Modelling support FMMP-C2 Stage 1

Appendix 7 to the Annex 1 to the

Draft Stage 1 Evaluation Report

August 2008

Draft Report

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1 Introduction

This Appendix 7 to Annex 1 gives an evaluation of the availability and adequacy of the hydraulic models for Flood Risk Assessment in the Focal Areas as available in the Mekong River Commission in April 2008.

The status of the models is discussed in Chapter 2. The conclusions and recommendations are presented in Chapter 3.

2 Status of models for pilot projects

2.1 Nam Mae Kok

The progress with the development of the ISIS model for the Nam Mae Kok River has been insufficient to use this model within FMMP-C2 for the evaluation of flood management scenarios. Currently, the model is being extended to cover the flood prone area upstream of Chiang Rai by entering newly measured cross-sections. The original work plan foresaw in the development of a coupled 1D/2D model based upon ISIS and the EIA (WUP-FIN) model. This concept has been abandoned, as the EIA modelling system is rather complex for use by the MRCS modelling staff. Moreover, coupling of ISIS and the EIA model is not straightforward. According to the current work plan, the model will be completed around the end of September 2008 and be based upon ISIS only.

However, there are still some constraints. At MRCS more modellers have to be contracted through the IKMP programme. Furthermore, the Water Resources Ministry of Thailand still has to deliver more cross-sections and boundary conditions for the model. An option that has been kept open so far is the use of an older Mike11 model developed for the Thai authorities, though MRCS has a preference to continue the model development on the basis of their ISIS system. Meanwhile it has also been concluded that the contribution of the Dutch Partners for Water programme to be executed by HKV will be limited to the application of flood risk analysis tools. This work can be started after the model development has been completed.

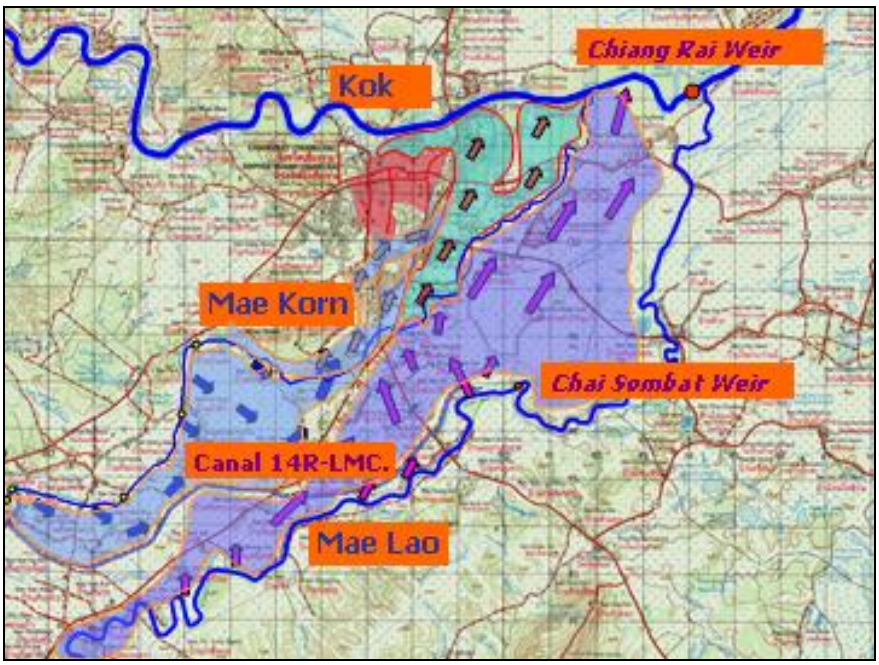


Figure 2.1 Nature of the flooding and flow directions in the Chiang Rai Province near the city of Chiang Rai

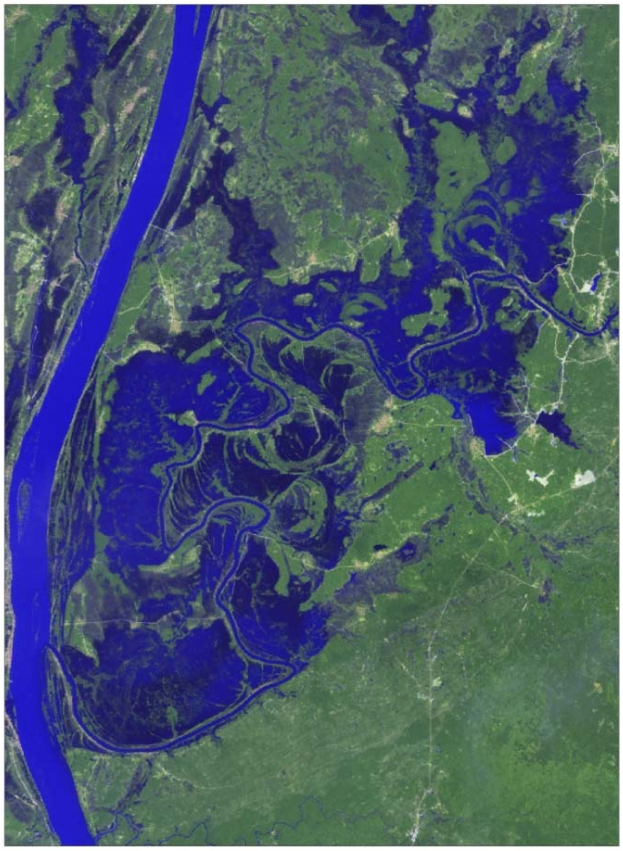
2.2 Bokeo Province bank protection

No models are available for the simulation of flow in the Mekong River in the Bokeo Province. For the evaluation of the erosion processes water velocities play an essential role. The hydraulic situation is quite complex, with river bends and the outflow of the Nam Mae Kok into the Mekong, leading to recirculation flow patterns. 3D models enable the simulation of such complex flow fields for selected combinations of Mekong and Nam Mae Kok flows.

During the Inception Phase of the project it was expected that modelling support to the FMMP2 project would be made available by the IKMP modelling team, supported by the EAI consultants. In the earlier proposal a demonstration project for bank erosion was proposed for the area of Vientiane. For this area a 3D EAI model was readily available. With the selection of the new area in Bokeo Province a new model would have to be constructed. The IKMP project has been approached for this development. However, no capacity is available. Given the fact that no new model development work has been foreseen under the FMMP2 project itself, empirical methods have to be used to support the bank erosion project in Bokeo Province with best estimates of flow velocities near the river banks.

2.3 Se Babg Fai

Severe flooding takes place in the lower Se Babg Fai River in the flood plain area between the highway crossing HW13 and the inflow point to the Mekong River. Figure 2.2 shows the extent of flooding for the year 2000. Around 2002 an embankment has been constructed along the left bank, reducing significantly the extent of flooding. This part of the Se Bang Fai has been selected as one of the focal areas for studying flood management options. It is seen that flooding is quite complex. In principle, such a focal area study has to be based upon the use of an integrated 1D/2D flood model.



Satelite Photo of Flood Extents on Sept 17, 2000 in Xe BangFai

Figure 2.2 Year 2000 flooding along the Se Babg Fai between HW13 and the Mekong River

Models developed for the Se Babg Fai Basin include the combination of SWAT, IQQM and ISIS (MRC's DSF tools), the hydrodynamic model HEC-RAS and the rainfall-runoff model URBS.

The HEC-RAS model was developed by the Nam Theun 2 Power Company in order to study the effect of downstream water level fluctuations due to turbine regulation, in particular the effects that could be expected at Mahaxai and at the bridge on route 13 (HW13). The model, generally referred to as NTPC, was designed and applied for dry season flow only and no floodplains were included (inbank flow only). Moreover, cross-sections were missing over a length of 20 km and the calibration has been rather crude. For these reasons it is no option to use this model for the Se Babg Fai flood management demonstration project.

