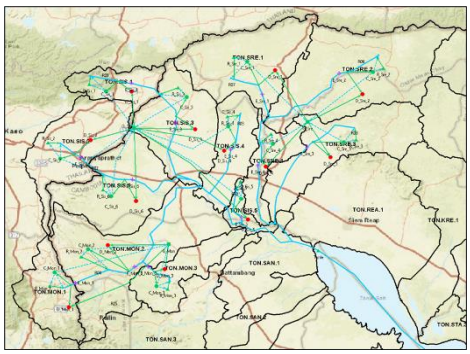
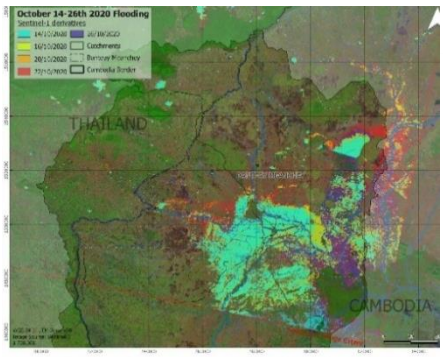
JBA Consulting
In association with
Mekong Modelling Associates
Future Water
Stockholm Environment Institute

Transboundary Water Management between Thailand and Cambodia as part of the adaptation of the agricultural sector in North- Western Cambodia to Climate Change

FINAL REPORT

April 2021





RED IV
Project No: 2019.2207.9.001

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1.0 10 March 2020	Initial Draft	GIZ
2.0 December 2020	Draft Final	GIZ
3.0 April 2021	Update and restricting following workshop	GIZ

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The Cambodian Provinces of Banteay Meanchey and Oddar Meanchey share an international border with the provinces of Surin and Sisaket in Thailand. Cambodia is undergoing rapid economic development whilst facing significant shifts in the climate that impact strongly on the agricultural sector. Within the framework of German technical cooperation for Cambodia, GIZ is supporting the Regional Economic Development Programme IV (RED IV) which aims to strengthen the capacity of the regional government I line with Cambodia's decentralisation. On the Thai of the border similar issues of climate and agricultural production and disaster management are faced and the aim of the project has been to complete analysis of water management on each side, seek opportunities for potential adaptations and build cross border capacity through exchanges at the province and local level and cross border working.

Integrated Water Resource Management (IWRM), catchment based approaches and the setting up of catchment based River Basin Organisations (RBO) has been promoted worldwide for river and water resource management but so far has not been sustainable in Cambodia except at the National level. Strengthening the regional government is a necessary pre-condition for IWRM as many of the key river basin functions are best managed at the more local level (consistent with decentralisation policy) such as land use planning, enforcement of building controls, disaster response, water sharing during critical drought periods, housing the RBO secretariat functions and management. The progress of Thailand in similar conditions is a good example for Cambodia and exchange of experiences was envisaged under the project but has not been possible due to the Covid situation. Nevertheless the project has provided a basis for this when conditions allow.

An analysis of the status quo for water resource management and for future change has been carried out for both flood and drought conditions including the effects of potential climate change. This has included modelling of flood area and depth under different storm severity and analysis of people, crops and assets at risk. A major storm event at the end of 2020 affected Banteay Meanchey greatly causing loss of life and damage to property and crops. This is documented and compared with the modelling. Further analysis for flood management measures better defining the flood measures could be carried out in future studies, at the time the provincial government was still engaged in the incident management and relief work. An analysis of the additional water storage needs was carried out for Oddar Meanchey together with additional storage need under climate change. The Provincial department of MOWRAM in Oddar Meanchey is working to obtain funding for a large number of medium sized storage rehabilitation or enlargement. Further facilities for storing water will also be needed to meet agricultural water demands.

The status quo analysis for water resource and flood issues was used together with socioeconomic analysis was used to identify priority areas. Focus Group meetings were then held in those areas, meeting with local Farm Water and Agricultural Community Groups. These meetings revealed further detail on the local issues and potential works that would help increase resilience.

In Thailand the National, Provincial and local organisation of water management, facilities and disaster management responses was discussed and documented. Meetings with various Thai local initiatives also gave many potential cross border learning points and examples for the Cambodian side and when it is possible to travel again exchanges within a project of improvement work could greatly benefit strengthening governance of water issues in each of the four provinces..

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!/	Agricultural Cooperative
!5.	Asian Development Bank
!²{	Automated Weather Station
.a/	Banteay Meanchey
/5.	Commune Database
9²{	Early Warning System
CD5	Focus Group Discussion
CIII	Female Headed Households
DL½	Deutsche Gesellschaft fur Internationale Zusammenarbeit
L5t22₪	Identification of Poor Households mechanism
[/t5	Litres per capita (person) per day
a!CC	Ministry of Agriculture, Forestry and Fisheries (Cambodia)
ah²w!a	Ministry of Water Resources and Meteorology
aw/	Mekong River Commission
ha/	Oddar/ Otdar Meanchey
t5!CC	Provincial Department of Agriculture Forestry and Fisheries
t5²w!a	Provincial Department of Water Resources and Meteorology
w95	Regional Economic Development (GIZ programmes)
{9L	Stockholm Environment Institute
²9!t	Water Evaluation and Planning system
²w	Water Resources
²wa	Water Resource Management

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This project focuses on the North- Western Cambodian provinces of Oddar Meanchey (OMC) and Banteay Meanchey (BMC) and the neighbouring North- Eastern Thai provinces of Surin and Sisaket. Transboundary projects aid the development of effective water resource management (IWRM) by helping to limit competition over resources and in creating a dialogue for the transferral of beneficial lessons between the countries. Considering water at a tNJ2ǀŃŷǑŃl·f Level is in line the move towards more de-centralisation to local governance in Cambodia. In Thailand there are already Province based plans and management for the water sector complimenting national and river basin planning but for Cambodia this is a new approach.

Cambodia is currently improving in economic standing, however the benefits of this are largely constrained to urban areas. As a major contributor to GDP and employment, ensuring the sustainability of Cambodia's agricultural sector is highly important, especially when coupled with the increasing awareness of the dangers of climate change. Access to water for agriculture, fisheries and domestic supply is an issue, with many rural and urban stakeholders competing for resources. Coupled with the effects of severe flood and drought events in recent years, the need for adequate and reliable water resource management in rural, agricultural areas is prominent.

In order to protect rural livelihoods and maintain agricultural production, communities should be supplied with regulated water year- round. Analysis of recent flood and drought histories and their effects in the provinces are first necessary to determine the most vulnerable areas both in terms of agriculture and households. In addition, water resource assessments of supplies and demand will identify the most crucial areas to ensure supplies are increased and sustained both for crops and domestic use. Socio-economic studies will also ensure 'cross- cutting' issues outlined in the GIZ RED projects are considered in WR planning, such as: gender, economic vulnerability and cultural factors related to WRM.

Both top- down and bottom- up processes are vital to the development of effective water management and in the transboundary border areas such as these there are lessons for management and better understanding.

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The project's main objectives were:

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4. 5ŜǾŜf2LJ ϒŜl·ădzNJŜă ű2 ăűNJŜƴ∃űKŜƴ űKŜ Ǒl·LJl·ǑŃűŃŜă 2Ŧ ǿl·űŜNJ ϒl·ƴl·∃ŜϒŜƴű l·ű ŘŃăűNJŃǑű l·ƴŘ f2Ǒl·f fŜǾŜfă l·ƴŘT
5. tNJŜăŜƴű ǿŃűK DL½ LJNJ2LJ2ăŜŘ ϒŜl·ădzNJŜă ű2 űKŜ LJ2LJdzfl·űŃ2ƴ űKNJ2dz∃K LJdzōfŃǑπ LJNJŃǾl·űŜ ŘŃl·f2∃dzŜ ŜǾŜƴűăΦ

During the study, due to the development of the Covid-19 pandemic, certain activities were not possible as borders closed and meetings were curtailed. Cambodia also suffered a severe drought and then

unusually late rains in 2020 caused widespread floods. The JBA team thus had to adapt and complete as much of the original intentions as possible within the available time and budget.

The analysis of the current water resource situation in the study area through collection of available data on water resources, flood and droughts and the socioeconomic issues in the area. Following this, more detailed analysis and modelling were completed through:

1. Analysis of Water Supply and Demands
2. Analysis of Floods
3. Modelling of Future Climate and Water Storage Requirements
4. Meetings with stakeholders at multiple levels including Province Offices, Provincial Ministries, Water Supply Companies, Farmer and Irrigation Water Groups

Within Thailand meetings were held with national and provincial bodies and information collected for Exchange of experiences between the neighbouring Thai and Khmer provinces

M¢o tNŽØλyÖŜ CŜI-ŭdzNŜă

The four provinces are broadly similar though Surin and Sisaket in Thailand are slightly larger and have larger populations. Oddar Meanchey in particular has a low population and is relatively less developed being formed only in 1999 from a heavily forested area. There are border passages between Oddar Meanchey and Surin at O'Smach and to Sisaket through Anlong Veng. Banteay Meanchey has borders with Sa Kaeo and shares transboundary rivers at Poipet and Svay Chet.

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.I-yűŜI-è aŜI-yÖKŜè	Sisophon	6149	835	Sisopon, Svay Chet Mongkol Borei
hŘŘI-N aŜI-yÖKŜè	Samraong	6635	276	Sreng, Srong
{λăI-1Ŝú	Sisaket	8877	1398	Mun,Tha, Tab Tan, Samran, Khayung
{dzNλy	Surin	8811	1473	Mun, Lam Chi Noi, Tab Tan

The features of the two Cambodian provinces are further described in Annex 1 and the Thai provinces in Annex 2.

Agriculture is important in each province, particularly rice production as shown in Table 1.2 with Sisaket having over 500,000ha under rice, more double Banteay Meanchey which in turn is more than three times Oddar Meanchey.

The planned expansion of irrigated area and associated storage development in Thailand is published by the Royal Irrigation department but for Cambodia, figures of the current situation have been estimated as they are not accurately recorded by Mowram, only estimates of area being made. It is envisaged in the Irrigation strategy of Mowram that irrigation development will be more concerned with rehabilitating and modernising irrigation systems than development of new schemes.

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² Ŝů {Ŝl-ă2y wňŎŜ	233,027	75,272	531,900	463,950
5Њè {Ŝl-ă2y wňŎŜ	18,036	210	11,670	7,500
/ l-ăăl-Øl- ówl-ňyŦŜŘú	68,366	40,933	11,192	7,039
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¢2ůl-ŧ LЊŊňЗl-ůŜŘ !ЊŜl- óKl-ú			75,900	53,500
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tfl-yySŘ LyŎЊŜl-ăŜ 2Ŧ LЊŊňЗl-ůň2y !ЊŜl- óKl-ú	*	*	40,000	29,860
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** Estimated from water body area. *Long term Planning of any increase in irrigation in Cambodia not available.

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The main body of the report is intended to be concise with supporting additional material placed in Appendices. In the main report the Status Quo analysis is presented followed by the implications for Water Resources Management and potential follow up work.

In the Appendices further detail is presented on:

Annex A. Province Features and Water Management in Banteay Meanchey and Oddar Meanchey

Annex B. Province Features and Water Management in the Thai Provinces Surin and Sisaket

Annex C. Modelling of Water Resources in Ottar Meanchey to illustrate Provincial Planning for Drought

Annex D. Remote Sensing of floods and water bodies by ESA September 2020

Annex E. Flooding in October/November 2020

Annex F. Focus Group Interviews completed in Cambodia with Farmer Water Groups and Agricultural Cooperatives

Annex G. Proposed Contents of a Provincial Water Management Plan

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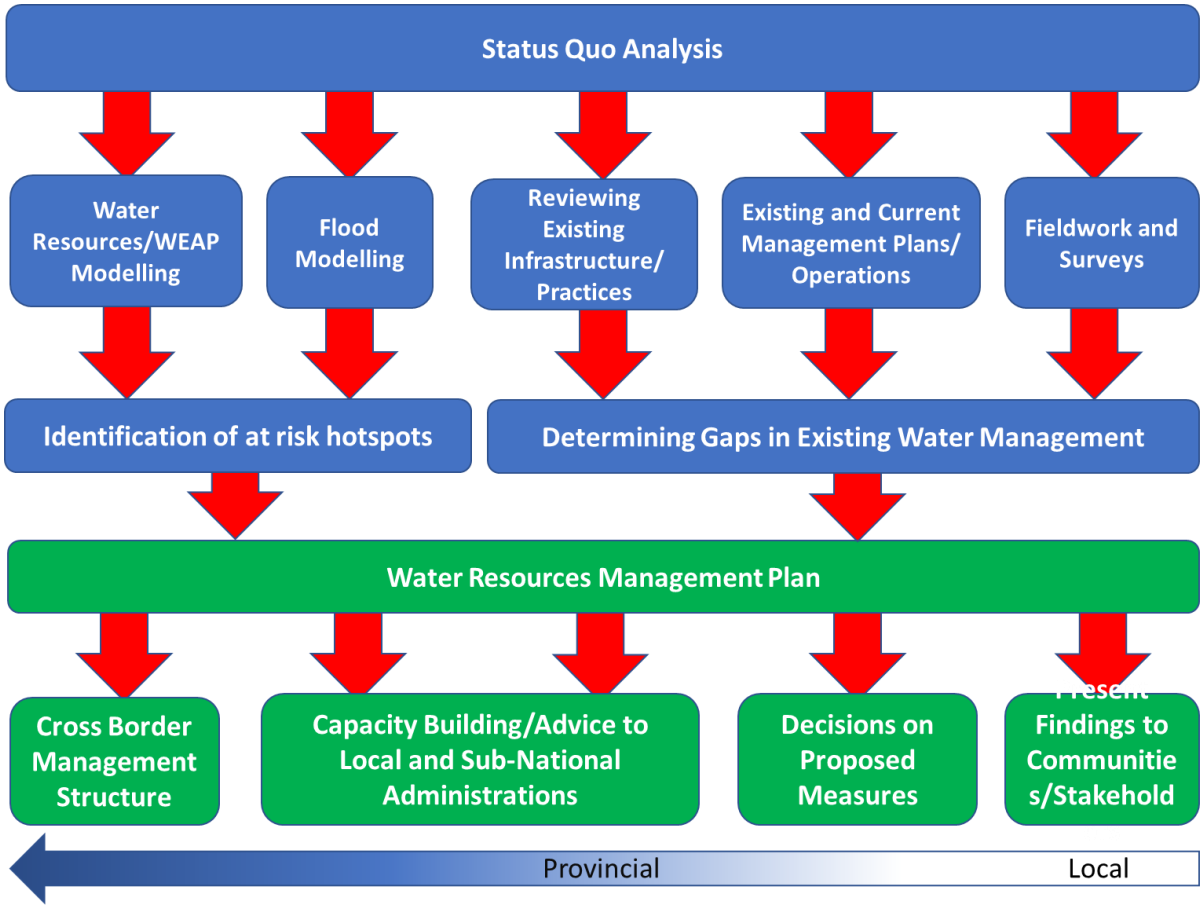
2.1.1 Status- Quo Analysis

The first objective of the project is to complete a status quo analysis of the current situation in each of the provinces. This then feeds into the identification of measures and informs consultation between the



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countries and the design of an example water resource management plan. The process envisaged is illustrated in Figure 2-1.

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The analysis of water resources needs to be viewed in the context of the availability and accessibility of supply compared wth the demands. For this project that balance has been approached for the Cambodia provinces using a water balance model 'Water Evaluation and Planning' system (WEAP) and from satellite imagery. For Thai provinces of Surin and Sisaket the demand and supply balance was taken from previous work.

As flood is relatively more straightforward, this is presented first including the approach for identifying 'hotspot' areas of priority for further investigation by using a standard risk approach set out in the Sendai framework for disaster risk reduction (UNDRR 2015) and management as used in a previous study for GIZ on the 9T/9C Area (JBA 2019) which includes part of Banteay Meanchey as well as the parts of the Thai province Sakeo.

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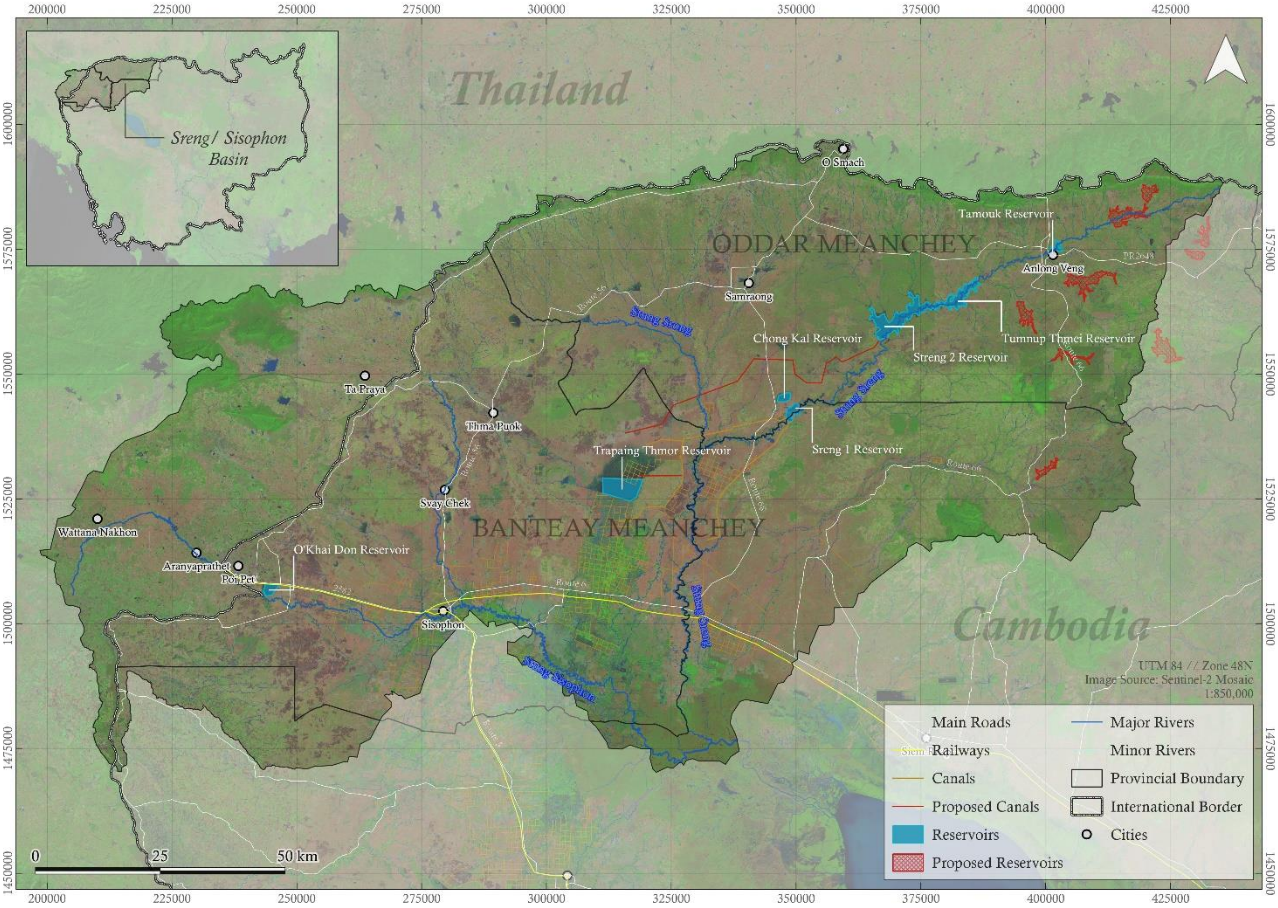
The Stung Sreng is main river of the two provinces and a number of reservoirs have been developed on the main stem by Mowram including the recently completed Sreng 2, and the smaller Tumnup Thmei and Tamouk reservoirs. In Banteay Meanchey the historic Trapeng Thmor reservoir has been rehabilitated and there are plans to raise the operating levels to gain more storage. For Oddar Meanchey other reservoir storages are being considered in the Anlong Veng area as shown in Figure 2-2. Unfortunately due to the terrain the area that may be supplied from the new reservoirs is primarily in other provinces including Banteay Meanchey and Siem Reap.



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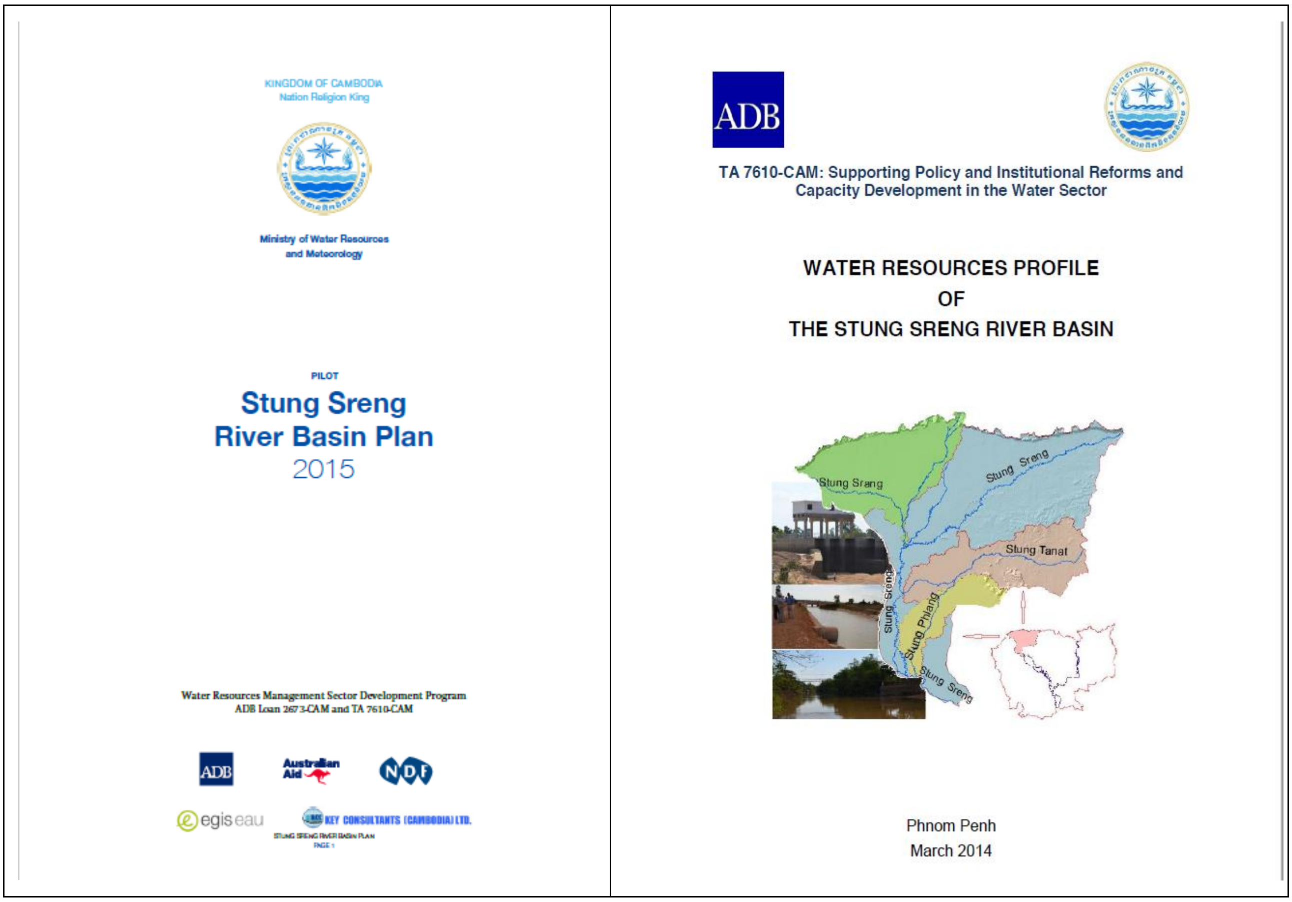
Planning for water resource development in Cambodia is relatively advanced in terms of availability of plans and strategy in the Stung Sreng area. There exists a National Strategy and plan for Water resource development developed and approved in 2019 and for the Stung Sen River Basin there exists a Pilot River Basin Plan, A Water Resources Profile and other papers such as strategy Issues and Objectives. These were developed as part of a pilot programme developed by ADB but unfortunately the lack of resource in the provinces and rural parts meant that without external funding the organisation ceased to function. More recently work on pilot River Basin organisations has focussed on the Stung Sen and Chinit as well as directly to the Farmer Water groups (FWUC), but as can be seen in Annex F, the operation of FWUC is constrained without external support.

During the period of control by the Khmer Rouge many irrigation facilities were developed and much of this infrastructure still forms the basis of irrigation development in Cambodia. However a lot of the schemes developed have been damaged, are incomplete or were never able to function as planned but still they may form the basis of an updated system as envisaged in the 2020-2030 strategy of Mowram. The records and understanding of irrigation operations is thus still a challenge for the upgrading and a number of initiatives are ongoing for improving data and management of irrigation systems supported by various partners including the ADB for a major National data centre. At the provincial level the availability of data is even less and more constrained by resources. The new Sreng 2 reservoir for example is handed over for operation but practical guidance for operators is lacking and whilst main canals are

completed secondary and tertiary systems were not built as part of the dam and irrigation system project. In some of the storage reservoirs, rice or crops are planted as he water levels decline. An issue has now arisen though that people depend on the land within the reservoir area so there is pressure not to completely fill the storage or to release too much water.

Disaster risk management and response is coordinated by the National Committee for Disaster Management (NCDM). The organisation has provincial municipal, district, commune and village organisation structure and a clear role for emergencies and working with CRC and others such as NGOs. The reduction of risk through 'build back better' is less clear for water resource infrastructure. Some information on flood response can be seen in Annex F on the 2020 floods.

In Thailand there is a similarly good availability of planning as outlined in Annex B. An issue for Thailand is to balance the rural development including basic agricultural activities with the national strategy to focus on creating an eonomy based on innovation, technology and creativity 'Thailand 4.0' to increase national incomes. This includes developing 'smart farmer' households .



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In Thailand, a National Water Resources Committee has been convened to improve the coordination in water resources development and disaster management following from the lessons of the 2011 Chao Phyra flood in Bangkok. The ONWRC has developed a Master Plan 2018-2037 to better align with the National Strategy and to manage the country's water security and development of all concerned agencies. The plan comprises various strategies and work plans in six major areas as detailed further in Annex B.

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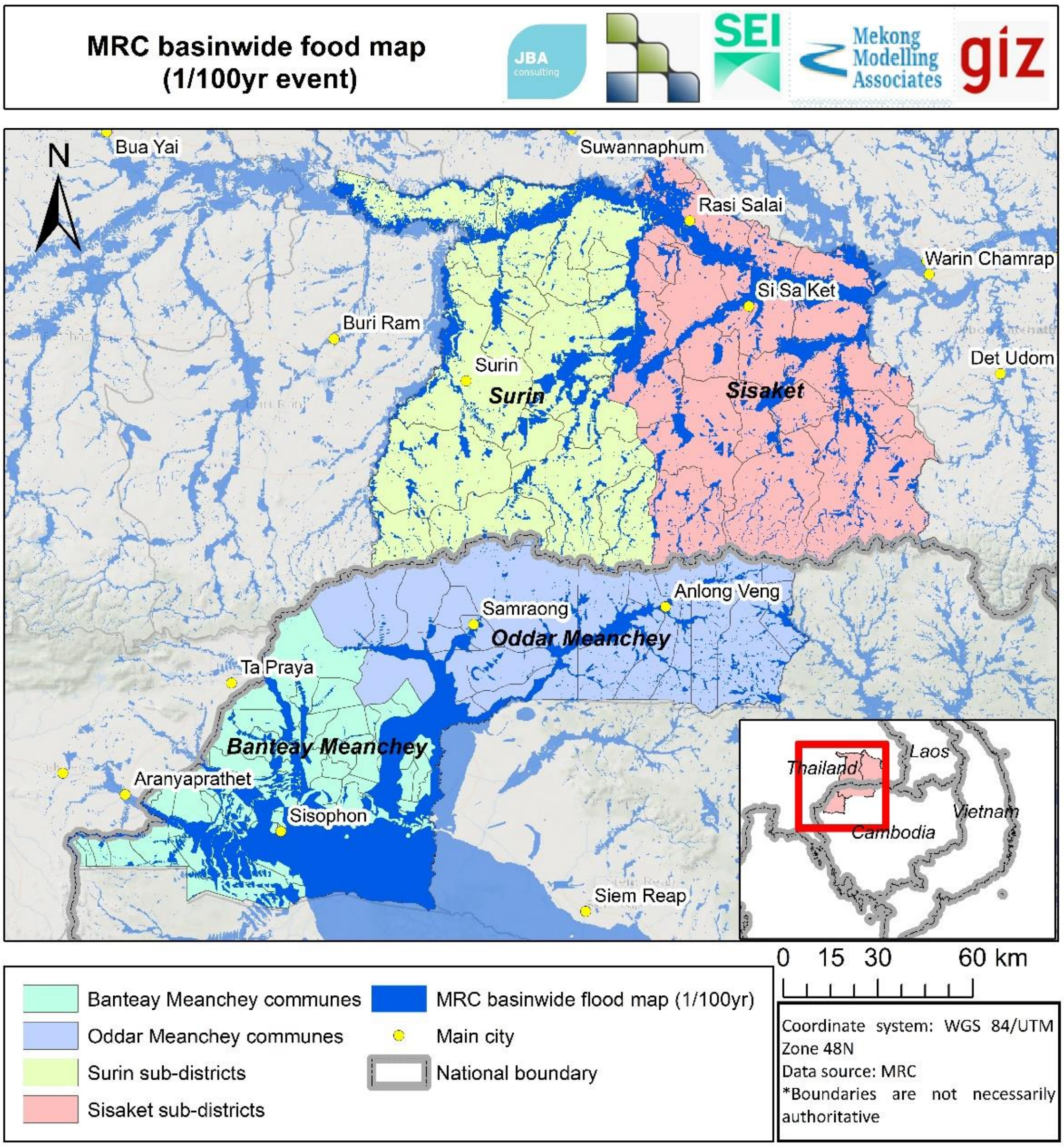
2.3.1 Flood Mapping and spatial analysis

During the 9T/9C Transboundary Flood and Drought Mapping project high resolution flood maps of Beanteay Meanchey[1]. The study created a 1/5, 1/20 and 1/100 year events with a resolution of 10 x 10m. However, for Oddar Meanchey a MRC basin wide flood map is used for risk analysis. To reduce error in the results, flood depths below 0.5m (MRC) and 0.3 (JBA) were removed. The analysis was computed on a 1/100-year event i.e. a rare once in a lifetime.

All analysis is to a commune scale in Cambodia and at a district level in Thailand. Initially, the flood maps were vectorised, and we extracted the area that were damaged. Using this data, we could review land-use, urban areas and population datasets to calculate the overall flood risk in a commune.



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[1] JBA and MMA (2019) – Transboundary Water Resource Management in the Lower Mekong Basin Joint Project Flood and Drought. Thailand and Cambodia 9T/9C. GIZ.

2.3.2 Hazard Risk Methodology

The Risk Model used was created in Excel and is designed to be near-identical in structure and parameterisation for flood and drought. It comprises of a raw data table and a standardised scoring system. The table follows the risk equation for each commune in Banteay and Oddar Meanchey:

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Whereby: hazard is a potential of natural geohazard or hydro-meteorological events that may cause damages in an area over a given period. Vulnerability is a collection of factors that exacerbate the initial hazard.

In this flood risk assessment, the hazard is simply the area of commune that is flooded over 0.3m in a 1/100 year event.

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LOCATION			RISK	FLOOD HAZARD			EXPOSURE						VULNERABILITY			
Province	District	Commune	Derived Risk Ranking	Flooded composite extents (ha) 5-year	20-year	100-year	Total Pop Flooded	URB POP Flooded	RUR POP Flooded	Crop 1 ha	Crop 2 ha	Urban Area ha	URB Inc $/person	RUR Inc $/person	Crop 1	Crop 2
		Weights		1.00	1.00	1.00	n/a	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Odtar Meanchey	Banteay Ampil	Ampil	76	n/a	n/a	260	163	0	163	151	227	0	$ 1,169.00	$ 867.00	$ 69,290.82	$ 306,362
Odtar Meanchey	Anlong Veaeng	Anlong Veaeng	47	n/a	n/a	2716	5589	3952	1637	76	416	508	$ 1,169.00	$ 867.00	$ 34,645.41	$ 561,664.13
Odtar Meanchey	Trapeang Prasat	Bak Anloung	74	n/a	n/a	3088	2270	264	2006	0	113	0	$ 1,169.00	$ 867.00	$ -	$ 153,181.13
Odtar Meanchey	Samraong	Bansay Reak	87	n/a	n/a	0	51	51	0	0	0	22.09	$ 1,169.00	$ 867.00	$ -	$ -
Beanteay Meanchey	Thma Puok	Banteay Chhmar	53	2175	2935	3838	354	99	255	0	1362	88.36	$ 1,169.00	$ 867.00	$ -	$ 1,838,173.50
Beanteay Meanchey	Mongkol Borei	Banteay Neang	3	554	663	737	17148	13890	3258	416	3442	927.78	$ 1,169.00	$ 867.00	$ 190,549.76	$ 4,646,494.13
Beanteay Meanchey	Mongkol Borei	Bat Trang	19	1781	2828	3892	7815	6769	1046	1324	2080	287.17	$ 1,169.00	$ 867.00	$ 606,294.68	$ 2,808,320.63
Odtar Meanchey	Banteay Ampil	Beng	7	n/a	n/a	6828	9906	2999	6906	6430	1929	265.08	$ 1,169.00	$ 867.00	$ 2,944,859.85	$ 2,604,079.13
Beanteay Meanchey	Malai	Boeng Beng	83	635	741	835	846	0	846	0	0	22.09	$ 1,169.00	$ 867.00	$ -	$ -
Beanteay Meanchey	Preah Netr Preah	Bos Sbov	31	2028	3480	4702	4551	2740	1810	3593	416	132.54	$ 1,169.00	$ 867.00	$ 1,645,656.98	$ 561,664.13
Odtar Meanchey	Samraong	Bos Sbov I	45	n/a	n/a	200	2531	996	1535	1853	454	287.17	$ 1,169.00	$ 867.00	$ 848,812.55	$ 612,724.50
Beanteay Meanchey	Mongkol Borei	Chamnaom	12	1112	2495	3731	4576	2345	2231	681	4463	154.63	$ 1,169.00	$ 867.00	$ 311,808.69	$ 6,025,124.25
Beanteay Meanchey	Ou Chrov	Changha	25	4478	5438	5810	5948	4711	1237	4766	303	176.72	$ 1,169.00	$ 867.00	$ 2,182,660.83	$ 408,483.00
Odtar Meanchey	Chong Kal	Cheung Tien	17	n/a	n/a	5512	3352	1460	1892	4614	908	375.53	$ 1,169.00	$ 867.00	$ 2,113,370.01	$ 1,225,449.00
Beanteay Meanchey	Preah Netr Preah	Chnuor Mean Chey	33	1492	1827	2235	4506	2816	1690	3177	567	132.54	$ 1,169.00	$ 867.00	$ 1,455,107.22	$ 765,905.63
Beanteay Meanchey	Preah Netr Preah	Chob Vari	44	1812	2228	2615	3585	2928	657	1286	681	265.08	$ 1,169.00	$ 867.00	$ 588,971.97	$ 919,086.75
Odtar Meanchey	Chong Kal	Chong Kal	65	n/a	n/a	6036	873	62	811	1172	227	0	$ 1,169.00	$ 867.00	$ 537,003.86	$ 306,362.25
Beanteay Meanchey	Serei Saophoan	Kampong Svay	51	568	1019	1289	3614	2967	646	2307	189	154.63	$ 1,169.00	$ 867.00	$ 1,056,685.01	$ 255,301.88
Beanteay Meanchey	Serei Saophoan	Kaoh Pong Satv	52	523	560	607	5224	2700	2525	340	681	176.72	$ 1,169.00	$ 867.00	$ 155,904.35	$ 919,086.75
Beanteay Meanchey	Ou Chrov	Koub	42	1777	2120	2484	2378	1851	527	1891	946	132.54	$ 1,169.00	$ 867.00	$ 866,135.25	$ 1,276,509.38
Beanteay Meanchey	Mongkol Borei	Kouk Ballangk	28	1416	1480	1695	6113	4445	1669	1475	1210	353.44	$ 1,169.00	$ 867.00	$ 675,585.50	$ 1,633,932.00
Beanteay Meanchey	Thma Puok	Kouk Kakthen	85	583	893	1181	0	0	0	76	0	22.09	$ 1,169.00	$ 867.00	$ 34,645.41	$ -
Odtar Meanchey	Banteay Ampil	Kouk Khpos	86	n/a	n/a	56	82	3	79	151	0	0	$ 1,169.00	$ 867.00	$ 69,290.82	$ -
Odtar Meanchey	Banteay Ampil	Kouk Mon	69	n/a	n/a	300	481	193	289	454	416	22.09	$ 1,169.00	$ 867.00	$ 207,872.46	$ 561,664.13
Beanteay Meanchey	Thma Puok	Kouk Romiet	14	7455	8090	8705	4285	3304	981	2345	2421	706.88	$ 1,169.00	$ 867.00	$ 1,074,007.71	$ 3,267,864.00
Odtar Meanchey	Samraong	Koun Kriel	67	n/a	n/a	3700	804	163	641	378	227	132.54	$ 1,169.00	$ 867.00	$ 173,227.05	$ 306,362.25
Beanteay Meanchey	Mongkol Borei	Koy Maeng	48	1694	1788	1894	5048	4091	958	378	1059	176.72	$ 1,169.00	$ 867.00	$ 173,227.05	$ 1,429,690.50
Odtar Meanchey	Chong Kal	Krasang	20	n/a	n/a	5124	836	399	437	3101	1513	508.07	$ 1,169.00	$ 867.00	$ 1,420,461.81	$ 2,042,415.00
Beanteay Meanchey	Thma Puok	Kumru	62	1516	1874	2200	1024	692	331	946	303	88.36	$ 1,169.00	$ 867.00	$ 433,067.63	$ 408,483.00
Beanteay Meanchey	Ou Chrov	Kuttasat	29	582	2069	2841	3824	2637	1187	2572	1286	176.72	$ 1,169.00	$ 867.00	$ 1,177,943.94	$ 1,736,052.75
Odtar Meanchey	Anlong Veaeng	Lumtong	59	n/a	n/a	8184	6193	1877	4316	0	113	154.63	$ 1,169.00	$ 867.00	$ -	$ 153,181.13
Beanteay Meanchey	Malai	Malai	68	670	797	888	3736	2071	1665	38	227	44.18	$ 1,169.00	$ 867.00	$ 17,322.71	$ 306,362.25
Beanteay Meanchey	Serei Saophoan	Mkak	41	2823	3802	4462	2516	2162	353	3139	303	198.81	$ 1,169.00	$ 867.00	$ 1,437,784.52	$ 408,483.00

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LOCATION			EXPOSURE			VULNERABILITY				Hazard	Exposure	Vulnerability			
Province	District	Commune	Crop 1 ha	Crop 2 ha	Urban Area ha	URB Inc $/per	RUR Inc $/per	Crop 1 $ M	Crop 2 $ M						
		Weights	1.00	1.00	1.00	1.00	1.00	ha	#REF!				1.00	HI	Rank
Odtar Meanchey	Banteay Ampil	Ampil	0.01	0.05	0.00	1.00	1.00	0.01	0.05	0.02	0.02	0.52	0.04	0	76
Odtar Meanchey	Anlong Veaeng	Anlong Veaeng	0.01	0.09	0.55	1.00	1.00	0.01	0.09	0.18	0.10	0.53	0.28	0.2	47
Odtar Meanchey	Trapeang Prasat	Bak Anloung	0.00	0.03	0.00	1.00	1.00	0.00	0.03	0.21	0.04	0.51	0.05	0.1	74
Odtar Meanchey	Samraong	Bansay Reak	0.00	0.00	0.02	1.00	1.00	0.00	0.00	0.00	0.00	0.50	0.01	0	87
Beanteay Meanchey	Thma Puok	Banteay Chhmar	0.00	0.31	0.10	1.00	1.00	0.00	0.31	0.26	0.08	0.58	0.21	0.1	53
Beanteay Meanchey	Mongkol Borei	Banteay Neang	0.04	0.77	1.00	1.00	1.00	0.04	0.77	0.05	0.43	0.70	0.95	0.4	3
Beanteay Meanchey	Mongkol Borei	Bat Trang	0.13	0.47	0.31	1.00	1.00	0.13	0.47	0.26	0.25	0.65	0.52	0.3	19
Odtar Meanchey	Banteay Ampil	Beng	0.62	0.43	0.29	1.00	1.00	0.62	0.43	0.46	0.42	0.76	0.84	0.4	7
Beanteay Meanchey	Malai	Boeng Beng	0.00	0.00	0.02	1.00	1.00	0.00	0.00	0.06	0.01	0.50	0.02	0	83
Beanteay Meanchey	Preah Netr Preah	Bos Sbov	0.35	0.09	0.14	1.00	1.00	0.35	0.09	0.32	0.18	0.61	0.36	0.2	31
Odtar Meanchey	Samraong	Bos Sbov I	0.18	0.10	0.31	1.00	1.00	0.18	0.10	0.01	0.11	0.57	0.28	0.1	45
Beanteay Meanchey	Mongkol Borei	Chamnaom	0.07	1.00	0.17	1.00	1.00	0.07	1.00	0.25	0.33	0.77	0.72	0.4	12
Beanteay Meanchey	Ou Chrov	Changha	0.46	0.07	0.19	1.00	1.00	0.46	0.07	0.39	0.21	0.63	0.43	0.2	25
Odtar Meanchey	Chong Kal	Cheung Tien	0.45	0.20	0.40	1.00	1.00	0.45	0.20	0.37	0.21	0.66	0.53	0.3	17
Beanteay Meanchey	Preah Netr Preah	Chnuor Mean Chey	0.31	0.13	0.14	1.00	1.00	0.31	0.13	0.15	0.17	0.61	0.35	0.2	33
Beanteay Meanchey	Preah Netr Preah	Chob Vari	0.12	0.15	0.29	1.00	1.00	0.12	0.15	0.18	0.12	0.57	0.28	0.2	44
Odtar Meanchey	Chong Kal	Chong Kal	0.11	0.05	0.00	1.00	1.00	0.11	0.05	0.41	0.06	0.54	0.11	0.1	65
Beanteay Meanchey	Serei Saophoan	Kampong Svay	0.22	0.04	0.17	1.00	1.00	0.22	0.04	0.09	0.11	0.57	0.24	0.1	51
Beanteay Meanchey	Serei Saophoan	Kaoh Pong Satv	0.03	0.15	0.19	1.00	1.00	0.03	0.15	0.04	0.12	0.55	0.23	0.1	52
Beanteay Meanchey	Ou Chrov	Koub	0.18	0.21	0.14	1.00	1.00	0.18	0.21	0.17	0.13	0.60	0.30	0.2	42
Beanteay Meanchey	Mongkol Borei	Kouk Ballangk	0.14	0.27	0.38	1.00	1.00	0.14	0.27	0.11	0.19	0.60	0.42	0.2	28
Beanteay Meanchey	Thma Puok	Kouk Kakthen	0.01	0.00	0.02	1.00	1.00	0.01	0.00	0.08	0.00	0.50	0.01	0	85
Odtar Meanchey	Banteay Ampil	Kouk Khpos	0.01	0.00	0.00	1.00	1.00	0.01	0.00	0.00	0.01	0.50	0.01	0	86
Odtar Meanchey	Banteay Ampil	Kouk Mon	0.04	0.09	0.02	1.00	1.00	0.04	0.09	0.02	0.04	0.53	0.09	0	69
Beanteay Meanchey	Thma Puok	Kouk Romiet	0.23	0.54	0.76	1.00	1.00	0.23	0.54	0.59	0.25	0.69	0.69	0.4	14
Odtar Meanchey	Samraong	Koun Kriel	0.04	0.05	0.14	1.00	1.00	0.04	0.05	0.25	0.04	0.52	0.10	0.1	67

Vulnerability in this assessment has been defined by the amount of people, urban areas and crops affected. Urban areas are defined by the MRC Land Cover dataset. For crops, we have divided it into two: wet season rice and field crops (maize and cassava). For the population, a Commune Raster is used and then divided into urban and rural through the MRC(2010) land cover shapefile.

This analysis requires heavily on the dataset available, which in turn are often difficult to access or low resolution. For example, to calculate the individual income is difficult to obtain at commune level. In Cambodia, the required economic statistics are only available at national level, therefore, values of $1,162 and $867 /person/year for urban and rural areas, respectively.

This study has also attempted to quantify the damage cost to crops. From remote sensing data it is difficult to be completely sure on what crop type is used, but this study used WISDOM land-cover dataset. As there is a good classification of rice and other crop plantation. In Cambodia, Wet Season Rice ("heavy rice") has a farm-gate value in the range $225-257/tonne, average gross revenue therefore of $458/ha. Crop 2 is cassava, where the gross revenue in non-drought years is $1350/ha.

The standardisation of scores is a relative exercise, where indicators between elements are scaled in order to establish a comparative scoring system (between 0-1). In order to make the comparisons between different communes, their individual values then require ranking with respect to each other. Therefore, for an individual hazard or vulnerability, the indicator is calculated by:

$$HI = 1 - (\frac{value - \min(values)}{\max(values) - \min(values})$$

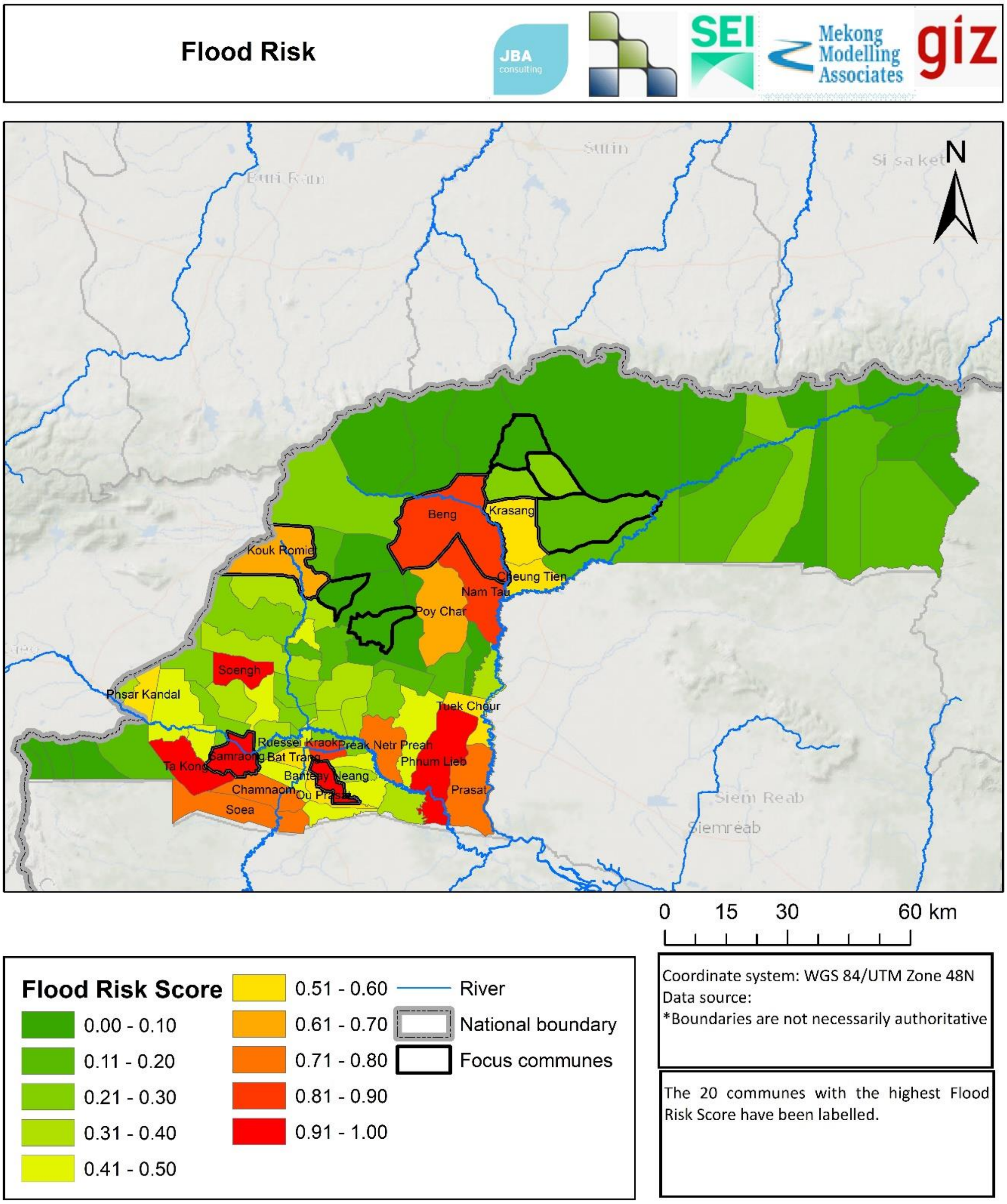
Where a low value indicates a high hazard or vulnerability.

$$HI = \frac{value - \min(values)}{\max(values) - \min(values}$$

Where a high value indicates a high hazard or vulnerability.

Assuming there are n individual indicators of e.g. exposure, then the composite exposure index (HI) is calculated as the arithmetic mean of the n-indicator values

$$HI = \frac{HI_1 + HI_2 + HI_3 + HI_4}{4}$$



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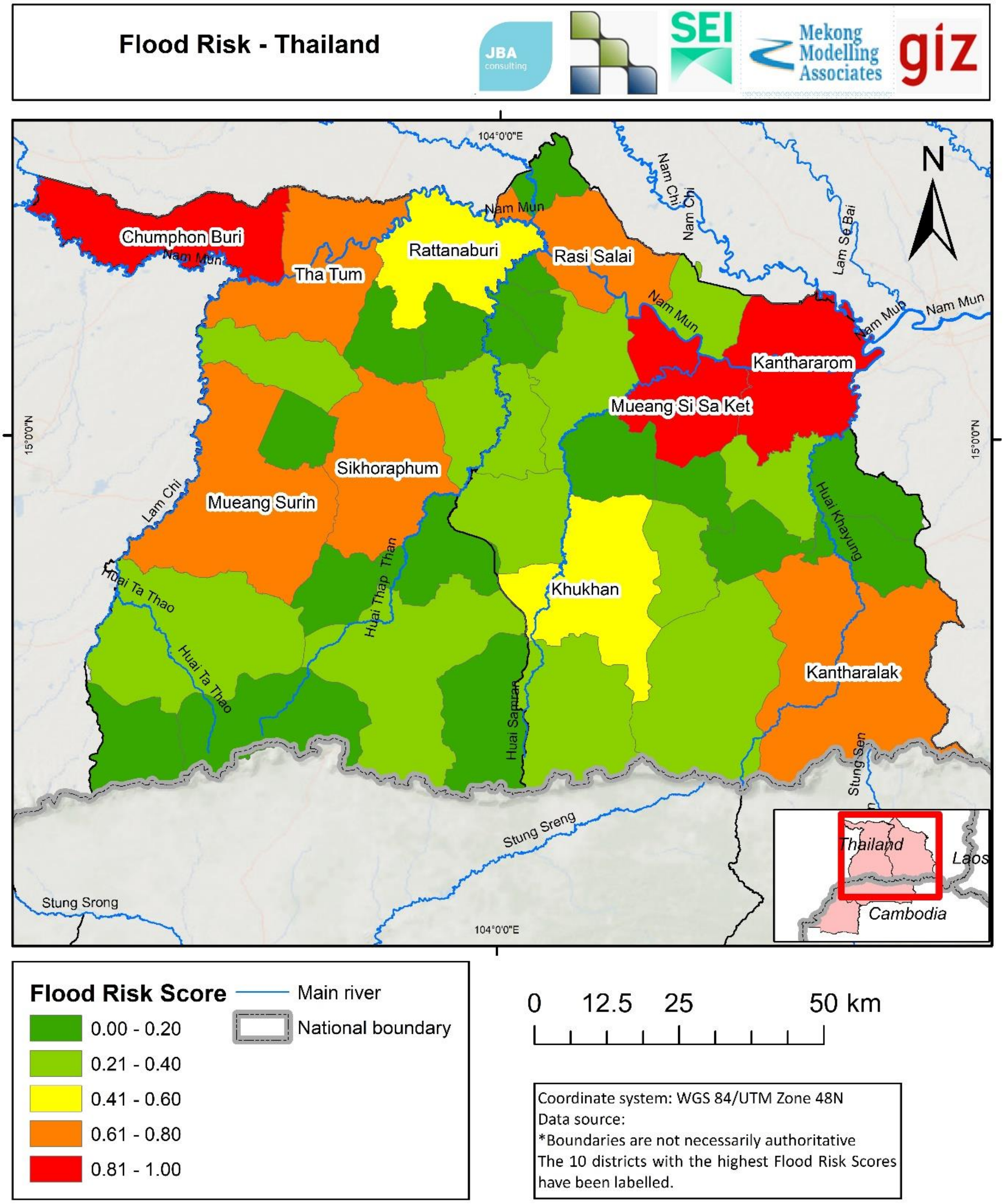

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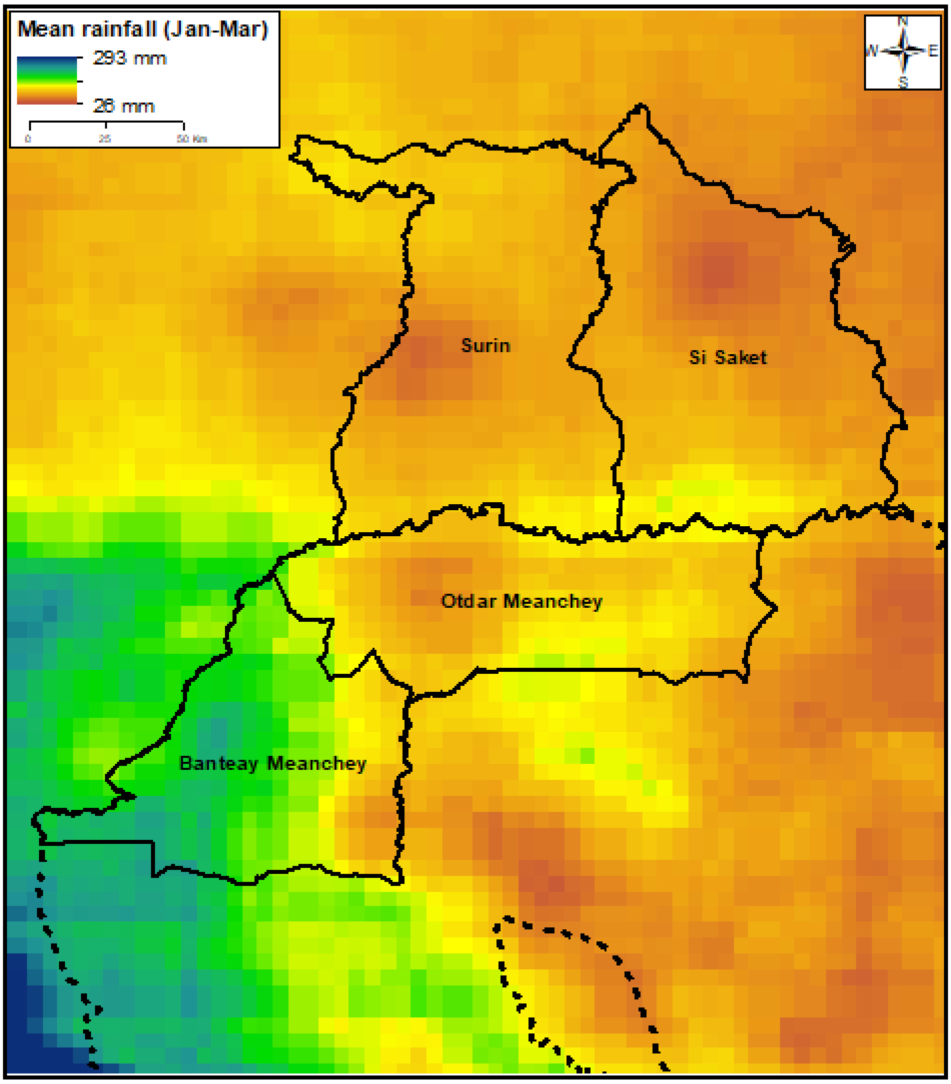
This section characterizes drought in the study area in two ways: (i) by examining impacts of a single historical event (2016) and (ii) by evaluating overall drought hazard, vulnerability and risk from the risk assessment method described earlier.

2.4.1 2016 Drought event

The severity of the 2016 drought event is illustrated by Figure 2-11 and Figure 2-12, which respectively show the mean rainfall in January to March over a 10-year period (2010 – 2019) and the percentage of this mean rainfall occurring in January – March, 2016. Data are derived from the CHIRPS satellite-based dataset[2]. It is clear that, in general, Banteay Meanchey is, on average, significantly wetter than the other three provinces considered in the study influenced by the higher rainfall from the coastal area and the effect of the Cardaman montains. However in 2016, only a maximum of 65% of normal rainfall amounts occurred in the study area. Most heavily affected in relative terms are large parts of Banteay Meanchey and the northeast of Si Saket. In absolute terms, areas that are red in Figure 2-7 and brown Figure 2-8 experienced the lowest rainfall in January – March 2016. This is especially the case for the northeast of Si Saket province.



