# DATA REQUIREMENT FOR PLANNING DEVELOPMENT AND OPERATION OF WATER RESOURCES PROJECTS

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## INTRODUCTION

In the expanding modern economy exploitation of natural resources if of primary importance. As water is one of main natural resource, extensive efforts are being made in every country to harness the water potential for the benefit of the people. For economic of optimum utilization, planning, design and development of water resources, determination of the extent and availability of surface and groundwater is the first requisite and this in turn requires readily accessible, reliable and adequate observation data on the elements of hydrological cycle and related factors. Long term hydrological and meteorological data and information about physical characteristics of watersheds provide the basis for all hydrological studies as well as development and management of water resources. Further, variations in climatic characteristics both in space and time lead to uneven distribution of precipitation in our country. This uneven distribution causes highly uneven distribution of available water, which leads to floods and droughts. As the hydrological processes are continuous and quite complex, therefore, an accurate assessment of quantities of water simultaneously passing through all these phases becomes quite a difficult task.

The planning, development and operation of water resources projects in solely dependent upon the hydrological data. The length of data required depends upon the type of storage, type of development and variability of inputs. The present lecture deals with data requirement and related considerations pertaining to some of the thrust areas of planning development and operation of water resources as well as for development of Decision Support System (DSS) Planning for Integrated Water Resources Development and Management.

## WATER AVAILABILITY STUDIES

Water availability studies are carried out to estimate percentage dependable flows depending upon the purpose of the project.

Data Requirement for Water Availability Study

(a) Runoff data of specific duration (daily, 10-daily, or monthly etc.) at the proposed site for atleast 40 to 50 years; or
(b) Rainfall data of specific duration for atleast 40 to 50 years for raingauge stations influencing the catchment of the proposed site as well as runoff data of specific duration at the proposed site for the last 5 to 10 years; or
(c) Rainfall data of specific duration of the catchment of the proposed site for the last 40 to 50 years and runoff data of the specific duration and concurrent rainfall data of the existing woark upstream of downstream of the proposed site for the last 5 to 10 years or more; or
(d) Rainfall data of specific duration of the catchment for the last 40 to 50 years for the proposed site and runoff data and concurrent rainfall data of specific duration at existing works on a near by river for 5 to 10 years or more provided topographic conditions of the catchment at the works are similar to that of the proposed site.

Further, the catchment characteristics are also utilized for estimating the dependable flows in case of ungauged catchments. In case the runoff data are not virgin because of construction of water resources structures upstream 0of the gauging site, the information about reservoir regulation such as outflows from runoff data series consists of records for the period prior as well as after the construction of the structure, the runoff series is considered to be non-homogeneous. Necessary modifications have to be made to the records belonging to the period prior to the introduction of the structure. So that all available runoff records become homogeneous. Water availability studies are also carried out modifying the runoff records for virgin condition of the catchment.

## DATA REQUIREMENT AND OTHER CONSIDERATIONS FOR MULTIPURPOSE PROJECT PLANNING AND OPERATION

Modern water resources projects are planned for more than one purposes because multiple-purpose projects usually have a greatly improved economic and social advantages to offer. Chow (1984) defined an multiple-purpose as one that can be operated on an assumed basis to provide more than one purpose and whose design is such that its method of operation can be altered from time to time, if desirable, to change the emphasis of its services so that it can always contribute most beneficially, whether it is to serve as a single-development project or as a productive element in a larger system of dams, rendering user either circumstance the optimum of economic benefits that are desired with each service at a cost that is warranted.

The author gives following condensed outline, which is stated to be primarily as an illustrative example and also as a checklist of major factors to be considered in an areas investigation for the project planning and development.

### PROJECT AREA

(a) Physical geography: location and size; physiography; climate; soils
(b) Settlement: history: population; cultural background both rural and urban
(c) Development: industry; transportation; communication commerce; power; landuse; water uses; minerals; undeveloped resources
(d) Economic conditions general: relief problem; community needs, national needs
(e) Investigations are reports: previous investigations; history; scope

### HYDROLOGIC DATA

(a) Hydrologic records are networks gauging and observation stations; data collecting agencies
(b) Hydro meteorological data; precipitation; evaporation and evapotranspiration
(c) Surface water: low flows; normal flows; maximum floods; "design flood", drought; quality
(d) Groundwater; aquifers; recharge; quality

### SUPPLY OF WATER

(a) Sources of supply: surface-water; groundwater supply; reservoirs

(b) Variation of supply; variability; consumptive use; regulation; diversion requirements; return flow; evepotranspiration losses, seepage losses or gains;
(c) Quality of water: physical, chemical, biological, and radioactive qualities; quality requirements; pollution
(d) Legal rights: water rights; development of project rights; operation rights

**GENERAL CONSIDERATIONS FOR DESIGN AND PLANNING**

(a) Geology: exploration; geological formations; foundation problems
(b) Design problem; design criteria; methods of analysis; project operation and maintenance.
(c) Construction problem: accessibility to project site; rights of way and relocation; construction materials; construction period; flow diversion; manpower; equipment accessibility
(d) Alternative plans: comparison of alternative plans; supplementary plans; possible alternative plans; relationships to area to be served
(e) Estimates of coasts
(f) Interstate, interstate, and international problem
(g) Organizations involved; public and/or private; technical, social, and political

