An Academic's Approach to Professional Problems

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Approach to work depends on the environment in which you are brought up. In my youth I have seen many of my countrymen from earlier generation sacrificing their careers and devoting their life for the cause of freedom from British rule. Their sacrifices created an urge in my generation to work to improve life in India after independence. We were given opportunities to gain technical knowledge on highly subsidized tuitions fees, hostel accommodation and other facilities. The times highly motivated us to make a mark and gain knowledge to solve the problems facing the country. Engineering education focuses on problem solving and it aptly matched my own determination to gain in depth knowledge and build knowledge base useful in the solution of problems in the area of water resources. The Water Resources group at IIT Delhi, which, I joined in 1961 encouraged professionals from Government organizations to discuss their problems and use our knowledge base to find solutions. In the next Paragraphs, I will discuss some cases to show how our mind worked to find solution to the problems using latest tools/analysis and synthesis in Hydrology/ Hydraulics.

1. Design of cavitation free transition for Sutluj-Beas link

The Bhakhra- Beas Board was seized with the problem of designing a transition from a circular section to a rectangular section supported on piers for Beas- Sutlej link. The Board had approach the best Laboratory in the India to suggest shape of the nose of piers, so that negative pressures do not develop in the area and damage the piers. The laboratory is famous for testing designs using hydraulic models. The report was examined by us in IIT. The Reynolds number which governs flow in closed conduits was calculated for the model. Its value was $1/25^{th}$. of that of prototype. Therefore, it became evident that shape of piers in the model derived at low Reynolds Number was not likely to work without cavitation. A suggestion was made to test the model in wind tunnel at 15 times the Reynold number of the hydraulic model and see whether changes are required to ensure cavitation free design. The Board accepted the proposal and experimentally determined shape of piers supporting the roof was provided to the Board. The model was $1/25^{th}$ of the size of Prototype. After determining the shape of the piers ellipses were fitted on either side of the piers and instead of supplying the engineers the coordinates of the nose curve from the model as multiplying them would have magnified the errors in measurement. The major and minor axes of the ellipses fitted to experimental data were given in the report. Before supplying the results model was remade using the calculated coordinates and found to work without generating negative pressures. The Board discussed our report and accepted the shape suggested by us. The structure is operating for the last 40 years without any cavitation even with an imperfect assumption and determination of shape of piers at a much lower Reynolds number. The engineers told us that fitting of ellipses helped them to precisely obtain the curved shapes for the nose of piers producing a streamlined shape.

2. Real-time flood forecasting of levels of Yamuna river at Delhi

In 1971, Central Water Commission was using Gage to Gage correlation to forecast the flood levels at Delhi. The problem was to forecast the levels as flood levels start rising at Delhi till the time flood recedes to a level below the danger mark. The past data was analyzed to understand the formation of floods in the river and it emerged that a simple reservoir and time delay could describe the formation of flood wave in the catchment using the input hydrograph data at an upstream point. Different alternatives methods could be better to solve the problems, is the underlying concept in this case.

The time delay was found using the travel time between the upstream point and at Delhi Bridge and reservoir characteristics were obtained from the past data. The model was tested by the Engineers in Central Water Commission by forecasting a flood in 1971 Monsoon. There was a good match between the observed and forecast values and the time for which the flood was above the danger mark at Delhi. The model was a behavior model and was imperfect to the extent that time of travel for various floods would vary between the upstream point and downstream. But it paved the way for useful interaction with the premier agency to upgrade their river forecasts on all India basis.

3. Location of hot water outlet in a man-made reservoir at Korba in relation to inlet point of water for cooling purposes in a thermal power plant

The problem was to locate the outlet so that hot water from the thermal power plant gets cooled by evaporation by the time it reaches the inlet point. The Engineers wanted that we make a 1/25 scale model of the system in IIT and show that hot water cooled before it reached the inlet. The cooling had to take place by evaporation from the water spread of hot water as it travelled from hot water outlet to the intake point. In actual reservoir in the field it was found that at different sections nearer to intake the water on the surface was hotter as compared to water at the bottom of the reservoir. When we took temperature measurement on the hydraulic model the water next to the bed was found to be hotter than at the surface. The $1/25^{th}$ scale model reduced the depth of the reservoir to $1/25^{th}$ of the depth in the prototype and the sun rays penetrated the water depth in the model to heat the bottom surface which in turn heated the water. The model was abounded and problem was split in to two sub-problems. First problem was the determination of area of reservoir surface which takes part in the evaporation to cool the hot water between the out let and inlet. The second problem was to develop a mathematical model using Energy balance approach to forecast the temperature reduction for various ambient temperatures, relative humidity, wind speed, and water temperature. The area was determined for an outlet inlet configuration, which gave the area required to cool the hot water in the hottest month of May each year. The experiment to determine the area for various inlet-outlet configurations was carried out in a flow visualization tank. A co-axial diagram for computing the inlet temperature using climate variables was provided to the thermal plant for adaptive management of cooling in the plant for the suggested configuration of inlet and outlet for various ambient temperatures using the mathematical model. Three dimensional problem in this case was split into two problems and an approximate approach was used to find solution to meet the deadline.

