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TOWARDS A NEW FLOOD FORECASTING SYSTEM FOR THE LOWER MEKONG RIVER BASIN

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ABSTRACT: The MRC RFMMC in Phnom Penh currently produces short-term one- to five-day flood forecasts for 23 locations along the Lower Mekong River, using the time-tested but by now outdated SSARR model. The May 2006 Road Map Mission (Malone, 2006) recognised that extension of the forecasts to a medium-term (ten days) and the introduction and development of improved hydrological models was a major step towards the improvement of flood forecasting services of the RFMMC.

In order to have a first version of the system operational by the flood season of 2008, the Australian URBS hydrological model was selected as trial model for the RFMMC. The URBS model is a semi-distributed non-linear model with build-in flood routing capability, used extensively for flood forecasting by the Australian Bureau of Meteorology and by the Chiangjiang (Yangtze) Water Resources Commission in China. To enable the flood forecaster to focus on major tasks, the implementation of FEWS is now planned. FEWS will take care of all data capturing, pre-validation and processing, model runs and output post processing; it will also enable easy access to graphs, maps and tables of input and output data, both for recent and historical situations, so comparisons can be made.

As a complementary exercise to these improvements, attention should be paid to data availability The input for the new hydrological models is primarily rainfall data, from both point and grid-based products. An analysis of the near real time rainfall network for Cambodia and Lao PDR showed that limited and relatively low-tech support will substantially increase both the availability and the spatial distribution of rainfall data, both for direct input and for bias reduction of grid rainfall products.

Key Words: Flood Forecasting; Mekong River Commission; URBS; FEWS; Regional Flood Management and Mitigation Centre (RFMMC).

1. INTRODUCTION

The Mekong River Commission (MRC) was formed on 5 April 1995 by an agreement between the governments of Cambodia, Lao PDR, Thailand and Viet Nam. The four countries signed and agreed on joint management of their shared water resources and development of the economic potential of the river. The MRC has been built on a foundation of nearly 50 years of knowledge and experience in the region, starting from 1957 when it began life as the UN-founded Mekong Committee. In 1996 China and Myanmar became Dialogue Partners of the MRC.

The MRC serves its Member States by supporting decisions and promoting action on sustainable development and poverty alleviation as a contribution to the UN Millennium Development Goals.

The Mekong River Basin (MRB) includes parts of China, Myanmar and Viet Nam, nearly one-third of Thailand and most of Cambodia and Lao PDR. The total land area is 795,000 km^2. From its headwaters, thousands of metres high on the Tibetan Plateau, it flows 4,800 km through six distinct geographical regions, each with characteristic features of elevation, topography and land cover. The Upper Mekong Basin is that part of the basin upstream of Chiang Saen near the Laos-China border, while the Lower Mekong Basin (LMB) is downstream of this point.

Large floods, such as those which occurred in 2000, 2001 and again in 2002, have the capacity to cause loss of life and huge property damages. Floods of these magnitudes can affect between one and eight million people throughout the LMB (MRCS, 2005). Improved flood forecasting was recognised as a key reason for the establishment of the MRC-RFMMC in 2005.

The Flood Management and Mitigation Programme (FMMP) is a rolling programme that commenced operations in January 2005 and is funded to a total value of around US$20 million. At the heart of the programme is the Regional Flood Management and Mitigation Centre (RFMMC) in Phnom Penh. This provides technical and coordination services to the four countries in the Lower Mekong Basin. Forecasts, flood data, technical standards and training packages are key outputs of the programme. The FMMP aims to prevent, minimise or mitigate people’s suffering and economic losses due to floods, while preserving the environmental benefits of floods.

The Road Map Mission, conducted in May 2006 (Malone, 2006), recognised that the existing forecasting models were outdated and unreliable, and that the development of improved forecasting methods was a major step towards the upgrading of flood forecasting services in the LMB. The introduction and development of new rain-based hydrological forecasting models to improve reliability, accuracy and lead-time is just the first step in this process. Improved data availability and the establishment of a real-time operational database, integrated with the models, is a logical precondition for improved forecasts.

