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Hydrological Network for Water Resources Development in Gujarat State

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Abstract : *For optimum planning of the utilisation of the water resources of Gujarat State, the urgent need of correct assessment of the availability of water resources on the basis of an efficient hydrological network has been greatly felt in the recent times. Such efficient network comprises the instrumentation for accurate observations of various hydrological parameters, viz. precipitation, evapotranspiration, runoff, silt, daily maximum and minimum temperatures, direction of wind and wind velocity etc. This paper describes the progressive development of the present modernised hydrological network established in Gujarat State. The existing established network has been found well satisfactory compared to the World Meteorological Organisation's (W.M.O.) criteria in respect of raingauge and river gauging. The present set-up of weather stations, when duly stepped up as per the programme, will strengthen it to achieve the desired standard.*

1. Introduction

1.1. The Gujarat State is located between Long. 68°-08', 74°-23' E and Lat. 20°-02' to 24°-45' N. The geographical area of the State is 1,96.000km². Most of the area of the State falls in the zone of scanty rainfall. From geographical as well as hydro-meteorological considerations the State has been divided into three regions, viz, (i) Gujarat main land, (ii) Saurashtra and (iii) Kachchh. The courses of rivers of the Gujarat main land are North-East to West flowing where as those of Saurashtra and Kachchh are short and steep.

There are in all 17 river basins in the main land of Gujarat having the catchment area ranging from 419 to 17,903km², 71 river basins in the Saurashtra region with the range of catchment area from 26 to 7,824 km² and 97 river basins in the Kachchh region of which the catchment area is ranging from 5 to 1,097 km².

1.2 There are 76 major and medium projects, 4,500 minor schemes and 3,500 Govt. tube-wells completed at the end of the Sixth Five Year Plan in June 1985. At the beginning of the Seventh Five Year Plan in 1985-86, 85

major and medium projects including the prestigious Sardar Sarovar Project, 900 minor schemes and 400 tube wells were under progress. In addition to this, the survey and investigation work to decide the possibility of taking up in future about 280 major and medium projects, 2,100 minor schemes and 4,000 tube wells has been taken up.

With the increased demand of water due to rapid industrialisation and growing population, the accurate assessment of availability of water for its optimum utilisation has been greatly felt in the recent times. For the development of water resources, the data in respect of rainfall, run-off, sediment, evaporation, temperature and several other meteorological parameters are very much essential. The well recognised awareness in this aspect has been felt in Gujarat from 1960 onwards and the development in the form of Hydrological Network is note-worthy.

2. Development of Hydrological Network

2.1 The methodology adopted earlier for the measurements of discharge was on the basis of Area-Velocity. In this method, the area of cross-section is worked out by taking the cross section of the river before the onset of the monsoon. The velocity of flow is measured simply by surface floats. According to the width of the river channel, the gauge run i.e. distance between guide posts, is kept about 30 to 100m. The main criterion considered in fixina the gauge run, is that the time of travel of float should be not less than 20 seconds.

Normally, the river flow velocity is observed twice a day. The flow of the river is divided into three segments only and in each segment, three sets of readings are being taken and the mean value is determined as the time of travel of the float. The time of travel of float is registered by means of a stop watch.

The velocity so observed by means of floats is the surface velocity which is reduced by applying appropriate factor known as reduction co-efficient value. This value varies in the range from 0.78 to 0.91 depending upon the depth of flow and the co-efficient of rougosity. In the event of floods, as frequent observations are not possible, the velocities of the entire flow mass are measured. For this purpose, the time taken by the floating debris, like wooden logs, etc. in the centre of flow is observed for clearing the distance of gauge run. From such observations even during the floods, discharges are calculated. Due to adoption of this method sometimes in flood period, only one observation during its peak period was taken. No attempts were made to take observations hourly. Since no arrangements were made for night observations, floods coming in the night remained unregistered.

