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THE COUNCIL STUDY

Study on the sustainable management and development of the Mekong river, including impacts of mainstream hydropower projects

Approach and methodology for economic impact assessment of development scenarios

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Document history

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Abbreviations and acronyms

ADB	Asian Development Bank
BDP	Basin Development Programme
BDP1	BDP Phase 1
BDP2	BDP Phase 2
CV	Contingent Valuation
DSF	Decision Support Framework
DMP	Drought Management Programme
EP	Environment Programme
EPC	Engineering, Procurement and Construction
FMMP	Flood Management and Mitigation Programme
FP	Fisheries Programme
GIS	Geographical Information System
GW	Gigawatt = 1,000 MW
GWh	Gigawatt-hour = 1,000 MWh
HEP	Hydroelectric Power
IBFM	Integrated Basin Flow Management
IKMP	Information and Knowledge Management Programme
ISH	Initiative for Sustainable Hydropower
IWRM	Integrated Water Resources Management
IWT	Inland Water Transport
KW	Kilowatt
KWh	Kilowatt-hour
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
MW	Megawatt = 1,000 KW
MWh	Megawatt-hour = 1,000 KWh
NAP	Navigation Programme
NMC	National Mekong Committee
NPV	Net Present Value
PV	Present Value
RTWG	Regional Technical Working Group
SEA	Strategic Environmental Assessment
TCU	Technical Co-ordination Unit
TEV	Total Economic Value
ToR	Terms of Reference
UMB	Upper Mekong Basin
WB	World Bank

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1 Introduction

1.1 Purpose of report and main tasks

The main purpose this report is to describe the approach and methodology being adopted for the economic assessment of direct benefits, costs and impacts[1] to be undertaken for the Council Study. The Inception Report of the Council Study 2 was the main guidance document.

The report forms part of a larger main report on the "Approach and methodology for the cumulative impact assessment of water resource development scenarios" (December 2015) to which this report is also appended.

For future reference, this report will also provide a record of the analytical techniques used in the economic assessment. In the preparation of the economic assessment methodology, the main tasks comprised:

- establishment of a clear approach and analytical framework for the economic assessment;
- description of the analytical tools which will be used in the economic assessment to quantify the assessment indicators;
- consultation with other discipline teams as well as thematic teams of the Council Study, including a mini-workshop, in order to identify data sources and information gaps;
- detailing of data requirements including data sources as well as the thematic/discipline teams and technical experts responsible for providing the information; and
- identification of key activities to be undertaken during the economic assessment, and preparation of a work plan and staff schedule.

[1] The term "macro-economic" assessment (as referred to in the Council Study Inception Report) has been replaced in this report by "economic assessment" in order to clearly distinguish between the assessment of the direct economic benefits, costs and impacts resulting from water resource developments with indirect economic benefits and impacts at the macro level which are discussed separately (see Appendix C: Economic assessment of Indirect Benefits and Impacts). Furthermore this distinction also reflects the terminology used in the MRC Indicator Framework.

[2] Inception Report of the MRC Council Study, Draft Final, 27 October 2014.

1.2 Report contents

The main objectives and general approach to the economic assessment are described in Chapter 2. The economic assessment indicators which will be used in the analysis are also presented.

The detailed methodology of the economic assessment is then presented in Chapter 3. Firstly, an overview of analytical methods used to assess the direct benefits, costs and impacts of water resource developments are outlined. This is followed by a discussion on economic valuation techniques. Finally, the economic assessment of development scenarios is described with respect to the development of hydropower, irrigated agriculture, flood protection, navigation, aquaculture and forestry, as well as the impact of proposed water resource developments on capture fisheries, wetlands/wildlife biodiversity, riverbank erosion, saline intrusion, recession cropping, floodplain crop productivity, and riverbank gardens.

Chapter 4 details the data requirements for the economic assessment and is divided by development sector and topic/issue. The data sources are specified together with the thematic/discipline teams and technical experts responsible for providing the information.

A work plan for the economic assessment is given Chapter 5 and this specifies the main tasks to be undertaken, the proposed work schedule and consultancy requirements.

2 Main objectives and general approach

2.1 Main objectives

The main objectives of the economic assessment of direct benefits, costs and impacts are to:

- Estimate the direct economic benefits and costs of the early development scenario (2007), the definite future scenario (2020) and the planned development scenario (2040);
- Estimate the direct economic benefits and costs of the sub-scenarios FPF2, FPF3, IRR1, DIW1, DIW2, and ALU3 (as defined in the Implementation Plan of the Council Study)
- Evaluate the economic impacts of existing and planned interventions (both positive and negative);
- Determine the distribution of economic benefits and costs, as well as impacts, between LMB countries; and
- Estimate the impact on employment and livelihoods (both positive and negative).

2.2 Key economic indicators

The promotion of economic development is key aim of the national plans for water resource development in LMB countries as well as the MRC's planning efforts. MRC operates in defined sectors and it is important to monitor and assess the economic performance of MRC sectors with respect to current and future development plans, as well as to assess their contribution to the overall basin economy. To guide the monitoring and assessment process, the MRC Indicator Framework[3], comprising strategic and assessment indicators as well as monitoring parameters (discipline-specific indicators), was established for five dimensions, i.e. social, environment, economic, climate change and cooperation.

In order to evaluate the strategic economic indicators, namely: (i) economic performance of MRC sectors, and (ii) contribution to the overall basin economy, a series of assessment indicators have been specified in the MRC Indicator Framework. These assessment indicators are presented in Table 2.1 and they will be evaluated in the assessment of the direct benefits, costs and impacts of water resource developments.

[3] MRC Indicator Framework for managing the Mekong Basin (draft), June 2015.

With respect to social dimension of the MRC framework, employment in MRC sectors is one of the strategic social indicators. In order to assist with evaluation of the employment indicators, estimates of the job opportunities created in the agriculture, fisheries, hydropower, navigation and forestry sectors, through the implementation of water resource development interventions, will also be undertaken in the economic assessment.

Table 2-1 Economic dimension: strategic and assessment indicators

Strategic Indicators	Assessment Indicators	Unit
Economic performance of MRC sectors	▫ Economic value of irrigated agriculture: ▫ Economic value of recession agriculture ▫ Economic value of lowland rain fed agriculture ▫ Economic value of hydropower production ▫ Economic value of mainstream navigation ▫ Economic value of flood damage ▫ Economic value of drought damage ▫ Economic value of capture fisheries ▫ Economic value of reservoir fisheries ▫ Economic value of aquaculture ▫ Economic value of river bank gardens ▫ Economic value of upland forestry ▫ Economic value of flooded forests ▫ Economic value of wetlands, key habitats and conservation areas ▫ Economic value of sand mining ▫ Economic value of productive activities in areas affected by salinity ▫ Economic value of assets in locations affected by river bank erosion ▫ Economic expenditure on tourism and recreation ▫ Aggregate economic value (from above)	▫ US$M/year
Contribution to basin economy	▫ Proportion of MRC sectors contribution to overall basin GDP	percent
	▫ Food security: % of national food grain demand met from basin resources	percent
	▫ Food security: % of national protein demand met from basin resources	percent
	▫ Energy security: % national demand met from hydropower generation	percent
	▫ Economic value of investments in MRC sectors	US$M/year

2.3 General approach

The first part of this assessment is focused on the impacts of the three development scenarios on the economic performance of MRC sectors, which is largely based on the economic assessment methodology employed during the BDP study in 2009-11 to ensure consistency. This approach implements conventional analytical methods for the economic valuation of benefits and costs, which have been well established by the major donor agencies (e.g. World Bank and ADB) over many years. This approach will be used in the economic assessment of impacts in form of direct benefits and costs of the three development scenarios considered.

MRC databases (e.g. hydropower, irrigation) and information and assessment results from the discipline teams (i.e. BioRA, hydrology, socio-economic and climate change) and the thematic teams (i.e. hydropower, agriculture and land use, flood protection, domestic and industrial water use, and transportation) of the Council Study will be used in the economic assessment.

Discussions were held with the thematic and discipline teams in order to: (i) determine the type of information which will be made available during the course of the study, and (ii) identify data gaps which will require further data collection and analysis by the economic assessment team. In addition, a mini-workshop was held on 24th October 2015 to further improve the assessment approach. The workshop was attended by country delegates, Council Study Team management and BDP team members. Feedback from the workshop is reflected in this report.

The design of the broader Council Study has implications for the economic assessment as it specifies 1985-2008 as the main timeframe for disciplinary assessments. The hydrological modelling work uses hydrological flow data for this period and overlays this time series with assumptions for future climate signals and with the various scenarios of water infrastructure. The other disciplinary teams calibrate their models for the same period and develop their baseline by adjusting parameters for the past period with a set of exogenous factors that introduce expected future pressures or changes (i.e. overfishing). The economic assessment related to MRC sector performance is processing results from disciplinary teams. This imposes a time-related challenge as provided results are largely static comparative results for the end of the selected 23-year period. Thus, we understand the selected timeframe as an abstract period that could equally represent the time until 2040 as exogenous drivers try to capture main future changes.

The direct benefits, costs and potential impacts (both positive and negative) which will be evaluated during the economic assessment of the development scenarios are summarised in Table 2-2. It can be seen that the direct benefits, as well as the capital and recurrent costs, of the various water resource developments, i.e. hydropower, irrigated agriculture, flood protection, navigation, aquaculture and forestry, will be evaluated in the economic assessment.

In addition, the potential impacts of water resource developments are also listed in Table 2-2 and the positive impacts are expected to include increased reservoir fisheries production, reduced flood damage, reduced saline intrusion, improved navigation, and reduced sedimentation. With regard to potential negative impacts, it is anticipated that these will include a decline in capture fisheries stocks, reduced environmental assets/ecosystem services (e.g. wetlands, wildlife biodiversity), reduced recession agriculture and riverbank gardens, reduced crop productivity in floodplain and delta, as well as increased riverbank and coastal erosion. This study aims to establish robust predictions of the nature and scale of likely impacts. At this stage it should be noted that it is yet to be confirmed whether some of these potential impacts will be positive or negative.

The economic indicators to be adopted in the assessment have been based on the MRC Indicator Framework. Economic assessment indicators will be quantified by applying economic values to the physical interventions, outputs and impacts of water resource developments within the development scenarios, as specified in the monitoring parameters of the MRC Indicator Framework.

The linkages between assessment indicators and monitoring parameters, together with the sources of data required to evaluate the assessment indicators and monitoring parameters, are illustrated in Figure 2.1.

