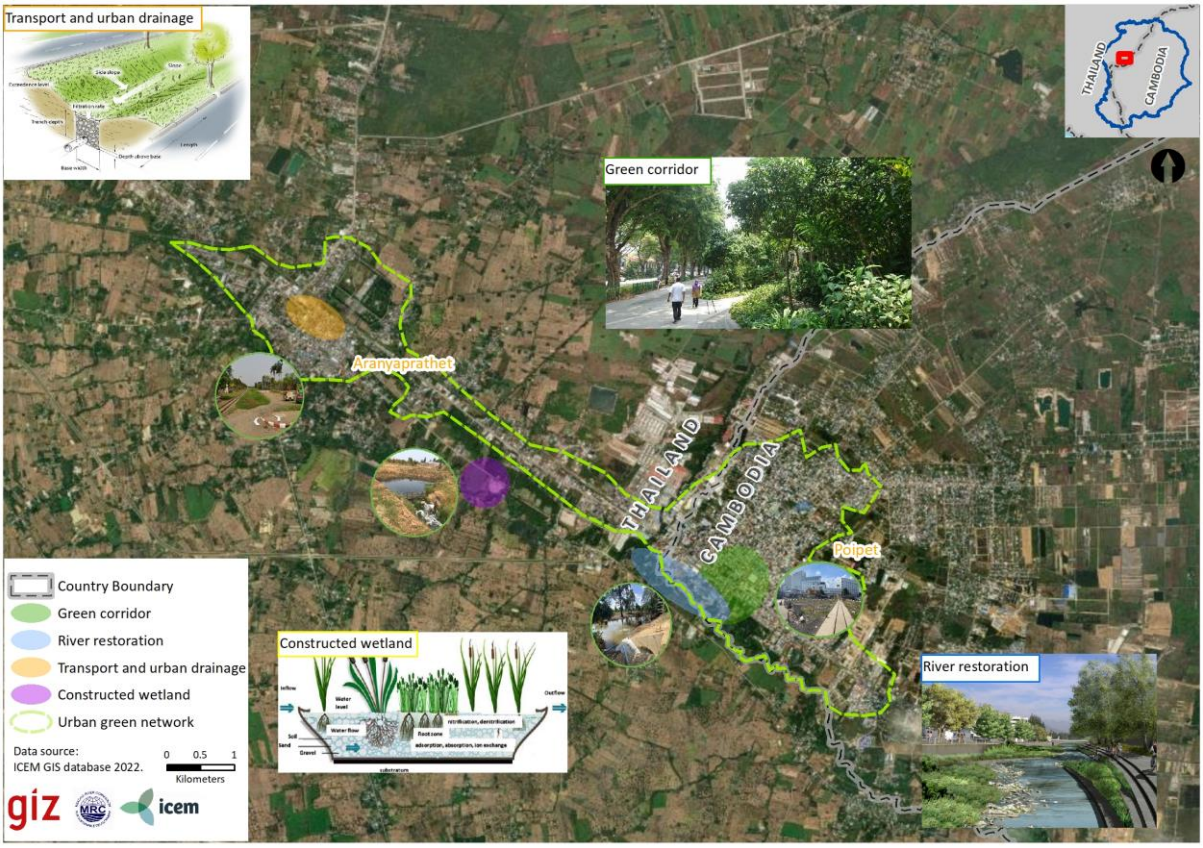
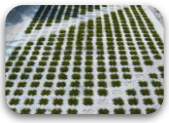
PROJECT 4: TRANSBOUNDARY URBAN AREA FLOODING – POIPET (CAMBODIA) AND ARANYAPRATHET (THAILAND)

1. Project Overview



7. Retention and infiltration of rooftop runoff



8. Permeable surfaces

9. Retention and infiltration of surface runoff

10. Constructed wetlands

11. River channel widening and rehabilitation

12. River bank stabilization and rehabilitation

14. Urban greening

Project 4 was identified as a key landscape, because of the serious water management issues and immediate cross-border implications. The project objectives for this area are:

- Define opportunities for the establishment of measures to foster cross-border waste and stormwater management, urban greening, river restoration, sediment traps, nature-based retention, constructed wetland and drainage improvements; and
- Work together with the lead and supporting agencies, as well as local and provincial stakeholders to ensure an integrated and transboundary approach to urban water management is implemented, that aligns with the 9C-9T Masterplan and Action Plan.

