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Yom-Nan Operation & Maintenance Project

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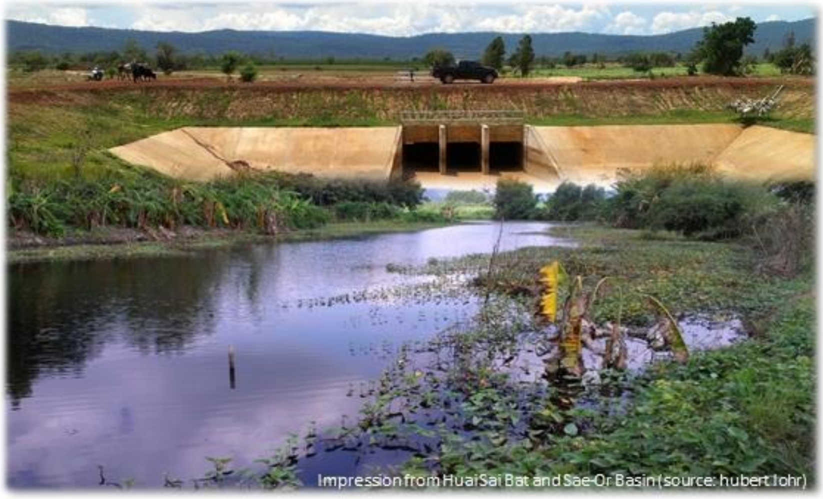

Gesellschaft für Internationale Zusammenarbeit (GIZ)

Project Number	705-16
Project Name	Yom-Nan Operation & Maintenance Project
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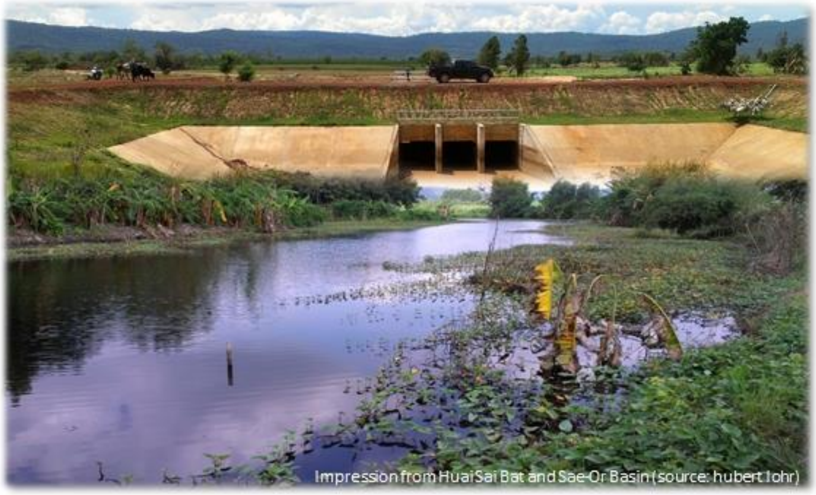
Yom-Nan Operation & Maintenance Project



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1 EXECUTIVE SUMMARY

The Royal Irrigation Department (RID) together with UNDP Thailand seeks support from the Green Climate Fund (GCF) and intends to submit a proposal addressing the *"Yom-Nan Operation & Maintenance Project"* (Yom-Nan O&M). The Yom-Nan O&M aims to rehabilitate hydraulic infrastructure and to irrigate farmlands of about 312,600 rai (≈ 500 km²) of four districts in three provinces of Phitsanulok, Sukhothai and Uttaradit. The establishment of this operation and maintenance project is supposed to result in more effective water management and to increase the number of irrigated farmlands.

The project area covers 514 km² and stretches from the North in the surrounding of Phichai down to the observation station at Bang Rakam in the South. The planned improvement measures within the current Yom-Nan O&M are located between the Yom and the Nan River. The area is dominated by agricultural use, mainly paddy fields, villages are scattered throughout the catchment and hydraulic infrastructure with canals provide the means to facilitate water management. Various ecological habitats are still present.

People are generally adapted to the marked dry and wet season: Houses are traditionally built on pillars to prevent inundation during flood events. Faster growing or water-resistant crops are used in regions that are submerged too long/often. During flooding, the submerged areas are used for fishery. However, the livelihood of people within the project area is hampered by shortened grow periods due to early onsets of the rainy season and droughts if the rainy season turns out to be below average.

The Yom-Nan O&M proposal focuses on data management and improvement of existing water infrastructure e.g. canal dredging, heightening of embankments and the construction of new retention ponds to improve water management. In the course of the proposal writing for the GCF, the necessity to pay more attention to the aims of the GCF became apparent and triggered actions. GIZ was addressed in order to introduce Ecosystem-based Adaption (EbA) measures. Given the fact, that EbA measures have not yet been considered in the current proposal, the aim of this report is to combine existing planning of RID and UNDP with EbA measures. The result of this report could be incorporated in the already existing GCF proposal to demonstrate an integrated concept for a climate-resilient development of the Yom-Nan O&M area.

Given the uncertain predictions about climate change, the need to come up with flexible approaches is paramount. EbA measures are by nature flexible and can adapt to future changes. EbA measures generally require a certain amount of space. Thus, they should be integrated in all future planning stages. As there are major links and interactions between agriculture, urban land use, water management and ecosystems, a future-proof approach for development should consist of adaption measures encompassing all relevant sectors. To meet the criteria of the GCF and ensure a sustainable development, a holistic approach is proposed that integrates all relevant aspects into a systemic procedure:

- Assessment of key features by modelling
    - Hydrologic modelling for hydrological regime and probabilities of occurrence
    - Hydraulic modelling for water levels, flow velocities, inundation maps and risk zones
- EbA as basis for sustainable climate change adaption measures
    - Like Agricultural EbA, Biodiversity EbA, Urban EbA, Water related EbA
    - Balance of provisioning, regulating and cultural ecosystem services
    - Systemic approach to utilize synergy effects by an interplay of components
- Completion of the holistic approach by

- Data management and dissemination
- Infrastructure development and enhanced operation
- Capacity building

The issue of competing land use between agriculture and EbA measures is clearly understood. Nevertheless, it needs to be addressed for a sustainable and resilient development of the Yom-Nan O&M area. Addressing this serious issue would truly support requirements of the GCF.

This report focuses on three EbA measures complementing the existing planning.

- Floodplain development or floodplain conservation
- River restoration
- Fish migration

The basic concepts are outlined and a strategic water resources approach is documented in which the Yom-Nan O&M could be extended geared towards a successful GCF application.

2 INTRODUCTION AND SCOPE OF WORK

Thailand has been struggling regularly with impacts of floods and droughts. Due to the 2011 flood and followed by consecutive years of drought, water management became the first priority on the national policy agenda.

The GIZ project ECOSWat addresses and supports Thailand in building a climate change resilient society and implements concrete pilot measures at local/regional levels. GIZ was requested by the Royal Irrigation Department (RID) to cooperate with UNDP on the application for a Green Climate Fund (GCF) Project called *"Yom-Nan Operation & Maintenance Project"* (Yom-Nan O&M).

Yom-Nan O&M is a newly established project aiming to irrigate farmlands of about 312,600 rai (≈ 500 km²) of four districts in three provinces of Phitsanulok, Sukhothai and Uttaradit. Situated in Phitsanulok's Phrom Phiram district, the project's two headworks have been designed to divert water from the Yom and Nan River, with support of the Naresuan Dam. Previously, the project area was located outside the irrigation zone but demand for water during the dry season has continuously increased, affecting the water management plan of Sirikit Dam. The establishment of this operation and maintenance project is supposed to result in more effective water management and be able to increase the number of irrigated farmlands.

The Royal Irrigation Department (RID) of Thailand is responsible for management, maintenance and operation of the water infrastructure within the project area. Based on the problems articulated by local stakeholders and changing boundary conditions regarding water availability and intensive precipitation events, the RID has initiated the Yom-Nan O&M. The proposed improvement measures mainly consists of

- dredging of canals (both form plants and sediments),
- maintenance and improvement of the existing weirs and diversion structures,
- heightening of embankment and dams, and
- constructing new retention ponds within the project area.

The main objective of the proposed measures is the enhancement of the existing water infrastructure in order to

- store more water within the irrigation network and the water retention ponds for irrigation purposes within the dry season,
- enhance the discharge capacity of the canals in order to manage flood events with higher return periods to prevent flooding of farmland,
- increase the protection of farmland against flooding and enable two rice harvests per year.

In the course of the proposal writing for the GCF, the necessity to pay more attention to the aims of the GCF became apparent and triggered actions. GIZ was addressed in order to introduce Ecosystem-based Adaption (EbA) measures. Given the fact, that EbA measures have not yet been considered in the current proposal, the aim of this report is to combine existing planning of RID and UNDP with EbA measures. The result should be an integrated concept for a climate-resilient development of the Yom-Nan O&M area to increase the chances of the GCF proposal.

