Using local knowledge to inventory deep pools, important fish habitats in Cambodia

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ABSTRACT

The Mekong River is the largest river in Southeast Asia and it supports a major inland fishery. The river flows through Cambodia for about 500 kms, traversing four provinces. Important fisheries habitats include deep pools, rapids, floodplains and associated wetlands. Deep pools (*un loong* in Khmer) have been mentioned by several researchers as important refuge habitats for fish. The definition of a deep pool is somewhat arbitrary; however, a deep pool is significantly deeper than surrounding riverbed and retains water in the dry season when it may be isolated from the main river. Deep pools must also be ecologically significant in the conservation of a number of fish species.

Local fishers from 25 villages along the Mekong from the Lao PDR border to Kratie were asked to identify deep pools based on water depth and importance to the local fishery, so that their location and significance might be accurately documented. Villagers identified 97 deep pools, of which two-thirds measured less than 10 ha during the dry season, and the largest of which measured approximately 200 ha. Most of these pools had a maximum dry season depth of between 20-30 m but some were up to 80 m deep. Most large pools, and the greatest concentration of deep pools, were 80-120 km downstream of the Lao PDR border. There was no apparent relationship between surface area of pools and their depth (i.e. some very small pools are very deep), rather depth depends on local conditions such as bedrock or islands that concentrate wet season flows and create scour holes.

Fishers interviewed for this study said deep pools were important habitats for at least 168 fish species, including six exotic taxa. They said nearly all the deep pools contain most of these species. The number of species they reported bore no apparent relationship to area of pools, villagers who live close to the deeper pools (>=35 m.), on average reported fewer species. The precise effect of habitat variables such as a rocky substrate requires further investigation.

Conservation of large adult fish in deep pools is important not only for maintaining fisheries locally, but also downstream in floodplain areas that depend upon this upstream brood-stock for an annual pulse of larvae and fry during the wet season. According to villagers, the critically endangered giant catfish (*Pangasiandon gigas*) still lives in pools near Kratie, and three other endangered species are widespread, highlighting the importance of this section of the Mekong. Use of gillnets has increased dramatically in the last decade; these are cheap and efficient and have reportedly had a major impact on stocks of fish in deep pools. Conservation of the fishery and the pools themselves will require management measures to limit the harvest of large fish, to control riparian clearing, and to effectively assess and mitigate impacts of dams upstream. Dams on the mainstream in this zone of the Mekong would be disastrous for the fishery. Measures are also needed to control the spread of exotic fish species from the aquarium trade in the region.

KEY WORDS: Cambodia, Mekong, river fisheries, deep pools, conservation

INTRODUCTION

The Mekong River flows through Cambodia for about 500 km traversing four provinces, Stung Treng, Kratie, Kampong Cham and Kandal. This stretch of the river contains a diverse range of important fluvial habitats including deep pools, rapids, floodplains and associated wetlands.

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The deep pools (*un loong* in Khmer) in the mainstream from the Khone Falls to the town of Kratie are important refuge habitats for fish (Poulsen *et al.* 2002). Large fish that live in these pools spawn at the start of the flood season and the rising waters carry the ensuing larvae downstream where they form the basis for recruitment for many of the floodplain fisheries.

However, as discussions with local fishers revealed, the deep pools documented up to now represent only a fraction of those in this stretch of the Mekong. The aim of this study therefore, was to fully document and map the location and general features of deep pools in the Cambodian Mekong as a first step towards developing plans for the management of fisheries in these pools.

The definition of a deep pool is somewhat arbitrary; it must be significantly deeper than the surrounding riverbed, retain water through the dry season (although it may become isolated from the mainstream during these times) and ecologically significant in the conservation of rare or endangered fish. Of course, there is a continuum between deep pools and the rest of the riverbed, but the concept of a deep pool is a useful starting point for prioritising the management of those stretches of the Mekong that are known to be of great importance to fisheries and fish conservation.

METHODS

Surveys were carried out during the 'dry' season (May to June) in 2003 and interviews and discussions held with fishers and provincial officers to gather some basic information about the deep pools and fish along the mainstream of the Mekong. Discussions with village leaders established where people mainly fished and additional discussions with five or six fishers from each village provided more background information. Groups of fishers sketched maps of the river in their vicinity pointing out the location of deep pools. We drew up preliminarily maps of the localities of deep pools by comparing the fishers' maps with information in the Mekong River Commission (MRC) Hydrographic Atlas; this contains accurate maps and partial sounding data. Global positioning system (GPS) readings, taken from local boats, gave accurate locations for the accessible 'corners' of deep pools. The maximum depths of most of the pools were verified using manual sounding or an echo sounder.

During further interviews, fishers were asked to identify the species they had caught in deep pools using a photo flipchart containing 166 common Mekong River species and six exotic species found in the wild in Cambodia as well as another ten exotic species sold in the aquarium trade in Phnom Penh. This is an updated version of the chart used by the Assessment of Mekong Fisheries Component in the four riparian countries: Cambodia, Lao PDR, Thailand and Viet Nam. The charts grouped fish species by family and gave the local as well as the corresponding scientific names. Subsequent reports on the survey use both names. Local fishers, who we asked to monitor and record their catches, provided additional data on fish populations. Villagers also gave other, more general, information about the pools.

Study area

The Mekong drops about 30m over the Khone falls, on the border between Lao PDR and Cambodia, and

another 45m in the 165km stretch between the border and the town of Kartie, which is at 20 m ASL. The adjacent land downstream of Kratie has mainly been converted to farmland (generally rice) so that riverside vegetation comprises mostly of smaller plants, such as swamp grasses, with few large trees. In Cambodia therefore, deep pools are more common in the upper section of the river where bedrock, boulders, islands and vegetation obstruct the flow producing large scour holes, or where large tributaries enter the mainstream and cause erosion of the riverbed.

Downstream from Kartie, the shallower gradient of the river and the soft substratum, together with erosion of the riverbank resulting from intensive farming, has caused the deeper parts of the riverbed to fill with sediment. As a result, there are fewer deep pools in this stretch of the river.

Fishers and villagers from 25 villages along the stretch of Mekong from the Lao PDR border downstream to Kratie town took part in the survey; in all, the survey encompassed twelve communes in five districts of the Stung Treng and Kratie provinces.

RESULTS

Distribution and size of deep pools

Maps giving the location of 95 deep pools identified by the fishers are included in Appendix 2. The maps run sequentially from the Lao PDR border in the north to the town of Kratie in the south. Appendix 1 gives more details on the location of each pool, including its size and geographic co-ordinates.

The location of deep pools in this section of the Mekong distribute in clusters (Figure 1, over page). These often occur where the river splits and flows through narrow channels between rocky islands. During the wet season, the increased flow in these confined channels scours sediment and debris from the bed of the pools. Along this section of the river, there is no obvious correlation between distance from the border with Lao PDR and maximum depth of pools. The section of the river upstream of Sambor (80-120km) contains the largest aggregation of deep pools. This stretch also holds most of the large pools (Figure 2, over page).

The 20 km stretch of the Mekong downstream from the border with Lao PDR has few large pools; most are smaller than ten hectares. These pools are usually confined by hard bedrock which, being more resistant to erosion, limits their size (Figure 2).

During the dry season most of the deep pools are quite small (<10 ha), the largest is about 200 ha (Figure 3, over page).

Although the maximum depth of the most of pools was between 11 and 30 metres (the deepest was about 80 metres), villagers classified some shallow pools, which were only three to five metres deep, as deep pools (*un long*) because they were deep in relation to the surrounding riverbed and because of their importance to the fishery.

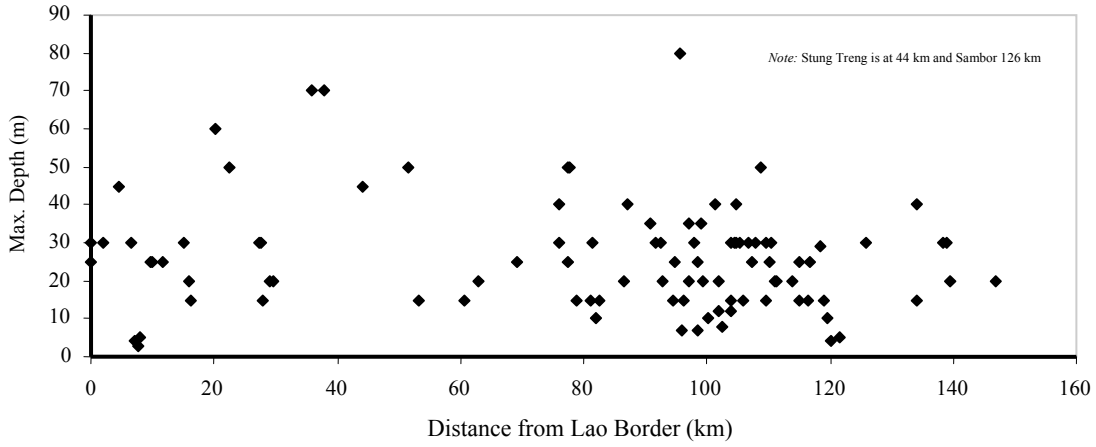


Figure 1. Distribution of pools along the Mekong between the Lao PDR border and Kratie showing their approximate maximum depth during the dry season

