MEKONG RIVER COMMISSION

THE COUNCIL STUDY

The Study on the Sustainable Management and Development of the Mekong River Basin, including Impacts of Mainstream Hydropower Projects

Thematic Report on the Positive and Negative Impacts of Domestic and Industrial Water Use on the Social, Environmental, and Economic Conditions of the Lower Mekong River Basin and Policy Recommendations

(Unedited Version)

28 December 2017

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These Council Study reports are considered final drafts prepared by the technical experts and specialists of the Mekong River Commission, through a process of consultation with representatives of member countries. The contents or findings of the reports are not necessarily the views of the MRC member countries but will serve as knowledge base and reference in the work of the MRC and its member countries in their ongoing technical and policy dialogues in ensuring the sustainable development of the Mekong river basin.

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Document History

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1	0	Impact Assessment Technical Report on Domestic and Industrial Water Use	14 March 2017	Dararath YEM
2	1	Impact Assessment Technical Report on Domestic and Industrial Water Use (all sections on sand mining, including sub-scenarios and impact assessment have been completely removed as suggested by the MCs at the 8th RTWG in Ho Chi Minh)	15 April 2017	Dararath YEM
3	2	Impact Assessment Technical Report on Domestic and Industrial Water Use (Section 5: Current Status of Industrial Sector and Water Use has been updated)	15 May 2017	Dararath YEM
4	3	Impact Assessment Technical Report on Domestic and Industrial Water Use (Section 5: Current Status of Industrial Sector and Water Use has been updated; Section 8: Impact has been provided the results of the main development scenarios as well as analysis of the impact on environment, economic, and social)	15 June 2017	Dararath YEM
5	4	Impact Assessment Technical Report on Domestic and Industrial Water Use (Section 9; Section 10; and Section 11)	15 July 2017	Dararath YEM
6	5	Impact Assessment Technical Report on Domestic and Industrial Water Use (Revised & update: Section 9; Section 10; and Section 11)	27 October 2017	Dararath YEM
7	6	Finalise the report by addressing the comments from the 10th RTWG. The final report has also been revised based on the comments of the four Member Countries.	28 December 2017	Dararath Yem

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Acronyms and Abbreviations

ADB	:	Asian Development Bank
ANOVA	:	Analysis of Variance
BDP	:	Basin Development Plan
BOD	:	Biological Oxygen Demand
CNMC	:	Cambodia National Mekong Committee
COD	:	Chemical Oxygen Demand
CS	:	Council Study
DO	:	Dissolved Oxygen
ESCAP	:	Economic and Social Commission for Asia and the Pacific
FDI	:	Foreign Direct Investment
GDP	:	Gross Domestic Product
GMS	:	Greater Mekong Sub-region
IFC	:	International Finance Corporation
IQQM	:	Integrated Quantity and Quality Model
LMB	:	Lower Mekong Basin
LNMC	:	Lao National Mekong Committee
MCs	:	Member Countries
MRC	:	Mekong River Commission
MRCS	:	Mekong River Commission Secretariat
MT	:	Modelling Team
NMCs	:	National Mekong Committees
SMEs	:	Small Medium Enterprises
TNMC	:	Thai National Mekong Committee
TOTN	:	Total Nitrogen
TOTP	:	Total Phosphorus
TSS	:	Total Suspended Solid
UN	:	United Nations
VNMC	:	Vietnam National Mekong Committee
WEPA	:	Water Environment Partnership Asia
WQGH	:	Protection of Human Health
WQMN	:	Water Quality Monitoring Network

Executive Summary

Since its inception, the MRC has undertaken a number of targeted studies through its implementation programmes to inform its river basin planning and development. Adopted by the MCs of the MRC, a Basin Development Strategy 2011-2015 with a fundamental objective of the 1995 Mekong Agreement is cooperation to achieve *"the full potential of sustainable benefits to all riparian countries and the prevention of wasteful use of Mekong River Basin waters"*. This aim is complemented with the Shared Vision for "an economically prosperous, socially just and environmentally sound Mekong Basin". The Strategy defines a dynamic basin development planning process that will be reviewed and updated every five years to ensure that decision-making on water and related resources is based on up-to-date knowledge and feedback. A first update of the Strategy is expected in 2015.

Domestic and Industrial Water Use is one of the six major thematic areas that need to be studied to address the current data gaps and uncertainties in assessing the impacts of industrial development and urbanisation in the LMB. The other thematic areas are Irrigation, Agriculture and Land use, Flood Protection Structures and Floodplain Infrastructure, Hydropower, and Transportation). The results of the study will contribute to facilitating informed basin development planning in the LMB with a clear, strategic, pragmatic and actionable set of recommendations.

The main objective of the Domestic and Industrial Water Use Thematic Study is *"to estimate changes in the domestic and industrial use on water resources' conditions within the LMB associated with the three main water development scenarios considered in the Council Study"*. The purpose of this report is to present the key findings of the Domestic and Industrial Water Use Thematic Area of the MRC Council Study.

The industrial sector development and urbanisation in the four countries in the LMB have been rapidly booming in the last decade. Rapid industrialisation and urbanisation can be resulted in the pollution of water bodies in the adjacent to the development areas, where wastewater have been discharged untreated into natural water systems or leached into ambient soils. However, the degree on which the rapid industrialisation and urbanisation impact the water bodies and public health is limited. Also, the water withdrawal for industrial and domestic sectors is limited compared to other sectors. Additionally, water demand conflicts between industrial and domestic sectors and other sectors in the LMB have not been well known.

The quantitative and descriptive analysis are conducted in this report to examine the impacts resulting from the urban and industrial development of the four MCs. To assess these impacts, the following key indicators have been taken into consideration, including: (i) identification of the impacts and benefits of the domestic and industrial water use; (ii) map of large existing and planned expanding urban ad industrial centres; (iii) estimated water demand; (iv) estimated general effluent and waste water discharge; (v) highlight of any possible risks of industrial spills or similar significant impacts; (vi) estimates of both positive and negative development impacts of other sectors on domestic an industrial water use; and (vii) transboundary indicators include impact of water use and waste discharge on water quality downstream. However, the study's limitations and implications are as follows:

Three main development scenarios of domestic and industrial water use have been formulated, which include: (i) Early Development Scenario 2007 (M1); (ii) Definite Future Scenario 2020 (M2); and (iii) Planned Development Scenario 2040 (M3). The impacts of these development scenarios are also addressed and assessed in this report.

Using the scenarios and assumptions (BDP-Phase 2, 2010), national populations in 2007 ranged between approximately 5.23 million in Lao PDR and 23.08 million in Thailand, which implied a national annual population growth rate ranging between 0.40% in Lao PDR to 2.59% in Cambodia. Cambodia experienced a relatively high population growth rate (2.59%) between 2000 and 2007. The IQQM Model's simulation indicates that population will be grown by 12.49% in 2020 (M2) and 32.59% in 2040 (M3).

The total domestic water demand of the basin in 2007 was projected to be approximately 1,816.40 million m^3 with approximately 50.46% of the LMB population located in Thailand and 27.96% in Viet Nam. Cambodia and Lao PDR accounted for 12.73% and 8.85% of the LMB population in 2007. The IQQM Model's simulation indicates that the total domestic water demand in the LMB will increase by 26.61% in 2020 (M2) and 76.48% in 2040 (M3). The M2 scenario indicates that the domestic water demand of Viet Nam has highly increased by 82.71% among the other Member Countries followed by Lao PDR (64.18%) and Cambodia (45.27%). The M3 scenario shows that Lao PDR is the highest increase of domestic water demand (90.27%) followed by Cambodia (70.12%). Thailand's domestic water demand has slightly increased by 3.34% in M2 and 12.63% in M3.

The total industrial water demand of the LMB Countries has been projected to be approximately 231.80 million cubic meters in 2007 (M1). It will steadily increase by 171.48% in 2020 (M2) and 192.02% in 2040 (M3). The highest growth takes place in Viet Nam (48.53%) followed by Thailand (39.52%). However, the industrial water demand in Viet Nam remains stabilised for M2 and M3. The industrial water demand in Thailand will increase by 3.38% (M1-M2) and 12.67% (M2-M3).

The total industrial wastewater is projected to be about 175.80 million cubic meters in 2007 (M1). It will highly increase by 168.15% in 2020 (M2), but slightly increase by 8.08% in 2040 (M3). The volumes of industrial wastewater in Viet Nam is higher than those of in other countries in LMB, which is accounted for 76.60% of the total industrial wastewater producing in the LMB countries.

The volumes of the urban wastewater discharging from Vientiane and Phnom Penh are higher than the volumes of the urban wastewater releasing from other cities along the Mekong mainstream. These may be resulted from the highly increasing in number of the population for the urban areas or expanding urban areas. However, the urban wastewater may not seriously impact on water quality of the rivers since the urban wastewater passes thought wetlands or is treated by wastewater treatment plants before releasing into the rivers or streams.

The concentrations of the total nitrogen in the urban wastewater in most cities along the Mekong mainstream and tributaries (ranged from 7.41 mg/L to 13.33 mg/L) exceed a permissible treated value of the TOTN from the domestic and industrial facility to be discharged to surface water is 10 mg/L by IFC's Guidelines. These concentrations, if the urban wastewater would be released directly into the river without passing through the wetland or being treated, are much higher than required values of the MRC Water Quality Guidelines for the protection of human health, which is 5 mg/L.

Similar with the total nitrogen, the concentrations of the total phosphorus in the urban wastewater for all cities along the Mekong mainstream and tributaries (ranged from 10.37 mg/L to 18.67 mg/L) exceed, if the urban wastewater would be released directly into the river without passing through the wetland or being treated, a permissible treated value of the TOTP from the domestic and industrial facility to be discharged to surface water is 2 mg/L by IFC's Guidelines.

By assessing additional water quality parameter of chemical oxygen demand (by the MRC's WQMN data) to see whether there is a transboundary impact between Lao PDR and Cambodia, and Cambodia and Viet Nam, the analysis result revealed that there was no significantly transboundary impact associated with the water quality. The assessment of the MRC's WQMN data (TOTN and TOTP) also indicated that there was no seriously transboundary impairment to the water quality.

1 Background

Since its inception, the MRC has undertaken a number of targeted studies through its implementation programmes to inform its river basin planning and development. Adopted by the MCs of the MRC, a Basin Development Strategy 2011-2015 with a fundamental objective of the 1995 Mekong Agreement is cooperation to achieve *"the full potential of sustainable benefits to all riparian countries and the prevention of wasteful use of Mekong River Basin waters"*. This aim is complemented with the Shared Vision for "an economically prosperous, socially just and environmentally sound Mekong Basin". The Strategy defines a dynamic basin development planning process that will be reviewed and updated every five years to ensure that decision-making on water and related resources is based on up-to-date knowledge and feedback. A first update of the Strategy is expected in 2015.

The BDP Assessment of Basin-wide Development Scenarios allow the Member Countries to identify the 'development space' available for the use of basin resources based on when unacceptable environmental and social repercussions set in. Based on expert opinion estimates, it assessed several scenarios over a 50-year timeframe including broad-based developments in the tributaries, the mainstream and the Lancang River providing a useful tool for the four Member Countries to plan their development initiatives in the basin. However, considering the broad-based approach, it does not provide significant resolution on the impacts of large-scale projects planned or already underway in the mainstream of the Lower Mekong Basin. Considering the urgency of understanding the sectoral, cross cutting and cumulative impacts of these impending developments, the Council Study will be conducted to close this gap.

Domestic and Industrial Water Use is one of the six major thematic areas that need to be studied to address the current data gaps and uncertainties in assessing the impacts of industrial development and urbanisation in the LMB. The other thematic areas are Irrigation, Agriculture and Land use, Flood Protection Structures and Floodplain Infrastructure, Hydropower, and Transportation). The results of the study will contribute to facilitating informed basin development planning in the LMB with a clear, strategic, pragmatic and actionable set of recommendations.

The economic development in the Lower Mekong Region has been rapidly growing, of which the industrial sector is quite modest. North-eastern Thailand and the Mekong Delta have been reported as the most advanced industrial areas in the region[1]. Thailand is one of the world's major primary products and agro-industrial producers. In 2010, the industrial sector contributed about 45.6 percent to the country's GDP and employed 19.7 percent of the total workforce[2]. Automobile is one of the most important industries, and so does electronics.

In 2012, the industrial sector in Viet Nam contributed to the country's GDP about 41.4 percent[3], which was accounted for more than one third of the country's GDP. The heavy industrial facilities are mostly located in the north while the medium- and light-size factories

[1] Industrial water use prepared by the Basin Development Plan of the MRC Programme in 2002 (p. 1)
[2] Economy Watch, extracted on 10 January 2014
[3] Data from Global Finance's website (www.gfmag.com), extracted on 13 January 2014

are mainly situated in the south (the Mekong Delta). The factories located in the Mekong Delta include agro-industries, breweries, canneries, and aqua-food processing industries.

The industrial sector in Lao PDR has been booming since 1996, which has played an increasingly important role in the country economy, growing from 15.4 percent in 2000 to 34.8 percent in 2012[4]. The large- and middle-size factories are mainly located in Vientiane Municipality.

In 2012, the industrial sector in Cambodia contributed to the country's GDP about 22 percent[5], which slightly increased compared to the year of 1999 (20.4 percent[6]). Most manufacturing is situated in Phnom Penh along the Tonle Sap River and the Bassac River. Water demand by industrial and domestic sectors significantly varies by country. In 2002, the water demand for the industrial sector was estimated about 0.5 percent, 5.7 percent, 4.8 percent, and 24.1 percent for Cambodia, Lao PDR, Thailand, and Viet Nam respectively[7].

The industrial sector development and urbanisation in the four countries in the LMB have been rapidly booming in the last decade. Rapid industrialisation and urbanisation can be resulted in the pollution of water bodies in the adjacent to the development areas, where wastewater have been discharged untreated into natural water systems or leached into ambient soils. However, the degree on which the rapid industrialisation and urbanisation impact the water bodies and public health is limited. Also, the water withdrawal for industrial and domestic sectors is limited compared to other sectors. Additionally, water demand conflicts between industrial and domestic sectors and other sectors in the LMB have not been well known.

2 Objective and Scope of the Study

2.1 Objective of the Study

The main objective of the Domestic and Industrial Water Use Thematic Study is *"to estimate changes in the domestic and industrial use on water resources' conditions within the LMB associated with the three main water development scenarios considered in the Council Study"*. The purpose of this report is to present the key findings of the Domestic and Industrial Water Use Thematic Area of the MRC Council Study.

2.2 Scope of the Study

The scope of this thematic study will include the following main activities:

- Review and analyse existing domestic and industrial sector development plans;

[4] Data from Global Finance's website (www.gfmag.com), extracted on 13 January 2014
[5] Data from Global Finance's website (www.gfmag.com), extracted on 13 January 2014
[6] Data from Royal Government of Cambodia, Second Five Year Socioeconomic Development Plan 2001-2005 (p. ii)
[7] Economic and Social Commission for Asia and the Pacific (ESCAP), Statistic yearbook for Asia and the Pacific 2011, extracted from http://www.unescap.org/stat/data/syb2011/ii-environment/water-availability-and-use.asp on 14 January 2014

- Assess domestic and industrial water consumption;
- Identify key impacts resulting from industrialisation and urbanisation development;
- provide clear, strategic, pragmatic and actionable set of recommendations; and
- Coordinate with and support activities of the other Council Study thematic and discipline teams.