Table 2-2 Summary of direct benefits, costs and impacts

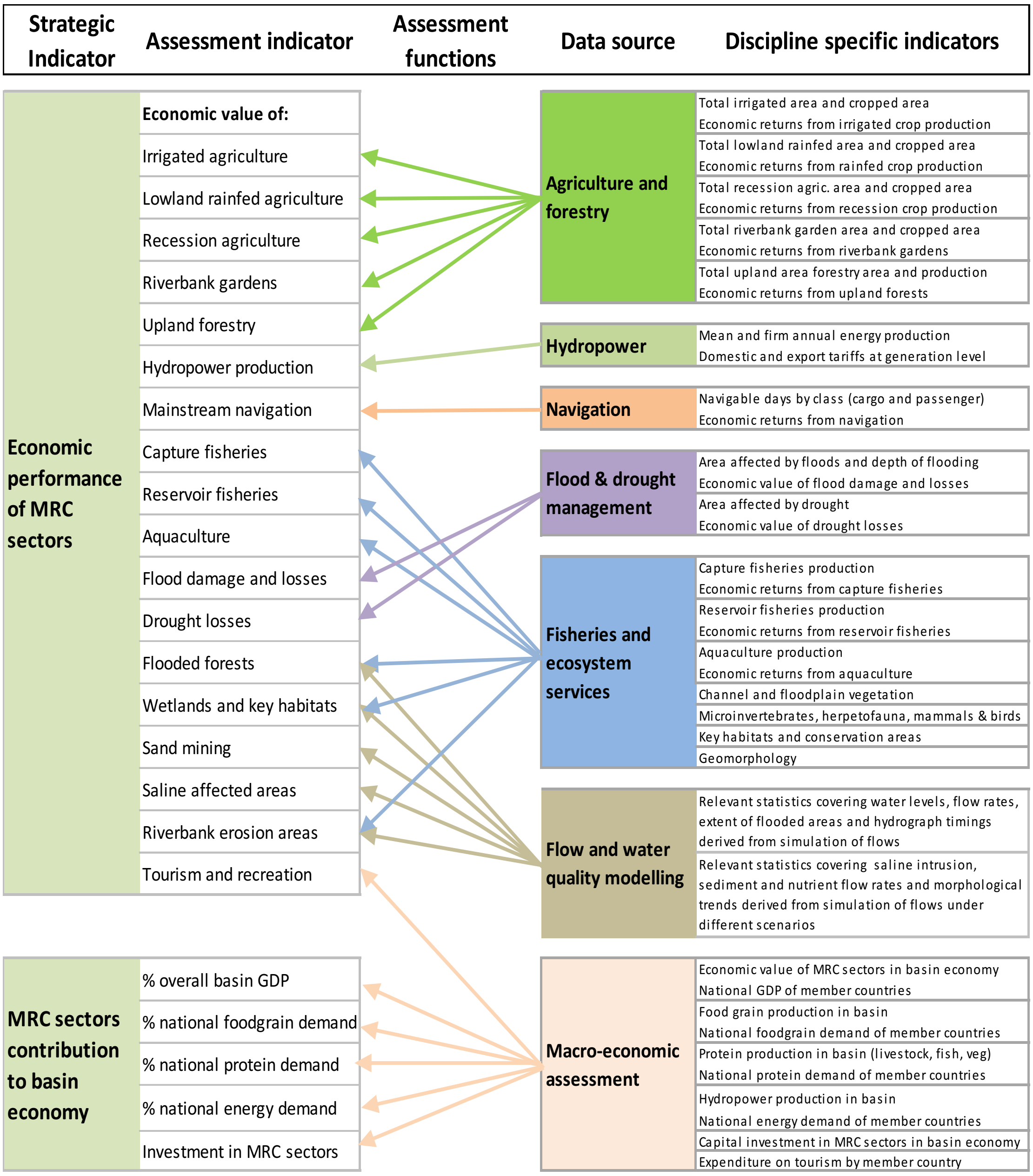
Direct Benefits	Costs	Potential Positive Impacts	Potential Negative Impacts
i. Power production from hydropower development ii. Increased crop production from irrigation development iii. Reduced flood damages from flood protection measures iv. Increased river transport from enhanced navigation measures v. Increased fish production from aquaculture including rice-fish systems vi. Increased forest area in catchments	i. Capital investment ii. Annual production costs	i. Increased Fisheries production in reservoirs ii. Reduced flood damage due to hydropower dams iii. Reduced saline intrusion due to hydropower dams iv. Improved navigation due to hydropower dams v. Increased life of reservoirs due to reduced sedimentation resulting from increased forests in catchments vi. Reduced flood damage due to lower rainfall and drought	i. Decline in capture fisheries stocks due to hydropower dams and flood protection measures ii. Reduced area of wetlands including flooded forests iii. Loss of wildlife biodiversity iv. Loss of land, houses and infrastructure due to increased river bank and coastal erosion v. Reduced area of recession agriculture vi. Reduced area of riverbank gardens vii. Reduced crop productivity in floodplain and delta due to less sedimentation viii. Reduced sand mining due to less sedimentation ix. Reduced crop production due to drought

Quantitative analysis to evaluate the direct benefits, costs and impacts will be undertaken using a spreadsheet format (MS Excel) and the specific methodologies that will be used for the economic assessment of the development scenarios are discussed in Chapter 3. The data sets assembled during the data collection exercise (see Chapter 4) will be applied in the analysis.

The second set of indicators relates to the basin economy and will describe macro-economic impacts. This part of the assessment will put the results for MRC sectors into the context of LMB economies. Instrumental will be the socio-economic assessment, which will allow for some of the necessary calculations to upscale from corridor-wide effects to basin-wide effects. The link from basin-wide to national effects will be informed by a variety of data published by the four riparian Governments or by international agencies such as OECD, ADB, and World Bank.

The key macro-economic impact domains will include GDP and GDP growth, food and energy security, and investment and asset related dimensions. Each of these three domains allows for the assessment of important dependencies between the national economies and the resources affected by the three development scenarios and the relevant sub-scenarios. Thereby, some important ripple effects can be quantified to further inform the economic persepctive of development-focused decision making.

Figure 2-1 Linkages between assessment indicators and discipline-specific indicators



3 Methodology for economic assessment of direct benefits, costs and impacts

3.1 Overview of assessment methodology

This economic assessment approaches the context at two levels. First, a sector level assessment will be conducted to establish the likely costs and benefits each MRC sector would experience for each scenario. The following sectors will be assessed:

- Agriculture/Crop production
- Hydropower
- Fisheries
- Wetlands
- Navigation
- Floods
- Salinity
- Erosion

Some parts of this assessment will be based on market values, for instance for agricultural products, fish, and power generation. For this sector where market prices are not available economic valuation results will be sourced to complement the assessment. This valuations will be sourced from recent valuations of comparable goods and services, and will consider uncertainty ranges.

The second level of economic assessment will employ a macro-economic perspective and estimate GDP related impacts for all scenarios. This macro-economic erspective will address three principle questions:

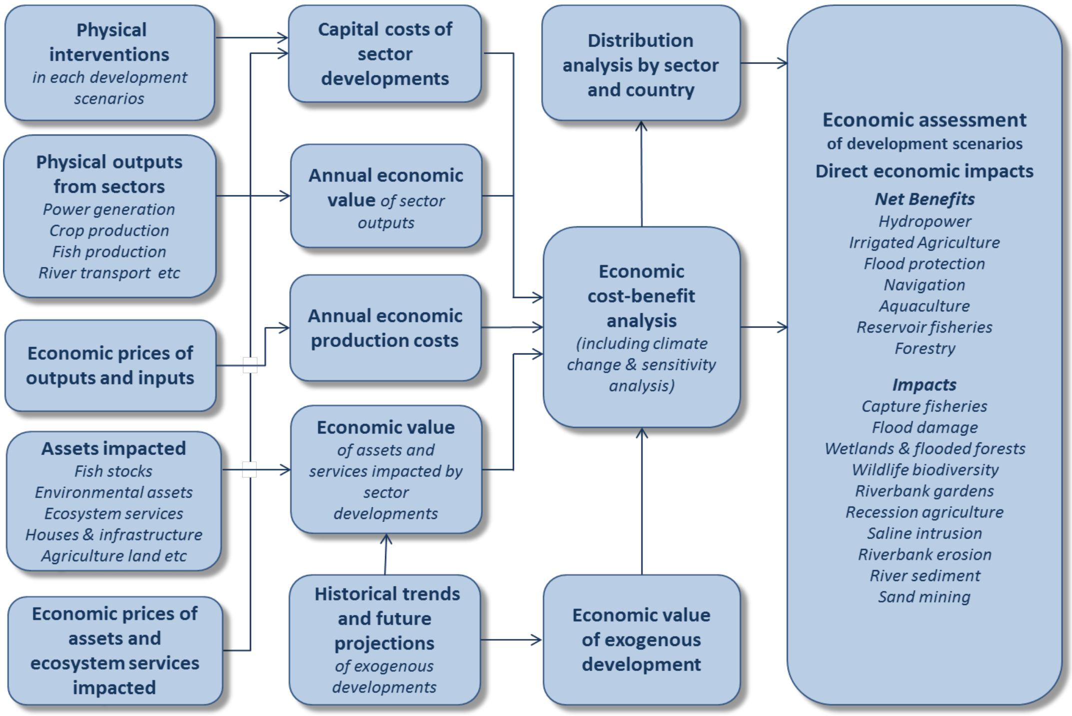
1. How will the structure of the basin economy (or composition of GDP) change in response to the scenarios.
2. How will GDP growth rates resposnse to the scenarios changes?
3. How sustainable will GDP growth be for each scenario?

The following provides details on the methods proposed to address these two assessment perspectives.

3.2 Sector assessment

An overview of the methodology to be used to estimate the direct economic benefits, costs and impacts of water resource developments is given in Figure 3.1.

Figure 3-1 Overview of methodology for economic sector assessment



3.2.1 Capital costs of sector developments

The cumulative capital cost for each type of water resource development (e.g. hydropower, irrigated agriculture, flood protection, navigation, aquaculture and forestry), which have taken place in the LMB during the 1900s and in the early 2000s up to 2015, will be estimated. The capital cost required for the planned infrastructure will then be determined for the on-going and planned water resource developments up to 2020 (i.e. definite future scenario) and 2040 (i.e. planned development scenario).

Economic capital costs will be estimated by applying economic unit values to the physical works required for each type of infrastructure (both existing and planned) within the various development sectors.

Furthermore, the annual recurrent costs required for the management, operation and maintenance of the various types of infrastructure (both existing and planned) will also be estimated.

3.2.2 *Annual economic value of sector outputs and production costs*

For both existing and planned water resource developments, the annual economic benefits which are likely to be generated by investments in water resources infrastructure will be estimated for each development sector. Annual economic benefits will be calculated by using economic prices to value the annual physical outputs and services (e.g. power generated, irrigated crops produced, fish produced, cargo/passengers transported and timber produced) and annual production saved (e.g. crops saved from flood damage).

In addition, annual economic production costs with respect to power generation, crop production, aquaculture production and forestry, as well as IWT costs, will also have to be estimated in order to derive the net annual economic benefits of existing and planned water resource developments (by subtracting annual production costs from the annual economic benefits).

3.2.3 *Annual economic value of assets and services impacted by sector developments*

With regard to the assets, outputs and services impacted by the existing and planned water resource developments, the annual economic benefits which are likely to be gained (positive impacts) or lost (negative impacts) by the development of water resources infrastructure will be estimated for each development sector. Annual economic benefits and losses will be calculated by using economic prices to value the annual physical outputs (e.g. crops produced in saline areas, cargo/passengers transported, reservoir fish produced) and annual production saved (e.g. crops saved from flood damage) as well as annual production lost (e.g. capture fisheries, crop production in floodplains and along riverbanks) and annual assets and services lost (e.g. wetlands, wildlife biodiversity, and eroded land/buildings).

In order to derive the annual net economic benefits and losses resulting from the positive and negative impacts of water resource developments, annual economic costs with respect to crop production, fish production, as well as Inland Water Transport (IWT) costs, will also have to be estimated.

3.2.4 *Historical trends and future projections of exogenous developments*

In addition to evaluating the direct benefits and costs of sector developments, the analysis will also assess the trends in key exogenous factors which will have a significant influence on the direct benefits and impacts (both positive and negative) of water resource developments. These exogenous trends could include key determinants such as: (i) population growth, (ii) industrial/urban development, (iii) sand mining, (iv) rising per capita incomes, (v) increasing demand for food and agricultural products, (vi) greater energy consumption, (vii) declining capture fisheries stocks, (viii) deforestation, and (ix) fluctuating commodity prices (particularly energy prices).

The integration of past trends and future projections of exogenous developments into the economic assessment will provide a more reliable estimate of the direct benefits as well as a better understanding of the positive and negative impacts. It is therefore important that these exogenous development trends are taken into account when evaluating the economic benefits and costs of water resource developments.