2. DATA AVAILABILITY

One of the clear drawbacks of the current flood forecasting system in use at the RFMMC is the inflexibility and limited availability of data, particularly rainfall information. The system is fragile: if water level data from one input station is missing the model cannot run. As inputs from a total of seven different sources in six different countries are used, it happens all too often that one or more of these sources have (technical) difficulties in sending the data, which means the data is received late or not at all, and the forecast is made late or not at all. The rainfall data reported by the sources is currently mostly used to check the model output and adjust it manually.

The input for the new hydrological models now being developed is primarily (observed and forecast) rainfall data. For best spatial distribution and because the station network in the Mekong Region is very sparse, grid-based (satellite) rainfall products will initially be used as input. These products need to be adjusted using ground-based observations. A minimum set of rainfall data for the region is available through the World Meteorological Organization Global Transmission System. However, to realise the objective of reliable short- and medium term forecasts, (improved) daily delivery of rainfall data transmitted directly from the MRC member countries to the RFMMC is essential.

As one of the main objectives of the MRC is to facilitate data exchange, several projects have been carried out to improve the hydro-meteorological network in the MRC Member States. Analysis of the raingauge network carried out under these projects (MRCS, March 2001), and others, consistently shows that for Thailand and Viet Nam the average coverage is sufficient but the spatial distribution needs improvement. Most of Cambodia and Lao PDR suffer from inadequate network coverage. It is also mentioned that "the network operation and maintenance problems are serious in Cambodia and Lao PDR" while Thailand and Viet Nam need only limited support for operation and maintenance (O&M) (MRCS, 2001).