Three main development scenarios of domestic and industrial water use will be addressed and assessed in this report, which include as follows:

- Early Development Scenario 2007: This scenario aims at estimating physical/socio-economic conditions as of 2007.
- *Definite Future Scenario 2020:* This scenario aims at projecting physical/socio-economic conditions as of 2020 in order to examine the impacts of developments already in place, under construction or for which commitments have been made to proceed with the development.
- Planned Development Scenario 2040: This scenario comprises the development plans for each country over the next 20 years and aims at projecting physical/socio-economic conditions as of 2040.

3 Domestic and Industrial Water Use Thematic Outputs

The main output of this team is *"Thematic Report on Impacts and Benefits of Domestic and Industrial Water Use in the Lower Mekong River Basin including Recommendations for Impact Avoidance and Mitigation Measures."* This report will contain an updated map of large existing and planned and expanding urban and industrial centres within the basin, estimate water demand over the period covered by the Council Study, estimate general effluent and waste water discharge and highlight any possible risks of industrial spills or similar significant impacts. The report will further provide an estimate of the impact (positive or negative) of development in other sectors on domestic and industrial water use.

The study will cover 2007, 2020 and 2040 Development Scenarios.

As stated above, the key indicators for the Thematic Study are:

- Identification of the impacts and benefits of the domestic and industrial water use;
- Updated map of large existing and planned expanding urban ad industrial centres;
- Estimated water demand for 2007;
- Estimated general effluent and waste water discharge;
- Highlight of any possible risks of industrial spills or similar significant impacts; and
- Estimates of both positive and negative development impacts of other sectors on domestic an industrial water use.

Transboundary indicators include impact of water use and waste discharge on water quality downstream.

Environmental indicators include water quality changes in the mainstream and impact corridor and impacts on biodiversity, wetlands, etc.
Socio-economic indicators include:

- Impacts and benefits of the domestic and industrial water use; and
- Impact of effluent discharge.

4 Current Status of Domestic Water Use

Based on the BDP-Phase 2 (2010), national populations in 2000 ranged between approximately 5 million in Lao PDR and 22.27 million in Thailand (Figure 1), and between 5.23 million and 23.08 million in 2007. These numbers imply a national annual population growth rate ranging between 0.40% in Lao PDR to 2.59% in Cambodia. Cambodia experienced a relatively high population growth rate (2.59%) between 2000 and 2007. Table 1 presents the population and water consumption per capita in each country.

Table 1: Population and Water Demand per capita in each Mekong Country

Country	Population (Person)		Average per Capita Use (litter/day)		Data Sources
	2000	2007	2000	2007	
Cambodia	10,830,483	12,953,880	32	90	– Cambodia Development Resources Institute – Capacity Building for Water Supply System in Cambodia Phase 2
Lao PDR	4,965,300	5,232,905	64	Rural: 60 Town: 140 Urban: 180	– Department of Statistics – Water Supply Authority (WASA)
Thailand	22,270,914	23,079,129	115	140	– Department of Provincial Administration – Provincial Waterwork Authority
Viet Nam	18,133,661	18,652,986	67	120	– Provincial Statistic Year books (2008) – Country verification
Total	**56,200,358**	**59,918,900**			

Source: BDP-Phase 2, 2010

The population domestic water consumption data were compiled during the BDP-Phase 2 and suggested by the Member Countries to be used as inputs for IQQM Model to project/estimate the population and water consumption. The team has however used additional data from United Nations and National Census to project/estimate the population, and water consumption and demand in the LMB. The projection of population is presented in Figure 2 below.

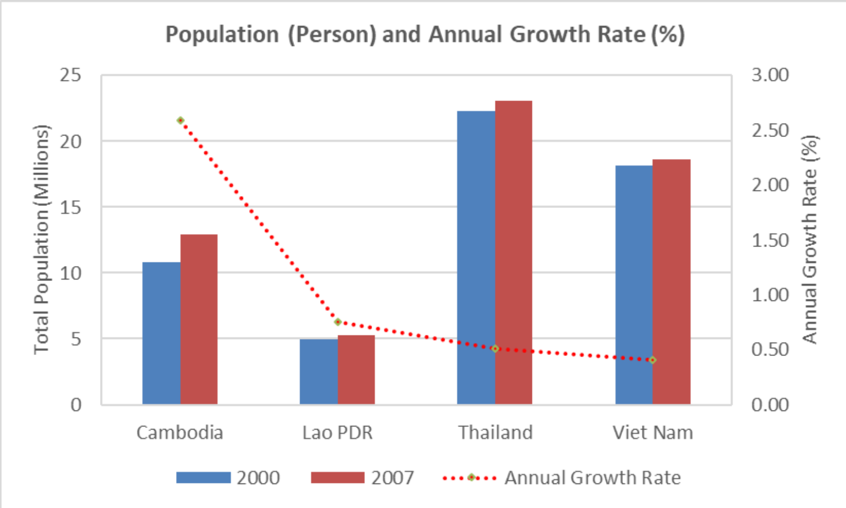


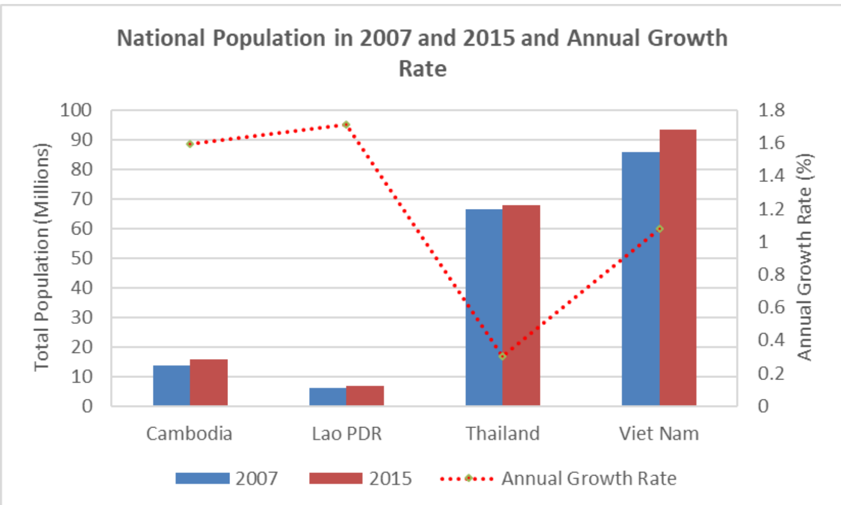
Figure 1: National Population (person) in 2000 and 2007 and Annual Growth Rate (%)

The team firstly uses the national population projections presented in the UN World Population Prospects of 2015 (UN, 2015). The national populations in 2007 range between approximately 5.93 million in Lao PDR and 85.77 million in Viet Nam (Table 2), and between 6.80 million and 93.45 million in 2015. These numbers imply a national annual population growth rate ranging between 0.30% in Thailand to 1.71% in Lao PDR. Similar with the BDP-Phase 2, Cambodia still experienced a relatively high population growth rate between 2007 and 2015.

Table 2: Total National Population (Person) across the Countries

Country	Population 2007	Population 2015	Implicit Annual Growth Rate over the Period (%)
Cambodia	13,728,700	15,577,899	1.592
Lao PDR	5,939,634	6,802,023	1.709
Thailand	66,353,572	67,959,359	0.299
Viet Nam	85,770,717	93,447,601	1.077

Source: United Nations, 2015



Source: United Nations, 2015

Figure 2: National Population (person) in 2007 and 2015 and Annual Growth Rate

However, according to the most recent World Population Prospects published by the United Nations (2015), national populations in 2007 range between approximately 5.94 million in Lao PDR and 85.77 million in Viet Nam (Figure 2), and between 6.80 million and 93.4 million in 2015. These numbers imply a national annual population growth rate ranging between 0.30% in Thailand to 1.71% in Lao PDR. Cambodia also experienced a relatively high population growth rate (1.6%) between 2007 and 2015.

5 Current Status of Industrial Sector and Water Use

5.1 Cambodia

According to the Cambodia Industrial Development Policy for 2015-2025 (2015), the Cambodian industry remains weak as reflected by its simple structure, narrow base and low level of sophistication, of which most of them are garment and food processing industries. Most production activities are family-based with lack of entrepreneurship and inadequate use of technology. Its key characteristics can be summarized as follows: a narrow industrial base, missing middle and informal industrial structure, weak and urban-centred entrepreneurship, low value addition and low level of technology application.

Narrow industrial base consists of three important activities, including garment production, construction and food and beverage processing. The garment sector played an important role in the industrial sector with its share jumping from a mere 8.2% in 1993 to 51.8% in 2004, the year of its highest growth. Subsequently, it slightly declined down to 42.4% in 2013. The construction sector, which represented 30% share of the industrial sector in 1993, had dramatically declined to its lowest level of 20.2% in 1998, but had rebounded back to 30.1% in 2013. Food processing continuously declined from 32.7% in 1993 to around 10% during the last 5 years.

Table 3: Types of Factories and Number of Employees in provinces located in the LMB

Cambodia	Garment Factory	Plastic Factory	Shoe Factory	Others	Total	No. of Employee
Banteay Meanchey	3	0	0	10	13	4,081
Battambang	0	1	1	7	9	2,401
Kampong Cham	5	0	5	14	24	14,922
Kampong Chhnang	11	0	3	5	19	16,641
Kampong Speu	43	3	9	30	85	68,883
Kampong Thom	0	0	0	4	4	567
Kampot	4	0	2	7	13	4,401
Kandal	135	6	15	70	226	181,069
koh Kong	1	0	0	4	5	3,464
Kratie	0	0	0	4	4	802
Mondul Kiri	-	-	-	-	-	-
Otdar Meanchey	-	-	-	-	-	-
Pailin	-	-	-	-	-	-
Phnom Penh	448	30	49	194	721	490,328

Cambodia	Garment Factory	Plastic Factory	Shoe Factory	Others	Total	No. of Employee
Preah Sihanouk	15	0	5	52	72	24,031
Preah Vihear	0	0	0	2	2	701
Prey Veng	0	0	0	2	2	146
Pursat	1	0	0	0	1	2,329
Ratanak Kiri	0	0	0	3	3	277
Siem Reap	0	0	0	2	2	177
Stung Treng	-	-	-	-	-	-
Takeo	19	0	7	4	30	28,984
Tonle Sap Lake	-	-	-	-	-	-
Total	**685**	**40**	**96**	**414**	**1,235**	**844,204**

Note: (-) No data
Source: datasheet provided by the national consultant, 2014

Approximately 97.3% of enterprises of *missing middle and informal industrial structure* are in the form of microenterprises, followed by 2.2% and 0.6% for SMEs and large enterprises respectively. Among these enterprises, 91.7% of them are in manufacturing.

Weak entrepreneurship is reflected by the structure of ownership and the fact that they are still in their early stage. Almost half of the total enterprises (42%) that have currently been operating in Cambodia were established since 2008, and even with the counting going back to 2003, the number of newly established enterprises have reached 68.39%. Similar situation applies in each industrial sub-sector.

The Cambodian industry is labour-based focusing on certain labour intensive and unsophisticated production chain. The majority of domestic enterprises focus only on food processing and semi-finished products with generally *low level of technology* usage. Low productivity is the main cause explaining why the majority of manufacturing sector serves only domestic consumption with *low value-added products*.

Table 4: Provincial Shares of Industrial Water Pollutants (kg)

Province	BOD	TSS	Total
Phnom Penh	517,865	16,579,797	17,097,662
Takeo	57,509	2,433,193	2,490,702
Kandal	96,496	1,894,238	1,990,734
Kratie	415	933,678	934,093
Kampong Cham	31,968	106,427	138,395
Stung Treng	794	60,178	60,972
Others	453,207	5,719,579	6,172,786
Total	**1,158,254**	**27,727,090**	**28,885,344**

Source: GMS Environment Operations Centre, 2016a.

Approximately 83.56% of the total factories is located in one city and two provinces: Phnom Penh, Kandal, and Kampong Speu (Table 3). Phnom Penh City accounts for more than half of all factories (58.38%). Garment, Knitting Apparel, and Cloth Embroidery represent approximately 55.47% of the total factories. Similarly, Phnom Penh represents more than half (58.08%) of all industrial employment.

According to the GMS Environment Operations Centre (2016a), the industrial water pollutants in Phnom Penh accounted for 59.19% of total discharges of water pollutants followed by Takeo 8.62% and Kandal province 6.89%). Table 4 provides the discharges of water pollutants for each province in Cambodia.

5.2 Lao PDR

As all provinces of Lao PDR fall into the LMB, the description below covers all of Lao PDR. In a recent study by GMS Environment Operations Centre (2016b) provides a description of manufacturing activity in Lao PDR based on a 2014 dataset of 4,881 enterprises in the manufacturing sect[8]. Grain mill products, furniture, and soft drinks represent approximately 40% of all enterprises in Lao PDR (Table 5).

While the *"grain mill products"* sector represents 18.05% of all enterprises in the country (881 enterprises), this same sector represents only 4.28% of all industrial employment. On the other hand, while *"wearing apparel"* represents only 5.12% of all enterprises, this sector represents 27.24% of all industrial employment. Approximately 56% of all enterprises are located in 3 provinces: Vientiane Capital, Savannakhet, and Bolikhamxai. Vientiane Capital accounts for 32.8% of all enterprises.

Table 5: Industrial Activities in Lao PDR (2014)

Name of Industrial Sector	Number of Enterprise	Number of Employees
Grain mill products	881	4,263
Furniture and fixtures (non-metal)	627	10,430
Soft drinks and carbonated waters industries	515	4,361
Non-metallic mineral products	348	4,184
Sawmills, planing and other wood mills	306	8,725
Structural clay products	294	3,024
Wearing apparel, except footwear	250	27,154
Wood and cork products	237	5,162
Dairy products	149	
Food product	130	1,802
Slaughtering, preparing and preserving meat	130	
Iron and steel basic industries	103	1,743
Tobacco manufactures	83	1,444
Spinning, weaving and finishing textiles	80	2,405
Bakery products	66	
Basic industrial chemicals except fertilizers	63	1,630
Non-ferrous metal basic industries	60	1,512
Plastic products not elsewhere classified	53	1,546
Glass and glass products	52	
Cement, lime and plaster		1,615

[8] The original database comprised a total of 12,172 enterprises. All entries reporting 1 or 2 employees were removed from the final dataset.

Name of Industrial Sector	Number of Enterprise	Number of Employees
Motorcycles and bicycles		1,389
Radio, television and communication equipment		1,282
Malt liquors and malt		1,189
Footwear		1,153
Printing, publishing and allied industries		1,008
Others combined	454	12,665
Total	**4,881**	**99,686**

Note: Cells without entry represent less than 1% of the total number of enterprises or of the total number of employees.

Source: GMS Environment Operations Centre, 2016b.

Estimates of water use by the industrial sector remains limited in number. According to WEPA (2012), agriculture consumed 82% of all water usage in Lao PDR and industry consumed 10% of all water consumption. On the other hand, according to World Bank (2007), an estimated 90% of water usage was used for agricultural purpose, while domestic and industrial sectors used approximately 4% and 6% respectively. It should be noted that the total water usage was significantly different in these two publications.

Table 6: Discharges of Water Pollutants by Provinces (Kg)

Province	BOD	TSS	Total
Vientiane Capital	1,113,979	19,030,636	20,144,615
Savannakhet	542,424	5,397,426	5,939,850
Khammuane	388,940	3,901,579	4,290,519
Borikhamxay	91,575	4,011,432	4,103,007
Huaphanh	615,785	1,801,260	2,417,045
Vientiane	184,920	1,308,273	1,493,193
Others	1,134,372	4,904,461	6,038,833
Total	**4,071,995**	**40,355,067**	**44,427,062**

Source: GMS Environment Operations Center, 2016b.

5.3 Viet Nam

In 2008, the value of industrial production in Mekong Delta reached 191,435 billion VND which shared up 9.13% of industrial production value for whole country. The restructuring of industrial production value does not increase much in some provinces. The provinces with high proportion are Can Tho, Long An, Dong Thap, and Vinh Long.