Systematic gauging of surface water in the form of gauging the river was started from 1958. In this initial stage, only one sub-division under the Water Resources Investigation Division was incharge of the gauging work of the rivers of the State. The objective was to simply collect the data for preparation of Irrigation Projects. Initially, 40 river gauging stations were established for this purpose in the whole of the State.

The year 1961 was the first land mark when the Water Resources Investigation Division of the State started publishing the data of rainfall and discharge. At that time, the data were published of 51 River Gauging sites out of which 32 sites were under the control of the W.R.I. Division. The gauging was done by float method. By 1979, the work of installation of the gauging sites was accelerated and the number of sites rose from 51 to 107.

2.2 At the instance of the World Bank, Mr. George Smoot, the river gauging expert,

arrived and inspected several river gauging stations in August/September 1977. He, in his report on the river gauging of Gujarat rivers, observed, inter alia, as under :

(i) The relatively difficult nature of the flashy high velocity streams.

(ii) Lack of adequate equipment.

(iii) The inadequate training of gauging personnel.

He also further observed that the gauge readings which are taken twice a day were inadequate to define the stage hydrograph because of the flashy nature of the streams. Owing to this in-adequacy, the storm events which could occur during the period when no observations are taken may pass undectected and may not appear on the gauging record. The existing procedure of taking cross-section of the gauging sites, only before the monsoon and calculating the discharge is not correct as the cross-sectional area of the flashy river may be different during the flood period particularly when the river bed is erodible.

With a view to improving upon a gauging operation, Mr. Smoot made the following recommendations so as to systematise the river gauging work and to improve upon the quality of data to the level of the required accuracy :

(i) Funds be provided for purchasing the required equipment.

(ii) Stilling wells and shelter for the continuous gauge recorder be constructed.

(iii) Cableway shall be designed and constructed where no bridge sites are available.

(iv) Detailed training be given to the site personnel.

(v) Discharge measurements be done using the currentmeters whenever possible by wadding and dividing the area into a number of sections and taking the velocity and depth measurements at each vertical.

According to these recommendations, an attempt was made to systematise and improve the river gauging work by developing sites with sophisticated equipment and also by imparting training to the personnel.

2.3 On all these sites, silt measurements were started to be taken using the Punjab Bottle type Sampler only at three places, viz. left bank, right bank and centre of the vertical. Taking of samples in this manner was found to be un-scientific as the number of samples were inadequate to define the silt concentration in the flow. From 1981, this method was, therefore, dispensed with and the silt measurements were started to be taken using the modern sampling equipment like D 48 and P 61 sediment samplers. Even the technique of taking samples is also reveiwed and now the samples are collected by depth integration method and the number of samples collected is also increased to accurately define the silt concentration in the flow.

For analysing the samples on sites, 37 field laboratories are established on the gauging stations.

2.4 Since the gauging personnel were not fully experienced in using the modern sampling equipment, the year 1979, being the first year of introduction met with considerable hardships. It was, therefore, essential to train the personnel for river gauging work and as such as a modest beginning was made in 1979 for training these personnel by the dedicated officers. The officers of the organisation had a tough time to train the gauging personnel in achieving the standards as desired by the World Bank in the river gauging technique. During the develepment stage of the gauging, the difficulties encountered were, (i) communication gap between all the gauging stations, (ii) attending repairs to the equipment when those went out of order and (iii) limitation of the gauging personnel to comprehened fully the methodology explained to them.

The experience of five years taught us that the concise and precise instructions to the gauging personnel should be coded and published in the forms of a mauual and supplied to each of the persons in-charge of the gauging work for guidance, reference and use. Accordingly, a manual on river gauging was published by the Irrigation Department of the Govt. of Gujarat in 1982.

