



MRC Management Information Booklet Series No. 4

Impacts of climate change and development on Mekong flow regimes: First assessment – 2009

February 2011



Meeting the needs, keeping the balance

INTRODUCTION

The waters of the Mekong River, flowing through one of the world's largest river basins, potentially provide a huge resource for hydropower and irrigation. While climate change will affect the river's flow regime, the potential impacts of hydropower and irrigation developments also need to be considered in prediction of the future flow regimes. National governments, as well as international organisations, are increasingly expressing concerns about the potential impacts of climate change and development on physical, environmental and ecological processes in the Basin. The productivity of the Tonle Sap Lake, the largest source of freshwater fish in South East Asia, relies on the reverse flow from the Mekong River to the lake. This creates complicated linkages between the hydraulic and ecological processes.

A study was carried out to assess the impacts of climate change and development on Mekong flow regimes and to provide recommendations for future work to improve adaptation strategies for the Mekong Basin. The study was part of a project on 'Reducing vulnerability of water resources, people and the environment in the Mekong Basin to climate change impacts' led by CSIRO with participation of MRC, SEA START Regional Centre and International Water Management Institute (IWMI) and supported by AusAID.

This booklet provides a summary of the preliminary impact assessment of climate change and development on Mekong flow regimes and recommendations to improve the assessment of these impacts. The results of two global emission scenarios (A2 and B2, IPCC 2000) were downscaled to the regional level covering the entire Mekong River Basin, consisting of the Upper Mekong Basin in China and Myanmar and the Lower Mekong Basin in Cambodia, Lao PDR, Thailand and Vietnam. The development scenario is a 20-year plan scenario defined by the MRC Member Countries within the Basin Development Plan process. The predictions cover the period 2010 through 2050.

KEY FINDINGS

The mean annual **temperature** is predicted to increase by 0.7°C over the entire basin; 0.9°C for the Upper Mekong Basin (UMB) and 0.7°C for the Lower Mekong Basin

(LMB). The highest temperature increase will occur in the uppermost parts of the Basin in China. The increase will be less in the LMB where the highest temperature changes would occur in southern Cambodia and the Mekong Delta.

The downscaled climate data showed an increasing trend in the mean annual **rainfall** throughout the Mekong Basin, except in Cambodia and the Mekong Delta. The predicted annual mean rainfall for the entire Mekong Basin increases approximately 5%, whereas the increase in UMB is about 10%, and unchanged conditions or even a decrease are predicted for Cambodia and the Mekong Delta. The wet season in particular will carry more rainfall. The dry season will also see more rainfall in the UMB, while changes in the LMB are predicted to be insignificant for the dry season.

The resulting predicted changes in the **flow regime** of the Lower Mekong River are increases in river flow both for the wet and the dry seasons. The predictions suggest an increase in annual mean flow at 4-13% for the wet season and 10-30% for the dry season. The largest increases are seen from the Chinese border to Kratie in Cambodia. This is caused by the predicted increase in rainfall in the upper parts of the LMB and unchanged or even a decrease in rainfall in the lower parts including Cambodia and the Mekong Delta.

Climate change and the effects on **snow melt** in the UMB could result in changes in the flow regime of the Mekong River. The increased temperature would mean earlier melting of snow. The snow melt contributes about 5% to the annual water yield at the Chinese-Lao border. This may increase to about 8% by 2050. The period with the highest snowmelt is in March, which is also the period of low flow. The snowmelt amounts to almost 70% of the flow at the Chinese-Lao border for the month of March. This proportion will remain unchanged according to the climate predictions as both flow and snowmelt are predicted to increase.

The increased flow in the Mekong River will boost water availability in the dry season, but it will also increase the **risk of flooding** in the wet season. The low-lying areas downstream of Kratie to the Mekong Delta including the Tonle Sap area are particularly at risk. The areas affected by flooding due to rainfall and upstream freshwater flow from the Mekong River Basin are estimated to increase by 9%. This estimate was made by comparing a previous extreme wet year (2000) and a predicted

future extreme wet year (2048) and did not include sea level rise. The area where the flooding depth is high e.g. 2 m would increase by almost 40%, meaning that the intensity of the floods is expected to increase.

