9 CLIMATE CHANGE

Theme	*Key issue (relevant to hydropower)*
Climate Change	1. What changes are foreseen in climate and hydrological variability and extremes? 2. What implications will those changes have for natural and social systems in the basin? 3. What implications will those changes and their effects have for development sectors in the basin including hydropower? (for example, in terms of energy generation, operations, GHG emissions and carbon financing)

9.1 PAST TRENDS AND CURRENT SITUATION

Already, climate changes in the Mekong region are influencing ecosystems, livelihoods and development through changes in regular weather – ie daily, seasonal and annual patterns – and through changes in the frequency of extreme events. The main influences (and indicators of change) are temperature, rainfall and runoff, sea level, tidal fluctuations and natural disasters such as storms, floods and drought.

Over the past 3 to 5 decades, trends of increasing mean annual temperature have been recorded in each LMB country. In Cambodia, for example, from 1960 to 2005, the average temperature increased by 0.8°C. The rate of increase is most rapid in the drier seasons at a rate of 0.2-0.23°C per decade and slower in the wet seasons at a rate 0.13-0.16°C per decade. Most notable is the increase in variability from one year to the next.

The trends in rainfall are less consistent with increasing variability and extremes between wet and dry in Laos and Cambodia, a decrease in Thailand, and decreases in most localities in the north of Vietnam with increases in most areas of the South during all seasons. In winter in Vietnam rainfall fell by 23%.

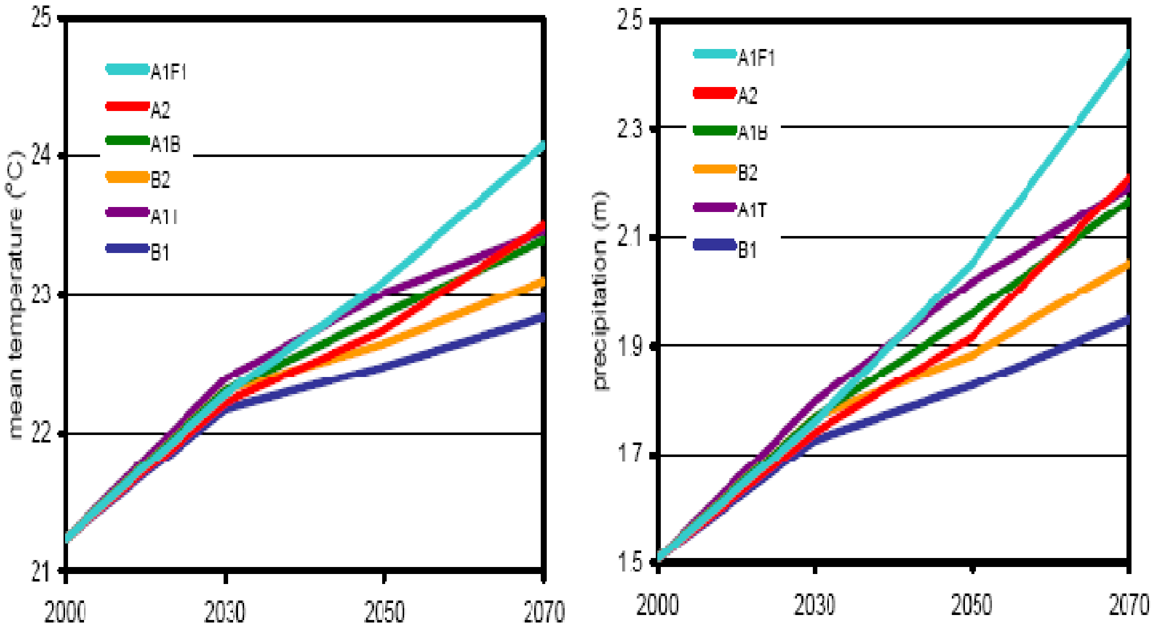
Seasonal changes are important, with most increases in rainfall occurring during the wet season. All countries have experienced decreasing rainfall during the dry season with aggravated drought and water stress situations in many catchments.