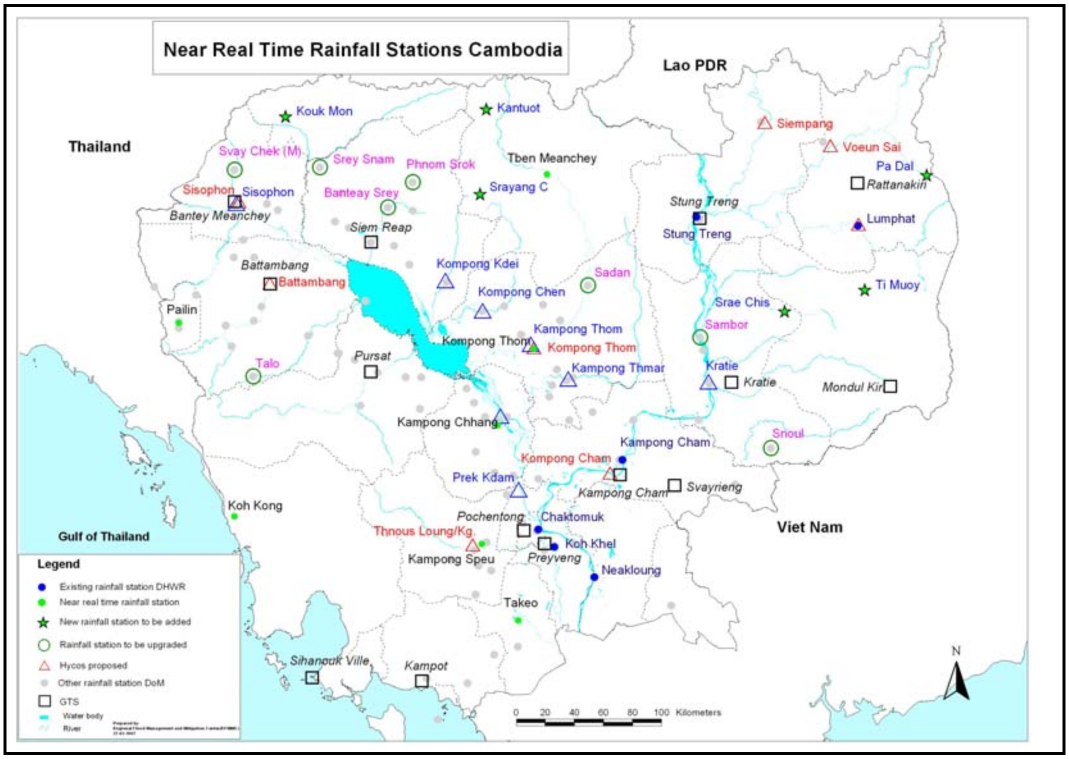

Figure 1. Map of daily reported rainfall stations in Cambodia

As capacity building was a major objective in those projects, state of the art telemetry equipment and rainfall and water level loggers were installed. Because of the earlier mentioned lack of resources for O&M these projects and instruments have often been beset by problems. The objective may have been to move immediately to modern technologies but the present meteorological networks in Lao PDR and Cambodia are still is far from ideal. To understand this one should consider the following observations:

- It appears that the responsible organisations in Cambodia and Lao PDR do not have adequate funding to ensure proper operation and maintenance. Moreover, all spare parts have to be imported at considerable cost;

- The advantage of a data logger with telemetry is the fact that data can be read immediately or at high frequencies. However, daily water level fluctuations on the main stream Mekong are usually not very big and loggers provide limited advantages over reliable manual observations in such cases;

- To date the number of automatic telemetry stations is far too low, even after implementation of the new Mekong Hydrological Cycle Observing System (M-HYCOS) project. This is especially true for rainfall stations in Cambodia and Lao PDR;

- The overriding reason for introducing automatic telemetry stations in industrialised countries has been the rising costs of labour. Investment and maintenance costs are high but are offset by much lower operation costs. This advantage does not apply in Cambodia and Lao PDR, where investment and maintenance is higher and observers are paid comparatively low salaries.

A significant increase in the number of rainfall stations which report daily to their respective head offices by using simple but robust and adequate technology is proposed. These stations use manual rain gauges and communicate through text messaging over the mobile phone network. Gaps in the station network are to be filled by setting up simple manual rainfall stations. Detailed analysis of the situation regarding rainfall stations in Cambodia, Lao PDR, Thailand and Viet Nam has been carried out (MRC-RFMMC, 2007a,b,c,d). With relatively simple and inexpensive methods, the number of daily reported rainfall stations in Cambodia can be increased from 26 to 52; for Lao PDR these numbers are 33 and over 50. For both countries the spatial distribution of the network can be significantly improved (Pengel et al, 2007). The map in Figure 1 shows the situation for Cambodia.

Further analysis of the available rainfall stations in Viet Nam and Thailand is needed. However, it seems that a sufficient number of rainfall stations report daily or at higher frequencies (MRC-RFMMC, 2007c and 2007d). An agreement on a method of timely and efficient data delivery to the MRC-RFMMC will be the next step.

3. MODELS

3.1 URBS

As the RFMMC needed to have a first version of the system operational by the flood season of 2008, the Australian hydrological model, URBS, was selected as a trial model. The URBS model is a semi-distributed non-linear model, and is used extensively for flood forecasting by the Australian Bureau of Meteorology and by the Chiangjiang (Yangtze) Water Resources Commission in China. URBS combines the rainfall-runoff and runoff-routing components of the modelling process and allows users to configure the model to match the characteristics of individual catchments. The model is robust, developed for use in a real time environment, and has several features which readily lend itself to application as a flood forecasting model. The URBS model will eventually be one of a suite of hydrological and hydraulic models available to forecasters in the RFMMC.

