OUTPUT: INCREASED CLIMATE RESILIENCE

A. Summary

1. The Royal Government of Cambodia (RGC) is one of the pilot countries participating in the Pilot Program for Climate Resilience (PPCR). The priority sectors for PPCR in the RGC include water resources, agriculture and infrastructure. In June 2011, the PPCR sub-committee endorsed RGC's Strategic Program for Climate Resilience (SPCR) with a funding envelope of up to $86 million ($50 million in grants and up to $36 million in concessional credit). Of this, an allocation of $14 million ($8 million concessional credit and $6 million grant) was agreed for "Enhancement of Flood and Drought Management and Mitigation in Pursat and Kratie Provinces", as subprojects under the ADB-funded GMS Flood and Drought Risk Management and Mitigation Project.

2. Base investment (without PPCR financing): The base investment of $35 million (Asian Development Fund loan) and $2.95 million (Royal Government of Cambodia [RGC] financing) will be invested in one structural subproject, the Damnak Chheukrom Irrigation Rehabilitation Subproject, in Pursat Province. However there is only sufficient water availability in the dry season to meet the demands of about half the total command area and the water availability will worsen with anticipated climate change. There is therefore a need to expand water storage capacity for use during extended periods without rain during the wet season and also to enhance the design to incorporate a delayed onset of the rainy season. While the base design already serves as flood control purpose to divert water during flood periods to reduce flooding in Pursat Township, with climate change predictions, larger peak water flows may not be accommodated with the base design.

3. Increased climate resilience (with PPCR concessional credit and grant financing): PPCR concessional credit ($ 4 million) will finance the incremental costs associated with ensuring the **structural** subproject described in para. 2, is more climate resilient. The following aspects of the base investment will be enhanced to accommodate climate resilience features: (i) the Damnak Cheukkrom Barrage; (ii) flood diversion using the Damnak Cheukkrom Barrage Main Canal; (iii) upgrading the existing structures on the Svay Donkeo River; and, (iv) increasing local drainage in the Damnak Cheukkrom Barrage. Besides structural measures, climate resilience will be increased through accompanying **non structural** measures. The PPCR grant ($5.8 million) will finance the costs of non structural measures to strengthen the capacity of the government and affected communities to reduce the risks associated with climate extremes, namely flood and drought events. The key measures are (i) effective early flood and drought warning system can be setup by provision of real time data through improved communication system among Department of Meteorology, the Provincial Department of Water Resources and Meteorology, Provincial Committee for Disaster Management, and the Farmer Water User Committees (FWUCs); (ii) improved hydraulic design standards in the Mekong Delta (iii) technical assistance to build community capacity to better manage and mitigate risks associated with increasing climate extremes, including the use of early warning systems. This will build on coping strategies and mechanisms of communities and promote community-based disaster risk reduction and management and (vi) promoting adaptation measures.

4. Overall, the proposed PPCR financing will contribute to strengthening the capacity of the government and affected communities to reduce the risks associated with climate extremes, namely flood and drought events. The PPCR financing will support the design and implementation of additional irrigation infrastructure for increased resilience to climate change in

Pursat Province; and will provide technical assistance to build community capacity to better manage and mitigate risks associated with increasing climate extremes, including the use of early warning systems. The Project will emphasize risk reduction strategies aimed at preventing flood and drought events from becoming disasters for the affected population. It will also build on coping strategies and mechanisms of communities and promote community-based disaster risk reduction and management.

5. Selected key features:

(i) Regional nature: The Cambodia project is part of the larger of the Greater Mekong Subregion (GMS) project, which covers similar structural and non structural investments in the Lao People's Democratic Republic and the Socialist Republic of Viet Nam. In each of the three countries, the project is structured around four similar outputs, while taking into consideration the local conditions and needs. In particular, the non structural activities are similar in the three countries – for example both Viet Nam and Cambodia will have activities on improved hydraulic designs, and both Cambodia and Lao PDR will be working on making their individual national flood warning or early warning systems operational. These regional aspects of the GMS project provide many opportunities for learning and knowledge sharing across countries.

(ii) Gender impacts**:** The Project is classified as effective gender mainstreaming (EGM)[1]. The key gender impacts of the Project include increased women's engagement in (i) management of data and information on floods and droughts; (ii) in local level disaster risk management activities; and (iii) employment generated through civil works and other project related activities. The Project Gender Action Plan which was developed based on a gender assessment, contains gender design features and gender related performance indicators are included in the project monitoring and evaluation framework.

(iii) Local participation: Local communities are beneficiaries and key stakeholders of the non-structural components of the Project. Firstly, farmer water user committees (FWUC) will receive training and support to effectively undertake their role as managers of the tertiary and distribution irrigation system; and will be supported in climate adaptation measures diversify their crops (rice or other crops) to reduce their crop irrigation requirement for the dry and early-wet season crops. Secondly, community based disaster risk management (Output 3) activities will be implemented to ensure that communities are able to obtain the full benefit from improved water control infrastructure and improved flood warnings. Community–driven flood and drought risk reduction measures will be implemented based on participatory local level flood and drought risk assessment and analysis and disaster risk reduction and management plans.

(iv) Knowledge development and sharing: PPCR grant financing will be used to generate knowledge (for example, the study on climate resilient hydraulic design standards) that will assist the RGC plan and develop future climate resilient

[1] A project is assigned EGM if the project outcome is not gender equality or women's empowerment, but project outputs are designed to directly improve women's access to social services, and/or economic and financial resources and opportunities, and/or basic rural and urban infrastructure, and/or enhancing voices and rights, which contribute to gender equality and women's empowerment.

infrastructure for flood protection and irrigation management. This knowledge developed will be shared across the border with linkages to the Viet Nam. Experiences and lessons learnt from the support to operationalising the national forecasting and early warning systems will be shared with the project in Lao PDR, where similar support is envisaged. Similarly, as all three countries are working on community based disaster risk management, there is ample opportunity for cross learning (for example, Viet Nam is rolling out the national CBDRM strategy and Cambodia also has training material for CBDRM based on previous ADB TA results on community based flood resilience.) The PPCR grant will also finance specific technical expertise to bring in knowledge for increased project efficiency and effectiveness

(v) Synergy with ADB portfolio: The Cambodia project fits well with ADB's water, climate change and rural development portfolio in the country. For example, the ongoing Water Resource Management Sector Development Program (WRMSDP), addresses institutional and capacity gaps needed to support the implementation of the country's Strategy on Agriculture and Water (SAW), including on climate change. The proposed Climate Resilient Rice Commercialization Sector Development Program (SDP) also will support the SAW, including the development of a climate resilient rice value chain. As another example, the Nordic Development Fund is administering a co-financing component to an ADB rural roads improvement project (loan 2670) with the Ministry of Rural Development (MRD). As part of this component, they are developing vulnerability maps for Pursat Province which will likely be highly relevant for this project.

B. Regional Project Overview

6. The GMS Flood and Drought Risk Mitigation and Management Project impact will be reduced economic losses resulting from floods and droughts. The project outcome will be improved capacities and preparedness to manage and mitigate the impacts of flood and drought events. The duration of the project is six years and will be implemented from 2013-2019. The total project cost (in the three countries) is estimated at $149.24 million. The sources of financing, besides the proposed PPCR loan and grant are: ADB loans and grant and a Government of Australia grant (for Viet Nam).

7. The Project covers three countries: Cambodia, Lao People's Democratic Republic and the Socialist Republic of Viet Nam. In each of the three countries, the project is structured around four outputs:

(i) Output 1: Enhanced regional data, information and knowledge base for the management of floods and droughts;

(ii) Output 2: Upgrading Water Management Infrastructure (rehabilitation of flood control embankments, associated water control structures, and access roads; rehabilitation of drainage canals, including increasing flow capacity and improving water control infrastructure; and rehabilitation and extension of canals, water control structures and irrigation distribution networks).

(iii) Output 3: Capacity Building of Community-Based Disaster Risk Management, and

(iv) Output 4: Effective project implementation.

C. Project area in Cambodia

1. National level

8. The Project in Cambodia will work at both at the national and the provincial level. For example, at the national level, output 1 covers the: (i) improvement of hydro-meteorological network and data acquisition; (ii) installation of flood and drought forecasting model; (iii) formulation of nation-wide flood and drought forecasting and early warning strategy; and (iv) capacity development of Department of Meteorology (DoM) and the Department of Hydrology and River Works (DHRW) and appropriate institutional frameworks for flood and drought forecasting and early warning.

2. Provincial level - Kratie Province

9. While the scope of the SPCR agreed for Component I: Climate-Resilient Water Resources and Infrastructure Development; Project 2 on the "Enhancement of Flood and Drought Management and Mitigation in Pursat and Kratie Provinces", the scope of the Project in Cambodia has been adjusted to cover a structural subproject in Pursat Province only. The base ADB investment will not finance activities in Kratie Province as originally envisaged. During technical and social due diligence ADB considered that the proposal in Kratie for 5 km of flood protection works would have caused involuntary resettlement that would be difficult to justify against the expected benefits of the Kratie subproject. In any case, the reduction of PPCR available funding for the project, from $14 million to $10 million would have made financing a Kratie subproject impossible. Therefore ADB and the Government agreed to concentrate the structural subproject on Pursat province only, to maximize the project impact and ensure a well focused drought management investment with flood management benefits in Pursat Province.

3. Provincial level - Pursat Province

10. The structural subproject and the associated local support on FWUC and CBDRM will take place in Pursat Province. The focus on Pursat Province for the structural subproject does not overly jeopardize the overall results of the proposed project. Table 9 of the SPCR (see para. 148, page 49) lists six interventions and their accompanying outcome and impacts. Out of the six interventions, only one is related to an investment in Kratie. All other five interventions remain in the project design, namely: (i) Damnak Choeukkrum Irrigation Works, Pursat River; (ii) Agricultural adaptation strategies; (iii) Community Based Disaster Reduction and Management; (iv) Improved hydraulic design standards and (v) national flood and drought forecasting.

D. Climate Change Trends, Projections and Impacts

11. In its 2001 report on impacts, adaptation and vulnerability to climate change, the Intergovernmental Panel on Climate Change (IPCC) concluded that there was high confidence that recent regional changes in temperature had discernible impacts on physical and biological ecosystems (IPCC, 2001). In particular, there is emerging evidence that human systems have been affected by increases in floods and droughts. Projected changes in climate could have major consequences on hydrology and water resources, agriculture and food security, terrestrial and freshwater ecosystems, coastal zones and marine ecosystems, and human health. General consensus for Cambodia is that there will be an exacerbation of extremes, such as increased floods and droughts. Adverse impacts include increased flood and drought magnitude and damages in temperate and tropical Asia, reductions in crop yields, decrease water availability,

and increase in the number of people exposed to vector and water-borne diseases. The Province of Pursat ranks as a medium risk for both floods and droughts (NAPA[2], 2006).

1. Impacts of Climate Change on Floods and Droughts

12. In preparing its National Adaptation Programme of Action (NAPA, 2006), the government undertook field-level surveys in 684 households in 17 provinces across the country. The top priority cross-cutting needs included the Strengthening of Community Disaster Preparedness and Response Capacity and Vegetation Planting for Flood and Windstorm Protection. In the agriculture and natural resource management sector, Development and Rehabilitation of Flood Protection Dikes came out as the third most important priority and Rehabilitation of Upper Mekong and Provincial Waterways was the fourth highest priority. Clearly, structural and non-structural measures for reducing the impacts of floods and droughts are a concern at both communities and governments. The Project will seek to address both.

13. Flooding in Cambodia is an annual natural occurrence and the agro-ecosystems are adapted to seasonal flooding. In the past, annual floods produced more benefits than harm and the concern regarding climate change is for an intensification of damaging flood and drought periods. Devastating floods affecting a significant population used to occur almost every five years (in 1961, 1966, 1978, 1984, 1991, and 1996). Recently, however, harmful floods have occurred every year since 1999, and the worst hit in 2000. Floods seem to be getting worse and more frequent, perhaps due to climate change and human activities including inappropriate land use planning that degrade the environment. Flooding patterns have significantly changed in several provinces, including Kampong Cham, Kampong Chhnang, Kampong Thom, Kandal, and Takeo. It is this change that often causes concern because the population, as well as the built environment, is often not equipped to manage them.

14. The frequency and intensity of floods may increase with changing climate conditions, and cause severe damage to rice production. Successions and combinations of droughts and floods have resulted in a significant number of fatalities and considerable economic losses. The 2000 floods were the worst to hit Cambodia in 70 years, while severe floods also occurred in 1996, 2001 and 2002. In 2000 for example, floods killed 362 people, most of them children. The cost of damage was US$157 million. In 2001, the floods killed 62 people and resulted in economic losses of about US$30 million, while in 2002, the Mekong River floods killed 29 people and caused over US$12 million in damage (Cambodian Red Cross, 2008). The 1984 and 2000 floods were due to increased water levels in the Mekong River, rather than heavy rainfall in Cambodia. In 2000 the flood continued through to mid October due to the occurrence of heavy rainfall in the west of the country. This flood reportedly destroyed the rice growing areas along the Mekong River and Mekong Basin (SNC Draft). Most recently, ADB unofficially estimates that the recent floods in 2011 have resulted in losses of $27 million for irrigation, $20 million for rural water supply (wells and ponds) and as much as $320 million for roads.

