'ROADS AND FLOODS'

Best Practice Guidelines for the Integrated Planning and Design of Economically Sound and Environmentally Friendly Roads in the Mekong Floodplains of Cambodia and Viet Nam

Synthesis Report

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Best Practice Guidelines for the Integrated Planning and Design of Economically Sound and Environmentally Friendly Roads in the Mekong Floodplains of Cambodia and Viet Nam

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Executive Summary

1. Introduction

During recent decades the regional economic development of the four countries of the Lower Mekong Basin has evolved at a fast pace. Such development goes in parallel with the upgrading and development of roads. For a number of reasons road development in a floodplain, like the still quite natural Mekong floodplain, requires a different approach to planning and technical design, compared to road development in areas that are not (regularly) inundated. On the one hand, floods can severely damage infrastructure including roads, whilst on the other hand, roads and associated infrastructure fragment the floodplains and interrupt the natural flow of water, sediments, nutrients and aquatic life. This is particularly relevant in the environmentally and economically valuable floodplains of the Lower Mekong Basin, where the total direct-use value of the fishery resources has been estimated at about $US 2 billion per annum.

The underlying question addressed by the ‘Roads and Floods’ project, is how to develop roads in a sensitive ecosystem like the floodplain of the Mekong in a sustainable manner that minimizes the impact on the benefits of the annual inundations and at the same time reduces damage to roads. The project (2006-2008) is part of the FMMP-Component 2 Programme ‘Flood Structures and Flood Proofing’ and is a cooperation between Delft Cluster, WWF and MRC-FMMP. The objectives of the project are (1) to raise awareness on the benefits of the Mekong floods and possible impacts of road developments on these benefits, (2) an in-depth analysis of the interactions between roads and floods, and (3) to develop Best Practice Guidelines for the improvement of road planning and design. The main findings of the project are presented in this synthesis report.

2. Current practice in Cambodia and Viet Nam

Both in Cambodia and Viet Nam, road planning and design takes into account the local flood flow patterns, however it focuses less on the floodplain hydraulics and related ecology. Road planning and design in Cambodia is based on international guidelines for roads located outside the floodplain, with the exception of the national guidelines for rural roads. As a result, roads are constructed under different international criteria. Viet Nam has a comprehensive set of road construction standards, but this set is not particularly aimed at planning and rehabilitation of roads in the Mekong floodplains. Both Viet Nam and Cambodia have an Environmental Impact Assessment system in place, although experience in its application, particularly in Cambodia, is limited. There are developments towards an environmental assessment system for the Lower Mekong Basin addressing the trans-boundary dimension at basin level. The findings of the review of current practice in Cambodia and Viet Nam support the need for better guidance on integrated planning and design of roads in the Mekong floodplains.

3. International experience and guidance

International literature provides ample guidance on planning and design of roads. Literature on the development of roads in ecologically sensitive areas is limited, and only a few studies were found on the development in floodplains. There is a broad range of

environmental assessment guidelines available, although they only address the interaction between roads and surface water, or floods specifically, to a limited extent. Few international examples and studies were found on strategies and measures for building infrastructure in river floodplains. Two general road development strategies – a strategy based on resistance and a strategy based on resilience - can be distinguished, both having their advantages and disadvantages. The resistance strategy, in principle, aims at preventing and regulating floods and hence has a strong impact on the natural floodplain dynamics, while the resilience strategy aims at minimizing the consequences of floods, but at the same time intends to maintain the natural floodplain dynamics as much as possible. The hypothesis behind the resilience strategy in the light of this study is that, although the strategy might require higher initial investment, the longer term costs in terms of road damage and ecological impacts, will be lower. It is clear that the selection of a strategy requires an integrated assessment of all relevant aspects and impacts. For this purpose, the report presents a framework for an integrated assessment of road development and rehabilitation in floodplains.

4. Results of the analysis of Cambodian and Viet Namese case studies

The report presents four road development and rehabilitation case studies in Cambodia and Viet Nam (Table 1). The case studies aim to understand the interactions between roads and floods better, as well as to investigate the impacts of the different road development strategies; namely resistance and resilience (see above). More specifically, the case studies were undertaken to answer the four main research questions underlying the 'Roads and Floods' project, which will be addresssed below. To analyse and present the cases a policy analysis approach was applied that helped to structure the road development process, in particular its planning phase where the concept development and (pre-)feasibility studies are undertaken. The analysis of the case studies was based on inundation modelling and analysis, damage analysis, economic analysis and environmental impact analysis supported by flood surveys carried out in both Cambodia and Viet Nam.

Table 1 The four case studies of the 'Roads and Floods' project.

Country	Case	Road	Description road and flow-through condition
Cambodia	1	NR 11 and PR 317	Existing road with damage problems. Currently limited flow-through and partly elevated.
	2	NR8	Construction new road crossing floodplain zone 5, perpendicular to the floodplain.
Viet Nam	3	PR855	Rehabilitation of Provincial Road.
	4	NR1A and HCM road	Development of new section National Road number 1 and Ho-Chi-Minh Road.

What is the significance of roads in the Cambodian and Viet Namese floodplains in changing flow patterns (including cumulative impacts)?

The case studies show that, both in Cambodia and Viet Nam, flow patterns are taken into account in road planning and design, as roads are often aligned not to block water flows and contain flow-through structures. The cases show that the impact of roads on water depth are less significant than the impact on velocities which may cause damage to the road and the flow through structures. Impacts on flood extent and duration of new planned roads without flow through structures are limited. Impacts are neglectable for roads that have sufficient flow-through capacity. Although small changes in flood dynamics may occur (flooded area, duration and beginning of the flooding) and have consequent impacts to aquatic ecology and related functions. These impacts may become more serious if more road developments take place. The cases (e.g. case NR8 in Cambodia or case PR855 in Viet Nam) show that such cumulative impacts should be investigated because they might lead to more serious consequences in terms of road damage and ecological deterioration at a larger floodplain scale. Obviously, extreme alternatives like increasing the levees along the Mekong have significant impacts because inundation will not occur anymore.

What is the significance of flow patterns in Cambodia and Viet Nam in terms of road damage?

The case studies show that there is limited impact on the flood levels (water height) and the corresponding damage mechanisms (macro-instability, waves, overtopping) if road embankments and flow structures are properly designed. For example embankments should not be too steep and measures to intercept waves should be incorporated into designs. The main damage mechnisms can be related to significant changes on flow velocities. Flow velocities well above critical values for the initiation of erosion may occur in the floodplains, in some occasions protection materials, for example small rocks, are eroded. To reduce these velocities to an acceptable level by increasing the number of flow through structures or their dimensions is too expensive. Properly designed protection, together with streamlined abutments, is a cheaper option and very often the best way to provide protection or at least to minimize the damage. The latter is demonstrated by several case studies. In the previous section several alternative impact mechanisms were mentioned which influence floodplain dynamics at larger scale. These may result in damage to a road at a similar scale. E.g. if alternatives that aim at flood protection are chosen, for example: raising levees along the Mekong, damage to roads in the flood plain reduces, but ecological consequences may be considerable.

What are the impacts of different road development and rehabilitation strategies (resistance and resilience) in Cambodia and Viet Nam on floodplain hydraulics and related benefits of floods and on economic costs of roads?

The results of this part of the study are based on the results of the hydraulic and damage analysis as presented above, and rapid assessments of ecological and socio-economic impacts. Hence, the results indicated below should be considered as indicative and should be used to illustrate possible impacts. The results of the study show that several resilience alternatives (alternatives 2 and 4 for Case 1, alternative 3 for Case 4, and alternative 4 for Case 5), indicate that higher initial investments in road design, are expected to result in positive effects on the medium term costs and the floodplain ecosystem. This is reflected in the overall high ranking of these alternatives with respect to sustainability considerations. Resilience alternatives score higher than resistance alternatives not only from the perspective of sustainability, but also from the perspective of flood protection and ecology. This is in contrast to the transport perspective, where resistance alternatives score slighlty higher then resilience alternatives. The results of the cases do not give indications that there are differences between Cambodia and Viet Nam. However, it is expected that it is easier to rehabilitate or design a road in line with the resilience strategy in Cambodia than in Viet Nam. The reason for this is that in Cambodia the floodplain is in a more natural state than Viet Nam where water in the flood zones is intensively managed already.

The analysis illustrates that, in the process of choosing a strategy (resistance or resilience) and related alternatives, the objectives and priorities of the project play an important role.

Additionally, project objectives can be conflicting. The cases show, for instance, that if an alternative scores highly (hence good) on road costs and ecological impacts it also has a low score on flood protection. Conversely, resistance alternatives which aim to protect the land from flooding, score badly (not good) on the maintenance of floodplain hydraulics and ecology. The purpose of the this part of the case study presentations is to illustrate how these trade-offs can be made more transparent to decision-makers.

The financial analysis has followed a relative simple approach using averages for flood damage. The analysis shows that in all cases the cheapest alternative will lead to the lowest cost for the owner of the roads. Hence, the extra investment costs are not covered by less damage and / or maintenance costs. However, road investments are usually not evaluated in a narrow financial sense as roads lead to many benefits for the economy as whole. Part of these benefits can be expressed in money and part of these benefits are non-monetary, such as less road casualties. Similarly, more sustainable roads, i.e. the more expensive alternatives, can lead to additional monetary and non-monetary benefits compared to the cheapest alternative that are not taken into account in a financial analysis. An economic analysis would provide more insight in these additional benefits. The results from such an an economic cost-benefit analysis (as opposed to a financial cost benefit analysis) will more likely lead to higher NPV and IRR figures for more sustainable options. It should also be mentioned that the costs and benefits may affect the poor relatively more: improved access to rural areas could help poor to start business that would otherwise not be possible.

> *What road development and rehabilitation practice would contribute most to the reduction of the socio-economic costs of flooding in the Lower Mekong Basin, whilst preserving the environmental and other benefits of floods?*

The cases illustrate that road planning and design in the Mekong floodplain, while reducing the socio-economic costs of flooding and preserving the benefits of floods, is a complicated task that requires an integrated approach. The cases clearly show that:

- During the development process of roads in the Mekong floodplains, coordination between the road and transport sector, the water sector, the flood risk management / dike sector, the environment sector, and the social sector is essential. Different sectors have a different perspective on floods and how to deal with them, and these perspectives should be balanced during floodplain development.
- The character of the floodplain system requires not only local (project) impacts to be considered, but also impacts and implications at a larger scale. The cases show that cumulative impacts of structural developments (including roads) occur. A solution at one location, might impact other locations. This requires coordination and integration at the (sub-)floodplain scale.
- It is important that the financial sector and donors better work together, in order to link infrastructure investment budgets to operation and maintenance and damage repair budgets, and hence have the possibility to use limited financial resources more efficiently. The results of the case studies indicate that higher initial investments may lead to lower medium term costs and ecological impacts. This requires an integrated financial assessment - integrated in terms of investment, operation and maintenance, and damage risk - at the early planning stages.

The report also discusses quality and representativeness of the case study results. The case studies undertaken in both Cambodia and Viet Nam allow us to answer the four research questions posed. Due to some data limitations and the fact that assessment of environmental and economic impact assessment was limited, the answers to questions 3 and 4 should be regarded as indicative. For the pupose of supporting the Best Practice Guidelines, the cases, do however, provide a sufficient basis. The case studies are representative for the Cambodian and Viet Namese Mekong floodplain. In general terms, the results give an indication of what could happen in Thailand and Laos as well, in, as far as the area considered has comparable flood characteristics.

5. A set of Best Practice Guidelines for road development and rehabilitation in the Cambodian and Viet Namese Mekong floodplain

Main output of the 'Roads and Floods' project presented in the report is a set of Best Practice Guidelines for road development and rehabilitation in the Mekong floodplains of Cambodia and Viet Nam. The Best Practice Guidelines are based on the case study results, the review of current international practice as well as the practice in the Mekong Basin. The guidelines are presented in the report and summarised below. They are intended for use by professionals and organisations involved in road planning and design in the Mekong floodplains, as well as those involved in environmental and integrated assessments of road developments in the Mekong basin or structural developments in this basin in general.

Best Practice Guidelines for Integrated Planning of Road Development and Rehabilitation in the Mekong Floodplains of Cambodia and Viet Nam

These Best Practice Guidelines are a list of recommendations proposed to take into account in the development and rehabilitation of a road in the Mekong floodplain (Box 1).

Box 1. Best Practice Guidelines for Integrated Planning of Road Development and Rehabilitation in the Mekong Floodplains of Cambodia and Viet Nam.

General recommendations related to planning process

- Apply an integrated planning approach when developing roads in the vulnerable and highly valuable Mekong floodplain system, that considers the consequences of the development throughout the system including environmental and social impacts.
- Strengthen the relationship between road development and rehabilitation and environmental assessment.
- Apply a (sub)-floodplain system's approach in which not only local impacts of roads but also regional and cumulative impacts are considered.
- Provide sufficient coordination between road development and rehabilitation planning and other sector planning.
- Assess possible transboundary (provincial, national, international) impacts of road development and rehabilitation in the Mekong floodplain and cooperate at the inter-provincial and/or international level.
- Tailor alignment and design solutions to the specific floodplain hydraulic and ecological situation of the local situation.

Economic considerations

- Recognise and quantify the value of the Mekong floodplain and its benefits for local population as much as possible.
- Apply integrated cost-benefit analyses while assessing and evaluating road development and rehabilitation alternatives.
- Consider road development and rehabilitation alternatives that allow for a gradual upgrading of the road system.

Institutional arrangements and financial resources

- Improve / strengthen the institutional framework to support integration between the relevant sectors and at the necessary scales.
- Enhance (or develop and maintain) sustainable financing mechanisms in order to facilitate implementation of integrated road policies/projects.

Research and capacity building

- Improve knowledge of the floodplain system in terms of interactions between floodplain hydraulics and basin developments, functions of the system, particularly the ecological functions, critical thresholds to maintain these functions and values of the functions.
- Invest in education, training and technical support to introduce and / or strengthen practice of integrated planning and environmental assessments of road development and rehabilitation.
- Promote Mekong-riparian countries cooperation and exchange of knowledge and practices.

Best Practice Guidelines for Environmental Assessment of Road Development and Rehabilitation in the Mekong Floodplains of Cambodia and Viet Nam

These Best Practice Guidelines are recommendations proposed to be followed in Environmental Impact Assessment (EIA) and / or Strategic Environmental Assessment (SEA) procedures related to the development and rehabilitation of roads (Box 2).

Box 2. Best Practice Guidelines for Environmental Assessment of Road Development and Rehabilitation in the Mekong Floodplains of Cambodia and Viet Nam.

General recommendations

- Strengthen the system and process of Environmental Impact Assessment, specifically the coverage of floodplain hydraulics and related ecology.
- Amend environmental regulations if they do not currently require EIA for most projects.
- Mainstream environmental assessment with road development and rehabilitation.
- Include at the EIA scoping and Environmental Impact Statement (EIS) review phases the assessment of impacts of road development and rehabilitation projects on the floodplain hydro-dynamics and ecology.
- Initiate and / or strengthen the use of Strategic Environmental Assessments of infrastructure policies, plans and programmes.
- Adopt regional initiatives to address transboundary environmental impacts, like the GMS and proposals for a environmental assessment system for the MRC.
- Improve the capacity of EIA practitioners in implementing and reviewing the EIA processes.

Recommendations for sectoral guidelines for the road sector

- Review the current EIA screening list in order to address the environmental impacts of building infrastructure (roads) in a floodplain system like the Mekong.
- Consult the screening checklist (Annex) as a guidance to whether an EIA for a road developments in the Mekong floodplain is needed.
- Consult the scoping checklist (Annex) as a guidance to develop terms of reference for EIS for road developments in the Mekong floodplains.
- Consult the EIS review guidance (Annex) to produce better quality EIS's of road developments in the Mekong floodplains, and to review them more effectively.

Best Practice Guidelines for Technical Design of Road Development and Rehabilitation in the Cambodian and Viet Namese Floodplain

These Best Practice Guidelines are targeted at the organisations involved in road planning and design, like transport and public works type of ministries and associated agencies. The Best Practice Guidelines give general recommendations for technical design and specific recommendations for flow through structures and road embankment geometry (Box 3).

Box 3. Best Practice Guidelines for Technical Design of Road Development and Rehabilitation in the Cambodian and Viet Namese Floodplain.

General recommendations

- Update and review the present Cambodian and Viet Namese road design standards and guidelines to better address the specific conditions of the Mekong floodplain so road designers have better guidance and best-practice examples of how to develop flood proofed and environmentally friendly roads in the Mekong floodplains.
- Refer in the road design standards and guidelines and the dike standards to the interrelation between dikes and roads.
- Enforce compliance of the updated and reviewed Cambodian and Viet Namese road design standards and guidelines also between the different government bodies within one country.

General recommendations for technical design

- Incorporate a hydraulic analysis or determination of the flood hydraulics and loads on road structures from existing databases.
- Differentiate and specify the different damage and failure mechanisms in the technical guidelines.
- Incorporate the methodology of hydraulics and damage potential assessment and the possible need for protection measures. The existing guidelines could be complemented with methods used in the Viet Namese Dike guidelines.
- Establish safety levels and threshold values per damage mechanism and per road class related to the hydraulic conditions and damage potential (or accepted damage).
- Make costs analysis for the different options of slope protection, costs of flow through structures (bridges and culverts etc) and quantify the options in the integrated approach.

Specific recommendations: flow through structures

- In an ‘open’ floodplain like south Cambodia a resilience design is much more preferred over a resistance design. In Viet Nam a resilience design is also preferred but should be closely integrated with the existing irrigation systems.
- The number and dimensions of flow though openings (bridges and culverts) should be such that interference with the natural hydraulics of the (sub) floodplain in terms of extent (flooded area) and duration is minimal.
- In Cambodia, particularly, the road should not obstruct fish migration routes and the location of bridges should correspond with the (major) migration routes.
- Culverts have relatively small openings and are less suitable to maintain the fish migration routes, bridges are preferred to minimize impact on fish ecology.
- Scour protection near bridges and other flow-through openings, which are part of the resilience design, need heavy scour protection in order to prevent massive and reoccurring damage to the abutments and eventually the structure itself.
- For the National and major Provincial roads slope protection is preferred using gabion mats or stone covers when the hydraulic studies indicate flow velocities exceeding 0.7 m/s and the soil conditions are unfavourable to erosion.
- Use vegetation hedges to prevent wave erosion of the upper part of the embankment slope and shoulder.

Specific recommendations: road embankment geometry

- The recommended crest level for National roads and (major) Provincial roads is the highest recorded flood level (level 2000) plus 0.5 meters. For (major) regional roads the crest level should correspond with a minimum height of the water level of floods with a recurrence of 10 years plus 0.25 meters.
- For road embankments up to 4 meters high a slope gradient of 1:3 provides sufficient safety protection against the macro-instability mechanism during the rise and fall of the water level.
- Investigate the geotechnical characteristics of the top soils and take adequate measures in road design, for example removal of inappropriate top soils.
- Provide the road surfaces of National roads and major Provincial roads with asphalt. Minor Provincial roads or major Regional roads are recommended to be covered with minimum of coarse gravel on a draining (convex) clay substrate.

6. Dissemination and application of the Best Practice Guidelines

The most effective way of supporting the potential use of the Road and Floods Report is to create awareness and proper understanding of the content of the Roads and Flood Report among the divisions/sections involved or responsible for the preparation of guidelines or improvement of guidelines.

It is however somewhat unfortunate that during the implementation period of the Roads and Floods Project, as a result of the lack of damage data, due to the lack of flood events in the flood plain, no strong convincing financial-economical outcome could be provided to demonstrate the advantages of the resilience option above the protection option in a life-time approach of flood plain road infrastructure. This weakens the package of convincing elements for the follow-up policy work. Nonetheless it is recommended to raise awareness for the resilience approach of flood plain road infrastructure in line agencies of the MRC member states, which have been involved in the development and implementation of the Road and Flood Project. MRC and WWF GMP could work out a set of recommendations and share these among line agencies of the four MRC member countries, but also with international development banks, and produce documentation of the concept and supporting material for dissemination.

Before entering into such next step of addressing the potential of influencing the policy and policy preparation of responsible line agencies, it would be recommendable to identify the key policy elements in terms of acceptability, sensitivity, methods and cost factors for dissemination of the concept and related documentation. There would be a need for a dedicated and targeted approach in consultation with MRC in order to optimize potential impact of the Guidelines and Recommendations developed under the Roads and Floods Project to the benefit of the MRC member countries.

Preface

In the Mekong Delta, yearly floods provide a crucial dimension to the livelihoods of local people, as they improve the agricultural and fishery resources. However, with growing economies and rapidly increasing population, values of the floodplain are being threatened. One of these threats is the construction or upgrading of roads. Roads influence the duration and extent of the inundations and the dynamics of the flooding. On the other hand, floods cause severe damage to roads. The likely impacts of infrastructure development, roads in particular, on the Mekong floodplain system was addressed by various studies, including Cross (1995). For the MRC Basin Development Plan the need was expressed to assess the impact of embankments (like roads) in the Mekong floodplains on its flood behaviour, including guidelines for minimum water openings (MRC, 2007a; MRC, 2007b). With the aim to 'reduce the socio-economic costs of flooding in the Lower Mekong Basin, whilst preserving the environmental and other benefits of floods, through a better understanding of the management of flood risk and flood behaviour by MRC ..' (MRC, 2007a). The underlying question is how to further develop roads in a sensitive ecosystem like the floodplain of the Mekong in a sustainable manner that minimizes the impact on the benefits of the annual inundations and at the same time reduces damage to roads. The 'Roads and Floods' project - a cooperation between MRC-FMMP, WWF Living Mekong Programme and three Delft Cluster research institutes (UNESCO-IHE, Delft Hydraulics and GeoDelft) - studied this question over the past two years.

This synthesis report of the Roads and Floods project presents an overview of the project results including Best Practice Guidelines for integrated planning, environmental assessment and technical design of road development and rehabilitation in the Mekong floodplains. The Best Practice Guidelines are introduced in Chapter 6 and presented in Annexes 4, 5 and 6. The guidelines are also presented in a separate document.

The synthesis report includes key recommendations of the following studies carried out under the Roads and Floods project:

- Inundation modelling report (Verheij, in preparation).
- Road damage analysis report (Van der Ruyt and Verheij, in preparation).
- Pre-flood, flood and post-flood monitoring plan and 2006 and 2007 survey reports (Verheij *et al.*, 2006).
- UNESCO-IHE MSc theses (Nyangu (2006), Phan Thi Thu Ha (2007), Beinamaryo (2007), Patarroyo (2007), Pratheepan (2007), Namgyal (2007), Dhakal (2007)).
- Wageningen University MSc theses (Do Nguyen Anh Tu, 2008).

Readers interested in further details on the synthesis report are referred to the above-mentioned source reports. Those interested in receiving the reports please consult either the Regional FMMP Centre (Phnom Penh) or UNESCO-IHE (Delft, The Netherlands).

The 'Roads and Floods' Best Practice Guidelines for road development and rehabilitation in the Mekong floodplains of Cambodia and Viet Nam presented in this report, are part of the set of guidelines under development by the FMMP-Component 2 Programme 'Flood Structures and Flood Proofing'. The aim of the FMMP-C2 Best Practice Guidelines is to enable the MRC and national line agencies to better take into account flood-related considerations in their day-to-day technical activities. There is, however, a difference in approach between the FMMP-C2 Best Practice Guidelines and the ‘Roads and Floods’ Best Practice Guidelines specifically. The former specifically focus at flood risk management, while the latter focus on road development and rehabilitation. The ‘Roads and Floods’ Best Practice Guidelines consider multiple objectives in the road planning and design process, such as transport, flood protection, and ecology, and give guidance on how to optimise between these multiple objectives in the road development and rehabilitation planning and design process.

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List of Abbreviations

General

AASHTO	American Association of State Highway and Transportation Officials
ADB	Asian Development Bank
AusAid	Australian Agency for International Development
BDP	Basin Development Plan
BPG	Best Practice Guidelines
CIA	Cumulative Impact Assessment
DC	Delft Cluster
EA	Environmental Assessment
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environmental Performance Assessment
ERM	Environmental Resources Management Group Inc
FMM	Flood Management and Mitigation
FMMP	Flood Management and Mitigation Programme
FRM	Flood Risk Management
GIS	Geographical Information System
GMS	Greater Mekong Subregion
IEIA	Initial Environmental Impact Assessment
IFM	Integrated Flood Management
IFRM	Integrated Flood Risk Management
IRBM	Integrated River Basin Management
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
Lao PDR	Lao People's Democratic Republic
LMB	Lower Mekong Basin
MCA	Multi Criteria Analysis
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
MTIDP	Mekong Transport Infrastructure Development Project
NGO	Non-Governmental Organisation
NMCs	National Mekong Committees
PPP	Policy, Plans and Programmes
RFMMC	Regional Flood Management and Mitigation Centre (MRC)
SEA	Strategic Environmental Assessment
SEF	Strategic Environmental Framework
UNESCO-IHE	UNESCO Institute for Water Education
USD	US Dollar ($)
WWF	World Wide Fund for Nature

Cambodia

MLMUPC	Ministry of Land Management, Urban Planning and Construction
MND	Ministry of National Defence Cambodia
MoE	Ministry of Environment Cambodia
MoPWT	Ministry of Public Works and Transportation Cambodia
MRD	Ministry of Rural Development Cambodia

Viet Nam

DoNRE	Department of Natural Resources and Environment
DoSTE	Department of Science, Technology and Environment Viet Nam
MoC	Ministry of Construction Viet Nam
MoSTE	Ministry of Science, Technology and Environment Viet Nam
MoT	Ministry of Transportation Viet Nam
PPC	Provincial Peoples Committee
RA	Road Administration

Glossary

Best practice: A way or method of accomplishing a business function or process that is considered to be superior to all other known methods. (www.qaproject.org/methods/resglossary.html)

Best practice guideline: An information resource/tool to be adapted according to each country and project context. In the context of FMMP-C2 BPG's can for instance be a reference to summarize an annexed set of tools or data collection method, a process that is to be followed step by step; a checklist to evaluate and improve national guidelines such as construction guidelines/building codes.

Biodiversity: The variability among living organisms from all sources including, *inter alia,* terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between and of ecosystems. (CBD) The totality of genes, species and ecosystems in a region (GBS). Convention on Biological Diversity, Secretariat. www.biodiv.org/secretariat (CBD) Global Biodiversity Strategy. www.wri.org/biodiv/pubs_description.cfm?pid=2550 (GBS) As read in 'Dictionary & Introduction to Global Environmental Governance' by Saunier and Meganck (Earthscan: 2007).

Culvert: A closed conduit used for the conveyance of surface drainage water under a roadway, railroad, canal, or other impediment. www.laportecounty.org/departments/surveyor/glossary.html

Cumulative impacts: The aggregate impacts from multiple activities (in this report road developments). They can be either additive (due to projects that do not require EIA according to existing legislation) or synergistic (when total impacts of several activities greatly exceed the sum of individual impacts). (UNIGIS, EIA module).

Ecosystem: A dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit. Ecosystems boundaries are not fixed and their parameters are set according to the scientific, management or policy question being examined (Saunier and Meganck, 2007).

Environmental assessment (EA): A term used almost interchangeably with environmental impact assessment, environmental appraisal and environmental analysis that refers to a formal procedure structured to ensure that selected environmental issues are considered in the early stages of the project cycle (Sanier and Meganck, 2007).

Environmental impact: Any change to the environment, whether bad or helpful, that wholly or partially results from an organisation's activities, products or services. www.actewagl.com.au/Education/Glossary/default.aspx

Environmental impact assessment (EIA): A process of evaluating and suggesting management and mitigation scenarios for the impacts arising for a new development at the various stages of the project cycle (Saunier and Meganck, 2007).

Floodplain: Any land area susceptible to being inundated by floodwaters from any source. www.floodsmart.gov/floodsmart/pages/glossary_A-I.jsp

Flood zone: Based on the ISIS report where the Mekong floodplains of Cambodia and Viet Nam are divided into several zones, based on hydraulic conditions and characteristics.

Habitat: The place where an organism lives and/or the conditions of that environment including the soil, vegetation, water and food (EES). Encyclopedia of Environmental Science. www.wkap.nl/prod/b/0-412-74050-8 (EES) as read in 'Dictionary & Introduction to Global Environmental Governance' by Saunier and Meganck (Earthscan: 2007).

Holistic: Looking at the whole system rather than just concentrating on individual components. The overall sum can be greater than a simple totalling of the individual parts, because the 'system' adds something in addition. Another term is 'systems thinking'. ag.arizona.edu/futures/home/glossary.html

Integrated planning: Planning using an holistic approach.

IRBM: Integrated River Basin Management (IRBM) can be considered as a tool to deliver IWRM at the basin scale (3rd World Water Forum).

IWRM: Integrated Water Resources Management (IWRM) is based on the understanding that in order to promote efficiency, equity and ecological integrity of natural resources, an integrated approach to engineering, policies, institutional development and management is essential.

Plan: A set of co-ordinated and timed objectives for the implementation of the policy; usually, it involves the identification of the different options to achieve the policy objectives.

Policy: A framework that provides inspiration and guidance for actions usually in the form of a broad statement of intent that defines and focuses the political agenda of a government.

Programme: A set of projects in a particular area or for a particular sector; it deals with the practical questions of how, when and where specific actions will be carried out.

Project development: Project development consists of the following phases: concept development, pre-feasibility, feasibility, project design, construction, operation and maintenance and monitoring.

Projects: the individual actions (i.e. a specific road rehabilitation project) set to implement the goals indicated by the plan and ultimately by the policy.

Rehabilitation: Rehabilitation of a building or property returns it to a state of utility by means of repair or alteration, which makes possible an efficient contemporary use while preserving those sections or features that are significant to its historical, architectural and cultural values. www.loudoun.gov/controls/speerio/resources/RenderContent.aspx

Resilience: The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures. (http://www.adrc.or.jp/publications/terminology/top.htm#R)

Resilience strategy: In this report the resilience strategy aims at minimizing the consequences of floods, but at the same time allow some flooding (Vis *et al.*, 2003).