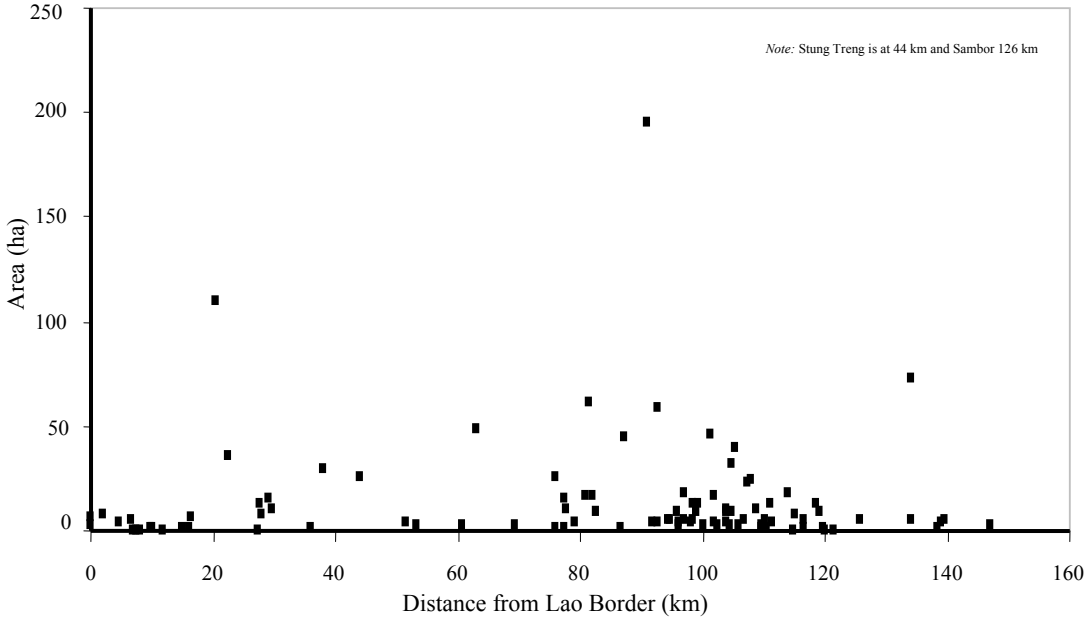


Figure 2. Distribution of pools along the Mekong between the Lao PDR border and Kratie showing their approximate surface area during the dry season

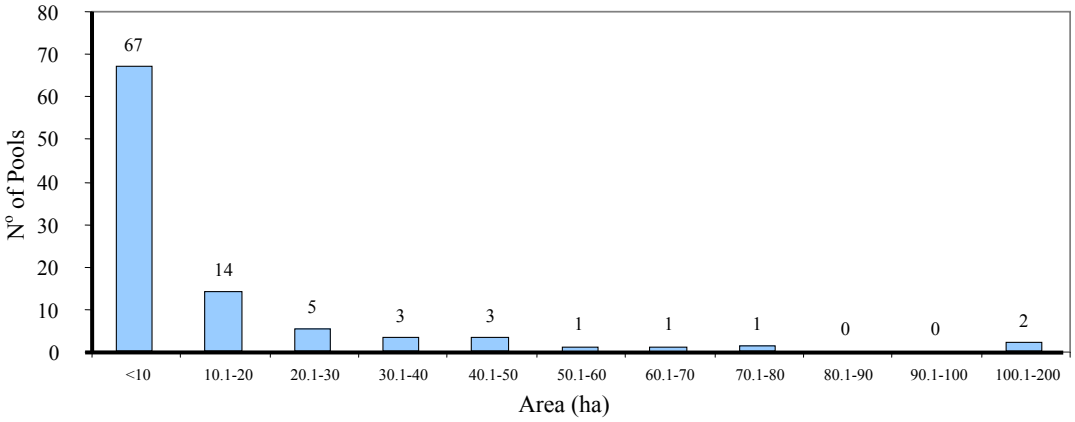


Figure 3. Distribution of deep pools by approximate area

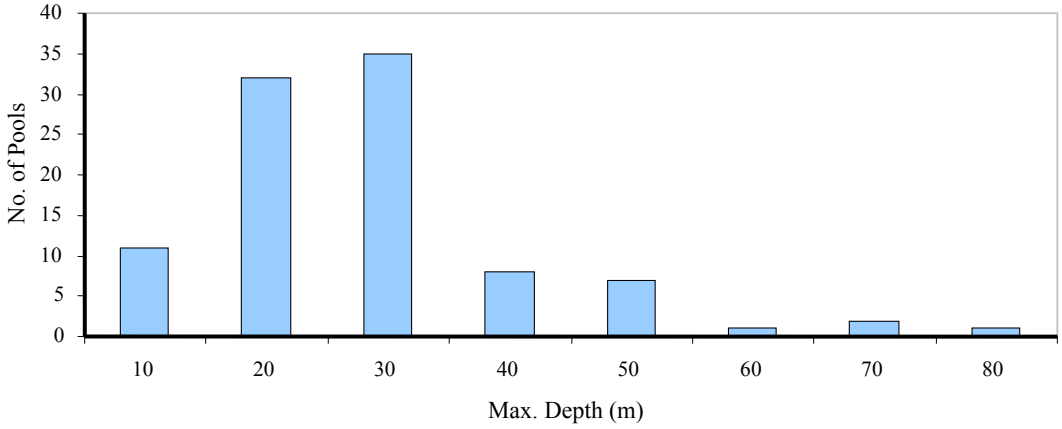


Figure 4. Distribution of deep pools by approximate maximum depth

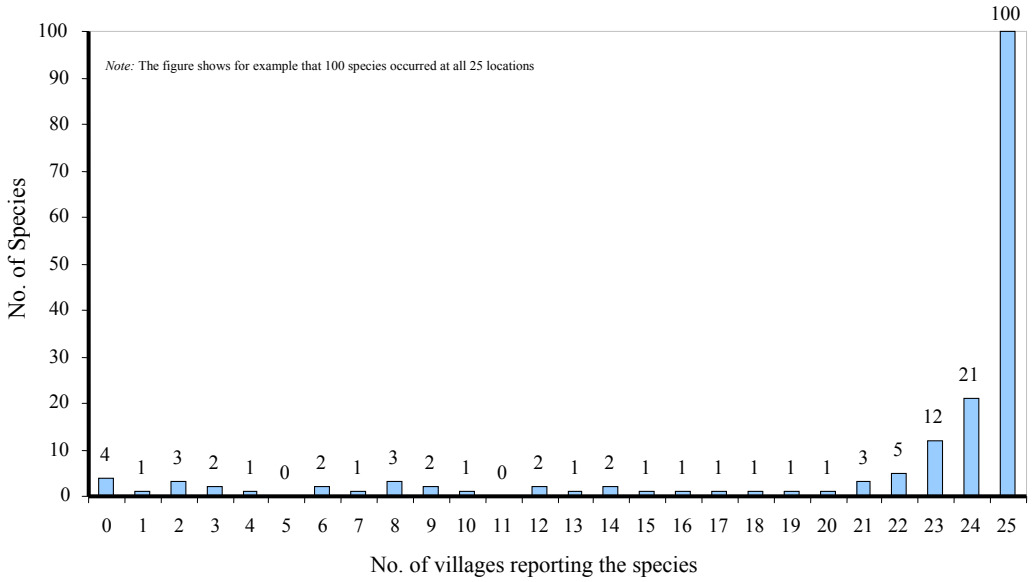


Figure 5. Species reports by location

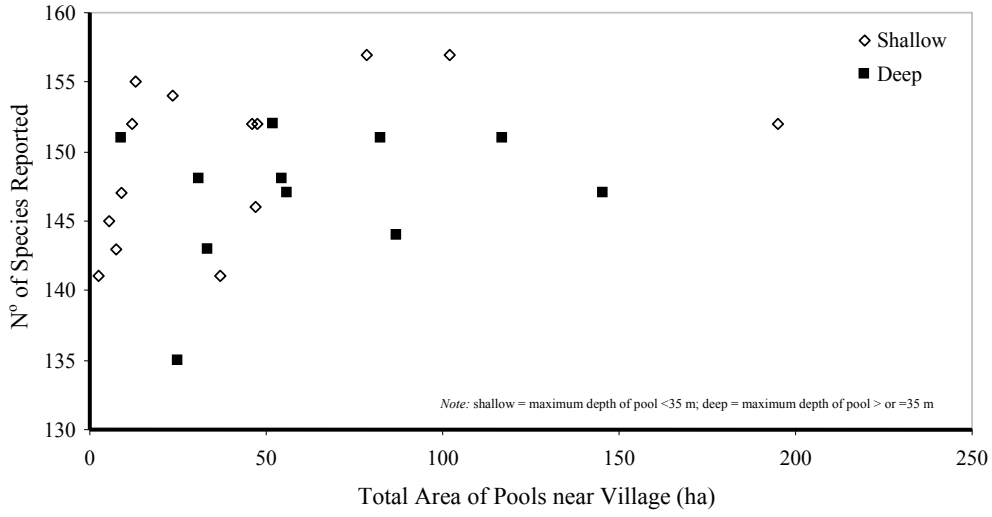


Figure 6. Distribution of species reports by area of pools

Fishing gear

Although a wide variety of fishing gear is available in Cambodia, the trend in recent years has been to use nylon monofilament gillnets as well as cast nets, hook and line, and some specialised nets for the deepest parts of deep pools. Other monitoring of commercial fishers catches along the upper Mekong by the Assessment of Mekong Capture Fisheries Component, shows that the majority of fish are now being caught with gillnets, which are very cheap and readily available. Though fishers did not elaborate on this point, the increasing dominance of gillnets is obvious from the presence of these nets in the villages and local markets and set in pools.

Species identification and location

The fishers, as a group, recorded 168 of the 172 species illustrated in the photo flipcharts. Twenty-two or more villages reported 80% of these species (138) showing that most species inhabit this entire section of the Mekong.

The composition of the fish fauna is broadly similar to that found throughout the Cambodian section of the Mekong. The most common species are, catfishes (Pangasiidae, Bagridae and Sisoridae), river carp (Cyprinidae) and snakeheads (Channidae). Not surprisingly, the fauna lacks many species of fish that normally live in other habitats, such as those found in montane, floodplain and estuarine environments. We could not attach significance to the fauna in any particular pool, as the distribution of most of the species is widespread. Moreover, as the photo flipchart is not representative of the whole fish fauna that has been recorded in the Cambodian section of the Mekong and its lowland tributaries (over 200 species are omitted from the charts), the list of species given in this paper may not be comprehensive.

Based on the current data there is no unequivocal relationship between the diversity of species and the size and depth of pools; although the shallower pools (less than 35m) appear to contain a more diverse fauna. Even so, it seems likely that other local environmental factors, such as substrate, snags or oxygen levels, may be more important. The relationship between the area and depth of pools and fish diversity may be resolved when data from individual pools are available. In the meantime, however, we can make a few interesting observations on the occurrence of introduced, rare indigenous and giant fish species.

Introduced species

The fishers identified only six of the 16 introduced species in the photo flipchart; of these, only three were widespread (Table 1).