Since then, the uniformity in procedure and standard started to take shape on the atlas of network of gauging in the State. The manual so prepared for the guidance, reference and use of the gauging personnel covers the instructions for, (i) the use of equipment (ii) the upkeep of equipment, (iii) gauging by cranes from bridges and by cable cars from ropeways, (iv) identification of duties, (v) installation of A.G.R., (vi) interpretation of A.G.R. graph, (vii) silt analysis of the sample in the laboratories established on site and (ix) responsibilities of Section Officers, Karkoons, etc.

These instructions have been devised on the basis of the experience gained during the period of five years and reference from the book "Technique of Water Resources Investigation of the United States Geological Survey" published by the United State Geological Survey.

2.5 With this new awakening in the era of river gauging technique in Gujarat and its network, the use of, (i) cable cars with cable ways, (ii) automatic gauge recorder both for rainfall and for river discharges. (iii) currentmeters, etc. came into being. The work of collection, compilation, processing and publication of the vast data was also channelised.

Uptil now, the emphasis has been given to developing the existing measuring sites, where formerly the flows were measured without using the sophisticated equipment. Hence, at present 191 discharging sites have been developed and the stations are provided with various sophisticated instruments of Indian make.

2.6.1 For the development of water resources of the State, the data base for planning of utilisation of water is very important. For this, the work of establishing the network of stations for collecting weather data has also been taken up by the State with equal importance. So far, the India Meteorological Department (IMD) has established 7 to 8 weather stations. The purpose of their establishment is with a view to forecasting weather. It is planning to install 784 weather stations spread over the State.

2.6.2 It has been verified that 784 weather stations in the entire State as planned will satisfy the criteria as enunciated by the World Meteorological Organisation. The area influenced by each weather stations has been worked out by Thisessen's Polygon Method and from this, it is seen that the proposed network of weather stations would satisfy the minimum criteria laid down by the World Meteorological Organisation. For establishment of the weather stations, the whole area of Gujarat is considered comprising three principal regions, viz. (i) Gujarat, (ii) Saurashtra and (iii) Kachchh. For Saurashtra and Kachchh regions the number of streams is more and as such the stations proposed are closely spaced.

2.6.3 The type of data to be collected from weather stations is specified as under :

(1) Amount of precipitation.
(2) Data on precipitation intensity and frequency.
(3) Variability of precipitation from year to year.
(4) Frequency and duration of drought.
(5) Run-off.

(6) Evapo-transpiration.

(7) Evaporation from water surface.

(8) Vapour pressure.

(9) Temperature of water surface.

(10) Total radiation.

(11) Soil moisture and deficit.

Proper integrated study of the whole package of the data mentioned above can be available with the use of the following sets of intruments in each weather stations;

(1) Anemometer and Windvane.

(2) Sunshine Recorder.

(3) Stevenson's Screen with Maximum and Minimum Thermometer, Dry and Wet Bulb Thermometer, Soil Thermometers of various depths.

(4) Pan Evaporimeter.

(5) Mercury Barometer.

(6) Self Recording Raingauge.

(7) Ordinary Raingauge.

200 sets of such equipment were supplied by the Gujarat Engineering Research Institute, Vadodara and 400 Pan Evaporimeters, Barometers, and Stevenson Screens, with Maximum Minimum Thermometers, Dry and Wet Bulb Thermometers and Soil Thermometers of various depths were procured for 784 weather stations. At present, there are 96 existing weather stations.

2.7. In the present set up of network for water resources development, the instruments that have been installed and are being installed, are as under :

(A) For Weather Stations :

(i) Anemometer and Windvane.

(ii) Sunshine Recorder.

(iii) Maximem and Minimum Thermometer.

(iv) Dry and Wet Bulb Thermometer with Stevenson Screen.

(v) Soil Thermometer.

(vi) Pan Evaporimeters.

(vii) Mercury Barometer.

(viii) Ordinary Raingauge equipped with S.R.R.G.

(B) For discharge and sediment measurement stations :

(i) Currentmeter.

(ii) A.G.R.