Resistance strategy: In contrast to the resilience strategy (see above) the resistance strategy, in this report, aims at the prevention of flooding by regulating and hence has a strong impact on the natural floodplain dynamics (Vis *et al.*, 2003).

Road design: Relates to the engineering design step in road development, and includes structural/pavement design and geometric design. Structural design involves selection of materials and thicknesses of the layers while geometric design involves selection of detailed alignment and cross-section of a road.

Road development: Consists of the following phases: project plannning (concept development, pre-feasibility, and feasibility), project design, construction, operation and maintenance and monitoring.

Road planning: Relates to two levels of road development: (1) the policy, plan and programme level, and (2) the project level, particularly the first phases - concept, pre-feasibility and feasibility - of road development. Alignment of a road under planning is the very general alignment in terms of the location of a road between e.g. two cities.

Road rehabilition: Refers to the upgrading of an existing road and includes renewed structural/pavement design and / or geometric design. Structural design involves selection of materials and thicknesses of the layers while geometric design involves selection of detailed alignment and cross-section of a road.

Stakeholder: A person or organisation representing the interests and opinions of a group with an interest in the outcome of (for example) a review or policy decision. (http://cot.food.gov.uk/moreinfo/cotglossary#s)

Strategic Environmental Assessment (SEA): A technique similar to environmental impact assessment (EIA) but normally applied to policies, plans, program and groups of projects. There are two main types of SEA: Sectoral, which is applied when many new projects fall within one sector and Regional, which is applied to cover development within a region (EEA). European Environmental Agency. www.eea.eu.int/; glossary. eea.eu.int/EEAGlossary/ As read in 'Dictionary & Introduction to Global Environmental Governance' by Saunier and Meganck (Earthscan: 2007).

Sustainability: Sustainability is an economic, social, an environmental concept. It is intended to be a means of configuring civilization and human activity so that society and its members are able to meet their needs and express their greatest potential in the present, while preserving biodiversity and natural ecosystems, and planning and acting for the ability to maintain these ideals indefinitely. Sustainability affects every level of organization from the local neighbourhood to the entire planet. 'Dictionary & Introduction to Global Environmental Governance' by Saunier and Meganck (Earthscan: 2007).

Wetland: 'Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.' Classification System for Wetland Type (www.ramsar.org).

1 Introduction

1.1 Roads and floods in the Lower Mekong Basin

Over the last few decades the regional economic development of the four countries of the Lower Mekong Basin has evolved at a fast pace. Such development goes in parallel with the upgrading and development of roads in order to transport goods and services and people. For a number of reasons road development in a floodplain system like the still quite natural floodplain system of the Lower Mekong Basin (LMB), requires a different approach to planning as well as technical design, compared to road developments in areas that are not (regularly) inundated. On the one hand, floods can severely damage infrastructure including the roads. On the other hand, roads and associated infrastructure can themselves have a considerable effect on the floods. They fragment the floodplains and interrupt natural flow of water, sediments, nutrients and aquatic life, which is particularly relevant in the floodplains of the LMB, as they are well-known for their biological diversity, fertile agricultural land and productive fishery sector. Moreover, future developments regarding urbanisation, climate change and economic growth in the Lower Mekong Basin, require higher quality roads. Hence, the question: how to further develop roads in a sensitive ecosystem like the floodplain of the Mekong in a sustainable manner that minimizes the impact on the benefits of the annual inundations and at the same time reduces the damage?

This introductory chapter starts with an introduction to road development planning and environmental assessment, with specific reference to the Cambodian and Viet Namese context since the report is structured along these concepts. Then, the objectives and target group of the report will be presented (Section 1.3), together with the main output of the project, the Best Practice Guidelines for road development and rehabilitation in the Mekong floodplains (Section 1.4). This section will also clarify how these Best Practice Guidelines link to the FMMP-Component 2 Best Practice Guidelines under development. The chapter continues with a brief description of the methodology in Section 1.7, and concludes with a reading guide of the report.

1.2 Road development and rehabilitation and environmental assessment

The development of roads and the role of environmental assessment in these processes are very much country and context specific. The two countries in focus in this project, Cambodia and Viet Nam, each have their own specific rules and regulations with respect to the procedures, guidelines and practice of the development and rehabilitation of roads. An overview of these aspects for both countries will be given in Chapter 3.

Below, a generic development and environmental assessment framework will be presented that will be used in this report to structure the analysis of road development and rehabilitation in Cambodia and Viet Nam, as well as the Best Practice Guidelines. This framework (Figure 1.1) based on Ramsar (2005), consists of the following four inter-related elements of road development and rehabilitation and environmental assessment:

- At the strategic and sub-basin level infrastructure policies, plans and programmes (PPP) are developed that are implemented through operational road development and rehabilitation projects.

- Environmental assessments analyse environmental impacts of development activities and identify mitigation measures. Strategic Impact Assessment (SEA) assesses at the strategic level decisions (policies, plans and programmes) and help determine the need for assessments at the project level which are usually completed through an Environmental Impact Assessment (EIA).

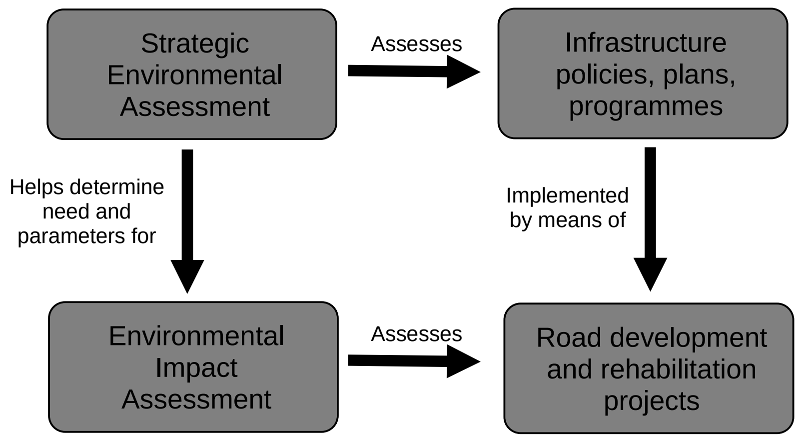

Figure 1.1 Relation between road development and rehabilitation and environmental assessments (adapted from Ramsar, 2005) [1].

In general one can say that the basic steps of the four development and environmental assessment elements as presented in Figure 1.1 are quite similar. First, a problem is identified (e.g. the need for future transport in the case of a transport plan or project, or foreseen environmental impacts in case of an EIA process), then objectives are set, different alternatives identified, impacts of these alternatives assessed, the programme, plan or project implemented and monitored and evaluated. There are however distinct differences, and they can be summarised as follows:

- Difference in scope. Policies, plans, programmes and projects are sector-oriented in general (in this case the transport sector), while environmental assessments are focused on environmental impacts and their mitigation strategies.
- Difference in objective. Policies, plans and programmes are focused on the strategic and planning levels often at the regional and national scales, while they are implemented by projects at the local scale.
- Difference in detail and methodology. The different levels (strategic versus operational) require different detail of information and hence methodology.

Road development and rehabilitation consist of various phases: project planning (including concept development, pre-feasibility, and feasibility), project design, construction, operation and maintenance and monitoring. This report and the Best Practice Guidelines presented address the planning and design phases of project development.

[1] Note that development and rehabilitation and environmental assessments consists of more steps then depicted in Figure 1.1, like enforcement and monitoring. For claity vreasons these are left out.

Both Cambodia and Viet Nam have Environmental Impact Assessments legislation in place, and this seems a key entry-point for ensuring that flood-plain related concerns are addressed in road project development and rehabilitation. Both the Cambodian and Viet Namese system to a large degree follow the general EIA steps as depicted in Box 1.1. However, in Cambodia and Viet Nam, environmental assessments are not legally required for all programmes, plans and projects. E.g. in general no EIA is required for rural road developments and for road rehabilitation. In those cases the recommendations presented in this report are still valid and worthwhile to consider, although the procedure in itself is not compulsory. Strategic Environmental Assessment is not yet practiced in Cambodia. Viet Nam has a few years of experience with this new tool. At the Mekong Basin level there are various initiatives to better address environmental aspects through SEA as well as CIA (Cumulative Impact Assessment), amongst others through the Greater Mekong Subregion (GMS) and MRC programmes.

Box 1.1 General EIA steps and questions addressed.

Screening	Is EIA required for this activity?
Scoping	What issues need to be addressed? I.e. those that have significant impact.
Production EIS	
- Baseline study	What is current status of the environment? What are current trends of the status in absence of the development?
- Impact prediction	What is the predicted change of the environment due to the development?
- Impact assessment	What is the importance and significance of the impacts?
- Mitigation	What measures can be taken to reduce or remove environmental impacts?
EIS review	Can the EIS be used in the decision on the development?
Project implementation	-
Monitoring end review	Where impact predictions accurate and did no unexpected effects occur?

Different actor groups are involved in both parts of the development and environmental assessment framework presented in Figure 1.1. The actors involved in road development and rehabilitation are mainly the government agencies (at different levels) involved in transport, public works and finance. The actors involved in the environmental assessment of road development and rehabilitation are mainly the government agencies dealing with environmental issues and the project proponents e.g. those who produce Environmental Impact Statements (EIS). Other stakeholders, such as local stakeholders, companies, research institutes and NGO's often contribute to both processes.

1.3 Objectives and target group of the report

The synthesis report presents the main findings of the 'Roads and Floods' project.

The overall objective of this report is to give guidance to road planners and designers in Cambodia and Viet Nam on integrated planning and design approaches in road development in the Mekong floodplains so they will take flood-related considerations in their design and planning activities better into account. The report has the following sub-objectives:

- To raise awareness on the benefits of the Mekong floods and possible impacts of road developments on these benefits.

- To present scientific information on the interactions between roads and floods and the impact of different road development strategies.
- To present Best Practice Guidelines to improve present road development and rehabilitation planning and design guidelines so they better address the inter-relation between roads and floods.

The target group of this project are professionals and organisations involved in road development and rehabilitation in the Mekong floodplains, particularly its planning and design phases, and those involved in environmental and integrated assessments of road developments and other structural developments in the Mekong basin.

1.4 Towards Best Practice Guidelines for road development

Main output of the 'Roads and Floods' project is the following set of Best Practice Guidelines for road development and rehabilitation in the Mekong floodplains of Cambodia and Viet Nam:

1. Best Practice Guidelines for Integrated Planning of Road Development and Rehabilitation.
2. Best Practice Guidelines for Environmental Assessment of Road Development and Rehabilitation.
3. Best Practice Guidelines for Technical Design of Road Development and Rehabilitation.

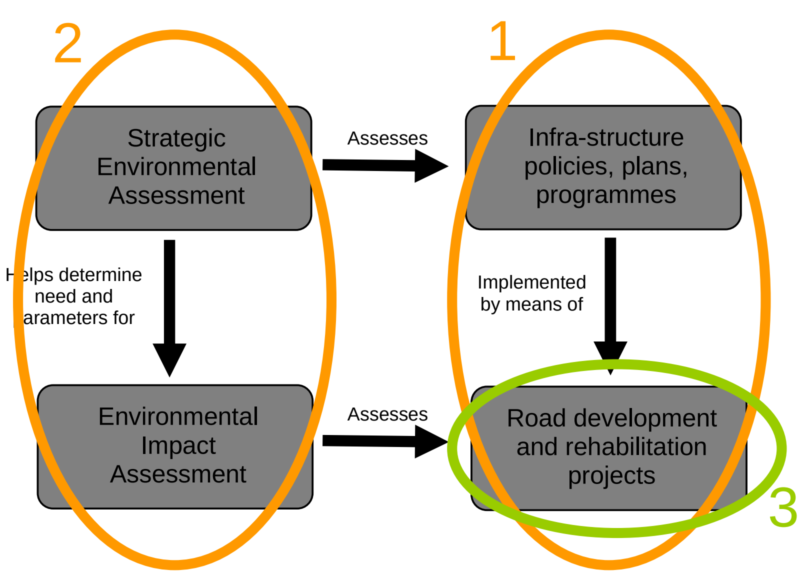

Figure 1.2 The scope of the set of Best Practice Guidelines in relation to the road planning and environmental assessment framework (numbers refer to the Best Practice Guidelines).

The recommendations describe major principles and actions needed, that are based on the outcomes of the Roads and Floods research project. Specific details are provided after each recommendation. Figure 1.2 illustrates the scope of the guidelines related to the development and environmental assessment framework presented in Figure 1.1. Table 1.1

shows the target group for each of the guidelines, in line with the development and environmental assessment framework presented in the previous section.

Table 1.1 Overview recommended improvements to existing road development and rehabilitation guidelines in the Mekong flood plain.

Best Practice Guidelines	Scope	Level of application	Target group
1. Best Practice Guidelines on Integrated Planning	Guidelines on integrated planning, taking better into account the various dimensions of road development in floodplains.	PPP level Project level	National governments and MRC (BDP) officers involved in transport and environmental assessments of road development and rehabilitation projects. But also infrastructure developers, consultants, research groups, NGO's, local stakeholder organisations and development banks.
2. Best Practice Guidelines on Environmental Assessments	Sector guidelines to improve screening and scoping and EIS review taking better into account impacts on floodplain hydraulics and ecology incl. cumulative (regional) effects.	SEA level EIA level Also projects for which no EIA is required	
3. Best Practice Guidelines on Technical Design	Guidelines to improve technical road alignment and design.		National governments involved in road planning and design. But also infrastructure developers, consultants, and development banks.

The Best Practice Guidelines for road development and rehabilitation presented in this report, are part of the set of Integrated Flood Risk Management (IFRM) Best Practice Guidelines under development by the FMMP-Component 2 Programme 'Flood Structures and Flood Proofing'. The aim of the FMMP-C2 Best Practice Guidelines is to enable the MRC and national line agencies to better take into account flood-related considerations in their day-to-day technical activities (MRC-FMMP, 2007d). There is, however, a difference in approach between the FMMP-C2 Best Practice Guidelines and the 'Roads and Floods' Best Practice Guidelines specifically. The former specifically focus at flood risk management, while the latter focus on road development and rehabilitation, while roads in the Mekong floodplain are often on top of levees that have a flood protection function. The 'Roads and Floods' Best Practice Guidelines consider multiple objectives in the road planning and design process, such as transport, flood protection, and ecology, and give guidance on how to optimise between these multiple objectives in the road development and rehabilitation planning and design process. Moreover, the Roads and Floods guidelines focus specifically at Cambodia and Viet Nam and not the Lower Mekong Basin as a whole.

The FMMP-C2 Best Practice Guidelines are presented in Box 1.2. The 'Roads and Floods' Best Practice Guidelines main contribution is to IFRM guideline set 2 with respect to the planning and design of roads. The 'Roads and Floods' guidelines, however, also contribute to set 3 with respect to the planning of roads, as planning of roads in the Mekong context strongly links to IFRM, and the evaluation of impacts of road developments.

Box 1.2 Four sets of IFRM guidelines to be developed by the MRC-FMMP-Component 2 (MRC-FMMP).

1. Best Practice Guidelines on Risk Assessment

2. Best Practice Guidelines on Structural and Flood Proofing Measures

3. Best Practice Guidelines on IFRM Planning and Impact Assessment

4. Best Practice Guidelines to evaluate the impacts of sub-area development scenarios on flood risks. (IFRM guidelines for BDP)

1.5 Development and scope of the Best Practice Guidelines

Criteria for the development of the Best Practice Guidelines, included:

- The guidelines are based on existing planning and design practice and they do not substitute the Mekong countries guidance.
- The guidelines are appropriate for the Cambodian and Viet Namese context.
- The guidelines take financial considerations into account (given the development context).
- The guidelines are based on scientific research and relevant international experience.
- The guidelines are consistent with the FMMP-C2 Best Practice Guidelines.

The recommendations given in this report are suggested improvements of the existing road planning and design guidelines in Cambodia and Viet Nam. They can be regarded as suggestions how the existing guidelines can be improved to arrive at more sustainable solutions.

The Best Practice Guidelines on Integrated Planning and Environmental Assessments specifically have been designed for Cambodia and Viet Nam, but this guidance will also be useful across the Lower Mekong Basin (see discussion Section 5.6).

The Best Practice Guidelines concentrate on roads and related structures (e.g. dykes and levees) in the floodplains of the Mekong and only addresses the issues relevant to the Mekong floodplains. They do not address sea dikes.

Social aspects will not be a main element of the Best Practice Guidelines, but some dimensions of social development will be covered in the recommendations, for instance the resettlement problem due to road rehabilitation and development.

Box 1.3 The use of terms 'standards' and 'guidelines' and FMMP-C2 Best Practice Guidelines.

In road development, the term 'standards' is mostly used in a technical context. Road design and planning standards are detailed technical references e.g. the minimum width of a national road, or the minimum thickness of asphalt cover. They are usually determined by and agreed upon by (groups of) engineers and need to be followed in the planning and design process. Guidelines are more general, they leave more flexibility for the user also to adapt to specific and local circumstances. Guidelines can be divers, e.g. a recommended approach, a course of action (e.g. how to apply standards) or a parameter, and can range from a few lines up to a complete document. They are prescribed by government and can be part of legislation. Standards and guidelines, both, can be either philosophical (e.g. 'in planning and design environmental aspects should be taken into account') or technical.

Best practice can be regarded as a way or method of accomplishing a business function or process that is considered to be superior to all other known methods. Best Practice Guidelines in the context of FMMP-C2 do not attempt to summarize or replace the national guidelines, nor are they intended as a recipe for carrying out planning or project design for FMM in the Lower Mekong Basin. Rather the BPGs are provided as an information resource/tool to be adapted according to each country and project context. BPG's can for instance be a reference to summarize an annexed set of tools or data collection method, a process that is to be followed step by step; a checklist to evaluate and improve national guidelines such as construction guidelines/building codes.

1.6 Methodology

The recommendations presented in this 'Roads and Floods' report are based on two interrelated project activities: a scientific research component and a policy component (Delft Cluster-WWF-MRC, 2006).

The *scientific component*, led by three Delft Cluster institutes (UNESCO-IHE, Delft Hydraulics and GeoDelft) adressed four main research questions:

- What is the significance of roads in the Cambodian and Viet Namese floodplains in changing flow patterns (including cumulative impacts)?
- What is the significance of flow patterns in Cambodia and Viet Nam in terms of road damage?
- What are the impacts of different road development and rehabilitation strategies (resistance and resilience[2]) in Cambodia and Viet Nam on floodplain hydraulics and related benefits of floods and on economic costs of roads?
- What road development and rehabilitation practice would contribute most to the reduction of the socio-economic costs of flooding in the Lower Mekong Basin, whilst preserving the environmental and other benefits of floods?

To address these questions a multi-disciplinary research approach was applied integrating policy analysis and technical analysis. The policy analysis was undertaken to better understand the institutional context of road development and rehabilitation as well as the current road development practice in both countries. Moreover, the policy analysis approach helped to structure the road development process, in particular its planning phase where concept development and (pre-)feasibility) studies take place. The planning phase can be divided into the following general steps: problem analysis, analysis present and future situation, identification of alternatives, assessment of impacts of alternatives and

[2] See Section 4.2 for an explanation of the terms 'resistance' and 'resilience' in the context of road development in floodplains.

evaluation of alternatives. The analysis of the different steps was supported by large flood surveys in 2006 and 2007 in four Cambodian and Viet Namese pilot sites and the technical analysis activities including inundation modelling and analysis, damage analysis, economic analysis and environmental impact analysis. The results of these analyses were important input to the development of the set of Best Practice Guidelines. Both the technical and policy analysis were supported by several field visits during the project period and regular interactions with stakeholders. Further details of the technical and policy analysis can be found in the folowing project documents:

- Inundation modelling report (Verheij, in preparation).
- Road damage analysis report (Van der Ruyt and Verheij, in preparation).
- Pre-flood, flood and post-flood monitoring plan and 2006 and 2007 survey reports (Verheij *et al.*, 2006).
- Review technical design guidelines and suggestions for improvements (Verheij and Van der Ruyt, in preparation).
- UNESCO-IHE MSc theses (Phan Thi Thu Ha (2007), Beinamaryo (2007), Patarroyo (2007), Pratheepan (2007), Namgyal (2007), Dhakal (2007)).
- Wageningen University MSc theses (Do Nguyen Anh Tu, 2008).

The *policy component* under the joint responsibility of WWF and MRC, aimed at raising awareness of impacts of road developments in floodplains amongst decision makers in the relevant government agencies representing e.g. road development, economic development, environment, fisheries and agriculture and senior staff of development banks. Moreover, to assist them in the translation of the findings of the scientific component into national road planning and design practice and investment policy. At various moments during the course of the study, meetings with stakeholders were held, including the inception workshops, January 2007 workshops, October 2007 technical consultations and November 2008 final workshops.

Further details of the technical and policy analysis can be found in the folowing project documents:

- Roads and Floods mission and consultation reports.
- Policy plan (Goichot *et al.*, in preparation).

1.7 Reading guide

The structure of the report is depicted in Table 1.2 that also serves as a reading guide for those interested in selected parts of the report. The rationale behind the Best Practice Guidelines will be described in Chapters 2, 3, 4 and 5. Chapter 5 presents the results of the five case studies in Cambodia and Viet Nam in which the results of the technical and policy analysis are presented. The Best Practice Guidelines are introduced in Chapter 6 and presented in the Annex of the report. Chapter 7 gives recommendations for the further dissemination and application of the guidelines.

Table 1.2 Reading guide for this report.

Chapter 1	Context, objectives and structure of the report
Chapter 2	What are the main characteristics of the Mekong floodplains? What are their functions and values? How do roads interact with the Mekong floods?
Chapter 3	What is the practice of road development and rehabilitation in the Cambodian and Viet Namese Mekong floodplain? What are aspects for improvement?
Chapter 4	Why is it important to apply integrated approaches in road development and rehabilitation planning and design in vulnerable floodplains and what does this mean for the Lower Mekong Basin?
Chapter 5	What are, for a number of cases, the impacts of different road development and rehabilitation strategies on floodplain hydraulics, road economics and the environment?
Chapter 6	Introduction to the set of Best Practice Guidelines for road development and rehabilitation in the Mekong floodplains of Cambodia and Viet nam: ▪ Best Practice Guidelines for Integrated Planning of Road Development and Rehabilitation (Annex 4). ▪ Best Practice Guidelines for Environmental Assessment of Road Development and Rehabilitation (Annex 5). ▪ Best Practice Guidelines for Technical Design of Road Development and Rehabilitation (Annex 6).
Chapter 7	Recommendations for the dissemination and application of the guidelines

2 The Mekong Floodplains and Interactions Between Roads and Floods

2.1 Introduction

Floods are an important natural process that is an integral part of the Mekong River system. The Mekong floods provide important ecological functions and values, which are essential for the Mekong population. These aspects should be taken into account, when planning and designing infrastructures in the Mekong floodplains, like roads. This chapter addresses the characteristics and importance of the Mekong floodplains in Section 2.2. Section 2.3 will give an outline of the damage due to floods, on the one hand, and the benefits of floods, on the other. Then, Section 2.4 will describe, the main interactions between roads and floods to be considered in road planning and design.

2.2 The floodplains of the Mekong River basin

For details on the Mekong floodplains, including a description by flood zone, the reader is referred to Annex 2.

The Mekong floodplain experiences a pronounced seasonal monsoon cycle, with a 'dry, cool' season from December-April (northeast monsoon) and a 'wet, hot' season from May-October (southwest monsoon) (April and October are transitional months), and the lifecycle of many flora and fauna in the plains are centered on the annual 'flood pulse' of the Mekong River. The total annual rainfall is between about 1,200 and about 1,600 mm in the area. Figure 2.1 shows the hydrographs of the Mekong River at Kampong Cham, in the upstream part of the basin. The period from July till November can be considered as the flood season, with the peak discharges usually in August and September.

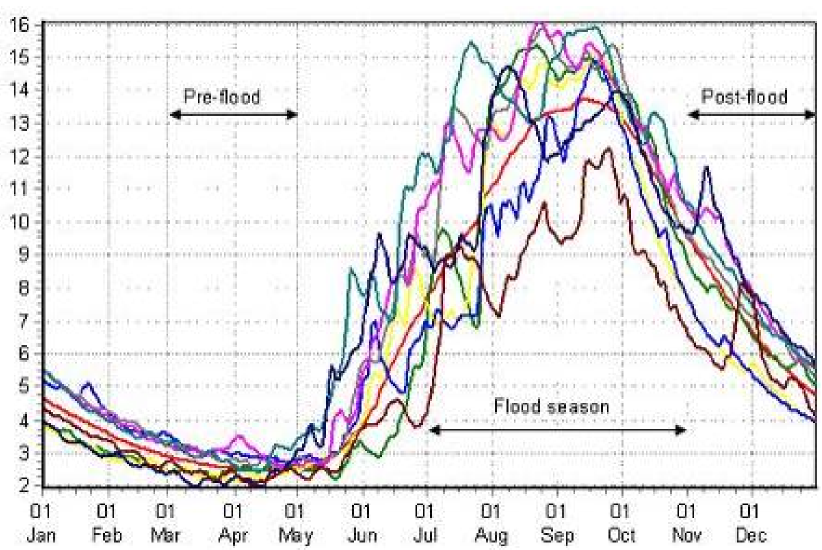

Figure 2.1 Mekong Flood Hydrographs at Kampong Cham (1998 until 2005) (on the vertical axis the peak discharges in 1000 m^3 / s).

The average annual peak discharge is about 45,000 m^3/s at Phnom Penh while the lowest discharge is about 1,500 m^3/s. The year 1978 flood is considered as the highest flood ever regarding the discharge: about 77,000 m^3/s at Kratie (MRC, 2007c). The year 2000 flood is the most recent severe flood with a discharge of about 50,000 to 55,000 m^3/s and a volume of about 475 km^3. The recurrence periods for the discharges are about 50 year for the year 2000 flood and about 10,000 year for the year 1978 flood. In the future the maximum discharge may change and, therefore, various scenario studies have been carried out by MRC taking into account global climate changes, construction of large dams in the Mekong basin upstream the Lower Mekong Basin, and the expected economical growth. These studies resulted in a maximum discharge of about 65,000 m^3/s and a minimum discharge of about 30,000 m^3/s.

The landforms and wetlands of the Mekong floodplain support a rich and diverse mosaic of terrestrial and aquatic habitats including the Mekong mainstream, Tonle Sap Lake, and the Mekong Delta. Over 700 fish species have been documented in the Lower Mekong Basin (Kottelat 2001a), although most fisheries research has focused on species of economic importance and new species to science, new national records, and range extensions, continue to be documented (e.g. Vidthayanon et al. 2008). The riverine and floodplain habitats in the Mekong Plain form critical migratory, feeding and breeding habitats for over 90 fish species which conduct seasonal migrations over hundreds of kilometers between the lower and upper regions of the Mekong Basin (Poulsen *et al.* 2002). These fisheries, and other wetland products, are the principle source of protein and cash income for over 55 million people in the Lower Mekong Basin (Baran *et al.* 2007b). See further section 2.3.2 on the benefits of floods.

Figure 2.2 The Cambodian and Viet Namese floodplain and division in sub-floodplains (as used in the Roads and Floods project).

The Cambodian and the Viet Namese Mekong floodplain systems (Figure 2.2) and their developments are quite different (Table 2.1). In Cambodia a system of colmatage canals has been developed over the centuries to partially control the water flow in and out of the floodplain depressions, to support the cultivation of rice. Still, the Cambodian Mekong floodplain is in a relatively natural state, with remaining large areas not under intensive use. This is in contrast with the much more intensively farmed Viet Namese side of the Mekong floodplain that is organised in parcels and crossed by a tight maze of straight canals. In

Cambodia, flood protection and water management are far less intense, although this situation might evolve rapidly under the current demographic and economic development trends. An important protected area in the Viet Namese Delta is Tram Chim national park (Figure 2.3), that can be classified as a freshwater reed marsh. Also within both countries regional differences of the floodplain are substantial as described in Annex 2).

Table 2.1 Characterisation of the floodplains in Cambodia and Viet Nam.

	Cambodia	**Viet Nam**
Floodplain	Still quite natural	Highly developed
Infra-structure	Few roads, colmatage irrigation systems, a few small-scale irrigation schemes	Dense network of canals, levees and roads; irrigation and flood management systems
Housing and development	Mainly along levees bordering rivers	Mainly along roads, rivers, levees and canals
Economy	Extensive agriculture and fisheries	Intensive agriculture, fisheries and aquaculture
Land use and ecology	No national parks, but floodplains and flooding essential for biodiversity in the region	Tram Chim national park, otherwise most of the land in use for agriculture
Hydraulics	Largely natural flooding, only obstructed by roads and to some extent levees	Floods partly controlled by sluices and other water infrastructure

For details on the Mekong floodplains, including a description by flood zone, the reader is referred to Annex 2.

2.3 Costs (damage) and benefits of floods

There are various economic and financial costs and benefits of floods, such as: damage to infrastructure and houses; lost lives and crops; sedimentation provides fertile lands; flooding creates breeding space, nutrient boost and migration trigger for fish.

2.3.1 Damage due to floods

Figure 2.3 Tram Chim national park in the Viet Namese Mekong delta.

The Cambodian and Viet Namese policy is to protect its population from the flood as much as possible by flood warning systems, protecting cities like Phnom Penh with dikes, building small levees to protect the agricultural fields, and to construct canals to guide the flood pattern. The local population has learnt over time to adapt to the constrain that floods imposed and to take advantage of their benefits, this includes living in houses built on stilts, transporting people and goods in boats, adjusting their agricultural pattern to the annual flood pulse, and developing seasonal fishing practices (e.g. MARD, 2003).

As a result of this cultural adaptation floods do not cause much damage to the traditional settlements, and on the contrary bring many benefits. However, the extra-ordinary floods cause loss of human lives and substantial damage to crops and infrastructure. The year 2000 flood was an exceptional flood with more then 300 casualties and a total damage of over 150 million USD, including damage to infrastructure of around 100 million USD (De Bruijn, 2005). The flood of 2006 on the contrary was relatively mild (MRC, 2007c) and this limits the benefits of flooding to agriculture and fisheries. Some examples of damage related to roads – the focus of this report – are shown in Figure 2.4.