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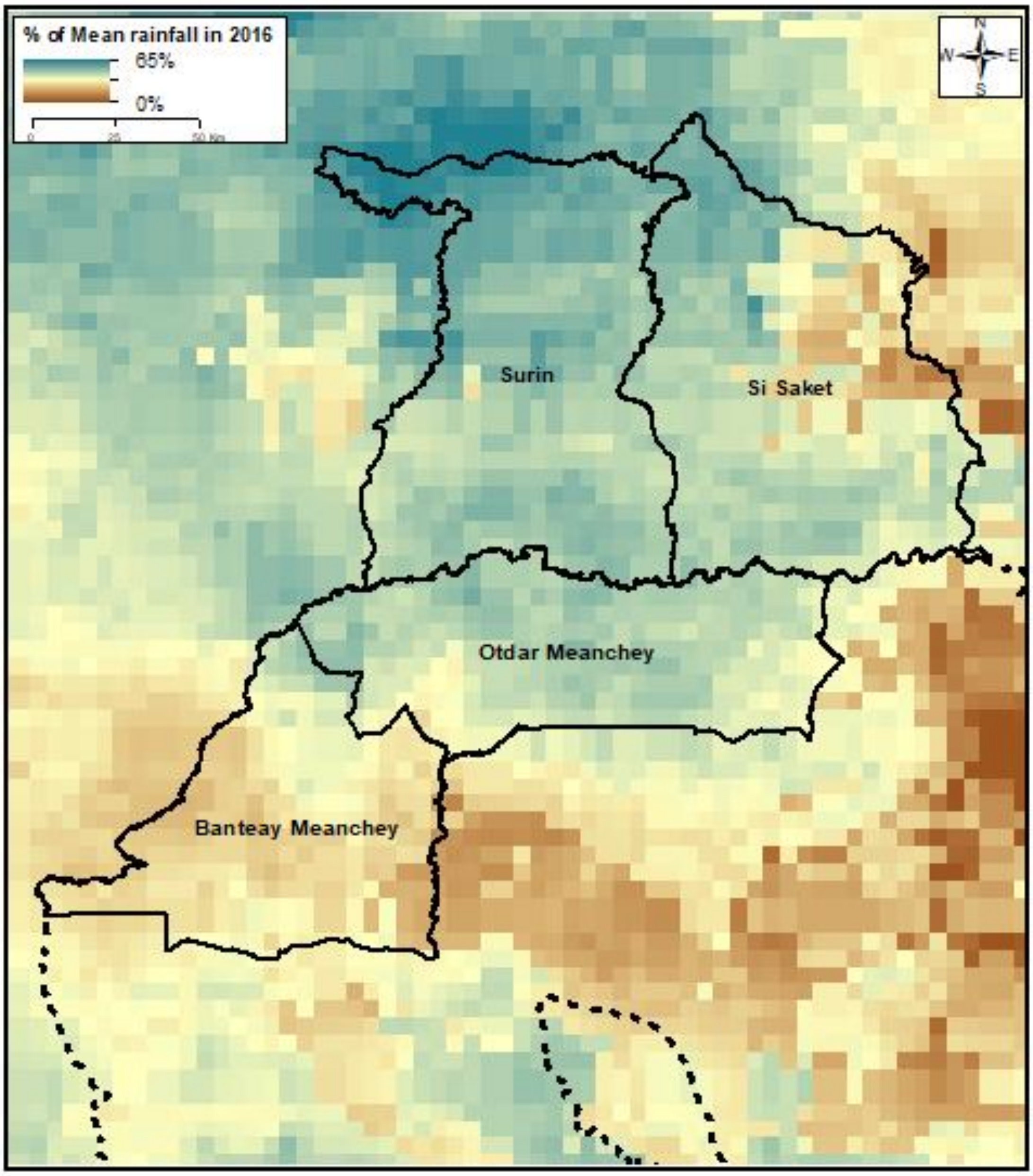
[2] https://www.chc.ucsb.edu/data/chirps



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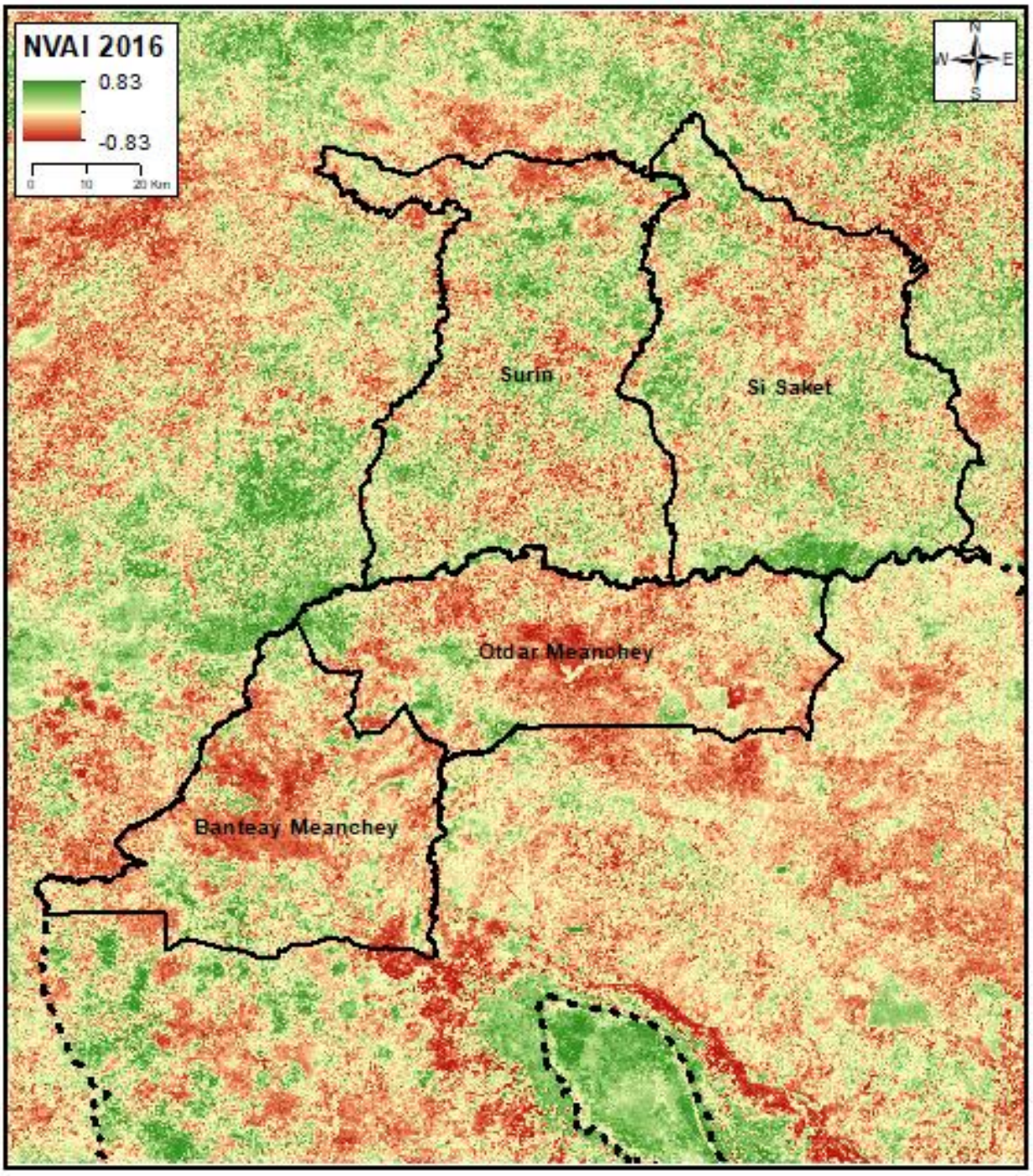
Spatial rainfall patterns are logically related through wetness of the surface and soil profile to vegetation health and land surface temperature. However, by managing water storage and supply, impacts of drought on vegetation can be mitigated. Figure 2-9 shows the Normalized Vegetation Anomaly Index (NVAI) for the four provinces, for January – March 2016. The NVAI compares the Normalized Difference Vegetation Index (NDVI) for a specific period to the range of values observed in the same period in previous years. The NVAI is expressed between -1 and 1 and provides an anomaly indicator relative to its long-term mean. Lower and higher values indicate bad and good vegetation state conditions, respectively. In a similar manner, the Normalized Temperature Anomaly Index (NTAI) expresses anomalies in satellite-derived land surface temperature (Figure 2-10). MODIS NDVI and LST products were used for creation of these maps. It is clear that, especially in the Cambodian provinces, vegetation (mostly cropland) was negatively affected by the lack of rainfall. The strong negative anomalies in NDVI and LST in Oddar Meanchey are likely exacerbated by deforestation which occurred since 2010.



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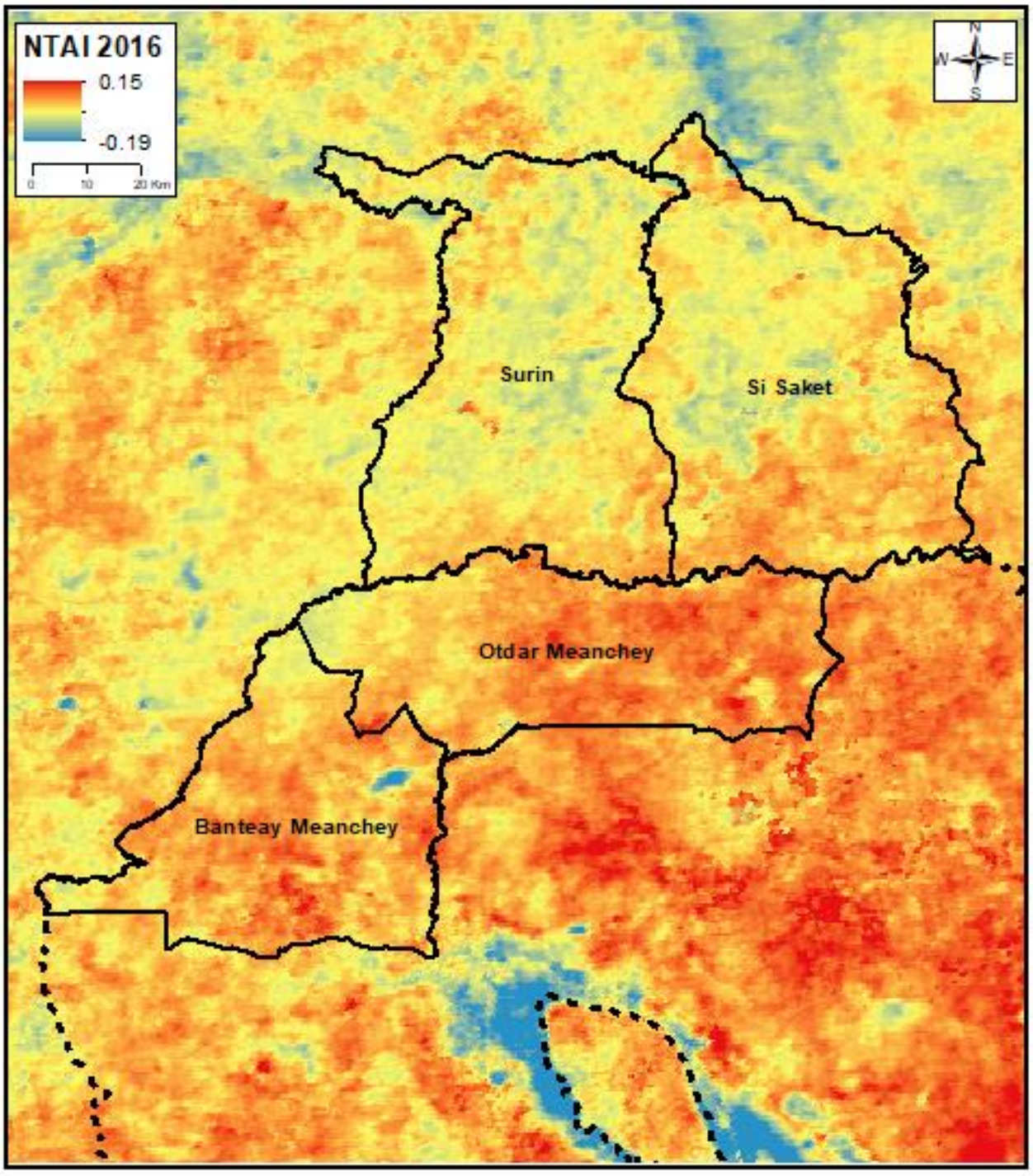

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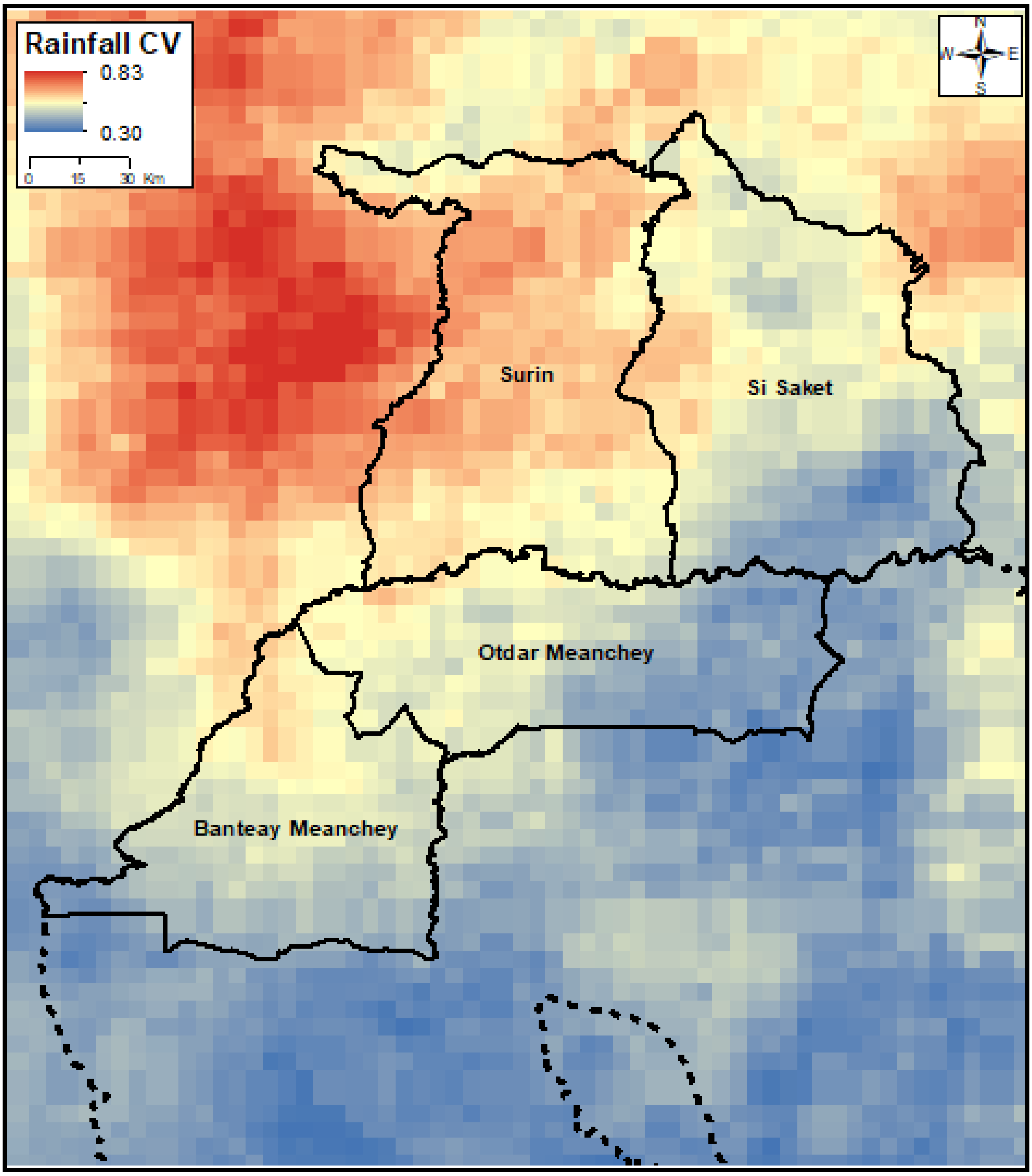
2.4.2 Drought Hazard

The approach of Terink et al (2011), previously applied in the Mekong Basin, integrates four hazard indices into an overall drought hazard index:

1. Average rainfall (P_{mean}), see Figure 2-7
2. Coefficient of variation of rainfall (P_{CV})
3. Average NDVI ($NDVI_{mean}$)
4. Coefficient of variation of ($NDVI_{CV}$)

A similar approach was pursued for the current analysis, also adding mean land surface temperature (LST_{mean}) as an extra indicator of drought hazard. The period of analysis is once again the months January to March.

P_{CV} is presented in Figure 2-11. Rainfall is especially variable in Surin province. In combination with an overall low rainfall in these months (Figure 2-7), this means that the meteorological drought hazard is particularly high in this province. Rainfall amounts are relatively stable in southern Banteay Meanchey and eastern Oddar Meanchey.



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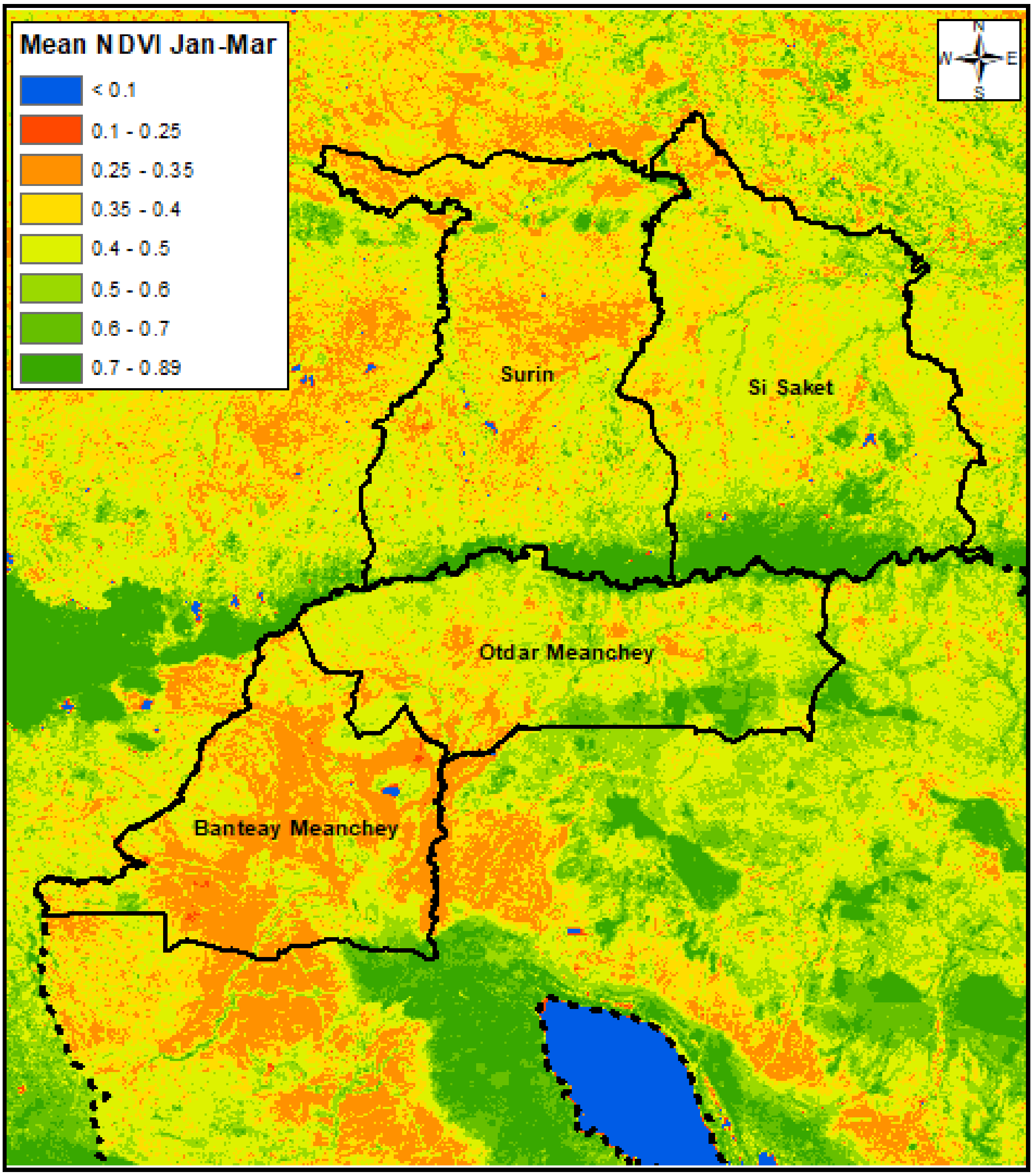
$NDVI_{mean}$ (Figure 2-12) is highest in the forested areas in the south of the Thai provinces, and the south of Oddar Meanchey. Particularly striking is the rather low $NDVI_{mean}$ of the croplands of Banteay Meanchey.



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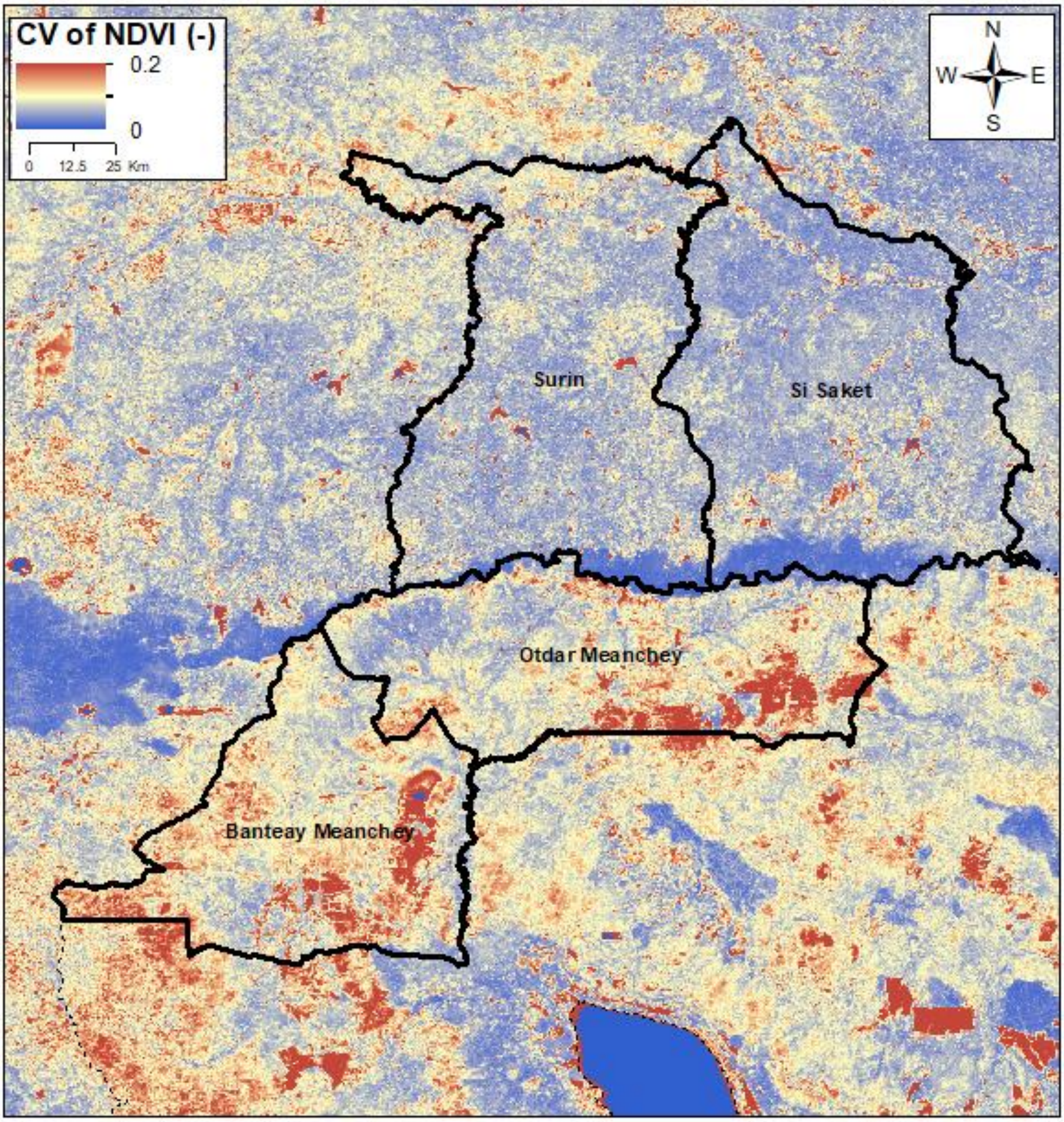
The fourth hazard index originally selected is $NDVI_{CV}$, which is presented in Figure 2-13. Striking are the blue colours on the Thai side along the border, indicating healthy forest cover with limited variability in NDVI. In general, the Thai provinces exhibit less variability in NDVI than their Cambodian counterparts. An interesting phenomenon is presented by the red patches in both Cambodian provinces, particularly in Oddar Meanchey. Here, the analysis shows a very high variability in NDVI in 2010 – 2019, which in our approach would increase the overall Drought Hazard Index. However, the contrasting red areas are in fact largely indicative of forest loss, which is strongly reflected in NDVI values. This is thus a variability not attributable to drought but more associated with significant land cover changes in the reference period. Although this is an interesting observation, it was decided to not include $NDVI_{CV}$ as a hazard index. Instead, mean land surface temperature (Figure 2-14) was added as the fourth index. LST can be regarded a proxy for moisture content at the land surface. It is a striking observation that LST on the Cambodian side of the border are higher than in the Thai provinces. This can be partly due to water management practices in the Thai provinces, with multiple

reservoirs enhancing options for water storage and thus for wetting the soil in dry times. It should however be noted that spatial patterns in climate, due to higher elevations occurring along the border, may also play a role.



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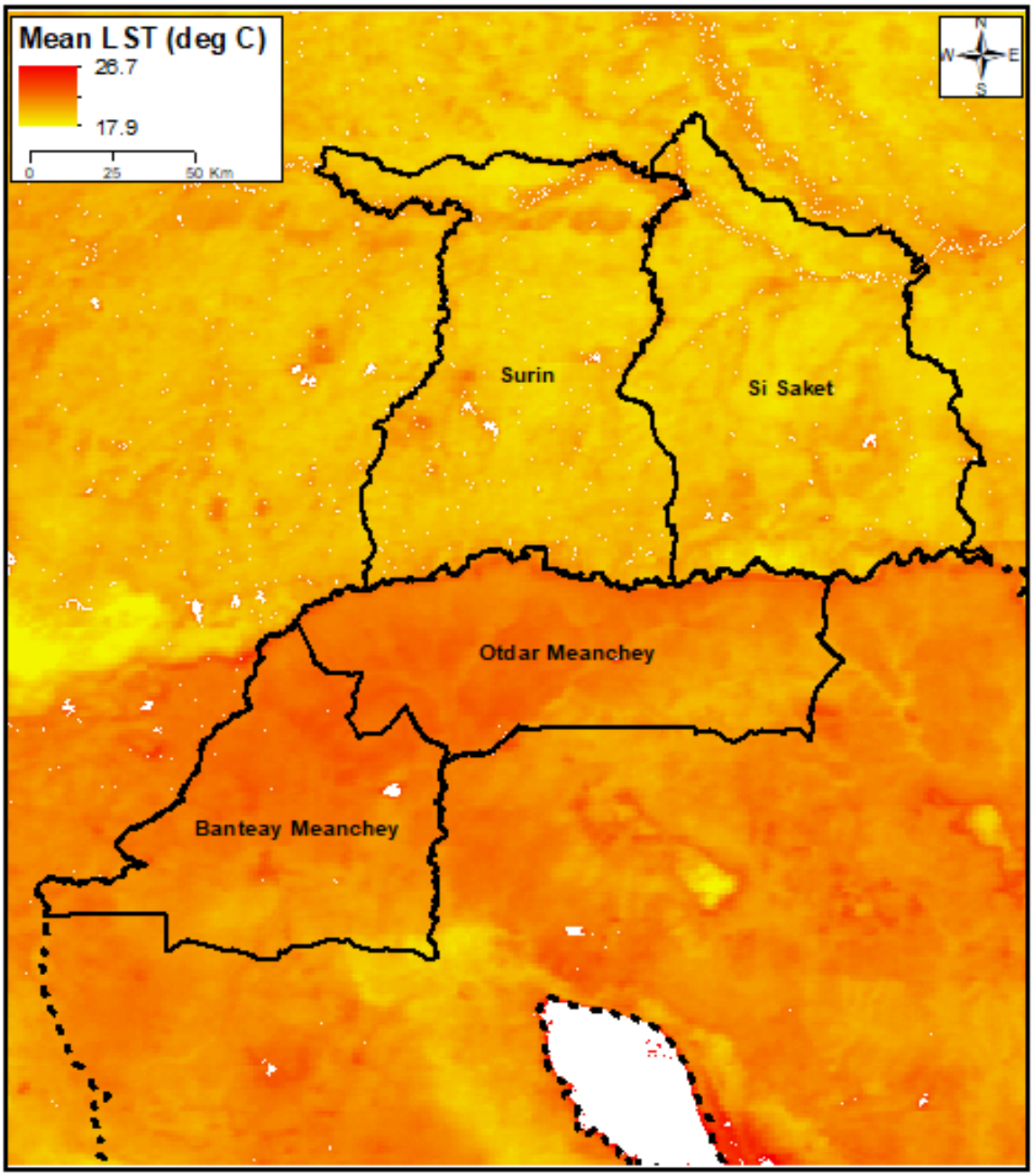

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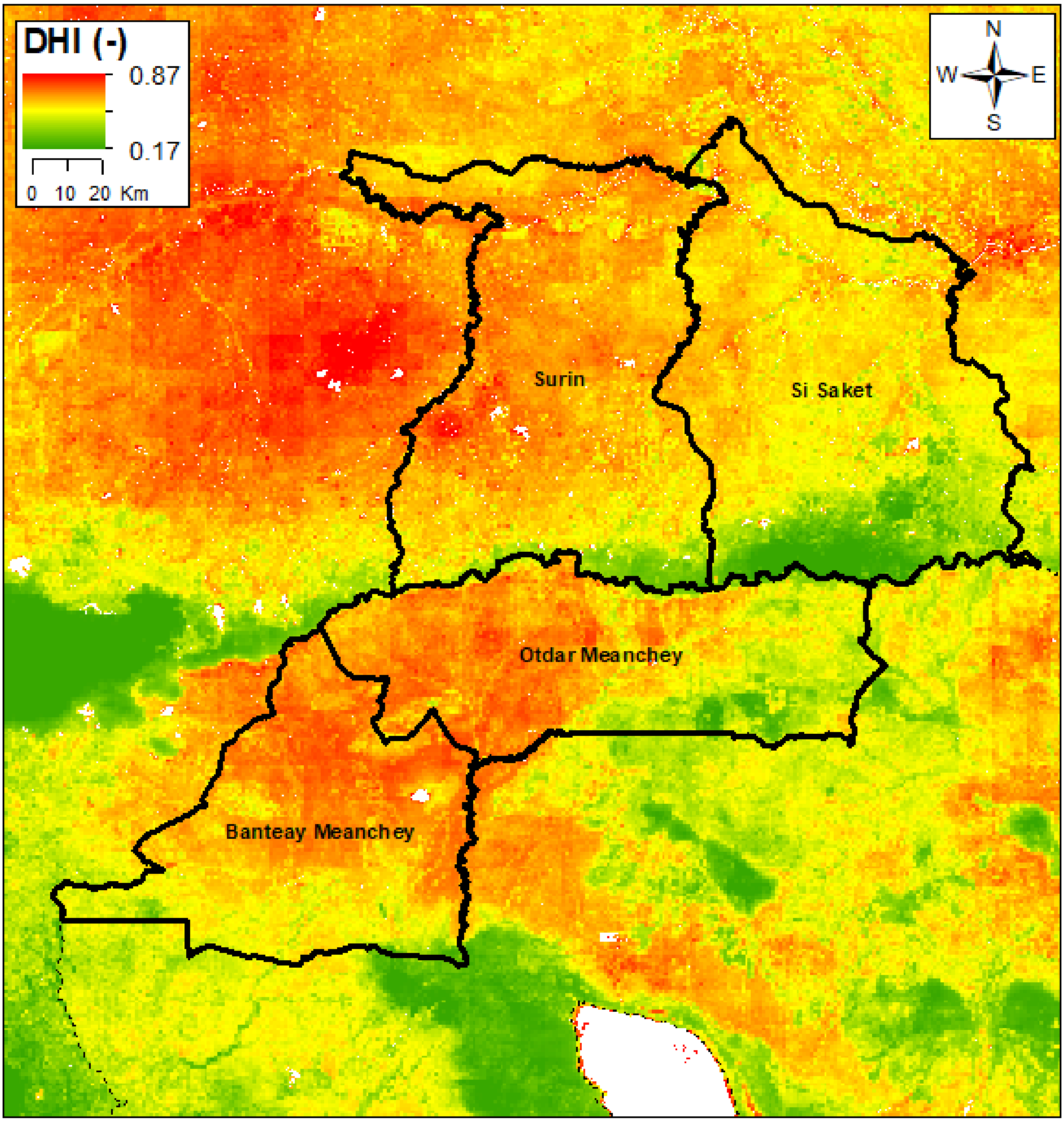
The map of the integrated Drought Hazard Index is presented in Figure 2-15. High drought hazards are expected in western Surin, northern Banteay Meanchey and western Oddar Meanchey. Overall, Sisaket is the province where the lowest values occur. Figure 2-16 aggregates the Drought Hazard Index values at the commune level for the Cambodian provinces.



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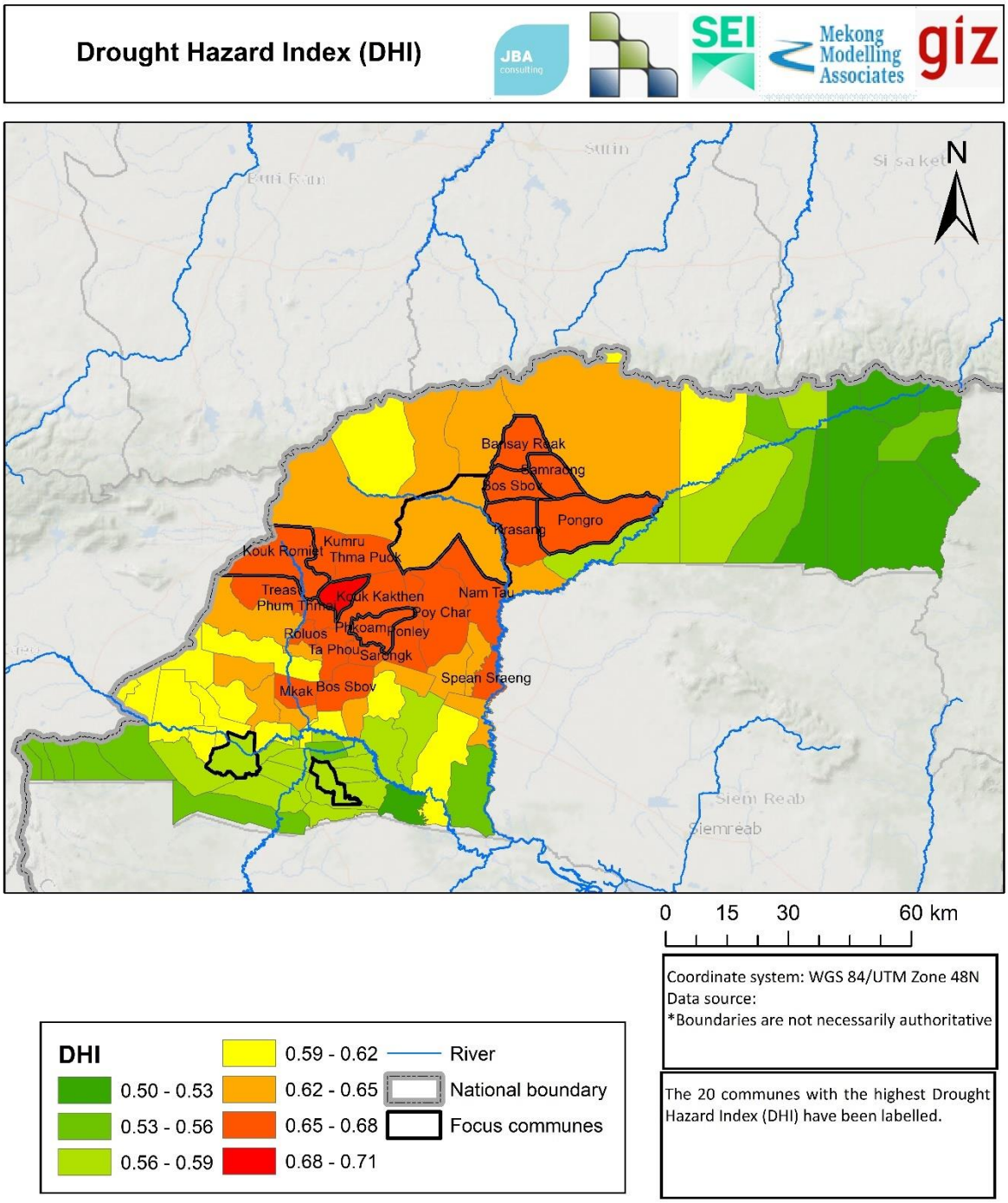
2.1.1 Methods

For drought planning it is already apparent that the changing climate must be fully integrated in planning and analysis. The approach uses a number of datasets to give an insight into climate trends in both the past and future. This allows for the anticipation of changes in climate which may be detrimental to project components. Trends in both average and extreme climate are analysed, with different datasets and methodologies used for each purpose.



CʌƎdzNŜ HTMCY LyűŜƎNI-űŜŘ 5N2dzƎKű I I-ÎI-NŘ LyŘŜĚ I-ØŜNI-ƎŜŘ LJŜN Ŏ2YY dzyŜ ʎy´úKŜ /I-Y ō2ŘʌI-y´LJN2ØʎyŎŜă¢

The ERA5[3] reanalysis product is used to represent historical trends in temperature and precipitation for the given area of interest. This product is used as it provides global, spatially gridded time series of a number of climate variables at resolutions of 31km and sub-daily (3hr) timescales. The dataset is fully operational (updated every month) and runs from 1979 to present. From this dataset, spatially averaged time series of precipitation and temperature are extracted for the project area at daily, weekly and yearly timescales for the entire period that the dataset covers. This allows for the analysis of annual and seasonal trends in historical climate alongside extremes.

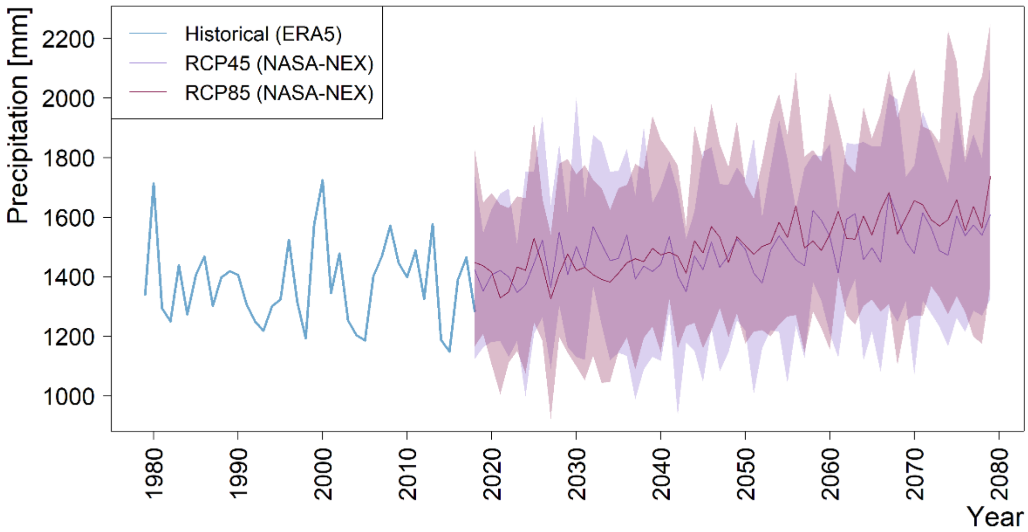
[3] https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5

NASA-NEX[4] dataset is used to provide analysis of future climate trends in temperature and precipitation. This product is used as it provides spatially gridded time series of temperature and precipitation outputted by 21 General Circulation Models with global coverage. Data is available at downscaled resolutions of ~25 km and daily timeseries, covering "historical" (1950 – 2005) and "future" (2005 – 2100) periods and varying emissions scenarios (RCP 4.5, 8.5). From this dataset, spatially averaged time series of precipitation and temperature are extracted for the project area at daily, weekly and yearly timescales for the entire period that the dataset covers. This allows for the analysis of annual and seasonal trends in future climate.

To determine future trends in extreme climate events, CLIMDEX[5] variables are used. These represent a standardised, peer reviewed way of representing extremes in climate data and are widely used in climate analyses. These are produced through processing the NASA-NEX dataset with Climate Data Operator (CDO) software. This takes as input spatially gridded daily time series and returns yearly series of CLIMDEX indices. This process is useful as it effectively reduces the amount of data analysis needed whilst retaining the ability to represent extremes within data in a standardised, comparable way.

2.1.2 Precipitation and temperature

Figure 2-17 shows historical and projected annual precipitation over the study area until 2080. A generally increasing trend can be identified, although the range of individual climate results is large. Limited differences exist between RCP4.5 and RCP8.5 scenarios.



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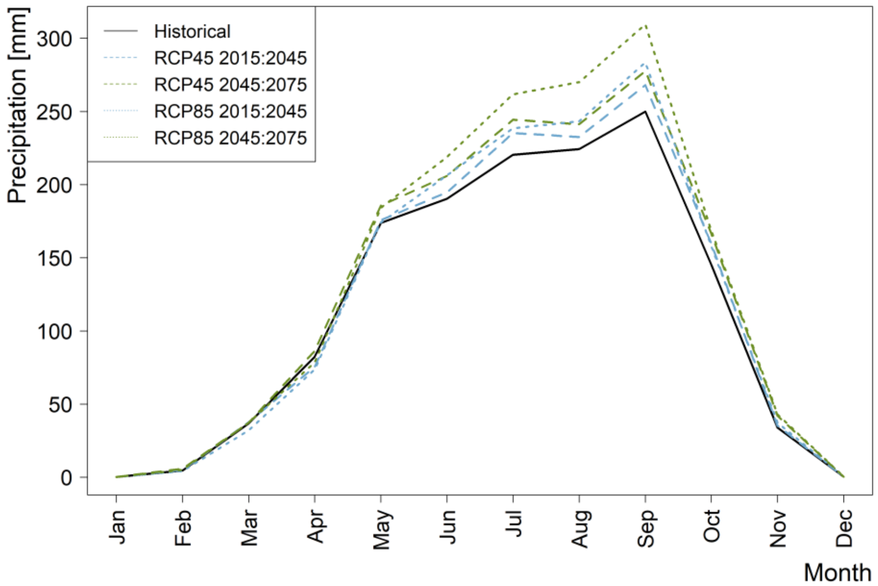
Looking solely at annual values suggests an increase in water resources, which could be considered beneficial to agriculture and other water uses. However, it is important to also take seasonality of precipitation patterns into consideration. Figure 2-18 shows that the increase in rainfall is projected to occur in the months that are already quite wet, with September expected to see the greatest increase. This means that the extent to which the additional rainfall can actually be put to beneficial use, will depend on storage options in the water system. Moreover, the extra precipitation occurring towards the end of the rainy season, when soils are already fully saturated, is likely to increase flood risk.

[4] https://www.nasa.gov/nex

[5] https://www.climdex.org/learn/indices/



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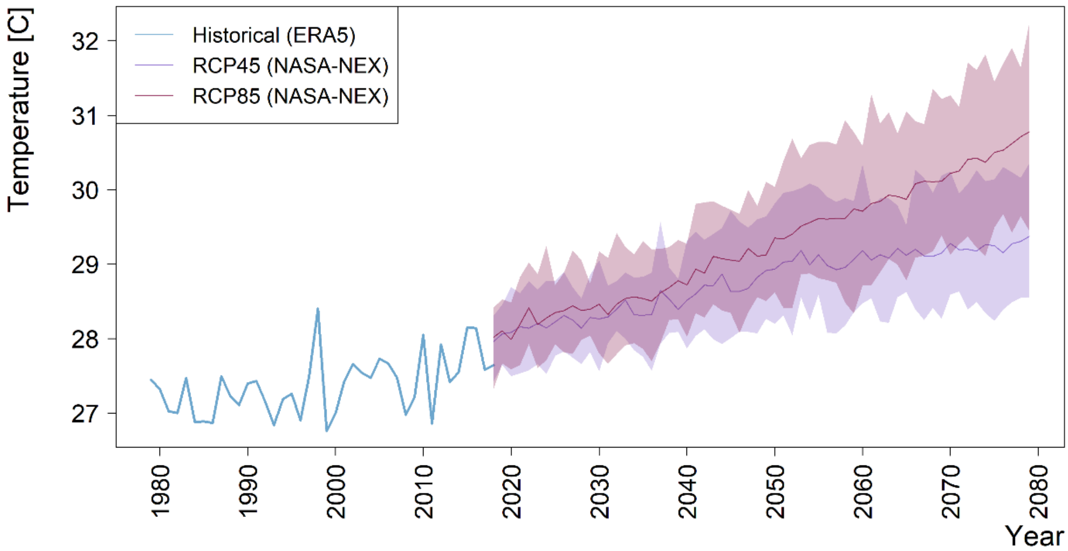
As an important variable in determining reference evapotranspiration, air temperature is another relevant parameter to consider when looking at climate change and the water cycle. Climate projections (Figure 2-19) show without exception a clear increase in temperature over the next decades, with an over 3 ˚C increase projected by 2080 under RCP8.5, compared to the historical period. Although this is an extreme scenario, higher temperatures are expected for all model / RCP combinations, meaning that atmospheric demand for water is highly likely to increase in the future. This will have implications for water consumption and occurrence of heat stress for crops and humans.



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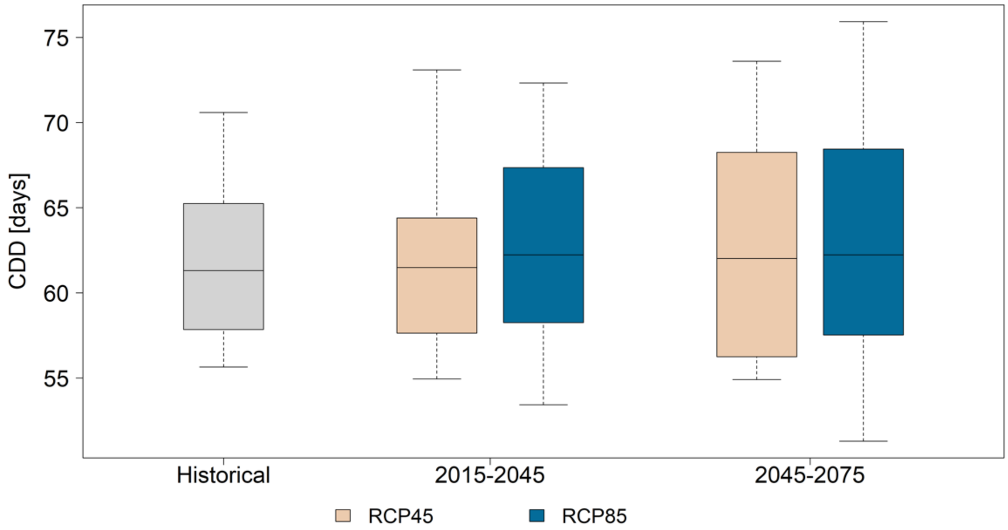
2.1.3 Climate extremes

Because of the significance of flood and drought events in the area, the impact of climate change on extremes was analysed in more detail. To this end, the climate indices Consecutive Dry Days (CDD) and the maximum daily precipitation (Rx1day) were evaluated. Figure 2-20 shows the CDD for the historical period as well as a near (2015-2045) and far future (2045-2075). Although slight increases in CDD are projected on average, the spread in climate model results is large and no clear trend can be discerned. This is different for the Rx1day indicator (Figure 2-21), which increases for both RCP4.5 and RCP8.5 in the future periods. Based on the average of all climate models considered, Rx1day will go from 59 mm in the reference period to 73 mm in 2045-2075 under RCP8.5.



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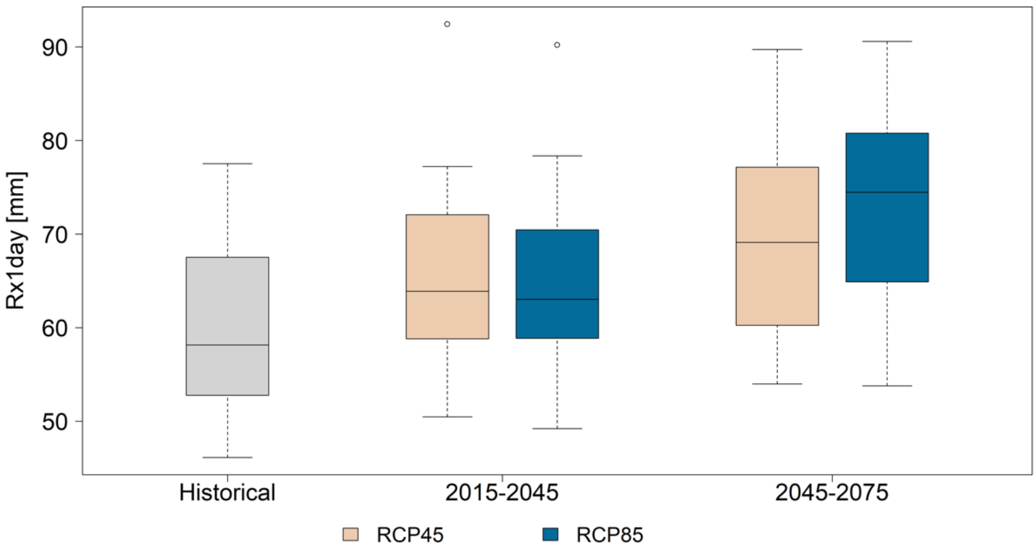

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HǂH Water Resource Modelling

A WEAP model was set up and used for assessing the current status of water resources in the Cambodia provinces, for assessing the impact of climate change, and for considering additional storage options in Oddar Meanchey. The set up and data requirements and assumptions are given in Annex C.

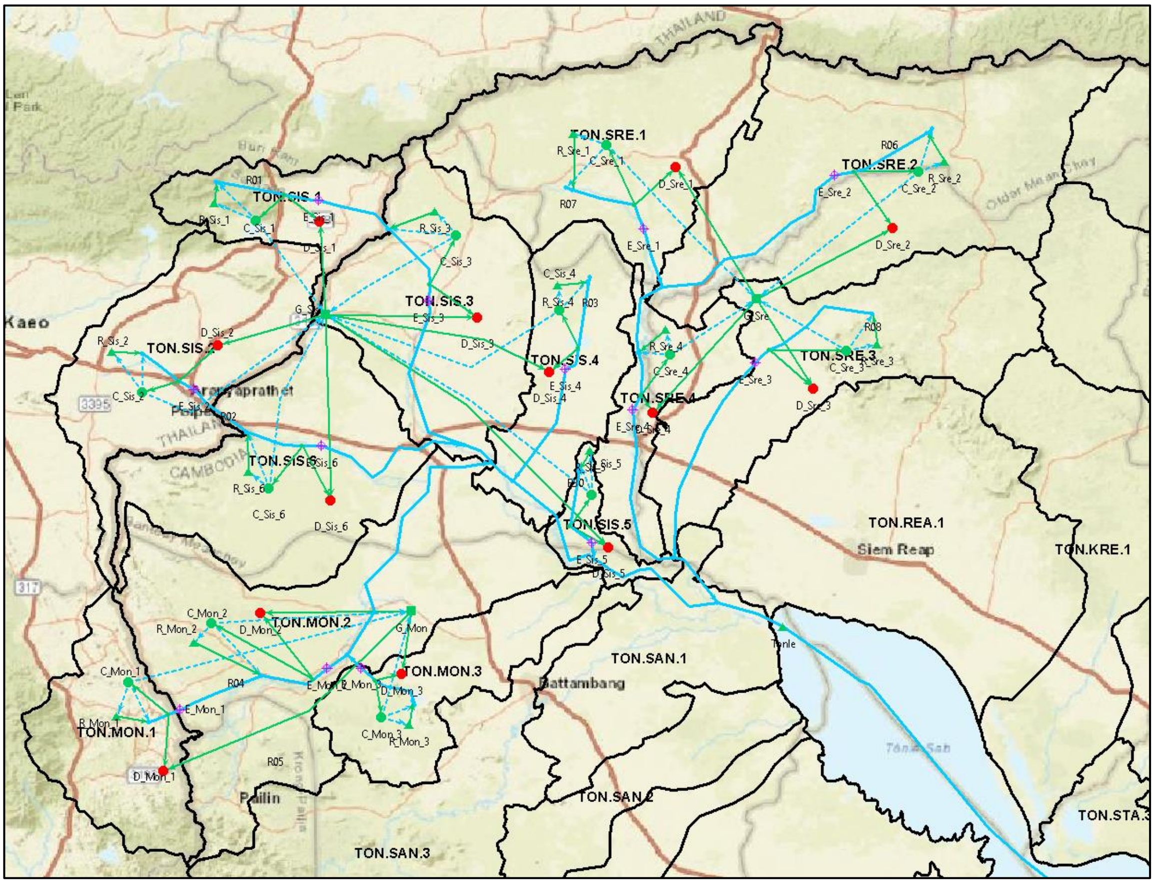
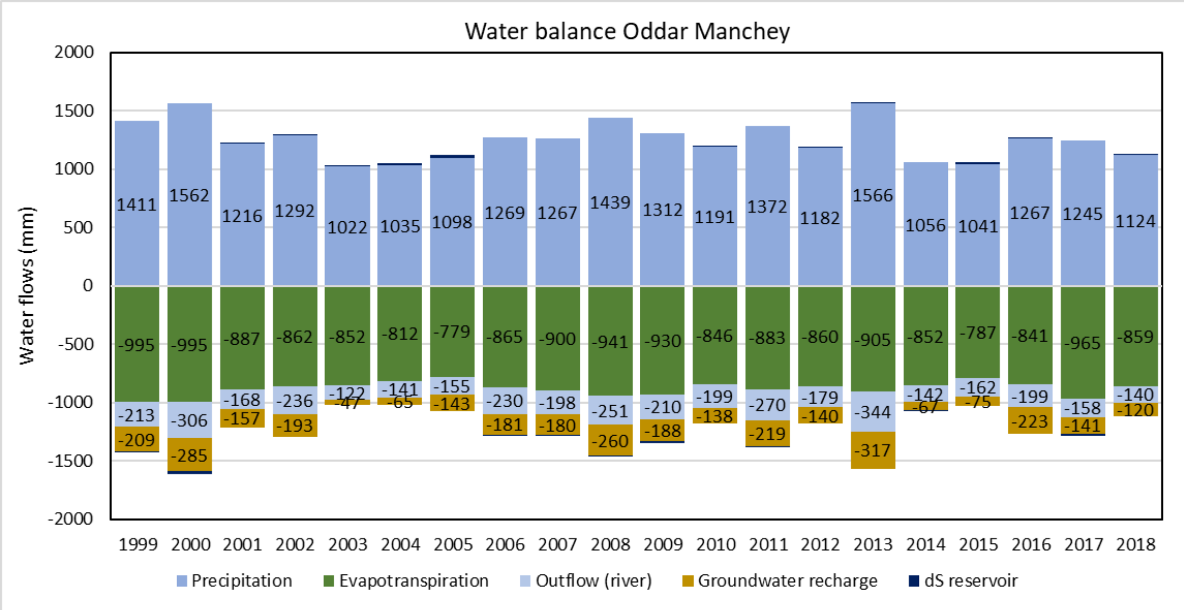


Figure 27: Schematic of WEAP Tool for Oddar Meanchey and Banteay Meanchey

The model includes demands from agriculture, domestic/Industrial supplies and losses to evaporation and groundwater, rainfall and runoff due to different land cover and cropping patterns. The model was run on a weekly and monthly time steps thus enabling an analysis of both the spatial and the timing of excess and water shortage.

Despite suffering from water shortages at certain times of the year, for example, Oddar Meanchey is generally having an excess of water on an annual basis which is realised in runoff and irrigation supplies to other provinces.



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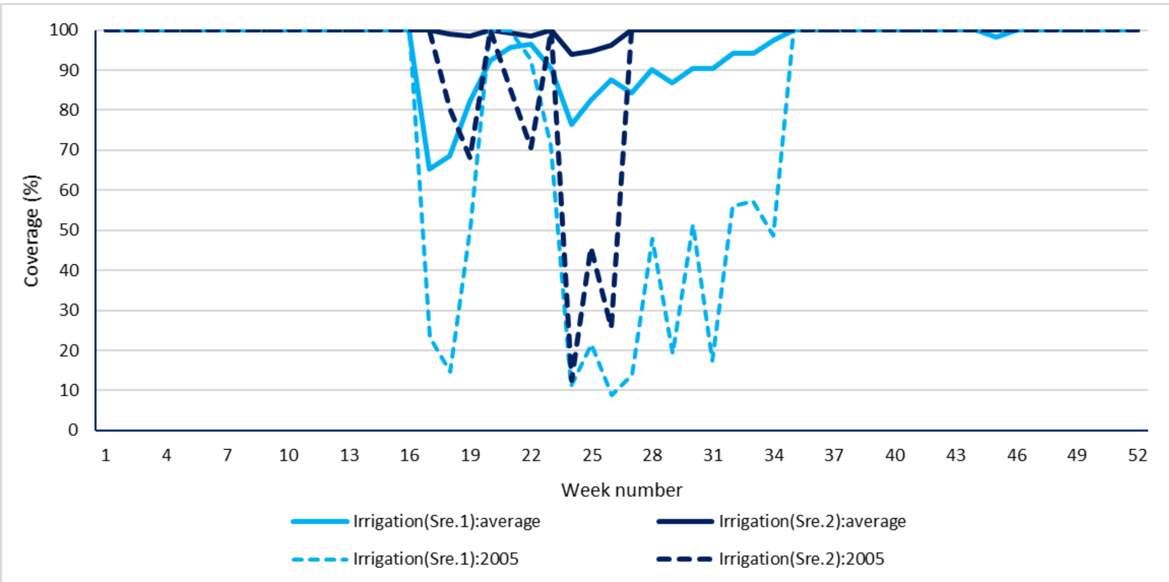
In certain years and at certain times of year, however, there is significant water shortages as show in Figure 2-24



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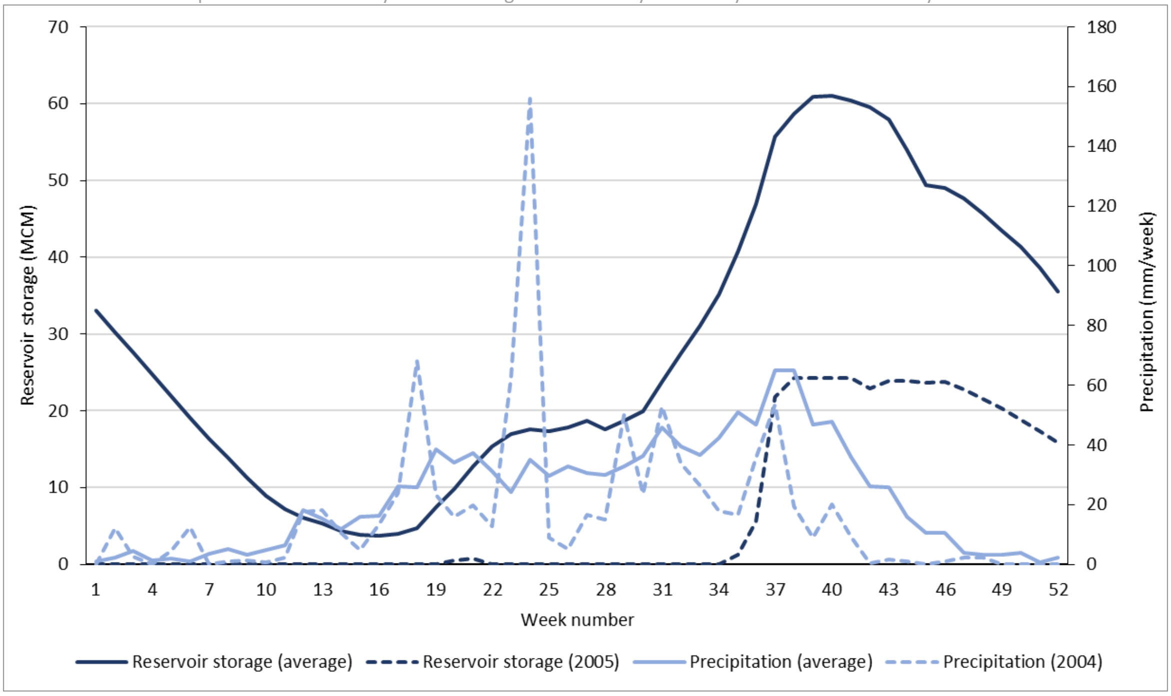
If we look at the modelled storage and use of water this also shows that I an average year, the storage may be sufficient but in a dry year there are long periods when water cannot be supplied. This is illustrated in Figure 2-25. In week number 16 (April) in a ‘normal’ year the storages reach a minimum whereas in a dry year there is decligeable storage available for the whole dry season from January to June likely impacting on drinking supplies as well as agriculture.



