DATA AND MODELS: A SYMBIOTIC RELATIONSHIP

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ABSTRACT

The problem of data quality afflicts every developing country. The absence resources prevents adequate supervision or the introduction of new technology. Data is very rarely processed and checked in time to have an impact on data quality. The paper discusses how mathematical modelling could be used to provide a more comprehensive check on data as well as a rapid feedback to the field. It advocates the maintenance of existing mathematical models for this purpose and for other future applications.

1. INTRODUCTION

The importance of collecting and maintaining databases of good water resources data continue to be emphasised whenever hydrologists meet. However, the reality is that the shortcomings of the quality, quantity and coverage of data are discussed only at the time such data is required for an important project and nothing further is done about it. As it is not possible to gather long time series of data within a limited project timetable, consultants such as we have to make use of our verbal and analytical ingenuity to create some useable data out of what is available.

In developing countries, with the exception of the national agency responsible for meteorological data, the other hydrological data collection is usually carried out by a "minor", in the sense of hierarchy and resourcing, division of a leading governmental agency. Such entities, such as the Hydrology Division of the Irrigation Department of Sri Lanka or the two Hydrology Directorates of the Bangladesh Water Development Board, would be expected to provide data (or even justification) for proposed major development programmes, as well for a long list of river diversion projects conceived by politicians and their advisors. Unfortunately, it is not possible to use the political will generated by these opportunities to obtain resources to improve *past* data. Neither is there political to make things easier for the development plans of future governments.

Maintaining quality of data is a major problem faced by hydrology organisations. The supervision of very poorly paid (invariably part-time) staff on a far flung network is never easy. A small poorly funded organisation would find it doubly difficult. As more intensive supervision of field data collection activities is not a realistic option, the only way one could achieve good quality is through better training, motivation and feedback. Feedback is most important because it is very important for the field staff to know that their data is being used and that any errors are rapidly detected.

The limited resources available for hydrological data makes it necessary to optimise and re-design networks to meet present *and future* needs. Some of our network is a legacy from the past when the priorities and the technologies available were different.

All the points mentioned above are under active consideration by the Water Resources Secretariat. Some work has already been done to identify problem areas and to devise a long term strategy. This paper discusses the current status and how mathematical modelling could be used to enhance quality control and the rationalisation of the hydrological network. Upgrading of some measurement techniques in keeping with the current techniques for data storage, analysis and modelling are also discussed.

2. THE PRESENT HYDROLOGICAL NETWORK IN SRI LANKA

2.1 The Network

The hydrological and hydrometeorological network of the country is maintained by two prime organisations. They are

- Department of Irrigation
- Department of Meteorology

The type of hydrometric data , the number of hydrometric stations and frequency of data collection in each station are presented in Table 1.

The density of these stations (see Table 2) were compared with the WMO standards during the study "Institutional Strengthening and Comprehensive Water Resources Management" [WRS,1998]. It in interesting to see that the station densities of rainfall and river gauging sites are satisfactory with respect to WMO standards. It should also be emphasised that these stations alone will not provide the required quantum of data needed for a specific study. Additional measurements will be done according to the need of the specific task in hand.

2.2 Methodology

The methodology employed for data collection is based on primary techniques. The Department of Meteorology collects most of the rainfall data on a daily basis using ordinary raingauges. Majority of these raingauges is located in plantations and tea estates. Recording raingauges, either flip bucket type or siphon type, are maintained in the 22 principal meteorological stations. Evaporation data are collected using evaporation pans in these principal meteorological stations and the other agro-meteorological stations.

Department of Irrigation too maintains some raingauges at their river gauging sites. Some of these raingauges are recording gauges while others are of non-recording type. River water levels are recorded manually using ordinary staff gauges in most of the places. However automatic water level recorders are employed at few sites.

River velocities are not recorded regularly in the gauging stations. However gauging is done according to need. This is about twice a year especially in case of floods and when the rating curve for the gauging station has to be updated. Little emphasis is paid in monitoring low flow conditions which is an essential requirement in terms of water quality etc. River velocities are measured using current meters deployed from boats and cableways.

2.3 Data Processing

It is difficult to say that a regular data processing exists. Rather in most of the occasions it is only a case of data compilation. Some of the data are processed to generate secondary data sets which are required for the day to day needs of these collector organisations.

The position of the Department of Irrigation is that they collect data to satisfy their internal needs rather than aiming at an island-wide hydrological data collection network for use nationally. In the Department of Irrigation still a very large proportion of collected data are in the form of hard copies. Velocity measurements and rating curves have been computerised. Most of the river discharges have been generated from the water level measurements. Water levels and other data are yet to be computerised. Even the computerisation process is *ad hoc* and is limited to the use of spreadsheets and some database software such as Dbase III. Specific water resources data cataloguing and processing software have not been used. Pluviographic data are extracted manually, without the help of a digitizer. Consistency checking and provision of feedback to the field is not a part of the chain. Data are checked in task specific work only.