Figure 2.4 Examples of damage due to floods; damage to an unpaved road (left) and damage to a bridge abutment (right).

2.3.2 Benefits of floods

Wetlands have been described as 'kidneys of the landscape', because of the functions they perform in the hydrological and chemical cycles and as 'biological supermarkets' to the extensive food webs and rich bio-diversity they support (Mitch and Gosselink, 1993). Box 2.1 presents the different function classes of wetlands.

Box 2.1 Functions of wetlands.

- Regulation functions as ecosystem regulate ecological processes that contribute to a healthy environment. Wetland services include ecosystem protection, water treatment and pollution retention. Indirect wetland uses comprise flood control, alluvial deposition, storm protection and ground water recharge.
- Carrier or supporting functions where ecosystem provides space for activities like human settlement, cultivation and energy conversion.
- Production or provisioning functions where ecosystems provide resources for humans, like food, water, raw material for building and clothing.
- Information or cultural function where ecosystems contribute to mental health by providing scientific, aesthetic and spiritual information.
- Preserving functions for future use.

(Source: de Groot, 1992; Millennium Ecosystem Assessment, 2005)

Floodplains are an important type of wetland. The Mekong floodplain is amongst the few remaining examples of a relatively intact and functioning floodplain in a large river basin worldwide. It is widely accepted that this feature is one of the main reasons behind the incredibly productive fisheries of the Mekong, as well as its biological diversity (MRC, 2003). The Mekong floodplain as an ecosystem regulates ecological processes that contribute to a healthy environment. It includes ecosystem protection, water treatment and pollution retention. More indirect uses comprise alluvial deposition, essential for agricultural production in the region. Box 2.2 presents an overview of the benefits of the Mekong floods.

Box 2.2 Benefits of flooding in the Lower Mekong Basin (FMMP-C2 IFRM lecture note).

- Increased agricultural productivity.
- Maintenance of freshwater ecosystems and of its resource productivity (e.g. fisheries).
- Improved possibilities for inland water transport / navigation.
- Flushing of stagnant water and pollutants.
- Reduction of the saltwater intrusion.
- Delta growth and maintenance of marine ecosystem productivity.
- Cultural / religious values.
- Aesthetic and recreational / leisure values (flood dependent wetlands).

One of the key benefits of the Mekong floodplain is that it provides resources for agricultural and fisheries production, which both are essential for local livelihoods and have large economic value (Box 2.3).

Box 2.3 Importance of fisheries in the Lower Mekong Basin.

The total direct-use value of the fishery resources of the Lower Mekong Basin has been estimated about $US 2 billion (Baran et al., 2007b), which demonstrates the overall importance of the fisheries. Typical floodplain fish production is in the order of 100 kg^{-1} ha^{-1} y^{-1} (Halls et al. 2006).

Hortle (2007) reports a per capita consumption of inland fish and other aquatic animals averages 34 kg/year as actual consumption. Cambodia and Viet Nam have above-average per capita consumption, while in Lao PDR and Thailand per capita consumption is below-average. Inland fish and OAAs provide 47 – 80% (country range) of animal protein with an average intake of 18.3 g/capita/day of a total animal protein intake of 32.5 g/capita/day, a high intake compared with the recommended daily allowance (Hortle, 2007).

The following fisheries are supported by the migratory fishes of the Lower Mekong Migration System:

- Floodplain fisheries, of which migratory species constitute a proportion of the total catch (e.g. Tonle Sap River floodplains, Great Lake floodplains and the Mekong-Bassac floodplains in southern Cambodia).
- Great Lake fisheries, of which migratory species constitute a proportion of the total catch.
- Fisheries which target migratory fishes when they leave the floodplain (lateral migration).
- The Samrah (brush park) fishery in the upper Tonle Sap River.
- Fisheries targeting migratory fisheries in the Tonle Sap (dai fisheries).
- Fisheries of the Mekong Delta in Viet Nam.
- Fisheries targeting migratory fishes in the Mekong between Phnom Penh and the Khone Falls.
- Fisheries at dry season refuges in northern Cambodia.
- Khone Falls fisheries – a proportion of which constitutes migratory fishes.
- Larvae and juvenile drift fisheries in southern Cambodia and Viet Nam.

In many cases existing data does not allow a quantitative estimate of the contribution of different types of fisheries that would be needed for planning and impact assessment purposes.

The differences in development between the Cambodian and Viet Namese Mekong floodplain gives rise to a marked difference in the fisheries sectors: the Viet Namese Mekong Delta is a very important area for aquaculture - 80% of the national land devoted to aquaculture is located in the delta (SCP Fisheries Consultants Australia, 1996; Torell and Salamanca, 2003) - while in Cambodia the fisheries sector consists mainly of freshwater fishing. Most fishes in the Mekong River basin are migratory and travel long distances (Poulsen *et al.*, 2002) (Figure 2.5).

2.4 Interactions between roads and floods

Road development is closely inter-related with economic growth. Economic growth means that the demand for transportation (and also the budget for roads) increases. The reverse causality is also true as roads facilitate economic development. The construction of roads is very often seen as a means to develop regions and provide people access to markets. For a number of reasons road developments in a floodplain system like the still quite natural Mekong floodplain, requires a different approach to planning and technical design, compared to road developments in areas that are not (regularly) inundated. On the one hand, as we saw in Section 2.3.1, Mekong floods cause yearly damage to infrastructure, including roads. On the other hand, roads and road development can themselves also have considerable effects on the natural flood patterns and its functions (Section 2.3.2). They fragment habitats and interrupt the flow of water, sediments, nutrients and aquatic life, thereby impacting the beneficial effects normally brought by the natural flood cycle. Construction of roads, e.g. could adversely affect the migration routes and thus negatively affect the livelihood of a large number of people.

Road development in floodplains will always alter the floodplain hydraulics and have its impact on the related aquatic ecosystems. Roads in floodplains are often built on dikes, which can have many intended and unintended external effects. Roads can act for instance as ‘reservoir dam’ to keep water for irrigation in the dry season and roads act as a dam to protect spring crop from the early stages of the flood. Floods can also damage roads with negative effects on transportation. This can hamper economic development, but also emergency relief actions, for instance.

There are both direct and indirect effects of roads on the environment (Box 2.4). Direct effects are easily seen and are easier to comprehend. In contrast, many indirect environmental effects of roads are cumulative and involve changes in community structures and ecological processes that may not be well understood. Yet, these long-term effects signal deterioration in ecosystems that far surpasses in importance the visual ones. As an example Figure 2.5 illustrates how the location of roads (in this case the international road between Phnom Penh and Ho-Chi-Minh City; map on the left) can interfere with the fish migration routes (map on the right).

Box 2.4 Effects roads on wetlands (Nyangu, 2006).

The main effects of roads on wetlands identified by most studies include the following:

- Alteration of the physical environment;
- Alteration of the chemical environment;
- Fragmentation of habitat;
- Increase in wildlife mortality rates due to collisions with vehicles;
- Modification of animal behaviour;
- Spread of exotic species
- Concentrating and accelerating sediment runoff (particularly from construction);
- Fill including alteration of circulation and movements of fish and wildlife;
- Channel straightening, deepening and widening;
- Water level increases or decreases, (most result from inadequate culverting, water table disturbance, or accelerated runoff);
- Constraining and diverting surface and subsurface flows and intercepting groundwater flow;
- Increasing sediment loading;
- Clearing vegetation and conversion to barren road surfaces and facilities;
- Introducing toxic runoff.

These above-mentioned impacts could be either short term or long term. Spellerberg and Morrison (1998) and Noss (2002) list a large number of short and long-term effects. Cusic (2000) mentions that even if the culverts are properly installed, roads act as dams, altering water flow from one side to the other. This can result in flooding on one side of the road and drying out on the other, altering vegetation and associated species. Roads also can cause subtle changes to hydrologic flow that appear only in extreme conditions. For example, roads can reduce nutrient transport during infrequent (25 year) storm events. Such storms may indirectly be critical to the productivity of downstream fishery food chains. See also World Bank (1997) for an extensive overview of environmental impacts of road development and rehabilitation and how to manage and mitigate these impacts.

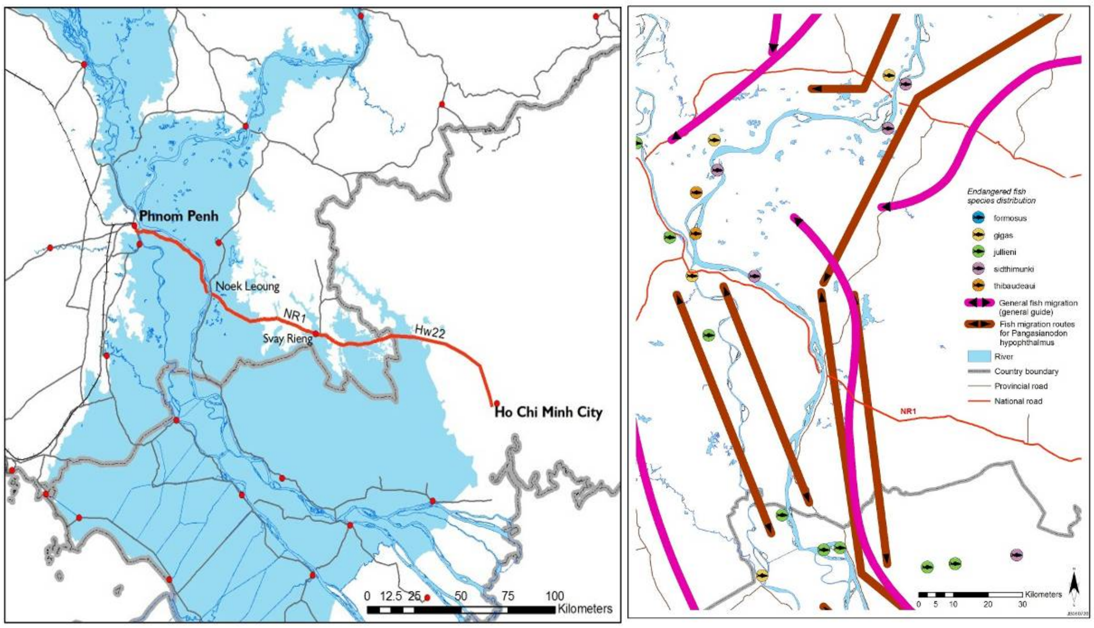

Figure 2.5 An example for the need of integration of road development and floodplain ecology. The international road from Ho-Chi-Minh City to Phnom Penh (left) and fish migration and endangered species distribution (right) (Source: MRCS Database and MRC Interactive Atlas). If the road alignment is incorporated in the pictures you can see clearly the potential blockage by the road end obstruction of fich migration.

The likely impacts of infra-structure development, roads in particular, on the Mekong floodplain system was addressed by various studies, including Cross (1995). Kruskopf (2006) in the context of the Worldfish study on structures on Tonle Sap, carried out an extensive literature review on the Impacts of different types of built structures such as embankments, roads, canalization, mining and fishing gear. Of these, dams and canalization has been discussed most in literature, due to their significant impacts on floodplain environments, fish and fisheries (Box 2.5).

Box 2.5 Effects of stress caused by built structures on fish (Kruskopf, 2006).

The effects of stress caused by built structures, such as dams or levees, on fish have been identified as the following:

- Obligate migratory species will tend to disappear in systems where the main channels are locked by large dams
- Floodplain spawners are selected against by chanellisation or other stream regulation processes which reduce or eliminate the annual flood.
- Within modified channels there is a tendency to lose obligate migratory species although management is usually directed at their protection through installation of fish pass structures or through stocking.
- There is a tendency for dominance in fish assemblages to shift from floodplain spawners toward main channel spawners.

Case study example:
Bangladesh has one of the richest and largest floodplain systems in the world, floodplains constituting about 80% of the country. Because of the large destruction to the human population caused by floods, many flood control programs have been built to mitigate the adverse impacts of the flooding. These constructions have affected the floodplain environment and fisheries, most strikingly through the drastic reduction in floodplain area of over 2 million hectares in the past 30 years, which has severely impacted floodplain dependent fish species.

2.5 Conclusions

- Floods are integral part of the natural Mekong River system, which bring many yearly benefits to the local population representing a value of around 2 billion USD per annum, but also causes yearly damage.
- The Cambodian and Viet Namese floodplain system show distinct differences, which need to be taken into account in road planning and design.
- Road developments in a floodplain system like the Mekong floodplain, require a different approach to planning and technical design, compared to road developments in areas that are not (regularly) inundated given the roads and floods interactions.

The challenge is to take these aspects into account in road planning and design, which will be further addressed in the next chapters.

3 Current Practices of Road Development and Rehabilitation in the Mekong Floodplains

3.1 Introduction

'Roads and Floods' is a field that involves many ministries, departments and other organisations at various administrative levels. The questions addressed in this chapter are: What are the main stakeholders involved in road planning and design in Cambodia and Viet Nam? What is the current practice of road development and rehabilitation in the Mekong floodplain? and To what extent are floodplain hydraulic and related aquatic ecological aspects taken into account in project development and environmental assessments?

As the differences between the Cambodian and Viet Namese Mekong floodplains are large in many respects, the Cambodian and Viet Namese situations are discussed separately in the sections below. These national analyses are structured along the elements of the road development and environmental assessment framework as presented in Figure 1.1. Apart from this national perspective, this Chapter will also describe developments towards regional environmental assessments at the Mekong Basin scale, to manage and mitigate trans-boundary environmental impacts (Section 3.4).

3.2 Current practices of road development and rehabilitation in Cambodia

Road development and rehabilitation planning

In Cambodia the Ministry of Public Works and Transportation (MoPWT) is in charge of development and management of roads, but also the Ministry of Rural Development (MRD), the Ministry of National Defence (MND) and the Ministry of Land Management, Urban Planning, and Construction (MLMUPC) are involved in these activities. The MoPWT is mainly responsible for planning and implementation of (inter)national and provincial roads. The other ministries are more involved in rural roads developments or in activities conducted in dangerous areas, where clearing of mines is necessary before construction can start, or in emergency areas, such as the MND, for instance.

The Cambodian road network covers about 35,500 km, including approximately 4,000 km of national roads, 3,500 km of provincial roads, and 28,000 km of rural and strategic roads (ADB, 2002). The roads have a significant number of bridges, about 4,000 on the primary roads alone. Years of war have left the Cambodian road network in a very poor state, and large floods in 1996 and 2000 have caused extensive damage. A road condition survey in 2002 revealed that 28% of the network was in good or fair condition, 35% in poor condition, 28% in bad condition, and 6% under reconstruction or rehabilitation (ADB, 2002).

To overcome these problems, in 2006 a masterplan for road development was prepared (JICA, 2006). The masterplan gives little attention to the interaction between roads and floods and possible impacts of roads on the floodplain system.

It is clear that most of the road construction activities in Cambodia are geared towards rehabilitation of the existing road network, including repair or replacement of existing bridges. Spatial planning and alignment of roads has not been relevant and also little attention has been paid to integrated design in relation to hydrology and hydraulics of the floodplain.

In a road development or rehabilitation project, the MoPWT starts with producing an initial request for a proposal on the basis of a feasibility study. The proposal is then discussed with relevant agencies and ministries like the Ministry of Planning. After internal discussion the proposal is sent to donor agencies for funding, as most road construction in Cambodia is funded by international donors. Most donors have quite powerful positions to determine the procedures and select consultants who carry out detailed studies. They also determine the alternatives for rehabilitation, although the ministry is involved. With improved and more detailed guidelines and standards the ministry would have a stronger bargaining position, and could ensure that projects are carried out according to similar standards.

A new road project, recently undertaken, is Road #8. Box 3.1 illustrates how a country like Cambodia with large needs, but limited funds for road infrastructure development cannot construct all roads at the highest standards, but needs to take a ‘frog’s leap strategy’ towards road development.

Box 3.1 National road 8 in Cambodia.

A new road is planned on the national Cambodian network. This road will cross the entire floodplains of the Mekong perpendicular to its main flow. H.E. Hung Sen, Prime Minister of Cambodia mentioned National Road 8 in a speech delivered for the inauguration of the Preah Kunlong Bridge in Kandal province on 31 January 2006:

‘Today I wish to reiterate that we will complete the construction of the national road 8 in the frog’s step strategy. The National Road 8 would extend from the National Road 6A at kilometre 24-365 in the Kandal’s district of Muk Kampoul to the National Road 11 at kilometre 8 or 9 in Prey Veng’s district of Prey Veng at the length of about 52 kilometres. We also see the possibility of extending this road to the border with Viet Nam, which is another 50 kilometres more. I have approved already the financial disbursement for the construction. The groundbreaking to start building this road was presided over by Finance Minister H.E. Keat Chhun and Transport H.E. Sun Chanthol held on June 18 last year. The road length to be asphalted will be 6,550 meters and at the width of seven meters. The part that runs on the national road number 8 will be 5,850 meters, 3,100 of which runs from the ferry port to the village of Anlong, 2,750 meters from the double drainage system to the pagoda of Preah Vihear Suor. Another 900 meters runs from the roundabout at Prek Tameak to the district office.

The proposal to increase the road size of the National Road 8 from Anlong village to the double-drainage system and the laterite covering of the 9,200 meter road between the Pagoda of Vihear Suor to Kompong Popil will be fulfilled by the Kandal province’s public works section. On the part of Prey Veng, I have approved the construction of a ten-meter-wide concrete bridge on the national road 8 in the village of Chrey, Prey Veng province and the basement work project for the part of 25 kilometres of the national road 8 in the province of Prey Veng. We could not afford from our small coffer to asphalt the road all at once, as we are practicing the policy of reducing expenses while increasing income. We have used the term of equitable distribution of economic growth and we have to fulfil this endeavour, while a focus is being given to the people’s need in the rural area – not only in the district of Khsach Kandal but the whole country.’

Apart from constructing and updating the national roads network, there is the Cambodian desire to become part of the Greater Mekong Subregion infrastructure network. The Phnom Penh - Ho Chi Minh City highway (National Road number 1 in Cambodia) is an example and has been recently upgraded (See Box 3.2). Based on this example it can be questioned whether during the planning phases sufficient attention was paid to potential impacts of the road on floodplain hydraulics and ecology.

Box 3.2 The National Road 1 (Cambodia) and Highway 22/Highway 1 (Viet Nam).

As the trade between Cambodia and Viet Nam resumed from the 1990 and has increased consistently since, it rapidly became evident that the very poor condition of the road was a major bottleneck for economic development. This road was therefore included as a major axis of a Greater Mekong Subregion project to link Bangkok - Phnom Penh - Ho Chi Minh City - Vung Tau corridor A proposal to rehabilitate the section from Neak Luoeng to HCM - following the alignment of the old road through a sparsely populated area - was submitted to the Board of Directors of ADB in November 1998 and was completed in 2004, about 2 years later than the estimated completion date in June 2002. The first part of the 105 km section from Neak Luoeng to HCM is the most prone to flooding, as it is cutting the floodplain from west to east, perpendicularly to the main flow of the Mekong floodplain.

The section from Phnom Penh to Neak Luoeng was also rehabilated recently under a JICA grant. The roads runs for about 55 kilometres on the right flood embankment of the Mekong River to Noek Luoeng, where a ferry crosses the river. This section is built on the natural elevated levee, perpendicular to the Mekong, and therefore less of an obstacle to the main flood flows. It recent rehabilitation consisted in widening, pavement reconstruction and resurfacing.

The design for the ADB funded section was based on traffic estimations up to 2012 (10 years after expected completion). The geometric, structural and pavement designs have been developed based on the broad assumption that in Cambodia a low-cost solution is used in the light of the low traffic volumes, while in Viet Nam a higher standard is used.

The estimated cost of the ADB loan is USD 195.5 million, of which USD 50.7 million for the Cambodian component and USD 144.8 million for the Viet Namese component (1998 prices). Note that these are very general figures as different sections have different characteristics; The costs includes improvements to customs facilities and improvement of border procedures.

An Initial Environmental Examination (IEE) was carried out, but the 1998 document on the basis of which the ADB board allocated the funding for the rehabilitation of Neal Luoeng section mentioned that it was not considered necessary to conduct an EIA, as the upgrading was not going to change the alignment and that this section was not going through any protected areas and that it could be therefore assumed that the impacts to the environment would be negligible.

This conclusion has since been challenged on the basis of literature demonstrating the importance of the of the flood pulse to sustain the ecological and morphological equilibrium of a delta. In the Mekong this should be put in the light of the scientific evidence indicating that the extremely high fish biodiversity of the Mekong and extremely productive fisheries, which are the direct consequence of its natural functioning floodplain. Any major infrastructure affecting the flood flow of water, sediment, nutrient or fish is therefore bound to have a significant environmental impact on these functions.

Current road development and rehabilitation standards and guidelines

Road planning and design in Cambodia is based on international guidelines for all types of roads located outside the floodplain, with the exception of the guidelines for rural roads. The country has limited national standards and guidelines. Both Viet Nam but especially Cambodia has insufficient funds to finance all the necessary road rehabilitation and construction programs. Many of the rehabilitation and construction works are financed by Donor organisations like ADB, World Bank, or countries like Japan and China. These

Donors however do not finance all rehabilitation and construction works. This means that for a e.g. 100 km of road which in such poor condition rehabilitation is necessary, the first part can be financed by the ADB, Japan might finance the next part etc. All Donors have different preferred companies and rules for contractors who could works for them. All these contractors use different guidelines and standards due to the lack of national guidelines. As a result the many rehabilitation works, result in a patchwork of different road sections constructed under different guidelines to different design standards.

There have been two donor-financed studies to develop guidelines; the Cambodian Road Standards of the Ministry of Public Works and Transportation (AusAid) and guidelines for the design of rural roads of the Ministry of Rural Development (ADB). Cambodia is currently in a process of harmonizing road standards and guidelines, focused at re-settlement issues, with the support of development banks like the ADB. This project could pave the path to harmonization of other aspects of road standards in Cambodia such as environmental impacts.

In road planning and design in Cambodia the floodplain is only considered from a hydraulics perspective focusing exclusively on stability, damage and passability of roads during floods. The impact of the road on the floodplain dynamics or ecology of the floodplains (hence beyond the immediate vicinity of the road) is often not included. The MRD guidelines for rural roads are an exception as they do include to some extent floodplain dynamics.

Environmental assessments of road development and rehabilitation

The first EIA legislation in Cambodia started in 1995. Main responsible agency is the Ministry of Environment (MoE) that was established in 1993. The different stages of the Cambodian EIA and the responsible parties are listed in Table 3.1. The screening to evaluate if an EIA or Initial Environmental Examination (IEE) is required is undertaken by the project proponent in accordance with the 1999 Sub Decree.

Table 3.1 Organizations responsible for EIA in Cambodia and Viet Nam (ERM and MRC, 2002).

EIA steps	Cambodia	Viet Nam
Screening	Project proponent via the relevant Ministry or Department	National Environment Agency; MoSTE (at national level) or DoSTE (at regional level)
Completing the EIA study	Project proponent via the relevant Ministry or Department	Project proponent
Reviewing the EIS	Ministry of Environment	Appraisal Council (set up by MoSTE/DoSTE)
Approving the EIS	Ministry of Environment	MoSTE - at national level DoSTE - at regional level

The road and embankment projects mentioned in the 1999 Sub Decree are (ERM and MRC, 2002): construction of bridge roads (> 30 Tons weight), and national road construction (> 100 km). Hence, EIA is not necessary for rural and provincial roads as well as the rehabilitation of roads. In general, environmental aspects are taken into account only at the construction stage. Broader environmental issues, like fish migration routes and the impact on the agriculture, are hardly taken into account. Box 3.3 presents some results of a review of EIA reports of structural developments around Tonle Sap (Baran *et al.* 2007b). It shows that environmental impacts to the Tonle Sap system are not sufficiently taken into account in most EIS's.

Box 3.3 Review of EIA process in Tonle Sap region (Baran et al., 2007b).

Environmental Impact Assessments (EIAs) should be improved for Tonle Sap infrastructure projects that may have a significant impact on water and aquatic resources. Access to Environmental Impact Assessments for Tonle Sap development projects is difficult, reports being scattered across various ministries and provincial and district government offices or with project developers. Very few are available at the Ministry of Environment or other relevant ministries. Assessments are not systematically recorded or classified. The study evaluated in detail only 10 reports, mostly involving projects funded by external donors. Reports for other projects were unavailable because they were either inaccessible or did not exist. Tonle Sap EIA's tend to be narrowly focused, covering a fraction of the area, the resources, the time period, and the people possibly impacted. These EIA's are often geographically limited to the project area, which provides at best a partial estimate of the impact on fisheries. They tend to be narrowly focused on short-term biological and physical changes to water flows and fish; few assessments mention other aquatic resources like crabs, shrimps and snails - important sources of food for many people, especially the poor. They neglect longer-term impacts on the ecological system and livelihoods. Moreover, they do not systematically address socioeconomic consequences of impacts on fisheries and there are wide variations in coverage. Last, participation of stakeholders is generally very limited due to lack of a systematic mechanism for the consultation of local communities, provincial authorities, and local or international NGOs in the EIA process.

There is a sectoral guideline for roads and highways under development financed by Swedish International Development Agency. Apart from the Cambodian EIA guidelines, ADB and JICA use their own EIA procedures.

ERM and MRC (2002) conclude that EIA experience in Cambodia is limited, EIA requirements are not well known or used within the government agencies. There is limited capacity to conduct EIA and environmental issues are seen by many parties as secondary in comparison with the need of development. The EIA department under the Ministry of Construction has not been involved yet in RN8 development, due to lack of funds and capacity. The result is limited awareness among the Cambodian people (specifically the public) regarding environmental issues arising from road developments. The inexperience and low priority within the responsible governmental bodies is illustrated by the fact that the government considered an EIA not necessary for the construction of NR8. The same is seen in rehabilitation works; an environmental impact assessment is in many cases not considered necessary as it is assumed that the improved roads would not cause any (new) impacts on the environment (see, for instance the Emergency Flood Rehabilitation Project). The MoE also reported that it hardly had any influence to change designs if the environmental impacts are negative, although they do suggest considering alternative designs. Their intention is to consider local and regional impacts, as well as impacts during construction and operational stages of roads. However, they suffer from insufficient funding, even for developing guidelines.

Main conclusions Cambodia

- Inclusion of natural floodplain dynamics in transport and road planning and management is limited, particularly the impacts or disturbance of the floodplain hydraulics on sub-floodplain level are not taken into consideration (with the exception of the MRD guidelines for rural roads). Impacts as far as they affect the stability of and damage to the road under construction are considered.
- Road planning and design is based on international guidelines for all types of roads located outside the floodplain, with the exception of the national guidelines for rural roads. As a result, different sections of the same road could be constructed under different international criteria depending on the choice of funding donors.
- There is a need for harmonisation of standards and guidelines and inclusion of the specifics of developing roads in a dynamic floodplain system.
- Cambodia has an EIA system in place, although experience in its application, is limited. In EIA, environmental aspects are only taken into account as far as it concerns the construction stage of the road.

3.3 Current practices of road development and rehabilitation in Viet Nam

Road development and rehabilitation planning

In Viet Nam the Ministry of Transportation (MoT) is the main actor in road infrastructure development at the national level, while the Ministry of Construction (MoC) for the planning of rural and regional roads. The Road Administration (RA), under the MoT, is the national body in charge of the development of roads for the national network. The Road Administration is involved in the road development planning and approves designs which are made by consultants and contractors according to the Viet Namese standards. The Sub-institute for Transportation Science and Technology, operating under the Road Administration, is responsible for the planning and design for both national and provincial roads and bridges. Their activities concern both construction of new roads and rehabilitation of existing roads. At the provincial or local levels roads are managed by the PPC.

The national highway network in Viet Namese Mekong Delta covers about 700 km. The road condition ranges from poor to good (MoT/Worldbank, 2005). Very poor sections are mostly secondary links with low traffic volume. In recent years, some sections of the national highway network have been rehabilitated and/or upgraded. One example, is the section of highway 1A between Ho Chi Minh City and Vinh Long, of which a part runs through the Mekong floodplain. At the end of 2005 the sections between Can Tho and Ca Mau of highway 1A and between Can Tho and Go Quao of highway 61 were being upgraded.

The provincial road network is about 2,400 km and nearly half of this is in fair to good condition (MoT/Worldbank, 2005). Very poor sections are mostly secondary links with low traffic volume. Many roads are however not passable during the flooding season, either because of floods level or inadequate rain drainage. Many households cannot be accessed by roads and use boats as the main means of transport. The Viet Namese government has formulated a project with the World Bank to upgrade the transportation network (including waterways), the Mekong Transport Infrastructure Development Project (MTIDP). Rehabilitation and reconstruction of bridges is evaluated for each road section individually. For provincial roads the policy is to maintain roads at tolerable standards and ensuring roads remain passable all year round. This implies that many dirt tracks need to be upgraded to roads. The MTIDP project has defined a preliminary short-list of priority projects. These include sections of national roads 54, 80 and 91 totalling 149 km. For provincial roads 13 sections have been proposed, about 245 km in total.

Road planning should be in compliance with flood control planning. Implicitly, this means that existing standards such as the design standards of river dykes and sea dykes should be considered.

Current road development and rehabilitation standards and guidelines

In Viet Nam, an extensive set of road construction and design standards is used (Verheij and Van der Ruyt, in prep.). The specifications and guidelines for road design are based on the AASHTO Guide for design of pavement structures, 1993 and very detailed. For the national roads the most comprehensive and extensively used manuals are the TCN's: 22TCN-273-01 for guidelines for road design, 22TCN-273-01 for the design of flexible pavements, and 22TCN-272-05 for Bridge Design. The impression is that they are adjusted to the Viet Namese situation, however, they are not particularly aiming at planning and rehabilitation of roads in flood plains. Although they recommend taking into account the effect of a proposed bridge on flood flow patterns, the potential for creating new or augmenting existing flood hazards, and the environmental aspects, particular guidance is not presented in the road and bridge manuals. From the interviews it seems that in road planning and design floodplain hydraulics as far as it affects the stability of or damage to the road were considered, and if the road remains passable during a flood. Effects of the road on the floodplain hydraulics and ecology in a larger area than only the vicinity of the road is not directly considered. The guidelines also prescribe the execution of EIA (see next section). In practice, environmental aspects in Viet Nam are mainly taken into account as far as it concerns the construction stage of the road. Furthermore, Viet Nam has standards for design of river or sea dikes, which can be useful since most of the roads are on top of an embankment which is comparable with a river or sea dike.