15. In Pursat province, severe flooding was recorded in 1996 and 2000 followed by severe drought in 2001 which caused damage to agricultural productivity in the province (SNC, Draft). Drought periods, lasting over one month in duration, have been observed by local officials more frequently in the middle of rainy season which starts in July or August. These episodes can lead to low yields or production losses in the absence of functioning irrigation schemes. Floods in Pursat are characterized by a combination of increased water level in Pursat River, run-off from the Cardamom Mountain range and the rising water level of the Tonle Sap Lake, which normally

[2] National Adaptation Programme of Action prepared by the Ministry of Environment

takes place in September and October. The most severe floods occur at the confluence of these events. Pursat town, which lies in the Tonle Sap floodplain and along the Pursat River, is most vulnerable to flooding, according to the Pursat PDWRAM, than areas upstream and floods in the town area can persist for over a month. Flooding in 2011 resulted in severe damage to over 17 thousand hectare of rice, and moderate damage to 23 thousand hectare of rice and 519 ha of cassava, mungbean and vegetables. Furthermore, the 2011 floods submerged over 10 km of rural road, affecting 13 thousand families, and loss of 10 human lives across Bakan, Kandeang and Krakor districts (NCDM, 2011). Though there is gauging station installed in Veal Veng District with automatic transfer of rainfall data to the central Department of Meteorology (DoM), real time information on rainfall is often not communicated to PDWRAM and local authorities, which limits the effectiveness of early flood warning activities.

16. Communities and assets in close proximity to the Tonle Sap and Mekong River flood-plains are more exposed to hazards across by proximity and due to population concentrations (SNC, Draft).

2. Climate Change Impacts in Pursat Province

17. Section (a) presents a discussion on the anticipated climate change impact on each phenomena that will influence flooding and water availability in Pursat Province; section (b) discusses how they impact the proposed subproject and how the project design is increasing climate resilience.

a. Climate Change Projections in the Pursat Subproject Area

18. **Temperature.** The UNDP report suggests that Cambodia's temperature is expected to increase on average 0.3°C to 0.6°C by 2025 and 0.7°C to 2.7°C by the 2060s. In low-altitude areas of central Cambodia where the project is located, temperature increase is predicted to be high with a rate of 0.036°C per year. Therefore, the present study assumes the changes shown in Table 1.

Table 1: Projected Climate Change Impact on Temperatures

Season	Temperatures (°C)	
	Observed Mean[a]	Projected Climate Change
December to February	24.9	28.0
March to May	27.8	31.0
June to August	26.7	29.1
September to November	25.7	28.4
Annual	26.3	29.0

[a] 1970-99

Source: McSweeney et al, 2008, UNDP Climate Change Country Profiles: Cambodia; ADB PPCR study team, 2012

19. **Water Availability.** The UNDP projections suggest that, under the high emissions scenario, the rainy season will start later, wet season rainfall will increase (bringing more flooding), and dry season rainfall will decrease. Under a low emissions scenario, the probability is lower but the trends are similar. The average rainfall in Cambodia is expected to increase, but the magnitude of change is uncertain. Estimates of the annual increase until the 2060s vary from as little as 7% to as much as 17%, with the most significant increase in the wet season: (i) June to August: 7% to +20%, and; (ii) September to November: 8 to +27%. In contrast, water flows in the dry season are predicted to decrease with decreases from December to February of 51% to +29%. Table 2 shows the projected climate change impact for seasonal rainfall from the UNDP report and highlights those values used for the present study. These are the extreme

cases: (i) for the dry seasons the minimum value is expected to occur; and, (ii) for the wet seasons the maximum value is expected. In summary, by the 2060s it is estimated for the period: (i) December to February there will be a 51% decrease in total rainfall; (ii) March to May there will be a 38% decrease in total rainfall; (iii) June to August there will be a 20% increase in total rainfall; and, (iv) September to November there will be a 27% increase in total rainfall. The present study assumes that the projected changes to the seasonal rainfall volumes will be directly linear to the runoff volumes, meaning that a 51% decrease in rainfall volume will result in a 51% decrease in stream flows.

Table 2: Projected Change in Seasonal Rainfall (%)

Period	Scenario	Projected Change in Seasonal Rainfall (%)		
		Minimum	Medium	Maximum
Annual	A2	-7	1	14
	A1B	-6	3	17
	B1	-2	2	11
December to February	A2	-38	-7	22
	A1B	-45	-9	29
	B1	-51[a]	-6	22
March to May	A2	-24	-6	11
	A1B	-32	-10	12
	B1	-38[a]	-7	31
June to August	A2	-7	7	19
	A1B	-19	5	20[a]
	B1	-4	5	17
September to November	A2	-8	5	16
	A1B	2	7	27[a]
	B1	-7	5	17

[a] Selected values
Source: McSweeney et al, 2008, UNDP Climate Change Country Profiles: Cambodia

20. **Extreme Rainfall and Floods.** A detailed analysis for the Tonle Sap region by the UNDP report suggests that, under a high emissions scenario, rainfall will increase with greater variability and extreme weather events are likely to become more frequent. During the wet season (June to November), when all historic maximum flood events have been observed, Table 2.3 shows that for all development scenarios there are projected increases in the magnitudes of the 1-day and 5-day rainfall depths (Table 3). Specifically, Table 3 shows a maximum increase of about 30% for both the 1-day and 5-day rainfalls except for the 1-day September to November period where much higher increases are expected. The present study considers high value as an outlier and assumes a broad 30% increase for 1-day and 5-day rainfalls[3]. As for seasonal runoff, it is also assumed by the present study that the rainfall-runoff relationship is linear, meaning a 30% increase in rainfall intensity will result in a 30% increase in flood flows.

[3]The present study treats the 38% to 47% increases shown for the 1-day September to November period as outliers to avoid significantly increasing the cost hydraulic structures. The structures are designed using these values. The general engineering design method includes provision for additional capacity (freeboard) to account for, amongst other uncertainties, this variability within climate projections.

Table 3: Projected Climate Change on Extreme Rainfall (%)

Period	Scenario	Projected Climate Change on Extreme Rainfall (%) Minimum	Medium	Maximum
Maximum 1-day Rainfall				
June to August	A2	-	5.0	19.8
	A1B	-	9.9	28.1
	B1	-1.7	1.7	11.6
September to November	A2	-	1.8	46.9
	A1B	-1.8	7.2	37.9
	B1	-16.2	5.4	45.1
Maximum 5-day Rainfall				
June to August	A2	-0.8	12.4	19.9
	A1B	-	8.3	29.8
	B1	-	5.8	9.9
September to November	A2	-	6.3	29.0
	A1B	-	11.8	22.6
	B1	-14.5	0.9	29.0

Source: McSweeney et al, 2008, UNDP Climate Change Country Profiles: Cambodia

21. The flood mechanism that affects the town of Pursat is a combination of extreme flow in the Pursat River and the downstream water levels of the Tonle Sap (which is directly influenced by water levels in the Mekong River). By extension of the general climate change projections for the region, the wet season water level in the Tonle Sap is likely to increase and as a result the seasonally flooded area and the height of the river flood peak will increase. The 2010 study "Modeling climate change impacts on the flood pulse in the Lower Mekong floodplains"[4] indicates that by 2050 the average water levels in the Tonle Sap may increase by 0.2m and peak water levels may increase by up to 0.3m. Furthermore, the 2010 study estimated flood durations to be 9% longer under anticipated climate change conditions and therefore the probability of coincidence with river floods is likely to increase. However, the 2010 study also considers the development of water infrastructure along the Mekong River and its impact on reducing downstream flood impact under climate change conditions. It concludes that while the two phenomena may balance each other, further detailed studies are required.

22. The combined flood mechanism described above is generally restricted to areas downstream of National Highway No.5. The flooding that occurs upstream of the highway is mainly caused by extreme flow within the Pursat River. To what extent the Tonle Sap water levels influence the Pursat River water levels should be considered in a later study that focuses on flood management for Pursat Town.

23. **Other Climate Parameters.** The present study uses the values provided by the United Nations Food and Agriculture Organisation's (FAO's) CLIMWAT database which is based on observations at Siem Reap and Battambang, the closest FAO stations.

[4] Vastila et al, 2010, Modeling climate change impacts on the flood pulse in the Lower Mekong floodplains, Journal of Water and Climate Change.

b. Anticipated Climate Change Impact on the Project Investment

24. To assess the impact of anticipated climate change on the DCIS, the present study incorporates the projections described in the preceding section on the current climate conditions experienced in the project area, namely rainfall and stream flow. Observed hydro-meteorological information on which to base the current climate conditions is limited analytical work undertaken by the present study relies on an amalgamation of the following sources:

(i) "Feasibility Study of Pursat Multipurpose Dam" (April 2010) prepared by K-water for MOWRAM.

(ii) "Stung Pursat No.1 Hydroelectric Project Pre-feasibility Report" (September 2010) prepared by Korea Hydro and Nuclear Power Co. Ltd et al for Ministry of Industry, Mines and Energy.

(iii) "Tonle Sap Lowland Stabilisation Project Report on Water Availability" (2006) prepared by GFA Consulting Group for ADB TA 4756-CAM: Tonle Sap Lowland Stabilisation Project.

(iv) "Feasibility Study of Rehabilitation of Dhamnak Chheukrom Irrigation Project in Pursat Province" prepared by Vision RI for ADB under TA 6456-REG: Preparing the Greater Mekong Sub Region Flood and Drought Risk Management and Mitigation Project – Cambodia.

(v) Daily hydrological records (water level and flow) for the Pursat River at Bac Trakoun Station (Station 580103) for the period September 1994 to September 2010, with intermittent gaps.

(vi) Daily rainfall records for Pursat (Station 120302) for the period January 2002 to December 2011, with intermittent gaps.

(vii) Daily rainfall records for Talo (Station 120309) for the period June 1999 to October 2010, with intermittent gaps.

25. In Pursat province, the structural subproject comprises upgrading flood and drought risk infrastructure and management through rehabilitation of the Dhamnak Chheukrom Irrigation Scheme (DCIS). Development of the DCIS began in the 1970s under the Khmer Rouge regime however never it functioned successfully. The DCIS headworks are located 40km upstream of Pursat Town on the Pursat River, Pursat Province. The 23,100ha gross project area is bounded by: the Pursat River and the Svay Donkeo Rivers in the east and west, respectively; and, by the Dhamnak Ampil Irrigation Scheme (DAIS) and Cardamom Mountain Range to the north and south, respectively. The net irrigable command area of the DCIS is 16,100ha.

26. The DCIS design uses the results of the UNDP Climate Change Country Profile – Cambodia [5] to quantify the anticipated climate change impact on each phenomena that will influence flooding and water availability, which may impact on the proposed DCIS. The specific projections estimated by the report are assessed for the 2060s horizon which is comparable to a 40- to 50-year design life of irrigation structures. This is appropriate for the concrete structures but is probably longer than required for the planning cycles of irrigation schemes (typically about 30 years) so values may be considered slightly conservative. For the present analysis, the worse-case values are used, however extreme outliers are excluded.

[5] McSweeney et al, 2008, UNDP Climate Change Country Profiles: Cambodia.

27. The DCIS subproject includes: (i) an upstream controlled and supply managed irrigation scheme to provide: (a) wet season supplementary irrigation for 16,100 ha of net command area in Pursat Province; and, (b) full irrigation to a smaller net command area during the dry season; (ii) a new headworks structure that will withdraw irrigation water from the Pursat River to the command area and facilitate peak flood diversion using the scheme's main canal, comprising of: (a) a new barrage located on the Pursat River about 40km upstream of Pursat Town that is designed to safely convey the 50-year flood under anticipated climate change conditions; and (b) an intake structure that can control river withdrawals for both command and flood diversion flows; (iii) construct a 30km main canal that will convey the peak flood diversion discharge of $40m^3/s$ from the Pursat River to the Svay Donkeo River, which comprises of: (a) rehabilitation of a 14km reach of an old non-functioning Khmer Rouge main canal; and (b) further construction of 16km of new main canal; (iv) construction of four new main canal cross regulator structures to control flows and water levels within the main canal for diversion of command flows into the secondary canals while allowing conveyance of the peak flood discharge of $40m^3/s$; (v) construction of a new outlet structure near the Svay Donkeo River; (vi) construction of four new secondary canals with a total length of 51.5km, including check structures and outlets to the tertiary system; (vi) construction of new tertiary and distribution canals, and new drainage systems; (vii) construction of canal cross-drainage and overflow structures along the main canal; and, (viii) construction of new road bridges along the main and secondary canals.

1. Flood Hydrology

28. For assessing flood hydrology, the present study has analyzed the daily flows observed for the Pursat River at Bac Trakoun Station[6] (Figure 2) using the EV1 method[7]. Flows at the barrage site, local catchments above the main canal, and for the Svay Donkeo[8] are then estimated based on catchment area ratios with that for the Bac Trakoun Station (Table 2.4). The EV1 results are shown in Figure 3 and Table 5[9] for both current and projected climate change conditions. The projected climate change values are based on increasing the annual maximum observed flows by the projected increase of 30% and then reapplying the EV1 analysis.

29. The mean annual flood at the Bac Trakoun Station is $855m^3/s$ and with anticipated climate change this is expected to increase to $1,110m^3/s$. Figure 2 shows that for years with available data at least one extreme event occurs in the Pursat River each year. The local government has undertaken riverbank training works through Pursat Town which they believe will protect the town against flows up to $1,000m^3/s$ (referred to as the threshold flow). Referring to Figure 1, flow in the river has exceeded this threshold four-, possibly five-[10], times since 1994. Therefore, a $1,000m^3/s$ flow is estimated to currently occur on average about four years.

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[6] Station 580103, Pursat River at Bac Trakoun Lat: 12.380, Long: 103.756; UTM: 365,176m East, 1,368,532m North. The station is located about 28km upstream of Pursat Town with no major inflows or abstractions between. Record period is 13 September 1994 – 30 September 2011 with significant gap from 1997 to 2001.

