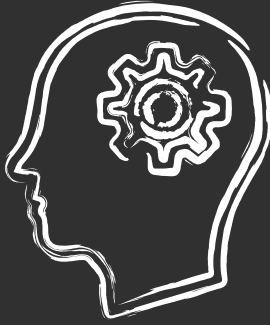


# 2.0 METHODOLOGY FOR DEVELOPMENT OF THE NAM OU RIVER BASIN PROFILE



17

Household surveys and case studies were conducted between December 2015 and February 2016. A total of 1,500 households were randomly selected from 75 sample villages within 5 km of the Nam Ou and the Nam Phak (15 villages per zone, 20 households per village for a total of 300 households per zone). Focus group discussions (FGD) with village heads and key local representatives were held in eight villages as case studies to obtain general information on communities, livelihoods, and trends in resource use. Social issues examined included: history of change in livelihoods in the village; livelihood dependency on water resources, including fisheries and OAA; water sources for agriculture and domestic uses; resilience; livelihood options; and local extreme events (floods and drought).

Staff members from the DWR, three provincial PONREs and 17 district PONREs participated in all field activities and stakeholder consultations. These organizations played key roles in the preparation of the Profile, including training, data collection, data entry, data review, analysis, and report writing.

### Box 3

#### The Nam Ou Fish Poster

Dr. Phouvin Phousavanh from the NUOL compiled an illustrated book and poster to introduce fishes of the Nam Ou as a supporting document to the Profile. This book and poster was based on a series of fisheries surveys he conducted on the Nam Ou between 2007 and 2011.

A total of 139 species found in the Nam Ou and its tributaries were identified and photographed. An analysis of all 139 species recorded in the Nam Ou and represented in the Fish Poster shows that they fall into nine orders and 24 families. Thirty-five of these species are endemic to the Mekong basin, 86 are native, and five are exotic or introduced species.

Five species (6% of the known fish fauna of the drainage) are known from no other drainage and are possibly endemic to the Nam Ou river basin. The highest numbers of endemic species were reported in the upper reaches (Ban Nagnao, Ban Pakban, and Ban Bouasom (Nam Phak)), and fewer species were found in the downstream reaches such as Ban Paknga and Ban Pak Ou.

The team showed the poster to villagers in the case studies to help them identify fish species from their part of the river and the types that were most commonly captured. The poster was also used in discussions about fisheries resources and other issues with local communities.



## The Profile was developed in 6 steps:



**1** Establishing the team comprising representatives from the national, provincial, and district water resource management agencies as well as IFC and its consultants.

while meter readings for pH, temperature (°C), dissolved oxygen (DO, mg/L), and electrical conductivity (µS/cm) were taken at the habitat survey sites. Benthic macroinvertebrates were collected and analyzed based on the South African miniSASS system (<http://www.groundtruth.co.za/river-health-and-water-quality.html>), the sensitivity of different taxonomic groups – ranging from the least sensitive such as the Diptera, worms, and beetles to the most sensitive mayflies, caddisflies, and the stoneflies – was used to determine overall general health of the river.



**2** Background (desktop) research and review of available literature from relevant agencies and organizations at both the central and local levels.



**4** Field survey of 1,500 households in 75 villages along a five-kilometer corridor of the Nam Ou in five zones, and detailed case studies of eight villages.



**5** Data analysis and reporting, including review and interpretation of the field data collected to determine trends in aquatic resource use over time, and writing the Profile document.



**3** Designing tools for primary data collection, including: developing questionnaires, household surveys, and habitat surveys; water-quality analysis; collection of benthic invertebrates; and, GIS/mapping.

