Status and Trends : Geomorphology, Sediment and Water Quality

Present by: Dr. Bounheng Southichak (Laos)
Mr. Toch Sophon (Cambodia)

1

Introduction

- The change in geomorphology, sediment and water quality will affect the overall change of nature and functioning of the river ecosystem, which will then affect the livelihood, economics and environmental sustainability of the Mekong basin.
- Once a development is "in place", the flow, sediment and other characteristics will be different upstream and downstream of each development and these need to be addressed.
- Therefore, the information of Geomorphology, Sediment and Water Quality from the past to the present are very important to provide the inputs required for identification, population and calibration of sediment, geomorphology and water Quality indicators in DRIFT.

2

Objectives

The objective of the status and trends assessments is to:

Past

Present

Future

- describe the past ecological status of the Lower Mekong River – both as a reference point from which to make predictions and to establish trends that can be used later on in the analyses;
- describe the present ecological status of the Lower Mekong River;
- In the future, this will also be used to assess ecological status of the Lower Mekong River in the absence of the water-resource developments included in scenarios.

3

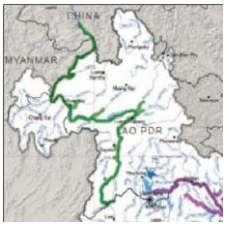
Geomorphology along the Lower Mekong River

Zone	Geomorphology
(UMB) & 1	Single bedrock channel-sediment throughput with little storage
2	Alluvial-braided with bars; sediment storage & reworking with high sediment input from tributaries;
3	Anastomosed bedrock channels, storage & reworking
4	Meandering alluvial channels, floodplain & Tonle Sap system
5	Deltaic alluvial channels & distributaries

4

Geomorphology in Zone 1: China Border to Vientiane

Zone	Location	Representative Zones	Zone characteristics
Zone 1	Chinese border to 5-km upstream of Vientiane	Single bedrock channel, with deep pools, bedrock benches	Gradient: 0.0003
			Channel width: 200 m to 2000 m
			Reach length: 250 km
			Low flow depth: c. 10 m
			Seasonal stage change: 20 m



Zone 1

5

Rocky reef scatters along the Mekong River in Northern Laos

6

Local villagers dry their weed crop on the sandy island along the Mekong river

7

Bedrock and sandy insets along the Mekong river Bank in Pak Beng, Laos

8

Sandy and bedrock on the bank of the Mekong river

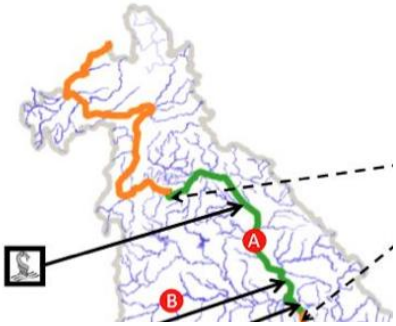
9

High Sediment and Total Suspended Solid (TSS) can be observed in Zone 1

10

Geomorphology in Zone 2: Vientiane to Pakse

Zone 2	Vientiane to Mukdahan	Alluvial braided channel, braid bar system	Gradient: 0.0001
			Channel width: 800 m to 1300 m
			Reach length: 100 km
			Low flow depth: c. 3 m
			Seasonal stage change: 13 m
Zone 2b	Mukdahan to Mun confluence near Pakse	Alluvial lozenge-bar channel,	Gradient: 0.00006
			Channel width: less than 2000m
			Reach length: 400 km
			Low flow depth: less than 5 m
			Seasonal stage change: 14 m



Zone 2

The reach of the Mekong River from Nong Khai to Pakse is characterised by the inflow of water and sediment from the 'left bank' tributaries in Northern Lao, with proportionately less water and sediment derived from the western (right bank) tributaries in Thailand.