The conceptual runoff routing model, URBS (Carroll, 2004), is a hydrologic modelling program that enables the simulation of catchment storage and runoff response by a network of conceptual storages representing the stream network and reservoirs. The URBS model combines two hydrological modelling processes into one model: rainfall runoff modelling, which converts the gross rainfall into net or excess rainfall; and runoff routing modelling, which takes the excess rainfall as input and converts it into flow. Users can select from several bucket-type rainfall runoff models that may be applied uniformly or spatially varied over a catchment. The selection of the most appropriate rainfall runoff model and its associated parameters is carried out as part of model calibration.

Because of the semi-distributed nature of the model, the temporal and spatial variation of rainfall across a catchment can be taken into account and generally provides more accurate results than traditional lumped models such as the unit hydrograph.

The URBS model can be set up as a rainfall runoff routing model or as a simple runoff routing or flood routing model, and it can be used as a design or as a flood-forecasting tool. The model may be applied as an event model or for continuous simulation. Typically for flood forecasting, the model is calibrated as an event model and then applied as a continuous simulation model.

The URBS model has several features that readily lend themselves to application as a flood-forecasting model. It has *enhanced data management:* input data such as rainfall and water level data are separate to the model and are accessed during running. It shows *robust performance:* the model still runs if key gauging station data is missing. *Forecast rainfall* can be added to the model with a variety of techniques using results from external sources. It allows the use of *linked ratings:* known stage-discharge relationships can be incorporated into the model to produce both flow and height results at gauging stations. *Dependent ratings*, where the upstream water level is dependent on downstream water level, can also be used. Runoff can be routed through *reservoirs* using known storage characteristics and simple operating rules applied. *Matching* forces the model to fit the observed data at gauging stations, thereby improving the forecast accuracy at downstream locations. Another key feature of the model is *adaptability*: it can be readily incorporated into any flood forecasting system.

The Bureau of Meteorology, Australia, uses the URBS model as an event model extensively for flood forecasting on basins of up to 250,000 km^2 (Malone, 1999 and 2003). It was tested against five other hydrological models in the Yangtze River Flood Control and Management Project (Markar, et al., 2002) and was one of three hydrological models adopted for real-time use as a continuous simulation model in the project (Markar, et al., 2005).

3.2 CatchmentSIM

For the Mekong River Basin, URBS catchment models were developed using the GIS package CatchmentSIM (Ryan, 2004). This is a 3D-GIS topographic parameterisation and hydrologic analysis model which automatically delineates watershed and sub catchment boundaries, generalises geophysical parameters, and provides in-depth analysis tools to examine and compare hydrologic properties of sub catchments. One of the advantages of CatchmentSIM is that it includes a macro language, which enables the user to write scripts to develop any hydrological modelling package based on sub catchment networks. The example in Figure 2 shows the Se Bangfai catchment (Lao PDR) derived using publicly available digital elevation data from the NASA Shuttle Radar Topography Mission

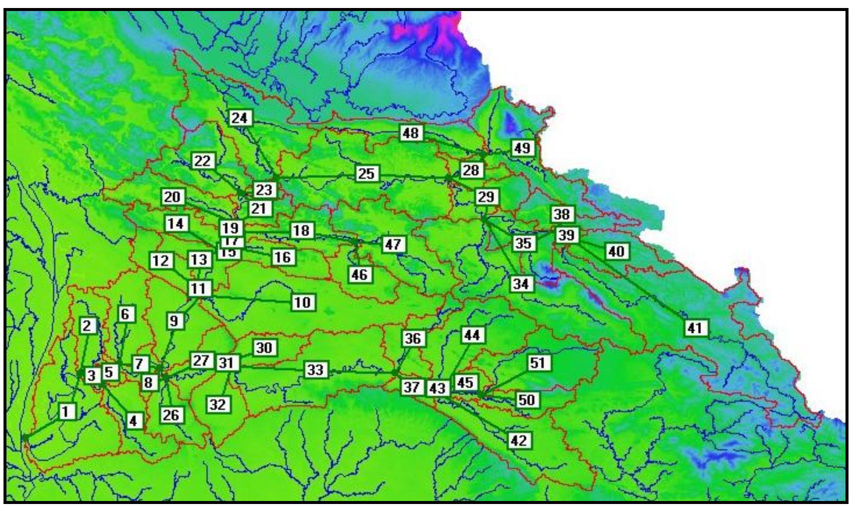

Figure 2. CatchmentSIM model of Se Bangfai River Catchment

Calibration was undertaken using the rainfall, height and flow data from the MRCS HYMOS database. Each model has been calibrated over several flood seasons.