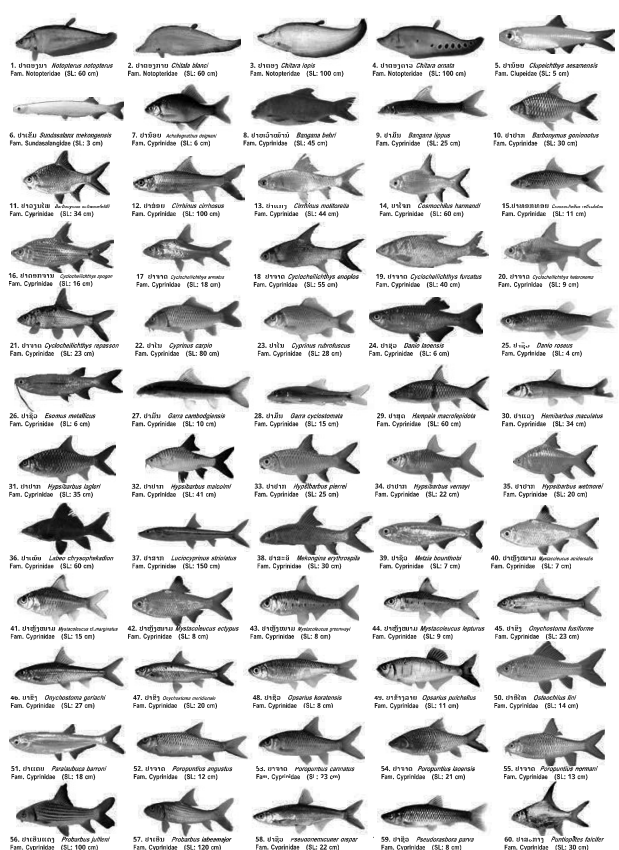


**6** Review and approval of the Profile by key Government of Lao PDR (GoL) stakeholders at the national, provincial and local levels through consultation workshops, discussions, and meetings. Capacity building for GoL staff was an integral part of the Profile development process. IFC provided on-the-job training to the central, provincial, and district water resources departments on how to collect and analyze data and information for river basin Profile development. IFC also produced a video to describe the methodology used in developing the Profile: <https://www.youtube.com/watch?v=sg7-jJN-GV8&feature=youtu.be>

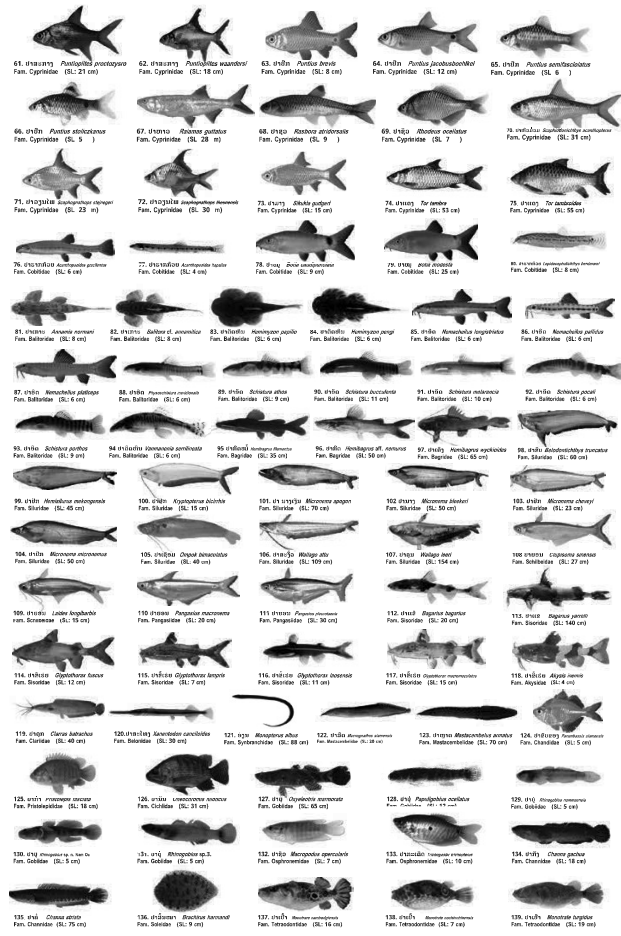
The Nam Ou was mapped using GIS techniques and Google Earth imagery to identify the key geomorphological features of the basin, according to the method developed by Saran (2010) and Meynell (2014) for the Sesan and Sakong Rivers. Livelihood dependence on water resources was mapped within a 5-, 10- and 15-km distance from the river. Key features such as river length, width, depth, habitat types, and vegetation were mapped and verified in rapid-river surveys and habitat surveys during the field program and case studies. Water samples were collected at eight water monitoring sites on the Nam Ou established by PONRE and DWR.