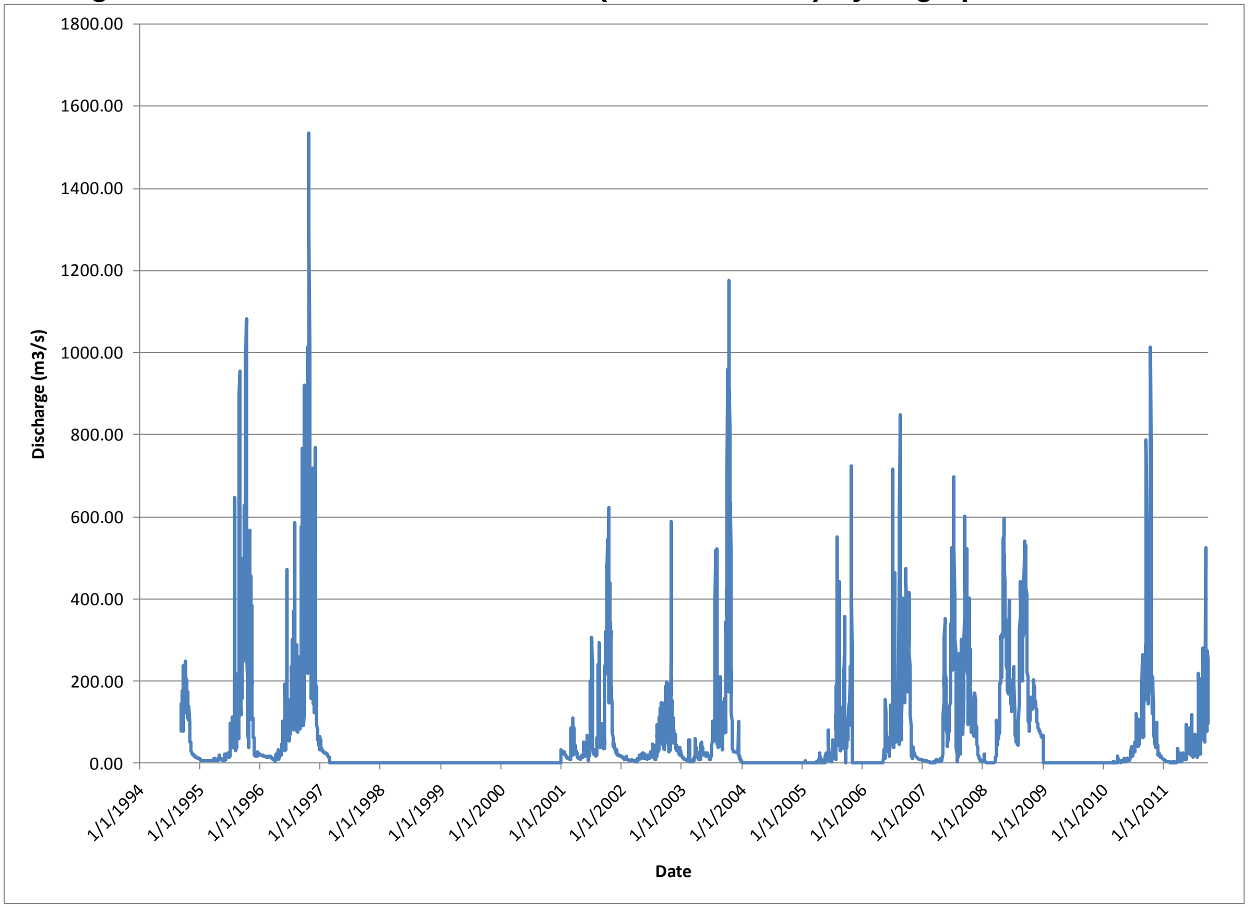
[7] Gumbel Extreme Value Type-1 (EV1) theory is used to model the distribution of extreme values under a normal statistical distribution and is used to estimate the values of unusually large events.

[8] The Svay Donkeo River has a water level monitoring station however it does not provide flow estimates.

[9] The results for current climate conditions are 10-20% more than those estimated by the PPTA study, possibly due to analysis of a longer record.

[10] The available record stops on 30 September 2011 and major flooding occurred in October 2011 so it is likely that flows again exceeded $1,000m^3/s$. There is also a significant gap in the record from 1997 to 2001 in which flooding could have exceeded $1,000m^3/s$.

Figure 1: Pursat River at Bac Trakoun (Station 580103) Hydrograph



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\- Source: MOWRAM, 2012

\- **Table 4: Catchment Areas and Ratios**

Location	Catchment Area (km^2)	Ratio to Bac Trakoun
Bac Trakoun	4,164	1.00
Pursat River Barrage	2,168	0.52
Svay Don Keo at Ampil Weir	285	0.07
Svay Don Keo at Anlong Svey Weir	488	0.12

Source: ADB, 2012

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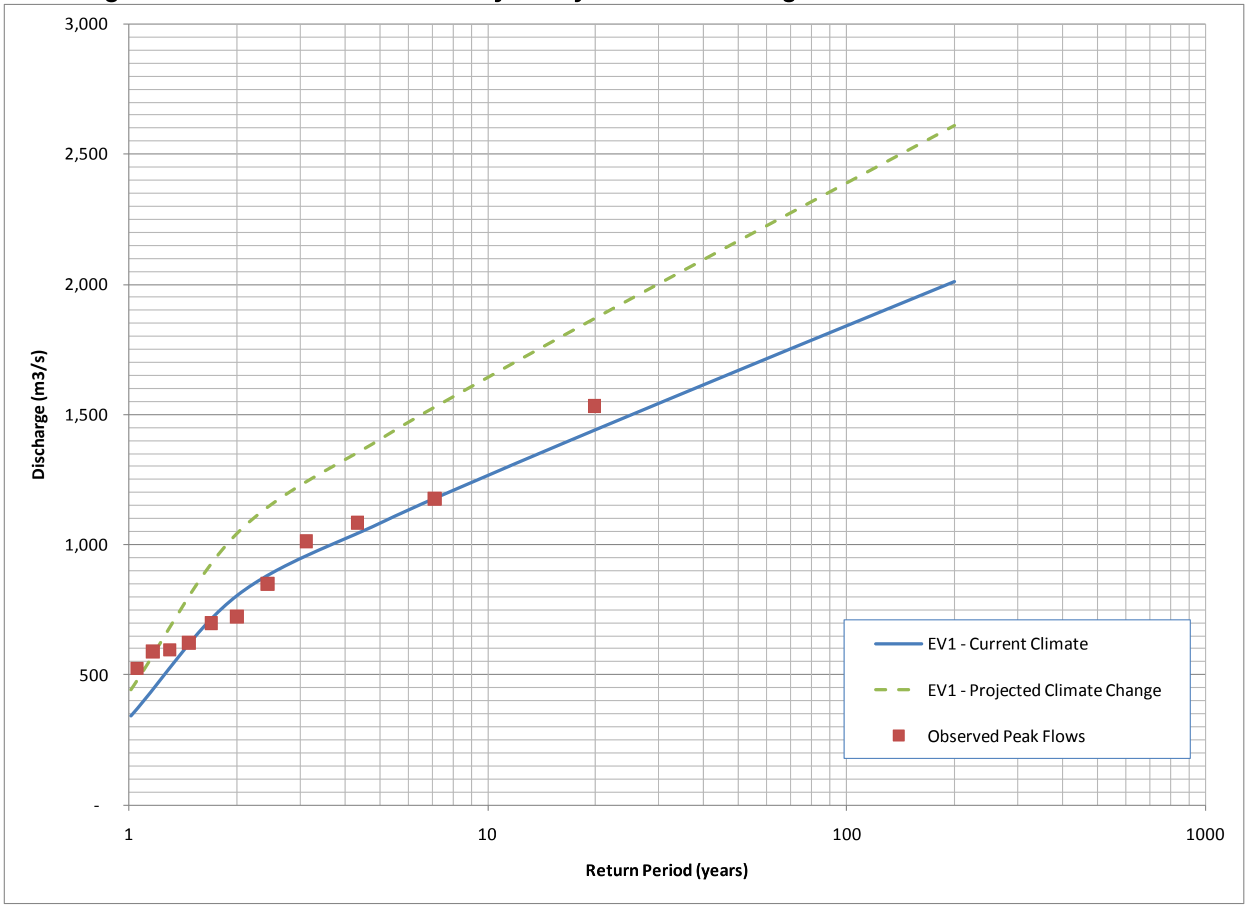
Table 5: Design Discharges

Return Period (years)	Design Discharge (m^3/s) Bac Trakoun	Barrage	Dhamnak Ampil[c]	Anlong Svay[c]
Current Climate Conditions				
2[a]	804	418	55	40
5	1,081	563	74	94
10	1,264	658	87	127
20	1,440	750	99	148
50[b]	1,668[b]	869[b]	114[b]	169[b]
100	1,839	957	126	195
200	2,009	1,046	138	215
Projected Climate Change Conditions				
2[a]	1,045	544	72	122
5	1,405	732	96	164
10	1,644	856	113	192
20	1,872	975	128	219
50[b]	2,169[b]	1,129[b]	149[b]	254[b]
100	2,391	1,245	164	280
200	2,612	1,360	179	306

[a] an anomaly of extreme statistical analyses is that the 2-year flood is slightly less than the mean annual flood which generally approximates a statistical 2.33-year return period; [b] Design flood event values; [c] on the Svay Donkeo River

Source: ADB PPCR study team, 2012

Figure 2: EV1 Extreme Probability Analyses for Discharges at Bak Trakoun Station



Source: ADB PPCR study team, 2012

30. The difference in discharge magnitudes between the two scenarios shown in Figure 2 reflects the 30% increase in extreme rainfall owing to climate change. The impact on flood risk[11] that climate change will have on flooded areas is also based on the flood's recurrence frequency which is shown on Figure 2's abscissa (return period). For example using Figure 2, a discharge of 1,000m^3/s is currently assessed to occur on average about every three to four years. Under anticipated climate change conditions this discharge is likely to occur more than once per year. Assuming flood damages remain unchanged between the current and future conditions, flood risk associated with 1,000m^3/s therefore will more than quadruple.

31. A component of the DCIS is that it will divert peak flood flows from the Pursat River to the Svay Donkeo River. The economic analysis of potential flood protection benefits on the area downstream of the diversion is based on flood impact data resulting from the October 2011 flood event. Unfortunately the peak discharge for this event observed at the Bac Trakoun Station is currently not available. So the daily rainfall at the Pursat Station is analysed (Table 6) which shows the 2011 maximum flood event highlighted and suggests that the event was about a 10-year event based on the total 1 to 3 day total rainfall volumes.

Table 6: Statistical Analysis of Rainfall at Pursat Station (120302)

	Moving Daily Rainfall Totals (mm)							
	Daily	**2-day**	**3-day**	**5-day**	**7-day**	**10-day**	**14-day**	**Annual**
2002	83.6	135.6	156.8	166.6	166.6	185.4	191.6	1408.9
2003	109.8	184.8	198.2	215	267.4	312.8	316.0	1582.6
2004	58.9	81.4	94.1	131.7	140.4	156.6	206.9	1174.2
2005	76.4	84.5	98.4	114.1	155.6	174.2	232.4	1323.8
2006	80.1	85.3	87.7	102.1	119.1	169.2	181.2	1393.3
2007	70.2	81.2	88.5	108.1	175.1	193.7	216.4	1495.5
2008	77.2	118.0	119.7	178.6	192.8	241.2	282.3	1962.2
2009	64.8	68.9	99.3	111.9	135.4	149.4	182.5	1155.8
2010	57.0	86.0	101.2	114.8	127.5	152.1	183.1	1430.3
2011	71.7	125.7	190.7	246.9	262.6	285.6	366.5	1599.4
mean	75.0	105.1	123.5	149.0	174.3	202.0	235.9	1,452.6
Max	109.8	184.8	198.2	246.9	267.4	312.8	366.5	1962.2
Return Periods								
1	50	46	54	66	88	107	130	1,070
2	72[a]	99[a]	116	141	166	192	225	1,414
5	86	131[a]	154	185	212	244	282	1,620
10	95	152	179[a]	215	243[a]	278[a]	320	1,756
20	103	172	203[a]	243[a]	273[a]	310[a]	356[a]	1,887
50	114	198	234	280[a]	311	352	403[a]	2,056
100	122	217	257	308	340	384	438	2,183
200	130	237	280	335	369	416	473	2,310

[a] 2011 flood event
Source: ADB PPCR study team, 2012

[11] Flood risk is assessed as the damage cost of an event multiplied by the events recurrence frequency.

2. Available and Effective Rainfall

32. Mean monthly available rainfall over the project area is taken from observations at the Talo Station (120309) which is located in the project area and shown in Table 7[12]. Also shown is the anticipated climate change impact and the resulting projected future rainfall. The effective rainfall is later calculated using the United States Bureau of Reclamation's (USBR's) method within the FAO's CROPWAT software.

Table 7: Projected Climate Change Impact on Monthly Rainfall

	Mean Monthly Rainfall (mm)		
	Current Climate Conditions	Climate Change Impact	Projected Climate Change Conditions
January	6.5	-51%	3.2
February	14.0	-51%	6.9
March	45.3	-38%	28.1
April	76.9	-38%	47.7
May	127.1	-38%	78.8
June	128.1	20%	153.7
July	141.8	20%	170.2
August	170.3	20%	204.4
September	193.3	27%	245.5
October	190.7	27%	242.2
November	80.2	27%	101.9
December	7.5	-51%	3.7

Source: ADB PPCR study team, 2012; GFA Consulting Group, 2006, Tonle Sap Lowland Stabilization Project Report on Water Availability, prepared for ADB TA 4756-CAM: Tonle Sap Lowland Stabilization Project.

33. The DCIS will supplement water supply for wet season irrigation to areas that currently rely on rain-fed irrigation only and suffers from intermittent dry periods during the critical vegetative growth stage. Transplanting for the wet and late season crops typically occurs in mid-July and Table 8 shows that, for each year of available record, during July and August there is a high occurrence of dry periods during the vegetative crop stage. Dry periods are shown to range from one day to more than five days. For the entire command area during the wet season, the DCIS will use Pursat River water to reduce water stress on the crops by guaranteeing water availability during critical growth stages.