The development of an integrated concept for a climate-resilient future of the *"Yom-Nan Operation & Maintenance Project"* is based on a review of existing documents and an onsite field trip combined with a stakeholder hearing in Phitsanulok's Phrom Phiram district carried out from February, 2nd to February, 4th.

3 PROJECT AREA

The project area of the *"Yom-Nan Operation & Maintenance Project"* (Yom-Nan O&M) is located in the north of Thailand between the Yom River in the West and the Nan River in the East (cf. Figure 1). The political boundaries of the study area are Sukhothai province in the west and Phitsanulok province in the east. Both Yom and Nan River constitute parts of the Chao Phraya River system, which is the main river system of Thailand. The Chao Phraya River begins at the confluence of the Ping and Nan rivers in Nakhon Sawan province and crosses the central plains along almost 400 km until the river reaches the Gulf of Thailand downstream of Bangkok.

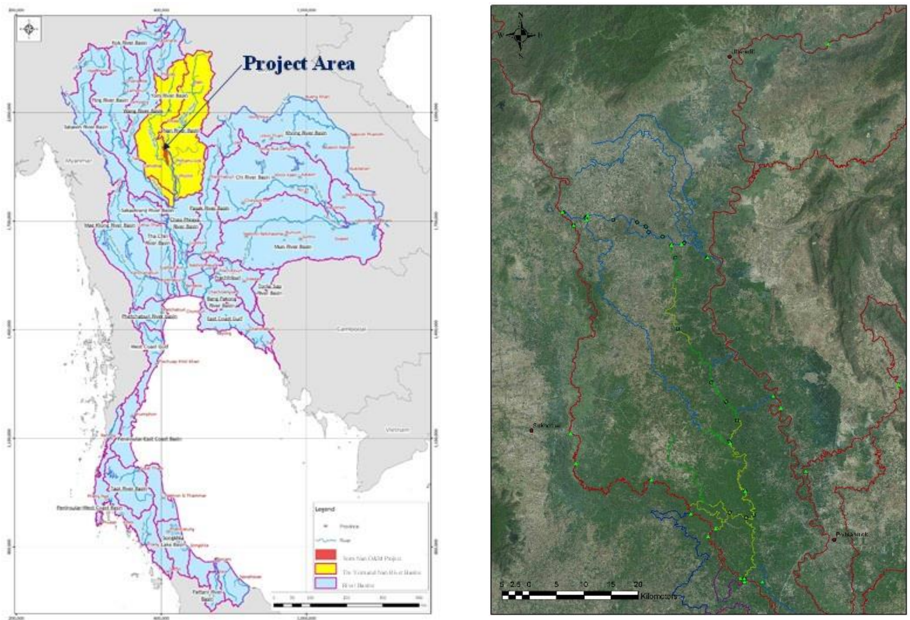


Figure 1: Project location (source: RID)

The project area covers 514 km² and stretches from the North in the surrounding of Phichai down to the observation station at Bang Rakam in the South. The planned improvement measures within the current Yom-Nan O&M are located between the Yom and the Nan River.

Figure 2 gives an overview of the project area with its main irrigation canals, the surrounding rivers, cities and the upstream catchments of both the Yom and the Nan River.

The Monsoon season in the project area occurs typically from June to September. However, rain can start in May causing early flooding. About 1100 to 1300 mm average rainfall is recorded in the project area resulting in 3.8 million-m³ runoff per year at gauging station Y.14 that is the Si Satchanalai gauging station, upstream of the project area in the Yom River.

Figure 2: Overview of the project area (source: RID)

Currently, water is diverted from both the Yom River in the West and the Nan River in the East into the project area as depicted in

Figure 3 that shows the long-term Management Plan of the project area.

Within the project area, the water is controlled and managed by several weirs, diversion structures and irrigation canals. The discharge capacity along the Yom River reduces from over 2500 m^3/s at the upstream diversion to 550 m^3/s at Sukhothai and about 350 m^3/s at the outlet of the project area. The reason is mainly the decreasing slope reducing the transport capacity and the encroachment of the natural floodplain at several cross sections.

Figure 3: Long-term water management plan (source: RID)

The Yom River has no water retaining structure (reservoir) in its upstream area, whereas the Nan River holds large structures along its course such as the Sikirit dam in the upstream area and the Naresuan Dam located parallel to the Yom-Nan O&M. The Yom River typically has periods without surface water flow during the dry season whereas the Nan River has surface water flow throughout the year as the Sikirit Dam provides discharge during the dry season.

Figure 4 gives an overview of the regulating structures within the project area, the enclosing rivers as well as the currently proposed improvement schemes of the Yom-Nan O&M. The Old Yom River (the Yom's river old natural river course) is located west of the project area in its upper part and within the Yom-Nan O&M in the lower part of the project area before it confluences with the main Yom River.

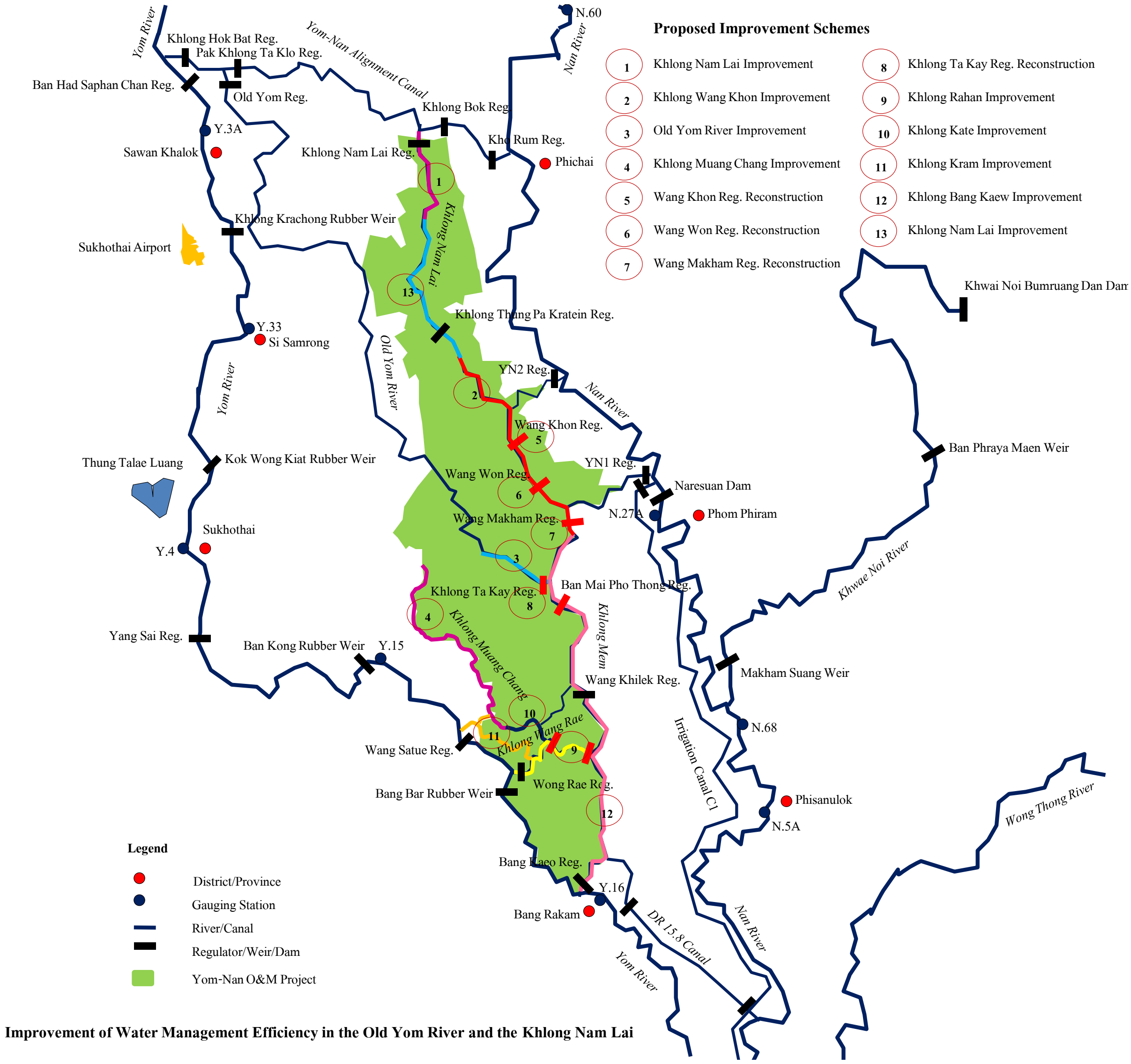


Figure 4: Structures and improvement measures in the project region (source: RID)

The diversion of water from the Yom and Nan River into and the water resources management structures within the project area serves two main purposes:

1. Flood protection
   Several cities are located along the Yom River downstream of the main diversion structure. Aside from dense residential areas and industry, especially in Sukhotai, there are areas of high cultural value. The “The Sukhothai Historical Park” ruins are one of Thailand’s most impressive UNESCO World Heritage Sites. By diverting water into the project area, the cultural, residential and industrial areas are protected against floods
2. Irrigation/Water storage
   Water diverted into the project area is used for irrigation. Irrigation canals, weirs, backwater areas, diversion structures and embankments provide possibilities for water management and water storage. This is widely used during the dry season.