18

## NAM OU FISH

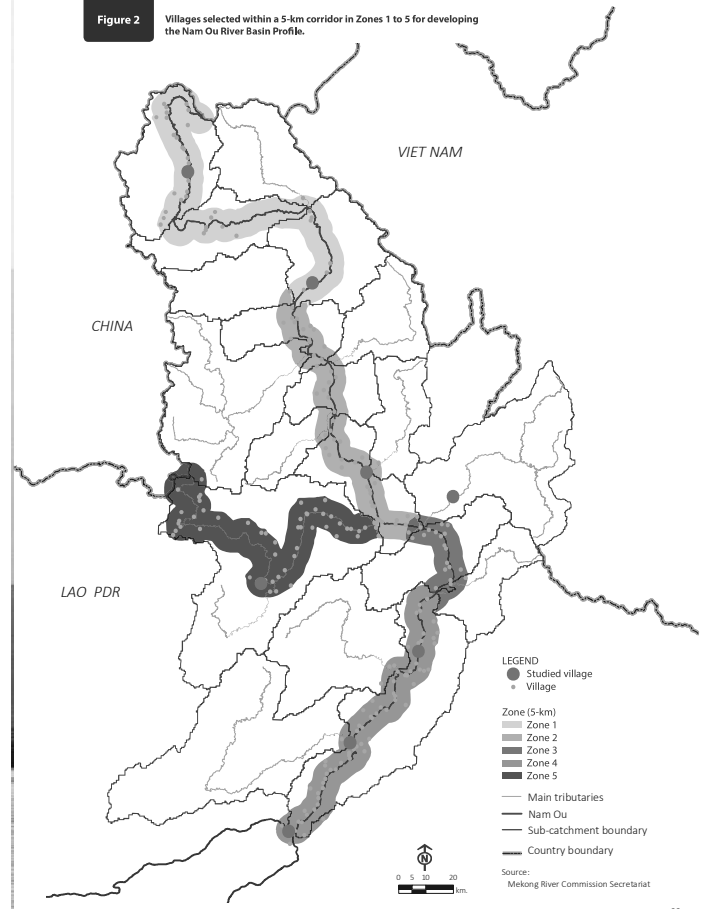


20



NAM OU RIVER BASIN PROFILE - SUMMARY DOCUMENT

Figure 2 Villages selected within a 5-km corridor in Zones 1 to 5 for developing the Nam Ou River Basin Profile.



NAM OU RIVER BASIN PROFILE - SUMMARY DOCUMENT

Box 4

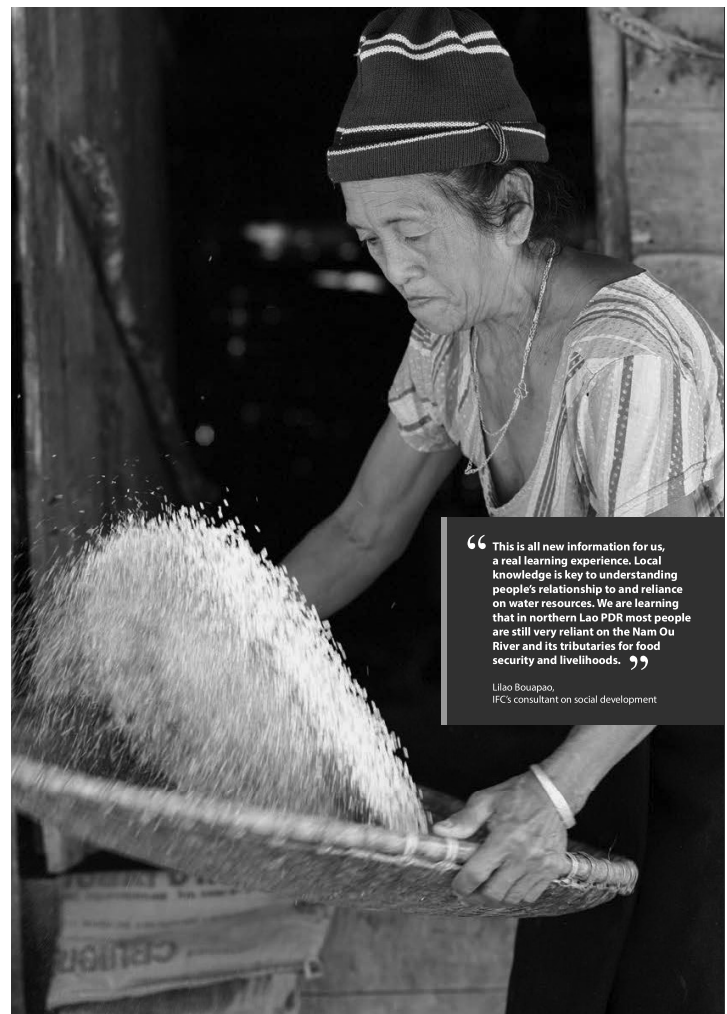
Case Studies & Zones in the Nam Ou Basin