3.2.5 *Economic cost-benefit analysis*

The economic cost–benefit analyses will be undertaken on an incremental basis by contrasting the annual net economic benefits[4] in the "future with" water resource developments and "future without" water resource developments projected until 2040. The future with development will include the capital and annual recurrent costs of the interventions/measures, e.g. hydropower, irrigation, flood protection, navigation infrastructure, aquaculture and forestry. Incremental net economic benefit streams will then be derived for each development scenario over the selected 23-year period by subtracting the annual net economic benefits in "future without" situation from the annual net economic benefits in "future with" situation.

The "future without" situation represents the likely trend in the development of resources without the specific intervention. For example, without irrigation development, rainfed crop productivity is likely to increase with the adoption of improved crop varieties and better management techniques and this trend will need to be taken into account in the analysis. Similarly, without the construction of hydropower dams, there could still be a decline in capture fisheries production due to overfishing or a reduction in wetland areas due to increasing urbanisation, so these **exogenous trends** will also be included in the economic assessment. By adopting this incremental approach over a given time period, it will therefore be possible to incorporate a number of exogenous trends in the analysis of both the "future with" and "future without" development situations.

To illustrate the incremental approach being adopted for the cost-benefit analysis, two hypothetical examples are given below.

The first diagram of Figure 3-2 shows the annual net benefits generated by a water resource intervention (e.g. irrigation development) over a 50 year period in both the "future with" and "future without" development situations. In the cost-benefit analysis, the difference between the "future with" and "future without" development situations, which takes account of exogenous trends (e.g. increasing rainfed crop yields), will be used to estimate the incremental annual net benefit stream. It can be seen from Figure 3-2 that, if exogenous trends were not taken into account, the incremental net benefits would be overestimated.

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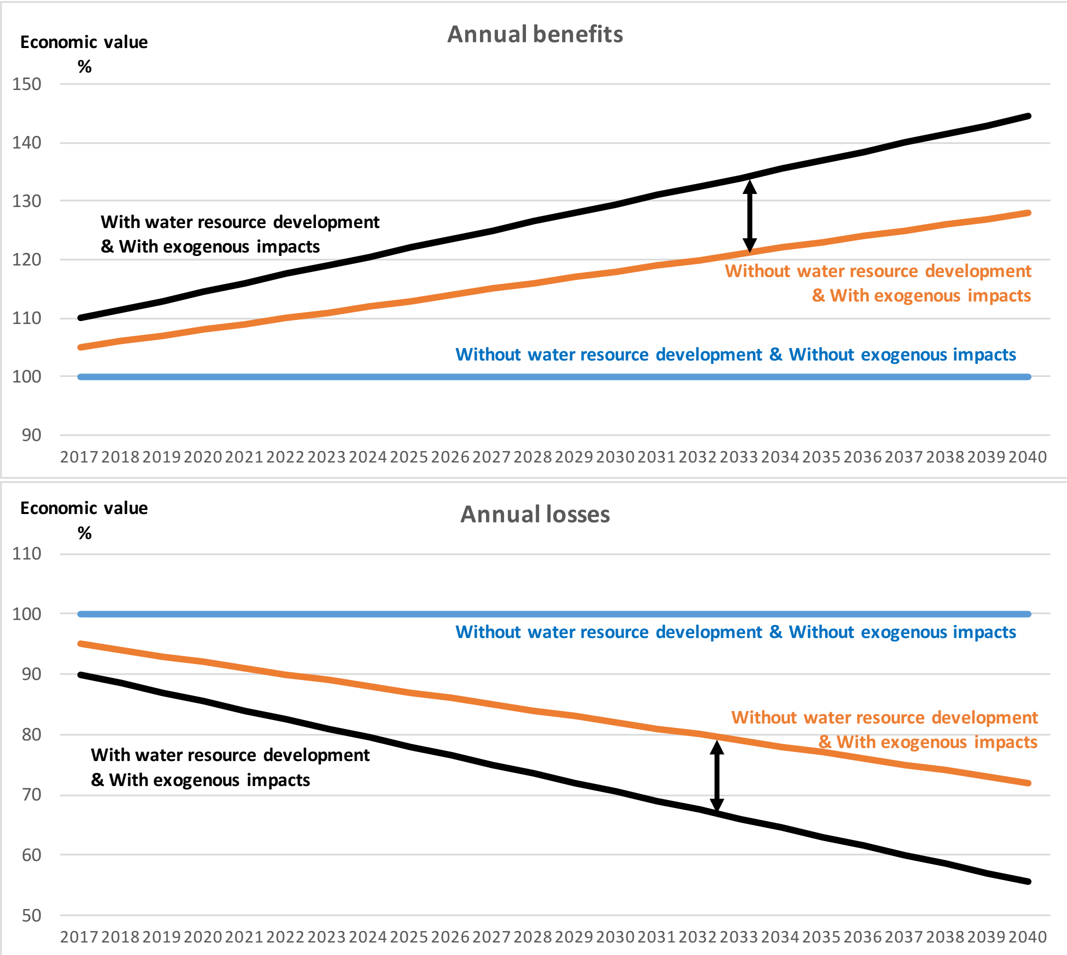
[4] Annual net economic benefits = annual economic value of sector outputs minus annual production costs

Figure 3-2 Incremental approach to cost-benefit analysis



The second diagram shows the annual losses resulting from an adverse impact of a water resource development (e.g. decline in capture fisheries resulting from a hydropower dam). The difference between the "future with" and "future without" development situations, which takes account of exogenous trends (e.g. decline in capture fisheries due to overfishing), will then be used to estimate the incremental annual losses. If exogenous trends are excluded, the incremental annual losses would be significantly higher.

This analysis will also permit further assessment of environmental conservation and sustainability issues by exploring changes in relative economic values over time. For example, if capture fish stocks, wetlands, or wildlife biodiversity become increasingly scarce over time (and of greater importance to future, wealthier generations), higher economic values can be assigned to capture fisheries, wetlands and wildlife in the future relative to the value of energy or irrigated crops.

The estimation of annual net economic benefits and impacts over the selected 23-year time period also permits the scheduling of capital investment during the construction period as well as the phasing of annual net economic benefit streams in the "future with" and "future without" development situations with respect to agriculture, fisheries, energy, navigation and forestry sectors. Based on the annual net economic benefit streams in the "future with" and "future without" situations, annual incremental net benefit streams will then be derived for each development sector. By using incremental annual net benefits streams, the contribution of the proposed interventions to economic development within each sector will be evaluated for the three development scenarios, the six selected sub-scenarios, and the two climate change scenarios.

This approach will significantly enhance the value of the economic assessment and will provide a greater insight into the relative economic benefits of the existing, ongoing and planned development interventions in the context of medium and long term trends in key economic, social and environmental indicators within the LMB. Furthermore, the analysis will permit the distribution of the annual incremental net benefits between development sectors and between the four riparian countries.

In addition to estimating the annual benefits, costs and impacts, the incremental annual net benefit streams will be also be used to calculate the net present values for each development sector using an appropriate discount rate which reflects the overall opportunity cost of capital in the LMB. Net present values convert future benefits into today's value. This involves the application of a social discount rate when converting future benefits. Such a conversion into net present value considers the fact that people have a strong preference for present consumption. The longer the benefit is placed in the future the less people value these benefits or costs. However, experiments have shown that the rate by which people discount future benefits drops the further one steps into the future. This means that people see a lot of difference between receiving a benefit now or in one year (hence the need to discount in the first place). But people do not distinguish (much) between receiving a benefit in twelve years or in thirteen years. Therefore, the social discount rate decreases the further we step into the future.This type of social discounting is referred to as hyperbolic discounting.

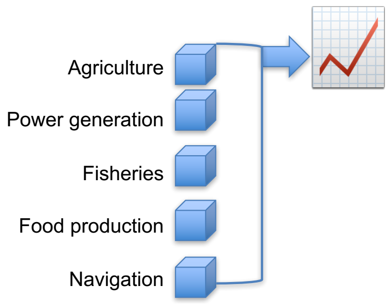
By using incremental net benefits streams and hyperbolic discounting to determine NPVs, the economic viability of the proposed interventions and their contribution to overall economic development will be evaluated for each development scenario.

3.3 Macro-economic assessment

3.3.1 Estimating the impact on the structure of the basin economy

Development economics puts an emphasis on understanding the structural composition of economies. This entails an understanding of how the reliance on particular sectors changes and how economies shift activities and investments between primary, secondary and tertiary sector employment. Primary sectors include agriculture, mining, fisheries and forestry. Secondary sectors include construction and manufacturing. Tertiary sectors include a wide range of service sectors and tourism. Historically, successful development included a shift from primary to secondary to tertiary employment. With this shift, economies often experience a reduction in dependence on natural resource input and an increase in human resource inputs. However, this pattern also involved in many cases a substantial increase in the demand in energy (e.g. electricity and fossil fuels).

Figure 3-3 Calculating sectoral contribution to GDP



This assessment step will build in the sectoral assessment results and calculate how proportions change. Additionally, it will establish how the combined value contribution of MRC sectors (see Figure 3-3) is likely to change considering GDP growth projections.

3.3.2 *Estimating GDP growth changes*

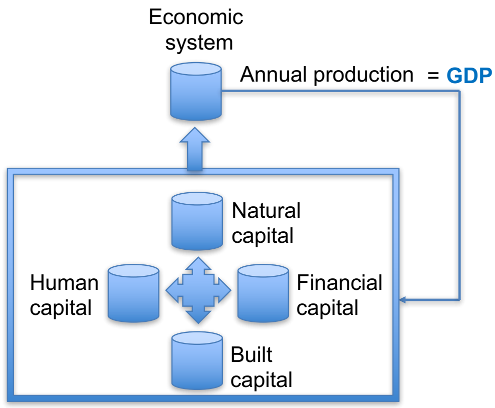
Estimating impacts of water infrastructure investments on GDP requires macro-economic models. Typically, economists employ either Computable General Equilibrium (CGE) models, Input-Output models, or micro-simulation models. Unfortunately, these models are not available for this assessment and cannot be developed within the provided timeframe and within the budget constraints.

In absence of robust macro-economic models, this assessment will combine three inputs. First, the sector assessment results (see above). Second, results from the socio-economic assessment will provide projections for changes in household income across many different livelihoods that are most relevant to the Mekong corridor and the Mekong related development options. Considering that GDP (by definition) can also calculated based on income information, these projections will be added to the (production focused) sector projections form the sector assessment. In a third step existing Input-Output table will be utilised to fill any remaining gaps. This third step will calculate the proportion of the sectors considered by step 1 and 2 and impose macro-economic projections provided by the Governments of the four Member countries and other international agencies (e.g. IMF and World Bank). Considering the methodological constraints, this step will include an uncertainty range when combining all three perspectives into scenario specific GDP growth projections.

3.3.3 *Understanding the sustainability of economic growth*

GDP is often criticised as an inadequate metric for understanding the sustainability of economic development. Considering that any economic activity requires different input factors it is obvious that economic growth would be constraint once one or multiple input factors are no longer available. The underpinning economic concept puts distinguished different capitals and their role as input factors for economic processes center stage. Figure 3-4 visualises this concept.

Figure 3-4 Conceptualisation of economic relationship between input factors and GDP



In this assessment four types of capital find explicit consideration. Natural capital involves all forms of natral resources, incl. forest, fish, and land. Human capital includes people's tme, their skill sets, or intellectual property. Financial capital includes various forms of savings and investments. Built capital includes machines, buildings, logistical infrastructure, and water infrastructure. In many studies, social capital is also considered. For this assessment, however, data for the assessment of existing or future levels of social capital is not available. Several methodologies employ this conceptualisation, including the five-capital approach or the inclusive wealth approach (see for the example by the UN http://www.ihdp.unu.edu/docs/Publications/Secretariat/Reports/SDMs/IWR_SDM_2014.pdf).

