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Application of MIKE 11 for Flood Forecasting (A Riew)

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Abstract—A flood is an unusually high stage in a river – normally the level at which the river overflows its banks and inundates the adjoining area. The damages caused by floods are in terms of loss of lives , property and economic loss due to disruption of economic activities are with great severity. Hence information about the flood has to be disseminated well in advance to the people likely to be affected so that an emergency evacuation plan may be prepared and properly implemented. On the other hand estimation and forecasting of flood is indeed necessary for demarcating the flood plain and to determine the required height of the flood control structures. In Flood forecasting accuracy is attained by developing models between upstream and downstream. These are worked out based on past records of concerned basin reach. Model is developed by collecting and validating of hydro-meteorological data where hydrology deals with the river hydraulics defines propagation of flood wave along the river channel by routing. Flow routing is the process used to predict the temporal and spatial variations of a flood hydrograph as it moves through a river reach .If the flow is flood, the procedure is specifically known as flood routing. Traditionally this flood routing is done with the Muskingum method developed by McCarthy in 1934 and Muskingum-Cunge method which was introduced later in 1969 by Cunge by. But these methods require too many computations and these are data intensive, researchers always tried for better approach which will save time and gives more professional accuracy than the earlier method, but all of they have mentioned the limitations of traditional methods. Whereas in recent years MIKE 11 became more popular tool for flood forecasting due to its inherent properties. MIKE11 plays an important role in today's world in the field of top quality river modeling covering more application in areas than any other river modeling package. Flood analysis, real-time flood forecasting, flood alleviation design studies, dam break analysis, optimization of reservoir are some of the typical applications of MIKE11. Hence intention of this paper is to present a review on few major MIKE 11 applications specifically for flood forecasting which were done by the earlier researchers in the last decade.

Keywords-Flood, flood forecasting, flood routing, MIKE 11, models

I. INTRODUCTION

Flood occurs due to natural as well as man-made causes. Major causes of floods in India include intense precipitation, inadequate capacity within riverbanks to contain high flows, and silting of riverbeds. In addition, other factors are landslides leading to obstruction of flow and change in the river course, poor natural drainage, cyclone and heavy rainstorms/cloud bursts, snowmelt and glacial outbursts, and dam break flow. For minimizing the losses due to floods, various flood control measures are adopted. The flood control measures which can be properly termed as "Flood Management" can be planned either through structural engineering measures or non-structural measures. Wise application of engineering science has afforded ways of mitigating the ravages due to floods and providing reasonable measure of protection to life and property. Hence an efficient Flood-Forecasting and advance warning systems are necessary in order to evacuate the life and movable goods, to as much extent as possible owing to the non-structural measures. The likely expenditure on developing such an efficient flood forecasting services automatically gets justified in view of the large scale savings generated by it. Flood forecasting operation intends to pass on the water level and discharge magnitudes of the approaching flood along with its time of occurrence. Receiving a set of accurate information well in advance to concerned authorities is essential to keep resulting losses to minimum. Implementation of flood forecasting system is crucial for reducing flood disasters urgently and effectively. Hence many conventional flood forecasting methods came into existence like Flood forecasting by using flood routing technique [16], by using inflow-outflow correlation curves [14], forecasting the time of travel and the duration of the peak [19], use of electrical analogy model, computer simulation [11].The Flood routing procedure may be in accordance with the hydraulic routing, hydrologic routing and routing machines for routing through channel or river and through reservoir. In river during floods the flow is non-uniform and unsteady. The hydraulic characteristics vary from stage to stage and also from channel to channel inclusive of later flows. The hydrologic routing is carried out traditionally by Muskingum, Muskingum-Cunge, etc. which are based on the physical properties of the channel as a procedure to determine the time and magnitude of flow at a point on a water course from known or assumed hydrographs at one or more points upstream[12]. Danish Hydraulic Institute have introduced product MIKE, which build's the conceptual and physically based models for flood forecasting. The modeling with MIKE 11 is now-a-days widely used for the flood forecasting on account of the output of the pervious modeling's [1, 2, and 3]