The leading industry is the processing industry, which develops gradually over the period surveyed, especially in the process of making agricultural, forest products, and seafood with over 60% of industrial production value. The manufacturing industry and electrical-water supply systems are focused to develop with the average annual growth at 6%, which made up 2% of production value in the whole field. By the end of 2008, the entire Mekong Delta region has 45 industrial parks with a total area of 10,239 ha (Figure 3) and 67 industrial clusters with a total area of 4,791 ha (Figure 4). Long An province consists of largest area of industrial parks (16 industrial parks with 3,984 ha) and clusters (11 industrial cluster with

806 ha). The Central Highland region has 7 industrial parks with a total area of 902 ha and 20 industrial clusters with a total area of 1,033 ha.

Table 7: Area and Number of Industrial Park and Cluster in the Mekong Delta in 2020

No.	Province	Industrial Park 2020			Industrial Cluster 2020		
		Number (park)	Area (ha)	Filled Area (ha)	Number (cluster)	Area (ha)	Filled Area (ha)
1	Long An	31	10,749	7,370	32	2,073	1,192
2	Tien Giang	7	2,083	937	36	1,500	688
3	An Giang	9	795	398	15	477	233
4	Bac Lieu	6	1,696	962	7	360	209
5	Ben Tre	8	1,602	1,112	14	533	274
6	Ca Mau	4	1,346	808	4	565	293
7	Vinh Long	6	1,584	805	14	794	416
8	Dong Thap	9	1,666	1,186	18	1,001	562
9	Tra Vinh	6	2,994	2,096	13	508	234
10	Can Tho	11	4,149	2,875	6	165	102
11	Soc Trang	6	1,106	564	19	769	391
12	Hau Giang	2	2,001	1,201	8	1,357	780
13	Kien Giang	6	3,959	1,386	13	845	425
	Total	**111**	**35,731**	**21,698**	**199**	**10,947**	**5,799**

Source: Report on Domestic and Industrial Water Use Thematic Team (Vietnam Team), 2015.

Table 8: Area and Number of Industrial Park and Cluster in Central Highland in 2020

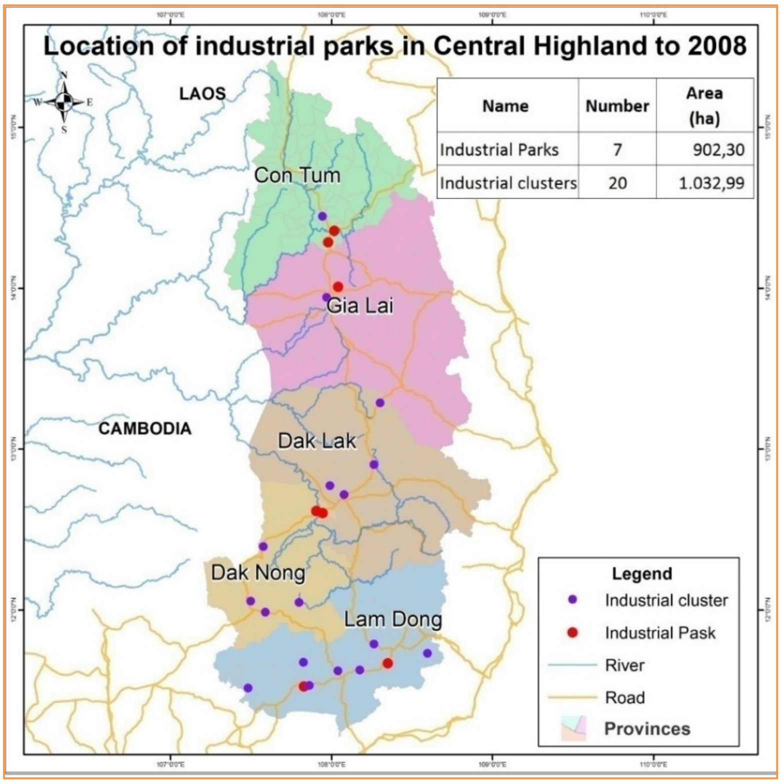
No.	Province	Industrial Park 2020			Industrial Cluster 2020		
		Number (park)	Area (ha)	Filled Area (ha)	Number (cluster)	Area (ha)	Filled Area (ha)
1	Dak Lak	1	182	146	8	375	238
2	Dak Nong	2	281	220	8	429	251
3	Gia Lai	5	709	555	9	270	118
4	Con Tum	4	630	492	7	476	216
5	Lam Dong	4	1,288	938	15	750	396
	Total	**16**	**3,090**	**2,351**	**47**	**2,300**	**1,219**

The National Vietnamese Team Report demonstrated that the speed of growth of industrial added value reached 15.12% during the period of 2011 – 2015 and 14.18% during the period of 2016 – 2020 respectively. The speed of growth of industrial production value reached 17.55% and 15.86% during the periods of 2011 – 2015 and 2016 – 2020 respectively.

Based on the National Vietnamese Team Report, the entire Mekong Delta region will consist of 111 industrial parks with a total area of 35,731 ha and 199 industrial clusters with an area of 10,947 ha by 2020 (Table 7). Long An province consists of largest area of industrial parks (31 industrial parks with 10,749 ha), and Tien Giang province has the largest area of industrial cluster (36 industrial cluster). The locations of industrial parks in Viet Nam's Mekong Delta in 2020 is presented in Figure 5.

Source: Report on Domestic and Industrial Water Use Thematic Team (Vietnam Team), 2015.

Figure 3: Location of Industrial Parks in Viet Nam's Delta in 2008

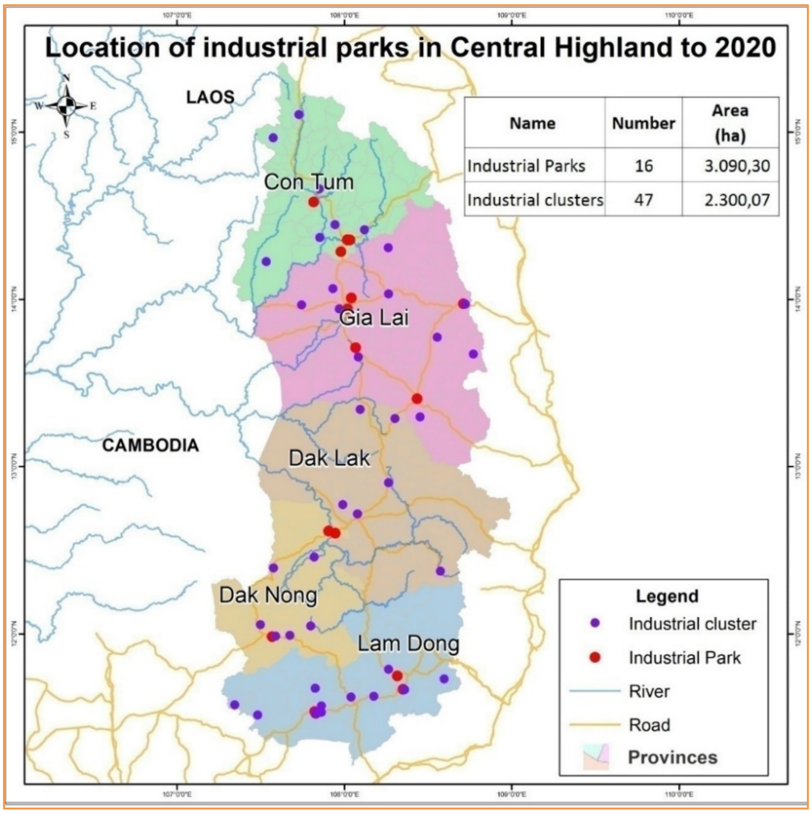


Source: Report on Domestic and Industrial Water Use Thematic Team (Vietnam Team), 2015.

Figure 4: Location of Industrial Parks in Viet Nam's Central Highland in 2008

Source: Report on Domestic and Industrial Water Use Thematic Team (Vietnam Team), 2015.

Figure 5: Location of Industrial Parks in Viet Nam's Delta in 2020



Source: Report on Domestic and Industrial Water Use Thematic Team (Vietnam Team), 2015.

Figure 6: Location of Industrial Parks in Viet Nam's Central Highland in 2020

The Central Highland has 16 industrial parks and 47 industrial clusters with a total area of 3,090 ha and 2,300 ha respectively by 2020 (Table 8). The Gia Lai province has a largest filled area rate (88%). Dak Nong province consists of largest filled area rate (93%). The locations of industrial parks in Viet Nam's Central Highland in 2020 is presented in Figure 6.

6 Current Status of Water Quality in the Mekong River

The MRC Water Quality Technical Guideline for protection of human health is intended to maintain the ambient water quality of the Mekong mainstream for domestic purposes and primary human contact. The main concern for water quality for domestic purposes and primary human contact is the protection of public health. However, the risk to human health does not only originate from the direct use of the river water but also from the use of other river derived resources for consumption, such as: fish and other aquatic products providing additional vectors for human exposure to waterborne diseases.

The MRC Water Quality Technical Guideline is used as a decision support tool for management by the Member Countries to maintain good/acceptable water quality of the Mekong mainstream. The users include decision makers, water quality managers, and any other stakeholders who have an interest to maintain good/acceptable water quality to protect human health. Furthermore, it is made available to the general public of the Member Countries as a guidance document on water quality management, providing a valuable source of information on different aspects of water quality and water management.

The approach used to select the water quality criteria is primarily based on the water quality criteria selected by the Member Countries for their national water quality guidelines and water quality standards. In addition, regional, international guidelines, research, and experience from Member Countries are considered to develop the set of guidelines and criteria which is appropriate for the Mekong River Basin. The selected criteria shall be based on a consensus of the Member Countries. The objective of the approach is to ensure consistency and to avoid confusion that can arise when different criteria and guidelines are applied by different stakeholders in the Mekong River Basin.

Table 9: MRC Water Quality Guidelines

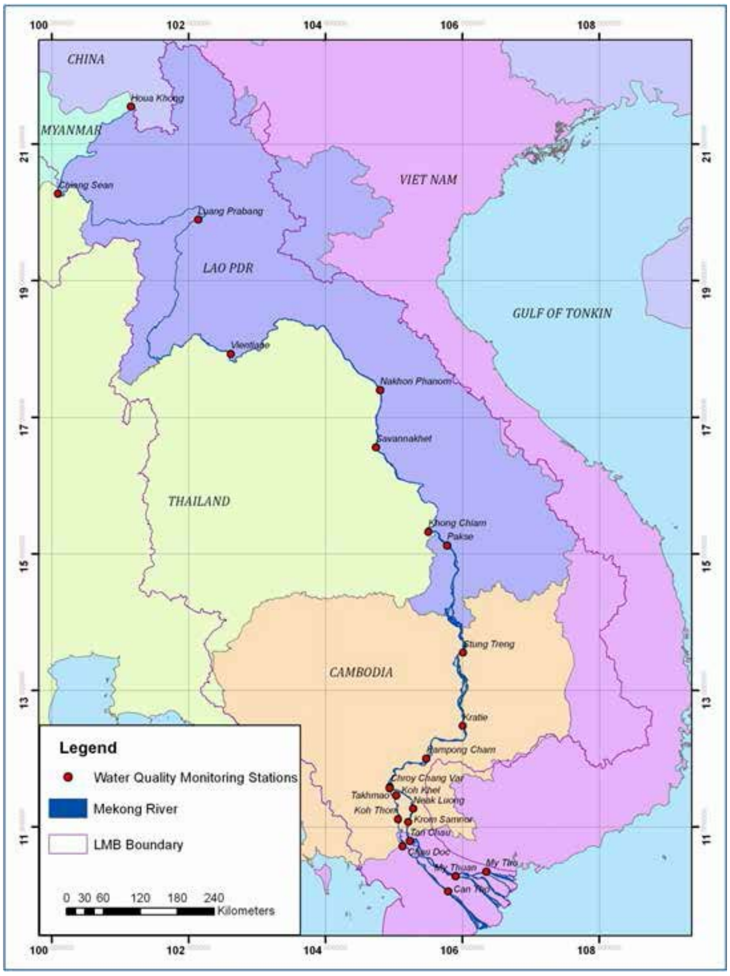
Parameters	Unit	Protection of Human Health	Protection of Aquatic Life
Temperature	^{o}C	Natural	Natural
pH	-	6 - 9	6 -- 9
TSS	mg/L	-	-
TOTN	mg/L	5	-
TOTP	mg/L	-	-
BOD_5	mg/L	4	3
COD	mg/L	5	-
DO	mg/L	≥ 6	> 5

Source: MRC, 2012

Table 9 provides criteria and target value for the protection of human health and aquatic life in the Mekong River Basin.

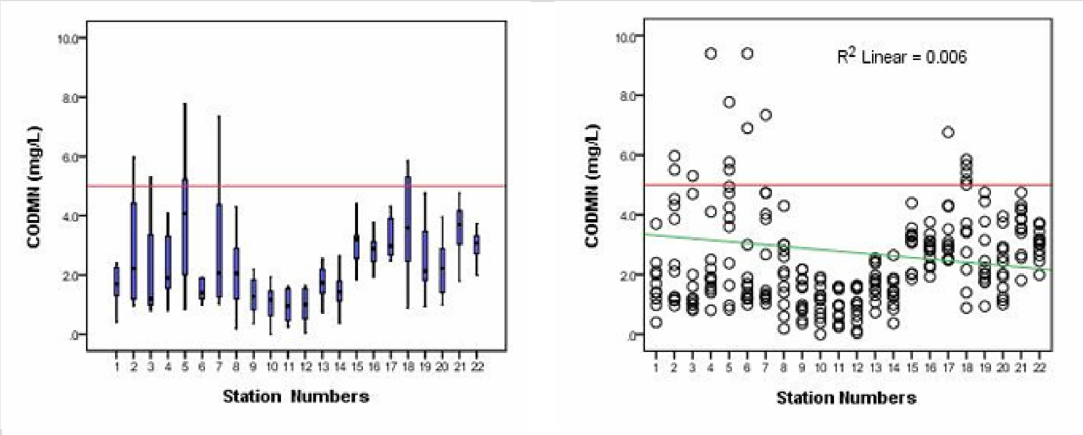
The MRC's Water Quality Monitoring Network (WQMN) has been monitoring the water quality of the Mekong mainstream and major tributaries. Forty-eight stations have been monitored by it, of which 11 stations were located in Lao PDR, 8 stations in Thailand, 19 stations in Cambodia, and 10 stations in Viet Nam. The locations of the water quality station in the LMB and Bassac river are illustrated in Figure 7. Details of sampling techniques and selected parameters were provided in the annual water quality monitoring report by MRC. All recorded data were assessed against the MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life.

According to the MRC (2016a), chemical oxygen demand (COD) concentration of seven stations in the Mekong River in 2014 exceeded the MRC Water Quality Guidelines for the Protection of Human Health of 5 mg/L. These stations were Chiang Saen, Nakhone Phanom, and Khong Chiam (Thailand); and Houa Khong/Xieng Kok, Luang Prabang, Vientiane, and Savannakhet in Lao PDR.



Source: MRC, 2016a

Figure 7: Water quality monitoring stations of the MRC WQMN in the Mekong and Bassac Rivers



Source: MRC, 2016a

Note: Horizontal line at 5 mg/L represents threshold values for the MRC Water Quality Guidelines for the Protection of Human Health

Figure 8: Spatial variation in COD (mg/L) at 22 stations along the Mekong (1-17) and Bassac (18-22) Rivers in 2014

The maximum concentration of COD was recorded in Houa Khong Station at 65.0 mg/L. Mean COD concentration in the Mekong River for 2014 was 2.7 mg/L compared to a historical mean COD concentration of 2.2 mg/L between 1985 and 2013. However, the mean COD concentration in the Bassac River in 2014 was 3.0 mg/L compared to the historical mean value of 3.4 mg/L from 1985 to 2013. The maximum COD concentration of 5.9 mg/L was recorded at Takhmao, Cambodia.

