Other Industrial Sectors

Of all the river basins in Lao PDR, the Nam Ou Basin has among the lowest number of industries. In 2013, the Asian Development Bank Core Environment Program carried out a study of industrial pollution in the country (ADB Core Environment Program, 2013). Most of the industries are in Oudomxay, especially in Meuang Xai; industries in Luang Prabang Province are concentrated in the urban areas and not in the Nam Ou Basin.

Riverine sand and gravel dredging in the basin occurs in many locations. A total of 22 sand extraction licenses have been granted: 14 on the Nam Kor, four on the Nam Muan, three on the Nam Phak, and one on the Nam Ngao – together, they extract 13,823 tons of sand per day. Sand and gravel extraction is usually a dry-season activity, when the flows and river levels are lower and the sediment transport is reduced.

Artisanal gold mining occurs in many villages and is usually conducted by women and children. Impacts from these small local operations are likely minimal and restricted to small areas. However, in the middle sections of the river, there are large gold mining operations, which may significantly affect water quality and fisheries habitats (i.e., pools and riverbed).

Navigation & Tourism

River transport on the Nam Ou has historically been very important. Boats move people and goods up and down the full length of the mainstem, bringing them to villages and towns that would have been difficult to access by land. Most parts of the river are navigable, except in some areas where rapids restrict movements of smaller vessels, especially during the dry season. Boats can carry up to 2,000 kg of people and cargo when river conditions are ideal (and 500 kg per boat in the dry season). The connectivity of the river enabled trade and socialization between different villages and ethnic groups in the basin.

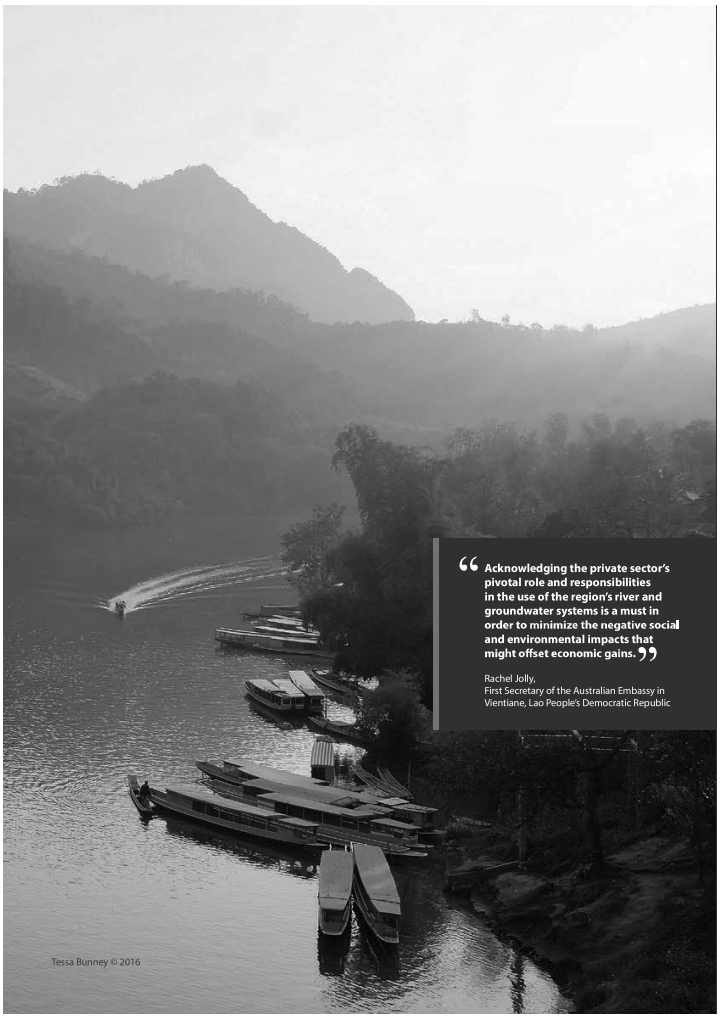
The construction of the Nam Ou dams 2, 5, and 6 has dislocated some of the boat routes. To address the issue, boat landings were built on the reservoirs above the dam wall. Villagers now have to portage around the dam sites, using local roads. To some extent, the reservoirs have made navigation easier and safer compared to the river, which was sometimes difficult to navigate, especially at low water levels. However, the dams are expected to pose significant and negative impacts on trade and overall vessel movement between communities.