3.3 Model Building

CatchmentSIM was used to compile a series of 51 linked URBS models, 48 runoff routing models and 3 flood routing models.

The model of the Se Bangfai River catchment is typical of the runoff routing models developed and consists of 55 sub-areas representing 9,300 km^2. Rainfall and stream flood data from the available stations was extracted from the MRC HYMOS database. The rainfall stations available from HYMOS typically do not provide full coverage of the observed rainfall in the Mekong Basin catchments. There are often no stations to indicate the rainfall in the headwater areas in the upstream sparsely inhabited parts of the catchments. A technique, based on the methodology described by Wei et al. (1973), was used to estimate the rainfall on each sub-area in the catchment. The Australian Bureau of Meteorology (Malone, 2003) and the Chiangjiang (Yangtze) Water Resources Commission in China (Markar, et al., 2005) adopted this same methodology.

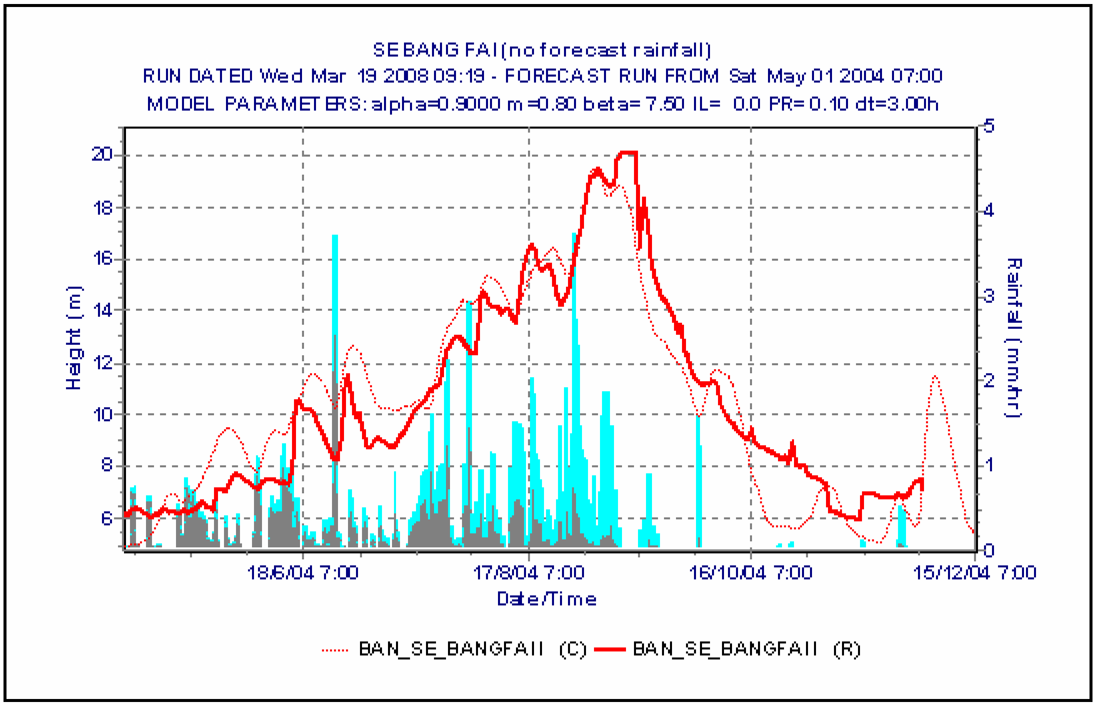

Figure 4. Model calibration at Se Bangfai 2004

For each flood season, rainfall runoff and runoff routing model parameters were varied to obtain the best fit to the observed water level data at the gauging station located near the outlet of each catchment.

