KEY POINTS

- The Tonle Sap and Mekong Delta river basin groups (RBGs)—the most productive regions in Cambodia—are facing increasing pressure on water resources. The situation is especially critical in the Tonle Sap RBG where water demands are not met.
- Integrated water resources development and management plans are needed at the river basin level, taking into account climate risks and current and future water demands including agriculture, domestic supplies, environment, and fisheries.
- Sustainable use of water resources and improved agriculture production in the Tonle Sap and Mekong Delta RBGs require modernization and enhancement of water infrastructure and more efficient and productive use of water. Crop diversification can have a beneficial impact on the state of water resources while increasing productivity.
- Scenario-based basin-level water resources assessment is useful to assess the potential impacts of water infrastructure investment options and make informed and evidence-based investment decisions.

Surface Water Resources Assessment of the Tonle Sap and Mekong Delta River Basin Groups: Improving Climate Resilience, Productivity, and Sustainability

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INTRODUCTION

The economy of Cambodia is highly dependent on water resources. The importance of water for food production, rural livelihoods, and economic development is recognized in national and sector-level strategies.¹ Rainfall distribution and river discharges in Cambodia are highly seasonal and variable, with a natural pattern of wet and dry seasons, typhoons, floods, and droughts. Coupled with these, the annual rise and fall of the Mekong River has both positive and negative effects—sustaining the critical water cycles of the Tonle Sap Lake and Lower Mekong Delta necessary for agriculture, fisheries production and ecosystem, but also being the cause for major flooding and damage to infrastructure and crops and loss of life.

Note: This brief draws from the report prepared by the Asian Development Bank (ADB). ADB. 2019. *Rapid Assessments on the Status of Water Resources and Eco-hydrological Environments for the Tonle Sap and Mekong Delta River Basin Groups and River Basin Surface Water Resource Assessments*. Consultant's report. Manila (TA7610-CAM). The brief has greatly benefited from comments from Ryutaro Takaku, David Freedman, and Piseth Long.

¹ The importance of water resources is recognized in the (i) Rectangular Strategy on Growth, Employment, Equity, and Efficiency, (ii) National Strategic Development Plan, and (iii) strategies for agriculture and water resources management, including the National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019–2033.

It is anticipated that climate change will increase the challenges of water management; less rainfall is anticipated during the dry season and more during the wet season, with more frequent extreme weather events and potentially worse seasonal water shortages and floods. The impact of climate change on water resources is likely to increase competition and conflicts over water in dry seasons, with adverse effects on the ecosystem as well as on the socioeconomic development of the country.

While there is potential to improve the water situation through water resources development and increased water supply for agriculture production and other uses, it is important to understand the availability of and demands on basin-wide water resources and potential impacts of the investment options and make informed and evidence-based investment decisions. This brief describes the surface water resources assessment of the Tonle Sap and Mekong Delta RBGs—two of the most productive RBGs in Cambodia—carried out by ADB and the Ministry of Water Resources and Meteorology of Cambodia and cofinanced by the Department of Foreign Affairs and Trade of the Government of Australia.

The assessment analyzed the surface water resources situation from the perspective of water availability and demands of various water users including the environmental water requirement. It also explored and assessed possible options for future water resources development and management and their potential impacts.

WATER RESOURCES IN CAMBODIA: CHALLENGES AND OPPORTUNITIES

Cambodia is a country rich in water resources, but about 70% of the annual water resources are comprised of water inflow from upstream countries. Most of the water resources pass through the Mekong River, which flows through Cambodia for about 500 kilometers (km) before entering the Mekong Delta. About 86% of Cambodian territory is within the Mekong River Basin, including the catchments of the Bassac River, the Tonle Sap River, and the Great Lake and its tributaries.

The river basins in Cambodia can be grouped into five RBGs based on their hydrological characteristics as shown in the map.

- (i) The Tonle Sap RBG is in the northwestern part of the country and covers about 45% of the territory, including the Great Lake, and the Tonle Sap River and each of its tributary catchments.
- (ii) The Upper Mekong RBG is the upper part of the Mekong River, from the border of Cambodia and the Lao People's Democratic Republic to about 20 km downstream of Kratié.