From a sustainability perspective, economic growth is vulnerable if the combined value and/or biophysical stock of these capitals is decreasing. Even the decline of one capital can constrain GDP growth if this input cannot be substituted and, thereby the economy's dependence on this input factor does not decline proportionately. Economies refer to the malleability (=ability to substitute) of this input factor.

Based on this understanding, this assessment aims to compare GDP with the change in these assets, particularly natural capital. Bearing in mind that GDP is an annual value, the assessment needs to derive the annual value change for natural capital. This can be achieved through the economic valuation of natural capital. Over the past decades, environmental economics has developed a wide range of valuation techniques for natural resources to assess also their non-market values. The following explains the approach of economic valuation.

3.3.4 Economic valuation

Market-based dimensions of natural resources are those values that are traded on economic markets and that have a market prces. price. These values will be derived from the sector assessments. Methodologically, this step adopts conventional market price techniques for commodities with a direct use value (e.g. energy, crops and fish) as well as resources which have alternative uses, e.g. land, labour and capital. Some market prices will need to be adjusted to reflect their opportunity cost within the overall basin economy. For example, the economic pricing of electricity will require the estimation of the costs of power generation by a thermal plant using fossil fuel, which is the least cost alternative to hydropower generation.

With respect to irrigated agriculture, the economic prices of crops will be derived from their internationally traded prices adjusted for shipping, processing and transport. For capture fish, there are a number of alternative methods to estimate the economic price, e.g. (i) market price at landing site, and (ii) replacement cost (i.e. unit production costs of culture fish). In the analysis, both methods will be considered.

Non-market values of natural resources will be estimated based on a database MERFI consolidated. This database consolidates all economic valuations of natural resources conducted since the year 2000 in the Lower Mekong Basin (Smajgl & Dugan, 2015). These values will be mainly grouped into four types of ecosystems:

- Evergreen forests
- Decidious forests
- Wetlands
- Mangroves

Valuation results consider a wide variety of ecosystem services for each of these ecosystems. These values will be consolidated as dollar per hectar and will be defined in ranges as the 504 available valuation results come from different parts of the Mekong basin and vary (see http://mekongarcc.net/ESV_tool/ESV.html for details). This provides the assessment with a robust method to consider the uncertainty of non-market valuation.

Table 3-1 Ecosystem valuation results in the Lower Mekong Basin since 2000

Total Economic Value (TEV)			
	MIN	Mean	MAX
Evergreen forest	$7,241	$17,578	$27,916
Deciduous forest	$6,665	$13,306	$19,946
Mangroves	$9,692	$20,324	$30,956
Wetland	$9,906	$12,776	$15,646
Coasts/Islands with coral reefs	$31,235	$44,173	$57,110

Disciplinary assessment results provided by the modelling team (e.g. hydrology) and BioRA will be combined with these Mekong specific data to establish changes in natural capital for each development scenario. Once combined with the GDP projections, the assessment can establish so-called conversion rates and dependency rates.

Conversion rates define how many dollars in annual benefits from natural capital are gained or lost for each dollar gained in GDP. The dependency factor will quantify how the dependency of GDP on natural capital is likely to change over time. The combination of these two indicators will provide important guidance on the sustainability of GDP growth.

4 Scenario-based assessment approach

4.1.1 Introduction

It can be seen in Figure 3.1 that the above methodology provides the analytical framework for the economic assessment of development scenarios. The following section presents a detailed description of the analytical methods used in the economic assessment of water sector developments with respect to: (i) direct benefits and costs of each sector development, and (ii) wide range of positive and negative impacts of water resource interventions.

This assessment will consider eleven scenarios, which include three main development scenarios, six thematic sub-scenarios, and two climate change scenarios. The three main development scenarios are: (i) early development scenario comprising the water resource infrastructure (e.g. irrigation, flood protection, navigation and hydropower) existing in the Mekong Basin in 2007 and mostly developed after 1900; (ii) definite future scenario comprising existing water resources infrastructure in the Mekong Basin, infrastructure under construction, as well as future water resource developments planned up to 2020; (iii) planned development scenario comprising existing and under construction infrastructure as well as water resource developments planned up to 2040.

Six additional sub-scenarios have been defined for this assessment to capture sector-specific variations of the main development projections. Two of these thematic sub-scenarios are focused on flood protection investment, including additional investments in flood protection of urban areas and floodplain management (FPF2). Then, the FPF2 scenario is combined with the assumption of joint operation of mainstream and tributary reservoirs (FPF3). One sub-scenario is defined for the irrigation sector (IRR1) by assuming an additional expansion by 2040. Variations in sand mining activity (sustainable=DIW1; high extraction=DIW2) define two additional sub-scenarios. One additional sub-scenario has been defined for the agricultural and land use change domain by assuming a higher level of agricultural expansion (ALU3). Two additional scenarios are linked to different assumptions on future climate change.

The economic assessment of the three development scenarios will focus on estimating the potential annual net benefits from:

- hydropower development in the mainstream of the LMB;
- irrigation development in the Vietnam delta, Cambodia floodplains, NE Thailand and Lao lowlands;

- flood protection infrastructure in Vietnam delta, Cambodia floodplains, NE Thailand and Lao lowlands;
- navigation infrastructure along the mainstream of Mekong river;
- aquaculture development, particularly in Vietnam delta and NE Thailand; and
- forestry development in vulnerable catchments of the LMB.

These water resource developments will also have a number of potential positive and negative impacts. The potential positive impacts include:

- fisheries production in LMB reservoirs;
- reduced flood losses and damage to crops, houses and infrastructure;
- reduced saline intrusion in the Mekong delta;
- enhanced navigation along the mainstream of the Mekong river;
- the construction of water resources infrastructure will also have a number of potentially adverse impacts such as:
- decline in capture fisheries stocks;
- reduction in the wetland areas (including flooded forests) resulting from a decline in flooding;
- loss of key habitats, wildlife biodiversity and conservation areas;
- loss of land, houses and infrastructure due to increased river bank erosion;
- reduction in the area of recession agriculture and riverbank gardens;
- reduction in agricultural productivity in the lowland floodplains;
- reduction in sand mining

4.1.2 *Direct benefits and costs of water resource developments*

(i) ***Hydropower production***

The economic assessment of the existing and planned hydropower projects in the LMB will be primarily based on the updating of the cost-benefit analyses that has been prepared for a wide range of the projects[5]. In the economic analysis of the hydropower projects, dependable HEP capacity and annual power production have been estimated for each hydropower project. The capital investments in existing hydropower projects, as well as the capital required for development of future hydropower projects (including transmissions lines), are also available in the hydropower database which is currently being updated by the hydropower thematic team. Furthermore, the respective operation and maintenance costs have been calculated for both existing and planned hydropower developments.

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[5] "Hydropower Sector Review for the Joint Sector Planning Process" (draft), BDP, February 2009.

The annual net economic benefits of the hydropower projects have also been estimated based on the costs of generating power from alternative thermal sources (i.e. diesel, natural gas and coal) in the consuming country. For the host country, the annual net benefit of hydropower is the sum of the benefits from power supply to domestic consumers and from exports to neighbouring countries less annual production costs. For importing countries, the annual net benefit of hydropower is the replacement value of imported power (calculated at the proxy trade price) less import costs. In addition, the assessment of alternative power generation options for each country will also be updated by the hydropower thematic team.

In the cost-benefit analysis, NPVs were also calculated in order to assess the economic viability of hydropower projects in terms of energy production.

In addition to updating the benefits and costs of hydropower production, the costs of resettling/compensating households displaced by reservoirs, as well as the costs of environmental mitigation measures, e.g. fish ladders, will also be estimated.

(ii) ***Irrigated agriculture***

The historical trends and future projections of irrigated areas in the LMB will be derived from the MRC irrigation database, which is currently being updated by the irrigation thematic team. The location of the existing and planned irrigated areas (based on national plans) will then be mapped following the integration of the irrigation database into the GIS. Future irrigation development in the LMB will be made possible by an increased supply of water during the dry season made available by increased storage capacity in the hydropower reservoirs.

Capital investment in existing irrigation infrastructure, as well as the investment required to construct the planned irrigation infrastructure, will be based on data available in the irrigation database and irrigation project reports. Furthermore, the annual costs of operating and maintaining the irrigation systems, will be estimated for different types of irrigation schemes.

The phasing of the irrigation development will also be undertaken and this will include the areas within the LMB that would be developed over the next 25 years (2020 and 2040 scenarios) in accordance with national planning. This extent and phasing of future irrigation development will also take account of the likely implementation constraints such as the capital investment required from government and the availability of skilled labour.

Within the existing irrigated areas, cropping patterns (i.e. proportion of area under each crop in both the wet and dry seasons) will be based on crop area data available in the irrigation database. For planned irrigated areas, cropping patterns (both rain fed and irrigated) will be derived for the present situation, as well as “future with” and “future without” development scenarios using data available from national crop area statistics and the irrigation database.

To estimate the net economic benefits per hectare for rice and non-rice crops under both irrigated and rain fed conditions, the following information will be needed: (i) present and future crop yields, (ii) seed, fertiliser and pesticide usage by crop, (iii) labour and machinery requirements by crop, and (iv) economic prices of crop outputs, inputs, labour, machinery and transport.

Following the collection of these data sets, annual crop budgets will be prepared for each crop type in the present situation, as well as "future without" and "future with" development scenarios. A crop budgets will comprise the value of production per hectare (average crop yield multiplied by economic output price) less production costs per hectare (seeds, fertilisers, pesticides, labour, machinery and transport requirements multiplied by the respective economic input prices, wage rates and hire charges in order to determine the annual net economic benefits per hectare for each crop.

Annual net benefits per hectare will then be derived for a range of rice and non-rice crops at various locations within NE Thailand, Lao PDR, Cambodia and Viet Nam benefiting from existing irrigated areas and the planned expansion of the irrigation infrastructure. The annual net benefits per hectare will then be applied to the respective crop areas within each of the rain fed and irrigated cropping patterns, and the overall annual net benefits per hectare will be determined in both the existing and planned irrigated areas.

By contrasting the "future with" and "future without" annual net benefit streams for a combination of cropping patterns, the incremental annual net crop benefits from a phased expansion of the irrigated area will then be derived. The crop benefit streams will then be used to estimate the NPV of incremental annual net crop benefits for the planned irrigation development areas within LMB.

(iii) ***Flood protection***

The existing types of flood protection measures in the LMB, as well as the flood protection infrastructure that could be developed over the next 23-year period, need to be identified. The capital investment in existing and planned infrastructure will be based on data made available by FMMP. Furthermore, the annual costs of operating and maintaining the flood protection measures will be estimated for different types of infrastructure.

The annual economic benefits of flood protection infrastructure in Vietnam delta, Cambodia floodplains, NE Thailand and Lao lowlands will be evaluated. These benefits will include lower crop losses as well as reduced damage to private property (i.e. households, businesses) and public infrastructure (i.e. roads, schools, health centres etc.) within the LMB. In addition, other benefits of mitigating flooding, such as reduced rescue/relocation costs and lower disruption losses, will also be taken into account.

The area of land benefiting from flood risk reduction will be estimated from the assessment of hydrological changes resulting from the construction of the flood protection infrastructure in each development scenario. The location of specific areas directly benefiting from flood protection in terms of reduced flood damages will be mapped using the GIS database. Within areas where flooding risk has been reduced, information on the numbers of households and types of land use (i.e. crop production, forestry, lakes/ponds, settlements, infrastructure and wetlands) will be obtained from the GIS database.