Figure 4 shows an example of the calibration at Ban Se Bangfai in 2004. While model performance based on daily rainfall data is adequate, it is expected that accuracy will improve using data from more (near-) real-time stations in the catchment, especially as more frequent rainfall observations than daily data are expected to become available.

The inflows from each of the 48 catchments are linked together via a series of flood routing models. For the Mekong between Chiang Saen and Kratie, a linear Muskingham routing model with an error correction matching feature is used to derive flows and heights at key locations. Downstream of Kratie, the behaviour of the system is more complex, with diversions and interaction between the Mekong River and the Tonle Sap, the largest fresh water lake in Asia. The URBS model was able to simulate this complex hydraulic situation by treating the lake as an off river water body, filling during the early part of the flood season and draining during the later part of the flood season.

3.4 Flood Early Warning System (FEWS)

Following completion of the model calibration programme, the next challenge for the MRC-RFMMC is to link the models to the real-time database and include forecast rainfall in order to extend forecast lead-times (Malone et al, 2007). This will be accomplished as part of the implementation of the flood forecasting 'environment' Delft-FEWS, which is planned for the first half of 2008.

The Flood Early Warning System (FEWS) was developed with the objective of creating a flexible system for the integration of flood data and flood simulation models for organisations such as the RFMMC. It provides a platform for data handling and can connect a wide range of monitored and forecasted weather inputs on one side with hydrological and hydraulic flood routing models on the other side. It has been equipped with generic tools providing a variety of data handling tasks, such as data validation, interpolation, aggregation and error correction in forecasts, including a variety of visualization and forecast dissemination options.

The many users have made Delft-FEWS a very robust and reliable instrument. It is used by quality conscious organisations such as the Environment Agency in the United Kingdom, the ministries in the Netherlands and Germany that deal with flood forecasting in the Rhine Basin, and the US National Weather Service. Delft-FEWS is used both by small and large organisations, and is also deployed in the Mekong Region, for instance for the Mun River Flood Forecasting System.

4. PLANNING AND FUTURE DEVELOPMENTS

The MRC-RFMMC considers that the URBS model shows sufficient potential for use as a flood-forecasting model and has embarkeded upon a programme to develop a suite of URBS models for the Mekong River Basin. It is envisaged that in the future URBS will be one of several hydrological models available to forecasting staff in the MRC-RFMMC. However, for expediency it has been selected as the initial model to fast track the introduction of improved forecasting techniques.

Eventually, the hydrological models will provide the inflows into a real-time hydraulic model of the LMB. The linking of the individual hydrological models to hydrodynamic models of the Mekong main stream will be considered at a later stage.

As each model was completed, a calibration report outlining the modelling processes, plus inputs and outputs was produced. These reports will be stored in the model database system and will be instantly retrievable. The individual model development program was completed by the end of 2007.

An important challenge is to match the expectations of the potential users of the RFMMC flood forecast products with a realistic view of the accuracy that can be achieved, especially for medium range (five-to ten-day) forecasts. The dissemination of the results should reflect the inherent uncertainty of forecasts. Forecasting further into the future involves increased uncertainties, especially regarding weather patterns. This issue has to be resolved by intensive contact and discussions with stakeholders, and by using international best practices in flood forecasting, especially for dissemination of the results.

5. CONCLUSIONS

Any new forecasting system for the Mekong should include significant updating of the existing observation network and data collection system in data sparse areas of the basin. A programme to upgrade the existing (rainfall) stations by providing a simple but effective means of communication at short notice, and by setting up simple new manual rainfall stations, has commenced. A first trial has been successfully conducted in Cambodia; further trials are planned in Cambodia and Lao PDR.