- (iii) The Mekong Delta RBG covers the Mekong River from downstream of Kratié to the border of Cambodia and Viet Nam. Most of the area is on the Mekong River floodplain, and most rivers are affected by the backwater effects of the Mekong River during the flood season and tidal effects during the dry season.
- (iv) The Coastal RBG is in the southwestern part of the country and is confined by the Gulf of Thailand in the southwest and the Elephant and Cardamom mountain chain in the northeast.
- (v) The 3S RBG is in the northeastern part of the country and includes the Se Kong, Se San, and Sre Pok rivers draining into the Mekong River at Stung Treng.

Agriculture accounts for 96% of all water use, domestic rural use 1%, and industry, domestic urban, and aquaculture use less than 1%.² The amount of water used is estimated to be only about 2% of total surface water volume, including water generated in the country and inflows from the Lao People's Democratic Republic and Viet Nam.³ However, water shortages do occur during the dry season—especially in the Tonle Sap RBG—due to the lack of stored water and limited access to water (footnote 2). This not only has serious consequences for the currently rice-dominant agriculture sector but also threatens fisheries and the health and sustainability of ecosystems.

Cambodia has significant potential to improve its irrigated agriculture and production. There are about 2,500 irrigation schemes, of which approximately 60% are in the Mekong Delta RBG and 35% in the Tonle Sap RBG. The irrigated command area is about 1.2 million hectares, which represents only 22% of all arable land, and more than 50% of irrigation schemes—especially those in the Tonle Sap RBG—are not yet achieving double cropping.⁴ The irrigation schemes in the Tonle Sap RBG constitute about 61% of the total irrigated area in the country, but the majority do not have access to reliable, year-round water sources.

The challenges of water resources management include the following:

- (i) lack of water storage and options for storing water to support all water user needs including agriculture, urban, and the environment;
- (ii) minimal water resources information to support evidence-based decision-making, including modern water analytical tools;
- (iii) lack of integrated water resources management and water allocation plans at river basin levels; and
- (iv) irrigation schemes that lack modern facilities to support efficient water delivery and higher agriculture production including diversification into high value crops.

² Government of Cambodia. 2019. *National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019–2033*. Phnom Penh.

³ ADB. 2014. *Cambodian National Water Status Report 2014*. Phnom Penh.

⁴ Annual irrigated area is about 1.75 million hectares.

River Basin Groups in Cambodia

Source: Government of Cambodia, Ministry of Water Resources and Meteorology.

These challenges result in annual water shortages and extreme flooding impacts and minimal water security for water users and the environment. To rectify these challenges, the Ministry of Water Resources and Meteorology of Cambodia prepared the *National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019–2033*, which sets out directions for water resources management and sustainable irrigation for the country and identifies priority actions to be implemented until 2033. It aims to achieve a whole-of-system approach to water resources management and irrigation development, where irrigation infrastructure development is part of more effective sustainable water resources management and contributes to increased agricultural productivity and

profitability by enabling response to agricultural needs such as crop diversification.

RAPID ASSESSMENT OF THE STATE OF SURFACE WATER RESOURCES

Rapid assessments of surface water resources and eco-hydrological environments of the Tonle Sap and Mekong Delta RBGs were carried out to understand water resource availability and identify critically stressed river basins.⁵ The assessment characterized the state of water resources for each of the 15 river basins in the Tonle Sap RBG and 8 river basins in the Mekong Delta RBG as shown in the set of figures.

⁵ The methodology is outlined in Box 1.

Rapid Assessment of the State of Surface Water Resources in the Tonle Sap and Mekong Delta River Basin Groups

Note: Shown are percentages of annual water demand supplied assuming that delivery infrastructure is in place and functioning.

Source: ADB. 2019. *Rapid Assessments on the Status of Water Resources and Eco-hydrological Environments for the Tonle Sap and Mekong Delta River Basin Groups and River Basin Surface Water Resource Assessments*. Consultant's report. Manila (TA7610-CAM).

The Tonle Sap RBG findings are as follows:

- The Tonle Sap RBG (81,663 km²) consists mainly of lowlands with gentle slopes and elevations of less than 100 m above mean sea level. Approximately half of the area is covered with different types of forest, including a relatively small flooded forest that is an important fish habitat. Another major type of land use is paddy rice fields, which cover about 30% of the area. The population was about 9.6 million in 2016.