The livelihood of the population within the project area mainly depends on farming. Traditionally, rice is grown in paddy fields for generations as farmers are used to it: Rice can be stored for long times and serve either as self-supply or can be sold. The area is a plain. Together with the terracing structures of the paddy fields, the farmland is not very erosion prone. To sustain their livelihood, farmers need at least one rice harvest per year. To improve their income situation, many farmers would like to achieve two rice harvests a year. However, especially in the downstream part of the project area, flooding of the farmland often starts already in May and the farmland stays submerged until the end of the rainy season in September/October, making already one rice harvest a year difficult. As adaption, local farmers have already started using alternative crops with shorter grow cycles in the more flood prone parts of the project area. The application of both fertilizers and pesticides is very high even though cost for both products are high. In areas where the growing period is fundamentally shortened by flooding, the amount of fertilizers is further increased to accelerate the crop growth.

Aside from farming, fishery and fish farming is common in the project area. Especially in the downstream part of the project area with long periods of inundation every year, fishery and fish farming plays a major role in sustaining people's livelihood as fish provides both nutrition and extra income.

In general, people within the project area are quite well adopted to the marked dry and wet season and the respective impacts of water scarcity (drought) and flooding: Houses are traditionally built on pillars, so that they are not submerged during flooding events (see Figure 5). People have learned to change to faster growing or water-resistant crops in regions that are submerged too long for rice cultivation. During flooding, the submerged areas are used for fishery and fish farming to gain an additional food source and extra income.

Two major problems have been identified during the field trip and in communication with RID:

- Shortened grow periods which are not long enough for one rice period (however, often caused by a late start)
- Flood events that raise so high that property is endangered or even destroyed

During the stakeholder hearing, representatives of different groups from the project area expressed a strong willingness for the implementation of climate change adaption measures.

Figure 5: Traditional construction of houses on pillars

The project's area is heavily altered by small settlements, farming and cultivation; villages are scattered throughout the catchment. Many irrigation canals cut through the area. Despite the utilisation of the land, there are still different ecological habitats present. Lines of bushes and trees can be found quite often in between paddy fields or other farmland areas, as for example shown in Figure 6.

Figure 6: Stretches of shrubs and trees in between the paddy fields

The canal embankments are often vegetated with different plants, ranging from grass over shrubs to bushes and trees (see left side of Figure 7). Often, small buffer strips are present before the paddy fields starts. Even though the water bodies within the project area are mainly canals for irrigation purposes, several stretches could be identified where different morphologic structures and relatively natural cross sections prevail (see right side of Figure 7). Often, embankments are low or only present at one bank, leaving huge areas as natural floodplains. Due to these natural features scattered throughout the area, close to nature habitats still exits and different bird species could be observed during the field trip.

Figure 7: Green canal embankments, canal morphology

The strong anthropogenic use of the catchment results in several problems and challenges:

- Urban settlements and intensive agricultural use put high pressures on still existing natural habitats.
- The network of irrigation canals is equipped with several weirs and diversion structures to manage and retain water especially during the rainy season. Most of these structures are blocking or disrupting flow and migration pathways for aquatic life. Not all stretches of the irrigation canals have natural cross sections, vegetated banks and different morphologic bed structures.
- Several parts of the irrigation canals are overgrown with water hyacinths. The hyacinths are considered as weed and are responsible for both a reduction of storage volume for irrigation purposes during the dry season and the cross sections transport capacity during the flood events in the rainy season.
- The high utilisation of fertilizer and pesticide causes a huge potential for water pollution. Local farmers report that water quality deteriorates during the first weeks of inundation, when agricultural land is flooded and nutrients and pesticides are remobilized into the water column. This process is to be considered especially dangerous. There is a huge risk of accumulation of toxic substances in the soil with the consequence that fish take in the substances and thus toxic material becomes part of the food chain.

Climate change will probably aggravate dry spells and (early) flooding due to higher weather dynamics and increased intensities of both droughts and floods.

Figure 8 gives an impression of some of the above listed problems and challenges within project area.


Pressure on natural habitats


Flow blocking structure


Water hyacinths within an irrigation canal


Straightened canal with bare embankements

Figure 8: Problems and challenges within the project region

4 COMPONENTS OF AN INTEGRATED APPROACH

In general, integrating ecosystem-based solutions always requires a holistic approach. The concept of making use of ecosystems as part of natural resources management entails a system approach as manifold interactions within and outside an ecosystem come into play and require attention. However, before the identification and/or location of EbA can take place, water resources management should be subject to scrutiny. This is necessary to assess hazards, exposure, vulnerabilities, needs, scenarios and options and to act on them accordingly.

A holistic and integrated approach with the aim of a future-proof and resilient management of the resources under changing boundary conditions will therefore need investigations and measures in the fields of

- Hydrology & Water Resources Management,
- Agriculture,
- Biodiversity,
- Urbanisation,
- Water related EbA.

4.1 Hydrology and Water Management

4.1.1 Strategic analysis and water resources modelling

The Yom-Nan O&M project offers new possibilities in terms of water resources management. A large variety of options on how to release, regulate and finally manage water in response to demands, necessities and environmental constrains become available when the project is implemented. The state-of-the-art methodology to identify most suitable operational schemes is hydrological and hydraulic modelling. Modelling is the first choice as it enforces a structured way of describing the river basin with all of its features and allows the application of scenarios.

Before modelling can be applied, major features of the river basin with their attributes must be assessed, so that river stretches, sub-basins, water infrastructures with their properties like geometry, etc. can be incorporated into a model. In addition, long time series of climate data and discharge are needed which should be addressed in the data management component. On top of that two more components are of great importance:

- Inventory of current water demand
- Projection of future water demand

The agricultural sector prevails in terms of water demand and thus, crop patterns, current irrigation practices and efficiencies must be evaluated to derive the major drivers for water consumption.

Concerning water resources management, the Yom-Nan O&M project cannot be seen as independent. Hence, boundary conditions must be defined which describe quotas of flow which may not be exceeded in order to avoid conflicts with downstream riparians. In doing so, restrictions need to be set but could itself become variables in certain scenarios which aim at finding trade-offs between quotas and agricultural yield within the Yom-Nan project.

In essence, water resource modelling is a prerequisite to accomplish a strategic analysis of water resources in the Yom-Nan O&M project which can finally lead to a water master plan. While working out a strategic analysis, operating rules can be reconsidered, effects of irrigation practice become clear and trade-offs between water availability, agricultural yield and boundary conditions can be assessed. Each of these components is an elementary factor in adopting a system to become more drought resilient and prepare for adverse impacts of climate change.

Moreover, it lays the foundation for incorporating ecosystem-based adaption due to its integrative system approach.

4.1.2 Scenario generation

As mentioned above, modelling provides the means to assess different development scenarios. The process has two stages:

- Stage 1 - Generation of scenarios
- Stage 2 - Evaluation of scenarios

Generating scenarios should be understood as an important participatory instrument to set out possible development strategies stakeholders identify as desirable, feasible, preferable and affordable. Each scenario needs to be evaluated against a baseline scenario which represents the current situation. Good practice is to include at least the following scenarios:

- Baseline scenario (current situation, benchmark for all other scenarios)
- Water supply management scenario (provision of water to meet water demand)
- Water demand management scenario (adaptation of water demand to the fluctuations of the hydrological regime)
- Incorporation of EbA measures

From the viewpoint of the Green Climate Fund it seems unavoidable to address the agricultural sector and to generate scenarios which introduce new farming concepts as mentioned in Section 4.1. In the light of GCF guidelines, scenarios should be included to assess the effects of:

- Alternative crops with different crop patterns
- Organic farming
- Avoidance of pesticides

Scenario generation conducted as a participatory process helps raise awareness among stakeholders to understand opportunities of development but also limitations. Results of scenarios are invaluable in terms of demonstrating possible achievements, containing unrealistic expectations as well as the contribution each group of stakeholders has to provide to be successful in total. This is especially important when it comes to land ownership. The issue of land ownership makes or breaks any effort towards sustainable land and water resources management. It is a mistake to believe that by avoiding this controversial topic sustainable solutions are obtainable in the long run.