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This shortage is concentrated more in the west than the east (Anlong Veng) part probably due to less water use in that part.

The model was then used to study the effect of additional storage distributed in the Sreng catchment (bit not necessary defined where at this stage). The magnitude of storage needed can thus be defined, how this is met through a combination of works such as small local ponds and tanks, larger interventions to improve reservoir effective capacity etc.

The unmet demands were simulated for the baseline climate – a series of years 1999-2018 for a range of additional storages 10 MCM to 100 MCM in steps of 10MCM. In some years the additional capacity is not needed whereas in an extreme even 100MCM additional storage is not sufficient.

! ŘŘ ǎǘ2ǈI-ƎŜ óa / aú	мффф	нллл	нллм	нллн	нлло	нллп	нллр	нллс	нллт	нллу	нллф	нлмл	нлмм	нлмн	нлмо	нлмп	нлмр	нлмс	нлмт	нлму
0	0.0	0.0	12.5	24.9	0.0	4.8	163.9	31.6	1.2	0.2	0.9	11.4	0.4	64.6	1.7	16.2	31.8	36.7	0.0	3.7
10	0.0	0.0	11.9	23.8	0.0	4.7	155.3	24.7	1.1	0.1	0.0	10.4	0.2	64.4	1.5	10.5	31.7	36.5	0.0	3.0
20	0.0	0.0	4.3	14.1	0.0	4.5	137.9	23.9	1.0	0.0	0.0	7.4	0.0	63.4	1.4	2.3	30.5	36.4	0.0	0.0
30	0.0	0.0	0.0	4.0	0.0	4.4	125.0	14.9	0.8	0.0	0.0	1.2	0.0	55.2	0.9	0.0	29.0	36.2	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	4.2	113.5	12.4	0.7	0.0	0.0	0.0	0.0	39.9	0.0	0.0	27.4	35.7	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	3.9	107.3	8.0	0.5	0.0	0.0	0.0	0.0	30.9	0.0	0.0	21.0	33.4	0.0	0.0
60	0.0	0.0	0.0	0.0	0.0	0.7	105.7	8.0	0.0	0.0	0.0	0.0	0.0	18.1	0.0	0.0	9.2	32.6	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.5	105.7	6.3	0.0	0.0	0.0	0.0	0.0	11.2	0.0	0.0	6.3	32.3	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.3	105.7	4.7	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	1.0	29.6	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.2	105.7	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.3	0.0	0.0
100	0.0	0.0	0.0	0.0	0.0	0.0	105.7	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.2	0.0	0.0

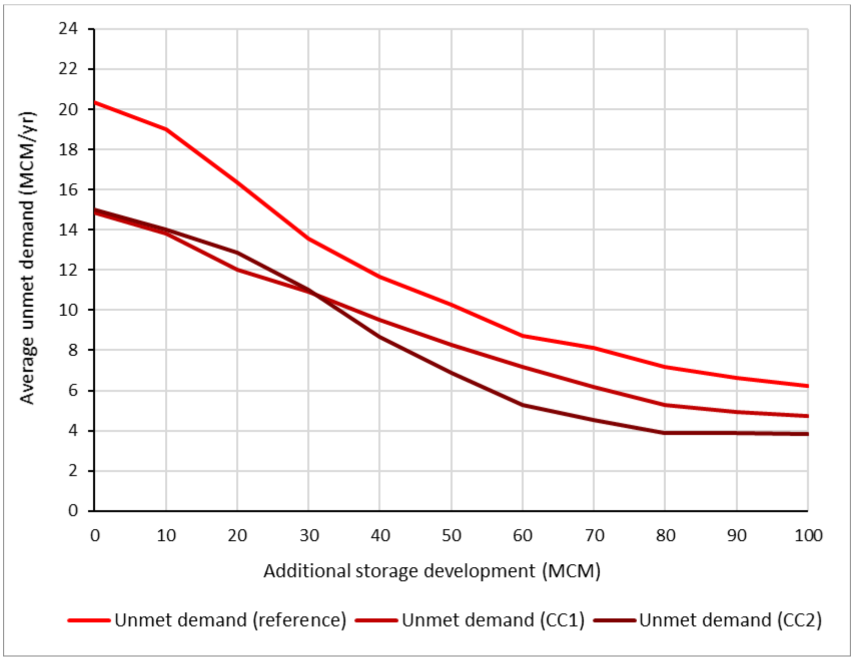
CÏƎdzǈŜ нπс ¦ yYŜú ² I-ǘŜǈ ŘŜYI-yŘ ŦȤǈ {ǈŜyƎ ʎY hŘŘI-ǈ aŜI-yÕKŜè ŘǈʎyƎ нл èŜI-ǈ KèŘǈ2ŦȤƎʎÕI-Ŧ ǘʎYŜ ǈŜǈʎ2Ř wŜǎdzŦǘǎ óǈYŜú ŘŜYI-yŘ ʎY a / aú I-ŧǎ2 ƎʎØŜy ŦȤǈ I-ŘŘʎǘʎ2yI-Ŧ ǎǘ2ǈI-ƎŜ I-ŘŘŜŘ ʎY ǘKŜ Y2ŘŜŦ мл a / a ǘ2 млл a / a

The same simulation was then repeated for 2 possible climate change scenarios, an overall increase associated with high emissions and a seasonal change scenario.

The results as shown in Figure 2-27 :

- The marginal benefit of developing additional storage is relatively high.
- Over the first +50 MCM, a total of 10 MCM reduction on average of unmet demand is achieved
- Over the next +50 MCM, this is only 4 MCM reduction
- In dry years, the beneficial impact of adding a first 50 MCM of storage is much higher, at 56 MCM (2005) and 34 MCM (2012).
- A wetter (CC1) or more erratic (CC2) climate increases benefit from additional storage, as extra water can be put to use. This reduces unmet demands with 19% and 32% under CC1 and CC2 conditions in the +50 MCM scenario

In both climate change scenarios, +100 MCM of storage leads to 19 out of 20 years with full coverage of irrigation and domestic demands and thus would be 'no regret' options.



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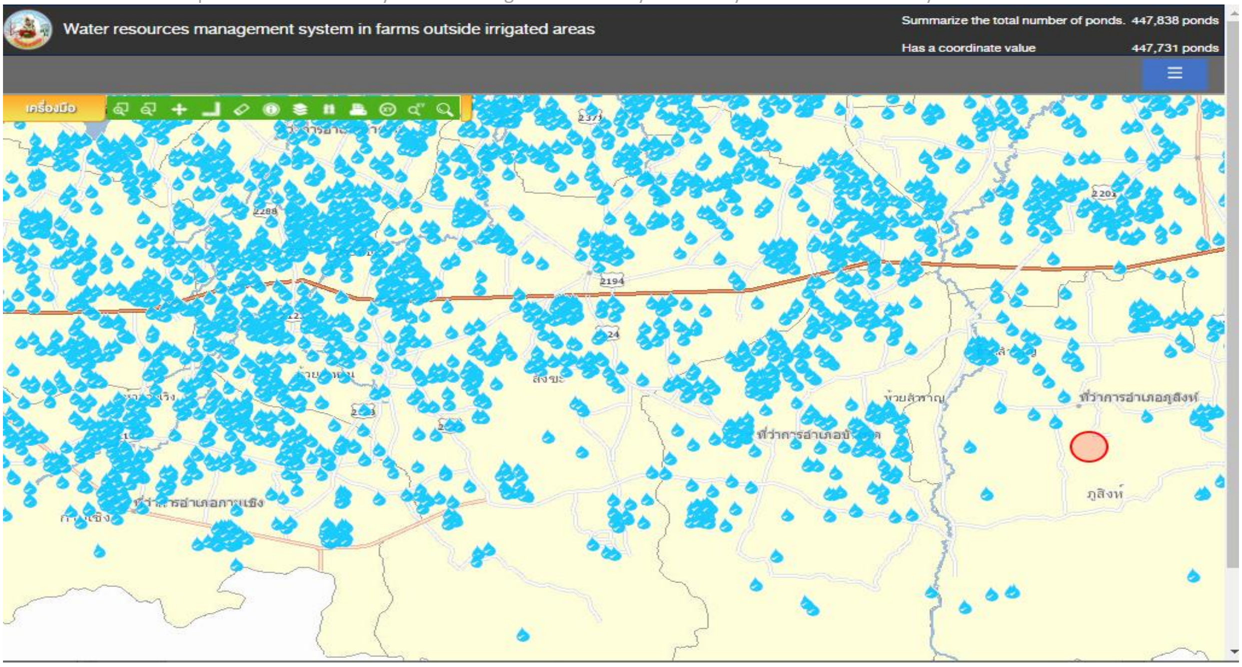
In the Thai provinces, as a comparison the Royal Irrigation department has planned irrigation developments of medium and small scale irrigation systems totalling 115MCM in Sisaket and 124MCM in Surin. The land development department will aid many thousand of local farmer or community ponds and has a policy of driving efficiencies in both pond and tubewell selection and provides a web based registration of requests and advice (https://lddzoning.ldd.go.th/webmapeis/)



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2.3.1 Methodology

Following on from the identification of areas of priority from flood risk, drought risk and poverty, communes were selected for additional local investigations. Focus group discussions (FGD) were used as the main research tool to assess vulnerability indicators and socioeconomic factors relating to WR and WRM in the agricultural communities of study provinces.

hǒ2ŜǑǘΆØŜǎY

- Assess vulnerability indicators for the most at-risk areas to provide appropriate support to areas in need and formulate recommendations that are scalable.
- Collect detailed information on the recent effects of flood and drought events on the agricultural sector.
- Understand water resource management strategies at the local, user level.
- Assess infrastructure: canals, irrigation systems, storages.
- Assess attitudes toward and knowledge of climate change.
- Collect information on crop patterns, water applications and crop requirements to inform future scenarios.

Focus group discussions were chosen as the most appropriate research method to meet these aims. FGD's allow participants to discuss and reflect on their experiences with water and agriculture. The participants were members of Agricultural Cooperatives (AC) and Farmer Water User Communities (FWUC) within the chosen communes.

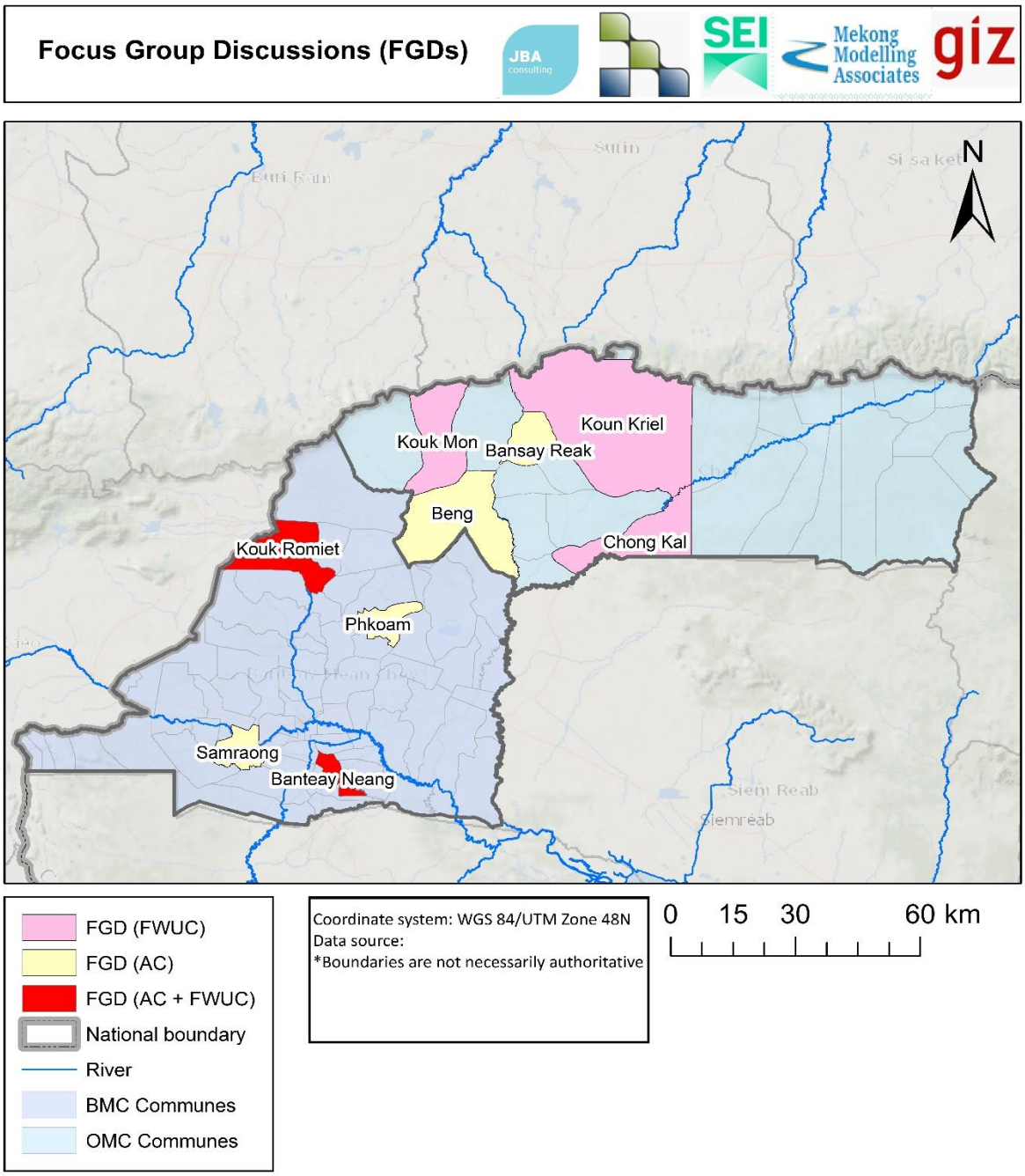
2.3.2 Locations:

Locations for the FGD's were selected along a criteria of risk. Risk was measured using 3 indicators:

1. Drought hazard: using satellite data to form a Drought Hazard Index rank (DHI) derived from a range of indicators.
2. Flood hazard: using satellite data to form a Derived Risk Ranking (DRR) using a range of indicators.
3. IDPoor: using data on percentage of IDPoor 1&2 households by commune in both provinces.

Analysis was then conducted to determine the most at-risk communes as a combination of the 3 indicators. 5 communes were chosen in each province and it was proposed that we conduct up to 10 FGD in each (5 AC, 5 FWUC).

Selecting communes based on flood, drought and poverty 'risk' ranking allows for an assessment of the currently most vulnerable areas in Oddar and Banteay Meanchey. This is important in ensuring that situations are analysed to prepare future strategies for WRM that can support the communities. In addition, using this approach allows for any future recommendations to be modelled around such scenarios for scalability.



2.3.3 Results

Each FGD was conducted in approximately 90 minutes. Notes and a recording were taken in the discussion which were then used to produce a written summary and translation to English of each FGD are included in Appendix F. These summaries were collated in the following matrices where key issues or suggestions have been highlighted in red. Additionally, time was allocated at the end of each FGD to allow the participants to make suggestions on how WRM could be improved in their local region.

OMC	Kon Kreal FWUC – Tumnup Lork	Bansay Reak AC – Sambour Meas	Beng AC – Beng Samaki Akphivot	Chong Kal FWUC – Kor village	Chong Kal 2 FWUC – Kor village	Kork Morn FWUC – Ou Angkrang
Flood	Not serious, water just runs through system and makes some small holes.	Flood has never damaged property or crops. Only this year, water killed cassava crops. In 2017, water damaged rice crops.	Kork Kabas village most affected (located downstream of dam), 2019 – roads damaged, 50-60ha of rice fields damaged, reservoir affected so studies being carried out	Flood in September 2019 – damaged wet rice. 15 different areas along main canal affected but PDWRAM intervened quickly to prevent further damage.	September 2019 flood, destroyed concrete embankment of canal and its bank. Reported to PDWRAM who came to fix it. 50% of wet rice crop was damaged/affected. Big flood in 2013.	Floods have never damaged the infrastructure nor households because the flood does not stay long, it flows to other areas as this is an upland area. 10-20ha of cassava are affected by floods whilst floods are a good thing for rice crops.
Drought	Hot weather kills weeds and grass that are grown to protect the system – can damage irrigation systems. Very hot in 2017, killed many animals and crops.	Most drought in August or September, in 2018 rice were completely damaged.	Been two years since rice and cassava affected by drought. More drought than usual in last two years. Used to get 20 sacks of rice (14 million), now only 5-6 sacks (4 million)	July-August 2019. PDWRAM brought 5 electronic water pump machines. Hot weather damages cassava crops.	Drought has never affected the system.	Experienced drought for 3 years in a row during July-August. Within 3ha of rice fields I could only harvest 7 sacks.
Adapation to F+D	In 2018 when there was a water shortage, farmers pumped out remaining water from dam. Don't grow anything in dry season.	Not use water wastefully, pump water to catch fish. PDWRAM provide some training e.g. don't shade under a tree during rain to avoid lightning.	No strategies. Wanted to conserve more water but its far and costly to pump. Recent project to rehabilitate main canal.	Construct more ponds, buy more tanks and jars.	Not much of an idea. Could plant more trees to reduce temperatures in hot season. Don't know how to prevent flood.	No strategies. Drought is the result of deforestation. Just 10% remains of what existed before. The cold season lasts only 3 days.
F+D Warnings	MOWRAM mentioned reducing land cultivation during water shortage. Government recommends not to grow anything.	Some news from media but farmers don't listen as they have to make a living.	Via village chief every year. No strategies for mitigation. Told to cultivate crops that consume less water but people still use water if they can access it.	Held meetings with nearby communities once or twice a year. Normally discuss about issues relating to maintenance and management.	Warnings from the government by telephone and the media. We are in the lowland area so we always prepare for flood and look after the vulnerable. MOWWRAM can notify over 1,000 people at the same time.	°

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2.3.4 Oddar Meanchey focus groups key suggestions:

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- Canal construction from newly constructed Chinese dam to supply Tumnup Lork dam (note - this has been considered by Mowram but is not possible due to difficult terrain and relative elevation).

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- No current major infrastructure, possible reconstruction of Khmer Rouge structures or suggested construction of a dam/dyke around 1km away to conserve water flowing downstream from upland areas.

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- Deepening and rehabilitating ponds in villages.

/K2yƎ Yl·f C ² ¦ / óHú

- Bring water from Ang Phnom Ah Tor reservoir to local reservoir – study already conducted?

- Lack of female involvement.

- Additional construction of sluice gates.

Y2Ŋʅ a2ŊyՎ

- Systems repairs and construction of additional secondary canals.

2.3.5 Banteay Meanchey focus groups key points/suggestions:

Ydz2ʅ w2YʌŜű C ² ¦ /Y

- Construct canal to bring water to Ta Song village

- Rehabilitation of existing systems

Ydz2ʅ w2YʌŜű ! /

- Request of wells per household – 1 basin per family

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- Rehabilitate tertiary canals

- More cooperation with local AC

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- Conflicts between villages over use of master canal

- Local water authority has issues opening the sluice gates

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- Rehabilitate old Khmer Rouge canals, from Khai Don river and Kanseng reservoir

- Famers don’t know how to use irrigation systems

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- Rehabilitate old streams and canals

- Lack of domestic storage – could construct clean water station in community.

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o¢M LyãűΛűdzűΛ2yl-f

The planning of the project was to firstly establish the Status Quo of the Water Resource Management in two adjoining provinces of Cambodia and two in Thailand, with a view to exchange experiences and begin development of a water management plan taking account of the transboundary water issues.

It has not been possible to achieve the completion of such a plan but extensive data collection analysis, modelling and local consultations has set a pathway to achieve this.

In Thailand the planning system is much more established and study of the differences and limitations is very useful for Cambodia. The replacement of earlier plan by a 20-year management plan on WRM by the Office of National Water Resources (ONWR) aligned with National priorities for development aims to align the plans of different agencies accepting that coordination needs to be strengthened. This includes the Provincial and local government who have their plans and responsibilities especially in planning for land use compatible with the National priorities and for Disaster response. The troika of Royal Irrigation Department, Agricultural Extension and Land development department to work with farmers to maximum effect without duplication is one that would merit further study and on the ground discussion for lessons learning.

Both countries are progressing the establishment of river basin bodies for management of water issues as promoted for efficient water management through IWRM principles. The issue with River Basin boundaries is the way that generally do not align with the political organisation of provincial and local governments. In the case of Ottar Meanchey and Banteay Meanchey the alignment is actually quite good although neither have the whole catchment of either the Sreng, Chet or Sisopon within their boundaries so a River basin plan may not align with the priorities for the province, something highlighted by the storage and export of water from Ottar Meanchey, potentially the best option at a catchment scale but for Oddar Meanchey having the land utilised for water storage for the benefit of other provinces is unlikely to be a high priority.

The fact that the Stung Sreng had an adequate set of planning documents and a river basin organisation set up in 2015 is instructive. The plan in reality needs significant updating with the completion of the major Sreng 2 dam project but the River basin organisation has already become defunct.

Provision of basic information on water management for the province governor and the various provincial arms of water and agriculture it is suggested would be beneficial. Such information must be in Khmer and be relevant to the expenditure available and plans for a 5 year cycle. The possible contents of such a plan similar to those used for local governments elsewhere is given in Annex G. Using the information gathered in this study together with that in the River Basin plans and consultation with the relevant agencies would not be a major task.

The recognition of a need to rationalise planning within the water sector and Interaction between Thailand and Cambodia therefore has the chance of creating a beneficial relationship whereby future WRM projects can be developed concomitantly and with lessons learned from previous projects particularly in areas with similar crop supply needs.

Exchanges between the Cambodian provinces and Thai provinces including possible joint projects would also be beneficial when this becomes possible again.

o¢H tKèăΛŎl-f ² 2Ŋ1ă

The identification of a number of small works that GIZ could help with funding fall into 3 categories from the results of this study:

I. The increase in local storages necessary has been quantified for Oddar Meanchey. The Provincial PDWRAM has a program of storage improvements of rehabilitation, deepening and enlarging that come to a total of 6 MCM. It is not clear if national funding will be available for this works. When possible a programme of support for local storages could be developed building on the work and efficiencies achieved in Thailand for such tasks. The provision of groundwater development where suitable could be combined with the storage or actual groundwater replenishment and use considered.

II. The Focal Group consultations has identified a wide range of water control improvements which through further loac study would benefit and involve the local agriculture and water groups.

III. In Thailand innovative solutions for 'smart' water use are encouraged and already a number of pilot schemes are underway and documented in Annex B. These or similar schemes could be developed and supported at the Provincial level of the RED.

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П¢M /ƨyǒfdzǎʎƨyã

The study has brought together a wide variety of data sources and presented the current 'Status Quo' of Flood and Drought Issues in Banteay Meanchey and Oddar Meanchey Provinces. The water management situation in the neighbouring provinces of Surin and Sisaket are also presented in terms of the physical and management situation.

The climatic situation in Banteay Meanchey especially is very variable with periodic extreme floods and extreme drought. In Oddar Meanchey the Water resource situation is less extreme but the topography of the area creates difficulties to bring water where it needs to be.

Through a combination of ground measurements, satellite detection, modelling and interviews with government and farmer groups a set of recommendations has been derived aligned with the original project purpose. As the work is carried out under the GIZ programme for Regional Economic Development in the two target provinces, the further work and suggested implementation is aligned with the regional/provincial perspective. This is a different approach for Cambodia where scheme, river basin or national based planning is more normal but consistent with decentralisation and capacity building at the most appropriate level. The example from the Thai provinces shows how this can work and future exchange between provinces would be beneficial when this is possible.

П¢H hdzűfʎyŜ ƨŦ wŜǒƨY Y ŜyŘI·úʎƨyã

The recommendations of the study are presented aligned with the objectives of the study:

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(ii) Design a water resource management plan based on a status- quo analysisŤ

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(iii) Develop measures to strengthen the capacities of water management at district and local levels and;

(iv) Identify possible water infrastructure/ management facilities to preserve or increase water resources for the rural population;

o¢ LY LJNƨƠŜ úKŜ /Nƨăă . ƨNŘŜN /ƨƨLJŜNI·úʎƨy I·yŘ ¦ yŘŜNăúI·yŘʎyƎ ōŜűØŜŜy ¢KI·ʎfI·yŘ I·yŘ /I·Y ō2ŘʎI·

(v) Learn lessons from the organisation of water management and support to the rural population at different levels of government in Thailand

(vi) Identify relevant water management measures which may applied

(vii) Recommend strategies to improve cross- border management structures;

4.3 Strengthening Capacity to better Manage Water Resources (Province Level)

In the two provinces of Banteay and Oddar Meanchey it was very clear that PDWRAM, the provincial arm of MOWRAM took the lead in all water resource related work and had the greatest capacity though limited

human and financial resources. The responsibilities are high and the coordination with national projects during design, construction and when completed can be challenging, for example:

Ottar Meanchey Province is home to the main storages of the Stung Sreng system (recently completed with Chinese funding) but must operate these primarily for the benefit of our provinces including Banteay Meanchey. During floods, the operation of the irrigation systems (including that on the Sreng funded by ADB) may be used to hold back water from causing floods downstream. In Banteay Meanchey, the floods and droughts are even more pronounced and there is much uncertainty about flows from the Thai part of the catchment.

A River Basin plan for the Stung Sreng was prepared in 2015 under an ADB project but this excludes the more recent water resource developments and is only available in English rather than Khmer language.

Taking a province viewpoint, the structure for a simple but very applied management plan for each province is given in Annex 2. This would include the summary information on existing infrastructure, suggested national works in progress or planned by Mowram and the local works planned by the provincial authority. The influence of road construction on the plan and the requirements of the province for roads and other major development may be included.

The provincial plans of Thailand and Germany/EU may be used as guidelines of good practice and risk based assessments. Where River Basin Organisations (RBO) exist, the provincial government and ministry is expected to lead and good local information would greatly benefit the production of RBO planning.

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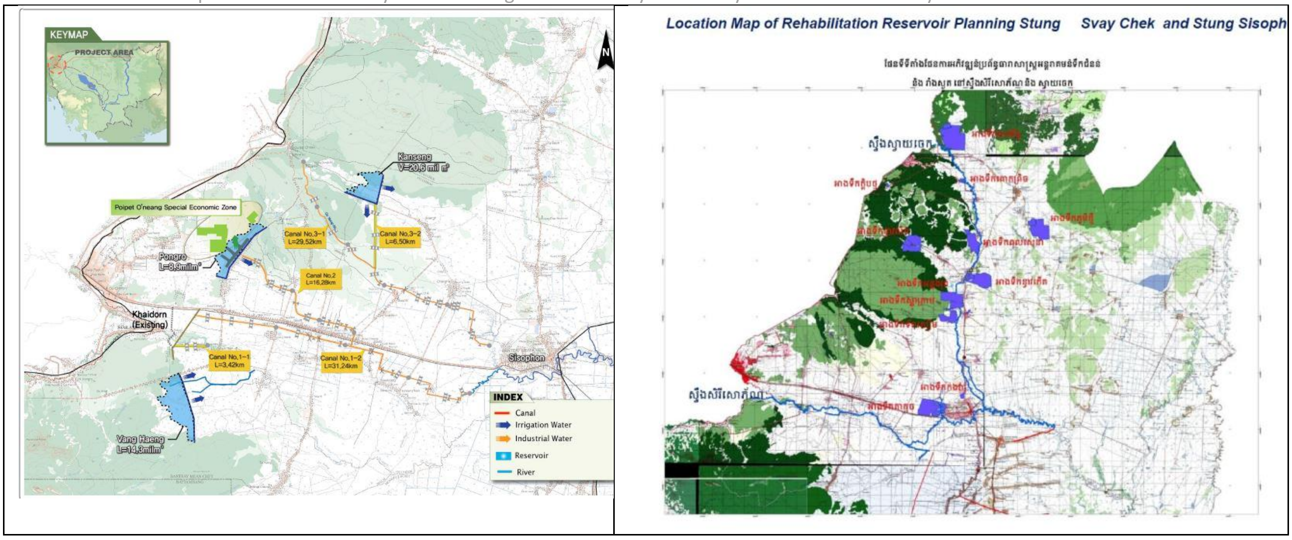

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The plan needs to include consideration of how to build the capacity of the provincial line agencies especially for planning improvements and operating the facilities available. In both provinces there are very few officers in the provincial departments of Mowram or MAF with the necessary knowledge and training to manage more complex systems that are being developed. The coordination of relief agencies and civil society through the Provincial and National Government during disasters such as the flood of 2020 is much stronger and a roadmap to ensure the resources to avoid the next disaster needs to be in the plan.

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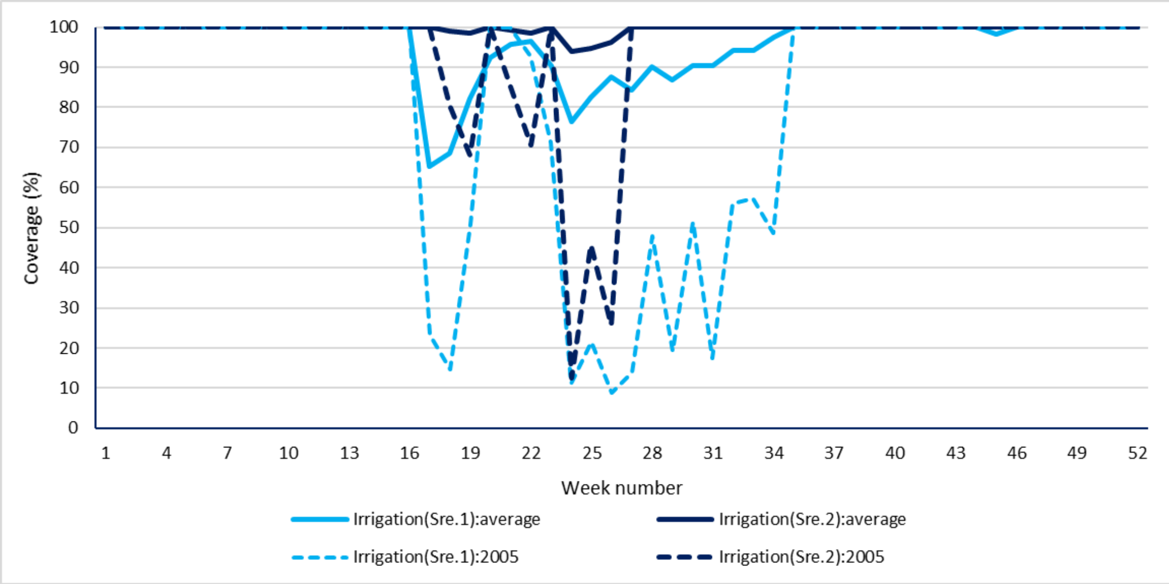
Although there is rapid development and change in Cambodia the themes of flood and drought issues continue every year including 2020. The longer term measures will be included in the Water Management plan but short term measures that future stages of the project could support were to be identified as two areas as described below.

4.4.1 Develop measures to strengthen the capacities of water management at district and local levels

This was addressed through analysis of both provinces and additional model simulation specifically for Water Resource and shortages in Oddar Meanchey and related to proposals being prepared by the PDWRAM.

In each year simulated there is an excess runoff relative to the provincial water demand but in a large number of years there are also water shortages both for agriculture but also for domestic demand in some areas. The modelling was therefore orientated to determine the level/amount of additional water storage that could be justified for reducing the water deficits that occur in the dry months taking account of agriculture, water supply and environmental considerations. This was also looked at considering climate change impacts and how much additional consideration could be given for the future proofing for a changed climate.



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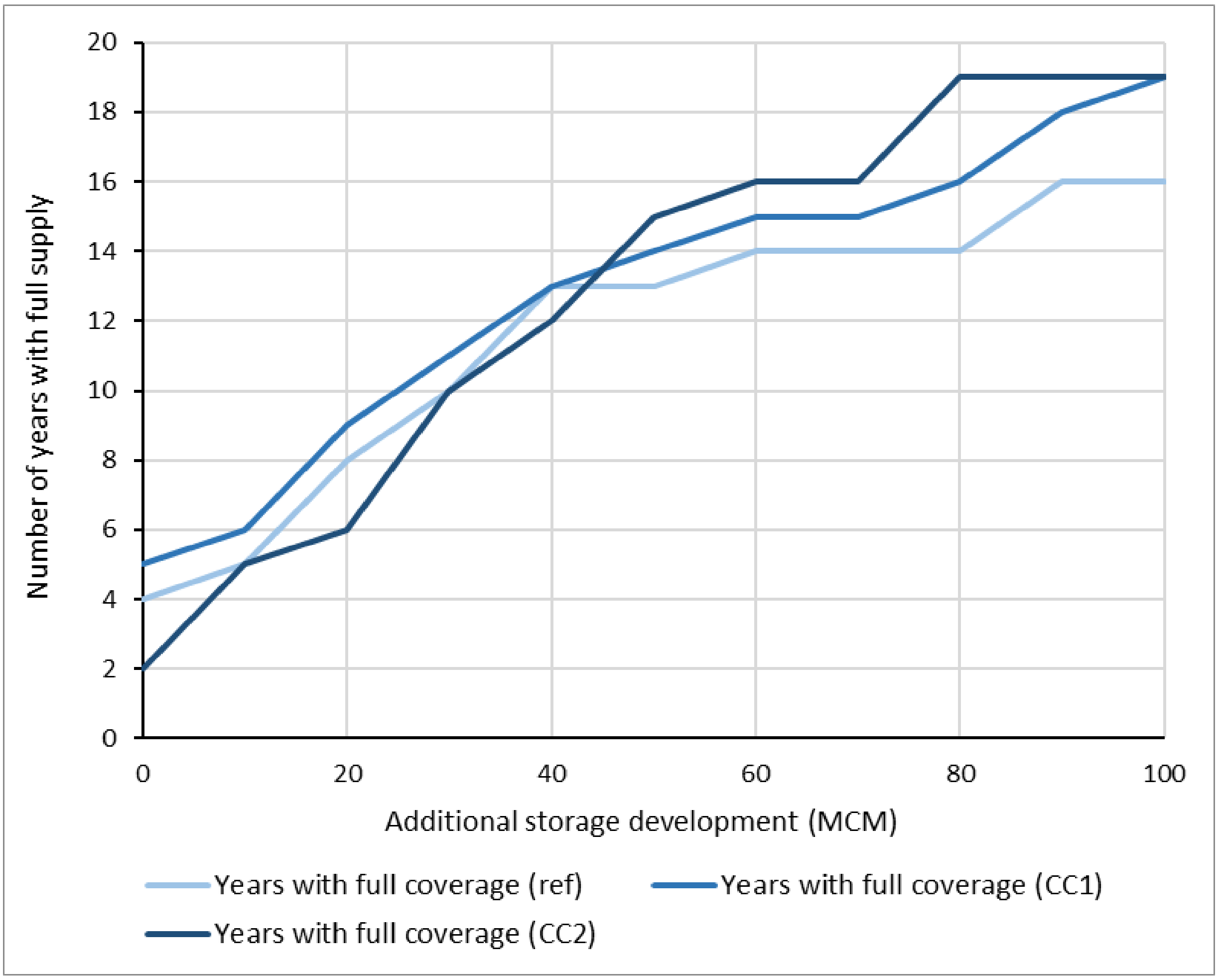
From this analysis the desirable additional water storage was derived considering the number of years when full supply could be maintained from a series of 20 years and also under two climate change scenarios.



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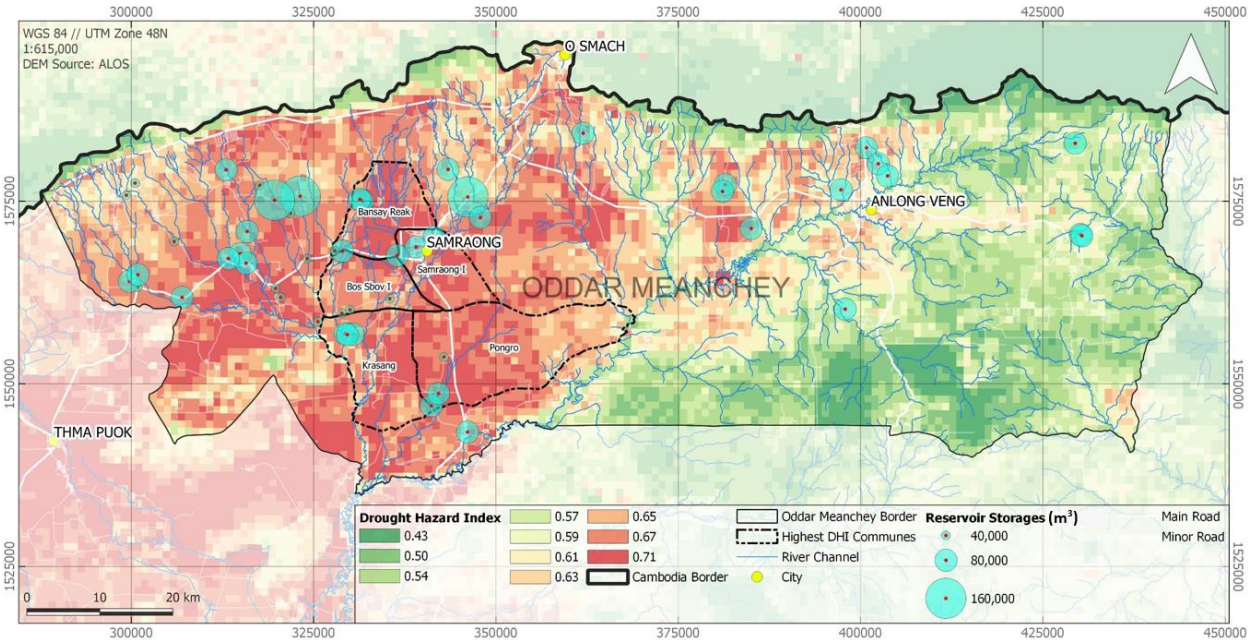
The province wide additional storage of 80-100 MCM is indicated as desirable though this could be implemented at a wide number of system and local farm ponds. The PDWRAM identified the potential for rehabilitating and improving existing storages some of which were overgrown or silted to a total of 6MCM.



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The funds availability for this work was not clear but it could certainly form part of the improvement indicated as necessary in the modelling. There are potential sites for additional storages on the eastern Sreng catchments though the availability of such water to catchments in the west would be limited.

Further storages at a local level including farm or village level storage would also be required to match the desirable storage total. Potential improvements in operations and efficiencies could help to reduce demands especially for irrigated agriculture.

4.4.2 Identify possible water infrastructure/ management facilities to preserve or increase water resources for the rural population;

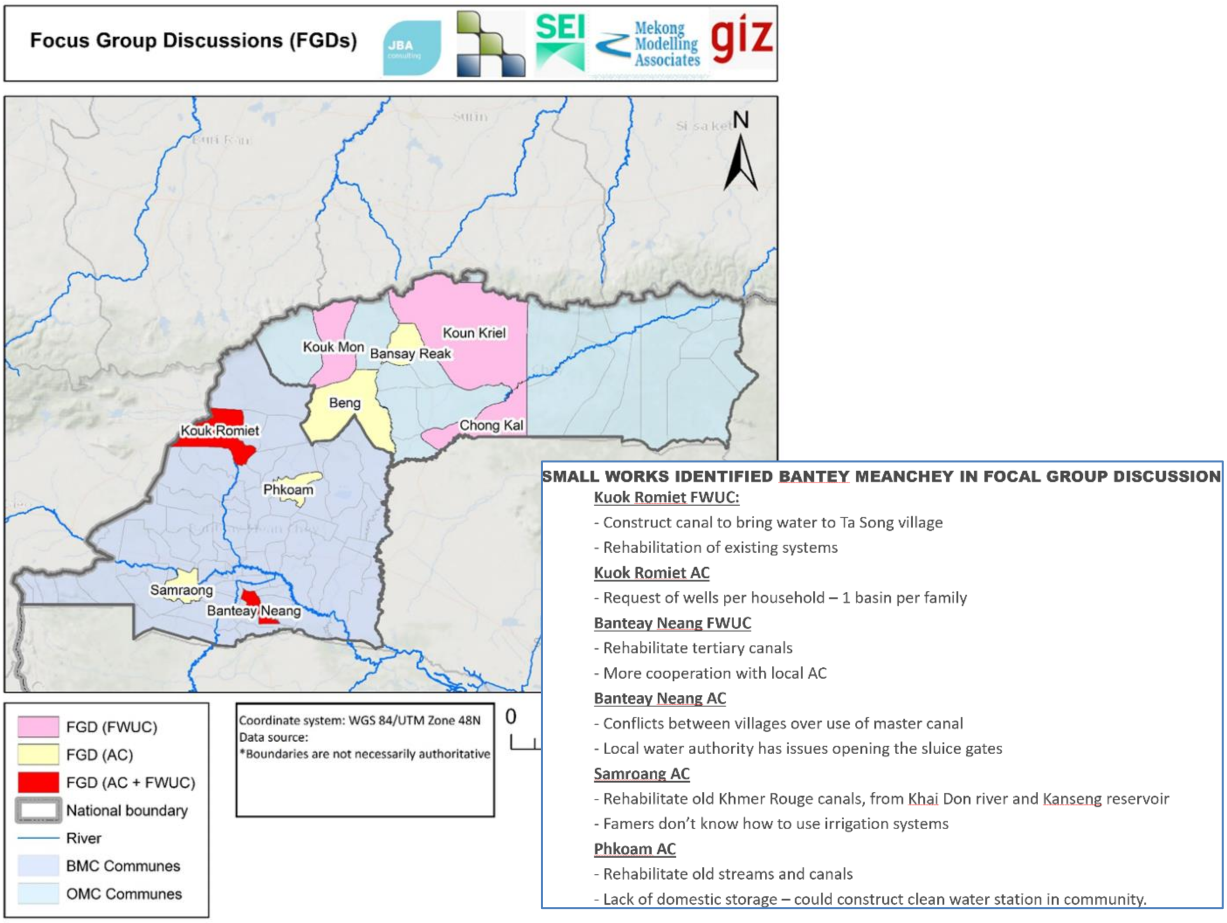
From the analysis of flood and drought risks and vulnerabilities at a commune level across the two provinces a number the most impacted communes were identified and focal group discussions held with the Agricultural Cooperative and Farm Water User Groups.

These revealed many small project suggestions ranging from rehabilitation and repair of local structures and storages to construction of better linking facilities. The full list is given in the main text but with some more detailed on the ground investigation this is likely to reveal a number of effective smaller projects.

What was notable also was that at the time of the interviews in early 2020, there was no identification of flood related issues or possible works necessary for flood control.

Later in 2020 significant floods occurs especially in Banteay Meanchey province and some of these areas will have been affected. Nevertheless it seems that for most rural communities, drought is more of an issue than flood. Specific flood management issues at a province level though could include aspects of:

1. Flood Forecasting Information at Province level
2. Operation of dams and sluice
3. Local flood defences and communication/evacuation routes for disaster relief.



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(viii) Learn lessons from the organisation of water management and support to the rural population at different levels of government in Thailand.

The availability of relevant plans and information for public and government officers in Thailand at National and local level is much better than in Cambodia and the management of water in the neighbouring provinces provides rich material for future cooperation. The Provincial water management plans for Oddar and Banteay Meanchey suggested can use the Thai examples for management.

One important lesson from Thailand is the need to integrate more closely the different government agencies concerned with water and this is done in Thailand under the recently formed Office for National Water resources (ONWR) which has an umbrella role to improve the efficiency of service delivery and water management.

(ix) Identify relevant water management measures which may applied

Thailand is still actively developing water systems for irrigation in the provinces in response to continuing water shortages but also has a clear path for support outside of the main irrigation areas. This includes

subsidies for improved water management, storage and more efficient pumping systems. A number of innovative approaches are also being tested such as using solar powered pumping and storage for local systems, improvement in the operation of the main storages etc.

(x) Recommend strategies to improve cross- border management structures;

Although Surin and Sisaket do not have a common river with the Cambodian provinces, Banteay Meanchey has significant rivers crossing from Sa Keo and all Provinces suffer from similar flood and drought weather systems and cross border flow of agricultural produce. The Sakeo -Banteay Meanchey rivers of Svay Chet and Sisopon are the subject of a separate project which aims to improve the understanding and communication including data sharing for each side. There is thus important cross border issues and potential for better cooperation and learning.

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M⌀M CŜI-ŭdzNŜă 2Ŧ ŜI-ŎK tN2ØłyŎŜ

The four focus provinces in this study are shown in Figure 1-1. The Thai provinces of Sisaket and Surin are slightly larger and have significantly higher populations, Oddar Meanchey is relatively sparsely populated with only 276,000 people as compared with 1.47million in Surin as shown in Table 1.1. The two Thai provinces are part of the Mun-Chi river basin whereas the Cambodian provinces fall in the Tonle Sap basin.

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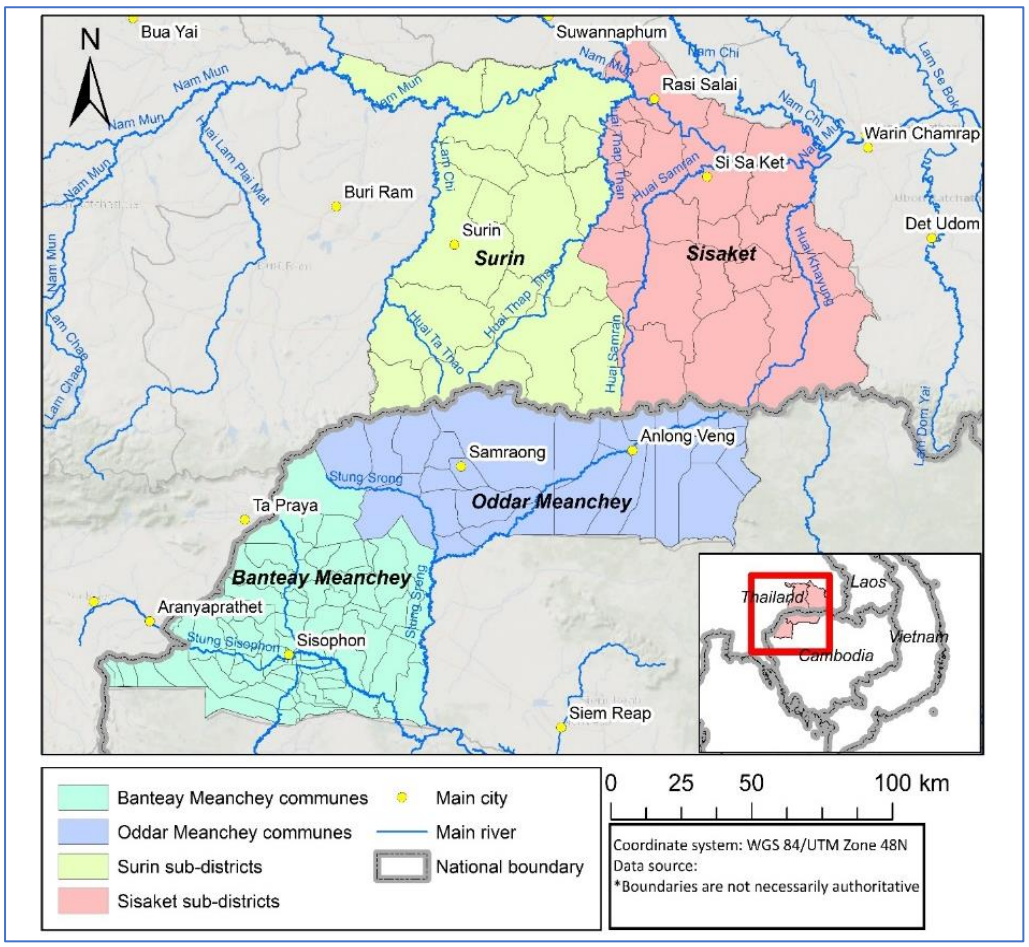
hŘŘI-N aŜI-yŎKŜè	Samraong	6635	276	Sreng, Srong
{łăI-]Sű	Sisaket	8877	1398	Mun,Tha, Tab Tan, Samran, Khayung
{dzNły	Surin	8811	1473	Mun, Lam Chi Noi, Tab Tan



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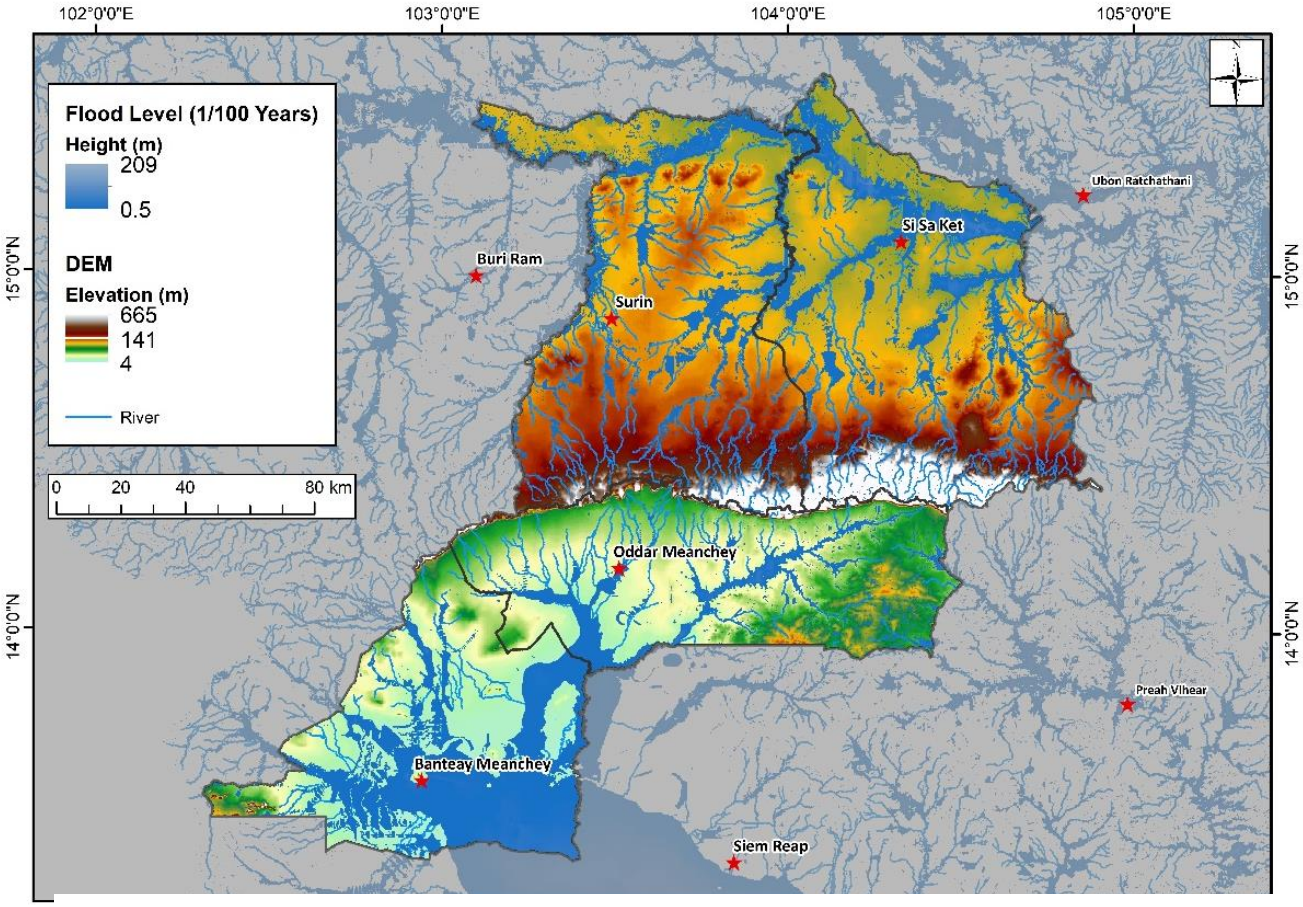
As Figure 1-2 demonstrates, the topography of the provinces in each of the two countries differ, but both plateaux away from the sharp escarpment at the divide between the Korat Plateau and the Tonle Sap Basin. The elevation ranges from 665m, which occurs in Sisaket, to 4m, occurring in the south-east of Banteay Meanchey. Within Thailand the elevation does not fall lower than 110m, as the topography decreases gradually from the area of high elevation along the Cambodia-Thailand border. In Oddar Meanchey, a steep decline in elevation is exhibited before it gradually decreases towards the south and the Tonle Sap Great Lake.



1 CłƎdzNŜ MTHY WAØŜNă I-yŘ Cf22ŘLJfI-ʎyã ʎy ŭKŜ Ŧ2Ödză LJN2ØʎyÖŜă

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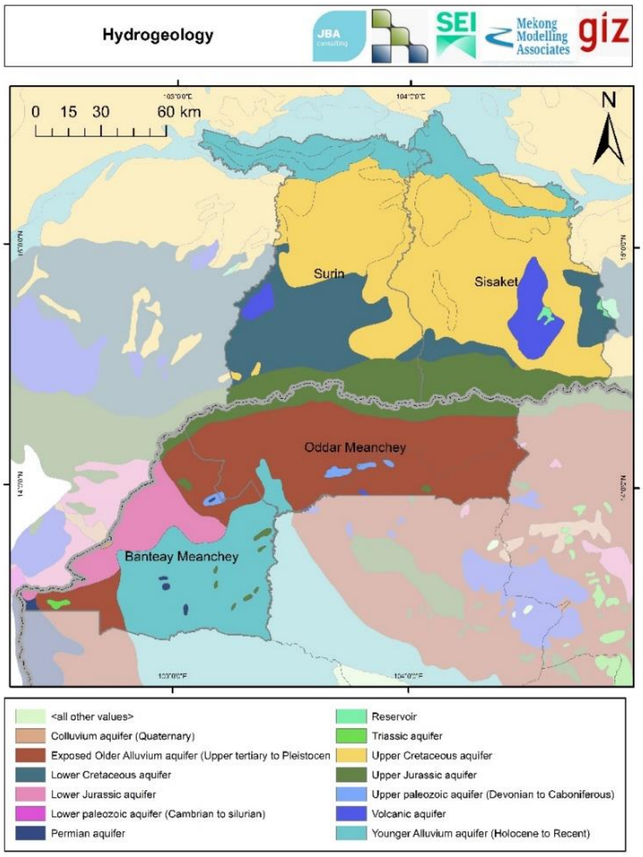
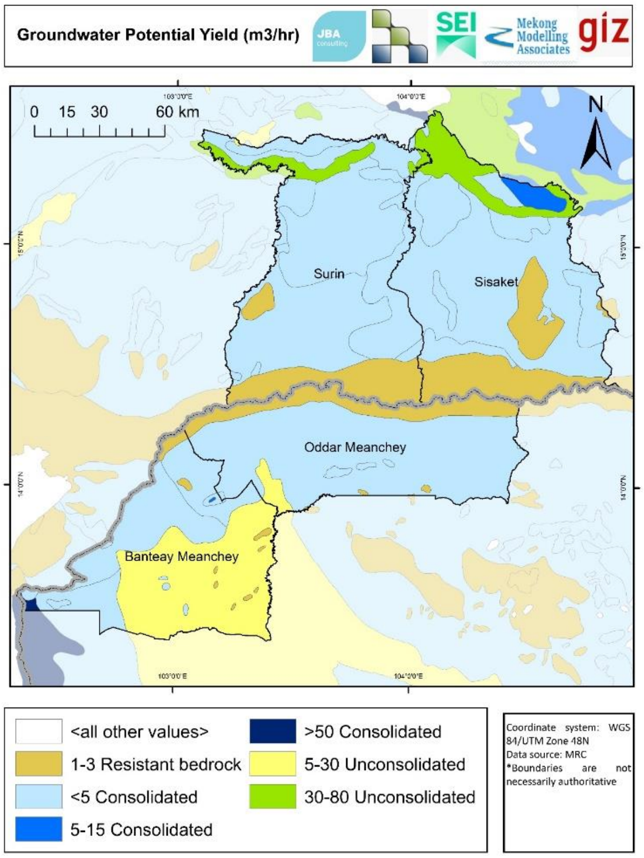
1.3.1 Surface Water

Oddar Meanchey is the source of the Stung Sreng which is one of the major tributaries of the Tone Sap basin with a total catchment of (9500km^2) and mean rainfall of 1580mm eventually joining the Sisopon and flowing to the northern part of the Great Lake. Banteay Meanchey falls within the Sisopon catchment (8866km2) but also has the confluence of the Mongkol Borei (6126km2) and the Stung Sreng. Part of Banteay Meanchey is also within the full wet season extent of the Great Lake. Further description of the rivers is given in the main report.

1.3.2 Groundwater

Hydrogeology:





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'Younger alluvium aquifer' (Holocene to recent) represents 29% of the total area and has the widest coverage across the focus provinces. The Thai provinces are dominated by Upper and Lower Cretaceous aquifers whilst the Cambodian provinces are dominated by Young and Old alluvium aquifers. Old alluvium aquifers are generally coarser textured and more productive aquifers than fine-textured Younger alluvium aquifers (Landon, 2011).