The spatial variations in COD along the Mekong and Bassac Rivers in 2014 are shown in Figure 8. The spatial variations observed for COD were high for certain stations, including Nakhon Phanom (5) and Khong Chiam (7). At Nakhon Phanom monitoring station, COD concentrations varied from 0.8 to 7.8 mg/L, with the mean concentration of about 3.9 mg/L. Similarly, at Khong Chiam, COD concentrations varied from 1.0 to 7.3 mg/L, with the mean concentration of about 2.9 mg/L.

Nine water quality monitoring stations in the Mekong and Bassac Rivers recorded COD levels above the MRC Water Quality Guidelines for the Protection of Human Health (WQGH) (5 mg/L). In comparison, the analysis of 2013 COD data reveals that 12 water quality monitoring stations reported COD values higher than the threshold value of the MRC WQGH (5 mg/L). No COD threshold value has been set for the MRC Water Quality Guidelines for the Protection of Aquatic Life.

7 Scenario Impact Assessments

7.1 Scenario Assessment

The impacts of the three main development scenarios of domestic and industrial water use will be addressed and assessed in this report. As mentioned in previous section above, the main three main development scenarios of the domestic and industrial water use are as follows:

- Early Development Scenario 2007;

- Definite Future Scenario 2020; and
- Planned Development Scenario 2040.

The industrial sector development and urbanisation in the four countries in the LMB have been rapidly booming in the last decade. The domestic and industrial water use has however minor impact, in terms of quantity, compared with other development activities in the LMB. Their volumes are also quite small compared to the Mekong Mainstream flow. Yet, rapid industrialisation and urbanisation can be resulted in the pollution of water bodies in the adjacent to the development areas, where wastewater have been discharged untreated into natural water systems or leached into ambient soils.

7.2 Assessment Indicators

The key indicators for the Domestic and Industrial Water Use Thematic Area are classified into three categories as follows:

Figure 9: Strategic and Assessment Indicators for the Domestic and Industrial Water Use

Strategic Indicators	Assessment Indicators	Explanations
Environmental	Domestic/urban water consumption and demand	Estimate of water consumption and demand by the individuals who live in the urban areas and industrial sector
	Industrial water demand	Estimate of industrial water demand
	Urban wastewater	By using the formula in Section 8.3, the urban population and wastewater have been projected in M2 & M3
	Industrial wastewater	By using the IQQM Model, the industrial water demand and wastewater in M1, M2, and M3 have been projected
	Water quality conditions in mainstream	By calculating the formula in Section 8.3, total nitrogen and total phosphorus have been estimated and used as polluted parameters to assess the water quality in the mainstream arising from the expansion of urbanisation and development of industrial sector in the LMB. Additionally, impacts of urban and industrial wastewater discharge into the river on water quality downstream have also been assessed. Furthermore, other pollutants used by the MRC's Water Quality Monitoring Network have also been used to compare between the modelling results and monitoring results to see the negative impacts on water quality.
	Water quality conditions in tributaries	By calculating the formula in Section 8.3, total nitrogen and total phosphorus have been estimated and used as polluted parameters to assess the water quality in the tributaries arising from the expansion of urbanisation and development of industrial sector in the LMB. Similar with the mainstream, additional impacts of urban and industrial wastewater discharge into the tributaries on water quality

		downstream have also been assessed. Furthermore, other pollutants used by the MRC's Water Quality Monitoring Network have also been used to compare between the modelling results and monitoring results to see the negative impacts on water quality.
Economic	Employment	The employment by industrial sector has been explored
Social	Changes in population in urban	Estimate of population in the LMB by each country and in major urban areas located along the Mekong mainstream and tributaries have been estimated and projected in M1, M2 & M3.
	Water security	The water security relating to access to safe water supplies, water availability for domestic has been explored and covered by the Socio-economic Assessment Disciplinary Team.

7.3 Impact Assessment Methodology and Data Availability

Population data of the BDP-Phase 2 has been used in this report. However, the national population census and UN data are also analysed to make the comparison.

The IQQM Modelling has projected data on (i) domestic water demand; (ii) industrial water demand; and (iii) industrial wastewater.

Due to insufficiently industrial data from most Member Countries, the industrial water demand was estimated from percent of domestic water demand in year 2007. The IQQM Modelling thus projected the industrial water demand and wastewater for M1, M2, and M3.

Amount of domestic wastewater has been estimated based on the population living in the cities along the mainstream and tributaries of the Mekong River. The total nitrogen and total phosphorus containing in the domestic wastewater have been calculated based on the projected population growth as inputs for eWater Source Modelling by the Modelling Team of the Council Study.

According to the BDP-Phase 2, the urban water consumptions differed from country to country. The water consumptions (litre per capita per day) in urban areas in 2007 were 100, 180, 105, and 100 for Cambodia, Lao PDR, Thailand, and Viet Nam respectively. The urban wastewater is calculated using the following formula:

$$Q_{ww} = KqP$$

Where:

- K is 0.9 for all cities in MB
- q is water consumption (litre/person/day)
- P is number of population in urban area (person)

The MRC's Modelling Team has assumed that amount of total nitrogen and total phosphorus containing in various products consumed by each person per day are 8g and

2.4g respectively. The amounts of total nitrogen and total phosphorus load to sewer per person per day are calculated by using the following formulas

$$TOTN = K_n P(1 - \frac{85}{100})$$

Where:

- K_n is 8g/person/day (consumed total nitrogen containing in consumed products
- P is number of population in urban area (person)

$$TOTP = K_p P(1 - \frac{30}{100})$$

Where:

- K_p is 4g/person/day (consumed total nitrogen containing in consumed products
- P is number of population in urban area (person)

Industrial locations and numbers of Cambodia were obtained from the national consultants, while the industrial locations and number of Lao PDR were secondary data from various sources. Data on industrial locations and numbers of Viet Nam were received from the national consultant of Viet Nam. Missing data on industrial locations and number of Thailand.

The approaches for the impact assessment for the domestic and industrial water use include as follows:

a) Identification of the impacts and benefits of the domestic and industrial water use:

- Develop a list for possible impacts (e.g. eutrophication) and benefits;
- Assessment transboundary, environmental, social, and economic importance of the listed items; and
- Use discipline teams to support the assessment (value of good quality drinking water by the Socio-economic team).

b) Updated map of large existing and planned expanding urban ad industrial centres:

- Update the urban area map prepared by the Modelling Team with the main industrial centre data; size of the industrial centre markers indicates water use;
- Use 2020 and 2040 urban population projection data to expand urban areas assuming population density remains the same; and
- Use 2020 Vietnam industrial data to update the 2020 map.

c) Estimate of water demand and effluent discharge:

- This will be produced based on the thematic data and Modelling Team data gap filling; and
- Nutrients from aquaculture need to be estimated with the help of fisheries experts (BioRA, MRC).

d) Highlight of any possible risks of industrial spills or similar significant impacts:

- Use information on type and size of industries to assess possible quality and quantity of possible spills;
- Assess risk of industrial spills on drinking water, irrigation, livestock, aquaculture, fisheries and environment; and
- In the assessment use information from other thematic and discipline teams.

e) Impacts of effluent discharge:

- Assess risk of eutrophication including toxic algal blooms caused by the effluent discharges;
- Use Modelling Team water quality and impact modelling data as well as support from BioRA; and
- Assess impact on drinking water, livestock, fisheries, aquaculture, and environment.

f) Estimates of both positive and negative development impacts of other sectors on domestic an industrial water use:

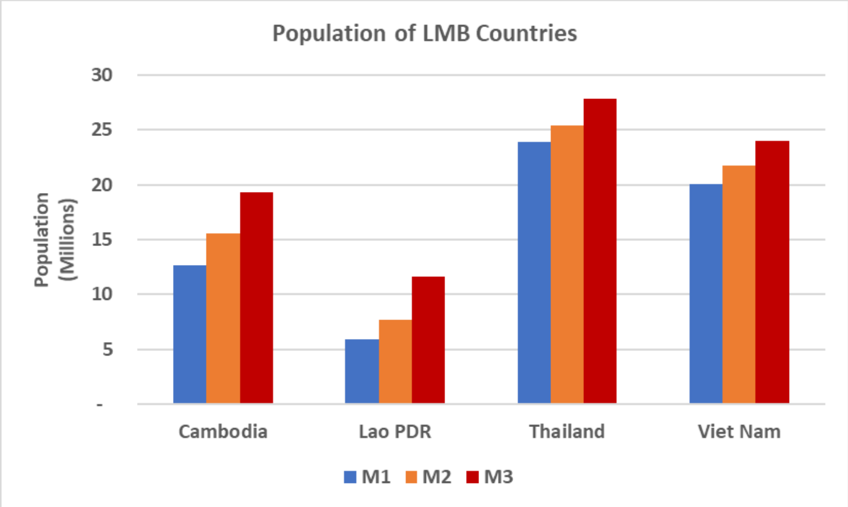
- Identify possible impacts, e.g. hydropower impacts on drinking water quality;
- Assess risk levels; and
- Assess benefits and costs.

7.4 Domestic Water Demand and Wastewater

The IQQM Modelling has been projecting the population and water use from provincial level.

In 2007, the total population of the basin is projected to be approximately 62.50 million with approximately 38.18% of the LMB population located in Thailand and 32.14% in Viet Nam. Cambodia and Lao PDR accounted for 20.28% and 9.40% of the LMB population in 2007 (Figure 9). The IQQM Model's simulation indicates that population will be grown by 12.49% in 2020 (M2) and 32.59% in 2040 (M3).

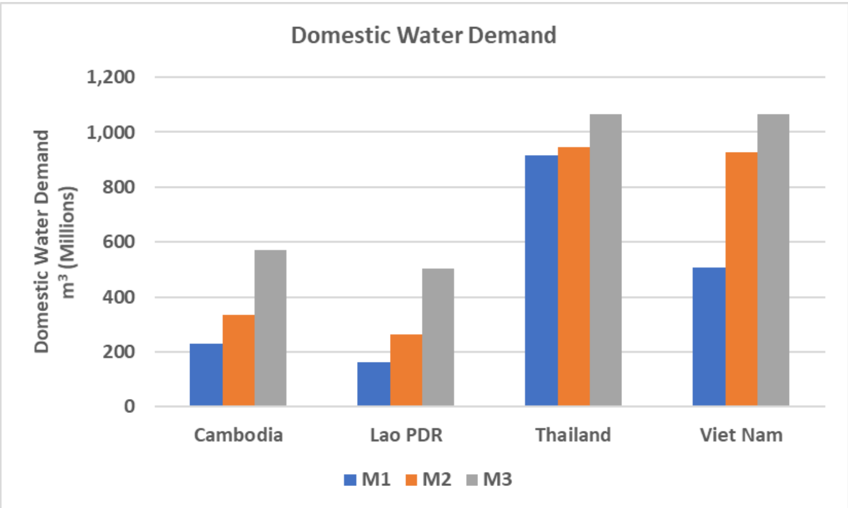
The population growth rate (%) over the period 2020-2040 is lower than over the period 2007-202. The population growth rates of Cambodia and Lao PDR remain high compared with other two Member Countries, which are 0.016% for Cambodia and 0.021% for Lao PDR respectively over the period 2007-2020 and 0.011% for Cambodia and 0.021% for Lao PDR over the period 2020-2040. The growth rates for Thailand and Viet Nam over the period 2007-2020 are 0.005% and 0.006% respectively. Viet Nam declines by 0.005% over the period 2020-2040, while Thailand remains stabilised.



Source: MRC, 2017

Figure 10: Population (person) in the LMB Countries in 2007, 2020, and 2040

Figure 10 shows that the total domestic water demand of the basin in 2007 was projected to be approximately 1,816.40 million m^3 with approximately 50.46% of the LMB population located in Thailand and 27.96% in Viet Nam. Cambodia and Lao PDR accounted for 12.73% and 8.85% of the LMB population in 2007. The IQQM Model's simulation indicates that the total domestic water demand in the LMB will increase by 26.61% in 2020 (M2) and 76.48% in 2040 (M3). The M2 scenario indicates that the domestic water demand of Viet Nam has highly increased by 82.71% among the other Member Countries followed by Lao PDR (64.18%) and Cambodia (45.27%). The M3 scenario shows that Lao PDR is the highest increase of domestic water demand (90.27%) followed by Cambodia (70.12%). Thailand's domestic water demand has slightly increased by 3.34% in M2 and 12.63% in M3.



Source: MRC, 2017

Figure 11: Domestic Water Demand (Million Cubic Meters)

Calculating by using the formula in Section 8.3, the volumes of urban wastewaters producing in Phnom Penh, Vientiane, and Can Tho for M1 are much higher than those in other cities along the Mekong mainstream (Figure 11).

The volumes of urban wastewater increase parallelly with the increases in number of population in those cities. High growth of populations gives right to increasing in volumes of the urban wastewater, total nitrogen and total phosphorus as well as other pollutants into the river. The increased volumes of urban wastewater range from approximately 4% to 25% over the period 2020-2007 (M2). The volumes of urban wastewater will highly grow up over the period 2040-2020 (M3), which range from 10% to 75% for the cities located along the Mekong mainstream. The lowest growths take place in Nakhon Phanom, Mukdahan, and Savannakhet, which is about 4%.

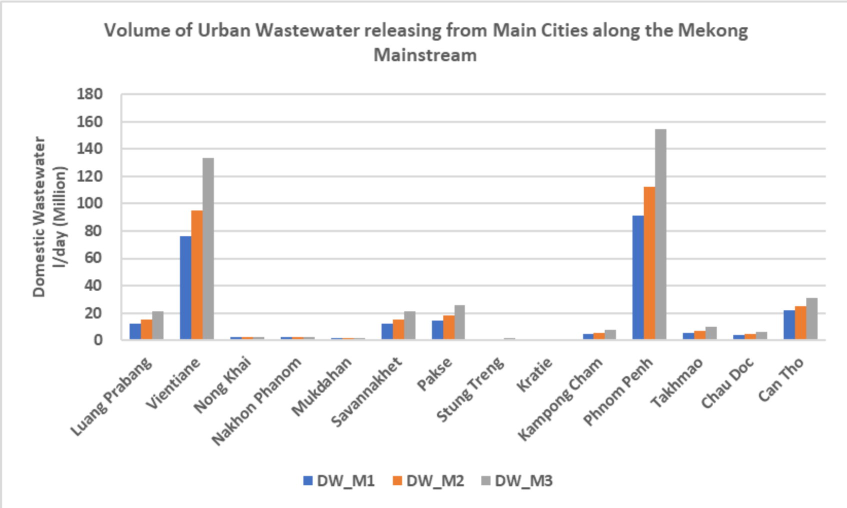


Figure 12: Volumes of Domestic Wastewater releasing from Main Cities along the Mekong Mainstream

Figure 12 shows that the volumes of urban wastewater of major cities along the Mekong tributaries. Long Xuyen produced huge volume of urban wastewater for M1 compared with other cities. The Long Xuyen's urban wastewater volumes remain high for M2 and M2.