Table 8: Incidence of Dry Periods at Start of Wet Season Crop

	Number of Days											
	1999	2000	2001	2002	2003	2004	2005	2006	2008	2009	2010	Mean
With Rain	19	18	19	21	17	29	19	32	18	14	26	21
Without Rain:												
1 day	3	1	6	5	3	6	2	9	0	1	5	4
2 days	3	1	3	2	2	9	6	3	2	2	3	3
3 days	2	2	-	-	1	3	2	5	2	1	5	2
4 days	1	-	-	4	1	-	-	-	2	-	1	1
5 days	1	-	1	-	1	-	1	-	-	1	-	-
> 5 days	2	3	3	2	3	-	3	-	4	4	1	2
Total	12	7	13	13	11	18	14	17	10	9	15	13

Source: ADB PPCR study team, 2012; Talo Rainfall Station 120309

[12] "Tonle Sap Lowland Stabilization Project Report on Water Availability" (2006) prepared by GFA Consulting Group for ADB TA 4756-CAM: Tonle Sap Lowland Stabilization Project.

3. River Water Availability

34. Water availability for the DCIS is estimated for two main sources: (i) the water available in the Pursat River at the Pursat River Barrage; and, (ii) runoff from local catchments above the main canal which have a combined catchment area of 186km^2. For the Pursat River Barrage the water availability is estimated from flows observed at the Bac Trakoun Station with the catchment ratio applied (from Table 4). Mean monthly discharges are shown in Table 10 along with the estimated reliable flows for: (i) dry year flows which are likely to occur on average every four out of five years (20% probability); (ii) median years when flow is available for one out of two years (50% probability); and, (iii) wet years when flows are available only one out of five years (80% probability).

35. Water availability for servicing the DCIS is calculated by subtracting from the Pursat River flow a residual environmental flow which will pass through the barrage to support the downstream environment (also shown in Table 9). This residual flow is estimated using the method used for the DAIS which estimates the environmental flow based on a specific yield of 0.1m^3/s/100km^2 of catchment area. For the Dhamnak Chheukrom Barrage this equates about 2.2m^3/s[13].

36. The water availability from the local catchments is calculated using an alternative method because the catchments are located in a rain-shadow area caused by the Cardamom Mountains. The present study uses rainfall data provided by the K-water report[14] for a previously conceived but not developed unnamed dam site located on the Pursat River but within the shadow area of the Cardamom Mountains. The water availability is estimated using the following methodology:

- (i) Step 1: The rainfall data for the unnamed dam site is analyzed to acquire the dry-year and wet-year reliable rainfall ratios.
- (ii) Step 2: The mean monthly specific discharges (l/s/km^2) for the Bac Trakoun Station are provided in the Tonle Sap Lowland Stabilization report[15] and are applied to the local catchment areas to estimate the mean monthly discharges.
- (iii) Step 3: The dry-year and wet-year reliable ratios derived in Step (1) are applied to the mean monthly discharges derived in Step (2) to calculate the dry-year and wet-year reliable flows. The median-year flows are assumed to be similar to the mean flows.

37. The resulting local catchment reliable flows are shown in Table 10 along with the total availability for the project area for both current and projected climate change scenarios. As shown in the table, water availability is plentiful for the wet season only. For limited periods in the dry season (for example, 2001, 2007 and 2008) there is available water in the river that could be used for irrigation purposes, however planning its effective use without storage would be difficult.

[13] "Feasibility Study of Rehabilitation of Dhamnak Chheukrom Irrigation Project in Pursat Province" prepared by Vision RI for ADB under TA 6456-REG: Preparing the Greater Mekong Sub Region Flood and Drought Risk Management and Mitigation Project – Cambodia.

[14] K-water, 2010, Feasibility Study of Pursat Multipurpose Dam, prepared for MOWRAM. From discussions with MOWRAM this dam is unlikely to be developed. The period of rainfall data is 1999 to 2008.

[15] GFA Consulting Group, 2006, Tonle Sap Lowland Stabilization Project Report on Water Availability, prepared for ADB TA 4756-CAM: Tonle Sap Lowland Stabilization Project.

Table 9: Monthly, Reliable and Available Flows at the Dhamnak Chheukrom Barrage

						Mean Monthly Discharge (m^3/s)						
Year[a]	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1995	2.27	1.83	1.74	3.39	3.42	7.59	26.27	104.57	156.66	190.23	79.53	9.39
1996	8.50	6.74	5.04	5.64	20.35	63.21	86.78	71.51	162.34	304.57	159.68	74.90
1999	6.67	0.48	3.91	33.53	21.14	18.61	37.77	33.04	70.93	71.82	85.55	79.65
2001	11.69	4.77	29.43	7.12	9.59	21.50	36.00	42.32	49.34	150.76	32.76	9.10
2002	5.04	2.67	1.63	4.35	7.65	7.15	9.66	30.97	45.24	54.95	35.26	13.19
2003	4.53	9.44	6.07	8.90	12.95	6.96	57.83	48.31	59.60	223.12	18.64	10.13
2004	0.65	3.70	4.64	9.39	13.54	5.50	21.79	60.43	53.00	97.76	27.28	28.08
2006	4.67	47.50	8.88	17.51	25.74	27.51	68.33	87.05	127.07	87.02	10.10	3.43
2007	1.66	6.53	8.95	2.11	77.08	88.12	124.75	62.61	159.73	83.69	44.29	4.74
2008	10.88	25.80	8.51	83.19	170.00	95.12	53.18	121.11	179.78	64.03	71.47	35.82
2010	5.39[b]	10.06[b]	1.75	1.85	3.57	9.57	25.45	55.80	123.02	184.39	26.71	8.18
2011	2.76	1.21	2.58	4.21	15.91	25.19	17.08	59.40	81.01	137.49[b]	53.75[b]	25.15[b]
Min	0.65	0.48	1.63	1.85	3.42	5.50	9.66	30.97	45.24	54.95	10.10	3.43
Mean	5.39	10.06	6.93	15.10	31.75	31.34	47.07	64.76	105.64	137.49	53.75	25.15
Max	11.69	47.50	29.43	83.19	170.00	95.12	124.75	121.11	179.78	304.57	159.68	79.65
						Reliable Discharge						
Dry	2.37	2.00	1.91	3.55	8.04	7.24	22.52	43.52	54.32	74.19	26.82	8.37
Median	4.86	5.65	4.84	6.38	14.73	20.06	36.89	59.92	102.01	117.62	39.78	11.66
Wet	8.13	9.94	8.81	15.89	24.82	56.07	66.23	83.94	159.12	189.06	77.92	34.27
						Available Discharge						
Dry	0.20	-	-	1.39	5.87	5.07	20.35	41.35	52.15	72.03	24.66	6.20
Median	2.69	3.48	2.67	4.21	12.56	17.89	34.72	57.75	99.85	115.45	37.61	9.49
Wet	5.97	7.77	6.64	13.72	22.65	53.90	64.06	81.77	156.95	186.89	75.75	32.10

[a] data is not available for 1997, 1998, 2000 and 2005.
[b] data is not available and overall monthly averages are used to help with the analyses.
Source: ADB PPCR study team, 2012

Table 10: Water Availability for the Dhamnak Chheukrom Irrigation Scheme

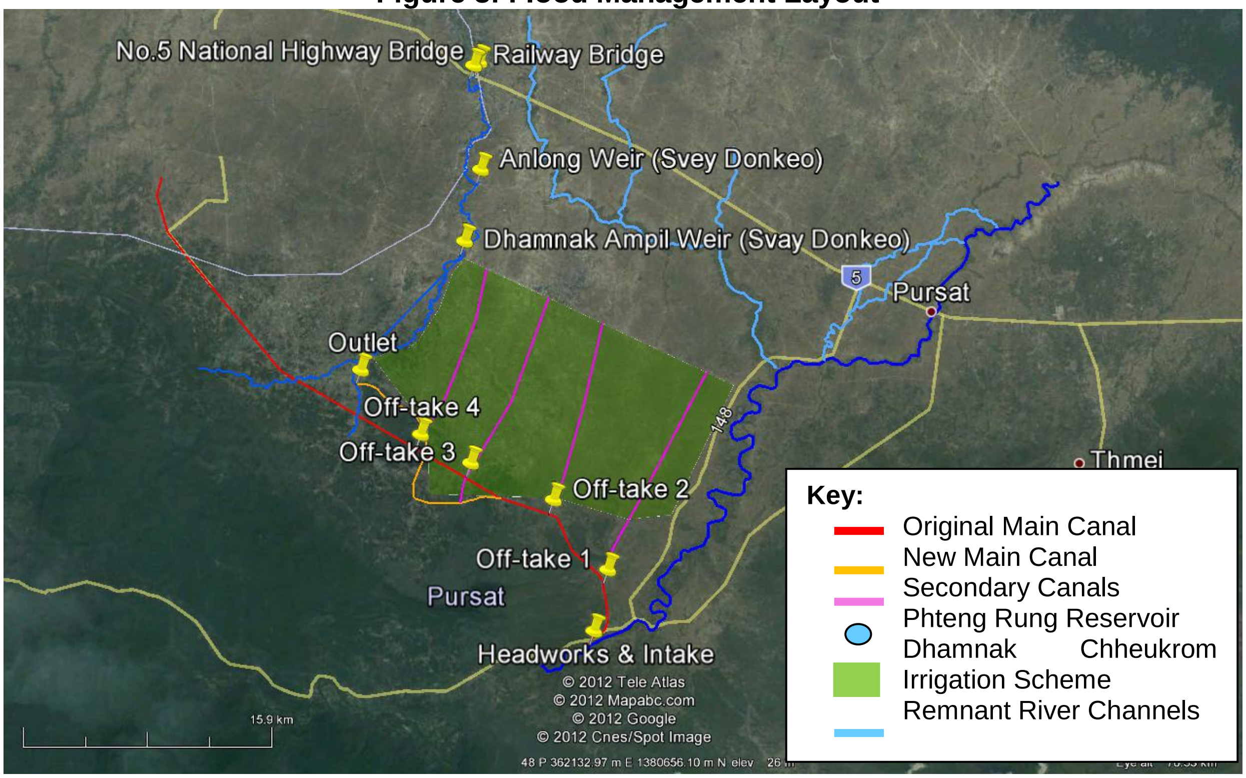
	Mean Monthly Discharge (m^3/s)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Local Catchment												
Dry	0.01	0.13	0.30	0.17	0.59	1.14	2.41	3.60	5.26	6.37	1.82	0.13
Median	0.56	0.36	0.55	0.35	0.70	1.46	3.26	4.94	7.11	12.79	4.71	1.59
Wet	1.01	0.65	0.77	0.61	0.89	1.74	3.87	5.91	8.65	17.75	6.07	2.33
Total Water Availability – Current Climate												
Dry	0.21	0	0.05	1.56	6.46	6.21	22.77	44.95	57.41	78.40	26.48	6.33
Median	3.25	3.84	3.22	4.57	13.26	19.35	37.97	62.68	106.96	128.24	42.32	11.08
Wet	6.97	8.42	7.40	14.33	23.54	55.65	67.93	87.68	165.59	204.64	81.82	34.44
Total Available Water Availability – Projected Climate Change												
Dry	-	-	-	0.14	3.18	7.88	27.75	54.37	73.49	100.15	34.21	1.99
Median	0.49	0.78	1.17	2.01	7.40	23.65	46.00	75.65	136.42	163.46	54.33	4.32
Wet	2.31	3.02	3.77	8.06	13.77	67.21	81.95	105.65	210.89	260.48	104.50	15.77

Source: ADB PPCR study team, 2012

c. Increasing Climate Resilience – Flood Measures

38. **DCIS barrage** Projected climate change will increase flood flows in the Pursat River. In order to maintain current design standards this will require the design capacity of the DCIS barrage to be increased. Under current climate conditions the 50-year design flow[16] at the barrage site is 870m^3/s (Table 5). With anticipated climate change the 50-year design flow will increase to 1,130m^3/s (Table 6). For the barrage to manage this 260m^3/s increase in design flow it requires additional flood gates. This additional capacity requires the barrage to use nine gates rather than six, increasing the size and cost of the structure by nearly 35%.

Figure 3: Flood Management Layout



Source: ADB PPCR study team, 2012; Google Earth

39. **Flood diversion using the DCIS main canal.** Pursat Town is located on the Pursat River about 40km downstream of the DCIS Barrage. The town and its surrounding area are routinely impacted by flooding from the Pursat River. The town has experienced flooding from the Pursat River at least five times in the past eighteen years. During floods the water levels in the river rise quickly and impact the riparian agricultural land, villages, infrastructure, and most significantly, Pursat Town. The local government has undertaken riverbank training works through the town which they believe will protect the town against flows up to 1,000m^3/s (referred to as the threshold flow).

40. To reduce the flood risk to Pursat Town and other riparian communities along the Pursat River downstream of the DCIS, the local government and MOWRAM identified using the DCIS Main Canal to divert peak flood flows from the Pursat River to the Svay Donkeo River with the intention to operate the diversion only when flows at Bac Trakoun exceed 960m^3/s thus

[16] Based on discussion with MOWRAM staff, irrigation and river structures are typically designed to safely convey the 50-year flood event.

reducing the frequency of floods exceeding the 1,000m^3/s threshold at Pursat Town[17]. The proposed flood diversion capacity of the main canal is 40m^3/s. Financial, economic and practical constraints do not allow this canal to convey larger flows.

41. The purpose of the proposed diversion is to reduce the frequency of flows exceeding the threshold event at Pursat Town from currently occurring on average every three to four years to occurring on average every four to five years. While this is only a minor reduction in frequency, it amounts to a 25% reduction in overall flood risk. Table 11 shows the benefits of the DCIS diversion to Pursat town.

Table 11: Reduction of Flood Risk from DCIS Diversion

	Return Period (years)	
	Current Climate	**Projected Climate Change**
Without DCIS Diversion	3 to 4	< Annually
With DCIS Diversion	4 to 5	~ Annually
Reduction in Flood Occurrence (%)	~25	~50

Source: PPCR preparation team, 2012

42. While peak flood diversion using the DCIS Main Canal will help Pursat Town with climate resilience it is clear from Table 11 that climate change will still adversely impact the town. Therefore the project will consider provision of flood resilient community infrastructure for use during flood periods including shelter, food and potable water provisions, and sanitation facilities, possibly under the CBDRM programme.