In the Department of Meteorology, however, a fairly organised data compilation system is in place but yet in its formative stages. The climatic data collection package CLICOM which conforms to WMO standards is used. Most of the daily rainfall figures are computerised. And remaining data are presently being entered to the database, although it is a time consuming process. However pluviograohic data are still extracted manually without making use of a digitiser and ancillary software. No consistency checks are being performed and getting feedback to the gauge readers is not practised to improve the quality of data.

2.4 Preliminary Recommendations of WRS Studies

A review of water resources information in Sri Lanka was done under the ADB funded project " Institutional Strengthening and Comprehensive Water Resource Management" (TA 2242-SRI) where most of the data collection agencies in the country were interviewed to determine the present status of the data collection networks, data processing, dissemination etc. and to identify any constraints faced by these organisations in carrying out their functions.

It was found during this study that there is no nationwide network for water quality data and ground water. However an *ad hoc* network for a groundwater network exists in the form of tube-wells, agro-wells etc., constructed by the National Water Supply and Drainage Board [NSWDB], the Water Resource Board and the Agriculture Development Authority. Nevertheless these wells are not being monitored as elements of a regular groundwater data collection network.

The study has given many recommendations with regard to data ownership, coordination, planning and *inter alia* data collection and processing. Following are some of the salient recommendations given in the study with respect to hydrological data collection and processing:

- Water resources data are identified in four major categories i.e. climate data, surface water data, ground water data and water quality data.
- Four prime organisations will act as the custodians for the foregoing four data categories. These organisations are Department of Meteorology, Department of Irrigation, Water Resources Board & National Water Supply and Drainage Board (collectively) and the Central Environmental Authority respectively.
- Water Resources Secretariat will be the overall co-ordinator.
- Water resources data collection networks coming under each organisation should be reviewed in terms of method of collection, equipment, manpower etc.

- Use of new equipment such as digital data loggers for measuring rainfall water level etc. to be adopted.
- Data compilation and processing should be done using a standard software package used for this purpose such as HYDSYS.
- Chart data should be digitized.
- The management of this database should be on a GIS interface so that the data are easily located and accessed and even easily be used for mathematical models which requires inputs in such formats.

3. USE OF MATHEMATICAL MODELS AS ANALYTICAL TOOLS

3.1 The Traditional Use of Mathematical Models

Mathematical models of hydrological systems are used as predictive tools in planning and less often in system operation and flood forecasting. Such models are usually as good as the basic data on which they are based. Good models have undergone a rigorous procedure of calibration and verification. It is usual that the initial process of setting up and calibration of a model requires the collection of data from a network large number of stations, usually installed specially for this purpose, a network more detailed than one would have for routine operation. If such a model is then verified using a new set of data then it is safe to use it for various planning and operational purposes.

Surface water models are regularly used for planning river engineering projects and for determining environmental impacts of such projects. Rainfall-runoff models form the basis of many water resources studies as well as serve as essential inputs to surface water models. Reliable models however can also be used for a variety of other purposes.

3.2 Other Uses of Mathematical Models

The other uses of mathematical models could be as follows:

a) to assess the quality of new data,

b) to detect changes within the basin and river system and

c) to interpolate and/or generate new time series data*.

a) and b) above require that one runs a model using a new set of data and examines the results for inconsistencies and mismatches. The types of errors that could occur in a river network model are discussed below:

i) Water Level Gauges: It is still very common to use staff gauges to monitor water levels at several stations along a river. It is also common that these gauges are washed away or removed for various reasons and later replaced. This usually results in a datum error which is readily visible in a model run result. However, a similar error can also result if the position of the gauge is shifted either upstream or downstream by a significant distance. An extrteme example of this was in the North Central Region of Bangladesh where the gauge was found to have been re-fixed on an entirely different river!

ii) Rating Curves: The rating curve is an expression of the conveyance factor and the channel resistance of a reach of river. Any change in these properties would show up as an error in the model result. It is sometimes the case that a river gauging station is constrained to be established where backwater effects (or as in the case of Deduru Oya, tidal effects) have a disrupting influence during certain seasons. Examination of the rating curve implied in a model result would reveal very easily any backwater effects which affect a gauging station. The change in a rating curve, other than at the low flow end, must be treated as evidence of major changes within the river, or more usually some change of field measurement methodology.

iii) Low Flows: It is notoriously difficult to estimate low flows in a river. The lower end of a rating curve usually exhibits a great deal of scatter as a result of changes in minor bed topography (bedforms etc). In this instance, a fixed bed model cannot help. Suffice it to say that direct measurements (ie a very recently constructed low flow rating curve) will be the only useful source of information.