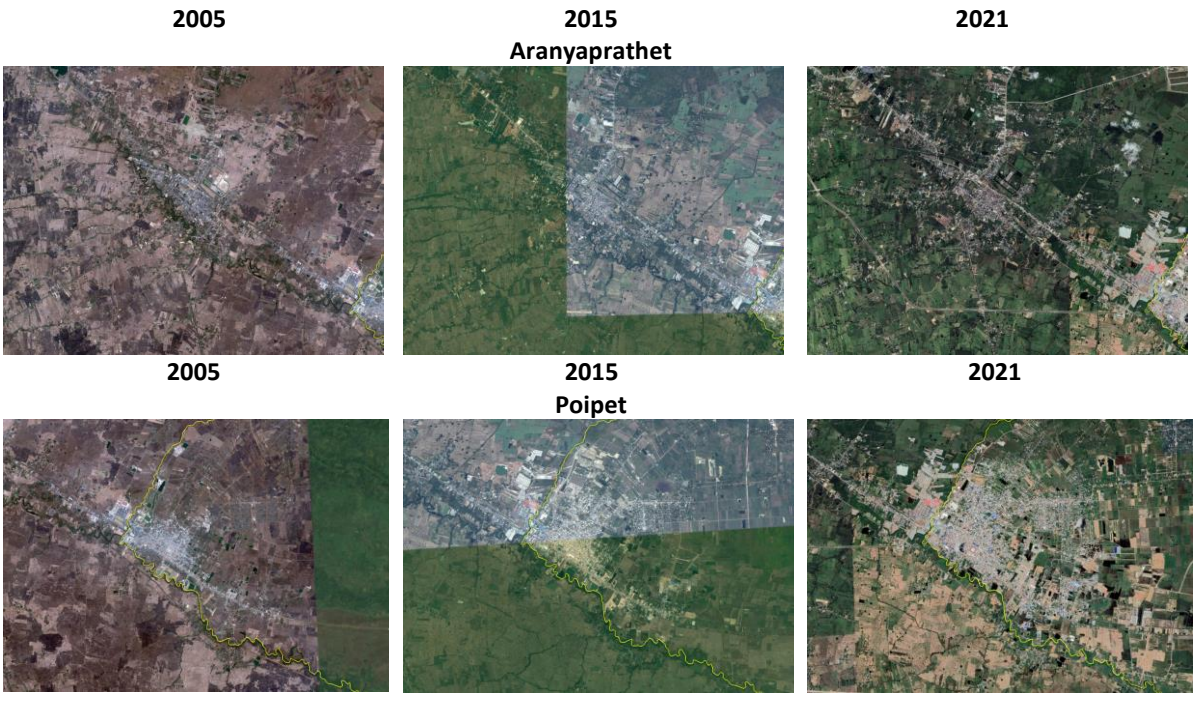
Table 1: Project 4 – Master Plan implementation factors