The URBS models only describe rainfall-runoff processes and cannot be used as stand-alone support to flood risk assessment. The models were recently developed and calibrated as part of the FMMP-C1 flood forecasting project. As URBS only provides discharges as output, it is no option to use this model for the Se Bang Fai flood management demonstration project.

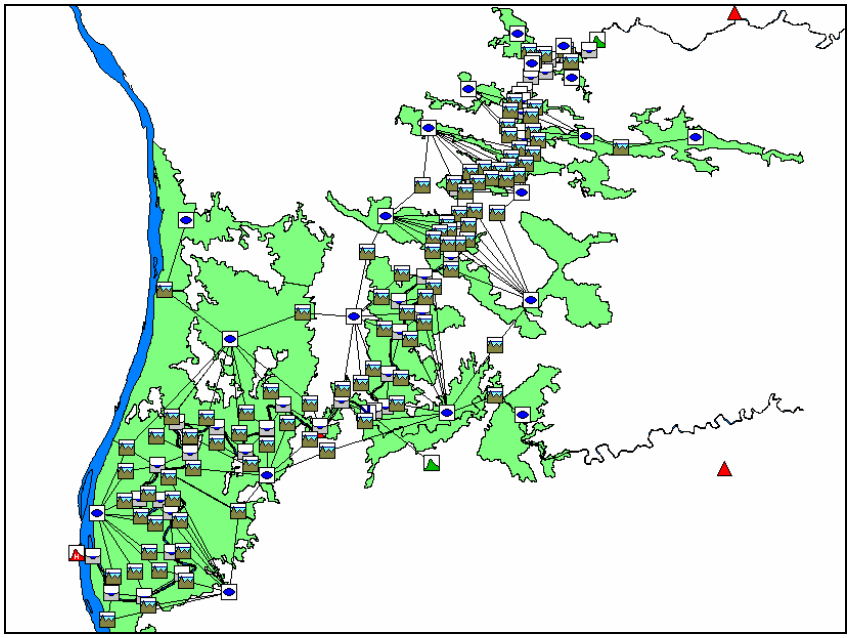


Figure 2.3 Schematization of Se Bang Fai in ISIS-hydraulic model

The SWAT, IQQM, ISIS models were developed as part of an MRCS support programme to the Lao National Mekong Committee (LNMC). It had been set-up as a demonstration project and the results were initially not of sufficient quality for any real planning purpose. Meanwhile, the model has been improved, partly by importing cross-sections from the HEC-RAS model. Flood plains have been modelled following the flood plain cell method. Discharges between flood plain cells mutually and between flood plain cells and the main river are exchanged on the basis of a weir description. The topography of the flood plains is available as a 50 x 50 m DEM based upon a 1:100,000 topographic map. There now exists a new 30 x 30m DEM based upon the same topographic map and developed by the Lao Geography Dept. In principle, its quality cannot be expected to be better than that of the 50 x 50 m DEM, though consistency may have improved. According to LNMC and the Lao modellers the quality is not excellent but sufficiently good for the model.

The quality of the calibration of the model has been investigated on the basis of the floods in the years 1995-2000. Despite the fact that lateral flows between the upstream station Mahaxai and the station HW13 had to be derived on the basis of correlations between these stations, Figure 2.4 shows that the computed hydrographs resemble the observed ones at HW13. This is by no means obvious, as upstream of HW13 the river still has extensive backwater effects. However, looking in more detail it appears the model consistently underestimates the observed water levels. For the investigated years for the higher levels an underestimation on average of about 6 dm was observed.
Such differences are too large for the model to serve as a tool for design, but acceptable for a first analyses of effects of alternatives. For this reason it is proposed to use this model in the Se Ban Fai FMMP2 focal area study.

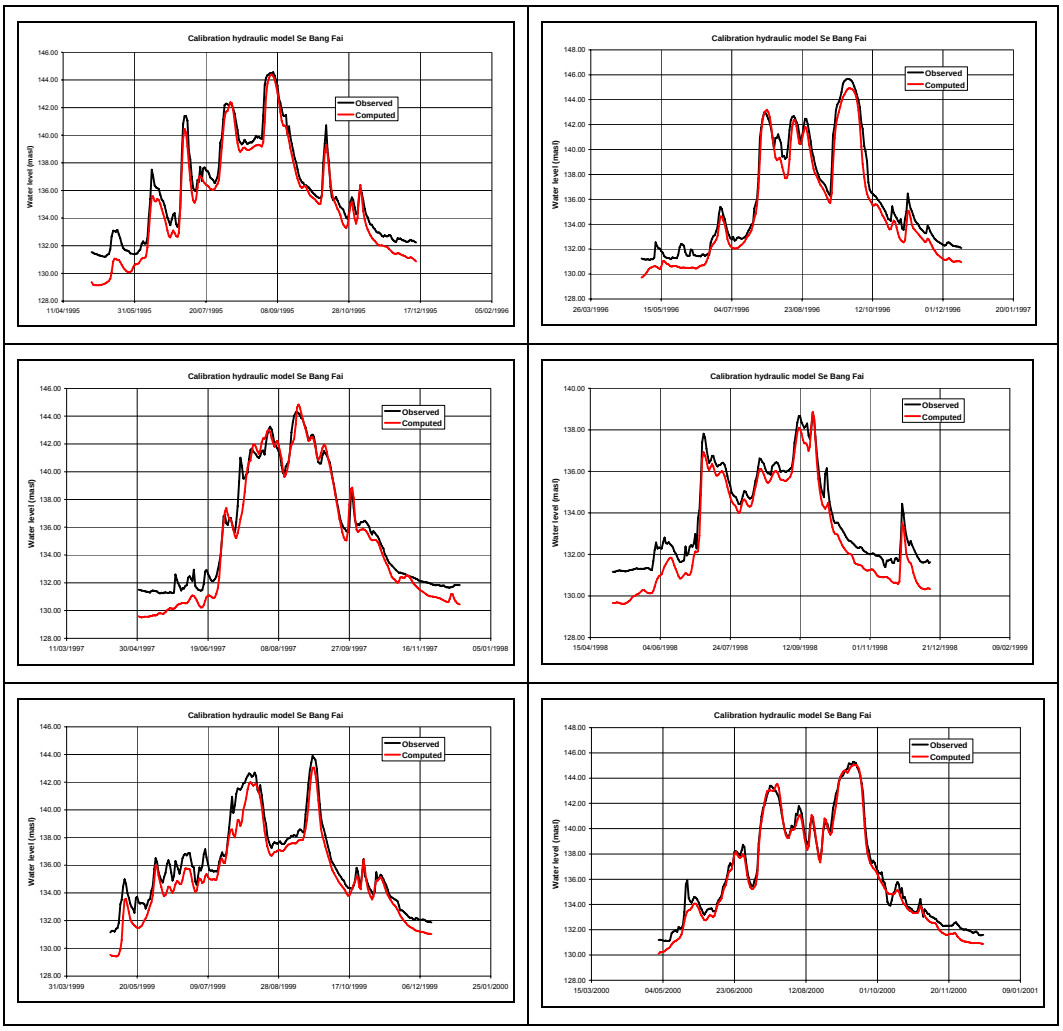


Figure 2.4 Calibration results of the ISIS model at HW13 for the years 1996 - 2000

Currently, MRCS is supporting LNMC by providing funding for additional field surveys. Further improvement of the model will be taken up from May 2008 onward. For the description of the flow in the flood plain the FLO2D model will be coupled to ISIS. There are no plans for extending the number of measuring stations. It is recommended, though, to reconsider this decision, for example by placing during the flood season a number of pressure transducers in the flood plain area between HW13 and the Mekong River. The improved 1D2D model will certainly not be available during Phase 1 of FMMP-C2.