The annual economic value of the direct benefits of flood protection, as well as the reduction in the annual flood benefits, which have been estimated by FMMP as part of their study on flood damage and flood risk in vulnerable areas of LMB, will then be applied to population and land use data within each location in LMB benefiting from flood protection measures.

By contrasting the "future with" and "future without" annual net benefit streams within the areas benefiting from flood protection, the incremental annual net benefits from the construction of flood protection infrastructure will then be derived. The annual net benefit streams will then be used to estimate the NPV of the incremental annual net benefits for each specific location benefiting from flood protection as well as the LMB as a whole.

(iv) ***Mainstream navigation***

The existing types of navigation infrastructure along the mainstream of the Mekong river, as well as the planned developments over the next 23 years, is being identified by the navigation thematic team. The capital investment and annual operation/maintenance costs of the existing and planned infrastructure will be based on data made available by the navigation programme (NAP).

The potential economic benefits from navigation infrastructure will also be assessed. These benefits mainly derive from an increase in the volume and value of cargo utilising the Mekong mainstream that can be directly attributed to the improvements in navigation infrastructure. Furthermore, there is also likely to be increase in the number of passengers using inland water transport (IWT) which will generate further revenue.

In addition, mitigation measures may also be required to divert IWT vessels around the hydropower dams. The capital investment required to construct the civil infrastructure (canals and locks), as well as the annual costs of operating and maintaining the navigation system, will be estimated by the navigation thematic team.

These capital and O&M cost will be deducted from the incremental benefit stream. The incremental net benefit stream will then be used to estimate the NPV of incremental annual net navigation benefits for each river reach/zone and the mainstream Mekong as a whole.

(v) ***Aquaculture production***

Aquaculture production systems have rapidly expanded in the LMB over the past 15 to 20 years, particularly in the Vietnam delta and NE Thailand. It is also anticipated that aquaculture production will continue to expand in all LMB countries over the next 23 years. For all LMB countries, historical trends in aquaculture development, as well as future projections of annual aquaculture production over the next 23 years, will be estimated by the agriculture/land use thematic group in consultation with the Fisheries Programme (FP).

Production data will be derived from estimates of the fish pond areas and the annual yields per hectare of fish pond.

In addition, past trends and future projections (up to 2040) of the rice-fish production systems will also be determined with respect to rice-fish areas and annual fish yields.

With regard to economic valuation, current market prices for culture fish species will be used as these closely reflect their economic value under relatively free and competitive market conditions. Production costs, as well as marketing expenses, will also be determined and these data will then be used to estimate the annual net economic value of aquaculture and rice-fish systems in the present and future development situations. The economic NPV of aquaculture production and rice-fish systems for each country, as well as the LMB as a whole, will also be calculated.

(vi) ***Upland forestry***

Past trends in upland forestry development and watershed management in the catchments of the LMB, as well as future projections of annual forestry development over the next 23 years, will be estimated by the agriculture and land use thematic group. Past and future trends in the annual area of deforestation within the catchments, as well as the annual volumes of timber production, will be assessed.

Current timber log prices for different tree species will be used to estimate the annual economic value of timber. Production costs will then be deducted in order to estimate the annual net economic value of timber production in the present and future development situations. The economic NPVs of timber production will also be calculated.

4.1.3 *Positive impacts of water resource developments*

(i) ***Development of reservoir fisheries***

The hydropower reservoirs created in the LMB will provide an opportunity to develop both capture and culture fisheries. The past and on-going development of reservoir fisheries, with respect to location, area and fish production, will be determined. The phasing of the future development of reservoir fisheries over a 23-year period up to 2040 will then be undertaken, and the annual production of fish will be estimated for each reservoir.

With regard to economic valuation, current market prices will be used. Production and marketing costs will also be determined which will be then be used to estimate the annual net economic value of reservoir fish production in the present and future situations. The economic NPV of reservoir fisheries production will also be calculated.

(ii) ***Reduced flood damage***

The annual economic benefits of mitigating floods during the wet season due to the improved regulation of river flows (as a consequence of the hydropower dams) will be evaluated. These benefits will primarily include lower crop losses as well as reduced damage to private property and public infrastructure. In addition, reduced disruption and relocation costs will also be taken into account.

The area of land benefiting from flood risk reduction will be estimated from the assessment of hydrological changes resulting from the construction of the hydropower dams. At locations where flooding risk will be reduced, information on the numbers of households and types of land use (i.e. crop production, forestry, settlements and infrastructure) will be obtained from district statistics. The annual economic value of flood mitigation will then be applied to population and land use data within each location benefiting from a reduction in flooding.

By contrasting the “future with” and “future without” annual net benefit streams, the incremental annual benefits of flood mitigation due to the construction of dams will then be derived. The NPV of incremental annual net flood reduction benefits will then be calculated for each specific area and the LMB as a whole.

(iii) ***Increased productive activities in areas affected by salinity***

The annual economic benefits of reducing saline intrusion, due to the increased river flows during the dry season, will also be evaluated. These benefits will include higher crop productivity and improved capture fisheries within areas in the Mekong Delta which currently experiences saline intrusion.

The area of land that is likely to benefit from reduced saline intrusion will be based on the assessment of hydrological changes which will result from the construction of hydropower dams, sea level rise, land subsidence, and sand mining (mining pits trap bedload). The location of specific areas directly benefiting from reduced salinity will be mapped using the GIS database. Within areas where salinity is likely to been reduced, information on the types of land use and cropping patterns will be obtained from district statistics.

The annual economic value of crop benefits will then be applied to crop patterns benefiting from a reduction in saline intrusion. By contrasting the “future with” and “future without” annual benefit streams within the areas benefiting from a reduction in salinity, the incremental annual net benefits will then be derived and this will then be used to estimate the NPV of salinity reduction benefits.

(iv) ***Enhanced mainstream navigation***

The potential economic benefits for navigation and river transport due to an increase in the depth and duration of flooding (as a result improved regulation of river flows by hydropower dams) will also be assessed. These benefits mainly derive from an increase in the number of days per annum in which the river system is navigable due to an increase in the depth and duration of river flows during critical periods in the year.

However, a clear relationship between changes in river flows and the value of additional river transport will be difficult to determine. It is generally the case that higher flows will facilitate the passing of larger boats, but it is not clear how total volumes and unit costs might be altered as a result of changes in flow.

Nevertheless, it may be possible to focus on specific river reaches that have high potential for future growth according to the emerging Navigation Regional Master Plan. Based on the minimum safe draft requirements for different types of vessel and data from the hydrological assessment, experts from the navigation programme should be able to estimate number of days per annum when the river systems are navigable by river reach/zone for both the present situation and in the future when hydropower dams are operational.

The increase in the number of days of navigation will then be converted into an economic benefit by estimating the annual volume of IWT cargo trade in both the "future with" and "future without" dams situations for each river reach/zone. The economic value of the incremental IWT cargo trade will then be estimated by applying the net value (i.e. gross value less haulage costs) per tonne to the tonnage of incremental cargo. The incremental annual economic benefits will then be used to estimate the NPV of navigation benefits.

4.1.4 *Negative impacts of water resource developments*

(i) ***(i) Decline in capture fisheries***

The annual economic losses associated with a decline in capture fisheries which can be directly related to the construction of hydropower dams and flood protection infrastructure will also be evaluated. The annual economic losses of capture fisheries will comprise the direct losses in terms of the decline in the net value of capture fisheries output that is likely to result from a barrier to stop the migration of certain fish species to their breeding, spawning and feeding grounds. Changes in water levels can also have an impact on capture fisheries both positive (as dry season flows increase) and negative (as wet season flows decrease), and this also will be taken into account in the economic assessment.

Future changes in the annual fish catch, with and without the construction of water resource infrastructure, will be estimated by the biological resources assessment team. The type of fish species that will be affected will also be specified. Annual economic losses will then be calculated for a number of river reaches by applying economic prices of different fish species to the annual fish catch with and without hydropower dams and flood protection infrastructure.

Annual economic values will then be estimated for the present situation, as well as "future without" and "future with" development scenarios (including exogenous developments such as overfishing) in order to determine the incremental economic value of fisheries losses due to hydropower dams and flood protection infrastructure for each riparian country and the LMB as a whole. Based on the incremental annual value of economic losses, the NPV of the decline in capture fisheries, due to water resources infrastructure, will then be calculated.

(ii) ***Reduction in wetland areas, key habitats and wildlife biodiversity***

The economic losses associated with a reduction in wetland areas (including flooded forests), as well as their composition in terms of biodiversity of ecosystems, which can be directly related to lower river flows in the wet season due to the construction of dams and flood protection infrastructure, will be evaluated. The area of wetlands and flooded forests expected to be lost, and the annual rate of decline, will be estimated by the BioRA discipline team. The types of wetland likely to be affected and the location of specific wetland areas which are likely to be lost should also be mapped using the GIS. This assessment will also include estimates of past reductions in wetland area which have be very substantial. In 2003, the proportion of wetland areas already lost were estimated at 99% in Vietnam, 96% in Thailand, 45% in Cambodia and 30% in Lao PDR. These wetland losses were mainly due to agricultural development and urbanisation.

The annual economic value of wetland areas already lost and likely to be lost at each location will be estimated by applying unit values to different wetland types. The valuation of different types of wetlands will primarily be based on the wetland valuation studies conducted by EP (as discussed in Section 3.4: Economic valuation) as well as an analysis of the valuations undertaken for different types of wetland throughout South East Asia.

By contrasting the “future with” and “future without” annual value of wetland areas, the incremental annual wetland losses due to agriculture, urbanization, and changes in the flow regime due to irrigation and hydropower dams and flood protection structures will then be derived. The wetland loss streams will then be used to estimate the NPV of incremental wetland losses for each specific area and the LMB as a whole.

Similarly, the economic losses associated with a reduction in key habitats and wildlife biodiversity (micro-invertebrates, herpetofauna, mammals and birds) that can be directly related to the development of agriculture and the construction of water resources infrastructure, will also be evaluated. A significant proportion of ‘pristine’ wildlife biodiversity has been lost during the past 100 years and the number of threatened species has increased from 327 in 1996 to 1,525 in 2014. This decline can mainly be attributed to agricultural development, urbanisation and the expansion of transport infrastructure.

The populations of different wildlife species are expected to fall in the future (both with and without water resource developments). Estimates of the reduction in wildlife populations, as well as the annual rates of decline, will be determined by the BioRA discipline team. The types of wildlife species likely to be affected and the location of specific sites of high wildlife biodiversity which will probably be lost should also be mapped using the GIS.

The incremental annual wildlife losses due to water resource developments will then be derived. The wildlife loss streams will also be used to estimate the NPV of incremental wildlife losses for each specific area and the LMB as a whole. It should, however, be noted that protected areas with high environmental value, e.g. Ramsar sites and world heritage sites, will not be adversely affected as appropriate mitigation measures will be include in the development costs.

(iii) ***Loss of economic assets in locations affected by riverbank erosion***

The economic losses associated with increased riverbank erosion (such as loss of agricultural land and infrastructure) which can be directly related the construction of hydropower dams through a reduction in sediment transport in the river systems will also be evaluated. The annual economic losses of riverbank erosion during the wet season will include both direct losses (e.g. agricultural land, forest, private property and public infrastructure) as well as the costs of relocation and resettlement.

The area of land expected to be lost to riverbank erosion and the rate of erosion will be estimated by the biological resources assessment team as part of their geomorphological assessment. The location of specific areas which are likely to be eroded will also be mapped using the GIS.