Environmental assessments of road development and rehabilitation

Environmental assessment in Viet Nam was first mentioned in the Law on Environmental Protection (1993) and its implementation further elaborated in various legal documents since then. EIA is required for a number of projects, as well as at a more strategic level for regional development plans and strategies, plans for development of provinces and cities under central government and strategies for urban and population development (ERM and MRC, 2002). The National Ministry of Natural Resources and Environment (MoNRE) is responsible for the EIA process in Viet Nam.

The main steps in the Viet Namese EIA system are screening, scoping, preparation of detailed EIA, and appraisal of EIA report. Table 3.1 presents the responsibilities for each step. Screening is the process to determine if an EIA is needed for a particular project. Projects are classified into two categories in Viet Nam: Category 1 projects which have an impact on the environment and for which an EIA report is mandatory and Category 2 projects for which no EIA is required.

The road and embankments projects requiring submission of an EIA report for appraisal and approval in Viet Nam are: railways, highways, roads for car transportation (from level I to level III according to the standard TCVN 4054-85) with length greater than 50 km. (ERM and MRC, 2002). There is limited guidance on how to carry out an EIA, as a result international or donor standards or guidelines are often used.

The execution of EIA and SEA (Strategic Environment Assessment) are included in the revised Law on Environment Protection in 2006, then MONRE has issued a Circular to guide the implementation of the Law. Viet Nam has a separate guideline for EIA of transportation projects developed by Ministry of Science, Technology and Environment in 1999, particularly for roads, railways, and bridges and sluices. Environmental aspects, according to the guideline, should be taken into account for the whole span of a project, including 3 stages: stage of selection and preparation of construction site, construction stage, and operation stage. In all the stages, all aspects including hydraulic regime of water bodies, soil, status of natural resources like aquatic, forestry and wildlife are taken into account. In the guideline for EIA of transportation projects developed by Ministry of Science, Technology and Environment in 1999, wetlands and floodplains are not mentioned.

The EIA's are undertaken by consultants on behalf of the investor. The EIA report has to be submitted together with the technical design report. If funds are insufficient the design should be modified i.e. cheaper mitigating measures for reducing environmental impact and a new approval procedure is required. Monitoring of environmental effects is carried out during the first 3 years and done by the management departments of the Ministry of Transport. MONRE receives these reports.

Environmental aspects of road development under MTIDP (MoT/World Bank, 2005) will be studied under separate environmental assessment studies. The chapter on environmental assessment does list a number of environmental aspects, mainly related to impacts during construction of the roads. MoT (2004) gives an environmental review of the Mekong Transport and Flood Protection (MTFP) project, mainly focusing on impacts during construction, but also with some reference to through-flow capacity of the road (upgrade existing culverts and add new ones) to relieve the water flow.

Despite the sectoral guidelines produced by MoSTE and other guidelines available in Viet Nam (e.g. from donor-financed projects), the effectiveness and quality of EIA reports is still limited (ERM and MRC, 2002). Many research centres who carried out and/or were consulted in the EIA preparation process appear reluctant to show their data or their EIA's and the EIA divisions in the NEA and provincial Department of Science, Technology and environment (DoSTEs) only collect paper copies of EIAs (ERM and MRC, 2002).

Main conclusions Viet Nam

- Viet Nam has a comprehensive set of road construction standards, but they are not particularly aiming at planning and rehabilitation of roads in floodplains. Although they recommend taking into account the effect of a proposed bridge on flood flow patterns, the potential for creating new or augmenting existing flood hazards, and the environmental aspects, detailed and specific guidance in what way this should be done is not presented in the manuals.
- Inclusion of natural floodplain dynamics in infrastructure policies, plans and programmes is limited, particularly the impacts or disturbance of the floodplain hydraulics on sub-floodplain level are not taken into account.
- There is a need for harmonisation of standards and guidelines and inclusion of the specifics of developing roads in a dynamic floodplain system.
- There is an EIA as well as SEA system in place in Viet Nam. Viet Nam also has a sectoral EIA guideline of transportation projects, although wetlands and floodplains are not mentioned.
- Various ministries and agencies in Viet Nam are involved in road infrastructure planning. There is a need for better cooperation.

3.4 Environmental assessments at the Mekong Basin level

Beside of national legislation regulating the environmental assessment procedures within their borders, the Mekong riparian countries tries to find ways for cooperation at the basin level in the fields related to harmonisation of their environmental assessments. This basin level perspective on environmental assessments is particularly relevant when dealing with transboundary impacts of wide range. As roads can also cause transboundary environmental impacts, this section presents some of the regional developments in this field.

Environmental assessments of the donor countries

In general, procedures for environmental assessments by the donor countries active in the Lower Mekong Basin appear to be similar to those adopted by the member countries of the MRC (ERM and MRC, 2002). ERM and MRC (2002) also note a number of differences between the donor EA systems and the MRC riparian countries systems. First, the decision-making framework that supports implementation of the donors’ EA systems, is different. The donors are individual, decision-making bodies who have ultimate control over what developments they will support in contrast to the four separate MRC jurisdictions that are involved in decision-making. The donor procedures relate to project-level activities and those at programme, plan and policy levels and do not provide a specific model for EA in a transboundary context. Finally, because of the very wide audience that needs to use and understand the EA requirements of the donor agencies, they have issued an extensive range of guidance scrutinized by the development and NGO community (ERM and MRC, 2002).

Towards a EIA/SEA system for the Lower Mekong Basin

The MRC Agreement 1995 laid the foundation for the establishment and improvement of environmental assessments in the Lower Mekong Basin. In 1998, the Secretariat proposed an MRC Environmental Policy and an outline of a method for EIA specifically focusing on the prevention and mitigation of transboundary environmental impacts. This outline was further detailed in ERM and MRC (2002) that provide initial technical background information for the development of an EIA/SEA system appropriate to the Lower Mekong Basin. The types of activities and developments specifically examined in this study are those that are of most relevance to the sustainable development and protection of the water and related resources of the lower Mekong River. These are the construction and operation of hydropower dams, inland navigation, ports and harbours, agriculture and irrigation, and flood management. Road infrastructure development, the subject of the report at hand, was not explicitly mentioned as a main activity relevant to the development and protection of the Mekong's water and related resources.

The Greater Mekong Subregion (GMS)

There is increasing emphasis on basinwide management in the Mekong River basin through the cooperation amongst the six countries of Greater Mekong Subregion (GMS) sharing the Mekong River: Cambodia, Lao People's Democratic Republic, Myanmar, Thailand, Viet Nam, and Yunnan Province and Guangxi Zhuang Autonomous Region of the People's Republic of China. Since 1992, Greater Mekong Subregion (GMS) countries have embarked on a program of economic cooperation that aims to promote development through closer economic linkages.

Cooperation on environmental issues is an important part of the GMS Economic Cooperation Program. The Core Environment Program (CEP) has been developed as a joint initiative of GMS member countries and was endorsed by the Second GMS Summit of Leaders held in Kunming, People's Republic of China (PRC), in July 2005 (http://www.gms-eoc.org/). The Core Environment Program consists of five components:

- Component 1: Strategic Environmental Assessments of GMS Economic Corridors and Priority Sectors (Figure 3.1).
- Component 2: Biodiversity Conservation Corridors Initiative.
- Component 3: Environmental

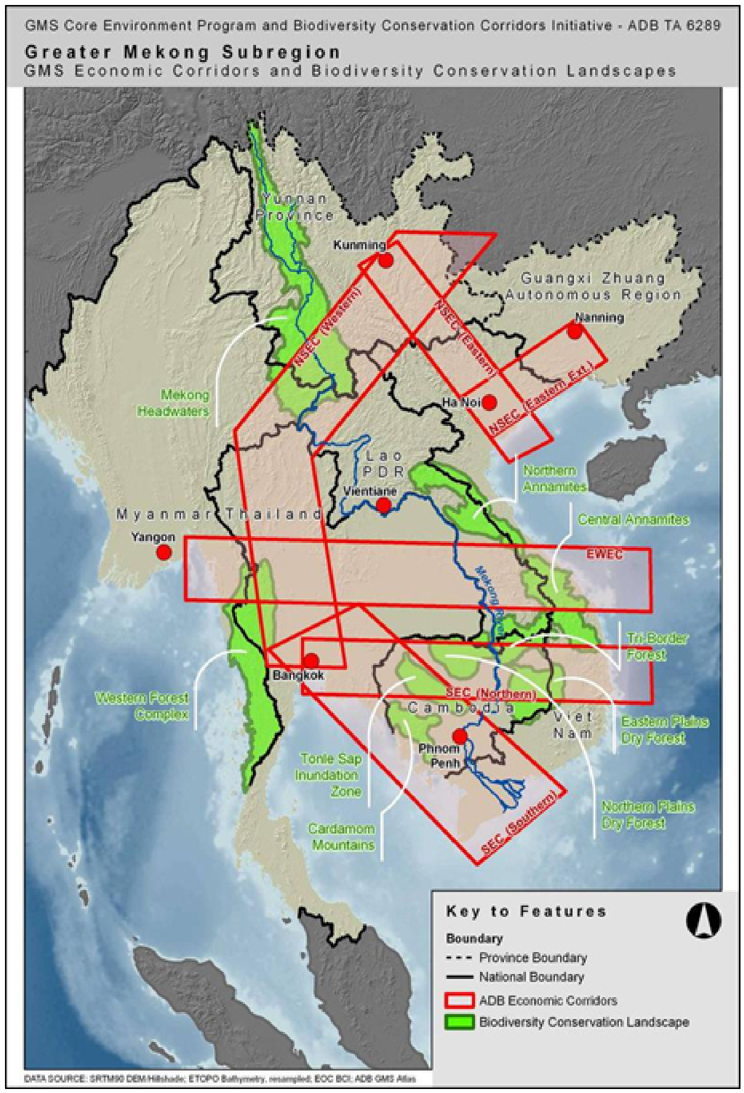

Figure 3.1 The 6 GMS economic corridors and the biodiversity landscapes (Source: http://www.gms-eoc.org/).

Performance Assessments (EPAs).
- Component 4: Capacity Building for Environmental Management.
- Component 5: Program Development, Delivery and Sustainable Financing.

See also SEI and ADB (2002) on a number of case studies reports in preparation of a Strategic Environmental Framework for the Greater Mekong Subregion.

The Strategic Environmental Framework (SEF) is promoting basin-wide management of environmental issues. The SEF provides the basis to promote basin-wide EA and also significant, it provides a framework for data collection and dissemination, identification of impacts and co-operation with the Upper Mekong states (ERM and MRC, 2002).

3.5 Conclusions

- In general road planning and design in Cambodia and Viet Nam takes into account the local flood flow patterns, however it focuses mainly on local effects and less on sub-floodplain hydraulics and related ecology.
- Road planning and design in Cambodia is based on international guidelines for all types of roads located outside the floodplain, with the exception of the national guidelines for rural roads. As a result, different sections of the same road could be constructed under different international criteria depending on the choice of funding donors.
- Viet Nam has a comprehensive set of road construction standards, but they are not particularly aiming at planning and rehabilitation of roads in floodplains. Although they recommend taking into account the effect of a proposed bridge on flood flow patterns, the potential for creating new or augmenting existing flood hazards, and the environmental aspects, detailed and specific guidance in what way this should be done is not presented in the manuals.
- The review also shows that infrastructure investment budgets and operation and maintenance and damage repair budgets are separated in both countries. This implies that an integrated financial assessment - integrated in terms of investment, operation and maintenance, damage risk – is difficult, which hampers a more efficient use of limited financial resources.
- Both Viet Nam and Cambodia have an EIA system in place, although experience in its application, particularly in Cambodia, is limited. There are developments towards an environmental assessment system for the LMB addressing the trans-boundary dimension at basin level.
- It can be concluded that there is a need for better guidance of road development and rehabilitation in the Mekong floodplains in both countries.

4 Road Development in Floodplains: Balancing Economic, Social and Environmental Dimensions

4.1 Introduction

The key issues of the Mekong floodplain system and its interactions with floods have been presented in Chapter 2. Chapter 3 showed that road planning and design practice in Cambodia and Viet Nam needs to better consider interactions with the floods in terms of road damage and ecological damage. This Chapter will start with an overview of regional and international guidance on developments in floodplain systems based on literature review (Section 4.2). To address the challenge of road development in the vulnerable Mekong floodplains there is a need for an integrated approach in road planning and design, which will be further discussed in Section 4.3.

4.2 International practice on planning and design of structures in floodplains

Road planning and design principles

There is a large number of publications discussing road planning and design principles (e.g., Brockenbrough and Boedecker, 2003; EMU, 2004; Jackson, 2003; Walder, 2005). The documents found for the literature study (Annex 1) discuss the planning and design principles from a wide range of perspectives: some are purely technical, some analyse environmental impacts, while others focus on tools and methodologies for design.

Road planning and design and the environment

Various studies within these address impacts of developments on floods and hydraulics in general. Some studies specifically mention effects of roads on floods, though a systematic study has not been carried out yet (e.g., Hoban and Tsunokawa, 1997; Konrad and Booth, 2002; Transportation Research Board of the National Academies, 2003). See also Kruskopf (2006) on impacts of structures on fish (Section 2.4).

In the international literature many standards and guidelines can be found for developments in environmentally sensitive areas. No specific standards or guidelines, however, exist other than engineering guidelines to avoid flood damage to a road or guidelines to deal with environmental effects of roads (Asian Development Bank, 1993). The topic that comes closest to the Roads and Floods project is the discussion of standards and guidelines for road construction in wetland areas (Marble and Riva, 2002) and stream and river crossing standards (MRSCSC, 2004).

Environmental assessment guidance

There is a broad range of environmental assessment guidelines available. These guidelines assist stakeholders involved in development projects - project proponents and developers, EIA practitioners, environmental agencies, research institutes and universities - to manage and mitigate environmental impacts of development projects. Most guidance is given to development projects in general, whereas larger road constructions often require an EIA (Environmental Agency, 2006; Nairn and Fossitt, 2001). To a limited extent guidelines address the interaction between roads and surface water or floods specifically. Box 4.1 and 4.2 present some examples from international guidelines. The examples cover both direct impacts to the water environment and indirect impacts to its dependent ecosystems.

Box 4.1 Example of scoping guidelines for surface water of Australia (source: http://www.dpi.vic.gov.au/CA256F310024B628/0/9DB9D60517A6DA42CA2573060008403C/$File/Assessment+Scoping+Guidelines+Geelong+Bypass.pdf).

The Environment Effects Statement (EES) should assess potential impacts related to surface drainage, water quality, flooding/hydrology, and the conditions and ecology of floodplains and waterways. Specifically the EES should:

- Assess the existing conditions of waterways including the Barwon River, Armstrong Creek and Waurn Ponds Creek, floodplains and drainage paths in the vicinity of the road alternatives.
- Assess the existing hydraulic behaviour of drainage paths, waterways and floodplains, with particular reference to known and potential flood levels in the vicinity of the road alternatives.
- Identify and assess the potential short- and long-term impacts of construction and operation of the Proposal on the quantity and quality of surface runoff, floodplain inundation and waterway water quality, as well as on the hydrology and character of local waterway and floodplain environments.
- Detail the proposed short- and long-term environmental mitigation measures to minimise the impact of the construction and operation of the Proposal on waterway functions and values.

The EES will need to address all relevant requirements for managing discharges and protecting water quality, in the context of the *State Environment Protection Policy (Waters of Victoria),* floodplain management plans and other water-related policies and strategies.

Box 4.2 DMRB guidance of the UK.

Guidance given in the Design Manual for Roads and Bridges (DMRB) indicates that any environmental assessment of roads crossing a floodplain should consider both the potential flood risk and the area of functional floodplain lost. The guidance manual asks the following questions:

- Will the project affect an existing water course or floodplain?
- Will the project change either the road drainage or natural land drainage catcments?
- Will the project lead to an increase in traffic flow of more than 20%?
- Will the project change the number or type of junctions?
- Is any of the project located within an Indicative Floodplain or Source Protection Zone?
- Will earthworks result in sediment being carried to watercourses?
- Will the project allow drainage discharges to the ground?

If the answer to any of the above questions is yes then some form of assessment, ranging from hydrological to hydraulic study should be undertaken with liaison with the relevant EPA. Further, the guidance states that if flood risk is increased (i.e. a resultant higher water level), then mitigation must be included to reduce the risk to an acceptable level. A range of measures may be considered for this purpose, however upstream and downstream impacts should be considered as well as the loss of functional floodplain area. Advice is then given on the design of these structures within the floodplain.

The Ramsar convention on the conservation and wise use of wetlands (*(www.ramsar.org)* has various guidance on how to integrate conservation and wise use of wetlands in planning and management (Box 4.3). This concentrates on impacts on biodiversity and ecosystems.

Box 4.3 Relevant Ramsar resolutions (www. ramsar.org).

Guidelines for incorporating biodiversity-related issues into environmental impact assessment legislation and/or processes and in strategic environmental assessment' adopted by the Convention on Biological Diversity (CBD), and their relevance to the Ramsar Convention, Resolution VIII.9. (Ramsar, 2002)

An Integrated Framework for wetland inventory, assessment and monitoring (IF-WIAM), Resolution IX.1 Annex E. (Ramsar, 2005)

Guidelines for integrating wetland conservation and wise use into river basin management, Resolution VII.18. (Ramsar, 1999)

For the Mekong River many studies focussing on fish ecology related to the wetland and floodplain ecosystems have been carried out in the past decade (See Chapter 2; Poulsen et al., 2002; Kottelat 2001a; Baran et al. 2005, 2007a, 2007b; Halls et al. 2006; Hortle, 2007). Box 6.2 gives an example how this knowledge has resulted in a number of recommendations on how to maintain the fish stocks and ecosystem of the Mekong.

Box 4.4 Recommendations for maintaining the fish stocks and ecosystem of the Mekong River (Poulsen et al., 2002).

- In a complex, multi-species ecosystem, such as the Mekong River basin, single-species management is not feasible. Instead, a more holistic ecosystem approach is suggested for management and planning. The migration systems mentioned above could be used as the initial, large-scale framework under which ecosystem attributes can be identified and, in turn, transboundary management and basin development planning can be implemented.
- The ecosystem attributes should be taken into account when assessing impacts of development activities. A pre-requisite for impact assessments is a valuation of the impacted resource (e.g. migratory fishes) from a fishery perspective. Undertaking such a valuation of migratory fishes is extremely difficult because they are targeted throughout their distribution range in many different ways, and with many different fishing gears and operations. Given the scale and complexity of such an undertaking in the Mekong River, it is probably not possible to fully assess the economic value of migratory fishes.
- However, a partial assessment of value, together with an assessment of information gaps is in many cases sufficient for planning and assessment purposes. It is also important to emphasize that in the decision-making process, qualitative information and knowledge from various sources should be included on equal terms with quantitative data. Furthermore, along with the direct value of fishery resources, the Mekong River ecosystem provides numerous intrinsic, non-quantifiable goods and services.
- To ensure that the Mekong River basin can continue to provide these important goods and services, we propose that development planning and environmental assessment should be based on an ecosystem approach within which the ecological functioning, productivity and resilience of the ecosystem are maintained. Experiences from other river basins suggest that from an economic, social and environmental point of view, this is best way to utilise a river.

Developments in floodplains: resistance versus resilience strategies

The topic of ‘Roads and Floods’ touches upon the discussion how one builds in a floodplain system. A common strategy is the so-called *resistance strategy* where embankments and roads are constructed to protect and/or extract areas from the influence of floods (Figure 4.1a). This strategy, however, has its disadvantages as pressure on the structure can be severe causing damage - thus high maintenance costs resulting from the inevitable repair - as well as the fact that the floodplain hydraulics are disrupted, which negatively impacts on the floodplain ecosystem (Table 4.1). Also, water quality problems may arise because dirt and polluted water are no longer removed by the flood waters. Internationally there is increased attention for so-called resilience strategies in flood risk management (e.g. Bruijn de, 2005; Vis *et al.* 2003). The *resilience strategy* basically employs a more natural way to mitigate flood risk, as it aims at minimizing the consequences of floods, but at the same time intends to maintain the natural floodplain dynamics as much as possible. This strategy hence could present a way to sustainability. The hypothesis behind the resilience strategy in the light of this study is that although the strategy might requires higher initial investment, the longer term costs in terms of road damage and ecological impacts, will be lower.

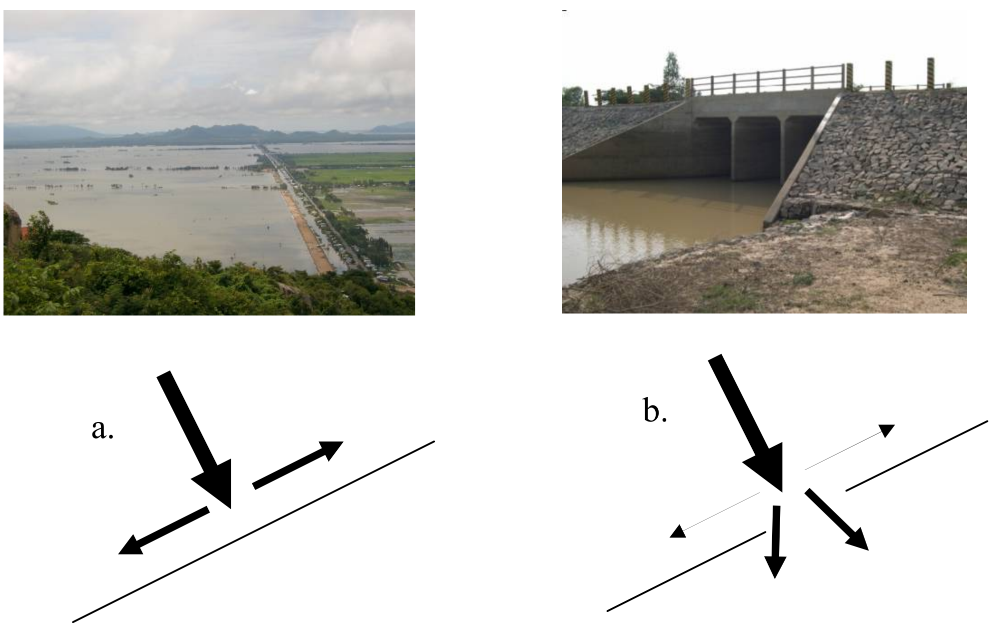

Figure 4.1 Strategies in roads development in vulnerable floodplains: resistance (a) versus resilience (b).

An example demonstrating this is the ‘room for the river’ approach adopted in the Netherlands, which creates safety against extreme river floods by widening river cross sections to lower flood levels (Ministry of Transport, Public Works and Water Management, 2006). This is done by situating the dikes further away from the river, or by lowering the river forelands, thereby reducing velocities and water levels by providing space for the watercourse. Within this approach old secondary branches in the floodplain will be opened again for floods, but roads should maintain passable. This requires properly designed flow-through structures that can withstand the high flow velocities. For other, international examples in the field of Roads and Floods see e.g. Jackson (2003).

Table 4.1 Pros and cons of the resistance and resilience strategies of road development in vulnerable floodplains.

	Pros	Cons
Resistance strategy	▪ Better protection against floods ▪ Reduction damage in high density areas	▪ Fragmentation of floodplains and hydraulic changes and impact on flood-related functions ▪ Downstream impacts ▪ More expensive to protect roads against damage ▪ Potential for increased complacency towards the dangers of floodplain living
Resilience strategy	▪ Less fragmentation floodplains and hydraulic changes ▪ Less damage to roads ▪ Long-term benefits to both financial investment in development and biodiversity conservation ▪ Increased awareness of dangers of floodplain living	▪ More costly due to construction through-flow structures ▪ Reduced access (lower roads) ▪ More need for integrated planning and management

A similar approach to flood management has been adopted in the UK where DEFRA (Department of Food and Rural Affairs) has developed the 'Making Space for Water' cross government programme for England and Wales. This attempts to reduce risks to people, property and the environment from flooding and coastal erosion. The programme is arranged around four themes:

- Holistic approach.
- Achieving sustainable development.
- Increasing resilience to flooding.
- Funding.

It aims to reduce vulnerability by ustilising a range of approaches to flood risk management from the provision of defences, flood forecasting and warning systems, increased flood resilience of property, to beneficial land management changes and discouragement of inappropriate development in areas at risk of flooding (DEFRA, 2008). A number of best practice examples can be found on the webbsite (DEFRA,2008) where recent land planning and resilience strategies have been employed with the purpose of reducing vulnerability.

English (PPS25, Planning Policy Guidance) and Scottish guidance (SPP7 – Scottish Planning Policy) follows the same approach, which shapes development policy with regard to flood risk within the UK. The latter states that no new development should increase the probability of flooding elsewhere. This would require that the design of any bridge across a major river or floodplain would require to demonstrate minimal change to flood levels either upstream or downstream of the structure (www.sepa.org.uk/flooding).

These examples indicate the European trend towards a different approach to flood risk and resilience and this has recently been translated into a strategic directive at the European level. The EU Floods Directive 2007/60/EC controls the management of flood risk considerations within Member States. It requires that all members should assess flood risk (both fluvial and coastal), ascertain vulnerable people and assets and take measures to reduce the risk, with the focus on prevention, protection and preparedness. Sustainable flood management is now at the heart of the European strategic level approach to flooding and indicates the trend to towards the adoption of Integrated Flood Management principles.

Integrated River Basin Management

The discussion on the two strategies of road development in floodplains and their pros and cons shows the need for integration, as road development in floodplains relate to many aspects, including regional development, agriculture, ecology, water management, social welfare. Integrated Water Resources Management (IWRM) and Integrated Flood Risk Management (IFRM) are two concepts that adress this integration, although from different perspectives.

Integrated Water Resources Management (IWRM) is based on the understanding that in order to promote efficiency, equity and ecological integrity of natural resources, an integrated approach to engineering, policies, institutional development and management is essential. IWRM, particularly in a region like the Mekong, implies allocation of water resources, implementation of strategies, and the operation of agencies and utilities in doing so. It brings together major technical and non technical aspects, including hydrological, biophysical, chemical, economic, institutional, legal, policy-making and planning aspects. Integrated River Basin Management (IRBM) can be considered as a tool to deliver IWRM at the basin scale (3rd World Water Forum). See also Box 4.5.

Box 4.5 Integrated Water Resources Management (IWRM) and Integrated River Basin Management (IRBM).

IWRM is a process that (GWP, 2000):

- Favours the co-ordinated management and development of water resources and of related land and other resources.
- For the purpose of maximising in an equitable way the economic and the resulting social welfare.
- Without compromising the sustainability of vital ecosystems.

'IRBM is now recognized as the tool, perhaps the best tool, to deliver IWRM at the basin scale.' (3rd World Water Forum)

As many roads in the Lower Mekong Basin, particularly in Cambodia and Viet Nam, are built on levees, they also have the purpose of flood protection. Hence, the development and planning of roads is strongly related to Integrated Flood Risk Management. It is the immediate objective of FMMP Component 2 to reduce the vulnerability of people living in the LMB to the negative impacts of floods. It does so by establishing sustainable flood risk management capacity in the MRC, the MRCS, NMCs and national line agencies to effectively and appropriately address flood-related considerations in the BDP, other MRC programs and in national FMM programs. Flood risk management is an approach to identify, analyse, evaluate, control and manage the flood risks in a given system (Inception report FMMP-C2; MRC, 2007d). The following steps are identified:

- Definition of the system, the analysed hazards and the scale and scope of the analysis.
- A quantitative analysis where the probabilities and consequences are assessed and combined / displayed into a risk number, a graph or a flood risk map (see also section 1.1.4).

- Risk evaluation: With the results of the former analyses the risk is evaluated. In this phase the decision is made whether the risk is acceptable or not.
- Risk reduction and control: Dependent on the outcome of the risk evaluation measures can be taken to reduce the risk. Measures can be structural or non-structural. It should also be determined how the risks can be controlled, for example by monitoring, inspection or maintenance.

Flood risk management measures should be evaluated based on their environmental impacts, hence there is a need to identify measures that on the one hand reduce flood risk and on the other hand maintain benefits of floods.

4.3 An integrated approach to road development and rehabilitation in floodplains

The question is how to develop infrastructures in a sensitive floodplain ecosystem as the Mekong Delta in a sustainable manner. This question becomes even more relevant as the population in the lower Mekong River basin is expected to rise from about 60 million to 100 million by 2025 and roads will be increasingly needed in the future. Considering the effects of road development and rehabilitation on the natural flood system, future developments should be addressed. Some developments will be regional. Flood mitigation measures upstream such as protection dikes, drainage from protected areas (irrigation schemes, cities, towns) or flushing of flood water from reservoirs will increasingly affect flood conditions downstream. Land-use development and construction of roads and through-flow structures have changed the natural flood flow patterns and have increased flood risks to adjacent areas as well. Other developments will influence the whole Mekong basin, such as the greenhouse effect, the construction of dams with large reservoirs in the upstream catchments of the Mekong, and socio-economic effects. This all shows that road alignment and design in the Mekong floodplain needs more attention to reduce impacts on floodplain functions and values in order to maintain its vulnerable and highly valuable floodplain system.

Figure 4.2 presents a framework for integrated analysis of road planning and design. The figure shows the relation between road development design and planning (A) and the various effects (B), and links this to the use of standards and guidelines (C). In road development and planning all effects should be taken into account through the use of economically sound and environmentally friendly guidelines for planning and construction of roads in floodplains (C).

Ultimately policy makers determine what guidelines and standards to use depending on the objectives they find important. It is clear that in this process multiple objectives should be taken into account. Table 4.2 gives as an example several road development and rehabilitation objectives and different options for criteria that will be applied by decision-makers when selecting alternatives.