Item	Description
Alignment to 9C-9T Masterplan	• **Focal Area 2**: Manage urban and rural flood and drought to reduce risk • **Outcome 2.1**: Outcome 2.1: Strengthened urban flood and drought resilience through innovative climate-sensitive and ecosystem-based planning tools and adaptation interventions • **Output 2.1.4**: Develop and implement protective, hybrid (green and grey) infrastructures to reduce urban flood risks (e.g. urban river channel improvement, bank stabilization and natural flood retention areas) and enhance water quality in two target towns (one in each country)
Implementing stakeholders	• *Lead agency (Cambodia)*: Ministry of Water Resources and Meteorology (MOWRAM) and Ministry of Land Management, Urban Planning and Construction (MLUC) • *Lead agency (Thailand)*: Ministry of Interior, Department of Public Works and Town and Country Planning • *Supporting agency (Cambodia):* Ministry of Environment (MoE), Ministry of Agriculture, Forestry and Fisheries (MAFF), and provincial government • *Supporting agency (Thailand)*: National Water Resources (ONWR), the Ministry of Agriculture and Cooperatives, the Ministry of Natural Resources and Environment (MoNRE) and provincial government
Alignment to agency priorities	In Cambodia, MLUC has the mission to lead and manage land use, urban planning, construction projects and land conflict and MOWRAM has the mission to lead flood management in the catchment. In Thailand, the Ministry of Interior is responsible for core areas including local administration, disaster management, road safety, land management and public works

1.1. Site description

Aranyprathet in Thailand and Poipet in Cambodia are neighbouring towns across the international border between the two countries. Both are fast growing cities (Figure 1) with expanding Special Economic Zones, with incoming residents and new development areas and industries. Aranyaprathet is in Amphoe Aranyaprathet district, Sa Keo province and Poipet is situated within the district boundaries of Poi Pet in Banteay Meanchey province.

Figure 1: Rapid development over time at Aranyaprathet and Poipet urban areas



The cities are linked by a railway line and National Highway No.5 in Cambodia which continues as Road 33 in north-west direction through Aranyaprathet. There are railway stations in each city. The channel of the Huai Phrom Hoad River (Thai name) or Ou Chrov river (Cambodian name) acts as the border dividing the two cities, and two countries, and then continues as the upper part of Serei Sisophon River in Cambodia although it encounters many blockages and obstructions due to development before reaching Sisophon city.

Both cities face serious flood problems. Overbank flow inundating residential and industrial areas situated next to the river can be observed almost annually. Poipet is a focal point of support from the Asian Development Bank for solid waste management and drainage. Current proposals are for a new drainage network following the natural topography, discharging stormwater collected towards the Ou Chhrov river[1]. On the Thai side, there are plans to build a large flood diversion canal and a concrete flood wall next to the existing channel, to protect Aranyaprathet with downstream implications.

Taking a transboundary perspective, both cities have similar development potential but also similar problems due to development. However, neither the planned diversion and flood wall on the Thai side nor drainage improvement in Poipet take transboundary issues into account. Coordination between the towns on flood management and water quality is not apparent.

The reasons for the flood problems are manyfold. The Huai Phrom Hoad River, draining an area of approximately 1,443 km², arrives at Aranyaprathet and flows parallel to both towns. A small reservoir upstream of Aranyaprathet functions to regulate the flow in the wet season but does not have the capacity to accommodate annual flood events.

The municipality has developed small scale constructed wetlands to provide some treatment of wastewater, with the wetlands located next to the local landfill site somewhat downstream of Aranyaprathet main city and upstream of Poipet. The wastewater is not treated according to standards, with the wetland flooded regularly during high flow which damages the planting efforts and degrades the effect of water treatment (Figure 2).

Figure 2: Constructed wetlands area developed by the municipality downstream of Aranyaprathet – after damage from annual flooding. Constructed wetland (left), plant and grass filtration (middle) and water flow to Phrom Hoad canal (right)

Urban settlements have encroached the flood plain of the meandering river and reduced space for floods. The discharge capacity of the river's cross-sections is too small to accommodate flood peaks that occur regularly. In addition, the cross-sections are not maintained and have become obstructed with debris and vegetation further reducing the flow capacity. Settlements are built directly at the river bank or even partly within the river cross-sections. The health of the river further is challenged by the waste dumped into the river and direct wastewater effluents partly without treatment. A river rehabilitation and restoration effort is needed including a waste management concept to further prevent this international river from being used as a waste dump on both sides of the border.