Within areas vulnerable to erosion, information on the numbers of households and types of assets (e.g. land, houses, shops, schools, health centres, roads etc.) which could be lost would be obtained from the GIS database and maps. The annual economic value of assets likely to be lost at each location will be estimated by applying unit values to a wide range of assets. For different types of land use (i.e. agriculture, forest, wetlands etc.), the present value (PV) of annual benefits will be used, while replacement cost estimates will be used to value buildings and infrastructure.

Relocation and resettlement costs will be based on the unit costs of transporting goods and equipment from the houses, businesses and public facilities which are vulnerable to riverbank erosion.

By contrasting the “future with” and “future without” annual losses within the areas vulnerable to erosion, the incremental annual riverbank erosion losses from the construction of hydropower dams will then be derived. The annual loss streams will then be used to estimate the NPV of incremental riverbank erosion losses for each specific area and the LMB as a whole.

(iv) ***Decline in recession agriculture, lowland crop productivity, and riverbank gardens***

The economic losses associated with a reduction in the areas of recession cropping and riverbank gardens, as well as a decline in floodplain crop productivity, which can be directly attributed to lower river and sediment flows in the wet season (due to the construction of dams and flood protection infrastructure) will be evaluated. The areas of recession cropping and riverbank gardens expected to decline, and the annual rate of decline, will be estimated by the hydrological discipline team in association with the agriculture/land use thematic team. Similarly, areas of the floodplain likely to be adversely affected and the anticipated decline in crop productivity will also be determined. The areas and location of recession cropping, riverbank gardens and floodplain cropping should also be mapped using the GIS.

The annual net economic value of recession cropping and riverbank gardens likely to decline at each location will be estimated by applying net economic values per hectare to the areas of recession cropping and riverbank gardens in both the “future with” and “future without” development situations. Similarly, the reduction in floodplain crop yields will be determined by applying economic crop prices per tonne to the annual crop production in the affected floodplain areas (both with and without water resource developments).

By contrasting the “future with” and “future without” annual economic value of recession cropping, riverbank gardens and floodplain crop productivity, the incremental annual reduction in the value of crop production (due to the construction of hydropower dams and flood protection structures) will then be derived. The economic loss streams will then be used to estimate the NPV of incremental crop losses for each specific location of recession cropping, riverbank gardens and floodplain cropping, as well as the LMB as a whole.

(v) ***Deforestation***

Past trends in forestry development and watershed management in the catchments of the LMB, as well as future projections of annual forestry development over the next 23 years, will be estimated by the agriculture and land use thematic group. Past and future trends in the annual area of deforestation within the catchments, as well as the annual volumes of timber production, will be assessed.

Current timber log prices for different tree species will be used to estimate the annual economic value of timber. Production costs will then be deducted in order to estimate the annual net economic value of timber production in the present and future development situations. The economic NPVs of timber production will also be calculated.

(vi) ***Reduction in crop production due to drought***

The economic losses associated with changes in crop production due to drought will be evaluated. The areas likely to be affected by drought and the expected decline in crop yields will be determined. The location of drought affected areas should also be mapped using the GIS. The annual net economic value of crop losses will then be estimated by applying net economic values per hectare to the areas likely to be affected by drought in both the “future with” and “future without” development situations.

By contrasting the “future with” and “future without” development situations, the incremental annual reduction in the value of crop production (due to water resource developments) will be derived. The economic loss streams will then be used to estimate the NPV of incremental crop losses for each drought affected location as well as the LMB as a whole.

4.1.5 Indirect macro-economic impacts of water resource developments

It should be noted that this document only discusses the methodology for estimating the direct economic benefits, costs and impacts of water resource developments. The assessment of wider, indirect benefits to the macro-economy through linkages with other sectors (e.g. industry and services), which could be induced by the planned water sector investments, are examined separately.

4.1.6 *Macro-economic impacts*

In addition to the economic cost-benefit analysis of natural resources, impacts on macro-economic indicators will also be estimated with respect to the selected water resource development scenarios. This macro-economic perspective will include impacts on basin-wide GDP and on food and energy security, which links to the national economies of the four riparian countries.

Changes in GDP will be estimated based on a combination of income and production changes in the particular sectors considering trends in productivity changes. Food security will compare the changes in domestic production and the expected income changes with expected population changes. Similarly, energy security will be estimated based on demand forecasts and increases in production levels. The third macro-economic assessment pillar will investigate changes in investments and assets. This assumes the widely-acknowledged link between assets (or stocks) of input factors relevant for the various production processes of the four economies. Changes in assets over time due to investment changes will provide an important set of sustainability indicators to quality the quality of economic growth.

5 Data requirements for economic assessment

5.1 Overview

The economic assessment of the development scenarios will require comprehensive and reliable data sets. The main sources for data are:

- Council study thematic groups: (i) land use, agriculture, aquaculture and forestry; (ii) irrigation development; (iii) domestic and industrial water use; (iii) flood protection and flood plain infrastructure, (iv) hydropower development, and (v) navigation;
- Council study discipline teams: (i) biological resources assessment, (ii) climate change assessment, (iii) hydrological assessment, and (iv) socio-economic assessment;
- MRC databases, e.g. (i) hydropower database, (ii) irrigation database, and (iii) socio-economic database, which have been developed in recent years;
- Government statistics, economic studies and socio-economic surveys.

Data collection comprises the gathering of all documents, maps and databases available from the above sources as well as other relevant information available from the four riparian countries. The main data requirements for the economic assessments are summarised below and detailed in Tables 4.1 to 4.10.

(i) ***Hydropower***

- Historical development of hydropower in LMB (installed capacity and location) up to 2015;
- Installed capacity (MW) and location of hydropower plants under construction and planned up to 2040;
- Power generation (kWh) of existing, under construction and planned plants;
- Capital investment and annual recurrent costs of hydropower plants;
- Scheduling of construction and construction periods of planned plants;
- Economic price of electricity based on production costs of alternative power sources (e.g. thermal power plants) including an assessment of alternative power generation options for each country
- Annual economic value of power generation for domestic consumption and export by producer country;
- Annual economic value of imported power by consumer country.

(ii) ***Irrigated Agriculture***

- Historical development of irrigated agriculture in LMB (irrigated area and location) from 1900 to 2015;
- Area and location of irrigation schemes under construction and planned up to 2040;
- Capital investment and annual recurrent costs of irrigation development;
- Irrigated/rainfed cropping patterns and crop yields by location;
- Annual crop production costs per hectare (inputs, labour and machinery) of irrigated and rainfed crops by location;
- Annual economic benefits per hectare of irrigated and rainfed land by crop.

(iii) ***Flood protection***

- Historical development of flood protection infrastructure in LMB (type and location) from 1900 to 2015;
- Type and location of flood protection works under construction and planned up to 2040;
- Capital and annual recurrent costs of flood protection works;
- Extent and value of damage and losses due to flooding – crops, houses and infrastructure – with and without flood protection measures;
- Projected increases in the future asset values (land, housing and infrastructure) vulnerable to flooding with and without flood protection measures;
- Annual economic benefits of flooding, e.g. increased crop yields and capture fisheries;

(iv) ***Navigation***

- Historical development of navigation works along the Mekong river (type and location) from 1900 to 2015;
- Type and location of mainstream navigation works under construction and planned up to 2040;
- Capital and annual recurrent costs of mainstream navigation works including navigation canal and locks;
- Quantity of cargo and number of passengers transported by river reach;
- Annual economic benefits and costs of cargo/passengers transported both with and without navigation works;
- Capital and recurrent costs of alternative modes of transport, i.e. road and rail.

(v) ***Fisheries***

- Historical changes in fish stocks and annual catches from 1900 to 2015 by fish species and location;
- Historical changes in fish stocks and annual catches due water resource developments, e.g. hydropower dams and flood protection works, creating barriers to fish migration;
- Historical changes in fish stocks and annual catches due to exogenous factors, e.g. overfishing, water pollution;
- Estimated future declines in fish stocks and annual catches due to existing and planned water resource developments as well as exogenous factors;
- Economic benefits and costs per ton of capture fisheries by fish species and location;
- Past, present and future production from reservoir fisheries, aquaculture and rice-fish systems;
- Economic benefits and costs per tonne of reservoir fisheries, aquaculture and rice-fish production.

(vi) ***Wetland areas***

- Historical changes in the area of wetland vegetation (e.g. plant cover, forests) from 1900 to 2015;
- Estimated future changes in the area of wetland vegetation due to existing and planned water resource developments, particularly hydropower and flood protection;
- Estimated future changes in the area of wetland vegetation due to exogenous factors, e.g. urban development;
- Economic value of each type of wetland vegetation per hectare.

(vii) ***Wildlife biodiversity***

- Historical changes in number of micro invertebrates, herpetofauna, birds and mammals from 1900 to 2015;
- Estimated future changes in the number of micro invertebrates, herpetofauna, birds and mammals due to existing and planned water resource developments;
- Estimated future changes in the number of micro invertebrates, herpetofauna, birds and mammals due to exogenous factors, e.g. pollution, hunting;
- Economic value of each species of micro invertebrate, herpetofauna, bird and mammal.

(viii) ***Geomorphology***

- Historical changes in the location and extent of riverbank erosion and saline intrusion from 1900 to 2015;
- Estimated future changes in the location and extent of riverbank erosion and saline intrusion due to existing and planned water resource developments, particularly hydropower dams;
- Estimated future changes in the location and extent of river bank erosion and saline intrusion due to exogenous factors, e.g. sand mining, deforestation;
- Annual economic losses (land, houses and infrastructure) associated with increased riverbank erosion;
- Annual economic gains/losses (crop and fish production) associated with changes in saline intrusion.

(ix) ***Recession agriculture, lowland crop productivity and riverbank gardens***

- Historical changes in the areas of recession cropping, floodplain crop productivity and riverbank gardens from 1900 to 2015;
- Estimated future changes in the areas of recession cropping, floodplain crop productivity and riverbank gardens and due to existing and planned water resource developments as well as exogenous factors;
- Annual economic losses associated with a reduction in the areas of recession cropping and riverbank gardens as well as the crop productivity in the floodplains.

(x) ***Forestry and watershed management***

- Historical development of forestry and watershed management in LMB (area and location) from 1900 to 2015;
- Area and location of forestry and watershed management interventions under implementation and planned up to 2040;
- Capital costs of forestry and watershed management interventions;
- Annual economic benefits and costs of forestry and watershed management per hectare.

(xi) ***Sand mining***

- Historical development of sand mining in the Mekong mainstream (area and location) from 1900 to 2015;
- Estimated future changes in sand mining activities due to planned water resource developments as well as exogenous factors;
- Annual economic benefits/losses associated with changes in sand mining activities.

(xii) ***Drought affected areas***

- Historical changes in the drought affected areas from 1900 to 2015;
- Estimated future changes in the drought affected areas due to existing and planned water resource developments as well as exogenous factors;
- Annual economic losses associated with a reduction in crop productivity in drought affected areas.

5.2 Hydropower data

The data required for the economic assessment of hydropower development within the LMB for the various development scenarios are outline in Table 5-1 below.