The URBS model has been demonstrated to be a useful flood-forecasting model on large river systems in Australia and China. Calibration and testing of the first version of the models is now complete. The complex hydraulic behaviour of floods in the LMB has been simulated using hydrologic techniques and initial results of the models are promising.

The FEWS system currently being installed will link the real time data to the URBS models and provide a streamlined interface to data, models and results, enabling forecasters to concentrate on producing accurate and timely forecasts.

If sufficient real-time data is made available to the MRC-RFMMC in time, and the FEWS system has been implemented, the new modelling system could be deployed prior to the wet season in 2008.

6. REFERENCES

Carroll, D.G., 2004. URBS: A Rainfall Runoff Routing Model for Flood Forecasting and Design, Version 4.00, April 2004

Malone, T., 1999. Using URBS for Real-time Flood Modelling, Water 99 Joint Congress, Institution of Engineers, Australia, Jul 1999

Malone, T., A. Johnston, J. Perkins and S. Sooriyakumaran, 2003. Australian Bureau of Meteorology, HYMODEL – A Real-time Flood Forecasting System, International Hydrology and Water Resources Symposium, The Institution of Engineers, Australia, 2003

Malone, T., 2006. Australian Bureau of Meteorology, Roadmap Mission for the Development of a Flood Forecasting System for the Lower Mekong River Basin- Technical Report, Mekong River Commission, September 2006

Malone, T., et al., 2007. Development of a flood forecasting database for the Lower Mekong River, Mission Report, Mekong River Commission, January 2007

Markar, M.S, Ricky T.F. Kwan, and A.L. Conroy, Li Mingxin, Zheng Jing, and An Lina, 2002. Evaluation of Five Hydrologic Models for Real-time Flood Forecasting Use in the Yangtze River Catchment, Flood Defence, 2002

Markar, M.S., S.Q. Clark, T. Malone, M. Gooda and W. Shallcross, Chen Yali and Min Yawou, 2005. A New Flood Forecasting System for the Yangtze River, Floods, from Defence to Management, 2005

Mekong River Commission (MRC), 2005. Overview of the Hydrology of the Mekong Basin, Mekong River Commission. ISSN: 1728:3248. November 2005

Mekong River Commission Secretariat (MRCS), 2001. Improvement of the Hydrometeorological Network (basin wide), Component 2 - Final Report Volume 1 - Main Report.

Pengel, B.E., Katry Phung and T. Malone. Requirements for Data Inputs to the New Flood Forecasting System - Improved Real-Time Data Exchange. 5th Annual Mekong Flood Forum Proceedings, Mekong River Commission. August 2007

Regional Flood Management and Mitigation Centre (MRC-RFMMC), 2007a. Data Acquisition - Collection and Communication Improvement - Preparatory Mission to Cambodia

Regional Flood Management and Mitigation Centre (MRC-RFMMC), 2007b. Data Acquisition - Collection and Communication Improvement - Preparatory Mission to Lao PDR

Regional Flood Management and Mitigation Centre (MRC-RFMMC), 2007c. Data Acquisition - Collection and Communication Improvement - Preparatory Mission to Viet Nam

Regional Flood Management and Mitigation Centre (MRC-RFMMC), 2007d. Data Acquisition - Collection and Communication Improvement - Preparatory Mission to Thailand

Ryan, C., 2004. CatchmentSIM: A Terrain Processing and Hydrologic Analysis Model, CRC Toolkit, Version 1.26, 2004

Wei, Tsong Chang and J.L. McGuinness, 1973., Reciprocal Distance Squared Method - A Computer Technique for Estimating Areal Precipitation, ARS-NC-8, Agricultural Research Service, US Dept of Agriculture, Aug 1973