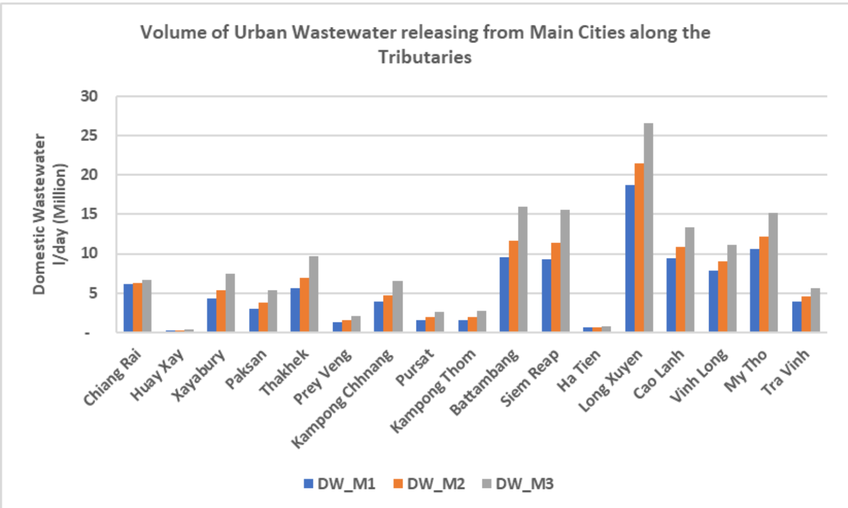
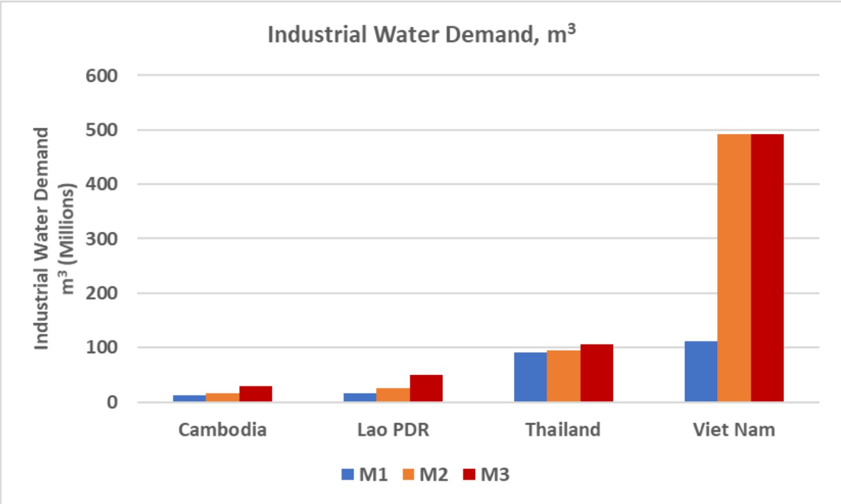


Figure 13: Volumes of Domestic Wastewater releasing from Main Cities along the Mekong Tributaries

The total urban wastewater of the cities located along the Mekong tributaries will increase by 17.76% for M2 scenario and by 29.12% for M3 scenario (Figure 12).

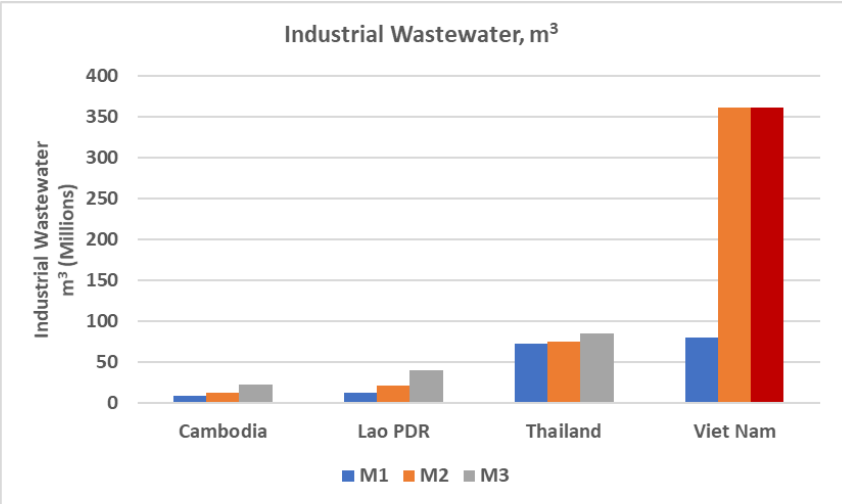
7.5 Industrial Water Demand and Wastewater

The scale of industrial development in the LMB is relatively low. Industrial development has the potential to increase pressure on aquatic resources substantially in the future. The MRC has reported that industrial water pollution has been concentrated around specific industrial contaminants and downstream from major urban areas. At present, limited information is available on industrial discharges or run-off from industrial sites.



Source: MRC, 2017

Figure 14: Industrial Water Demand (MCM) in the LMB Countries (M1, M2, M3)



Source: MRC, 2017

Figure 15: Industrial Wastewater (MCM) in the LMB Countries (M1, M2, M3)

According to the IQQM Modelling, the total industrial water demand of the LMB Countries has been projected to be approximately 231.80 million cubic meters in 2007 (M1). It will steadily increase up to 171.48% in 2020 (M2) and to 192.02% in 2040 (M3). The highest growth takes place in Viet Nam (48.53%) followed by Thailand (39.52%). However, the industrial water demand in Viet Nam remains stabilised for M2 and M3. The industrial water demand in Thailand will increase by 3.38% (M1-M2) and 12.67% (M2-M3) (Figure 13).

Similar with the industrial water demand, the total industrial wastewater is projected to be about 175.80 million cubic meters in 2007 (M1). It will highly increase by 168.15% in 2020 (M2), but slightly increase by 8.08% in 2040 (M3). The volumes of industrial wastewater in Viet Nam is higher than those of in other countries in LMB, which is accounted for 76.60% of the total industrial wastewater producing in the LMB countries (Figure 14).

The volumes of the industrial wastewater in Viet Nam remain the same for M2 & M3 because the industrial sector development will steadily increase over the period 2007-2020 (M2).

8 Impacts

The major environmental issue associated with domestic water is the threat to water quality resulting from disposal of contaminated waste water. Potential impacts include:

- Reduced recreational amenity;
- Threats to human health due to microbial contamination;
- Impacts on irrigation and other uses due to decreased water quality;
- Eutrophication and toxicity causing algal blooms, fish/invertebrate kills, and/or disruption of fish migration; and
- Changes in ecosystem function due to increased turbidity and nutrient loadings.

8.1 Environmental Impacts

The increasing urban pressure on water demand and environmental problems resulting from discharge of urban untreated wastewater into the river, and further increases the risk of incidence of pathogen contamination, oxygen stress, and toxic micro-organisms.

Health problems due to wastewater pollution can become severe for the large population living in the areas where are in the adjacent of the pollution sources. Numerous reasons can be identified for inefficient or even failing wastewater management services, such as low prestige and recognition, weak policies and institutional frameworks, lack of adequate funding and political will, inappropriate technologies, low public awareness and neglect of consumer preferences.

Nitrogen and phosphorus are nutrients that are natural parts of aquatic ecosystems. Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish and other aquatic organisms in the river. Too much nitrogen and phosphorus enter the river water can become polluted. Nutrient pollution has impacted on fish and other aquatic life in the river, resulting in serious environmental and human health issues, and impacting the economy.

Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish. Some algal blooms are harmful to humans because they produce elevated toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water.

Wetlands can however improve water quality by removing pollutants from surface waters. Three pollutant removal processes provided by wetlands are particularly important: sediment trapping, nutrient removal, and chemical detoxification. As much as 90 percent of the sediments that are present in runoff or in streamflow may be removed if the water passes through wetlands; for instance, pollutants such heavy metals are attached to soil particles may be removed and the settling of sediments in wetlands further improves water quality. Some of the toxic chemicals carried into a wetland in runoff or in streamflow are trapped along with settled soil particles. Some of these pollutants may be buried in the sediments, while others may be converted into less harmful chemical forms by biological processes or by exposure to sunlight for extended periods. Other pollutants may be taken up by the plants.

The team intends to analyse all pollutants such as chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solid (TSS), total nitrogen (TOTN), total phosphorus (TOTP), dissolved oxygen (DO), etc. to see whether the river is affected by these pollutants. Once discussing with the modelling team, the modelling cannot however produce such required outputs. Consequently, only two parameters (TOTN and TOTP) have been provided by the modelling team. Yet, the team has reviewed other polluted parameters from reliable source such as MRC's Water Quality Monitoring Network to make transboundary impact analysis and assessments.

8.1.1 Total Nitrogen containing in the Urban Wastewater

Based on the model simulations, the TOTN is a measure of all forms of nitrogen (organic and inorganic) containing in the urban wastewater. This means that these amounts of the TOTN are not directly discharged into the river systems. Some cities, where the wastewater treatment facilities are not installed, are surrounded by wetland areas where can play critical functions to remove some amounts of the nitrogen in the urban wastewater prior to entering into the streams or rivers. The amounts of the TOTN releasing into the river can therefore be lower than those showing in Figure 15 & Figure 16.

The amounts of the TOTN presented in the Figure 15 and Figure 16 are estimated by using the formula in Section 8.3 of this report. The TOTN's amounts can be high or low dependent upon the number of the population living in the cities. In other words, the more the population grows, the more the amounts of the TOTN increase. The increases in TOTN's amounts of all cities along the mainstream and tributaries in M2 will range from 4% to 25%. The TOTN's amounts will be highly grown up in M3, which range from 10% to 75%. These may be resulted from the highly increasing in number of the population for the urban areas or expanding urban areas. By converting to concentration, it is noted that the TOTN's concentration varies from city to city, which ranges from 7.41 mg/L to 13.33 mg/L (Figure 17 & Figure 18). However, these concentrations may decrease after the urban wastewater passes thought wetlands or is treated by wastewater treatment plants before releasing into the rivers or streams.

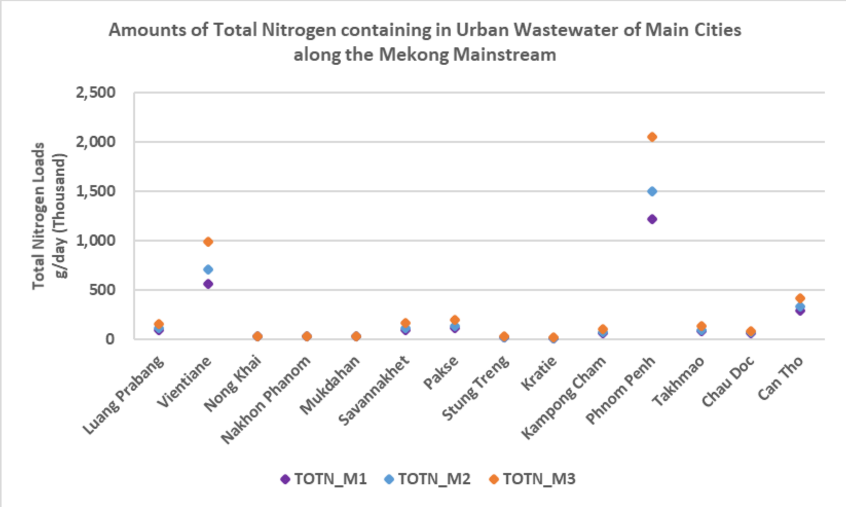


Figure 16: Amounts of Total Nitrogen Loads in Urban Wastewater of Main Cities along Mekong Mainstream

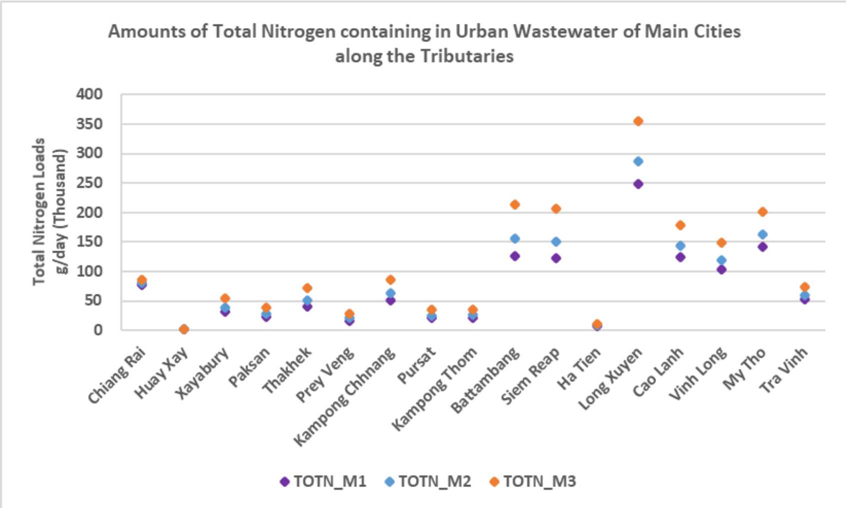


Figure 17: Amounts of Total Nitrogen Loads in Urban Wastewater of Main Cities along Mekong Tributaries

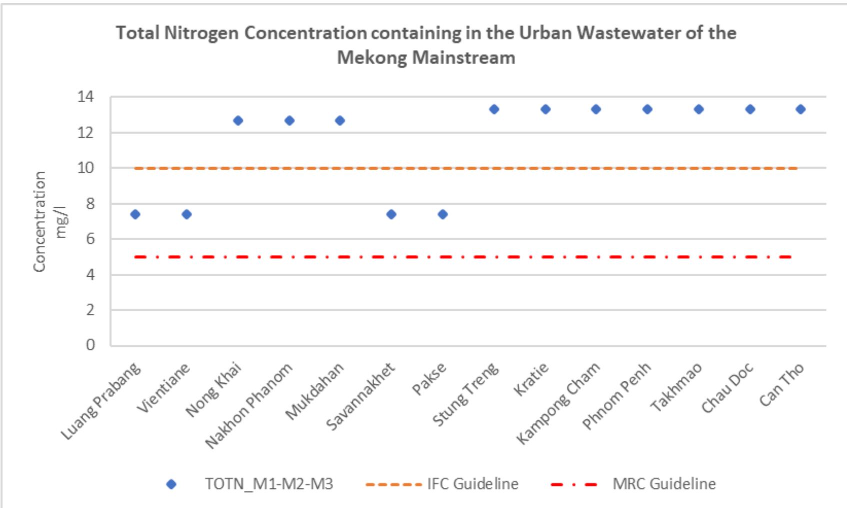


Figure 18: Total Nitrogen Concentrations in Urban Wastewater of Main Cities along the Mekong Mainstream

According to the Wastewater and Ambient Water Quality under the Environmental, Health, and Safety (ESH) Guidelines by International Finance Corporation (IFC, 2007), a permissible treated value of the TOTN from the domestic and industrial facility to be discharged to surface water is 10 mg/L. The MRC Water Quality Guidelines stipulates that the TOTN for the protection of human health shall be 5 mg/L (Table 9).