To understand the dynamics of the river and its use, the Nam Ou Basin is divided into four key mainstream zones and one large tributary zone to represent the different geographic and biophysical features of the river and to better manage the case studies. These five zones are described below:

- **Zone 1:** Headwaters and upland river from the source to the confluence with the Nam Ngay, with a protected area covering the eastern tributary, the Nam Khang.
- **Zone 2:** Medium-sized, fast-flowing upland river, geologically-coherent sandstone, ecologically similar, from the confluence of the Nam Ngay to Muang Khoa, the confluence with the Nam Phak.
- **Zone 3:** Large, fast-flowing river with transition from sandstone to limestone, including the area from Muang Khoa (the Nam Phak) to the Nam Bak (Nong Khaw); includes the tributary from Vietnam (the Nam Noua).
- **Zone 4:** Large, low-lying river flowing through mainly limestone karst landscape, from the Nam Bak confluence (Nong Khaw) to the Pak Ou confluence with the Mekong.
- **Zone 5:** The Nam Phak, the largest tributary flowing through Oudomxay to Muang Khoa.

The field visits conducted in January and February 2016 aimed to familiarize the core team with the hydrological, environmental, and social conditions along the entire length of the Nam Ou and its main tributaries. The visits also helped validate the statistical and geographic information to be used in developing the Profile. The eight villages selected for case studies, along with their corresponding zones, were as follows (see also Figure 2):

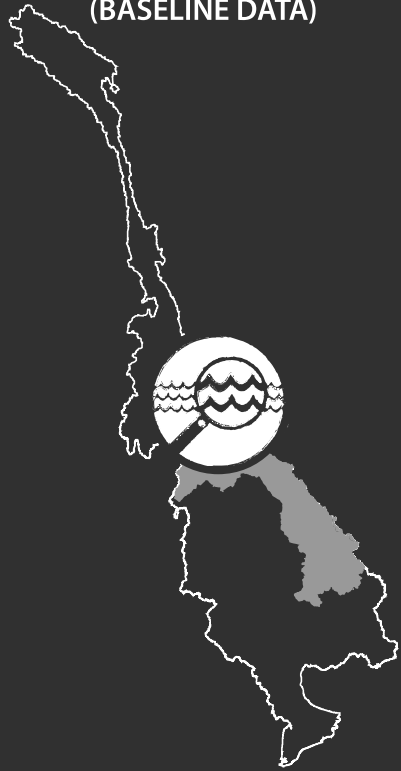
- **Zone 1:** Ban Nagnao and Ban Phoumouang (now Ban Homsang).
- **Zone 2:** Ban Pakban and Ban Bouamsom (the Nam Phak, also in Zone 5).
- **Zone 3:** Ban Sobnao (the Nam Noua) and Ban Sopkong.
- **Zone 4:** Ban Paknga (the Nam Nga) and Ban Pak Ou.



“ This is all new information for us, a real learning experience. Local knowledge is key to understanding people’s relationship to and reliance on water resources. We are learning that in northern Lao PDR most people are still very reliant on the Nam Ou River and its tributaries for food security and livelihoods. ”

Lila Bouapao, IFC’s consultant on social development

# 3.0 RIVER BASIN CHARACTERISTICS (BASELINE DATA)



The density of villages along the river increases in the lower end between km 120 and Pak Ou, and many of these lie on the right bank (see Figure 1). This distribution of villages is clearly influenced by the presence of the road along Road No. 13 from Luang Prabang, with many villages on the right bank up as far as km 50, which is where the road diverts to follow the Nam Nga to Oudomxay. There are also large numbers of villages in Pak Bak and Nong Khiao to Meuang Ngoy (km 90 to km 120). The number of villages decreases upstream, but usually there is at least one village on both sides within each 10-km stretch. The larger number of villages around Meuang Kho (km 180) and Meuang Samphan (km 220) also stand out.