The sedimentation in Pakse is lower than in the northern Laos

Aerial view of a newly developing extraction site on a large convex sand bar, at low flow, downstream of Vientiane

Sand deposit and annual fluctuation along the river bank of Mekong River

13

Wider River and lower slope in the Mekong river in Southern Laos

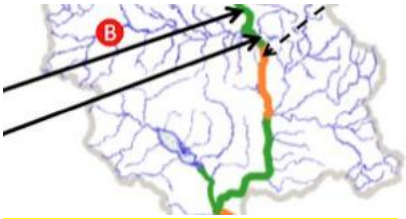
14

Sand deposit on the river bank

15

Zone 3: From Pakse to Stung Treng

Zone 3a	Pakse to Muang Khong	Anastomosed bedrock channels; 4000 islands reach	Gradient: 0.00006 Channel width: 750 to 5000 m Reach length: 150 km Low flow depth: variable Seasonal stage change: 15 m
Zone 3b	Muang Kong to Stung Treng	Anastomosed alluvial channels, secondary channels, i.e. near Stung Treng	Gradient: 0.0005 Channel width: less than 15000 m Reach length: 200 km Low flow depth: c. 8 m Seasonal stage change: 9 m



Zone 3

The geomorphic attributes of the Mekong River in this reach include the inflow of the very large 3S River catchment (Srepok, Sesan Sekong), and the transition of the river from a partially bedrock controlled channel to a floodplain system. The floodplain system is more susceptible to changes in sediment transport affecting bank erosion over the long term because of the lack of bedrock controls.

16

Many Bedrock at Khone Waterfall (Laos-Cambodia Border)

17

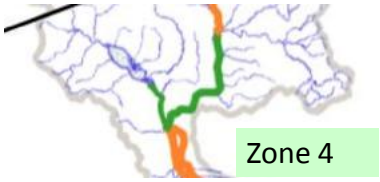
Sandy island along the Mekong river in Stung Treng (December, 2014)

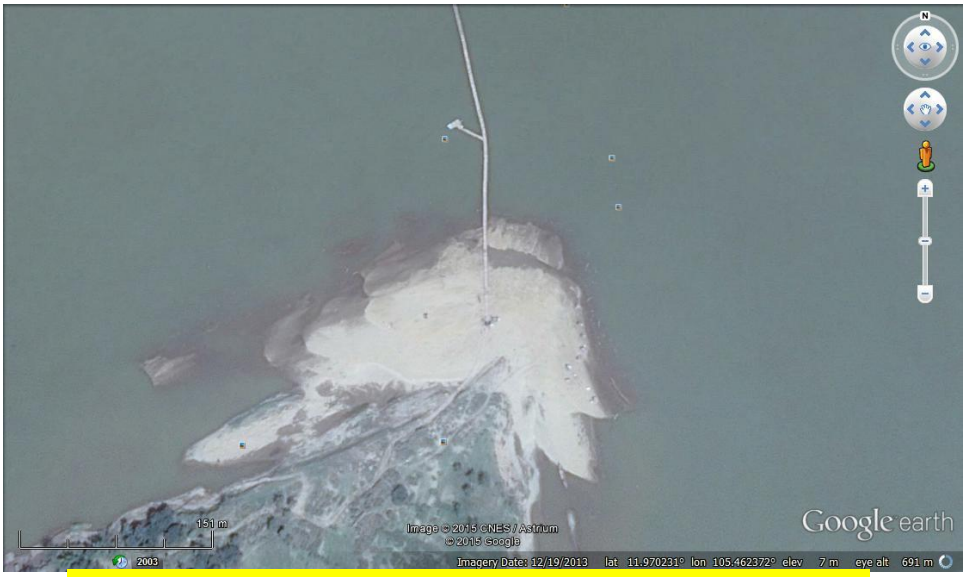
18

Vegetation along the Mekong river in Stung Treng

Zone 4: From Stung Treng to Tonle Sap River

Zone 4a	Stung Treng to Kampong Cham	Meandering alluvial channel, scroll bars, backwaters, overbank flooding, i.e. upstream of confluence with Tonlé Sap	Gradient: 0.000005 Channel width: less than 4 km. Floodplain width: 8 to 64 km Reach length: 50 km Low flow depth: c. 5m Seasonal stage change: 18 m
Zone 4b	Kampong Cham to Phnom Penh	Meandering alluvial channel, scroll bars, backwaters, overbank flooding	Gradient: 0.000005 Channel width: less than 4 km. Floodplain width: 8 to 64 km Reach length: 50 km Low flow depth: c. 5 m Seasonal stage change: 18 m
Zone 4c	Tonle Sap River[7]	Meandering alluvial channel, scroll bars, backwaters, overbank flooding	Reach length: 150 km