Tourism is an important economic sector in the Nam Ou Basin, especially in the lower reaches of the river between Meuang Ngoy through Nong Khiaw to Pak Ou. These include the areas with dramatic limestone-karst landscape, caves, and river transport to the Mekong. In 2015, there were 13,541 domestic visitors and 38,863 foreign tourists visiting the Nam Ou according to data presented at the Luang Prabang provincial validation workshop. Tourism also depends on boat transport on the river, especially from Meuang Khoa to Nong Khiaw and Pak Ou. The construction of Nam Ou 3 and 4 within the main tourist area will likely have a significant impact on tourism.

Urban & Rural Water Supply

Urban areas in the Nam Ou Basin are relatively small. The largest is the provincial capital of Oudomxay, which has a population of around 25,000 people, followed by Phongsaly provincial capital. The district headquarters have smaller populations of under 5,000 people. Total urban water usage in the Nam Ou Basin, including Vietnam, is likely to be in the range of 12,000–19,000 m^3/day. In Vietnam, the town of Dien Bien Phu has an estimated population of 100,000 people, making it the largest urban area in the basin.

There are many rural water supply schemes. In M. Pak Ou, 50 villages are supplied with water, five of which come from springs and the rest from streams and rivers; a total of 27,634 people are served by these schemes. Eight schemes have problems with the water source drying up and not producing sufficient quantity, while the water is too hard for two of these schemes.



> **“Acknowledging the private sector’s pivotal role and responsibilities in the use of the region’s river and groundwater systems is a must in order to minimize the negative social and environmental impacts that might offset economic gains.”**
>
> Rachel Jolly,
> First Secretary of the Australian Embassy in Vientiane, Lao People’s Democratic Republic

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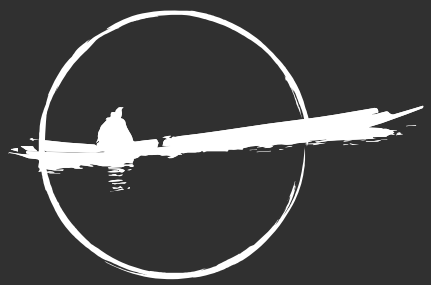
5.0
THE FUTURE OF THE NAM OU BASIN



5.1 CHANGES IN WATER FLOW PATTERNS

Flow patterns in the Nam Ou experienced significant changes in 2015 mainly because three of the dams in the cascade (Nam Ou 2, 5, and 6) were constructed and the associated reservoirs filled. This resulted in very low water levels downstream. After the dams became operational in April 2016, flow patterns throughout the basin became more regular, with increased flows in most of the dry season and slightly reduced peaks in the wet season. Construction of the other four dams in the cascade (Nam Ou 1, 3, 4, and 7) is expected to be completed by the end of 2020.

During the dry season, the outflows will increase by more than 20% compared to the baseline flows in January, rising to 73% in April. By contrast, the outflows are 13% lower than the baseline flows in June and July; they return to the baseline level or above from October to December.

Flow patterns also change daily among all seven dams as the plants are operated for 10 to 12 hours a day. During the night, the plants will only release minimum flows; the turbines will be brought up to full flow in the morning with peaking operation. Ramping rates, or actual changes in flow over time, can have significant environmental impacts on aquatic biota and ecosystem health. For example, excessively fast ramping of flow rates can result in fish stranding or isolation, leading to a loss of habitats critical for fish; rapidly rising water levels can also pose health and safety issues for local communities living downstream of the dams.

In terms of water availability, the Nam Ou cascade will not affect the flows in the tributaries, where most of the offtakes for irrigation and water supply are located. The potential of irrigation projects in the basin is large: 492 schemes have been proposed, with 20,031 ha of irrigation in the wet season and 5,675 ha in the dry season. This is a significant increase from the current 3,979 ha of irrigated area in the dry season and will require discussions among various stakeholders, including the hydropower developers, on ways to achieve this.