This suggests that these species are spreading rapidly through the river system, probably from sites using them for aquaculture. (Note that the African catfish hybridises with the native *Clarias batrachus* and villagers may confuse these two species and their hybrids.) Four sites reported mosquito fish (two in Stung Treng and two in Kratie) and 12 reported swordtails. These escapees from the aquarium trade are apparently becoming widespread. Only two villages reported Nile tilapia (Khohtnot and Trarlork, both in Kratie); this species is apparently still quite rare in the upper Cambodian Mekong, despite its

widespread use in aquaculture along the river upstream in Lao PDR and downstream in Cambodia. Most probably the habitat through much of this section of the river is unsuitable for the species that originates from a lentic environment.

Table 1. *The number of villages reporting introduced species in deep pools*

Species	Common name	Origin	Records
Clarias gariepinus	African walking catfish	Africa	25
Cyprinus carpio	Common carp	West Europe to China	23
Hypophthalmichthys molitrix	Silver carp	China to Eastern Siberia	23
Gambusia affinis	Mosquito fish	North and Central America	4
X*iphophorus* spp	Swordtail	North and Central America	12
Oreochromis niloticus	Nile tilapia	Africa	2

Rare indigenous species

Aaptosyax grypus is an unusual and distinctive large carnivorous cyprinid endemic to the middle Mekong. Although the species has reportedly declined greatly in recent years (Poulsen *et al.* 2004), it was recorded three villages (Kos Sneng, Krohlapies and Chuetealthom); these are all located in section of the river in upper Stung Treng province that has smaller deep pools. These records are consistent with the known distribution of this particularly interesting endemic species, and could form a starting point for work on its conservation.

The giant catfish, *Pangasianodon gigas*, is one of the four 'giant' Mekong species (Coates *et al*. 2003), and is the only Mekong species currently listed by the IUCN as 'critically endangered', the category which denotes the highest risk of extinction (Table 2). Fishers from three villages (Kos Dam Bong, Pontachea and Oukok) recorded this species. All are in a relatively small area in the Sambor district of Kratie province where there is a high density of deep pools, many of which are large.

Table 2. *Locality records of Mekong species listed as endangered or critically endangered on the 2003 IUCN Red List*

Scientific name	Common name	Status	N^{o} of localities
Pangasianodon gigas	Mekong giant catfish	Critically endangered	3
Dasyatis laosensis	Mekong freshwater stingray	Endangered	25
Himantura oxyrhynchus	Marbled freshwater stingray	Endangered	No data
Pristis zijsron	Green sawfish	Endangered	No data
Probarbus jullieni	Jullien's golden carp	Endangered	25
Scleropages formosus	Asian arowana	Endangered	0
Tenualosa thibaudeaui	Laotian shad	Endangered	10

Interestingly, the presence of two other giant species (*Catlocarpio siamensis* and *Probarbus jullieni*) listed by Coates *et al.* (2003) was confirmed by fishers at all 25 villages, suggesting that these species are still reasonably abundant despite increasing fishing pressure. *Pangasius sanitwongsei,* the other giant species, was not in the photo flipchart, and we were unable to confirm if it lives in this section of the Mekong. Two other endangered species featured on the flipchart, the Mekong freshwater stingray and Jullien's golden carp, were apparently still quite widespread, occurring at 25 locations, whereas the

once common Laotian shad is now restricted to only ten locations. The last endangered species, the Asian arowana, is indigenous to south-west Cambodia and may not even inhabit the Mekong.

DISCUSSION AND CONCLUSIONS

Poulsen *et al*. (2002) reviewed previous records of deep pools in northern Cambodia. Hill and Hill (1994) listed 28 deep pools, and Vannaren and Kin (2000) listed 58 deep pools. Most of these are in this study, and we have expanded the list to 97 pools, with data on locations, coordinates, approximate size and maximum depth. Poulsen *et al.* (2002) record 53 species that use the pools as dry season habitats, but during this study, we recorded least 162 native Mekong species, and, given that Cambodia has over 400 freshwater species, we assume that many not featured on the flipcharts also live this in this stretch of the river. Furthermore, a number smaller species that are difficult to identify may have been 'lumped' together in a single species.

In some cases, as some similar species are difficult to differentiate using only photographs, the records of a few individual species require confirmation. Nevertheless, the use of flipcharts provides an efficient way of accessing considerable information about the distribution of fish populations, and is probably reliable for the larger and more distinctive species.

We recorded only six exotic species and only two of these, the common carp and silver carp, were widespread; this suggests that deep pools still support a largely indigenous fauna, a factor that emphasises the need to conserve these special habitats. Exotic species have yet to invade these wild habitats in large numbers despite the burgeoning aquarium trade in Southeast Asia. Local villagers report that *Xiphophorus* spp is becoming widespread even though in a recent review Welcomme and Vidthayanon (2003) did not record the taxa. This demonstrates the value of interviews with local fishers in rapid assessments of the incursion of introduced fish.

The pools identified in this study are important habitats, particularly as they provide dry season refuges for large fish that form the brood-stock supporting local fisheries and floodplain fisheries downstream. Unpublished catch monitoring data collected by the Mekong River Commission (MRC) show that the pools in this part of the Mekong contain many more large adult fish than the river and floodplains further downstream in Cambodia and Viet Nam further highlighting the importance of deep pools to the sub-basin's fisheries.

Two giant species of river barb (*C. siamensis* and *P. jullieni*) previously thought to be in serious decline are apparently still widespread, as evidenced by records from all 25 villages. Unfortunately, the same is not true for the giant catfish, *P. gigas*, considered critically endangered by IUCN and still rare in this stretch of the Mekong. Two other endangered Mekong species are still quite widespread in the deep pools. The presence of giant and endangered species in these pools again demonstrates the importance of these habitats in fish conservation and provides a starting point for the preservation of these species as well as others of special interest such as the Mekong endemic, *A. grypus.*

Deep pool fisheries face two major threats: over-fishing and hydrological change.

Over-fishing of large species is accelerating with improved security, better access, and superior equipment. In the past, fish were relatively safe in the deepest parts of pools as traditional methods of fishing were comparatively inefficient. Nowadays, boats with outboard motors are used to travel long distances from population centres, gillnets line the edges of many of the deep pools so that fish moving to shallower water to feed (especially at night) have become more vulnerable, and specialised nets attached to heavy weights are set in the deepest parts of the water. Large fish are caught and stored in iceboxes then sold on to traders who export them, removing vital brood-stock from Cambodia. While hard data are lacking, all fishers agree that catches, especially of large fish, are increasing. Currently there are no effective measures to control fishing periods or the equipment used in deep pools; the current 'closed season' is during the flood period (June – September) and does not limit the capture of large fish when they are at their most vulnerable (i.e. during the dry season from January-May).

The persistence and quality of deep pools depends on the maintenance of existing hydrology and habitats. If dams upstream attenuate the river's peak flow, the river will lack the force to scour sediments during the wet season. Moreover, if upstream dams trap sediment, the resulting disruption to the equilibrium between deposition and suspension may lead to increased erosion and the pools to infill as the riverbanks slump. Already early feasibility studies include plans for a dam at Sambor (OTCA 1969). Any dam on the Mekong mainstream in this part of Cambodia could be disastrous for fisheries, but this site is the worst possible location from this perspective. Clearing of land adjacent to the river is also likely to cause the riverbank to slump and reduce the depth of pools.

Invasion of the river by exotic species presents a new threat. The Mekong system is species-rich, so it is perhaps less vulnerable to invasion than depauperate systems. Nevertheless, invading species have competitive advantages if the environment is altered to suit them. They, unlike native fish, are isolated from their natural enemies, parasites and pathogens and fishers do not target them because of their small size and poor taste. Furthermore, exotic species escaping from aquaculture supply continuous recruits. Exotic species may continue to establish themselves as has already occurred in the case of at least six species, two of which (mosquito fish and swordtails) have no utility and compete with native fish.

This paper serves as a starting point as we have clearly identified deep pools and summarised their main attributes. Concerted efforts are now needed to develop management plans for the pools in co-operation with fishers, to limit riparian clearing, to ensure that environmental impact assessment of upstream developments takes into account the effects on this important section of the river, and to restrict the spread of exotic species river system.

REFERENCES

Coates, D., Ouch, P., Suntornratana, U., Nguyen, T. T., and Viravong, S. (2003) Biodiversity and fisheries in the Mekong River Basin. *Mekong Development Series* No. 2.

Hill, M. T. and Hill, S. A. (1994) *Fisheries ecology and hydropower in the Lower Mekong River: an evaluation of run-of-the-river projects*. Mekong Secretariat. Bangkok, Thailand.

OTC (1969) *Sambor project report. Lower Mekong River Basin. Volume VI. Fishery. [Volume VI Irrigation and agriculture, Supplementary material to volume I]*. Overseas Technical Cooperation Agency, Tokyo, Japan.

Poulsen, A. F., Ouch, P., Viravong, S., Suntornratana, U., and Nguyen, T. T. (2002) Deep pools as dry season fish habitats in the Mekong River Basin. *MRC Technical Paper* No. 4.

Poulsen A.F., Hortle K.G., Valbo-Jorgensen J. *et al.* (2004) Distribution and Ecology of Some Important Riverine Fish Species of the Mekong River Basin. *MRC Technical Paper* No. 10.

Vannaren C.S. and Kin, S. (2000) *Fisheries preservation in the Mekong River pools in Stung Treng and Kratie Provinces.* Internal Technical Report, Dept of Fisheries, Phnom Penh.

Welcomme, R. and Vidthayanon, C. (2003) The impacts of introductions and stocking of exotic species in the Mekong Basin and policies for their control. *MRC Technical Paper* No. 9.