River-bank gardens can be observed on Google Earth and it is evident that these tend to be associated with the villages, especially along the lower reaches of the river between Pak Ou and Meuang Ngoy. Above this there appear to be fewer river-bank gardens that can be seen on the imagery. This may reflect the steeper rocky banks, which are less favourable for cultivation.

The main soil types are Acrisols with four sub-types present (Ferric, Gleyic, Haplic, and Humic), making up 82.8% of the basin's area. Haplic Acrisols are the predominant type. They tend to be acidic with a low base status (<50% base saturation) and strongly leached. Most soils in the Nam Ou Basin are relatively infertile and, unless well-managed, liable to degradation; as a result, crop yields tend to be low.

### Box 5

#### Karst & Caves in the Nam Ou Basin

There are five recognized karst areas with documented caves within the Nam Ou Basin. These are at Oudomxay, Nong Khiao, Meuang Ngoy Neua, Nam Bak, and Pak Ou. There is no record of karst or caves in Phongsaly. The Nam Ou cuts through impressive karst peaks and massifs, at one point via a very deep limestone gorge. Caves occur both close to present river level and at 50-100 m above it. At the Nam Ngoy-Nam Ou confluence, the limestone mountains in the Meuang Ngoy Neua area are cut by a spectacular gorge with vertical rock walls up to 600 m high, where the village of Ngoy Neua is situated.

The Pak Ou Caves are located on the Mekong near the confluence of the Nam Ou with the Mekong, about 25 km upstream from Luang Prabang. Two of the caves contain large numbers of Buddha Images and are an important tourism site.

Source: (Kiernan 2009)

The following are the Nam Ou's baseline sediment transport characteristics as described by HydroChina Kunming Engineering Corporation (HKEC) (ESL 2011):

- Sediment concentrations in the Nam Ou are low in the dry season but are relatively high during floods (mainly in the wet season).
- The average annual sediment flux at Meuang Ngoy is estimated at 233 tonnes/km<sup>2</sup> per annum, more than doubling the rate of 113 tonnes/km<sup>2</sup> per annum reported by the Water Quality Monitoring Network (1997).
- Meuang Ngoy's average annual sediment flux corresponds to a sediment flux of 142.4 kg/s and an average annual sediment concentration of 0.346 kg/m<sup>3</sup>. These figures represent suspended sediment loads.

At the average annual flow rate of 100-600 m<sup>3</sup>/s in the Nam Ou's cascade sites, the estimated bed load of 150-830 × 10<sup>6</sup> tonnes/day would represent around 10-15% of the total sediment load, which is typical of mixed load systems (Lane and Borland 1951). Assuming an average sediment transport rate of 113-250 tonnes/year/km<sup>2</sup> and a bed load sediment flux equivalent to 5-15% of the total sediment load in the Nam Ou, it is estimated that the average total sediment load (suspended plus bed load) is around 120-290 tonnes/year/km<sup>2</sup>.

The average total sediment load of 120-290 tonnes/year/km<sup>2</sup> estimated for the Nam Ou Basin is likely to be higher than various estimates of the natural (pre-clearing) sediment yield from catchments in the humid tropics, which range from 80 to 150 tonnes/year/km<sup>2</sup> (Yu 2005). Furthermore, the sediment load could be significantly higher based on erosion events triggered by land clearing, mining, dredging, and hydropower construction in the catchment.

## Climate & Meteorology

The Nam Ou catchment has a tropical monsoonal climate, with a distinct wet season between May and October and a pronounced dry season for the rest of the year (Figure 4). Average annual rainfall within the catchment ranges from around 1,250 mm (Luang Prabang) to 1,750 mm (Meuang Ngoy). In 2009, annual rainfall was 1,752 mm at Phongsaly, 1,340 mm at Oudomxay, and 1,260 mm at Luang Prabang, while evaporation rates represented 43% (747.8 mm), 66% (879 mm), and 67% (847 mm) of rainfall at these stations, respectively (ESL 2011). Around 84% of the total rainfall occurs during the wet season, with the highest rainfall occurring in the months of July and August.