9.2 FUTURE TRENDS WITHOUT THE LMB MAINSTREAM HYDROPOWER DEVELOPMENT

9.2.1 FUTURE TRENDS IN CLIMATE AND HYDROLOGY

During the past decade, future climate change has been assessed using a range of models, IPCC scenarios and methods. The projections vary according to the IPCC development scenario modeled, which is to be expected, given the range of GHG emissions across scenarios. Projected changes in the basin vary from catchment to catchment, North to South, season to season and year to year – findings also to be expected given the differences in latitude, altitude, topography and other climatic influences such as marine and coastal forces. Projections also vary with the models used, which is a concern and reflects the embryonic nature of climate change science. Despite this variability and continuing uncertainty, distinctive and consistent trends are discernable across all studies and models – just varying in extent. For all IPCC scenarios, increases in temperature and rainfall are projected, with sharper increases and divergence between scenarios from 2030 (Figure 1).

Figure 1: Projected mean annual temperature and mean annual rainfall for the Mekong Basin for different IPCC scenarios at 2030, 2050 and 2070



Source: Eastham et al. 2008

Results for A1B – selected by CSIRO as it represents a mid-range scenario in terms of development impacts on GHG emissions – provide a good indication for the overall trends in the region, and for the hydro-ecological zones. They are used here as the main basis for summarising trends to 2030 as reflected in Table 1 and Figure 2.

Temperature: Steady increases in mean basin temperature by 0.8°C. Greater increases are expected in northern zones of the basin up to 1.4°C in Yunnan Province.

Rainfall: Annual rainfall to increase by 13.5% (0.2m) mainly due to increases during the wet season (May to Oct). Dry season rainfall will increase in northern hydro-ecological zones (1 and 2) and decrease in southern zones (3 to 6 – ie from Vientiane to the Delta). The overall disparity between wet and dry seasons will increase especially in zones 3 to 6.

Runoff: Total annual runoff from the basin is projected to increase by 21% mainly during the wet season with the annual discharge at Kratie increasing by 22% with increases in all months but mainly the wet season. This projection takes into account estimates for water use by future populations in the basin and irrigation.

Table 1: Climate change in the Mekong basin – annual averages (2030 for A1B)

Indicator	Historical record 1951-2000	2030	Increase
Temperature	▪ 21.2°C	▪ 22.0°C	▪ **3.7%** or 0.8°C
Rainfall	▪ 1.509 m	▪ 1.712 m	▪ **13.5%** or 0.2m
Runoff	▪ ~512,000 mcm	▪ ~619,000 mcm	▪ **21%** or ~107,000 mcm
Flow (the mean annual discharge at Kratie)	▪ 13600 m3s-1, (from 1924-2006)	▪ 16592 m3/s	▪ **22%**
Flooding (incidence of extreme wet events at Kratie – zone 5)	▪ Annual probability 5% ▪ Duration 5.1 months	▪ Annual probability 76% ▪ Duration 5.7 months	▪ **71%** increased probability ▪ **12%** increase in duration ▪ Increase of 3,800km^2 area of flooding in delta

Flooding: Flooding is projected to increase throughout the basin – with downstream zones affected most. For example at Kratie (zone 5) the annual probability of extreme wet flood events will increase from 5% (ie historic conditions) to 76%. It will increase to 96% in the wet season. The duration of flooding will increase in this zone with an earlier onset. The maximum and minimum area and water levels in Tonle Sap would increase annually. The annual average flooding in Delta would also increase by 3,800km^2 The impacts of this increase in flow and flooding could be expected to be greatest on the mainstream Mekong due to cumulative contribution from tributaries.

Drought and dry seasons flow: Despite rainfall increases, zones 3 to 6 are projected to experience reduced rainfall and runoff during the dry season. Southern Laos, Northeast Thailand, Central and Southeastern Cambodia, including the Tonle Sap catchment and the Delta region are still susceptible to high water stress during the dry season. More dry spells and a greater severity in drought periods are expected. The past trend of increasing variability with greater extremes between wet and dry seasons, especially in southern and eastern areas, is projected to continue.