Top view of Sand Sediment in Kampong Cham

21

Sand sediment in Kampong Cham

22

Temporary bridge across the sand deposit in Kampong Cham

23

Zone 5: From Phnom Penh to Ocean

Zone 5	Phnom Penh to ocean	Deltaic alluvial channel; distributaries	Gradient: 0.000005
			Channel width: less than 3 km
			Delta inundation width: c. 180 km
			Reach length: 330 km
			Seasonal stage change: very variable

Zone 5

The Mekong Delta is a highly modified geomorphic area owing to the presence and operation of the extensive canal system. The delivery of sediment to the Chaktomuk confluence has decreased due to sediment capture in dams and aggregate mining.

24

Aluvian deposit along the bank of the Tien River in the Mekong Delta

25

Nipa palm along the Mekong Delta

26

A bucket dredge in the delta, Mekong channel, Vietnam

Table 1. River reaches considered with respect to the geomorphic indicators

No.	Area
1	Mekong River in Laos PDR (Chinese border to Nong Khai)
2	Mekong River in Laos PDR/Thailand (Nong Khai to Pakse)
3	Mekong River in Cambodia (Stung Treng to Chaktomuk)
4	Tonle Sap River (Chaktomuk to Great Lake)
5	Tonle Sap Great Lake
6	Mekong Delta (Chaktomuk to delta front)

Linking Indicators of Geomorphology for each Focus Area (FA)

Legend:

- Used
- To be added, (A)dd
- To be deleted, (D)elete / (U)ndelete

		Sites							
		FA1-Pak Beng	FA2-Vientiane	FA3-Se Bang Fai	FA4-Stung Treng	FA5-Kampong Cha	FA6-Tonle Sap Riv	FA7-Tonle Sap Lak	FA8-Delta
Non-native	%Base	■	■	■	■	■	■	■	■
⊟ Geomorphology									
Erosion (bank / bed incision)	%Base	■	■	■	■	■	■	■	■
Sediment fining / coarsening	%Base	■	■	■	■	■	■	■	■
Availability sandy habitat on banks&	%Base	■	■	■	■	■	■		■
Availability rocky habitat on banks&l	%Base	■	■	■	■				
Width of active back channels	%Base				■	■			■
Pool depth	%Base	■	■	■	■	■	■		■
Water clarity	%Base	■	■	■	■	■	■	■	■

29

Erosion (Bank / Bed Incision)

This indicator will be linked to channel shear stress, sediment loads and timing of delivery and geomorphic model outputs. The aim is to assess how flow and sediment changes will translate into changes in the physical attributes of the river channel (bed and banks).

Erosion along the Mekong River (Chiang Khong district, Chiang Rai province, Thailand)

Sediment fining / Coarsening

Sediment fining / coarsening will be linked to the sediment load and sediment grain-size analysis output from the models and will be used to assess how flow and sediment changes will change the characteristics of the channel. It is aimed at understanding physical changes to the river which could also affect the ecology through changes in habitat quality and distribution.

High sediment in the Mekong river in northern Laos

Exposure of Sandy bars, Islands and Insets

This indicator has two aims – the first is to inform whether bank erosion or aggradation is altering the size/explosure of sandy bars, islands and insets. Geomorphically this is important as these sandy features exert important controls on channel stability. Sandy substrates are also important from a habitat perspective, so the second aim of this indicator is to inform how/if habitat distributions are changing.

Sand bank at the confluence between Ou river and Mekong river

Exposure of Rocky Reef

Exposure of rocky reefs is linked to erosion / deposition and water level. Geomorphically, changes to the exposures of rocky reefs result from increased or decreased erosion / deposition of sands in river channel areas underpinned by bedrock. Ecologically, rocky reefs are important aquatic and terrestrial habitats.

Rocky reef in Northern Laos

Pool depth

The deep pools in the LMB are important hydraulic characteristics of the river and are directly related to sediment transport patterns. Pool depth will be sensitive to energy and sediment alterations in the river. Ecologically, pools provide important aquatic habitat and refuge.