(iii) Wadding Rod

(iv) P-61 Sediment Sampler

(v) Cable-ways with Cable Cars

3. The Present Status of the Network :

3.1 During the span of 1980 to 1986, the development of hydrological network has attained the status as brought out in the table given below :

3.2 The status as shown above reveals quite a good state and standard in respect of hydro-meteorological requriement when compared with the WMO standard. The present status of 97 weather stations, when stepped up to 784, as envisaged in the programme, will strengthen the network to achieve the desired standards. The Irrigation Department of the State plans to achieve the hydrological network planning as under :

(1) River Gauging Stations

At present, there are 191 river gauging stations. A network for the future planning of the river gauging stations has been prepared keeping in view the following criteria :

(i) Upstream of the project

(ii) Downstream of the project

(iii) Within the reservoir

(iv) About 30 m downstream beyond the spillway bucket

Table

Year	Rain Gauge Stations				S.R.R.G.				River		Weather
	Irri-gation Department	IMD	Other Agencies	Total	Irri-gation Department	IMD	Other Agencies	To-tal	Gauging Stations Gauge site	Gauge and Discharge and sediment sites	stations Irrigation Department
1	2	3	4	5	6	7	8	9	10	11	12
1980	315	19	280	614	138	19	—	157	8	92	—
1986	467	10	201	678	281	10	—	291	19	172	*97

* One sample weather station is installed at Gandhinagar

The status as indicated above when compared with the W.M.O. Standards works out as under :

Stations	NETWORK	
	As per WMO Standards one station fed (Km^2)	As per 1986 Gujarat State one Station fed (km^2)
S.R. R.G.	630 to 900	200 to 300
River Gauging Stations	1000 to 2500	1000 to 1100
Weather Stations	200 to 250	2000 to 2100

(v) Proposed Irrigation Schemes

(vi) Minimum one station in unmeasured basin

It was planned to establish 20 stations per year but in view of the financial stringencies arising out of the drought situation in the State the work of installation of new stations would be taken up with the availability of required funds.

4. Administrative Set-up

4.1 191 river gauging stations and 278 S.R. stations are being operated and maintained by one Division office headed by an Executive Engineer. There are 5 sub-divisions and 19 section offices working under this Division Office.

4.2 When the modernisation of the river gauging commenced, the gauging personnel were imparted the necessary training periodically in the Division Office. Further, when needed, the training was also accorded in the sub-divisions and the section offices. Moreover, during every monsoon season the gauging staff is trained.

4.3 In each gauging station, 1 karkoon and 2 Khalasis are employed to record the requisite observations. The data collected on the site are sent to the Section Office for calculations and checking. The Section Office is generally

provided with Assistant Engineer/Additional Assistant Engineer, Technical Assistant/Survey Mistry or Karkoon and Chowkidar. The compiled data are then furnished to the Sub-Division Office. The data thus collected are scrutinised and submitted in the prescribed format by the Sub-division office to the Division office, where the data are checked and scrutinised and compiled by A.E./A.E.E. Thus, the thoroughly checked and compiled data are forwarded for publication in two parts. Part-I contains the daily record of the rainfall data and Part-II gauge and discharge is graphical form and gauge, discharge and sediment data in numerical form.

The weather stations already existing are looked after by the concerned project authorities.

4.4 At present, the Division office in-charge of the gauging work is dealing with the publication of hydrological data yearly. This Division will work in future as a data bank if the data retrieval system with modern computer facility is implemented properly, Thus, the Division Office can serve as a big agency for the Hydro-meteorological Data Bank.

5. Conclusion

We all are aware of the pace with which the science of hydrology and water planning is developing. But, without the support of an adequate and reliable data base, the out-turn of hydrological studies would be lacking from their realistic perspective. It is with this view that the adequate network of river gauging with proper data scrutiny, compilation and up-dating of the record in the desired format should be planned out. In this direction, Gujarat State is probably ahead of many States in the country and is endeavouring to achieve a higher standard for establishing the hydrological network to cover all the river basins adequately.

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