APPENDIX 1

Basic location data on deep pools in northern Cambodia

Province	Village	Deep Pool (Eng)	Distance from border (km)	Lth(m)	Wdth (m)	DpthMax	Area (ha)	North Start and East Start	North End and East End
Stung Treng	Chueteal thom	Phsot	0	580	100	25	5.8	N 13^0 55 682’ E 105^0 57.225’	N 13^0 55 691’ E 105^0 57.544’
Stung Treng	Ourun	Vien khao	0.1	360	70	30	2.5	N 13^0 55 204’ E 105^0 59.895’	N 13^0 55 280’ E 105^0 59.711’
Stung Treng	Chueteal thom	Ta heng	2	1,050	70	30	7.4	N 13^0 53 668’ E 106^0 00.342’	N 13^0 53.782’ E 106^0 00.292’
Stung Treng	Ourun	Vien soat	4.5	440	80	45	3.5	N 13^0 50 970’ E 105^0 59.023’	N 13^0 50 937’ E 105^0 59.267’
Stung Treng	Krolapies	Kro la peas	6.5	**500**	**100**	**30**	5.0		
Stung Treng	Krolapies	Luk	7	**30**	**15**	**4**	0.0		
Stung Treng	Krolapies	Outa pray	7.6	**30**	**15**	**3**	0.0		
Stung Treng	Krolapies	Ou doung	8	**50**	**30**	**5**	0.2		
Stung Treng	Ourun	Ky ke	9.8	280	60	25	1.7	N 13^0 49.513’ E 105^0 58.814’	N 13^0 49.626’ E 105^0 58.916’
Stung Treng	Ourun	Sen lay	10	180	60	25	1.1	N 13^0 49 353’ E 105^0 58.916’	N 13^0 49 430’ E 105^0 58.980’
Stung Treng	Veunsien	Bong krak	11.7	**100**	60	25	0.6		
Stung Treng	Veunsien	Vien phong	15	190	50	30	1.0	N 13^0 46.983’ E 105^0 58.539’	N 13^0 47.056’ E 105^0 58.463’
Stung Treng	Veunsien	Vien sen	16	180	60	20	1.1	N 13^0 46.608’ E 105^0 59.068’	N 13^0 46.662’ E 105^0 58.988’
Stung Treng	Krolapies	Ou ta las	16.3	**1,000**	70	15	7.0		
Stung Treng	Chom thom	Kom bor	20.3	3,640	300	60	109.2	N 13^0 43.954’ E 105^0 59.632’	N 13^0 45.171’ E 105^0 58.049’
Stung Treng	Chom thom	Con theay	22.5	3,630	100	50	36.3	N 13^0 43.091’ E 106^0 00.665’	N 13^0 41.434’ E 106^0 01.739’
Stung Treng	Koh Sneng	Om pil	27.2	100	50	30	0.5		
Stung Treng	Koh Sneng	Ta prum	27.5	1,270	100	30	12.7	N 13^0 41.161’ E 106^0 02.609’	N 13^0 40.534’ E 106^0 02.892’
Stung Treng	Koh Sneng	Koh kon dul	28	910	90	15	8.2	N 13^0 40.764’ E 106^0 01.221’	N 13^0 40.276’ E 106^0 01.150’
Stung Treng	Koh Sneng	Ta thau	29	1,000	150	20	15.0	N 13^0 39.121’ E 106^0 02.201’	N 13^0 38.606’ E 106^0 02.364’
Stung Treng	Koh Sneng	Throm thom	29.5	1,040	100	20	10.4	N 13^0 38.950’ E 106^0 01.543’	N 13^0 38.501’ E 106^0 01.892’
Stung Treng	Phum thmay	Kan tui koh tang	36	**150**	**80**	**70**	1.2	N 13^0 35.499’ E 106^0 00.533’	
Stung Treng	Phum thmay	Phum thmei	38	1,480	200	70	29.6	N13^0 34.763’ E 105^0 59.662’	N13^0 35.226’ E 105^0 00.333’
Stung Treng	Bachong	Ou trel	44	1,260	200	45	25.2	N 13^0 32.058’ E 105^0 56.858’	N 13^0 31.683’ E 105^0 56.276’
Stung Treng	Svay	Svay or kang praech	51.5	480	80	50	3.8	N 13^0 27.965’ E 105^0 55.460’	N 13^0 27.712’ E 105^0 55.503’
Stung Treng	Svay	Phnao	53.3	300	80	15	2.4	N 13^0 26.788’ E 105^0 55.853’	N 13^0 26.635’ E 105^0 55.905’
Stung Treng	Svay	Tavan	60.7	240	80	15	1.9	N 13^0 22.707’ E 105^0 55.675’	N 13^0 22.579’ E 105^0 55.709’
Stung Treng	Svay	Beong Kok	62.9	2,400	200	20	48.0	N 13^0 21.342’ E 105^0 55.083’	N 13^0 21.831’ E 105^0 55.328’
Stung Treng	Siembok	Kang chong e	69.3	290	80	25	2.3	N 13^0 17.842’ E 105^0 55.634’	N 13^0 17.990’ E 105^0 55.579’
Stung Treng	Siembok	Yi keo	76	190	80	30	1.5	N 13^0 17.653’ E 105^0 55.705’	N 13^0 17.749’ E 105^0 55.675’
Stung Treng	Siembok	Nak ta	77.5	190	80	25	1.5	N 13^0 17.454’ E 105^0 55.722’	N 13^0 17.554’ E 105^0 55.715’
Stung Treng	Koh chrum	Thmor thom	76	2,520	100	40	25.2	N 13^0 14.683’ E 105^0 58.284’	N 13^0 13.453’ E 105^0 58.880’
Stung Treng	Koh chrum	Chhor long	77.5	2,600	60	50	15.6	N 13^0 14.048’ E 105^0 59.453’	N 13^0 13.351’ E 106^0 00.700’
Stung Treng	Koh chrum	Preas tro phang	77.8	**1,000**	**100**	**50**	10.0		
Stung Treng	Koh chrum	Koh Dom Long	79	500	70	15	3.5	N 13^0 13. 865’ E 105^0 59.384’	N 13^0 13.925’ E 105^0 59.654’
Kratie	Kohnorung	Koh kampeung	99.3	830	150	20	12.5	N 13^0 11.416’ E 106^0 01.821’	N 13^0 11.207’ E 106^0 02.229’
Kratie	Koh dam bong	Koh dam bong	81.5	2,040	300	30	61.2	N 13^0 10.957’ E 106^0 01.448’	N 13^0 09. 858’ E 106^0 01.525’
Kratie	Kohnorung	Ou kandear	81	1,390	120	15	16.7	N 13^0 10.959 ’ E 106^0 02.679’	N 13^0 10.422’ E 106^0 03.219’
Kratie	Kohnorung	Me dut or phem chrus	82	1,110	150	10	16.7	N 13^0 05. 465’ E 106^0 03.420’	N 13^0 04.883’ E 106^0 03.570’
Kratie	Koh dam bong	Koh om pil	82.5	880	100	15	8.8	N 13^0 09.885’ E 106^0 01.424’	N 13^0 09.411’ E 106^0 01.437’
Kratie	Koh dam bong	Cheong Kel or Kampong kbeung	86.6	250	70	20	1.8		
Kratie	Koh dam bong	Kandor moui roi	87.2	2,260	200	40	45.2	N 13^0 08.678’ E 106^0 02.001’	N 13^0 07.482’ E 106^0 01.761’
Kratie	Khsach leav	Koh khnhe Srey Koki	90.8	4,870	400	35	194.8	N 13^0 07.957’ E 106^0 03.914’	N 13^0 05.415’ E 106^0 03.232’
Kratie	Trarlok	Phreas theat	91.8	350	100	30	3.5	N 13^0 05.415’ E 106^0 03.232’	N 13^0 05.465’ E 106^0 3.420’
Kratie	Oukok	kbal koh ta chan	92.6	3,870	150	30	58.1	N 13^0 04.883’ E 106^0 03.570’	N 13^0 05.465’ E 106^0 03.420’
Kratie	Trarlok	Chha hung	94.5	460	100	15	4.6	N 13^0 03.467’ E 106^0 04.030’	N 13^0 03.226’ E 106^0 03.980’
Kratie	Trarlok	Lo vear	96.1	**200**	150	15	3.0		
Kratie	Pontachea	Mokphum	96	340	100	7	3.4	N 13^0 04.903’ E 106^0 03.970’	N 13^0 04.769’ E 106^0 04.095’
Kratie	Kohtnot	Khsach leo	92.8	840	50	20	4.2	N 13^0 04.529’ E 106^0 00.937’	N 13^0 04.090’ E 106^0 00.822’
Kratie	Pontachea	Prestvea	97	900	200	20	18.0	N 13^0 02.450’ E 106^0 04.575’	N 13^0 01.968’ E 106^0 04.646’