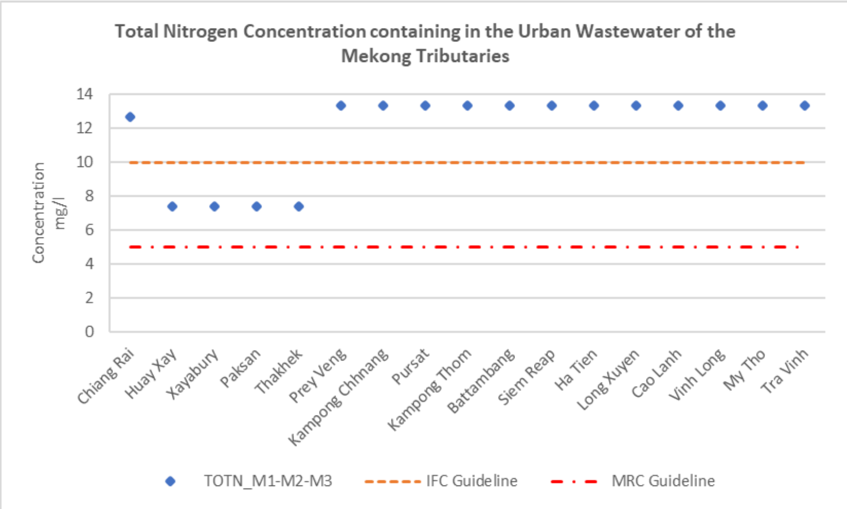
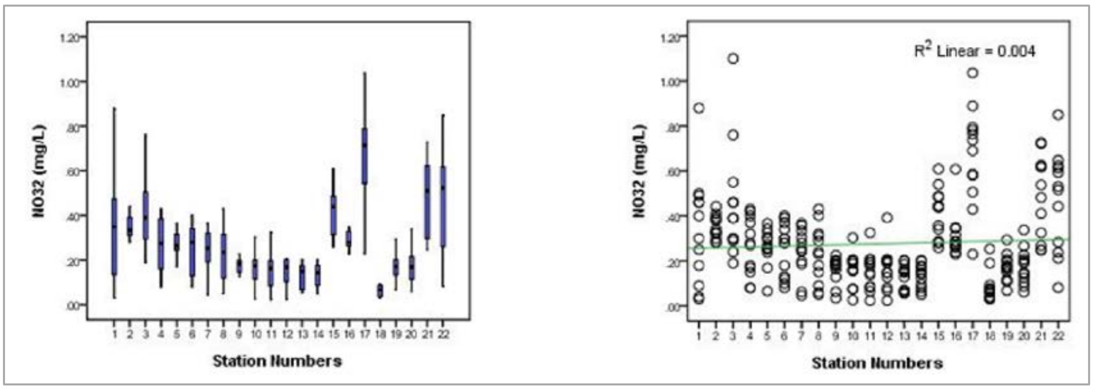


Figure 19: Total Nitrogen Concentrations in Urban Wastewater of Main Cities along the Mekong Tributaries

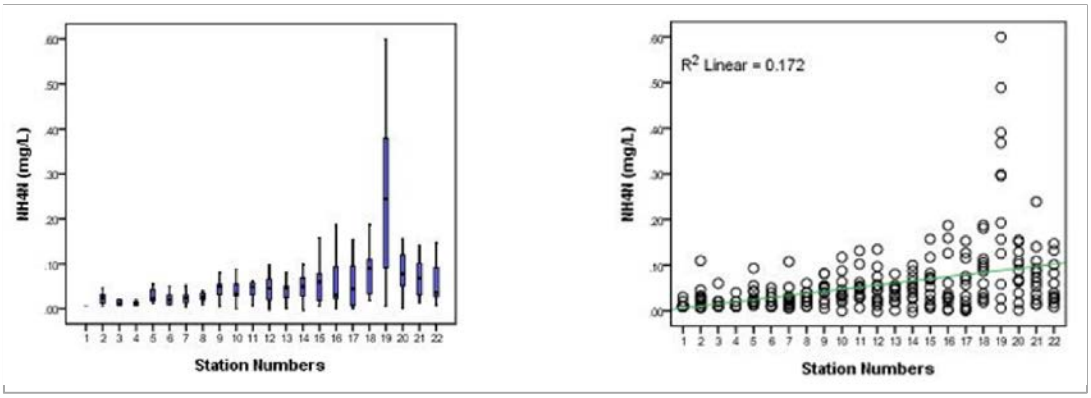
According to MRC (2016a), a spatial analysis of water quality data revealed that nitrate-nitrite concentrations were highly variable in a number of stations located in the upper-most part of the Mekong River (Houa Khong (1), Luang Prabang (3), and Vientiane (4)) and a number of stations located in the Mekong Delta (My Tho (17), Chau Doc (21), and Can Tho (22)). At these stations, the highest concentrations of nitrate-nitrite were observed during the onset of the monsoon season (May and June) (Figure 19). The measured values were well below the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (5 mg/L).



Source: MRC, 2016a

Figure 20: Spatial Variation in Nitrate-Nitrite Concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2014

Temporal analysis of data from 2000 to 2014 for the Mekong River shows that ammonium concentrations remain relatively constant (Figure 20). The average monthly ammonium concentrations in the Mekong River were recorded remained stabilised in 2000 and 2014 at about 0.04 mg/L. Ammonium levels at Koh Khel (19) were however highly variable with values (measured as N) ranging from 0.006 to 0.60 mg/L. It is unclear what caused elevated ammonium levels at Koh Khel, but the elevation does not seem to be seasonally based as all but two measured values exceeded the threshold value used for calculating Water Quality Index for Human Impact (0.05 mg/L).



Source: MRC, 2016a

Figure 21: Spatial Variation in Ammonium Concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2014

Key messages from the main development scenarios for domestic and industrial sector in relation to domestic and industrial wastewater and total nitrogen are as follows:

- The volumes of the urban wastewater discharging from Vientiane and Phnom Penh are higher than the volumes of the urban wastewater releasing from other cities along the Mekong mainstream. These may be resulted from the highly increasing in number of the population for the urban areas or expanding urban areas. Increase volumes of the untreated wastewater from the domestic and industrial sector will, if the urban wastewater would be released directly into the river without passing through the wetland or being treated, exacerbate the ecological impacts, including fish biomass, biodiversity, and other aquatic lives.
- The concentrations of the total nitrogen in the urban wastewater in most cities along the Mekong mainstream and tributaries (ranged from 7.41 mg/L to 13.33 mg/L) exceed a permissible treated value of the TOTN from the domestic and industrial facility to be discharged to surface water is 10 mg/L by IFC's Guidelines. These concentrations, if the urban wastewater would be released directly into the river without passing through the wetland or being treated, are much higher than required values of the MRC Water Quality Guidelines for the protection of human health, which is 5 mg/L.

8.1.2 Total Phosphorus

The increases in TOTP's amounts of all cities along the mainstream in M2 will range from 15 Kg/day to 2,099 Kg/day. Similar with the TOTN, the TOTP's amounts will be highly grown up in M3, which range from 10% to 75%. These may be resulted from the highly increasing in number of the population for the urban areas or expanding urban areas. By converting to concentration, it is noted that the TOTP's concentration varies from city to city, which ranges from 10.37 mg/L to 18.67 mg/L (Figure 23 & Figure 24). However, these concentrations may decrease after the urban wastewater passes thought wetlands or is treated by wastewater treatment plants before releasing into the rivers or streams.

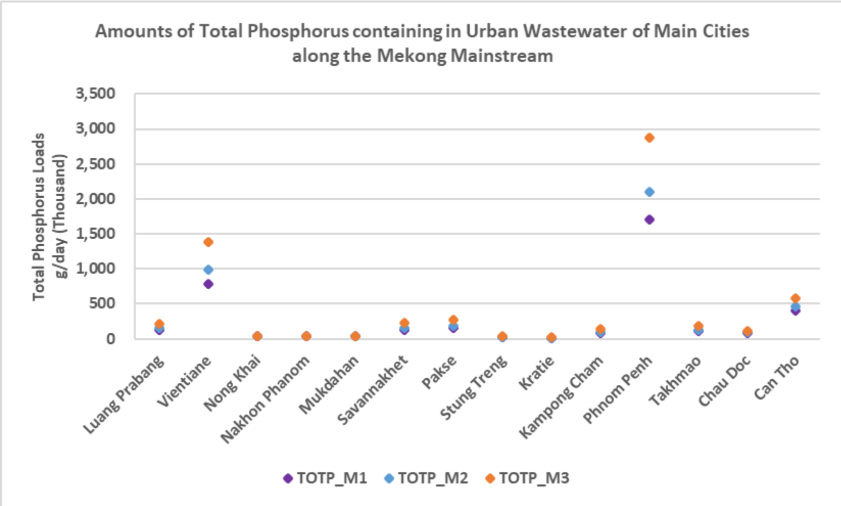


Figure 22: Amounts of Total Phosphorus Loads in Urban Wastewater of Main Cities along the Mekong Mainstream

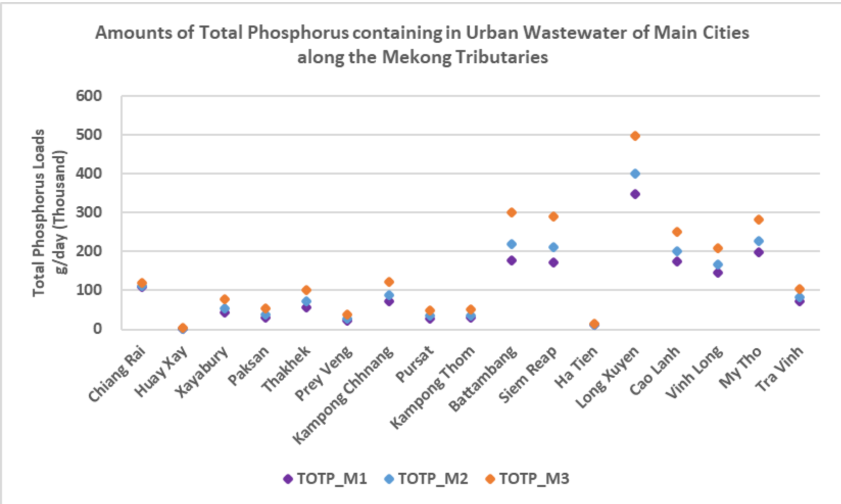


Figure 23: Amounts of Total Phosphorus Loads in Urban Wastewater of Main Cities along Mekong Tributaries

According to the Wastewater and Ambient Water Quality under the Environmental, Health, and Safety (ESH) Guidelines by International Finance Corporation (IFC, 2007), a permissible treated value of the TOTP from the industrial facility to be discharged to surface water is 2 mg/L. The MRC Water Quality Guidelines does not provide any thresholds of the TOTP for the protection of human health and aquatic life purposes.

The 2014 Annual Water Quality Monitoring (MRC, 2016a) indicated that elevated concentrations of total phosphorus were observed at a number of monitoring stations. Two stations (18 & 19) were however recorded that the total phosphorus concentrations could be of greater than 0.13 mg/L on at least one monitoring occasion.

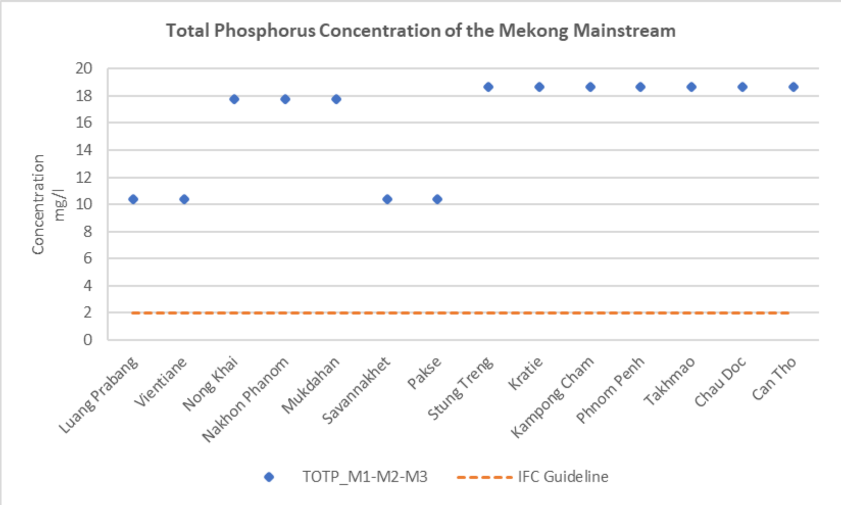


Figure 24: Volumes of Total Phosphorus Concentrations in Urban Wastewater of Main Cities along the Mekong Mainstream

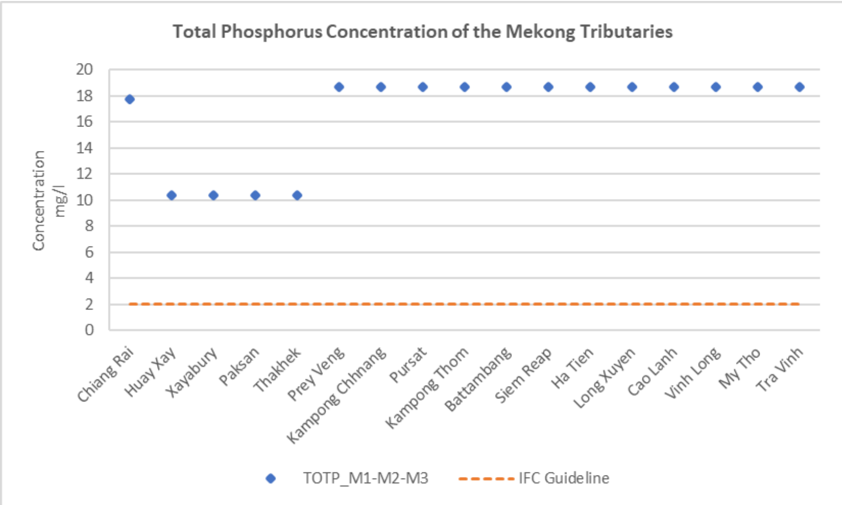
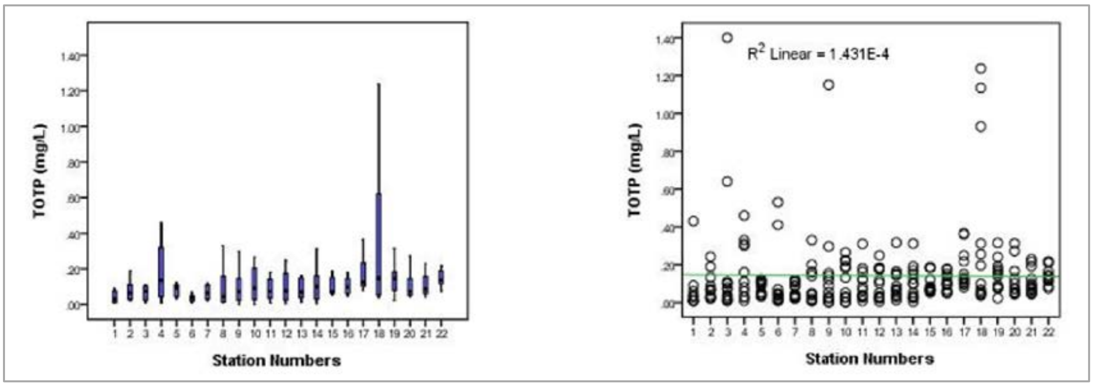


Figure 25: Volumes of Total Phosphorus Concentrations in Urban Wastewater of Main Cities along the Mekong Tributaries



Source: MRC, 2016a

Figure 26: Spatial variation in total phosphorus concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2012

Between 2000 and 2014, total phosphorus concentrations in the Mekong River increased slightly, from mean concentration of about 0.058 mg/L in 2000 to about 0.13 mg/L in 2014 (Figure 25). One-way ANOVA analysis of means reveals that the increase is statistically significant with a P value of less than 0.001. A result of increased human activities, such as agricultural runoff and municipal wastewater discharge in the downstream part of the basin, was likely the reason for the increasing trend.

Key messages from the main development scenarios for domestic and industrial sector in association with the total phosphorus are as follows:

- Similar with the total nitrogen, the concentrations of the total phosphorus in the urban wastewater for all cities along the Mekong mainstream and tributaries (ranged from 10.37 mg/L to 18.67 mg/L) exceed, if the urban wastewater would be released directly into the river without passing through the wetland or being treated, a permissible treated value of the TOTP from the domestic and industrial facility to be discharged to surface water is 2 mg/L by IFC's Guidelines.
- Large amount of the total phosphorus discharging into the river exacerbates the water quality, where the low flow occurs, especially during the dry season.