9.2.2 GOVERNMENT POLICIES AND TARGETS FOR THE THEME

Mekong countries are launching climate change plans and programs which set out the issues and needed responses. For example, China's National Climate Change Program (CNCCP), June 2007[9] sets out a wide range of adaptation and mitigation principles and targets for 2010. Adaption targets involve extensive ecological restoration, the expansion of protected area systems and the wise use of water resources. The CNCCP requires government ministries and departments to strengthen co-ordination and

[9] Downloadable at http://en.ndrc.gov.cn/newsrelease/P020070604561191006823.pdf

Figure 2: Summary of predicted regional climate change impacts by hydro-ecological zone (A1B)

LMB Catchment	Agricultural Productivity	Food Availability	Temperature	Annual Precipitation	Dry Season Precipitation	Annual Runoff	Dry Season Runoff	Annual Water Stress	Dry Season Water Stress	Flooding Potential	Max Flows/water level	Flood Duration	Flooded Area	Dry Season Minimum Flows	Saline Intrusion
Zone 1 – China to Chiang Saen – headwaters and mountain river	-	-	+	+	=	+	=			+	+	+		+	
Zone 2 – Chiang Saen to Vientiane – upland river in steep narrow valley	-	-	+	+	+	+	+			+		+	+		
▪ **Moung Nouy: Northern Lao PDR**	-	-	+	+	+	+	+			+					
▪ **Luang Prabang: Northern Thailand and Northern Lao PDR**	-	-	+	+	+	+	+			+					
▪ **Vientiane: Northern Lao PDR and of North-east Thailand**	+	- [1]	+	+	+	+	+			+					
Zone 3 – Vientiane to Pakse – the Thai/Lao midstream section and tributaries	+	- [1,2]	+	+	-	+	+/-	+ [3]	+ [5]	+					
▪ **Tha Ngon: Central Lao PDR**	-	-	+	+	-	+	+			+					
▪ **Nakhon Phanom: Central Lao PDR and North-east Thailand**	+	- [2]	+	+	-	+	-			+					
▪ **Mukdahan: Southern Lao PDR and North-east Thailand**	=	- [2]	+	+	-	+	+			+					
▪ **Ban Keng Done: Central Lao PDR**	+	- [1]	+	+	-	+	-			+					
▪ **Yasothon: Northeast Thailand**	+	- [1]	+	+	-	+	+	+ [3]	+ [5]	+					
▪ **Ubon Ratchathani: Northeast Thailand**	+	+	+	+	-	+	+	+ [4]	+ [5]	+					
Zone 4 – Pakse to Kratie, including wetlands of Siphandone, Khone Falls, Stung Treng and Kratie, including a	+	- [1]	+	+	-	+	-	+	+	+	+	+			

LMB Catchment	Agricultural Productivity	Food Availability	Temperature	Annual Precipitation	Dry Season Precipitation	Annual Runoff	Dry Season Runoff	Annual Water Stress	Dry Season Water Stress	Flooding Potential	Max Flows/water level	Flood Duration	Flooded Area	Dry Season Minimum Flows	Saline Intrusion
number of significant tributaries															
▪ **Pakse: Southern Lao PDR and Northeast Thailand**	+	- [1]	+	+	-	+	-	+	+	+					
▪ **Se San: Southern Lao PDR, NE Cambodia & Central Highlands of Vietnam**	+	- [1]	+	+	-	+	-			+	+	+			
Zone 5 – Kratie to Phnom Penh and the Tonle Sap - Floodplains and the Great Lake	+	- [1]	+	+	-	+	-		+	+	+	+	+	+	
▪ **Kratie: Far southern Lao PDR and Central Cambodia**	+	- [1]	+	+	-	+	-			+	+	+	+	+	
▪ **Tonle Sap: Central Cambodia**	+	- [1]	+	+	-	+	-		+	+	+	+	+	+	
Zone 6 – Phnom Penh to the sea – Mekong delta, tidal zone	-	-	+	+	-	+	-	+2	+	+	+	+	+	+	+
▪ **Phnom Penh: South-eastern Cambodia**	-	- [1]	+	+	-	+	+	+2	+	+			+		
1. **Border: Southern Cambodia and South Vietnam**	-	- [2]	+	+	-	+	-	+2	+	+	+	+	+	+	+
2. **Delta: South Vietnam**	-	- [2]	+	+	-	+	-	+2	+	+	+	+	+	+	+