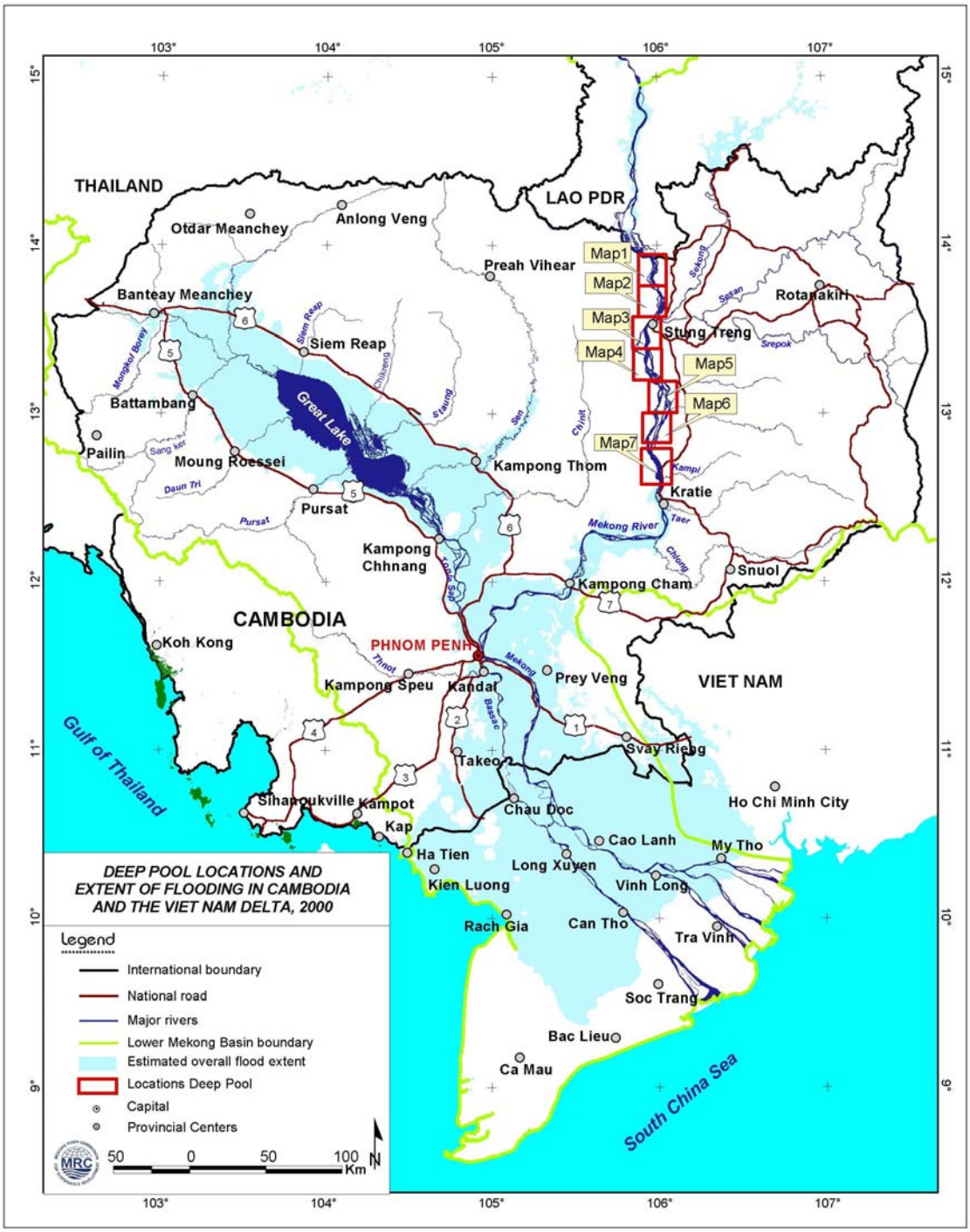
APPENDIX 1

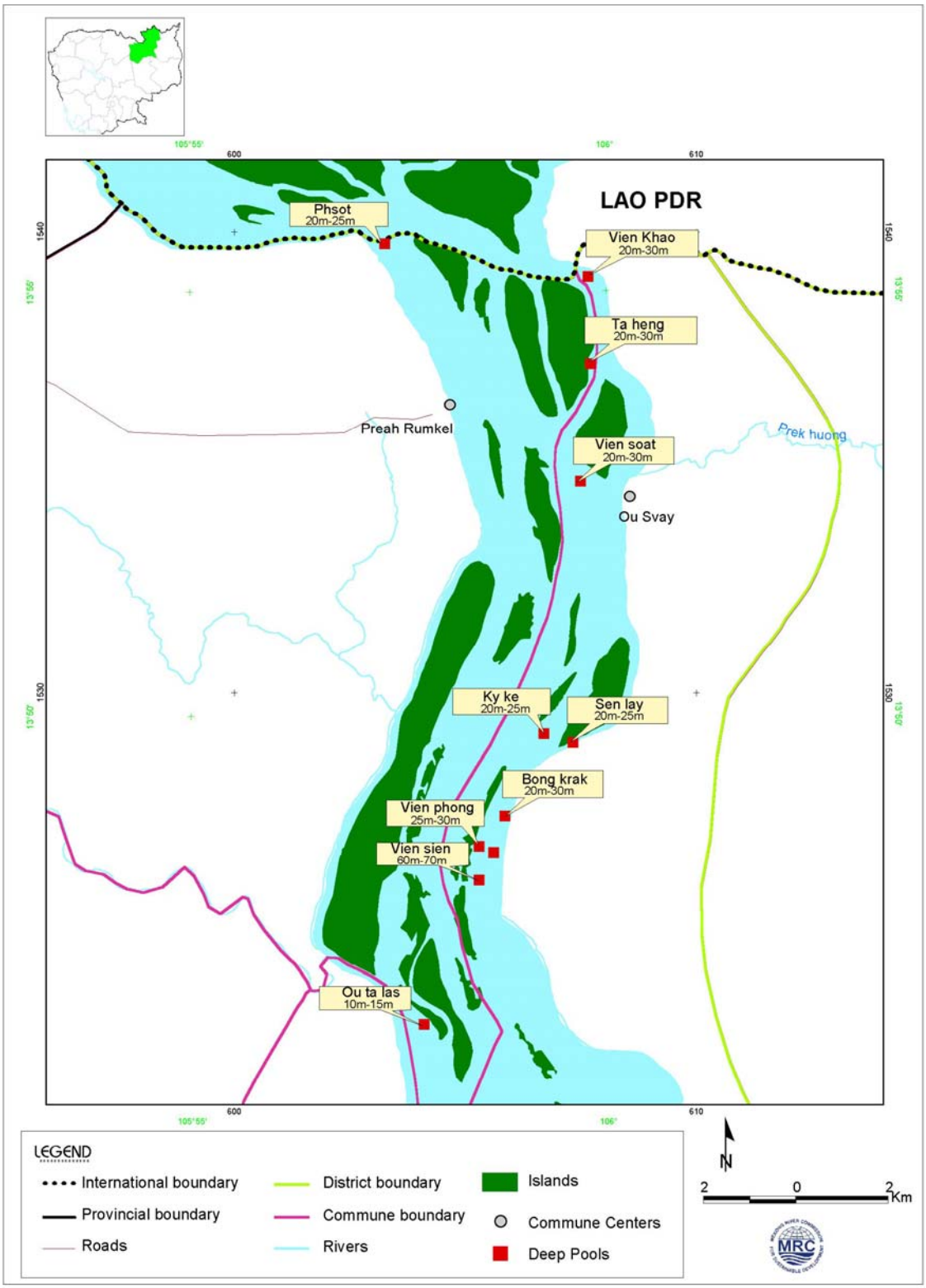
Basic location data on deep pools in northern Cambodia

Province	Village	Deep Pool (Eng)	Distance from border (km)	Lth(m)	Wdth (m)	DpthMax	Area (ha)	North Start and East Start	North End and East End
Kratie	Pontachea	Peamkreang	98.4	1,300	100	7	13.0	N 13^0 01.383' E 106^0 04.740'	N 13^0 00.716' E 106^0 04.513'
Kratie	Damrey	Khul pra or Pra	95.8	1,720	50	**80**	8.6	N 13^0 03.282' E 106^0 00.349'	N 13^0 02.461' E 105^0 59.904'
Kratie	Damre	Kom pong cheav	97	610	80	35	4.9	N 13^0 02.394' E 105^0 59.826'	N 13^0 02.170' E 105^0 59.580'
Kratie	Trarlok	Tro loak	98.5	300	150	25	4.5	N 13^0 02.480' E 106^0 03.499'	N 13^0 02.382' E 106^0 03.368'
Kratie	Damrey	Chhui som yong	98	430	80	30	3.4	N 13^0 02.153' E 105^0 59.565'	N 13^0 01.965' E 105^0 59.429'
Kratie	Damrey	Chap chhnout	99	1,040	80	35	8.3	N 13^0 01.965' E 105^0 59.429'	N 13^0 01.575' E 105^0 59.017'
Kratie	Oukok	Sandan	100.1	580	50	10	2.9	N 12^0 59.565' E 106^0 03.809'	N 12^0 59 272' E 106^0 03 702'
Kratie	Oukok	Andash	102.5	430	50	8	2.2	N 12^0 59.856' E 106^0 03.949'	N 12^0 59.650' E 106^0 03.837'
Kratie	Damrey	Boung cha	103.8	1,270	80	30	10.2	N 13^0 01.575' E 105^0 59.017'	N 13^0 01.035' E 105^0 58.588'
Kratie	Damrey	Kul run teas	101.3	2,270	200	40	45.4	N 13^0 02.046' E 106^0 03.136'	N 13^0 01.140' E 106^0 02.294'
Kratie	Damrey	Leng	104.5	270	80	30	2.2	N 13^0 01.035' E 105^0 58.588'	N 13^0 00.891' E 105^0 58.564'
Kratie	Pontachea	Chaktea	101.8	960	170	20	16.3	N 12^0 59.304' E 106^0 02.994'	N 12^0 59.793' E 106^0 03.174'
Kratie	Oukok	Ancheng	102	870	50	12	4.4	N 12^0 58.898' E 106^0 03.387'	N 12^0 58.464' E 106^0 03.206'
Kratie	Kohtnot	Ver val	105.4	1,580	250	30	39.5	N 13^0 00.095' E 106^0 02.163'	N 12^0 59.278' E 106^0 01.915'
Kratie	Trarlok	Phsa kang kep or val pronang	104.8	2,110	150	40	31.7	N 12^0 58.117' E 106^0 01.550'	N 12^0 57.004' E 106^0 01.319'
Kratie	Oukok	Kampong phnouve	105.9	400	50	15	2.0	N 12^0 57.775' E 106^0 02.489'	N 12^0 57.566' E 106^0 02.435'
Kratie	Pontachea	Sbeu	104	550	170	15	9.4	N 12^0 58.509' E 106^0 02.626'	N 12^0 58.767' E 106^0 02.780'
Kratie	Oukok	Kbalchuortachor	104	640	50	12	3.2	N 12^0 58.031' E 106^0 03.024'	N 12^0 57.948' E 106^0 02.680'
Kratie	Damre	phreas tvie lich	104.8	950	100	30	9.5	N 12^0 58.716' E 105^0 59.030'	N 12^0 58.254' E 105^0 59.252'
Kratie	Trarlok	phreas pon lich	106.9	460	100	30	4.6	N 13^0 03.467' E 106^0 04.030'	N 13^0 03.226' E 106^0 03.980'
Kratie	Damre	som phan	107.2	2,240	100	25	22.4	N12^0 58.134' E 105^0 59.659'	N 12^0 56.829' E 105^0 59.517'
Kratie	Oukok	Tachan yeimau	108	1,200	200	30	24.0	N 12^0 56.720' E 106^0 01.592'	N 12^0 56.088' E 106^0 01.464'
Kratie	Kohtnot	Yeimau	109.6	470	50	30	2.4	N 12^0 55.608' E 106^0 01.168'	N 12^0 55.367' E 106^0 01.094'
Kratie	Ampilteok	Ksach mokak	108.8	1,990	50	50	10.0	N 12^0 56.452' E 105^0 59.754'	N 12^0 55.552' E 105^0 59.151'
Kratie	Vatanak	Skum thom	109.5	180	50	15	0.9	N 12^0 55.705' E 106^0 00.891'	N 12^0 55.617' E 106^0 00.854'
Kratie	Ampilteok	Ksach kpus	110.1	980	50	25	4.9	N 12^0 55.079' E 105^0 58.666'	N 12^0 54.779' E 105^0 58.222'
Kratie	Ampilteok	Kul lbar	110.5	310	50	30	1.6	N 12^0 55.247' E 105^0 59.100'	N 12^0 55.107' E 105^0 59.003'
Kratie	Oukok	Koh chbar	111.4	860	50	20	4.3	N 12^0 54.816' E 106^0 00.624'	N 12^0 54.385' E 106^0 00.442'
Kratie	Ampilteok	Veal Pro Loung	111	2,440	50	20	12.2	N 12^0 58.134' E 105^0 59.659'	N 12^0 56.829' E 105^0 59.517'
Kratie	Pontachea	Kampeang	114	1,070	170	**20**	18.2	N 13^0 00. 490' E 106^0 03.572'	N 13^0 01.000' E 106^0 03.846'
Kratie	Kohpdau	Koh peng	114.9	100	50	15	0.5	N 12^0 50.489' E 105^0 55.898'	N 12^0 50.459' E 105^0 55.944'
Kratie	yey	Ar chhen	115	1,540	50	25	7.7	N 12^0 52.647' E 105^0 56.886'	N 12^0 51.977' E 105^0 56.386'
Kratie	Ampilteok	ksach svay	116.6	1,010	50	25	5.1	N 12^{0}51.977' E 105^0 56.386'	N 12^0 51.497' E 105^0 56.118'
Kratie	Oukok	Kbal koh thkor	116.5	170	50	15	0.9	N 12^0 51.665' E 105^0 58.583'	N 12^0 51.753' E 105^0 58.596'
Kratie	Kohpdau	Koh preng	119	1,860	50	15	9.3	N 12^0 53.169' E 105^0 59.796'	N 12^0 52.218' E 105^0 59.467'
Kratie	Kohtnot	Kon tui koh thkor	119.7	250	50	10	1.3	N 12^0 49.938' E 105^0 58 233'	N 12^0 50.068' E 105^0 58.270'
Kratie	Kohpdau	Koh pdau	118.5	2,620	50	29	13.1	N 12^0 50.705' E 105^0 56.396'	N 12^0 49.405' E 105^0 56.966'
Kratie	Damre	Kon thmor har	120	**50**	**20**	4	0.1		
Kratie	Kohpdau	Koh dom long	121.5	**100**	**50**	5	0.5		
Kratie	Vatanak	Pak vek	125.7	1,000	50	30	5.0	N 12^0 39.570' E 106^0 00.050'	N 12^0 39.037' E 105^0 59.973'
Kratie	Vatanak	Vil pronang	134	2,900	250	40	72.5	N 12^0 41.024' E 106^0 00.692'	N 12^0 39.441' E 106^0 00.576'
Kratie	Vatanak	Preas kor	134.1	1,000	50	15	5.0	N 12^0 39.570' E 106^0 00.050'	N 12^0 39.037' E 105^0 59.973'
Kratie	Kampee	Bai som nom	138.5	300	50	30	1.5	N 12^0 36.685' E 106^0 01.331'	N 12^0 36.523' E 106^0 01.340'
Kratie	Vatanak	Chroy bantay	139	690	50	30	3.5	N 12^0 39.441' E 106^0 00.576'	N 12^0 39.071' E 106^0 00.602'
Kratie	Kampee	Phsot #2	139.5	990	50	20	5.0	N 12^0 36.376' E 106^0 01.315'	N 12^0 35.863' E 106^0 01.458'
Kratie	Kampee	Phreas song	147	500	50	20	2.5	N 12^0 34.913' E 106^0 01.505'	N 12^0 34.648' E 106^0 01.461'