1.3.1 Groundwater potential yield:

(Charuratna and Phu, 1992) in (Landon, 2011)

Along the border between Cambodia and Thailand there is a low potential for groundwater abstraction due to the high elevation sandstone ridge (resistant bedrock) that can only

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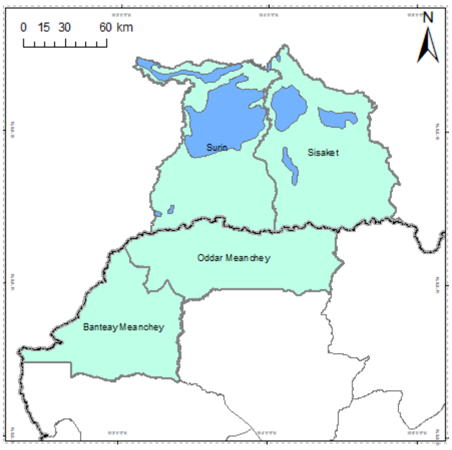
accommodate storage in its fractures (CHAIN, 2011). Over 50% of the total area consists of consolidated deposits that have a low groundwater abstraction potential of <5m^3/hr. One area with a high potential for abstraction is the unconsolidated deposit in the south-east of BMC which has a potential of 5-30m^3/hr. This is an area of younger alluvium than the older alluvium deposit that covers most of OMC, which you would expect to have a larger groundwater potential yield according to Landon (2011). Small pockets of northern Surin and Sisaket have the potential for a 30-80m^3/hr yield from unconsolidated deposits. These areas with high groundwater potential in northern Thailand border but do not intersect the areas of saline groundwater. There is also a consolidated deposit in the far north of Sisaket which has a 5-15m^3/hr potential yield.

1.3.2 Saline groundwater:



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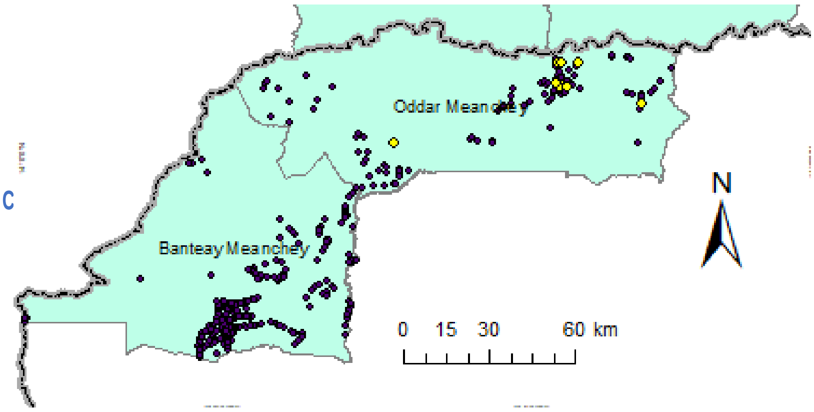
Saline groundwater is an issue in Thailand but not Cambodia due to the different setting and geology. Whilst no saline water has been recorded in Cambodia, 30.1% and 11.8% of Surin and Sisaket provinces, respectively, are affected. Salt can be extracted from wells in these locations if the water is left to evaporate however, it is unsuitable for drinking.

1.3.1 Arsenic in groundwater:

Arsenic has been found at dangerous levels in some parts of Oddar Meanchey as shown below.

Testing of the water quality of groundwater in BMC and OMC (ODC, 2010) shows issues of high arsenic concentration of between 10-25mg/l at some locations in Oddar Meanchey. 10mg/l is considered the maximum tolerable limit by humans according to the WHO (CHAIN, 2017).



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1.4.1 Agriculture

Rice is the most important agricultural commodity in all four provinces in Thailand and Cambodia. The Cambodian provinces are also major cassava and mixed vegetable producers. In Banteay Meanchey cassava production doubled in the 5 years prior to 2018 and quadrupled in Oddar Meanchey (GIZ, 2018). It can be seen that the areas of rice in the Thai provinces far exceeds that of the Khmer but the dry season area in Bantey Meanchey is actually the largest. In Cambodia the wet season Cassava area is high relative to Thai provinces and relative to dry season rice.

Annual MAFF studies into crops in various Cambodian provinces including OMC and BMC gives dry and wet season breakdowns of major crops: rice, maize, sugarcane and cassava. In terms of the 2018 annual production area (ha) as shown in Table 1.2.

BMC has seen an increased dry season area possibly due to the recent completion of the Sreng 2 reservoir and associated irrigation systems. 36, 295 ha whilst OMC's records a small area of around 200 ha only. Despite the recent investment in irrigation infrastructure in Oddar Meanchey much of the water is utilised in downstream provinces.

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The Thai provinces produce the same major agricultural commodities: a combination of rice, cassava, tapioca, vegetables and maize though rice predominates. Both Surin and Sisaket are significant rice producing areas for Thailand as is Banteay Meanchey for Cambodia.

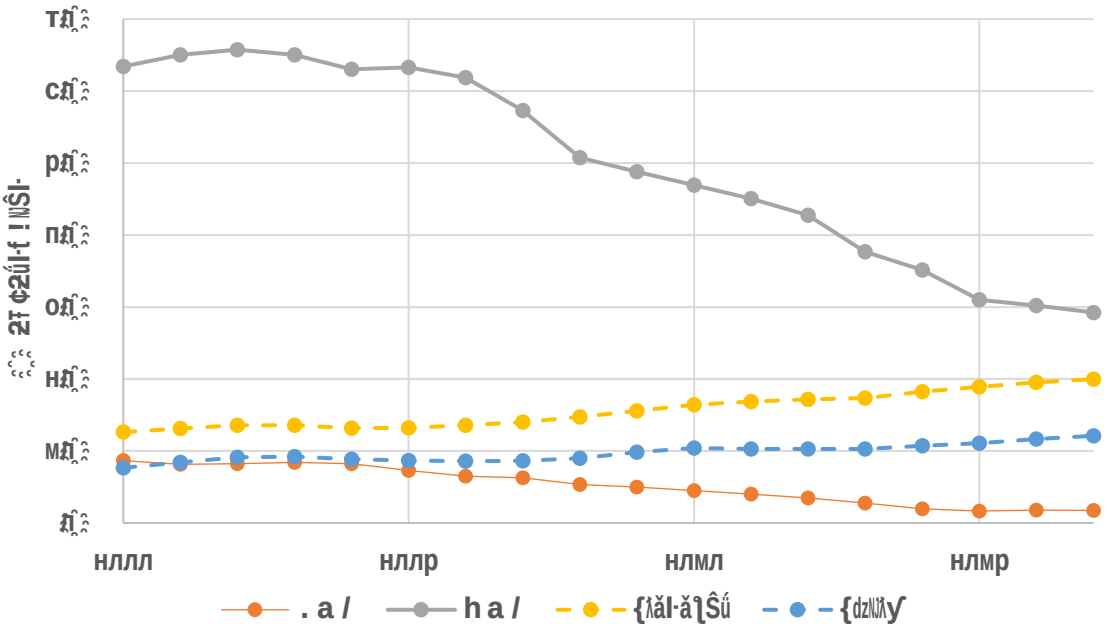
1.4.2 Fisheries

Fisheries are also a major source of food production and subsistence in Cambodia: requiring a sustained and consistent water supply throughout the year to protect livelihoods. The Tonle Sap Lake region is an important site for freshwater fishing and is one of the world's most productive inland fishing waters, with 26% of the countries cage aquaculture concentrated around the lake (MAFF, 2017). Unsurprisingly then, the communities of Banteay Meanchey have a greater reliance on fishing for their economies than in the neighbouring O. Meanchey. BM reportedly has a production amount of around 2, 500 tons per year whereas OM is much less at 40 tons (gov.kh, 2014). Neither Stung Sreng I nor II are equipped with fish passes.

Fishing and aquaculture total as a small fraction of the economic and food production in rural north-eastern Thailand.

1.4.3 Forest

Between 1973 and 2009, Cambodia lost 22% of its forest area, greatly affecting the natural resources of the country (WWF, 2013). In both provinces efforts have been made to protect forests through Community Forestry (CF) initiatives. These initiatives present communities with a legal basis to protect their resources. As of 2014 both Cambodian provinces have one Ministry of Agriculture Forest and Fisheries (MAFF) approved forest-site securing the forested area further against harmful practices.



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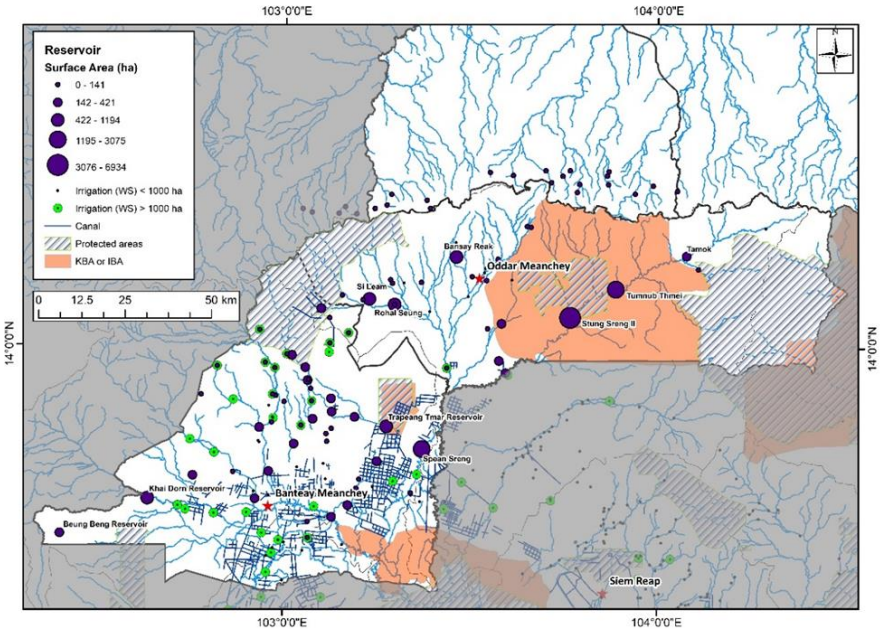
Since 2000, the forest cover has increased from a relatively low level by 36% in both Sisaket and Surin. Through remote sensing analysis, it is evident that the biggest loss of canopy cover is in Oddar Meanchey, reducing from 65% to 30% of total land area. A previous REDD+ international initiative in Oddar Meanchey focussed towards reducing the emissions from deforestation and forest degradation, by giving developing countries an incentive to reduce emissions from forested lands and to protect their resources (Cambodia Atlas, 2014). By adding financial value to the carbon within forests, known as carbon stocks, the initiative was pitted at developed stakeholders investing in the stocks and therefore making the areas more valuable. Unfortunately, due to illegal land grabbing, the pulling out of core funders and a lack of local stakeholder knowledge of the voluntary carbon stock market, the project did not meet all of its objectives (CJNH, 2018).

1.4.4 Protected areas

9NJN2NH wŜ₹ŜNŜyŎŜ ă2dzNŎŜ y2ű ₹2dzyŘ¢ reveals the protected areas and Key Biodiversity Areas (KBA) within the Cambodian provinces. A large central area of O. Meanchey is a KBA, along with the area around Trapaeng Thmor, which is an Important Bird Area (IBA). It is a requirement for all of



these areas to be considered throughout the planning process.

In Surin province the Tha Tum Nam Mun freshwater KBA serves to protect numerous freshwater species in the area (Maiz- Tome, 2019). Khao Phra Wihan National Park is a major protected area of Sisaket province that abuts the border into Cambodia's Phreah Vihear province.

1.4.5 Soils

Acrisol is the dominant soil type, representing 63% of the total area of the four catchments. Cambisol, The Cambisol, Gleysol, Luvisol and Slope Complex soil types represent 10%, 8%, 7% and 6% of the total area, respectively.

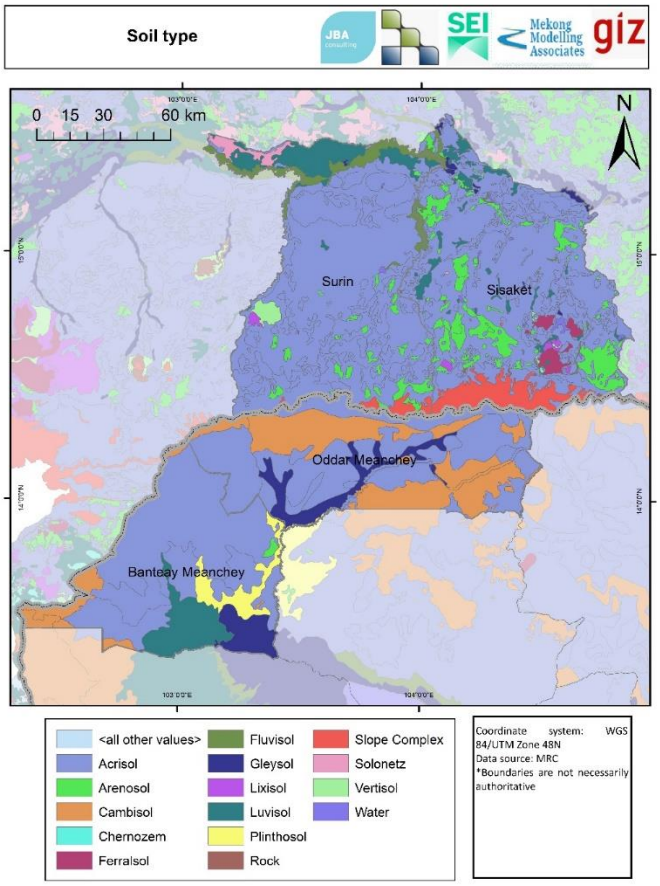


Figure 1-9 S Soil map

1.5 Socio-economics

The nationwide mechanism for the 'Identification of Poor Households' (IDPoor), implemented by the Ministry of Planning with support from GIZ, German and Australian governments has been running since 2006. In order to identify vulnerable households and to assess poverty, villagers elect representatives amongst themselves to conduct household interviews using standardised poverty criteria. A list of poor households is then finalised in each village against criteria of IDPoor 1 or 2, the former referring to greater relative poverty. For Banteay Meanchey and Oddar Meanchey, IDPoor data is the most accessible tool to determine those most vulnerable in economic and social terms. Furthermore, experiencing recent environmental changes serves as an IDPoor indicator, supporting the use of the database to aid in identifying target areas. Figure 1-10: ID Poor HouseholdsFigure 1-10 shows the percentage of IDPoor 1 and 2 households at commune level for both Cambodian provinces.

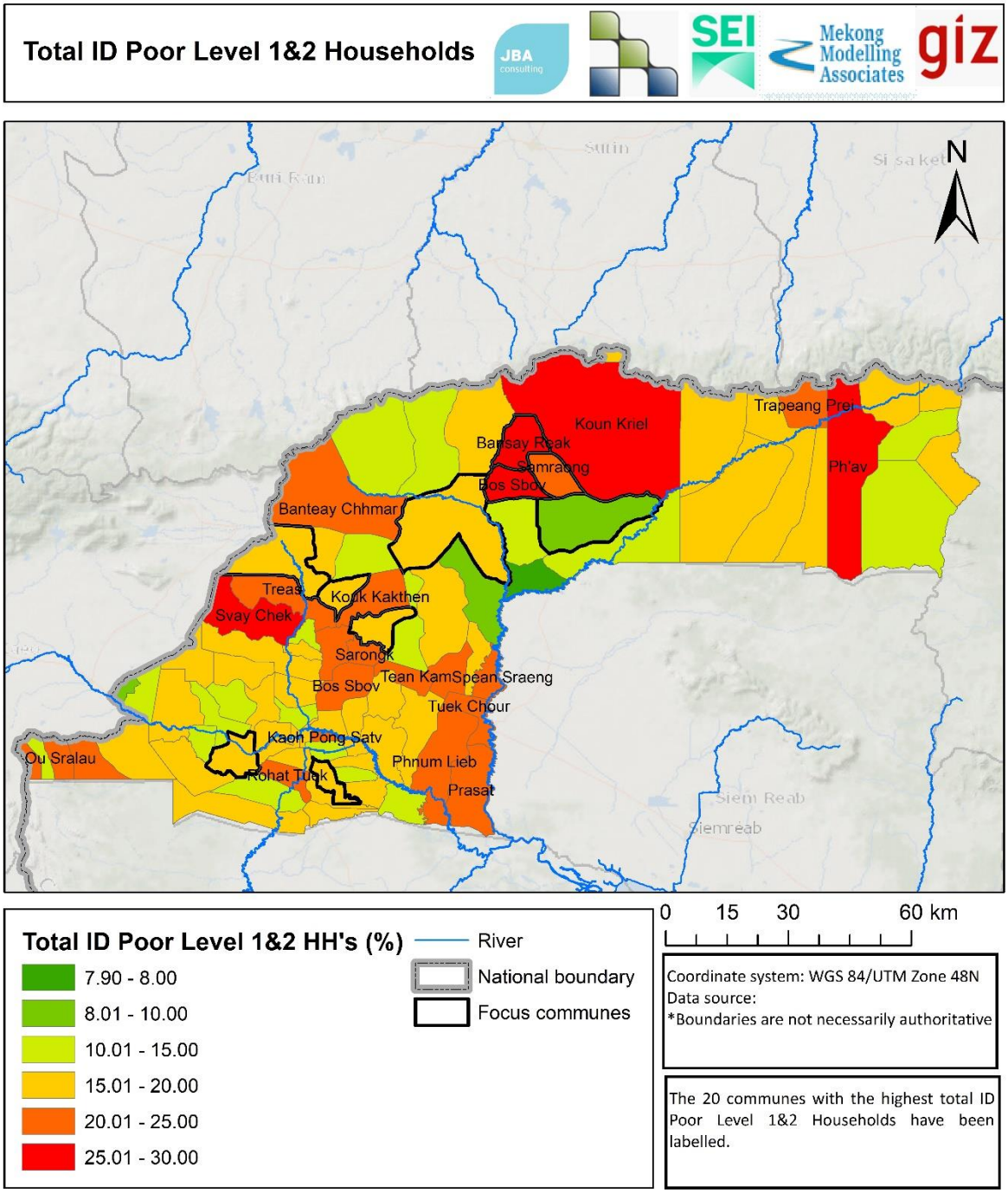


Figure 1-10: ID Poor Households

Findings from GIZ studies into the process of reaching IDPoor households in Oddar Meanchey and Banteay Meanchey reveal, “challenges due to climate and environmental changes” which is also an indicator for identifying poor households (GIZ, 2018). Questions included:

- Has your commune experienced (any of the following) environmental changes in the last 5 years?
- Has your livelihood been affected by any of these environmental changes?
- How did it affect you and how did you deal with the changes?

General findings:

- All households were economically affected by droughts during the past three years and sometimes with floods.
- Two third of the households have potable water scarcity during the dry season. In OMC the ground water table can stay below 60m deep. Therefore a deep well is too expensive.

Source: GIZ Internal Paper 142: On reaching ID poor households & drivers behind Migration in NW-Cambodia, Final Report, March 2018.

1.5.1 Market Access

The GIZ RED IV programme is currently working to promote local markets and agricultural value-chains via various training schemes and workshops. Therefore, to aid the development of these local markets and of agricultural markets as a whole, studies into the relationship between WRM, floods and drought on agricultural markets may be beneficial. Such studies would focus upon:

- Effects of flood and drought on commodity prices, production levels and markets
- Responses of agricultural organisations and local authorities to flood and drought
- Current management strategies with relation to water resources and markets

These studies would have to be checked for feasibility in the future, however the results produced could also aid in providing information to improve financial and agricultural public-private dialogue events.

1.5.2 Access to water resources

An important indicator of economic and social vulnerability is the extent of access to water resources within communities. The Commune Database (CBD) for Cambodia holds extensive information by province, district and village in terms of various socio-economic values from rates of domestic violence to the number of families with piped water or private pump wells. Figure 1-11 below demonstrates some of these values for the chosen Cambodian provinces and Phnom Penh, as a comparison, to illustrate the difference in water access between rural and urban areas.

CDB Indicator	B.Meanchey (no. of families)	O.Meanchey (no. of families)	P. Penh (no. of families)	B.Meanchey (%)	O.Meanchey (%)	P. Penh (%)
Piped water, private pump well or private rung well, useable year-round at their house (less than 150m)	**26, 437**	**14, 459**	**205,844**	**14. 37**	**25.26**	**76.38**
Use water from rivers, lakes, natural ponds and reservoirs	**17, 855**	**5, 116**	**2,898**	**9.71**	**8.94**	**1.08**
Usually using water from protected rain water storage	**11, 845**	**859**	**1,230**	**6.44**	**1.5**	**0.46**
Usually using water from ponds	**74, 575**	**16, 757**	**6,727**	**40.55**	**29.28**	**2.5**
Usually using water from protected dug wells	**7, 800**	**5, 039**	**1,860**	**4.24**	**8.8**	**0.69**
Usually using water from pumps and mixed wells	**33, 495**	**22, 074**	**12,017**	**18.21**	**38.56**	**4.46**
Usually using water from purified system equipment	**34, 792**	**4, 246**	**244,054**	**18.92**	**7.42**	**90.56**

Figure 1-11 Water resources indicators Banteay Meanchey and Oddar Meanchey (Commune Database 2016)

These statistics indicate how Oddar Meanchey and Banteay Meanchey in 2016 had comparatively less connections to modern and sustainable forms of WRM than urban centres such as Phnom Penh. For example, less than 20% of families in both provinces have access to purified water whereas in Phnom Penh over 90% have access, exhibiting the clear difference in water quality. Furthermore, only 14% and 25% of families in BMC and OMC, respectively, have year-round access to water from a well or through piped water. In Phnom Penh this figure is 76%, again highlighting the disparity in water access. These differences become more crucial when the increased risk of flood and drought is considered; increasing vulnerability.

1.5.3 Gender

An important element of Cambodia's socio-economic make-up to consider is gender. In Cambodia 39.3% of women are involved in agriculture (CSES, 2017, p.60). However, due to accepted gender norms, in particular within rural areas, there are disproportionate opportunities for women in comparison to men in agricultural activities. demonstrates the number of female headed households (FHHH) by district in the provinces. In addition, in the table below agricultural land ownership is

disaggregated by sex, with women making up **15.4%** of household heads and men making up **84.6%** in Cambodia as a whole.

Table 1.3 Agricultural land by sex of household head and zone in thousands and percent. Source: Cambodia Socio- Economic Survey (2017

Zone	Women		Men		Both sexes
	Hectares	Percent	Hectares	Percent	Hectares
Cambodia	508	15.4	2,790	84.6	3,298
Phnom Penh	2	22.6	8	77.4	10
Plain	163	15.3	898	84.7	1,061
Tonle Sap	225	17.0	1,096	83.0	1,321
Coast	22	13.3	140	86.7	162
Plateau/Mountain	97	13.0	648	87.0	745

Education and Vulnerability

Previous studies, such as that of the 9T/ 9C report discussed in the next section have also indicated the lack of women in WRM. A factor in the restriction of women in WRM and decision-making discussed above is the belief that women are thought to lack enough agricultural knowledge. Therefore, the education levels of men and women in rural communities are important. As of 2017, the percentage adult literacy rate for all men in Cambodia was 87.3% and 78.1% for women, with around a 4% drop in rural areas respectively to 84.6% and 74.4% (CSES, 2017).

In application of any future workshops to help improve the disparity between men and women in decision-making and WRM it will be important to consider literacy rates and education levels. For example, it may be more effective to use diagram-focused and interactive approaches to capacity building workshops rather than word-heavy presentations.

In Thailand, the literacy rate for ages 15+ was 95% for men and 91% for women in 2015 and members of the population between 15-24 achieved a total literacy rate of 98% with women almost 0.3% higher (uis.unesco, 2015). A compelling point to note is whether the literacy rates in Thailand and education levels as a whole have an effect on the involvement of women in WRM and decision-making. It is, however, more probable that it is due to a combination of factors, weighted toward cultural constraints.

To conclude, providing greater support to the agricultural sector as a whole must consider the current issues surrounding gender and education to ensure outputs are fully tailored.

1.5.4 Institutions

Agricultural communities:

Oddar Meanchey has 39 agricultural communities, totalling 4,610 members, of whom 3,025 are women. The number of agricultural development communities per district are as follows: Samraong (10), Chong Kal (3), Banteay Ampil (12), Anlong Veng (9), Trapaeng Prasat (5).

Agricultural cooperatives:

Agricultural communities in Cambodian provinces are often organised and supported by 'Agricultural Cooperatives' (AC). Agricultural cooperatives provide financial, practical and technical support to their

local agricultural sector. These cooperatives can accumulate capital to help in building small- scale irrigation systems for example. OMC and BMC have AC's in various districts, of whom it will be vital to access and support through establishing their needs in terms of water resources. It is however important to note that not all agricultural communities within provinces are represented by an AC.

1.6 Previous and Ongoing Studies

For the status quo analysis, a review of previous studies in the catchment area is necessary to ensure the approach and planning processes have all the relevant information and possible recommendations in mind.

1.6.1 RED Projects

The previous GIZ Regional Economic Development (RED) programmes, with focus on III and IV, are important to this project in terms of work in supporting agricultural and economic development in Banteay Meanchey and Oddar Meanchey.

RED III:

The objective of RED III was to provide the poor, rural population with new sustainable business and employment opportunities to increase their income and overcome poverty. The 'RED' projects also feature a series of 'cross- cutting' issues

The four fields of activity promoted were:

1. Local government action for inclusive growth
2. Stakeholder cooperation for local economic development
3. Sustainable services and business links for increased competitiveness of local products
4. Knowledge partnership with national level stakeholders

The value- chain approach was used to improve the employment opportunities for these populations

RED IV:

The fourth programme, which is currently ongoing and due to finish in 2021, aims to improve the economic and employment situation of disadvantaged rural households. This project identifies equal economic and political participation of women as a key contributor towards increased family income.

This project promotes:

1. Local value chains for rice, vegetables and manioc e.g. promoting a local market in Chong Kal (Oddar Meanchey), training courses for sustainable cultivation and processing
2. Local economic promotion projects e.g. artisanal activities and vegetable production, new tourism products
3. Dialogue between stakeholders accommodating the involvement of the rural population in local economic development
4. Selecting representatives from public administration to create the right conditions for local economic production

To summarise, both RED projects promote the opportunity of using horizontal scaling- up strategies to implement socioeconomic development projects in the arena of water resource management. It will be useful to assess ongoing projects in these areas, such as those promoting value- chains to improve local markets, to approach the possibility of working concomitantly to improve the economic security within the provinces whilst also avoiding overlap.

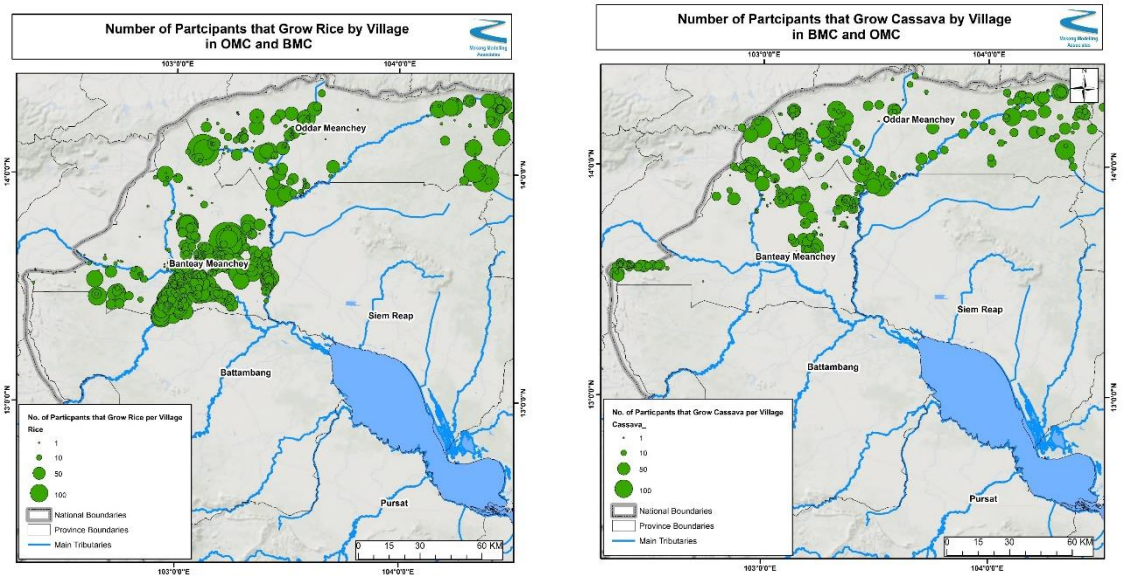


Figure 1-12: Number of participants involved in RED III and IV Cassava projects in BMC and OMC by village (2019)

In the figures above the number of participants involved in RED III and IV initiatives to improve cassava, rice and vegetable production are shown, for example through technical trainings, promotion of local markets and value- chain promotion. Identification of these villages allows this present project to assess which areas need sustained and regulated water supply, whilst also ensuring that there are no overlaps with recommended projects. There is no data for OMC for vegetable production due to an SDC project in the area focussed on the promotion of vegetable value- chains.

presents the number of participants by village in OMC and BMC that are involved in RED projects to improve the organisational development of agricultural communities in the provinces.

1.7 ADB TA- 7610

The ADB funded rapid and detailed surface water resources assessments, which focus on the Tonle Sap river basin group (RBG) and Mekong Delta RBG in Cambodia, provide insight into some of the overriding constraints on water resources and some possible improvements to WRM.

From overall evaluations of the water resources in the Mekong Delta RBG, findings demonstrated that water resources were mostly sufficient to meet annual demands. However, due to irregularities in resource availability with reference to dry seasons, location (distance to rivers and streams) and source of supply there are still frequent water shortages occurring.

Upon more detailed analysis of the catchments (focussing on the Stung Sreng and Stung Sisophon for the purposes of this project), the competition for water resources for both environmental flows and irrigation, revealed clear issues of water availability.

Catchment	Domestic Delivered Surface Water (%)	Environmental Flow Delivered (%)	Irrigation Delivered (%)
Stung Sisophon	59	49	19.9
Stung Sreng	61	55	47.7

Table 1.4: ADB TA-7610 modified table on water outputs by catchment area. Vol.1 Sep 2019.

Phase 2 Study Catchments

Phase 2 of the study, conducted following the outcomes and recommendations of the Rapid Assessment suggested the development of further linkages between the Stung Sreng II reservoir and Trapaeng Thmor, B. Meanchey (Down), O. Meanchey (Upper).

Recommendations for further studies in phase 2 corroborate the areas proposed for further data collection within the current report. They are as follows:

- To obtain better insight into small storage capacities within catchment sites.
- To have enhanced verification of water resources through collection and collaboration of observational data and results from previous studies.
- Improve data of current and potential water demands by agricultural, environmental and domestic sectors.
- To refine environmental flow requirements downstream to priority catchments.

In further eco- hydrological assessment of the Sreng and Sisophon, the catchments were shortlisted for more in-depth research due identified interventions for the Ang Trapaeng Thmor dam and along the Stung Sreng; with the possibility of leading to WRM strategies for irrigation. Canals linking the Stung Sreng I and II have also been proposed.

Water Supply and Demand Framework (WEAP)

Applying the Water Supply and Demand Framework (WSDF), experts in TA- 7610 identified the Water Evaluation and Planning (WEAP) model as the most appropriate tool for water resources planning. The model is said to best compliment the WSDF for various reasons: due to its focus on scenario analysis for policy implementations, its scalability, use of the tool worldwide for IWRM and the fact that WEAP is freely available for organizations in developing countries.

1.8 9T/ 9C Transboundary WRM

GIZ have supported the MRC and National Agencies in Thailand and Cambodia on the 9T/ 9C transboundary water resources management project in Thailand and Cambodia; a joint project into flood and drought analysis and mitigation plans. As shown in the map below, one of the focus provinces was Banteay Meanchey and the catchment areas of the Stung Sisophon and Svay Chet.

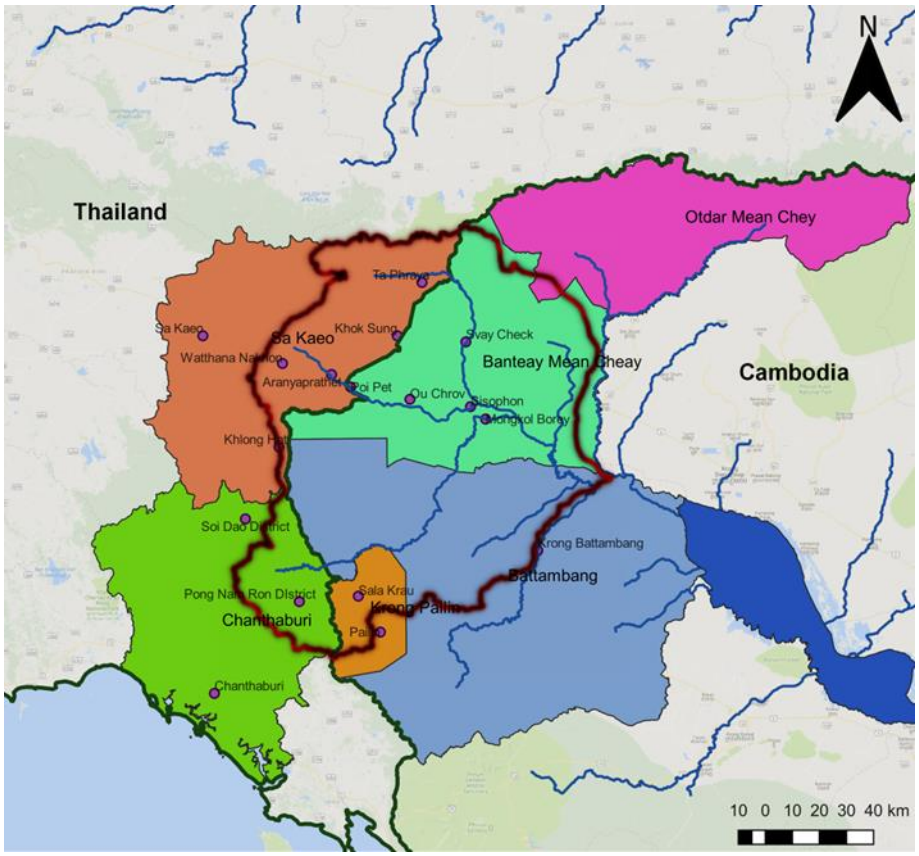


Figure 1-14: 9T/9C Catchments by province

The most at- risk areas in the sub- catchments were identified via risk assessments for both flooding and droughts as part of the IWRM approach and as an initial decision- making tool to propose mitigation measures. The importance of a joint database of knowledge and information was specified in the mitigation activities. Within the transboundary project at hand, going forward we will place focus on trying to develop bilateral relationships that aid the production of a large- scale knowledge base.

The results of the risk- based assessments were suggestions for a range of transboundary, regional, district and local level mitigation projects. Some key project proposals that it will be necessary to build upon in this project include those targeted toward local level involvement such as:

1. **Project L-1: Identification of floodway potential and Flood Zoning:**

- This project is pitted at establishing key flood pathways via targeted data collection in close consultation with local- level stakeholders. Development of localised flood mapping requires discussing in much greater detail via field visits, the most affected areas from historical flood patterns. Successful outcomes of the effective implementation of this would improve local planning systems to aid development of provinces outside of areas that have high risk of flooding.

2. **Project L-6: Rural Drought Risk Management:**

- Developed for districts in 9C catchments such as Mongkol Borei or Thma Puok, this proposal for a fully coordinated drought risk management plan (DRMP) holds the possibility of scalability when applied to other at- risk districts.

1.9 KOICA Master plan for Water Resource Development

KOICA's (2008) 'Master Plan of Water Resource Development in Cambodia' identified critical areas and river- basins for predicted water deficits in 2025. Notably, figure 7 identifies the Stung Sreng and Stung Mongkol Borey; basin catchments for Oddar Meanchey and Banteay Meanchey respectively as having a water deficit of between 160- 250 MCM.

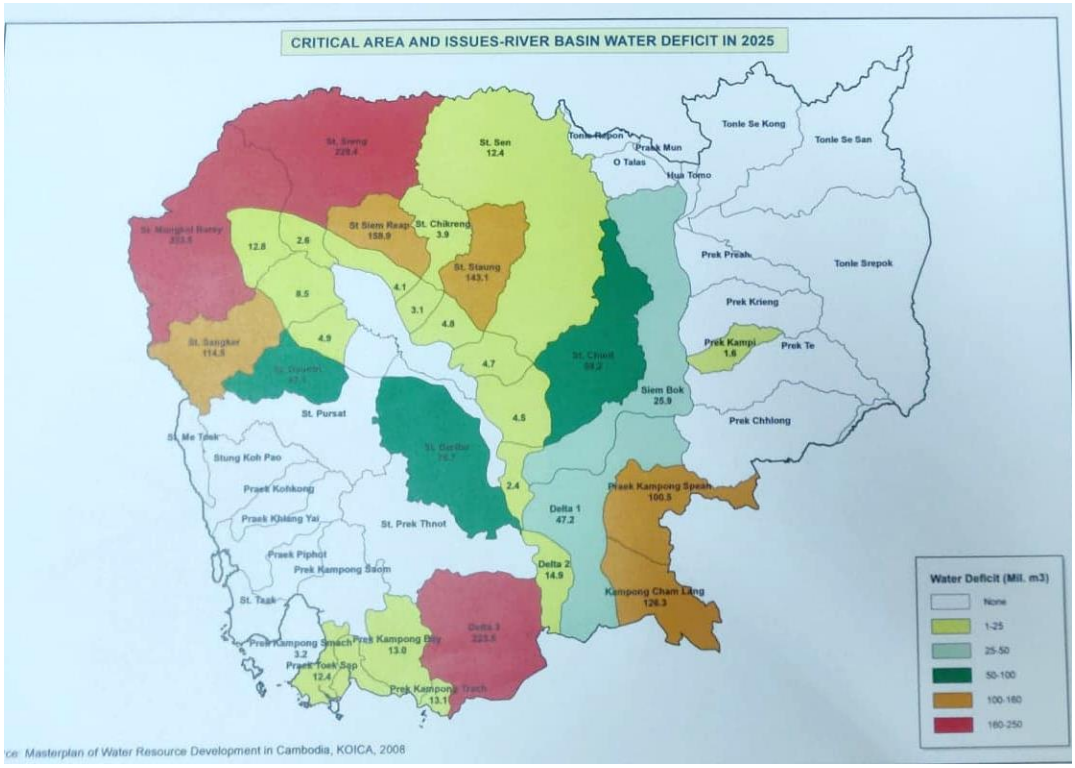


Figure 1-15: KOICA (2008): Critical Area and Issues: River Basin Water Deficit in 2025

This reiterates the critical standing of these provinces whereby development of greater water resource management strategies are required with immediate effect if the populations are to avoid the effects of a water deficit of this scale.

Annex B. Province Features and Water Management in Thailand Provinces of Surin and Sisaket

Annex B

Water Management in Thailand for Flood and Drought (Surin and Sisaket Provinces)

Prepared by SEI Bangkok

Current Status 1

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Current Status

Irrigation Development

Surin

Surin Province is located in the Mun River Basin. The Mun River is aligning on the north of the province, flowing west-east direction through Surin with the total length of 241 km. Tributaries of Mun River in Surin consisting Lam Chi Noi, Huai Ra Wee, Huai Phai, Huai Plub Pla, Huak Kaew and Huai Tab Tan.

By 2017, there are 528 irrigation projects in the province with total storage of 179 MCM, serving 84,627.68 ha or 528,923 rai of irrigated areas. Details are presented in the table and figure below.

Table 1: Existing Irrigation Project in Surin Province

Project Type	Large-Scale	Medium-Scale	Small-Scale	Total
Reservoir				
• Number		17	260	277
• Capacity (MCM)		137.08	0.67	137.75
• Irrigated Area (rai)		112,003	105,888	217,891
Monkey Cheek				
• Number			35	35
• Capacity (MCM)			26.92	26.92
• Irrigated Area (rai)			6,300	6,300
Weir				
• Number	5	1	146	152
• Irrigated Area (rai)	59,722	-	52,016	111,738
Regulator				
• Number			1	1
• Irrigated Area (rai)			-	-
Pump Station				
• Number	1		56	57
• Irrigated Area (rai)	49,064		97,920	146,984
Conveyance System				
• Number			3	3
• Irrigated Area (rai)			480	480
Others				
• Number		1	2	3
• Capacity (MCM)		-	14.60	14.60
• Irrigated Area (rai)		5,000	40,530	45,530
Grand Total				
• **Number**	**6**	**19**	**503**	**528**
• **Capacity (MCM)**	**-**	**137.08**	**42.19**	**179.26**
• **Irrigated Area (rai)**	**108,786**	**117,003**	**303,134**	**528,923**

Source: RID 2018

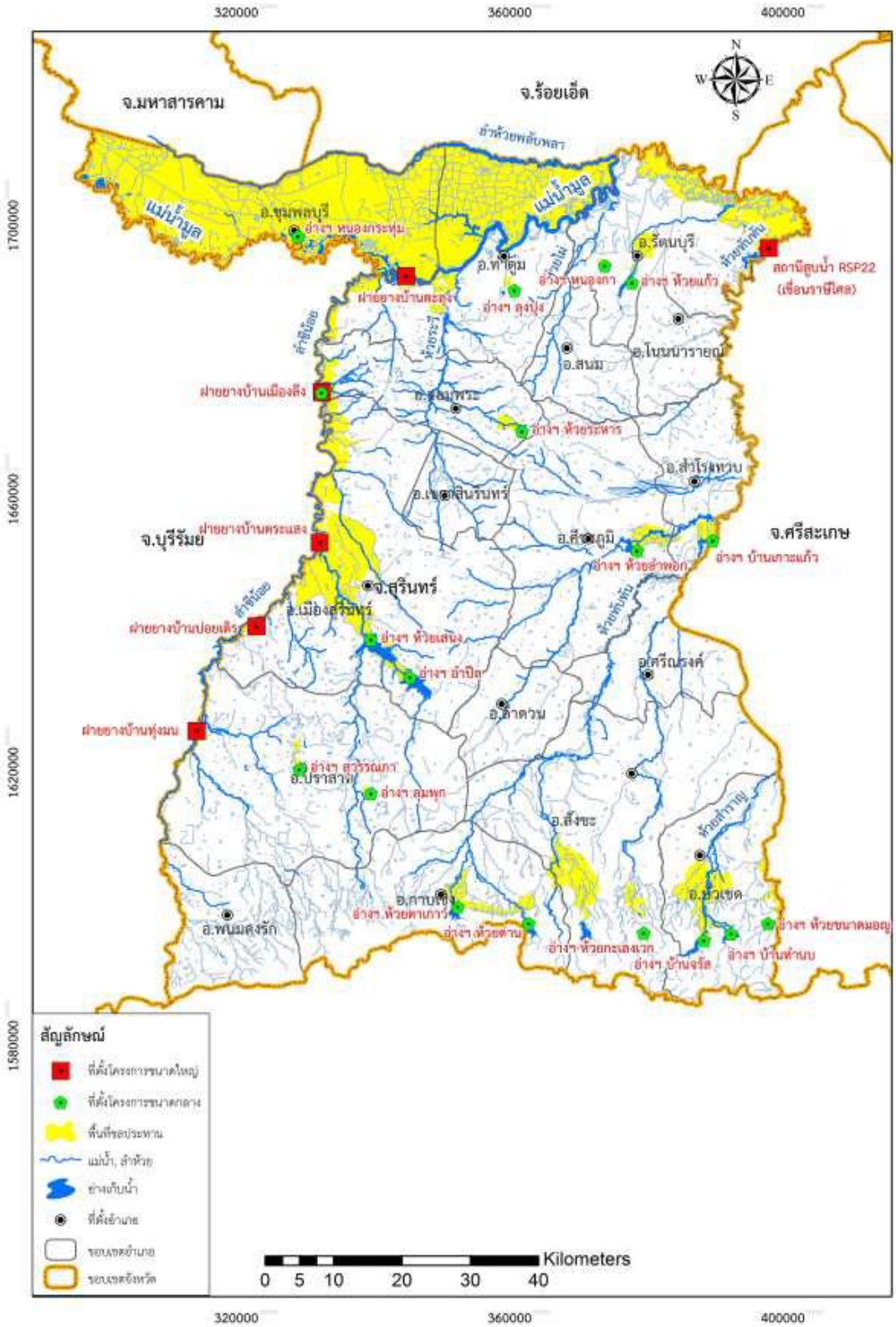


Figure 1: Large-scale and medium-scale irrigation projects in Surin Province
Source: RID 2018

Table 2: List of large-scale and medium-scale irrigation projects in Surin Province

No	Project Nam	Tambon	District	Capacity	Irrigated Area	Construction	
				(MCM)	(rai)	Start	Finish
Large-Scale Irrigation Project							
1	Lower Mun O&M Project						
	RSP22 Pumping Station (Rasi Salai Dam)	Don Rad	Ratanaburi	-	49,064	1994	1995
2	Middle Mun O&M Project						
	Ban Tra Saeng Rabber Weir	Tha Sawang	Muang	1	9,257	1995	1999
	Ban Poi Doem Rabber Weir	Sawai	Muang	1.4	3,000	2009	2010
	Ban Muang Ling Rubber Weit	Muang Ling	Chom Phra	8.5	37,203	1995	1999
	Ban Talung Rubber Weir	Nong Rua	Chumphon Buri	14.6	8,513	1988	1990
	Ban Thung Mon Rubber Weit	Thung Mon	Prasart	0.27	1,750	1995	1998
	Total			**25.77**	**108,786**		
Medium-Scale Irrigation Project							
1	Huai Saneng Reservoir	Chiangnieng	Muang	20.02	48,565	1970	1978
2	Am Phuen Reservoir	Ten Mi	Muang	27.68	2,923	1970	1974
3	Huai Ta Kao Reservoir	Kab Choeng	Kab Choeng	8.6	4,508	1982	1982
4	Huai Dan Reservoir	Dan	Kab Choeng	9.4	7,477	1985	1988
5	Huai Choeng Royal Initiative Project	Dan	Kab Choeng		5,000	2013	2014
6	Huai Rahan Reservoir	Bu Kraeng	Chom Phra	1.01	2,518	1955	1955
7	Ban Mung Ling Weir	Muang Ling	Chom Phra			2015	2017
8	Nong Kra Tum Reservoir	Chumphon Buri	Chumphon Buri	0.54	314	1958	1958
9	Lung Pung Reservoir	Tha Tum	Tha Tum	0.78	483	1956	1956
10	Ban Charas Reservoir	Charas	Bua Ched	15	9,198	1985	1993
11	Ban Tam Nob Reservoir	Chars	Bua Ched	12	8,502	1985	1990
12	Suwanpha Reservoir	Kan Ann	Prasart	1.07	1,047	1951	1956
13	Lum Phuk Reservoir	Ta Bao	Prasart	0.36	293	1953	1962
14	Huai Kaew Reservoir	Ratanaburi	Ratanaburi	4.92	3,694	1965	1965
15	Nong Ka Reservoir	Nam Kheo	Ratanaburi	0.59	107	1956	1956
16	Lam Phok Reservoir	Yang	Si Khon Phum	11.2	8,832	1953	1955
17	Huai Khanat Mon Reservoir	Ta Dom	Sangkha	15.5	7,453	1990	1995
18	Huai Kaleng Wek Reservoir	Ta Tum	Sangkha	3.4	2,321	1991	1996
19	Ban Ko Kaew Reservoir	Ko Kaew	Samrong Tab	5	3,769	1988	1989
	Total			**188.62**	**334,575**		

Source: RID 2018

Figure 2: Huai Saneng Reservoir, Maung District, Surin Province

Sisaket

Sisaket Province is located in the Mun and Chi River Basins, however the Mun basin occupies most parts of the province. The Mun River is aligned on the north of the province, flowing west-east direction through Surin with the total length of 121 km. Other tributaries of Mun River in Sisaket consisting Huai Tab Tan, Huai Samran, Huai Tha and Huai Khayung. Parts of Chi Basin in the Province are on the north of the province. They are most downstream areas of the Chi River before its confluence with the Mun River.

By 2017, there are 546 irrigation projects in the province with total storage of 311.5 MCM, serving 75,907.68 ha or 474,423 rai of irrigated areas. Details are presented in the table and figure below.

Table 3: Existing Irrigation Project in Sisaket Province

Project Type	Large-Scale	Medium-Scale	Small-Scale	Total
Reservoir				
• Number		14	227	241
• Capacity (MCM)		182.32	86.08	268
• Irrigated Area (rai)		90,349	141,919	232,268
Monkey Cheek				
• Number			54	54
• Capacity (MCM)			40.94	41
• Irrigated Area (rai)			12,995	12,995
Weir				
• Number		12	182	194
• Irrigated Area (rai)		300	32,765	33,065
Regulator				
• Number	2			2
• Irrigated Area (rai)	109,342			109,342
Pump Station				
• Number			39	39
• Irrigated Area (rai)			67,422	67,422
Conveyance System				
• Number		1	4	5
• Irrigated Area (rai)		3,800	7,780	11,580
Others				
• Number			11	11
• Capacity (MCM)			2.14	2
• Irrigated Area (rai)			7,750	7,750
Grand Total				
• **Number**	**2**	**27**	**517**	**546**
• **Capacity (MCM)**	**-**	**182.32**	**129.16**	**311.48**
• **Irrigated Area (rai)**	**109,342**	**94,449**	**270,631**	**474,423**

Source: RID 2018

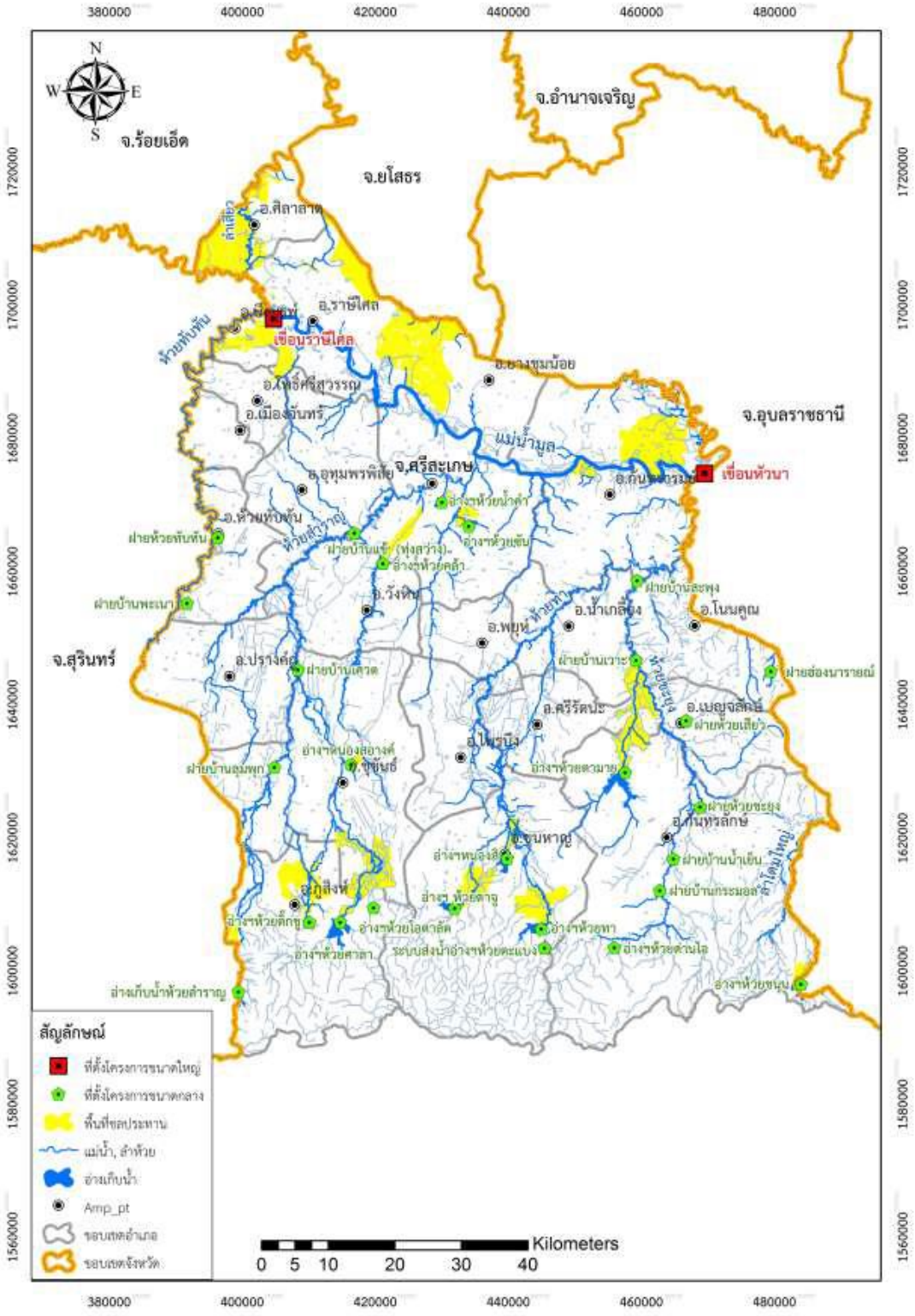


Figure 3: Large-scale and medium-scale irrigation projects in Sisaket Province
Source: RID 2018

Table 4: List of large-scale and medium-scale irrigation projects in Sisaket Province

No	Project Nam	Tambon	District	Capacity (MCM)	Irrigated Area (rai)	Construction	
						Start	Finish
Large-Scale Irrigation Project							
1	Lower Mun O&M Project						
	Hua Na Dam	Nong Kaew	Khantharrom	64.98	87,858	1992	2012
	Rasisalai Dam	Nong Khae	Rasisalai	74.46	21,484	1992	1993
	Total			**139.44**	**109,342**		
Medium-Scale Irrigation Project							
1	Huai Sun Reservoir	Phon Kha	Muang	2.71	2,564	1952	1952
2	Huai Nam Kham Reservoir	Nong Krok	Muang	1.01	486	1951	1951
3	Huai Khla Reservoir	Mak Kieb	Muang	3.78	3,812	1956	1958
4	Huai Khanun Reservoir	Khao Thongchai	Kantharalak	10		1990	1993
5	Ban Kramol Reservoir	Tung Yai	Kantharalak	1.5		2008	2008
6	Huai Khayung Reservoir	Nam Oom	Kantharalak	1.9		2004	2004
7	Huai Ta Mai Reservoir	Phu Ngoen	Kantharalak	38.2	22,276	1969	1982
8	Ban Nam Yen Reservoir	Muag	Kantharalak	1.3		2006	2006
9	Huai Dan Ai Reservoir	La Lai	Kantharalak	7.5		1995	1997
10	Ban Lum Phuk Weir	Kanthararom	Khu Khan	0.44		1997	1997
11	Huai Sala Reservoir	Khok Tan	Khu Khan	31	22,263	1984	1991
12	Ban Sawet Weir	Samrong Tajen	Khu Khan	1		1997	1997
13	Nong Sa-ang Reservoir	Huai Hua	Khu Khan	0.88		1952	1952
14	Huai Ta Ju Reservoir	Kan Trom	Khun Han	12	11,257	1989	1996
15	Huai Tha Reservoir	Bak Dong	Khun Han	30	10,732	2003	2006
16	Huai Tabaeng system	Bak Dong	Khun Han		3,800	2016	2016
17	Nong Si Reservoir	Si	Khun Han	2.89	2,030	1970	1975
18	Weir	Khup	Na, Klieng	1.3		2015	2016
19	Hong Narai Weir	Nongkung	Non Khun	0.1	300	2014	2014
20	Ban Woe Weir	lao Kwang	Non Khun	2.3		2009	2009
21	Huai-Seao 8 Weir	Seao	Benjalak			2015	2016
22	Huai Tik chu Reservoir	Khok Tan	Phu Sing	26.2	14,929	1996	1999
23	Huai O-talat Reservoir	Khok Tan	Phu Sing	3.8		2002	2003
24	Huai Samran Reservoir	Huai Ta Mon	Huai Tab Tan	12.35		1991	1994
25	Huai Tab Tan Weir	Kantharalak	Huai Tab Tan	10		1990	1993
26	Bang Phanao Weir	Huai Tab Tan	Huai Tab Tan	3.68		2005	2007
27	Ban Khae (Tung Sawang) Weir	Khae	Uthumpone Phisai	1.08		2013	2013
	Total			**206.92**	**94,449**		

Source: RID 2018

Figure 4: Hua Na Weir, Kanthararom District, Sisaket Province

Water Demand

Surin

Water demands for 4 major activities: domestic consumption, ecology, agriculture, and industry were estimated by RID (2018) as summarized in the table below.

Table 5: Estimated Water demand in Surin at present and in the future

No.	Activities	Water Demand (MCM/year)			
		Present (2017)	5-year (2022)	10-year (2027)	20-year (2037)
1	Domestic	76.50	77.29	78.10	79.73
2	Ecology	1,382.60	1,382.60	1,382.60	1,382.60
3	Agriculture				
	- -Irrigated Area	846.07	1,086.58	1,144.60	1,144.60
	- Non-irrigated Area	4,710.43	4,710.43	4,710.43	4,710.43
	- Total	5,556.50	5,797.02	5,855.03	5,855.03
4	Industry	6.35	6.67	6.98	7.62

Total	**7,021.94**	**7,263.58**	**7,322.71**	**7,324.98**

Source: RID 2018

Sisaket

Water demands for 4 major activities: domestic consumption, ecology, agriculture, and industry were estimated by RID (2018) as summarized in the table below.

Table 6: Estimated Water demand in Sisaket at present and in the future

No.	Activities	Water Demand (MCM/year) Present (2017)	5-year (2022)	10-year (2027)	20-year (2037)
1	Domestic	80.59	81.67	82.76	84.98
2	Ecology	1,382.60	1,382.60	1,382.60	1,382.60
3	Agriculture				
	- -Irrigated Area	575.57	790.88	879.59	879.59
	- Non-irrigated Area	3,574.84	3,574.84	3,574.84	3,574.84
	- Total	4,150.41	4,365.72	4,454.43	4,454.43
4	Industry	3.57	3.75	3.92	4.28
	Total	**5,617.17**	**5,833.74**	**5,923.71**	**5,926.29**

Source: RID 2018

Flood and Drought Situation

Surin

Drought in Surin occurs almost every year particularly in areas located remotely from water sources. The drought risk-prone areas of Surin prepared by the Land Development Department (2013) is shown in Figure 5. It is concluded that 76% of the province is within the low risk zone. There is no high drought-risk prone area in Surin.