- Water sources of the Tonle Sap RBG—apart from the water of the Great Lake—are mainly restricted to regional rainfall. The entire Tonle Sap RBG receives on average 110 billion cubic meters (m³) of precipitation per year, mostly from May to October. Of this, about 78 billion m³ is evaporated through vegetation. Only a small amount of water is consumed by domestic supply. The remainder goes to groundwater recharge and flows to the Tonle Sap Great Lake and subsequently to the Mekong Delta.

Box 1: Methodology Applied for the Rapid Water Resources Assessment

The rapid assessment of the state of surface water resources used a Water Supply and Demand Framework covering 20 years (1999–2018) of data to ensure that the most recent conditions were incorporated and that there were sufficient years to cover average, wet, and dry conditions. The Water Evaluation and Planning model was used to build the Water Supply and Demand Framework.

The 16 river basins in the Tonle Sap River Basin Group (RBG) were divided into 42 subbasins, and the 8 river basins in the Mekong Delta RBG were divided into 15 subbasins. Each subbasin was further divided into 12 land use classes. Surface water flow in rivers and streams were modeled using 20-year rainfall data and topographical, soil, and land cover characteristics as well as evapotranspiration. Existing water storage and reservoir operation rules were also considered in determining water availability. Water demands were estimated and described as follows. Water shortage was calculated in case water demand exceeds water availability in rivers and streams in the subcatchment. The time step was set at 7 days to have a good balance between accuracy and calculation time and to align with the irrigation rotational system of 7 days in the region.

Agriculture

Irrigation for agriculture is the major water user. Water demand was calculated using the Penman-Monteith equation considering antecedent precipitation and climate data, such as temperature, windspeed, humidity, and sunshine hours. Water demand was

set for the four main paddy-growing seasons based on the cropping calendar of the subbasins. In Cambodia, planting during flood recession helps reduce overall water demands and was included in the modeling.

Domestic

Although the majority of urban and rural domestic water supply in Cambodia comes from groundwater, conservative estimates of surface water sources were used for this assessment given that groundwater can be recharged through surface water seepage. Urban and rural domestic water demands were estimated based on the population and per person water demand. For this rapid assessment, 160 liters (L) per person per day (L/person/day) was used for urban water demand and 90 L/person/day for rural water demand.

Environment

In-stream water demands for ecosystems should be considered for wetland ecosystems and aquatic biota. The environmental requirement was set at 30% of the mean annual flow during the wet season and 0.2 m/second per 100 km² during the dry season. For specific sites of environmental importance, an additional evaporative demand of 5 billion m³/hectare was considered.

Hydropower

Water use for hydropower was not included in the assessment as hydropower dam development is limited in the target RBGs.

Source: ADB. 2019. *Rapid Assessments on the Status of Water Resources and Eco-hydrological Environments for the Tonle Sap and Mekong Delta River Basin Groups and River Basin Surface Water Resource Assessments*. Consultant's report. Manila (TA7610-CAM).

- There are 15 river basins in the Tonle Sap RBG, and 11 tributaries discharge into the Great Lake. River discharges are highly variable. The largest tributary is Stung Sen, which has an average flow of 245 cubic meters per second (m³/sec), with a maximum monthly average flow of about 600 m³/sec in August. However, the river almost dries up during the dry season, with most of the water being extracted from the river. Although reservoirs have been constructed to mitigate the pronounced seasonality of water availability, primarily aimed at irrigation supply, water supplies in the dry season are limited. Water demands are substantial for paddy cultivation (9.48 billion m³/year).⁶ The analysis indicates that on average, only 30% of irrigation demand is being delivered annually and only 15% in the non-wet season.
- Domestic demand compared to paddy cultivation is significantly lower at 235 million m³/year but must be delivered year-round. Most domestic water supplies come from groundwater sources, but the analysis assumed that the water is extracted from surface water. The analysis showed that water resources are sufficient to cover about 70% of annual demand.
- The environmental water requirement was estimated based on a rapid eco-hydrological assessment. The assessment indicated

that only 52% of the annual environmental water requirement (8.54 billion m³/year) can be met. In some river basins that are especially short of water, the minimum environmental flow requirement can only be met about 40%–50% of the time.

- The Tonle Sap RBG is unable to match water demands in the current situation. Water shortages are exacerbated outside the wet season. The Mounge Russei, Sisophon, and Siem Reap river basins are especially short of water. Considerable challenges exist in ensuring water delivery outside the wet season.