1= due to decrease in surplus; 2 = due to population growth; 3 = moderate level; 4 = medium level; 5 = high level

+	Predicted increase	-	Predicted decrease	=	Status quo		Unstated

Source: ICEM drawing from Eastham et al. 2008, TKK 2009, MRC 2010 and other sources co-operation, so as to achieve integration in addressing climate change. Vietnam's National Target Program for Climate Change 2008[10] is similar in its coverage but gives greater emphasis to "Mainstreaming the NTP in Strategies, Plans, Socio-economic Development Planning and other Sectoral/Local Development Plans".[11] In Cambodia and Lao PDR, the national policy framework takes the form of a National Adaptation Program of Action to Climate Change (NAPA). Thailand has prepared the 'Action Plan on National Climate Change as the Five Year Strategy on Climate Change 2008 to 2012'. In general, climate change issues are not integrated into the broader policy frameworks of national Governments or in specific sector and local government development plans.

9.2.3 MODIFYING EFFECTS OF HYDROPOWER AND IRRIGATION

Some of the projected trends in climate change would be moderated by economic developments in the basin. The planned hydropower dams and irrigation projects, in particular, would interact in various ways to modify the hydrological effects of climate change. Hydropower storage reservoirs can control the release of water and affect daily, seasonal and annual flows. Irrigation extracts water from rivers or reservoirs affecting flow volume. Other water users such as industry and domestic sectors are expected to double over the next 20 years but will remain relatively small consumers.

The SEA baseline assessment works with a projected baseline to 2030 – taking in the BDP Definite Future Scenario and the LMB 20 year scenario without LMB mainstream dams. The DFS includes 40 tributary dams constructed since 2000, under construction or committed and 6 China mainstream dams. In the DFS, the total live or active storage of the tributary dams and of the Chinese reservoirs[12] is 21,222 MCM or 4.6% and 22,189 MCM or 4.7% respectively of the annual water volume leaving the Delta – making a total of 9.3%. Under the LMB 20 year "without" scenario, there are 70 tributary dams (30 additional to the DFS with a live storage of 20,185 MCM or 4.2%) and the 6 Chinese dams – with a total active storage making up 13.5% of Mekong water.

During full operation of all the existing and planned hydropower dams, one might expect a significant effect in seasonal regulation of the 21% increase in total annual flow projected with climate change. During the annual flood, the dams might hold back water, and during the dry they might increase normal flows. In practice over the next 20 years to 2030, the regulatory influence of the planned dams will be determined by their construction schedules – most take 5 to 10 years to construct once approved and inevitably, development of projects will be staggered, potentially expanding the influence of the construction phase over several decades. The total storage (ie active and dead) of these reservoirs could be three times the live storage. While dams are being filled, water is being withheld from the Mekong effecting both wet and dry season flows.

The expansion of the irrigated areas in the basin will increase 10.9% annually mainly for dry season irrigation when water runoff and flow is lowest. Until 2030, that development and increasing consumption (35% on 2000 levels) will occur while the hydropower dams are under construction. The combined "withdrawal" of storage water for the reservoirs and for irrigation would have significant effects on wet and dry season flow.