4. Spacing of embankments on both sides of the River Yamuna so that Delhi is not flooded if 1978 flood reoccurs in the Yamuna Basin

It took three days of active consultation with the engineers of Central Water Commission to define the deliverable by IIT. It was decided that IIT will prepare a report showing the impact of various spacing of the Embankments on water levels at Delhi Bridge, for the passage of 1978 flood wave in the basin. The gauge data available with the commission along the river as 1978 flood breached the existing

embankments was supplied to IIT. IIT formulated a conceptual model of the river reach and developed a new methodology in three months to answer the question. Recommendations were also made to get one foot contour survey of the Yamuna flood plain so that we could use St. Venant equations to recalculate the results for comparison with the new methodology. We repeated the work when survey data was made available to us after two years and found that the earlier work gave as good results as the established methods we used after the data were made available. These results were used to determine the water way and foundation depths of all bridges constructed on River Yamuna in Delhi state and to rebuild the embankments from Kalanaur to Delhi. This again illustrates the point that engineers need quick answers and are willing to accept reasonable assumptions as long the results are validated.

5. Impact of forests on floods in Ramganga

The impact of catchment treatment and tree planting by Forest department of U.P on floods in Ramganga river basin on the basis of hydrological/ hydro-meteorological and data on treated portions of the basin was an other interesting problem. One of our PhD students decided to work in this area and collected hydrological, hydro-meteorological and catchment treatment data. After analysis of the data it emerged that catchment treatment has no effect on floods of 50 years and higher return period. Given the monsoon climate and topography in this area, low flows in the river decreased during low rainfall periods. These were controversial statements. Most people believed that floods in rivers decrease because of forestation, and flows increase in dry periods. Our conclusions were explained by drawing the attention of the forest officials, that the soil absorbs low intensity rainfall as infiltration capacity of the soil is greater than the intensity of rainfall thus decreasing surface runoff. During the rainless periods the new plantation transpires the water in the soil emptying it for next rain. However, during high intensity rains which are usually preceded by low intensity rainfall, the soil is saturated and it has practically no effect on floods higher than 50 year flood. Our conclusion is supported by the historical fact that this region has faced catastrophic floods in last weeks of August and first week of September when the catchment is saturated by rain in the earlier periods. It also emerged from the study that plantation in central portion of the catchment can increase the intensity of floods. The reason being, that delay time of runoff increases due to plantation in middle reaches. The runoff from this area, in some cases matches with the arrival time of flood from upper catchment thus increasing the flood intensity just downstream of middle catchment. In this case data was analyzed to bring out the impact of treatment of the catchment. It required a number of meetings with the agencies to convince them that each catchment/ basin is different and its behavior is a function of topography, geology and hydrology and results cannot be generalized.

6. Creating an interactive simulation model for Lago-di -Trassimino Perugia Italy for developing solutions to improve tourism in the lake area

This problem was identified to help the environmental and tourism department as well as the local administration to improve the foot fall of tourists in the area to boost the local economy. This required that the lake has sufficient water during the tourist season so that all recreational facilities on the lake are operational. It was decided to augment the water in the lake from adjacent basins. The problems posed was to develop a simulation model of the lake so that the quantum of augmentation is decided. Thirty years of data of lake levels was available to check the validity of the software which was designed at IIT and delivered to Hydraulics department of Perugia University, our clients to develop a project report for funding to the government in Rome.

The experience I gained in solving problems for the diverse groups helped me to coordinate the implementation of computerization of administrative functioning at IIT Delhi. The stakeholders were, the IIT administration which funded it, the average worker who had to use the application, technical group whose advice I sought to develop the infrastructure, technical committee ably supported by Administrative computerization support service, consisting of software professionals and chaired by Head computer centre who coordinated the design of software with the consultancy firm, the humanities department which planned the training of the staff and the one page support pamphlet for each desk in the sections. It is heartening to note that the application is fully operational in IIT since last 20 years and has been updated over time by including new rules and procedures.

7. Disposal Of silt from balancing reservoir in Bhakra Beas Sutluj Link

The following cases pertain to the period, after my superannuation from IIT Delhi.