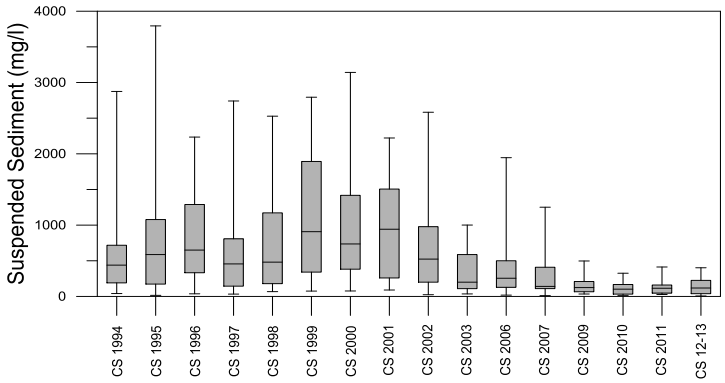
An aerial view of a deep pool on the Mekong just below the Khone Falls region very near the Laos-Cambodian border

Water clarity

Water clarity is directly linked to sediment transport and grain-size distribution of suspended material. It is an important ecological indicator for primary production.

High sediment in the Mekong river near Luang Prabang, Laos

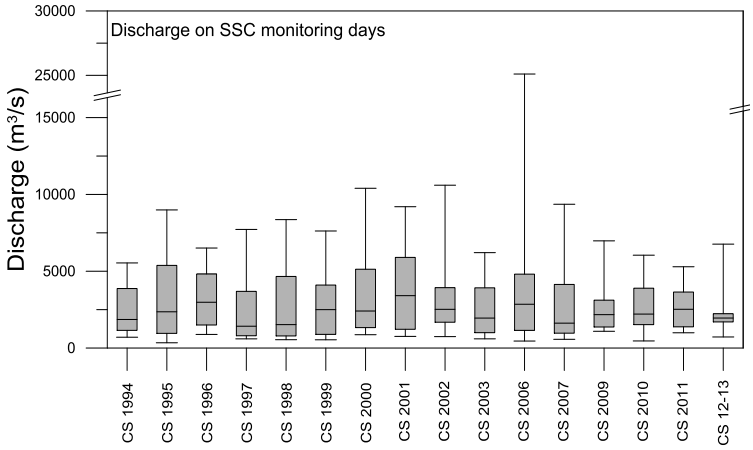
Overview about Sediment Transport in LMB



- Flow and sediment delivery in this part of the LMB is dominated by inflows from the UMB.
- Comparing recent and historical measurementsthe sediment load from the UMB has reduced by up to ~50 Mt/yr, with measured loads decreasing from ~60 Mt/yr to ~10 Mt/yr.

33

Overview about the flow in the LMB

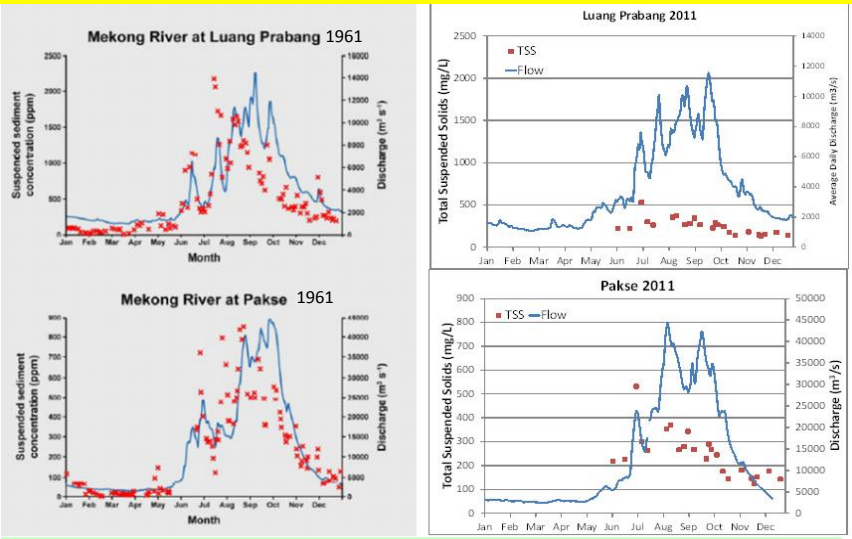


Average daily flow on monitoring days (bottom) at Chiang Saen (Koehnken 2014).