II. MODELLING WITH MIKE 11

2.1. Introduction to MIKE 11

The Danish Hydraulic Institute (DHI) is one of the world-leading software developers for incorporating water resources related time-series data into modeling. The DHI has provided MIKE Zero, MIKE HYDRO, MIKE 11, MIKE 21, MIKE 3, MIKE 21/3 Integrated Models, LITPACK, MIKE FLOOD, MIKE SHE to the society of Water Resources .Where MIKE HYDRO is modeling shell used for a variety of model applications covering Integrated Water Resources Management (IWRM), Water resources assessment, Water allocation, Reservoir operation and other types of analysis, planning and management model studies. The size of these may range from local project scale to international river basin scale. MIKE 11 is package for the simulation of flows, water quality and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies. It is a dynamic, user-friendly one-dimensional modeling tool for the detailed design, management and operation of both simple and complex river and channel systems. It is for 1D modeling. MIKE 21 software package contains a comprehensive modeling system for 2D free-surface flows and is applicable to the simulation of hydraulic and related phenomena in lakes, estuaries, bays, coastal areas and seas where stratification can be neglected while the MIKE 3 is a comprehensive modeling system for 3D free-surface flows which is applicable to the simulation of hydraulic and related phenomena in lakes, estuaries, bays, coastal areas and seas where stratification or vertical circulation is important. The MIKE 21/3 integrated models contains a comprehensive modeling system for 2D and 3D free-surface flows. LITPACK combines a technically very strong deterministic sediment transport model with user-friendly facilities for the simulation of a large number of wave/current scenarios and for the combination of these simulations into predictions of the net littoral drift, developments of coastal profiles, and long-term coastline evolution. MIKE FLOOD is an integrated flood modeling package for rivers (MIKE 11), surface flow (MIKE 21) and urban drainage (MIKE URBAN).It dynamically couples well proven 1D and 2D modeling techniques into one single powerful tool which approaches to modeling inundation caused by the overtopping of river embankments or overloaded storm water systems. MIKE SHE is a dynamic, user-friendly modeling tool for a wide range of water resources and environmental problems related to surface water and groundwater and can be applied on scales ranging from local infiltration studies to regional watershed studies linked [15].The MIKE 11 is an implicit finite difference model for one dimensional unsteady flow computation and can be applied to looped networks and quasi-two dimensional flow simulation on floodplains. The model has been designed to perform detailed modeling of rivers, including special treatment of floodplains, road overtopping, culverts, gate openings and weirs. MIKE 11 is capable of using kinematic, diffusive or fully dynamic, vertically integrated mass and momentum equations (the "Saint Venant" equations). The solution of the continuity and momentum equations is based on an implicit finite difference scheme. This scheme is structured so as to be independent of the wave description specified (i.e. Kinematic, Diffusive or dynamic). Boundary types include water level (h), Discharge (Q), Q/h relation, wind field, dam break, and resistance factor. The water level boundary must be applied to either the upstream or downstream boundary condition in the model. The discharge boundary can be applied to either the upstream or downstream boundary condition, and can also be applied to the side tributary flow (lateral inflow). The lateral inflow is used to depict runoff. The Q/h relation boundary can only be applied to the downstream boundary. MIKE 11 is a modeling package for the simulation of surface runoff, flow, sediment transport, and water quality in rivers, channels, estuaries, and floodplains. The most commonly applied hydrodynamic (HD) model is a flood management tool simulating the unsteady flows in branched and looped river networks and quasi two-dimensional flows in floodplains. When using a fully dynamic wave description. MIKE 11 HD applies the 'Saint Venant' equations and for Kinematic wave description Muskingum or Muskingum-Cunge equations are applied; which based on conservation of mass-continuity and momentum equations [5].

2.2. Governing Equations

MIKE11 is based on the 1D Saint-Venant equations as illustrated below-

- Continuity equation:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \qquad \ldots\ldots (1)$$

- Momentum equation:

$$\frac{\partial Q}{\partial t} + \frac{\partial\left\{\propto \frac{Q^2}{A}\right\}}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2AR} = 0 \qquad \ldots\ldots (2)$$

Where Q – Discharge, (m^3/s)
A – Flow area, (m^2)
q – Lateral inflow, ($m^3/m/s$)
h – Stage above datum, (m)
R – Hydraulic or resistance radius, (m)
C – Chezy resistance coefficient,
α – Momentum distribution coefficient

The four terms in the above momentum equation are local acceleration, convective acceleration, pressure and friction. In MIKE 11, a network configuration depicts the rivers and floodplains as a system of interconnected branches. Water levels and discharges (h and Q) are calculated at alternative points along the river branches as a function of time as shown in figure 1 [7]. It operates on basic information from the river and floodplain topography to include manmade features and boundary conditions. The 6 point Abbott-Ionescu Finite Difference scheme for the dynamic, diffusive and kinematic wave approximation is used in MIKE11. The conservation of mass i.e. continuity equation is applied between elevation points and conservation of momentum is applied at discharge points.

