoirs, perennial snowfields, glaciers, aquifer systems, etc) and water utilization information using mathematical modelling techniques, application of latest technology tools like Remote Sensing and GIS

ii. Maintaining a basin / sub-basin database of annual water resources availability; linking to INDIA-WRIS; etc

iii. Developing and applying predictive modeling tools for long-term trends in change in availability of water resources

4.2.2.3 Utilizable Water Resources Assessment

i. Analysis of information related to topography, hydro-meteorology, ecology, projected trend of water use, etc for assessment of annual utilizable water resources potential in the river basins / sub-basins.

ii. Maintaining a basin wise / sub-basin wise database of utilizable water resources potential; linking to INDIA-WRIS; etc

5.0 SUMMING UP

The paper is summed up with the following highlights:

- ❖ Assessment of water resources in the country is the corner stone of planning process
- ❖ Assessment studies have been carried out by many Committees / Commissions / Agencies using different methodology and approach in the past.
- ❖ Pilot studies are being carried out jointly by CWC and NRSC for two river basins through water balance approach using GIS and Remote Sensing technology.
- ❖ National assessment of water availability and utilization of water resources in the river basins of such a vast and diversified country like India has to be a long term strategy.
- ❖ USA and Australia have developed appropriate legal and institutional framework for assessment of availability and utilization of water resources.
- ❖ A well developed water information system having database on hydro-meteorology, topography, storage projects, water utilization, ecology, etc is necessary for carrying out the assessment studies.
- ❖ National Water Availability and Utilization Assessment (NWAUA) is a synergy of data collection and analysis using mathematical modelling techniques and latest technology tools like Remote Sensing and GIS.This requires substantial technical know-how and gradual built up of the knowledge base.

The views expressed in the paper are those of the authors and not of the Organisation they belong to.

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Brief Bio-Data of the Authors

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