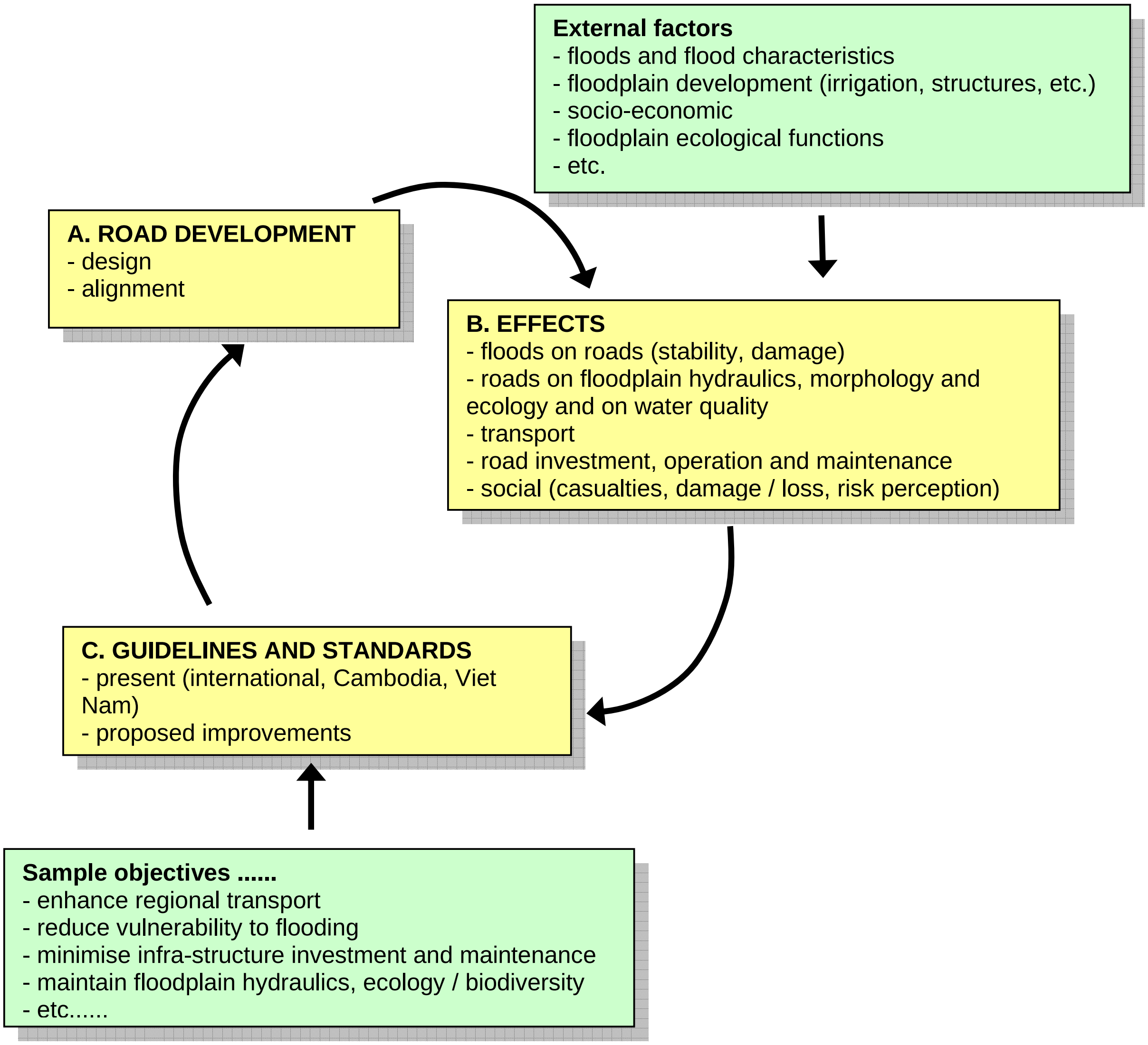

Figure 4.2 Conceptual framework of road design and planning in floodplains.

These objectives are often conflicting and then a compromise has to be made. This is illustrated by two examples.

A first example is that roads with more bridges, culverts and other measures to deal with floods are expensive. In developing countries like Cambodia and Viet Nam budgets are limited and cheaper options may be preferred. Hence it is important to locate bridges and culverts at the best possible locations and recommend solutions that have only small additional construction costs. This might imply that objectives on vulnerability or environment will not be completely met.

Table 4.2 Example of road development and rehabilitation objectives and different options for criteria.

Objectives	**Criteria**	
Enhance Regional Transportation	Travel Time	▪ Road flooding accepted (limited reduction travel time) ▪ Once in few years flooding accepted (medium reduction of travel time) ▪ Road never flooded (large reduction of travel time)
Reduce Flood Vulnerability	Damage of Flooding (Housing, Infrastructure, Agriculture, Roads)	▪ No damage accepted ▪ Yearly limited damage accepted ▪ 5 yearly limited damage accepted ▪ Damage accepted
Maintain fisheries and agricultural harvest	Fisheries and Agriculture Harvest	▪ No change in harvest accepted ▪ Small decrease accepted ▪ Increase harvest
Minimise Road Investment and Maintenance	Initial Investment	▪ No budget constraint ▪ Medium budget ▪ Limited budget
	Maintenance Cost	▪ No budget constraint ▪ Medium budget ▪ Limited budget
Maintain Flood Plain Hydraulics and Ecology	Flood Pattern and Dynamics (within zone)	▪ No change accepted ▪ Limited change accepted ▪ Change accepted
	Flood Pattern and Dynamics (outside zone)	▪ No change accepted ▪ Limited change accepted ▪ Change accepted in less valuable areas
	Habitat Fragmentation	▪ No fragmentation loss accepted ▪ Limited fragmentation is accepted if adaptation is possible ▪ Fragmentation accepted

A second example is emergency works versus integrated design: many road improvement works focus on emergency repairs after roads have been damaged by floods; integrated design of roads has different investment and maintenance costs associated as roads may have less damage during floods, but are more expensive to build. The main point is that effects are to be considered in an integral manner and the best solutions found given objectives and constraints.

Another approach would be to search for a win-win solution where robust technical designs lead to benefits for various construction cost, infrastructure maintenance, ecology, natural resources and vulnerability of population. Will a greater initial investment be beneficial in the medium and long term, as it would reduce maintenance of the infrastructure and environmental and social mitigation measures. The question then is how to design standards in the face of these trade-offs. The Mekong floodplains, especially in Cambodia, offers potential for a more resilient planning and design of roads, by using more flow-through (culverts, bridges) or spill-over capacity within a design. This could have benefits on two sides: reducing annual damage to roads, thus ensuring a year round transport service, and a more pristine floodplain from an hydraulic, geo-morphological and ecological perspectives. Although investments on the short term may be higher, the longer-term overall benefits could be substantial to the transport sector, and other sectors like agriculture, rural development, fisheries and environment. Applying this approach to the highly developed, and intensively used, Viet Namese floodplain will be more challenging as it will affect flood protection and water management schemes already in place. But, as land use is more intense and the stakes higher so would the benefits from less altered natural resources.

Literature presents limited evidence that resilient planning and design of roads (ie by using more flow-through (culverts, bridges) or spill-over capacity within a design) can effectively mitigate ecological impacts. Some evidence is given by Bruijn de (2005) and Vis et al. (2003) (Section 4.2). Most convincing evidence was found during fieldtrips in the Cambodian and Viet Namese Mekong floodsplains where it was observed that if bridge openings are not so wide, the damage was larger. The purpose of the four cases studies carried out in the context of the Roads and Floods project and presented in the upcoming chapter is to further investigate this hypothesis.

4.4 Conclusions

The main conclusions of this chapter are:

- Ample guidance exists on planning and design of roads in general, mainly in (inter)national standards and guidelines. Literature on the development of roads in ecologically sensitive areas is limited, and only a few studies were found on the development in floodplains.
- There is a broad range of environmental assessment guidelines available, although they only to a limited extent address the interaction between roads and surface water or floods specifically.
- Few international examples and studies were found on different strategies to building infrastructure in river floodplains. Two general road development strategies – resistance and resilience - can be distinguished, both having their pros and cons.
- Selection of a strategy requires an integrated assessment of all relevant aspects and impacts, and the report presents a framework for an integrated assessment of road development and rehabilitation in floodplains. The Chapter presented a framework for integrated assessment of road development and rehabilitation.

Next Chapter, presents for four case studies in Cambodia and Viet Nam impacts of a number of road development and rehabilitation alternatives and addresses the underlying question whether it can be expected that a resilience strategy (Section 4.3) indeed leads to lower road damage and reduced ecological impacts at the longer term compared to a resistance strategy.

Chapter 6 presents the set of Best Practice Guidelines for road development and rehabilitation in the Mekong floodplains of Cambodia and Viet Nam floodplains, which are based on the case study results of Chapter 5, as well as the findings of Chapters 2, 3 and 4.

5 Analysis of Four Road Development and Rehabilitation Cases in Cambodia and Viet Nam

5.1 Introduction

Chapters 2 and 3 presented the context of road development and rehabilitation in the Mekong floodplain and Cambodian and Viet Namese practice. One of the conclusions was that there is a need for better guidance in Cambodia and Viet Nam on the planning and design of roads in the Mekong floodplains. Chapter 4 gave an overview of international practice in this area and presented a framework for an integrated approach of road development in the Mekong floodplain. This Chapter will present four case studies aimed to understand the interactions between roads and floods better, as well as to investigate the impacts of the different road development strategies; namely resistance and resilience (see Chapter 4). More specifically the cases are applied to answer the four main research questions underlying this report which were presented in Chapter 1. The cases considered are presented in Table 5.1 and cover both road rehabilitation and new road development. The location of the cases in both countries is presented in Figure 5.1.

Table 5.1 The four case studies of the 'Roads and Floods' project.

Country	Case	Road	Description road and flow-through condition options
Cambodia	1	NR 11 and PR 317	Existing road with damage problems. Currently limited flow-through and partly elevated.
	2	NR8	Construction new road crossing floodplain zone 5, perpendicular to the floodplain.
Viet Nam	3	PR855	Rehabilitation of Provincial Road.
	4	NR1A and HCM road	Development of new section National Road number 1 and Ho-Chi-Minh Road.

To analyse and present the cases a policy analysis approach was applied that helped to structure the road development process, in particular its planning phase where concept development and (pre-)feasibility) studies take place. The planning phase can be divided into the following general steps: problem analysis, analysis present and future situation, identification of alternatives, assessment of impacts of alternatives and evaluation of alternatives. The analysis of the different steps was supported by the surveys carried out in both Cambodia and Viet Nam and the technical analysis activities including inundation modelling and analysis, damage analysis, economic analysis and environmental impact analysis. For further details on the methodology followed the reader is referred to the Annex 3 of the Annex document of this Synthesis Report.

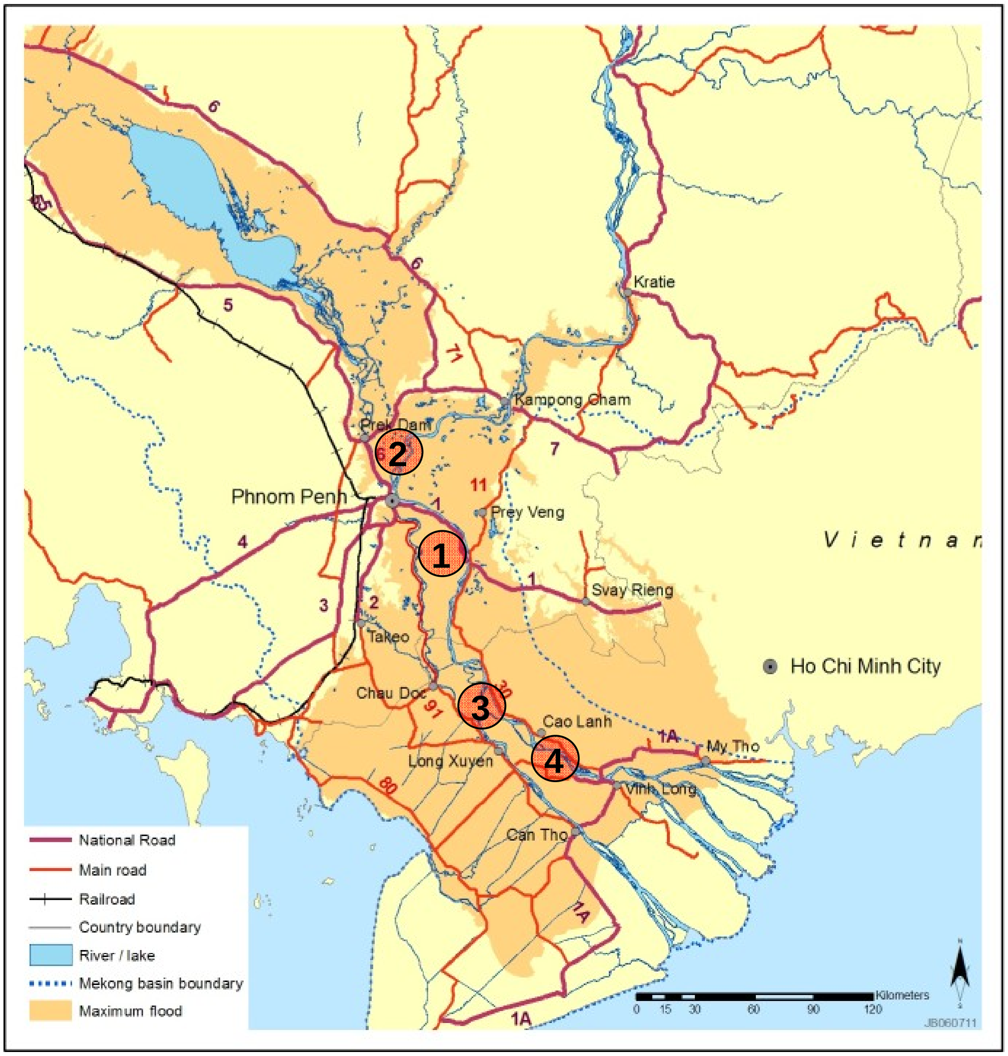

Figure 5.1 Overview of main roads in the study area and location of the four case studies.

5.2 Case 1: Rehabilitation of NR 11 and PR 317 (Cambodia)

5.2.1 Introduction[3]

National Road (NR) 11 runs between NR1 along the village of Prey Veng until the intersection with Provincial Road (PR) 317 (see Figure 5.2 and 5.3). The southern part of NR11 is along the left bank of the Mekong River. Both roads are located in Flood Zone 5 (Annex 2). Provincial Road 317 can be considered a typical Cambodian Provincial Road in a rural area.

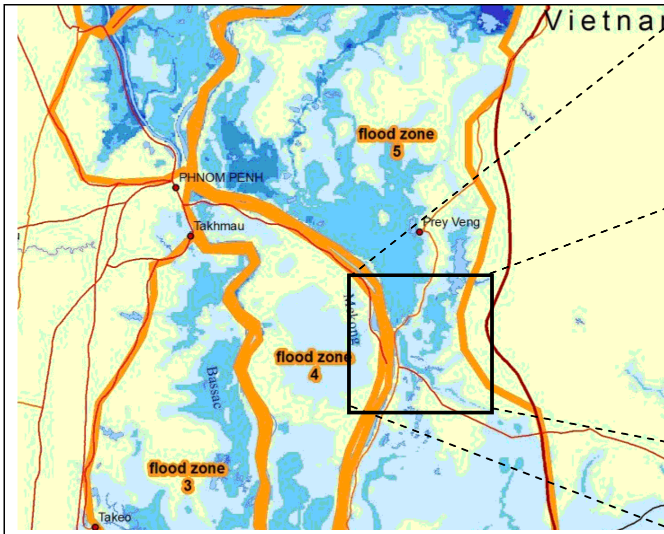

Figure 5.2 The location of the case in the Cambodian floodplain.

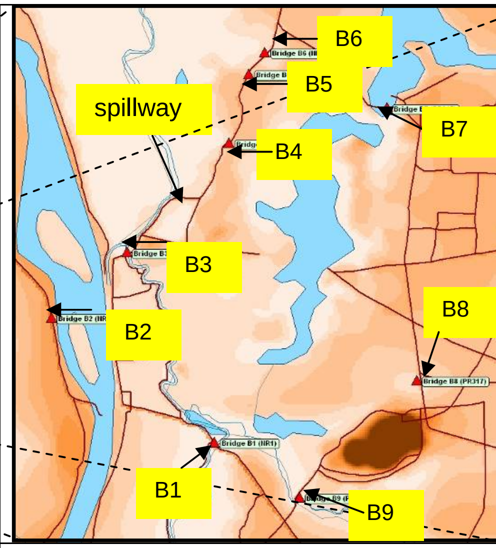

Figure 5.3 Location of roads NR 11 and R317 and their main bridges, including the spillway of NR11.

5.2.2 Analysis of the present and future situation

NR11 was seriously damaged during the floods in 2000, with breaches in the road embankments in the road section at southern part along the river. After this flood the damage was repaired, the road level was elevated to the 2000 flood level and the river banks were protected with a rock protection (Figure 5.4). The northern part, however, still has unprotected slopes. The embankment slopes are steep and therefore vulnerable to macro-instability (sliding). PR317 is not paved and has no slope protection. Also the road elevation is less liable to frequent flooding with consequently damage to both road surface and slopes. To enable the flow to pass the road embankments bridges have been constructed (Figure 5.3) and in NR11 also a spillway (Figure 5.5).

As a consequence roads and road embankments are vulnerable to damage during floods as a result of unprotected slopes and absence of pavement (mainly PR317). Without further strengthening of the roads, more damage can be expected in the future with impacts on traffic. This is certainly the case if higher flood discharges occur due to changes in the use

[3] The case presented is discussed in more detail in the technical guidelines report (Verheij and Van der Ruyt, in prep.).

of the flood plain and the upper river basins and/or climate changes. Moreover, impacts of both roads will include habitat loss due to changes in floodplain patterns as well as obstructed fish migration routes.

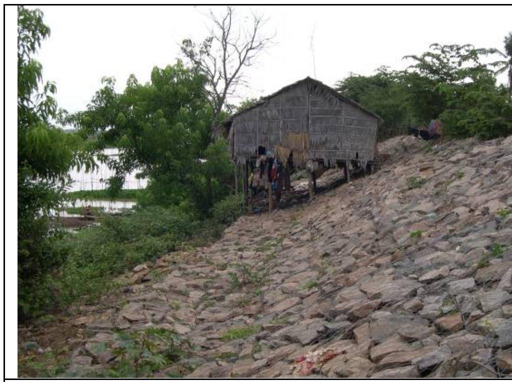

Figure 5.4 NR11 section with slope protection (rock filled gabion mattresses).

Figure 5.5 NR11 at the spillway.

5.2.3 Alternatives considered

In this case study the following alternatives are considered:

1. **Zero option** (the do nothing alternative). This alternative is according to the present condition of the roads (Section 2), and with the expected future flood discharge of 65,000 m^3/s (the 2000 flood had a peak discharge of about 50-55,000 m^3/s).
2. **Upgrade.** In this alternative both roads will be upgraded (mainly protection[4]), including the protection of the northern part of NR11 and the upgrading of PR317.
3. **Upgrade and removal of the spillway.** In this alternative the spillway in NR 11 (see Figure 5.5) is removed in order to allow traffic throughout the year, and the road at this location elevated. Upgrade of NR 11 and PR 317 is included here as well.
4. **Upgrade and wider bridge openings.** This alternative creates 1.5 times larger through-flow capacity at the existing bridges and the upgrade of both NR 11 and PR 317.
5. **Heigthening of levees along the left of the bank Mekong.** In this alternative flooding of the left bank floodplain of the Mekong (Flood Zone 5; Figure 5.2) is not allowed and therefore, left bank levees are heigthened up to 6 meter. In this alternative, roads NR 11 and PR317 are not upgraded. This alternative is also considered in Cross (2005).

In line with the strategies presented in Chapter 4, alternatives 3 and 5 would be part of a resistance strategy and alternatives 2 and 4 of a resilience strategy.

5.2.4 Assessment of hydraulic impacts of the alternatives

Based on inundation modelling and damage assessment the effects of the various alternatives have been quantified (see Technical Design Guidelines report; Verheij and

[4] Henk needs to check to what extent upgrading in sense of heigthening of roads is taken into account in the model calculations.

Van der Ruyt, in prep.). Table 5.2 presents a summary of the hydraulic conditions and distinguishes between conditions near the road (depth and velocity) and at Flood Zone scale (flooded area and duration). The effects of the water level changes at the upstream side of the road of the alternatives compared to the zero option are in the order of centimetres. The exception to this is the heighthened levees alternative, with changes of up to 8 m. Figure 5.6 shows that alternative 5 results in water level differences that at some locations are 1 meter higher than at other locations which occur for up to 20 days. The effect of water level changes for the zero option situation and alternative 3 (no spillway) at Bridge 4 is shown in Figure 5.7. The figure shows that the initial higher water levels of alternative 3 results (10-20 centimetres), disappears after a period of one month. Table 5.2 shows also the changes in flooded area compared to the zero option alternative. A decrease with 5% equals about 100,000 ha. Table 5.2 as well as Figure 5.9 show that the effect of the heightened levees alternative on the sub-floodplain scale are large. Apart from the Flood Zone 5 impacts presented in Table 5.6 (area and duration), another impact might be the fact that flooding begins at a different date compared to the zero option. However, for the alternatives considered these latter impacts are limited as the inundations starts only a few days later. Figure 5.9 shows that alternative 5 does not achieve its objective 'to protect the region from flooding' as after a few days the water eventually reaches the area (although smaller and shorter), through different paths, for example downstream.

Table 5.2 Hydraulic conditions along NR11 and PR317 for the alternatives (alternative 1: absolute values; alternatives 2-5 difference with alternative 1).

Alternative [-]	**Road**		**Flood Zone 5**	
	Water depth [m] [1]	**Flow velocities [m/s]** [2]	**Flooded area [%]** [3]	**Duration of flooding [days]** [3]
	Absolute value			
1. Zero option	2.4 to 8.5 m	1.1 to 7.2 m/s	52 %	34
	Relative value (difference with zero option)			
2. Upgrade	0	0	- 5	0
3. Upgrade and removal spillway	+0,05 to +0,15	0 to +0.8	- 5	+ 3
4. Upgrade and wider bridge openings	+0,05 to +0,1	-5.0 to -3.0	- 5	0
5. Heigthening Mekong levees	-8.5 to -2.4	-7.2 to -1.1	- 13	- 34 to -15

[1] Spatial scale: upstream location of road; Temporal scale: days that maximum water level difference upstream and downstream road occurs, [2] Spatial scale: bridges along road; Temporal scale: see water depth,, [3] Spatial scale: Flood Zone 5; Temporal scale: flood season.

The main difference in the hydraulic change concerns the flow velocities. The largest difference can be observed near the bridges, in particular at bridge B4 in NR1 and bridge B8 in PR317. Both bridges have relatively small through-flow dimensions. In alternative 4 this results in a considerable decrease in the flow velocities (Figure 5.8), which can be explained by the 50% wider bridge openings. The only exceptions are bridges 2 and 9. Bridge 2 is located at the other side of the Mekong (see Figure 5.3) and is not considered relevant. Bridge 9 attracts more water resulting in higher flow velocities for this particular alternative. However, the water levels hardly change which leads to the conclusion that, in general, widening the bridge sizes affects the flow velocities but not the water levels. The decrease in the flow velocities due to alternative 5 has to do with the fact that the flooded area is decreased.

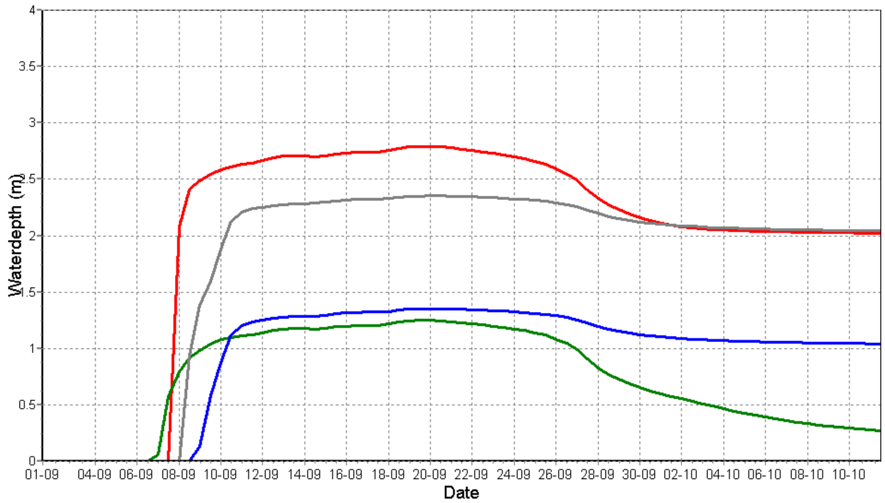

Figure 5.6 Flood levels in case of the heightened levees alternative (from September 1st until October 10th at various locations in the case study area) (vertical axis: water levels; horizontal axis: date).

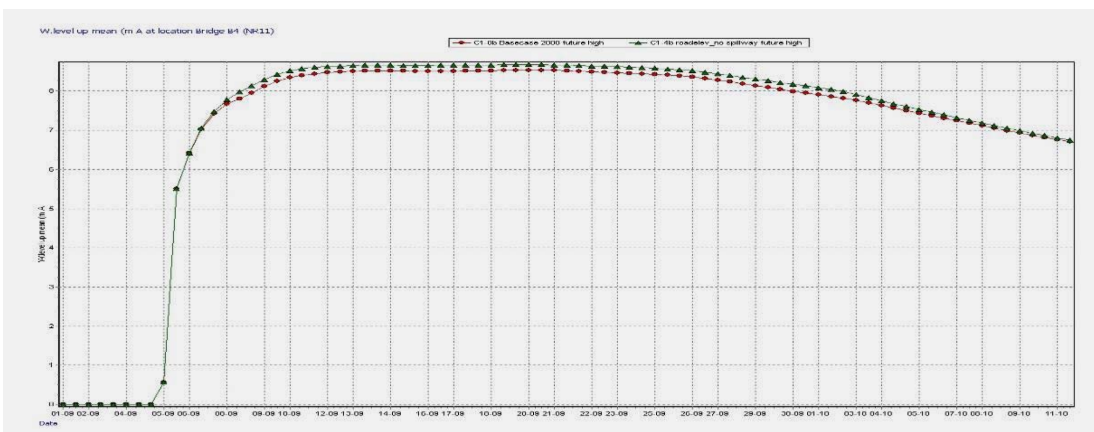

Figure 5.7 Comparison of water levels from September 1st until October 10th at Bridge B4 for two alternatives: in red the zero option and in green alternative 3 (vertical axis: water levels; horizontal axis: date).

5.2.5 Impacts of hydraulic changes on road damage and floodplain ecosystem

What are the implications of flooding in terms of damage to roads and consequences to the floodplain ecosystem? A qualitative assessment of these impacts is presented in Table 5.3, which will be further explained in this Section.

Road damage

Changes in hydraulic conditions may result in erosion and macro-instability of embankment slopes. Most changes are insignificant with respect to increasing damage potential with the exception of the impact on flow velocities. For bare slopes these velocities are highly damaging and will cause erosion. Locally, the flow velocities for the alternatives 1, 2, 3 and 4 exceed by far the estimated critical flow velocity of about 0.7 m/s. This is the threshold velocity for the erosion of cohesive soil. For the heightened levee alternative the flow velocities at the bridge locations drop almost to 0 m/s. Some further effects are: NR11 has been (partly) protected up to 2000 flood level, but not for higher floods; this requires increasing the through-flow capacity. Suppose NR11 was not strengthened (alternative 1), than a flood of a similar magnitude to that recorded in 2000 would result in higher damages. Taking the spillway out of service (alternative 3) will require additional through-flow capacity to avoid damage. Although taking the spillway out might have a small negative impact on fish migration, increasing flow-through would compensate this. PR317 is a dirt road with unprotected embankment slopes and thus very vulnerable for flood damage. A bitumen surface and/or protected embankment slopes will reduce damage but increase costs considerably (Table 5.4).

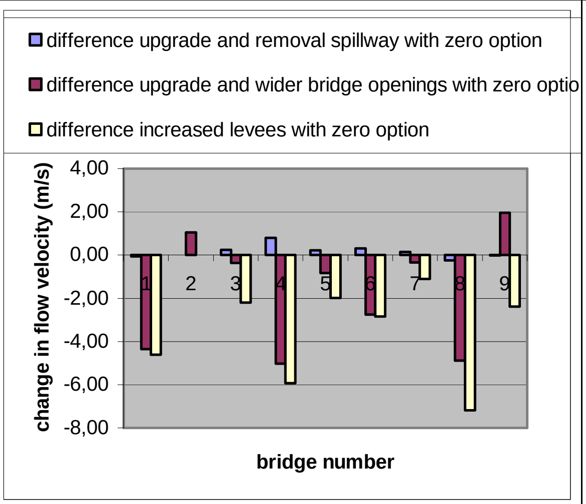

Figure 5.8 Differences in flow velocities at bridges for alternatives 3, 4 and 5 compared to 1 (see Figure 5.3 for the bridge locations).

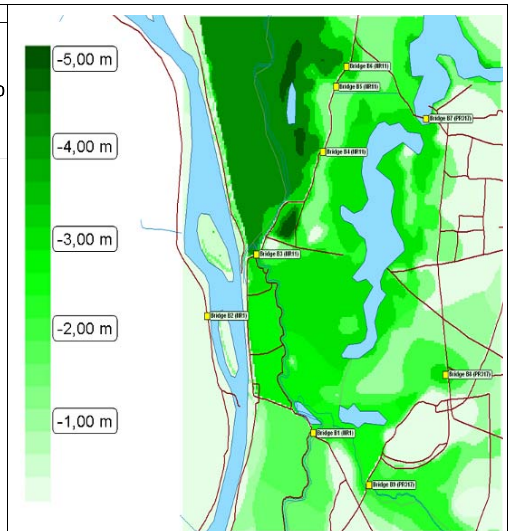

Figure 5.9 Heightened left Mekong levees: maximum water level differences with zero option (time scale: days).