2.3. Solution Scheme in MIKE 11

The finite difference scheme used in MIKE11 is 6-point Abbott scheme. A graphical view of this method is shown in figure 2 below [7]. As we can see at n+1/2 step the model bring data from steps n and n+1, so unknowns will obtain simultaneously for each time step. MIKE11 model is fully implicit method to solve the problems and usually there is no limitation about computational steps.

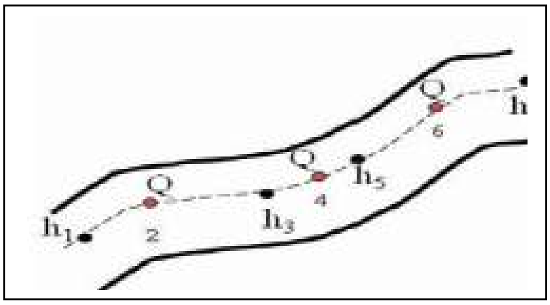

Figure 1. *Channel Section with computational grid*

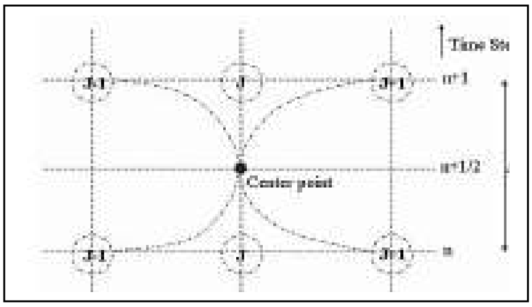

Figure 2. *Centred 6-point Abbott scheme*

2.3. Methology for Model Setup

MIKE 11 includes multiple editors, each operating on different types of data. Where Data from these editors must be saved in separate editors, the integration and exchange of information between each of the individual data editors is achieved by use of the MIKE 11 Simulation editor. The Simulation Editor contains simulation and computation control parameters which are used to start the simulation as it provides a linkage between the graphical view of the network editor and the other MIKE 11 editor's .The following steps have to be followed in order to setup the one-dimensional

- *Defining the River Cross-section:* MIKE 11 model's River Network file is the common link to the various MIKE 11 files. It also has an XY coordinate system, allowing the model to import and export data to and from other software. The River Network file allows the modeler to define the river network, reference cross-sections, and control structures to the network and to obtain a graphical overview of model information in the current simulation. Figure 3 shows the river network file which is digitized and defined graphically in MIKE 11 network platform [7].
- *Inserting River Cross-section:* The geometry of cross-sections obtained from field-surveyed data. The raw data was entered into a MIKE 11 cross-section file and the graphical display of the cross-section could be visualized in figure 4 [7].
- *Boundary Cross-section*: Boundary conditions can be defined for the river reach by inserting the time-series for the upstream and downstream boundary condition.

- *Hydrodynamic (HD) Parameter:* The final data required to run a simulation is the HD parameters. In this study, the river bed resistance value and the initial conditions of discharge and water level/depth are specified. The global values are specified. The resistance
- formula is adopted and specified as an overall resistance for the whole stretch of the river