Field missions have been conducted along with expert exchange on cause-effect issues in both towns. Addressing the repetitive riverine and pluvial flood problems was identified by local stakeholders as

[1] ADB, 2022. Feasibility Study for Cambodia: Livable Cities Investment Project (Poipet). https://www.adb.org/sites/default/files/project-documents/52064/52064-001-tacr-en_0.pdf

of the highest priority. Urban rainwater retention was acknowledged as a necessity given the increasing expanse of impermeable areas, and the expansion of industries and urban development with little spatial planning and controls. Wastewater discharge and solid waste disposal were also recognised as urgent issue that should be addressed.

Measure 12 focuses on flood mitigation by means of river rehabilitation and restoration. The difficulty in rehabilitating the river is its location constituting the border between Thailand and Cambodia. Access is limited especially from the Thai side. Despite the administrative hurdles the necessity to improve the situation is evident and pressing. Indeed, the space for rehabilitating the river is available so NbS and hybrid measures are possible if the two countries collaborate. This project and its various nature based and hybrid measures seeks to improve the flood and water quality situation.

1.2. Flood and drought drivers and impacts

1.2.1. Drivers

Uncoordinated urban development

Uncoordinated and poorly assessed urban development takes place in both cities. It is the major driver of the flood and water quality problems. Poipet is one of the fastest growing cities in Cambodia and subject to a massive inflow of foreign investment. The urban area is expanding into former agricultural lands with little regard to maintenance of the natural drainage corridors. The growing trade flow and number of large entertainment facilities and casinos attracts tourists, real estate ventures and further development like hotels and industry. Large access roads were built on the Thai side connecting Poipet. Water demand has risen as has the volume of waste water following the development.

While urban development took place, stormwater, wastewater, and solid waste management especially in Poipet has not kept pace. The increase of impermeable areas and impediments to natural drainage has increased flash flooding. The river has lost its drainage capacity. Cross-sections are obstructed with debris, waste, and pipes. There is no maintenance of the river cross-sections and extensive encroachment on the river profile. This problem is visible in both cities but is significantly worse further downstream parallel to Poipet with frequent flooding of residential and commercial areas.

The flood problem is worsened by encroachment. Urban settlements reach up to the river bank and into the river channel, especially in Poipet, which will make it difficult to improve maintenance and increase the channels capacity.

Waste problem

The river is used as a waste dump. Waste can be found in the streets, on fields and in particular in the river and along the river banks. Water quality is very poor with an unpleasant odour.

No maintenance of the river

Both the Thai and the Cambodian stakeholders stated that the river cross-section is not maintained. A problem for effective management is the borderline, which follows the river. Poipet is located on the left side in direction of flow with Thailand on the right side.

Inappropriate hydraulic structures

There are several weirs and culverts along the course of the river parallel to Aranyaprathet. The dimension of these structures is not aligned or effectively designed to meet the need giving rise to backwater conditions. Some storm and waste water pipes are in the river parallel to Poipet. Some are damaged. It is unclear what original purpose those pipes served. It is very clear, however, that they obstruct the flow.

Landfill discharging directly into the river

A landfill is situated immediate upstream the Thai/Cambodian border on the Thai side. The land fill drains into the river and gives rise to further deteriorating the water quality.

1.2.2. Impacts

The mission teams have identified the following issues for the project in Aranyaprathet and Poipet.

Regular flooding

Flooding affects both cities. Flood problems and flood damage occurs almost every year. Especially in Poipet, which is severely affected with residential areas inundated and flood waters baking up.

Poor water quality

The river has bad water quality. Photos taken during the field mission show an alarming level of pollution at the banks and in the river itself. Discharge of untreated waste water is a serious issue in both towns.

Lack of an observation stations and early warning system

The field teams identified the need to install observation stations upstream of Aranyaprathet and Poipet to record water levels and flow and communicate information to both town authorities. This would be an important first step in establishing an early warning system and effective information sharing protocol.

1.3. Nature based and hybrid solutions project concept

1.3.1. Concept design of NbS

1.3.1.1. Urban rainwater retention

Urban rainwater management manifests in two principles: 1) runoff prevention and 2) a functioning drainage system.