43. **Existing Svay Donkeo River Structures.** The DCIS Main Canal will divert peak flood flows from the Pursat River to the Svay Donkeo River up to a maximum discharge of 40m^3/s. On the Svay Donkeo River downstream of the DCIS main canal outlet, there are two existing irrigation weirs that would be impacted by the diversion flows: the Dhamnak Ampil Weir and the Anlong Weir. Also further downstream within the Svay Donkeo River environment are bridges for the national railway and the No.5 National Highway. However, these bridges are large structures with their soffit levels elevated well above the incised river and are unlikely to be affected by the additional of the proposed 40m^3/s flood diversion flow. This project proposes to increase the capacity of the two Svay Donkeo weirs to ensure they will be protected from the additional diversion flows. Because this project will impact on these weirs, their upgrade will include allowance for anticipated climate change impact on flood flows.

44. **Local Drainage in the DCIS.** Runoff from local catchments above the DCIS main canal and also within the project area will increase as a result of the anticipated climate change. The size of necessary drainage channels and structures (drainage inlets, canal overflow weirs and drainage outlets to the DAIS) will need to be sized appropriately. The increase in extreme rainfall owing to anticipated climate change is estimated to be 30%. Assuming a linear relationship between rainfall and runoff, the size and cost of the drainage channels is also expected to increase by 30%.

d. Increasing Climate Resilience – Maintaining Productive Command Areas

45. The impact of projected climate change will manifest as delayed onset of the wet season (and hence a shorter wet season) and drier dry seasons. Anticipated climate change will halve

[17] This proposed flood diversion scheme does not account for flows in the Stueng Peam which is a main tributary of the Pursat River and joins it about 4km downstream of the proposed barrage site but upstream of the Dhamnak Ampil Irrigation Scheme and the Bac Trakoun Station. There are two dams under construction on branches of the Stueng Peam which may also contribution to flood attenuation at Pursat Town.

dry-season water availability from the current climate conditions. There are primarily two solutions available to adapt to this impact: (i) utilize the abundant runoff and non-consumed flow during the wet season by providing bulk storage for use in both the dry season and also to bridge the intermittent wet-season droughts; and, (ii) reduce the gross water demand.

46. The Project proposes to retain excess wet season runoff and store it in reservoirs for supplementing water availability for dry season crops. Options for providing bulk storage are:

(a) **Phtenh Rung Reservoir.** Located within the project area near the main canal and Secondary Canal No.1 is the Phtenh Rung Reservoir which is currently used to irrigate a small area downstream during the dry season.[18] Most inflow to the reservoir is from its small local catchment of about 840ha.[19] The current capacity of the reservoir is estimated to be about 1.8 million m^3 with a reservoir surface area of about 240ha[20] and elevation of 25mAD[21]. The surveyed elevation of its outlet's invert is about 24mAD and its top of embankment is about 27.4mAD. The reservoir discharges into a modified natural watercourse from which the farmers use hand-tractor pumps to lift the water to their fields. Outflows from the reservoir are controlled through manual operation of the outlet sluice gate. There is potential to directly connect and integrate the reservoir to the DCIS Main Canal to supplement inflows to the reservoir via gravity.[22]

(b) **Traditional Field Reservoirs.** Small distributed field reservoirs which are a local traditional water management system will be developed. They comprise of excavated and impounded ponds that trap and store rainfall-runoff for use during the dry season. They are also used to avoid dry spells during the early stages of the wet season crops. Their size and location can be identified with participation of farmers during the detailed design of the scheme. They can be both centralised and distributed throughout the tertiary and distribution system based on the needs of the local communities and Farmer Water User Groups (FWUGs).[23] With confirmed supply scheduling to the tertiary system by the Scheme Operator, the farmers can manage the reservoirs in consideration of their irrigation requirements: they can fill the reservoirs from the tertiary and distribution canals when they're not irrigating and then use the stored water for irrigation on-demand by using either the gravity-fed tertiary and distribution system or using hand tractor pumps. The reservoirs can also be used for diurnal flow balancing and aquaculture.

e. Increasing Climate Resilience – Improved Water Demand Management

47. Reducing water demand is also an effective measure to improve and maintain the scheme's productivity by: (i) increasing dry season command areas; and, (ii) maintaining climate change resilience. Reducing the net water requirement independent of climate conditions will require diversifying rice varieties and crop types.

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[18] In the last few years PDWRAM has carried out some rehabilitation works on the reservoir including strengthening its embankment and rehabilitating the outlet structure.
[19] Some runoff from the hill catchments located to the southwest of the reservoir may ultimately discharge into the reservoir however based on field visits and review of available topographical information, the present study believes that runoff will mostly be diverted around the reservoir by the old Khmer Rouge main canal.
[20] Measured from Google Earth
[21] From topographical survey results
[22] With the proposed new full supply level at the intake of 27mAD.
[23] FWUGs are subgroups of the apex Farmer Water User Community (FWUC).

48. Reducing the gross water requirement will require an improvement in the scheme irrigation efficiency ratio[24] which is currently assumed to be 50%.[25] The scheme irrigation efficiency ratio comprises of the: (i) conveyance efficiency which represents the efficiency of water conveyed by the canal system; (ii) field application efficiency which represents the efficiency of water application on the field; and, (iii) management efficiency which accounts for management losses incurred through spillage, wastage, incorrect allowance for response time, and incorrect gate operation in the canal system.

49. A scheme efficiency of 50% to 60% is considered to be good by the Food and Agriculture Organization (FAO).[26] Achieving and maintaining it under climate change conditions will require the scheme to be well operated and maintained. This will only be possible with: (i) good design of the scheme; (ii) capacity development of the Scheme Operator and the Farmer Water User Community (FWUC); (iii) use of effective and appropriate flow monitoring and gate control systems; and (iv) sufficient human and financial resources to support operating and maintenance activities. Improving the scheme irrigation efficiency will help counterbalance the impacts of anticipated climate change. It will translate to additional command area under both under current and future climate conditions. The following sections consider each of the three components of the scheme irrigation efficiency to assess whether improvements are possible.

50. Issues and possible climate resilient measures to be considered for the DCIS for conveyance, field application and management efficiencies are shown in Tables 12 to 15.

Table 12: Conveyance Efficiency

Issue	Climate Resilient Measures
Seepage	
Water will seep through unlined canal beds and walls. The total amount of water lost will depend on the wetted perimeter and length of the canals. The soils in the project area are Gleyic Acrisols with a silty-clay texture and have a low permeability. Seepage rates are likely to be less than 10mm/day and for the DCIS, with a total length of main and secondary canals of about 80km, the loss to seepage will be about 160l/s.	Seepage can be reduced if the canals are lined with concrete or another suitable material. Where topography allows, low pressure pipelines can be considered for the tertiary and distribution areas. Conjunctive use of groundwater is not practiced in the area so will not be impacted by reducing seepage. However, if lining and pipes are not used, conjunctive use could be considered and trialled to recover some of the seepage water. Tube-wells can be installed in the tail-end areas of the scheme and linked to the tertiary and distribution system.
Leakage	
Leakage of water can occur through: (i) poorly maintained gates and structures; (ii) animal holes within embankments (for example rats); and (iii) deliberate damage by people, typically upstream farmers wanting unscheduled access to canal water.	Ensure effective management and maintenance by the Scheme Operator and FWUC. Participatory design of the scheme with the farmers to avoid conflict. Establishment of an effective FWUC that will educate their farmers to monitor the condition of the DCIS infrastructure, report issues, prevent deliberate damage, and resolve disputes between farmers.

[24] The ratio of the diverted water for the irrigation which is effectively used by the plants.
[25] Recommended by MOWRAM engineers
[26] The FAO considers a 40% scheme efficiency to be reasonable and anything less than 30% to be poor.

Absorption	
An unlined canal in clay soil will absorb water every time the canal is flooded after a period of drying out. This is effectively dead storage (see below) which has to be replenished before water can flow any further along the canal.	Provide canal lining in the main, secondary and tertiary canals, and low pressure pipes in the appropriate tertiary and distribution canals. Effective operation by filling the canals quickly which is best achieved from the tail-end upwards. This is achieved by ensuring outlets are kept closed until the canals are filled and by using under sluice gates for cross regulators and check structures, as proposed for the DCIS.
Dead storage	
Dead storage is water that cannot be utilized in reservoirs and canals. When the canal is not being used, the dead storage is lost to seepage and evaporation. Furthermore when the canal becomes operational, filling the dead storage slows the response time of the canals (refer to Table 3.5) which impacts delivery schedules. Unlined canals generally have more dead storage because they have a larger cross-sectional area compared to lined canals owing to their higher roughness and lower velocities.	For the DCIS most dead storage will be in the main canal since its capacity is sized for flood diversion rather than irrigation. Lining would help reduce the canal's sectional area by two-thirds while maintaining its flood diversion capacity. Designing the main canal off-takes to be able to draw water from the invert of the main canal immediately upstream of the cross-regulators. Optimizing the water delivery schedule to minimize filling and emptying of dead storage areas.
Evapotranspiration	
Generally evaporation rates from flowing canals are low however they do increase when the canal water is impounded, for example when the main canal operates as high-level canal which for the DCIS will occur during normal irrigation operations. With an average observed evaporation rates in Pursat of about 4mm/day this amounts to an evaporation loss of about 40l/s along the main canal. Evaporation will also affect the proposed reservoirs. Evapotranspiration rates owing to the presence of pervasive water plants in the canals and reservoirs are double that of clear water evaporation rates.	Apart from minimizing dead storage there are no practical options to reduce evaporation from the canals and reservoirs. Effective management and removal of water plants will have significant benefits to reducing evapotranspiration losses (see Blockage from Plant Growth).[27]
Blockages from Plants	
Pervasive water plants such as water hyacinth can block canals and control structures. This reduces response times of the canals and disrupts and even prevents delivery of water to tail-end areas. Furthermore, they reduce storage volume in the high-level canal and reservoirs. Blockages can also cause flooding.	Prevent the establishment and spread of the plants through biological (insects and fungi) and physical (labour, dredging, etc) mechanisms. Water hyacinth can have productive uses such as: paper, fibre board, charcoal briquetting, biogas, animal fodder, fertilizer and fish feed. The FWUC could be mobilized to establish these industries as an alternative income stream which would incentivize the plant's harvest and reduce its management cost.

Source: ADB PPCR study team, 2012

[27] Removal of the plants also helps prevent mosquitoes and snails from inhabiting the water thereby helping prevent diseases (malaria and schistosomiasis).

Table 13: Field Application Efficiency

Issue	Climate Resilient Measures
Excessive Non-consumed Water Irrigation water can be significantly wasted by poor field practices when farmers: (i) use more water than they need and spill the excess non-consumed water into the drainage system, (ii) turnout inflow directly to the drainage system when not irrigating their field; and, (iii) use additional water to control weeds growing within their crop.	Non-consumed water that either seeps into the ground or discharges into the drainage system is recoverable through: (i) conjunctive use; and (ii) designing the system to reuse drainage flows. For the DCIS, ultimately all drainage flow is recoverable as it will discharge into the main canal of the DAIS.

Source: ADB PPCR study team, 2012

Table 14: Management Efficiency

Issue	Climate Resilient Measures
Gate Operation Poor operation of the canal system is typically responsible for a significant amount of localized water wastage and reduced supply to the fields. For example, gates and regulators left open when they should be closed will waste a lot of water and gates insufficiently opened during canal filling will reduce canal response times.	Ensure the Scheme Operator has sufficient resources and capacity to monitor and operate the scheme effectively, including: (i) staff resources; (ii) vehicles to allow regular visits to control structures; (iii) budget to fund staff and vehicles; and, (iv) flow measurement at key locations so operators can monitor the scheme effectively. The FWUC will be responsible for water management in the tertiary and distribution system. The same requirements apply to their organization however they are likely to require additional training and support as water management will be a new responsibility.
Canal Response Time The response time of the scheme is the time it takes to move water around the scheme, for example redirecting irrigation water from Secondary Canal No.1 to Secondary Canal No.2 following rotational supply schedules. Productivity in the scheme can slow down if the response time is long and it takes a number of days or even weeks before the full command flow reaches the new destination. Ineffective water management and delivery because of slow canal response times can impact on agreed delivery schedules causing: (i) crop stress; (ii) interrupted supply; and, (iii) conflict between farmers. Also, any water still running after it is needed may be wasted unless it can be stored or recovered.	Managing canal response times is both a conveyance and management issue. The response times can be kept optimal by: (i) good design of the canal system layout; (ii) using lined canals; (iii) using a piped system in the tertiary and distribution systems; (iv) conjunctive use of groundwater in the tail-end areas; (v) minimized inline dead storage; (vi) optimized rotational delivery schedules; (vii) effective gate management by the scheme operator and FWUC; (viii) flow monitoring to support effective management; and, (ix) effective scheme maintenance.
Deliberate Damage Deliberate damage to canals and structures is common and is normally caused by farmers and others to: (i) take unscheduled water; (ii) prevent downstream users from receiving water; and (iii) use materials elsewhere (for example clay lining and embankment material is used to make bricks, and materials from gate structures can be sold as scrap-metal and used for other purposes).	Occurrences of deliberate damage can be reduced or eliminated by: (i) design of the scheme and delivery schedules with participation with the FWUC and farmers; (ii) lining the canals with appropriate materials or replacing with a piped system; (iii) resolving conflicts using the FWUC; (iii) ensuring regular monitoring and maintenance by the scheme operator and FWUC.

Source: ADB PPCR study team, 2012

E. Summary of PPCR financed Climate Resilience Improvement Measures

51. From the above analyses, the climate resilience measures proposed for the project in Pursat area are both structural and non structural. A summary is presented below and the details in Appendix 2.