2.4 Upper Se San (upstream of Kon Tum)

For this focal area the methodology described in the Inception Report (Appendix 2, § 4.4) remains valid.

2.5 Kratie bank protection

The flow fields causing bank erosion near Kratie look less complex than those in the Bokeo Province. To support the studies on these flow fields, the only model readily available is the ISIS model developed for the DSF. The model only covers part of the

area subject to bank erosion. Moreover, the current ISIS does not seem to represent the river island and the resulting splitting of the cross-section near Kratie. For these reasons, the ISIS model is not very useful in deriving conclusions on flow velocities along the eroding banks.

For the support to this demonstration project, a similar approach can be followed as for the one in the Bokeo Province. On the basis of the rating curve near Kratie, and the selected design discharge, the water level for the approximately 4 km stretch of the river considered can be derived from the slopes. On the basis of the river bathymetry, flow cross-sections can be determined. A first estimate of flow velocities can be based upon a local conveyance based velocity computation for cross-section strips as follows:

$$u_j = \frac{1}{n_j} h_j^{2/3} \sqrt{I} \qquad (2.1)$$

where u_j is the average flow velocity of strip j, n_j the local Manning coefficient, h_j the local depth, I the water level slope. An integration of this relation over the cross-section leads, for the given water level and slope, to the discharge:

$$Q = K\sqrt{I} = \sum_{j=1}^{jj} \frac{1}{n_j} A_j R_j^{2/3} \sqrt{I} \qquad (2.2)$$

where Q is the total river discharge, K the overall channel conveyance, jj the total number of strips along the cross-section, A_j the cross-sectional area of strip j and R_j the hydraulic radius of strip j.

This relationship allows for the calibration of the Manning values, based upon a pre-assumed relative roughness distribution over the cross-section, through a dimensionless weight function. Successively, local velocities can be defined by using the logarithmic velocity distribution over the vertical. The near-shore velocities will have to be corrected for the influence of momentum exchanges in the lateral direction, to be based upon expert judgement. In addition, corrections may be required to take into account the effect of channel bends.

2.6 Plain of Reeds, Long Xuyen Quadrangle and adjacent Cambodia

At the border of Vietnam and Cambodia, two focal areas have been selected for study under Phase 1 of FMMP2: the Plain of Reeds and the Long Xuyen Quadrangle, both including adjacent areas in Cambodia. In the Inception Report three options were given for modelling support to the Plain of Reeds demonstration project: ISIS, VRSAP and Mike11. In principle, the same model can be used for the Long Xuyen Quadrangle, unless significant differences exist in the quality of the model for these two areas. Preference is given to the use of ISIS, as this tool has been developed at MRC under the WUP programme specifically to support planning studies, including flood risk analyses.

2.6.1 Status of the ISIS model

Since the delivery of the ISIS model by Halcrow in 2004 two model improvement steps have been made. In 2007 Mr To Quang Toan of the Southern Institute for Water Resources Research (SIWRR) introduced changes in the model schematisation and recalibrated the model. Changes were partly based upon data contained in the Mike11 model built as needed in the WUP-JICA project. Various adaptations to the schematization and parameter values were made as follows:

- Increase of the number of flood plain cells;
- Some cross-sections were updated;
- Introduction of sluice gates for the drainage of water from the flood cells;
- Compensation for the storage of neglected tertiary and secondary canals of the network.

After recalibration of the ISIS model it was concluded that at 80 % of the locations available for comparison of measured and computed results the threshold criteria, set out by the international panel of experts during the development of the original iSIS model for MRC, had been met.

As the ISIS model still did not meet the overall required standards, it was concluded that further improvements had to be made in the Cambodian flood plain and in the border zone between Vietnam and Cambodia. In 2008 a follow-up contract was given to Mr Toan of the Southern Institute for Water Resources Research in Ho Chi Minh City, Vietnam, jointly with Mr. Tony Green of JBA Consulting, United Kingdom, to further improve the ISIS schematization and to re-calibrate the model, by bringing in flood extent information collected by satellite observation. At the same time, the outdated calibration for the year 2000 had to be replaced by one for a more recent year. The assignment stated:

> *the updated model should contain a significantly improved realistic representation of the infrastructures (e.g. roads, openings and banks) and topographical conditions of the Cambodian flood plain and the border zone between Vietnam and the Cambodia area, using infrastructure available and any new survey of topography, flood water level and channel sections such that changes can be accurately simulated*.

Although the work has not been completed yet, preliminary conclusions had to be drawn in order to judge whether the ISIS model is accurate enough to serve the modelling needs of these two focal area projects. Preliminary results of the new calibrations are shown in Table 2.1 as differences between observed and computed flood peak values (dh_{peak}) and the average of absolute values of mean daily differences between observed and computed water levels (dh_{mean}), at some main stations and a number of temporary stations installed during the year 2000 flood as follows:

Table 2.1 Differences in water levels between observations and April 28, 2008 ISIS calibration results

Station / location	**dh_{peak} (m)**	**dh_{mean} (m)**
Main Mekong branches		
Tan Chao	.07	.10
Chao Doc	.28	.13
Long Xuyeân	.26	.32
My Thuan	-.19	.06
Can Tho	-.19	.15

My Tho	.03	.04
West Vaico Basin		
TB3	.14	.37
TB4	.71	.55
TB5	1.17	.90
TB8	.47	.43
TC5	1.12	1.31
Moc Hoa	-.19	.28
Tuyen Nhon	-.08	.19
Plain of Reeds		
Hung Thanh	-.12	.28
Kien Binh	-.25	.18
Tan Hung (TH1)	.12	.34
TB1	.02	.35
HN7	.05	.27
HN3	.12	.32
Long Xuyen Quadrangle		
Tri Ton	-.55	.53
Xuan To (XT7)	-.34	.59
GT11	.21	.21

Along the main Mekong branches two of the stations do not satisfy the maximum value criteria ($dh_{peak} \leq 20$ cm), with one station also not satisfying the dh_{mean} criterion ($dh_{mean} \leq 15$ cm). In the Plain of Reeds the peak level difference criterion is satisfied at all the points where this information currently is available ($dh_{peak} \leq 30$ cm). However, the criterion $dh_{mean} \leq 30$ cm is satisfied only at half the number of stations. This is primarily due to the phase shift between observed and computed wave.

In the Long Xuyen Quadrangle the peak level difference criterion is satisfied only one of the three points where this information currently is available ($dh_{peak} \leq 30$ cm) and the same applies to the criterion $dh_{mean} \leq 30$ cm. In the first place this is due to the error in gauge reference level and partly also due to the phase shift between these waves.

Some points of the West Vaico Basin show excessive deviations. However, these locations are outside the pilot project area and even outside the Mekong Basin, though during the floods the water bodies are connected.

Conclusions drawn from these exceedance of criteria should be treated with care as there are obvious errors in the gauge reference levels at the stations TB4, TB5 and TC5, with observed water levels consistently higher than the computed ones and stations XT7 and Triton with observed water levels consistently lower than the computed ones. This is a common problem associated with the installation of temporary gauges and can often not be corrected properly as these differences are often discovered after these temporary gauges have been removed. From Figure 2.5 to Figure 2.16 it is clear that once best assumed corrections are made, all stations satisfy the criteria set for the computed peak values.