4.1.3 Evaluation of hazards, exposure, vulnerability and risk

A component which is not yet accounted for in the GCF proposal is hazard and risk assessment including the identification of risk zones. Hazards can emerge from both natural and man-made causes. The focus here is on natural hazards like droughts and floods. Whereas droughts have a slow onset and timely identification is a major issue, floods can be contained up to a certain level if and when operation during periods of high flow is clearly assessed. The rehabilitation of the hydraulic structures enables RID to control the flow of water up to a certain extent. Again, modelling is the first choice to provide information what volumes of flow are manageable and which areas can be protected at the expense of other areas which will be deliberately flooded first. The knowledge and demarcation of risk zones which can be protected up to a certain probability of occurrence of a flood event is an ideal entry point for selecting crops and ecosystem-based measures like floodplains. The establishment of floodplains as target zones which first receive excess water in order to delay inundation at other sensitive agricultural areas is a common principle and widely used.

Moreover, floodplains are good examples of win-win situations. While agricultural areas benefit due to delayed inundation, floodplains benefit from being regularly inundated and provide increased groundwater recharge with the possibility to create aquatic, riparian and terrestrial habitats.

4.2 Agriculture

As described in Section 3, the project area is mainly used for rice production. Areas that have probably been natural flood plains in the past are nowadays used as farmland. Embankments along canals protect the farmland from flooding up to a certain extent and huge amounts of water are abstracted from the natural water resources. As a consequence, natural water resources and floodplains with wetlands have been significantly reduced. Agricultural use of catchments generally increases the provisioning service of crop production (rice). In contrast, regulating ecosystem services are significantly reduced. Thus, natural pest control and ecological regulating systems have been diminished. This is backed by the reported flood problems and the heavy use of pesticides.

Enhancing provisioning ecosystem services, e.g. increased crop production by using more fertilizers, growing crops in seasonal wetlands and by using larger amount of water for irrigation, will have negative effects on the ecosystems providing regulating (and cultural) services. These regulating services are mainly responsible for a catchment's overall resilience to changing boundary conditions, i.e. changes in precipitation patterns.

The competition for land

Focusing solely on provisioning ecosystem services (here: promoting agriculture) while regulating (and cultural) ecosystems are reduced at the same time, induces the risk to reach a tipping point, where the regulating ecosystem services are irreversibly damaged and collapse. This can, adversely feedback to the agriculture (providing) service resulting in a substantial degradation which, in turn, entails more and more costs for compensation. An unwanted vicious circle is established.

Using more and more land for agricultural purposes at the expense of regulating water bodies paves the way for above mentioned vicious circle. Awareness is needed to recognise, that heightening of embankments and cut-off of natural floodplains might bring about short benefits but leads water management into an unsolvable dead end street.

The pesticide time bomb

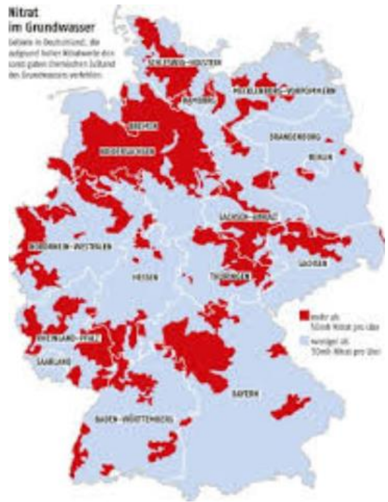
Fertilizers and pesticides are applied in the Yom-Nan O&M. Based on information from RID and clearly visible during the field trip the amount of pesticides used is high. Intensive use of fertilizers and pesticides poses a huge risk. Pesticides will gradually contaminate the soil and percolate into the groundwater where they aggregate step by step. Unfortunately, the effect is not immediately visible and it takes a couple of years until it becomes measurable.

To counter long-lasting processes is difficult as farmers neither understand the physical process and its inertia nor feel the immediate pressure to act. This calls for education, capacity building and regulatory framework with strong enforcement. In the wake of intensive use of pesticides, fish production will drop, loss of habitats for aquatic and terrestrial wildlife can be predicted, natural pest control will be lost reinforcing the vicious circle of ecosystem degradation.

Example Box

The German Nitrate Problem

To emphasize this problem, an example from Germany is outlined: After years of lax enforcement of agricultural regulations in Germany, nitrate exceeds legal limits defined by health-standards in large areas of Germany. A currently published study revealed that the price for 1m³ of drinking water must rise approximately 60% to cover the costs to remove nitrate from the raw water to keep the health-standard for drinking water. The whole process came up after the EU Commission sued Germany for failing to take stronger measures to combat water pollution caused by nitrates. This problem is expected to keep Germany busy for a long time as groundwater remediation takes long and is extremely cost-intensive.



4.3 Biodiversity

As outlined in Section 3, there are still different terrestrial and aquatic habitats present within the project area. These remnant natural habitat patches are generally responsible for maintaining much of the biodiversity present in agricultural landscapes[1]. Aside from the habitats in canals and water bodies of the project area and some conserved areas between the paddy fields, paddy fields itself can be seen as kind of "irrigated wetlands". Rice and the related irrigated wetland seems to be a form of agriculture that supports the greatest diversity of birds compared to other forms of agriculture.

- **Wetlands and floodplains** provide unique ecosystem services such as flood control, groundwater replenishment, sediment and nutrient retention and export, water purification, habitats with high biodiversity as well as cultural and recreational values. Areas prone to frequent flooding should be excluded from intensive agriculture. Together with the already planned ponds and reservoirs these wetlands and floodplains should be re-connected by ecologically enhanced irrigation canals. The construction of floodplains and wetlands need several prerequisites. The riverbed needs to be widened to facilitate the creation diverse river channels, inhomogeneous flow conditions within cross-sections and along river stretches and enable a meandering process. Landscaping and river rehabilitation must ensure a connectivity of the floodplain or wetland with the main river. Regular flooding is crucial. Thus, flood paths need to be established ensuring sufficient overflows. Different flow paths enhance the diversity of flow regimes and provide opportunities for different water-related plants and the development of wetland areas. Agriculture is not necessarily banned from floodplains but require crops adapted to the specific hydrological conditions and an adjusted farmland management (i.e. extensive agriculture and no fertilizer or pesticides).

The increase of biodiversity and the necessary actions are generally considered difficult, as they require a shift in values and a broad public understanding and even willingness to accept the benefits of biodiversity. Often, farmers may view such changes as unnecessary "trade-offs"[1]. However, not paying close attention to regulating services of catchments ecosystems may sooner or later lead to reach tipping points entailing drastic consequences in which ecosystem services are totally lost

[1] Blann 2006: Habitat in agricultural landscapes: How much is enough? A State oft he Science literature review, Defenders of Wildlife, 2006

followed by enormously rising costs. Then, even worse "trade-offs" will be imposed on the catchment inhabitants in response to the unsustainability of the current agricultural and food system[1].

Example Box

Why biodiversity matters

"Because modern agriculture is primarily oriented towards maximizing a single variable — crop production — it has gradually shed its connection with and resemblance to natural ecosystems. Maximizing "efficiency" of production has come at the expense of other ecological services, whose value is often poorly captured by markets or subsidies[1]."

Gurr et al. (2016)[2] showed that "Biodiversity [....] is key to the provision of ecosystem services such as pest control". Multi-site field studies replicated in Thailand, China and Vietnam showed that the plantation of nectar producing plants around rice fields significantly reduced population of two key pests, reduced insecticide applications by 70% and increased grain yields by 5% and delivered an economic advantage of 7.5%. Additional field studies showed shoed that predators and parasitoids of the main rice pests, together with detritivores, were more abundant.[2]

4.4 Water related EbA

Water-related components which could be integrated into the GCF proposal are fish migration, floodplains development and river restoration.

River restoration, fish migration and floodplains should go hand in hand. Whereas river restoration encounters problems in the implementation of instream habitat structures in high energy streams like those in the Yom-Nan O&M project during peak flows, it should be possible to restore a fish passable flow path along the Old Yom River. Apart from the large weir at the confluence with the Yom River, bypassing other weirs and hydraulic structures along the Old Yom River should be technically feasible without large hydraulic measures.

4.4.1 Fish migration

The longitudinal connectivity of a river has a determining impact on the character and quality of river ecosystems. Referring to the project area between the Yom River and the Nan River hydraulic structures such as weirs and dams constitute an obstacle interrupting the connectivity of aquatic ecosystems, causing ecological damage by decreasing the population size of not only resident fish species but to all aquatic organisms that perform migrations in the project area.