Table 5.3 Impact of the hydraulic conditions of NR11 and PR317 alternatives on road and ecological damage.

Alternative [-]	**Related to water level (macro-instability, waves, overtopping/overflow)**	**Related to flow velocities (toe scour, abutment scour)**	**Related to duration and extent (fish, agriculture)**
1. Zero option	Medium negative	Medium negative	None
2. Upgrade	None	Low negative	Low negative
3. Upgrade and removal spillway	None	Low / medium negative	Low / medium negative
4. Upgrade and wider bridge openings	None	Low negative	Low positive
5. Heigthening Mekong levees	High positive	Low positive	High negative

Impact on the floodplain ecosystem

A significant decrease in flooded area and flood duration as a result of road planning and design is considered to be important as this seriously influences fish migration, agriculture and wetland characteristics. Such a decrease can be observed in alternative 5 (13% or 250,000 ha of the flood zone will not inundate anymore), but also for the other alternatives (5% or 100,000 ha reduction of flooded area). This has serious implication to the fisheries sector as every hectare of floodplain lost due to road development could lead to a loss of 100 kg of fish each year (Halls et al. 2006). Ecological impacts and particularly those related to blocking fish migration routes are expected to be considerable. The main impact of alternatives 2, 3 and 5 will be on fish migration. However, alternative 4 will have a positive effect on migration, although the exact location and dimensions of bridges would need further study.

5.2.6 Costs of the alternatives

The results for the financial analysis for the NR11 and PR317 are presented in Table 5.4. See Annex 3 (Section 1.5.2) of the Annex document of the Synthesis Report for an explanation of how the financial analysis is carried out. For reasons of comparison all costs for each of the alternatives are included, including the past costs of construction (column 'Total investment cost'). The results in the table show that the "zero option" is the cheapest alternative at an OCC of 12%, even though annual operating costs and flood damage are higher than in the other alternatives. The NPV of investment costs, annual operating and maintenance costs, and flood damage amounts to about 7 million USD. At an OCC between 3.1% to 3.8% the three upgrade alternatives are equally costly. Increased levees would be the most expensive alternative at any positive discount rate.

Table 5.4 Results financial analysis NR11 and PR317 alternatives.

Alternative	Current investment cost	Total investment cost	Total annual operating costs	Flood damage per 5 year	NPV of total costs at 12%	IRR <> zero option
1. zero option	0	5,350,000	270,000	270,000	7,101,911	-
2. upgrade	4,400,000	9,750,000	130,000	95,000	9,807,085	3.8%
3. upg. + removal spillway	4,800,000	10,150,000	145,000	100,000	10,281,689	3.1%
4. upg. & wider bridge openings	4,460,000	9,810,000	135,000	60,000	9,839,009	3.8%
5. increased leeves left bank Mekong	0	20,350,000	270,000	0	24,955,333	-2.2%

Note: all figures are in USD

5.2.7 Integrated impact assessment of the alternatives

In order to analyse the total impact of the identified alternatives of the rehabilitation of NR 11 and PR 317 it is important to consider all relevant issues at the early stages of planning and design (Chapter 4). Relevant issues transport, finance, hydraulics, ecology and social welfare. These issues are reflected in the objectives and related impact indicators presented in Table 5.5 and include short-term and long-term impacts and local and sub-floodplain impacts. Table 5.5 presents a first qualitative assessment of the different alternatives of NR11 and PR317 based on the hydraulic, damage and economic analyses presented in the previous Sections and a qualitative judgement of the other indicators.

The following comments and observations can be made based on Table 5.5:

- All, but alternatives 1 and 2, have a positive effect on traffic, because roads become more accessible throughout the year.
- Given the recent upgrade in standard of protection of the roads (to the 2000 year peak), floods less than this are less likely to cause damages as can be seen in better scores for the alternatives 2 to 4 compared to 1 for the objectives O&M costs and flooding vulnerablity. However, one should keep in mind that flows above this level are more likely to cause considerable damage.

Table 5.5 Integrated impact table (+++ best alternative, --- worst alternative).

Objectives	**Impact indicators**	**1. Zero option**	**2. Up-grade**	**3. Up-grade and no spill-way**	**4. Upgrade and wider bridges**	**5. Heigthen Mekong levees**
Enhance regional transportation	Travel time (road)	---	-	+	+	+++
Minimise road investment	Initial current investment costs (road)	++	--	--	--	++
Minimise road operation and maintenance costs	Operation and maintenance (damage rehabilitation) costs (road)	---	++	+	++	-
Reduce flooding vulnerability (vicinity of the road)	Damage of flooding to structures in the vicinity of the road	--	+	+	++	+++
	Damage of flooding to NR11 and PR317	--	-	+	++	+++
Reduce flooding vulnerability	Damage of flooding to other roads than NR11 and PR317 (sub-floodplain)	-	-	+	--	+++
Minimise social impacts	Resettlement (road)	+	-	-	-	-
	Water quality (sub-floodplain)	+	+	+	++	-
Maintain floodplain hydraulics and ecology	Flood pattern and dynamics (sub-floodplain)	+	+	-	++	--
	Habitat fragmentation (sub-floodplain)	+	-	-	++	---

- The zero option alternative results in flow velocities above 0.7 m/s. Strengthening and erosion protection or annual repair is needed. Alternatives 2 and 3 lead to a very limited change of the flow velocities (see Table 5.2) because the upgrading does hardly or not effect the flows near the existing bridges. There is still a need for protection of the bridge abutments.
- Alternative 5, aimed to increase the height of the levees, reduces flow velocities to a minimum, reducing rehabilitation costs and thus the need for damage protection.
- Both the alternatives 3 (upgrade and removal spillway) and 4 (upgrade and wider openings) are expected to have limited impacts on fisheries, agriculture or wetlands ecology. Obviously, the alternative 5 will affect these uses of the floodplain as it will result in less flooding. Fish migration routes will be blocked, agricultural area will lack yearly nutrient supply by the flooding, and the floodplain will be fragmented resulting in negative effects on the wetlands.

- The alternatives show that higher initial investments (alternatives 2, 3 and 4) are likely to lead to lower operation and maintenance costs as well as lower damage. Alternative 4 is expected to achieve the highest damage reduction.

5.2.8 Ranking of the alternatives

In this Section, we illustrate that a different perspective on road development (e.g. transport, flood protection, ecology) will lead to a different ranking of alternatives as each perspective prioritizes objectives differently. An example of this different weighting of objectives (listed in Table 5.5) for each perspective is illustrated by Table 5.6 The weights in Table 5.6 are exaggerated to make differences between the perspectives more explicit; in reality objectives and their relative importance are set by decision-makers during the planning process. Apart from the transport, ecology and flood protection perspectives a fourth perspective is added called 'sustainable development' that aims to minimise long-term 'costs' in terms of investment, road maintenance and flood damage repair costs, social costs and ecological costs.

Table 5.6 Example of weights by objective for various perspectives on road development and rehabilitation (5 highest importance; 1 lowest importance).

Objectives of road development and rehabilitation	Example perspectives (total = 20)			
	Transport	**Flood protection**	**Ecology**	**Sustainability**
Enhance regional transportation	**5**	**4**	2	1
Minimise road investment	**5**	2	2	**3**
Minimise road operation and maintenance costs	**4**	2	2	**3**
Reduce flooding vulnerability (vicinity of the road)	2	**5**	2	**3**
Reduce flooding vulnerability (sub-floodplain)	2	**5**	2	**3**
Minimise social impacts	1	1	**5**	**3**
Maintain floodplain hydraulics and ecology (sub-floodplain)	1	1	**5**	**4**
Total	20	20	20	20

Based on the perspectives as presented in the table above, a ranking of alternatives is calculated using the impact table (Table 5.5). This exercise shows that the 'do nothing' option, ranks second for the ecology perspective, but low for the other perspectives (Table 5.7). The heightened levees alternative ranks highest for the transport and flood protection perspectives, but obviously not for the ecological perspective. Alternative 4 (widening bridges) ranks overall highest in all four perspectives. In the sustainability perspective the heightened levee alternative ranks third, which is mainly because long-term cost reductions in road maintenance and rehabilitation occur, but ecological impacts can be serious.

Table 5.7 Ranking alternatives based on impact table (Table 5.5) and perspectives (Table 5.6) (1 highest ranking; 5 lowest ranking).

Alternative	Perspectives			
	Transport	**Flood protection**	**Ecology**	**Sustainability**
1. Zero option	5	5	2	5
2. Upgrade	3	4	3	2
3. Upgrade and no spillway	4	3	4	4
4. Upgrade and wider bridges	2	2	1	1
5. Heigthening Mekong levees	1	1	5	3

5.3 Case 2: Construction of new National Road 8 (Cambodia)

5.3.1 Introduction[5]

National Road (NR) 8 is a new road, which is under construction but not yet finished and crosses Flood Zone 5 (Figures 5.10 and 5.11). See Annex 2 for a more detailed description of Flood Zone 5. The road runs in east-west direction from the east bank of the Mekong River, where it connects with NR6 via a bridge over the Mekong, and then goes in eastern direction intersecting with NR11 to Ho Chi Minh City.

5.3.2 Analysis of the present and future situation

NR8 is under construction and its design in terms of flood vulnerability comprises slope protection and various through-flow structures such as bridges and culverts. The alignment is perpendicular to the flow direction of the flood. The location of bridges and culverts is related to existing canals and the main flow pattern during floods. NR8 can have a large effect on hydraulic conditions downstream, for instance by changed flood patterns. These changes may effect agriculture and fish habitat due to changes in floodplain patterns as well as obstructed fish migration routes.

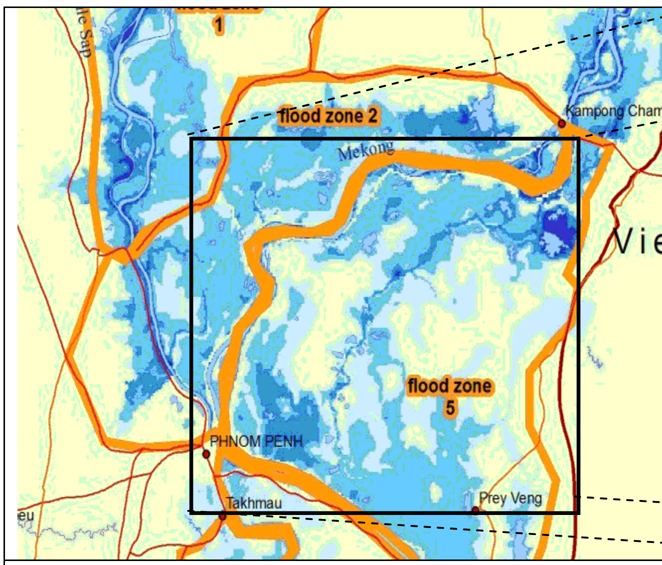

Figure 5.10 The location of the case in the Cambodian floodplain.

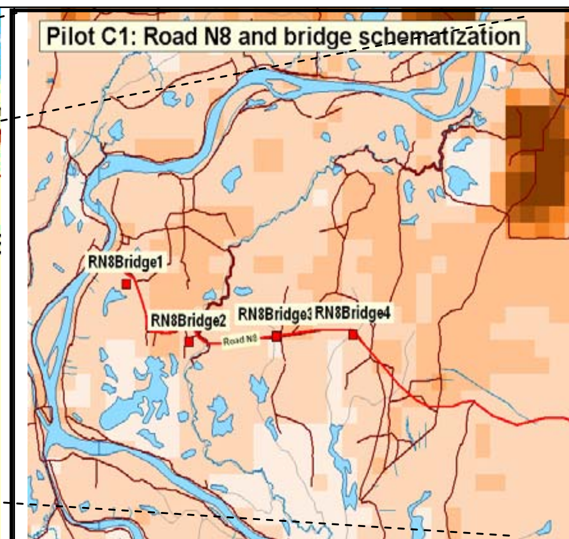

Figure 5.11 Planned location of road NR 8 and the main bridges.

5.3.3 Alternatives considered

For a new constructed road two main alternatives are eminent. The zero option is the reference situation without NR8. The planned situation (alternative 3) incorporates a number of bridges and culverts. In the model the number of bridges is reduced to 4, but the total flow-through capacity of these 4 modelled bridges is equal to the total flow-through capacity of the actual number of bridges designed. To compare the planned alternative with a more resistance alternative the NR8 is also modeled without bridges (alternative 2). To

[5] The case presented is discussed in more detail in the technical guidelines report (Verheij and Van der Ruyt, in prep.).

better understand the impact of resilience in road development, alternative 4 is considered which is equal to alternative 3, but with 1.5 times wider bridge openings. In summary, this case study considered the following alternatives:

1. **Zero option** (the do nothing alternative). This alternative is representing a situation without the NR8 with an expected future discharge of 65,000 m^3/s (the 2000 flood had a peak discharge of about 50-55,000 m^3/s).
2. **No bridges.** This is an extreme alternative, in which NR8 is designed without any bridges and culverts. The purpose is to assess hydraulic impacts.
3. **Planned bridges.** In this alternative the planned bridges and culverts are taken into account; the total through-flow capacity of the actual number of bridges and culverts in the planned situation is equal and concentrated at four locations (see Figure 5.11).
4. **Wider bridges.** This alternative is the same as alternative 3, but all bridge openings are 1.5 times wider to assess the effect on floodplain dynamics.

In line with the strategies presented in Chapter 4, alternative 2 would be part of a resistance strategy and alternatives 3 and 4 of a resilience strategy.

5.3.4 Assessment of hydraulic impacts of the alternatives

Based on inundation modelling and damage assessment the effects of the various alternatives have been quantified (see Technical Guidelines Report; Verheij and Van der Ruyt, in prep.). Table 5.8 presents a summary of the hydraulic conditions and distinguishes between conditions near the road (depth and velocity) and at Flood Zone scale (flooded area and duration).

The various alternatives do change the hydraulic conditions in the direct vicinity of NR8. The effects of the water level changes are in the order of decimetres for alternatives 3 and 4, but up to 8 to 11 m for alternative 2 shortly after the flood starts. When upstream NR8 the area has been flooded already, downstream NR8 the area is still dry. The changes in flow velocities near the bridges compared to the zero option change from a decrease of 0.3 m/s for the no bridges alternative, implying that the flow velocities decrease to almost zero, and an increase of 0.2 m/s for alternatives 3 and 4.

The impact on the flood extent and flood duration in case of the no bridges alternative is large as the flooded area decreases with 50%. The situation of alternatives 3 and 4 does not change compared to the zero option. Figure 5.12 shows the effects of the no bridges alternative 2 regarding the changes in maximum water depth; downstream a reduction of flood water can be seen, while upstream water is blocked and water depth increases.

Table 5.8 Hydraulic conditions along NR8 for the alternatives (alternative 1: absolute values; alternatives 2-4 difference with alternative 1).

Alternative [-]	**Road**		**Flood Zone 5**	
	Water depth [m] [1]	**Flow velocities [m/s]** [2]	**Flooded area [%]** [3]	**Duration of flooding [days]** [3]
	Absolute value			
1. Zero option	8.5 to 11 m	0 to 0.3 m/s	100 %	34
	Relative value (difference with zero option)			
2. No bridges	-8.4	-0.3	-50	+3
3. Planned bridges	+0.10	+0.2	0	0
4. Wider bridges	+0.05	+0.1 to +0.2	0	-1

[1] Spatial scale: upstream location of road; Temporal scale: days that maximum water level difference upstream and downstream road occurs, [2] Spatial scale: bridges along road; Temporal scale: see water depth, [3] Spatial scale: Flood Zone 5; Temporal scale: flood season.

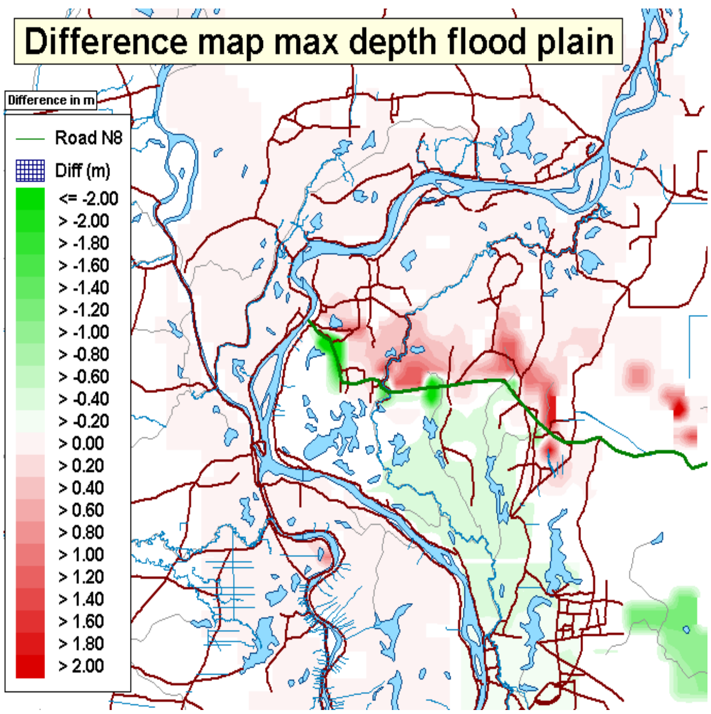

Figure 5.12 Water depth differences between zero option and no bridges alternative.

5.3.5 Impacts of hydraulic changes on road damage and the floodplain ecosystem

What are the implications of flooding in terms of damage to roads and consequences to the floodplain ecosystem? A qualitative assessment of these impacts is presented in Table 5.9, which will be further explained in this Section.

Road damage

Changes in hydraulic conditions may result in erosion of slope and road material and macro-instability of embankments. Most changes are insignificant with respect to increasing damage potential as the water levels and velocities along NR8 do not change significantly for the various alternatives. For the resistance alternative without bridges the flow velocities drop to almost zero and the damage potential becomes low. This alternative could, however, pose a risk of slidings shortly after the start of the flood, due to the large water level difference over the road embankment. The construction of road NR8, that is to say alternatives 3 and 4, neither results in significant changes in the hydraulics of the sub-flood plain in terms of changing damage potential on the surrounding roads such as N11 and PR 317, because the flow patterns are maintained.

Table 5.9 Impact of the hydraulic conditions of the NR8 alternatives considered on road and sub-floodplain damage.

Alternative [-]	**Related to water level (macro-instability, waves, overtopping/overflow)**	**Related to flow velocities (toe scour, abutment scour)**	**Related to duration and extent (fish, agriculture)**
1. Zero option	None	None	None
2. No bridges	Medium negative	None / medium negative	High negative
3. Planned bridges	None	Medium	Low negative
4. Wider bridges	None	None	Low negative

Impact on the floodplain ecosystem

With respect to the impact on the floodplain ecosystem and related fisheries and agriculture, alternatives 3 and 4 imposed no significant impact. The extent and duration of the flood was not significantly altered. An impact, although not quantified in this study, will be the blocking of migration routes even though various bridges are planned. The no bridges alternative did have a great negative impact on fish migration routes. Shortly after the flooding started the water depth can be very high for the no bridges alternative. In the first 4 to 5 days the water is building up in the northern part of the NR8 while due to the lack of openings the southern part of the road is still dry or relatively dry. This can have implication to the fisheries sector as every hectare of floodplain lost due to road development could lead to a loss of 100 kg of fish each year (Halls et al. 2006). This is shown in Figure 5.11. Blocking the flood pattern consequently means a serious impact on the fish migration paths. It is unclear whether the fish population will be able to adapt, if not the impact on the fish industry might be significant as well. This alternative also influences agriculture due to the considerable decrease in flood extent.

5.3.6 Costs of the alternatives

Table 5.10 shows the results of the financial analysis for NR8. As the zero option is defined as “doing nothing” no investment costs, operating costs or flood damage are associated with this option. Hence the options “planned bridges” and “extra bridges” are compared to the “no bridges” option. At an OCC of 12% the no bridges option is the cheapest from a financial perspective. An OCC below respectively 4.9% and 5.9% would make “planned bridges” or “extra bridges” the preferred option.

In case a low standard would be used for alternative 3 the NPV of the costs would be about US$ 14 million. Hence, purely from a financial perspective a cheaper design would pay off. However, the financial perspective does not include other disbenefits of a poorer design, such as obstruction to traffic (potholes), which should be included in a full evaluation.

Table 5.10 Results financial analysis NR8, high standard.

Alternative	Total investment cost	Total annual operating costs	Flood damage per 5 year	NPV of total costs at 12%	IRR <> no bridges option
1. zero option	0	0	0	0	-
2. no bridges	16,000,000	320,000	320,000	17,041,419	-
3. planned bridges	16,350,000	330,000	170,000	17,252,644	4.9%
4. extra bridges	16,525,000	330,000	90,000	17,315,199	5.9%

Note: all figures are in USD

Table 5.11 Comparison of costs according to a high standard and a low standard for alternative 3 with planned bridges.

Costs	High standard	Low standard
Investment costs [USD]	16,350,000	12,250,000
Operation and maintenance costs [USD/year]	330,000	370,000
Flood damage costs [USD per 5 years]	170,000	250,000

5.3.7 Integrated impact assessment of the alternatives

In order to analyse the total impact of the identified alternatives of the new road NR 8 it is important to consider all relevant issues at the early stages of planning and design (Chapter 4). Relevant issues include transport, finance, hydraulics, ecology and social welfare. These issues are reflected in the objectives and related impact indicators presented in Table 5.12 and include short-term and long-term impacts and local and sub-floodplain impacts. Table 5.12 presents a first qualitative assessment of the different alternatives of NR8 based on the hydraulic, damage and economic analyses presented in the previous Sections and a qualitative judgement of the other indicators.

The following comments and observations can be made based on Table 5.12.

- All alternatives, except the zero alternative, have a positive effect on traffic, because of the extension of the road network with the new NR8.
- Higher floods in the future, up to 65,000 m^3/s, do have a influence on the damage to roads independent of the amount of through-flow structures. Flow velocities will increase the damage from medium expected damage to high expected damage if the road embankments have no slope protection; with a protection the damage is low.
- The construction of NR8 in the no bridges alternative obstructs the fish migration paths because no through-flow capacity will be realized. This alternative will also seriously affect agriculture, floodplain hydraulics and ecology due to the decreased flooded area.
- The alternatives show that slightly increased initial investments (alternatives 2, 3 and 4) do not result in different operation and maintenance costs, but do lead to reduced flood damage costs. Alternative 4 is expected to achieve the highest damage reduction. A lower standard means a higher probability of flood damage costs.

Table 5.12 Integrated impact table according to high standard design (+++ best alternative, --- worst alternative).

Objectives	Impact indicators	1. zero option	2. No bridges	3. Planned bridges	4. Extra bridges
Enhance regional transportation	Travel time (road)	--	++	++	++
Minimise road investment	Initial current investment costs (road)	+++	--	--	--
Minimise road operation and maintenance	Operation and maintenance (damage rehabilitation) costs (road)	+++	--	--	-
Reduce flooding vulnerability (vicinity of the road)	Damage of flooding to housing, infrastructure, agriculture, casulaties	++	---	--	-
	Damage of flooding to NR8	++	---	--	-
Reduce flooding vulnerability	Damage of flooding to other roads than NR8 (sub-floodplain)	++	-	+	+
Minimise social impacts	Resettlement (road)	-	--	+	--
	Water quality (sub-floodplain)	-	--	+	++
Maintain floodplain hydraulics and ecology	Flood pattern and dynamics (sub-floodplain)	+++	---	+	++
	Habitat fragmentation (sub-floodplain)	+++	---	+	++

5.3.8 Ranking of the alternatives

In this Section, we illustrate that a different perspective on road development (e.g. transport, flood protection, ecology) will lead to a different ranking of alternatives as each perspective prioritizes objectives differently. An example of this different weighting of objectives (listed in Table 5.12) for each perspective is illustrated by Table 5.13. The weights in Table 5.13 are exaggerated to make differences between the perspectives more explicit; in reality objectives and their relative importance are set by decision-makers during the planning process. Apart from the transport, ecology and flood protection perspectives a fourth perspective is added called ‘sustainable development’ that aims to minimise long-term ‘costs’ in terms of investment, road maintenance and flood damage repair costs, social costs and ecological costs.

Table 5.13 Example of weights by objective for various perspectives on road development and rehabilitation (5 highest importance; 1 lowest importance).

Objectives of road development and rehabilitation	**Example perspectives (total = 20)**			
	Transport	**Flood protection**	**Ecology**	**Sustainability**
Enhance regional transportation	**5**	**4**	2	1
Minimise road investment	**5**	2	2	**3**
Minimise road operation and maintenance	**4**	2	2	**3**
Reduce flooding vulnerability (vicinity of the road)	2	**5**	2	**3**
Reduce flooding vulnerability (sub-floodplain)	2	**5**	2	**3**
Minimise social impacts	1	1	**5**	**3**
Maintain floodplain hydraulics and ecology (sub-floodplain)	1	1	**5**	**4**
Total	20	20	20	20

Based on the perspectives as presented in the table above, a ranking of alternatives is calculated using the impact table (Table 5.12). This exercise shows that the do nothing option, according to all perspectives, ranks highest from all perspectives (Table 5.14). The main reason for this ranking is the high costs for constructing a road. The zero option has also a high ranking because it does not influence the floodplain hydraulics and the ecology and has no negative effects with respect to resettlement. Obviously, the do nothing alternative is not an option because roads are essential in developing the region and negative effects have to be accepted as long as they are within certain limits. The second best alternative for most perspectives is the extra bridges alternative; for the transport perspective this alternative ranks third. The no bridges alternative ranks lowest for all perspectives.

Table 5.14 Ranking alternatives based on impact table (Table 5.12) and perspectives (Table 5.13) (1 highest ranking; 5 lowest ranking).

Alternative	**Perspectives**			
	Transport	**Flood protection**	**Ecology**	**Sustainability**
1. Zero option	1	1	1	1
2. No bridges	4	4	4	4
3. Planned bridges	2	3	3	3
4. Extra bridges	3	2	2	2

5.4 Case 3: Rehabilitation of PR-855 (Viet Nam)

5.4.1 Introduction[6]

Provincial Road (PR) 855 runs from NR30 along the Mekong to the north to the junction with PR843 and PR844 (see Figures 5.13 and 5.14). The road is perpendicular to the main flood pattern and, subsequently, many bridges are incorporated in the road design to allow the water flow to pass. Provincial Road 855 can be considered a typical Viet Namese Provincial Road in a rural area. The road is located in Flood Zone C (Annex 2).

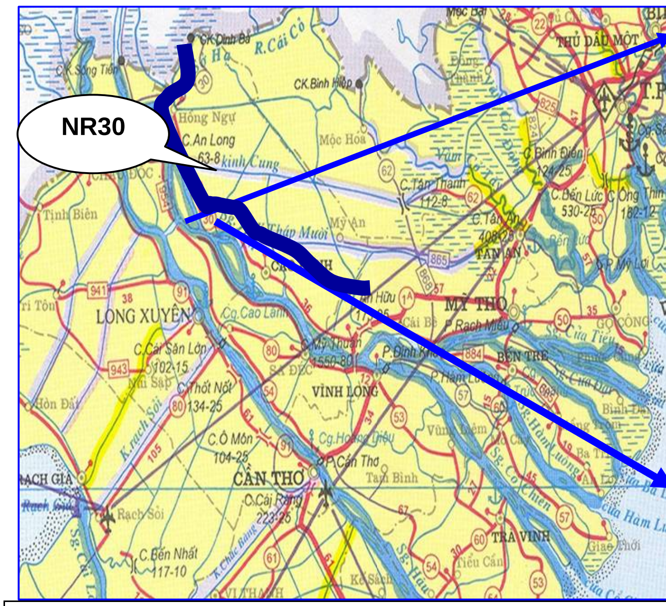

Figure 5.13 Location NR855 in Flood Zone C in Viet Nam.

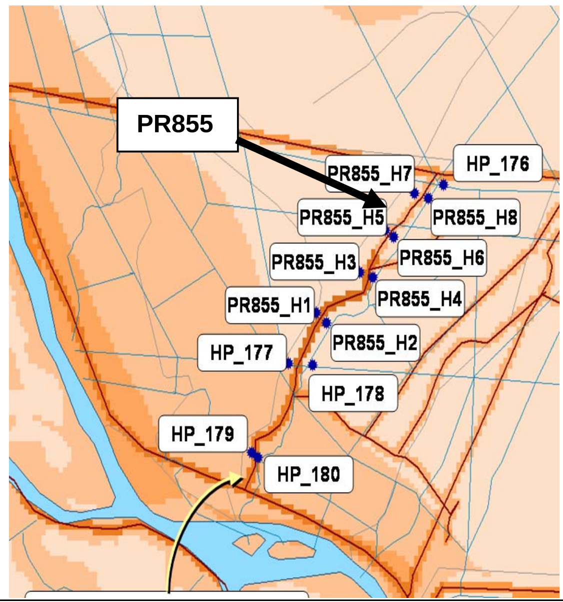

Figure 5.14 Main existing flow-through locations in the study area.

5.4.2 Analysis of the present and future situation

PR855 was seriously damaged during the 2000 flood. In the following years the damage has been repaired, the road level elevated to the 2000 flood and the river slopes protected with a stone protection. The northern part, however, still has unprotected slopes which are vulnerable for wind waves, overflowing water and for rain induced gullies. Figure 5.15 shows a damaged road slope as a result of the 2007 flood. The embankment slopes are steep and therefore vulnerable to macro-instability; see Figure 5.21. To enable the flow to pass the road embankments, bridges have been constructed (Figures 5.14 and 5.16).

Many provincial and local roads still have unpaved surfaces which are not favourable for modern traffic, and in addition create dust clouds that are unhealthy to the people living along the road. Without further strengthening of the roads, damage due to floods can be expected with impacts on traffic. In particular, if floods are higher than taken into account up to now e.g. due to climate changes and changes in the flood plain and the upper river basins. Moreover, impacts might include habitat loss due to changes in floodplain patterns as well as obstructed fish migration routes.