From 1971 to 2006, average maximum temperatures at Luang Prabang ranged from 34°C to 44°C, while Phongsaly recorded average maximum temperatures of 26°C to 35°C from 1988 to 2006. The hottest months are from April to June. Average minimum temperatures range from 3.4°C to 20°C at Luang Prabang and 0.4°C to 12.4°C at Phongsaly. Temperatures are lowest in December and January. Spatial temperature trends exist across the Nam Ou catchment, with average monthly temperatures becoming increasingly cooler in the north (toward Phongsaly) and warmer in the south (toward Luang Prabang).

In December and January, temperatures in the north of the basin can drop significantly, even down to 0°C. Prolonged periods of up to 10 days of cold weather have been recorded in several years, most recently in 2016, and can lead to livestock mortality. In January 2016, cold weather caused the deaths of large numbers of fish, especially *Puntigriltes procyonatus* (61), in the Nam Noua, according to villagers in Ban Sopnoa.

Rainfall distribution is even more distinct. Between May and October, most of the upper (northern) parts of the Nam Ou Basin receive between 1,200 mm and 1,500 mm of rainfall, while the lower parts of the basin (effectively Luang Prabang) receive between 1,100 mm and 1,200 mm. In the dry season, the lower rainfall range of 200-300 mm appears to follow the river valley from a drier area around Gnot Ou and then an increasingly wetter area from the Nam Phak confluence down to the Mekong. Outside of these drier areas (on the higher ground), rainfall in the dry season ranges from 300-400 mm.

# 3.1 PHYSICAL CHARACTERISTICS & GEOGRAPHIC SETTING

## Physical characteristics

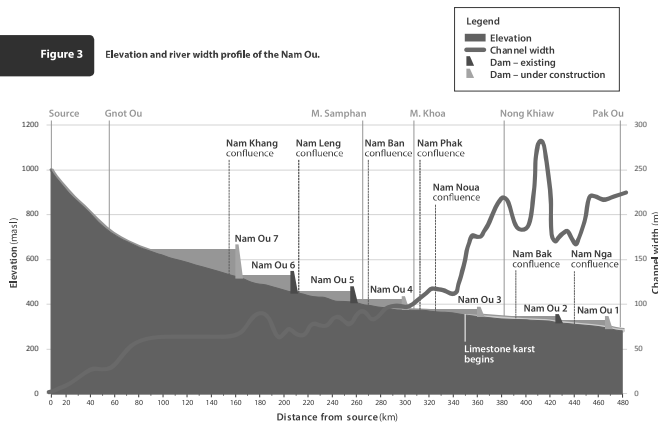
The Nam Ou Basin lies in three provinces of Lao PDR: Phongsaly, Oudomxay, and Luang Prabang. The basin is characterized by rugged, hilly, and sometimes mountainous terrain with steep-sided river valleys and fast-flowing rivers over rocky river bed and banks. In a classification of the watersheds of the Mekong, the MRC estimated the slopes and watershed classes of the Nam Ou as follows: 10% of the basin is very steep (>40% slope), 48.5% is steep (30-60% slope), and 24.3% is medium steep (15-30%). Only 22.2% of the basin is flat (0-2% slope) (MRC 2001).

The Nam Ou rises in the mountains of northern Lao PDR in Phongsaly Province, just south of the border with China. An elevation profile of the Nam Ou shows that it rises at over 1,000 m above sea level (masl) and meets the Mekong at 290 masl, after a distance downstream of 465 km (Figure 3). During the early courses of the Nam Ou, it widens from a fast-flowing mountain stream with a rocky bottom about 2 m wide, to a recognizable river over 10 m wide within a few kilometers. The surrounding hill slopes are forested or have been cleared for cultivation of tea and banana plantations in some areas. A further 20 km downstream in one of these steeper stretches, a mini-hydropower plant has recently been constructed – the Nam Ou 9. This is a run-of-river plant that diverts water from a small headpond through about 700 m of headrace channel to the powerhouse; it has an installed capacity of 450 kW.

The river falls consistently from 527 masl at the Nam Khang confluence to 279 masl at Pak Ou. This is equivalent to a fall of 0.75 m per kilometer of the river. Changes in the river width show a trend of widening with passage downstream from the confluence with the Nam Khang. The sites of the hydropower plants have been built near some of the narrowest points in the river.