The Mekong Delta RBG findings are as follows:

- The Mekong Delta RBG (35,839 km²) covers the Mekong River from about midway between Kratié and Kampong Cham to the border of Cambodia and Viet Nam, excluding the drainage area of the Tonle Sap River and the Great Lake. Most of the area is comprised by the Mekong River floodplain, where rivers are affected by Mekong River floodwater. The agricultural paddy land heavily dominates the RBG area, with some forests in the upper part. The population was about 6.8 million in 2016.

⁶ Wet season irrigation water demand is 6.74 billion m³/year for paddy cultivation area of 6,684 km², and non-wet season irrigation water demand is 2.74 billion m³/year for paddy cultivation area of 1,218 km².

- Total water resources of the Mekong Delta RBG are sufficient to meet the demands of urban, paddy cultivation, and environmental flow requirements. Main inflows from the Mekong and Tonle Sap rivers and annual rainfall are sufficient to meet annual demands. However, given the irregularity of resource availability in terms of timing (dry season), location (distance to rivers and streams), and source (flood recession, rivers, and streams), water shortages are frequent.
- The water requirement of paddy cultivation is 6.37 billion m³/year, of which over 60% is covered by recession flooding water that remains in the paddy fields and soil, and about 25% is from rivers, streams, and canals.⁷
- Domestic demand compared to that for paddy cultivation is significantly lower at 220 million m³/year but requires year-round delivery. The analysis showed that water resources are sufficient to cover 90% of the annual demand.
- The environmental flow requirement (3.79 billion m³/year) can be met most of the time.

In the Tonle Sap RBG, the uneven distribution (spatially and temporally) indicates a need to improve the productive use of water and modernize irrigation infrastructure to reduce water losses while at the same time preserving environmental water requirements. Measures that could improve the water situation are

- (i) modernization of irrigation infrastructure to improve water efficiency, and
- (ii) storage development to regulate flows and increase availability in the dry season.

The analysis also revealed that increasing water storage by supplementing water from neighboring river basins with more water could be an option in critical areas, although possible negative environmental impacts need to be carefully assessed.

The Mekong Delta RBG has an adequate water supply on an annual basis, although there are limitations on delivery, especially in the dry season. The area also has some important environmental features—such as wetlands—that need to be conserved. The type of measures that could be considered to improve the water resources situation include

- (i) measures and infrastructure to preserve designated wetland reserves and other environmental features,
- (ii) modernization of irrigation infrastructure to improve water efficiency,
- (iii) improvement of the linkage of canals between basins to balance demands,
- (iv) small-scale pumping irrigation schemes to expand irrigation,
- (v) flood control and drainage improvements to mitigate flood impacts and increase productivity, and
- (vi) expansion of urban water provision.

SURFACE WATER RESOURCES: ASSESSMENT OF SELECTED RIVER BASINS

Building on the findings of the rapid assessment, a detailed surface water resources assessment was carried out for selected river basins in the Tonle Sap and Mekong Delta RBGs to study possible future scenarios for water resource allocations and interventions. Based on the guidelines set out in the national road map and investment program, the aim is to improve agricultural production through better water use and allocation, modernization of infrastructure, and promotion of crop intensification and diversification while meeting the water demands for livelihoods and the environment.

The assessments were performed in eight river basins aggregated into three larger river basins: two river basins in the Tonle Sap RBG and one river basin in the Mekong Delta RBG.

- (i) **Sreng and Sisophon river basin.** Water demand exceeds supply in the irrigated areas—mainly around the Trapeang Thmar reservoir—and several environmentally protected areas are threatened.
- (ii) **Sangker, Pursat, Moug Russei, and Svay Don Keo (Pursat–Sangker) river basin.** Water demand exceeds supply in the irrigated areas, especially in the Stung Moug Russei river basin. Increased water resource utilization may impact habitats along the banks of the Tonle Sap. Currently, water is scarce in several agricultural areas.
- (iii) **Slakou and Toan Han river basin.** The flood dynamics of the Mekong delta cause several challenges for agricultural expansion and environmental conservation in this area. Access to water is limited in certain areas.