There exist many consistency checks that could be applied to detect errors that could occur in field observations. However, such check would nevertheless allow many other errors and inaccuracies to pass muster. A well calibrated model can allow the data to be checked both globally and locally and in space and time. Such models, where they exist, could be used to improve.

The frequent use of mathematical modelling automatically leads on to the need to make data available in digital form. Thus even manually collected data must be entered into the database. This must be done as quickly as possible so that the data could be checked and the necessary feedback provided while the data is still current. Even in a developing country, the value of water resources are such that the need to automate data collection and in some cases even the use of telemetry are becoming viable options.

3.3 Generating Time Series Using Mathematical Models

The use of mathematical models to generate new time series is a frequently used technique. This is best illustrated by an example:

Prior to the 1960s the entrance to the Panadura River (ie the exit of the Bolgoda Basin) was not open all year round. At times of floods, the river mouth had to be excavated to allow the flood waters to subside. A groyne and a sand by-passing culvert which was built by the Irrigation Department in the 1960's was successful in keeping the river mouth open permanently, allowing fishing craft to use the river as an anchorage mainly during the calm season. Due to an increased demand for access around the year, the entrance was to be modified to allow safe navigation for a longer period during the monsoon.

The new design had to satisfy Bruun's criterion for stability of tidal inlets. This criterion is based on the ratio of the volume of longshore sediment transport and the average tidal volume. While information existed that could be used to compute the monthly volume of longshore sediment there was no available record of the variation of tidal exchange at the Panadura River entrance.

It was not practical to try and measure tidal discharges so many times to obtain an estimate of monthly average volumes. Thus it was decided to use the model of the Bolgoda Basin originally developed by the Sri Lanka Land Reclamation and Development Corporation as a part of a research project on the Bolgoda system. The model, which was based on the MIKE 11 modelling system, was adapted for this purpose. Sufficient boundary conditions (rainfall time series and the measured sea levels in Colombo) to run the model for a long period. The model was calibrated against measured water levels and the ten tidal discharge measurements that were carried out. (see Fig 1 and Fig 2). The calibrated model was then used to make a 12 month simulation, which yielded a twelve month tidal discharge time series (at 15 minute time steps) more than sufficient to compute the average

average ebb flood volume. This was repeated for the new entrance geometry where the river mouth was displaced seawards. The changes in tidal flow regime were then estimated.

Mathematical models are now used widely to fill in gaps as well as generate data at places where no measurements have been made. All this however precludes the existence of good models. While, mathematical models have been devised for several river basins in Sri Lanka, they are not all freely available for use when necessary. These models, in order to be useful, must be maintained and kept in good working order by regular verification.

4 CONCLUSIONS

Mathematical models are being used increasingly in water resources management all over the world. These models have the capacity of being used over and over again to support different types of activities. Thus it is necessary to maintain the models in a reasonable state of verification so that they can be conveniently deployed when required. In order to run such models require a moderate amount of hydrometric data as boundary and initial conditions. They also predict/simulate the values of parameters at many other points in the model. Thus they also serve as a diagnostic device for checking data or conversely as a means of checking whether the system itself had changed.

Thus, regular verification of existing models could serve the following purposes:

a) Maintaining the model in good order for future users

b) Serving as a diagnostic tool for data quality maintenance

c) Serving as a diagnostic tool for changes in the system

It is also necessary for the engineering community in Sri Lanka to accept that new tools and methodologies are available and they must be used. While some models are costly to establish, they can be put to many other uses than originally intended. The example of the use of such models for a variety of projects quite unrelated to the original objectives might be found in Bangladesh where the models have been used to assist even highway projects and even to investigate the migration of fish on the flood plain (SWMC, 1993). When the tool already exists it is not necessary to re-invent the wheel as we sometimes do. For this to occur, there should be free exchanges of data and models between agencies. We should also try to repatriate some models (such as Nilwala Ganga, Kalu Ganga etc) that have been set up in the past by foreign consulting firms, so that we could benefit from their re-use.

Widespread use of mathematical models, however, should induce the use of modern data recording techniques, which could also eliminate the drudgery of data entry. The existence of the models might make it possible to optimise the number and location of hydrometric stations.