A serious problem observed, though, is the consistent late computed arrival of the flood peak at all stations, as shown in Figure 2.5 to Figure 2.16. On average the computed flood peak arrives 1 week later than observed in reality. This points at a lower computed flood wave celerity in the Cambodian Plain than observed and the reason should be investigated. One week difference has quite some impact on the agricultural flood

damage in the Plain of Reeds and the Long Xuyen Quadrangle and affects the conclusions drawn in the focal area demonstration projects.

The ISIS model calibration results shown in Figure 2.5 to Figure 2.16 have also been influenced by a correction in the rating curve at Kratie, applied after completing most of the calibration process. As part of the FMMP2 study, the rating curve applied at Kratie has been investigated and made consistent with upstream observations. The new rating curves give lower discharges for 2000. However, it is not completely sure that the new rating curve is correct (see Appendix 8). It shows consistency with ADCP measurements made in the Delta over the period 2002-2003. The curve is also consistent with 2007 ADCP measurements at Kratie. However, there is still some doubt that the ADCP measurements give lower discharges than those measured with traditional current meters, used earlier.

It must be concluded that the current ISIS model still has to be improved before it can be used as a reliable instrument in the study of flood management scenarios. Currently, it does not satisfy the criteria that have been set by MRCS for acceptance of the model. However, part of the shortcomings has the obvious reason of errors in the reference level of some of the worst performing stations. What remains, though, is the error in the celerity of flood wave propagation, leading to an approximately one week late arrival of the flood wave in the Plain of Reeds and the Long Xuyen Quadrangle. It will be acceptable to use the current model for demonstration purpose to study the selected focal areas in the border area between Cambodia and Vietnam. For a final analysis the ISIS model has to be improved further. In the light of the current uncertainties, the following steps are proposed:

- Verify the rating curve at Kratie by simultaneous ADCP and traditional current meter instruments and generate most likely flood hydrographs at Kratie;

- Calibrate the model for a recent year (e.g. 2004), with the infrastructure correctly presented in the model for that year and based upon the verified inflow hydrograph at Kratie. Make sure that apart from peak levels also the wave phase and the length of the flood wave compare satisfactorily with observed data;

- Strip the model from infrastructural changes made after 2000 and verify the model for the year 2000 flood.

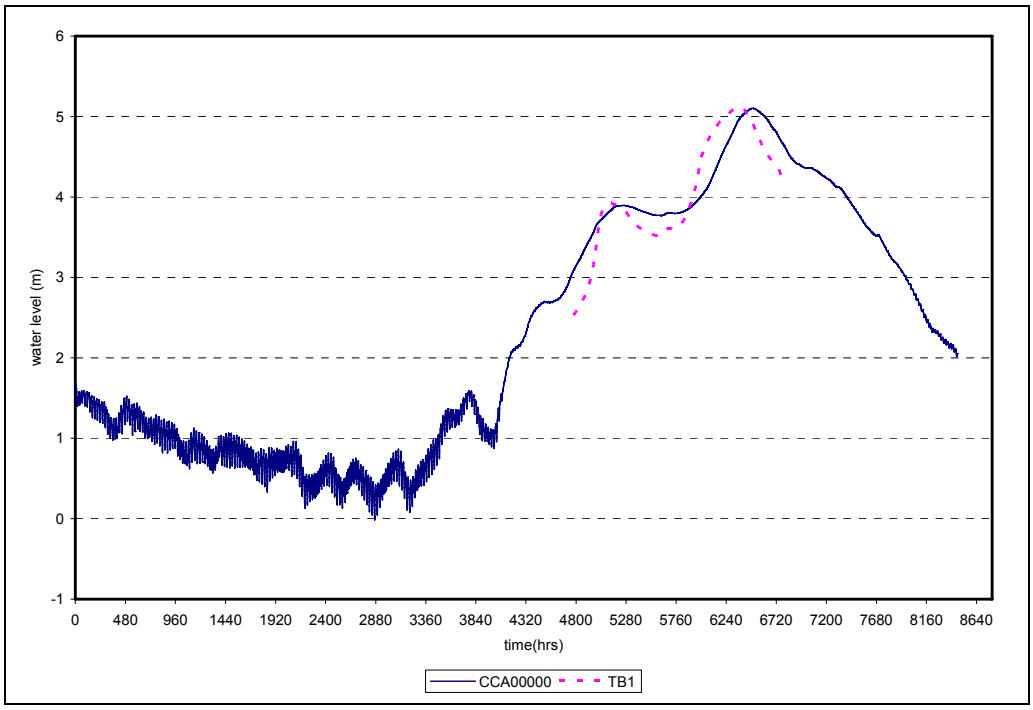


Figure 2.5 Comparison computed and observed water levels for the 2000 flood at TB1

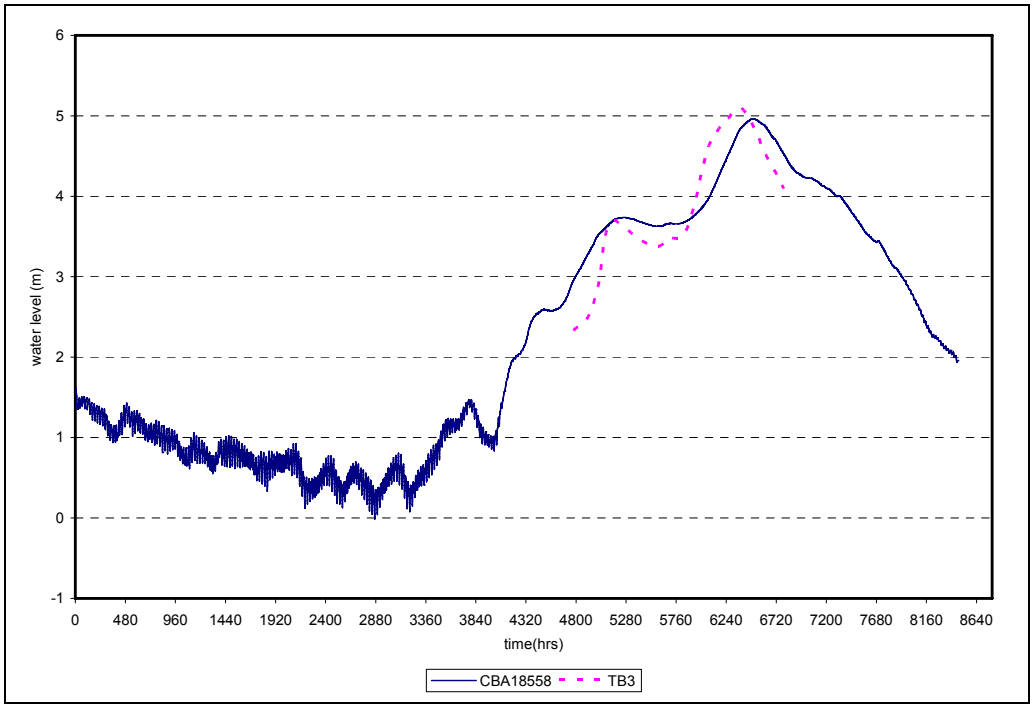


Figure 2.6 Comparison computed and observed water levels for the 2000 flood at TB3