Table 15: Proposed Water Availability Climate Resilience Measures for the Structural Subproject

Climate Resilience Measures (adaptation to reduced water availability)
Flood Management: (i) Designing the DCIS Barrage and internal drainage system to account for projected climate conditions; (ii) designing the DCIS Main Canal to divert peak flood flows from the Pursat River to the Svay Donkeo River to help Pursat Town maintain its existing level of flood protection; and, (iii) upgrading the capacity of the existing Svay Donkeo Weirs to account for the DCIS flood diversion and anticipated climate change. **Increase Dry Season Water Availability:** (i) integrate the existing Phtenh Reservoir and strengthen/upgrade features where necessary; and (ii) construct new traditional field reservoirs and integrate existing reservoirs to the DCIS tertiary and distribution systems. **Water Demand Management:** (i) include modern flow monitoring systems into the DCIS system; in appropriate areas design and implement trial programmes of using: (i) low pressure pipelines in tertiary and distribution system to replace canals and flood-conveyance of irrigation water; (ii) drip irrigation in conjunction with crop diversification; and, (iii) conjunctive use of surface and groundwater in the tail-end areas of the DCIS if an aquifer exists and its conditions are appropriate. Participation (through FWUCs): (i) design and implement a new programme of training for the FWUC and farmers; (ii) training and support to the Scheme Operator to facilitate effective management of the overall scheme; and, (iii) training and support of the FWUC to effectively undertake their role as managers of the tertiary and distribution system; support the FWUC and farmers to diversify their crops (either rice or crop variety) to reduce their crop irrigation requirement for the dry and early-wet season crops.

Source: ADB PPCR study team, 2012.

52. The non structural components of the project which will contribute towards improving climate resilience are on:

(a) the local level : (i) support to the Farmer Water User Communities and (ii) support to community based disaster risk management;

(b) the national level : (i) improving national flood and drought forecasting, (ii) improved hydraulic design standards; (iii) improved project implementation.

1. Farmer Water User Communities

53. In 2000 Cambodia introduced Participatory Irrigation Management and Development (PIMD) to facilitate irrigation management transfer (IMT) to the farmers allowing them to take over management and responsibility of their irrigation schemes in order to reduce government capacity constraints and improve their livelihoods through increased crop production and income. For individual schemes the farmers are organised into a hierarchal Farmer Water User Community (FWUC) with an apex management body (committee of FWUC) and sub-management Farmer Water User Groups (FWUGs) generally delineated on the secondary and tertiary levels of the irrigation scheme. It is intended that the FWUC have responsibility to manage, repair and improve the schemes, manage delivery of water services, and resolve local conflicts. To fund their routine activities and undertake emergency repairs, the FWUC collect Irrigation Service Fees (ISFs) from their members (i.e. the farmers). The government ideally

ensures the schemes are functioning well[28] prior to handing over to the FWUC and should provide the FWUC with technical and financial support for the first five years of the PIMD programme.

54. The recent study "Mainstreaming of Actions in Support to FWUC under NWISP"[29] reviewed the formation and operation of FWUCs in twelve irrigation schemes developed by the North West Irrigation Sector Project (NWISP). It concluded the FWUCs require support with the following:

(i) Capacity development of the FWUCs is needed to support: (a) planning and budgeting for their activities; (b) practical implementation of accounting and financial management; (c) effective communication between the FWUC and farmers for water management, coordination of activities, and general management of the FWUC; (d) good water management; and, (e) planning and implementing routine maintenance.

(ii) Initial financial support to fund the FWUCs until they collect the first instalment of the ISF from the farmers which generally happens towards the end of the first crop season.

(iii) Provision of improved or rehabilitated irrigation infrastructure from the outset so that water demand schedules previously agreed with the farmers can be accurately met.

(iv) Empowerment to support their coordination with the scheme operators (PDWRAM) to facilitate management and decision making so water availability is ensured according to agreed water demand schedules.

2. Community Based Disaster Risk Management

55. The Project will assist communities to strengthen their preparedness for management of flood and drought events. This will include training of men, women and children to minimize their exposure to flood risks, including the associated health risks. For both flood and drought risks the communities will be assisted to develop community based disaster risk management plans. With respect to the Damnak Cheukrom Irrigation Project in Pursat the communities will be assisted to form farmer water user communities (FWUC) to manage the irrigation infrastructure and to be the anchor for community based flood and drought management. Community based disaster risk management will, to the extent possible, be integrated with the implementation of the upgrading of water management infrastructure in collaboration with the programs of the National Disaster Management Office (NDMO). This component will be implemented through NGOs, or similar entities to be recruited by the CPMU.

56. Activities will fall under three categories: (i) small-scale structural measures, including embankments and safety areas, rainwater harvesting and storage structures, provision of pumps for draining flood water, supporting vulnerable houses and development of evacuation routes and high ground areas, development of flood resilient dwellings, fresh water supply and sanitation facilities for community use during disasters, (ii) livelihoods diversification, including promotion of home gardening for income generation, trials for more appropriate drought resilient seed varieties for increased temperatures and changes to water availability, water use efficiency techniques, potentially including micro-credit, savings programs and raising awareness on alternative livelihoods; and (iii) social / organizational / capacity building, e.g. organizing

[28] Case studies show that this is critical for the success of IMT. For this project the scheme will be new and assuming it is well designed, this shouldn't be an issue.

[29] Brun, J., 2011, Mainstreaming of actions in support to FWUC under NWISP", prepared for Agence Francaise de Developpement.

community groups, training, and awareness raising of community members on disaster preparedness and early warning. A number of these activities follow from recommendations from ADB TA 4574: Community Self-Reliance and Flood Risk Reduction.

3. Improving national flood and drought forecasting

57. The overall objective is to assist DoM and DHWR to establish the National Flood Forecasting and Early Warning Center in Cambodia.

58. The scope of activities includes but not be limited to the following:

(i) Assess the hydro-meteorological network and data acquisition system required for flood forecasting and early warning in the major tributaries and to implement priority network and data acquisition improvement activities

(ii) Assess the current forecasting capacity and install necessary flood and drought forecasting tools (hydrological and hydraulic models, rainfall forecasting including regional storm tracking and satellite based rainfall estimates)

(iii) Develop and pilot a operational strategy for disseminating nationwide flood forecasting and early warning at the community level

(iv) Provide necessary trainings and capacity development for sustainable operation of the center including recommendations of the institutional setup within DoM and DHWR to operate the Center

4. Improving hydraulic design standards

59. The project will support MOWRAM and other agencies to have improved guidelines for climate resilient design of structure in the Mekong Delta and better capacity for cross border flood management. This work will include:

(i) risk assessment of impact of floods and droughts with different probabilities;

(ii) evaluation of residual risk under varying degrees of protection;

(iii) comparison of flood and drought hazards with the standards currently applied;

(iv) estimates of the cost of infrastructures related to flood and drought proofing for floods and droughts of different frequencies

(v) development of design criteria for structural flood and drought control in the Mekong area (and elsewhere) in Cambodia; and

(vi) provision of guidelines for climate resilient design of structures in the Mekong area (and elsewhere) of Cambodia.

5. Improved effective project implementation

60. The project implementation consultants (PIC) will support the CPMU and PIUs in technical areas of engineering design and construction supervision, as well as provide valuable quality assurance with respect to safeguard issues and sustainability of the subproject. International expertise will be provided in: (i) project management, (ii) technical engineering -

flood and drought management, including flood drainage and irrigation canal, river bank protection, embankments, mechanical structures (gates, sluices); (iii) economics; (iv) procurement and (v) social and environmental safeguards. National specialists will be required in similar technical areas to facilitate technology transfer from international specialists and to handle the project activities in the absence of the international consultants. National consultants will also support the community-based disaster risk management, mechanical engineering components, monitoring and evaluation activities under the supervision of the Team Leader.

61. PIC positions will be cofinanced by ADB loan ($0.9 million) and PPCR grant ($1.3 million) as follows:

Table 16: Project implementation consultants

	Location	Unit	Total
1. International Consultants (financing)			
a. Flood/Drought Risk Management Specialist / Team Leader (ADB)	PP	Months	**24**
b. River Engineer – Hydrologist (PPCR)	Pursat	Months	**3**
c. Civil/Irrigation Engineer (PPCR)	Pursat	Months	**12**
d. Environmental Specialist (PPCR)	Pursat	Months	**5**
e. Social Safeguards/ Resettlement Specialist (ADB)	Pursat	Months	**5**
Subtotal			**49**
2. National Consultants (financing)			
a. Water Resources – Flood and Drought Management Specialist (PPCR)[a]	PP	Months	**36**
b. River Engineer – Hydrologist (PPCR)	Pursat	Months	**6**
c. Civil – Irrigation Engineer (PPCR)	Pursat	Months	**24**
d. CBDRM /Gender Specialist (PPCR)	Pursat	Months	**12**
e. Structural Engineer (PPCR)	Pursat	Months	**3**
f. M&E specialist (PPCR)	PP	Months	**8**
g. Environmental Specialist (PPCR)	Pursat	Months	**7**
h. Social Safeguards Specialist (PPCR)	Pursat	Months	**8**
i. Procurement Specialist (PPCR)	PP	Months	**12**
j. Economist /Financial Spec, (PPCR)	PP	Months	**8**
Subtotal			**124**
Total			**173**

Notes: /a – Deputy Team leader
Source: Staff estimates

F. Cross cutting issues

1. Gender Mainstreaming

62. An Oxfam study[30] found that the impacts of drought were greater on women than on men. Men are responsible for earning income for the household, while women – in addition to their farming activities – carry out almost all of the essential domestic tasks such as cooking, buying food, washing clothes, and taking care of children and sick members of the family. These take considerable time and drudgery. In a drought year particularly, the stress is increased further as women have to fetch drinking water. Men and women share agricultural work.

63. The Project will involve women at various stages of the project cycle including project

[30] Drought Management Considerations for Climate Change Adaptation: Focus on the Mekong Region CAMBODIA. Oxfam Cambodia and Graduate School of Global Environmental Studies of Kyoto University, Japan.

design, construction, operation and management, and monitoring and evaluation. Opportunities to consider women's concerns range from participation of women in the consultation process, and an active role in community activities, particularly in community-based disaster risk reduction and management (CBDRM), and integrated water resources management. Women will be included in training activities for livelihood diversification such as the introduction of climate-resilient farming and irrigation practices, improved pest and disease management; and disaster risk management. The women will also take part in disseminating knowledge and information on early warning of floods and droughts.

64. The Project is classified as effective gender mainstreaming (EGM)[31]. The key gender impacts of the Project include increased women's engagement in (i) management of data and information on floods and droughts; (ii) in local level disaster risk management activities; and (iii) employment generated through civil works and other project related activities. The Project Gender Action Plan is shown below.

Table 16: Gender Action Plan

Project outputs	Gender design features/activities
1. Enhanced regional data, information and knowledge base for the management of floods and droughts	Actively identify and recruit qualified women staff" Ensure at least 2 women are trained on forecasting models and climate change Gender and community vulnerability issues will be assessed and addressed study on trans-boundary flood management.
2. Water Management Infrastructure upgraded	At least 40% of participants of technical training (flood and drought resilience farming, animal health, water and sanitation, wetland and water conservation, trafficking, domestic violence, agricultural production technique) and any other related training identified by stakeholders should be women. Provide equal opportunity and equal pay for equal work to both females and males for labour construction. Ensure at least 30% of unskilled labourers are women through condition of bid documents.
3. Community capacity for disaster risk management enhanced	Ensure at least 40% participants in all public consultations for the development of safer village and commune plans are women Schedule of CBDRM training for community should be conducted to fit the schedules of both men and women in the community schedule to ensure effective participation of both . Ensure CBDRM training materials are gender sensitive. At least 30% women be representative in Water User Group Committees Women in Project communes participate in the formulation,

[31] A project is assigned EGM if the project outcome is not gender equality or women's empowerment, but project outputs are designed to directly improve women's access to social services, and/or economic and financial resources and opportunities, and/or basic rural and urban infrastructure, and/or enhancing voices and rights, which contribute to gender equality and women's empowerment.

	implementation and training on CBDRM – a At least 40% of women in commune should participate in training event. At least 30% of CBDRM committee members are women Gender sensitive awareness material for CBDRM prepared (Gender sensitive materials for CBRM will be tested with communities ensuring they, especially women clearly understand)
4. Effective project management	Ensure qualified women are encouraged to apply for position in the project Strengthen capacity building of Existing Gender Focal Point at PDWRAM on gender issues in flood and drought, on implementation and monitoring Conduct a consultation workshop on the project Gender Action Plan to introduce and get feedback, on the gender actions with all project consultants, all government counterparts as well as project management team at national and provincial levels. Adjust GAP as required based on further gender analysis during implementation to ensure effective gender mainstreaming actions are implemented Provide capacity building on gender issues in Flood and Drought, how to mainstream gender in DRM to all consultants, government counterparts, and management levels Conduct regular meeting with gender focal points and GFP, and monitoring on the implementation of the project GAP by project gender consultant. Provide capacity building on monitoring, gender mainstreaming in DRM, gender issues in Flood and Drought to the gender counterparts by CBDRM/ Gender Specialist Ensure adequate funds available to implement GAP

MOE = Ministry of Environment, MOWA = Ministry of Women Affairs; MOWRAM = Ministry of Water Resources and Meteorology; PDWRAM = Provincial Director of Water Resources and Meteorology; CBDRM: Community Based Disaster Risk Management; CDD: Community Driven Development; GAP: Gender Action Plan.
Source: Staff assessments

2. Participation of Local Governments, Civil Society and the Private Sector

65. A Farmer Water User Committees (FWUC) consisting of several smaller Farmer Water User Groups (FWUG) is typically established at the scale of an irrigation scheme. A FWUC is constituted of farmers with farm land in the irrigation command area who pay fees to support the activities of the FWUC which include the management of the irrigation system at the local level. Responsibilities include developing water sharing and management plans, maintaining canals through excavation or small scale erosion control such as grass planting and stone walls, prevention of activities harmful to irrigation structure, intervening in the case of conflicts over water users (such as between farmers and fishermen), controlling the use of flood gates during storms and receiving and issuing flood and drought warnings. Local contractors are available in Pursat with experience in undertaking such physical works. Because of the scale of the project, PDWRAM will be responsible for managing the main and secondary canals while the FWUCs, once established, will assume responsibility for operating and maintaining the tertiary and farm

delivery and drainage canals. Training and capacity building for managing climate change risks for the Pursat PDWRAM and the eventual FWUCs will therefore be important. Such training should not be limited to FWUC members and particular training programs for women will be developed. Their role will be particularly important for community based disaster management and early warning systems.