APPENDIX 2

Location of Deep Pools

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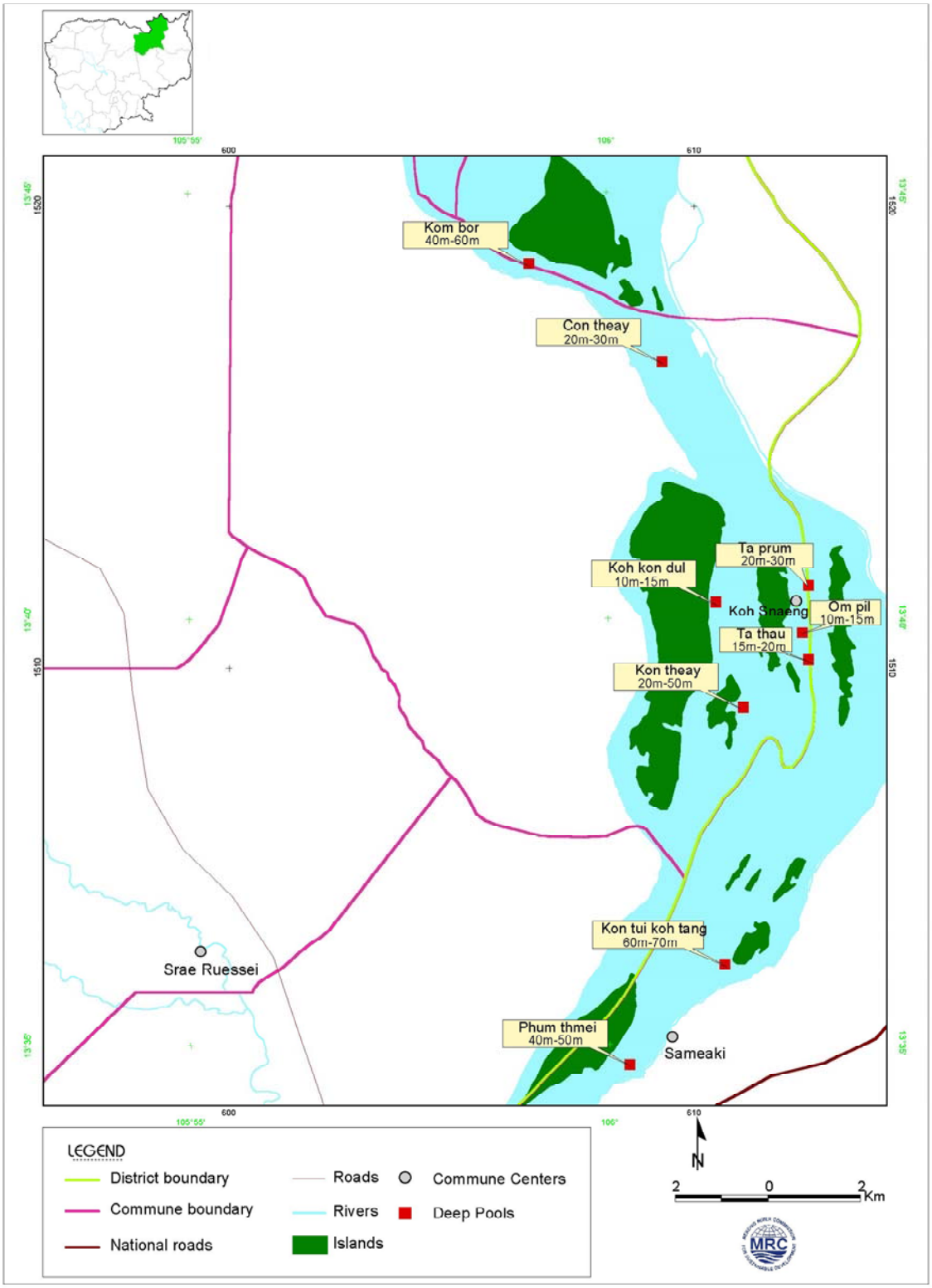
Phsot
20m-25m
Vien Khao
20m-30m
Ta heng
20m-30m
Preah Rumkel
Prek huong
Vien soat
20m-30m
Ou Svay
Ky ke
20m-25m
Sen lay
20m-25m
Bong krak
20m-30m
Vien phong
25m-30m
Vien sien
60m-70m
Ou ta las
10m-15m
105°55'
106°
600
610
1540
1530
13°55'
LEGEND
International boundary
Provincial boundary
Roads
District boundary
Commune boundary
Rivers
Islands
Commune Centers
Deep Pools
N
2
0
2
Km
MRC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Con theay
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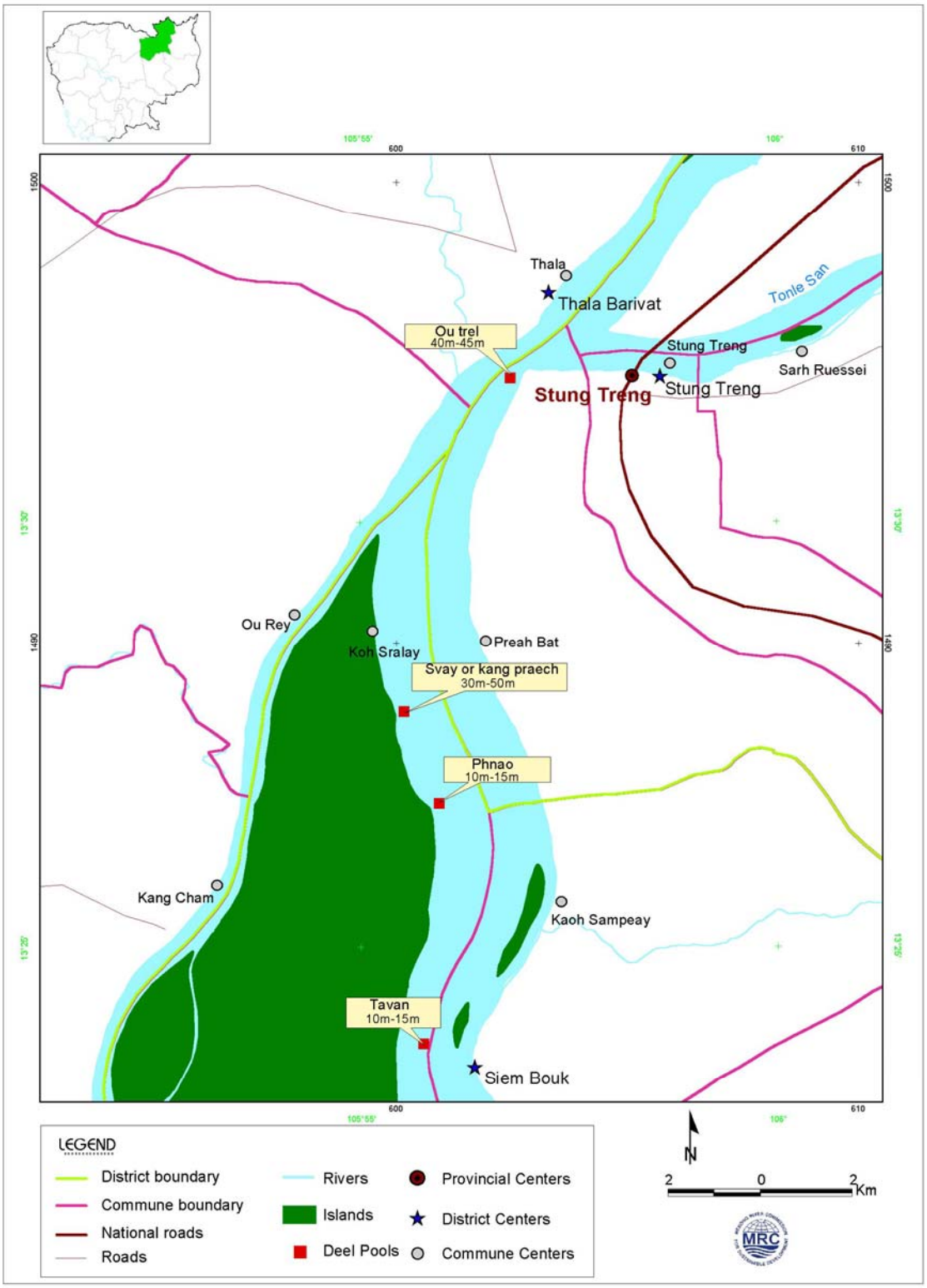
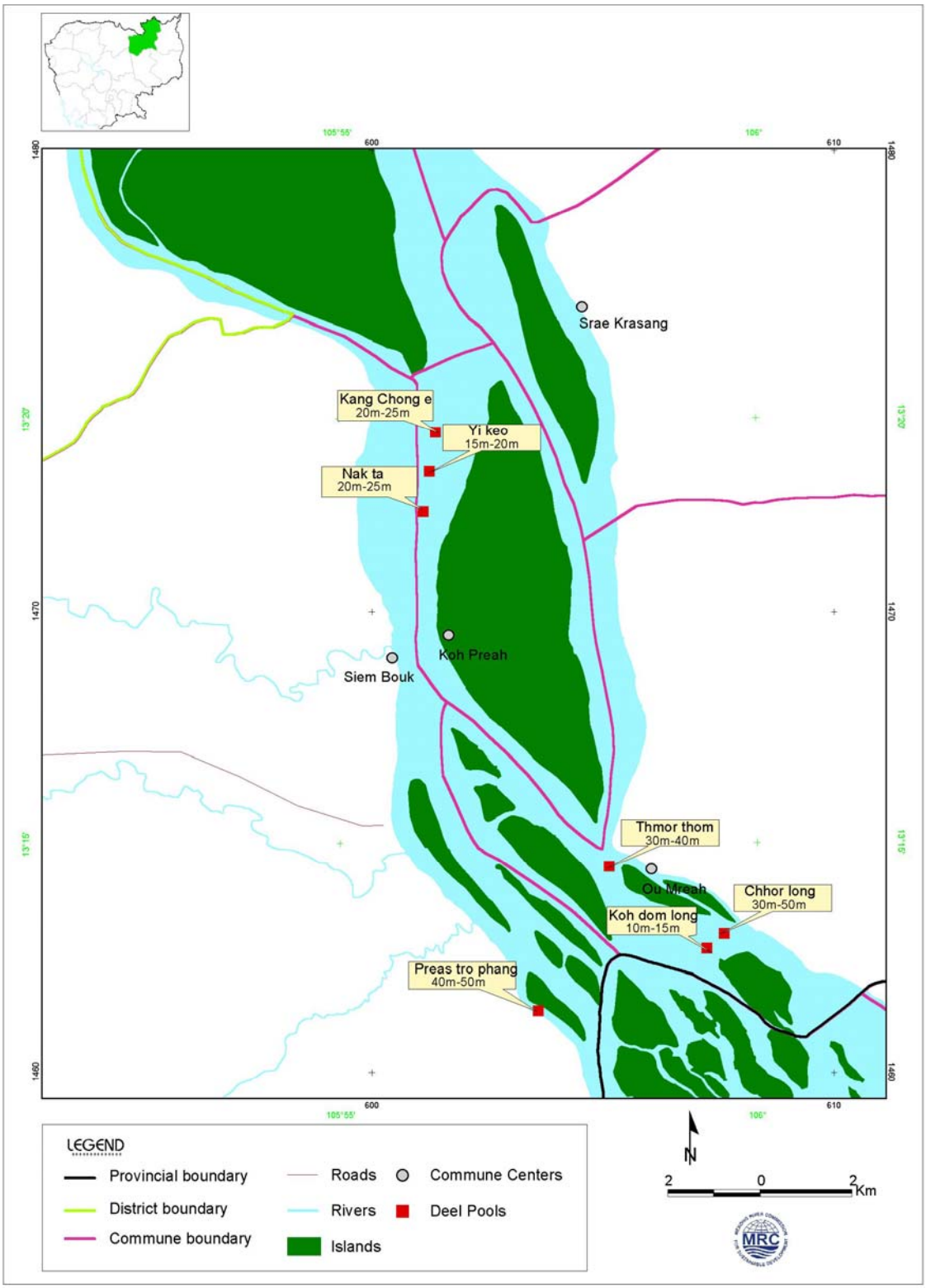
Ta prum
20m-30m
Koh kon dul
10m-15m
Koh Snaeng
Om pil
10m-15m
Ta thau
15m-20m
Kon theay
20m-50m
Kon tui koh tang
60m-70m
Srae Ruessei
Phum thmei
40m-50m
Sameaki
LEGEND
District boundary
Commune boundary
National roads
Roads
Rivers
Islands
Commune Centers
Deep Pools
N
2 0 2 Km
MRC