**FLOOD CONTROL**

(a) flood characteristics of the project area; historical floods; flood magnitude and frequency
(b) Design criteria; project design storm and floods; degree of protection
(c) Damage: survey of flooding areas and things effected by floods, nearby or quite a distance away, including commerce, good will, dates of delivery of goods, etc
(d) Measure of control: reduction of peak flows by reservoirs; confinement of flow buy leaves, floodwalls, or a closed conduit; reduction of peak stage by channel improvement; diversion of floodwater through bypasses or floodways; floodplain zoning and evacuation; floodproofing and flood insurance of specific properties, reduction of flood runoff by watershed management;
(e) Existing remedial works

**AGRICULTURAL USE OF WATER**

(a) Factors for land classification: soil texture; depth to sand, gravel, shale, raw soil, or penetrable lime zone; alkalinity; salinity; slopes; surface cover and profile drainage, water logging.
(b) Present and anticipated development: crops; livestock; financial resources; improvements; organizations; development period
(c) Water requirements, if any: total crop requirements, irrigation water demand; farm delivery losses; diversion amounts
(d) Available water: sources; quality; quantity; distribution
(e) Irrigation methods: flooding furrow irrigation; sprinkling; sub irrigation; supplemental irrigation
(f) Structural works: storage reservoirs; dams; spillways; diversion works; canals and distribution systems;

**HYDROELECTRIC POWER**

(a) Development: sources; present potential and future capacities
(b) Alternative sources of power: stream; oil; gas; nuclear power, interties;
(c) Types of power plants: run-of-river; storage; pumped storage
(d) Structural components: dams, canals, tunnels; penstock; forebay; power-house tailrace
(e) Power problem: load demand and distribution; interties (interconnections with other power transmission systems)
(f) Markets: revenues; costs

**NAVIGATION**

(a) Water traffic: present and future needs and savings in shipping costs, if any on the basis of which the just9ificaitons are primarily judged at the present time
(b) Alternative means of transportation: air; land
(c) Navigation requirement: depth, width, and alignment of channels, locking time; current velocity; terminal facilities.
(d) Methods of improving navigation: channel improvement by reservoir regulation; contraction works; bank stabilization, straightening, and snag removal; lock and dam construction; canalization; dredging;

**DOMESTIC AND INDUSTRIAL WATER SUPPLY**

(a) Sources of supply: surface and/or groundwater, location and capacity; desalinization
(b) Water demand; climate; population characteristics; industry and commerce water rates and metering size of project area; fluctuation
(c) Water requirements: quantity; pressure; quality (tastes, odors, color, turbidity, bacteria content, chemical, temperature, etc )
(d) Method of purification: plan sedimentation; chemical sedimentation or coagulation; filtration; disinfection; aeration; water softening
(e) Treatment plant: location; design; purpose or purposes
(f) Distribution systems: reservoirs; pumping stations; elevated storage; layout and size of pipe systems; location of fire hydrants
(g) Water woks organizations: maintenance and operation of supply, distribution, and treatment facilities

**RECREATIONAL USE OF WATER**

(a) population tributary (population near enough to the project area to use it for recreational purposes)
(b) Facilities: boating; fishing, swimming etc
(c) Water requirements: Depth of water; area of water surface sanitation

**FISH AND WILDLIFE**

(a) Biological data: species; habits
(b) Facilities: reservoirs; fish ladders
(c) Water requirements: temperature; current velocity biological qualities

## DRAINAGE

(a) Existing projects
(b) Drainage conditions: rainfall excess, soil condition; topography; disposal of water
(c) Drainage system: urban, farmland

## WATER QUALITY CONTROL

(a) Problem involved: sources, nature and degree of pollution, sediment; salinity; temperature; oxygen content; radioactive contamination
(b) Hydrologic information and measurement
(c) Methods of control

## ECONOMIC ASPECTS OF PROJECT FORMULATION

1. Benefits and damages: identification and evaluation
2. Costs: identification and estimation
3. Financial feasibility
4. Allocation of costs
5. Reimbursement requirements and sharing of allocated costs
6. Methods and costs of financing the project, whether federal, state, or local, bringing all benefits and all costs to an annual basis and recognizing interest on the investment not only during construction, but throughout the entire proposed "life of the project".
7. Benefit –cost-ratio analysis: alternative plane;

## DATA REQUIREMENT FOR RESERVOIR OPERATION

The following data are needed for operation of a reservoir;

i) Reservoir elevation-area-capacity curve
ii) Carrying capacity of downstream channel
iii) Evaporation raters form reservoir
iv) Inflows to the reservoir
v) Demand of water for various uses viz. irrigation, power generation, drinking and industrial water supply, navigation recreation and low flows.

## DESIGN FLOOD ESTIMATION

The engineers and scientists involved in the design of water resources structures such as storm sewers, spillways, diversion works, bridges, culverts and other flood control works often require the design flood at a certain location in order to estimate the size and cost of these structures. In the design of water resources structure, it is not practical. From economic considerations to provide for the safety of the structure and the system at the maximum possible flood in the catchment. Small structures such as culverts and storm drainages can be designed for less severe flood as the consequences of higher than the design flood may not be very serious. It may cause temporary inconvenience like the disruption of traffic and sometimes property damage and loss of life. On the other hand, storage structures such as dams demand greater attention for their design flood estimation. The failure of these structures leads to large loss of life and great property damage in downstream region of the structure.