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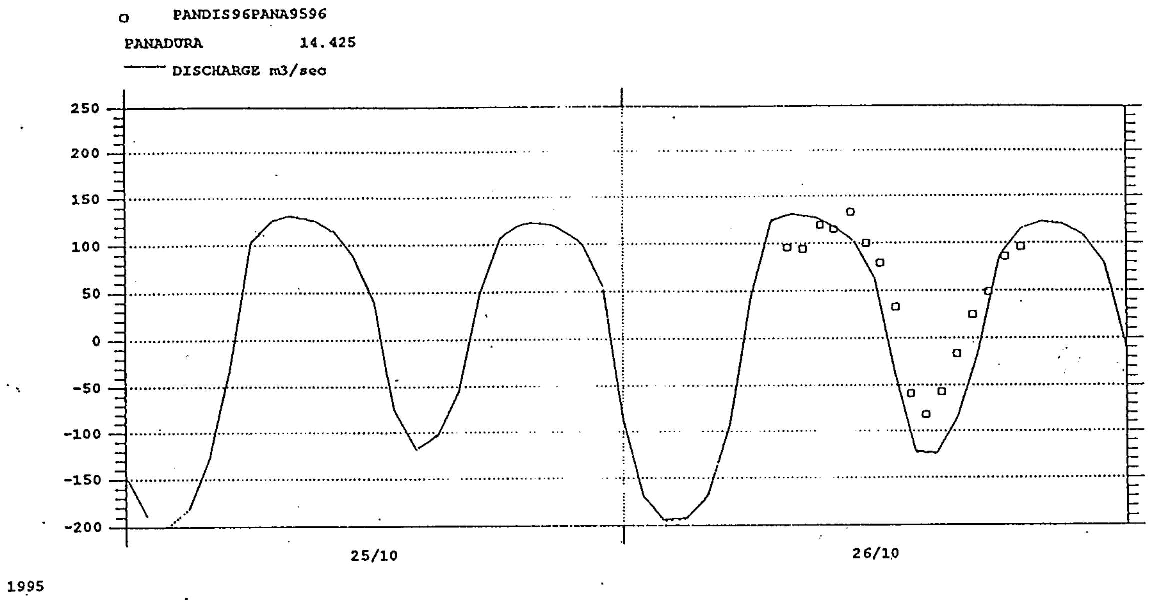

Figure 1: Panadura River: Example of Discharge Calibration

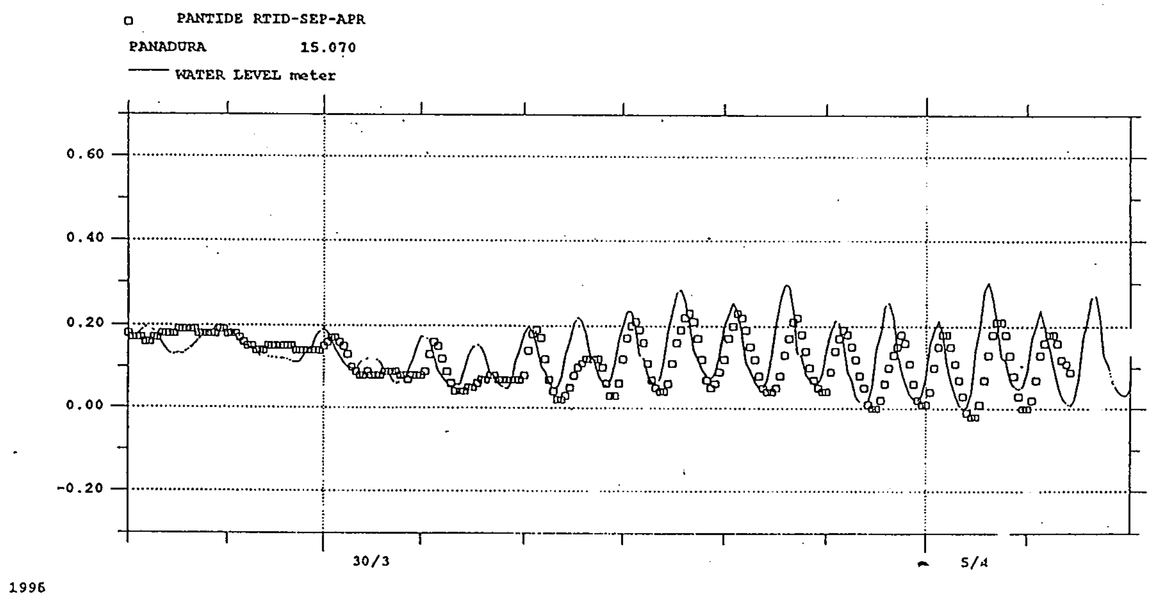

Figure 2: Panadura River: Example of Water Level Calibration