The common trends (which can be observed at most stations) of change in flow regime due to potential **development and climate change** are: i) hydropower dams could result in a lower flow in the high-flow season and increased flow in the low-flow season; and ii) climate change could result in higher flow in both seasons. The storage capacity of hydropower installations can therefore potentially reduce impacts of flooding on some areas. There is, however, a high degree of uncertainty and variation by location and between the different development and climate change scenarios.

ASSESSMENT SCENARIOS

The framework of the climate change and BDP development scenarios for the first assessment (Figure 1 and Box 1) comprised six scenarios (S1-S6). In this assessment, two BDP scenarios, namely the baseline and the LMB 20-year plan scenarios, were selected to compare the impacts of climate change on the flow regime. Climate change data were based on daily climate projection of two emission scenarios (A2 and B2) from the Intergovernmental Panel on Climate Change. The emission scenarios reflect different international development paths (IPCC, 2000).

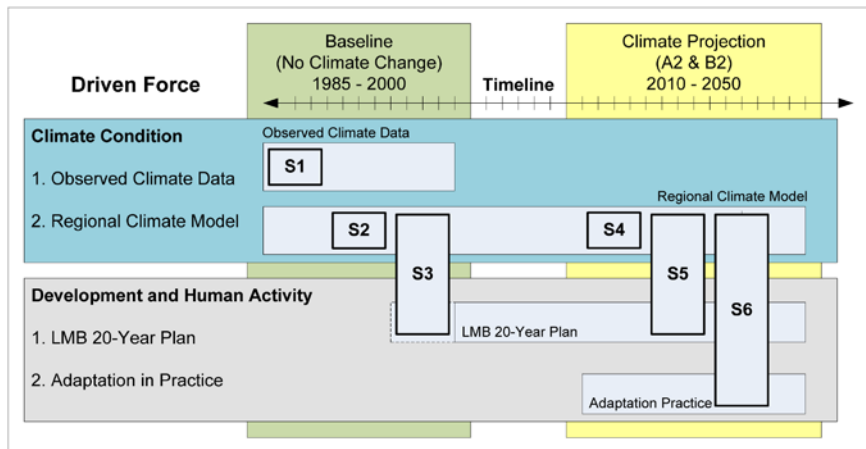


Figure 1. Framework scenario analysis for impacts of climate change and development

Box 1: Scenario Definition

- S1: baseline scenario based on the observed climate data in 1985–2000
 - S2: baseline scenario based on the climate data from adjusted RCM in 1985–2000
 - S3: LMB 20-year plan scenario based on the climate data from adjusted RCM in 1985–2000
 - S4: baseline scenario under climate change projection in 2010–2050
 - S5: LMB 20-year plan scenario under climate change projection in 2010–2050
 - S6: S5 scenario with adaptation strategies. This scenario is not implemented in the present assessment.
- Baseline:** used as a “reference scenario” representing the development conditions that existed in the Basin in 2000 including water supply, irrigation and 18 hydropower dams in Lao PDR, Thailand and Viet Nam.
- LMB 20-Year Plan:** representing the ongoing and planned developments in the Basin (Figure 2); 6 proposed and existing mainstream dams in UMB; 11 proposed mainstream dams and a number of proposed dams in the LMB tributaries; projected water supply and irrigation need.



Figure 2. Location of proposed and existing hydropower dams (MRC 2009)

MODELS USED FOR PREDICTIONS

The climate change projections at the regional scale, for example for the Mekong River Basin, are associated with a range of uncertainties. These uncertainties are related to the underlying assumptions of the global climate change drivers (expressed in the global IPCC scenarios), the selection of international development scenario, the uncertainties of the General Circulation Models (GCM) used and uncertainties of regional downscaling of the global modelling results.

Several GCMs exist. The uncertainties related to these simulations can be dealt with by considering the results from many models and deducting common trends rather than relying on one particular model (Eastham et. al. 2008). The spatial grids are however very large for the global models (grid cells typically 300 km in each direction) and are unable to reflect regional physical variability. To consider this and to provide results that are at a sufficient scale, for example for hydrological modelling, various methodologies for downscaling global results are used. This includes statistical downscaling or dynamical downscaling providing data at a scale of typically 20-50 km. This type of downscaling enables more accurate representation of different surfaces such as mountains, coastlines, islands and peninsulas. To reduce uncertainty, the downscaling models are adjusted by comparison with historical data. The trade-off of this type of downscaling is that it will be based on results from only one GCM.