The Nam Ou is characterized by its rapids interspersed with deep pools, which are present for more than a third of its total length. The sinuosity of a river (SI) is a measure of the extent to which the channel bends and turns. Alluvial rivers tend to be more sinuous than upland rivers, though this depends on the underlying geological formations. This highlights the fact that the Nam Ou is generally a very straight river (where the SI is between 1 and 2); there is at least one tributary entering on each side per 10 km for most of the length of the river, except between km 140-160, and at km 270. A few of the 10-km stretches have several streams and tributaries entering on both banks.

Figure 3 Elevation and river width profile of the Nam Ou.



Source: Google Earth survey for Nam Ou profile and S-molydco.

### Box 6

#### Flood Events & other Disasters

Key flood characteristics of the Nam Ou at Meuang Ngoy are summarized below (HKEC 2009):

Flood hydrographs are typically unimodal, with a duration of 5-15 days, with major floods occurring in 1994 and 1996.

August 15-19, 1996	Heavy monsoon rainfall from the east gave rise to a peak flood discharge of 7,017 m <sup>3</sup> /sec, damaging agricultural crops. The maximum average daily discharge was 9,290 m <sup>3</sup> /s.
July 15-20, 1994	A monsoon typhoon caused damage to agricultural crops and livestock. The storm rainfall was 1,090 mm, giving rise to a peak flood discharge of 7,771 m <sup>3</sup> /sec.
July 26, 1992	Minimum average daily discharge was 1,660 m <sup>3</sup> /s.

In Phongsaly, three major floods have taken place since 2001:

- 2016 Nam Lan and Nam Leng in Boun Tai.
- 2011 Meuang Mai and all tributaries of the Nam Neua.
- 2001 In Meuang Gnot Ou, the urban area close to the river was flooded with significant damage, including the concrete irrigation water pipe.

Meuang La appears to be the district most affected by flash flooding, with three big recorded events in 1975, 1991, and 2008. In 1991, 17 people were killed and 20 injured, but no casualties were recorded in the other floods. Drought, in terms of water supply and agriculture, has not occurred in the Nam Ou Basin. (Source: Provincial validation workshops)

## Nam Ou Water Resources

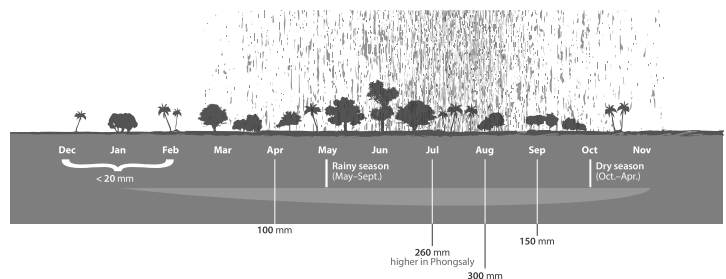
### Hydrology

#### Tributaries and Catchment Area

The Nam Ou has 11 major tributaries. The size and ranking of their catchment areas are shown in Table 1. The Nam Phak, the Nam Nga, and the Nam Leng are the top three tributaries by catchment area and percentage of the river basin, with the Nam Noua being the fourth-largest tributary.

Information on the Nam Ou's surface water hydrology was obtained from the official hydrological gauging station at Meuang Ngoy (20°42'38.01"N, 102°40'25.52"E), which had records dating back to the 1970s. Several other hydrological stations have been put in place recently for other purposes such as hydropower development, but the records for these are either unavailable or are not of long duration. Daily flow data from 1987 to 2003 were used to generate hydrological estimates for the design of the seven-dam cascade (HKEC 2009) and the IDOM training study between 1999 and 2003 (IDOM 2014, ESL 2011).

Figure 4 Long-term mean monthly rainfall in Nam Ou Basin.



**Hydrology – Key characteristics (HKEC 2009):**

- The average discharge of the Nam Ou at Meuang Ngoy was 440 m<sup>3</sup>/s, based on data collected from 1987 to 2003.
- The maximum average annual discharge was 710 m<sup>3</sup>/s (1971) and the minimum was 221 m<sup>3</sup>/s (1992).
- Runoff increases each year from May, peaking between July and September, and decreases from November to April.
- Around 83.6% of the annual runoff occurs in the wet season (June to November), while only 16.4% occurs in the dry season (December to May).
- The lowest average monthly discharge occurs around March to April, with a minimum of 57 m<sup>3</sup>/s observed in April 1979.
- Based on an average annual rainfall of 1,650 mm and an average annual runoff depth of 721 mm, the runoff coefficient for the catchment is estimated at 44%.