Runoff prevention and an adequate drainage system has not kept pace with urban development. Densely built-up areas generate more surface runoff and higher peak flows. These compound an inadequate drainage capacity of the existing drainage channels and the river to cope with new volumes and speed to runoff. The flood problem in Aranyaprathet and Poipet cannot be solved solely by developing upstream flood retention structures since a significant source of the flood problem is within the urban areas. Therefore, retention measures in the upstream catchment, retention improvement of the channel itself (widening and clearing) and decentralized rainwater retention are all needed.

Measure 7: Retention and infiltration of rooftop runoff; Measure 8: Permeable surfaces; and Measure 9: Retention and infiltration of surface runoff

Flood retention measures in built-up urban areas are achievable. Decentralization of runoff prevention is an urban water management concept that needs to be embedded into the urban development and spatial plans for the towns. On-site rainwater retention should be made mandatory for planning permission, infiltration on-site should become a drainage standard and permeable surfaces should replace hard surfaces wherever possible.

Decentralized retention measures are less prone to failure during significant rainfall events, with fewer consequences than centralized retention structures upstream. Three locations have been selected to demonstrate the measures as illustrated in Figure 3: (i) the market in Poipet (Measure 7), (ii) an unused roundabout surrounded by impervious areas (Measure 8) and (iii) a strip following the railway (Measure 9). All three have a high potential for replication in many areas of the town. The three measures present different urban rainwater management measures, which can be combined or applied selectively depending on the location. The most suitable measure for the three locations will be further detailed in the engineering design process.

Figure 3: Areas for urban rainwater retention demonstration measures

1.3.1.2. Wastewater treatment

Measure 10: Constructed wetlands

A challenge within the landscape area is presented by landfill site leachates and waste water sewer outflows just south of Aranyaprathet. To improve the existing constructed wetland is proposed to help with mitigating this wastewater problem (Figure 24). A more detailed assessment is needed to determine the feasibility and effectiveness of this measure. It may be that the area of land available for the wetland is not adequate for the volume of untreated waste water now and projected with increasing population and development. For a functioning wastewater treatment, a separated storm- and wastewater drainage system is required. Wastewater is a very serious public health and environmental problem which is being passed on downstream to Poipet so requires concentrated attention and investment.

Constructed wetlands are an alternative wastewater treatment that can reduce suspended solids, biochemical oxygen demand (BOD), pathogens, heavy metals and nutrients. Generally, most constructed wetlands in tropical countries are soil- or gravel-based horizontal flow-systems. Design criteria are the inflow in m^3/d, the quality of the wastewater in terms of concentration, the required treatment related to the outflow concentration, slope of the area, permeability of the soil and associated grain size distribution.

On the conditions that the untreated BOD is 11.8 g/l, and target BOD is 100 mg/l with 30°C water temperature, the required area of a constructed wetland would result to approx. 9,250 m² in case the inflow is 850 m³/d. The larger the daily inflow is and the larger the difference between in and out concentration, the larger is the necessary area. The current area is estimated at approximately 600-800 m^2. The values were taken from the field mission to Aranyaprathet combined with estimates on the inflow rate. The formulas used stem from Tanaka (2011).[2]

[2] Tanaka, et.al., 2011: Wetlands for tropical applications. Wastewater treatment by constructed wetlands. Imperial College Press, London, UK

The constructed wetland should be completed with natural river channel treatments (Measure 11 and 12) and vegetated filtration buffers (Measure 1) around the landfill site.