In the Cambodian context, a river basin may not be a unique hydrological unit. For example, floodwater can flow across river basins due to low-lying topography. This was the case in the 2019 flood, when floodwaters of the Sreng River Basin spilled over to the Sisophon River Basin via the Trapeang Thmar reservoir. In other cases, old river courses or transfer canals connect neighboring river basins. The assessment considered and selected river basins in groupings based on current water shortage situations, the potential for additional water resources development, ecological interests, and alignment with existing studies and government plans for future water resources development.

Box 2 shows an example of the assessment carried out for the Sangker, Pursat, Moug Russei, and Svay Don Keo river basins. Several scenarios that influence the demand and supply of water resources were studied for each of the selected river basins:

- (i) **Baseline or reference scenario.** Current infrastructure and irrigation areas.
- (ii) **Improved irrigation efficiency.** Better water efficiency through irrigation system modernization.

⁷ Wet season irrigation water demand is 3.5 billion m³/year for a paddy cultivation area of 3,230 km², and non-wet season irrigation water demand is 2.87 billion m³/year for a paddy cultivation area of 2,752 km².

- (iii) **Crop intensification.** Increased agricultural production by crop intensification and diversification.
- (iv) **Increased water supply and irrigation expansion.** Combination of water resources and irrigation development with investments in water resources infrastructure, including water storage, water transfers, or expansion of irrigation schemes.

For all future scenarios assessed, domestic water was given the priority in water allocation during dry periods. For the environmental water requirements, analysis was made of hydrological requirements for maintaining key features and ecosystem services and how these may be impacted by anticipated water resources interventions.

The analysis made use of data collection and modeling in the rapid assessment but further investigated specific areas and possible interventions. Detailed basin models were built with hydrological and hydraulic models. Data on inflow into the rivers and streams were obtained from the hydrological model. Irrigation water demands were calculated dynamically with the advanced soil-moisture module. Withdrawals, storage, and return flows were calculated in the hydraulic model. Data spanning 20 years were used to introduce annual and weekly climate data variations. For future scenarios, the same climate variability was assumed, as the climate risk analysis showed that annual flows are likely to increase in this area, and there is no clear trend in the drought (dry period) characteristic that was studied (Box 3).

The findings of the surface water resources assessment include the following:

- (i) Modernization of irrigation schemes that allow more efficient water use (the scenario assumed reduced water losses from 25% to 10% and increased water reuse from 25% to 50%) leads to more efficient crop water use and can reduce the annual irrigation water shortage by about 45% in Pursat–Sangker, 17% in Sreng–Sisophon, and 8% in the Slakou–Toan Han river basin.
- (ii) Doubling of crop intensities, from the current level of slightly more than 100%–200%, without changing the present paddy–rice–dominant cropping pattern has a large

impact in increasing water demand and water consumption for irrigation. The water resources situation will likely be aggravated, and its impact may be felt hard especially by the subsistence farmers who do not have access to reliable water supply.

- (iii) Crop diversification by mixing rice and vegetables outside the wet season has the potential for reducing water requirements compared to the rice-only double cropping scenario in Point (ii). The diversification scenario—assuming 30% of non-wet season crops would be converted from rice to vegetables—would result in a reduction of water demand by 8% and irrigation water shortage by 15% in the Pursat–Sangker river basin, for example. A more drastic scenario, which assumed that 100% of non-wet season crops would be converted to vegetables, resulted in a reduction of water demand by 32% and irrigation water shortage by 58%. This finding suggests that the government’s strategy of diversifying crops has the potential for improving the water resources situation and leading to significant economic benefits. This will need to be supported by significant improvements or remodeling of irrigation schemes to allow for flexibility and reliability of supply in irrigating non-rice crops.
- (iv) In the selected basin groups in the Tonle Sap RBG, expansion of irrigated areas is not possible in the current water situation. Water storage capacity will need to be significantly increased to support irrigation expansion. Developing water storage upstream may reduce flood occurrence downstream; however, its effectiveness in protecting against extreme floods that have severe impacts on livelihoods and potential environmental impacts will need to be carefully assessed.
- (v) In the selected basin group in the Mekong Delta RBG, improvements in drainage and flood protection of irrigated areas have the potential to boost total crop production in the area by enabling another crop cycle in the early wet season.
- (vi) Water allocation options and investments related to irrigation and water resources development will likely impact environmental flows. Some environmental reserves that suffer from water shortages may benefit from water conservation interventions by providing more controlled hydrological conditions. However, careful assessment and analysis of potential environmental impacts and risks will be required.