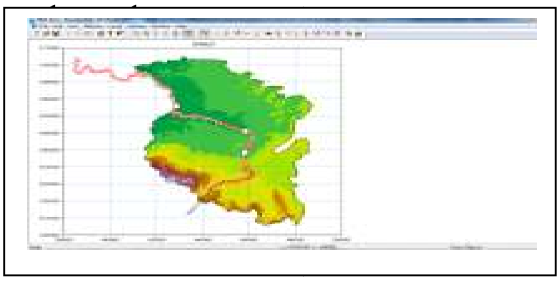

Figure 3.Network Editor

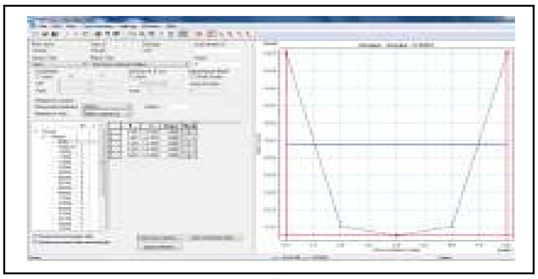

Figure 4.Raw data view in the cross sections editor

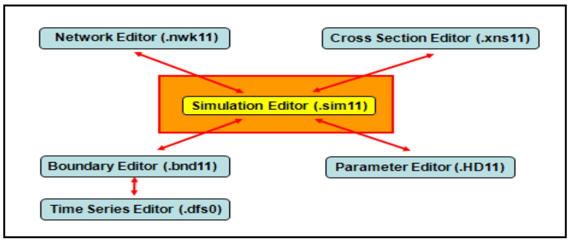

Figure 5.Files to be attached in Simulation Editor

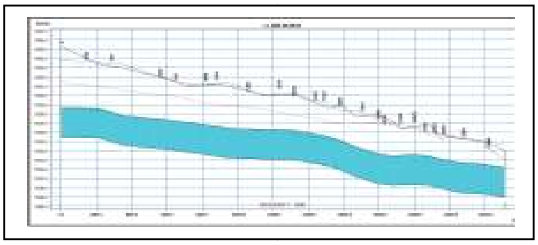

Figure 6.MIKE VIEW file illustrating result

- *Simulation by MIKE 11 :*The simulation editor serves three purposes i.e. it contains the simulation, computation and control parameters, it is used to start the simulation and it provides a link between the network editor and the other Mike11 editors as illustrated in figure 5 [6].Once all information are edited in the file editors described above section, the new simulation file is generated and all the editor file described above are browse in this new simulation file; identifies any errors with the established conditions before running simulation.
- *Viewing Result in MIKE 11:* The results of MIKE 11 simulations are visualized using the MIKE View program. MIKE View displays longitudinal profile animations of both stage height and discharge resulting from a MIKE 11 unsteady simulation. It also display stage height at any given cross-section, as well as provide rating curves at a specified location along the river network. MIKE View can also aid the visualization of time-series results of stage heights at cross-section locations and time-series results of discharge at midpoints between two cross-section locations. The water level profile is illustrated figure 6 [7]. The blue-coloured section represents water in the river channel. The red dotted line denotes the maximum water level simulated during the period. The dark continuous line represents the right river bank, while the dark broken represents the left one [5] and [15].

III. APPLIED MODELS OF MIKE 11

3.1. Flood Forecasting at Tapi River

The study carried out by [1] addresses the simulation of floods for the years 2003 and 2006 and the development of stage–discharge relationship along the lower Tapi River in India. The river network and cross- sections, for the study, were extracted from the field surveyed contours of the Tapi River. The MIKE 11 hydrodynamic model was calibrated for the 1998 flood using releases from the Ukai Dam (flood hydrograph) and the tidal water level in the Arabian Sea as the upstream and downstream boundary conditions respectively. The calibrated model was validated using low-flood and high-flood data of the years 2003 and 2006 respectively. The time series of the simulated flood levels were compared with the corresponding observed values at four intermediate gauging stations: Kakrapar Weir, Mandavi Bridge, Ghala village and the Surat city (Nehru Bridge).The model performance was also evaluated using root mean square error (RMSE) and was found to be 0.2137, 0.5750, 1.974 and 0.9610 during the calibration period for Kakrapar Weir, Mandavi Bridge, Ghala village and Nehru Bridge respectively. For the validation period the values of RMSE was found to be 1.1592, 0.8527, 2.1947 and 0.7469. Based on the hydraulic analyses of the river, the following conclusions were drawn:

(a)The complete geometry of the study reach was developed using the MIKE 11 model. The resistance coefficient (i.e. Manning's *n*) was calibrated for the study which led to the recommended value of 0.03 for future simulations.

(b) The simulated levels of the lower Tapi River were consistently higher than the observed flood levels for the year 2006. This overestimation was due to the fact that, at higher discharge levels, the water starts to spill over either of the banks as the flow becomes two dimensional in nature.

(c) The hydraulic parameters and rating curves along the river were computed subsequently. These may be helpful in designing flood protection measures and development of flood inundation map of the lower Tapi River. The accuracy of the developed stage–discharge curves would have improved, had the data of several floods been considered in their development.

(d) The results of the model can be further improved by giving due consideration to sediment transport in the river during a flood.