In the present study, the global scenario prediction data were downscaled to the Mekong region using the PRECIS model system. The PRECIS data of climate change emission scenarios A2 and B2 were generated by a dynamic downscaling method that took into account regional characteristics. The downscaled data from PRECIS were separated into two periods; 1985–2000 (baseline) and 2010–2050 (with climate change). The downscaled data in 1985–2000 were compared with the observed data over the same period to identify any bias in the downscaled data. The downscaled data for 2010-2050 were then adjusted accordingly.

The combination of climate conditions and development scenarios that were modelled are illustrated in Figure 1.

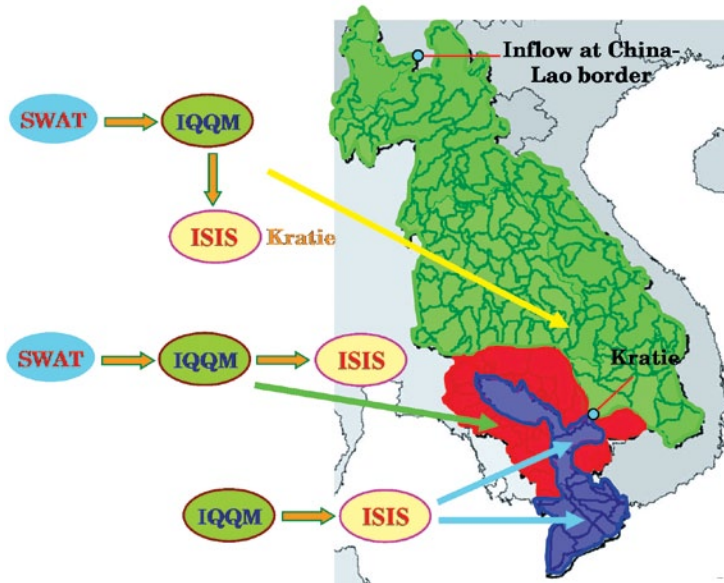


Figure 3. Application areas of DSF models (acronyms explained in endnotes).

The hydrological and hydrodynamic model complex of the MRC Decision Support Framework (DSF) was used to predict the impacts of climate change on the Mekong flow regime (Figure 3). The modelling system did not take into account sea level rise, focusing on the consequences of predicted changes in rainfall and temperature on fresh water flow.

A comparison of predicted precipitation and temperature for the Mekong Basin for 9 different studies was also undertaken. While most studies provide a common projected increase of temperature in the range of 0.01-0.06 °C/year with the CSIRO-MRC study suggesting 0.020 - 0.023°C/year, the projected changes in precipitation vary. The annual and seasonal precipitation increases or decreases depending on the selection of the GCM or downscaling model, the chosen emission scenarios, the duration of the past and future periods studied and the type of data used (observed data in the basin, data from the global database or data from models). This comparison shows the high degree of uncertainty in projecting precipitation. These uncertainties are important to note when using results from any climate change scenario analysis.

TEMPERATURE AND RAINFALL

The mean annual temperature for scenario A2 is predicted to increase by 0.7°C over the entire basin; 0.9°C for the UMB and 0.7°C for the LMB. Under scenario B2 the temperature increase is slightly higher. Similar changes are also predicted for the maximum and minimum temperatures. The highest temperature increase will occur in the uppermost part of the UMB (Figure 4). The increase will be less in the LMB; with the highest temperatures occurring in the lower part of LMB and the Mekong Delta. The higher temperatures in 2010–2050 are likely to lead to increased demands for water for agriculture which in turn lead to the projection of more water diversions for irrigation. In summary, the study predicted that temperature in the Mekong Basin will increase at about 0.020–0.023°C/year, which was a similar result to other studies.

Under scenarios A2 and B2 mean annual precipitation in 2010–2050 will increase for the entire Mekong Basin compared with 1985–2000 (Table 1). The increase is higher for the Upper than the Lower Basin. By season, precipitation is projected to increase relatively more in the dry season (November–April) than in the wet season (May–October), although dry season precipitation is only 11–13% of the annual precipitation. The results for scenario A2 indicate that the rainy season will be wetter, with an increased precipitation rate of 1.2–1.5 mm/year. These values are lower under scenario B2. The dry season will also be wetter in the UMB with an increase in precipitation of 0.9 mm/year, but the changes in the LMB are insignificant. Figure 5 shows the highest increase in the mean annual sub-basin precipitation of about 44–45% in the UMB for both scenarios A2 and B2. In most of the LMB, rainfall will increase by 1–10%, except in some sub-basins in northern Lao PDR and central Viet Nam. On the other hand, rainfall will decrease by up to 8% in the Mekong Delta.