These obstacles can be made passable by the construction of fish passes, which does not eliminate the basic ecological damage but increases their ecological compatibility by re-linking waterbodies and potential spawning waters to facilitate the recolonization of rivers by endangered fish species and all aquatic organisms.

It is known that the Yom River can run dry regularly. Nevertheless, assessing the fish population and the potential for fish migration can serve two aims:

[2] Gurr et al. 2016: Multi-country evidence that crop diversification promotes ecological intensification of agriculture, Nature Plants, 2016

- Fulfilling the requirements of the GCF criteria
- Improving fishery

Basic figures about the effect of removing fish migration barriers were derived from investigations carried out at the Lower Mekong Basin. Along the mainstream Mekong and in its tributaries, a remarkable number of dams and weirs will be built by 2030. These dams and weirs will constitute barriers for fish migration. An investigation of the impact of fish migration barriers on fish production revealed an estimated loss of 58% of total fish yield in river-floodplain wetland habitats in all four member countries Cambodia, Lao PDR, Thailand and Viet Nam[3]. The highest losses are expected in Lao PDR as a rather high proportion of its fish population is assumed to be river-dependent. Taking these figures into account, it is possible to conclude that by removing fish migration barriers, a significant increase in fish productivity is likely to occur. Hence, making the Old Yom River fish passable is likely to increase fish productivity. An increase of 58% seems very optimistic and is not assumed. However, the high adverse impact is apparently an indicator that providing suitable conditions for fish migration has a high potential to increase fish production.

4.4.2 Floodplain development

The Old Yom River at its downstream part has large areas of ecologically sound riverbanks and even floodplains. However, the concept of the Yom-Nan O&M project considers erecting an embankment along both river banks to obtain control of the flooding process. The intention is to keep the water at the beginning of the rainy season inside the embankments and to open gates to flood the hinterland when harvest is finished. Inundation of agricultural land is delayed by means of retaining water volumes in the cross-sections instead. This concept contradicts the goals of the Green Climate Fund and should not be promoted. Farmers next to the river have already developed flood resilient farming and adjusted themselves to frequent flooding. Not only that invaluable ecosystems will be destroyed, flood resilient agriculture will turn to flood vulnerable crop production by changing the hydrological regime of these areas.

As an alternative, the development of floodplains should be promoted with dyke setbacks.

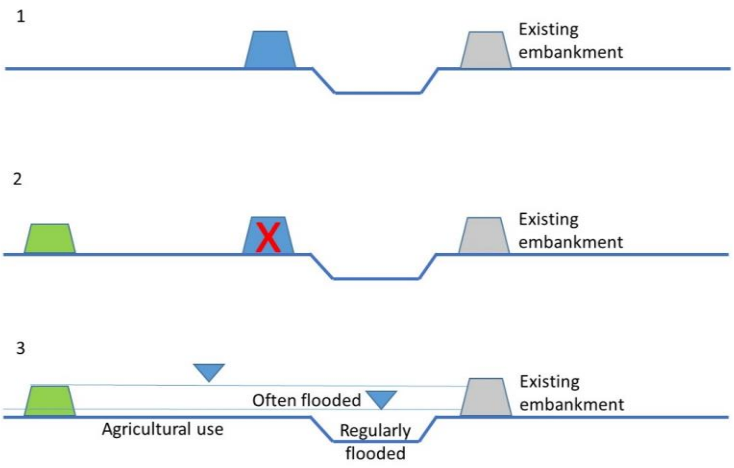


Figure 9: Dyke setbacks to foster existing floodplains

[3] MRC (2011): Assessment of Basin-wide Development Scenarios. Cumulative impact assessment of the riparian countries water resources development plans, including mainstream dams and diversions. Main Report April 2011. Vientiane, Lao PDR.

Number 1 in Figure 9 shows the current concept expressed in the proposal. Number 2 and 3 show the alternative. If the hinterland really needs more protection, it has to be made without losing valuable ecosystems. A dyke can be erected in a larger distance from the river bank to conserve existing floodplains and their functions. Furthermore, the volume of water gained in the floodplains should outstrip the water that can be stored in the riverbed with high embankments and results in an even longer time to prevent the hinterland from flooding.

Figure 10.1 and Figure 10.2 show two examples of existing floodplains within the Yom-Nan O&M project. Natural floodplains like these should be preserved as a cut-off from the main riverbed by heightened embankments or dykes would destroy these ecosystems. Subsequently, these areas would lose their ability to provide regulation ecosystem services (e.g. water storage and flood protection).

Figure 10.3 shows a situation in which farmers encroached RID land and sell fertile soil. This is a situation that should be prevented within the Yom-Nan O&M project area in general. As outlined in Sections 4.2 and 4.3, Ecosystem based Adaption measures require space. As pressures on natural ecosystems are already quite high within the Yom-Nan O&M project, areas already in the possession of RID should be provided for EbA measures.

(1)

(2)

(3) 

Figure 10: Examples of floodplains along the river

4.4.3 River restoration

Dredging is part of the Yom-Nan O&M project. Cross sections will be renewed and shaped to implement a trapezoidal form with berms on both sides. The section between the berms usually facilitates low flow to mean flow conditions. Berms become submerged during flow conditions exceeding mean water level.

Figure 11: Cross-section with an unvegetated berm (foreground)

The design of cross-sections is regarded to contain a frequent flood event. The volume between the berms and the maximum level is regarded as manageable water retention volume.

Figure 12: Standard cross-section with berms

5 KEY CONSIDERATIONS FOR IMPLEMENTATION

5.1 Modelling

The application of modelling comprises three different methodologies each of which build on each other:

- Hydrological river basin and water allocation modelling
- Hydraulic modelling
- Erosion and sediment transport

Hydrological modelling comprises the assessment of flow, management and allocation of water including different sectors, all water consumers, operating rules. It covers the whole project area with the major inflow and outflow components. Hydraulic modelling is confined to river stretches and inundation areas. It aims at calculating water levels and flow velocities and provides the means to perform erosion and sediment transport evaluations.

Hydrology and water management form the basis for the Yom-Nan O&M project and frame all other components. It is key to know the hydrological regime, probabilities of occurrence for flow volumes. Hydrological modelling starts, is followed by hydraulic modelling and finally complemented by erosion and sediment transport calculations.

5.1.1 Hydrological and water allocation modelling

Hydrological modelling at project scale is one core element as stated in Section 4.1. It should be applied in two different forms:

- Continuous long-term simulation
- Event-based simulation

Continuous long-term simulation is state-of-the art to identify all effects of water management strategies including all water consumers. It is based on the principle of modelling all hydrological elements in the model including the atmosphere-vegetation-soil interface in a continuous way. Each element (sub-catchments with their hydrological units and soil-columns, river stretches, hydraulic elements, storage facilities and more) calculates its states from time step to time step by considering current boundary conditions (rain, temperature, abstraction, diversion, position of gates and so on) based on previous states. This ensures that at any time during the calculation all hydrological components are continuously known. Results are available as time series of each state, which can be evaluated subsequently. Figure 13 shows an example of a hydrological model with its different elements and flow network. A list of data requirements is given in Table 1.

Table 1: Data requirements for state-of-the-art hydrological and water allocation modelling

Data	Format	Comments
Catchment		
Size	GIS Shape Map	
Topography	DEM (Raster, georeferenced) Contour lines	A DEM is not only useful for the hydrological modelling but also for 2D modelling. This needs to be composed from different sources if not available as one homogenous model.
Agricultural map	GIS Shape	An inventory is unconditionally necessary if not available. As agricultural dominates the water use, this topic must be clarified and should be known with best possible certainty.