3.2 Flood Forecasting at Brahmani River

Reference [2] carried out comparison of variable parameter McCarthy-Muskingum (VPMM) model with the extensively used MIKE11 hydrodynamic (HD) model. Although both the models are amplified physically based, the MIKE11-HD model requires number of cross section details at closer intervals unlike the VPMM model which needs only two end-cross sections. Herein, the VPMM model uses the cross sectional details of the two-end sections of the river reach, whereas the MIKE11 model uses 10 intermediate cross-sections. The performances of both the models are evaluated in estimating the discharge and stage variables in the Bolani-Gomlai reach (45 km length) of the Brahmani River basin of Odisha state in the eastern India. Based on the performance evaluations indicators the Nash-Sutcliffe efficiency criterion, error in peak, time to peak, and error in attenuation to peak, it is found that the VPMM model in stage estimation is far better than the MIKE11 model routed with two end sections and 10 intermediate sections; whereas for discharge routing the Mike 11 model is better than the VPMM model. Out of the six flood events one event (Sep 30, 1986) was selected for calibration. It is found that MIKE11 (without intermediate cross section) gave the maximum value of *NSE* =89.95% and *NSE* =90.11and with intermediate cross section gave the maximum value of *NSE*=90.23% and *NSE* =90.10% for 0.03 and 0.045 roughness coefficients. The VPMM model with coefficients 0.038 and 0.07 gave the maximum value of *NSE*=91.27% and *NSE*=89.81%. These calibrated values of roughness coefficients were used for model validation using five flood events occurring during the years 1980-1995 Therefore, it is summarized that the VPMM model could be very much useful for most of the ungauged river basins with limited cross sectional data availability.

3.3 Comparison of HEC-RAS with MIKE 11

The Results of flood plain zone were compared with the two hydraulic models, MIKE11 and HEC-RAS by [3]. Initially the analysis of hydraulic flood is performed with entry data geometric cross sections, boundary conditions and initial data after calibration then the results of the model that consists of flood zones as layers of data transfer to ARCVIEW software and overlay with topographic maps 1/2500 national mapping agency. Finally, results are shown in flood zone maps for the HEC-RAS and MIKE11 models. When the results of the two models were compared, insignificant difference i.e. square regression values were found to be 0.914, 0.8847 and 0.8747 for the 2-years, 25-years and 500-years flood event between the models according to the results shown in the graphs. The results calculated by both hydraulic model for flood mapping very close to each other, and simulation results for a region that has been used both mathematical models.

3.4 Flood Forecasting at Nzoia River

In the [4] 1-D unsteady model Mike 11 was studied and applied to the lower Nzoia River, about 25 km in length. The study's focus was the development of a MIKE 11 river model based on surveyed river cross-section data. The flooding problem in the lower Nzoia (Budalangi floodplains) in Kenya has been perennial each time causing a reversal of gains on economic and social development. The main objective of this study was to implement a one dimensional hydrodynamic model for the lower part of Nzoia river using the MIKE 11 modeling software. This was done with an aim of investigating the nature of the 2008 Budalangi floods. Two scenarios were considered, namely; reference case (intact dyke) and the breached dyke case. Longitudinal river stretch profiles were produced for the two cases and it was conclusive that the 2008 flooding was mainly necessitated by dyke breach.

3.5 Real-time Flood Forecasting at Krishna and Bhima River Basin

The Real Time Stream flow Forecasting and Reservoir Operation System (RTSF&ROS) is built upon the MIKE11 modelling system which comprises the hydrological rainfall-runoff model, the hydraulic river routing model based on a fully dynamic solution of the St. Venant's equations, the data assimilation process used in real time flow and flood forecasting. The hydrodynamic model contains updated river cross sections from the field surveys carried out in 2012. The stream flow and flood forecasting model has been tested with historical events in hindcast mode capturing all types of average, dry and flood events that occurred in the Krishna and Bhima basins in the recent past. In absence of real time from RTDAS the system was tested and demonstrated with data from various Government Websites in 2012. The RTSF and ROS have been fully tested with real time data from RTDAS during the monsoon (July-August) of 2013. The "live test" and implementation of the RTSF and ROS during the monsoon season of 2013 has been completed satisfactorily [6].