8.2 Economic Impacts

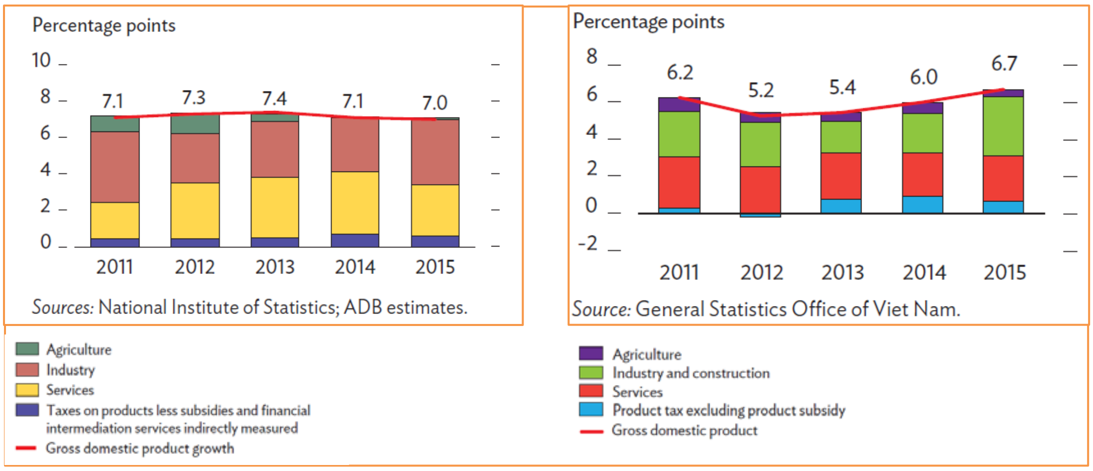
Urbanization is a by-product of economic development for most developing countries. The urban population is rising faster than overall population growth across the LMB's countries. The growth sectors of an economy, particularly manufacturing and services, are generally located in cities where they benefit from agglomeration economies, ample markets for inputs and outputs and readily available labour. Industrialization is often essential for economic growth, and for long-run poverty reduction. The pattern of industrialization, however, impacts remarkably on how the poor benefit from growth.

One of the driving forces for industrial development is the change in domestic and international demand. At relatively low-income levels, individuals spend a significant part of their income on food. As income rises, this share tends to decline, whereas demand for manufactures rises. Similarly, as income rises further, demand for manufactures increases at diminishing rates, whereas demand for services rises rapidly. Changes in demand will also change sectoral employment and output shares and impact the economy's labour productivity. Furthermore, trade has an impact on countries' specialization patterns and on the rate of industrialization or structural change within industries.

The direct socio-economic impacts resulting from the domestic and industrial development have positive and negative impacts. The direct impacts from the domestic water development include (i) people can access to clean water with reasonable cost; (ii) potentially affect human health caused by infectious diseases due to limited access to clean water can be decreased; and (iii) cost expenditure to cover health impact resulting from access to unclean water can be reduced.

Industrial development has an important role in the economic growth of countries, and for long-run poverty reduction. Poverty rates have declined in many countries due to accelerated growth of the industrial development. The poor have remarkably benefited from the industrial development through employment generation from construction to operational phases. A huge number of people has increasingly been employed from year to year due to the increase and expansion of the industrial development.

Industrial development in Cambodia and Vietnam has been selected as a case of major infrastructure development in this report. Asian Development Bank (2016) indicated that Cambodia's large supply of inexpensive, low-skilled labour has attracted substantial foreign direct investment (FDI) into the production of garments and footwear for export. Growth in such manufacturing accelerated to 9.8% last year.



Source: Asian Development Bank, 2016

Figure 27: Supply-side contributions to growth

Vietnamese industry expanded by 9.6% and contributed nearly half of total growth. Powered by high foreign direct investment (FDI), the manufacturing subsector rose by a rapid 10.6%, and construction grew by 10.8% on foreign investment in factories, a recovery in the property market, and higher spending on infrastructure (ADB, 2016).

Additional positive impacts from the industrial development are as follows:

- The potential for employment generation and associated skills development and income generation during all project phases both directly for project works and indirectly through support services. The potential for positive impacts to occur in the project area are however very much dependent on local labour being utilised and trained; and
- Support to the local and regional economy through generation of income opportunities, stimulating demand for services and providing a locally produced source of products (reducing reliance on expensive imports of all products producing by those factories).

8.3 Social Impacts

The potential impacts resulting from the expansion and development of the urban and industrial sector include:

- Impacts on soil quality, surface water quality, groundwater quality, and public health and safety as results of the management and disposal of solid and liquid waste. The concern relates to the limited capabilities and facilities for the disposal of wastes in the development area; and

- Compensation for land acquired for development facilities to local landowners and users. Most land is currently used by local communities has been acquired for the industrial development.

Access to safe drinking water, the security of domestic water supplies are the main elements to be included in the assessment of water security. Despite improvements in drinking water sources in the LMB Corridor, river water is still used for drinking water, especially in Cambodia and Lao PDR, with a mean percentage of 82% and 55% respectively of sampled households using river water as one of several drinking water sources (MRC, 2017b). Changes in access to and the diversity of drinking water sources due to the Development scenarios are unlikely to be altered substantially, although water quality is factor requiring additional consideration

8.4 Transboundary Impacts

According to the MRC (2008), five main transboundary areas were defined, which included as following:

a) *People's Republic of China/Lao PDR:* A boundary station at Houa Khong (Lao PDR) was established in 2004 to monitor the boundary between the Upper and Lower Mekong Basin.

b) Lao PDR/Myanmar: No water quality station exists in this part of the river since it is remote and sparsely populated.

c) *Thailand/Lao PDR (at the Mekong River):* Thailand and the Lao PDR have similar concerns over sediment erosion and transport into the Mekong, nutrient pollution from riparian cities, towns and villages along the mainstream, the potential for contaminants from developing industrial areas (especially on the Thai side), agricultural chemicals, and salinity from the Khorat Plateau of Thailand. A number of monitoring stations exist along this stretch of the Mekong River, including those located in the vicinity of urban areas such as Vientiane, Nakhon Phanom and Savannakhet. However, none of the stations can be referred to as transboundary stations since they receive run-off from both countries and water is normally sampled in the middle of the river.

d) *Lao PDR/Cambodia:* While not located directly at the border of the two countries, Pakse and Stung Treng monitoring stations have, in the past, been considered as transboundary stations. Data from these stations have been used to assess transboundary effects on water quality.

e) *Cambodia/Viet Nam:* Both the Mekong and the Bassac Rivers have stations that can be used to capture transboundary effects on water quality. On the Mekong side, K'orm Samnor station in Cambodia and Tan Chau in Viet Nam are located not too far from the Cambodian/Vietnamese border. Similarly, Koh Thom station in Cambodia and Chau Doc station in Viet Nam, which are located on the Bassac River, can be considered as transboundary stations, due to their proximity to the Cambodian/Vietnamese border.

8.4.1 Vientiane vs. Nakhon Phanom

Based on the results of the main development scenarios calibrated by the MT, the total nitrogen and phosphorus are influenced by the number of population and volume of domestic wastewater discharging into the mainstream.

Figure 28 indicates that the amounts of the total nitrogen and phosphorus containing in the domestic wastewater of Vientiane are extremely higher than those of Nakhon Phanom.

It is noted that the amounts of the total nitrogen and phosphorus (containing in the urban wastewater) in Vientiane steadily increase from M1 to M3, while they slightly increase for Nakhon Phanom (C & D). It reflects that there may be a transboundary water quality issue associated with these two parameters between the two cities while Nakhon Phanom is located downstream of the Vientiane city in case that the urban wastewater of Vientiane discharging directly into the Mekong River. However, the TOTN's and TOTP's amount or the concentrations of urban wastewater of Vientiane may be released by passing through the surrounding wetlands; consequently, the pollutants can be treated by those wetlands before being discharging into the sewer, then into the river.

Note: A & B are amounts of total nitrogen and phosphorus influenced by both natural and anthropogenic activities in the Basin, including urban runoff, industrial effluents, agricultural runoff, and natural and/or human induced.
C & D are amounts of total nitrogen and phosphorus containing in the domestic wastewater.

Figure 28: Total Nitrogen and Total Phosphorus at Vientiane and Nakhon Phanom Stations

In contrast, the amounts of total nitrogen and phosphorus influenced by both natural and anthropogenic activities in the Basin (including urban runoff, industrial effluents, agricultural runoff, and natural and/or human induced) of Nakhon Phanom are higher than those of Vientiane. However, it is noted that the amounts of the total nitrogen and phosphorus for both cities decrease in M1 and M3 (A & B).

8.4.2 Pakse vs. Stung Treng

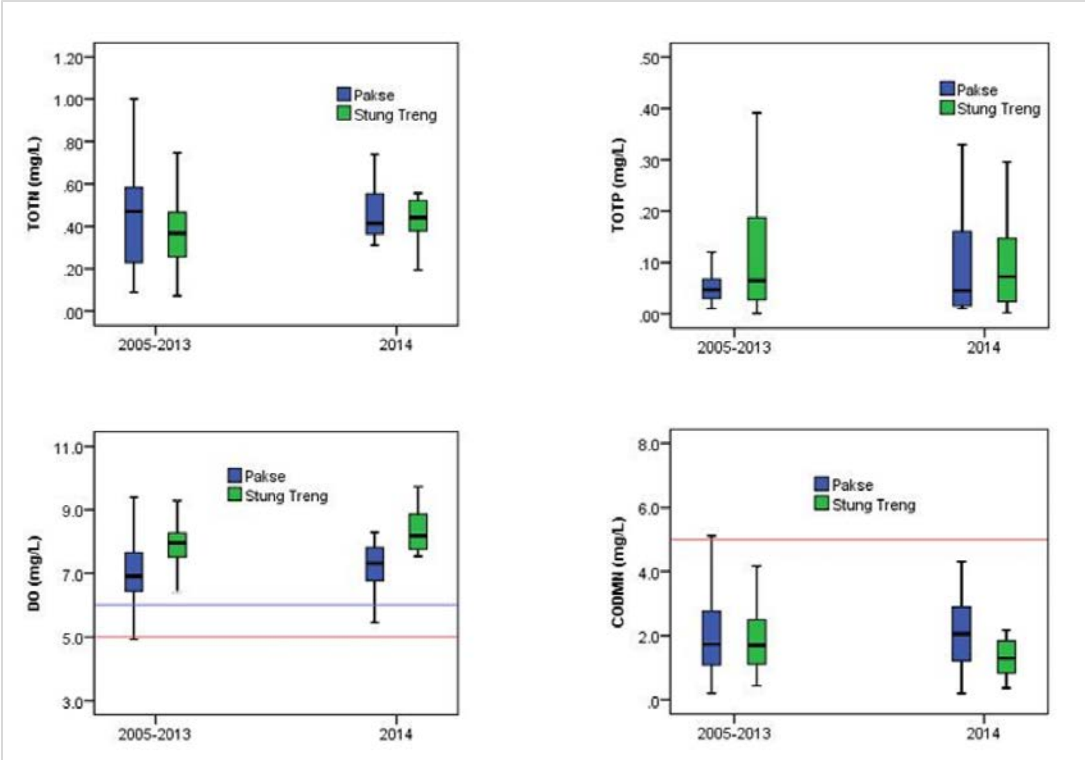
By comparing between the two cities of Pakse and Stung Treng, the amounts of the total nitrogen and phosphorus containing in the domestic wastewater of Pakse (simulated by the MT) are extremely higher than those of Stung Treng. The amounts of these two parameters sharply increase from M1 to M3 for Pakse city, while they slightly increase from M1 to M3 for Stung Treng city. However, the amounts of overall total nitrogen and phosphorus in the basin at Stung Treng are higher than those at Pakse (Figure 28); and they decrease from M1 to M3.

Note: A & B are amounts of total nitrogen and phosphorus influenced by both natural and anthropogenic activities in the Basin, including urban runoff, industrial effluents, agricultural runoff, and natural and/or human induced.
C & D are amounts of total nitrogen and phosphorus containing in the domestic wastewater.

Figure 29: Total Nitrogen and Total Phosphorus at Pakse and Stung Treng Stations

In 2014, the MRC's WQMN examined potentially transboundary water quality issues of the Mekong River between Lao PDR and Cambodia. Six major parameters were selected based on the availability of data to support the transboundary assessment. These parameters were nitrate-nitrite, ammonium, total nitrogen, total phosphorus, dissolved oxygen, and chemical oxygen demand. Concentrations of total nitrogen, total phosphorus, and chemical oxygen demand are described in this report to illustrate the potentially transboundary water quality issue between Lao PDR and Cambodia.

Figure 30 shows that the concentrations of total nitrogen and chemical oxygen demand were slightly higher at Pakse than at Stung Treng in 2014. A statistical test for total phosphorus at the two stations by the MRC in 2014 indicated that the difference observed in mean concentrations at Pakse (M = 0.1 mg/L, Std. = 0.10) and Stung Treng (M = 0.2 mg/L, Std. = 0.32) was not statistically significant, with a P value of 0.44. Additionally, the average concentration of COD at Stung Treng was recorded to be 1.3 mg/L (Std. = 0.64) compared to 2.1 mg/L (Std. = 1.17) recorded at Pakse. The independent t-test for COD revealed that the difference observed between the two mean values was not statistically significant, with a P value of 0.06. These indicated that there was no potentially transboundary water quality issue associated with these parameters.



Source: MRC, 2016a

Note: The horizontal lines represent threshold values for the MRC Water Quality Guidelines for the Protection of Human Health and for the Protection of Aquatic Life

Figure 30: Comparisons of Water Quality Data at Pakse and Stung Treng Stations

8.4.3 *Takhmao vs. Chau Doc*

According to the results of the main development scenarios by the MT, the amounts of the total nitrogen and phosphorus containing in the domestic wastewater at Takhmao city are higher than those at Chau Doc city. The amounts of these two parameters steadily increase from M1 to M3. However, it is difficult to say that Chau Doc's water quality is influenced by the Takhmao water quality since the two cities are far from each other.