Data	Format	Comments
Urban areas, villages	GIS Shape	
Conservation areas	GIS Shape	
Forest, wetland map	GIS Shape	
Soils		
Soil type distribution	GIS Shape	
Soil types	Spreadsheet Database	
Soil characteristics	Spreadsheet Database	Permeability, water holding capacity
Groundwater contour lines and storage capacity	Documentation/Info	Spatial distribution
Groundwater flow parameter	Spreadsheet Database	e.g. hydraulic conductivity (permeability for water), aquifer transmissivity and resistance, aquifer porosity and storage coefficient, as well as the capillarity of the unsaturated zone
Bedrock conditions	GIS Shape	Depth
Land use		
Land use distribution	GIS Shape	
Crop grow cycles/patterns	GIS Shape Documentation	
Crop parameter/coefficients	Spreadsheet Database	
Hydrology		
Climate boundary conditions	Documentation	available
Precipitation	Time series, daily values	
Temperature	Time series, daily values	
Humidity	Time series, daily values	
Potential Evapotranspiration	Time series, daily values	If a station is nearby which observes pan evaporation
Solar radiation	Time series, daily values	
IPCC (2013) projections	Time series	Downscaled products are most likely available
River network		
River network Channel network	GIS Shape	River course + River names
Weir locations	GIS Shape	
Weir information	CAD Drawing Calculations Documents (Operation Rules)	
Storage volume of weirs	Shape, Volume	
Cross sections	Spreadsheed Database	

Data	Format	Comments
Parameters (Roughness, vegetation)	Spreadsheed Database	
Flow Gauges	GIS Shape (Location) Time Series (Data)	
Water demand		
Size of supplied area	GIS Shape	
Pipeline network (existing)	GIS Shape	
Pipeline network (panned)	GIS Shape	
Irrigation schemes (existing)	Documentation Operation Rules	
Irrigation schemes (planned)	Documentation Operation Rules	
Irrigation water demand (existing)	Time series	Inner-annual
Irrigation water demand (planned)	Time series	Inner-annual
Domestic water demand (existing)	Time series	Inner-annual, projection should comprise at least 10 years
Domestic water demand (planned)	Time series	Inner-annual, projection should comprise at least 10 years

The steps for hydrological modelling are in brief:

- Delineation of the area of interest and delineation of sub-catchments
- Identification and localisation of all hydrological relevant features
- Assessment of parameters and characteristics (see Table 1)
- Assessment of agricultural water demand according to FAO Paper 24[4]
- Generation of a flow network
- Assessment of operating rules and generating of a control & rule network with cause-effect relationships
- Check external links like subsidies, market structures
- Define rules how external links affect water management and implement them into the model
- Create projections of external links as time series

Steps for establishing the time series management for modelling are:

- Compile all available time series with metadata
- Check for gaps and outliers and fill or correct them
- Derive longest time period for which all driving time series are available

[4] Doorenbos and Pruitt (1977): Crop water requirements, FAO Irrigation and Drainage Paper No 24, FAO, Rome.

Calibration

- Select time periods which show corresponding observations for precipitation and discharge and water levels
- Calibrate parameters, mainly soil characteristics, storage coefficients, river roughness

Verification

- Select time periods which show corresponding observations for precipitation and discharge and water levels but haven't been used for calibration
- Run the model and compare simulated to observed discharge

Results should be:

- Time series of flow and duration curves at all model nodes
- High flow conditions associated with return periods
- Low flow conditions associated with return periods and duration
- Water consumption based on various agricultural patterns and supply safety respectively
- Impact of operation rules and impact of various allocation concepts
- Groundwater recharge for all sub-basins in the model

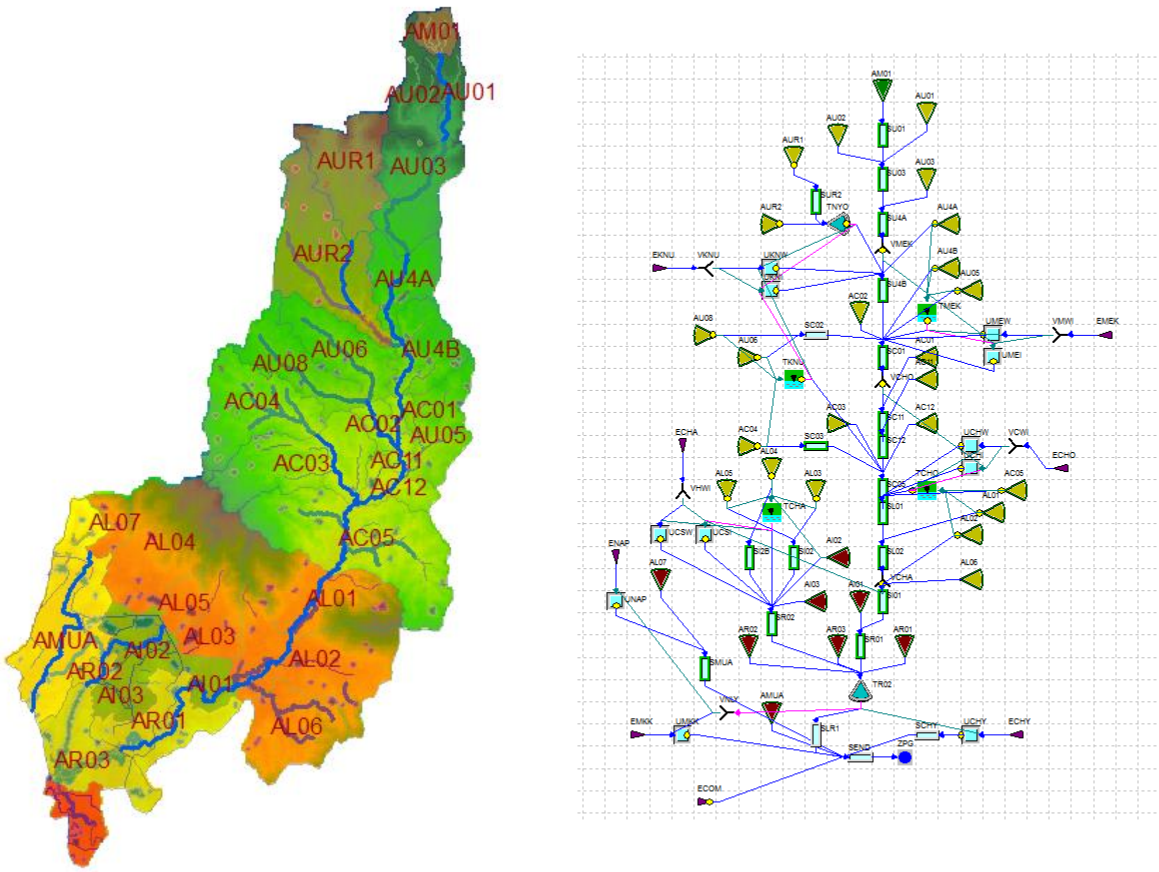


Figure 13: Example of a hydrological model with its flow network

5.1.2 Hydraulic modelling

Hydraulic modelling is the appropriate tool to assess the flow of water, to derive water levels and flow velocities and to generate inundation maps and derive risk zones. Figure 14 shows an example of a mesh for hydraulic modelling and the results of a 2D modelling.

Steps towards hydraulic modelling are in brief:

- Delineate the area which is considered for 2D modelling (the area should be large enough to cover the possible inundated space, otherwise results are falsified by wrongly set boundary conditions)
- Establish the DEM with the highest spatial resolution available for the delineated area
- Refine the DEM at key locations within sensitive areas by means of terrestrial surveys or UAV applications if the spatial resolution is inadequate (adequate resolution is 1x1m with a precision of ± 2-5cm in height)
- Estimation of roughness parameters along the river channels and in the hinterland
- Create an appropriate mesh for hydraulic modelling by using the DEM
- Incorporate the river channels into the mesh
- Incorporate all hydraulic structures into the mesh and the hydraulic model
- Assign roughness coefficients to the mesh

Calibration

- Select time periods which show high flow conditions and corresponding observations for discharge and water levels
- Calibrate roughness coefficients

Verification

- Select time periods which show high flow conditions and corresponding observations for discharge and water levels but haven’t been used for calibration
- Run the model and compare simulated to observed water levels

Results are:

- Water level or depth for different flow scenarios
- Water level – discharge curves at all cross sections
- Extent of inundation
- Flow velocities
- Force of momentum