66. While a FWUC does not yet exist in the project area, the project design team interviewed neighboring groups with functioning FWUCs as a means of information gathering. The farmers in these committees receive training from Ministries such as from the Provincial Departments of Agriculture as well as Water Resources and Meteorology. Those that appear to be most effective are ones which are practical in nature and which take place over longer periods of time, or with continuous support. The lessons learned from other FWUCs which can be applied to this project are that: training should be very specific to actual tasks at hand and be designed based on needs assessment; farmers need to be consulted in selecting any agricultural productivity technologies; conflict between upstream and downstream water users is nearly inevitable and must be managed with possible formation of similar FWUC for downstream water users; farmers are sensitive and keenly aware of market fluctuations for their products and so strategies much be in their best interest economically; and, groups should be formed in advance of the design of irrigation schemes so that they may be consulted.

67. The provincial, district and commune level governments also have important roles to play in issuing and coordinating disaster response. The Project will work closely with them to develop a risk management and disaster prevention approach. Currently, gaps in effective disaster management coordination appear to be from the lower levels of local government, such as commune chiefs, and more marginalized populations. Also, the stakeholders currently involved in disaster management, such as the Provincial Committee for Disaster Management and the Provincial office of the Cambodian Red Cross, appear to be well coordinated to respond to disasters once they occur, but not to forecast and prevent them through improved management. Though few farmers were interviewed, they were not aware of any early warning systems in place or disaster management plans in their area.

G. Implementation Arrangements

68. MOWRAM will implement this output through its Central Project Management Unit (CPMU). The Project including the portion financed by PPCR grant and loan will follow the implementation arrangements as detailed in the project administration manual. MOWRAM will be the executing agency for the project. The project utilizes the experience of both MOWRAM and the PDWRAM of Pursat Province, and will also provide technical assistance through project implementation consultants.

69. The Executing and Implementing Agencies, supported by the project implementation consultants will need to coordinate with other stakeholders implementing activities related to adaptation and to disaster risk management in Pursat Province. While MOWRAM is responsible for “hard” structural measures to manage water related disasters, the National Committee for Disaster Management (NCDM), though under-resourced, is responsible for coordinating “soft” non-structural measures in disaster preparedness and response. The Mekong River Commission (MRC) broadcasts daily flood heights and corresponding risks at key points in Cambodia, Lao PDR, Thailand, and Viet Nam. MOWRAM’s Department of Hydrology and River Works also broadcasts flood levels to affected districts within Cambodia. A gap in the institutional arrangements is evident in coordinating the management of large-scale land-use and degradation control as it pertains to disaster risk management. While the infrastructural elements of disaster risk management are more clearly allocated to different ministries, green

measures and soft measures, such as emergency response, is less clearly delineated.

H. Learning and knowledge sharing

70. ADB implemented RETA 6149 GMS: Support to MRC Flood Management and Mitigation Program. Through this initiative, the question of improved coordination on disaster risk management, including prevention and response, is being addressed. Because this PPCR financed project is seeking to improve both local national and regional early warning systems, coordination with those activities during implementation will be essential. As a first step (PPCR preparation), the team met with the Provincial Disaster Management Committees, Provincial Departments of Water Resources and Meteorology and Cambodian Red Cross offices in Pursat Province to identify local needs. Furthermore, the Nordic Development Fund is administering a co-financing component to an ADB rural roads improvement project (loan 2670) with the Ministry of Rural Development (MRD). As part of this component, they are developing vulnerability maps for Pursat Province which will likely be highly relevant for this project.

71. A number of ministries, in addition to non-governmental organizations, are currently working on adaptation initiatives that include elements related to early warning systems and emergency response. For instance, ADB, through the PPCR, is supporting the Ministry of Public Works and Transport (MPWT) is piloting green measures and emergency response systems in Kampong Chhnang as a means of protecting transport infrastructure and communities. The Ministry of Rural Development (MRD), through support of the Nordic Development Fund and ADB is doing likewise in Kampong Thom, Kampong Speu and Pursat, also protecting transportation infrastructure. Both of these projects are implemented by ADB and therefore they will facilitate coordination. To further support coordination in the country on climate change activities, the Project will provide annual updates to the National Climate Change Coordination Committee as well as through the country-wide and CIF-wide learning mechanism.

I. Outline Terms of Reference for Consultants

72. All the terms of references are included in the project administration manual (PAM).

J. PPCR financing and costs

73. The overall financing plan of the project is shown below:

Table 17: Costs by component and financier ($ ‘000)

	Total
1. Enhanced regional data, information and know ledge base for the management of floods and droughts	2,538.6
2. Upgraded Water Infrastructre	33,620.6
3. Capacity Development for CBDRM	1,048.0
4. Effective project implementation	3,558.3
Total BASELINE COSTS	40,765.5
Physical Contingencies	3,150.4
Price Contingencies	2,912.6
Total PROJECT COSTS	46,828.5
Interest During Implementation	926.2
Total Costs to be Financed	47,754.7

MONITORING OF CLIMATE RESILIENCE OUTPUT THROUGH SPECIFIC INDICATORS

Results	Indicators	Source of verification
Reduced economic losses from floods and droughts by 2020	Average annual economic losses reduced by 50% in Project areas. Baseline (2011 Pursat flood damages): $13.4 million Increased flood protection for 10,000 people. Baseline (2011 Pursat flood) : 1991 households displaced 16,100 ha of agriculture lands improved, making up to 8,000 ha of dry season paddy possible. Baseline (2011) : 0 hectares dry season paddy	National Committee for Disaster Management reports for Pursat township. National Committee for Disaster Management reports on household evacuation for Pursat township. MOWRAM statistics
Enhanced regional data, information and knowledge base for the management of floods and droughts (formerly named "Improved sub-regional cooperation for flood and drought management")	NFFC operational and issuing flood warnings to NCDM and linked to MRC Regional Flood Management and Mitigation Center by 2015. NFFC staff trained and operational by 2Q 2016 NFFC forecasting models calibrated and operational by 2017 Baseline: NFFC is not operational Design criteria for flood and drought mitigation schemes in the Mekong Delta developed and disseminated by mid-2014. Transboundary (Cambodia-Viet Nam) flood management options endorsed by both Governments by 2015.	DHRW PIU progress reports Design criteria as agreed by the governments of Viet Nam and Cambodia
Enhanced capacity of communities to manage flood and/or drought events	6 communes have disaster risk management plans and organizations to coordinate response.	PPCR Progress Reports MOWRAM Annual Report; MPWT website; ADB Project Completion report PPCR Progress Reports

Results	Indicators	Source of verification
	At least 200 women are trained on CBDRM and at least 30% of CBDRM committee members are female Baseline: 0	PPCR Progress Reports MOWRAM Annual Report; MPWT website; ADB Project Completion report PPCR Progress Reports

Source: Asian Development Bank.

DETAILS OF STRUCTURAL CLIMATE RESILIENCE IMPROVEMENT MEASURES FOR DCIS

1. The ADB PPCR study team applies an FAO method[1]to quantify the overall scheme efficiency based on: (i) the conveyance efficiency for which FAO recommends an indicative value of 80% for long unlined clay canals; and (ii) the field application efficiency for which FAO recommends an indicative value of 60% for flood irrigation schemes and values up to 90% for drip irrigation schemes. The FAO methodology does not include management efficiency but the present study assumes that its efficiency can be included with the same weighting. The efficiency values selected for the DCIS are shown in Table 3.9 and they assume the above climate resilience measures are successful: (i) the conveyance efficiency will rise from 80% to 85%; (ii) the field application efficiency will rise from 60% to 70%; and the management value will rise from 80% to 90%. The resulting scheme efficiencies are: (i) 40% without the measures and 55% with the measures. It is noted that the scheme efficiency value without the measures is less than the 50% suggested by MOWRAM engineers so the present study adopts their value.

Table A2.1: Benefit of Water Availability Climate Resilience Measures

Category	Efficiency Values	
	Without Measures	**With Measures**
Conveyance	80%	85%
Field Application	60%	70%
Management	80%	90%
Average Scheme Efficiency [a]	~40%	~55%

[a] values are indicative and rounded to nearest denomination of 5
Source: ADB PPCR study team, 2012; FAO, 1989

[1] FAO, 1989, Irrigation Water Management: Irrigation Scheduling, Training Manual No.4.

Table A2.2: Irrigation Water Requirement for Current Climate

	D[a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)		24.9	24.9	27.8	27.8	27.8	26.7	26.7	26.7	25.7	25.7	25.7	24.9
ETo (mm/day)		3.6	4.0	4.6	4.6	4.3	3.9	3.8	3.7	3.5	3.5	3.5	3.5
Crop Factor, Kc													
Early Wet Season				1.20	1.10	1.30	0.95						
Wet Season							1.20	1.10	1.10	1.30	0.95		
Late Season							1.20	1.10	1.10	1.10	1.10	1.30	0.95
Dry Season		1.30	0.95									1.20	1.10
Irrigation Requirement (mm/dec)													
	1			87.8	53.0	45.6	53.5						
Early Wet Season	2			87.4	51.4	40.3	52.4						
	3			102.0	49.9	46.7	29.5						
	1							79.4	23.1	24.6	18.8		
Wet Season	2						23.7	49.2	24.3	23.4	9.0		
	3						83.0	22.9	24.7	23.5	4.4		
	1						64.5	64.7	22	19.9	19.8	36.7	53.5
Late Season	2						60.1	40.7	21.4	19.1	20.2	44.2	51.5
	3						65.5	22.9	20.5	20.2	28.7	51.1	40.8
	1	60.5	68.7	48.1									119.7
Dry Season	2	64.6	69.8	20.0									94
	3	67.5	61.8									30.6	59.6
Rainfall (mm)		6.5	14.0	45.3	76.9	127.1	42.7	141.8	170.3	193.3	190.7	80.2	7.5
Effective Rainfall (mm)		6.4	13.7	42	67.4	101.3	39.8	109.6	123.9	133.5	132.5	69.9	7.4
Scheme Irrigation Requirement (l/s/ha)													
Net		0.74	0.77	0.90	0.60	0.51	0.63	0.54	0.26	0.25	0.19	0.56	0.81
Gross (50%)[b]		1.48	1.54	1.80	1.20	1.02	1.26	1.08	0.52	0.5	0.38	1.12	1.62
Gross (55%)[b]		1.35	1.40	1.64	1.09	0.93	1.15	0.98	0.47	0.45	0.35	1.02	1.47

[a] D is a ten day period; [b] the scheme efficiencies for without (50%) and with (55%) water demand climate resilience measures.

Source: ADB PPCR study team

Table A2.3: Irrigation Water Requirement for Projected Climate Change

	D[a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)		28.0	28.0	31.0	31.0	31.0	29.1	29.1	29.1	28.4	28.4	28.4	28.0
Eto (mm/day)		3.9	4.4	5.0	5.0	4.7	4.2	4.0	3.9	3.8	3.8	3.8	3.8
Crop Factor, Kc													
Early Wet Season				1.20	1.10	1.30	0.95						
Wet Season							1.20	1.10	1.10	1.30	0.95		
Late Season							1.20	1.10	1.10	1.10	1.10	1.30	0.95
Dry Season		1.30	0.95									1.20	1.10
Irrigation Requirement (mm/dec)													
Early Wet Season	1			90.0	64.0	62.7	43.3						
	2			92.7	63.3	59.8	27.1						
	3			110.7	63.1	53.4	11.6						
Wet Season	1							74.0	22.0	22.5	16.7		
	2						22.7	50.1	22.4	21.2	6.7		
	3						76.0	22.8	22.8	21.4			
Late Season	1						62.4	58.5	20.9	17.5	17.7	35.1	57.3
	2						50.0	41.6	19.3	16.7	18.2	42.8	55.7
	3						54.9	22.8	18.3	17.8	26.9	52.0	45.2
Dry Season	1	65.6	75.1	56.4									121.6
	2	70.1	76.7	23.1									97.6
	3	73.6	69.4									30.8	64.4
Rainfall (mm)		3.2	6.9	28.1	47.7	78.8	137.1	170.2	204.4	245.5	242.2	101.9	3.7
Effective Rainfall (mm)		3.2	6.8	26.8	44.1	68.9	107.0	123.9	137.6	149.1	148.3	85.3	3.7
Scheme Irrigation Requirement (l/s/ha)													
Net		0.81	0.85	0.97	0.73	0.68	0.50	0.52	0.24	0.23	0.17	0.55	0.85
Gross (50%)[b]		1.62	1.70	1.94	1.46	1.36	1.00	1.04	0.48	0.46	0.34	1.10	1.70
Gross (55%)[b]		1.47	1.55	1.76	1.33	1.24	0.91	0.95	0.44	0.42	0.31	1.00	1.55

[a] D is a ten day period; [b] the scheme efficiencies for without (50%) and with (55%) water demand climate resilience measures.