The problem arose in Himachal Pradesh, because of pumping of silt slurry from balancing reservoir to a natural stream between the balancing reservoir and the river Beas. The silt settled in the stream. During high intensity rain the stream overflowed its banks and flooded the agricultural area, depositing coarse silt and ruining crops. I was invited to join as non-official member of the committee constituted by the court for suggesting a suitable solution to solve the problem. The solutions on the table ranged from a pipeline to carry the silt from balancing reservoir to either the river Beas or Sutluj. After lot of discussion, the colleagues on the committee agreed to use the hydrological characteristics of the stream to solve the problem. The innovative solution was to pump the silt whenever the flows could carry the silt in the stream to the river to a level when it starts flooding the adjoining agricultural lands. A Communication system was set up on the stream, nearest to flooded area to communicate levels in the stream to the dredging party to enable them to start dredging and pumping silt within the specified levels. The court accepted the solution and requested the committee to monitor the functioning of the solution for next two years. The system is functioning to the satisfaction of all parties saving money and installing a system which constantly monitors the applicability of solution.

8. Quantitative analysis for equitable distribution of water between Riparian States of The Krishna basin

I joined Interstate water resources Andhra Pradesh as a senior consultant in 1997 to assist the state, before the Tribunal which was set up to allocate water of the river Krishna between riparian states. My terms of reference were, to assist the Legal, Technical and Administrative teams to create the basis on which the state of Andhra Pradesh could logically present their case before the Krishna Water disputes Tribunal II for equitable distribution of water between the Riparian states. The riparian states are Maharashtra, Karnataka and Andhra Pradesh. After assessing the availability of data, it emerged that the utilization data which is needed to develop a virgin time series were not available on monthly basis to A.P from upper states. Annual utilizations for the state and cropping patterns in the basins was used to determined utilizations required at appropriate time scale. Rainfall data was obtained for all the IMD stations within the Krishna basin. The density of rain gauges were augmented in various sub-basins with time. For example, there were 10 rain gauges for first 10 years, they were increased to 20 for the rest of record. In such cases rainfall to rainfall regression models for the common data time interval was used to homogenize the data. It was decided to determine the water availability in the 12 sub-basins of River Krishna on monthly basis for the sub-basins using measurements on the river at central water commission data stations and rainfall data from IMD. The strategy employed was to use measured data after validation using standard methods. The utilization data on annual basis was used to develop annual time series for all the basins, and water generated by each state was determined. Since

all these basins contribute to flow at the terminal point of Vijayawada, the contribution of each sub-basin was suitably modified so that annual contributions from sub-basins match the virgin flows at the terminal point. These annual flows were divided using gauged flows at central Water Commission stations in to monthly flows. A multiple reservoir simulation Mike Basin model was used to determine how the projects were impacted in the state of Andhra Pradesh because of allocation by the previous Tribunal and additional allocation to Upper States. I filed an affidavit as an expert witness on behalf of state of Andhra Pradesh on water availability and impact of allocations upstream on A.P in 2008. I was cross-examined for over three months by the other states on the Issues identified by the tribunal to determine the new allocations to various states as well as to address their concerns on my statements in the affidavit and conclusions. The affidavit was based on whatever data was available with the state of Andhra Pradesh and paved the way for the tribunal to introduce quantitative methods to address the issues. The states were asked to supply latest data. CWC provided the expertise to the tribunal with two assessors and other engineers to work out the water availability with the new data available with the tribunal. It is heartening to note that my affidavit set a precedent to use quantitative methods in the allocation of water between the states keeping principles of equity, hydrological factors, demography, and riparian rights in mind. A major recommendation accepted by the tribunal was to set up a Board with adequate powers to implement the decisions of the tribunal with online data exchange from projects to make the process of utilization by various projects totally transparent.

During my dealings with the engineers since 1968, I find that they are devoted to find creative solutions to the problems in hand and are result driven. Usually the problems are under or over specified and need to be diagnosed. Deliverables can only be defined after assessing the data available with the organization. The methodologies to be followed are identified. Professional's time frame is more or less immediate; therefore, standard software to analyze the problems is preferred. The solution is found using the identified methodologies and checked with other formulations using simplified assumptions. The result is evaluated to see whether it matches the observation in the field and can be explained to a logical group. Otherwise, new methodology such as the one described in the inlet outlet case is evolved. The results are presented as per the deliverables and should be in a format which helps them in implementation. Fitting of ellipses to the nose of piers instead of coordinates of experimental data helped considerably in implementing recommendations. Mathematical/ conceptual models or simulation models help immensely in solving hydrological problems quickly and ensure that law of conservation of mass is not violated in the computation processes at all junction points.

The data availability decides the methodology, deliverables and the choice of model. Models help to develop consensus between diverse group of stakeholders involved in real life situations. The impact of conclusions reached in the Krishna case was determined by the riparian states using data in my affidavit, and I was interrogated with their interpretation for weeks to demolish or accept the line of reasoning. Such an approach brings transparency to the decision processes, a boon in multi stakeholder groups for consensus building. They also help to build confidence in the accepted solutions. The underlying concept followed by us as engineering academics in all above cases as well as others I had the good fortune to be associated with is, that different or alternative methodologies are better even though our understanding of the physical processes that were modeled were not perfectly understood. Integrating new tools/ technologies to find solution to professional problems in reasonable time was the guru mantra.