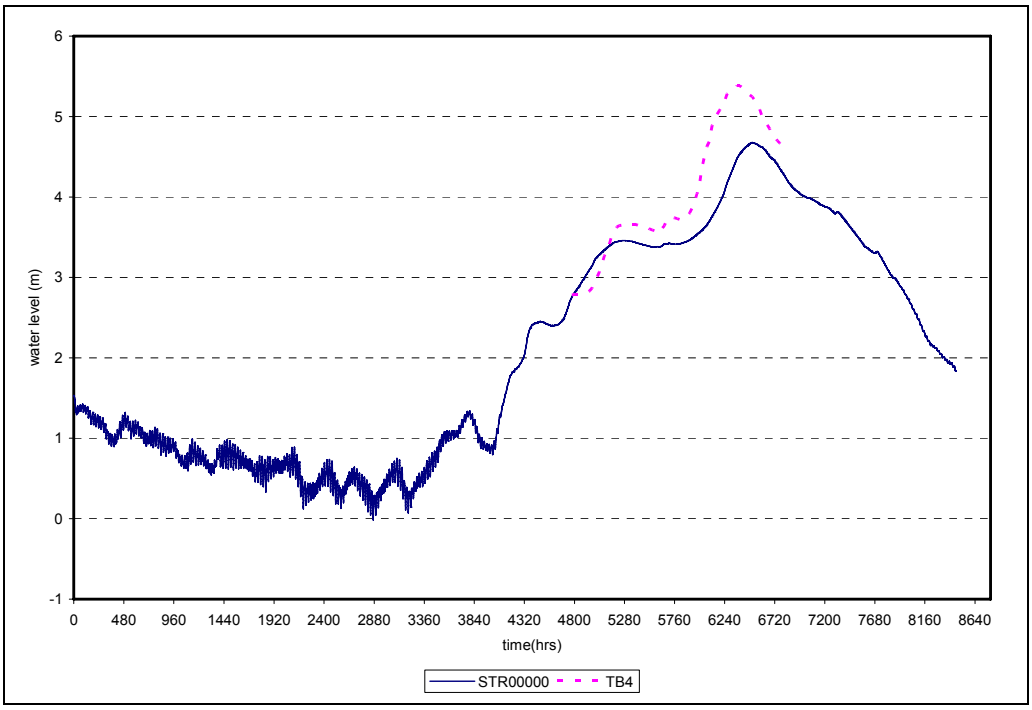


Figure 2.7 Comparison computed and observed water levels for the 2000 flood at TB4

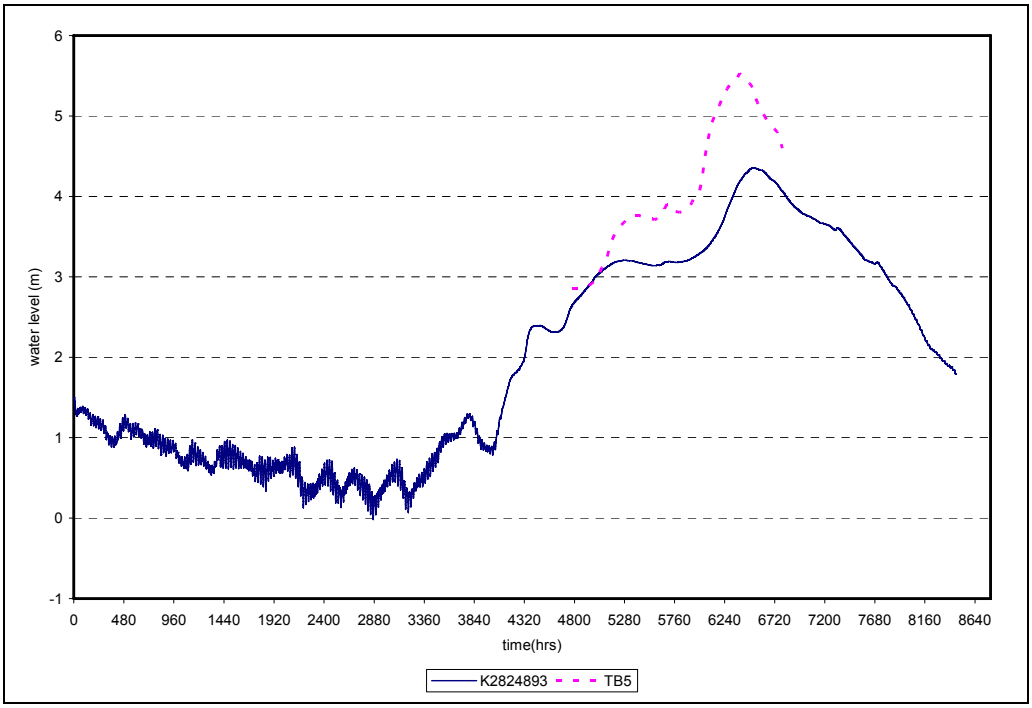


Figure 2.8 Comparison computed and observed water levels for the 2000 flood at TB5

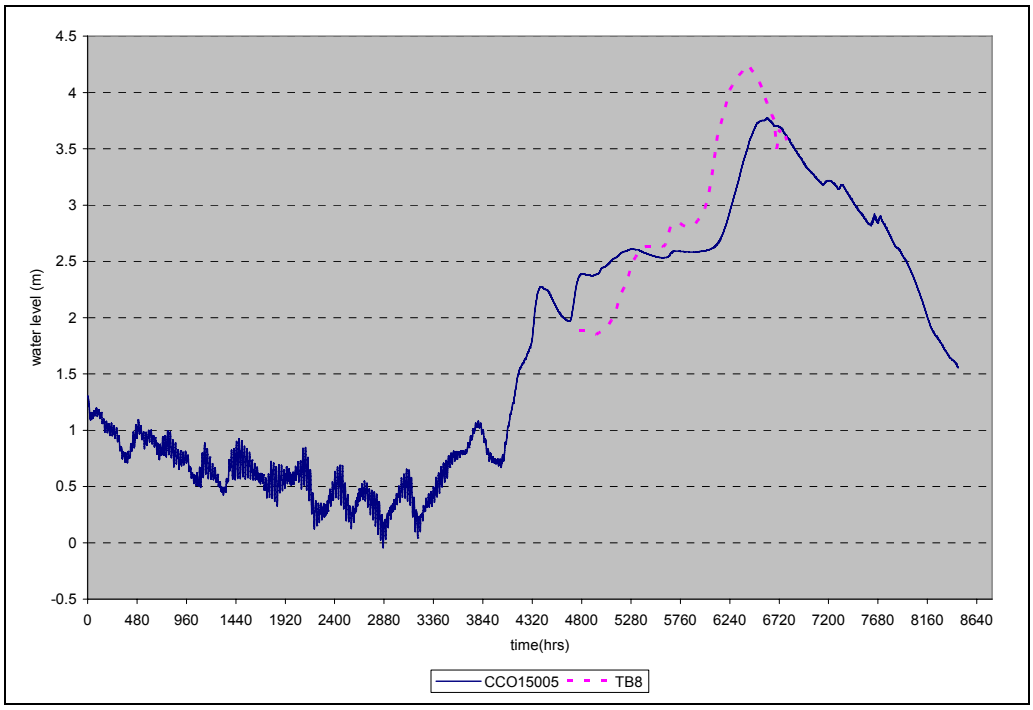


Figure 2.9 Comparison computed and observed water levels for the 2000 flood at TB8