Under baseline conditions, the Nam Ou on average contributes about 16.1% to the flows in the Mekong at Luang Prabang. The monthly contributions vary from 21.6% in July to 11.5% in April. The overall annual flow contribution will remain the same at 16.1% following dam construction, but in the dry season from January to April, the flow contribution will increase from 11–15% to 18–22%; for example, the flow rate for March will rise from 137 m^3/sec to 229 m^3/sec. In the wet season, the Nam Ou's contribution to Mekong flows would drop from 20.6% to 17.9% in July (from 1,370 m^3/sec to 1,136 m^3/sec), and from 21% to 19.5% in August (from 1,844 m^3/sec to 1,712 m^3/sec).

5.2 CHANGES IN LAND USE & SOIL EROSION

The Nam Ou Basin stands out with a very high degree of land cover change of more than 60% (Vo, et al. 2015). These changes in land use have been largely driven by the patterns of upland cultivation and the conversion of shifting-cultivation areas into rubber and banana plantations, especially in the northern parts of the basin in Phongsaly.

Changes in land use often lead to severe soil erosion: degraded forests have more than 10 times the erosion rate of virgin and regrowth forests, and crops like cassava and upland rice also have significantly higher erosion rates. Industrial plantations of rubber and coffee also cause soil erosion, especially in the early stages of establishment.

Since the Nam Ou Basin is characterized by steep and very steep slopes with over 80% of the land having slopes of more than 15 degrees, the potential for erosion with changes in land use is very high. Soil erosion will likely decrease when the rubber plantations mature, as this land has been converted from shifting cultivation and upland rice/corn. In 2010, there were 1,064 km^2 of shifting cultivation, 94 km^2 of industrial plantations (mainly rubber), 33,174 ha of upland rice and corn, and 16,020 ha of rubber plantation. Although only 110 ha of coffee were cultivated in 2010, the prospect of an additional 3,000 ha of coffee will potentially increase soil erosion in Phongsaly.

5.3 CHANGES IN SEDIMENT TRANSPORT

With the construction of the first three dams on the Nam Ou mainstream, the sediment transported by the river will increase and sediment trapping will rise significantly following the completion of all seven dams (Shrestha 2013). During the construction of the dams, associated roads and other infrastructure, some of the sediment will settle in the river and some will be transported into the Mekong. Similarly, sand mining and alluvial-gold mining in the river also releases considerable quantities of sediment from the banks and riverbed, which increases the sediment load and concentration of suspended solids in the river for many kilometers downstream.

With the completion of the three dams, much of the sediment in the river, especially bed loads (that is, the rocks, stones, and gravel that move down the river during times of high flows), will be trapped in the reservoirs, especially at the top end where the rate of water flow slows down as it enters the reservoirs, forming a delta.

The net effect will be a significant decrease in annual sediment transport rates downstream of Nam Ou 1. However, sediment loads will tend to increase with distance downstream of Nam Ou 1 because of increasing contribution of flows (and sediment) from tributaries and increased entrainment of sediment within the Nam Ou. Seasonal changes to the erosion and sediment transport regime of the Nam Ou could affect the channel morphology and thus have an impact on aquatic ecosystems and fisheries downstream of Nam Ou; for example, scouring may reduce fish habitat during the dry season.