Source: ADB PPCR study team

Table A2.4: Potential Command Areas for Current Climate

	Available Flow (m^3/s)			Command Area (ha) without Measures			Command Area (ha) with Measures		
	Dry-Year	Median-Year	Wet-Year	Dry-Year	Median-Year	Wet-Year	Dry-Year	Median-Year	Wet-Year
January	0.2	3.2	7.0	139	2,194	4,711	153	2,414	5,182
February	-	3.8	8.4	-	2,495	5,470	-	2,744	6,017
March	0.1	3.2	7.4	29	1,789	4,114	31	1,967	4,525
April	1.6	4.6	14.3	1,296	3,805	11,940	1,426	4,186	13,134
May	6.5	13.3	23.5	6,332	12,999	23,076	6,965	14,299	25,383
June	6.2	19.3	55.6	4,926	15,355	44,163	5,418	16,891	48,579
July	22.8	38.0	67.9	21,080	35,160	62,900	23,188	38,676	69,190
August	45.0	62.7	87.7	86,444	120,547	168,623	95,088	132,601	185,485
September	57.4	107.0	165.6	114,816	213,917	331,189	126,297	235,309	364,308
October	78.4	128.2	204.6	206,305	337,486	538,535	226,935	371,234	592,388
November	26.5	42.3	81.8	23,640	37,782	73,056	26,004	41,560	80,362
December	6.3	11.1	34.4	3,905	6,839	21,258	4,295	7,523	23,384

Source: ADB PPCR study team

Table A2.5: Potential Command Areas for Projected Climate Change

	Available Flow (m^3/s)			Command Area (ha) without Measures			Command Area (ha) with Measures		
	Dry-Year	Median-Year	Wet-Year	Dry-Year	Median-Year	Wet-Year	Dry-Year	Median-Year	Wet-Year
January	-	0.5	2.3	-	300	1,427	-	330	1,569
February	-	0.8	3.0	-	457	1,778	-	503	1,955
March	-	1.2	3.8	-	604	1,942	-	665	2,136
April	0.1	2.0	8.1	96	1,375	5,520	106	1,512	6,072
May	3.2	7.4	13.8	2,339	5,439	10,124	2,573	5,983	11,137
June	7.9	23.7	67.2	7,881	23,651	67,208	8,669	26,016	73,929
July	27.8	46.0	82.0	26,685	44,231	78,800	29,354	48,654	86,680
August	54.4	75.7	105.7	113,281	157,614	220,113	124,609	173,375	242,125
September	73.5	136.4	210.9	159,768	296,572	458,458	175,745	326,229	504,303
October	100.1	163.5	260.5	294,553	480,753	766,124	324,008	528,828	842,736
November	34.2	54.3	104.5	31,101	49,388	95,000	34,211	54,326	104,501
December	2.0	4.3	15.8	1,173	2,543	9,276	1,290	2,797	10,203

Source: ADB PPCR study team

A. Flood Climate Resilience Components

2. PPCR will finance the incremental costs associated with ensuring the DCIS is climate change resilient and identifies the following components of the DCIS as being directly related: (i) the DCIS Barrage; (ii) flood diversion using the DCIS Main Canal; (iii) upgrading the existing structures on the Svay Donkeo River; and, (iv) increasing the local drainage in the DCIS. As a new scheme, the DCIS Barrage and Main Canal are designed based for the anticipated climate conditions: (i) the barrage is designed to be about 50% larger than if it had been designed for current climate conditions; and, (ii) the main canal is designed to divert 40m^3/s of peak flows within the Pursat River to the Svay Donkeo River which is almost double the capacity required for command flows (21.9m^3/s).

3. The internal drainage system for the DCIS is also new and will be designed for anticipated future climate conditions. The size of the drainage channels and associated structures (drainage inlets, canal overflow weirs and drainage outlets to the DAIS) will need to be sized appropriately. The increase in extreme rainfall owing to anticipated climate change is estimated to be 30%. Assuming a linear relationship between rainfall and runoff, the size and cost of the drainage channels is also expected to increase by 30%.

4. The only existing structures that will be directly and adversely impacted by the DCIS and climate change are the Dhamnak Ampil and Svay Anlong Weirs on the Svay Donkeo River. The flood capacity of these weirs is unknown so their current capacities are based on estimated dimensions from field visits and Google Earth. This project will ensure they can convey the climate change projected 50-year flood flows with the additional diversion flows by raising their abutments and upstream embankments as also shown in Table 5.9.

Table A2.6: Proposed Upgrade for Existing Svay Donkeo Weirs

	Dhamnak Ampil	Anlong Svay
Existing Flood Capacities		
Crest Length (m)	100	125
Existing Flood Capacity (m^3/s)	130	160
Approximate Flood Magnitude (Years)	100	20
Proposed 50-year Design Flood Capacities		
Current Climate (m^3/s)	114	195
Current Climate with DCIS Flood Diversion (m^3/s)	154	235
Projected Climate with DCIS Flood Diversion (m^3/s)	189	294
Proposed Structural Changes		
Abutment Level Raised (m)	0.5	1.0
Total Abutment Length (m)	50	100
Upstream Embankments Raised (m)	0.5	1.0
Total Upstream Embankment Length (m)	2,000	1,000

Source: ADB PPCR study team, 2012

B. Command Area Climate Resilience Components

5. The two main structural measures for climate resilience identified are: (i) retention of excess wet season runoff to store for dry season irrigation; and, (ii) reducing the gross water demand by improving the scheme's design, efficiency and management. Proposed components of these measures are discussed in the following sections except for the good design component which should be inherent within the standard of work of the DCIS detailed designers should they take into account the recommendations discussed in this report.

6. **Phtenh Rung Reservoir.** The existing Phtenh Rung Reservoir is located near the off-take to the Secondary Canal No.1. It is currently used as storage for dry season irrigation of an area located along vicinity of proposed Secondary Canal No.1. This recommended climate resilience measure comprises of: (i) connecting the reservoir to the DCIS main canal and Secondary Canal No.1; (ii) providing new gate structures to control flow to and from the reservoir; and, (iii) strengthening the reservoir's embankment where necessary. The intervention seeks to supplement and guarantee water supply during the dry season crop. The elevation of the reservoir is close to that of the main canal and care will be needed during its design to ensure gravity flows are achievable. However, this also presents an opportunity to use the reservoir for intermediate storage within the main canal for reducing response times, increasing flexibility within the system and balancing flows between supply and demand needs.

7. The reservoir is currently fed by local runoff. The Talo Rainfall Station (120309) is the nearest rainfall monitoring station to the reservoir. For 8 years of record the mean annual rainfall is about 1,180mm. [1] Assuming a volumetric runoff coefficient of 50%, the mean annual runoff from its 840ha catchment is about 5 million m^3. Most of this runoff occurs during the wet season when it is not required for irrigation so the reservoir has been engineered by PDWRAM to store the wet season runoff to supplement dry season irrigation to a small downstream command area. The maximum capacity of the reservoir, shown in Table A2.6 and Figure 1, is about 9-10 million m^3 (allowing for some freeboard) which is about twice the mean annual runoff. Therefore this climate resilience intervention proposes to supplement and also guarantee inflow by linking the reservoir to the DCIS main canal.

8. The reservoir is located at about chainage 5.5km along the main canal where the full supply level (FSL) within the canal is about 26.5mAD. Allowing for 0.2m head loss between the main canal and the reservoir, the reservoir would be capable of maintaining a constant operating storage of about 6 million m^3 which is within the confines of the existing reservoir. Hence this option should require only minor works to link the main canal to the reservoir and adapt existing structures. Land acquisition and resettlement should not be necessary.

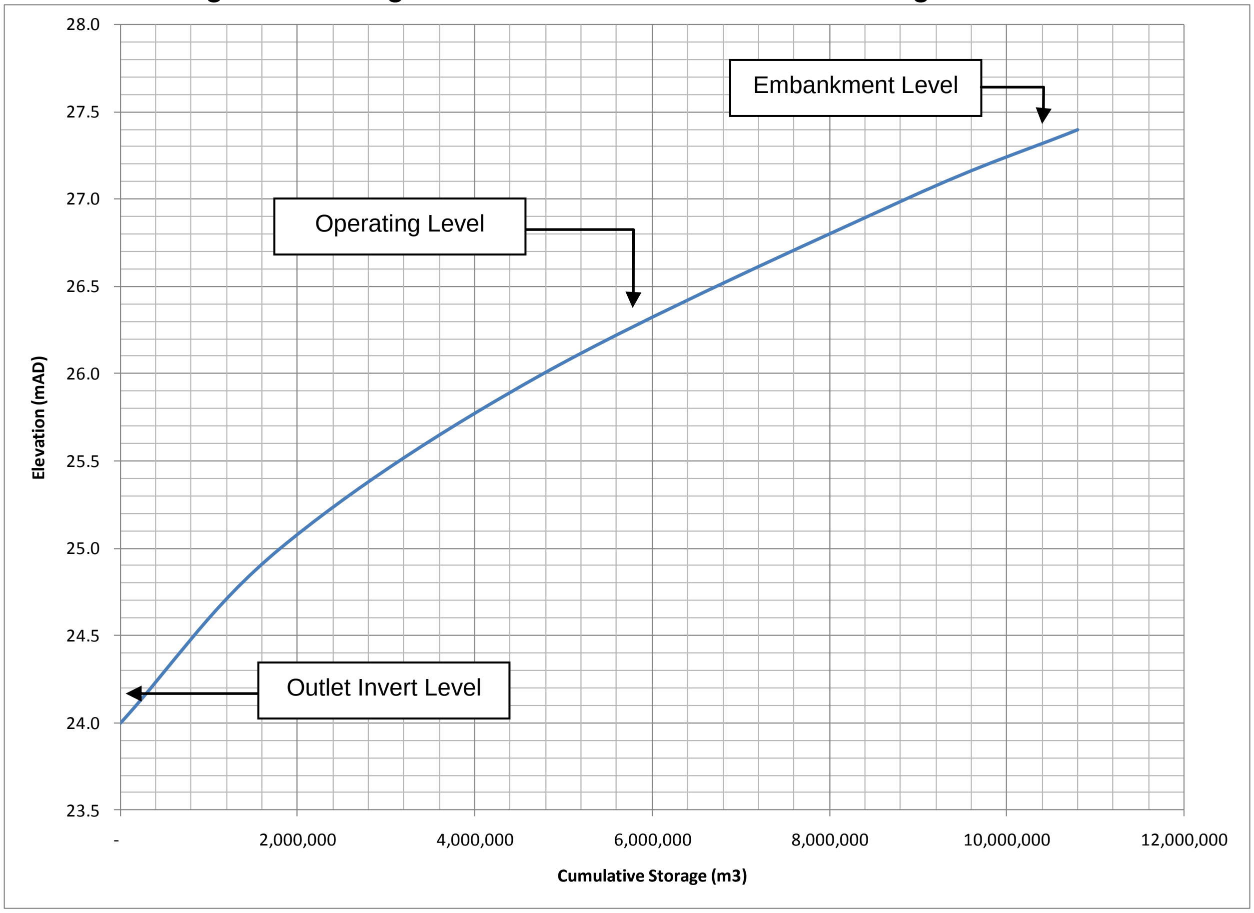
Table A2.7: Surface Area and Volume of the Phtenh Rung Reservoir

Elevation (mAD)	Surface Area (ha)	Cumulative Volume (m^3)	Comment
24.0	120	0	Outlet Invert Level
25.0	240	1,800,000	Surveyed reservoir level
26.0	350	4,800,000	Interpolated
27.0	470	8,850,000	Interpolated
27.4	510	10,800,000	Surveyed embankment level, maximum area within existing road and main canal alignment

Source: ADB PPCR study team and Google Earth, 2012

[11] GFA Consulting Group, 2006, Tonle Sap Lowland Stabilisation Project Report on Water Availability, prepared for ADB TA 4756-CAM: Tonle Sap Lowland Stabilization Project.

Figure 1: Storage-Elevation Curve of the Phtenh Rung Reservoir



Source: ADB PPCR study team, 2012.

9. Raising the Pursat River Barrage and Intake to a FSL of 27.5mAD[1] would increase the guaranteed storage capacity of the reservoir. This could raise the normal reservoir level to about 26.8mAD and provide a total storage capacity of about 8.0 million m^3. At this elevation the surface area of the reservoir will increase to about 450ha which means about 210ha of private land will be permanently inundated. Strengthening of the embankment and outlet structure may also be needed and provisional cost estimates are included in Section 8.

10. The dry season benefits of this intervention are shown in Table A2.8. Flows are calculated assuming the storage volume is discharged over a 90-day dry season. For assessing water availability the present study uses Option 1.

Table A2.8: Potential Water Availability from the Phtenh Rung Reservoir

Option	Storage (m^3)	Dry Season Discharge (l/s)	Incremental Benefit (l/s)
Current	1,800,000	230	-
Option 1	6,000,000	770	540
Option 2	8,000,000	1,030	800

Source: ADB PPCR study team, 2012.

[1] Based on surveyed river cross-sections, the present study considers that a permanent water level of about 27mAD to 28mAD upstream of the barrage is the maximum before extensive inundation of riparian land. The impacts and costs of raising the water level further needs to be considered and balanced against the benefits of increasing the capacity of the Phteng Reservoir.

C. Traditional Field Reservoirs

11. This recommended climate resilience measure continues local traditional irrigation practices of constructing small localized excavated and impounded storage reservoirs in the tertiary and distribution system. Their size and general locations can be planned with the participation of the farmers however they will need to be connected to the tertiary and distribution canals. The reservoirs will be filled by the farmers during the wet season with excess non-consumed canal water and local runoff. The stored water can then be used by the farmer's on-demand using either the tertiary and distribution gravity system or hand-tractor pumps to lift the water to irrigate their fields. Hand-tractor pumps are already common throughout the scheme.

12. This construction of this intervention comprises mainly of earthworks. On average 1 million m^3 of earthworks will cost on average about $200,000 and provide an additional dry season flow of 130l/s. This additional flow will increase the dry season command area by 40ha under current climate conditions and 80ha under anticipated climate change conditions. The final total amount of reservoirs will depend on available budget however the present study assumes that a total storage volume of about 3.6 million m^3 is achievable and, if used over the 90-day dry season period, will supplement water supply by 470l/s.