Table I. Changes in mean annual and seasonal precipitation in Scenarios A2 and B2 (2010-2050) compared with observed data in 1985-2000

	Emission scenario A2 Percent increase	Emission scenario B2 Percent increase
Mean annual rainfall – entire Mekong basin	5.3	3.2
Upper basin	10.9	9.1
Lower Basin	4.5	2.4
Wet season rainfall – entire Mekong basin	4.5	3.6
Upper basin	7.7	5.8
Lower Basin	4.0	3.3
Dry season rainfall – entire Mekong basin	10.7	1.2
Upper Basin	27.5	25.5
Lower Basin	7.9	-2.8

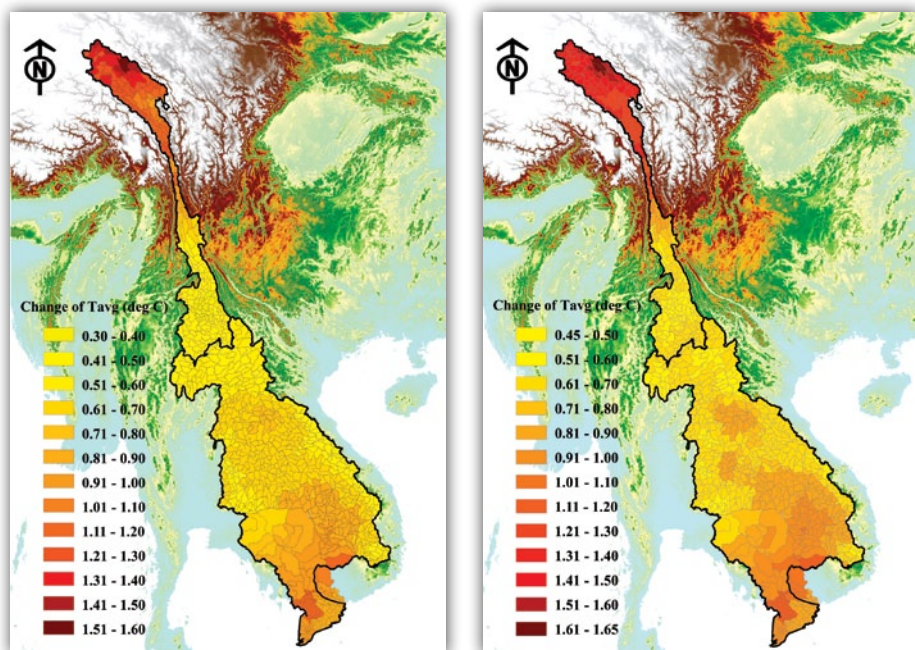


Figure 4. Change in annual sub-basin average temperature (°C) during 2010–2050 compared to 1985–2000 for Scenario A2 (left) and Scenario B2 (right)