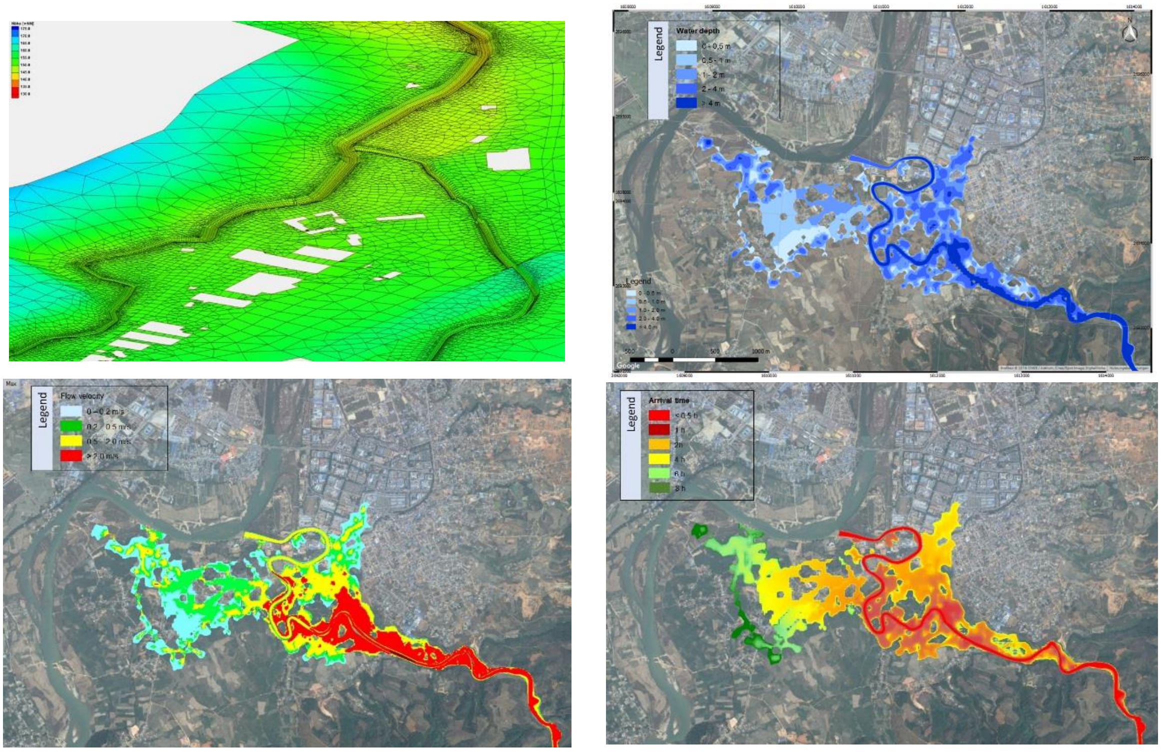


Figure 14: Example of a mesh and 2D modelling results (taken from Sydro's Myanmar project)

5.1.3 Erosion and sediment transport modelling

The third part of necessary assessments before measures can be set up is erosion and sediment transport modelling. Both goes hand in hand and is one approach. It is necessary to identify erosion prone and sediment deposition prone river reaches. This plays a vital role for all aspects of river engineering works as well as the considerations regarding river morphology and river restoration.

Ideally, erosion and sediment calculation is directly combined with hydraulic modelling owing the same steps in conducting the assessment. Required information that come on top compared to 2D hydraulic modelling are:

- Grain size distribution
- Sediment load at the inflow cross sections

Results should be obtained at longitudinal sections about

- Critical flow velocities triggering sediment transport
- Critical shear stress
- River reaches with erosion and sediment deposition
- Aggregation with annual erosion / sediment deposition

5.2 River restoration

River restoration requires the results from modelling as outlined above. From the model results, duration curves and depth-discharge curves need to be derived. If both is given, the shape of cross-sections can be designed. From the viewpoint of river restoration, it is worth noting that berms should be positioned at a height that allows plants to survive and plants should be selected according to expected days of inundation. Inundation should occur occasionally but not permanently during the wet season. As a rule of thumb, frequent flood levels should submerge the berms while mean conditions should remain beneath the berms.

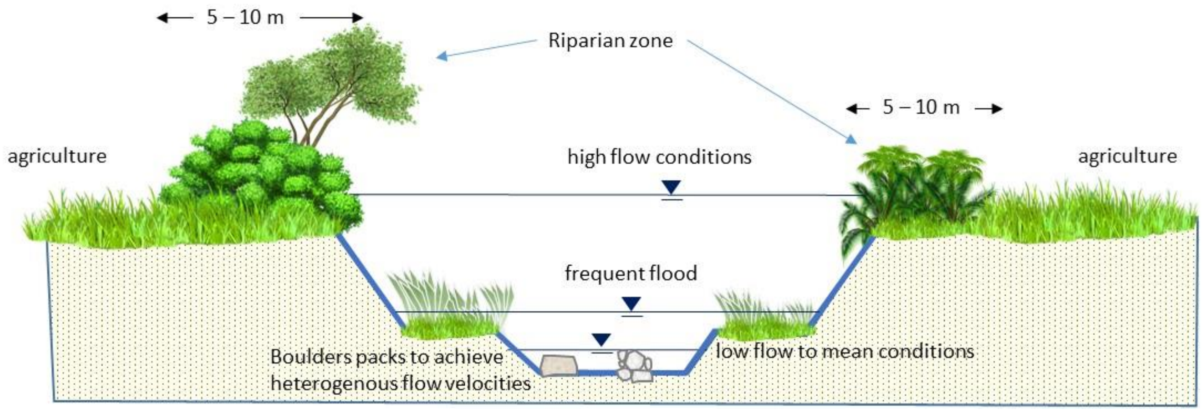


Figure 15: Example of a typical cross-section with berms and vegetation

Additionally, hydraulic calculations need to be adjusted in two ways when it comes to naturally shaped cross-sections with vegetation.

First, weediness is quite common and cannot completely avoided. It must be considered with regard to hydraulic calculations, that is, roughness coefficients need to be adjusted. A practical approach according to the Hydraulics Research Laboratory Wallingford is:

$$nc = n + b \times K/Fr$$

with:

- nc: Manning coefficient with vegetation
- n: Manning coefficient without vegetation
- b: ≈ 0.2 (depends on the structure of the river)
- K: Area covered with vegetation
- Fr: Froude number without vegetation

Second, vegetation within cross-sections is exposed to the flow velocity. The strength of vegetation to resist the force of flow should be assessed:

$$Fveg = 0.5 \cdot cWR \cdot Aveg \cdot \rho \cdot vm$$

with:

- Fveg: Force of flow imposed on the vegetation [N]
- cWR: Flow resistance of the vegetation [-]
- Aveg: Area of the vegetation perpendicular to the flow velocity [m²]
- ρ : Density [kg/m³]
- vm: Mean flow velocity [m/s]

Critical flow velocities for various vegetation can be obtained from[5]. The equation above does not account for modulus of elastics of vegetation. The higher the elasticity of plants is the higher is the resistance itself against force of flow. Based on this principle, it seems adequate to use flexible plants in flood-exposed sections.

As a result, vegetation planning for river restoration requires the information about flow velocities and carful considerations about localisation. Hence, attention should be paid to properly locate vegetation in zones with reduced velocities to be on the safe side.

An additional key principle is to widen cross-sections regularly within a river reach. This creates pools with lower flow velocities, allows for development of rich habitats and generates additional water storage. The authors are well aware of the issue of competing land use problems among agricultural/farmers and the water sector. Nevertheless, it needs to be addressed rather sooner than later to pave the way for a sustainable development of both water and agricultural requirements.

5.3 Fish migration

One of the main factors is the assessment and identification of migrating fish species. Thus, the first step towards fish migration is to conduct a fish survey. Identifying the compositions of fish species is a prerequisite to derive facts which influence the approach of a longitudinal connectivity. In reference to the different migrating fish types diverse migration behaviour can be identified. In general, the following migration types are distinguished:

- Spawning
- Migration between rainy and dry seasons
- Intra-annual migrations: inhabitation of different parts of a river in the course of the life cycle, that offer specific conditions required during their different development phases6
- Downstream migration
- (Diadromous migration)

Based on the identified migrating fish species and the migration type, conclusions can be drawn from the body shape and the migration/spawning seasons. The body shape of both fish and benthic (bottom-dwelling) invertebrates are adapted to their respective habitats and have a big effect on the construction types of fish passes. In addition, the identification of spawning seasons and grounds is important to ensure the function of a fish pass during the migration times.

5.3.1 Fish passes requirements and types

Before conceptualising a fish pass the first step must be the verification if migration obstacles can be removed. In case that its original purpose has been abandoned, the removal should be preferential to a constructive solution. Besides the hydraulic structures which are still in use identification of removable obstacles is necessary and should obtain the same priority as the longitudinal connectivity.

The planning of a fish pass includes different aspects depending on individual aspects and local conditions. Since fish generally follow the strongest current, the position of a fish pass and the entrance at a dam is of crucial importance for its effectiveness and traceability. The entrance of a fish pass must be positioned where fish concentrate while moving upstream. The positioning of a fish pass

[5] Fischenich, C. (2001): Stability Thresholds for Stream Restoration Materials. U.S. Army Corps of Engineers Ecosystem Management and Restoration Research Program

[6] FAO and DVWK (2002): Fish passes – Design, dimensions and monitoring. Food and Agriculture Organization of the United Nations in arrangement with Deutscher Verband für Wasserwirtschaft und Kulturbau e.V. (DVWK), Rome 2002

exit and the exit conditions constitute another part of the planning which needs to be equally proven based on hydraulic conditions. Furthermore, dimensions of a fish way such as length, slopes, resting pools or the discharge, required to ensure optimum conditions for migration, need to be individually defined depending on prevailing circumstances at each migration obstacle. [7]

Above mentioned influencing factors clarify the need of an in-depth assessment about the requirements in the project area. On this basis the optimum fish pass type can be determined for each migration obstacle. Generally, three fish pass types exist[8]:

- Close-to-nature fish pass
  - Bottom ramps and slopes
  - Bypass channels
  - Fish ramps
- Technical structures
  - Slot passes
  - Pool passes
  - Denil passes
- Special constructions
  - Eal ladders
  - Fish locks
  - Fish lifts

The advantages and disadvantages of each fish pass type must be weighted depending on the migrating fish species, spawning season, discharge, boundary conditions and spatial constraints individually for each location.

