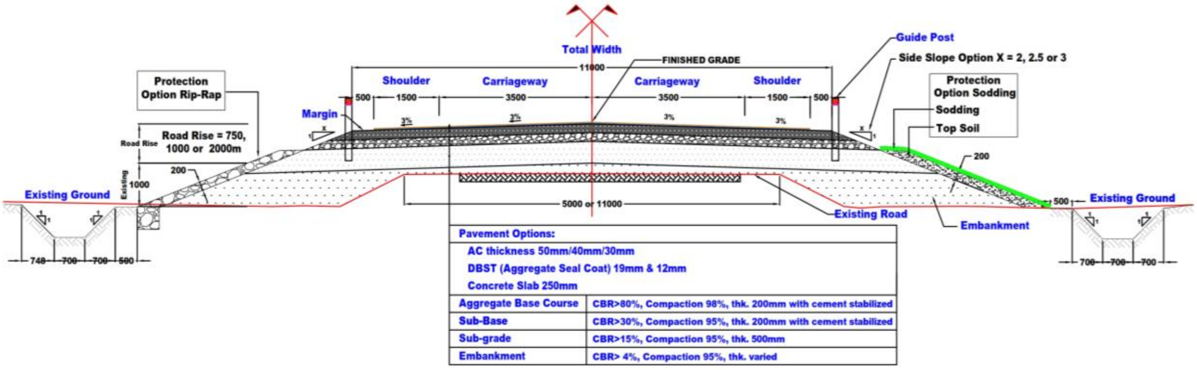
Kingdom of Cambodia
Nation Religion King

Ministry of Public Works and Transport

Non Mandatory Guidelines for Flood Proofing Roads



September 2015

Foreword

This document is intended as a reference document for road designers in view of facilitating the flood proofing of roads in Cambodia.

Drawing from international experience and documents on hydrology, climatology and engineering, it consist of proposed changes and adjustments to the Cambodia road design Standard, comprising five documents; Geometry Design, Pavement Design, Drainage Design, Bridge Design and Construction Specifications.

The proposed changes were developed in the course of the ADB financed Provincial Road Improvement Project – Climate Resilience Output. Full background, examples of application and explanations can be retrieved from the Road Design Standard Changes Report available at MPWT PMU3 and from the Flood Risk Management Interface Library (FRMI - DVD).

Comments and suggestions from the road designers, managers and practitioners are welcome and should be forwarded to MPWT – PMU3.

Contents

Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ADB	Asian Development Bank
DEM	Digital Elevation Model
FRMI	Flood Risk Management Interface
GTFM	Generalized Tropical Flood Model
IDF	Rainfall Intensity Duration and Frequency curves
MOWRAM	Ministry of Water Resources and Meteorology
MPWT	Ministry of Public Works and Transport
MRC	Mekong River Commission
PMU	Project Management Unit

1 Text changes: Part 1 – Geometry Standards

DRAFT ADJUSTMENTS TO

CAM PW 03-101-99 Road Design Standard – Part 1 – Geometry

The adjustments shall apply to the Flood Affected Areas indicated in the maps, Overview of Flood Affected Areas, following. Historical extreme flood elevation maps and 100Y flood depth maps are provided for general guidance only. Engineers must visit the site areas and enquire for local characteristics of floods and update flood information from the relevant authorities before deciding on a design elevation.

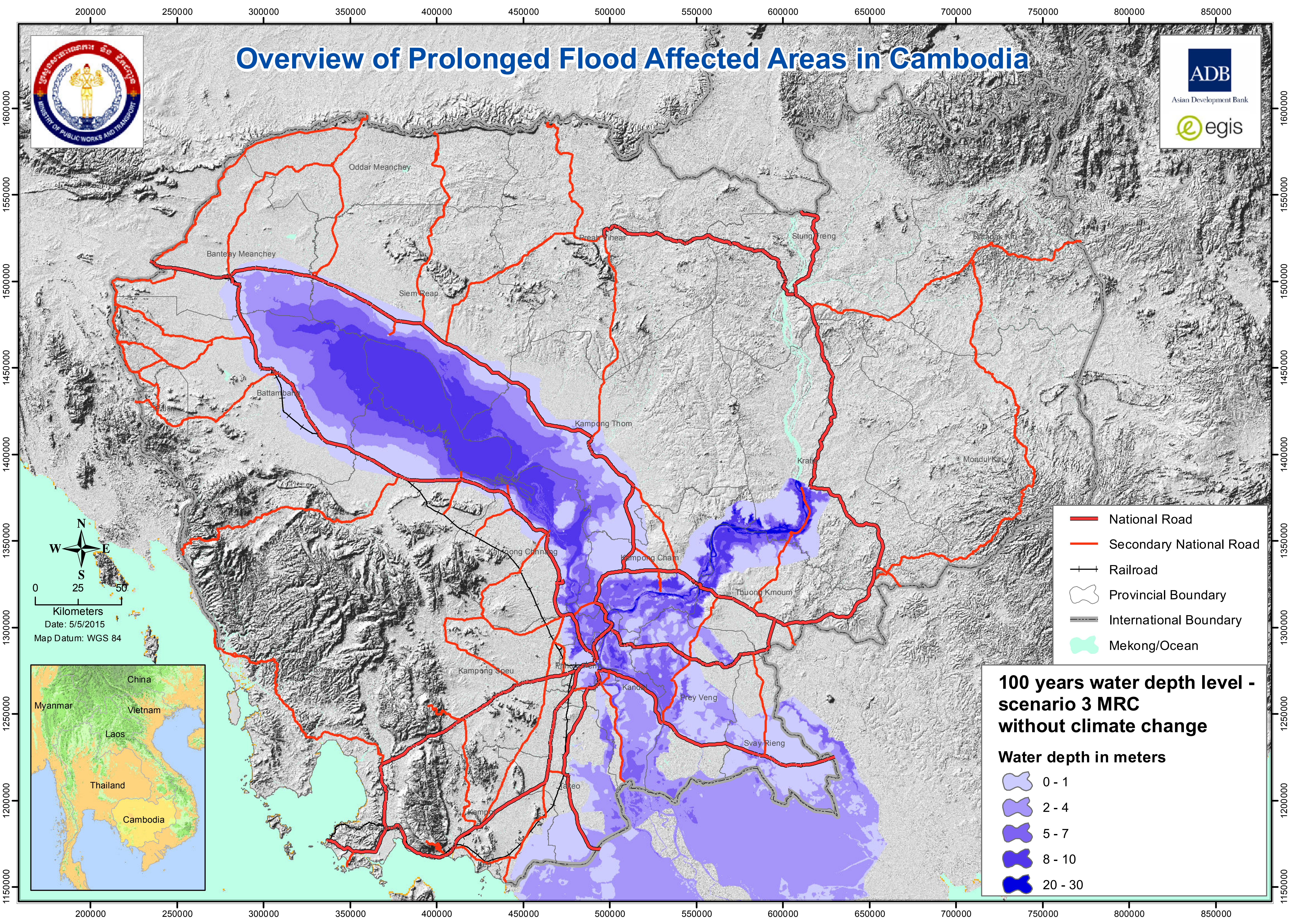
Insert new section:

1.9 Elevation of Roads on Embankments in Areas of Prolonged Flooding

The recommended crest level for National roads and Provincial roads should be based preferably on a flood frequency for example 100 year plus an additional 0.5 meters for factors such as wave runup. For district and local 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.

Reference

Mekong River Commission, Roads and Floods, MRC Technical Paper No. 35, 2011, p. 93.