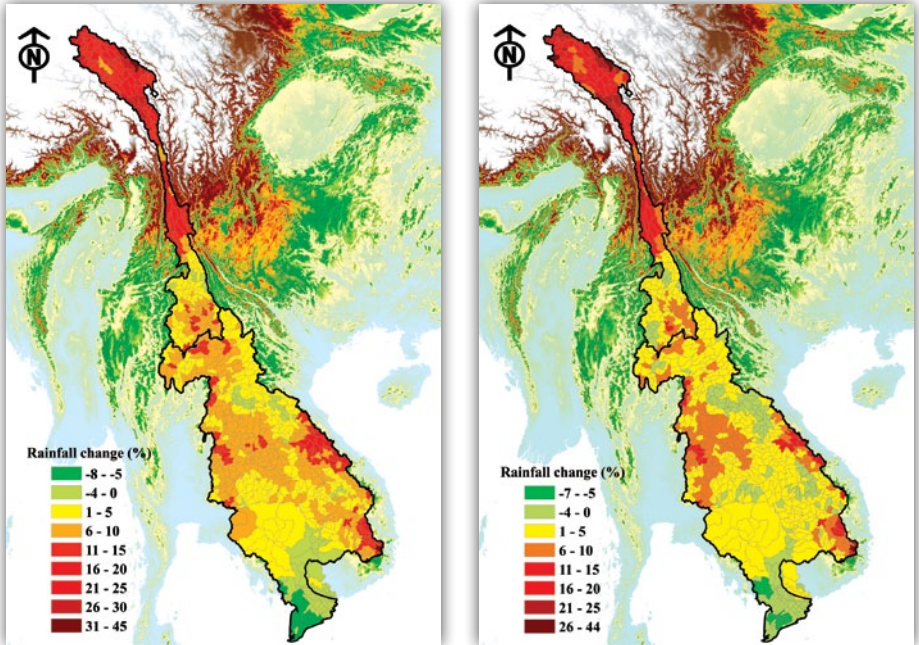


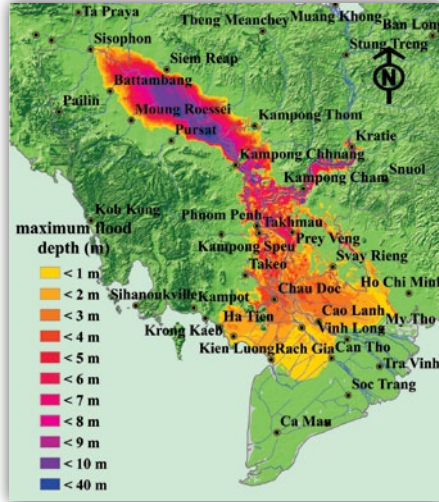
Figure 5. Change in mean annual sub-basin precipitation (%) during 2010–2050 compared to 1985–2000 for Scenario A2 (left) and Scenario B2 (right)

IMPACT OF DEVELOPMENT AND CLIMATE CHANGE ON MEKONG FLOW REGIME

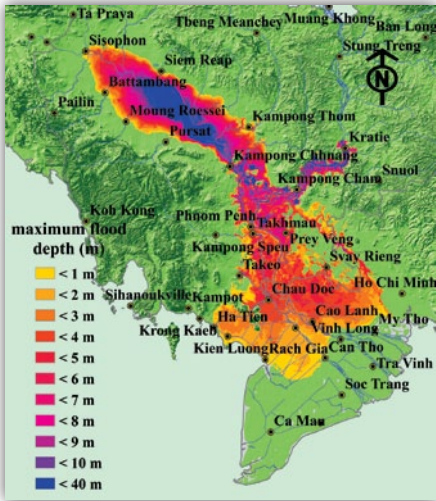
The impacts of development and climate change on the Mekong flow regime are summarised as follows:

- In the high-flow season, the impacts of climate change and development have contrasting effects. Under the LMB 20-year plan, river flow is expected to decrease by 7–17%. The effect of climate change is projected to increase the flow by 2–11%. The combined effect of development and climate change may cause a decrease of up to 13% in discharge at one station, but an increase of 3% at another station, depending on the climate change scenario and the location. Such variations clearly show that the current development plan will require adjustments to encompass an optimal adaptation to climate change.

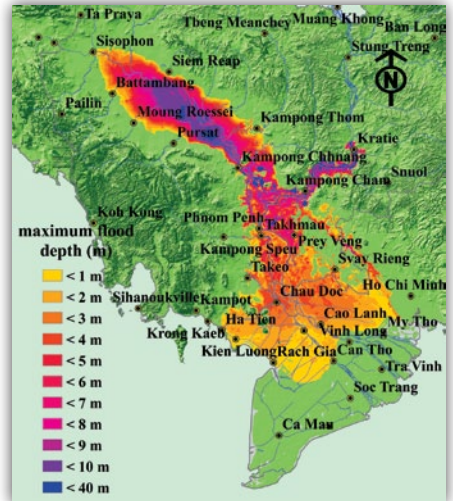
- In the low-flow season, the impacts of either climate change or development bring about increases in river flow, but their combined effect is more complex. If the development scenario is applied with the baseline climate condition (1985–2000), river flow could increase by 30–60%. The Mekong flow is predicted to increase by about 18–30% due to climate change. Development and climate change could result in 40–76% more water during the dry season than under existing conditions. The discharge in the low-flow season is about 12–20% of the annual discharge, depending on the location.
- Considering annual flow change, development under the LMB 20-year plan could reduce discharge by 3–8% based on baseline and future climate conditions. Conversely, river discharge is projected to increase by 6–16% due to climate change. Overall river flow under development and climate change would increase by 2–12% annually. Again, the magnitude of the change depends on the climate change scenario and location being considered.
- Although, over a long period, the mean discharge will increase under climate change, the annual variation is quite large. For example, the predictions show that low-flow seasonal discharges under climate change can be lower than in certain past years. These results suggest that a seasonal analysis is needed to deal with the detailed consequences of development and climate change.
- The number of days with a discharge higher than the high-flow seasonal mean is expected to increase under climate change. Development has a great impact in reducing this number at upstream stations but less so at the downstream stations. While development can help in reducing the area of flooding, climate change will increase these areas in worse years (Figure 6). Climate change could also increase the areas with saline intrusion in the Mekong Delta, while development can help to reduce those affected areas.