5.3.2 Conception of longitudinal connectivity at the Yom River

For longitudinal connectivity from Yom River above the Had Sapham Chan Floodgate to the weir at the confluence of Old Yom River with Yom River, two options can be taken into account:

Option A: Yom-Nan Alignment Canal ↔ Old Yom River ↔ Khlong Mem River

Option B: Yom-Nan Alignment Canal ↔ Khlong Nam Lai River ↔ Khlong Mem River

[7] FAO and DVWK (2002): Fish passes – Design, dimensions and monitoring. Food and Agriculture Organization of the United Nations in arrangement with Deutscher Verband für Wasserwirtschaft und Kulturbau e.V. (DVWK), Rome 2002

[8] FAO and DVWK (2002): Fish passes – Design, dimensions and monitoring. Food and Agriculture Organization of the United Nations in arrangement with Deutscher Verband für Wasserwirtschaft und Kulturbau e.V. (DVWK), Rome 2002

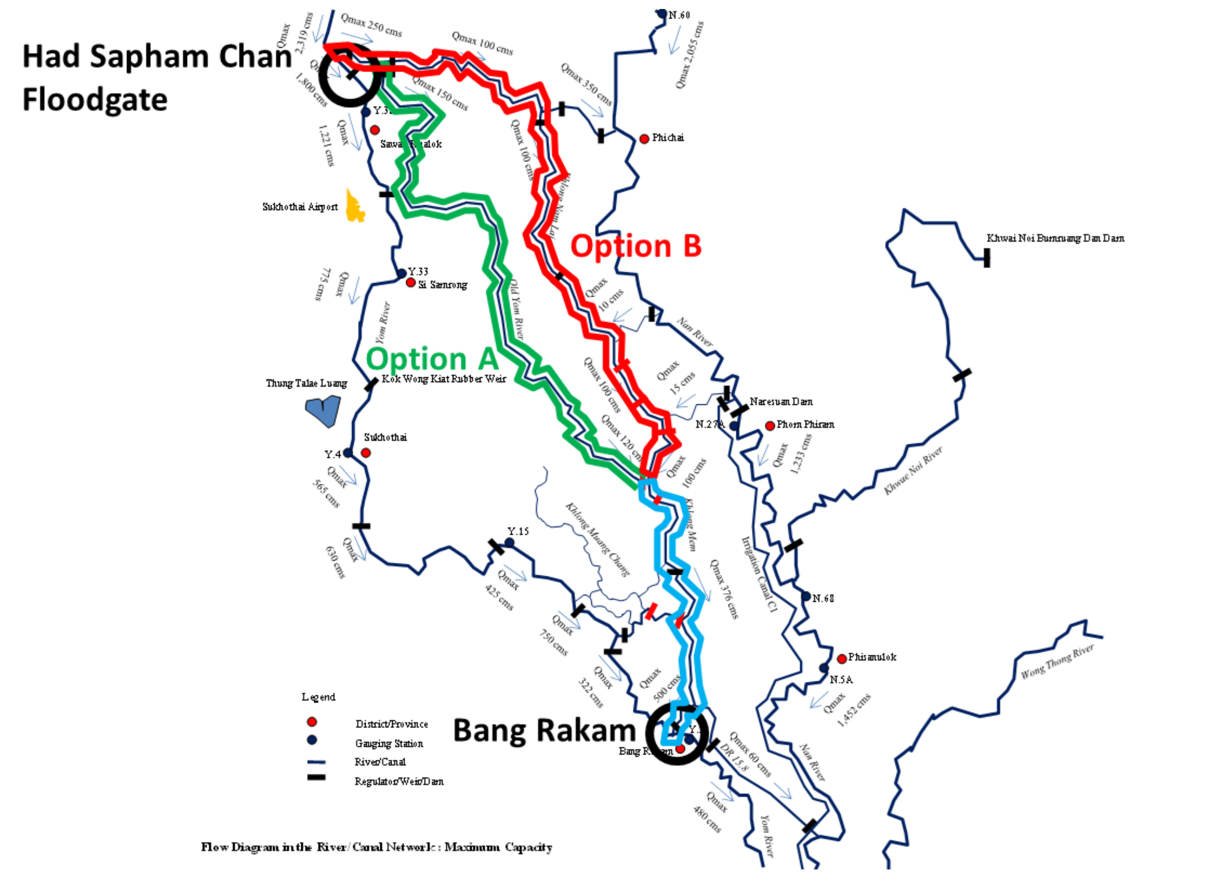


Figure 16: Longitudinal connectivity Yom River - Option A and Option B

The two options illustrated in Figure 16 should be evaluated in the course of the initial assessments. In both options, the Khlong Mem River is part of the planning.

The first Option A considers the utilization of the Old Yom River to re-link the upper part of the Yom River above the Had Sapham Chan Floodgate with the lower part of the Yom River in the area of Bang Rakam. The benefits of this option are less anthropogenic changes and migratory obstacles compared to the watercourses along the Khlong Nam Lai in Option B. A less number of migratory obstacles cause less effort along the river and thus less interference with ecosystems.

The second Option B has the advantage that it is inside the Yom-Nan O&M. Considering the hydraulic structures, such as weirs and dams at the Khlong Nam Lai River, the high amount of migratory obstacles could give rise to higher costs in achieving a longitudinal connectivity up to the Yom River.

In both options the weir immediate upstream the confluence of Old Yom River with Yom River sets the main point for the realization of an upstream longitudinal connectivity. The weir has leakage and thus provides an unintended environmental flow. This amount of water could be used to provide a fish bypass to connect the Old Yom with the Yom River. At present, this weir is not part of the rehabilitation programme of the Yom-Nan O&M project.

Figure 17: Weir upstream the confluence of Old Yom River with Yom River

For longitudinal connectivity of Yom River by re-linking the waterbodies through Khlong Mem River and Old Yom River (**Option A**) or Khlong Nam Lai River (**Option B**) to the Yom River upstream of Had Sapham Chan Floodgate, the confluence shown in Figure 17 plays a crucial role. At this weir a fish pass needs to fulfil a wide variety of hydraulic and hydrological requirements, traceability for the migrating fish species downstream and upstream by optimum positioning and dimensioning to attract migrating fish to Khlong Mem River.

5.3.3 Summary

Based on the previous chapters the necessary assessments and objectives for a longitudinal connectivity of Yom River can be summarized as follows.

1. Fish inventory with electro fishing in the Yom River (upstream of Had Sapham Chan Floodgate and downstream of the confluence of Old Yom River with Yom River)
2. Determination of migration types and periods
3. Identification of potential spawning grounds in the Old Yom River (Option A) and Khlong Nam Lai River (Option B) and upstream
4. Inventory and localisation of all migration obstacles in the project area
5. Assessment based concept of a longitudinal connectivity
6. Design, dimension and positioning of fish pass construction types (close-to-nature/technical) individually for each migration obstacle (discharge, attraction flow, conditions of entrance and exit, length, slopes, resting pools, design of bottom)
7. Integration into the landscape
8. Concept for maintenance including budgeting, roles and responsibilities
9. Monitoring longitudinal connectivity

Based on this overview a basic framework is outlined constituting one pillar of integrating ecosystem-based measures geared towards achieving the requirements of GCF. It constitutes yet another milestone in approaching the GCF's objective of thinking big.

5.4 Capacity building

It is recommended to establish a capacity building programme which accompanies each pillar of the Yom-Nan O&M by means of training courses. Training courses should be conducted at different levels:

- Strategic water resources management
- Implementation of operating rules
- Grass root level with farmers

This report suggests setting up regular courses one of which should be aimed at training for trainers. This is important to enable RID and other parties involved replicate the approach independently. That would make the project stand out of the crowd and achieves the function of a role model for Thailand.

Moreover, training courses are needed to convey the approach and vision of the project and more concrete the measures. As a result, campaigns to raise awareness and to obtain support seem to be key factors for success in the long run.

5.5 Institutional settings

Quite a few authorities are involved in water-related actions and do have the potential to cause overlap concerning roles and responsibilities. Additionally, exchange of information seems to be considerably hindered due to many, partly overlapping responsibilities and mandates. It is recommended to use the Yom-Nan O&M project to embark on recognising the need to streamline procedures in terms of monitoring, data management, decision-making, water and natural resources management. Even though the administrative structure cannot be changed easily and should not be the aim, but effort should be expended to trim the institutional settings as to achieve an efficient decision-making structure at least within the project.

Signature

Consultant	SYDRO
Representative	Dr. Hubert Lohr
Position	Managing Director
Date	March 10, 2017
Signature	