Figure 4: Proposed constructed wetland site south of Aranyaprathet

1.3.1.3. River restoration and rehabilitation

Measure 11: River channel widening and rehabilitation and Measure 12: River bank stabilization and rehabilitation

The river linking Aranyaprathet and Poipet requires significant rehabilitation as an important component of a major flood and water quality management strategy for the towns and further downstream. This section focusses on the Poipet section of the river to illustrate what needs to be done. River restoration and rehabilitation seeks to develop and improve the river's ecosystem health and to achieve an adequate hydrological function including sufficient flow capacity. Restoration and rehabilitation of a river embraces the development of the following:

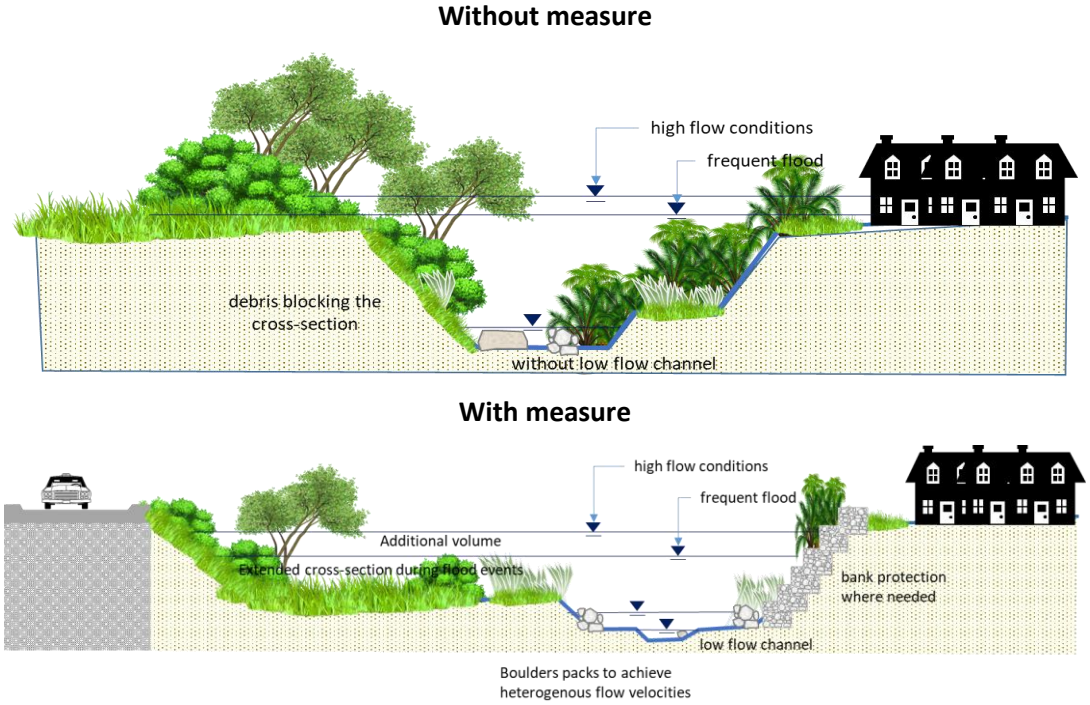
- River cross-sections;
- River bed material;
- River bank stabilization; and
- Incorporating natural structures to diversify flow velocity and to improve the interconnectivity of the river bed surface with the immediate underground

Cross-sections are developed with the aim of establishing various flow channels. Each channel has a specific purpose and a specific hydrological and ecological function. A low flow channel aims at ensuring a minimum water depth and flow velocity to preserve a river continuity and wetted perimeter to maintain ecosystem activities. The normal, medium flow channel is above the low flow channel and is designed to accommodate the range of conditions from low flow up to mean flow. The

next level covers flood events up to annual or bi-annual floods (frequent flood). These flood events are considered to be relevant for sediment mobilization and lead to a natural restructuring of the river bed. The top channel is reserved for rare flood events causing high flow conditions. The term rare flood event defines return periods that need to be determined based on available space for the cross-section development, available budget for the measure and a decision on the extent to which settlements should be protected against flooding. The return period selected requires a decision by managers considering hydrological and financial aspects. For flood events exceeding the defined high flow conditions, emergency measures and early warning systems should be put in place.

Two cross sections one without and one with measures are illustrated in Figure 5.

Figure 5: Cross-sections without (top) and with (bottom) measure



The starting point for river restoration and rehabilitation is to enable a natural development so that it shifts back into a virtually natural state. That means a sound sediment and nutrient balance, vegetation adopted to site-specific conditions and morphology to unfold its potential to compensate regular flood events within its flood plain.