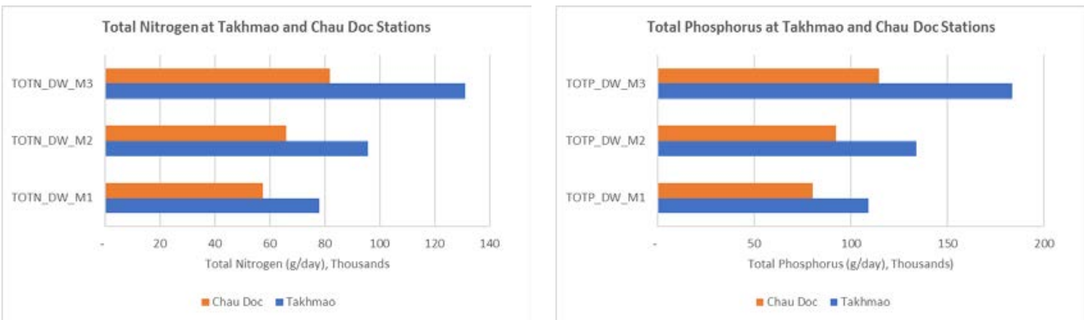
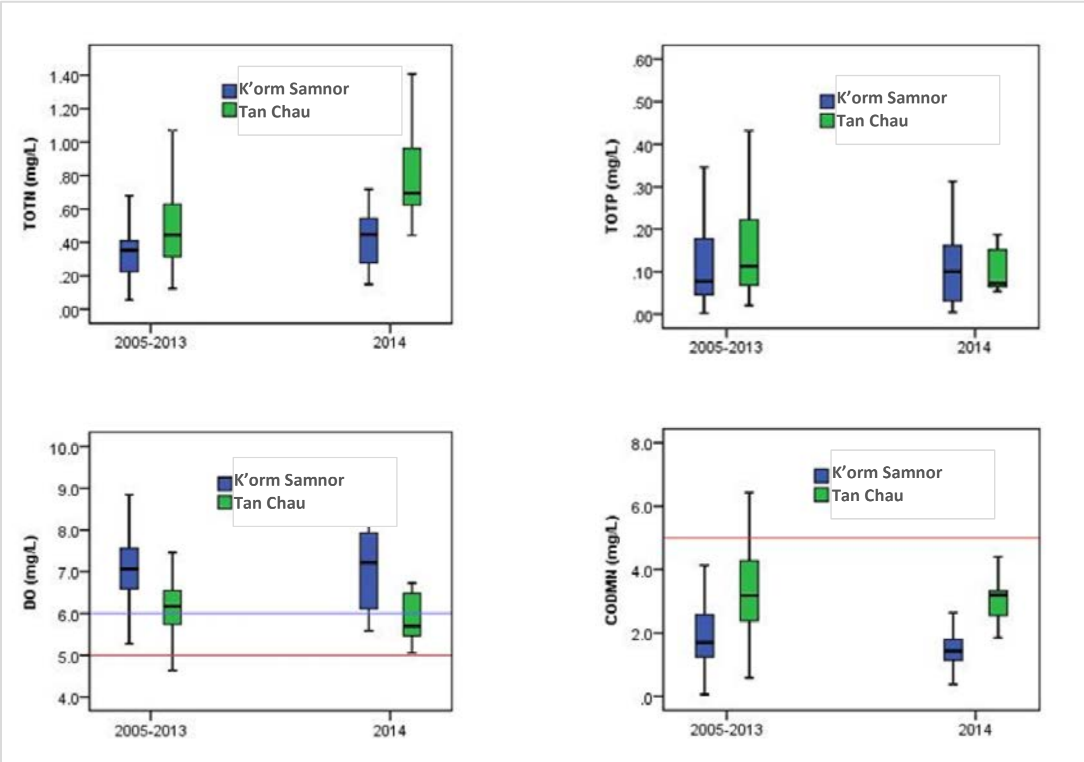


Figure 31: Total Nitrogen and Total Phosphorus containing in the Domestic Wastewater at Takhmao and Chau Doc Stations

However, based on the annual water quality report by MRC (2016a) indicated that the water quality of the Mekong River in 2014 was more degraded in Tan Chau than in K'orm Samnor indicating there was transboundary water quality issues in relation to the parameters of total nitrogen and COD (Figure 32).

While concentrations of these parameters were high in the downstream station compared to the upstream one, it is important to note that only total nitrogen and COD significantly differed between the two stations. However, when comparing the maximum COD concentrations of the two stations (2.6 mg/L for K'orm Samnor and 4.4 mg/L for Tan Chau) to the MRC WQGH (5 mg/L), the mean concentrations were still lower than the threshold spelt out under the guideline, which reflects an indicator of no transboundary issue.



Source: MRC, 2016a

Note: The horizontal lines represent threshold values for the MRC Water Quality Guidelines for the Protection of Human Health and for the Protection of Aquatic Life

Figure 32: Comparisons of Water Quality Data at K'orm Samnor and Tan Chau

Elevated chemical oxygen demand, total nitrogen, and total phosphorus levels in surface water can deplete dissolved oxygen, which is vital for aquatic life. However, the levels of these three parameters recorded in 2014, at both K'orm Samnor and Tan Chau monitoring stations were still low and did not give right to serious impairment to water quality at either station due to relatively high dissolved oxygen recorded at both stations (7.0 mg/L and 5.9 mg/L at K'orm Samnor and Tan Chau respectively).

Key messages from the analysis of the transboundary impacts in relation to the water quality are as follows:

- Based on the modelled result receiving from the Modelling Team, the amounts of the total nitrogen and phosphorus (containing in the domestic wastewater) in Vientiane steadily increase from M1 to M3. As a result, there may, if the urban wastewater would be released directly into the river without passing through the wetland or being treated, be a transboundary water quality issue associated with these two parameters between the two cities while Nakhon Phanom is located downstream of the Vientiane city.

- For the transboundary impacts between Lao PDR and Cambodia, and between Cambodia and Vietnam, the analysis result revealed that there was no significantly transboundary impact associated with the water quality in terms of total nitrogen and phosphorus.

8.5 Industrial Spills

There is no serious case in associated with the industrial spill reported by the MCs. However, the MRC's Navigation Programme (2012b) has prepared risk analysis of the carriage, handling and storage of dangerous goods along the Mekong River. National Working Groups were established in 2010 to collect data and national staff were also trained to identify and evaluate the association risks. Oil spills and industrial waste are emerging threats from storing, handling and carrying dangerous goods along the river. These need to be addressed through regional action plans as well as environmental management and monitoring systems.

Water pollution caused by the industrial spills, especially oil spills or chemical spills pose a serious threat to the aquatic environment. Once oil or liquid chemicals have been spilled, they cannot be completely contained and recovered. Whatever means are deployed to combat navigation spills, some product will always escape recovery, remain in the aquatic environment and migrate away from the spill site. As even very low concentrations of oil or liquid chemicals might exert some detrimental effects on the aquatic environment, the highest priority should be given to prevention of accidental and operational spills. Further risk analysis methodology and assessment can be explored in the report on risk analysis of the carriage, handling and storage of dangerous goods along the Mekong River.

However, emergency preparedness and response plan to combat the industrial spills should be in place for implementation in case there is a spill taken place. The emergency preparedness should include major items as following:

a. *Hazard Identification:* All potential on-site and off-site hazards of the operation, and the type of damage that may result should be identified.

b. *Risk Analysis:* The risk of an incidence associated with each hazard should be determined. The risk analysis procedure should include: (i) identification of frequently potential failures or accidents; (ii) calculation of the quantity of material that may be released in each failure and estimate of the probability of such occurrences; and (iii) evaluation of the consequences of such occurrences based on scenarios such as most probable and worst-case events.

c. *Emergency Organisation and Responsibilities:* Appropriate lines of authorities and decision making should be clearly identified and shown in the emergency organisation chart.

d. *Resources:* Sources of local assistance, equipment, personnel, technology, and expertise should be determined.

e. *Internal and External Alerting System:* Information must be communicated quickly and accurately throughout the affected organization.

The emergency response plan should include the key following items:

a. Response Action Decision;
b. Plan Activation and Response Mobilization;
c. Response Action and Clean-up;
d. Emergency Operations Centre;
e. Evacuation;
f. Disposal of Spilled Contaminants;
g. Site Restoration and Remediation; and
h. Post-Incident Evaluation.

However, training and periodic simulation exercises or practice drills should be frequently provided enough to responsible person and team to ensure that the response team maintains proficiency in all aspects of the contingency plan.

9 Implications of Findings, Recommendations, and Conclusion

The main objective of the Domestic and Industrial Water Use Thematic Study is *"to estimate changes in the domestic and industrial use on water resources' conditions within the LMB associated with the three main water development scenarios considered in the Council Study"*. The purpose of this report is to present the key findings of the Domestic and Industrial Water Use Thematic Area of the MRC Council Study.

The quantitative and descriptive analysis are conducted in this report to examine the impacts resulting from the urban and industrial development of the four MCs. To assess these impacts, the following key indicators have been taken into consideration, including: (i) identification of the impacts and benefits of the domestic and industrial water use; (ii) map of large existing and planned expanding urban ad industrial centres; (iii) estimated water demand; (iv) estimated general effluent and waste water discharge; (v) highlight of any possible risks of industrial spills or similar significant impacts; (vi) estimates of both positive and negative development impacts of other sectors on domestic an industrial water use; and (vii) transboundary indicators include impact of water use and waste discharge on water quality downstream. However, the study's limitations and implications are as follows:

Three main development scenarios of domestic and industrial water use have been formulated, which include: (i) Early Development Scenario 2007 (M1); (ii) Definite Future Scenario 2020 (M2); and (iii) Planned Development Scenario 2040 (M3). The impacts of these development scenarios are also addressed and assessed in this report.

Using the scenarios and assumptions (BDP-Phase 2, 2010), national populations in 2007 ranged between approximately 5.23 million in Lao PDR and 23.08 million in Thailand, which implied a national annual population growth rate ranging between 0.40% in Lao PDR to 2.59% in Cambodia. Cambodia experienced a relatively high population growth rate (2.59%) between 2000 and 2007. The IQQM Model's simulation indicates that population will be grown by 12.49% in 2020 (M2) and 32.59% in 2040 (M3).

The total domestic water demand of the basin in 2007 was projected to be approximately 1,816.40 million m^3 with approximately 50.46% of the LMB population located in Thailand and 27.96% in Viet Nam. Cambodia and Lao PDR accounted for 12.73% and 8.85% of the LMB population in 2007. The IQQM Model's simulation indicates that the total domestic water demand in the LMB will increase by 26.61% in 2020 (M2) and 76.48% in 2040 (M3). The M2 scenario indicates that the domestic water demand of Viet Nam has highly increased by 82.71% among the other Member Countries followed by Lao PDR (64.18%) and Cambodia (45.27%). The M3 scenario shows that Lao PDR is the highest increase of domestic water demand (90.27%) followed by Cambodia (70.12%). Thailand's domestic water demand has slightly increased by 3.34% in M2 and 12.63% in M3.

The total industrial water demand of the LMB Countries has been projected to be approximately 231.80 million cubic meters in 2007 (M1). It will steadily increase by 171.48% in 2020 (M2) and 192.02% in 2040 (M3). The highest growth takes place in Viet Nam (48.53%) followed by Thailand (39.52%). However, the industrial water demand in Viet Nam remains stabilised for M2 and M3. The industrial water demand in Thailand will increase by 3.38% (M1-M2) and 12.67% (M2-M3).

The total industrial wastewater is projected to be about 175.80 million cubic meters in 2007 (M1). It will highly increase by 168.15% in 2020 (M2), but slightly increase by 8.08% in 2040 (M3). The volumes of industrial wastewater in Viet Nam is higher than those of in other countries in LMB, which is accounted for 76.60% of the total industrial wastewater producing in the LMB countries.

The volumes of the urban wastewater discharging from Vientiane and Phnom Penh are higher than the volumes of the urban wastewater releasing from other cities along the Mekong mainstream. These may be resulted from the highly increasing in number of the population for the urban areas or expanding urban areas. However, these urban wastewater may not seriously impact on water quality of the rivers since the urban wastewater passes thought wetlands or is treated by wastewater treatment plants before releasing into the rivers or streams.

The concentrations of the total nitrogen in the urban wastewater in most cities along the Mekong mainstream and tributaries (ranged from 7.41 mg/L to 13.33 mg/L) exceed a permissible treated value of the TOTN from the domestic and industrial facility to be discharged to surface water is 10 mg/L by IFC's Guidelines. These concentrations, if the urban wastewater would be released directly into the river without passing through the wetland or being treated, are much higher than required values of the MRC Water Quality Guidelines for the protection of human health, which is 5 mg/L.

Similar with the total nitrogen, the concentrations of the total phosphorus in the urban wastewater for all cities along the Mekong mainstream and tributaries (ranged from 10.37 mg/L to 18.67 mg/L) exceed, if the urban wastewater would be released directly into the river without passing through the wetland or being treated, a permissible treated value of the TOTP from the domestic and industrial facility to be discharged to surface water is 2 mg/L by IFC's Guidelines.

By assessing additional water quality parameter of chemical oxygen demand (by the MRC's WQMN data) to see whether there is a transboundary impact between Lao PDR and Cambodia, and Cambodia and Viet Nam, the analysis result revealed that there was no significantly transboundary impact associated with the water quality. The assessment of the MRC's WQMN data (TOTN and TOTP) also indicated that there was no seriously transboundary impairment to the water quality.

10 References

Asian Development Bank. (2012). Water supply and sanitation sector assessment, strategy and road map. ADB: Manila.

Asian Development Bank. (2013). Water supply and sanitation project. Report and recommendations of the president. Economic analysis. RRP LAO 45301-002.2013. ADB: Manila.

Asian Development Bank. (2014). Lao People's Democratic Republic: Northern and central regions Water supply and sanitation sector project, Completion Report. Project Numbers: 3419703 and 3419704; Grant Numbers: 0016 and 0205. ADB: Manila.

Asian Development Bank. (2015). Characterizing industrial pollution in Lao PDR. ADB: Manila.

Asian Development Bank. (2016). Asian development outlook 2016: Asia's potential growth. Mandaluyong: Asian Development Bank.

Biswas, A.K.; and C. Tortajada. (2010). Water supply of Phnom Penh: An example of good governance. Water Resources Development. 26: 157–172.

Frankel, R.J. et al. (1973). Water consumption in small communities of northeast Thailand. Water Resources Research. 9: 1196-1207.

Global Water Partnership South East Asia. (2013). National stakeholder consultations on water: Supporting the Post-2015 Development Agenda.

GMS Environment Operations Centre. (2016a). Estimating industrial pollution in the Kingdom of Cambodia: Final report. Bangkok: Author

GMS Environment Operations Centre. (2016b). Estimating industrial pollution in Lao PDR: Final report. Bangkok: Author

Mongphachan, S. (2010). Urban water sector regulation in Lao PDR: Reform, key measures, successes and challenges. Paper presented at the United Nations UNCTAD Conference Multi-Year Expert Meeting on Services, Development and Trade: The Regulatory and Institutional Dimension. Geneva. 17-19 March 2010.

MRC. (2002). Regional sector overview, domestic water and sanitation, and industrial water use. BDP 012-6. MRC: Phnom Penh.

MRC. (2008). An assessment of water quality in the Lower Mekong Basin: Technical paper no. 19. Vientiane: Author

MRC. (2012a). 2011 Annual Water Quality Report. Vientiane: Author

MRC. (2012b). Carriage, handling, and storage of dangerous goods along the Mekong River (Volume I): Risk analysis. Vientiane: Author

MRC. (2015). Development trends and future outlook in the Lower Mekong Basin countries. Draft report, August 2015. MRC, Vientiane.

MRC. (2016a). 2014 lower Mekong regional water quality monitoring report: Technical paper no. 60. Vientiane: Author

MRC. (2016b). The phase II implementation plan (draft version 4). Phnom Penh: MRC

MRC. (2017a). The IQQM Model for the Council Study: Main and sub-scenarios. Phnom Penh: MRC

MRC. (2017b). The Council Study: Approach and methodology for social impact assessment of development scenarios. Vientiane: Author

Nauges, C., and D. Whittington. (2010). Estimation of water demand in developing countries: an overview. The World Bank Research Observer. 25: 263-294.

Organisation for Co-operation and Development. (2015). Green growth in Bangkok. OECD Green Growth Studies. OECD: Paris.

Udomratanasilpa, V. (2008). Water situation in Thailand. Presentation at the Singapore International Water Week. 24-25 June 2008.

United Nations Environment Program. (2009). Cambodia environment outlook. Ministry of Environment of Cambodia: Phnom Penh.

United Nations. (2015). World population prospects: The 2015 revision. Department of Economic and Social Affairs, Population Division. UN: New York.

WEPA. (2012). State of water environmental issues in Lao PDR. Water Environment Partnership Asia. http://www.wepa-db.net/policies/state/laos/groundwater.htm (accessed on 20 March 2012).

World Bank. (2007). Lao environment monitor. World Bank: Washington, DC.

World Bank. (2010). Water supply and sanitation sector review. World Bank: Washington, DC.

World Bank. (2011). Thailand environment monitor. World Bank: Washington, DC.