Flooding in Surin mostly happens on low-lying lands as a result of upstream floodwaters from Phnom Dongrak Mountain range that spread southward into the central parts of the province causing inundation particularly in Surin Municipality. On the areas adjacent to the Mun River, flooding occurs from backwater of Mun River that causes overtopping floods. Rapid urban development that increases activities and infrastructures has blocked waterway thus reducing drainage capacity of the lands. Flood management could be done more effectively and efficiently if those obstructions could be minimized since some control structures are already existed. A flood risk map of recurrent flooding of Surin was prepared by GISDA in 2013 as shown in Figure 6. It was found that the low and medium risks of recurrent flooding in Surin are spread over most area of the province. The high risks of recurrent flooding are mostly concentrated along both banks of Mun River and Huai Tab Tan as depicted in the Figure 6.

In Surin, Huai Saneng and Amphuen Reservoirs are the major sources for water supply production of the province. At present, water from Huai Saneng reservoir is produced and supplied for consumption as the first priority, not sufficient for agriculture. With changing land uses and increasing infrastructures, inflow to reservoirs has been decreased somehow. Water diversion from other sources are needed to supplement water supply. It is suggested to

use water from Chi River for water supply production then water in Huai Saneng reservoir can be used for agriculture. Surin Provincial Waterworks Authority has set up a plan to manage water and prevent drought in the province. The plan includes preparedness, monitoring, and coordinating with relevant agencies as well as managing water during a drought crisis. It is necessary to store water during wet season as much as possible in available storages (swamps, ponds, canals) to secure water for dry season uses.

Sisaket

The drought risk-prone areas of Sisaket prepared by the Land Development Depart (2013) is shown in Figure 7. It is concluded that 93% of the province is within the low risk zone. There is no high drought-risk prone area in Sisaket.

Flooding in Sisaket occurs every year mostly in the same area. Flooding in the vicinity area of the Mun River is caused by either upstream floodwaters that flowing into the province and overtopping the banks; and/or backwater of the Mun river from Ubon Ratchathani that flows back into the tributaries and flooding low-lying lands on the river banks.

Another flood-prone area in Sisaket is situated in the vicinity area of Lam Huai Samran (major river in Siaket) that flows through Sisaket Municipality which is a hilly land. Huai Samran before emptying in the Mun River flows quite slowly and thus whenever river level in the Mun river is high, backwater occurs that lifts up the level of Huai Samran then floods wide areas.

The total capacity of existing storages in the province could not bear floodwater occurs from above-normal rainfall events. The natural drainage capacity is also less than the capacity of regulating structures thus flooding could not be well-managed.

A flood risk map of recurrent flooding of Surin was developed by GISDA in 2013 as shown in Figure 8. It was found that the high risks of recurrent flooding are situated along both banks of major rivers i.e. Mun River, Chi River, Lam Seao, Huai Tab Tan, Huai Samran, Huai Tha, and Huai Khayung as depicted in the Figure 8.

The water sources for water supply production in Sisaket are mainly taken from the Mun, Huai Samran and Huai Tab Tan rivers. Currently water from these sources is sufficient for water supply and consumption hence water from existing reservoirs are not taken.

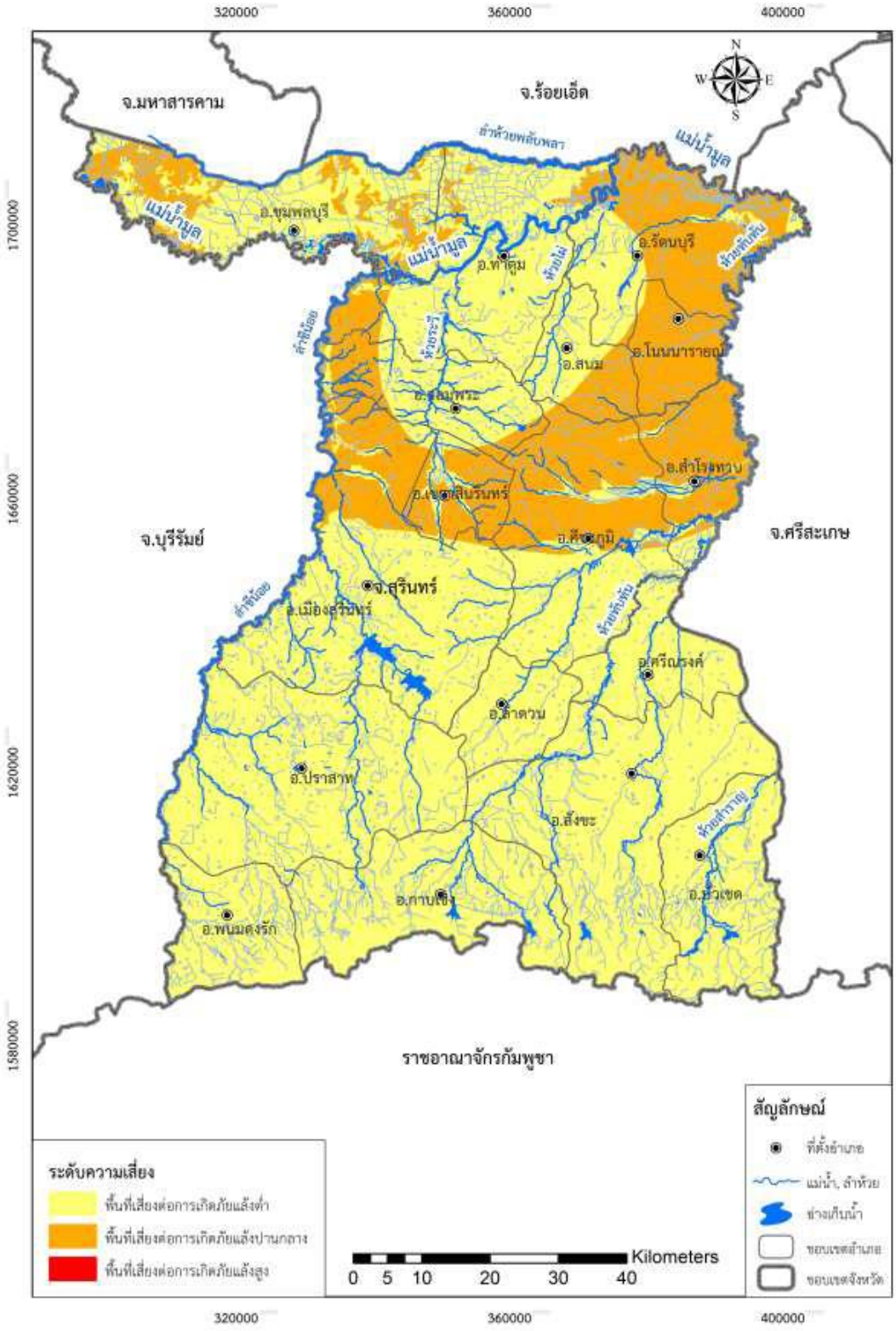


Figure 5: Drought-Risk Prone Area of Surin by Land Development Department (2013)
Source: RID 2018

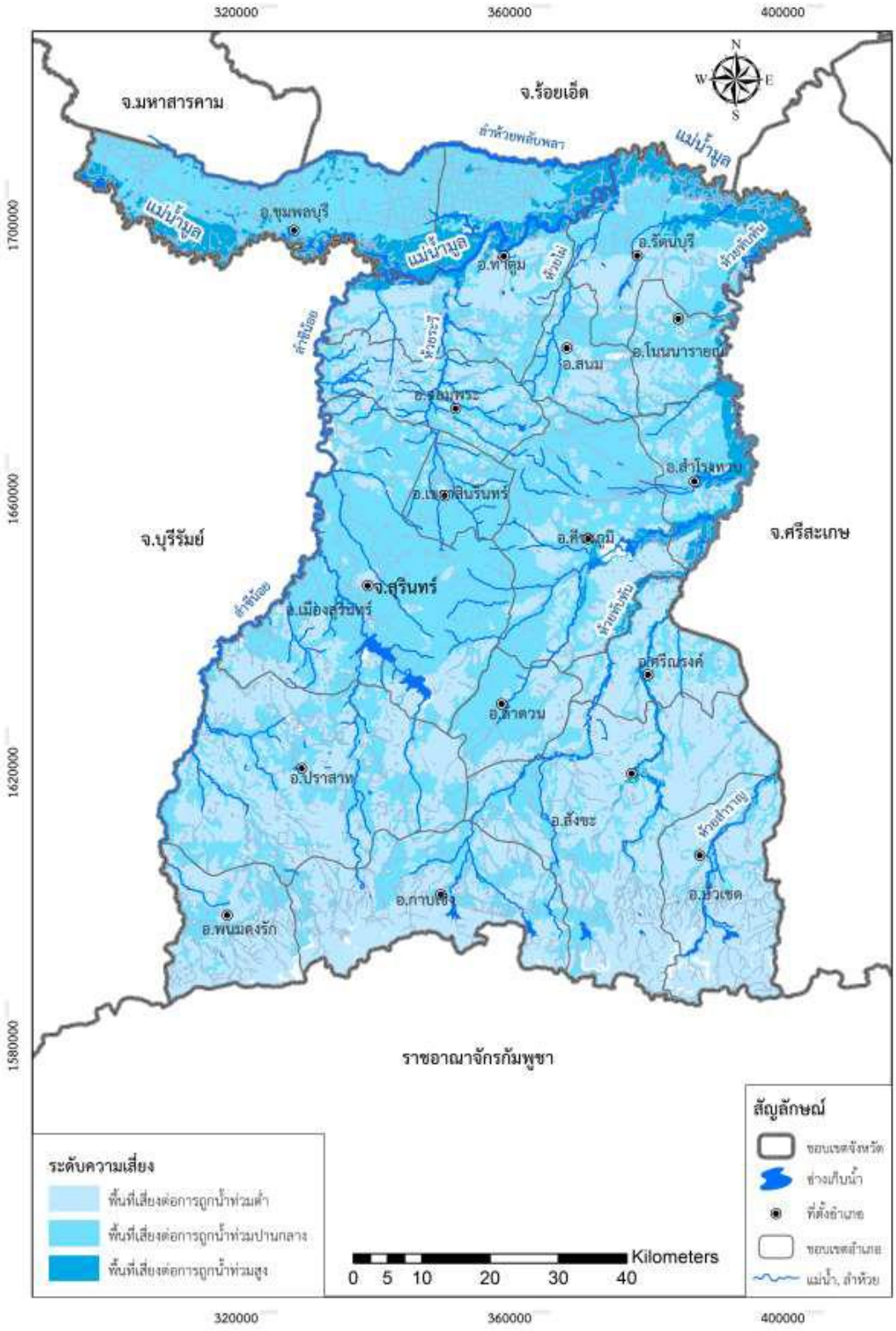


Figure 6: Flood Risk Area of Surin by GISTDA (2013)
Source: RID 2018

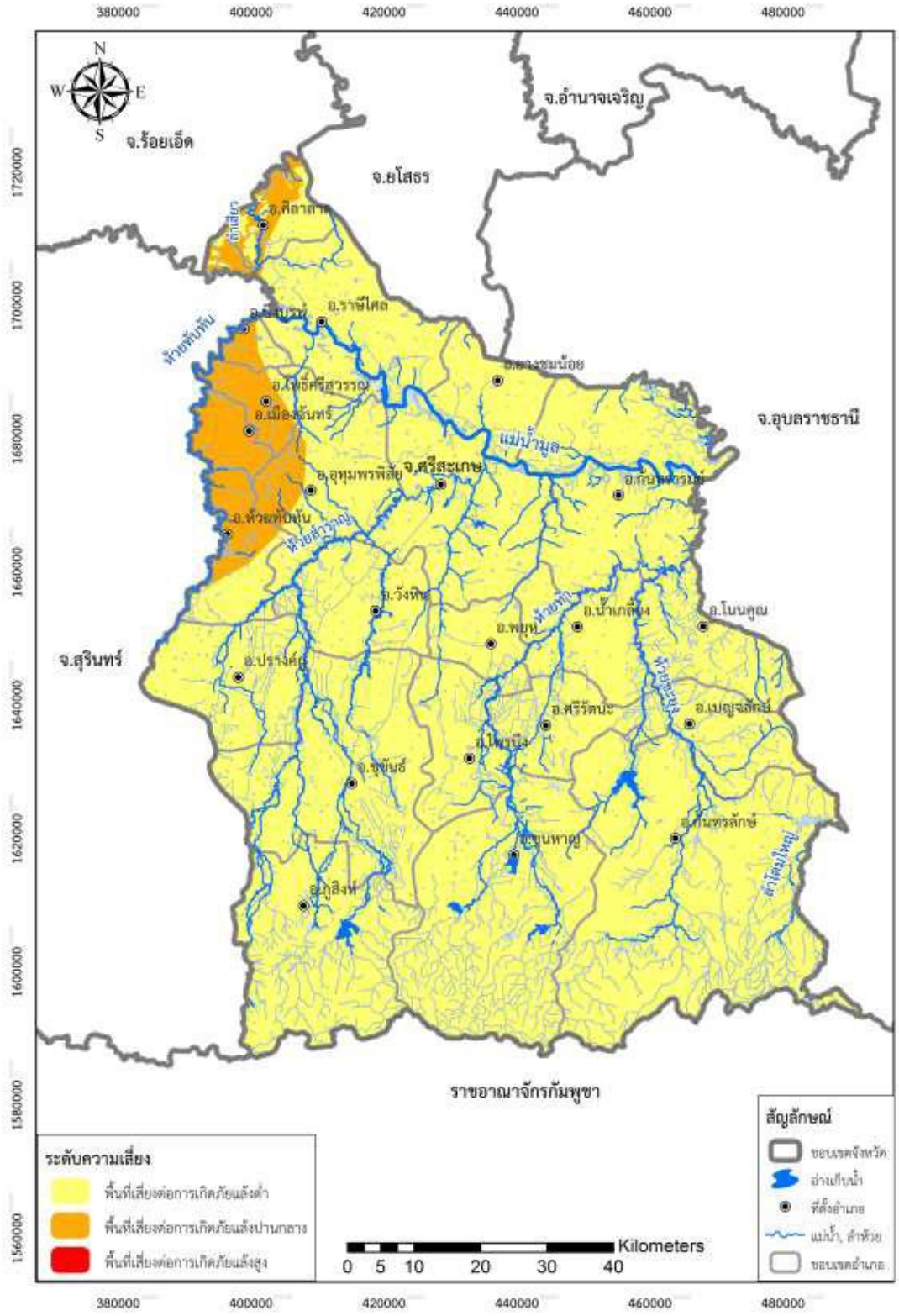


Figure 7: Drought-Risk Prone Area of Sisaket by Land Development Department (2013)
Source: RID 2018

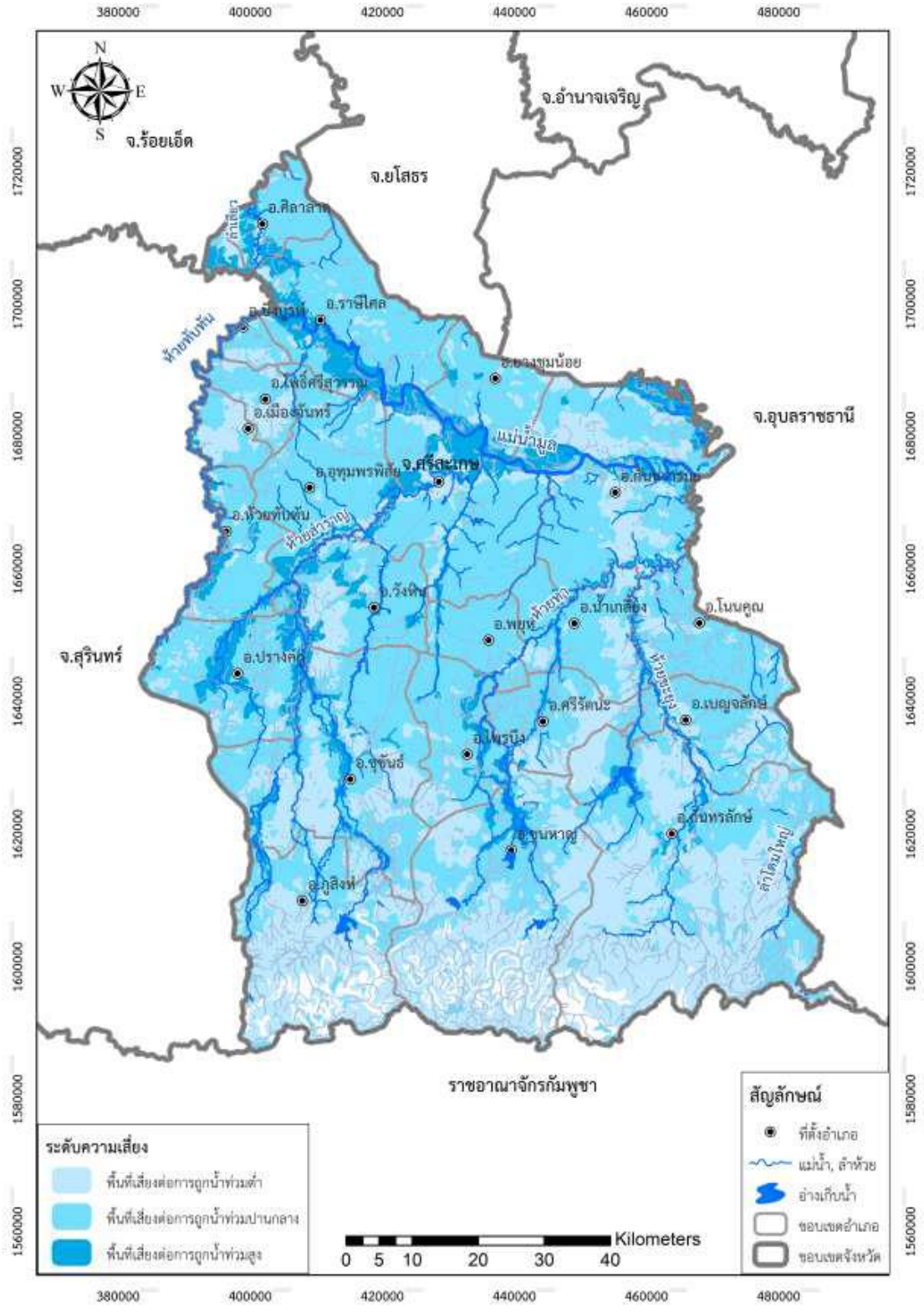


Figure 8: Flood Risk Area of Sisaket by GISTDA (2013)
Source: RID 2018

National Water Management Strategies/Plans

Thailand's 20-year National Strategy (2018-2037)

The National Strategy (2018-2037) is the country's first national long-term strategy developed pursuant to the Constitution. It shall be pursued to ensure that the country achieves its vision of becoming "a developed country with security, prosperity and sustainability in accordance with the Sufficiency Economy Philosophy" with the ultimate goal being all Thai people's happiness and well-being. The National Strategy is designed to uphold the country's national security, independency and sovereignty; to build the country's capacity to effectively deal with changes generated by internal and external factors at all levels; to upgrade Thailand's agricultural, industrial, and service sectors with technology and innovation for higher added values; to develop new economic drivers that will enhance the country's competitiveness, leading to higher income per capita and more adequate benefits distribution to all parts of the country; to develop Thais to be virtuous, skillful, disciplined, considerate, equipped with analytical skill and consistently able to "Know, Obtain, and Adapt" new technology; to have equal access to basic public services, welfare and justice system, with no one left behind. National development during the National Strategy's timeframe shall focus on an appropriate balance between security, social, economic and environmental developments, with participation from all sectors in the form of Pracharat model. The six strategies comprising the national strategy are (source: Strategic Transformation Office):

1. ***National Strategy on Security***

Aims to ensure national security and public contentment, with primary emphasis on national contexts management to promote security, safety, independency, sovereignty, peace and order at national, social, and community levels; to prepare and develop human capital, related tools and technology as well as Big Data technology to be ready to address all forms of threats and challenges at all levels of intensity, together with preventing and addressing existing and future national security problems; to employ integrated mechanisms designed to effectively deal with security problems in the public sector, private sector and civil sector as well as non-governmental organisations, neighbouring countries and global alliances, based on good governance principle. These will result in collective efforts to help the implementation of other National Strategies to be effectively successful.

2. ***National Strategy on Competitiveness Enhancement***

Aims to enhance national multidimensional capacity based on the three ideologies: (1) "Learning from the Past for Further Development" with a focus on acquiring true understanding of the origins of the national economy; 8 local identity, culture, tradition and lifestyles; natural resource diversity as well as other multidimensional comparative advantages. Lessons learned will later be integrated with available technologies and innovations to respond to existing global economic and social contexts; (2) "Adjusting the Present" to prepare for the future through national infrastructure development, including transport and logistics, science, technology, and advanced digital systems, as well as environmental adjustment, to facilitate future industrial and service development; and (3) "Creating New Future Values" to enhance entrepreneurs' capacity; develop younger generations; adjust business models to meet fast changing market demand; implement

strategies to accommodate anticipated future contexts with a focus on learning from the past and adjusting the present for further development; and leveraging governmental support to help generate income and employment, expand trading and investment opportunities in global markets, enhance income and general well-being of Thai people, increase the number of middle-class citizens, and reduce inequality.

3. National Strategy on Developing and Strengthening Human Capital

Aims to develop Thai people of all ages in a multidimensional manner to become good, skilful, and quality citizens. The scope covers promotion of physical, mental and intellectual qualities, adequate multidimensional developments, sustainable welfare at all stages of life, promoting public mindedness, and generating social responsibility. Citizens are also expected to be frugal, generous, disciplined, and ethical, equipped with logical thinking and 21st century skills, communication skills in English and a third language. Furthermore, citizens are also encouraged to preserve local languages while encouraged to acquire lifelong learning and development habits. Developments following this Strategy will help promote modern innovators, thinkers, entrepreneurs, farmers, and so forth based on personal skills and abilities.

4. National Strategy on Social Cohesion and Equity

Aims to develop cooperation between private sector, general public, and local communities for strategy implementation. Public involvement will be encouraged as a mechanism to enable cooperation for society in general. This will promote decentralization of power and responsibilities among local administrative organizations, strengthen independent management of local communities, and create viable and healthy economic and social surroundings aimed for quality citizens, who can contribute to families, communities, and society in perpetuity. Furthermore, the government is committed to ensuring equitable and inclusive access to quality public services and welfare practices.

5. National Strategy on Eco-Friendly Development and Growth

Aims to achieve all development aspects of the Sustainable Development Goals (SDGs), including society, economy, environment, good governance, and cooperation partnerships at both national and international levels. Strategic and operational plans formulation and implementation will be area-based, with the promotion of all related sectors' direct involvement to the extent possible. Implementation will target the promotion of mutual growth in terms of the economy, environment, and quality of life. The focus is to create balance among these three factors to promote sustainability for future generations

6. National Strategy on Public Sector Rebalancing and Development

Aims to reform the public sector based on the concept of "a public sector of the people, for the people and the public interest". In pursuit of this goal, the size of the public sector must be appropriate in accordance with its roles and missions, with the roles of regulatory agencies clearly defined and distinguished from those of operating agencies. Furthermore, the public sector needs to be open for intersectoral-operations and participation from all relevant parties, to be integrated, and operate on a result-based basis, with good governance and

commit to the general public interest at large, flexibility and capacity to adequately adapt to any changes, especially the employment of Big data and digital technologies to help improve the public sector's performance in accord with international standards. These will result in better, faster, more transparent and responsive public services accurately in accordance with the public needs. All sectors in the society will be promoted to have value honesty, integrity and frugality while resisting all kinds of malfeasance. Laws shall not be ambiguous, redundant and outdated; shall be in line with international standards and practices which will both promote growth and development and eradicate justice system discrimination. The country's justice system will be administrated in a fair, effective, non-discriminating manner based on the rule of law principle.

20-year Master Plan on Water Resources Management (2018-2037)

The Master Plan on Water Resources Management (2018-2037), prepared by the National Water Resources Committee, is an improvement from the Water Resource Management Strategy (2015-2026), to be in line with the 20-year National Strategy, which seeks to manage water resources throughout the whole system for the country's water security. the 20-year master plan provides water-resource management guidelines for all related agencies. It The master plan comprises 28 strategies and 54 work plans, in six major areas as briefly summarized below.

Strategic Area 1: Managing water for consumption

This strategy's objectives are to provide clean-consumable water for communities country-wide, extensively to every villages or households, urban communities, economic areas and important tourist attractions; to reserve other water sources for water-scarce areas as well as to leverage the production of drinking water with reasonable price including to save water by reducing water uses in households, service and government sectors.

Strategic Area 2: Providing water security in production sectors

This strategy aims to develop water storages and conveyance systems to full potential; to secure water in rain-fed areas to increase the potential of small projects and reduce risk to 50% as well as increase productivity and restructure water uses. These are conducted conjunctively with the national strategy on building capacity on competition and building opportunity and equality in society to leverage the whole system of water productivity.

Strategic Area 3: Managing floods and flood disasters

The aims are to increase the drainage capacity; to improve flood protection system in urban communities; and to relieve spatial flood disasters systematically in the basin level and critical zones (Area Based), large river basins, tributaries by decreasing risk and severity to not less than 60%.

Strategic Area 4: Managing water quality and conserving water resources

The aims are to develop and increase the efficiency of collection and treatment systems of community wastewater to be reused again; to prevent and reduce wastewater upstream; to

control ecological flow maintenance as well as to restore rivers, canals, and national water resources those are significant in all dimensions in order to preserve, restore and utilize nation-wide.

Strategic Area 5: Conservation and restoration of watershed and degraded forests and the protection of soil erosion

The aims of this strategy are to conserve, restore watershed and degraded forests and to protect and reduce soil erosion in the watershed and sloping areas.

Strategic Area 6: Management and Administration

This strategy aims to establish water resources management organizations (national water resources committees, river basin organizations, etc.; to modernize the laws; to enhance international cooperation to seek for capital funds; to improve decisional support system (national water portal); to support river basin organizations; to support knowledge exchange between private and government sectors, irrigation management, researches, preparation; to enhance public relations and participation of public and relevant sectors; to increase conscious in water resources conservation; to develop researches, innovations and technologies those create the added values in service and production sectors; as well as to develop the prototypes on leveraging the water resources management in specific areas and basins (connected to markets, energy, production and waste).

20-year Strategic Plan of Royal Irrigation Department

To meet the Vision of the Royal Irrigation Department as an intelligence organization aimed at creating water security and increasing service value by the year 2036, the department has set up below strategic issues to meet their targets:

1. Water resources development and irrigation area increase by basin-based approach

2. Water management efficiency increase according to water use objectives

3. Water hazards prevention and mitigation support

4. Networking and participation in all sectors of networking collaboration participation

5. Turnaround to intelligent organization

The roadmap of RID to implement this strategic plan has been divided into 4 phases each for 5 years.

Irrigation Development Plan

The Royal Irrigation Department has prepared irrigation development plan in basin level which includes small-, medium-, and large-scale irrigation projects as well as rehabilitation of existing projects in all 25 major river basins of Thailand. The aims are to develop water

storages, irrigation areas and prevent floods which are in accordance with the strategies mentioned above.

Surin

According to the 20-year irrigation development plan (2018-2037), there are 273 projects in Surin, consisting 14 and 259 medium- and small-scale irrigation projects, respectively (Table xxx). These projects altogether will increase storage volume of 124.44 MCM and irrigation areas of 186,628 rai (29,860 ha).

Table 7: 20-year Irrigation Development Plan of Surin by Project Scale and Implementation Period (RID, 2018)

Project Scale	20-year Irrigation Development Plan			
	Short-term (2018-2022)	Medium-term (2023-2027)	Long-term (2028-2037)	Total 20 years (2018-2037)
1. Large-Scale				
• Number				
• Capacity (MCM)				
• Irrigated Area (rai)				
• Budget (Million Baht)				
2. Medium-Scale				
• Number	13	1		14
• Capacity (MCM)	36.96	3.50		40.46
• Irrigated Area (rai)	46,455			46,455
• Budget (Million Baht)	2,045.14	30.00		2,075.14
3. Small-Scale				
• Number	168	81	10	259
• Capacity (MCM)	44.27	35.73	3.98	83.99
• Irrigated Area (rai)	103,906	36,267	-	140,173
• Budget (Million Baht)	3,381.19	1,306.81	153.00	4,841.00
Grand Total				
• Number	181	82	10	273
• Capacity (MCM)	81.23	39.23	3.98	124.44
• Irrigated Area (rai)	150,361	36,267	-	186,628
• Budget (Million Baht)	5,426.33	1,336.81	153.00	6,916.14

Note: 1 rai = 0.16 ha

These planned projects can be grouped to meet the objectives of the 20-year master plan on water resources management under Strategy 2 and 3 as shown in the table below. However, some project types especially reservoir projects can fulfill both strategies as they are enabled to provide water security and manage flood.

Table 8: 20-year Irrigation Development Plan of Surin by Water Strategy (RID, 2018)

Project-Scale	Strategy 2: Providing water security in production sectors		Strategy 3: Managing floods and flood disasters		Total	
	Number	Budget (M. Baht)	Number	Budget (M. Baht)	Number	Budget (M. Baht)
Large-Scale						
Medium-Scale	14	2,075			14	2,075
Small-Scale	233	4,326	26	515	259	4,841
Total	247	6,401	26	515	273	6,916

Note: 1 rai = 0.16 ha

Table 9: Planned Irrigation Projects in Surin Province according to the 20-year Plan by Project Types (RID, 2018)

No.	Project Type	Number/ Amount	Capacity (MCM)	Irrigated Area (rai)
	Medium-Scale Projects			
1	Reservoirs (including increasing reservoir capacity)	4	37.26	3,500
2	Weirs	3	3.2	10,000
3	Pump Stations (and conveyance systems)	1	-	4,375
4	Regulators	1	-	6,000
5	Monkey Cheeks	1	-	-
6	Conveyance Systems	4	-	22,580
7	Dredging			
	Total	***14***	***40.46***	***46,455***
	Small-Scale Projects			
1	Reservoirs (including improvement)	6	2.01	550
2	Weirs	30	2.86	-
3	Pump Stations (and conveyance systems)	37	0.17	82,681
4	Regulators	4	6	-
5	Monkey Cheeks	153	71.86	54,142
6	Conveyance Systems	5	0.49	2,800
7	Dredging	7	0.63	-
8	Dykes (including improvement)	3	-	-
9	Drainage Systems	14	-	-
	Total	***259***	***84.02***	***140,173***
	Grand Total	**273**	**124.48**	**186,628**

Note: 1 rai = 0.16 ha

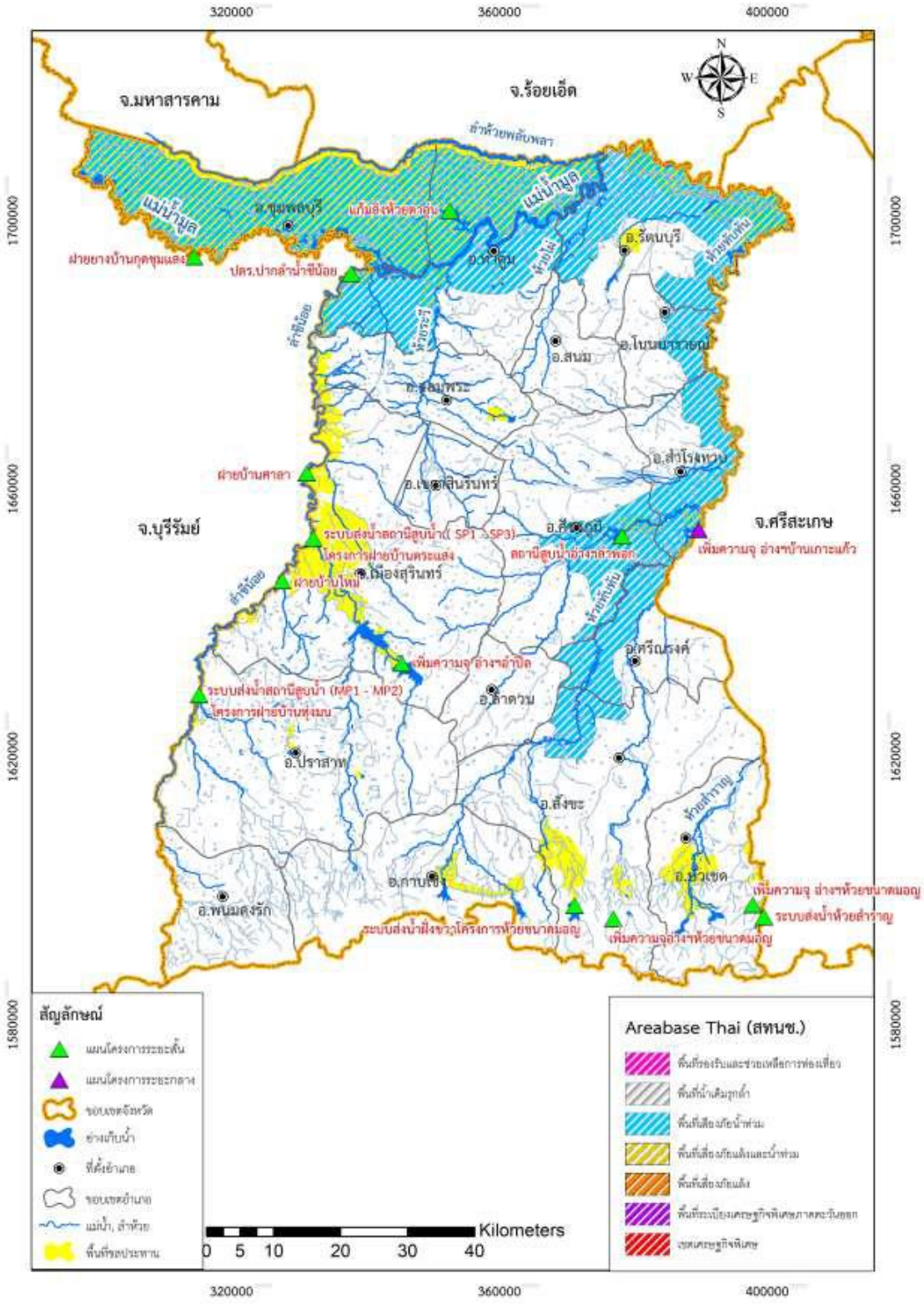


Figure 9: Planned Medium-Scale Projects of Surin according to the 20-year Plan
Source: RID 2018

Sisaket

According to the 20-year irrigation development plan (2018-2037), there are 97 projects in Surin, consisting 17 and 80 medium- and small-scale irrigation projects, respectively (Table xxx). These projects altogether will increase storage volume of 115.48 MCM and irrigation areas of 250,594 rai (40,095 ha).

Table 10: 20-year Irrigation Development Plan of Sisaket by Project Scale and Implementation Period (RID, 2018)

Project Scale	20-year Irrigation Development Plan			
	Short-term (2018-2022)	Medium-term (2023-2027)	Long-term (2028-2037)	Total 20 years (2018-2037)
1. Large-Scale				
• Number				
• Capacity (MCM)				
• Irrigated Area (rai)				
• Budget (Million Baht)				
2. Medium-Scale				
• Number	13	4		17
• Capacity (MCM)	78.89	29.38		108.27
• Irrigated Area (rai)	128,355	70,620		198,975
• Budget (Million Baht)	3,434.00	860.00		4,294.00
3. Small-Scale				
• Number	56	24		80
• Capacity (MCM)	5.63	1.58		7.21
• Irrigated Area (rai)	49,119	2,500		51,619
• Budget (Million Baht)	1,264.38	371.00		1,635.38
Grand Total				
• Number	69	28	-	97
• Capacity (MCM)	84.52	30.96	-	115.48
• Irrigated Area (rai)	177,474	73,120	-	250,594
• Budget (Million Baht)	4,698.38	1,231.00	-	5,929.38

Note: 1 rai = 0.16 ha

These planned projects can be grouped to meet the objectives of the 20-year master plan on water resources management under Strategy 2 and 3 as shown in the table below. However, some project types especially reservoir projects can fulfill both strategies as they are enabled to provide water security and manage flood.

Table 11: 20-year Irrigation Development Plan of Sisaket by Water Strategy (RID, 2018)

Project-Scale	Strategy 2: Providing water security in production sectors		Strategy 3: Managing floods and flood disasters		Total	
	Number	Budget (M. Baht)	Number	Budget (M. Baht)	Number	Budget (M. Baht)
Large-Scale						
Medium-Scale	16	4,204	1	90	17	4,294
Small-Scale	75	1,569.	5	66	80	1,635
Total	91	5,773	6	156	97	5,929

Note: 1 rai = 0.16 ha

Table 12: Planned Irrigation Projects in Sisaket Province according to the 20-year Plan by Project Types (RID, 2018)

No.	Project Type	Number/ Amount	Capacity (MCM)	Irrigated Area (rai)
	Medium-Scale Projects			
1	Reservoirs (including increasing reservoir capacity)	9	106.97	47,770
2	Weirs	1	1.3	6,000
3	Pump Stations (and conveyance systems)	4	-	131,505
4	Regulators	2	-	9,200
5	Monkey Cheeks	-		
6	Conveyance Systems	1	-	4,500
7	Dredging	-		
	Total	***17***	***108.27***	***198,975***
	Small-Scale Projects			
1	Reservoirs (including improvement)	10	1.52	600
2	Weirs	20	1.32	-
3	Pump Stations (and conveyance systems)	23	0.17	41,135
4	Regulators	3	0.2	-
5	Monkey Cheeks	11	3.64	2,234
6	Conveyance Systems	11	0.33	7,650
7	Dredging	1	0.03	-
8	Dykes (including improvement)	1	-	-
9	Drainage Systems	-		
	Total	***80***	***7.21***	***51,619***
	Grand Total	**97**	**115.48**	**250,594**

Note: 1 rai = 0.16 ha

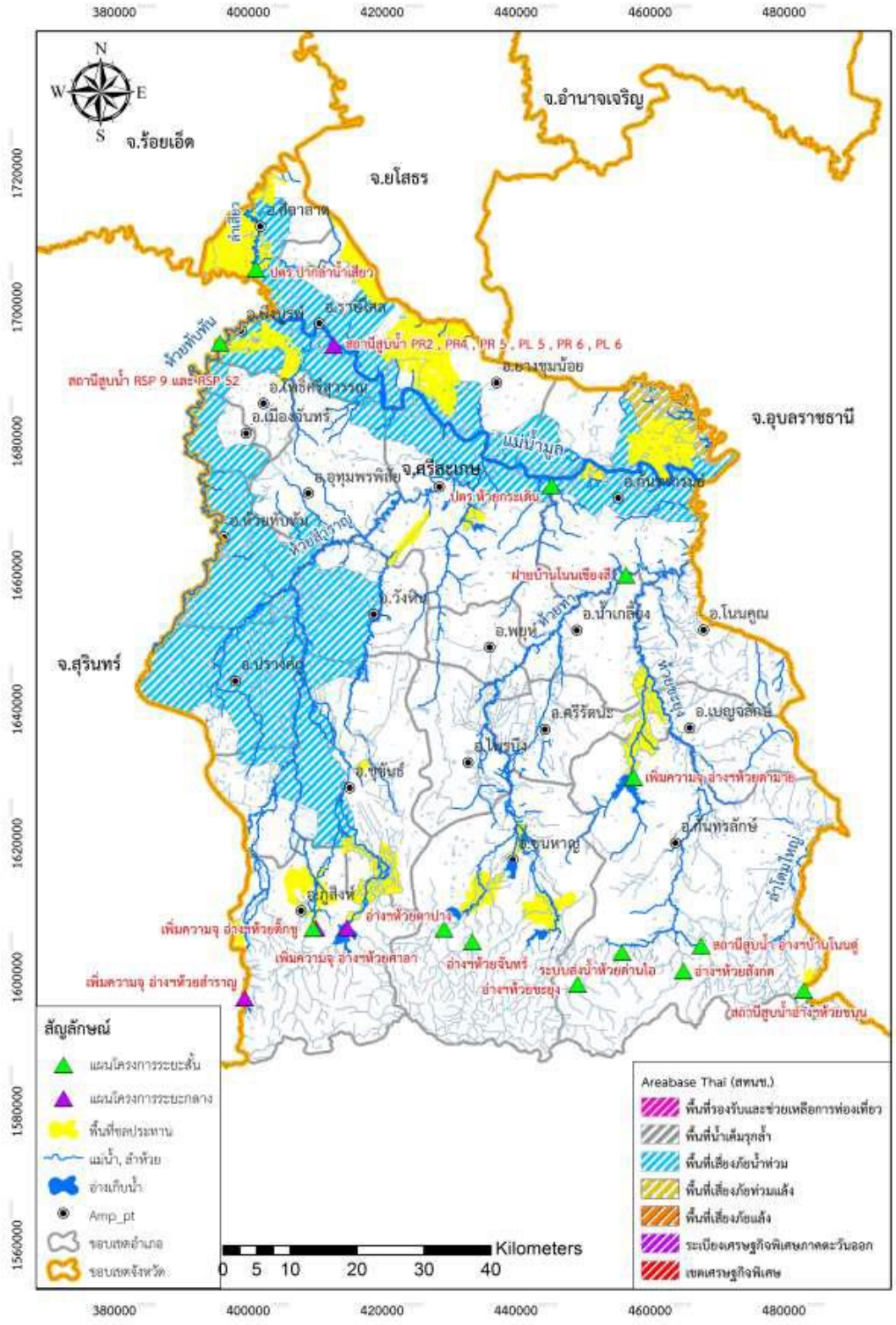


Figure 10: Planned Medium-Scale Projects of Sisaket according to the 20-year Plan
Source: RID 2018

Area Based Approach

To address the country's water problems in accordance with the government policies and goals, the Office of Natural Water Resources (ONWR) has identified 'target areas for systematic water resources problems resolution' or 'Area Based' underlined by the area-based approaches in 66 provinces by considering problems, frequency, severity, damage from drought, flood, seawater and intrusion. The approaches will be implemented through both structural (for instances, monkey cheek, regulator, reservoirs, diversion, flood protection) and non-structural measures depending on the problems in each area.

In Surin, there is only 1 Area Base that suffered from flood in the Lower Mun. The area of 1,345,705 rai or xxx ha is located in the north and east of the province along the Mun River and Huai Tab Tan as illustrated in Figure 11.

In Surin, there are 2 Area Bases (Figure 12) consisting an area suffered from flood in the Lower Mun with the total area of 1,275,056 rai or xxx ha, locating in the west and north of the province along Huai Tab Tan and the Mun River. Another area of 63,311 rai suffered from both drought and flood along the middle Chi is located in the north of the province along the Chi River.

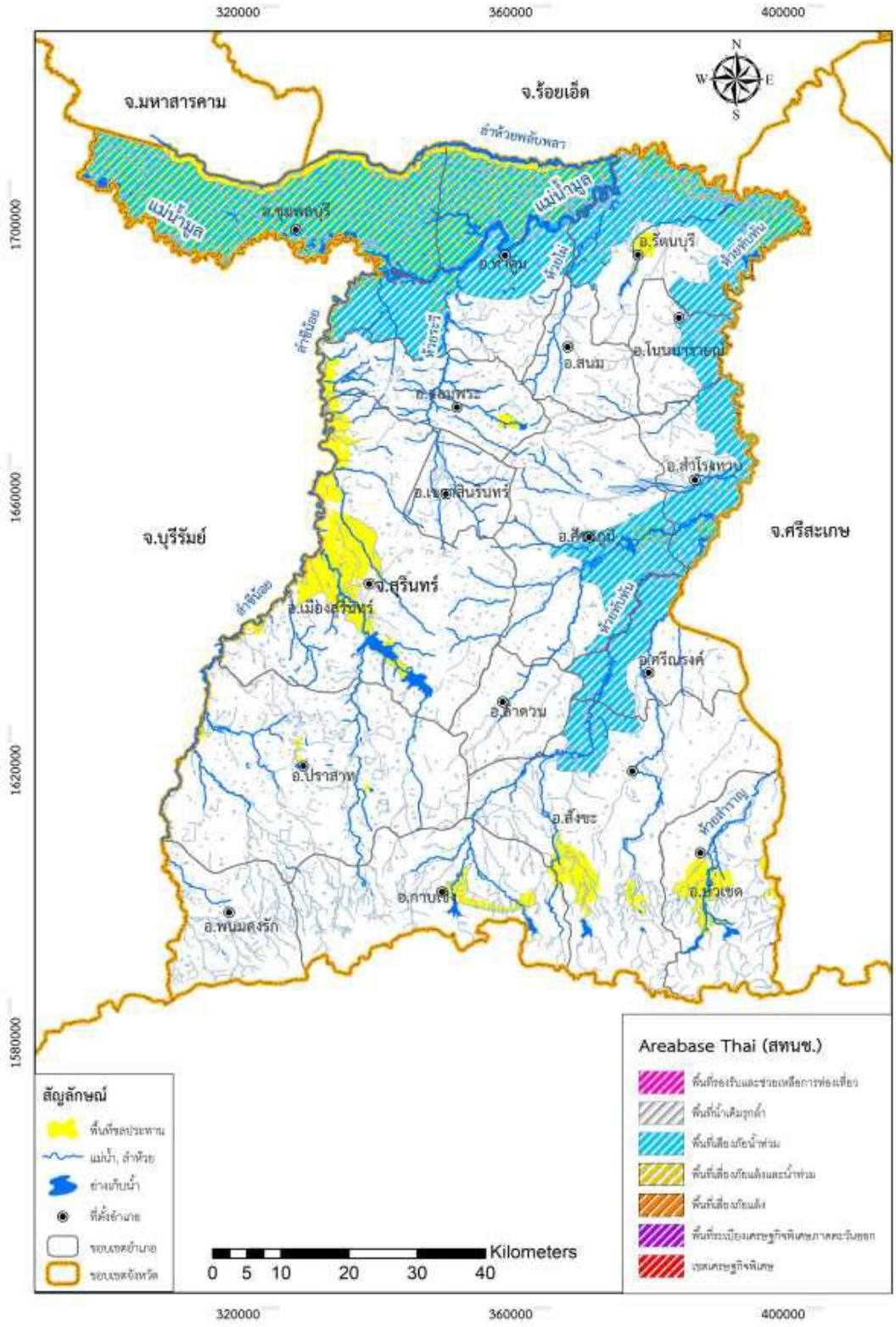


Figure 11: Target areas for systematic water resources problems resolution or 'Area Base' by ONWR (2018) in Surin (RID, 2018)

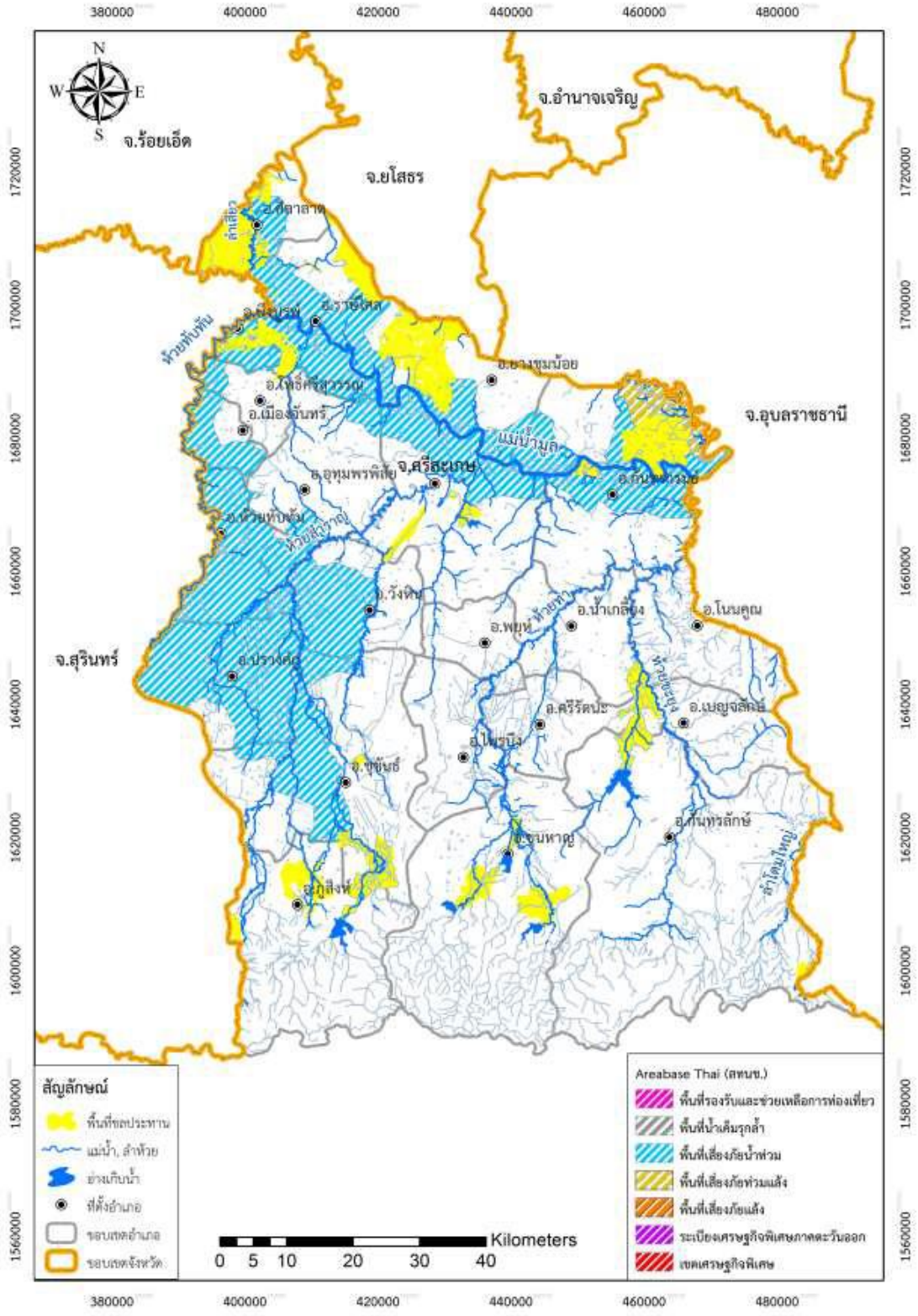


Figure 12: Target areas for systematic water resources problems resolution or 'Area Base' by ONWR (2018) in Sisaket (RID, 2018)

National Disaster Risk Management Plan (2015)

The National disaster Risk Management Plan (2015), prepared by the National disaster Prevention and Mitigation Committee and approved by the Cabinet on 31 March 2015, has consolidated disaster risk management – related new thinking and concepts, including the development of disaster prevention and preparedness system and the creation of disaster immunity through developing knowledge and wisdom as well as strengthening disaster surveillance system and coping capacity, living in harmony with nature and creating the self – immunity into the communities in line with an approach entitled "sufficiency economy philosophy". In addition, it has also brought together the thinking on disaster risk reduction for disaster prevention according to the universally recognized thinking…" the building of resilience to disaster and sustainability through the creation and enhancement of awareness for disaster risk reduction before, during and after disaster and to provide strategic direction for the implementation of this National Plan in conformity with Disaster Prevention and Mitigation Act B.E. 2550 (2007) and in line with Sendai Framework for Disaster Risk Reduction 2015 – 2030.

The strategies for an implementation of this National Plan comprise a focus on disaster risk reduction, an application of integrated emergency management system, strengthening and enhancing efficiency of sustainable disaster recovery or building back better and safer, and promoting international cooperation on disaster risk reduction. These focused strategies will serve as guidelines to achieving objectives set forth in this National Plan and contributing to successful disaster risk reduction which is a foundation for sustainable development.

All relevant agencies are required to use this plan as a blueprint, framework and guideline in handing national disaster management actions. The National disaster Prevention and Mitigation Committee has anticipated that this national Plan will serve as a tool for reducing the impact of disasters, realizing disaster risk management standards in every community as well as for further integrating disaster risk reduction thinking and methods into the national sustainable development process.

Disaster Risk Management Strategy

The strategies for disaster risk management outlined in this National Plan are intended to enhancing the national efficiency and effectiveness in fulfilling national disaster risk management targets and the objectives set forth, in order to meet international standards ; to ensure public safety and protection of life and of public and private property ; as well as boosting and maintaining social and economic sustainable stability. The followings are four key strategies for disaster risk management.

Strategy 1 Focusing on disaster risk reduction

Strategy 2 Applying integrated emergency management system

Strategy 3 Strengthening and enhancing the efficiency of sustainable disaster recovery

Strategy 4 Promoting and strengthening international cooperation on disaster risk management

Figure 13: Disaster Risk Management Strategy (National disaster Prevention and Mitigation Committee, 2015)

Disaster Risk Management Mechanisms

A. **Policy level**

(1) **National Disaster Prevention and Mitigation Committee**

This committee has been tasked with the following functions, among others, to formulate national disaster management policy; integrate public – private partnerships for the development of efficient and affective disaster management system, etc; as stipulated under the provisions of Article 6 and 7 of Disaster Prevention and Mitigation Act B.E. 2550 (2007).

(2) **National Safety Council**

The main functions of this council are, among others, to propose the national safety policy; propose practice guidelines and has a responsibility to undertake inter – agency coordination. The composition and functions of this council have been set out in the Prime Minister's Office Regulation on National Safety B.E. 2538 (1995), and addendum.

B. **Operational level**

(1) **National Disaster Command Headquarters**

As a national command and control facilities, this headquarters' responsibilities are to direct, oversee, and coordinate the emergency management practices of all sub-ordinated disaster management centres. The Minister of Ministry of Interior (MOI) has been designated as the National Incident Commander, and the Permanent Secretary for the Ministry of Interior to be the Deputy National Incident Commander.

In case of large – scale incident management (level 3), the Minister of Ministry of Interior will assume the role and responsibility of National Incident Commander, whilst in case of catastrophic incident management, the Prime Minister or the Deputy Prime Minister whom assigned by the Prime Minister will assume the National Incident Commander's role and responsibility.

(2) **Central Disaster Management Centre**

The Department of Disaster Prevention and Mitigation (DDPM) is required to set up the Central Disaster Management Centre, and the Director – General of DDPM has been designated as the Central Incident Commander. Its functions and authority are set forth as follows:

(2.1) In a non-emergency situation: coordinates and integrates the emergency response information, resources, and plans of all relevant government agencies in order to ensure the overall state of readiness for handling any type of potential disaster.

(2.2) Likelihood of disaster: undertakes full scale preparation for potential response operations, keeps a close watch on the disaster situation, conducts data analysis and rapid situation assessment, disseminates early warning message as well as reporting and providing recommendations to the National Incident Commander as the Prime Minister as the case may be for the purpose of making decisions related to disaster relief and

emergency response operations to be jointly conducted by all participating agencies in a coordinated and seamless manner.

(2.3) During a disaster: directs, integrates, and coordinates the joint response operations for small – (level 1) and medium scale (level 2) disasters. In this context, the Central Disaster Management Centre is required to take responsibilities for directing, conducting disaster situation assessment and providing technical support and assistance to the National Incident command Headquarters; keeping a close watch on the disaster situation and disseminating early warning massage; and providing information and recommendations to the National Incident Commander for the purpose making any decision on raising the level of the disaster incident to level 3 (large – scale incident), and to the Prime Minister or to the Deputy Prime Minister whom assigned by the Prime Minister in case of the upgrade to level 4.

Nevertheless, the Central Disaster Management Center is required to continue acting as the constituent part of in the Emergency Response Coordination Centre under the National Disaster Command Headquarters in case of the upgrade to level 3 and level 4.

(3) **Provincial Disaster Management Centre**

This centre has been tasked to direct, control, provide support for and coordinate disaster risk management efforts within the respective provincial jurisdiction. In this connection, the provincial governor has been designated as the Provincial Incident Commander, the vice – provincial governor whom assigned by the provincial governor and chairman of the provincial administrative organization have been designated as Deputy Provincial Incident Commanders. The administration component of this centre has been designed to be composed of several committees from relevant agencies at provincial level.

Functions and Authority

1. Develop the Provincial Multi – Hazard Specific Action Plan on Disaster Risk Management in conformity with the Provincial Disaster Risk Management Plan.

2. Set forth the guidelines to be observed by Provincial, district and Local Administrative Organization Disaster Management Centers in specific locality in undertaking disaster risk management and disaster preparedness activities.

3. Monitor and conduct disaster situation analysis and assessment. And when a disaster actually occurs or is likely to occur, in case of medium scale (level 2) this Centre is required to make recommendations to the Provincial Incident Commander in the context of setting up the Provincial Emergency Operations Centre to undertake emergency response interventions.

4. Collect data and establish data bank of disaster related resources required to carry out disaster risk management activities within provincial jurisdiction.

5. Promote and support cooperation between public and private agencies and neighboring provinces through mutual – aid agreement/the mutual sharing of personnel, equipment and other resources for disaster risk management.

6. Perform other functions and responsibilities as assigned by person possesses additional authority to issue directives.

(4) **Bangkok Metropolitan Disaster Management Centre**

This centre has been tasked to direct, control, and coordinate disaster risk management efforts within its jurisdiction ; to develop action plan based on its vulnerability and exposure to specific hazards in line with the Bangkok Metropolitan Disaster Risk Management Plan ; as well as providing technical assistance support for implementation of disaster risk management activities and functioning as emergency response unit when an actual disasters occur within its jurisdiction. The governor of Bangkok Metropolitan Administration, as the Bangkok Metropolitan Incident Commander has been tasked to perform duties and responsibilities as stipulated in item (3) of Disaster Prevention and Mitigation Act B.E. 2550 (2007). All this, the administrative component as well as duties and responsibilities of this centre will be subject to the governor of Bangkok Metropolitan Administration approval.

(5) **District Disaster Management Centre**

As a district command and control centre, it has been tasked to direct, provide support for and coordinate disaster management efforts of local administrative organizations located in its jurisdiction, as well as performing any function as assigned by the provincial governor or by the Provincial Disaster Management Centre. The chief district officer has been designated as the District Incident Commander. The administration component has been designed to be composed of several committees from relevant agencies at district level.

Functions and Authority

1. Develop the District Disaster Risk Management Plan and other relevant plan for the purpose of directing, coordinating, and providing support for disaster management efforts of the local administrative organization, in accordance with the Provincial Disaster Risk Management Plan.

2. Set forth guidelines to be observed by District and Local Administrative Organization Disaster Management Centres in specific locality in undertaking disaster risk management and disaster preparedness activities as well as in undertaking post – disaster recovery interventions.

3. Monitor, and conduct disaster situation analysis and assessment. When a disaster actually occurs or is very likely in its jurisdiction, this centre is required to make recommendations to the District Incident Commander in the context of setting up the District Emergency Operation Centre to take responsibility for the command and control of incidents.

4. Collect data and establish data bank of disaster related resources required to carry out disaster risk management activities within district jurisdiction.

5.Perform other functions and responsibilities as assigned by the provincial governor or the Provincial Disaster Management Centre.