[6] The case presented is discussed in more detail in the Technical guidelines report (Verheij and Van der Ruyt, in prep.).

	
Figure 5.15 Road slope damaged due to flood wave.	*Figure 5.16 Bridge as through-flow structure.*

5.4.3 Alternatives considered

Obviously, the do nothing alternative has to be considered. In addition, the effect of partly blocking the bridges or the opposite, extra through-flow capacity, is considered but in particular at the northern part of PR855 (alternatives 2 and 3). Then, the impact of upgrading the road along the Mekong is considered. In summary, this case study considered the following alternatives:

1. **Zero option** (the do nothing alternative). This alternative is according to the present condition of the roads (as described in Section 2), and with the expected future flood discharge of 65,000 m^3/s (the 2000 flood had a peak discharge of about 50-55,000 m^3/s).
2. **No bridges.** In this alternative all bridges in the northern part of PR855 are removed (see Figure 5.17). This alternative is identified to analyse the effect of such, exteme, measure on the floodplain hydraulics.
3. **Extra through-flow.** In this alternative the through-flow capacity of the bridges in the northern part of PR855 is twice the present capacity by widening the openings (Figure 5.18). This alternative is also identified to analyse its effect on the floodplain hydraulics.
4. **Heighthened NR30 along Mekong**. In this alternative the crest level of NR30 has been upgraded without bridges thus relieve of water from the floodplain to the Mekong is blocked.

In line with the strategies presented in Chapter 4, alternatives 2 and 4 would be part of a resistance strategy and alternative 3 of a resilience strategy.

5.4.4 Assessment of hydraulic impacts of the alternatives

Based on inundation modelling and damage assessment the effects of the various alternatives have been quantified (Verheij and Van der Ruyt, in prep.). Table 5.15 presents a summary of the hydraulic conditions and distinguishes between conditions near the road (depth and velocity) and at Flood Zone scale (flooded area and duration).

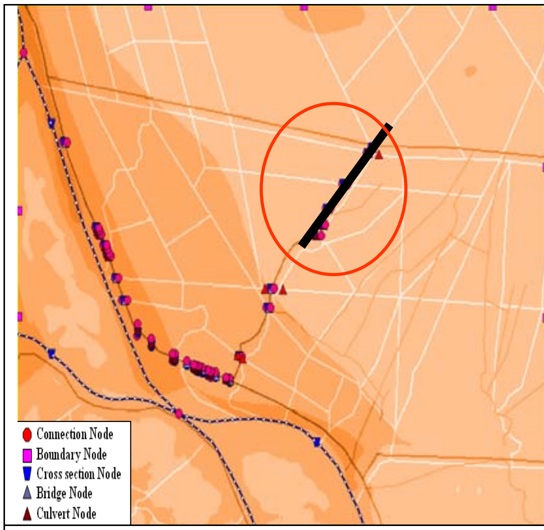

Figure 5.17 Alternative 2: blocked bridges.

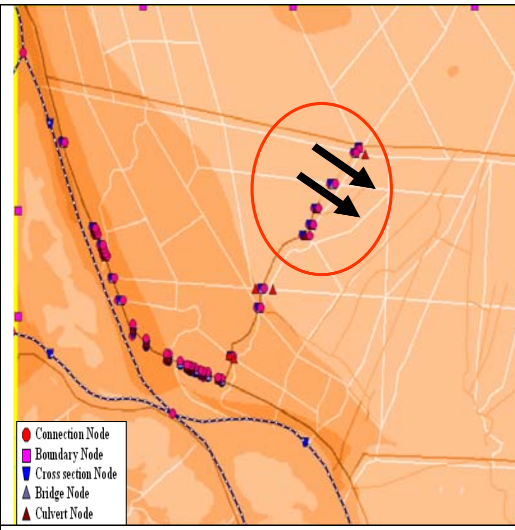

Figure 5.18 Alternative 3: extra through-flow capacity.

The effects of the water level changes are in the order of centimetres. The main differences in the hydraulic changes concern the flow velocities near the bridges. Depending on the alternative the flow velocities in the southern part increase (alternative 2) or decrease (alternative 3). At the bridge sites in the northern part the velocities decrease to zero for alternative 2 and with 0.5 m/s for alternative 3 due to the 50% wider bridge openings.

Table 5.15 Hydraulic conditions along PR855 for the alternatives (alternative 1: absolute values; alternatives 2-4 difference with alternative 1).

Alternative [-]	**Road**		**Flood Zone C**	
	Water depth [m] [1]	**Flow velocities [m/s]** [2]	**Flooded area [%]** [3]	**Duration of flooding [days]** [3]
	Absolute value			
1. Zero option	3.5 to 4 m	0 to 4.5 m/s	89 %	34
	Relative value (difference with zero option)			
2. No bridges in PR855	+0,05 to 0,15	0 to +1.5	0	+3
3. Extra though-flow PR855	+0,05 to +0,1	-0.5	0	0
4. Heighthened NR30 with no bridges	0	0 to +1.5	0	+5

[1] Spatial scale: upstream location of road; Temporal scale: days that maximum water level difference upstream and downstream road occurs, [2] Spatial scale: bridges along road; Temporal scale: see water depth,,[3] Spatial scale: Flood Zone C; Temporal scale: flood season.

Figures 5.19 and 5.20 show the effect on the flow patterns for blocking the bridges (alternative 2) or widening the opening dimensions of the bridges (alternative 3). Blocking means that the flow is forced in southern direction to bridges in PR855, but also to NR30. This results in higher flow velocities in that area, in other words: changing the situation locally may result in problems elsewhere.

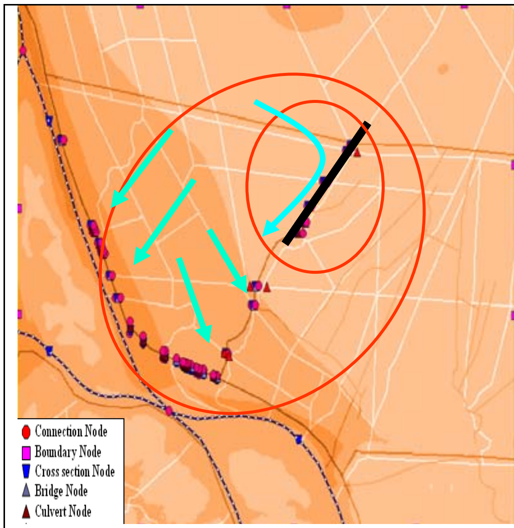

Figure 5.19 Alternative 2: increased flow in the northern part.

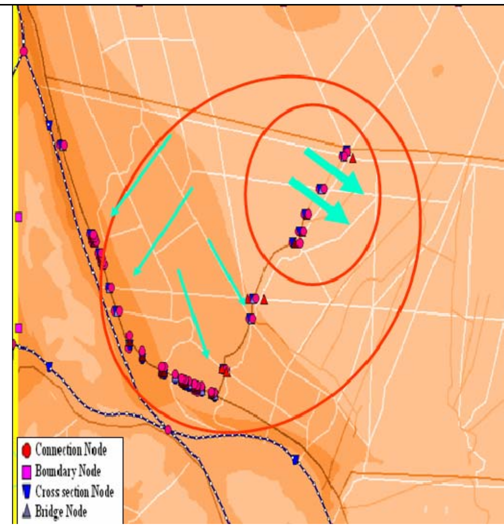

Figure 5.20 Alternative 3: decreased flow in the southern part.

Impacts of alternatives 2 to 4 on flooded area and flood duration are limited. The longer duration is mainly due to the partly blocking of the runoff of the water after the flood wave.

5.4.5 Impacts of hydraulic changes on road damage and the floodplain ecosystem

What are the implications of flooding in terms of damage to roads and consequences to the floodplain ecosystem? A qualitative assessment of these impacts is presented in Table 5.16, which will be further explained in this Section.

Table 5.16 Impact of the hydraulic conditions of the NR1A and HCMR alternatives considered on road and sub-floodplain damage.

Alternative [-]	**Related to water level (macro-instability, waves, overtopping/overflow)**	**Related to flow velocities (toe scour, abutment scour)**	**Related to duration and extent (fish, agriculture)**
1. Zero option	None to medium	Medium	None
2. No bridges in PR855	None to high negative	Medium to high negative	Medium negative
3. Extra though-flow PR855	None to Medium negative	Medium negative	None to positive
4. Heighthened NR30 with no bridges	None	None to low	Medium negative

Road damage

Changes in hydraulic conditions may result in erosion of slope and road material and macro-instability of embankments. Most hydraulic changes described above are insignificant with respect to increasing damage potential except the flow velocities. Locally, the flow velocities for all the alternatives exceed by far the critical flow velocity of 0.7 m/s with respect to erosion of soil material. For bare slopes these velocities are highly damaging and will cause erosion. As we saw in Section 5.4.2, parts of PR855 have already been protected up to 2000 flood level, but not for higher floods. Part of PR855 is a dirt road with unprotected slopes and thus very vulnerable for flood damage. A bitumen surface and/or protected slopes would reduce damage cost considerably. The examples of damage are shown in Figures 5.21 and 5.22.

Figure 5.21 Sliding of PR855 after the 2007 flood.

Figure 5.22 Damaged bridge abutment PR855.

Impact on the floodplain ecosystem
With respect to the impact on fisheries and agriculture alternative 1 (zero option). Alternatives 2 and 4 show medium negative impacts in the sense that the duration of the flooding days increases. The extra flow-through alternative shows no impact on flooded area as well flood duration given the calculations made.

5.4.6 Costs of the alternatives

The results of the financial analysis are also provided in Table 5.17. For reasons of comparison, the total investment costs are calculated assuming no construction has taken place yet. The "no bridges" option is the cheapest option, closely followed by the "zero option" (the current design) and the "extra bridges" option. At an OCC of 6.3% the costs of the zero option would be equal to the "no bridges" option. At an OCC of 2.5% the costs of the zero option would be equal to the "extra bridges" option. Evaluation of the upgrade of the other road is difficult as the benefits to that road are not known.

Table 5.17 Results financial analysis PR855.

Alternative	Current investment cost	Total investment cost	Total annual operating costs	Flood damage per 5 year	NPV of total costs at 12%	IRR <> zero option
1. zero option	0	4,225,000	211,250	256,250	5,644,220	-
2. no bridges	0	4,000,000	200,000	400,000	5,527,982	6.3%
3. extra bridges	4,450,000	4,450,000	222,500	165,000	5,821,947	2.5%
4. upgrade other road	0	44,225,000	211,250	312,500	41,424,386	N/A

Note: all figures are in USD

5.4.7 Integrated impact assessment of the alternatives

In order to analyse the total impact of the identified alternatives of the rehabilitation of PR855 it is important to consider all relevant issues at the early stages of planning and design (Chapter 4). Relevant issues include transport, finance, hydraulics, ecology and social welfare. These issues are reflected in the objectives and related impact indicators presented in Table 5.18 and include short-term and long-term impacts and local and sub-floodplain impacts. Table 5.18 presents a first qualitative assessment of the different alternatives of PR855 based on the hydraulic, damage and economic analyses presented in the previous Sections and a qualitative judgement of the other indicators.

Table 5.18 Integrated impact table (+++ best alternative, --- worst alternative).

Objectives	**Impact indicators**	**1. Zero option**	**2. No bridges PR855**	**3. Extra through-flow PR855**	**4. Heighthen ed NR30**
Enhance regional transportation	Travel time (road)	+	+	+	++
Minimise road investment	Initial current investment costs (road)	++	++	--	++
Minimise road operation and maintenance	Operation and maintenance (damage rehabilitation) costs (road)	-	-	+	-
Reduce flooding vulnerability (vicinity of the road)	Damage of flooding to structures in vicinity of road	+	-	+	--
	Damage of flooding to PR855	-	---	+	--
Reduce flooding vulnerability	Damage of flooding to other roads than PR855 (sub-floodplain)	-	--	+	+
Minimise social impacts	Resettlement (road)	-	--	+	--
	Water quality (sub-floodplain)	-	--	+	++
Maintain floodplain hydraulics and ecology	Flood pattern and dynamics (sub-floodplain)	++	---	+	++
	Habitat fragmentation (sub-floodplain)	++	---	+	++

The following comments and observations can be made based on Table 5.18.

- All alternatives have a positive effect on traffic, because of the improved road condition of PR855 and the heighthened of NR30.
- Alternative 3 have highest initial investment (heighthened NR30 is not considered in the impact table), while operation and maintenance costs do not differ much. In alternative 2 the highest damage to the road is foreseen, while in alternative 3 the lowest.
- The construction of PR855 in the no bridges alternative obstructs the fish migration paths because no through-flow capacity will be realized. This alternative will also seriously affect agriculture, floodplain hydraulics and ecology due to the decreased flooded area.

5.4.8 Ranking of the alternatives

In this Section, we illustrate that a different perspective on road development (e.g. transport, flood protection, ecology) will lead to a different ranking of alternatives as each perspective prioritizes objectives differently. An example of this different weighting of objectives (listed in Table 5.18) for each perspective is illustrated by Table 5.19. The weights in Table 5.19 are exaggerated to make differences between the perspectives more explicit; in reality objectives and their relative importance are set by decision-makers during the planning process. Apart from the transport, ecology and flood protection perspectives a fourth perspective is added called ‘sustainable development’ that aims to minimise on long-term ‘costs’ in terms of investment, road maintenance and flood damage repair costs, social costs and ecological costs.

Table 5.19 Example of weights by objective for various perspectives on road development and rehabilitation (5 highest importance; 1 lowest importance).

Objectives of road development and rehabilitation	**Example perspectives (total = 20)**			
	Transport	**Flood protection**	**Ecology**	**Sustaina bility**
Enhance regional transportation	**5**	2	2	1
Minimise road investment	**4**	3	2	3
Minimise road operation and maintenance	**4**	3	2	**3**
Reduce flooding vulnerability (vicinity of the road)	2	**4**	4	3
Reduce flooding vulnerability (sub-floodplain)	2	**5**	2	3
Minimise social impacts	2	3	3	**3**
Maintain floodplain hydraulics and ecology (sub-floodplain)	1	0	**5**	**4**
Total	20	20	20	20

Based on the perspectives as presented in the table above, a ranking of alternatives was calculated using the impact table (Table 5.18). This exercise shows that the zero option alternative, ranks highest for the ecology and sustainability perspective (Table 5.20); it does not influence the floodplain hydraulics and the ecology and has no negative effects with respect to resettlement. Obviously, the do nothing alternative is not an option because roads are essential to develop the region, and negative effects have to be accepted as long as they are within certain limits. From transport perspective an upgraded NR 30 is the best alternative. Alternative 3 (extra through-flow) scores high for all perspectives, except for the transport perspective.

Table 5.20 Ranking alternatives based on impact table (Table 5.18) and perspectives (Table 5.19) (1 highest ranking; 5 lowest ranking). Note that in both the ecology and sustainability perspective two alternatives rank the same.

Alternative	**Perspectives**			
	Transport	**Flood protection**	**Ecology**	**Sustainability**
1. Zero option	2	2	1	1
2. No bridges in PR855	4	4	4	4
3. Extra through-flow PR855	3	1	1	2
4. Heighthened NR30	1	3	3	2

5.5 Case 4: Construction of new NR1A and HCM road (Viet Nam)

5.5.1 Introduction[7]

National Road (NR) 1A is a new road, which is soon to be constructed. The road runs just north of the existing NR1 with bypasses at most villages. HCM road is a new road connecting Cao Lanh and the south with NR 2 in the north. The area of both roads considered in this case study is located in Flood Zone C (Annex 2).

5.5.2 Analysis of the present and future situation

NR1A and HCM road are not yet constructed. The design in terms of flood vulnerability is still open, but many flow-through structures such as bridges and culverts are planned. The alignment is perpendicular to the flow direction of the flood. The locaton of bridges and culverts is related to existing canals and the main flow pattern during floods. NR1A and HCM road can have a large effect on hydraulic conditions downstream, which may effect agricultural production. The consequences of a non-optimal road design can be local damage or less agricultural crops. Also ecological impacts should be considered like agricultural imopacts and impacts on fish habitat as well as obstructed fish migration routes.

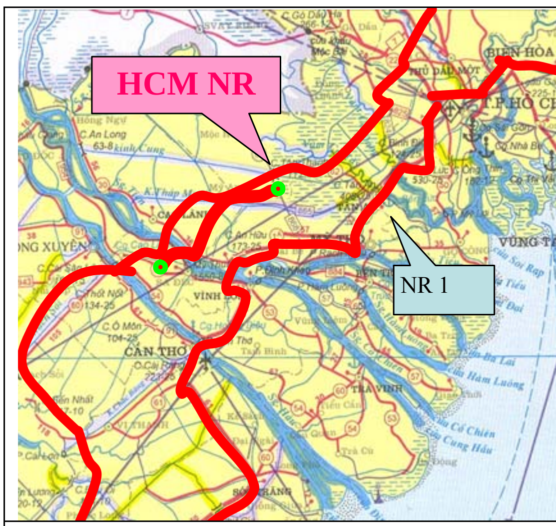

Figure 5.23 Location of HCM road in Flood Zone C.

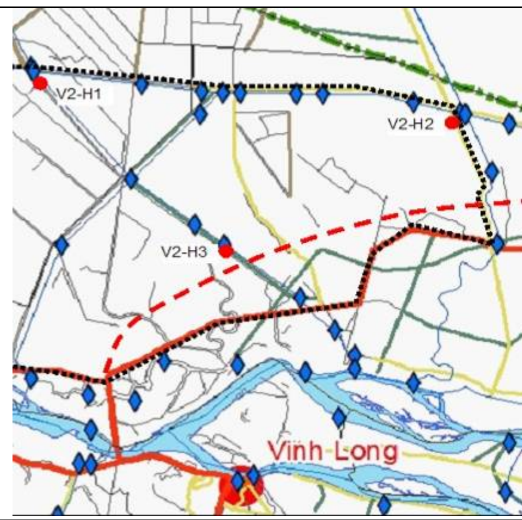

Figure 5.24 Location of NR1A in Flood Zone C.

5.5.3 Alternatives considered

The effects of new roads should be compared at least with the zero alternative which is the situation without road NR1A and HCM road. Then, of course the planned situation (alternative 4) incorporating a number of bridges and culverts. In addition, the planned alternative will be compared with more resistance alternatives where the NR1A and HCM road are also modeled without bridges (alternatives 2 and 3). In summary, this case study considered the following alternatives:

[7] The case presented is discussed in more detail in the Technical guidelines report (Verheij and Van der Ruyt, in prep.).

1. **Zero option** (the do nothing alternative). This alternative is the reference situation and represents a situation without NR1A and HCM road with the expected future discharge of 65,000 m^3/s.
2. **NR1A and no bridges**. This is an extreme alternative in which NR1A is designed without any bridges and culverts. This alternative is identified to analyse the effect of such, exteme, measure on the floodplain hydraulics.
3. **HCM road and no bridges**. This is an extreme alternative in which HCM road is designed without any bridges and culverts. Also this alternative is identified to analyse its effect on the floodplain hydraulics.
4. **NR1A and HCM road planned bridges**: In this alternative the bridges and culverts as planned are taken into account.

In line with the strategies presented in Chapter 4, alternatives 2 and 3 would be part of a resistance strategy and alternative 4 of a resilience strategy.

5.5.4 Assessment of hydraulic impacts of the alternatives

Based on inundation modelling and damage assessment the effects of the various alternatives have been quantified (Verheij and Van der Ruyt, in prep.). Table 5.21 presents a summary of the hydraulic conditions and distinguishes between conditions near the road (depth and velocity) and at Flood Zone scale (flooded area and duration).

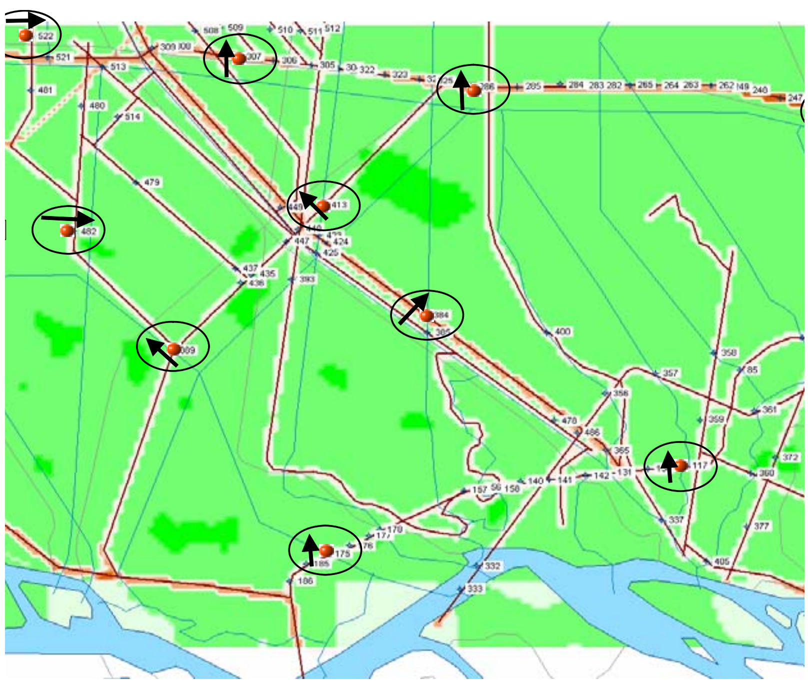

Figure 5.25 Bridge locations in study area case 4 where flow velocities where computed.

The different alternatives do change the hydraulic conditions in the direct vicinity of NR1A and HCM road. The effects of the water level changes are in the order of a decimetre for the planned bridges alternative 4, but are up to 2 meters (lower than zero option) downstream for both no bridges alternatives 2 and 3. Changes in flow velocities range from -0.3 m/s to +0.2 m/s; the latter for the planned bridges alternative. Flood zone impacts for the no bridges alternatives are large, as shown by Table 5.21 as well as Figure 5.26 for HCM road. Figure 5.26 shows that upstream HCM road the area has been flooded already, whereas downstream HCM road the area is still dry. The total reduction of flood area in alternatives 2 and 3 is 48 %.

Table 5.21 Hydraulic conditions along NR1A and HCMR for the alternatives investigated (alternative 1: absolute values; alternatives 2-4 difference with alternative 1).

Alternative [-]	**Road**		**Flood Zone C**	
	Water depth [m] [1]	**Flow velocities [m/s]** [2]	**Flooded area [%]** [3]	**Duration of flooding [days]** [3]
	Absolute value			
1. Zero option	1.5 to 2.5 m	0 to 1.5 m/s	100 %	34
	Relative value (difference with zero option)			
2. NR1A and no bridges	0 upstream to -2.5 downstream	-0.3	-48	+3
3. HCRM and no bridges	0 upstream to -2.5 downstream	-0.3	-48	+3
4. Planned bridges	+0.10	+0.2	0	-1

[1] Spatial scale: upstream and downstream location of road; Temporal scale: days that maximum water level difference upstream and downstream road occurs, [2] Spatial scale: bridges along road; Temporal scale: see water depth,, [3] Spatial scale: Flood Zone C; Temporal scale: flood season.

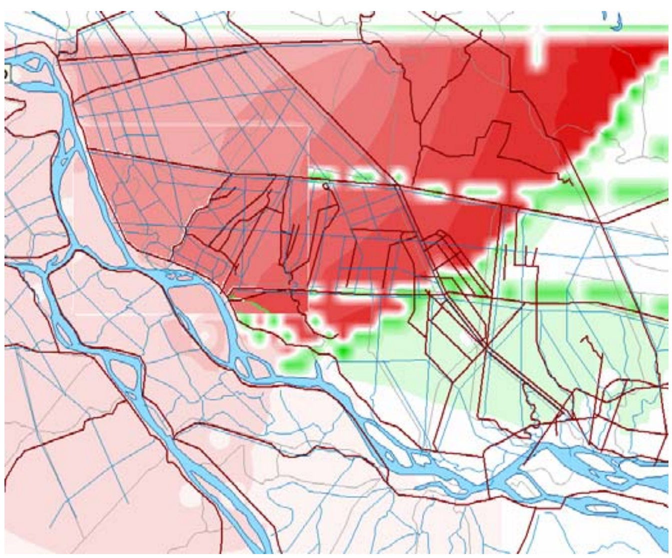

Figure 5.26 Water depth differences due to the planned new HCM road without bridges (alternative 3) (in red flooded area upstream HCM road; in green the dry area downstream HCM road).

5.5.5 Impacts of hydraulic changes on road damage and floodplain ecosystem

What are the implications of flooding in terms of damage to roads and consequences to the floodplain ecosystem? A qualitative assessment of these impacts is presented in Table 5.22, which will be further explained in this Section.

Road damage

Changes in hydraulic conditions may result in erosion of slope and road material and macro-instability of embankments. Most changes are insignificant with respect to increasing damage potential except the flow velocities. Although the changes are small, for bare slopes they are highly damaging and will cause erosion. For the resistance alternatives without bridges the flow velocities drop to almost zero along the new roads, and with 0.3 m/s at other locations; thus the damage potential becomes low. The decrease of flooded area is significant with 48%, and this might endanger the stability of road embankments due to the large water level difference a both sides. This is shown in Figure 5.26. The changes in the flood duration seem to be limited and will not result in road damage. This blocking of the flood pattern will have serious impacts on fish migration and agriculture.

Table 5.22 Impact of the hydraulic conditions of the NR1A and HCMR alternatives considered on road and sub-floodplain damage.

Alternative [-]	**Related to water level (macro-instability, waves, overtopping/overflow)**	**Related to flow velocities (toe scour, abutment scour)**	**Related to duration and extent (fish, agriculture)**
1. Zero option	None to medium	None to medium	None
2. NR1A and no bridges	Medium to high negative	None to low negative	High negative
3. HCRM and no bridges	Medium to high negative	None to low negative	High negative
4. Planned bridges	None to medium	None to medium	None to medium

Impact on the floodplain ecosystem

With respect to the impact on fisheries and agriculture the resilience alternative 4 impose no significant impact. The duration and extent hardly change. For the resistance alternatives 2 and 3 the extent of the flood does change significantly, and this effect is not temporarily as it is assumed that the levees along the Mekong River do not allow inundation of the flood zone from downstream. This has serious implication to the fisheries sector as every hectare of floodplain lost due to road development could lead to a loss of 100 kg of fish each year (Halls et al. 2006). If the levees are not raised the downstream area will be inundated later than the upstream area because the water has to enter this area form downstream. Then, the effects are temporarily. The duration of the flooding in the upstream area will be a few days longer due to the limited ways for the water to flow back to the river. The resistance alternative without bridges does have a significant negative impact on fish migration routes. The resistance alternatives influence also the agriculture due to the considerable decrease in flood extent.

5.5.6 Costs of the alternatives

Table 5.23 shows that designs without bridges are the least expensive and that the OCC should be below respectively 5.5% and 3.6% for the other alternatives to be less expensive than the NR1a & no bridges option. Design against a lower standard, for which the figures are given in Table 5.24, will lead to a NPV of US$ 275 million.

Table 5.23 Results financial analysis NR1a and HCMC Road.

Alternative	**Total investment cost**	**Total annual operating costs**	**Flood damage per 5 year**	**NPV of total costs at 12%**	**IRR <> NR1a & no bridges**
1. zero option	0	0	0	0	-
2. NR1a & no bridges	120,000,000	2,400,000	2,400,000	127,810,641	-
3. HCM & no bridges	300,000,000	6,000,000	6,000,000	319,526,602	5.5%
4. NR1a & HCM road & planned bridges	490,000,000	9,800,000	6,400,000	517,911,405	3.6%

Note: all figures are in USD

Table 5.24 Comparison of costs according to a high standard and a low standard for alternative 4 with planned bridges.

Costs	**High standard**	**Low standard**
Investment costs [USD]	490,000,000	240,000,000
O & M costs [USD/year]	9,800,000	7,200,000
Flood damage costs [USD per 5 years]	6,400,000	5,700,000

5.5.7 Integrated impact assessment of the alternatives

In order to analyse the total impact of the identified alternatives of the construction of the NR1A and HCM road it is important to consider all relevant issues at the early stages of planning and design (Chapter 4). Relevant issues include transport, finance, hydraulics, ecology and social welfare. These issues are reflected in the objectives and related impact indicators presented in Table 5.25 and include short-term and long-term impacts and local and sub-floodplain impacts. Table 5.25 presents a first qualitative assessment of the different alternatives of the NR1A and HCM road based on the hydraulic, damage and economic analyses presented in the previous Sections and a qualitative judgement of the other indicators.

The following comments and observations can be made based on Table 5.25.

- All alternatives, except the zero option, have a positive effect on traffic, because of the extension of the road network with the new NR1A and HCMR.
- Higher floods in the future, up to 65.000 m^3/s, do have a slight influence on the damage to roads independent of the amount of through-flow structures. Flow velocities will increase from medium expected damage to high expected damage (considering no slope protection, with a protection the damage is low).
- The construction of NR1A and HCMR without bridges (alternatives 2 and 3) obstructs the fish migration paths because no through-flow capacity will be realized. These alternatives might also seriously affect agriculture, floodplain hydraulics and ecology due to the decreased flooded area.
- Alternative 4, the alternative planned for NR1A and HCMR, receives a good score on most objectives, expect of course for investment and operation and maintenance costs and flood damage costs.

Table 5.25 Integrated impact table according to a high standard design (+++ best alternative, --- worst alternative).