a) Year 2000



b) Year 2048 (Scenario A2)



c) Year 2047 (Scenario B2)

Figure 6. Estimated flooded area without climate change (a) and with climate change (b) and (c)

RECOMMENDATIONS FOR FUTURE STUDY

The study is considered a preliminary assessment of development and climate change impacts on Mekong flow regime. The following recommendations are made for future work to improve the assessment:

- i) Analysis with more climate change datasets would be useful to reduce the uncertainty in climate projection;
- ii) Further study and testing of the adjustment methods are needed to ensure that the projection trend is properly maintained and any bias from climate modelling is removed;
- iii) More observed climate data (i.e. from more stations and over a longer period) and other data used in modelling, such as land use, water use and reservoir regulation rules should be collected;
- iv) Supporting tools are needed to handle large datasets for climate change analysis. Simplification of the Mekong model and development of sub-models for groups of sub-basins are also needed;
- v) The DSF, designed and set-up only for the analysis of changes in flow regime under different scenarios, should be supported by other models and analyses or improved with new components to become an integrated modelling package for analysing changes other than just those of the flow regime.

ENDNOTES

1. Hoanh C.T., Jirayoot K., Halls A.S., Lacombe G., Srinetr V. 2010. Impacts of Climate Change and Development on Mekong Flow Regimes: First assessment 2009. MRC Technical Paper No. 29. Mekong River Commission, Vientiane, Lao PDR.
2. Mainuddin M., Hoanh C.T., Jirayoot K., Halls A.S., Kirby M., Lacombe G., Srinetr V. 2010. Reducing Vulnerability of Water Resources, People and the Environment in the Mekong Basin to Climate Change Impacts. CSIRO: Water for a Healthy Country National Research Flagship.
3. MRC. 2009. Supplement Note for 5th Regional Technical Working Group meeting on scenario formulation and assessment of hydrological changes. Internal Technical Note, Basin Development Plan Programme Phase 2. Mekong River Commission Secretariat, Vientiane, Lao PDR.
4. IPCC. 2000. IPCC Special Report – Emission Scenarios: Summary for Policy Makers. A Special Report of IPCC Working Group III Published for the Intergovernmental Panel on Climate Change.
5. Acronyms (not included in the text)

AusAID	The A ustralian Government's Overseas AID Program
BDP	B asin D evelopment P lan
CSIRO	The C ommonwealth S cientific and I ndustrial R esearch O rganisation
IPCC	I ntergovernmental P anel on C limate C hange
ISIS	A comprehensive modelling software
IQQM	I ntegrated Q uantity Q uality M odel
SEA START	S outh E ast A sia - G lobal C hange S ys T em for A nalysis, R esearch and T raining
SRES	S pecial R eport on E mission S cenarios
SWAT	S oil and W ater A ssessment T ool

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February 2011

Edited by: Robin Taylor and Hanne Bach
Mekong River Commission

**Office of the Secretariat in Phnom Penh
(OSP)**
576 National Road, #2, Chak Angre Krom,
P.O. Box 623, Phnom Penh, Cambodia
Tel. (855-23) 425 353. Fax (855-23) 425 363

**Office of the Secretariat in Vientiane (OSV),
Office of the Chief Executive Officer**
184 Fa Ngoum Road,
P.O. Box 6101, Vientiane, Lao PDR
Tel (856-21) 263 263. Fax (856-21) 263 264

Email: mrcs@mrcmekong.org

Website: www.mrcmekong.org