105°55'
600
106°
610
1500
1490
13°30'
13°20'
Thala
Thala Barivat
Tonle San
Ou trel
40m-45m
Stung Treng
Sarh Ruessei
Stung Treng
Stung Treng
Ou Rey
Koh Sralay
Preah Bat
Svay or kang praech
30m-50m
Phnao
10m-15m
Kang Cham
Kaoh Sampeay
Tavan
10m-15m
Siem Bouk
LEGEND
District boundary
Commune boundary
National roads
Roads
Rivers
Islands
Deel Pools
Provincial Centers
District Centers
Commune Centers
N
2
0
2
Km
MRC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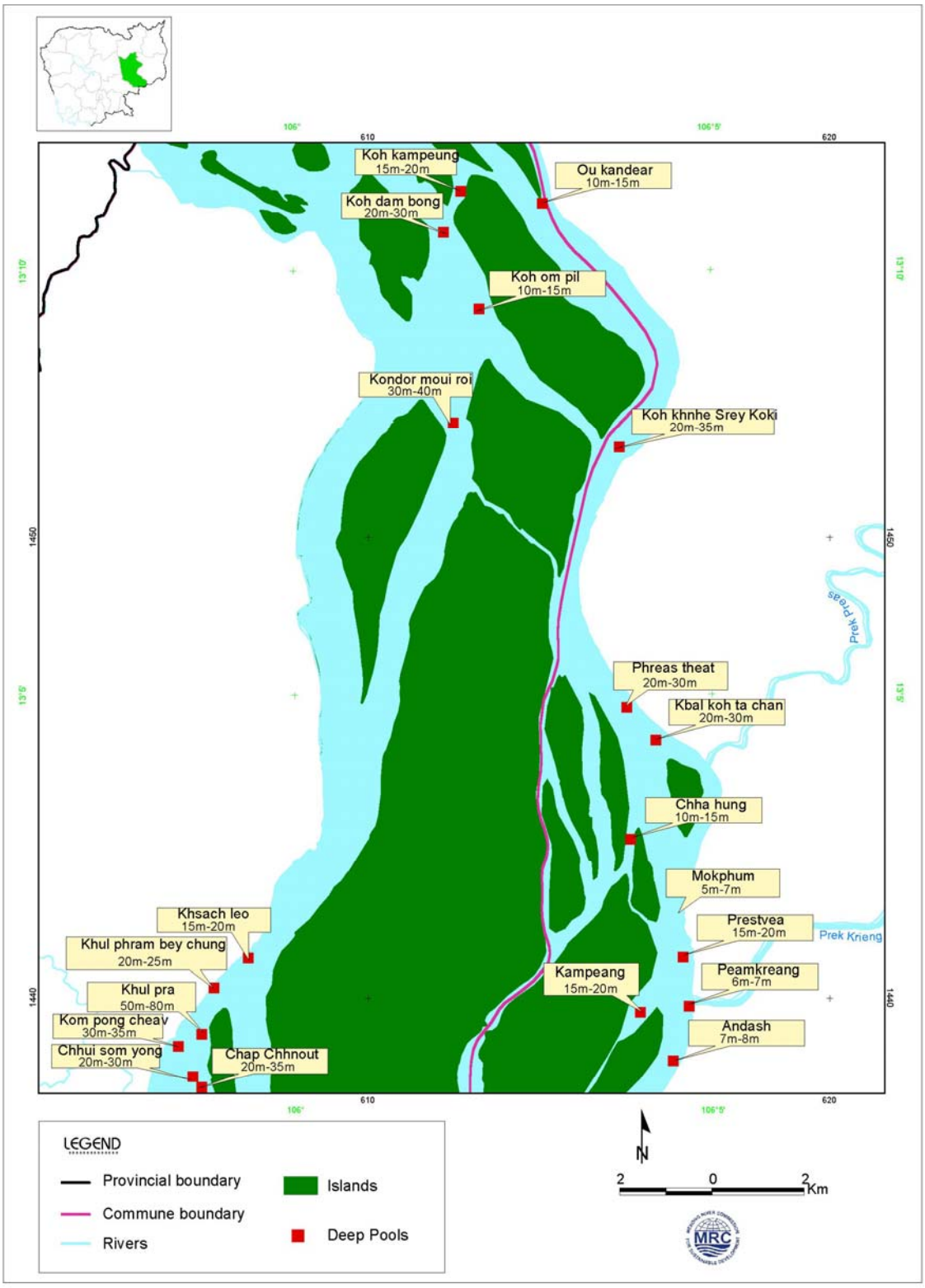
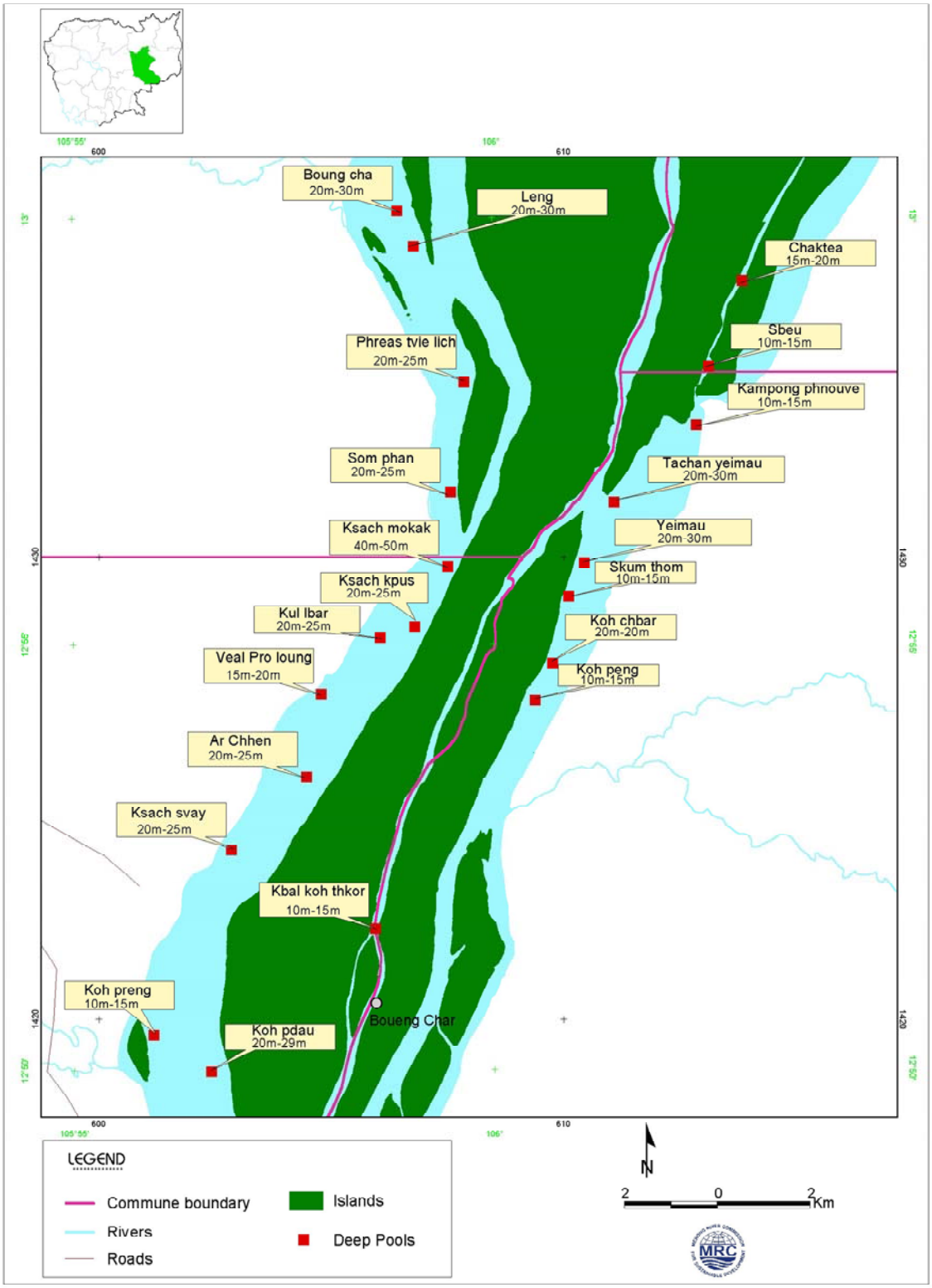
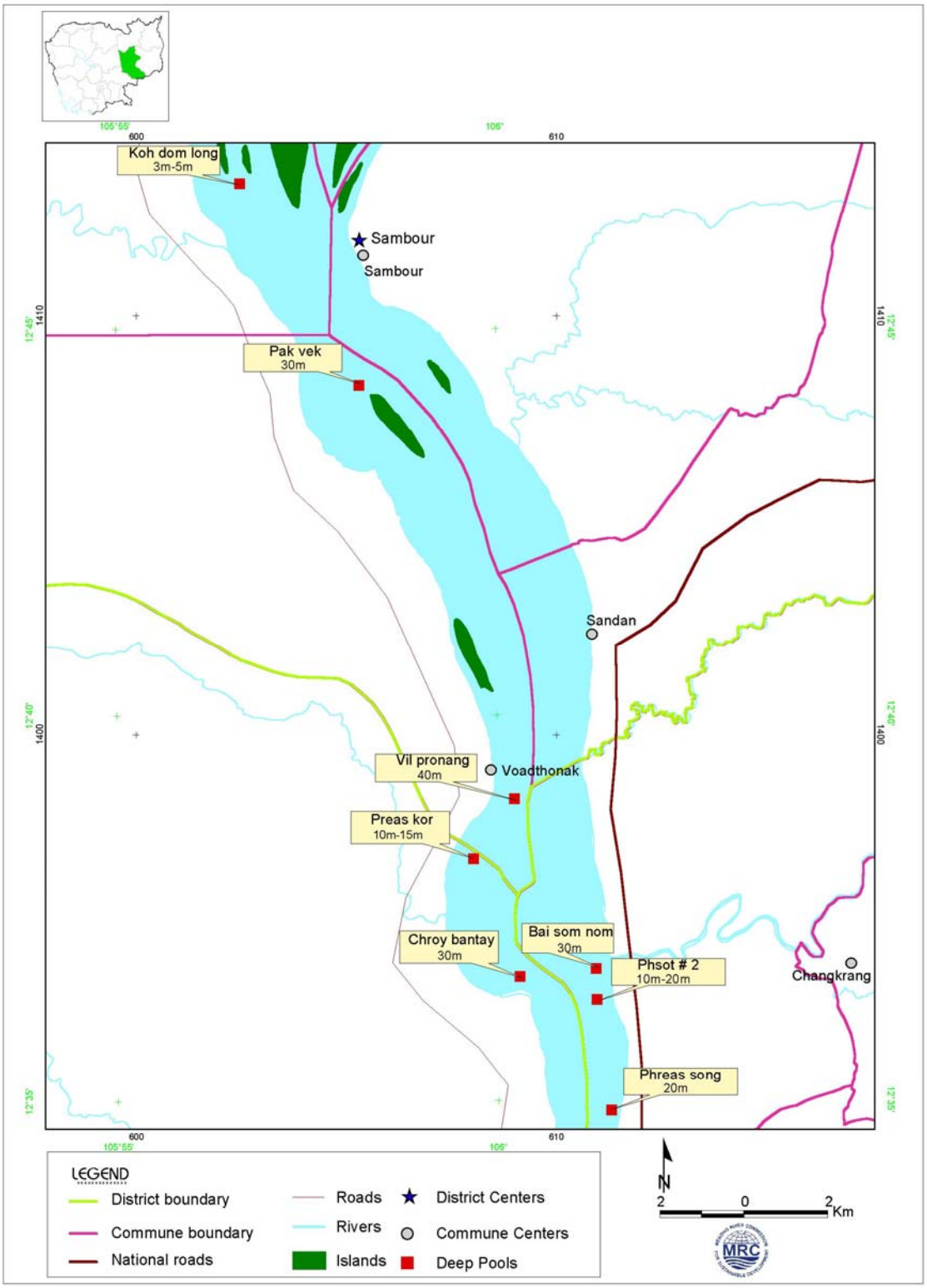
Kang Chong e
20m-25m
Yi keo
15m-20m
Nak ta
20m-25m
Koh Preah
Siem Bouk
Thmor thom
30m-40m
Ou Mreah
Chhor long
30m-50m
Koh dom long
10m-15m
Preas tro phang
40m-50m
LEGEND
Provincial boundary
District boundary
Commune boundary
Roads
Rivers
Islands
Commune Centers
Deel Pools
N
2 0 2 Km
MRC