This ideal development potential must be aligned with socio-economic constraints like available space, existing illegal settlements encroaching on the river, legally binding concessions for water abstraction and other possible restrictions.

2D hydrodynamic modelling of a river for detailing restoration and rehabilitation is state-of-the-art. First, the current situation is surveyed through cross-sections including the river banks and the potentially flooded areas on both sides. The survey must consider the full extent of potential flooding. The distance between the cross-sections depends on the variation of the river. Changes in the cross-sections require a new profile so that a replication of natural conditions can be replicated in the hydraulic model.

The river channel was modelled via a 2D hydrodynamic model with extent (see Annex 2). In order to further promote river restoration and rehabilitation, coarse surveys of cross-sections were conducted during the field missions and used to develop the model, with sample profiles provided in Annex 2. The model applied was HEC-RAS Version 6.0, a free software from United States Army Corps of

Engineers (USACE)[3]. Close up detail of some river stretches in 2D is provided in Annex 2. Both without and with measures were calculated using a flood event that occurred in 2019 with a peak flow of roughly 180 m^3/s (Annex 2).

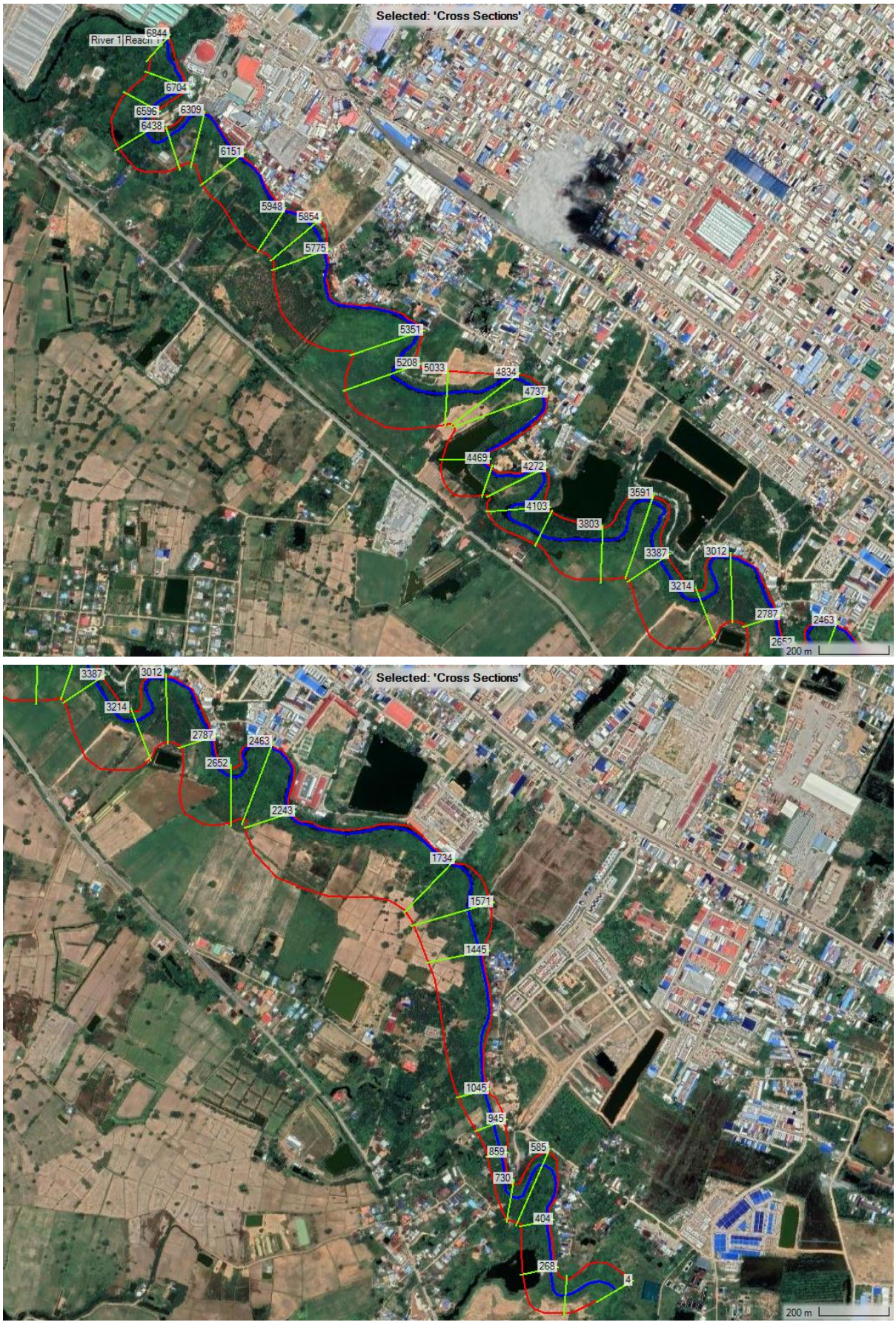
The results indicate the potential for flood mitigation with river rehabilitation and restoration. The new cross-sections have more space to accommodate floods, thus reduce flow velocities and avoid flooding. Further detailing requires adequate hydrological, hydraulic and ecological design where all three components fulfil their desired functions and bring about a healthy river stretch. The ecosystem health, however, depends on accompanying measures like waste management, upstream waste water treatment and others, although flood mitigation could be achieved by primarily looking at the development of the river geometry.