3.6 Flood Forecasting at Jamuneswari River

A flood forecasting system was been developed using MIKE11 river-modeling software modules rainfall-runoff (RR) [Nedbor-Afstromnings model (NAM)], hydrodynamic (HD), and flood forecasting (FF) for the Jamuneswari river catchment of the northwestern part of Bangladesh [8]. Errors in forecast results have been assessed by computing efficiency index, coefficient of correlation, volume error, peak error, and peak time error. Integration of the MIKE 11 HD module with the MIKE NAM module improved the result by 10.84% for efficiency index, 20.7% for volume error, 25.61% for peak error, and 95.83% for peak time error. The MIKE 11 FF module was applied along with the integrated MIKE 11 NAM and HD modules to minimize error in the forecasted result. The efficiency index, volume error, peak error, and peak time error of the hind cast result was calculated, before updating by MIKE 11 FF. After updating by the MIKE 11 FF modules, results were calculated. The steps for developing the flood forecasting system described in this case study are generic and can be applied under similar geographic conditions in other locations worldwide. In Bangladesh, decision makers will have more time to develop responses to imminent the flooding as a result of the increased forecast lead time provided by the analysis method in this work.. Among different state of the art methods, dependent deterministic computer-based hydrodynamic or rainfall-runoff models, or a combination of both, are being used for flood forecasting. In this study, the Jamuneswari flood forecasting system (JFFS) was developed by calibrating and validating the MIKE 11 NAM, HD, and FF modules.

3.7 Flood Forecasting at Karun River

In this study the result of Muskingum Cunge as a simplified hydraulic method and MIKE11 model was compared for Flood Routing in the reach between Mollasani to Ahwaz stations located at desired region of the mentioned river [9]. The results of this study demonstrated successful performance of the simplified routing methods and showed that in situations where the availability of intensive data required by hydrodynamic model are limited, relying on such simplified method would provide satisfactory results. It was observed that there is a good accuracy by selecting Fully Dynamic method for flood routing in this reach of Karun river By MIKE11 model. Obviously the calculated error of this method in this reach is acceptable. On the other hand, usage of Muskingum Cunge method as simplified one can be useful when observational data are insufficient. The Muskingum Cunge method can be used for flood routing between the reach Mollasani to Ahvaz stations of Karun River with high accuracy, and numerical solution, semi analytical and analytical schemes of this method are usable. According to performance of MIKE11 as a numerical model is higher than Muskingum Cunge method, because this model uses Fully Dynamic method for solving Saint -Venant equations. Unfortunately application of Muskingum Cunge method for flood routing in mountainous regions can lead to absolutely wrong results, because of wrong approximation of flood storage in this regions and rapidly variations of momentum value. So the author recommends fully dynamic method for that reaches of river. The inherent mathematical diffusion of Muskingum Cunge method, with possible under prediction of downstream water levels, is a potential problem. The principal advantage of the approximate method is that the Muskingum Cunge parameters can be directly estimated from the properties of the inflow and outflow hydrographs.

3.8 Flood Forecasting at the Maritsa and Tundzha River

Reference [13] this paper describes a forecasting system recently developed in cooperation with the National Institute for Hydrology and Meteorology (NIHM) and the East Aegean River Basin Directorate (EARBD) for the rivers Maritsa and Tundzha. To improve the management of flood hazards, a flood forecasting system (FFS) was set up. The system exits of two model concepts i.e. a numerical, calibrated model consisting of a hydrological part (MIKE11-NAM) and hydraulic part (MIKE11-HD);a flood forecasting system. For some basins both meteorological and discharge measurements were available. These basins were calibrated individually. The hydraulic models were calibrated based on the 2005 and 2006 floods. The hydrological and hydraulic model were combined and calibrated again. The flood forecasting system (using MIKE-Flood Watch) uses the combined calibrated hydrological and hydraulic models and produces forecasted water levels and alerts at predefined control points. Depending on the available input the forecast lead-time is short but accurate, or long but less accurate. If one of the input data sources is not available the system automatically uses second or third order data, which makes it extremely robust. A data assimilation routine was used to update calculated water levels and discharges at the inflow points with the observed data. The difference between the calculated and measured series during the forecast period was used to correct the water levels during forecast period. If there was a hydraulic model at that time, the effect of the upstream inundations could by simulated by lowering the embankments in the model. The recommendation is therefore made to use the water management model with the information from the Flood Forecasting System about a forecasted high water period in order to simulate and analyze particular mitigation measure.