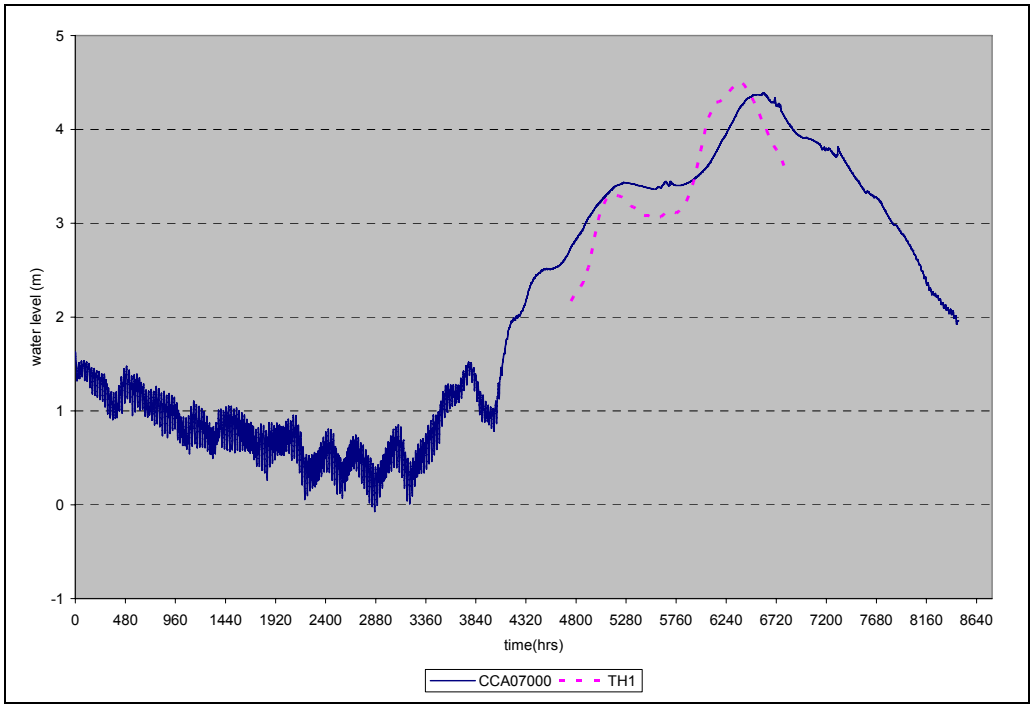


Figure 2.10 Comparison computed and observed water levels for the 2000 flood at TH1

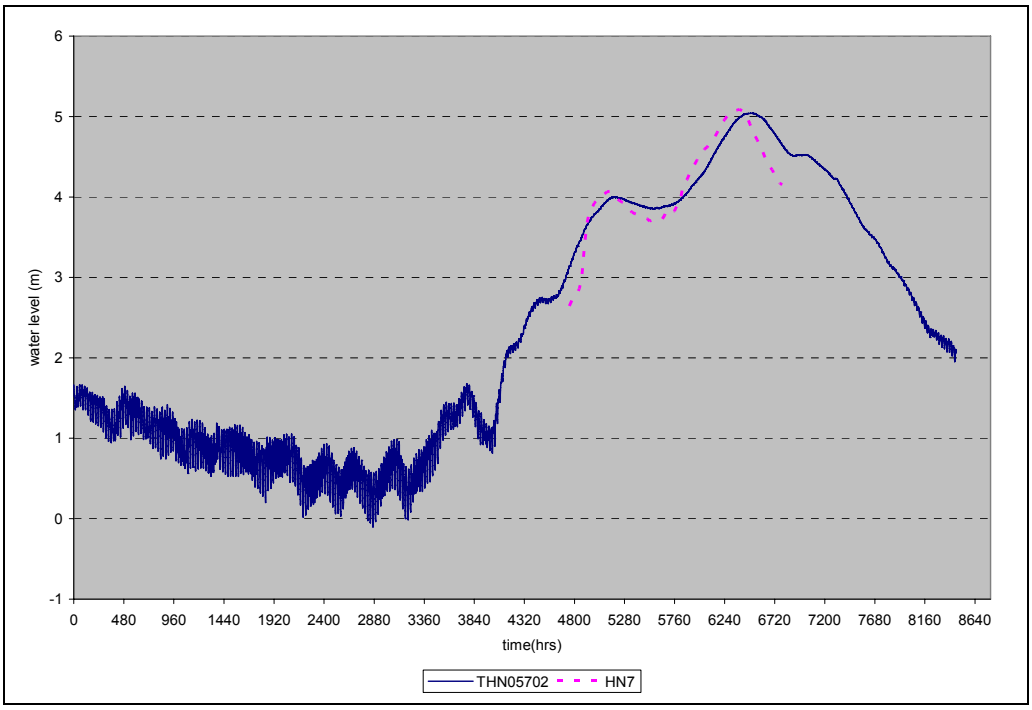


Figure 2.11 Comparison computed and observed water levels for the 2000 flood at HN7

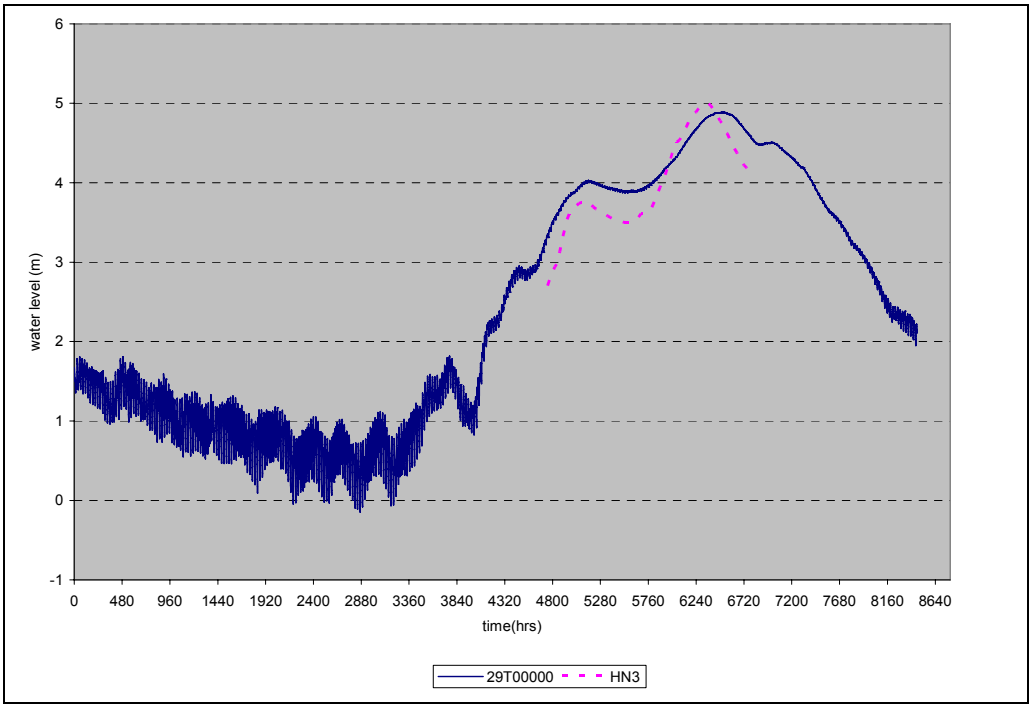


Figure 2.12 Comparison computed and observed water levels for the 2000 flood at HN3