Table 5-1 Data required for economic assessment of hydropower development

Data Type	Unit	Data Source	Comment/Responsibility
HEP capacity: Existing and future development of dependable capacity of HEP projects planned for next 25 years within LMB by riparian country.	MW	Hydropower database	Hydropower database requires updating by hydropower thematic team ((ISH)
Annual HEP production: Past, present and future annual HEP production within LMB by riparian country.	GWh	Hydropower database	Hydropower database requires updating by hydropower thematic team (ISH)
Energy exports/imports: Past, present and future annual energy exports and imports, as well as power trade prices, for alternative power generation options within LMB by riparian country.	GWh US$ per MWh	Hydropower database	Hydropower database and assessment of alternative power generation options requires updating by hydropower thematic team (ISH)
Capital costs: Development costs of HEP projects and transmission lines by riparian country	US$ million	Hydropower database	Hydropower database requires updating by hydropower thematic team (ISH)
Operation & maintenance costs: Annual O&M costs of HEP projects and transmission lines by riparian country	US$ million	Hydropower database	Hydropower database requires updating by hydropower thematic team (ISH)
Employment: Labour required for the construction and annual O&M of HEP projects and transmission lines by riparian country	person years	Hydropower database	To be estimated by Economist in consultation with the hydropower thematic team (ISH)

Data Type	Unit	Data Source	Comment/Responsibility
Costs of resettlement and compensation for households displaced by reservoirs and structures	No. households US$ per household	HEP project documents	To be estimated by Economist and Social Scientist in consultation with the hydropower thematic team (ISH)
Costs of mitigation adverse environmental impacts, e.g. fish passes for capture fisheries.	US$ million per HEP project	HEP project documents	To be estimated by the hydropower thematic team (ISH) based on mitigation measures undertake for other HEP projects

5.3 Irrigated agriculture data

The data required for the economic assessment of irrigation development within the LMB for the various development scenarios are outline in Table 5.2.

Table 5-2 Data required for economic assessment of irrigation development

Data Type	Unit	Data Source	Comment/Responsibility
Irrigated areas: Past and present area of existing irrigation schemes, as well as area of new irrigation schemes planned for next 25 years within LMB by riparian country	ha	MRC irrigation database	Existing and planned irrigated areas to be updated and locations mapped by irrigation thematic team (AIP)
Irrigated cropping patterns: Proportion of area under each crop (rice and non-rice) for variety of irrigated cropping patterns within each riparian country[1/]	% of cultivated area	MRC irrigation database	Existing cropping patterns to be updated by irrigation thematic team (AIP) Economist to derive future irrigated cropping patterns in consultation with irrigation thematic team (AIP)
Rain fed cropping patterns: Proportion of area under each crop (rice and non-rice) for variety of rain fed cropping patterns within each riparian country	% of cultivated area	Based on existing cropping patterns available in MRC database	To be derived by Economist in consultation with agriculture/land use thematic team (AIP)
Crop yields: Past, present and future annual crop yields (with & without irrigation project over 25 years) for different rice and non-rice crops within each rain fed and irrigated cropping pattern	tonne per ha	District level govt. statistics within each country MRC Irrigation Sector Review - National Reports	Past and present crop yield data need to be collected from national statistics Future crop yields (with and without irrigation) to be estimated by Economist in consultation with irrigation thematic team (AIP)
Crop inputs: Past, present and future (with & without	kg per ha	Govt statistics within each	Past and present crop inputs to be estimated based on national

Data Type	Unit	Data Source	Comment/Responsibility
project) use of seed, fertilisers and pesticides for different rice and non-rice crops within each rain fed and irrigated cropping pattern		riparian country	statistics Future crop inputs (with and without irrigation) to be estimated by Economist in consultation with irrigation thematic team (AIP)
Labour and machinery requirements: Past, present and future (with & without irrigation) labour and machinery/equipment requirements for different rice and non-rice crops within each rain fed and irrigated cropping pattern	person days per ha machinery hours per ha	Irrigation and agricultural project reports	Past and present labour and machinery requirements based on available statistics Future labour and machinery requirements (with and without irrigation) to be estimated by Economist in consultation with irrigation thematic team (AIP)
Output and input prices: Farm gate and market prices for farm produce (rice and non-rice crops), seeds, fertilisers, pesticides, as well as rural wage rates and hire charges for machinery/equipment and transport within each riparian country.	US$/tonne US$/person day US$/ mach. hour US$/tonne/km	Govt statistics within each riparian country. World Bank commodity price projections	Financial prices to be collected by Economist. Economic prices to be derived by Economist.
Capital costs: Costs of civil works and equipment for different types of irrigation/drainage scheme, e.g. gravity and pumping (low lift, high lift) by riparian country	US$ million per ha	MRC irrigation database Irrigation project reports	To be estimated by Economist in consultation with irrigation thematic team (AIP)
Operation & maintenance costs: Annual O&M costs of different types of irrigation scheme, e.g. gravity, pumping (low lift, high lift) by country	US$ per hectare	Irrigation project documents	To be estimated by Economist in consultation with irrigation thematic team (AIP)
Employment: Labour required for the construction and annual O&M of irrigation projects by country	person years	Irrigation project documents	To be estimated by Economist in consultation with irrigation thematic team (AIP)

5.4 Flood protection data

The data required for the economic assessment of flood protection and mitigation measures for the various development scenario are outline in Table 5-3 below.

Table 5-3 Data required for economic assessment of flood protection measures

Data Type	Unit	Data Source	Comment/Responsibility
Past, present and future development (up to 2040) of different types of flood protection infrastructure by zone/river reach and riparian country	Number	Flood protection thematic team	To be determined by the flood protection thematic team (FMMP)
Flood water level reduction: Location, flooded area and maximum flood level by zone/river reach and riparian country	ha m	Hydrological model results (IKMP)	Flooded areas, maximum flood water levels and location to be determined by flood protection thematic team (FMMP)
Flood damage assessments in focal areas: Location, extent and type of flood damages	various	FMMP reports	Location, extent and type of flood damages estimated by FMMP in focal areas
Areas benefiting from flood protection and mitigation measures: Location, extent and type of land use in areas benefiting from flood protection infrastructure in Mekong floodplain and delta as well as reduced flooding (from HEP dams) by river reach and riparian country	various	Flood protection thematic team	Location, extent and type of land use in areas benefiting from flood protection and mitigation measures to be determined by flood protection thematic team (FMMP)
Population benefiting from flood protection and mitigation measures: Number and location of households and businesses benefiting from flood protection by river reach and riparian country	number of HHs	Flood protection thematic team	Populations benefiting from flood protection and mitigation measures to be estimated by flood protection thematic team (FMMP).
Direct losses and damage due to flooding: Past, present and future values (with and without flood protection/mitigation) of annual damage to agriculture, property and public infrastructure due to floods by river reach and riparian country	US$ million	Flood protection thematic team	Direct losses and damage due to flooding to be estimated by flood protection thematic team (FMMP).
Increases in net agricultural benefits resulting from changes in cropping patterns: Past, present and future (with & without flood protection/mitigation) annual net benefits from different rice based cropping patterns (including irrigated cropping in dry season) by riparian country	US$ per ha	District statistics on crop production	To be determined by Economist in consultation with agriculture/land use (AIP) and flood protection (FP) thematic teams

Data Type	Unit	Data Source	Comment/Responsibility
Increases in net benefits from aquaculture: Past, present and future (with and without flood mitigation) annual net benefits from aquaculture production due to flood mitigation measures	US$ per ha	District statistics on aquaculture production	To be determined by Economist in consultation with agriculture/land use (AIP) and flood protection (FP) thematic teams
Capital and O&M costs for different types of flood protection and mitigation measures by river reach and riparian country	US$ per ha	Flood protection thematic team	To be estimated by the flood protection thematic team (FMMP)
Costs of resettlement and compensation for households displaced by structures	US$ per ha	Flood protection thematic team	To be estimated by Economist based on data from flood protection thematic team
Costs of mitigating adverse environmental impacts, e.g. fish passes for capture fisheries, biodiversity conservation.	US$ per ha	Fisheries programme and BioRA discipline team	To be estimated by Economist in consultation with flood protection thematic team (FMMP), FP and BioRA

5.5 Navigation data

The data required for the economic assessment of navigation development along the mainstream Mekong for the various development scenarios are outline in Table 5-4 below.

Table 5-4 Data required for economic assessment of navigation development

Data Type	Unit	Data Source	Comment/Responsibility
Past, present and future development of different types of navigation infrastructure along the mainstream Mekong by zone/river reach and riparian country	Number	Navigation thematic team	To be determined by the navigation thematic team (NAP)
Annual number of days the Mekong river is navigable along different reaches: Based on minimum safe draught requirements for different classes of vessel, in the past, present and future (with and without water resource developments) situations by zone/river reach and riparian country	Days	Navigation thematic team	To be estimated by the navigation thematic team (NP) based on the hydrological assessment (IKMP)

Data Type	Unit	Data Source	Comment/Responsibility
Annual volume of IWT cargo trade in past, present and future (with and without water resource developments) over next 25 years by zone/river reach and riparian country	million tonnes	Navigation thematic team Govt statistics in each country	To be estimated by the navigation thematic team (NAP)
Annual IWT cargo value added: Gross value, transport costs and value added per tonne of cargo transport by IWT	US$ per tonne	Navigation programme data Govt statistics in each country	To be estimated by Economist in association with navigation thematic team (NAP)
Capital and annual O&M costs for different types of navigation infrastructure, including navigation canals and locks, along the mainstream Mekong by zone/river reach and riparian country	US$ million	Navigation thematic team	To be estimated by the navigation thematic team (NAP)
Mitigation costs: Capital and annual O&M costs for different mitigation measures such as construction of canals and locks to divert river transport around mainstream dams	US$ million	Navigation thematic team	To be estimated by Economist in association with navigation thematic team (NAP)

5.6 Fisheries data

The data required for the economic assessment of the aquaculture development, as well as the impact on capture fisheries, within the LMB for the various development scenarios are outline in

Data Type	Unit	Data Source	Comment/Responsibility
Capture fisheries production: Past changes in capture fisheries catch and estimated changes over next 25 year (with and without water resource developments) within LMB by fish species, location and riparian country	tonnes	Biological resource assessment using DRIFT	To be estimated by BioRA discipline team (FP)
Reservoir fisheries production: Past annual fisheries production from reservoirs and estimated changes over next 25 years within LMB reservoirs	tonnes	Fisheries programme data and reports	To be estimated by agriculture/land use thematic team (AIP) in consultation with FP
Aquaculture fisheries: Past, present and future annual aquaculture fisheries area within LMB by riparian country	ha	Fisheries programme data and reports	To be estimated by agriculture/land use thematic team (AIP) in consultation with FP

Data Type	Unit	Data Source	Comment/Responsibility
Rice-fish systems: Past, present and future annual rice-fish area within LMB by riparian country	ha	Fisheries programme data and reports	To be estimated by agriculture/land use thematic team (AIP) in consultation with FP
Aquaculture fish yields: Past, present and future annual fish yields for different aquaculture systems, such as (i) high input pond culture, (ii) rice-fish culture, and (iii) coastal shrimp.	tonne per ha	Fisheries programme data and reports	To be estimated by agriculture/land use thematic team (AIP) in consultation with FP
Capture fisheries labour: Number of fishers in past, present and future (with and without HEP dams) within LMB by zone/river reach.	person years	Fisheries programme data and reports	To be estimated by Economist in consultation Social Scientist and FP
Aquaculture, rice-fish and reservoir fisheries input and labour costs: Past, present and future capital and annual recurrent costs of inputs, labour and equipment for different reservoir, aquaculture and rice-fish systems	US$ per ha	Fisheries programme reports, e.g. "Financial analysis of aquaculture & fishery activities in LMB"	To be estimated by Economist in consultation with agriculture/land use thematic team (AIP) and FP
Output prices and marketing costs: Landed/farm gate and market prices as well as marketing/transport costs and marketing margins for different types of fish produced by capture, reservoir and aquaculture systems within each riparian country.	US$ per tonne	Fisheries programme Govt statistics within each riparian country	Financial prices and costs to be collected by Economist. Economic prices and costs to be derived by Economist.