(6) **Pattaya City Disaster Management Centre**

As Pattaya City command and control centre, it has been tasked to direct, provide support for, and coordinate disaster management efforts of Pattaya City as well as functioning as emergency response unit during an actual disaster, along with developing Pattaya City Disaster Management Action Plan in line with the Provincial Disaster Risk Management Plan and the District Disaster Risk Management Plan. In addition, this Centre has been tasked to provide support and assistance to the Provincial Incident Commander and the District Incident Commander as being assigned, including provision of assistance and support to the neighboring or adjacent local administrative organizations related to the implementation of disaster management activities upon their requests. The mayor of Pattaya City has been designated as the Local Government Incident Commander

(7) **Municipal Disaster Management Centre**

As a municipal command and control centre, it has been tasked to direct, provide support for, and coordinate disaster management efforts of the respective municipality as well as functioning as emergency response unit during an actual disaster, along with developing the Municipal Disaster Risk Management Action Plan in line with the Provincial Disaster Risk Management Plan and the District Disaster Management Plan. In addition, this centre has been tasked to provide support and assistance to the Provincial Incident Commander and the District Incident commander as being assigned, including provision of assistance and support to the neighbouring or adjacent local administrative organizations related to the implementation of disaster risk management activities upon their requests. The municipal mayor has been designated as the Local government Incident Commander.

N.B.: Category of Municipality in Thailand

1. City municipality

2. Town municipality

3. Subdistrict municipality

(8) **Subdistrict Administrative Organization Disaster Management Centre**

As a subdistrict administrative organization command and control center, it has been tasked to direct, provide support for, and coordinate disaster risk management efforts of the respective sub – district as well as functioning as emergency response unit during an actual disaster, along with developing the Subdistrict Disaster Risk Management Action Plan in line with the Provincial Disaster Risk Management Plan and the District Disaster Management Plan. In addition, this Centre has been tasked to provide support and assistance to the neighbouring or adjacent local administrative organizations related to the implementation of disaster management activities upon their requests. The chairman of subdistrict administrative organization has been designated as the Local government Incident Commander.

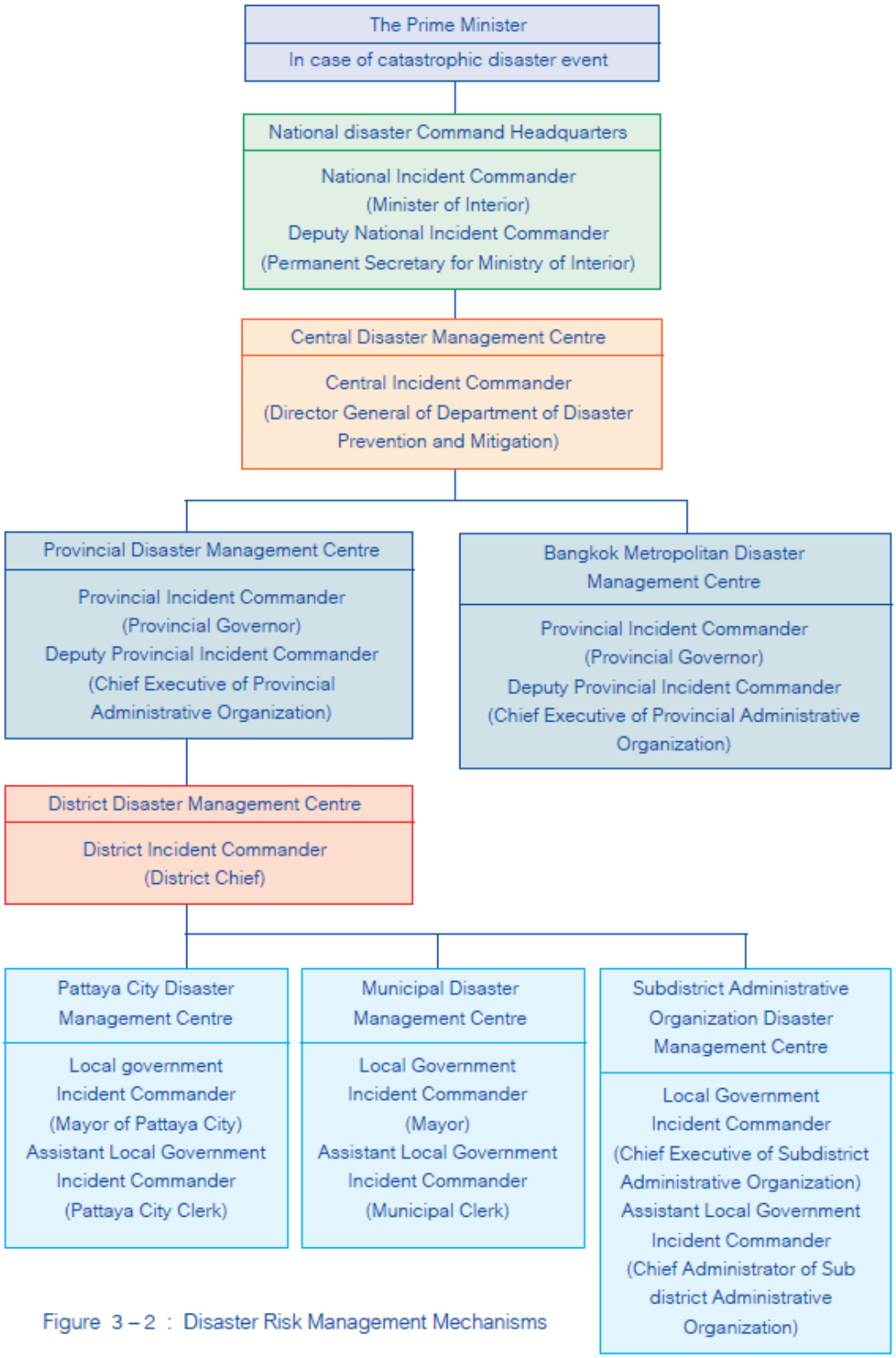


Figure 3 – 2 : Disaster Risk Management Mechanisms

Figure 14: Disaster Risk Management Mechanisms (National disaster Prevention and Mitigation Committee, 2015)

Level of Emergency and Incident Management

An emergency and incident management in Thai context is classified into four levels based on a wide range of parameters, including areas affected, size, severity level and complexity, number of population, existing capacity for emergency management as well as the availability and capability of resources capability. These who have legal authority must take these parameters into account when making decision to assume the role of Incident Commander.

Level	Management Scale	Authority in Charge
1	Small-scale disaster	District Incident Commander, Local Government Incident Commander and/or Bangkok Metropolitan Assistant Incident Commander is responsible for directing and/or controlling functions
2	Medium-scale disaster	Provincial Incident Commander or Bangkok Metropolitan Incident Commander is responsible for directing, controlling and commanding functions
3	Large-scale disaster	National Incident Commander is responsible for directing, controlling, and commanding functions
4	Catastrophic disaster	The Prime Minister or the Deputy Prime Minister whom assigned by the Prime Minister is responsible for directing, controlling and commanding functions.

Emergency Management

Emergency management encompasses actions taken to reduce the adverse impacts of disasters as well as sustaining general public's morale and confidence and maintaining the orderly performance of emergency management functions of all participating agencies and personnel. saving life and protecting the property of the people from disaster must be regarded as first priority of actions. Therefore, all agencies concerned should consider undertaking emergency preparedness efforts to be able to deal with disaster situation in an efficient, rapid and timely manner.

Based on Disaster Prevention and mitigation Act B.E. 2550 (2007), those who are authorized by law will assume the role of Incident Commander at each emergency management level accordingly.

Three (3) Strategies for Emergency Management has been set up (Strategy 1: Developing standards for Emergency Management ;Strategy 2: Developing Emergency Response Support System/Mechanisms; and Strategy 3: Strengthening Disaster Relief System and Procedures) with several associated guidelines.

An Incident Management Unit (in local levels) and a Command Centre (District, Provincial levels) is to be set up within respective jurisdictions by respective management centres where and when a disaster occurs or is imminent according to the scales of disasters.

The Central Disaster Management Centre is tasked to manage the disasters at level 1 and level 2 with directing, coordinating incident management, assessing the situation, and providing operational support to help the Incident Management Units and Command Centres at all levels. Additionally, it is in charge of monitoring and conducting situation analysis as well as reporting and providing advice and recommendations to the National Disaster Commander or the Prime Minister for decision making related to upgrading the level of emergency and incident management to level 3 or level 4. The National Disaster Command Headquaters has been tasked with commanding, directing, making decision, controlling and coordinating joint efforts for level 3 or level 4 incident operations. The figure blow illustrates the National Disaster Command Headquaters and Command Centre Operational Structure.

To augment and support government operations during the incident, the National Disaster Command Headquarters may establish and activate one or more Emergency Support Function (ESF) based on the complexity of the situation as illustrated in the below Figure. The Emergency Support Functions provide a mechanism for coordinating operations among agencies with particular functions which are designated for each Emergency Support Function to ensure their seamless collaborative efforts and to avoid duplication or overlap of support and assistance particularly among agencies that typically perform similar functions. In this connection, 18 Emergency Support Functions are organized, and each Emergency Support Function is comprised of one or more primary agency (ies) and support agencies.

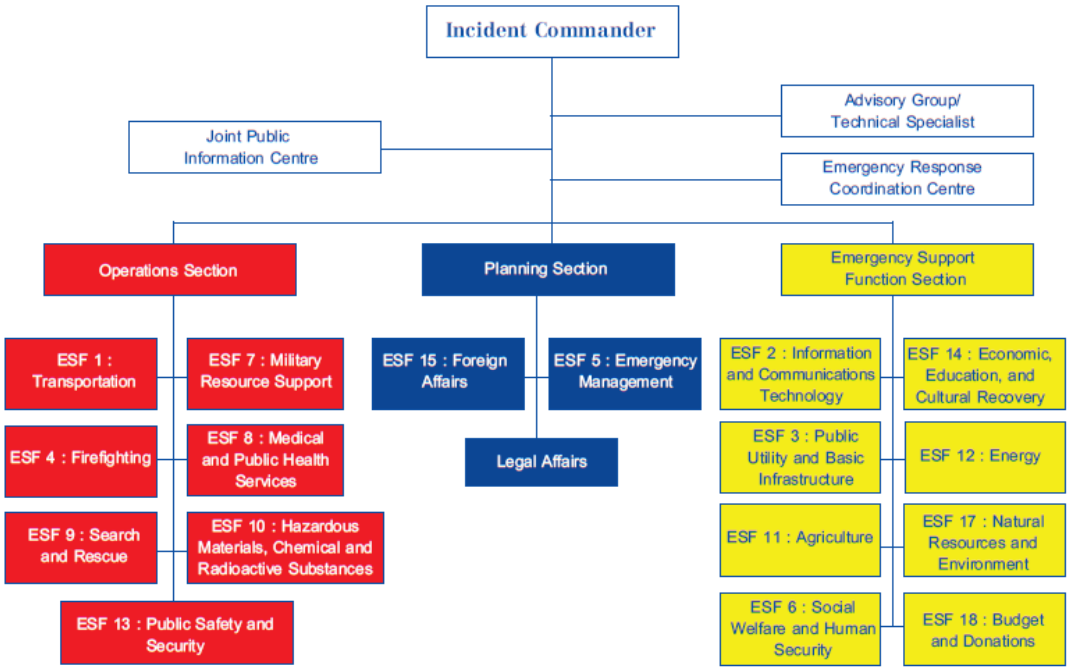


Figure 15: National Disaster Command Headquarters/Command Centre Operational Structure and Emergency Support Function (ESF)

Provincial Command Centres and Provincial Front Area Command Centres

When a disaster occurs within the provincial jurisdiction or is imminent, it is imperative to immediately set up Provincial Command Centre in each respective jurisdiction. In this connection, the Provincial Incident Commanders is responsible for all aspects of emergency response including managing all incident operations until the situation returns to normal. These command centres also serve as coordination centres or focal points for mobilization of personnel, equipment, and other resources necessary for managing emergency situation from government and non-governmental organizations. In addition, the Provincial Incident commanders is accountable for directing and coordinating joint emergency response operations amongst a wide range of agencies, including civilian government agencies, military, local administrative organization, and civil society organization to ensure more unified, seamless, and integrated efforts.

In case where the level of emergency and incident management has been raised to level 3 or level 4, the Provincial Command Centres will be turned into front area command centres of the National Disaster Command Headquarters, and are in charge of performing duties under the authority, direction, and command of the National Disaster Command Headquarters. The reassigned duties include directing, controlling, and coordinating emergency management efforts as well as managing all incident operations within the respective jurisdiction; serving as coordination centre or focal point for mobilization of personnel, equipment, and other resources necessary for carrying out all emergency functions from government and non-governmental organizations; and coordinating joint emergency response operations amongst a wide range of agencies including civilian government agencies, military, local administrative organization, and civil society organization within respective

Case Studies/Practices in Surin and Si Saket for Water Resources Management in response to Flood and Drought

Groundwater Resources Development for Agriculture using Solar Energy

At present, there are many non-irrigated agricultural lands especially in the Northeast Thailand those are suffering from water shortage for agriculture. Some farmers use groundwater by drilling/digging their own wells but they also face problem of increasing electricity cost at the same time. Recently, some agencies in Thailand (the Department of Groundwater Resources, Department of Alternative Energy Development and Efficiency, Provincial and Local Administration Offices, etc.) have promoted, enhanced and supported a project to use groundwater in conjunction with surface water in agricultural areas vulnerable to droughts. Those areas are mostly not irrigated, often suffered from drought and depend only on rainwater. Access to electricity is also a limitation. Installation of solar cells together with digging a groundwater well is an approach to such areas to solve the water shortage problem for agriculture. The practice also reduces a production cost that spends for pumping water using electricity. The farmers are also enabled to install, operate and maintain the system at basic level by themselves.

A case study in Saen Suk Village, Nong Yai Sub-District, Prasart District, Surin Province, a group of farmers had requested the Department of Water Resources to construct a groundwater system for agriculture using solar energy. The investment cost of the system is around 130,000 Baht which is paid by the govern while the farmers bought and installed the meters themselves at farm inlets. The water is distributed to 13 farm holders. Water management is done by the group.

Figure 16: A case study in Nong Yai Sub-district, Prasart District, Surin Province, supported by the Department of Groundwater Resources

(Storage Capacity: 20 m^3, Pumping capacity: 10 m^3/hour, depth: 70 m, beneficial areas: 126 rai or 20.169 ha)

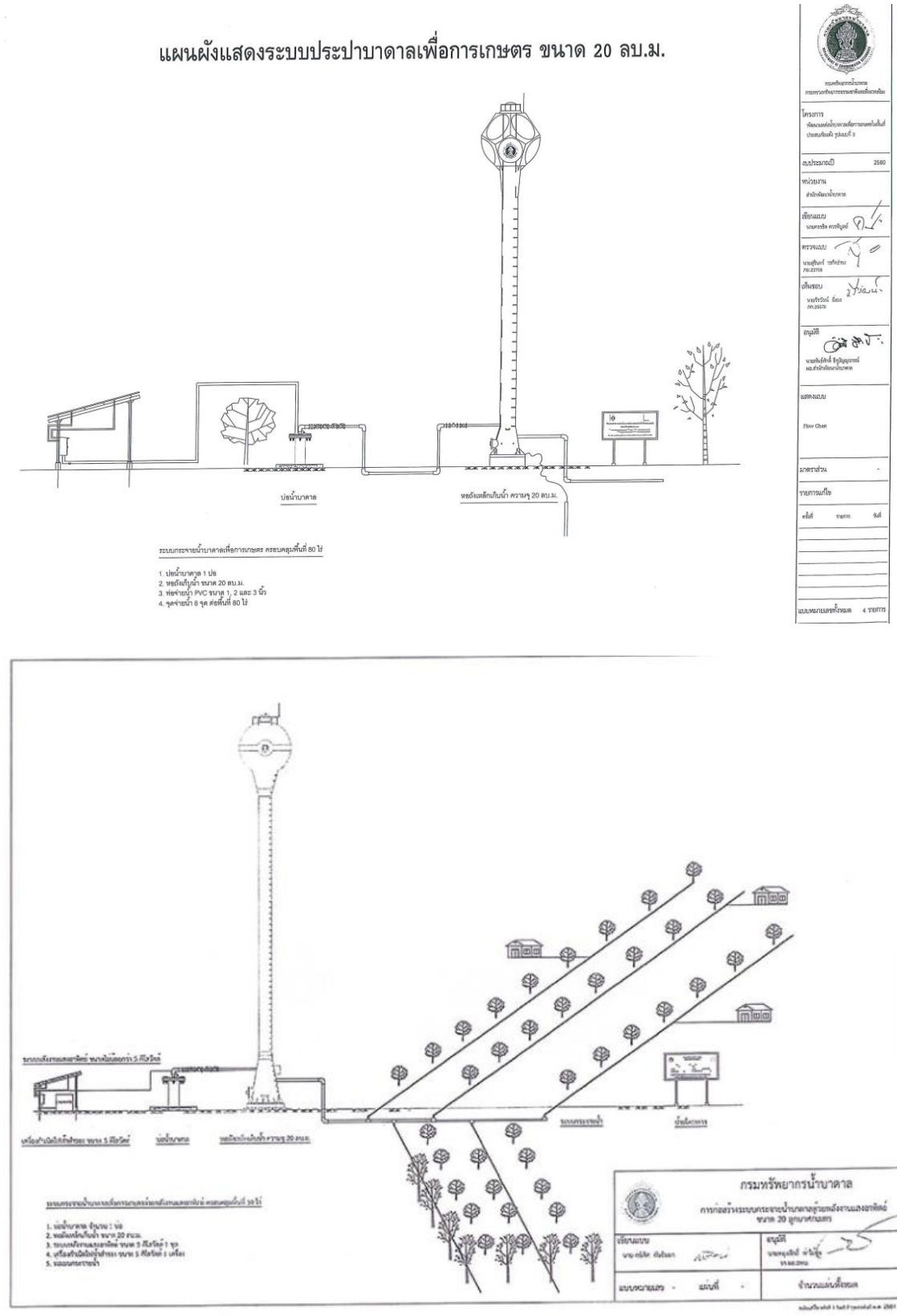


Figure 17: General Plan of Groundwater System (20 m^3) for Agriculture by Department of Water Resources

Another practice is to request budget from the *Energy Conservation Fund Management Office* for a groundwater pumping system using solar energy which is constructed by the Provincial Energy Office after fund received. The farmers are needed to be grouped by 7 households with total agricultural areas of not less than 15 rai (2.4 hectares). They are required to already have a groundwater well in the areas that has been permitted by the Department of Groundwater Resources. These groups of farmers are formed as water user groups or enterprises and manage water by themselves. They may schedule the pumping period and duration, charge water use per unit price, collect money from members as a fund for maintenance, etc. The water from the well is mainly used to supplement rainwater during the wet season and growing crops during the dry season e.g. vegetables, upland crops as well as used for livestocks, fish ponds, etc. Other benefit is saving money for pumping water from the well which hence reduce their production costs.

Figure 18: Overall Components of Solar-cell Pumping System by Ministry of Energy

A case study in Nong Hang Sub-district, Uthumphon Phisai District, Sisaket Provin where a solar-cell groundwater system is installed by the Ministry of Energy, the farmers had dug a well and requested budget from the Energy Conservation Fund Management Office for other components of the whole system. The investment of the system excluding the well is around 520,000 Baht which include 1 km of conveyance pipe. It is found that after the system is in place, their incomes have increased twice.

Figure 19: Mixed-Farming in Nong Hang Sub-district, Uthumphon Phisai District, Sisaket Province using solar-cell groundwater system (supported by the Ministry of Energy)

One Canal, two roads, for Conservation and Rehabilitation of Khlong Huai Tong Canal

The project is initiated by local community/farmers, proposed to the Water Resources Regional Office 5. The project area during the first phase of the project is situating on the middle basin of Huai Saneng, a sub-basin of Mun River, locating in two adjacent sub-districts, Kantuatramuan and Khok Yang in Amphoe Prasart District, Surin Province. Situating on flat plateau alternating with rolling lands, in the past water passed by the area quickly. The area always suffered from recurrent drought.

The project is the first model of Khok Yang sub-district. It is implemented by enlarging the existing canal namely “Khong Huai Tong” which is a tributary of Huai Saneng River. The headwater of Huai Saneng is from Phnom Dongrak mountain range which passing through Prasart District before draining into Amphuen Reservoir Amphuen Reservoir is located 5 km upstream of Huai Saneng Reservoir. Both reservoirs are major water sources for water supply production of Surin Province.

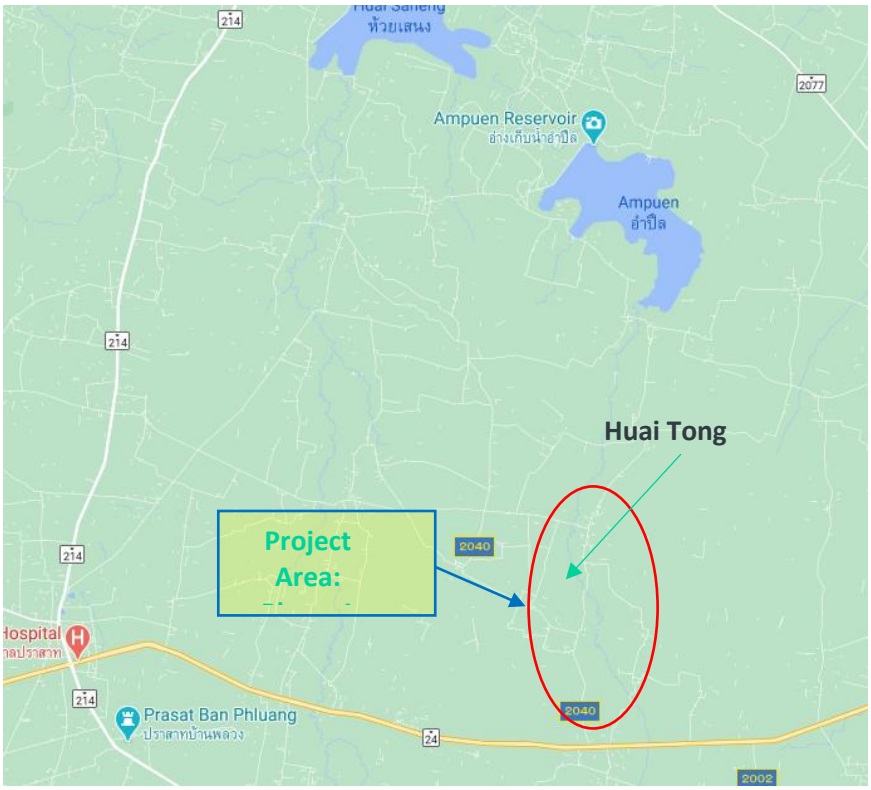


Figure 20: Location of one canal, two roads project in Khok Yang Sub-district, Prasart District, Surin Province

The current project components in the first phase compost of two canals (2 km-Khong Huai Tong and 3 km-Cha Kae Siplueat which are connected), two roads (8 m wide) on both sides of the canal and 3 regulators. The canals were expanded to the width of 40-50 m and dredged to the depth of 4-5 m. The roads enable farmers to access into their lands easier. The water stored in the canal is to supplement rainwater during the wet season and to be used for dry season crops during the dry season. Some farmers have extent their activities from cropping to fish farming and livestock. Crops in the project consisting wet season rice, dry season rice, and other small crops.

The project is managed by the *large-scale farmer enterprise water management committee of Huai Saneng basin*. The project will continue its next phases with budget provided by the Water Resources Office Regional Office 5. Next steps are to extend canal dredging further upstream and construct water distribution system to convey water to individual farmlands. It is planned to combine with the Groundwater Bank concept in future.

Figure 21: Conservation and Rehabilitation of Khlong Huai Tong Canal Project

Groundwater Bank

The concept of "Groundwater Bank" has been initiated in the Northeastern Region of Thailand, it has been adopted and applied widely in the north and north east of Thailand by Local Administrative Organizations. The concept is to replenish excess water in aquifer by digging a well at an inundated spot or at a water collective point in order to store water and penetrate into aquifer to collect water which functioned as same as a bank. Another method is using rubbles, pebbles, billets, glasses or other local materials to fill up a well to replace water and let water spills quicker whenever there is enough groundwater. The concept is like deposing water for use during dry season or carrying water during flood season. It is an integration of technical knowledge and local intelligence which can be applied for sustainable water management. The benefits of the groundwater bank are to alleviate inundation and drought problems, increase the level of groundwater table, increase soil moisture, decrease evaporation losses, reduce polluted water, etc.

There are two types of ground water bank: 1) the open system which is applied to solve flood and drought problem while the water can be reused for agriculture, domestic and industrial consumption; 2) the close system which is applied to solve drainage problem, prevent pollution and contaminated water from both household and farmlands.

Open System of Groundwater Bank

The concept is to excavate a well or pond through a clay zone underground to a depth that reach an aquifer zone which is connected to the groundwater zone. This is to enable the aquifer to absorb water into the groundwater. The pond can store much water as the water can be distribute thoroughly with no limit. The water can be used directly by pumping from the recharge pond, alternatively it can be used by drilling a groundwater well. It is suitable for farmlands. When the water level dropped down, groundwater will be recharged to maintain the water in the pond. The open system is aimed at solving water shortage, flood and salinity problems.

The size of the recharge pond depends on the land topography, the necessary usage of the water and available space. The depth of the recharge pond varies from area to area which can also depend on the soil profile. Hydrogeologically, the depth of the recharge pond must reach a zone where water can percolate into the aquifers.

A prototype of a pond in an open system of Netedsasanakun Water Institute (who initiated the concept of Groundwater Bank in Thailand) suggests the dept from 7-15 m.

For optimal efficiency, there should be at least 3 ponds in an area with distance from 1,000-1,500 m each. The opened ponds of the groundwater bank are functioned to replenish water to aquifer in which they are interconnected and supplemented the others. At the same time, water from underground will also constantly permeate to increase the water volume in the well or pond. A well design of an open system will ensure sufficient water thoroughly the year.

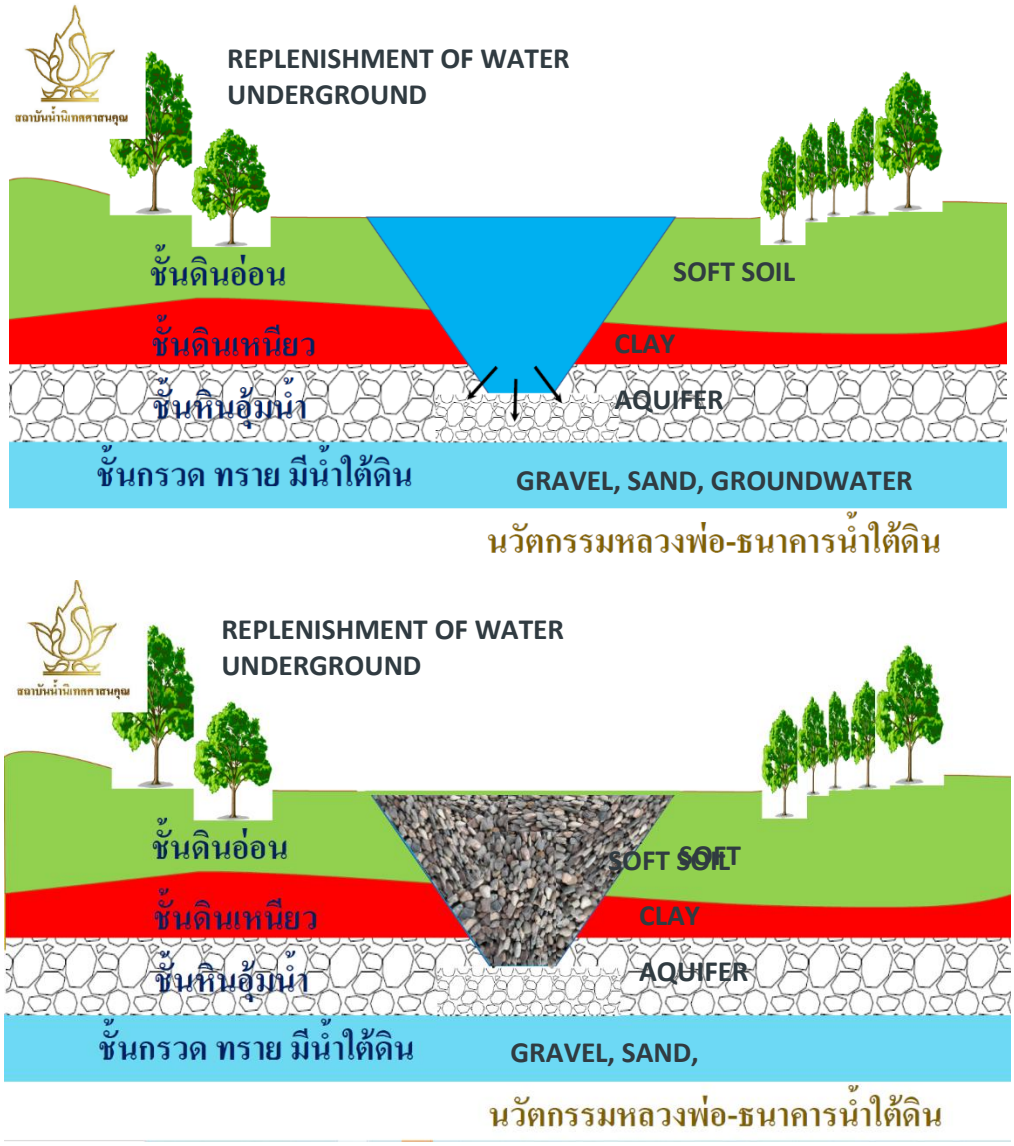


Figure 22: Concept of Ground Water Bank by the Netedsasanakun Water Institute

Figure 23: Storage and Recharge Pond (Open System)

Source: Netedsasanakun Water Institute

Figure 24: Storage and Recharge Pond (Closed System)

Source: Netedsasanakun Water Institute

An open system of groundwater bank is going to be implemented next year in Phon Kha Sub-district, Muang district, Sisaket Province. The network of recharge ponds is designed to take water from Mun river into the area.

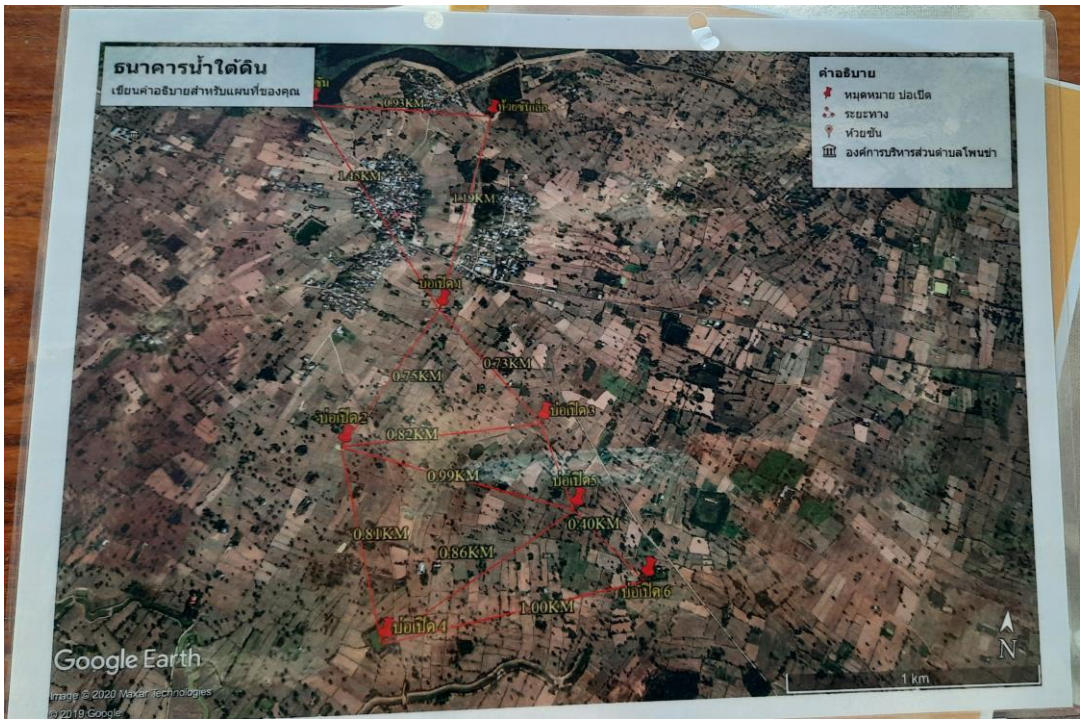


Figure 25: Layout of recharge ponds for an open system ground water bank in Phon Kha Sub-district, Muang District, Sisaket Province

Closed System of Groundwater Bank

The concept of the closed system is to open soil surface to recharge water underground directly. The replenished water is remaining water or excess water e.g. surplus rainwater that exceeds the capacities of rainwater storages which can create inundation problem and thereafter accumulated and became polluted water which is harmful to ecosystem or public health.

The concept of closed system ground water bank is to store water underground at the layer above clay zone which is above aquifer. The purposes are to increase soil moisture, solve inundation problem, decrease floodwater flow, and solve water pollution problem. The stored water cannot be utilized directly from the well but it will enhance and increase water in adjacent shallow wells or deep wells. In some areas, there could be found water at the dept of not more than 2-3 m in a shallow well. The closed system can be applied in both urban and rural areas. The system can help to reduce stormwater by saving excess water underground in monsoon season, then pumping out and using it during dry season.

Figure 26: Closed and Recharge Wells at Surface Level

Source: Netedsasanakun Water Institute

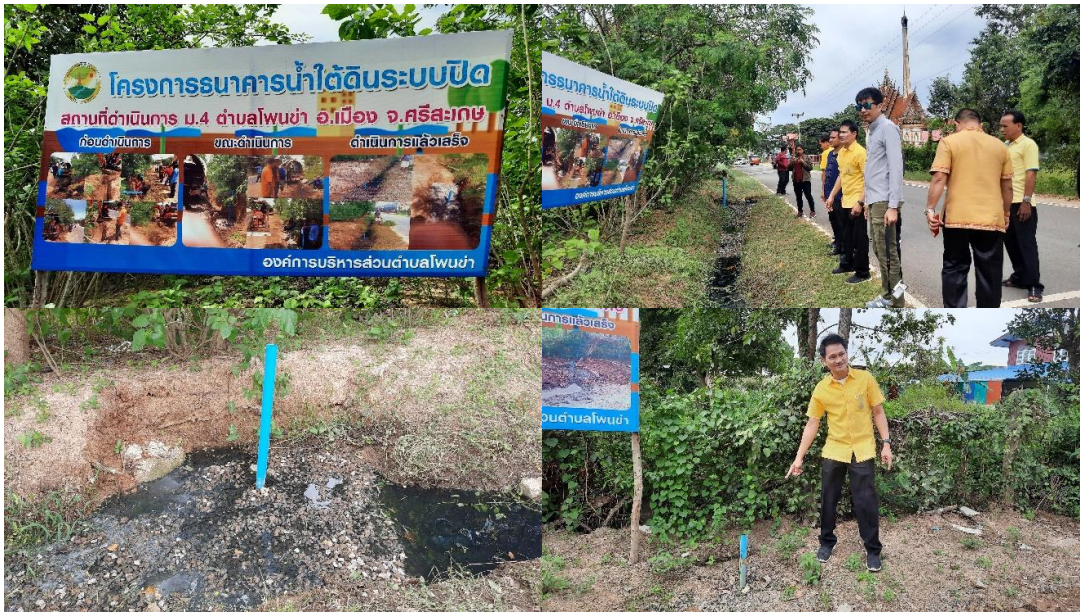


Figure 27: Closed system groundwater bank in Phon Kha Sub-district, Muang District, Sisaket Province

Steps to construct a closed system groundwater bank

(1) Determine a water collection point of village/community, drill a well or pond (e.g. a pond size 1.5m x 1.5m x 1.5m is suitable for household water management);

(2) fill the well with course materials e.g. rubbles, pebbles, billets (uncontaminated materials) for a depth about 1.20 m. There should be a ventilation pipe to ventilate air in the well and rapidly disperse the water that flows into the well;

(3) Cover the remaining edges of the well by net or mesh to filter dirt;

(4) Cover the well with rocks size 3/5 or 3/8 or course sands to the same level of the mount of the well or topsoil in order to prevent contaminated objects those come with water e.g. fat or dirt to go down into the well. This will also ease the maintenance;

(5) A well with the size of 1.5 m x 1.5 m x 1.5 m could absorb water at the rate of not less than 5 m^3/hour or approximately 5,000 liter/hour. The groundwater travels through spaces of roots which is induced by air.

It is suggested that before constructing a system, basic information on mineral resources, soil boring or geophysical surveys, flow direction should be collected, conducted and carefully studied for more accurate planning before selecting a site.

Some information for groundwater bank concept in the forms of plans and drawings are provided by the American Groundwater Solution or AGS, an organization group who is also working on Groundwater Banks Projects in the region, are provided in the following Figures.

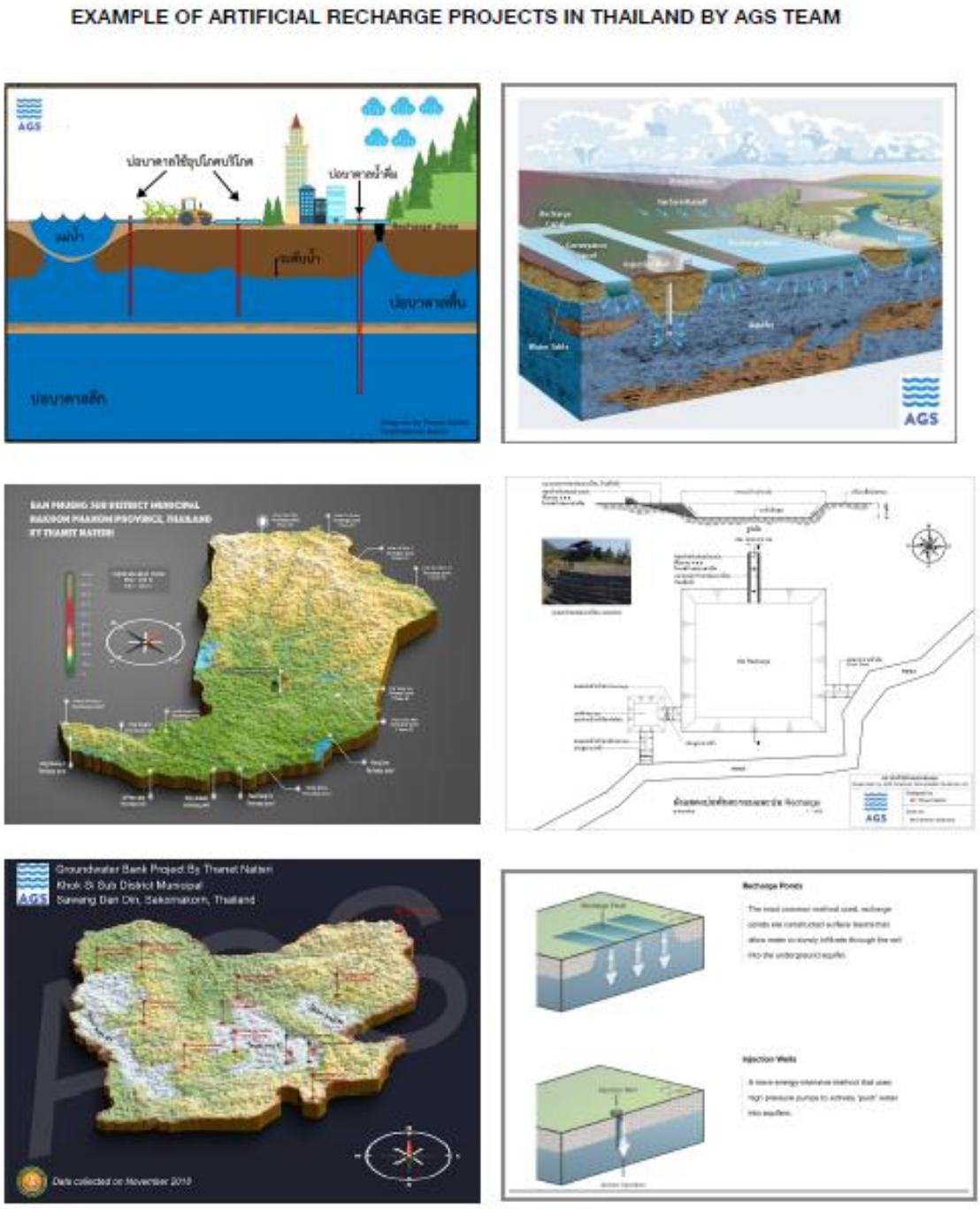


Figure 28: Example of Artificial Recharge Projects in Thailand by AGS Team

Source: American Groundwater Solutions

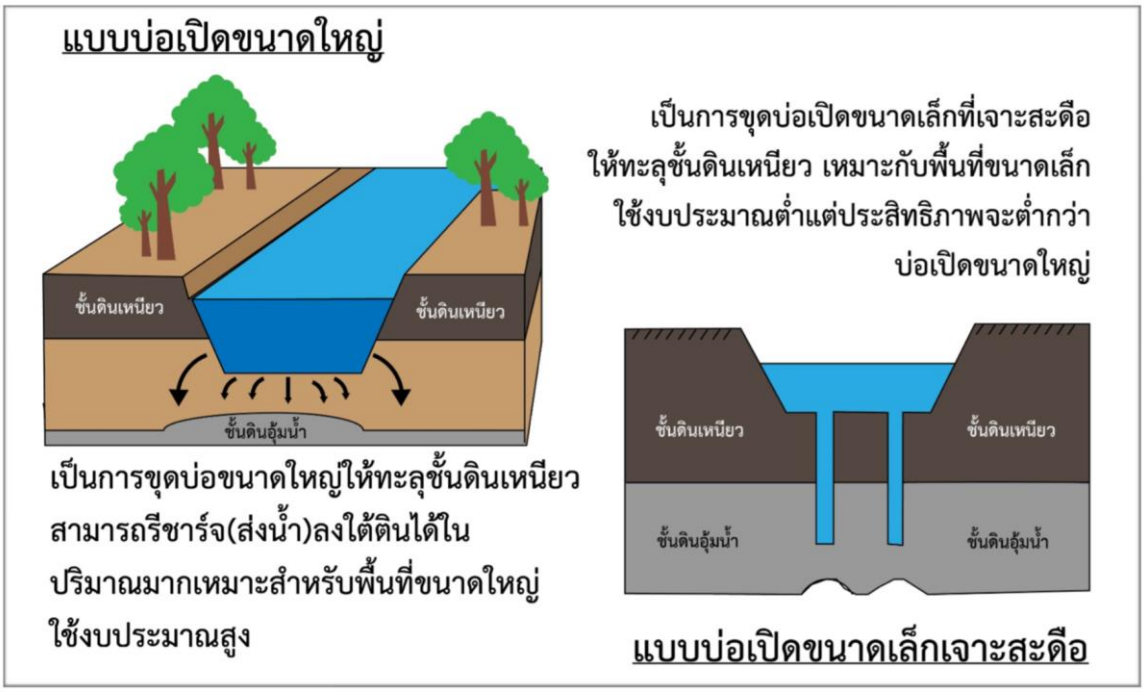


Figure 29: Concept of Open System Groundwater Bank (Large and Small)

Source: American Groundwater Solutions

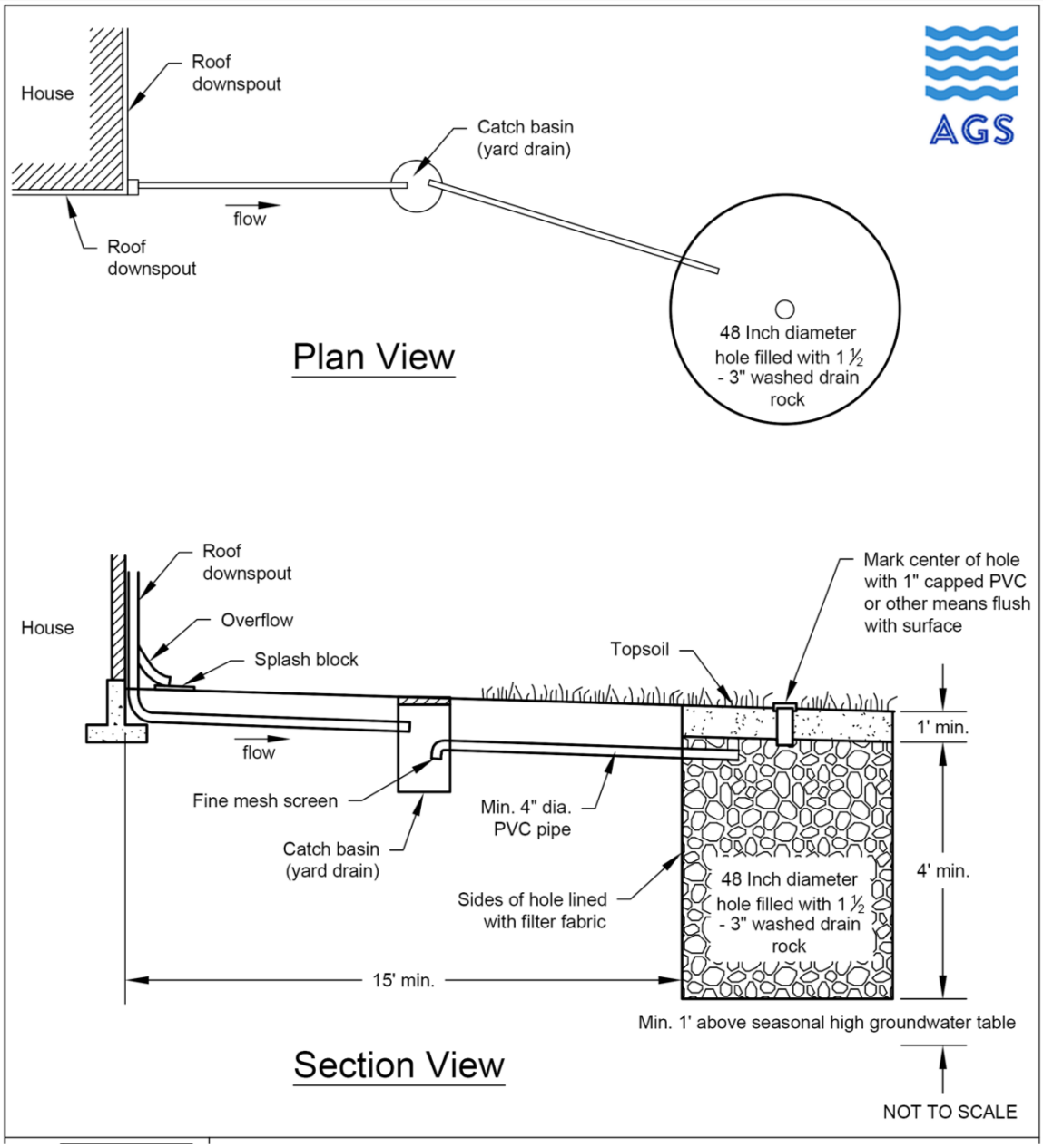
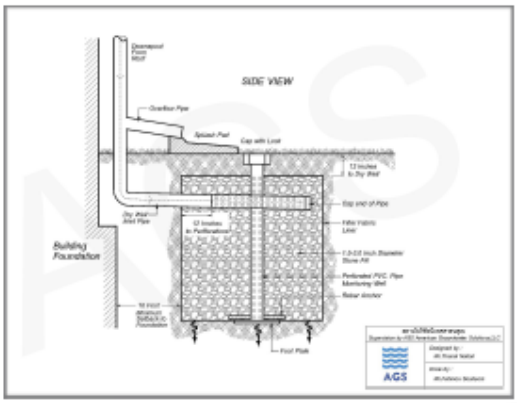
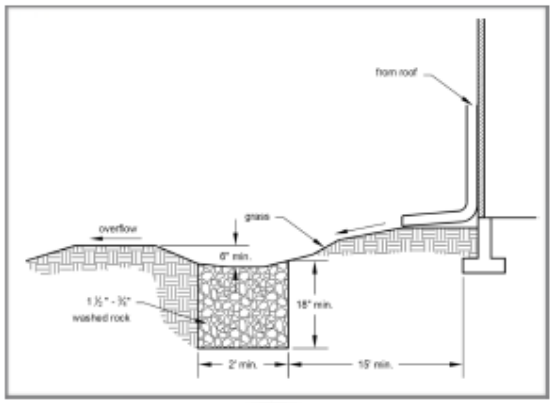


Figure 30: Typical Plan and drawings for Dry Well Construction (Closed System)

Source: American Groundwater Solutions

SPECIFICATION AND REQUIREMENT OF "CLOSE SYSTEM" (DRY WELL)





Key Design Elements

- Maintain minimum distance from building foundation (typically 10 feet)
- Provide adequate overflow outlet for large storms
- Size to retain and infiltrate the difference in runoff volume for the 2-year storm, pre- to post- development
- Depth of Dry Well aggregate should be between 18 and 48 inches deep
- At least one observation well; clean out is recommended
- Wrap aggregate with non-woven geotextile
- Maximum drain-down time is 48 hours
- Provide pre-treatment for some situations

Potential Applications

Residential Subdivision:	YES
Commercial:	YES
Ultra Urban:	YES
Industrial:	LIMITED
Retrofit:	YES
Highway/Road:	NO

Stormwater Functions

Volume Reduction:	Medium
Recharge:	Medium
Peak Rate Control:	Medium
Water Quality:	Medium

Pollutant Removal

Total Suspended Solids:	x
Nutrients:	x
Metals:	x
Pathogens:	x

Figure 31: Specification and Requirement of "Closed System" (Dry Well)

Source: American Groundwater Solutions

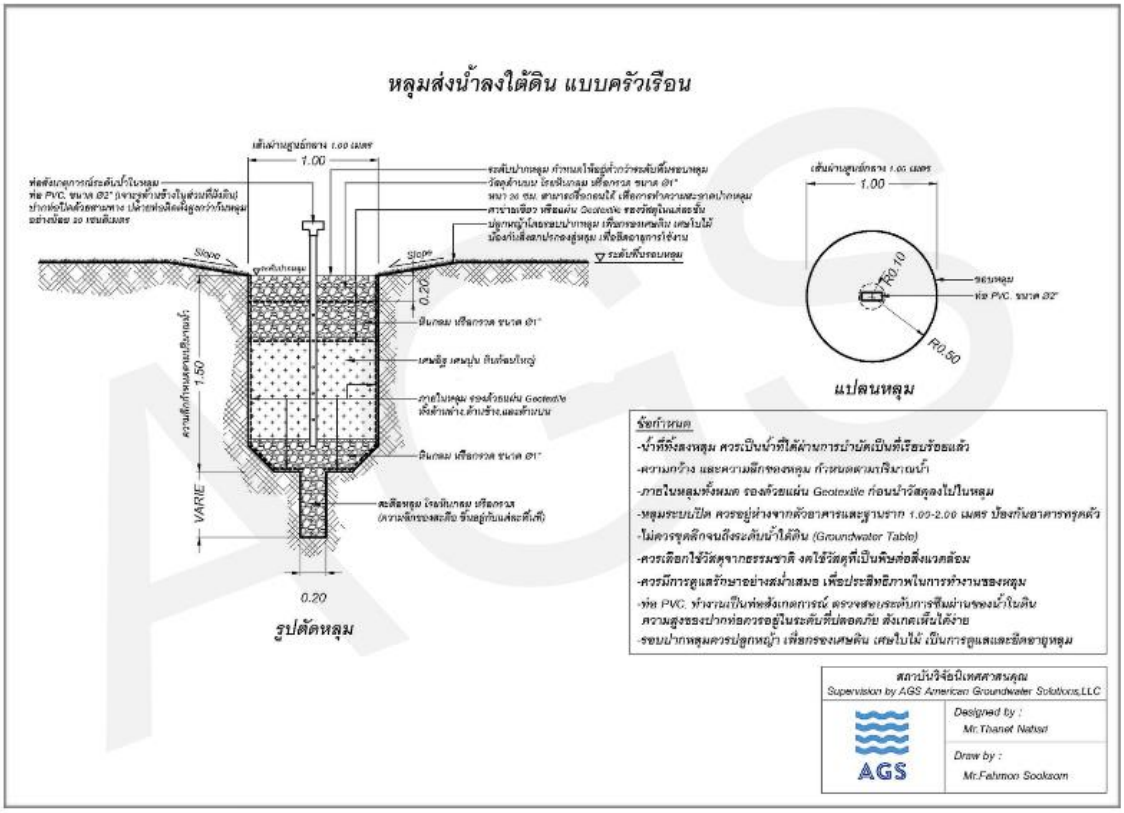


Figure 32: Typical Drawing of Household Groundwater Bank (Closed System)

Source: American Groundwater Solutions

Integrated Farming System

Agricultural activities in the Northeast Thailand depend much on climate, water resources and topography. Both diversified and integrated farming exist in mixed form. The integrated farming system is a good example of sustainable agricultural production. It involves the wise use of limited farmland to increase the range and number of farm activities, thus reducing risk and making use of waste from one type of production in another type. Integrated farming implies at least two kinds of agricultural production operating simultaneously, and complementing each other in one way or another to reduce production costs. Mixed farming is a system of farming in which a farmer conducts different types of agricultural practices together, on a single farm in view of increasing his income through different sources. Farmers practice integrated crop production in order to minimize production risks and ultimately provide a stable source of income and nutrition while at the same time maximizing economic and energy returns using primarily local farm technology. Farmers practice integrated farming in different ways depending on their activities and management which should be coincided with physical, biological and socio-economic conditions of individual farmers.

A good example of diversified or mixed farming in Sisaket Provinces are illustrated in the Figures below.

The use of a single farm in Sisaket Province for multiple purposes, growing of paddy and cash crops and fish farming

Intercropping of paddy and coconut trees

Coconut juice as a product of the farm, it is sold in a local market by the farmer himself.

The groundwater bank concept is applied in this farm too

Figure 33: A farmer in Sisaket Province grows different crops and takes up different types of practices for income generation while doing other businesses of agriculture products (food processing and selling)

References

Annex C. Modelling of Water Resources in Banteay and Ottar Meanchey under different storage capacity and climate change scenarios

Annex C

Modelling of unmet demands in Oddar Meanchey under different storage capacity and climate change scenarios

Contents

1 Data and methods

1.1 WEAP model

1.1.1 General

The basis for the water resources simulation modelling is the WEAP model of Tonle Sap River Basin Group that was previously developed by the consultant team, under assignment of Asian Development Bank[1]. The WEAP model is set up covering a total of 20 years (1999 - 2018) to ensure that most recent conditions are incorporated and also to have a sufficient number of years to cover average, wet and dry conditions. Initialization of the model was accomplished by running an initial 2 years of model warm-up (1997-1998) which were ignored in the output analysis. The timestep of the model is 7 days, to have a good balance between accuracy and calculation time.. Model performance was assessed with available streamflow data and found to be satisfactory (Droogers et al., 2019)[2].

1.1.2 Schematization

The model is subdivided into catchments and subcatchments. An objective of the current project is to support water management plans on a regional scale defined by administrative boundaries rather than physical watersheds. For this reason, the subcatchments intersecting with Oddar Meanchey and Banteay Meanchey provincial boundaries were extracted from the original model, as well as their upstream areas to be consistent with hydrological reality. Figure 1 shows the provincial and hydrological boundaries. In line with this map, the following categorization was maintained in interpreting the WEAP results on supply and demand:

- Oddar Meanchey
  - TON.SRE.1
  - TON.SRE.2
- Banteay Meanchey
  - TON.SIS.3
  - TON.SIS.4
  - TON.SIS.5
  - TON.SIS.6

[1] https://www.futurewater.eu/projects/water-resources-and-eco-hydrological-assessments-of-tonle-sap-and-mekong-delta-basins/

[2] Droogers, P., A. Green, G.W.H. Simons, I. Brownhall, C. Oeurng, T. Bonvongsar, J.E. Hunink. 2019. Rapid Assessment of the State of Water Resources for the Tonle Sap River Basin and Mekong Delta River Basin, Cambodia. FutureWater Report 205

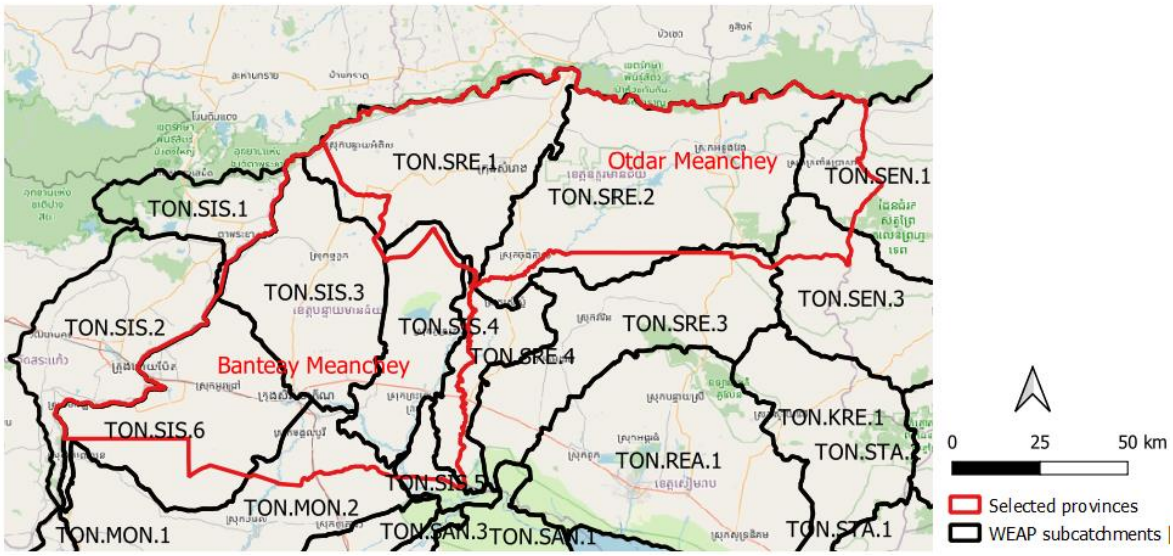


Figure 1. Provincial boundaries and WEAP subcatchments.

The WEAP model makes use of a rainfall-runoff module. Each subcatchment is schematized as consisting of a "Catchment" node, which contains rainfall-runoff characteristics as well as agricultural water requirements to ensure that demand follows water availability. The Catchment Nodes are the core of the WEAP model. Different from the more traditional rainfall-runoff models (such as SWAT, IQQM, HEC-HMS, amongst others), the Catchment Nodes also calculate water demands by the various crops. Moreover, the Catchment Nodes include also advanced options for re-use of water within a catchment, recoverable and non-recoverable flows and beneficial and non-beneficial water consumptions. Figure 2 shows the core processes as calculated by WEAP.