**Surface Water Quality**

The Mekong River Commission has been collecting monthly water quality data from different sites on the Mekong since 1985, including one location on the Nam Ou at Ban Hat Kham downstream from the Pak Ou bridge (Station Name and ID: Ban Hat Kham, H100101). Figure 5 shows general trends in water quality observed at this station over time.

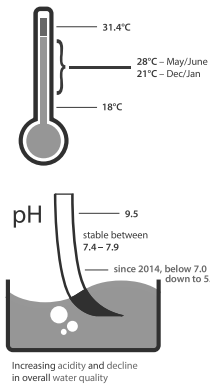
When compared to the United Nations Economic Commission for Europe (UNECE)'s river quality standards regarding DO, chemical oxygen demand, manganese, Total P, Total N, pH, and alkalinity, most of the samples collected since 1985 fall into Aquatic Health Classes 1 and 2 (UNECE 1994). Historically, the aquatic health of the Nam Ou waters at Ban Hat Kham before discharge to the Mekong was generally very good to good, especially for DO, pH, and chemical oxygen demand. Upstream waters in Phongsaly have better water quality than downstream in Luang Prabang near the confluence with the Mekong.

**Table 1** Catchment area (km<sup>2</sup>) and estimated average annual flow rate (m<sup>3</sup>/s) for the Nam Ou Basin and its main tributaries.

Tributary	Code	Catchment area (km <sup>2</sup> )	% of basin area	Annual Avg. flow (m <sup>3</sup> /s)	Rank*
1. Nam Khang	(NK)	1,097	4.2	21.7	6
2. Nam Ngay	(NNy)	879	3.4	18.6	8
3. Nam Leng	(NL)	2,092	8.1	40.9	3
4. Nam Houn	(NH)	881	3.4	19.5	7
5. Nam Pok	(NP)	517	2.0	10.0	11
6. Nam Ban	(NB)	742	2.9	15.3	9
7. Nam Phak	(NPk)	3,342	12.9	68.4	1
8. Nam Noua	(NNa)	2,089	8.1	32.1	4
9. Nam Hub	(NHb)	713	2.8	12.9	10
10. Nam Bak	(NBk)	1,722	6.6	15.8	5
11. Nam Nga	(NNg)	2,677	10.3	47.1	2
<b>Total Tributary area (km<sup>2</sup>)</b>		<b>16,752</b>	<b>64.7</b>		
<b>Nam Ou Basin total area (km<sup>2</sup>)</b>		<b>25,910</b>			

Source: GIS analysis and HKEC 2009.  
\*Ranked by catchment area and flow contribution

**Figure 5** Average monthly water temperature and pH at Ban Hat Kham since 1985 (Source MRC).



In recent years, there has been an increase in nutrient levels such as Total P and Total N (perhaps indicating a tendency toward eutrophication) and lower alkalinity, suggesting that the water has less potential for buffering acidity. There are some marked peaks in COD up to 16 mg/l between 2012 and 2014. These figures all point toward a general decline in the Nam Ou's water quality in recent years, especially in downstream areas, probably coinciding with large infrastructure construction activities upstream of Ban Hat Kham.

Key sources of water pollution include: industrial discharges in urban areas, untreated sewage, hydropower development, sand and gravel dredging, gold mining (including use of mercury), and overuse of agricultural chemicals on banana and rubber plantations. To date, no comprehensive surveys of toxic chemicals, including persistent organic pollutants, have been conducted on the Nam Ou, and there are limited data on heavy metals and other parameters of concern.

**Wetlands & Associated Waterbodies**

The total area of water bodies found in the Nam Ou is estimated at 5,554 ha. This includes the river itself and standing bodies of water, lakes, ponds, and reservoirs. As a very steep-sided and rather narrow valley, the Nam Ou Basin is generally not suitable for the formation of natural lakes and wetlands; there is little floodplain area where such wetlands could form. However, floodplain areas on the banks of the main river and tributaries are important spawning areas for many fish species and are used as riverbank gardens during the dry season.