Koh kampeung
15m-20m
Ou kandear
10m-15m
Koh dam bong
20m-30m
Koh om pil
10m-15m
Kondor moui roi
30m-40m
Koh khnhe Srey Koki
20m-35m
Phreas theat
20m-30m
Kbal koh ta chan
20m-30m
Chha hung
10m-15m
Mokphum
5m-7m
Prestvea
15m-20m
Peamkreang
6m-7m
Andash
7m-8m
Kampeang
15m-20m
Khsach leo
15m-20m
Khul phram bey chung
20m-25m
Khul pra
50m-80m
Kom pong cheav
30m-35m
Chhui som yong
20m-30m
Chap Chhnout
20m-35m
Prek Preas
Prek Krieng
106°
610
106°5'
620
13°10'
13°5'
1450
1440
LEGEND
Provincial boundary
Commune boundary
Rivers
Islands
Deep Pools
N
2
0
2
Km
MRC


Boung cha
20m-30m
Leng
20m-30m
Chaktea
15m-20m
Sbeu
10m-15m
Phreas tvie lich
20m-25m
Kampong phnouve
10m-15m
Som phan
20m-25m
Tachan yeimau
20m-30m
Ksach mokak
40m-50m
Yeimau
20m-30m
Skum thom
10m-15m
Ksach kpus
20m-25m
Kul lbar
20m-25m
Koh chbar
20m-20m
Veal Pro loung
15m-20m
Koh peng
10m-15m
Ar Chhen
20m-25m
Ksach svay
20m-25m
Kbal koh thkor
10m-15m
Koh preng
10m-15m
Koh pdau
20m-29m
Boueng Char
600
610
105°55'
106°
13°
12°55'
12°50'
1430
1420
LEGEND
Commune boundary
Rivers
Roads
Islands
Deep Pools
N
2
0
2
Km
MRC


Koh dom long
3m-5m
Sambour
Sambour
Pak vek
30m
Sandan
Vil pronang
40m
Voadthonak
Preas kor
10m-15m
Chroy bantay
30m
Bai som nom
30m
Phsot # 2
10m-20m
Changkrang
Phreas song
20m
LEGEND
District boundary
Commune boundary
National roads
Roads
Rivers
Islands
District Centers
Commune Centers
Deep Pools
N
2 0 2 Km
MRC