- The flows have changed over the past few years, with moderate reduction in the range of 25th to 75th percentile of water flows (, Koehnken, 2014)

34

The change in the relationship between sediment delivery and flow



Flow and suspended sediment concentrations for Luang Prabang and Pakse show that large flows continue to occur within the river, but suspended sediment concentrations remain low throughout the year

35

Largest impacts on bank erosion

The main anthropogenic drivers considered to have the greatest influence on bank erosion / bed incision include:

1. **Impoundments** which reduce sediment delivery and alter the flow regime;

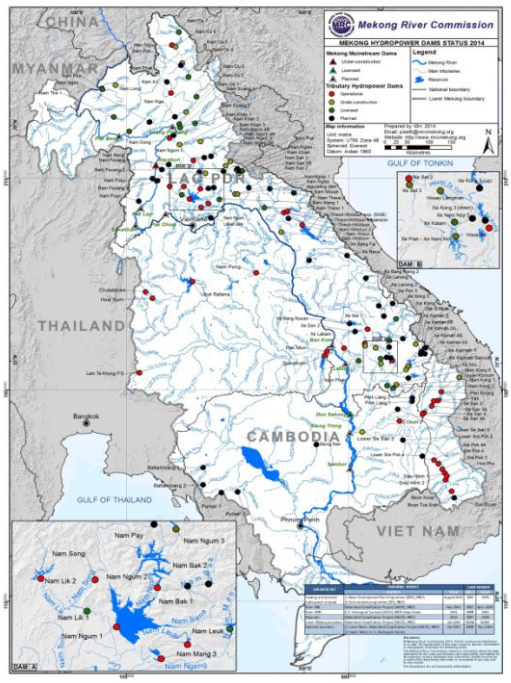
2. **Sediment mining** which alter channel morphology and induce bank erosion through steepening

3. **Land cover changes** which alter the quantity of sediment delivered to the river;

4. **Irrigation and other extractions** which alter the flow regime

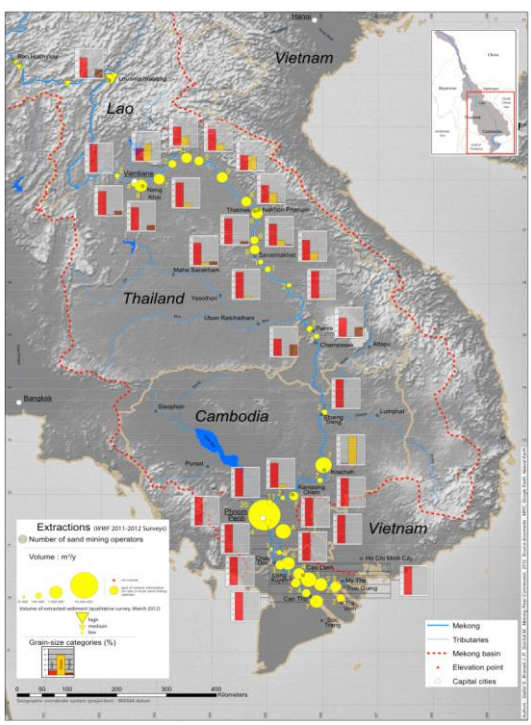
36

Existing and planned hydropower projects



These changes to sediment delivery are likely to translate to changes in bank erosion, due to a large reduction in the potential for deposition.

37



Sediment extraction is one of the threats to the transportation of sediment

Map of sediment extraction in the LMB. Size of circle is relative to the volume of material extracted. Red, orange and brown bars indicate proportion of sand, gravel and pebble extracted at each site, respectively.