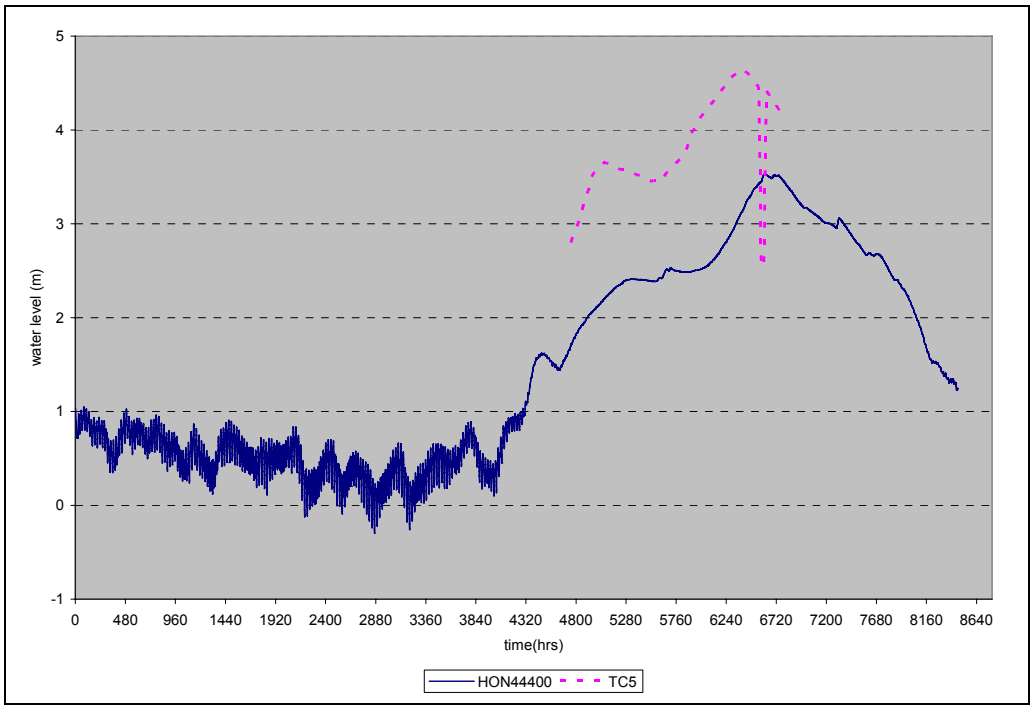


Figure 2.13 Comparison computed and observed water levels for the 2000 flood at TC5

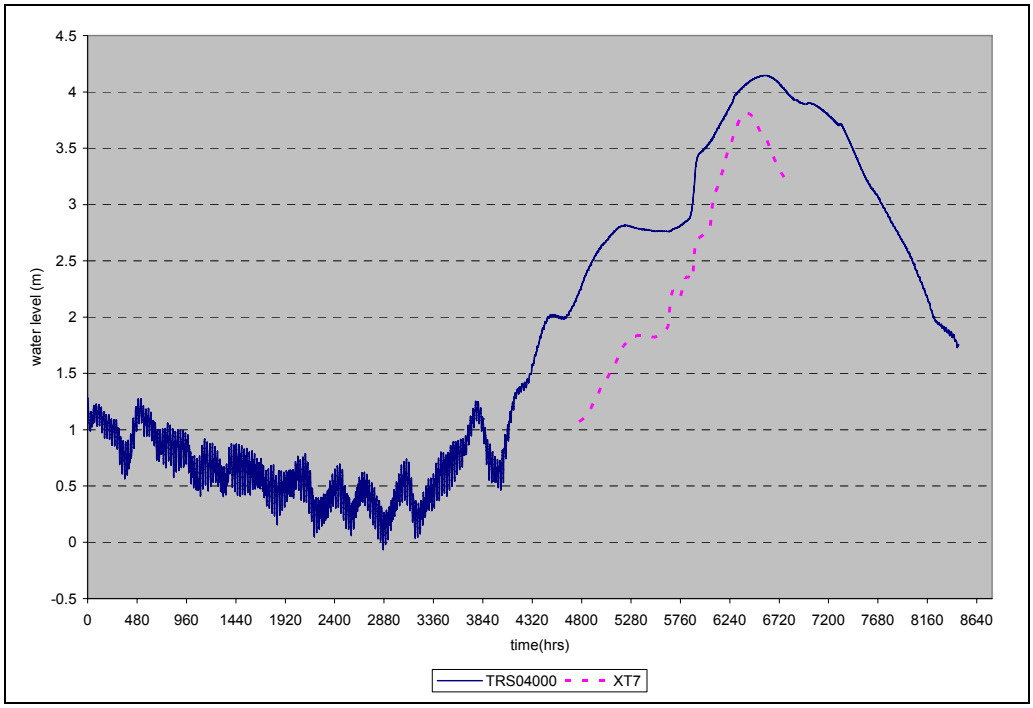


Figure 2.14 Comparison computed and observed water levels for the 2000 flood at XT7

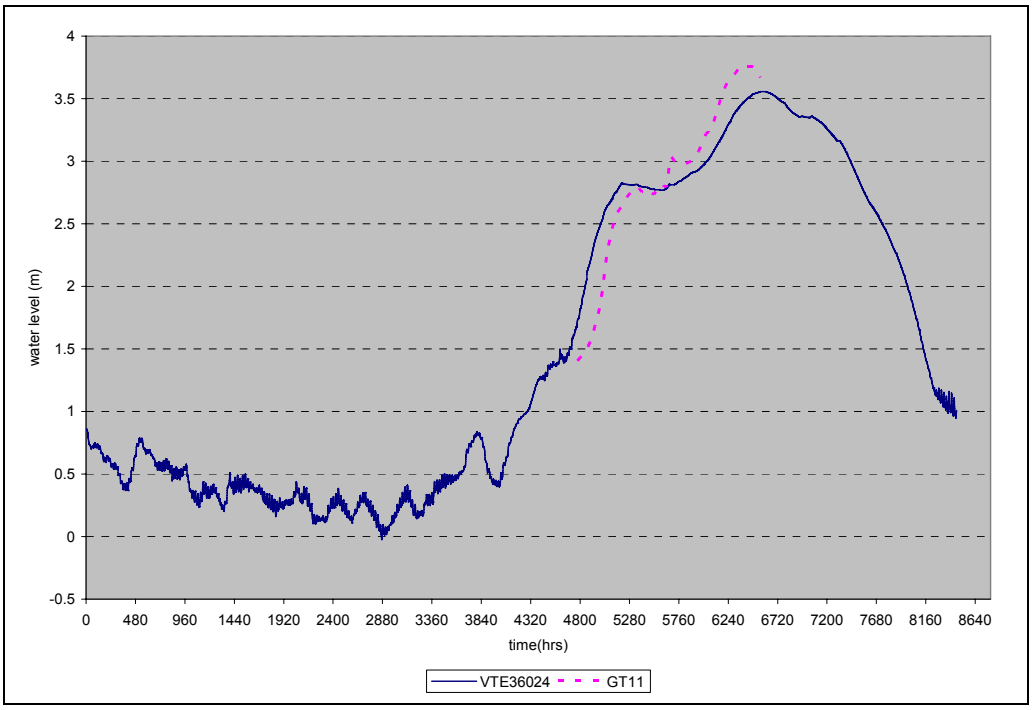


Figure 2.15 Comparison computed and observed water levels for the 2000 flood at GT11