From the above, it is evident that the type and importance of the structure and economic development of the surrounding are indicate the design criteria for choosing the flood magnitude. From this, it is apparent that the data used for development, planning and operation of any structure depends upon the importance and size of the water resources project. In the following text some the terms used in designed flood estimation and data requirements for some of the important methods of design flood estimation are discussed.

**DESIGN FLOOD**

**FLOOD ADOPTED FOR DESIGN OF A STRUCTURE**

**PROBABLE MAXIMUM FLOOD (PMF)**

It is the flood discharge that may be expected from the most severe combination of critical meteorological and hydrological conditions that the reasonably possible in the region. The probable maximum flood is used in the design of projects, for example dams-where virtually complete security from potential floods is sought.

**STANDARD PROJECT FLOOD (SPF)**

It is the flood discharge that may be expected from the most severe combination of meteorological and hydrological conditions that is considered reasonably characteristics of the geographic area in which the study drainage basin is located, extremely rare combinations of those conditions ar4e not considered. The peak discharge for a standard project flood is generally about 40 to 60 percent of that for the probable maximum flood for the same basin. The standard project flood is often used where failure of structure would have somewhat less disastrous effect. For example, it is used in the design of flood control facilities whose failure might be disastrous.

**GUIDELINES FOR SELECTING DESIGN FLOODS**

A summary of the guidelines adopted by CWC (1969) to select design floods in India is as follows.

**METHODS OF FLOOD ESTIMATION**

The following methods are generally used for flood estimation:

(a) Empirical Methods
(b) Flood frequency analysis
(c) Unit hydrograph techniques and
(d) Watershed models

**EMPIRICAL MEHTODS**

Empirical methods and flood frequency methods are generally used for estimating the magnitude of flood peak. However, the unit hydrograph technique and watershed models can be used to estimate the design flood hydrograph in addition to the magnitude of design flood peak. The data used and suitability of a par6ticular method depends upon a) the desired objective, b) the available data and c) the importance of the project.

The rational formula is only applicable to small size (50 km) catchments. The empirical formulae are essentially the regional formulae based on statistical correlation of the observed peak and important catchments properties. These formulae are only applicable in the region for which they were developed with in the range of flood peaks used. If these formulae are applied to other areas they can at the best give approximate values. These formulae generally require information about rainfall and catchment characteristics.

## FLOOD FREQUENCY ANALYSIS

The flood frequency analysis is the approach based on statistical methods to predict the flood peak of specified return period. Most of the flood frequency studies are concerned with peak flows and the data comprise of selected observed peaks. Usually, two types of data series are used in flood frequency studies.

a) Annual peak series
b) Partial duration series

a) **Annual Series**
Annual series of data includes largest or smallest values with aeach value selected form one water year.

b) **Partial duration series**
Partial duration series comprises of data which are so selected that their magnitude is greater than a certain base value.

The data must deal with the problem. Most of the flood studies are concerned with peak flows are data series will consist of selected observed peaks. If the problem is of duration of flooding e.g. for what period of time a highway adjacent to a stream is likely to be flooded, that data series should represent the duration of flows in excess of some critical value. If the problem is of interior drainage of leveled area, the data required must consist of those flood volumes occurring when the main river is too high to permit gravity drainage.

Frequency analysis of hydrologic data begins with the treatment of raw hydrologic data and finally determines that frequency or probability of a hydrologic design value.

## DATA REQUIREMENT FOR FLOOD FREQUENCY ANALYSIS

a) For frequency analysis it is required that samples are purely random. In other words they should be unbiased, independent and homogenous.
b) Annual peak flow series or the flow values which are adequate to form partial duration series, if required,
c) In case annual peak series data are not available, then hourly stage values along with the rating curve at the gauging site are required to convert hourly stage values in hourly discharge and find peak flood for each year,
d) When the sufficient length of peak flood record is not available then the regional flood frequency may be adopted to estimate design flood. This requires information about catchment characteristics. Such information may be derived from toposheets and other maps of the basin.

Roudkivi (1979) states that frequency analysis of flood flow records is, in principle, a good method. Unfortunately, records, if available adequate definition of extreme floods. An extrapolation of a 25 year record to a 500-year return flood yields a very unsatisfactory answer of low confidence value. The author further mentions that if, for example, the Gumbel distribution is assumed then the theoretical 68% confidence limits of the 50, 100 and 500-year return period floods, in terms of years, are according to Bell (1969) as follows:

| | | |
|---|---|---|
| 25 years of record: $12 \leq 50 \leq 200$, | $15 \leq 100 \leq 400$, | $16 \leq 500 \leq 2200$ |
| 100 years of record: $25 \leq 50 \leq 100$, | $40 \leq 100 \leq 250$, | $60 \leq 500 \leq 1500$ |

The author further mentions that the problem may arise with longer discharge records from the fact that catchment conditions may get changed over the period of record.

If the sample is to small the probabilities derived cannot be expected to be reliable. Some estimates in this regard derived form data synthetic data (Linsley et al., 1975) are given below;. Length of record in years required to estimate floods of various probabilities with 95% confidence

| Design Probability | Return Period | Acceptable Error | |
|---|---|---|---|
| | | 10% | 25% |
| 0.1 | 10 | 90 | 18 |
| 0.02 | 50 | 110 | 39 |
| 0.01 | 100 | 115 | 40 |

From the above, it is clear that extrapolation of frequency estimates beyond probability of 0.01 is extremely risky with data series generally available (30-40 years).