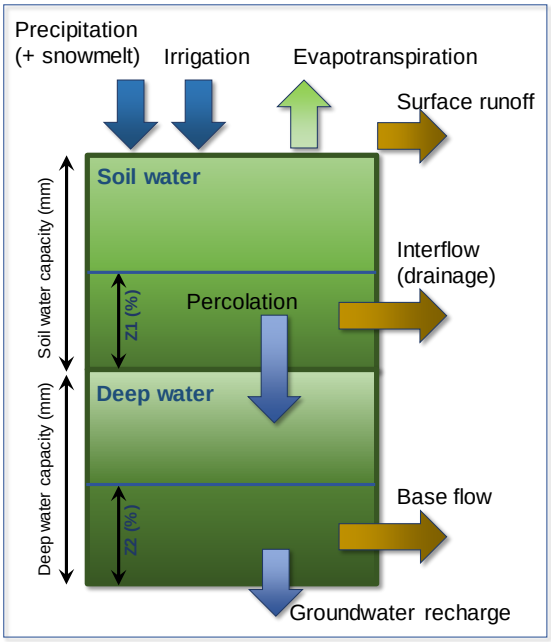


Figure 2. Schematic overview of the core processes in the WEAP catchments' calculations.

Next to the Catchment nodes, "Demand Sites" with domestic water requirements are explicitly included for each subcatchment. Each demand site has two specific water users: urban and rural water supply. Following data gathered in the ADB TA7610 project, the following domestic water requirements were used: (i) urban - 160 liter

per person per day and (ii) rural - 90 liters per person per day. Within each subcatchment, a storage "Reservoir" node is defined. Runoff from a "Catchment" node can enter a river and/or reservoir, and infiltration can occur to a groundwater element that is defined at basin scale (Sreng and Sisophon). For each Groundwater Node recharge is calculated by WEAP and abstractions are based on the domestic demands and the actual groundwater storage. Finally, downstream in every subcatchment an environmental flow requirement is defined. The environmental requirement is set at 30% of the mean annual flow during the wet season, and 0.2 $m^3 s^{-1}$ per 100 km2 of catchment area during the dry season. Mean annual flow was simulated by WEAP based on a scenario with no minimum flow requirements.

A full overview of the model schematization is shown in Figure 3.

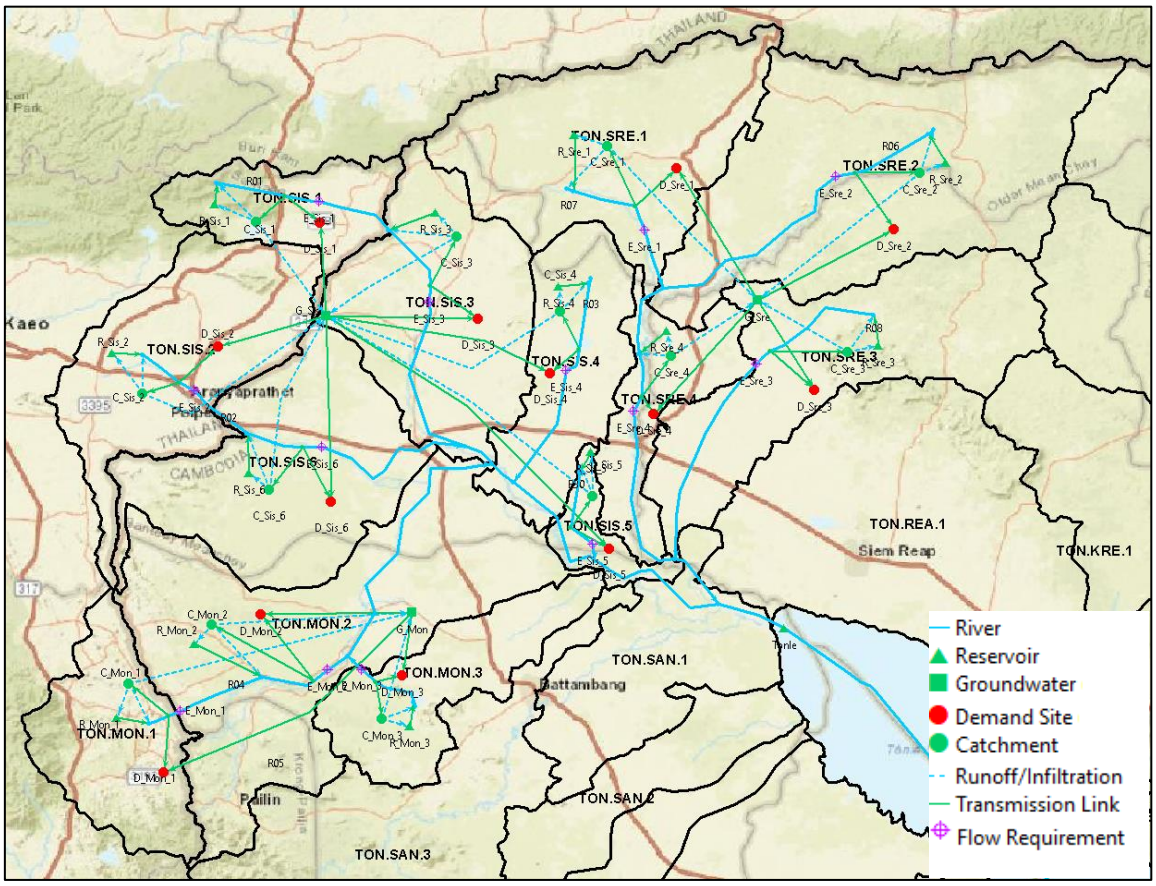


Figure 3. Schematization of the WEAP model for Oddar Meanchey and Banteay Meanchey.

1.1.3 Land use and irrigation

Each Catchment Node is divided into twelve land use classes, making a total of 156 (13*12) calculation units within the entire model. The distribution of eight of those classes is shown in Figure 4 (data source: MRC land cover mapping, 2016). An obvious difference between the two provinces is the relatively large stretch of forest that is still present in Oddar Meanchey.

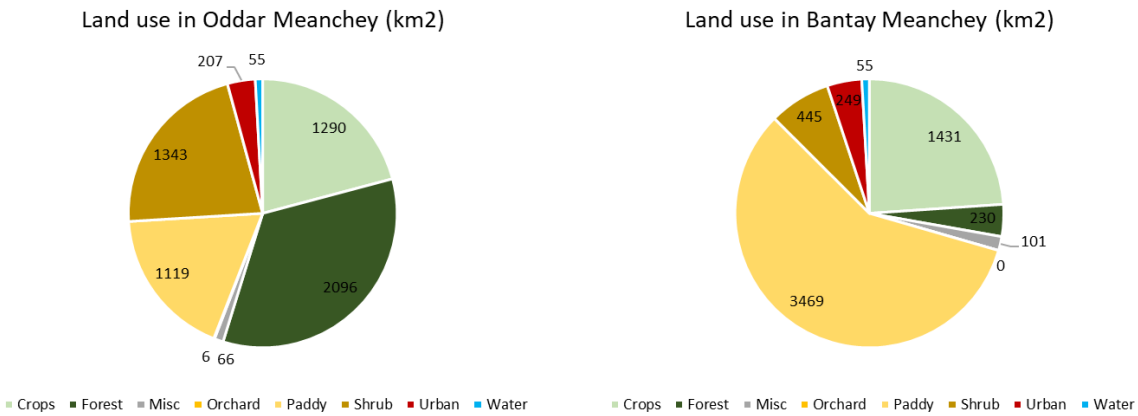


Figure 4. Land use in Oddar Meanchey and Banteay Meanchey as incorporated in WEAP (values indicate areas in km^2).

The other four land use classes are representative of different irrigation practices. Actual water demand by the paddy cultivation is not well known and is calculated by the WEAP model using the Penman-Monteith equation. Additional irrigation requirement is calculated based on the actual available soil water, This irrigation water requirement is abstracted from the streams and rivers in the sub-catchment. In case insufficient water is available, WEAP calculates the water shortage ("unmet demand"). There are three main paddy growing practices in the area (Figure 5):

- Wet Season
  - Land preparation: 1-Jun / 15 Jun
  - Planting: 15-Jun / 30-Jun
  - Harvesting: 1-Nov / 15 Nov
- Dry in Wet (Early Dry Season Short Duration variety)
  - Land preparation: 15-Apr / 30-Apr
  - Planting: 1-May / 15-May
  - Harvesting: 15-Jul / 31-Jul
- Dry Season
  - Land preparation: 1-Dec / 15-Dec
  - Planting: 15-Dec / 30-Dec
  - Harvesting: 1-Mar / 15-Mar

For each of the sub-catchments, acreages of the MoWRAM CISIS database have been used in the model.

	01-Jan / 15-Jan	15-Jan / 01-Feb	01-Feb / 15-Feb	15-Feb / 01-Mar	01-Mar / 15-Mar	15-Mar / 01-Apr	01-Apr / 15-Apr	15-Apr / 01-May	01-May / 15-May	15-May / 01-Jun	01-Jun / 15-Jun	15-Jun / 01-Jul	01-Jul / 15-Jul	15-Jul / 01-Aug	01-Aug / 15-Aug	15-Aug / 01-Sep	01-Sep / 15-Sep	15-Sep / 01-Oct	01-Oct / 15-Oct	15-Oct / 01-Nov	01-Nov / 15-Nov	15-Nov / 01-Dec	01-Dec / 15-Dec	15-Dec / 31-Dec
Wet Season											1	2	3	3	3	3	3	3	3	3	4			
Recession	3	3	3	3	4																1	2	3	3
Dry in Wet								1	2	3	3	3	3	4										
Dry Season	3	3	3	3	4																		1	2

Figure 5. Cropping calendar for four paddy seasons. 1 = land preparation, 2 = planting, 3 = growing, 4 = harvesting. Note: in reality quite some variation in paddy cultivation periods exists in the region.

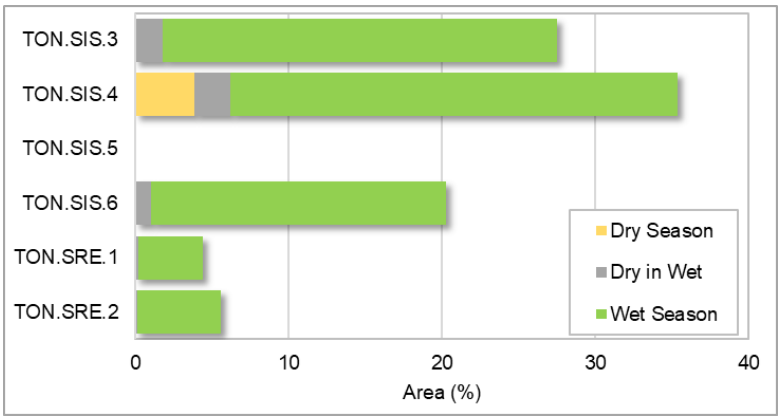


Figure 6. Area of irrigation crop calendar season for each sub-catchment presented as total area of the sub-catchment.

1.2 Storage data

It is essential for the model to simulate well the carrying over of water from wet to dry seasons by making use of the available storage capacity in the subcatchments. To quantitfy the capacity of the Reservoir nodes in WEAP, two main data sources are available: (i) the CISIS database, and (ii) the ESA EO Clinic report "Mitigation of Climate Change Risks in the Agricultural Sector of Cambodia" and the accompanying satellite-derived data. Reservoirs included in the CISIS database for Oddar Meanchey and Banteay Meanchey are listed in the Annex to this document. Where capacities where not included, these were computed based on listed reservoir surfaces and an average depth of 2.2 m derived from other reservoirs having all data available. The ESA EO Clinic data consist of set of 10m rasters of surface water extent in 2017-2019 in Oddar Meanchey.

Table 1 provides an overview of both datasets for Oddar Meanchey. ESA data listed here are the maximum extents for the 2019 wet season, which has the greatest surface water coverage in the period of analysis. Although the spatial distribution of included reservoirs generally is similar (Figure 7), it is clear from the table that the two datasests are somewhat difficult to reconcile. Likely reasons for this are that (i) the reservoirs, particularly the large ones, were not filled to their maximum capacity at the time of monitoring, and (ii) CISIS particularly misses data on storage sites in communes with small reservoirs and ponds.

Table 1. Overview of storage in Oddar Meanchey districts and communes, according to the ESA EO Clinic and CISIS datasets

District	Commune	Total area	ESA	CISIS
		km²	*km²*	*km²*
Anlong Veaeng	Anlong Veaeng	391.4	1.7	5.2
	Lumtong	477.2	2.4	-
	Thlat	211.0	0.0	-
	Trapeang Prei	112.9	0.1	-
	Trapeang Tav	340.3	10.0	30.8
Banteay Ampil	Ampil	364.6	0.3	0.1
	Beng	446.9	0.6	8.6
	Kouk Mon	270.5	2.0	6.6
	Kouk Khpos	271.3	0.3	0.7
Chong Kal	Cheung Tien	93.9	1.7	-
	Chong Kal	291.2	12.6	6.9
	Krasang	163.0	0.5	-

District	Commune	Total area	ESA	CISIS
		km²	*km²*	*km²*
Samraong	Pongro	292.5	8.6	73.2
	Bansay Reak	116.9	0.1	6.0
	Bos Sbov I	98.2	0.1	-
	Koun Kriel	1087.8	10.1	1.2
	Ou Smach	20.4	0.2	-
	Samraong I	95.3	2.0	1.3
Trapeang Prasat	Bak Anloung	137.4	0.2	-
	Ou Svay	162.0	0.5	-
	Ph'av	471.1	1.3	-
	Preah Pralay	68.0	0.0	-
	Trapeang Prasat	502.0	0.1	-
	Tumnob Dach	146.4	0.1	0.4
Total			**55.5**	**141.0**

CISIS storage data as listed in the Annex were aggregated per subcatchment for usage in the WEAP model. For Oddar Meanchey, a total of 435 MCM (62.5 MCM in SRE.1 and 372.5 MCM in SRE.2) were included. Total maximum storage capacity in Banteay Meanchey is 192.1 MCM.

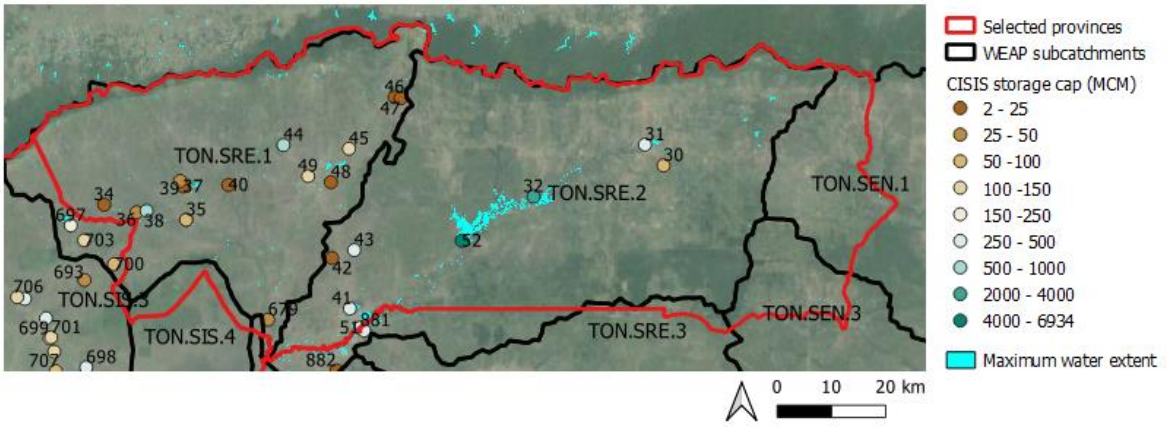


Figure 7. ESA EO Clinic (maximum water extent in 2019 wet season) and CISIS storage data for Oddar Meanchey Province.

1.3 Scenario development

1.3.1 Rationale and overview of scenarios

For the purpose of this study, it was required to perform several scenario runs with varying reservoir storage capacity per subcatchment, for the current situation as well as under climate change. This should provide the necessary insight at the provincial level to quantify the added benefit of developing additional storage capacity, taking into account extreme years and climate change. The key parameter to evaluate is the unmet water demand of agriculture and domestic water use.

In total, 33 model simulations were performed:

- A reference run for 1999-2018;

- 10 simulations with progressively adding storage from 10 MCM to 100 MCM per subcatchment, in steps of 10 MCM, forced by the current climate;
- A run to simulate the likely impact of a first climate change trajectory (CC1) on the provincial water balance, further specified below;
- 10 simulations with progressively adding storage from 10 MCM to 100 MCM per subcatchment, in steps of 10 MCM, forced by the CC1 climate.
- A run to simulate the likely impact of a first climate change trajectory on the provincial water balance (CC2), further specified below;
- 10 simulations with progressively adding storage from 10 MCM to 100 MCM per subcatchment, in steps of 10 MCM, forced by the CC1 climate.

1.3.2 Climate change scenarios

As listed above, two possible projections regarding the future climate were used to force the WEAP model. The first one, CC1, is based on the average of the RCP8.5 projections for the 2045-2075 period, according to all 21 General Circulation Models (GCMs) included in the NASA-NEX[1] dataset. Figure 8 shows without exception a clear increase in temperature over the next decades. Figure 9 indicates the average of all GCMs regarding projected changes in monthly precipitation. Based on the average trends predicted by the models in the NASA-NEX database, the CC1 WEAP run implements an overall temperature increase of 2ºC and an overall 5% precipitation increase throughout the year.

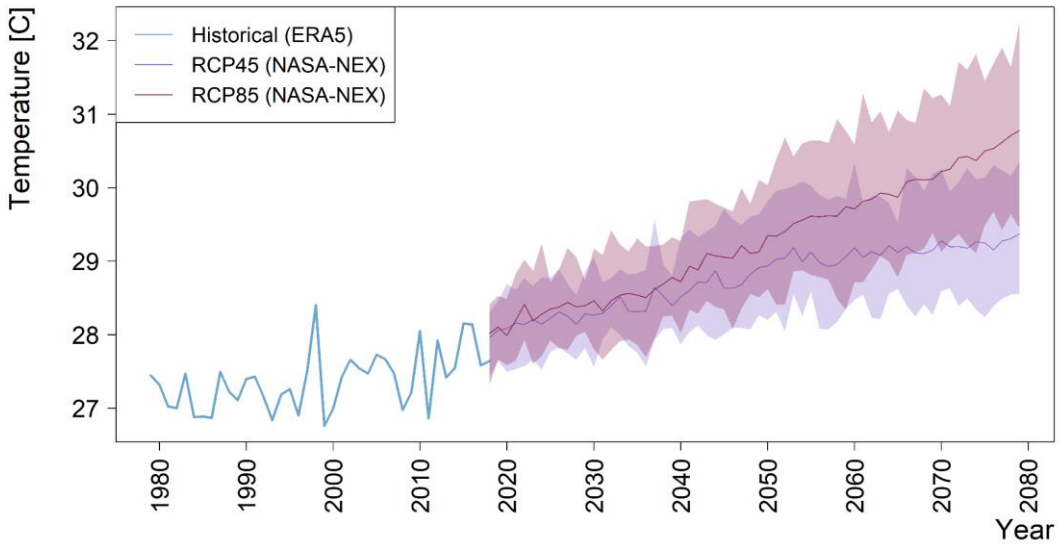


Figure 8. Historical and projected mean temperature under RCP4.5 and RCP8.5 according to the NASA-NEX climate models. Red and blue bands indicate the range of values from the individual models.

[1] https://www.nasa.gov/nex

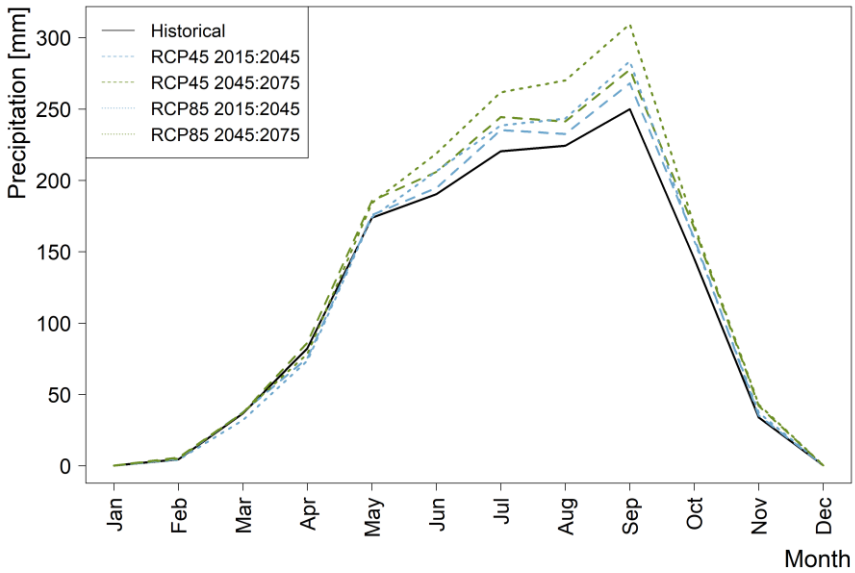


Figure 9. Historical and projected (2015-2045 and 2045-2075) monthly precipitation under RCP4.5 and RCP8.5 according to the NASA-NEX climate models.

As the variability in precipitation projections among the models is much higher than for temperature, a second climate change scenario (CC2) was simulated by the WEAP model. To this end, a GCM with extreme seasonality (drier dry seasons and wetter wet seasons) was selected from an overall assessment of various precipitation change indicators per model. Figure 10 shows for all GCMs in NASA-NEX the projected changes in three precipitation indicators, based on a 1975-2005 historical period and the 2045-2075 future period (RCP8.5). To be suitable for implementation in WEAP as CC2, a GCM should in particular project a substantial decrease in average dry season rainfall (upper panel), and a significant increase in the P99 indicator (lower panel), which is defined as the 99th-percentile of daily precipitation. In other words, the latter indicator is representative of the impacts of climate change on the wettest days of the year. Based on these criteria, the IPSL.CM5A.MR was ultimately selected for usages in WEAP for the CC2 simulations. This is in line with the findings of MRC, who recommended this model for analyses of extreme seasonality in the Lower Mekong Basin.[1]

The extracted change indicators were applied to the historical daily rainfall data to produce a synthetic daily rainfall time series as input to WEAP, which matches the projected changes in the various indicators. Both CC1 and CC2 incorporate the same temperature increase of 2ºC.

[1] Mekong River Commission (2015), The incorporation of climate change into flood simulation modelling for future climates in the Lower Mekong Basin, Flood Management and Mitigation Programme 2011-2015.

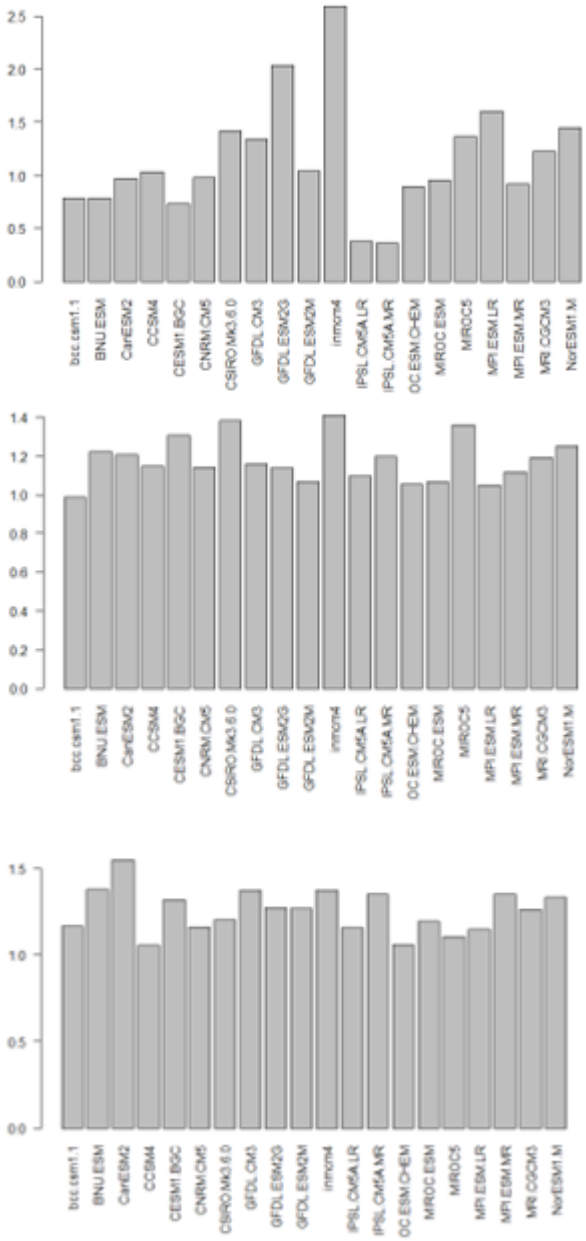


Figure 10. Three indicators of projected changes (unitless) in precipitation patterns for each GCM in NASA-NEX: change in average daily precipitation in dry season (top), change in average daily precipitation in wet season (top), change in P99 (99th-percentile of daily precipitation, bottom).

2 Results

2.1 Oddar Meanchey

2.1.1 Current water balance and unmet demand

Figure 11 presents annual values for the different water balance components computed by the WEAP model for Oddar Meanchey. Clearly, the province is a water-producing area, thanks to the natural vegetation that is still in place. On average over the 1999 – 2018 period, 201 mm/yr (1.2 BCM/yr) of water leaves the province through the Sreng River. Over the same period, 167 mm/yr (1.0 BCM/yr) on average was added to the regional groundwater reserve.

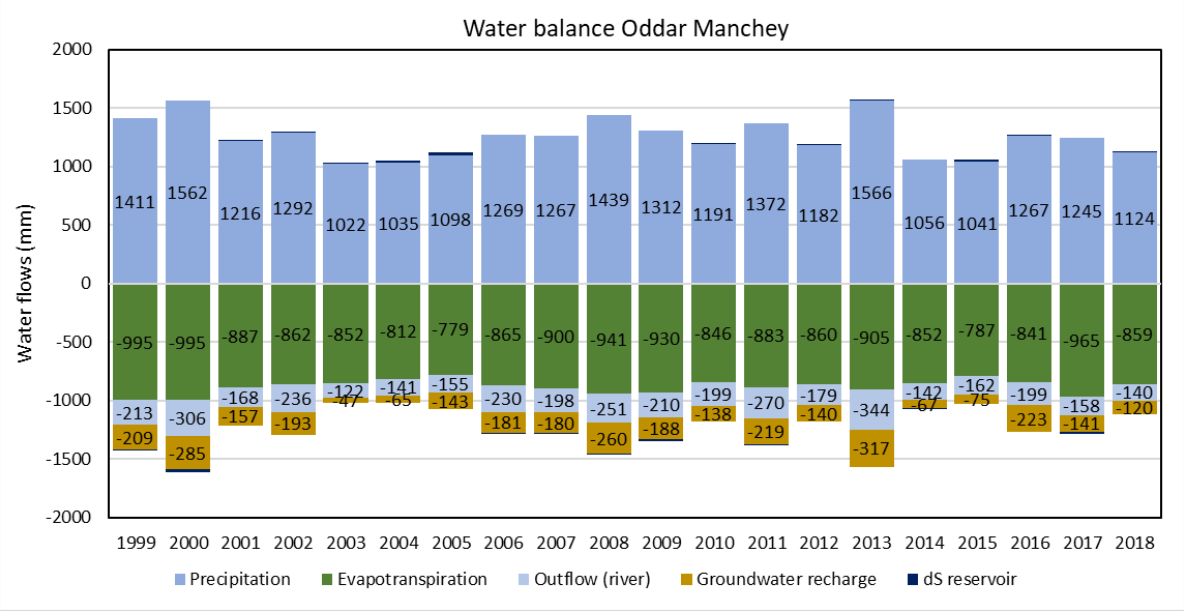


Figure 11. Water balance of Oddar Meanchey as produced by the WEAP model. All values are in mm/year.

Although the runoff produced in Oddar Meanchey is substantial and benefits downstream areas, the province itself is known to suffer from water shortages in dry periods. Table 2 shows how unmet demands occur for both domestic use and the irrigation sector in the 20 years under consideration. In this analysis, it is assumed that the 20-year period suffices to capture typical climate variability in Oddar Meanchey. Particularly the storage capacity in SRE.1 appears to be insufficient to avoid water shortages, as unmet demands occur in most years of the modeling period.

Table 2. Unmet demand (supply requirement minus supply delivered) for irrigation and domestic sectors in Oddar Meanchey. All values are in MCM/yr.

	SRE.1			*SRE.2*			*Oddar Meanchey*		
Year	*Domestic*	*Irrigation*	*Total*	*Domestic*	*Irrigation*	*Total*	*Domestic*	*Irrigation*	*Total*
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.4	12.1	12.5	0.0	0.0	0.0	0.4	12.1	12.5
2002	0.5	24.4	24.9	0.0	0.0	0.0	0.5	24.4	24.9
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	1.6	3.3	4.8	0.0	0.0	0.0	1.6	3.3	4.8

	SRE.1			*SRE.2*			*Oddar Meanchey*		
Year	*Domestic*	*Irrigation*	*Total*	*Domestic*	*Irrigation*	*Total*	*Domestic*	*Irrigation*	*Total*
2005	2.6	105.1	107.8	0.5	55.6	56.1	3.1	160.8	163.9
2006	0.6	15.8	16.4	0.1	15.1	15.2	0.8	30.8	31.6
2007	0.9	0.3	1.2	0.0	0.0	0.0	0.9	0.3	1.2
2008	0.2	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.2
2009	0.0	0.9	0.9	0.0	0.0	0.0	0.0	0.9	0.9
2010	0.5	11.0	11.4	0.0	0.0	0.0	0.5	11.0	11.4
2011	0.4	0.1	0.4	0.0	0.0	0.0	0.4	0.1	0.4
2012	1.2	63.5	64.6	0.0	0.0	0.0	1.2	63.5	64.6
2013	0.7	1.1	1.7	0.0	0.0	0.0	0.7	1.1	1.7
2014	0.2	15.9	16.2	0.0	0.0	0.0	0.2	15.9	16.2
2015	1.2	30.7	31.8	0.0	0.0	0.0	1.2	30.7	31.8
2016	1.1	35.6	36.7	0.0	0.0	0.0	1.1	35.6	36.7
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	0.3	3.5	3.7	0.0	0.0	0.0	0.3	3.5	3.7
Average	**0.6**	**16.2**	**16.8**	**0.0**	**3.5**	**3.6**	**0.6**	**19.7**	**20.3**

To put the unmet demand values into perspective, it helps to quantify the “coverage” indicator in WEAP, which is defined as the degree to which the supply delivered meets the total supply requirement of a demand node (in %). Figure 12 depicts the average dynamics of the coverage parameter throughout the year, for irrigation in Oddar Meanchey. However, the severity of water shortages can vary greatly between years. The curve for 2005 (the year with the highest unmet demand) is also plotted to illustrate this. During several weeks in 2005, water supply in SRE.1 subcatchment was below 20% of the irrigaiton water requirement.

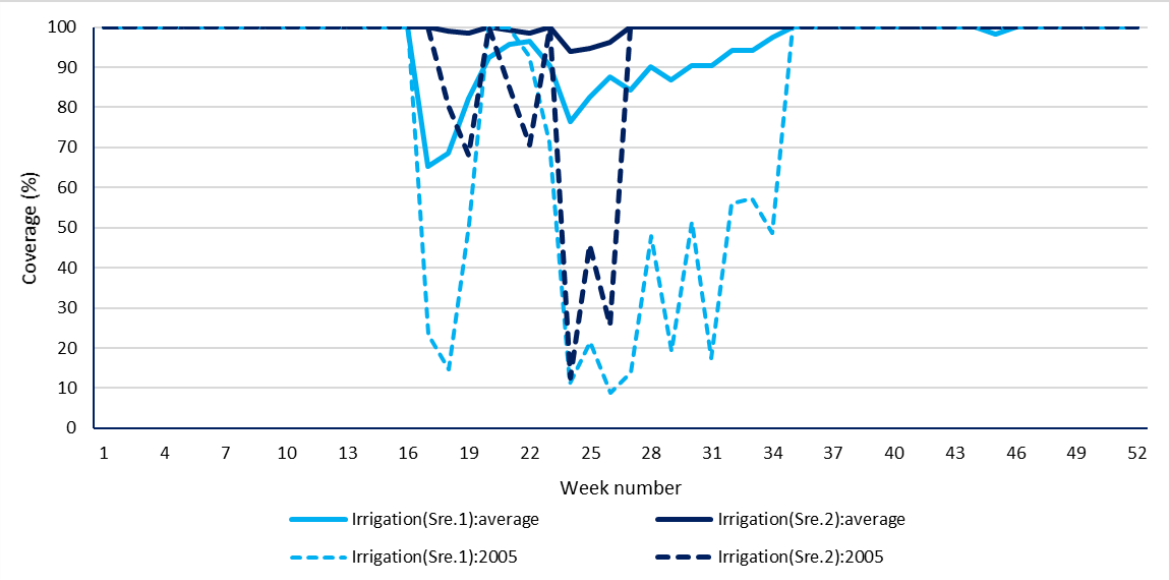


Figure 12. Coverage (supply delivered divided by supply required) of irrigation demand in Oddar Meanchey Province. Continuous lines plot average values per week for both WEAP model units SRE.1 and SRE.2. Dashed lines show the values for 2005, the year with the greatest unmet demand in the period of analysis.

The fact that Oddar Meanchey is water-producing while at the same time experiencing significant unmet water demands, is indicative of a lack of storage capacity in the province. Particularly in the western part of the province, the total storage capacity of 62.5 MCM appears insufficient to buffer the water needed for domestic

and agricultural use in periods of drought. As WEAP computes the storage of water in the reservoirs on a weekly basis, the intra-annual patterns of precipitation, demands and storage can be analyzed to determine the nature of the shortages. Figure 13 examines the cause of the high unmet irrigation demand occuring in 2005 in SRE.1 subcatchment. The graph shows that reservoir storage is far below the average amount throughout the year, and even close to zero for a large part of the year. The reason for this lack of water can be found in the rainfall dynamics in the preceding year 2004. This was an erratic year in terms of rainfall, with a peak of 156 mm/week (= 382 MCM) in week 24, which could not be stored due to a lack of capacity. As rainfall amounts in the remainder of the year were far below average, this resulted in insufficient water availability at the start of the wet season irrigation in early June.

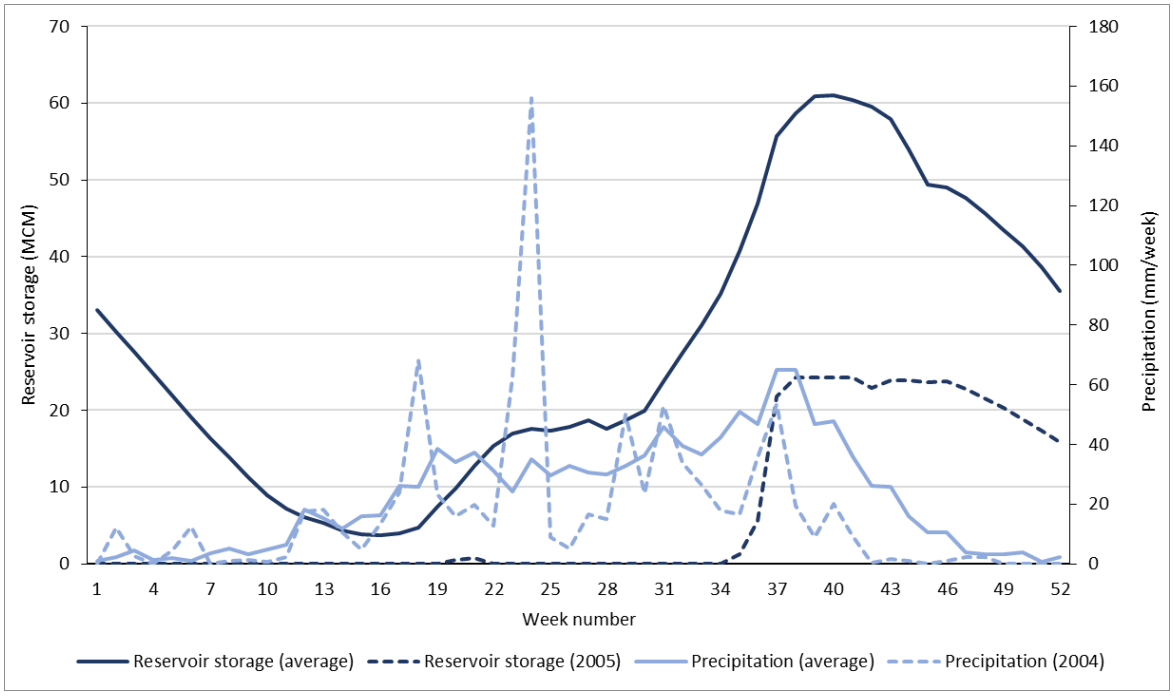


Figure 13. Reservoir storage in SRE.1 on average for 1999-2018 and in the year 2005. Clearly, storage is close to zero for a large part of that year. This is due to the precipitation pattern in the preceding year (2004), which had a highly concentrated rainfall peak relatively early in the year and very low rainfall afterwards.

2.1.2 Water balance under climate change

Figure 14 and Figure 15 present the water balance for the two climate scenarios implemented in WEAP; an overall slightly wetter climate (CC1), and a scenario with more extreme seasonality (CC2). Interestingly, for most years, the additional water available from rainfall in the CC1 scenario leads to an increased evapotranspiration, as this water can be partly put to (human or natural) use in the province due to the even distribution of the extra rainfall over time. This is however not the case in the CC2 scenario, where evapotranspiration is mostly lower than in the historical situation, and especially river flow out of the province substantially increases. This is due to the fact that especially the additional rainfall on the wettest days cannot be stored, either in the soil profile or in artificial reservoirs.

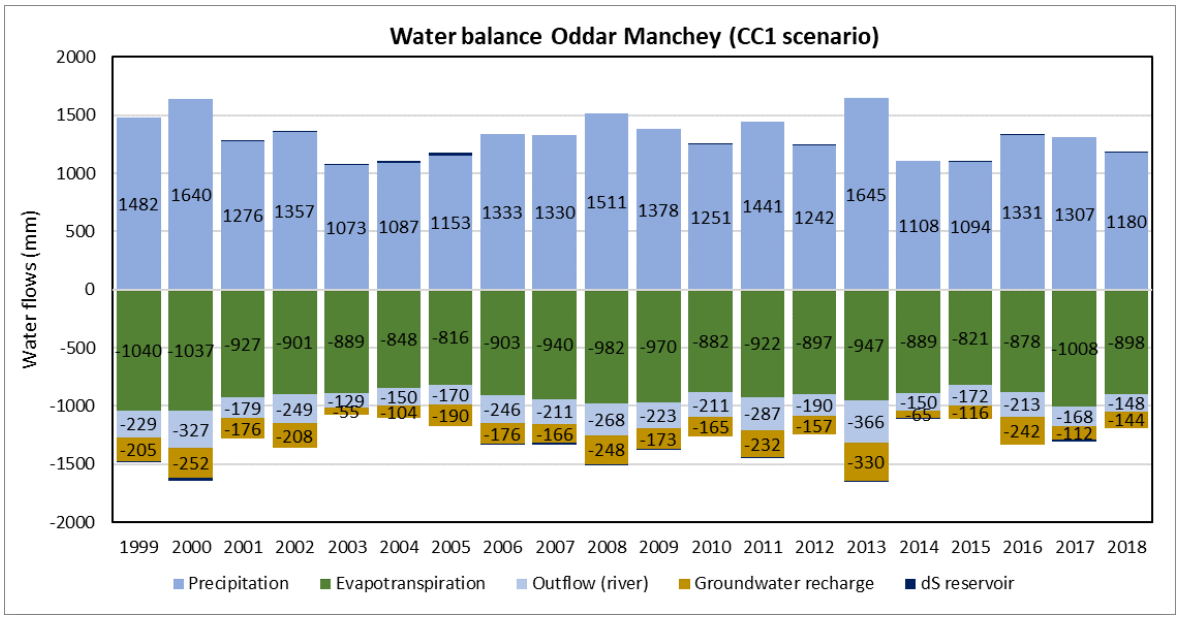


Figure 14. Water balance of Oddar Meanchey as produced by the WEAP model for the CC1 climate scenario. All values are in mm/year.

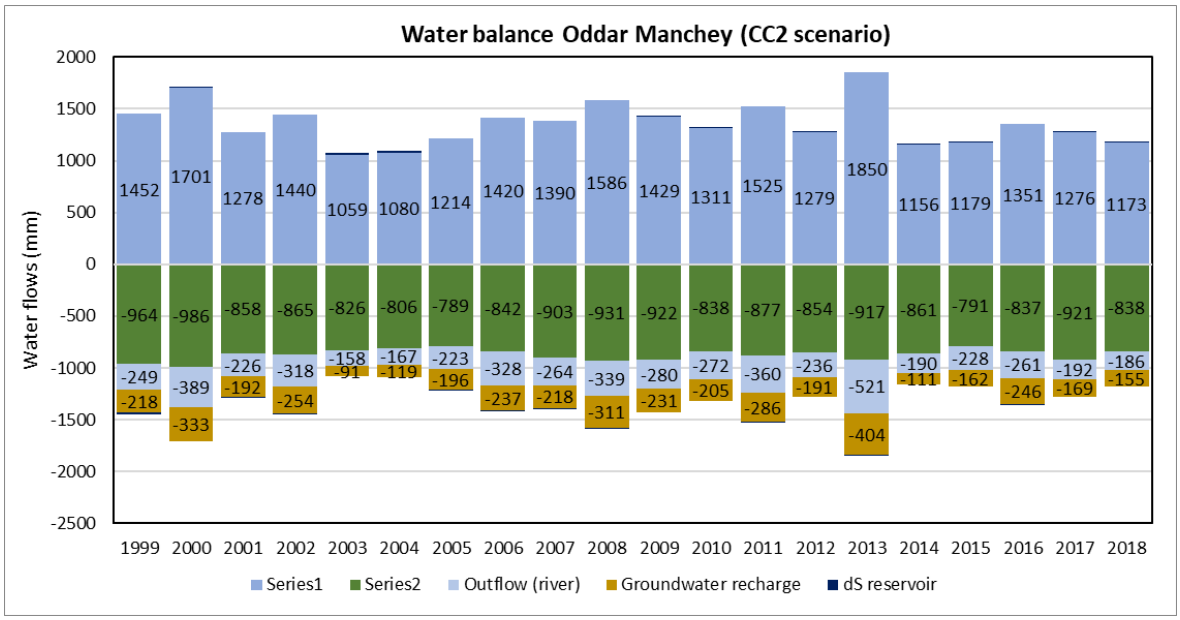


Figure 15. Water balance of Oddar Meanchey as produced by the WEAP model for the CC2 climate scenario. All values are in mm/year.

2.1.3 Storage capacity scenarios

The impact of developing additional storage capacity in Oddar Meanchey on unmet domestic and agricultural water demand was evaluated by performing a set of scenario runs. Table 3 shows the yearly total water shortage in the province for each of the scenarios, each expanding the provincial storage capacity by 10 MCM. The non-linear nature of the hydrological processes involved is clear from these results, with an additional 10 MCM sometimes having only a minor impact, while in other cases the unmet demand is reduced with more than 10 MCM. The result show that e.g. when storage is expanded by 20 MCM, unmet demands are eliminated in 6

additional years compared to the reference run. For three years (2005, 2006, 2016), even an expansion of 100 MCM is insufficient to completely eliminate water shortages. Interestingly, unmet demand in 2005 stabilizes from 60 MCM of additional storage, as apparently there is simply not enough water supplied to buffer for meeting the demands.

Table 3. Total yearly unmet water demand (MCM) for domestic and agricultural use, for the reference situation and 10 scenarios with additional storage development. The red colour indicates the magnitude of the unmet demand relative to the reference model run for each year.

Add. storage (MCM)	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0	0.0	0.0	12.5	24.9	0.0	4.8	163.9	31.6	1.2	0.2	0.9	11.4	0.4	64.6	1.7	16.2	31.8	36.7	0.0	3.7
10	0.0	0.0	11.9	23.8	0.0	4.7	155.3	24.7	1.1	0.1	0.0	10.4	0.2	64.4	1.5	10.5	31.7	36.5	0.0	3.0
20	0.0	0.0	4.3	14.1	0.0	4.5	137.9	23.9	1.0	0.0	0.0	7.4	0.0	63.4	1.4	2.3	30.5	36.4	0.0	0.0
30	0.0	0.0	0.0	4.0	0.0	4.4	125.0	14.9	0.8	0.0	0.0	1.2	0.0	55.2	0.9	0.0	29.0	36.2	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	4.2	113.5	12.4	0.7	0.0	0.0	0.0	0.0	39.9	0.0	0.0	27.4	35.7	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	3.9	107.3	8.0	0.5	0.0	0.0	0.0	0.0	30.9	0.0	0.0	21.0	33.4	0.0	0.0
60	0.0	0.0	0.0	0.0	0.0	0.7	105.7	8.0	0.0	0.0	0.0	0.0	0.0	18.1	0.0	0.0	9.2	32.6	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.5	105.7	6.3	0.0	0.0	0.0	0.0	0.0	11.2	0.0	0.0	6.3	32.3	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.3	105.7	4.7	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	1.0	29.6	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.2	105.7	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.3	0.0	0.0
100	0.0	0.0	0.0	0.0	0.0	0.0	105.7	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.2	0.0	0.0

Table 4 shows the results of the set of model runs which involve an overall slightly wetter climate (CC1). Interestingly, overall unmet demands are lower already in the reference run. Although the increase in temperature leads to higher water consumption and thus potential greater shortages, this is compensated by the increase in rainfall in the wet season, which can under current conditions apparently already be sufficiently stored to reduce unmet demands somewhat. The figure shows that the potential of additional storage to reduce water shortages significantly is even greater under a changed climate, with shortages in 19 out of 20 years completely eliminated in the +100 MCM storage capacity scenario.

Table 4. Total yearly unmet water demand (MCM) for domestic and agricultural use, under climate change (CC1) and 10 scenarios with additional storage development. The red colour indicates the magnitude of the unmet demand relative to the reference model run including climate change, for each year.

Add. storage (MCM)	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0	0.0	0.0	8.4	18.1	0.0	1.8	110.4	15.1	1.1	0.2	0.0	9.4	0.4	56.7	1.6	11.6	24.8	36.0	0.0	1.3
10	0.0	0.0	7.6	17.2	0.0	1.7	99.4	15.0	1.0	0.0	0.0	8.6	0.2	56.5	1.4	7.3	24.6	35.8	0.0	0.4
20	0.0	0.0	1.7	7.6	0.0	1.5	94.3	14.4	0.8	0.0	0.0	4.7	0.0	55.6	1.3	0.0	23.1	35.7	0.0	0.0
30	0.0	0.0	0.0	2.3	0.0	1.3	94.3	13.3	0.6	0.0	0.0	0.0	0.0	48.7	0.6	0.0	21.5	35.6	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	1.1	94.3	7.1	0.5	0.0	0.0	0.0	0.0	33.8	0.0	0.0	19.5	33.8	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.5	94.3	2.9	0.0	0.0	0.0	0.0	0.0	25.6	0.0	0.0	9.8	32.4	0.0	0.0
60	0.0	0.0	0.0	0.0	0.0	0.4	94.3	0.0	0.0	0.0	0.0	0.0	0.0	13.2	0.0	0.0	7.6	27.7	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.2	94.3	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0	0.0	1.4	19.7	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.1	94.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	11.2	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	94.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0
100	0.0	0.0	0.0	0.0	0.0	0.0	94.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5 shows the results of the set of model runs which involve a climate with more extreme seasonality (CC2). The impact on unmet demands with zero additional storage differs per year, e.g. a higher unmet demand in 2001 and a lower unmet demand in 2002, when compared to the historical climate. This is due to the non-linear changes in daily precipitation dynamics that were applied in this scenario. Again, similar to CC1, the benefit of

additional storage capacity is higher than under the historical climate, with now shortages in 19 out of 20 years completely eliminated in the +80 MCM storage capacity scenario

Table 5. Total yearly unmet water demand (MCM) for domestic and agricultural use, under climate change (CC2) and 10 scenarios with additional storage development. The red colour indicates the magnitude of the unmet demand relative to the reference model run including climate change, for each year.

Add. storage (MCM)	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0	0.0	0.0	17.4	17.7	0.0	1.4	77.8	22.7	1.0	0.2	3.3	14.6	0.6	44.0	1.6	22.2	31.3	37.7	0.0	6.5
10	0.0	0.0	17.2	16.6	0.0	1.2	77.8	22.2	0.9	0.1	0.0	14.4	0.5	43.8	1.5	10.0	31.1	37.5	0.0	5.9
20	0.0	0.0	16.2	9.3	0.0	1.0	77.8	20.6	0.7	0.0	0.0	12.9	0.3	43.0	1.3	5.1	29.8	36.5	0.0	2.9
30	0.0	0.0	12.6	3.4	0.0	0.9	77.8	16.9	0.5	0.0	0.0	8.2	0.0	37.3	0.0	0.0	28.1	34.4	0.0	0.0
40	0.0	0.0	4.4	0.0	0.0	0.7	77.8	9.1	0.0	0.0	0.0	1.7	0.0	22.1	0.0	0.0	26.4	31.5	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	77.8	2.8	0.0	0.0	0.0	0.0	0.0	15.3	0.0	0.0	18.5	23.3	0.0	0.0
60	0.0	0.0	0.0	0.0	0.0	0.0	77.6	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0	8.0	15.1	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	77.5	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	4.3	6.8	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	77.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	77.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.0	0.0	0.0	77.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 16 synthesizes the scenario results of unmet water demands. The curve for the historical climate shows that especially in the current situation with relatively low storage capacity in Oddar Meanchey, the marginal benefit of developing additional storage is relatively high. Over the first 50 MCM of extra storage, a total of 10 MCM reduction on average of unmet demand is achieved (whereas this is only 4 MCM reduction over the second 50 MCM of additional development). In dry years with significant shortages such as 2005 and 2012, the beneficial impact of adding a first 50 MCM of storage is even much higher, at 56 MCM and 34 MCM respectively (see Table 3). A similar phenomenon is observed for the two climate change simulations. At the same time, the occurrence of an overall wetter (CC1) or more erratic (CC2) climate enhances the potential benefits to be gained from additional buffering of water, as extra water can be put to beneficial use. This leads, for example, to a reduction of 19% and 32% of unmet demands respectively for under CC1 and CC2 conditions, in case 50 MCM of additional storage capacity is developed.

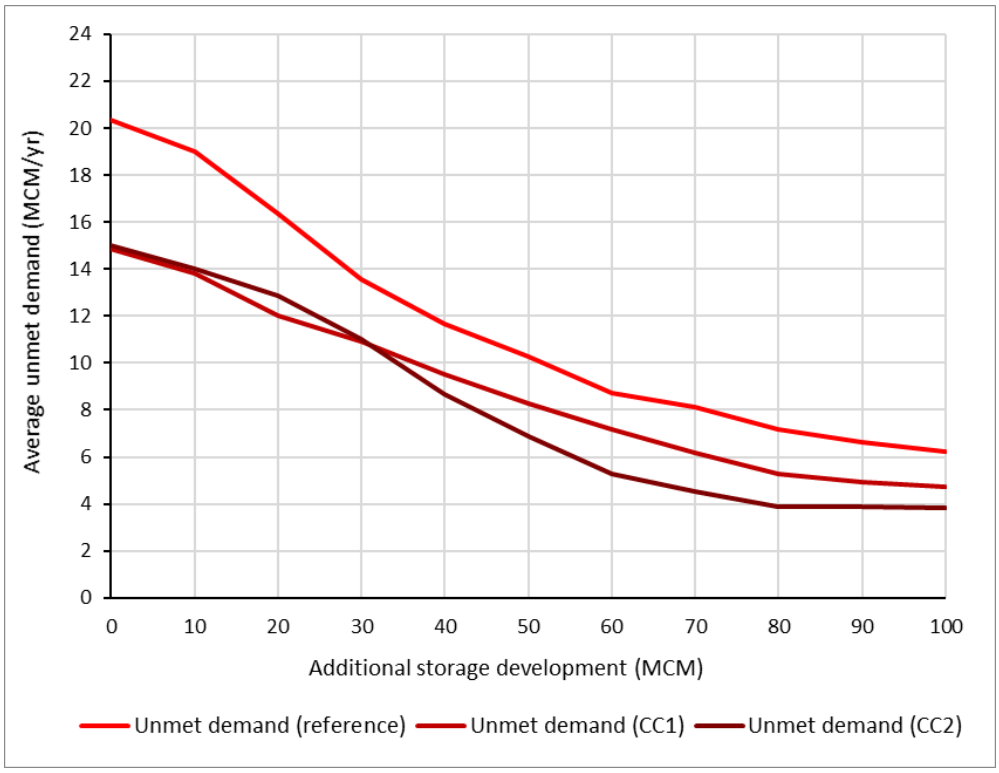
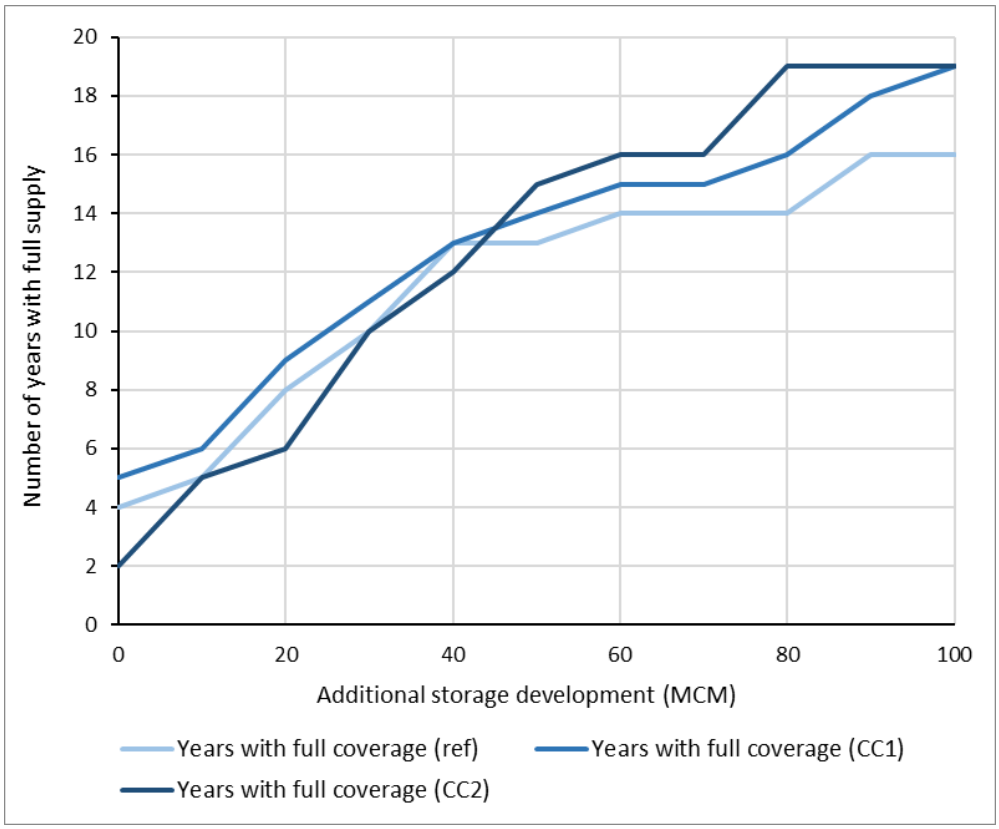


Figure 16. Impacts of developing additional storage capacity, expressed in reduced average unmet demand and the number of years without water shortages (full coverage).



2.1.4 Implications

A main conclusion to be drawn from the analysis is that the development of additional storage capacity is likely to reduce unmet domestic and agricultural water demand in Oddar Meanchey. Only in the most extreme dry year in a 20 year period, a point is reached (at 60 MCM of storage development) where no additional benefit is gained from further development because simply not enough water is available from the preceding rainy season. Under both simulated future conditions related to precipitation dynamics and temperature change, there is further benefit to be had from additional storage development as higher rainfall extremes can be buffered to mitigate water shortages in subsequent dry periods.

An interesting observation is that the marginal benefit of additional water storage capacity generally decreases with total storage capacity in the province. This means that a cost-benefit analysis will be instrumental to inform a regional water retention strategy.

The observation of having the greatest unmet demands in western OM (e.g. Banteay Ampil District) is very well in line with the results of the drought hazard mapping peformed under the same project, which saw communes in these areas having high drought hazard index values. This indicates that the lack of water storage has its impacts on e.g. vegetation / crop health and land surface temperature in these areas. In the WEAP schematization, the Reservoir nodes are representative of a much larger amount of smaller and larger ponds and reservoirs at lower levels of spatial disaggregation. Additional storage development should focus at the communes within western OM where high drought hazard values are calculated.