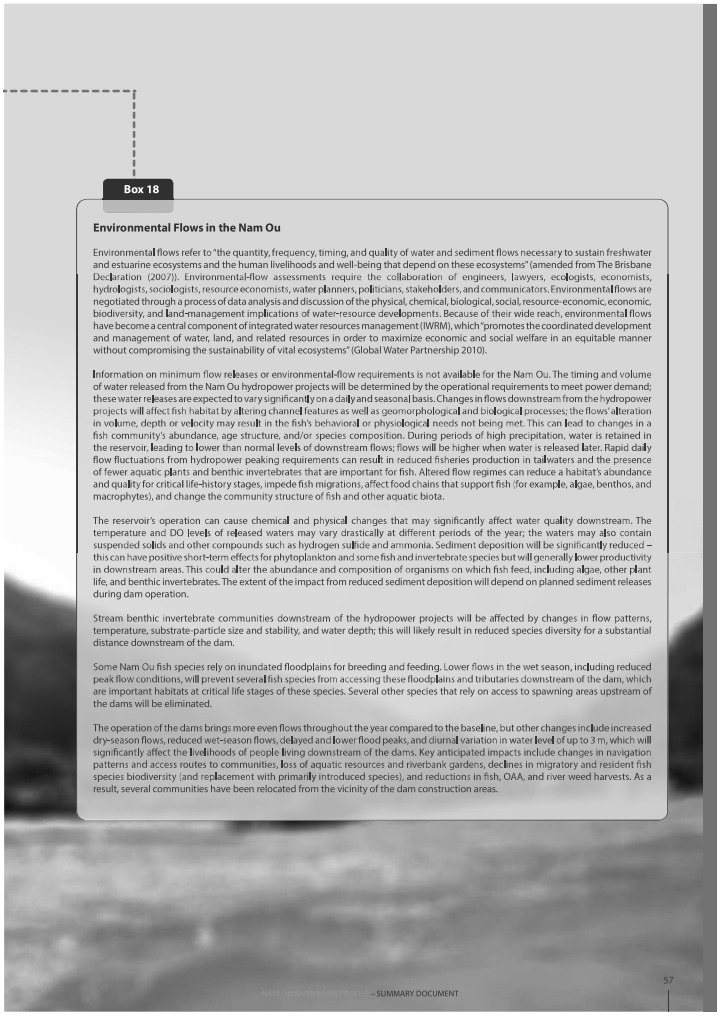
The annual total sediment load of about 140 million tons (Mt) per year in the Mekong comes from two principal areas: the upper basin in China and the Central Highlands of Vietnam. The former, sourced from less than 20% of the overall basin, produces some 700 t/km^2/yr or 60 Mt per year representing about 50-60% of the regional total, while the latter produces an estimated 30% of the total sediment load reaching the delta. The remaining 10% comes from all the other tributaries combined, of which the Nam Ou is the largest contributor with a historic total of about 6.7 Mt per year. This is about 4.8% of the total sediment load added to the Mekong. With the seven Nam Ou dams in place and only 1.94 Mt per year being released, the contribution of sediment from the Nam Ou will drop significantly to about 9% of the sediment transported at Luang Prabang.

5.4 CHANGES IN FISHERIES RESOURCES & AQUATIC HABITATS

As a result of the hydropower cascade development, one of the biggest changes in the Nam Ou will be the alteration of aquatic habitats from a free-flowing river (with regular alternation of rapids, runs, and pools as deep as 20 m) to a series of slow-moving or semi-stagnant reservoirs ranging from 40 to 60 m deep near the dam walls.

With the completion of all seven dams in the cascade by 2020, the total length of the reservoirs will extend almost continuously from the bridge over the Nam Ou at Ban Tang, on the road to Gnot Ou (forming Arm 2 of Nam Ou 7), and down to Nam Ou 1 (18 km upstream from the confluence). The total reservoir length will be 417 km, with 372 km of the Nam Ou mainstream being converted into reservoirs. These reservoirs will be long and thin following the river valley of the Nam Ou and its tributaries; they will be generally 200-300 m wide with steep sides. Apart from the Nam Ou 7 reservoir, which has significant storage and drawdown, the inundated area is relatively small.

The transformation from a free-flowing river into deep, steep-sided reservoirs will have profound implications for the river's overall productivity and the different species living in the aquatic habitats, including fish, amphibians and invertebrates, and aquatic plants and algae. In general, a free-flowing river has greater biodiversity and productivity than steep-sided, deep upland reservoirs, which tend to be oligotrophic. The spawning habitats of many fish species will be lost, and the dams will prevent fish migration both from the Mekong and the Nam Ou mainstream to its tributaries, resulting in a decline in biodiversity. This is already evident from observations by villagers of Ban Phoumeuang, who stated that fewer fish species are caught in the new Nam Ou 6 reservoir compared to what they were able to catch in the river.



Box 18

Environmental Flows in the Nam Ou

Environmental flows refer to "the quantity, frequency, timing, and quality of water and sediment flows necessary to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems" (amended from The Brisbane Declaration (2007)). Environmental-flow assessments require the collaboration of engineers, lawyers, ecologists, economists, hydrologists, sociologists, resource economists, water planners, politicians, stakeholders, and communicators. Environmental flows are negotiated through a process of data analysis and discussion of the physical, chemical, biological, social, resource-economic, economic, biodiversity, and land-management implications of water-resource developments. Because of their wide reach, environmental flows have become a central component of integrated water resources management (IWRM), which "promotes the coordinated development and management of water, land, and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership 2010).

Information on minimum flow releases or environmental-flow requirements is not available for the Nam Ou. The timing and volume of water released from the Nam Ou hydropower projects will be determined by the operational requirements to meet power demand; these water releases are expected to vary significantly on a daily and seasonal basis. Changes in flows downstream from the hydropower projects will affect fish habitat by altering channel features as well as geomorphological and biological processes; the flows' alteration in volume, depth or velocity may result in the fish's behavioral or physiological needs not being met. This can lead to changes in a fish community's abundance, age structure, and/or species composition. During periods of high precipitation, water is retained in the reservoir, leading to lower than normal levels of downstream flows; flows will be higher when water is released later. Rapid daily flow fluctuations from hydropower peaking requirements can result in reduced fisheries production in tailwaters and the presence of fewer aquatic plants and benthic invertebrates that are important for fish. Altered flow regimes can reduce a habitat's abundance and quality for critical life-history stages, impede fish migrations, affect food chains that support fish (for example, algae, benthos, and macrophytes), and change the community structure of fish and other aquatic biota.

The reservoir's operation can cause chemical and physical changes that may significantly affect water quality downstream. The temperature and DO levels of released waters may vary drastically at different periods of the year; the waters may also contain suspended solids and other compounds such as hydrogen sulfide and ammonia. Sediment deposition will be significantly reduced – this can have positive short-term effects for phytoplankton and some fish and invertebrate species but will generally lower productivity in downstream areas. This could alter the abundance and composition of organisms on which fish feed, including algae, other plant life, and benthic invertebrates. The extent of the impact from reduced sediment deposition will depend on planned sediment releases during dam operation.

Stream benthic invertebrate communities downstream of the hydropower projects will be affected by changes in flow patterns, temperature, substrate-particle size and stability, and water depth; this will likely result in reduced species diversity for a substantial distance downstream of the dam.

Some Nam Ou fish species rely on inundated floodplains for breeding and feeding. Lower flows in the wet season, including reduced peak flow conditions, will prevent several fish species from accessing these floodplains and tributaries downstream of the dam, which are important habitats at critical life stages of these species. Several other species that rely on access to spawning areas upstream of the dams will be eliminated.

The operation of the dams brings more even flows throughout the year compared to the baseline, but other changes include increased dry-season flows, reduced wet-season flows, delayed and lower flood peaks, and diurnal variation in water level of up to 3 m, which will significantly affect the livelihoods of people living downstream of the dams. Key anticipated impacts include changes in navigation patterns and access routes to communities, loss of aquatic resources and riverbank gardens, declines in migratory and resident fish species biodiversity (and replacement with primarily introduced species), and reductions in fish, OAA, and river weed harvests. As a result, several communities have been relocated from the vicinity of the dam construction areas.

Areas with ecological features can be classified as of global, national, provincial, and local importance. The reach of the Nam Ou mainstem from above M. Ngoy to Pak Ou is viewed as globally important because it is a KBA within a karst-limestone landscape with many caves and serves as a spawning area for the endangered Giant Barb (*Catlocarpio siamensis*). The other large sets of river reaches of national and provincial importance are: (i) the mainstem from M. Khoa to M. Samphan and up to the confluence with the Nam Leng; (ii) the reaches within the Phou Den Din NPA in Phongsaly; and (iii) the tributaries of the Nam Nga and the Nam Bak because of their karst landscape and caves.

The entire mainstem of the Nam Ou is already heavily compromised by completed dams (Nam Ou 2, 5, and 6) and those under construction (Nam Ou 1, 3, 4, and 7). It is anticipated that most of the river's important reaches will come under pressure from human activities.