Overview of Prolonged Flood Affected Areas in Cambodia
MINISTRY OF PUBLIC WORKS AND TRANSPORT
ADB
Asian Development Bank
egis
Oddar Meanchey
Banteay Meanchey
Siem Reap
Preah Vihear
Stung Treng
Ratanak Kiri
Battambang
Kampong Thom
Kratie
Mondul Kiri
Kampong Chhnang
Kampong Cham
Tbuong Kmoum
Kampong Speu
Kandal
Prey Veng
Svay Rieng
Takeo
National Road
Secondary National Road
Railroad
Provincial Boundary
International Boundary
Mekong/Ocean
100 years water depth level - scenario 3 MRC without climate change
Water depth in meters
0 - 1
2 - 4
5 - 7
8 - 10
20 - 30
N
S
W
E
0
25
50
Kilometers
Date: 5/5/2015
Map Datum: WGS 84
China
Myanmar
Vietnam
Laos
Thailand
Cambodia
200000
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300000
350000
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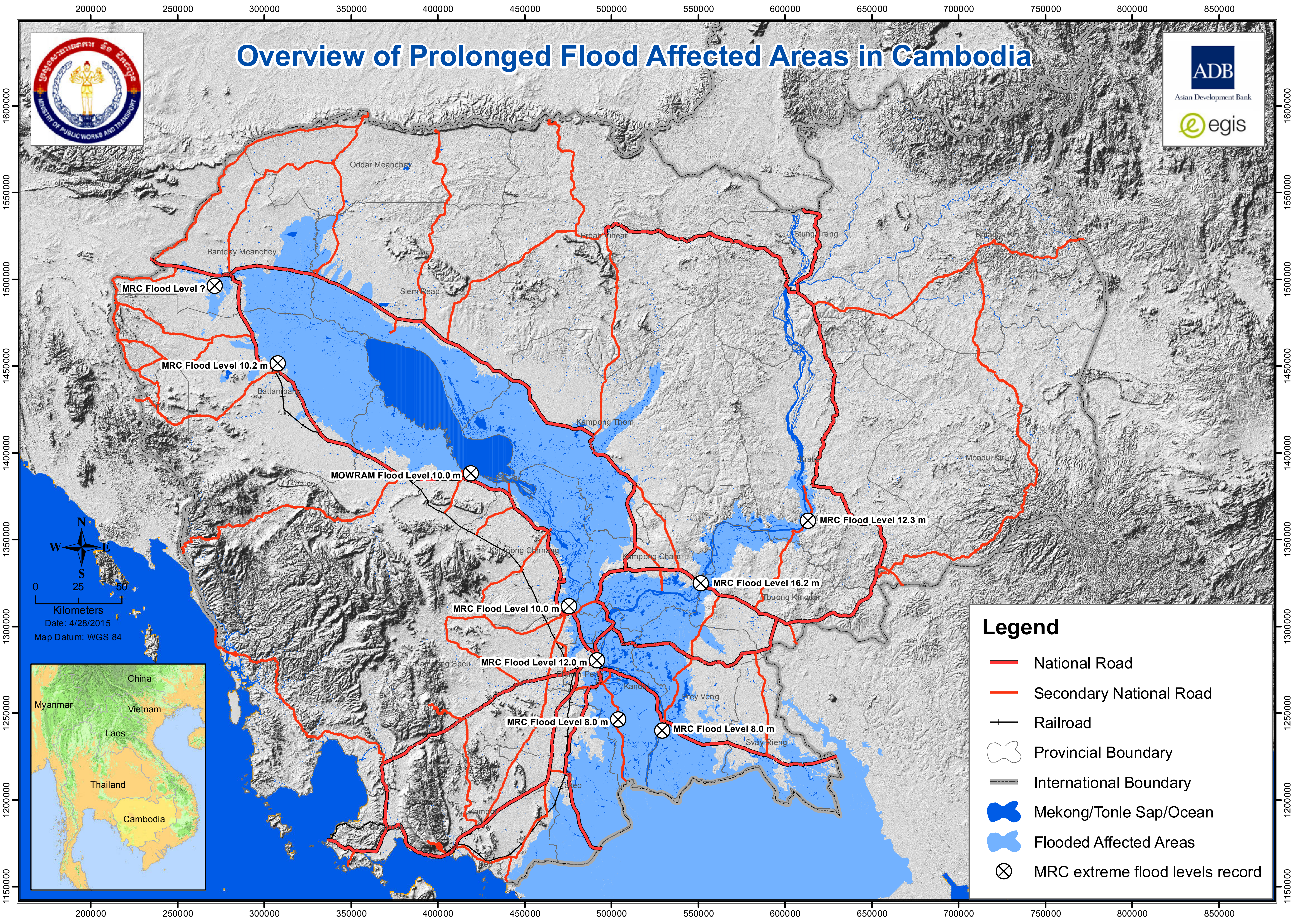
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Kratie
Mondul Kiri
Kampong Chhnang
Kampong Cham
Tbuong Khmum
Kampong Speu
Kandal
Prey Veng
Svay Rieng
Takeo
Kampot
MRC Flood Level ?
MRC Flood Level 10.2 m
MOWRAM Flood Level 10.0 m
MRC Flood Level 12.3 m
MRC Flood Level 16.2 m
MRC Flood Level 10.0 m
MRC Flood Level 12.0 m
MRC Flood Level 8.0 m
MRC Flood Level 8.0 m
N
W
E
S
0 25 50
Kilometers
Date: 4/28/2015
Map Datum: WGS 84
China
Myanmar
Vietnam
Laos
Thailand
Cambodia
Legend
National Road
Secondary National Road
Railroad
Provincial Boundary
International Boundary
Mekong/Tonle Sap/Ocean
Flooded Affected Areas
MRC extreme flood levels record

2 Text changes: Part 2 - Pavement Standards

Draft Adjustments To

CAM PW 03-102-99 Road Design Standard – Part 2 – Pavement

Section 2.7 DESIGN OF NEW FLEXIBLE PAVEMENTS

Insert KEY TO STRUCTURAL CATALOGUE (the second page following) between pages 34 and 35 *and replace the tables*.

In the Key, the traffic classes are defined by the equivalent numbers of standard axles (esa) in millions.

Section 2.4.3 (b) Compaction Moisture Content Used and Field Density Achieved

Insert after Table 2.4.4 the following:

NOTES

1. Values shown are ratios of the subgrade support at given densities and compaction moisture content, to the support provided by a subgrade material which is compacted to Maximum Dry Density at optimum moisture content (standard compaction) and immersed in water for 4 days prior to testing.

2. The ratios given above are indicative only and may vary considerably depending on the material concerned.

3. The values are derived from California Bearing Ratio Tests but it is considered that the trends shown would apply to other strength/stiffness parameters.