3.9 Flood Forecasting at Pinios River

The aim of this research work carried by [17] was the application of two hydrodynamic models the first model has been developed on the basis of the Strelkoff's implicit finite difference computational scheme and the second is the hydrodynamic module of the widespread conceptual MIKE 11 software package; to estimate flood wave propagation along a section of the Pinios river traversing a high flood risk agricultural area in central Greece. The same values of hydraulic and geometric parameters have been used to estimate the flood routing of two inflow hydrographs computed from recorded water levels of two flood events and the computational results are compared to each other. The flood wave propagation caused by two inflow hydrographs has been studied applying the MIKE 11 and Strelkoff's hydrodynamic models. The flow rates, as well as, the time of peak flows predicted by both models were almost the same, while the differences in the values of flow depths were less. The mean absolute relative percentage difference in computed discharges, for the whole simulation period, at 11, 23 and 33.8 Km from the upstream end, ranges between 0.23% and 0.89% .The outflow hydrographs predicted by both models for the studied flood events did not show significant change of the inflow hydrographs.

3.10 Flood Forecasting at Sungai Kayu Ara Catchment

References [18] in this paper, two programs HEC- RAS and (DHI)-MIKE 11 was applied to these benchmark tests. Both models performed well in tests. In addition to the theoretical benchmarks, this paper also demonstrates that both models are capable of simulating observed transients in the California Aqueduct. The tests ranged from simple single reach models to looped networks. Boundary conditions were designed to be at the edge of expected stability. In spite of computational differences, both the HEC-RAS and MIKE 11 models successfully demonstrated the ability to model these benchmark cases. For the rough discretization in some of the benchmark tests, the MIKE 11 code demonstrated an ability to respond more quickly to disturbances presented by the initial conditions. In addition to the theoretical tests, HEC-RAS and MIKE 11 were applied to a measured transient generated from closing gates in the San Joaquin canal. Both models performed well in simulating the observed magnitude.

3.11 Numerical Limitation of Model :

As all the numerical models are required to make some form of approximations to solve the basic principles and consequently all have their limitations. The physical modelling was undertaken for the experiment and the capability and limitations of the various software packages i.e. HEC-RAS, MIKE 11 and MIKE 21 were tested by [10] .By comparing the model predictions with the results of two simple physical model experiments. The physical modelling was undertaken at the University of Queensland.

From the Weir experiment results it was visualized that because of numerical limitations MIKE 11 cannot model the supercritical flow at the downstream of the weir. For the low-flow case, the downstream water level is over-estimated .The high tail-water impacts on the flow conditions on the weir, causing a significant error in the upstream water level. The incorrect tail-water has less impact for the high-flow case. Significant error in the predictions across the weir was observed, but the upstream water level was almost correct. While in the case of open channel flow experiment it was observed that the solutions of the Saint Venant equation in MIKE 11 was incapable of modelling supercritical flow. Although able to match the subcritical flow measurements, significant disparity was observed in both the supercritical flow region and hydraulic jump

IV. CONCLUSION

In the present paper a detail review of MIKE 11 applications is presented through the different cases which suffice the aim of the work. It can be said that while the traditional and empirical methods requires huge data measurements and time consuming , the MIKE 11 which is completely based on theoretical Saint-Venant equations provides more accurate results within less time. It is clear from the above examples that when compared with the HEC-RAS and other mathematical models, MIKE 11 is proved its superiority. The inherent mathematical diffusion of Muskingum Cunge method shows a potential problem of under predictions whereas MIKE 11 overcomes this problem by providing more accurate and fast results. It is noticed that results generated by MIKE 11 in MIKE VIEW can also be useful for generating the relationship among variables of the gauge discharge sides in the catchment by plotting rating curves. Also it is most useful technique for complex flood forecasting processes due to its powerful user-friendly river modeling toolbox with advanced features. It is evident from the earlier research that there is need of a technique which will work fast, give more accurate results along the reach which is successfully accomplished by MIKE 11. It is best simulation tool for flood forecasting which can be used effectively in the same field of interest and should be explored further in detail. Therefore it can be concluded that MIKE 11 is a powerful river modeling tool and its applications for flood forecasting proved to be efficient overall the entire world. As the capability and limitation are the two sides of the same coin, visualizing the capability the limitations cannot be ignored all the times. Although MIKE 11 proved to be the efficient modelling tool but it is incapable to model the supercritical flow.

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