In summary - For the "construction" period from now until 2030, tributary and Chinese hydropower dams could:

[10] MONRE, 2008, National Target Program to respond to Climate Change *(Implementing the Government's Resolution No. 60/2007/NQ-CP dated 3rd December 2007).* As of August 2008, the second draft of the NTP prepared by MONRE was before Government for approval.
[11] Draft 1 of the NTP, May 2008, section 4.8.
[12] The Manwan reservoir in Yunnan has been in operation since 1993, but its live storage is minor (250 MCM) therefore it is included with the other Chinese reservoirs

(i) Reduce dry season flows and make them more unpredictable – offsetting the benefits of increased flows due to climate change in zones 1 and 2 and compounding reduced dry season flows in the others.
(ii) Reduce wet season flows potentially reducing the increased threat of flooding due to climate change up to a defined capacity – after which more serious flooding might occur because of the need for substantial releases from many dams
(iii) Compound the trend of increasing saline intrusion in the Delta by further reducing dry season flows.

Increased extraction for irrigation could:

(i) Reduce dry season flows and make them more unpredictable – offsetting the benefits of increased flows due to climate change in zones 1 and 2 and compounding reduced dry season flows in the others.
(ii) Compound the trend of increasing saline intrusion in the Delta by further reducing dry season flows.

9.2.4 CLIMATE CHANGE EFFECTS ON DEVELOPMENT SECTORS

The projected 2030 increases in temperature, rainfall and runoff with more extreme climate events will influence the productivity of economic sectors and livelihoods.

Agriculture: Overall agricultural productivity will increase in the basin (around 3.6% by 2030) but food security will decrease, despite the increasing areas under irrigation. Those decreases are due to:

(i) Reduced dry season rainfall and runoff in central and southern zones
(ii) Increasing saline intrusion in the Delta due to storm surge and tidal influences and decreases in dry season rainfall and runoff.
(iii) Increasing populations and reduced production in excess of demand

Fisheries: Overall fish biodiversity and stability in fisheries sector production is expected to decrease in the basin despite some climate change benefits of increasing flooded area and nutrient loading. The decreases are due to the complex interplay between:

(i) Decreased agricultural productivity and food security increasing demand and pressure on fish populations
(ii) Increased riparian populations and fishing pressure
(iii) Dramatically reduced fish migration and aquatic biodiversity in zone 1 and in Mekong tributaries due to dam and infrastructure construction
(iv) Reduction of flooded forest habitat in Central Cambodia due to increased area and depth of Tonle Sap
(v) Reduced fresh water habitat in the Delta due to increased saline intrusion (not adequately offset by increases in dry season releases from upstream reservoirs during hydropower dam operational period – ie following 2030 for most projects)
(vi) Increased disturbance and destruction of fish habitat due to flooding of riverine wetlands, construction of infrastructure and pollution from expanding settlements and industry.
(vii) The benefits to productivity of increased nutrients due to increased runoff and erosion with climate change may be offset by reduced sediment due to China and tributary dams, especially in the central highlands of Vietnam.

Hydropower: Overall the hydropower sector will benefit from climate changes from increased capacity in basin catchments, but there are risks.

(i) Increased rainfall, runoff and flow throughout basin would increase potential capacity of tributaries for hydropower
(ii) Some catchments will experience very high increases in runoff and water volume – possibly beyond the capacity of existing tributary dam schemes – creating risk of failure and need for retrofitting
(iii) Increase in extreme wet events and incidence of flood events brings a risk of catastrophic failure (climate change may turn a 1 in 10,000 year flood risk into a more regular event – eg a 1 in 1000 flood?)
(iv) Dam design and retrofitting would need to take into account changing and more variable conditions of rainfall and runoff and of extreme events

Livelihoods: Aquatic and terrestrial natural systems are under increasing stress in the Mekong basin. While there are benefits, overall climate change will increase that stress by

(i) Increasing the need to make agriculture more productive and extensive and by increasing pressure to exploit aquatic resources.
(ii) Reducing fish habitat, feeding and nursery areas
(iii) Increasing water stress in some catchments and the frequency and intensity of drought periods

The negative natural systems impacts of climate change have knock-on effects on livelihood activities. Other developments, such as hydropower dams, intensify natural system stress and the negative effects of climate change.

Climate changes such as temperature and rainfall increases and increased incidence of flooding will also increase health risks which would reduce labour productivity and increase levels of poverty.

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