KEY TO STRUCTURAL CATALOGUE

Traffic classes
(10^6 esa)

T1 =	< 0.3
T2 =	0.3 - 0.7
T3 =	0.7 - 1.5
T4 =	1.5 - 3.0
T5 =	3.0 - 6.0
T6 =	6.0 - 10
T7 =	10 - 17
T8 =	17 - 30

Subgrade strength classes
(CBR%)

S1 =	2
S2 =	3 , 4
S3 =	5 - 7
S4 =	8 - 14
S5 =	15 - 29
S6 =	30+

Material Definitions

Double surface dressing

Flexible bituminous surface

Bituminous surface
(Usually a wearing course, WC, and a basecourse, BC)

Bituminous roadbase, RB

Granular roadbase, GB1 - GB3

Granular sub-base, GS

Granular capping layer or selected subgrade fill, GC

Cement or lime-stabilised roadbase 1, CB1

Cement or lime-stabilised roadbase 2, CB2

Cement or lime-stabilised sub-base, CS

CHART 1 GRANULAR ROADBASE / SURFACE DRESSING

	T1	T2	T3	T4	T5	T6	T7	T8
S1	SD 150 175 300	SD 150 225* 300	SD 200 200 300	SD 200 250* 300	SD 200 300* 300	SD 225 325* 300		
S2	SD 150 150 200	SD 150 200 200	SD 200 175 200	SD 200 225* 200	SD 200 275* 200	SD 225 300* 200		
S3	SD 150 200	SD 150 250	SD 200 225	SD 200 275*	SD 200 325*	SD 225 350*		
S4	SD 150 125	SD 150 175	SD 200 150	SD 200 200	SD 200 250	SD 225 275		
S5	SD 150 100	SD 150 100	SD 175 100	SD 200 125	SD 225 150	SD 250 175		
S6	SD 150	SD 150	SD 175	SD 200	SD 225	SD 250		

Note: 1 * Up to 100mm of sub-base may be substituted with selected fill provided the sub-base is not reduced to less than the roadbase thickness or 200mm whichever is the greater. The substitution ratio of sub-base to selected fill is 25mm : 32mm.

2 A cement or lime-stabilised sub-base may also be used.

CHART 2 COMPOSITE ROAD BASE (UNBOUND & CEMENTED) / SURFACE DRESSING

	T1	T2	T3	T4	T5	T6	T7	T8
S1	SD 150 150 300	SD 150 175 300	SD 150 200 300	SD 150 225 300	SD 150 275 300	SD 150 125 150 300	SD 150 125 175 300	
S2	SD 125 150 200	SD 150 150 200	SD 150 175 200	SD 150 200 200	SD 150 250 200	SD 150 125 125 200	SD 150 125 175 200	
S3	SD 125 150 100	SD 125 150 125	SD 150 150 125	SD 150 175 150	SD 150 225 150	SD 150 125 125 150	SD 150 125 150 150	
S4	SD 125 150	SD 125 175	SD 150 175	SD 150 200	SD 150 250	SD 150 125 125	SD 150 125 175	
S5	SD 125 125	SD 125 125	SD 150 125	SD 150 150	SD 150 175	SD 150 200	SD 150 250	
S6	SD 150	SD 150	SD 175	SD 200	SD 225	SD 125 150	SD 150 175	

Note: Sub-base to fill substitution not permitted.

CHART 3 GRANULAR ROADBASE / SEMI-STRUCTURAL SURFACE

	T1	T2	T3	T4	T5	T6	T7	T8
S1			50 175 200 300	50 175 250* 300	50 175 300* 300	50 200 325* 300		
S2			50 175 175 200	50 175 225* 200	50 175 275* 200	50 200 300* 200		
S3			50 175 225	50 175 275*	50 175 325*	50 200 350*		
S4			50 175 150	50 175 200	50 175 250	50 200 275*		
S5			50 150 100	50 175 125	50 175 150	50 200 175		
S6			50 150	50 175	50 200	50 225		

Note: 1 * Up to 100mm of sub-base may be substituted with selected fill provided the sub-base is not reduced to less than the roadbase thickness or 200mm whichever is the greater. The substitution ratio of sub-base to selected fill is 25mm : 32mm.

2 A cement or lime-stabilised sub-base may also be used.

CHART 4 COMPOSITE ROADBASE / SEMI - STRUCTURAL SURFACE

	T1	T2	T3	T4	T5	T6	T7	T8
S1			50 150 175 300	50 150 200 300	50 150 250 300	50 150 125 125 300	50 150 125 150 300	50 150 150 150 300
S2			50 150 175 200	50 150 200 200	50 150 225 200	50 150 125 125 200	50 150 125 150 200	50 150 150 150 200
S3			50 150 150 125	50 150 150 150	50 150 200 150	50 150 250 150	50 150 125 125 150	50 150 150 125 150
S4			50 150 150	50 150 175	50 150 225	50 150 250	50 150 125 150	50 150 150 150
S5			50 125 125	50 150 125	50 150 150	50 150 175	50 150 225	50 150 125 125
S6			50 150	50 175	50 200	50 100 150	50 150 150	50 150 150

Note: Sub-base to fill substitution not permitted.

CHART 5 GRANULAR ROADBASE / STRUCTURAL SURFACE

	T1	T2	T3	T4	T5	T6	T7	T8
S1						100 200 225 * 350	125 225 225 350	150 250 250 350
S2						100 200 225 * 200	125 225 225 200	150 250 250 200
S3						100 200 250	125 225 250	150 250 275
S4						100 200 175	125 225 175	150 250 175
S5						100 200 100	125 225 100	150 250 100
S6						100 200	125 225	150 250

Note: 1 * Up to 100mm of sub-base may be substituted with selected fill provided the sub-base is not reduced to less than the roadbase thickness or 200mm whichever is the greater. The substitution ratio of sub-base to selected fill is 25mm : 32mm.

2 A cement or lime-stabilised sub-base may also be used.

CHART 6 COMPOSITE ROADBASE / STRUCTURAL SURFACE

	T1	T2	T3	T4	T5	T6	T7	T8
S1						100 150 200 350	125 150 250 350	150 150 125 125 350
S2						100 150 200 200	125 150 250 200	150 150 125 125 200
S3						100 150 175 125	125 150 200 125	150 150 225 125
S4						100 150 175	125 150 200	150 150 225
S5						100 150 150	125 150 150	150 150 150
S6						100 100 150	125 100 150	150 100 150

Note: Sub-base to fill substitution not permitted.

CHART 7 BITUMINOUS ROADBASE / SEMI-STRUCTURAL SURFACE

	T1	T2	T3	T4	T5	T6	T7	T8
S1				SD 150 200 350	50 125 225* 350	50 150 225* 350	50 175 225* 350	50 200 250* 350
S2				SD 150 200 200	50 125 225* 200	50 150 225* 200	50 175 225* 200	50 200 250* 200
S3				SD 150 250	50 125 250	50 150 275*	50 175 275*	50 200 275*
S4				SD 150 175	50 125 200	50 150 200	50 175 200	50 200 200
S5				SD 150 125	50 125 125	50 150 125	50 175 125	50 200 125
S6				SD 150	50 125	50 150	50 175	50 200

Note: 1 * Up to 100mm of sub-base may be substituted with selected fill provided the sub-base is not reduced to less than the roadbase thickness or 200mm whichever is the greater. The substitution ratio of sub-base to selected fill is 25mm : 32mm.

2 A cement or lime-stabilised sub-base may also be used but see Section 7.7.2.

CHART 8 CEMENTED ROADBASE /' SURFACE DRESSING

	T1	T2	T3	T4	T5	T6	T7	T8
S1	SD 150 150 350	SD 150 175 350	SD 175 175 350	SD 200 200 350	SD 200 225 350	SD 200 250 350		
S2	SD 150 150 225	SD 150 175 225	SD 175 175 225	SD 200 175 225	SD 200 225 225	SD 200 275 225		
S3	SD 150 150 125	SD 150 150 125	SD 175 150 125	SD 200 175 125	SD 200 200 125	SD 200 225 125		
S4	SD 150 150	SD 150 150	SD 175 150	SD 200 100 100	SD 200 150 100	SD 200 200 100		
S5	SD 150 100	SD 150 100	SD 175 100	SD 175 150	SD 200 175	SD 200 200		
S6	SD 150	SD 150	SD 175	SD 200	SD 225	SD 250		

Note: A granular sub-base may also be used.