Table 5-5 Data required for economic assessment of capture and culture fisheries

Data Type	Unit	Data Source	Comment/Responsibility
Capture fisheries production: Past changes in capture fisheries catch and estimated changes over next 25 year (with and without water resource developments) within LMB by fish species, location and riparian country	tonnes	Biological resource assessment using DRIFT	To be estimated by BioRA discipline team (FP)
Reservoir fisheries production: Past annual fisheries production from reservoirs and estimated changes over next 25 years within LMB reservoirs	tonnes	Fisheries programme data and reports	To be estimated by agriculture/land use thematic team (AIP) in consultation with FP
Aquaculture fisheries: Past, present and future annual aquaculture fisheries area within LMB by riparian country	ha	Fisheries programme data and reports	To be estimated by agriculture/land use thematic team (AIP) in consultation with FP

Data Type	Unit	Data Source	Comment/Responsibility
Rice-fish systems: Past, present and future annual rice-fish area within LMB by riparian country	ha	Fisheries programme data and reports	To be estimated by agriculture/land use thematic team (AIP) in consultation with FP
Aquaculture fish yields: Past, present and future annual fish yields for different aquaculture systems, such as (i) high input pond culture, (ii) rice-fish culture, and (iii) coastal shrimp.	tonne per ha	Fisheries programme data and reports	To be estimated by agriculture/land use thematic team (AIP) in consultation with FP
Capture fisheries labour: Number of fishers in past, present and future (with and without HEP dams) within LMB by zone/river reach.	person years	Fisheries programme data and reports	To be estimated by Economist in consultation Social Scientist and FP
Aquaculture, rice-fish and reservoir fisheries input and labour costs: Past, present and future capital and annual recurrent costs of inputs, labour and equipment for different reservoir, aquaculture and rice-fish systems	US$ per ha	Fisheries programme reports, e.g. "Financial analysis of aquaculture & fishery activities in LMB"	To be estimated by Economist in consultation with agriculture/land use thematic team (AIP) and FP
Output prices and marketing costs: Landed/farm gate and market prices as well as marketing/transport costs and marketing margins for different types of fish produced by capture, reservoir and aquaculture systems within each riparian country.	US$ per tonne	Fisheries programme Govt statistics within each riparian country	Financial prices and costs to be collected by Economist. Economic prices and costs to be derived by Economist.

5.7 Wetlands and wildlife biodiversity data

The data required for the economic assessment of the impact on wetlands areas and wildlife biodiversity within the LMB for various development scenarios are outline in Table 5-6 below.

Table 5-6 Data required for economic assessment of impact on wetlands and wildlife

Data Type	Unit	Data Source	Comment/Responsibility
Wetlands areas: Changes in area from 1900 to 2015 of different types of wetland ecosystems[6] and estimated changes over next 25 years (with and without water resource developments) by riparian country	ha	Biological resource assessment using DRIFT	To be estimated by BioRA discipline team
Annual economic value of wetlands: Present and future annual values of different types of wetlands	US$ per ha	EP study on wetland valuation Wetland valuation database. Recent wetland valuation studies in SE Asia	To be estimated by Economist in consultation with BioRA discipline team and EP.
Wildlife biodiversity: Historical changes from 1900 to 2015 in number of different types of wildlife[7] and estimated changes over next 25 years (with and without water resource developments) by river reach and riparian country	ha	Biological resource assessment using DRIFT	To be estimated by BioRA discipline team
Annual economic value of wildlife biodiversity: Present and future annual values of wildlife biodiversity	US$ per ha	Recent wildlife valuation studies in SE Asia	To be estimated by Economist in consultation with BioRA discipline team

[6] Wetland eco-systems include: (i) marshes, swamps and grassland, (ii) flooded forests, (iii) rice fields, and (iv) mangrove forests.

[7] Types of wildlife include: (i) macroinvertebrates, (ii) herpetofauna, (iii) birds and (iv) mammals.

5.8 Riverbank erosion data

The data required for the economic assessment of the impact on riverbank erosion within the LMB for each of development scenarios are outline in Table 5-7.

Table 5-7 Data required for economic assessment of the impact of riverbank erosion

Data Type	Unit	Data Source	Comment/Responsibility
Areas affected by riverbank erosion: Location, extent and type of assets, e.g. land, property and infrastructure, expected to be lost to riverbank erosion within vulnerable areas in present and future (with and without water resource developments) by riparian country	ha	BioRA's geomorphology assessment Land us mapping	Areas affected by river bank erosion to be estimated by BioRA discipline team. Land use mapping of areas vulnerable to riverbank erosion by agriculture/land use thematic team
Population vulnerable to riverbank erosion: Number and location of households and businesses vulnerable to riverbank erosion in LMB by riparian country	number of HHs	Socio-economic data	Mapping of populations vulnerable to riverbank erosion by socio-economic discipline team
Value of assets vulnerable to riverbank erosion: Past, present and future unit value of land, property and infrastructure vulnerable to riverbank erosion in the LMB over next 25-year period by riparian country.	US$/ha US$/property US$/km infra-structure	District level govt. statistics	To be estimated by Economists
Relocation and resettlement costs: Relocation and resettlement costs per household in areas affected by riverbank erosion	US$ per HH	District level govt. statistics	To be estimated by Economists

5.9 Saline intrusion data

The data required for the economic assessment of the impact on productive activities in areas vulnerable to saline intrusion for various development scenarios are outline in Table 5-8 below.

Table 5-8 Data required for economic assessment of the impact of saline intrusion

Data Type	Unit	Data Source	Comment/Responsibility
Areas affected by saline intrusion: Location, extent and type of land use in coastal areas affected by saline intrusion[1/] in past, present and future (with and without water resource developments) by riparian country	ha	Hydrological model results (IKMP) District level govt. statistics (Vietnam)	To be estimated by hydrology discipline team (IKMP) based on hydrological modelling Land use mapping of areas vulnerable to saline intrusion by agriculture/land use thematic team
Changes in crop productivity: Past, present and future (with and without water resource developments) annual changes in crop yield due to saline intrusion within affected coastal areas over the next 25-year period	tonne per ha	District level govt. statistics (Vietnam)	Changes in crop yields to be estimated by agriculture/land use thematic team
Annual net value of crop production: Past, present and future changes in annual net value of crop production over next 25 years	US$ per ha	District level govt. statistics (Vietnam)	Annual net values of crop production to be estimated by the Economist in consultation with agriculture/land use thematic team
Changes in capture and culture fisheries: Past, present and future changes in the net value of annual capture and culture fisheries resulting from saline intrusion over next 25 years within affected coastal areas	US$ per ha	District level govt. statistics (Vietnam)	Changes in annual net value of capture and culture fisheries to be estimated by the Economist in consultation with the BioRA discipline team (FP) and agriculture/land use thematic team

1/ In areas affected by salinity, duration of saline intrusion and salt concentration will also be taken into account.

5.10 Recession agriculture, lowland crop productivity and riverbank garden data

The data required for the economic assessment of the impact on recession cropping, floodplain crop productivity, and riverbank gardens are outline in Table 5-9 below.

Table 5-9 Data required for economic assessment of the impact on recession agriculture, floodplain productivity and riverbank gardens

Data Type	Unit	Data Source	Comment/Responsibility
Recession cropping: Area and location of recession cropping in past, present and future (with and without water resource developments) over next 25 years by riparian country	ha	Hydrological model results (IKMP) District level govt. statistics	Recession cropping area to be estimated by hydrology discipline team (IKMP) Land use mapping of recession cropping areas by agriculture/land use team
Crop productivity: Past, present and future (with and without water resource developments) annual crop yields in recession cropping areas over next 25 years by riparian country	tonne per ha	District level govt. statistics	Crop yields to be estimated by agriculture/land use thematic team
Annual net value of crop production: Past, present and future changes in annual net value of crop production in recession cropping areas over next 25 years by riparian country	US$ per ha	District level govt. statistics	Annual net values of crop production to be estimated by Economist in consultation with agriculture/land use thematic team
Lowland crop productivity: Area and location of floodplains vulnerable to a reduction in sediment deposits in past, present and future (with and without water resource developments) over next 25 years by riparian country	ha	Hydrological model results (IKMP) District level govt. statistics	Floodplain area to be estimated by hydrology discipline team (IKMP) Land use mapping of areas with declining sedimentation by agriculture/land use team
Crop productivity: Past, present and future (with and without water resource developments) annual crop yields in areas with declining sedimentation over next 25 years by riparian country	tonne per ha	District level govt. statistics	Crop yields to be estimated by agriculture/land use thematic team
Annual net value of crop production: Past, present and future changes in annual net value of crop production in areas with declining sedimentation over next 25 years by riparian country	US$ per ha	District level govt. statistics	Annual net values of crop production to be estimated by Economist in consultation with agriculture/land use thematic team

Data Type	Unit	Data Source	Comment/Responsibility
River garden areas: Past, present and future area (with and without water resource developments) of river gardens over next 25 years by river reach and riparian country	ha	National statistics and land use maps	Riverbank garden area to be estimated by agriculture/land use thematic team
Annual net value of river gardens: Present and future annual net values of river gardens	US$ per ha	District level govt. statistics	To be estimated by Economist in consultation with agriculture/land use thematic team

5.11 Forestry data

The data required for the economic assessment of forestry development are outline in Table 5-10 below.

Table 5-10 Data required for economic assessment of forestry development

Data Type	Unit	Data Source	Comment/Responsibility
Area and location of forestry developments in past, present and future over next 25 years by riparian country	ha	District level govt. statistics	Forest area to be estimated, and locations mapped, by agriculture/land use thematic team
Timber production: Past, present and future annual yields of timber logs over next 25 years by riparian country	Cu m per ha	District level govt. statistics	Timber log yields to be estimated by agriculture/land use thematic team
Capital investment in forestry development in past, present and future over next 25 years	US$ million	District level govt. statistics	Capital investment to be estimated by agriculture/land use thematic team
Annual net value of timber production in past, present and future over next 25 years by riparian country	US$ per ha	District level govt. statistics	Annual net values of timber production to be estimated by Economist in consultation with agriculture/land use thematic team

5.12 Sand mining data

The data required for the economic assessment of sand mining are outline in Table 4-11 below.

Table 5-11 Data required for economic assessment of sand mining

Data Type	Unit	Data Source	Comment/Responsibility
Area and location of sand mining along the Mekong mainstream in past, present and future (with and without water resource developments) over next 25 years by riparian country	ha	District level govt. statistics	Sand mining area to be estimated, and locations mapped, by domestic/industrial water use thematic team
Past, present and future (with and without water resource developments) production of sand over next 25 years by riparian country	tonne	District level govt. statistics	Sand production to be estimated by domestic/industrial water use thematic team
Annual net value of sand production in past, present and future over next 25 years by riparian country	US$ million	District level govt. statistics	Annual net values of sand production to be estimated by Economist in consultation with domestic/industrial water use thematic team

5.13 Drought impact data

The data required for the economic assessment of the impact on drought affected areas are outlined in Table 5-12 below.

Table 5-12 Data required for economic assessment of drought prone areas

Data Type	Unit	Data Source	Comment/Responsibility
Area and location of drought prone areas in past, present and future (with and without water resource developments) over next 25 years by riparian country	ha	District level govt. statistics	Drought prone area to be estimated by DMP Mapping of drought prone areas by DMP
Past, present and future (with and without water resource developments) annual crop yields in drought prone areas over next 25 years by riparian country	tonne per ha	District level govt. statistics	Crop yields in drought prone areas to be estimated by agriculture/land use thematic team
Annual net value of crop production: Past, present and future changes in annual net value of crop production in drought prone areas over next 25 years by riparian country	US$ per ha	District level govt. statistics	Annual net values of crop production to be estimated by Economist in consultation with agriculture/land use thematic team and DMP

Smajgl, A., & Dugan, S. (2015). *Ecosystem Value Estimation*. Retrieved from Bangkok: