# 6. ASSESSMENT OF PRIMARY AND SECONDARY IMPACTS—ALL PATHWAYS

## 6.1 Flow Regime Change

Hydropower projects can disrupt natural flows and alter the magnitude, frequency, duration, and timing of flow regimes and sediment. Because all parts of the flow regime play a role in sustaining the riparian ecosystem, altering any part can lead to physical and biological change. The more the natural flow, sediment, and water quality regimes are changed, the greater the impact on the river ecosystem (World Bank Group 2018). See detailed assessment of flow regime and water balance and modeling in Appendix C. Several important thresholds are of particular importance:

- Loss of longitudinal connectivity—preventing free movement of sediment, fish, and organic material along the system
- Loss of floods—leading to drying out of the river's floodplains and loss of lateral connectivity along the river
- Significant reduction of base flows—resulting in periodic drying out of all or part of a previously perennial channel

### 6.1.1 Flood Frequency

The construction of large reservoirs in the Sekong Basin affects flood conditions in the basin. The degree of impact depends greatly on the chosen pathway because of the larger impact of dams on the mainstream than of smaller dams on tributaries. Although it is beyond the scope of this study to establish the exact impact on the flood extension along the main river and its tributaries, which would require hydrodynamic modeling based on a detailed digital terrain model (for example, Lidar), it is possible to estimate based on frequency analysis of yearly maximum daily discharges at the basin outlet. For this purpose, an analysis was conducted using a three-parameter log-normal distribution, which gives adequate fit to the data points. The results are shown in Table 6.1 and Figure 6.1.

The highest flood for a chosen return period can be expected in the unregulated flow situation, whereas flood values would be dramatically lower under the full development pathway, with the largest number of hydropower reservoirs in place (for example, from 7,463 cubic meter

**Table 6.1: Results of Frequency Analysis of Yearly Maximum Discharges, 1991–2014**

| Pathway | Return period (years) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 25 | 50 | 100 | 250 | 500 | 1,000 |
| | (Cubic meters per second) | | | | | | | | |
| Un-regulated[a] | 3,697 | 4,634 | 5,286 | 6,139 | 6,793 | 7,463 | 8,378 | 9,097 | 9,842 |
| Present | 3,142 | 3,914 | 4,440 | 5,119 | 5,634 | 6,156 | 6,863 | 7,414 | 7,980 |
| Full development | 2,807 | 3,394 | 3,765 | 4,216 | 4,542 | 4,862 | 5,279 | 5,592 | 5,906 |
| Conservative development | 3,065 | 3,777 | 4,250 | 4,847 | 5,292 | 5,738 | 6,334 | 6,792 | 7,258 |
| Intermediate development | 2,869 | 3,509 | 3,933 | 4,470 | 4,871 | 5,273 | 5,810 | 6,223 | 6,644 |

[a] Historical condition, with no dams.

per second (m³/s) to 4,862 m³/s for a return period of 100 years). Comparisons among the three development pathways should be made with reference to the present situation, under which there is already a substantial drop in flood frequency. The largest impact occurs for the full development pathway, with much lower, albeit still significant, impacts for the intermediate and conservative development pathways.

Figure 6.1 shows how floods of a certain size will occur less frequently as a result of hydropower reservoirs regulating the flow. A typical average flood experienced in the 1990s, when the Sekong River was unregulated (about 4,000 m³/s with a return interval of 2.3 years), now returns every five years, but under the full development pathway, the return interval is 12 to 15 years.

A larger flood of approximately 5,000 m³/s, with an original return interval of eight years, is expected to return every 20 years under the present situation, every 30 years under the conservative development pathway, and every 130 years under the full development pathway. Along many of the rivers in the floodplains of the Lower Mekong, significant flood plain inundation happens every five to 10 years.

This modeling shows that floodplain overtopping is less frequent than in the past and will become rarer under the full development pathway than under the conservative development pathway.

A decade ago, when the river was unregulated by hydropower, a flood event of 7,000 m³/s was a once-in-50-year event. Under the present situation, it has become a once-in-250-year event. Under the full development pathway, such a flood will become extremely rare, perhaps only once every 5,000 years. Fewer large flood events mean less damage and disruption to riverbank settlements and riparian livelihoods but also less deposition of nutrient-rich sediment beneficial for agriculture on alluvial plains.

### 6.1.2 Low-Flow Simulations Along Mainstream Sekong

More significant changes in flow can be observed during the low-flow months from January to March. Seasonal storage reservoirs to ensure reliable power year-round will result in higher river flows during the dry season (Figure 6.2).

**Figure 6.1: Results of Frequency Analysis of Daily Maxima at the Sekong Outlet**

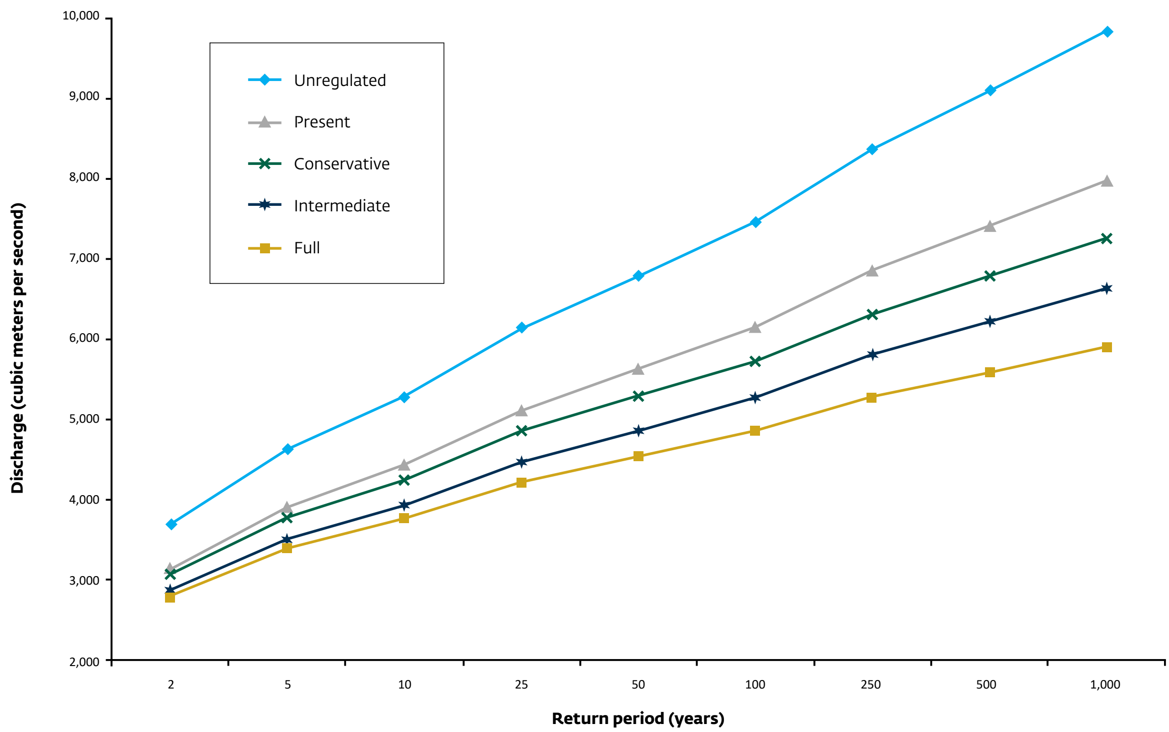
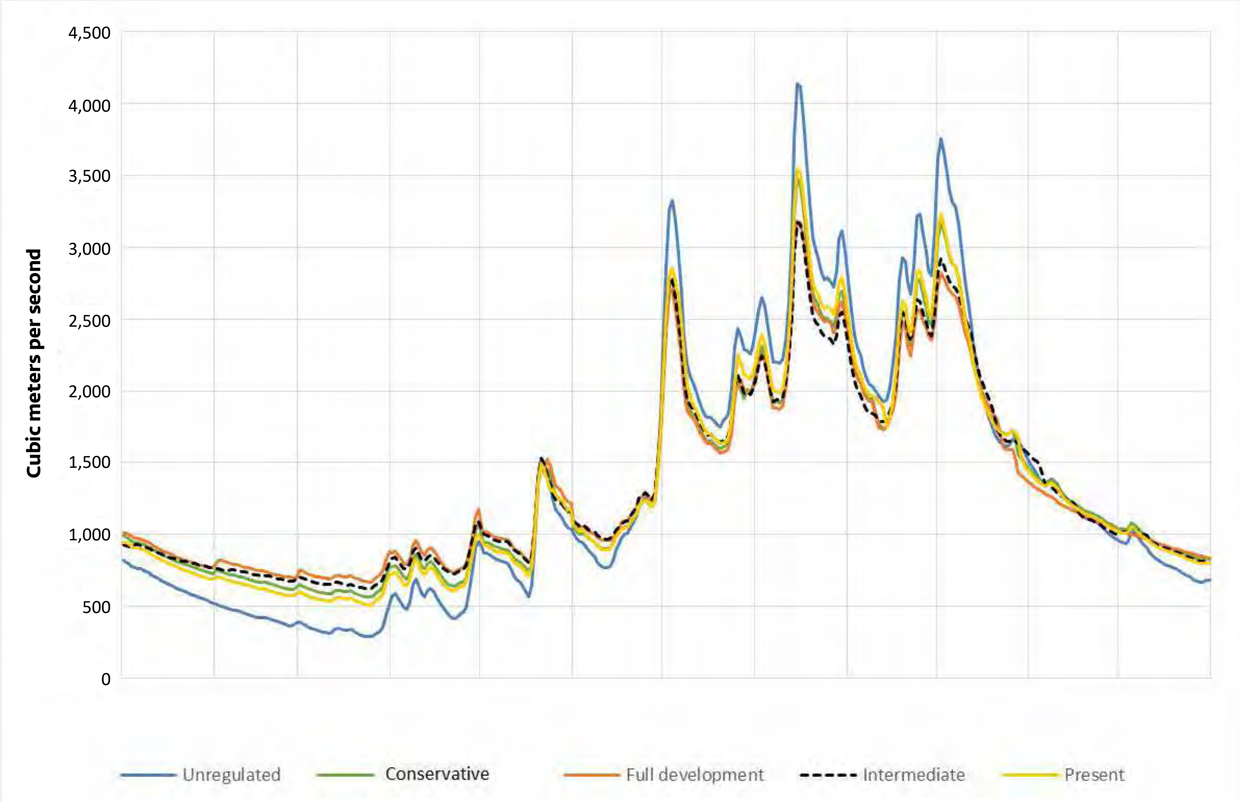


**Figure 6.2: Sekong River Flow Regimes at the Lao People's Democratic Republic–Cambodian Border under Various Pathways**




Previously, low flow in the Sekong below the confluence with the Nam Kong could fall to less than 150 $m^3/s$ in the dry season. In the present situation, low flow has nearly trebled and is expected to exceed 500 $m^3/s$ under all future development pathways. The increase in low flows already witnessed is because large regulating reservoirs generate power and release water during the dry season. Higher flows in the dry season mean that river crossings, sand bars, beaches, and riverbank gardens may no longer be accessible, whereas river navigation might benefit.

## 6.2 Changes in Sediment Transport

Hydropower reservoirs tend to capture sediment and reduce the volume transported downstream. A reduction in sediment transport will have a variety of effects downstream. Sediment is an important conduit of nutrients for fisheries and agriculture. Sediment also maintains the geomorphology of the river system, so a reduction may lead to changes in substrate, riverbank erosion, and riverbed erosion. There will also be risks to alluvial sand extraction operations in Cambodia and stabilization of the Mekong Delta.

### 6.2.1 Transboundary Impacts of Sediment Reductions in the Sekong Basin

The change in downstream transport of medium-sized sediment (for example, river sand) has been modeled for each development pathway using historical impoundment dates of existing hydropower projects and estimated completion dates of projects proposed up to 2030 (Figure 6.3). (For further detail, see Appendix E.)

Under the present situation in 2020, with 12 hydropower plants (HPPs), the sediment load in the Lower Sekong is approximately 24 percent lower than when the basin was in an unregulated state.

Under the full development pathway, the annual sediment load will fall 67 percent, from 6.4 million tons to 2.1 million tons (Figure 6.3).

**Figure 6.3: Comparison of Effects of Pathways on Sediment Transport (Medium Fractions) Downstream of the Lao People's Democratic Republic–Cambodian Border**


In the conservative development pathway, significantly more sediment would be transported because of the omission of the seven mainstream Sekong dams. The free-flowing Sekong and Xe Xou tributaries would continue to provide significant sediment to the Lower Sekong. The proposed new dams and reservoirs in the tributaries of the Nam Kong, Xe Kaman, and Xe Namnoy would have a negligible impact because of the existing large sediment-trapping reservoirs on these rivers. Consequently, total sediment transport would be only slightly less than current levels.

In the intermediate development pathway, the addition of the two Upper Sekong dams (Sekong 4B and 5) reduces sediment transport to 4.0 million tons, a reduction of 38 percent (blue line in Figure 6.3).

The size of sediment makes only a moderate difference. Modeling shows that, compared with medium-sized sediment, slightly more fine sediments and slightly less coarse sediment would be transported downstream (Figure 6.4). No matter what sediment size is considered most representative and whatever other assumptions are varied in sensitivity tests, the cumulative impact of all reservoirs is a significant reduction in sediment content passing from the Sekong Basin into the Mekong River (see background information and further detail in Appendix E.)

Figure 6.5 illustrates the limited increase in sediment transport obtained by sediment flushing through bottom outlets. The modeling assumes flushing is feasible only in the five smallest reservoirs in the Sekong Basin. It is not possible in practice to flush sediments from large reservoirs in the early years of their design life, but it is usually a good idea to include in the HPP design facilities to flush in the future.

The results of this modeling of sediment transport are clear. Each new dam and reservoir constructed will further reduce downstream sediment transport; including large sediment sluicing gates will have only a minor mitigating effect. In the full development pathway, no effective measures for preserving sediment flows nearer to a natural state are possible with so many large reservoirs in cascade along a large sediment-laden river. Omission of dams altogether is the only effective measure; in particular, omission of the dams furthest downstream on the Sekong mainstream will have the most significant effect.

**Figure 6.4: Impacts of Full Development Pathway on Transport of Fine, Medium, and Coarse Sediments Downstream of the Lao People's Democratic Republic–Cambodia Border**

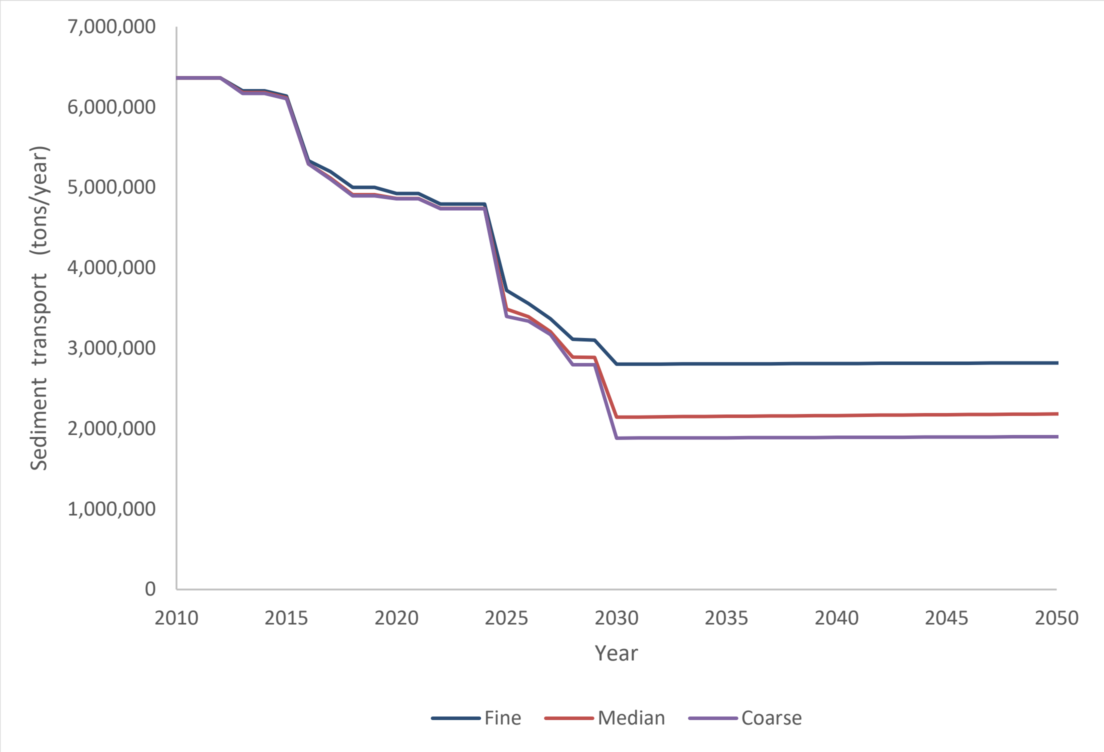


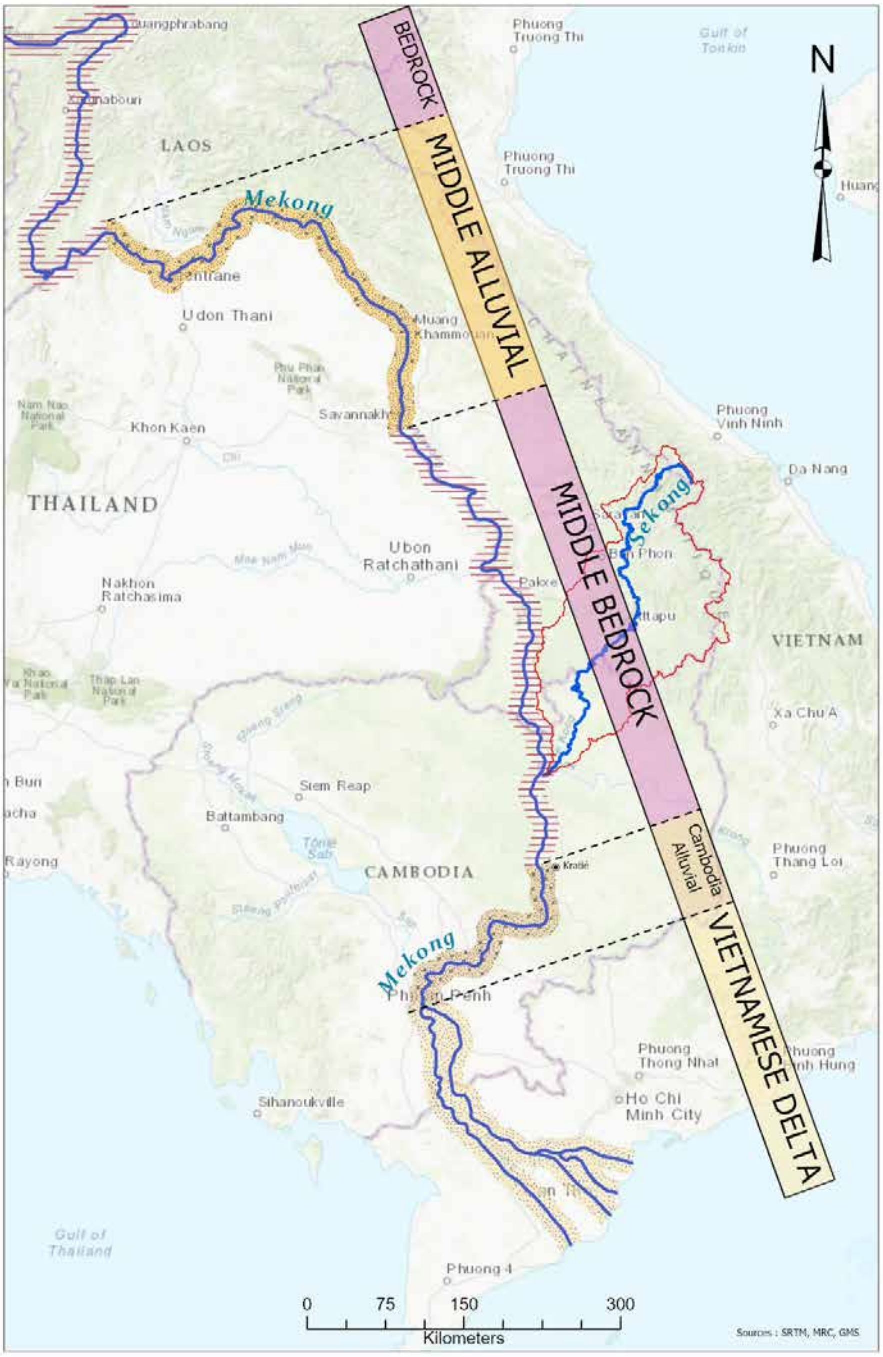

**Figure 6.5: Impacts of Full Development Pathway of Flushing on Sediment Transport Downstream of the Lao People's Democratic Republic–Cambodia Border**

### 6.2.2 Transboundary Impacts of Sediment Reductions for the Mekong River and Delta

Sediment transport has transboundary implications for the Mekong River and its delta. Starvation of sediment along the Mekong by many reservoirs constructed upstream has been studied (Kondolf, Rubin, and Minear 2014). If all the large reservoirs proposed on the Sekong mainstream are constructed, the alluvial stretch of the Mekong River and the Mekong Delta will experience sediment starvation (Map 6.1).

This will probably result in bank and bed erosion in reaches with alluvial deposits, fewer nutrients reaching the flood plains and delta areas, morphological changes along the Mekong, and coastline retreat in the Mekong Delta (Kondolf, Rubin, and Minear 2014).

**Map 6.1: Reduction of Sediment Loads at Kratie on the Mekong River**



For this cumulative impact assessment, the downstream significance of reduced sediment movement from the Sekong Basin to the Mekong River will depend on what hydropower development occurs elsewhere in the Mekong Basin. If all dams planned for Mekong tributaries are built, but none are built on the mainstream Mekong River, there will be a 67 percent reduction in historic sediment transport loads (from 144 million tons to 47 million tons) at Kratie, which is just below the confluence of the Sekong River and the Mekong River (Kondolf, Rubin, and Minear 2014).

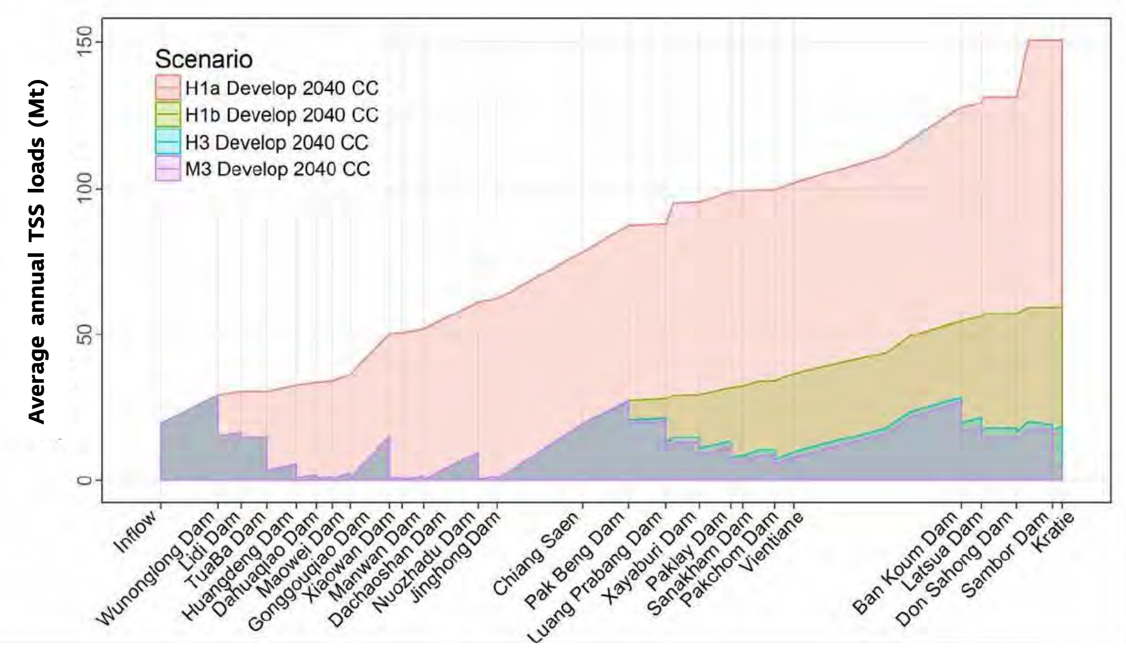
Table 6.2 compares the volume of sediment leaving the Sekong Basin under different development pathways based on sediment modeling. Sediment leaving the Sekong Basin has already been reduced from an estimated 5.2 million tons (original load) to 3.7 million tons (present situation) as a result of dams constructed so far. Sediment leaving the Sekong Basin would be reduced further in the case of the full and intermediate, but not the conservative development pathways.

Sediment capture because of hydropower development on the Mekong mainstream is shown in Figure 6.6 (MRC 2020). Dams already constructed on the Upper Mekong in China cause the largest reductions (pink area), but the proposed cascade of dams from Pak Beng to Pakchom would cause further significant reductions (green area). The proposed Sambor Dam, which has been designed without a sediment passage, results in a final sharp drop in sediment transport.

**Table 6.2: Mean Annual Sediment Load (Million Tons) Generated by the Sekong Basin under Different Development Pathways**

| | Original load | Present 2020 | Full development | Intermediate development | Conservative development |
|---|---|---|---|---|---|
| Sekong at Cambodia | 5.2 | 3.7 | 1.7 | 2.9 | 3.7 |
| Mekong at Kratie | 144 | 47 | 45 | 46 | 47 |
| Mekong Delta | 160 | 49 | 47 | 48 | 49 |

**Figure 6.6: Cumulative Sediment Capture by Dams on the Mekong River**




*Source*: MRC 2020.

*Note:* M3 is the 2040 full development scenario without mitigation, and H3 is the same scenario with mitigation. H1a is a baseline scenario (no post–2007 dams), and H1b is development without mainstream dams. TSS = total suspended solids; Mt = million tons; CC: climate change.

The relative importance of sediment from the Sekong Basin for the Lower Mekong River will depend on the intensity of new Mekong mainstream hydropower development and which development pathway is chosen for the Sekong Basin. If the proposed 11 Mekong mainstream dams within Lao PDR are developed, the contribution of sediment from the Sekong Basin would be relatively large (except in the case of the full development pathway). The Sekong Basin would be among the last major contributors of sand to the Mekong River. Alternatively, if the 11 Mekong mainstream dams within Lao PDR are not developed, the contribution of the Sekong Basin to downstream sediment would be relatively small (irrespective of which development pathway is chosen). Hydropower developments downstream are also relevant. If the Sambor Dam in Cambodia is developed on the Mekong mainstream without a sediment passage, most sediment from the Sekong Basin would be captured there.

## 6.3 Pollution and Water Quality Change

Construction of hydropower dams can release large amounts of suspended sediment into a river. During local community consultations, this was mentioned as a past cause of fish mortality and fish decline.

During reservoir filling, when the area is inundated and massive amounts of organic material begin to decompose, algae can grow and deplete oxygen. Depending on the depth of the reservoir, stratification can occur, which leads to oxygen deprivation in the lower layers of the reservoir. Environmental and social impact assessments for the Nam Kong 2 and 3 state that no long–term water quality problems are expected (HAGL Group 2010a and 2010b), but based on the experience of other hydropower projects in Lao PDR, short–term water quality problems can be expected. This was the case with the reservoir of the Houay Ho Dam, for example, where valuable timber was selectively cleared, but a large amount of soft vegetation was present when the reservoir was inundated, resulting in poor water quality downstream (Ambasht and Ambasht 2003).

During the operational phase of a hydropower project, stagnant conditions in reservoirs can create water quality problems. Impacts are expected to increase with hydropower expansion, especially under the full development pathway, under which most of the Sekong mainstream will be converted into a cascade of reservoirs.

Additional pollution sources are mining (for example, coal and gold) and industry (for example, coffee-processing plants), which are point sources. Agriculture (for example, sugar cane, eucalyptus, fruit trees, and rubber) causes runoff pollution from fertilizer, pesticides, and nutrients. During stakeholder consultations, these issues were mentioned as a cause of reduced fish catches and occasional fish mortality events in recent years.

The flow regime of the river influences the effect of runoff pollution. Larger floods or greater flooding frequency can increase pollution loads in the river because nutrients and pesticides are washed into the water (Nguyen 2017); during the dry season, pollution loads are more concentrated. For these reasons, flow regime alterations because of climate change may create water quality problems, although dams with storage reservoirs will tend to reduce wet season floods and increase dry season flows and so dampen the effect of climate change on water quality.

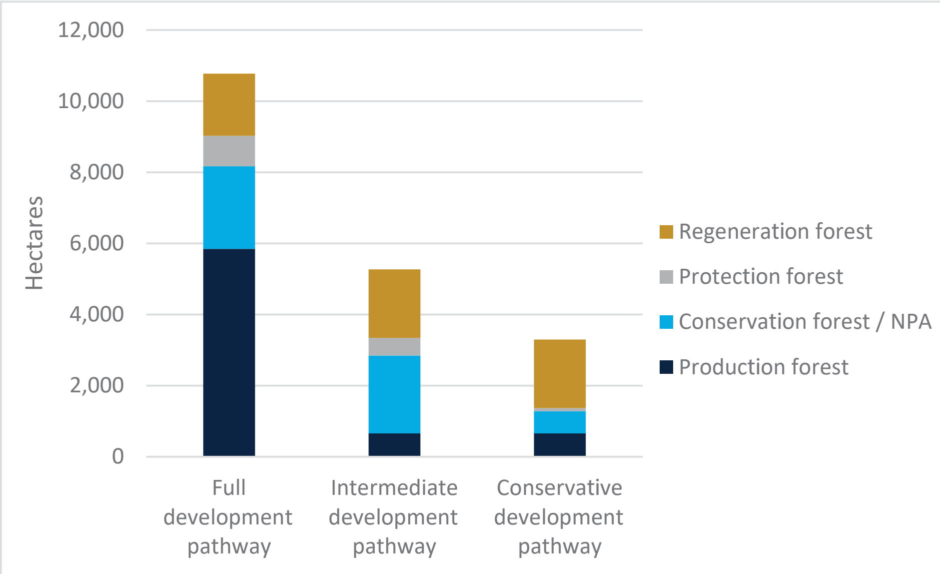
## 6.4 Inundation and Land Acquisition

Inundation and land acquisition are intermediate impacts relevant to two VECs in particular: valued flora (loss of forested areas) and livelihoods (loss of agricultural land).

It is estimated that 16,900 hectares of forest has already been lost because of hydropower development (present situation). Under the full development pathway, an additional 11,200 hectares of forest land would be inundated, compared with 5,300 hectares under the intermediate development pathway and 3,300 hectares under the conservative development pathway (Table C.5 in Appendix C).

Different categories of forest are affected to differing degrees under each development pathway (Figure 6.7). In the full development pathway, the area of production forest affected is much greater than in the other two pathways. The conservative development pathway affects a smaller area of conservation forests, national protected areas,, and protection forest than the other two pathways.

**Figure 6.7: Forest Types Affected by Each Development Pathway**




*Note:* NPA = National Protected Area.