3 Text changes: Part 3 – Drainage Standard

DRAFT ADJUSTMENTS TO

CAM PW 03-103-99 Road Design Standard – Part 3 – Drainage

Section 3.1.1 General

Insert additional last paragraph:

The document uses hydrology for water catchments clear of area-wide flooding, and for flow in one direction only. Where area-wide flooding is possible, methods other than described in the document will be applicable.

Section 3.2.2 RATIONAL METHOD

Insert two line spaces after the line beginning: A =

Note 2. *Replace* 25 km2 (2500 ha)

By 10 km2 (1000 ha)

Note 3. *Replace* 25 km2

By 10 km2

Note 4. *Replace* Appendix 1

By Appendix A

Insert Section 3.2.4:

3.2.4 Catchments of 10 to 200 Sq.Km.

Overview of Method

The following flood estimation model is advised for catchment areas larger than 10km^2. The model has been introduced by Fiddes and Watkins (1984) and is generally known under the name ***'Generalised Tropical Flood Model' (GTFM).***

It contains elements of the TRRL Method developed for Eastern Africa (Fiddes,1977) and the ORSTOM Method (Rodier and Auvray, 1965), but has been adjusted to fit conditions in most tropical environments. The model is applicable for catchment areas up to 200 km^2.

The fundamental idea of the model is to estimate the average flood flow during a storm event of a specific time period on the basis of rainfall data, runoff coefficients and catchment geometry. Factors are then applied to estimate peak flow values.

The peak flow Q_p is calculated from the following formula:

(ECC- 3-3)

$$Q_p = \frac{C_A \times P \times A \times F \times ARF}{360 \times T_B}$$

Where
Q_p : is peak discharge in m^3/s.
C_A : is the combined percentage runoff coefficient.
P : is the design storm rainfall (i.e. total rainfall in mm over the base time of the hydrograph).
A : is the catchment area in km^2.
F : is the peak flow factor to convert the average flow generated by the model to peak flow, see TCC-8
ARF : is the area reduction factor (as defined below).
T_B : is the hydrograph base time in hours.

The values of the parameters required for the Generalised Tropical Flood Model originate from Fiddes and Watkins (1984).

Percentage runoff coefficient 'C_A'

The percentage runoff coefficient C_A is expressed by the formula:

(ECC-3-4)

$$C_A = C_S \times C_W \times C_L$$

Where C_S : is the standard value of contributing runoff coefficient, from Table TCC-1, and is dependent on Soil Class L from Table TCC-2 and Slope Class S, from Table TCC-3.

C_W : is the catchment wetness factor which is dependent on soil moisture recharge (SMR) and which is tabulated in Table TCC-4. Because Cambodia is within a wet zone (SMR > 75 mm) the default value is 1.00.

C_L : is the land use factor from Table TCC-5.

Base Time 'T_B'

The hydrograph base time can be thought of as being made up of three components: the storm duration, the time taken for the surface runoff to drain into the stream system; and the flow time down to the culvert or bridge site. Base time 'T_B' is expressed by the formula:

(ECC-3-5)

$$T_B = \frac{C \times A^{0.5}}{S^2} + T_S$$

Where C : is a constant, which is 30 for humid zone catchments.

A : is the catchment area in km^2 .

S : is the Slope Class 'S '.

T_S : is the surface cover flow time from Table TCC-6

Design Rainfall

The GTFM does not use IDF curves, but it requires basic information about what is called the 'Rainfall Ratio'. This is a value between 0 and 1, which expresses the percentage of a 24 hour rainfall event of a certain return period (2, 5, 10 or 50 years - depending on the design period) which can be recorded during the actual design storm duration, which is usually shorter than 24 hours. The Rainfall Ratio relates to the relevant IDF - Curves via 2 parameters, n and b, which determine the shape of the IDF curve.

The Road Design Standards, Part 3 Drainage for Cambodia provides 3 IDF curves for Battambang, Kompong Thom and Pursat. The curves have been analysed in view of the calculated Rainfall Ratios. Rainfall Ratios for periods shorter than 1 hour have been increased in order to add a safety margin in view of climate change.

The design storm P is obtained by multiplying the 24 hour rainfall depth of the nearest appropriate rainfall station and the relevant return period (2, 5, 25, 50 years) with the Rainfall Ratio provided by the graph in Figure FCC - 1.

Area reduction factor '*ARF*'

The area reduction factor (*ARF*) is introduced to account for the spatial variability of point rainfall over the catchment.In simple terms the average rainfall at any instant for a catchment will be less than the rainfall measured at a single point (rain gauge) in the catchment, and the difference increases with increasing size of catchment.

The relationship adopted for '*ARF'* is suitable for convective rainfall has been taken from Fiddes and Watkins (1984)

(ECC-3-6)

$$\mathrm{ARF} = 1 - 0.04\, T^{-0.33} A^{0.50}$$

Where T : is duration in hours

A : area in km^2

This equation applies for storms of up to 8 hours duration. For longer durations on large catchments the *T* = 8 value is adopted. The values proposed for design are presented in Table TCC-7.

Summary of Design Method

1. Estimate catchment area and channel slope from maps or Digital Elevation Model (DEM).
2. From site visit establish catchment type and estimate Surface Cover Flow Time T_S from TableTCC-6.
3. From site inspection and desk study establish soil permeability class and slope class from Table TCC-2 and Table TCC-3 and estimate Basic Runoff Coefficient C_S for humid catchments from Table TCC-1.
4. Estimate land use C_L , and catchment wetness, C_W , factors from Tables TCC-4 and TCC-5
5. Calculate runoff coefficient, C_A, , from equation (ECC-3-4).
6. Estimate Base Time, T_B, from equation (ECC-3-5).
7. Multiply max. 24 hour rainfall value of relevant return period (depending on design period of the structure to design) and relevant rainfall station with Rainfall Ratio at Base Time T_B, . The Rainfall Ration is obtained from Figure FCC-1.
8. Calculate the average flow Q_{av} during the base Time

$$Q_{av} = \frac{C_A \times P \times A \times ARF}{360 \times T_B}$$

9. Calculate the design flow by multiplying with the Peak Factor F, according to Table TCC-8.
10. The above procedure is for catchment areas of average shape with a length to width ratio (L/W) between 2 and 6. For fan shaped catchments (L/W =1) the design flood should be increased by 50%. For very long basins it should be halved.
11. Add base flow, if appropriate.

Application Example

Calculate 10 year flood runoff for 20 km^2 catchment in Kampong Chhnang.

Area, from map or DEM and field visit	A = 20 km^2
Agricultural land use, cultivated, from satellite imagery and field visit	Ts = 2 h, from Table TCC-6
Fairly permeable soil, from soil map and field visit	L = 4, from Table TCC-2
Land slope 3%, from map or DEM	S = 3, from Table TCC-3
C_S	25 %, from Table TCC-1
C_L	1.5 from Table TCC-5
C_W	1, standard value for Cambodia, from Table TCC-4
C_A	25% x 1.5 = 37.5 %
Base Time T_B	[(30 x $20^{0.5}$)/9] + 2 = 14.9 + 2 = 16.9 hour base time
10 year, 24 h rainfall for Kampong Chhnang, from MOWRAM data or other sources. The value is used as a example only. For design application specific data research has to be carried out and the max. 24 h rainfall might have to be calculated used the Gumbel Distribution.	128 mm 16.9 h Rainfall Ratio from Figure FCC-1 = 0.96 Design Rainfall = 0.96 x 128 = 123 mm Area Reduction Factor from Table TCC-7 = 0.91 Design Rainfall = 123 x 0.91 = 112 mm
Calculation of Q_{av}	(37.5 x 112 x 20)/(360 x 16.9) = 13.8 m^3/s
Peak Flow Factor from Table TCC-8, no base flow and normal catchment area shape, thus design flow	**13.8 x 2.5 = 34.5 m^3/s**

Table TCC-1 Basic runoff coefficient for humid catchments (CS, in %)

Soil class (*I*)	**1**	**2**	**3**	**4**	**5**
Slope class (*S*)					
1	48	36	23	11	0
2	55	43	30	18	6
3	62	50	37	25	13
4	69	57	45	32	20
5	76	64	52	39	27
6	83	71	59	46	34

Note: Values in the above table are based on the relationship:
PRO = 53 - 12 I + 8 S, which applies to humid catchments

Table TCC-2 Soil Permeability Classification

Soil class (*I*)	**Description**
1	Impermeable - rock surface.
2	Very low permeability. Clay soils with high swelling potential; shallow soils over largely impermeable layer, very high water table.
3	Low permeability. Drainage slightly impeded when soil fully wetted.
4	Fairly permeability. Deep soils of relatively high infiltration rate when wetted.
5	Very permeable. Soils with very high infiltration rates such as sands, gravels and aggregated clays.

Table TCC-3 Catchment slope classification

Slope Class (*S*)	**Average catchment slope (%)**
1	0 - 0.2
2	0.2 - 1.0
3	1.0 - 4.0
4	4.0 - 10.0
5	10.0 - 20.0
6	> 20.0

Table TCC-4 Catchment wetness factor (CW)

	Catchment wetness factor (C_W)	
Rainfall zone	**Perennial streams**	**Ephemeral streams**
Semi-arid zone	1.00	1.00
Wet zone (SMR > 75 mm)	1.00	1.00
Dry zone (SMR < 75 mm)	0.75	0.50

Table TCC-5 Land use factor (C_L)

Catchment type	**C_L (h)**
Semi arid zone	1.00
Largely bare soil (humid zone)	1.50
Intensive cultivation	1.50
Grass cover	1.00
Dense vegetation (particularly in valleys)	0.50
Forest (a) shallow impermeable soils	1.00
(b) very steep (S_5, S_6) permeable soils	0.67
(c) other	0.33

Table TCC-6 Surface cover flow time (TS)

Catchment type	**T_S (h)**
Arid zone	0.0
Poor pasture / scrub (large bare soil patches)	0.0
Good pasture	1.0
Cultivated land (down to river bank)	2.0
Forest (a) shallow impermeable soils	2.0
(b) very steep (S_5, S_6) permeable soils	2.0
(c) other	12.0
Swamp filled valleys	20.0

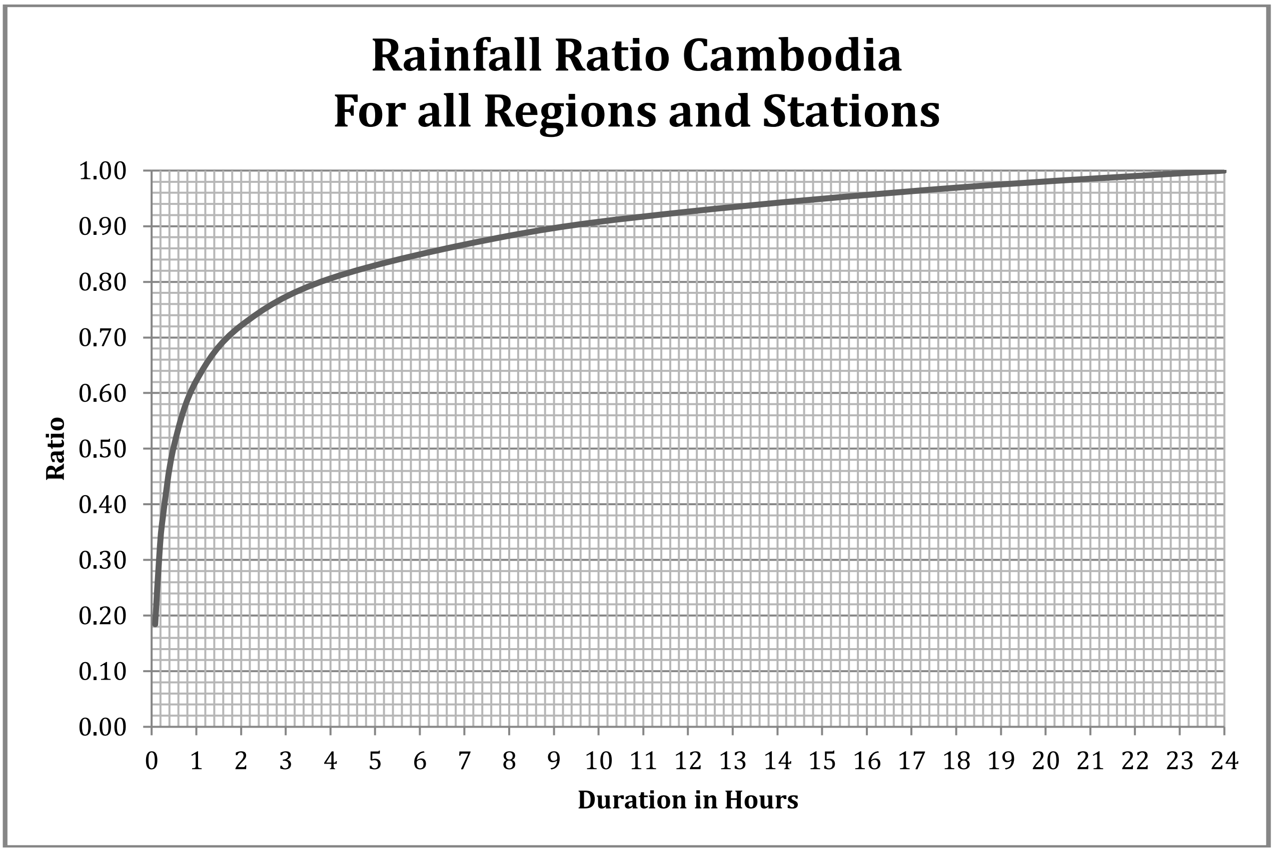
Table TCC-7 Area Reduction Factors

Storm Duration '*T*'	**Catchment Area '*A* ' (km^2)**										
	1	**2**	**3**	**5**	**10**	**25**	**50**	**100**	**250**	**500**	**1000**
8 h	0.98	0.97	0.97	0.96	0.94	0.90	0.86	0.80	0.68	0.55	0.37
4 h	0.97	0.96	0.96	0.94	0.92	0.87	0.82	0.75	0.60	0.44	0.20
2 h	0.97	0.96	0.95	0.93	0.90	0.84	0.78	0.68	0.50	0.29	
1 h	0.96	0.94	0.93	0.91	0.87	0.80	0.72	0.60	0.37	0.11	
30 min	0.95	0.93	0.91	0.89	0.84	0.75	0.64	0.50	0.20		
15 min	0.94	0.91	0.89	0.86	0.80	0.68	0.55	0.37			
10 min	0.93	0.90	0.87	0.84	0.77	0.64	0.49	0.27			
5 min	0.91	0.87	0.84	0.80	0.71	0.54	0.35	0.08			

Table TCC- 8 Peak Flow Factors (F)

Type of catchment	Peak flow factor (*F*)
Arid zone	3.0
Humid zone	2.5
Forest	1.7

Figure FCC-1 Rainfall Ratio



RR = 0.1426ln(duration in h) + 0.5814

APPENDIX A

Rainfall Intensity – Duration – Frequency

Replace the three tables in the Appendix
By the six following tables

Table A.1 Rainfall Intensity – Duration – Frequency at Battambang

Battambang Rainfall Intensity (mm / hr.)					
Time (hours)	Frequency (Return Period) (Years)				
	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.
0.5	90.6	107.7	123.9	144.7	160.6
1	54.6	64.1	73.1	84.6	93.4
3	23.1	26.8	30.2	34.7	38.1
6	13.1	15.1	17.0	19.4	21.2
12	7.3	8.4	9.4	10.7	11.7
18	5.2	5.9	6.6	7.5	8.2

Battambang Rainfall Intensity (mm / hr.)					
Time (hours)	Frequency (Return Period) (Years)				
	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.
24	4.2	4.7	5.3	6.0	6.5
48	2.6	3.0	3.3	3.7	4.0
72	2.0	2.3	2.5	2.8	3.0
96	1.7	1.9	2.1	2.4	2.6

Table A.2 Rainfall Intensity – Duration – Frequency at Pochentong (Phnom Penh Airport)

Pochentong Rainfall Intensity (mm / hr.)					
Time (hours)	Frequency (Return Period) (Years)				
	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.
0.5	98.6	111.0	122.7	137.7	149.2
1	60.9	68.6	75.8	85.1	92.2
3	26.5	29.8	32.9	36.9	40.0
6	15.2	17.1	18.9	21.2	22.9
12	8.6	9.6	10.6	11.9	12.9
18	6.1	6.8	7.6	8.5	9.2
24	4.9	5.5	6.1	6.8	7.3
48	2.9	3.2	3.6	4.0	4.3
72	2.2	2.5	2.8	3.1	3.4
96	2.0	2.3	2.5	2.9	3.2

Table A.3 Rainfall Intensity – Duration – Frequency at Pursat

Pursat Rainfall Intensity (mm / hr.)					
Time (hours)	Frequency (Return Period) (Years)				
	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.
0.5	91.3	106.4	120.7	139.0	153.1
1	56.4	65.7	74.6	85.9	94.6
3	24.5	28.5	32.4	37.3	41.1
6	14.0	16.4	18.6	21.4	23.5
12	7.9	9.2	10.5	12.1	13.3
18	5.6	6.6	7.4	8.6	9.4
24	4.5	5.3	6.0	6.9	7.6
48	3.1	3.6	4.1	4.8	5.3
72	2.4	2.7	3.1	3.5	3.9
96	2.0	2.3	2.6	3.0	3.3

Table A.4 Rainfall Intensity – Duration – Frequency at Kampong Thom

Kampong Thom Rainfall Intensity (mm / hr.)					
Time (hours)	Frequency (Return Period) (Years)				
	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.
0.5	93.4	100.5	107.3	116.0	122.6
1	59.1	64.6	69.8	76.5	81.6
3	26.2	29.1	31.8	35.3	37.9
6	15.2	16.9	18.6	20.7	22.3
12	8.6	9.7	10.6	11.9	12.9
18	6.1	6.9	7.6	8.5	9.2
24	4.9	5.5	6.0	6.7	7.3

Kampong Thom Rainfall Intensity (mm / hr.)					
Time (hours)	Frequency (Return Period) (Years)				
	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.
48	3.2	3.7	4.1	4.7	5.1
72	2.5	2.8	3.2	3.6	3.9
96	2.6	3.0	3.3	3.7	4.1

Table A.5 Rainfall Intensity – Duration – Frequency at Koh Kong

Koh Kong Rainfall Intensity (mm / hr.)					
Time (hours)	Frequency (Return Period) (Years)				
	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.
0.5	193.0	228.3	261.9	305.0	338.0
1	119.2	141.1	161.8	188.5	208.8
3	51.8	61.2	70.2	81.8	90.7
6	29.7	35.1	40.3	46.9	52.0
12	16.7	19.8	22.7	26.4	29.3
18	11.9	14.1	16.1	18.8	20.8
24	9.3	10.9	12.4	14.2	15.7
48	6.5	7.4	8.3	9.5	10.3
72	5.2	5.9	6.5	7.3	8.0
96	4.5	5.1	5.6	6.3	6.8

Table A.6 Rainfall Intensity – Duration – Frequency at Siemreap

Siemreap Rainfall Intensity (mm / hr.)					
Time (hours)	Frequency (Return Period) (Years)				
	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.
0.5	128.5	146.7	164.0	186.2	203.2
1	79.1	90.3	101.0	114.6	125.1
3	32.7	37.4	41.8	47.4	51.7
6	18.0	20.6	23.0	26.1	28.5
12	9.8	11.2	12.5	14.2	15.5
18	6.8	7.8	8.7	9.9	10.8
24	5.3	6.0	6.7	7.5	8.2
48	3.2	3.6	4.0	4.5	4.9
72	2.4	2.7	3.0	3.4	3.6
96	2.0	2.3	2.5	2.8	3.0

4 Text Changes: Bridge Standards

DRAFT ADJUSTMENTS TO

CAM PW 04-102-99 Bridge Design Standard – Amendments to the Base Document and Amendments to the Commentary

Replace Table 2.9.2 (a) *By*:

Table 2.9.2 (a) Shade Air Temperatures

CLIMATIC REGION[1]	SHADE AIR TEMPERATURES (^{0}C)	
	Maximum	Minimum
Coastal[2]	43	11
Flat Land and High Land [3]	45	8

Notes:

1) For the extent of climatic regions refer to Figure 2.9.2
2) For locations less than 20 km from the sea coast the maximum temperature may be reduced by 2 ^{0}C and the minimum temperature increased by 3 ^{0}C
3) For locations with altitude greater than 1000 m above the sea level the maximum temperature shall be reduced by 10 ^{0} C and the minimum temperature shall be reduced by 5 ^{0}C.

C2.9.2 VARIATION IN AVERAGE BRIDGE TEMPERATURE

Insert the following paragraph at the end:

Recent climate change modeling in Cambodia carried out by The Ministry of Environment for the UNFCC 2nd National Communication indicates that temperatures will increase in the future and that this increase is likely to be a maximum of 3.2 degrees Celsius for a high CO2 scenario. Therefore the historical maximum shade air temperatures for bridge design have been increased by 3 degrees C.

5 Text changes: Construction Specifications

DRAFT ADJUSTMENTS TO

Cambodia, Ministry of Public Works and Transport, Construction Specification, 2003

The adjustments shall apply to the indicated high risk road segments in the attached maps for different types of floods. Most critical flood type for each road segment shall prevail.

This section to be added as an addendum since the existing text still applies for non affected roads.

2.6 EMBANKMENT

2.6.2 MATERIALS

Replace the third paragraph by:

These CBR values shall be for samples compacted to 97% of the maximum dry density determined by AASHTO T 99, or in the case of subgrade selected materials, 100%. All test samples shall be soaked in accordance with the requirements of AASHTO T 193. Further, the period of soaking shall be not less than 7 days. Materials with a CBR value less than 3 shall be considered unsuitable.

In the sixth paragraph, *replace* 4-day soak *by* 7-day soak

2.6.3.2 Placing Embankment

(a) General

Insert additional paragraph:

The side slopes of embankments shall not be steeper than 1 vertical on 2 horizontal for embankment covered with rip rap and 1 vertical on 2.5 horizontal for those without rip rap cover.

2.6.3.3 Compaction of Embankments Other Than Rock Embankments

(a) *Replace the first sentence by:*

Before compaction, each layer shall be processed as required to bring the moisture content uniformly throughout the layer to within 1 percent to 4 percent below the optimum moisture content as determined in AASHTO T 99.

(c) *Replace* 90% of the maximum dry density of the material as determined by AASHTO test method T 180 *by* 97% of the maximum dry density of the material as determined by AASHTO test method T 99.

(g) *Replace* depth of 150 mm *by* depth of 300 mm

Replace 95% of the maximum dry density determined by AASHTO test method T 180

by 100% of the maximum dry density determined by AASHTO test method T 99

3.1 SUB-BASE

3.1.1 DESCRIPTION

Insert additional paragraph:

Except where otherwise specified, sub-base on embankment shall be constructed to the full width of the subgrade surface.

3.1.2.2 Soil Aggregate Mixture

Replace after 4 days soaking *by* after 7 days soaking

3.3 AGGREGATE BASE

3.3.1 DESCRIPTION

Insert additional paragraph:

Except where otherwise specified, aggregate base on embankment shall be constructed to the full width of the road including the shoulders.

3.3.2.1 Base Course Materials

In the 1st paragraph, 1st sentence:

Replace grading limits A, B or C *by* grading limits B or C

Replace Table 3.1-2 *by* Table 3.1-1

After the 1st sentence, *insert:*

The portion that passes the 0.075 mm sieve shall be not less than 8 percent and not more than 15 percent.

In the 2nd paragraph, *after* plasticity index:

Replace of not more than 6 percent

by of not more than 3 percent

Replace after 4 days soaking

by after 7 days soaking

3.6 SHOULDERS

Replace the contents of the section by:

The shoulders shall be constructed as the pavement structure. The shoulders shall be sealed with an approved bituminous treatment up to the edges of the embankment or, where guard rail is constructed, up to the line of guard rail. Each part of the bituminous shoulder treatment which is the same as for the pavement shall be applied simultaneously with the pavement treatment.

4. BITUMINOUS WORKS

4.1 BITUMINOUS PRIME COAT

4.1.3.4 Preparation of Surface

Insert additional paragraph:

Priming of aggregate base shall be prohibited when the moisture content of the aggregate base exceeds 70 percent of the optimum moisture content determined by AASHTO T 180.

6. DRAINAGE AND PROTECTION WORKS

6.2 RIP RAP AND CONCRETE SLOPE PROTECTION

6.2.1 DESCRIPTION

Insert additional paragraph:

Rip Rap protection is recommended to cover the full surface of embankments of roads at high risks of flash floods and of low land floods.

6.2.3.4 PLACING RIP RAP

Insert additional paragraph:

For full coverage of embankments of roads at high risk of flash floods and of low land floods, a minimum thickness of 200 mm shall be used.

6.6 GRASSING OF SLOPES, and 6.7 TOPSOIL

Insert additional section:

6.6a & 6.7a TOPSOIL & GRASSING COMBINED

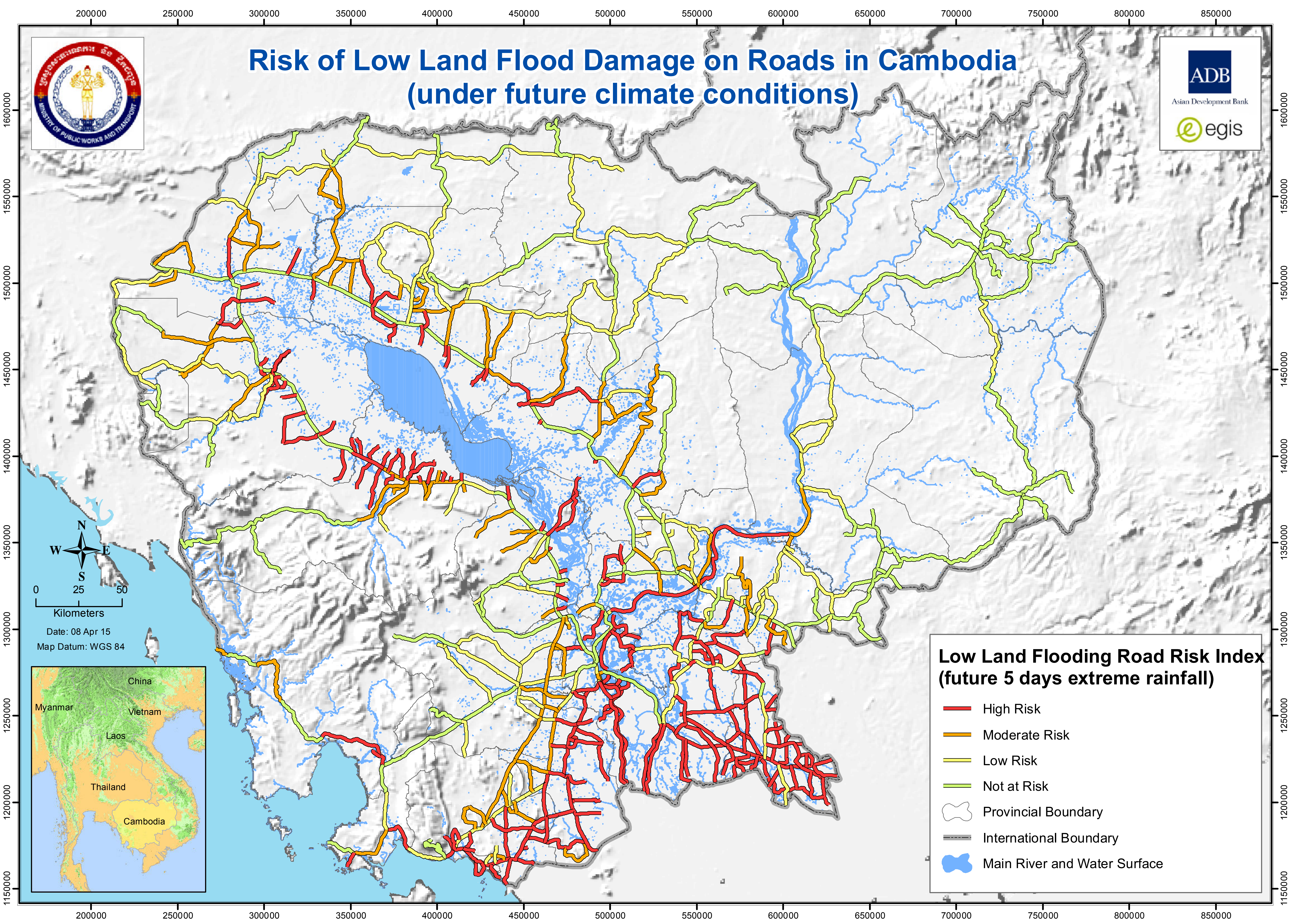
A layer of soil shall be constructed over the completed and trimmed side slopes of embankments. A complete dense cover of growing grass shall be established on the soil covering the side slopes. In accordance with an approved bio-engineering specification to include progressive outcomes: the layer of soil shall be constructed; and the grass shall be specified and established, resisting erosion of the soil and withstanding periods of inundation.

Insert additional section:

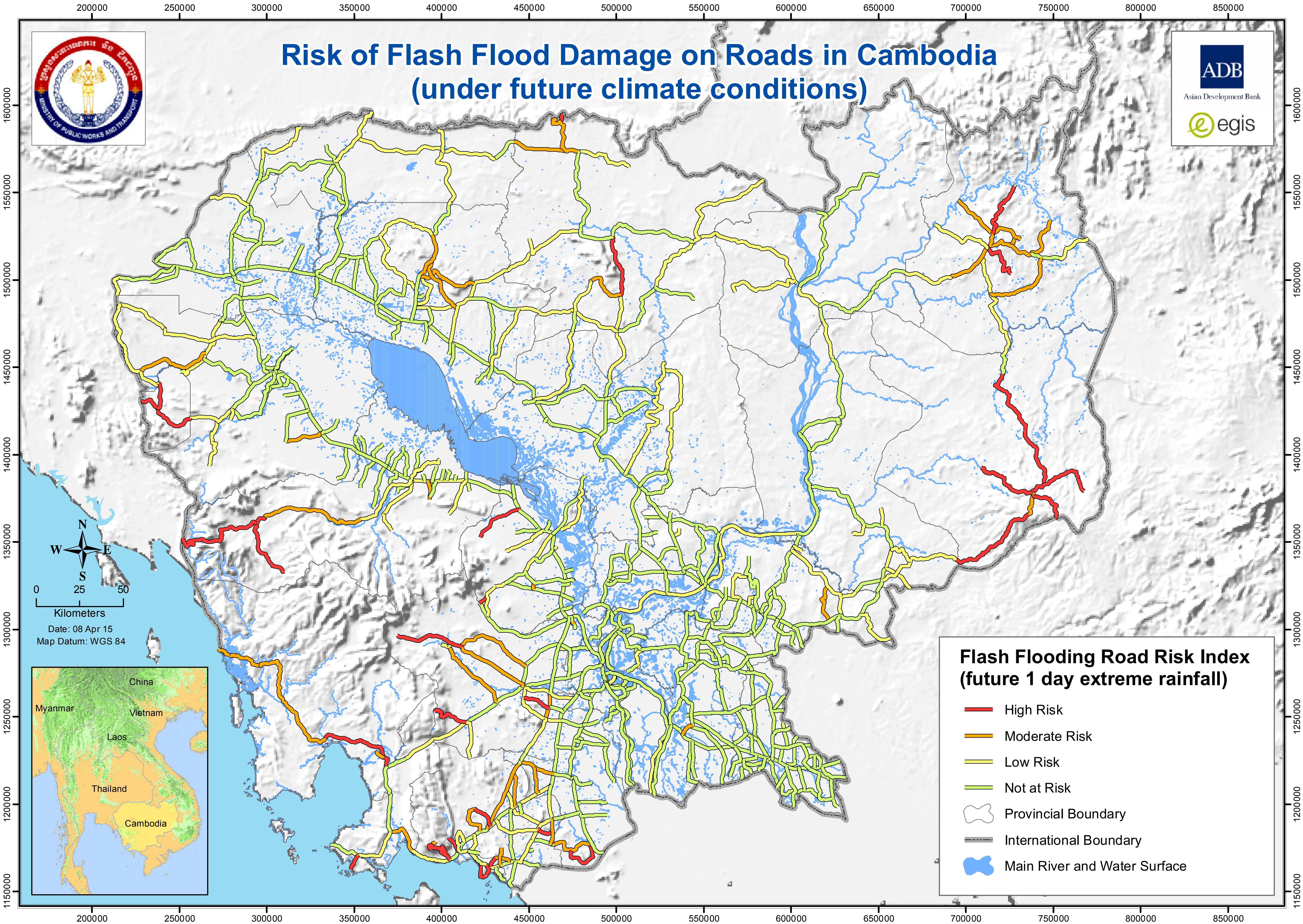
6.10 HEDGE ON EMBANKMENT SLOPES

Where the side of an embankment is subject to wave action, a hedge of shrubs in accordance with an approved bio-engineering specification shall be established growing on a line 1.2 m in elevation below the top edge of the roadway.

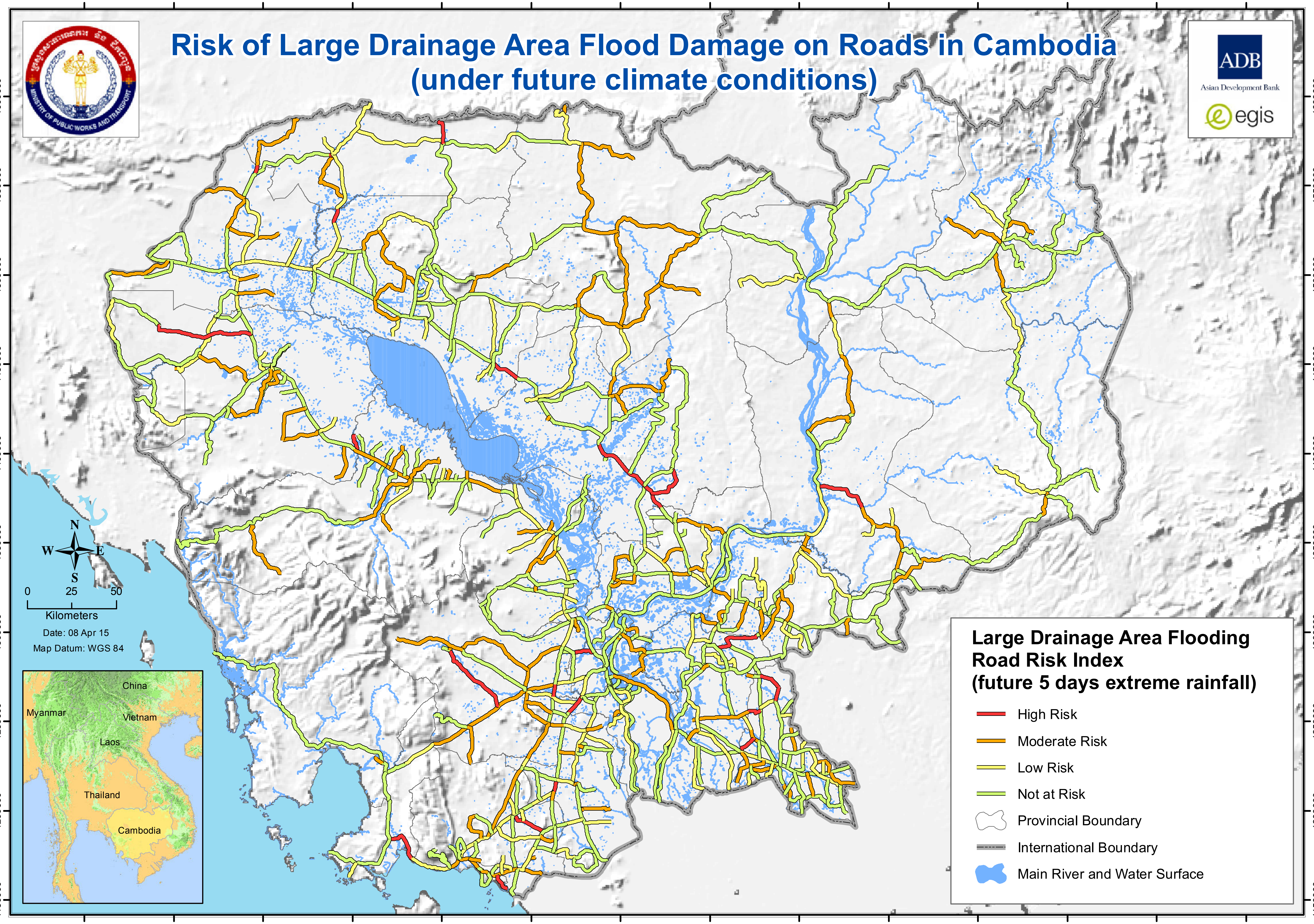
Risk of Low Land Flood Damage on Roads in Cambodia (under future climate conditions)



Risk of Flash Flood Damage on Roads in Cambodia (under future climate conditions)



Risk of Large Drainage Area Flood Damage on Roads in Cambodia (under future climate conditions)



Risk of Buildup Area Flood Damage on Roads in Cambodia (under future climate conditions)