Box 2: Water Resources Assessment of the Sangker, Pursat, Moung Russei, and Svay Don Keo River Basins

This river basin group lies predominantly within the provinces of Pursat and Battambang but also lies within areas of Pailin. It constitutes four river basins with an area of 17,767 km², which was further divided into 27 subcatchments to allow for a more detailed assessment. In terms of discharge, the Pursat and Sangker rivers are the largest within this basin group.

The Pursat has a maximum flow of 1,264 cubic meters per second (m³/sec) and the Sangker has a maximum flow of 1,020 m³/sec. The discharge within each of these rivers tends to peak in October, which usually coincides with the highest Tonle Sap lake level. The elevation within the region ranges from 1,650 meters to -0.2 meters and generally

decreases from west to east, from the Cardamom mountains towards the Tonle Sap.

The river basin group had a population of about 1.1 million in 2016 and an annual irrigated command area of about 211,000 hectares (ha), of which only 9% is used outside the wet season, with a cropping intensity of about 108%. There are 12 environmentally protected areas, 30 river blockages, and 99 community fish refuges within the region.

The assessment analyzed several potential scenarios that combine management and/or water use options (A to C) and infrastructure investment options (D to L).

Scenarios Assessed

Scenarios		Management options							Infrastructure options					
		A	B	C	C'	D	E	F	G	H	I	J	K	L
	Reference													x
Improved efficiency	Scenario 1	x				x								x
Crop intensification	Scenario 2	x	x			x								x
	Scenario 3	x		x		x								x
	Scenario 4	x			x	x								x
Increased supply and irrigation expansion	Scenario 5	x		x		x	x		x		x			x
	Scenario 6	x		x		x	x	x	x	x		x	x	x
	Scenario 7	x		x		x	x	x	x	x	x	x	x	x

A: Priorities given to domestic water during water shortage periods

B: Rice intensification (rice cropping intensity of 200%)

C: Intensification and diversification (30% vegetables outside wet season)

C': Intensification and diversification (100% vegetables outside wet season)

D: Irrigation modernization (water losses in canals reduced from 25% to 10%, reuse of runoff and drainage from irrigated areas increased from 25% to 50%)

E: Prek Chik irrigation scheme expansion (additional 10,000 ha)

F: Link Sangker to Moung Russei

G: Link Svay Don Keo to Moung Russei

H: Increased reservoir capacity—Pursat (1,335 million m³)

I: Increased reservoir capacity—Sangker (1,040 million m³)

J: Large irrigation expansion in Kamping Puoy (18,000 ha) and Battambang (10,000 ha)

K: Diversion to Kamping Puoy

L: Dauntay reservoir completed (currently under construction)

IRRIGATION WATER SUPPLIED AND IRRIGATION SHORTAGE

Notes: Irrigation shortage = irrigation water demand – irrigation water supplied. ET = evapotranspiration.

The results are based on 20-year averages.

Source: ADB. 2019. *Rapid Assessments on the Status of Water Resources and Eco-hydrological Environments for the Tonle Sap and Mekong Delta River Basin Groups and River Basin Surface Water Resource Assessments*. Consultant's report. Manila (TA7610-CAM).

POTENTIAL AND ACTUAL CROP WATER CONSUMPTION

RECOMMENDATIONS

- Water resources development needs to be aligned with agriculture and urban development policies and plans while ensuring the sustainability of the rich eco-hydrological system of the country.⁸ Integrated water resources development and management plans need to be prepared at the river basin level taking into account climate risks and current and future water demands—including domestic supplies, environment, and fisheries—and increasing irrigation demand, especially in the dry season. The basin-level water resources assessment should be used to properly assess the potential impacts of water-related investments on basin-wide water availability and explore mitigation strategies that can offset possible negative impacts. Improved water resources data information is also needed.
- Future water resources interventions should target not only supply-side measures but also the water user-side measures through carefully looking at mitigation measures to reduce water consumption.
- Crop diversification—an agricultural strategy of the government—could have a beneficial impact on the state of water resources by reducing irrigation water demands per unit area in currently rice-dominant areas that are facing water shortages and contributing to increased productivity.
- Given the highly vulnerable and sensitive ecosystems in the basins, environmental hydrological requirements need to be assessed and accounted for in future water resources investments. The impacts of blockages on hydraulic structures such as dams, reservoirs, and weirs are significant for fisheries and aquatic ecosystems. The hydraulic structures should be “fish friendly” by using overshot gates and fish passages appropriate for the Mekong fish species, and community fish refuges should be considered in determining water requirements in the irrigation scheme preparation.⁹
- Despite the high levels of uncertainty regarding future climate risks, investments on water resources need to be resilient against potential climate impacts by adopting adaptation measures, such as the improvement of hydrometeorological forecasting, the development of early warning systems and hazard management plans, and use of climate-resilient agricultural practices. Adaptation measures should be incorporated into each intervention to increase resilience to already prevalent extreme events as well as future changes in climate and extreme events.