It is acknowledged that the new-cross sections have the potential to encroach onto private agricultural land and sensitive military zones on the Thai side. Extensive consultation is proposed to discuss the potential implications of this intervention. In addition, further studies will assess the cost-benefits of reducing seasonal flooding on these areas – especially as the two towns are rapidly developing as important trading, economic and touristic hubs in both countries.

A similar approach will be taken for the Aranyaprathet stretch of the river. Although hydrodynamic modelling has not yet been undertaken for this stretch of river, similar approaches for flood mitigation with river rehabilitation and restoration are proposed. As in Poipet, further consultation and studies will need to be undertaken to confirm the suitability and viability of the proposed interventions.

[3] https://www.hec.usace.army.mil/software/hec-ras/download.aspx.

Figure 6: (Top) Upper segment: with location of cross-sections used in the model; (bottom) Lower segment: with location of cross-sections used in the model



Measure 14: Urban greening

Nature-based solutions for urban resilience can be applied across spatial scales and settings in and around cities. Figure 3 identifies opportunities for green corridors in Poipet, to connect the central market, temple area and transport hub with the river corridor to the south (see Measure 14, Annex 1). It is understood that the roundabout area in Poipet of approximately 0.15 ha is becoming an urban green feature with amenity, shading and biodiversity benefits. Other green streets, transport areas, open spaces, landscaped areas and gardens should be connected via green spaces and corridors. Accessibility and planning considerations will need to be further identified to facilitate such a development going forward. Surrounding paved surfaces could also drain into the area. The runoff would be retained and treated by a bioswale (see Measure 7 and 8, Annex 1).

In Aranyaprathet similar opportunities exist to rehabilitate and reconnect the existing Aranyaprathet green areas and also establish green spaces and corridors within the city. This should connect to the city park to the north. The existing park comprises large areas of hardened surfaces, degraded canal networks and homogenous vegetation. These could be improved to form a mosaic and connected network of NbS interventions. A green corridor, comprising tree pits and vegetated areas, should connect the park with the adjacent transport hub (Figure 7).

Figure 7: Aranyaprathet city park and transport hub

1.3.2. Project benefits

- A significant reduction in flood risk for the two cities post-implementation of channel and bank rehabilitation;
- Rehabilitation of over 60 ha of existing park land and the establishment of new green spaces and green corridors in both cities; and
- A significant reduction in runoff and excess drainage, through a network of decentralized urban rainwater retention measures.