Box 19

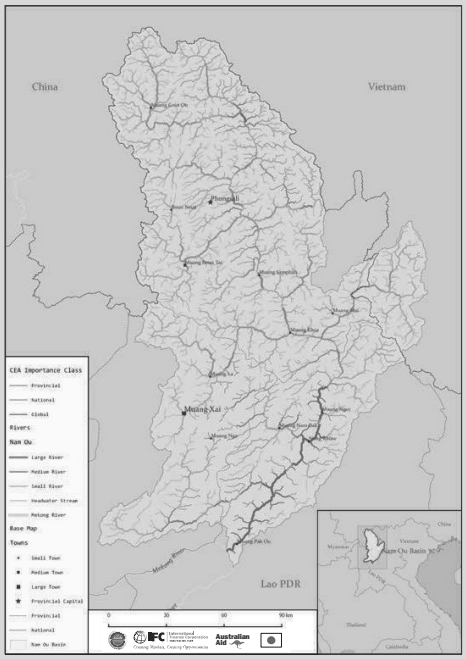
Mapping ecologically sensitive areas & human pressures on the Nam Ou

An analysis of the ecologically sensitive river reaches in the Nam Ou Basin affected by existing and planned human activities has been applied following the method developed by the MRC – Initiative on Sustainable Hydropower 01 project (MRC, 2015). It uses the river-reach classification of the Nam Ou established by WWF (Lehner and Ouellet Dallaire, 2014) and assesses the ecological importance of different reaches based on the following criteria:

- River reach lies within a KBA and protected areas – national and provincial
- Scarcity of the river-reach type within the Nam Ou Basin, especially karst-limestone areas
- River reaches above and below major confluences
- Presence of hot springs and caves, culturally important areas
- Recognized spawning areas of endangered fish species and areas known for endemic fish species

Existing and planned pressures from human activities have been mapped, including urban areas (all the provincial and district centers), influencing water quality downstream, mining operations at the exploitation stage, sand and gravel extraction and alluvial-gold mining in the river, dry-season irrigation schemes, land use change (especially loss of forest cover), and existing and planned hydropower plants (Figures 9 and 10).

Figure 9 **Ecologically Sensitive Reaches in the Nam Ou River Basin.**



5.5 WATER QUALITY

The MRC has been measuring the Nam Ou's water quality at Ban Hat Kham since 1985 and the results generally ranged from good to very good. However, since the construction of the three dams in the Nam Ou cascade in 2013, the river's water quality has shown signs of deterioration. Water-quality analysis carried out by the MRC near the mouth of the Nam Ou shows a trend of decreasing pH and DO as well as rising COD. Results from the biomonitoring carried out during the 2016 field studies indicate that the upper reaches and some tributaries have good aquatic health, but the lower reaches (Ban Pak Nga, Ban Pak Ou, the Nam Phak, and the Nam Noua) are variable and in poorer condition. More detailed water-quality and aquatic-health monitoring data are needed to confirm these findings.

Factors that may be contributing to the deterioration of water quality include:

- Infrastructure construction activities, especially hydropower projects
- Changes in water levels and flow rates
- The release of reservoir water
- Sand and gravel extraction, and gold mining
- Increased urbanization, for example, around Meuang Xai town on the Nam Kor, a tributary of the Nam Phak
- Increased industrial activities
- Increased commercial agriculture and agro-forestry
- Poor waste disposal practices and lack of sewage treatment plants in the Nam Ou Basin.

5.6 CLIMATE CHANGE IMPACTS ON WATER RESOURCES

Climate-change downscaling and modelling projections for the whole of the Lower Mekong have recently been undertaken by the MRC, and some of the projections used in the Council Study have been applied to the Nam Ou Basin. Based on these studies, changes in temperature and rainfall are expected in the Nam Ou Basin, although the extent of change remains unclear and modeling results vary.

Modeling results suggest up to a 3° C shift in seasonal temperature and a 27% decrease to 41% increase in seasonal precipitation. The largest increase in temperature is observed in the dry season, while the largest change in precipitation is observed in the wet season.

Changes in annual stream discharges are likely to range from a 17% decrease to a 66% increase in the future, which will lead to predicted changes in annual sediment yield, ranging from a 27% decrease to about a 160% increase. Shrestha (2013) estimated that under current conditions, about 7 Mt of sediment per year are discharged from the Nam Ou into the Mekong. The final sediment discharge will be significantly influenced by the trapping of sediment in the Nam Ou cascade, which will reduce sediments to between 1 and 2 Mt per year regardless of which climate-change scenario is applied.

Figure 10 **Existing and Planned Pressures on Nam Ou River Basin.**