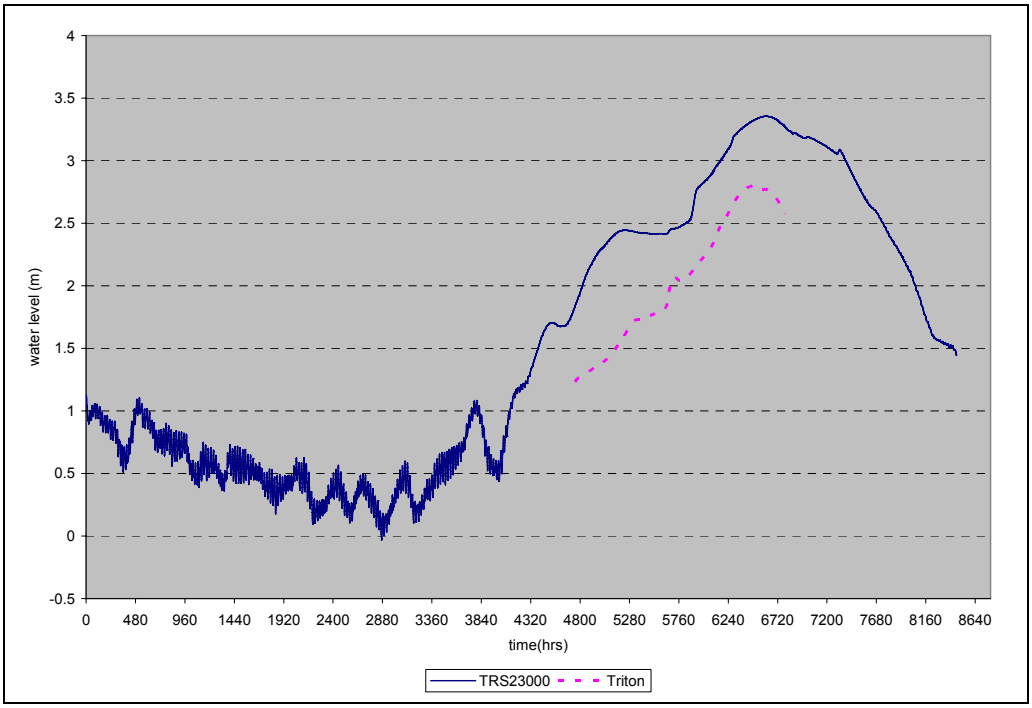


Figure 2.16 Comparison computed and observed water levels for the 2000 flood at Triton

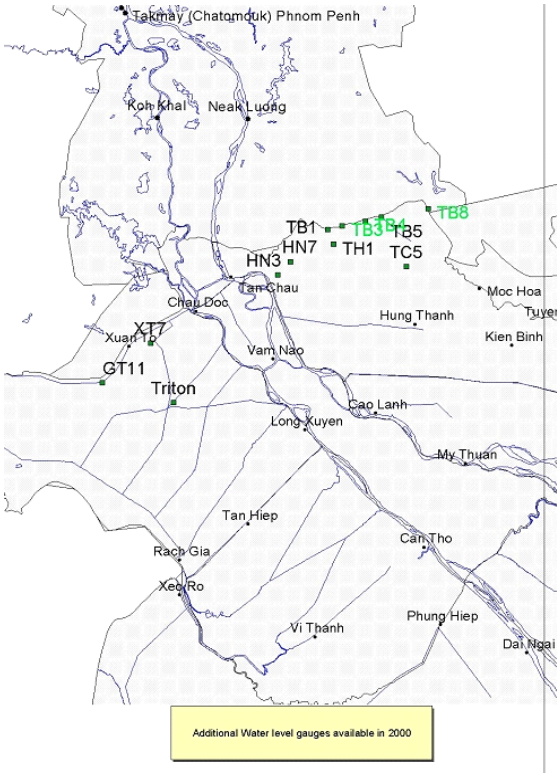


Figure 2.17 Locations of temporary stations in the Plain of Reeds and the Long Xuyen Quadrangle during the 2000 flood

2.6.2 Guidelines on using the model

For the simulation of structural measures to change the nature of the floods in the project areas, adaptations in the model schematization are required. As the current model serves as a reference, any changes in the schematization and its associated parameter settings must be introduced in a way consistent with the procedures applied in the development of the reference model.

The splitting of flood plain cells (through new or redesigned channels, the construction of embankments, roads or railways) requires a choice of new flood plain cell parameters for the separate cells, such as roughness parameters, equivalent weir width assigned to conveyance etc. As a first step the meaning of the current parameter values has to be analyzed, e.g. relation to cell surface area, cell average surface level, composition of roughness value, incorporation of the conveyance of local drainage channels etc. Subsequently, new parameters are to be assigned following the same principles as applied in the reference model.

2.6.3 Further recommendations

It is recommended to extend the model for the area downstream of Kratie with a 2D component, preferably leading to a fully integrated 1D/2D model. It is also recommended to acquire the newly surveyed DEM for the Vietnamese part of the model.

3 Conclusions and Recommendations

3.1 Conclusions

Based on the evaluation presented in Chapter 2 the following conclusions can be drawn:

Nam Mae Kok

1 The progress with the development of the ISIS model for the Nam Mae Kok River has been insufficient to use this model within FMMP2 for the evaluation of flood management scenarios.

2 The flooding phenomenon near Chiang Rai is very complex and requires the use of a 1D/2D hydraulic model for adequate simulation of the flood extent

Bokeo

3 No models are available for the simulation of flow in the Mekong River in the Bokeo Province.

4 For the evaluation of the erosion processes water velocities play an essential role. The hydraulic situation is quite complex, with river bends and the outflow of the Nam Mae Kok into the Mekong, leading to recirculation flow patterns. 3D models enable the simulation of such complex flow fields for selected combinations of Mekong and Nam Mae Kok flows.

Lower Se Babg Fai

5 The available 1D hydraulic model developed by LNMC and MRC of the lower Se Babg Fai seems acceptable for a first screening of protection options. It is of insufficient quality for design: the high water levels are consistently underestimated on average with about 6 dm.

6 The flooding phenomenon in the lower Se Babg Fai is very complex and requires the use of a 1D/2D hydraulic model for adequate simulation of the flood extent

Upper Se San

7 No model is currently available for hydraulic modelling in the Upper Se san upstream of Yali dam

Kratie

8 The current ISIS model of the Mekong Delta does not represent the river island and the resulting splitting of the cross-section near Kratie, the model is not very useful in deriving conclusions on flow velocities along the eroding banks. A first estimate of flow velocities can be based upon a local conveyance.

Mekong Delta

9 The current ISIS model still has to be improved before it can be used as a reliable instrument in the study of flood management scenarios. Currently, it does not satisfy the criteria that have been set by MRCS for acceptance of the model.

10 Apart from differences in peak levels, which may partly be due to reference errors, the error in the celerity of flood wave propagation pose a more serious problem, leading to an approximately one week late arrival of the flood wave in the Plain of Reeds and the Long Xuyen Quadrangle.

11 It will be acceptable to use the current model for demonstration purpose to study the selected focal areas in the border area between Cambodia and Vietnam. For a final analysis the ISIS model has to be improved further.

12 For the simulation of structural measures to change the nature of the floods in the project areas, adaptations in the model schematization are required. As the current model serves as a reference, any changes in the schematization and its associated parameter settings must be introduced in a way consistent with the procedures applied in the development of the reference model.

3.2 Recommendations

Bokeo

For appropriate description of the erosion processes and to support the design of protection 3D hydraulic models will be required to enable the simulation of the anticipated complex flow fields for selected combinations of Mekong and Nam Mae Kok flows.

Lower Se Babg Fai

The recommendation made for the Nam Mae Kok regarding 1D2D modelling also applies for the lower Se Babg Fai. Furthermore it is recommended to extend the monitoring network, for example by placing during the flood season a number of pressure transducers in the flood plain area between HW13 and the Mekong River.

Mekong Delta

For a final analysis the ISIS model has to be improved further. In the light of the current uncertainties, the following steps are proposed:

- Verify the rating curve at Kratie by simultaneous ADCP and traditional current meter instruments and generate most likely flood hydrographs at Kratie;
- Calibrate the model for a recent year (e.g. 2004), with the infrastructure correctly presented in the model for that year and based upon the verified inflow hydrograph at Kratie. Make sure that apart from peak levels also the wave phase and the length of the flood wave compare satisfactorily with observed data;
- Strip the model from infrastructural changes made after 2000 and verify the model for the year 2000 flood.

Reference is further made to the Sections 2.6.2 and 2.6.3 for further recommendations on the improvement of the model for simulation of effect of structural measures, as the present layout is not suitable for analysis of flood plain developments in Cambodia.

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