⁸ The relevant policies in agriculture include the Agricultural Sector Strategic Development Plan 2019–2023, which calls for (i) improved agricultural productivity, (ii) promotion of animal production and animal health, (iii) sustainable fisheries resources management, (iv) sustainable forestry and wildlife resource management, and (v) strengthening of institutional capacity.

⁹ The climate-resilient design guidelines for structural flood and drought control measures have been developed by the Greater Mekong Subregion Flood and Drought Risk Management and Mitigation Project.

Box 3: Climate Risks Assessment

Cambodia is considered to be highly vulnerable to climate change. The climate risks were assessed in relation to the selected river basins in the Tonle Sap and Mekong Delta river basin groups.

The assessment considered the historical trends in climate and extreme climatic events, and climate change projections were derived from an ensemble of general circulation model (GCM) projections.^a Key findings are as follows.

Water resources and agriculture projects are sensitive to weather and climate conditions, and changes in climate can result in significant impacts on project outputs and outcomes. The climate sensitivities related to the possible water resources investments in Tonle Sap and Mekong Delta RBGs include the following:

- (i) **Precipitation changes.** Leading to changes in water availability and demand.
- (ii) **Temperature increases.** Forcing changes to crop suitability, water requirements and yield, and potential risks to wildfire.
- (iii) **Flooding.** Incurring damage to irrigation infrastructure and irrigated areas; also leading to increased erosion and sedimentation problems.
- (iv) **Drought.** Leading to reduction in the productivity of irrigated areas and increasing water resources and management issues in relation to water storage and distribution.
- (v) **Typhoons and landslides.** Leading to damage to water and agricultural infrastructure.

The climate projections indicate the following for the near future (2020–2050):

- (i) Extreme temperature events (represented by an indicator for maximum annual 1-day temperature) are likely to increase in intensity by 1°C–2.2°C. Uncertainty in this prediction is medium.
- (ii) An increase in average annual precipitation in all basins, in the range of 5%–15%. This is uncertain due to a range of predictions within the GCM ensemble.
- (iii) An expected increase in temperature for all basin groups, in the range of 0.9°C–1.2°C. The uncertainty is lower in the case of temperature but increases with more extreme climate scenarios.
- (iv) Extreme precipitation events (represented by an indicator for maximum annual 1-day precipitation) are likely to increase in intensity by 10%–70%. Uncertainty in this prediction is medium-high.
- (v) Trends in drought events (represented by an indicator of consecutive dry days) are unclear, with some GCMs predicting increases and some decreases. Uncertainty in this prediction is high.

Despite the high level of uncertainty in many of the parameters previously mentioned, the principal potential climate risks are found to stem largely from increased frequency or intensity of flooding or drought. These may impact water-related infrastructure development by directly damaging them and also lead to reduced agricultural productivity and water availability.

^a Climate change projections were constructed using the NASA Earth Exchange Global Daily Downscaled Projections dataset, which is comprised of global downscaled climate scenarios derived from the Coupled Model Intercomparison Project Phase. The NASA Earth Exchange Global Daily Downscaled Projections dataset includes downscaled projections for two greenhouse gas emission scenarios known as Representative Concentration Pathways (RCPs), RCP4.5 (medium stabilization scenario), and RCP8.5 (very high baseline emission scenario).

Source: ADB. 2019. *Rapid Assessments on the Status of Water Resources and Eco-hydrological Environments for the Tonle Sap and Mekong Delta River Basin Groups and River Basin Surface Water Resource Assessments*. Consultant's report. Manila (TA7610-CAM).

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