38

Classification of Present Status of river

A	**Unmodified, natural**: As close as possible to natural conditions.
B	**Largely natural**: Modified from the original natural condition but not sufficiently to have produced measurable change in the nature and functioning of the ecosystem.
C	**Moderately modified**: Changed from the original condition sufficiently to have measurably altered the nature and functioning of the ecosystem, although the difference may not be obvious to a casual observer.
D	**Largely modified**: Sufficiently altered from the original natural condition for obvious impacts on the nature and functioning of the ecosystem to have occurred.
E	**Seriously to critically modified**. Important aspects of the original nature and functioning of the ecosystem are no longer present. The area is heavily negatively impacted by human interventions.

39

Ecological status rating for Erosion

Indicator: Bank erosion (including bed incision)

Area	Status	Abundance estimates as % relative to 2015			
	2015	1900	1950	1970	2000
Mekong River in Laos PDR	D	50	50	50	60
Mekong River in Laos PDR/Thailand	D	50	50	60	70
Mekong River in Cambodia	D	50	50	60	70
Tonle Sap River	C	50	50	60	70
Tonle Sap Great Lake	C*	50	50	60	70
Mekong Delta	D	50	50	60	70

*Considered as the erosion / depositional rate of sediment in the Lake

50% 'Natural' bank erosion & sediment delivery
60% minor reduction in sediment delivery due to aggregate mining and dams
70% Moderate reduction in sediment delivery due to aggregate mining and dams
80% Major reduction in sediment delivery due to capture by dams and aggregate mining
100% 2015 rate of bank erosion & sediment delivery

40

Ecological status rating for Fining / Coarsening of Bed Materials

Sediment size is controlled by the sediment supply and flow regime of a river. For this exercise it is assumed that the capture of bedload in impoundments will result in an overall decrease in the availability of coarse material, which will push the median grain-size towards smaller grain sizes. It is recognised that impoundments can also result in a coarsening of bed material in the immediate downstream environment due to the winnowing of fines, and armouring of beds which typically occurs downstream of dams.

Fining / coarsening of bed material: Historic abundance estimates as % relative to 2015 (100%)

Area	Status	Abundance estimates as % relative to 2015			
	2015	1900	1950	1970	2000
Mekong River in Laos PDR	B	150	150	150	150
Mekong River in Laos PDR/Thailand	B	150	150	150	150
Mekong River in Cambodia	B	150	150	150	150
Tonle Sap River	B	150	150	150	150
Tonle Sap Great Lake	B	100	100	100	100
Mekong Delta	B	100	100	100	100

41

Ecological status rating for Sandy Bars and Islands and inset

The availability of sub-aerially exposed sandy bars, islands and insets is an important component of riverine habitat. The availability of sandy habitats is controlled by the presence of sandy depositional environments and the water level of the river. Hence, changes to sediment delivery, bank erosion or the flow regime will affect the availability of the sandy habitats.

Exposure of sandy bars and islands / Exposure of Rocky Reefs Historic abundance estimates as % relative to 2015 (100%)

Area	Status	Abundance estimates as % relative to 2015			
	2015	1900	1950	1970	2000
Mekong River in Laos PDR	C	120	120	120	110
Mekong River in Laos PDR/Thailand	C	120	120	120	110
Mekong River in Cambodia	B	110	110	110	105
Tonle Sap River	B	110	110	110	105
Tonle Sap Great Lake	NA				
Mekong Delta	B	110	110	110	105

42

Ecological status rating for Rocking Habitats

The availability of sub-aerially exposed rocky habitats within the river channel is important for providing appropriate riverine habitat for both flora and fauna. The availability of rocky environments is controlled by the presence of exposed bedrock and the water level of the river. Hence, changes to sediment delivery, erosion or the flow regime can affect the availability of the sandy habitats.

Exposure of sandy bars and islands / Exposure of Rocky Reefs Historic abundance estimates as % relative to 2015 (100%)

Area	Status	Abundance estimates as % relative to 2015			
	2015	1900	1950	1970	2000
Mekong River in Laos PDR	C	120	120	120	110
Mekong River in Laos PDR/Thailand	C	120	120	120	110
Mekong River in Cambodia	B	110	110	110	105
Tonle Sap River	NA				
Tonle Sap Great Lake	NA				
Mekong Delta	NA				

43

Ecological status rating for Active Back Channels

Back channels in the LMB are generally limited to Southern Lao PDR, in the 4,000 Islands area, and northern Cambodia, between Stung Treng and Kratie. The width of active back channels is directly related to river level stage and it is likely that this parameter will be directly derived from the MRC Decision Support Framework (DSF) output rather than via a response curve in DRIFT.