Objectives	**Impact indicators**	**1. Zero option**	**2. NR1A and no bridges**	**3. HCRM and no bridges**	**4. NR1A and HCRM with planned bridges**
Enhance regional transportation	Travel time (road)	--	+	+	++
Minimise road investment	Initial investment costs (road)	+++	+	--	---
Minimise road operation and maintenance	Operation and maintenance (rehabilitation) costs (road)	+++	+	--	---
Reduce flooding vulnerability (vicinity of the road)	Damage of flooding to structures in vicinity of road	+	-	-	++
	Damage of flooding to NR1A and HCMR	+++	+	-	--
Reduce flooding vulnerability	Damage of flooding to other roads than NR1A and HCMR (sub-floodplain)	++	-	-	+
Minimise social impacts	Resettlement (road)	+	--	--	--
	Water quality (sub-floodplain)	+	-	-	++
Maintain floodplain hydraulics and ecology	Flood pattern and dynamics (sub-floodplain)	+++	---	---	++
	Habitat fragmentation (sub-floodplain)	+++	---	---	++

5.5.8 Ranking of the alternatives

In this Section, we illustrate that a different perspective on road development (e.g. transport, flood protection, ecology) will lead to a different ranking of alternatives as each perspective prioritizes objectives differently. An example of this different weighting of objectives (listed in Table 5.25) for each perspective is illustrated by Table 5.26. The weights in Table 5.26 are exaggerated to make differences between the perspectives more explicit; in reality objectives and their relative importance are set by decision-makers during the planning process. Apart from the transport, ecology and flood protection perspectives a fourth perspective is added called ‘sustainable development’ that aims to minimise long-term ‘costs’ in terms of investment, road maintenance and flood damage repair costs, social costs and ecological costs.

Table 5.26 Example of weights by objective for various perspectives on road development and rehabilitation (5 - highest importance; 1- lowest importance).

Objectives of road development and rehabilitation	Example perspectives (total = 20)			
	Transport	**Flood protection**	**Ecology**	**Sustainability**
Enhance regional transportation	**5**	**4**	2	1
Minimise road investment	**5**	2	2	3
Minimise road operation and maintenance	**4**	2	2	**3**
Reduce flooding vulnerability (vicinity of the road)	2	**5**	2	3
Reduce flooding vulnerability (sub-floodplain)	2	**5**	2	3
Minimise social impacts	1	1	**5**	**3**
Maintain floodplain hydraulics and ecology (sub-floodplain)	1	1	**5**	**4**
Total	20	20	20	20

Based on the perspectives as presented in the table above, a ranking of alternatives was calculated using the impact table (Table 5.25). This exercise shows that the do nothing option, according to all perspectives (Table 5.27), ranks highest, as already could be distilled from the impact table (Table 5.25). This is because it has no effect at all on flood patterns, sustainability and ecology, while also no costs are required in contrast to alternatives 2, 3 and 4. The highest ranking for the do-nothing alternative, even for the transport perspective, indicates that the weight for the 'enhance regional transport' objectives, might have been too low (Table 5.26). Alternative 3 ranks lowest in all perspectives. The planned alternative 4 (with bridges) scores third in the transport perspective and second in the other perspectives. The extra costs for the bridges have a negative impact on the score, but from a ecology and sustainability perspectives they score better than the no bridges alternative.

Table 5.27 Ranking alternatives based on impact table (Table 5.25) and perspectives (Table 5.26) (1 highest ranking; 5 lowest ranking).

Alternative	Perspectives			
	Transport	**Flood protection**	**Ecology**	**Sustainability**
1. Zero option	1	1	1	1
2. NR1A and no bridges	2	3	3	3
3. HCRM and no bridges	4	4	4	4
4. NR1A and HCRM with planned bridges	3	2	2	2

5.6 Discussion of the case study results

This Section discusses the results of the case studies. First the quality of the results will be discussed. This will be done for each of the technical analysis steps taken in the project (Section 5.6.1). In this Section also the representativeness of the case study results for the entire Cambodian and Viet Namese Mekong floodplain system as well as for Thailand and Lao PDR will be discussed. Section 5.6.2 will discuss the results based on the four research questions underlying this report. Finally, conclusions are drawn about the use of the case study results in supporting the set of Best Practice Guidelines (Chapter 6), and suggestions for further research are given (Sections 5.6.3 and 5.6.4).

5.6.1 Quality and representativeness of the results

Flood surveys and historical data collection
In 2006 and 2007 flood surveys in four pilot sites were carried out to collect hydraulic and road damage data. Both surveys resulted in valuable hydraulic data that was used as input in the inundation modelling (see further). Data collected on road damage, however, was limited given the mild floods in both years (Verheij and Van der Ruyt, in prep). An attempt was done to collect available historical data on road damage in both countries, but this data proved of limited value for this study due to lack of detail.

Inundation modelling and analysis
Hydraulic models were built for the floodplains in both countries, and linked to each other (Verheij, in prep.). The models show high accuracy in the pilot sites – thanks to the data collected in these sites – and lower accuracy in the surrounding floodplains. The models were based on digital elevation models improved by data derived by the two flood surveys (see above). The models were calibrated with data on water levels and discharges in the main river and in the floodplain of the 2000 flood. Validation of the models was based on the floods in other years. Comparison of the predicted and observed data showed a good resemblance, which supported the conclusion that the models are reliable.

Road damage analysis
Main focus of this activity was the identification of the main road damage features and mechanisms in relation to floods in Cambodia and Viet Nam, and the quantification of the link between hydraulic conditions and road damage. As the results of the damage surveys, given the mild floods were limited (see above), a quantified relation between hydraulics and specific road damage features proved impossible. In this study, this relation is therefore based on information from international literature including road design manuals and codes (Van der Ruyt, in prep.).

Analysis of roads costs
The aim of the financial analysis was to make clear for the road owner/designer the trade-off between short-term investment and medium-term operation and maintenance and flood damage for the various alternatives considered. Therefore, information was needed on the cost of construction of roads, operational and maintenance costs, and flood-related damage costs. In the study assumptions have been made of these cost categories, e.g. for constructing a bridge, built a slope protection, or rehabilitate a road in both countries, which have been checked with stakeholders during the consultations. This resulted in improved data and enabled to come up with indicative cost estimates for different road

planning and design alternatives in the specific cases. For more accurate assessments, more detailed financial data and data analysis would be needed.

Environmental impact analysis

Substantial information is available on the ecological importance and functions of the Mekong floodplains (Chapter 2). Limited information is however available on the sub-floodplain scale; the scale considered in this study. Chapter 2 also presented the information available on the values of the floodplain functions, mainly in terms of fish production. Studies on the relation between the floodplain hydraulics and ecological functions have since recently been undertaken (e.g. Baran *et al.* 1997), particularly also the effects of hydrology on floodplain fish populations (Welcomme 1985; Welcomme & Halls, 2001; Halls & Welcomme 2001). In the report the assumption is made, in line with Poulsen *et al.* (2002), that any impact on the hydraulic regime of the Mekong and its floodplains has consequences on the aquatic ecology and hence the benefits for the local population. The assessment of the environmental impacts of road development and rehabilitation strategies on floodplain functions and values in the case studies therefore is indicative and qualitative. For example, it is demonstrated in the cases that bridges effectively mitigate the effects of road embankments on flood extent and duration, but we assumed that bridges mitigate also the effects of road embankments on fish migrations, but did not find prove for this in the literature. It is anticipated that in the coming years better information will become available, that can be used to refine the environmental impact assessments made in the cases presented.

Policy analysis

As mentioned in Section 5.1, a policy analysis framework was applied to analyse the cases and present the results. Information on the first step, the problem analysis, was based on discussions with stakeholders and literature review. Identification of objectives was based on discussions with stakeholders and the MSc work of Beinamaryo (2007) for Cambodia and Thu Do (2008) for Viet Nam. In reality, however, this process of stakeholder consultations needs to go more into depth. Alternatives identified (step 3) were based on discussions with stakeholders and input from the workshops. The assessment of impacts of alternatives (step 4) was based on the hydraulic and damage analyses presented before, and on qualitative assessments and expert judgements. The integrated impact assessment (the impact tables) should therefore be considered as indicative. The ranking of alternatives (step 5) is shown to illustrate how alternatives given different perspectives could rank. The ranking is however highly dependant on the weights given to objectives, which are for the purpose of the case studied assumed. The methods are based on international cases, and not tested in the Mekong region.

Representativeness of the results for various floodplain zones of Cambodia and Viet Nam

The cases are related to the 4 pilot sites of about 20 by 20 kilometres in which the 2006 and 2007 surveys were held. The pilot sites were selected in those Flood Zones in which most road developments have taken place or were foreseen in the future and the floodplain had highest ecological value in terms of fish migration routes. Flood Zone 1 in Cambodia was not selected as this region was already subject of another related study (Baran *et al.*, 2007b). The Flood Zones covered by the cases are: Flood Zone 5 in Cambodia (Cases 1 and 2), and Flood Zone C in Viet Nam (Cases 3 and 4) (see Figure 5.27)

Figure 5.27 Mekong Flood Zones in Cambodia and Viet Nam.

Main criteria in the selection of the pilot sites within the Flood Zones were the presence of different directions of the road compared to the main flow direction, and the presence of different types of roads (national, provincial and rural). As the roads in the pilot sites comply with both criteria, it can be concluded that the situations in the pilot sites in Viet Nam and Cambodia are representative for all roads in the lower flood plain. The roads are mainly constructed on embankments consisting of clayey and loamy soil and with culverts or variously sized bridges at old and known flow courses, which is considered to be similar to roads in the rest of the Cambodian and Viet Namese Mekong floodplains. The foregoing means that the results of the study are representative for Flood Zones 2 to 5 in Cambodia and A to C in Viet Nam (Figure 5.27).

Representativeness of the results for Thailand and Lao PDR

The 'Roads and Floods' study, including its surveys and case study research, focused on Cambodia and Viet Nam. The question is to what extent the case study results are representative for Thailand and Lao PDR, as well. In general terms, the results give an indication of what could happen in both countries as far as the area considered is characterised by a comparable type of floodplain. In those cases, the results and the Best Practice Guidelines build on these results are appropriate to be used in both countries. However, when applying the guidelines, the specific physical environment and flood characteristics of the region should be considered, as this can be quite different from the Cambodia and Viet Nam one, e.g. more flash floods in tributaries in more mountainous areas (MRC, 2007d).

5.6.2 Discussion of the results

This Section will discuss the results, along the four research questions presented:
.

- *What is the significance of roads in the Cambodian and Viet Namese floodplains in changing flow patterns (including cumulative impacts)?*
- *What is the significance of flow patterns in Cambodia and Viet Nam in terms of road damage?*
- *What are the impacts of different road development and rehabilitation strategies (resistance and resilience) in Cambodia and Viet Nam on floodplain hydraulics and related benefits of floods and on economic costs of roads?*
- *What road development and rehabilitation practice would contribute most to the reduction of the socio-economic costs of flooding in the Lower Mekong Basin, whilst preserving the environmental and other benefits of floods?*

What is the significance of roads in the Cambodian and Viet Namese floodplains in changing flow patterns (including cumulative impacts)?

The cases show that existing roads in the Cambodian and Viet Namese floodplains to a large extent are tailored to the local flow channels. Either they are situated on top of the main levees following the alignment of the channels (see Case 1 with road 11), or they are designed to obstruct the flow patterns as less as possible during floods (such as bridges in Case 3 and spillways or low-water crossings in Case 1). In general, this is more the situation for rural and Provincial Roads, and less for National Roads, for instance National Road 1 in Cambodia (Case 1) which is aligned perpendicular to the Mekong flows. In Viet Nam particularly, most existing roads are part of the diking system used to protect from floods and to manage water for agricultural purposes, but many flow-through structures are part of the system. Rehabilitation of existing roads (e.g. increasing the road elevation like after the 2000 floods, replacing old bridges by new ones, removal of a spillway) is unavoidable because modern society requires their upgrading to enhance traffic. However, rehabilitation of roads in floodplains (like presented in Cases 1, and 3) requires mitigating measures to reduce the effect of the road on the flow pattern locally as well as on sub-floodplain level. This holds even more when planning and constructing a new road (presented in Cases 2 and 4). In the cases presented in this Chapter we analysed in detail the impacts of different road development and rehabilitation alternatives on water depth, flow velocities, flooded area and flood duration. These impacts will be discussed below.

The case results show that the different alternatives had a limited impact on the **flood level (water height)**. In Cambodia this is mainly due to the ‘open’ character of its Mekong floodplain. The newly constructed road NR8 (Case 2) for instance will result in a local obstruction of the flood, because the flood is forced to pass the planned bridges. Even in the alternative with no bridges the area downstream of road 8 will be inundated from downstream due to the so ‘open’ (sub) flood plain. Thus, temporarily the water depth at both sides of the road embankment will show some difference, but after a few days the water levels will be equal again. In Viet Nam the flood pattern is much less ‘open’; rather it is more controlled and channelled by irrigation works. Existing and new roads are expected to be tailored to this situation and the water levels are much less likely to be attenuated on the floodplain as it is observed in Cambodia (as is also shown by the results of the Viet Namese Cases 3 and 4).

Impacts on **flood extent and duration** in the case of alternatives of new planned roads without flow-through structures that block the flow patterns, such as alternative 5 Case NR 11 and PR 317 in Cambodia, are significant. These alternatives obstruct the flood pattern completely. The consequences are fragmentation of the floodplain which blocks the fish migration routes, but also significant change in duration and extent of the flooded area downstream of the new road. For instance, a decrease of about 50% of the flooded area. These impacts are less significant for those alternatives that include flow-through structures. In Case 1 these alternatives result in a change in flooded area of 5% which still is about 100,000 ha of mainly agricultural area that will not be fertilised by the floods. Hence, although these alternatives cause relatively small changes in flood dynamics (flooded area, duration, flood beginning), impacts on aquatic ecology and related functions should be considered. However, as more (road) developments in the flood zone and upstream of the zone can be anticipated in the near future, these effects will become larger. The cases (e.g. Case NR8 in Cambodia or Case PR855 in Viet Nam) show that such cumulative impacts are relevant to consider and might lead to more serious consequences in terms of road damage and ecological deterioration at a larger sub-floodplain scale.

Apart from the impacts of individual roads, also **cumulative impacts**, being aggregated impacts from multiple (road development) activities, have been analysed in the cases. Blocking the flow patterns also means that the flood has to find another way in downstream direction. The consequence is that other areas might be exposed more than before and with higher damage due to the flood. These impacts are e.g. illustrated in Case 3 where in alternative 2 the flow-through openings in the northern part of the road are blocked. More specific, it is not only the change of flow pattern but also the characteristics of the new flow patterns: higher discharges with higher flow velocities. Another example is the removal of the spillway in Case 1 road 11. This results in larger amounts of water elsewhere, for instance at the bridges in the northern part of road 317, and higher flow velocities if no compensating measures are taken in a sense of adjusting the opening size to the increased flow. More dramatically is the heighthening of the left Mekong levees in alternative 5. This will result in an increase of the water level in the Mekong River with about 0.5m at Phnom Penh because the water can not flow anymore over Flood Zone 5 (see also Cross, 2003). Not only new roads cause cumulative effects, also road rehabilitation might have the same impacts, but their effects are mainly local.

What is the significance of flow patterns in Cambodia and Viet Nam in terms of road damage?

During a flood period large areas are inundated and flow patterns cross sub-floodplains. During the initial stages of the inundation the flood follows the irrigation canals in Viet Nam and the colmatage system in Cambodia. At higher flood stages the land will inundate and the flood patterns may cross roads with an alignment perpendicular to the flow pattern alignment, for example existing National Road 1 (Case 1) and the new road 8 (Case 2) in Cambodia, and the Provincial Road PR855 in Cambodia (Case 3). Obviously, if a flood pattern and a road embankment meet each other the forces exerted by the flood might cause damage to the road embankment including its flow-through structures (bridges, culverts, spillways). The damage is the result of water level differences over the road embankment, or flow velocities in the flow-through structures or along the slopes of the road embankments, or water flowing over the embankment in the case the water levels are higher than the road level, or wind waves. In Case 3 a picture is shown of a sliding during the 2007 flood. This type of damage is the result of a too steep road embankment. Slidings (macro instability) may also occur in the early stages of a flood when there is a water level difference between both sides of the road embankment. In particular, this happens for resistance alternatives such as in Case 4 with the alternatives 2 and 3 with new roads without any flow-trough openings.

The flow velocities are the most important effect of the flow patterns on the roads, as a not properly designed road with bridges may suffer serious damage. Flow velocities well above critical values for the initiation of erosion of 0.5 m/s occur, sometimes even above critical values for protection materials as for instance small rock. See for instance Case 3 in Viet Nam. To reduce these velocities to an acceptable level by increasing the amount of flow-through structures or the opening dimensions is economically not possible. A proper protection together with streamlined abutments is a cheaper option, and very often the best way to protect the bare soil or to minimize the damage. The latter is demonstrated by alternative 4 of Case 2. The resistance alternatives which block the flow patterns reduce the flow velocities to zero for the particular road section and, subsequently, do not result in damage but are likely to cause damage elsewhere (as shown in Case 3 for the alternative with the blocked bridges in the northern part).

What are the impacts of different road development and rehabilitation strategies (resistance and resilience) in Cambodia and Viet Nam on floodplain hydraulics and related benefits of floods and on economic costs of roads?

In Chapter 4, two general strategies in road development in floodplains have been presented and their advantages and disadvantages discussed. The resistance strategy, in principle, aims at preventing and regulating floods and hence has a strong impact on the natural floodplain dynamics, while the resilience strategy aims at minimizing the consequences of floods, but at the same time intends to maintain the natural floodplain dynamics as much as possible. The hypothesis behind the resilience strategy in the light of this study is that although investment might be higher, on the longer term costs in terms of road damage and ecological impacts will be lower. The above-mentioned research question is posed to test this hypothesis for the cases under study. The answering of this research question is based on the technical analyses results presented before, and qualitative assessments and expert judgements. In the light of the discussion about the quality of the analysis in Section 5.6.1, the results should be considered as indicative. What the impacts are in individual cases should be based on a more in-depth analysis of environmental and financial impacts.

The case results show for new roads that the zero option is the most interesting alternative, see for instance Cases 2 and 4. This is because it has no effect at all on flood patterns, sustainability and ecology, while also no costs are required in contrast to the other alternatives. Nevertheless, it is not a solution because it does not address the traffic objective, which also indicates that the weight for the ‘enhance regional transport’ objectives, might have been too low (e.g. Table 5.26). If we consider the ‘rehabilitation’ Case 1 the zero option is not the best, because of the high operation and maintenance costs and damage costs. Several resilience alternatives (alternatives 2 and 4 Case 1, alternative 3 Case 3, alternative 4 case 5), indicate that higher investment in road design, are expected to results in positive effects on medium term costs and floodplain ecosystem. This is reflected in the high ranking of these alternatives for the sustainability perspective. Table 5.28 below, gives an overview how resistance and resilience alternatives in the four cases have ranked for the four perspectives considered. The results, which should be considered as indicative, show that for all perspectives, except the transport perspective, the resilience alternatives score higher than the resistance alternatives. The resistance alternatives score highest for the transport sector, and lowest for the ecology perspective.

Table 5.28 Overview how road development and rehabilitation alternatives as part of a resistance or resilience strategy rank taking four different perspectives.

Strategies	Case	Alternative	Perspectives			
			Transport	Flood protection	Ecology	Sustainability
Resistance	1	5	1	1	5	3
	2	2	4	4	4	4
	3	2 and 4	4 and 1	4 and 3	4 and 3	4 and 2
	4	2	2	3	3	3
Resilience	1	4	2	2	1	1
	2	3 and 4	2 and 3	3 and 2	3 and 2	3 and 2
	3	3	3	1	1	2
	4	4	3	2	2	2

The results of the cases, presented in Table 5.28, do not give indications that there are differences between Cambodia and Viet Nam. However, we expect that is easier to rehabilitate or design a road in line with the resilience strategy in Cambodia than in Viet Nam. The reason for this, in our opinion, is the more natural floodplain in Cambodia, while in Viet Nam the water management in the flood zones has reached a high level already.

The analysis illustrates that in the process of chosing a strategy (resistance or resilience) and related alternative, objectives and priorities play an important role. And objectives can be conflicting. The cases show, for instance, that if an alternative scores high (hence good) on road costs and ecological impacts it scores low on flood protection. Resistance alternatives aiming at protecting the land from flooding, scores low (not good) on maintaining floodplain hydraulics and ecology. The purpose of the methodology applied to structure and present the cases, is to illustrate how these trade-offs could be made more transparent to decision-makers.

The financial analysis has followed a relative simple approach using averages for flood damage. A more sophisticated analysis could include a probability analysis of flood damage occurrence and variation in the amount of damage sustained with different levels of floods.

The financial analysis shows that in all cases the cheapest alternative will lead to the lowest cost for the owner of the roads. Hence, the extra investment costs are not covered by less damage and / or maintenance costs. However, road investments are usually not evaluated in a narrow financial sense as roads lead to many benefits for the economy as whole. Part of these benefits can be expressed in money and part of these benefits are non-monetary, such as less road casualties. Similarly, more sustainable roads, i.e. the more expensive alternatives, can lead to additional monetary and non-monetary benefits compared to the cheapest alternative that are not taken into account in a financial analysis. An economic analysis would provide more insight in these additional benefits.

However, at (sub)floodplain level economic costs and benefits of roads and floods are difficult to determine. For instance, resilient and resistant roads provide a more reliable transport system, reducing transportation costs (less days with flooded roads; higher speeds due to less holes, lower vehicle operating costs etc.) and providing indirectly more (hardto-quantify) economic opportunities to areas in the floodplain, including trade opportunities, increased land values. Roads that are not or less affected by flood damage are also safer roads, hence reducing road fatalities and traffic injuries. Similarly, floods have even harder-to-assess benefits. Although the hydraulic analysis shows that in most cases the impacts on the flood plain are minimal or small, roads or networks of roads that do have significant impacts could lead to negative externalities in the form of a reduction in environmental services that the floodplains provide, such as reduced revenues from fisheries and poorer soil quality, subsidence or salt infiltration in the Delta leading for instance to lower agricultural revenues.

Some studies on benefits of roads have been carried out in the past, though not specifically for flood plains. For instance a World Bank study by Buys et al. (2006) estimates that a road upgrade project for the African continent would lead to an increase in trade of US$ 250 billion over 15 year with major direct and indirect benefits for the rural poor. Financing the program would require about $20 billion for initial upgrading and $1 billion annually for maintenance.

Hence, the result from an economic cost-benefit analysis (as opposed to a financial cost benefit analysis) will more likely lead to higher NPV and IRR figures for more sustainable options.

It should also be mentioned that the costs and benefits may affect the poor relatively more: improved access to rural areas could help poor to start business that would otherwise not be possible. (For instance road accessibility during the flood season could support fishery-based industries).

What road development and rehabilitation practice would contribute most to the reduction of the socio-economic costs of flooding in the Lower Mekong Basin, whilst preserving the environmental and other benefits of floods?

The cases make clear that road planning and design in the Mekong floodplain while reducing the socio-economic costs of flooding, and preserving the environmental and other benefits of floods is a complicated task that requires an integrated approach. The cases clearly show the need for the following types of integration:

- The cases show that when developing roads in the Mekong floodplains, coordination between the road and transport sector and the water sector, flood risk management / dike sector, environment sector, and social sector is essential. Different sectors have a different perspective on floods and how to deal with them, and these objectives should be balanced in developments in floodplains, like road developments.
- The character of the floodplain system, also requires that not only local (project) impacts are considered, but also impacts and implications at a larger scale. The cases show that cumulative impacts of structural developments (including roads) occur. A solution at one location, might impact other locations. This requires coordination and integration at (sub-)floodplain scale.
- Also integration / coordination with the financial sector and donors, in order to link infrastructure investment budgets with operation and maintenance and damage repair budgets. The case results indicate that a higher initial investments might probably lead to lower medium-term costs and ecological impacts. This requires an

integrated financial assessment - integrated in terms of investment, operation and maintenance, damage risk - at the early planning stages. Such analysis would also contribute to a more efficient use of limited financial resources.

These different dimensions of integration will be reflected in the set of Best Practice Guidelines for road development and rehabilitation in the Mekong floodplains of Cambodia and Viet Nam which will presented in Chapter 6.

5.6.3 Conclusions and suggestions for further research

The case studies undertaken in both Cambodia and Viet Nam allow us to answer the four research questions posed. Due to some data limitations and the fact that assessment of environmental and economic impact assessment was limited, the answers to questions 3 and 4 should be regarded as indicative. For the pupose of supporting the Best Practice Guidelines, the cases, do however, provide a sufficient basis. Moreover, apart from the case study results, the Best Practice Guidelines are based on the review of current international practice as well as the practice in the Mekong Basin.

Based on this discussion the following suggestions for further research are identified:

- Gathering geological and geotechnical data to classify geotechnical units to be coupled with hydraulic units within the LMB to allow the development of road damage relations.
- Developing of detailed road damage functions and flow-through structure damage functions based on observed flood related damage and observed hydraulic conditions. Therefore, more surveys during flood conditions should be carried out in order to built up a data base.
- Detailed hydraulic modelling of the flow conditions near and in flow-through structures in order to determine accurate flow velocities. This is important for the design of the protection of bridge abutments and guiding structures to culverts.
- Study of the requirements of design and location of culverts and related structures for fish to pass these type of structures.
- More in-depth economic analysis of costs and benefits of road development and its impacts, further supporting the integrated analysis and assessment of alternatives.
- Further quantification of functions and values of the Mekong floodplain, also at Flood Zone level. Also analysis of minimum flow requirements to sustain the floodplain functions and analysis of how to incorporate in decision-making processes.

6 A Set of Best Practice Guidelines for Road Development and Rehabilitation in the Mekong Floodplains of Cambodia and Vietnam

6.1 Introduction

Main output of the ‘Roads and Floods’ project is a set of Best Practice Guidelines for road development and rehabilitation in the Mekong floodplains of Cambodia and Viet Nam. The guidelines are based on the review of local practice, international experience, and case study results. They are intended for use by professionals and organisations involved in road planning and design in the Mekong floodplains, as well as those involved in environmental and integrated assessments of road developments in the Mekong basin or structural developments in this basin in general.

The Best Practice Guidelines are based on the case study results, the review of current international practice as well as the practice in the Mekong Basin. In the presentation of the Best Practice Guidelines, each of the recommendations is followed by an explanation including reference to their origin.

The set of Best Practice Guidelines for road development and rehabilitation in the Mekong floodplains of Cambodia and Viet Nam consists of the following three Best Practice Guidelines:

- Best Practice Guidelines for Integrated Planning of Road Development and Rehabilitation.
- Best Practice Guidelines for Environmental Assessment of Road Development and Rehabilitation.
- Best Practice Guidelines for Technical Design of Road Development and Rehabilitation.

The Best Practice Guidelines are presented in a separate ‘Roads and Floods’ document and can be found in Annexes 4 to 6 of this report.

7 Recommendations for Application of the Best Practice Guidelines

The aim of this report was to highlight the importance of evaluating the environmental, social and economic arguments for sustainable road planning and construction by considering the advantages of the resilience option and the application of lifetime approaches for roads/bridges construction in the Mekong floodplains.

The national staffs in the divisions or section responsible for policy preparation may look into the need of strengthening, complementing the existing guidelines. The technical divisions/sections of the line agencies of the MRC member countries will have to come-up with their internal plan to propose and develop the improvements of rules, procedures and guidelines, related to the development, design and construction of road infrastructure in flood plain areas. Generally this is not undertaken through the simple publication of a report (such as the ‘Road and Flood’ Report). It generally is undertaken, if and when such a subject or intention is identified as a requirement/activity in a year plan of Ministries like the Ministry of Land Management, Ministry of Transport, and / or Ministry of Agriculture and Rural Development.

This leads to the conclusion that a Roads and Floods Report will not directly lead to adjustments/improvements of existing guidelines, or the drafting of hitherto not existing guidelines. The most effective way of supporting the potential use of the Road and Floods Report is to create awareness and proper understanding of the content of the Roads and Flood Report among the divisions/sections involved or responsible for the preparation of guidelines or improvement of guidelines.

Particularly WWF GMP, being part of the initiators of the Roads and Floods Project, has earlier shown interest in implementing a targeted project to actively sharing the information with these target groups, however such implementation would be considered a post project phase. Relevant for such a “policy oriented’ project is to identify clearly what are the specific “lessons learned” from the Roads and Floods Project.

It is however somewhat unfortunate that during the implementation period of the Roads and Floods Project, as a result of the lack of damage data, due to the lack of flood events in the flood plain, no strong convincing financial-economical outcome could be provided to demonstrate the advantages of the resilience option above the protection option in a life-time approach of flood plain road infrastructure. This weakens the package of convincing elements for the follow-up policy work.

Even though many will understand and support the resilience option theory in view of securing the sustainability of flood plain infrastructure at lowest life time costs, for very practical reasons protection options will continue to be applied, due to a variety of reasons (lack of funds, limited funds, lack of availability of loans, limited availability of loan funds, limiting engineering knowledge and experience or existing models to refer too, hydrodynamic modelling capacities in line agencies, preference to limit construction period, preference to limit complexity, gaps in integrated water resources strategy for the flood plain, weaknesses in the strategy for infrastructure development in the flood plain, weak level of interaction and exchange between technical and policy levels in water resources sector, etc.).

Nonetheless it is recommended to raise awareness for the resilience approach of flood plain road infrastructure in line agencies of the MRC member states, which have been involved in the development and implementation of the Road and Flood Project. MRC and WWF GMP could work out a set of recommendations and share these among line agencies of the four MRC member countries, and produce documentation of the concept and supporting material in the riparian languages for dissemination. By making the information available in the riparian languages and by disseminating the material to policy and technical divisions/sections of line agencies in Cambodia and Vietnam, but also to the other MRC member countries like Lao PDR and Thailand, the possibilities for later uptake and use of the concept and recommendations is facilitated.

The international development banks are among the target group, as these institutions provide loans for infrastructure to “qualifying” MRC member countries. These institutions, could explore how this report can contribute to improve their own safeguards. They could also be invited to contribute to a dialogue on the need and feasibility of developing national guidelines under following phases of the Roads and Floods project. The dialogue may result into a commitment by these institutions to further look into options for improving there technical criteria/requirements for loan projects related to infrastructure development in flood plain areas.

Before entering into a next step of addressing the potential of influencing the policy and policy preparation of responsible line agencies, it would be recommendable to identify the key policy elements in terms of acceptability, sensitivity, methods and cost factors for dissemination of the concept and related documentation. There would be a need for a dedicated and targeted approach in consultation with MRC in order to optimize potential impact of the Guidelines and Recommendations developed under the Roads and Floods Project to the benefit of the MRC member countries.

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