Ott (1971) stated that with 20 years of record the probability is 80 percent that the design flood will be over estimated and that 45 percent of over estimates will exceed 30 percent, so it thus appears that records shorter than 20 years should not be used for frequency analysis; 40-50 years data series have been found to define event magnitude up to 50 years appreciably well.

## UNIT HYDROGRAPH ANALYSIS

Unit hydrograph analysis is a simple and versatile technique which is widely used for determination and prediction of flood peaks. Unit hydrographs can be derived from analysis of rainfall and runoff records for those catchments where such records are available.

Unit hydrograph techniques are applicable to small catchment viz. having area less than 5000 sq.km. However, these techniques along with routing can be used to estimate the design flood for larger size basins by dividing the basin in sub-basins.

### Data Requirement for Design Flood Estimation Using Unit Hydrograph Analysis

1. Drainage basin map showing the contours and river network
2. Network of ordinary and self-recording rain gauge stations
3. Observed rainfall data for ordinary and self recording rain gauge stations for major historical flood events. (Atleast the data for 4 to 5 flood events are needed for gauged catchments).
4. Daily gauge and discharge data at the gauging site
5. Rating curve for the gauging site

6. Hourly gauge (or hourly discharge, if available) values for the corresponding 4 to 5 flood events.
   Daily gauge and discharge data are usually required to develop the stage-discharge relationship (rating curve). In case the rating curve is available, the above data may be utilized to verify its accuracy.
7. Design storm (probable maximum precipitation or standard project precipitation values for different durations viz. 1. day, 2. days etc are required depending upon the of structure for which the design flood is to be estimated).
8. Time distribution for PMP or SPS (A time distribute the PMP or SPS values at shorter time interval viz 1hr, 3 hrs etc.)
9. Design loss parameters-For computing the excess design rainfall uniform loss rate for design condition is required It represents a part of precipitation which does not contribute to the direct surface runoff. This amount of precipitation is lost in the form of infiltration, evaporation etc.
10. Design Base Flow- The discharge hydrograph consists of two components i) direct surface runoff resulting due to excess rainfall and ii) baseflow, which it contribution form groundwater reservoirs to the stream. The application of unit hydrograph technique provides an estimate for design direct surface runoff. In order to obtain the design discharge hydrograph the design baseflow should be added to the direct surface runoff hydrograph.

A study by CWC (1973) on rainfall runoff correlation envisages the following relationships for the estimation of uniform loss rate ($\phi - index$) for flood producing storms and soil conditions prevalent in India.

$$R = \alpha \ \mathrm{T}^{1.2}$$

and, $\phi = \dfrac{I - R}{24}$

Where,

R = runoff in cm from a 24 hr. rainfall of intensity I cm/day and

$\alpha$ = a coefficient which depends upon the soil type as given below

| S.No. | Type of soil | Coefficient ($\alpha$) |
|---|---|---|
| 1. | Sandy soils and sandy loam | 0.17-0.24 |
| 2. | Coastal alluvium and silty | 0.25-0.34 |
| 3. | Red soils, clay loam, grey and brown alluvium | 0.42 |
| 4. | Black cotton and clayey soils | 0.41-0.46 |
| 5. | Hilly soils | 0.46-0.50 |

U.S Army crops of Engineers has recommended to use an infiltration $\phi - index$ of 1.0mm/hour thereafter. An alternative practice being used in India recommended by CWC as the use of constant loss rate of 1.0 mm/hour throughout the storm. The rates adopted for a particular project are primarily influenced by the nature of soil type and vegetal cover of the basin and the purpose of the estimate.

A study (CWC, 1973) conducted for base flow for small catchment revealed that the base flow during flood season varies from 0.05 cumec/sq.km to 0.44 cumec/sq.km. depending upon the meteorological zones in which the basin are located. The values given below were considered reasonable.

| S.No. | Region | Baseflow (Cumec/sq.km.) |
|---|---|---|
| 1. | For Luni, Chambal, sore, Punjab plains, Gangetic plains, Upper Narmada Tapi basins, Upper Godavari, Krishna, Cauveri, Jammu and Kashmir and Kumaon hills | 0.05 |
| 2. | Betwa, Mahi, Sabarmati, Lower Narmada, and Tapi, Lower Godavari indrawati basin, east cost | 0.11 |
| 3. | Mahanadi basin and west cost | 0.22 |
| 4. | Brahmputra basin | 0.44 |

## WATERSHED MODELS

Since the hydrological processes are continuous and quite complex, therefore an accurate assessment of quantities of water simultaneously passing through the various processes become quite a difficult task. The problem becomes even more complex, when the natural hydrological cycle gets disturbed by the man's activities, such as land use changes, agricultural pract9ices and construction of water resources structures etc. A number of watershed models such as USGS model, NWSRFS Model, USDAHL model, HBV Model, CREAMS Model and NAM Model.

Due to a large number of parameters involved in the application of the watershed models the scope of such models for the estimation of design flood is limited. However, event based watershed models requiring limited number of parameters viz. HEC -1 model have been successfully applied for design flood estimation.

## PHYSICALLY BASED-DISTRIBUTED MODELS

With the advancement in computer technology, the hydrologists are currently making efforts to develop physically based distributed models.

THE SHE Model (Systeme Hydrologique European-European Hydrological Systems) is one of the physically based, distributed models, jointly developed by three European organizations (Abbott et. al., 1986). The data requirements for the physically based, distributed models are quite exhaustive. The data requirements for an application of the SHE Model have been given below:

## DATA REQUIREMENT FOR SHE MODEL

The physically based, distributed modeling system SHE in principle does not require long term hydro meteorological data for its calibration but it requires the evaluation of a large number of parameters defining the physical characteristics of the catchment on a spatial distributed basis. It should of course be emphasized, that different hydrological regimes being considered may call for various degrees of accuracy in the estimation of the individual basin parameters, and the evaluation of some parameter values may simply be based on experience. The data availability, however, will in any case determine the degree of reliability, which can be put into the simulation results. Abott et. al., (1986) mention that in principle the parameters and their spatial distributions can be measured in the field but the expense of such a survey applied to all the parameter would prohibit practical implementation of such a model. Hence it is necessary to reduce the number of direct measurement and to employ more indirect evaluations. Bathurst (1986a) states a typical approach which involves a few measurements at representative site in the catchment, providing information on soil properties and channel flow resistance especially. These parameters are likely to have the most influence on simulations of runoff response. These measurements are then assumed, on the basis of their physical nature, to apply to other areas of the catchment. In this manner it is possible to evaluate parameters on the basis of vegetation or soil type within a catchment and also to transfer information from studies carried out elsewhere.

The information about parameters like hydraulic conductivity of soil, soil moisture retention curve, leaf area index, root zone depth required for the model can be obtained from measurements reported in the literature for other field or laboratory studies. Some of the data such as land use and soil types can be provided by remote sensing techniques. Even after procurement of available data there remains the problem of sampling and evaluating the parameters in such a way as to be representative of the grid scale adopted in the model. Many hydrological measurements, for example, are made at the point scale, of the order of a meter, and may or may not be representative of conditions at grid scale of a kilometer or more. It important, therefore, that techniques of measurements used should as far as possible, correspond to the structure and scale of the model. Remote sensing technique may play an important role, by providing average parameter values on a grid basis in such cases. In the same way, tracers can be used to provide information on the integrated characteristics of overland and channel flow over given reaches. In the following a brief introduction to the required data is listed. This comprises of;

## CATCHMENT GEOMETRY

- Topography (from top sheets on e.g 1:50,000 scale)
- Soil depths (distance to impervious layer)
- River geometry (cross sections, the river network and information about structures)

## LAND USE AND SOIL PARAMETRIC DATA

- The spatial distribution of soil an d vegetation types (from e.g. 1,25,000 maps).
  For each vegetation type:
- Temporal variation of either 1) root depth and leaf area index or 2) canopy drainage parameters, soil shading indices and canopy and aerodynamic resistances.

## FOR EACH SOIL TYPE

- Soil moisture characteristic $\theta - \psi$ relationship
- Hydraulic conductivity function $k - \theta$ relationship
- Horizontal hydraulic conductivity

## SURFACE PARAMETRIC DATA

These data are required for each grid square, and include:

- Stickler roughness coefficient for overland flow and river flow
- Soil cracking coefficients
- Depth to drains and subsurface drainage coefficients

## SNOWMELT PARAMETRIC DATA

- Rainfall and meteorological station network, and records of data obtained at these stations (possibly including potential evapotranspiration data).
- Streamflow data
- Other relevant data which can be utilized in the model calibration and validation, e.g. water table, soil moisture data etc.
- Boundary and initial conditions

As mentioned previous, some of these data may not be generally available. For example, a complete information of $\theta - \psi$ relationship is seldom available. However other application studies already have gained some knowledge about the possible form of this relationship, and information available in current literature may be utilized for the evaluation of this relationship.

## FLOOD PLAIN ZONING

One of the thrust areas of water resources engineering is flood plain zoning, which is a non-structural measure for flood management. The following data are required for flood plain zoning.

## DATA REQUIREMENT FOR FLOOD PLAIN ZONING

i) Information about reservoirs and major water resources structures.
ii) Contour map preferably at a shorter contour interval
iii) Location of the rain gauge stations and stream gauging sites
iv) Index plan showing details of meandering river
v) Map providing geological details about the basin
vi) Map giving details of land use of the basin
vii) Cross-sections and longitudinal sections of the river at different locations
viii) Rating curves at different gauging sites
ix) Annual flood peak series and hydrographs of the corresponding flood peaks at the confluence
x) 100, 200, 500 and 1000 years return period floods and other typical floods observed at the confluence
xi) Roughness characteristics for flood plain and channel from velocity measurement or sediment size of river bed at various sites.
xii) Satellite data viz. LISS-III, PAN etc.

## DAM BREAK STUDIES

Dam failures are often caused by over topping of the dam due to inadequate spillway capacity during large inflow to the reservoir from heavy precipitation runoff, Dam failures may also be caused by seepage or piping or piping, slope embankments slides, earthquake etc. The protection of public from the consequences of dam failures has taken on increasing importance as population have concentrated in areas venerable to dam break disasters. This has created general interest in the dam safety analysis in recent years. The organization which are responsible for the safety of dams should plan in such a way, so that in the eventuality of dam failure the disaster does not struck the lives of public living downstream of the dam. There are a number of models available now for dam break analysis. The present section describes data requirement for one of such models viz DAMBRK model developed by National Weather Services, USA.

## DATA REQUIREMENTS FOR DAM BREAK STUDIES

The DAMBRK model was developed so as to require data that was accessible to the forecaster. The input data requirement are flexible in so far as .much of the data may be ignored (left blank on the input data cards or omitted altogether) when a detailed analysis of a dam break flood inundation event is not feasible due to lack of data or insufficient data preparation time Nonetheless the resulting approximate analysis is more accurate and convenient to obtain than that which could be computed by other techniques. The input data can be categorized into tow groups.

The first data group pertains to the dam (the breach spillways, and reservoir storage volume). The breach data consists of the following parameters: (failure time of breach, in hours), b (final bottom width of breach), Z (side slope of breach), $h_{bm}$ (final elevation of breach bottom), $h_o$ (initial elevation of water in reservoir), $h_f$ (elevation of water when breach begins to form), and $h\alpha$ (elevation of dam). The spillway data consists of the following: $h_s$ (elevation of uncontrolled spillway crest), C (coefficient of discharge of uncontrolled spillway), $h_g$ (elevation of center of submerged gated spillway, $C_g$ (coefficient of discharge of gated spillway), $C_d$ coefficient of discharge of crest of dam, Q (constant head independent discharge from dam). The storage parameters consists of the following : a table of surface area(A) in acres or volume in acre ft. and the corresponding elevations within the reservoir, The forecaster must estimate the values of r, b, Z, $h_{bm}$' and $h_f$

The remaining values are obtained from the physical description of the dam, spillways, and reservoir. In some cases $h_s$ ,C, $h_g$ and $C_g$ and $C_d$ my be ignored and Q used in their place.

The second group pertains to the routing of the outflow hydrograph through the downstream valley. This consists of a description of the cross-sections, hydraulic resistance coefficients, and expansion coefficients. The cross sections are specified by location mileage, and tables of top width (active and inactive) and corresponding elevations. The active top widths may be total widths as for a composite detection, or they may be left floodplain, right flood plain, and channel widths. The channel widths are usually not as significant for an accurate analysis as the over bank widths. The number of cross sections used to describe the downstream valley depends on the variability of the valley widths. They also depends on the availability of cross section measurements. However, a minimum of two must be used. Additional cross-sections are created by the model via linear interpolation between adjacent cross-sections specified by the forecaster. This feature enables only minimum of cross-sectional data to be input by the forecaster according to such criteria as data availability, variation , preparation time tc. The number of interpolated cross-sections created by the model is controlled by the parameter DXM which is input for each reach between specified cross-sections. The expansion-contraction coefficients (FKC) are specified as non-zero values at sections where significant expansion or contractions occur. But they may be left blank in most analyses.

## TENTATIVE DATA REQUIREMENT FOR DSS ( PLANNING )

## I. DATA REQUIREMENT FOR SURFACE WATER PLANNING DSS

### (A) STATIC DATA

#### (i) General data

- Basin Map
- Topographical map (contour and spot level map)
- Land use map
- Soil map
- Soil properties like soil texture, field capacity, wilting point, hydraulic conductivity, soil salinity and specific gravity etc.
- Litho logs and fence diagram
- Hydraulic conductivity and storage coefficients of ground water aquifers at various locations/pumping test data
- Command and non command area map (if possible canal irrigable areas)
- Map showing layout of main, branch and distributory canals in the command area
- Cross-sections of main canals (up to distributory level) in different reaches
- River network configuration (i.e., catchment maps indicating the location of main river reaches, tributaries, and projects);
- System node locations (indicated on maps along with location, longitude and latitude); System nodes include major tributary confluences; river locations where reliable flow records are available; sites of existing and planned reservoirs, barrages, or other hydraulic works (such as diversions); locations of water supply withdrawals (for agricultural, domestic, or industrial use); and flood prone or environmentally sensitive areas
- Cropping pattern, sowing and harvesting time of different crops grown in the study area and water application, crop coefficients.

**(ii) Reservoirs:**

- Reservoir name and location on major river reaches and tributaries, i.e., location relative to river network; Year of construction and reservoir filling;
- Location of irrigation and water supply withdrawals relative to reservoir or barrage sites (e.g., withdrawal from the river upstream of the reservoir, withdrawal directly from the reservoir storage, or withdrawal from the river downstream from the reservoir)

**(iii) Hydropower Facilities:**

- Number and type of hydropower turbines;
- Water release pattern – quantity and timings for hydropower generation.
- Turbine operational ranges, i.e., minimum and maximum generation limits;
- Turbine generation characteristics (power vs. net hydraulic head vs. discharge curves);

**(iv) Large Scale Water Use:**

- Location of large domestic, irrigation and industrial water supply withdrawals relative to system nodes
- 

## (B) SEMI-STATIC DATA

### (i) General Data

- River/channel discharge capacity and design irrigation demands
- Data pertaining to seepage from canals
- Field channel efficiency and water application efficiency under different branches/distributaries/groundwater use
- Active reservoir (or barrage) storage/level ranges (i.e., buffer zone, conservation pool, top of flood control pool);
- Change of reservoir (or barrage) storage over time due to siltation (i.e., siltation rate); Tail water curve (i.e., downstream discharge versus downstream elevation curve); Spillway and other outlet characteristics (i.e., outflow discharge capacity vs. reservoir level curves);
- Flood prone areas (relative to the river network).

### (ii) Hydropower

- Hydropower demand
- Installed capacity of the power plants in MW
- Minimum drawdown level for power production
- Efficiency of power plants
- Tail water elevation (monthly) in meters.
- Full reservoir level
- Dead storage level
- Minimum flow requirements
- Gross capacity upto FRL ($m^3$)
- Gross capacity upto intake of WS outlet ($m^3$)
- Rule levels for various purposes in meter
- Minimum reservoir storage in $m^3$
- Maximum reservoir storage in $m^3$
- Elevation Area capacity Table
- Spillway rating
- Downstream river capacity

### (iii) Crop water requirement

- Irrigated area
- Demands to be met from the reservoir
- %age of downstream location demands to be satisfied

### (iv) Dependable Flow

- 50% dependable monthly inflow to the reservoir
- 75% dependable monthly inflow to the reservoir
- 90% dependable monthly inflow to the reservoir.

### (v) Water availability and demand

- Water availability per person (l/day/capita)

- Water diverted per person (l/day/capita)
- Water consumed (depleted) per person
- Water use and demand per sector (Agricultural, Industrial, Domestic and others)
- Groundwater Withdrawal rate (current abstraction/safe yield)

**(vi) Large Scale Water Use:**

- Current water use requirements (e.g., irrigation requirements on weekly, ten-day, or monthly time resolution);

**(vii) Population Data**

- Human Population and Growth rate based on the recent census and projected population
- Cattle population and growth rate

## (C) HYDROLOGICAL AND HYDRO-METEOROLOGICAL TIME SERIES DATA

**(i) Hydro-meteorological data**

- Daily rainfall data and other climatological data like evaporation, temperature, radiation, wind velocity etc. along with location map

**(ii) River Hydrology:**

- Streamflow records at hourly interval during monsoon, daily, weekly, 10-day, or monthly time resolution for other periods at system nodes; Streamflow records should preferably be unimpaired, indicating streamflows that would have been realized in the absence of upstream withdrawals and returns
- Estimated streamflow losses between system nodes

**(iii) Groundwater:**

- Monthly water table data along with location and RL of observation wells
- Groundwater development, monthly groundwater draft (blockwise no. of wells/tubewlls and avg. pump capacity, number of running hours of pump)

**(iv) Reservoirs:**

- Historical (evaporation-rainfall) rate sequences (weekly, 10-day, or monthly); Historical temperature data (minimum, maximum, average; daily, 10-day, or monthly);
- Historical sequences of reservoir inflows, levels, discharges, and energy generation at weekly, 10-day, or monthly time resolution); The sequences of levels and releases are required since the time when the project became operational;

**(v) Canals:**

- Monthwise number of running days and discharge of the canals

**(vi) Water Use:**

- Historical water use withdrawals (weekly, 10-day, or monthly) from various river network nodes;
- Return flows as percentage of water withdrawals;
- Future (potential) water use scenarios at system nodes consistent with national water development plans at weekly, 10-day, or monthly time resolution;
- In-stream flow requirements (for pollution abatement and ecological purposes) at system nodes, if any;

**(D) RELATIONAL DATA**

- Rating Curve
- Reservoir water elevation vs. storage vs. surface area curves;
- Reservoir or barrage operating rules (i.e., seasonal level targets and relationship to releases)
- Turbine generation characteristics (power vs. net hydraulic head vs. discharge curves);

**(E) OTHER DATA**

**(i) River Network:**

- River L section, River cross-section, Rating curves and other river hydraulics data

## II. DATA REQUIREMENT FOR WATER QUALITY MANAGEMENT – DSS

**(A) STATIC DATA**

- Basin map with major streams, canals, towns, industries
- Soil map
- Hydro-geological features (types of rock/soil, litholog, faults/fractured zones etc.).

**(B) SEMI-STATIC DATA**

- Cross-section at different sampling stations
- Land use/land cover map
-

**(C) HYDROLOGICAL AND HYDRO-METEOROLOGICAL TIME SERIES DATA**

- Rainfall data (storm wise, daily)
- Discharge data (hourly for storm events, daily, 10-daily, monthly, and annual)
- Water quality data (see below) on 10-daily and/or monthly basis (physical, chemical and biological variables).
- Sediment data (daily/10-daily/monthly).
- Water depth at different sampling stations
- Groundwater level of wells
- Groundwater quality (see below ) data (physical, chemical and biological variables at monthly/seasonal intervals).
- Ecological data (phytoplankton, zooplankton, fish, invertebrates, reptiles etc.)

## (D) WATER QUALITY DATA REQUIREMENT

**Essential**

pH, temperature, electrical conductivity, coliform, dissolved oxygen, biochemical oxygen demand, nitrate, phosphate, pesticides, fisheries (fish cycles and production) and location specific water quality variable.

**Optional**

Turbidity, calcium, magnesium, sulphate, sodium, potassium, carbonate, alkalinity, chemical oxygen demand, iron, metal ions, phytoplankton, zooplankton, invertebrates, reptiles other important water quality variables of the region (arsenic, iodine, fluoride, salinity).

## Remarks

Water is one of the most essential natural resources for sustaining life and it is likely to become critically scarce in the coming decades, due to continuous increase in its demands, rapid increase in population and expanding economy of the country. Variations in climatic characteristics both in space and time are responsible for uneven distribution of precipitation in India. This uneven distribution of the precipitation results in highly uneven distribution of available water resources both in space and time, which leads to floods and drought affecting vast areas of the country. Better and scientific structural and non-structural measures are required for mitigating the floods and droughts. Mathematical models are needed for forecasting the monsoon rainfall accurately, which may be utilized by the decision makers and farmers for adopting appropriate strategies for management of droughts and floods. There is a need for increasing the availability of water and reducing its demand. For increasing the availability of water resources, there is a need for better management of existing storages and creation of additional storages by constructing small, medium and large sized dams considering the economical, environmental and social aspects. The availability of water resources may be further enhanced by rejuvenation of dying lakes, ponds and tanks and increasing the artificial means of ground water recharge. In addition to these measures, interbasin transfer of water provides one of the options for mitigating the problems of the surplus and deficit basins. However, for interbasin transfer of water the scientific studies need to be carried out for establishing its technical and economic feasibility considering the environmental, social and echo-hydrological aspects.

Integrated and coordinated development of surface water and ground water resources and their conjunctive use should be envisaged right from the project planning stage and should form an integral part of the project implementation. There is a need for proper management of groundwater resources, which presently require adequate inputs including manpower, financial inputs, technologies etc. Some of the important measures which may be taken up for sustainable development of groundwater resources include improving public water supply, use of energy pricing and supply to manage agricultural groundwater draft, increasing rain-water harvesting and ground water recharge, transfer of surface water in lieu of groundwater pumping, increasing the economic growth and reduction in dependence on agriculture and formalizing the water sector.

The components of the hydrologic cycle are being affected because the hydrological processes are no longer stationary due to point and non-point changes taking place in the river basins. An accurate assessment of available surface and ground water resources, considering the man made changes, is needed for planning, design and operation of the water resources projects as well as for watershed management. There should be a periodic reassessment of the surface and ground water potential on a scientific basis, taking into consideration the quality of water available and economic viability of its extraction. Since the hydrological processes are continuous and quite complex, therefore, an accurate assessment of quantities of water simultaneously passing through all these processes is quite a difficult task. Mathematical modelling of hydrological processes would provide an opportunity to both the research hydrologists and the water resources engineers involved in developing the integrated approaches for planning, development and management of water resources projects for sustainable development as well for preserving the eco-systems.

The available information and data collected so far by different operational and field organizations, scientific groups and engineering community are inadequate for planning, development and management of the vast water resources in the country. The time series data of the hydrological and meteorological variables, the space oriented data and relation oriented data are generated in a fragmented manner for specific locations and extrapolated to larger regions or river basins. Thus, in this regard, a comprehensive, reliable and easily accessible Information System for water resources data is a pre-requisite. The effort made in the World Bank aided Hydrology Project – I, is an important step in this direction. Decision Support Systems are required to be developed for planning and management of the water resources projects. Such systems provide an integrated approach for water resources management considering the various water related disciplines together with socio-economic aspects. These systems may be utilized for studying the different scenarios of water demand for arriving at the optimum allocation of water for various demands under varying water availability conditions.

Climate change is posing a challenge before the water resources engineers. Hydrological studies are required to be taken up for assessment of water resources under changing climatic scenarios. For predicting the future climatological variables on micro, meso and macro watershed scales , a comprehensive general circulation model is required to be developed for India, giving due consideration to the global scenarios. With the rapid industrialization and increasing use of fertilizers and pesticides, the quality of surface and groundwater resources is deteriorating. The movement of pollutants in the rivers, lakes and ground water aquifers needs to be regulated. In this regard, regular water quality monitoring programme has to be launched for identifying the areas likely to be affected because of the water quality problems. For maintaining the quality of freshwater, water quality management strategies are required to be evolved and implemented. Minimum flow must be maintained in the rivers for meeting the criteria of EFR. The eco-hydrological approach based on the concepts of blue and green waters may be considered as an integral part of the water resources management practices by balancing water between human beings and nature. Also, the concept of virtual water transfer requires to be introduced at policy level for food trade, water management and agriculture. The capacity building and awareness programmes may be organised for the users and public for encouraging their effective participation in water management practices and developing ethical concepts for making efficient use of water resources. Capacity building is also needed for the water resources managers and developers for updating the knowledge and technology in the area of water resources management.

**REFERENCES**

Abbot, M.B., Bathurst., J.c., Cunj, dJ.A., O'Connell.P.E. and Rammussen, J. (1986 a ), "An introuduction to the Europeon hydrological system- systeme hydrologique European, "SHE, 1: History and Philosophy of a physically based distributed modeling system". Journal of Hydrology, 87, 45-59"

C.W.C (1969), "Estimation of Design Flood –Recommended Proceduares".

C.W.C. (1973), "Estimation of Design Flood Peak", Flood Estimation Directorate Reprot No. 1/73, New Delhi

Chow, V.T. (1964), "Handbook of Applied Hydrology", McGraw Hill, New York.

Hiranandani, M.G. and Chitale, S.V. (1965), "Water Level Measurement" in the book, "Stream Gauging".

Linsley, R.K., Kohler, H.A. and Paulhus, J.L.H., J.L.H (1975), "Hydrology for Engineer" McGraw Hill Publicaiton.

Ott, R.F. (1971), "Streamflow frequency using stochastically generated hourly rainfall", Stenford University, Civil Engg. Deptt., TR-151

Raudkivi, A.J. (1979). "Hydrology"-Pergaman Press.

U.S. Army Corps of Engineers (1959), "Flood Hydrograph Analysis and Applicaiton", Engineering Manual 1110-2-1405.

W.M.O. (1974), "Guide to Hydrological Practices", Chapter on "Design of Networks, WMO No. 168.