Width of active back channels: Historic abundance estimates as % relative to 2015 (100%)

Area	Status	Abundance estimates as % relative to 2015			
	2015	1900	1950	1970	2000
Mekong River in Laos PDR	NA				
Mekong River in Laos PDR/Thailand	C	50	50	50	60
Mekong River in Cambodia	C	50	50	50	60
Tonle Sap River	NA				
Tonle Sap Great Lake	NA				
Mekong Delta	C	50	50	50	60

44

Ecological status rating for Depth of Pools

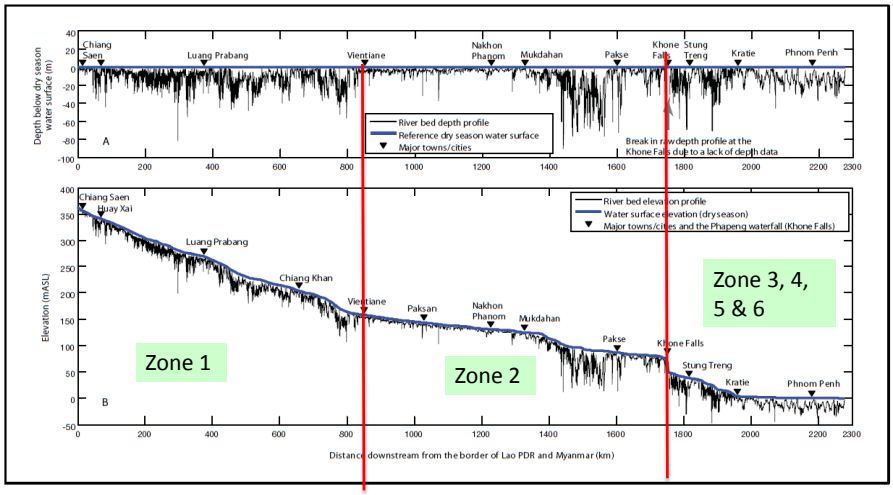
Pools provide important refuge and spawning habitat, especially during periods of low flow. Over 400 'deep pools' have been identified in the LMB based on local ecological knowledge and an analysis of hydrographic surveys (Figure 6.7; MRC 2011). The pools occur at a variety of geomorphic settings in both bedrock and alluvial reaches.

Depth of pools: Historic abundance estimates as % relative to 2015 (100%)

Area	Status	Abundance estimates as % relative to 2015			
	2015	1900	1950	1970	2000
Mekong River in Laos PDR	B	90	90	90	95
Mekong River in Laos PDR/Thailand	B	90	90	90	95
Mekong River in Cambodia	B	90	90	90	95
Tonle Sap River	B	90	90	90	95
Tonle Sap Great Lake	NA				
Mekong Delta	B	90	90	90	95

45

Overview of the Depth of pool



- ❑ Pools provide important refuge and spawning habitat, especially during low flow.
- ❑ Pools tend to be longer and deeper in downstream compared to upstream reaches !

46

Ecological status rating for Water Clarity

Water clarity is important for ecological systems as it controls the depth of light penetration which is important for plant growth, and affects organisms which depend on sight for feeding. Water clarity is related to the surface area of material suspended in the water column rather than the mass of suspended sediment; relatively low concentrations of very fine-suspended sediment can reduce water clarity as compared to higher concentrations of coarse grained material.

Water clarity: Historic abundance estimates as % relative to 2015 (100%)

Area	Status	Abundance estimates as % relative to 2015			
	2015	1900	1950	1970	2000
Mekong River in Laos PDR	B	80	80	80	90
Mekong River in Laos PDR/Thailand	B	80	80	80	90
Mekong River in Cambodia	B	80	80	80	90
Tonle Sap River	B	80	80	80	90
Tonle Sap Great Lake	B	80	80	80	90
Mekong Delta	B	80	80	80	90

47

Thank you for your attention !