Estimation of Storage Volumes from data within Cambodia Irrigation System database (CSIS)

Subcatchment	*District*	*Commune*	*X*	*Y*	*Reser_Surf (ha)*	*Cap_calc*
TON.SIS.3	Phnom Srok	Pun Ley	304403	1528185	300	6.00
TON.SIS.3	Serei Sophon	Makak	279421	1512561	390	1.10
TON.SIS.3	Thmar Puok	Thmar Puok	297254	1549615	30	0.75
TON.SIS.3	Thmar Puok	Kouk Romeat	278594	1544024	75	1.13
TON.SIS.3	Thmar Puok	Kouk Romeat	264700	1543118	50	1.25
TON.SIS.3	Thmar Puok	Kouk Romeat	281367	1542494	30	0.65*
TON.SIS.3	Thmar Puok	Kouk Kathen	297578	1533546	340	7.50
TON.SIS.3	Thmar Puok	Phum Thmey	290812	1538876	180	3.89*
TON.SIS.3	Thmar Puok	Phum Thmey	291115	1539068	120	2.60*
TON.SIS.3	Thmar Puok	Kamrou	286282	1546152	314	6.79*
TON.SIS.3	Thmar Puok	Thmar Puok	290164	1542592	257	5.56*
TON.SIS.3	Thmar Puok	Kouk Romeat	276999	1553536	110	1.60
TON.SIS.3	Thmar Puok	Kamrou	284854	1546465	105	2.27*
TON.SIS.3	Thmar Puok	Kouk Kathen	291983	1532850	89	1.93*
TON.SIS.3	Thmar Puok	Phum Thmey	291687	1536432	141	3.05*
TON.SIS.3	Svay Chek	Ta Ben	276805	1525254	230	5.75
TON.SIS.3	Svay Chek	Treas	281547	1534451	15	0.15
TON.SIS.3	Svay Chek	Treas	280665	1534837	15	4.50
TON.SIS.3	Svay Chek	Ta Phou	288845	1525826	26	1.50
TON.SIS.3	Svay Chek	Ta Phou	286786	1520453	189	4.09*
TON.SIS.3	Svay Chek	Ta Phou	292236	1527647	266	5.75*
TON.SIS.3	Svay Chek	Roluos	280385	1526757	82	1.77*
TON.SIS.3	Svay Chek	Phkam	297645	1524867	42	0.91*
TON.SIS.3	Svay Chek	Phkam	297775	1529749	261	5.65*
TON.SIS.3	Svay Chek	Saroung	296326	1521157	61	1.32*
TON.SIS.3	Svay Chek	Saroung	296113	1523405	100	2.16*
TON.SIS.3	Svay Chek	Treas	283991	1532707	3	0.06*
TON.SIS.3	Svay Chek	Svay Chek	260046	1534863	39	0.84*
TON.SIS.4	Phnom Srok	Pouy Char	313552	1525449	1194	22.82
TON.SIS.4	Phnom Srok	Spean Sreng	323822	1518879	2747	59.42*
TON.SIS.4	Preah Neth Preah	Preah Neth Preah	302315	1502652	300	6.00
TON.SIS.4	Preah Neth Preah	Phnom Leab	320554	1506141	10	0.25
TON.SIS.4	Preah Neth Preah	Chob Vary	304781	1507564	57	1.23*
TON.SIS.4	Preah Neth Preah	Preah Neth Preah	297585	1499307	272	5.88*
TON.SIS.4	Preah Neth Preah	Chob Vary	305626	1510145	44	0.95*
TON.SIS.4	Preah Neth Preah	Tean Kam	310805	1515361	347	4.50
TON.SIS.6	O Chrov	Seung	269116	1512420	88	1.90*
TON.SIS.6	O Chrov	Nimit	244403	1504837	703	1.00

TON.SIS.6	O Chrov	Koub	257484	1511451	178	3.85*
TON.SIS.6	Serei Sophon	Teuk Thlar	275463	1504646	325	1.00
TON.SIS.6	Malai	Beung Beng	219017	1494814	335	7.25*
TON.SRE.1	Banteay Ampil	Beng	315983	1560698	863	21.58
TON.SRE.1	Banteay Ampil	Ampil	300887	1563478	8	0.20
TON.SRE.1	Banteay Ampil	Kouk Khpos	315983	1560698	65	1.63
TON.SRE.1	Banteay Ampil	Kouk Mon	306866	1562097	35	0.63
TON.SRE.1	Banteay Ampil	Kouk Mon	315396	1566862	19	0.38
TON.SRE.1	Banteay Ampil	Kouk Mon	308700	1562340	558	12.07*
TON.SRE.1	Banteay Ampil	Kouk Mon	314869	1567859	43	0.77
TON.SRE.1	Banteay Ampil	Kouk Khpos	323755	1567107	8	0.24
TON.SRE.1	Samraong	Bansay Reak	333908	1574463	603	13.04*
TON.SRE.1	Samraong	Koun Kriel	345973	1573791	102	2.21*
TON.SRE.1	Samraong	Koun Kriel	354382	1583286	6	0.13*
TON.SRE.1	Samraong	Koun Kriel	355472	1583054	11	0.24*
TON.SRE.1	Samraong	Samraong	342638	1567632	22	0.48*
TON.SRE.1	Samraong	Samraong	338449	1568754	107	2.31*
TON.SRE.1	Phnom Srok	Nam Tao	331076	1542337	30	0.65*
TON.SRE.1	Thmar Puok	Banteay Chhmar	294748	1559652	210	1.50
TON.SRE.1	Thmar Puok	Banteay Chhmar	302703	1552536	81	1.75*
TON.SRE.1	Thmar Puok	Banteay Chhmar	297221	1556932	124	2.68*
TON.SRE.2	Anlong Veaeng	Anlong Veaeng	403923	1570713	100	3.50
TON.SRE.2	Anlong Veaeng	Anlong Veaeng	400490	1574534	417	20.85
TON.SRE.2	Anlong Veaeng	Trapeang Tav	379985	1564987	3075	153.75
TON.SRE.2	Chong Kal	Chong Kal	346139	1544365	421	12.60
TON.SRE.2	Chong Kal	Pongro	342872	1553670	18	7.46
TON.SRE.2	Chong Kal	Pongro	346934	1555125	370	7.46
TON.SRE.2	Chong Kal	Chong Kal	348011	1540837	271	5.86*
TON.SRE.2	Chong Kal	Pongro	366749	1556843	6934	149.98*
TON.SRE.2	Srei Snam	Chrouy Neang Nguon	340149	1530170	66	1.43*
TON.SRE.2	Srei Snam	Sleng Spean	348761	1540332	444	9.60*
TON.SRE.2	Srei Snam	Sleng Spean	343691	1532971	2	0.04*
Total OM						**435.0**
Total BM						**192.1**

*Capacities calculated based on reservoir suface area included in CISIS and the average depth of 2.2.m derived from reservoirs with all characteristics available

Annex D. Remote Sensing of Water Bodies by ESA

EO Clinic project:

Mitigation of Climate Change Risks in the Agricultural Sector of Cambodia

Work Order Report

Support requested by:
United Nations Development Programme (UNDP)

Reference: EOC0010_WOR_ v01
Date: 2020 September 21

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[RD-1]	ESA Request for Proposal: EOC0010_RFP_v02
[RD-2]	Technical Proposal: EOC0010_PRO_C_T_v01 by GeoVille Gmbh and SIRS
[RD-3]	Financial Proposal: EOC0010_PRO_C_F_v02 by GeoVille Gmbh and SIRS

ABOUT THIS DOCUMENT

This document is the final Work Order Report of the ESA EO Clinic project EOC0010 *Mitigation of Climate Change Risks in the Agricultural Sector of Cambodia*.

This publication was prepared in the framework of the EO Clinic (Earth Observation Clinic, see below), in partnership between ESA (European Space Agency), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) / GIZ Regional Economic Development Program IV (RED IV) and a team of service providers contracted by ESA: GeoVille GmbH (Austria) and SIRS (France).

This Work Order Report (WOR) is structured as in the following:

- **Section 1** describes the context of GIZ's activities on Mitigation of Climate Change Risks in the Agricultural Sector of Cambodia, the project objectives and requested EO products and services.
- **Section 2** highlights the applied work logic and responsibilities among the EO Clinic service providers.
- **Section 3** describes the services and products provided, their specifications, methods and outcomes.

ABOUT THE EO CLINIC

The EO Clinic (Earth Observation Clinic) is an ESA (European Space Agency) initiative to create a rapid-response mechanism for small-scale and exploratory uses of satellite EO information in support of a wide range of International Development projects and activities. The EO Clinic consists of "on-call" technically pre-qualified teams of EO service suppliers and satellite remote sensing experts in ESA member states. These teams are ready to demonstrate the utility of satellite data for the development sector, using their wide range of geospatial data skills and experience with a large variety of satellite data types.

The support teams are ready to meet the short delivery timescales often required by the development sector, targeting a maximum of 3 months from request to solution.

The EO Clinic is also an opportunity to explore more innovative EO products related to developing or improving methodologies for deriving socio-economic and environmental parameters and indicators.

The EO Clinic was launched in March 2019 and is open to support requests by key development banks and agencies during the 2 years project duration.

AUTHORS

The present document was prepared and coordinated by Christian Treml (Framework Coordinator, GeoVille) with support from the following contributors: Björn Dulleck (Technical Lead Service 1, GeoVille), Norman Kiesslich (Head of International Development, GeoVille), Antoine Masse (Technical Lead Service 2, SIRS).

ACKNOWLEDGEMENTS

The following colleagues provided valuable inputs, insights and evaluation feedback on the work performed: Dr. Stefan Hanselmann (Program Director Regional Economic Development Program IV) and Zoltan Bartalis (ESA Coordinator and Technical Officer).

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1 DEVELOPMENT CONTEXT AND BACKGROUND

1.1. Climate Change Risks in the Agricultural Sector

Cambodia is highly vulnerable to the effects of climate change. It is facing a climate condition which presents increasing extreme weather events and negative impacts in the forms of casualties and obstructions to the country's economic growth and development, especially on those living in rural and remote areas where subsistence agriculture and natural resources are their main sources of livelihoods and local economy.

The Regional Economic Development (RED IV) program, co-financed by Switzerland and GIZ Germany, aims at strengthening the capacity of subnational and local governments and support rural poor to increase their income and actively participate in local economic development, thereby reducing poverty of the rural population. Hard-won rural improvements are fragile as climate change is an increasingly serious threat facing many communities in rural Cambodia. Main concern moving forward is rising temperatures, erratic weather patterns, and water shortages.

Thus, water management is an important issue for the RED IV program, which has been working on an analysis of the local availability of surface water in the north-western provinces of Cambodia since October 2019. Data availability in Cambodia is a challenge, as data are either out of date or not accurate enough.

Technical support is required by RED (IV) to improve flood and water resource management for the two provinces Oddar Meanchey and Kampong Thom. Within the framework of a comprehensive water resources management approach, information is required on the mapping of surface waterbodies as well as wetlands and their associated dynamics.

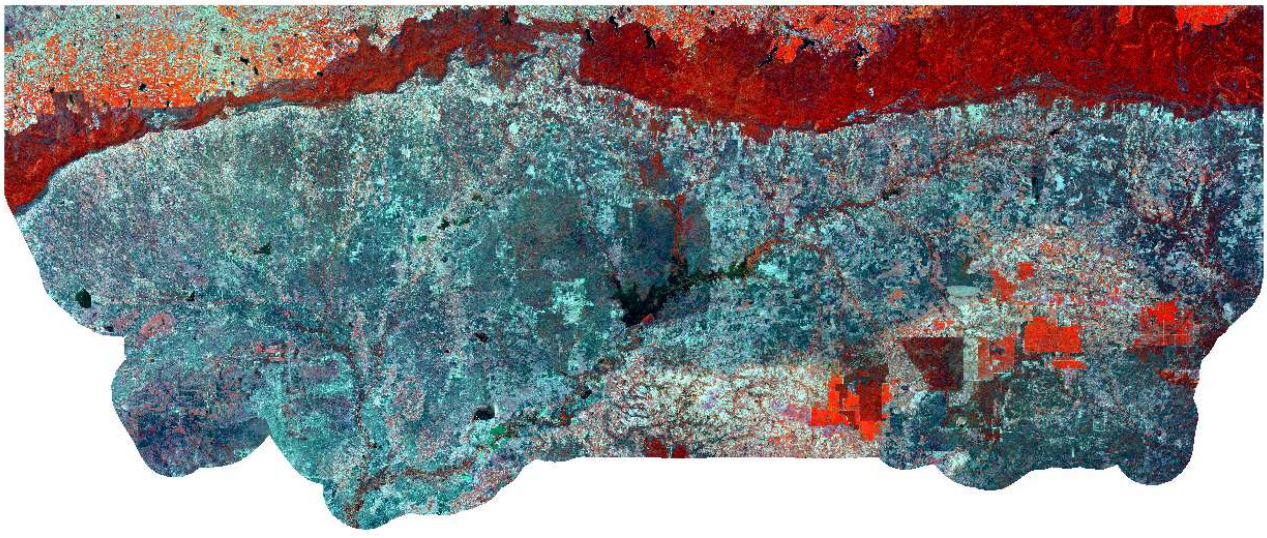


Figure 1: False colour Sentinel-2 image composite - Oddar Meanchey province (Feb. 2020) (Source: ESA)

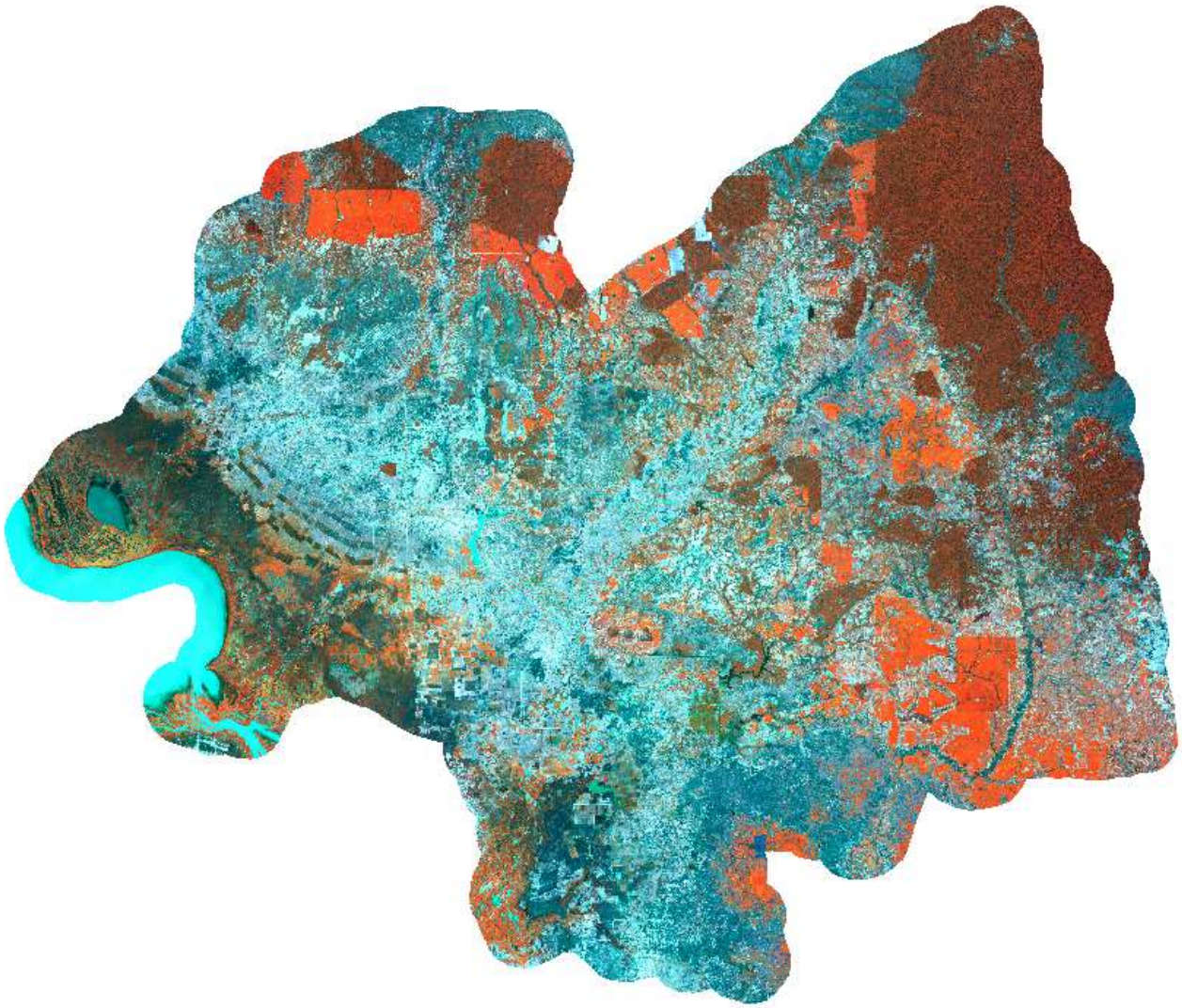


Figure 2: False colour Sentinel-2 image composite - Kampong Thom province (Feb. 2020) (Source: ESA)

1.2. Objectives

In response to these requirements and challenges, GIZ has requested Technical Assistance from the ESA EO Clinic. The need for proper and timely information on water (non-) availability is the most important requirement for water management activities. Hence, the aim of this EO Clinic activity is to support GIZ on the mapping and monitoring of surface waterbodies / wetlands and the assessment of their dynamics with a focus on the two provinces Oddar Meanchey and Kampong Thom.
The mapping shall demonstrate the capabilities and limitations of satellite Earth Observation (EO) data for an independent water / wetland monitoring and improve flood and water resource management for the two provinces.

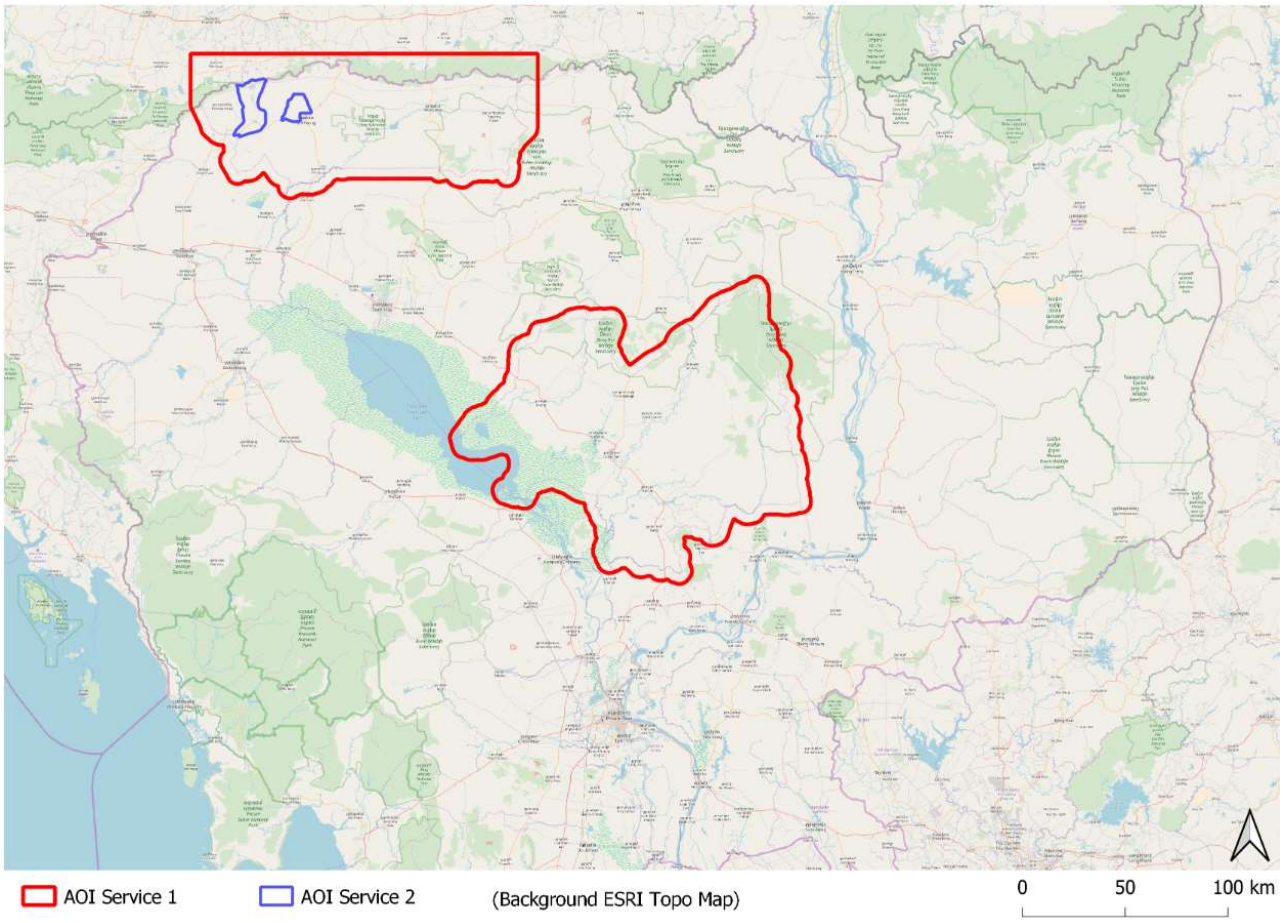


Figure 3: Service 1 and 2 - Areas of Interest

The following information services have been requested:

- **Service 1: Waterbody Inventory and Dynamics** – mapping of surface waterbodies (streams, rivers, lakes, reservoirs, creeks, irrigation canals) and wetlands as well as monitoring of the dynamics / temporal fluctuations in waterbody extent, taking into account the variability between wet and dry seasons.
- **Service 2: Detailed Waterbody Inventory** – mapping of small water features, such as narrow irrigation canals, in complement to the products of Service 1 based on very-high-resolution imagery (VHR) for two communes Kouk Mon and Bansay Reak within province Oddar Meanchey.

The initial set of information products and insights generated within this activity shall be used mainly by the GIS expert currently working with RED IV, the provincial and district administrations (Departments for Water Management, Departments of Agriculture). Moreover, outcomes shall serve to further encourage the adoption of EO within GIZ and other stakeholders.
The goal is to upscale the EO contributions and transfer the lessons learned to other GIZ programs in Cambodia working with agriculture in different provinces – depending on the interest of GIZ.

2 WORK LOGIC

The overall work logic and organisation between GeoVille (coordinator of EO-Clinic framework contract, interface towards ESA and GIZ, and service provider) and SIRS (service provider) is presented in the below. GeoVille has acted as focal point towards ESA as the contracting authority and GIZ Cambodia.

During the implementation phase the following stakeholder representatives were involved:

- Dr. Stefan Hanselmann, Program Director Regional Economic Development Program IV

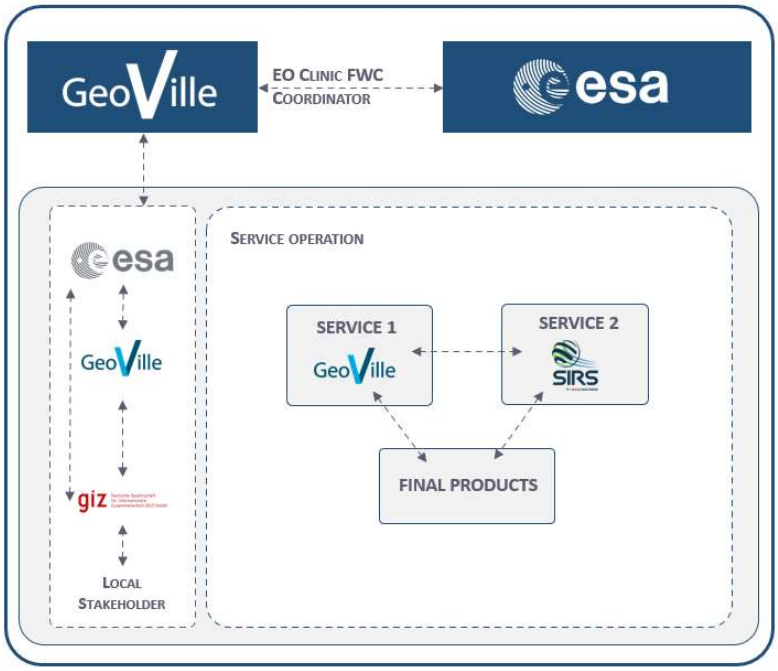


Figure 4: Overall Work Logic and interaction between organisations and services

Service 1 was implemented by GeoVille and Service 2 was generated by SIRS.

This work was initially planned over a tight period with a Work Completion Deadline (WCD) for both services of 5 weeks from the issuing of the Work Order (WO). Due to late kick-off meeting, vacation time and coordination of VHR data acquisition the Work Completion Deadline was extended in agreement with all stakeholders to September 21, 2020.

3 DELIVERED EO-BASED PRODUCTS AND SERVICES

3.1 Service 1 – Waterbody Inventory and Dynamics

3.1.1 Specifications

The technical specifications of the products adhere to the proposed properties in the technical proposal. This includes the following water products for each province (Oddar Meanchy and Kampong Thom): 39 Monthly Water Masks, 6 Water Frequency maps, 6 Minimum Water Extent maps and 6 Maximum Water Extent maps. In addition to the waterbody maps, 3 AnnualWetland Maps were delivered.

All products are based on Sentinel-1 and Sentinel-2 in 10m resolution.

Table 1: Service 1 product list

Product	Count	Pixel size	Reference period	File name example
Monthly Water Masks	39	10m	monthly	OM_waterMask_2019_05.tif KT_waterMask_2019_05.tif
Water Frequency	6	10m	seasonal	OM_waterFrequency_dryseason_18.tif * OM_waterFrequency_wetseason_18.tif
Minimum Water Extent	6	10m	seasonal	KT_minimumWater_dryseason_20.tif * KT_minimumWater_wetseason_20.tif
Maximum Water Extent	6	10m	seasonal	OM_maximumWater_dryseason_20.tif * OM_maximumWater_wetseason_20.tif
Annual Wetland Maps	3	10m	annual	KT_wetlandMap_2017

* seasons-definition:

- the Dry Season products cover the yearly period from October - April of the following year – product name refers to the end-year (2018) of the Dry Season.
- The Wet Season products cover the period from May – September within the same year

A detailed overview of the satellite-based input data, the data specifications and thematic information is provided in Table 2 below.

Table 2: Service 1 Product specifications – Waterbodies / Wetlands

General	
Resolution and Data Input	10m – Sentinel 1 and Sentinel 2
Geographic Projection	UTM Zone 48
Format	GeoTIFF
Datatype	Byte
Thematic information	
Classes and Codings	**Monthly Water Masks** - 001 Water - 000 No Water - 255 No Data

	Minimum Water Extent - 001 Minimum water extent - 000 No Water - 255 No Data **Maximum Water Extent** - 001 Maximum water extent - 000 No Water - 255 No Data **Water Frequency Maps** - 000% water to 100% water **Wetland Maps** - 000 Dry - 001 Permanent Water - 002 Temporary Water - 003 Permanent Wet - 004 Teporary Wet - 255 No Data
Accuracies	
Geometric positional accuracy:	Sub-pixel (<10m)
Overall thematic accuracy:	>90%
Minimum Mapping Unit (MMU)	
Minimum Mapping Unit (MMU)	2x2 pixels (400m²)
Minimum Mapping Width	1 pixel (10m)

Visual examples of the delivered products can be seen in Figures 5-8:

Figure 5: Monthly Water Mask

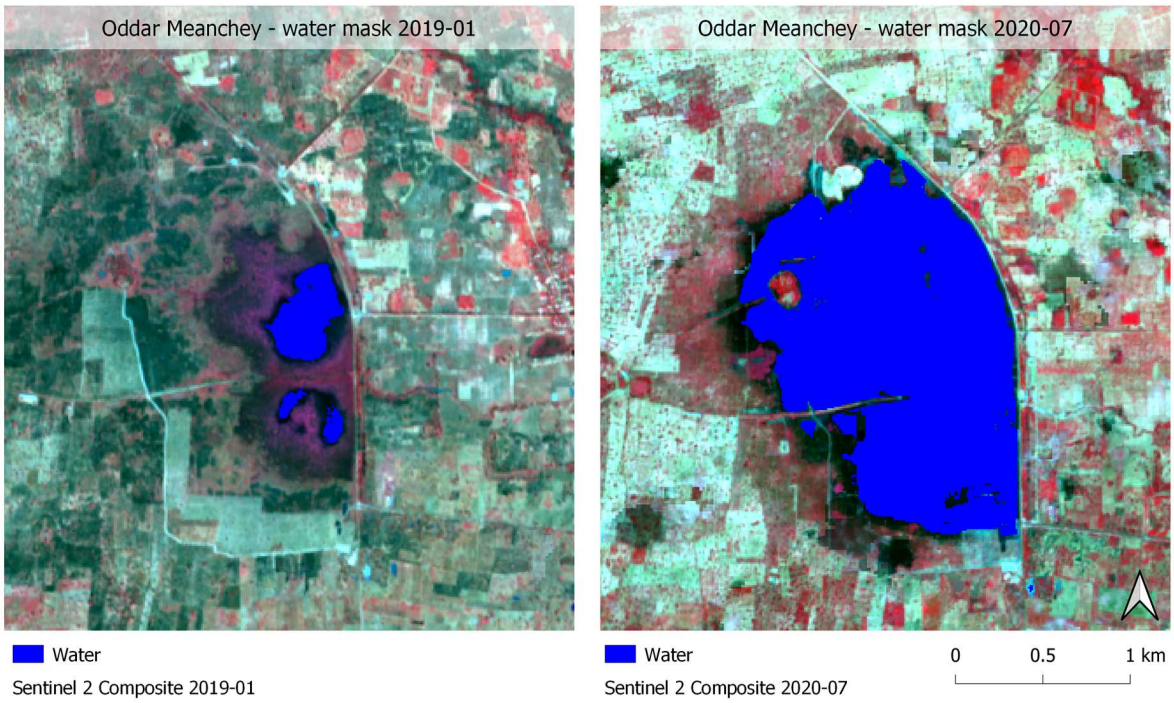


Figure 6: Water Frequency map

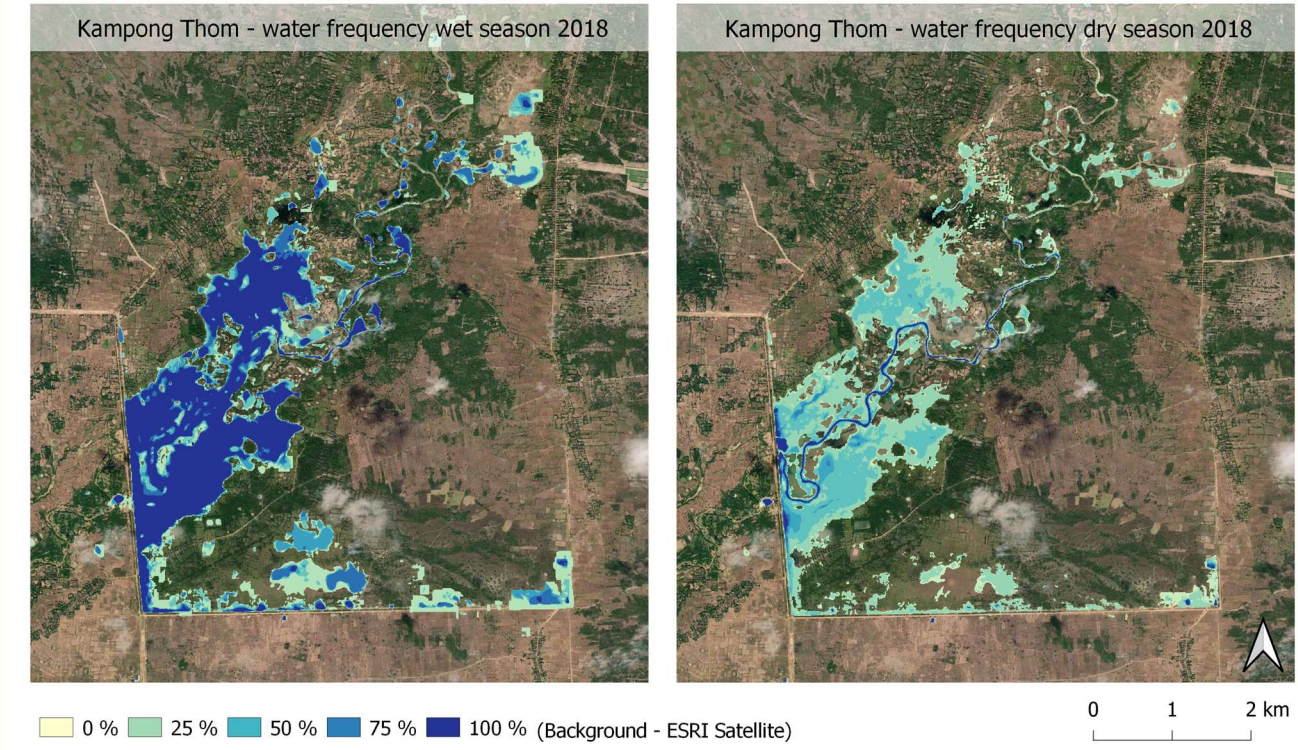


Figure 7: Minimum/Maximum Water Extent maps

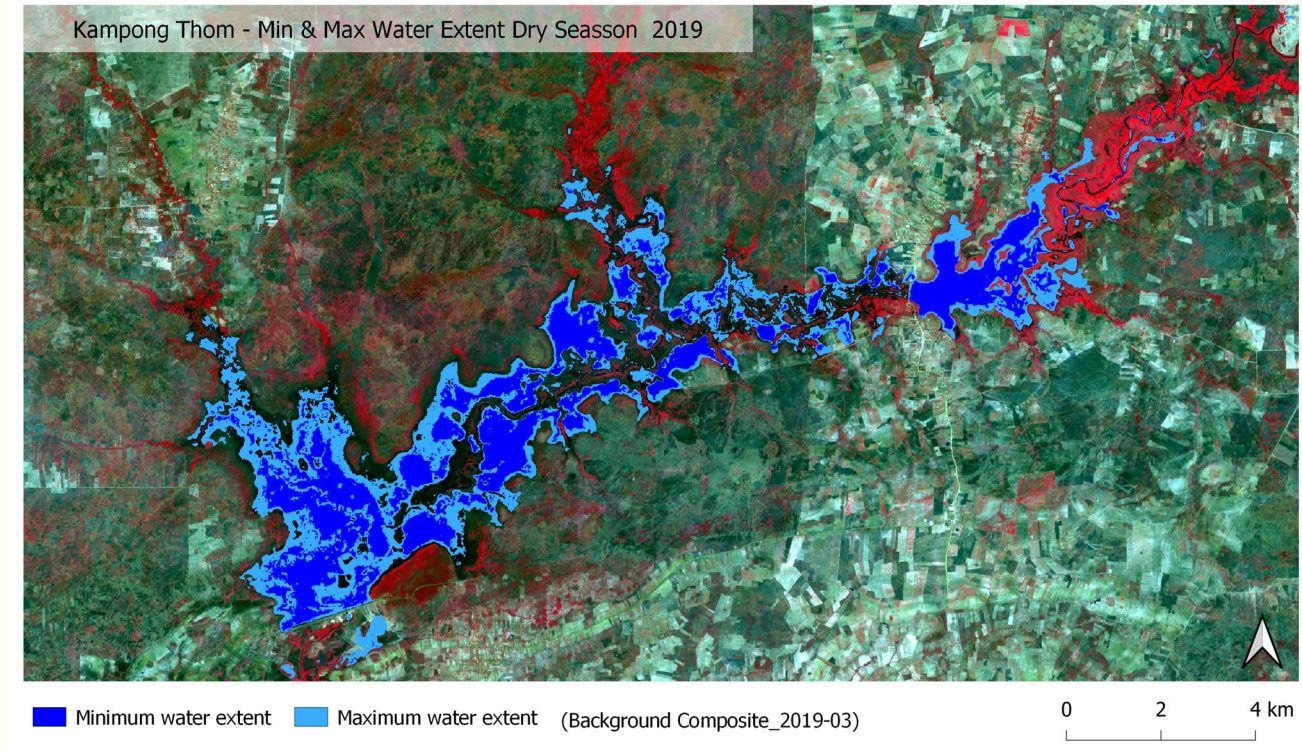
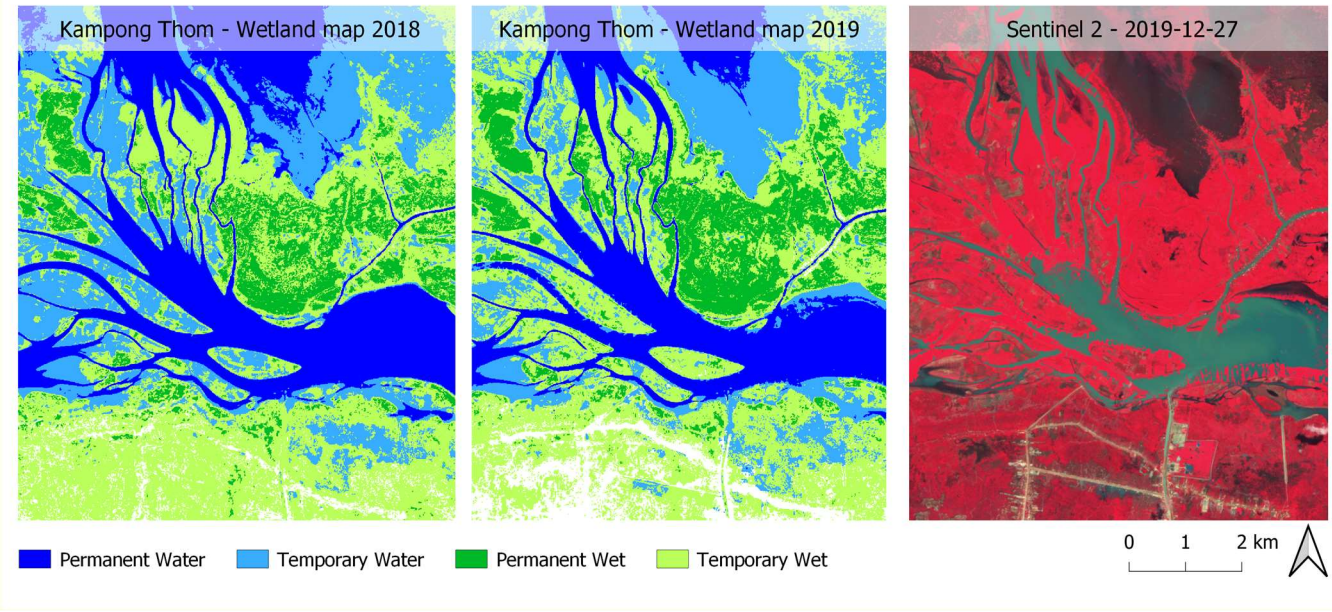


Figure 8: Annual Wetland map



Input Data

Generally, two input data types were distinguished for the water and wetland products. These consist of optical satellite imagery derived from the **Sentinel-2** Archive and **Sentinel-1** Radar imagery. In addition, **SRTM** DEM data were used to derive topographic indices.

Availability and limitations:

Sentinel-2B data is available from July 2017 onwards which can have an impact on the quality of the products from former dates. SCL masks supplied with Sentinel-2 L2A can have higher omission errors especially for cloud shadows and thin clouds.

Methods used

Pre-processing:

Sentinel-1 data were pre-processed using the ESA SNAP engine by applying:

- Orbit geometry corrections
- Border noise removal
- Radiometric calibration
- Speckle filtering
- Terrain correction.

ESA does not provide Sentinel-2 L2A imagery across Cambodia for the entire time series from 2017-2020. Data which has been ingested before that time is available as L1C only, thus, the correction of atmospheric influences (gaseous and molecular scattering and absorption, aerosol scattering and absorption) as well as cloud and cloud shadow masking had to be completed. The most recent Sen2Cor version (2.8) was used for atmospheric correction and cloud detection for data captured prior to May 2017 and December 2018, aiming at a maximum consistency among the entire Sentinel-2 time series.

Additionally, a multitemporal cloud shadow detection algorithm (Ludwig et al, 2019) was applied to reduce the Sen2Cor cloud shadow omission error rate.

For monthly compositing, the geometric median is used instead of a best-pixel approach (BPA). BPA composite methods only select the 'best' pixel of the whole time series, whereby valuable information can be lost (e.g. changes in water level or vegetation cover). Contrasting this, statistical based methods taking all valid observations into account are more representative than a single time step of the time series. Geometric median compositing is a suitable approach, as it is "using a high-dimensional summary statistic that applies to all bands at once to guarantee that the biophysical relationships among all spectral bands are maintained" (Roberts et al, 2017). In contrast to simple summary statistics such as the mean, the geometric median has a higher breakdown point (0.5) and is more robust against outliers, e.g. undetected cloud pixels. In addition to the more meaningful pixel values, the geometric median yields to smoother composites with less noise and artefacts.

Water Detection:

Based on the corrected and combined optical imagery, spectral indices and biophysical parameters such as Normalized Difference Water Index (NDWI) and Modified Normalized Difference Water Index (MNDWI) were derived from each monthly composite due to its sensitivity to surface water.

Sentinel-1 time series backscatter have been reduced to monthly metrics such as minimum backscatter to capture all monthly water occurrences.

Within the optical domain, water is detected based on the enhancement of the spectral signature using biophysical indices sensitive to water and including automated dynamic image thresholding methodologies (Martinis et al., 2009) as described in Ludwig et al. (2019).
The radar-based algorithm uses a pixel-based adaptive thresholding approach of the radar backscatter signals applying a dynamic variable backscatter threshold for each pixel based on statistical information from the adjacent pixels. The resulting water mask is then compared against the Height Above Nearest Drainage (HAND) index (Rennó et al., 2008) to exclude unrealistic water occurrences.
After processing the optical and radar imagery separately, the data were fused into monthly surface water extent masks – thus the advantages of both sensor systems could be used. To reduce commission errors, masking was applied using a potential water mask derived by percentile statistics on the aggregated water indices over the whole time series (2017-2020).

Wetness Detection:

Surface soil moisture sensitive biophysical spectral indices such as the Normalized Difference Moisture Index (NDMI) or the Angle Based Drought Index (ABDI) have been calculated, grouped and aggregated to monthly wetness probabilities sensitive to bare soil, sparse and dense vegetation moisture. As in the case of water detection, dynamically Otsu thresholding was applied to the probabilities to derive wetness masks for each month.

Classification:

Based on the cumulative water, wet and dry masks, and the total number of valid monthly observations, frequencies (in percent) are calculated for water and wet (soil, dense vegetation, sparse vegetation). These relative frequencies form the basis to swiftly generate the thematic classification of permanent and temporary water/wetness classes.

The products were derived from the intermediate cumulative water/wet/dry occurrence layers and their associated relative frequency layers (i.e. cumulative occurrence layers in relation to the total number of valid observations). The relative frequencies form the basis for the classifications according to the rules summarized in the tables below.

Wetland Map (annual):

Code	Class	Water relative frequency	Wet relative frequency
1	Permanent water • always water	> 80% Water	
2	Temporary water • alteration of dry and water • alteration of wet and water • with varying degrees of wetness • water instances dominate over wet	>25 - 80% Water	Water > Wet
3	Permanently wet areas • always wet		> 80% Wet
4	Temporary wet areas • alteration of dry and wet • with minor instances of water • wet instances dominate over water	< 80%	Wet > Water

Table 3: Classification criteria for the Wetland product

Minimum and maximum water extent (seasonal):

Code	Class	Water relative frequency
1	Minimum water extent • always water	> 80% Water
1	Maximum water extent • alteration of dry and water	> 10% Water

Table 4: Classification criteria for the Minimum and Maximum water extent products.

3.1.2 Quality Control and Validation

We applied a stratified random sampling approach to assess the accuracy of the water mask product. To extract the sample points in each stratum, the "LACOVAL – validation tool for land cover and land cover changes" has been used. This tool was developed within an ESA funded project in 2013 and is available open source. For the underlying validation the ArcGIS add-in of LACOVAL has been applied to the data. LACOVAL ensures that the sample selection and quality assessment follow a standardized protocol.

The first part of the validation consists of creating validation sample points, for which the samples were randomly selected (by the LACOVAL tool) in each stratum. After creating the stratified random samples, each point needed to be visually interpreted by an operator. This interpretation can be done in two ways, either *blind* (operator has no information about the classification and assigns a LC class to the reference point) or *plausible* (operator has to decide – yes or no – whether a reference point belongs to particular class without knowing the underlying classification). For the validation herein, we applied the *blind* approach.

The point by point interpretation is based on particular reference data sets and/or the inspection of the production data (if no appropriate reference data set is available). The choice of the reference data is depending on the resolution of the data being validated. According to the accuracy of the product either images with a low, medium, high or very high (VHR) resolution are used, also aerial photographs are possible. In addition, spectral indices can support the decision making in tricky situations, for which the land cover is not exactly identifiable from the HR/VHR imagery. After dealing with all sample points, LACOVAL is generating a validation report, yielding the producer's, user's and overall accuracy including the 95% confidence interval.

The number of validation points has been selected according to best practice guidelines (e.g., Congalton and Green, 2009; Olofsson et al., 2014). Validation was performed at the Oddar Meanchey site on the monthly water mask of January 2019.

Table 5: Summary of the accuracy assessment for Service 1

	Reference Data				
Classification	No water	Water	Row Total	User's Accuracy	95% Confidence Interval
No water	348	2	350	99,43%	0,40
Water	5	45	50	90,00%	4,67
Column Total	353	47	400		
Producer's Accuracy	98,58%	95,74%			
95% Confidence Interval	0,63	3,05			

Overall Accuracy	98,25%
Overall 95% Confidence Interval	0,65
Kappa	0,92

3.1.3 Outputs & Analyses

3.1.3.1 Outputs

The first category of outputs for Service 1 are the Monthly Water Masks for the provinces Oddar Meanchey and Kampong Thom each and for the time period May 2017 – July 2020. The second category of outputs is the Seasonal Product Suite including the following products: Water Frequency, Minimum Water Extent and Maximum Water Extent. The third category of outputs are the Annual Wetland Maps.

Delivery package (for each province):

- 39 Monthly Water Masks
- 6 Water Frequency maps
- 6 Minimum Water Extent maps
- 6 Maximum Water Extent maps
- 3 Annual Wetland Maps
- Metadata.xml files

3.1.3.2 Analyses

An initial analysis of the water time series (monthly masks) was performed to check the three-year series for significant trends in the lateral extent of water bodies in both provinces. Figure 9 shows the water extents of both regions. The curve for Kampong Thom (KT) clearly follows a seasonal pattern that appears less pronounced for Oddar Meanchey (OM). With an average of about 800 km2, water covered areas in KT are larger than those in OM by about an order of magnitude with around 90 km² for OM. This is mostly due to the

inclusion of larger swaths of permanent water bodies to the south-west as a result of a buffer that was applied to the area of interest, but also, to a lesser extent, due to the regular flooding of large parts of agriculturally used lands, presumably for the cultivation of rice, during the growing season. Each of the areas are illustrated separately in Figure 10 and Figure 11 and the area values by month are listed in APPENDIX B.

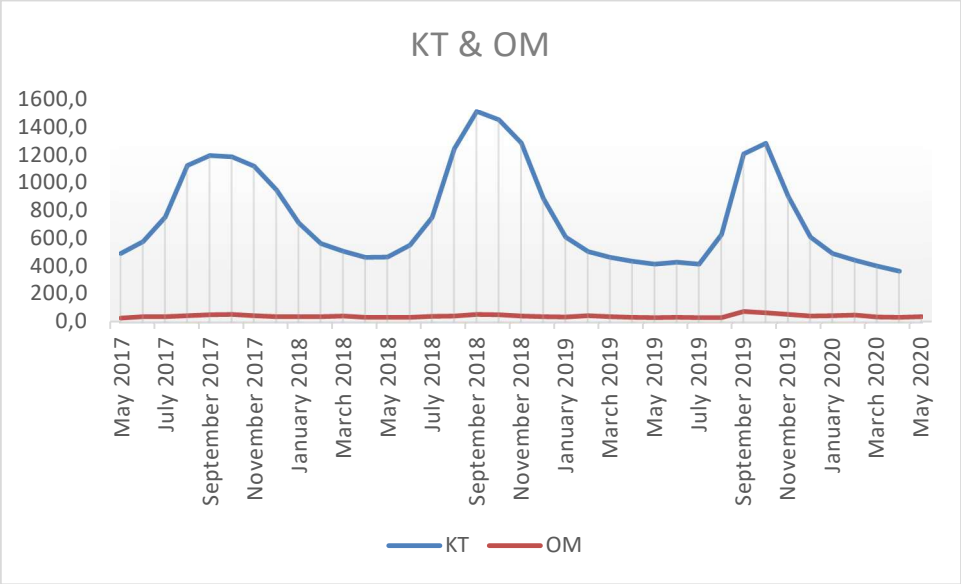


Figure 9: Water extents in km² for both provinces over the period of three years.

Fitting a linear trend through the 3-year series for province Oddar Meanchey reveals a significant negative trend, implying that water resources become scarcer at least during the observed period. The seasonal increase in surface water extents toward the end of the calendar years appear to become more pronounced with steeper increases and decreases before and after the maximum. A sample size of three years is low and extending the series back into the past as well as continuous monitoring in the future will help assess whether these findings are limited to the years 2017 to 2020 or part of a longer term trend.

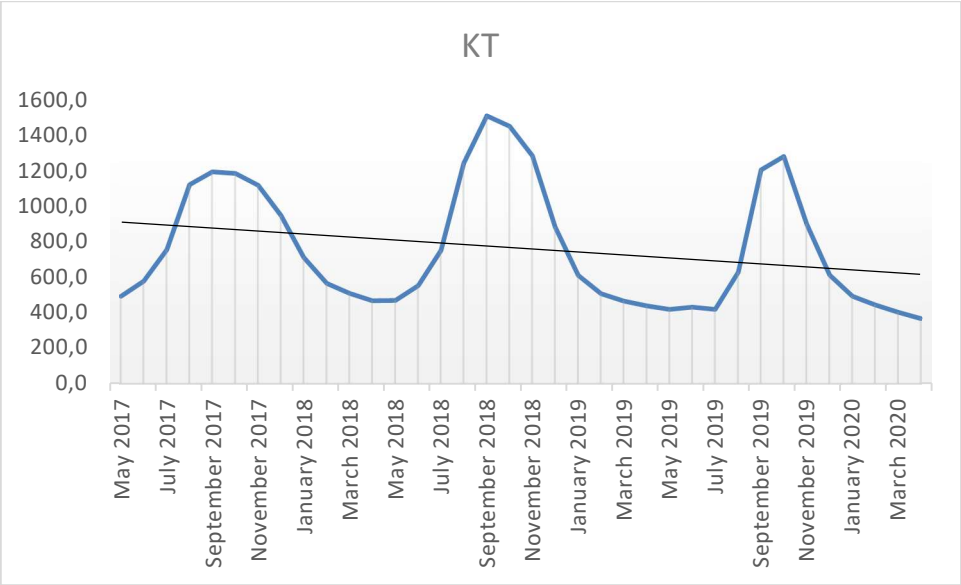


Figure 10: Water extents in km² for Kampong Thom over the period of three years with a linear trend.

The seasonal trends in the surface water extents in the Oddar Meanchey province are significantly less pronounced than for Kampong Thom. There is a slightly positive trend though that may not be statistically significant.

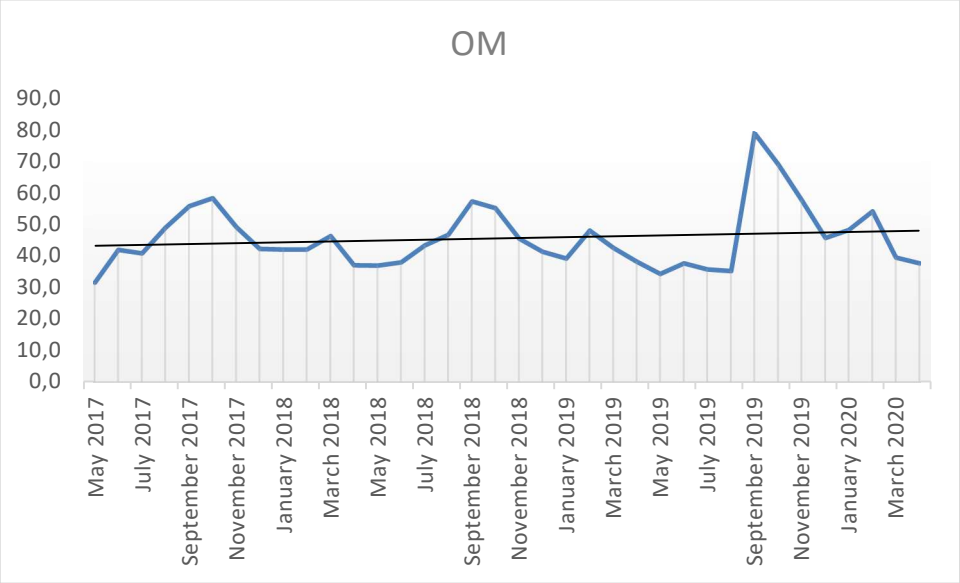


Figure 11: Water extents in km² for Oddar Meanchey over the period of three years with a linear trend.

3.1.4 Usage, Limitations and Constraints

All outputs of service 1 are based on Sentinel-1 and 2 imagery. For Sentinel-1 the revisit frequency is 12 days over Cambodia, means more speckle noise and in turn higher commission error rate in the monthly water masks especially at bare soils and very smooth surfaces.

As mentioned in 3.1.1, Sentinel-2 coverage is limited in 2017. During the wet seasons, high amounts of clouds can reduce the quality of the monthly composites. Sen2Cor misclassified clouds are also influencing the quality of the monthly image composites. Due to the shorter time frame of the wet season data gaps have a higher impact on the frequency-based classifications.

3.2 Service 2: Detailed Waterbody Inventory

3.2.1 Specifications

The technical specifications of the product comply with the properties issued in the technical proposal. The Small Water Features product is based on Very High-Resolution data, Pléiades 1-A and Worldview2. Each Province (Kouk mon and Bansay Reak) were delivered.

Table 6: Service 2 Product List

Product	Count	Pixel size	Reference Period	File name
Small water features mask	2	0.5m	2018-12-31 to 2019-01-26	KM_smallWaterFeaturesMask_2019.tif BR_smallWaterFeaturesMask_2019.tif

Table 7: Service 2 Product Specification

General	
Resolution and Data input	0.5m (Pléiades-1A, Worldview-2)
Geographic Projection	WGS84 / UTM zone 48N (EPSG : 32648)
Format	GeoTIFF
Datatype	Byte
Thematic information	
Classes and Codings	0 : no Small Water Features / 1 : Small Water Features / 255 : NoData
Accuracies	
Geometric positional accuracy	<1 meter
Overall thematic accuracy	85%
Geometric specifications	
Minimum Mapping Unit (MMU)	100m²
Minimum Mapping Width	1 meter

Input Data

List of input EO data used is described in Table 8.

Table 8: Description of the input data

Dataset	Spatial resolution	Spectral channels	Acquisition date	Spatial coverage
AOI 01 – Kouk Mon (270 km²)				
Pléiades 1-A	0.5m	4	2018-12-31	95%
Worldview-2	0.5m	3	2019-01-26	5%
Global Surface Water	30m	-	-	100%

AOI 02 – Bansay Reak (117 km²)				
Pléiades 1-A	0.5m	4	2019-01-19	75%
Pléiades 1-A	0.5m	4	2019-01-19	25%
Global Surface Water	30m	-	-	100%

Method

The methodology to extract small water features is based on Geographic Object-Based Image Analysis (GEOBIA).

The first task consists of collection and preparation of VHR data. Four scenes, Pléiades-1A and Worldview-2 were selected to cover the two area of interests. To reach the minimum horizontal resolution specification a pan-sharpening was carried out.

Secondly, a random sampling of ground truth based on Global Surface Water product and Open Street Map was carried out. However, representativeness of small water features and up-to-date sample of groundtruth was required to reach the product specification. Therefore, a manual fitting was performed to ensure a reliable sampling of ground truth. After a first classification iteration, a manual addition of counterexample was performed to improve the classification output.

The next step used a Machine Learning method to classify water elements based on the pansharpened multispectral scenes. This method extract texture features (Sobel, Pantex) and indices (NDVI) from EO data to allow water elements detection using a Random Forest classifier.

As expected with automatic detection of water using only VHR imagery, results showed some classification artefacts (see section 3.2.4). Therefore, a manual enhancement was carried out by focusing on specific omission or commissions artefacts like flooded fields, roads or built-up.

3.2.2 Quality Control and Validation

Classification correctness should be evaluated using misclassification rate and/or misclassification matrix. Thematic accuracy cannot be subjected to an exhaustive check. A thorough thematic assessment would imply a very time-consuming work. Misclassification rate is estimated by sampling and product information is compared to reference data.

The aim of the first paragraph is to provide a description of suggested procedures for a scientifically and statistically sound sampling scheme for assessing the thematic quality of the Water Presence products obtained for each area of interest.

Thus, thematic accuracy assessment has three components: (i) the sampling design, (ii) the response design and (iii) the estimation and analysis procedures.

The **stratification** and the sampling design primarily consist in selecting an appropriate sampling frame and sampling units. These sampling units can either be "defined on a cartographic representation of the surveyed territory" (Gallego, Area Frames for Land Cover Estimation: Improving the European LUCAS Survey, 2004[1]), in which case it is an area frame, or on a list of the features. According to this study, area frames give a better representation of the population as the spatial dimension is kept. In an area frame, sample units can be points, lines (often referred to as transects) or areas – often referred to as segments, described in (Gallego, Sampling

[1] Gallego, J., 2004. Area Frames for Land Cover Estimation: Improving the European LUCAS Survey., in: Proceedings of the 3rd World Conference on Agricultural and Environmental Statistical Application, Cancun, Mexico. pp. 2–4.

Frames of Square Segments, 1995[1]). For most cases, point samples will be used, but areas or segments may be used in specific cases such as when not only thematic accuracy needs to be reported, but also the geometry of mapped objects. Polygons have also the drawback of being specific to a single map. **Points are considered as the most appropriate unit for our products.**

Sampling design refers to the protocol whereby the samples are selected. A probability sampling design is preferred for its objectivity. "Simple random, stratified random, clustered random and systematics designs are all examples of probability sampling designs" (Stehman & Czaplewski, 1998[2]). Even though a simple random design is easy to implement, its main drawback lies in the fact that some portions of the population may not be adequately sampled. Cluster sampling is often used to reduce the costs of the collection of reference data but does not resolve geographic distribution problems. A systematic approach would solve this problem, yet it is not appropriate if the map contains cyclic patterns. A stratified approach consists in allocating a pre-defined number of samples per land-cover class. As explained in Stehman's paper, stratification ensures that each class is correctly represented.

The validation approach chosen combines **random and stratified approaches** and benefits from the advantages of both.

The stratification is applied based on a series of omission and commission strata:

- Commission: Small Water Features
- Omission: no Small Water Features

The **response design** "is the protocol for determining the reference land cover classification of a sampling unit" (Stehman & Czaplewski, 1998).

The datasets against which the interpretation is performed are divided in two main groups, guiding data and reference data. The guiding data used in the production of the classifications are VHR Pléiades 1A and Worldview-2 data. The guiding data are mandatory due the high seasonality of the areas of interest. The reference data provide more spatial details and stronger landscape context to the assessment. The available reference data are:

- Bing maps image / cartography layer
- Google Earth image / cartography data

The Table 9 gives a summary of the validation exercise and the accuracy assessment of the Water Presence products on each area of interest (Kouk Mon and Bansay Reak). It shows the Producer Accuracy and the User Accuracy related to the Omission and Commission Errors.

Table 9: Summary of the accuracy assessment for service 2

AOI	Producer Accuracy	User Accuracy
Kouk Mon	100.00%	95.92%
Bansay Reak	97.30%	100.00%

The accuracy assessment shows very satisfying results with very few omission and commission errors.

[1] Gallego, J., 1995. Sampling Frames of Square Segments (No. EUR 16317), Official Publication of the European Communities.
[2] Stehman, S. V., & Czaplewski, R. L. (1998). Design and analysis for thematic map accuracy assessment: fundamental principles. *Remote sensing of environment*, *64*(3), 331-344.

3.2.3 Outputs

The outputs for Service 2 consist of Water Presence Products for each area of interest (Kouk Mon and Bansay Reak).

Delivery package:

- 2 water presence raster layers (one for each area of interest)
- INSPIRE compliant metadata .xml file

The Water Presence layers generated for both area of interest are presented in Figure 12 and Figure 13.

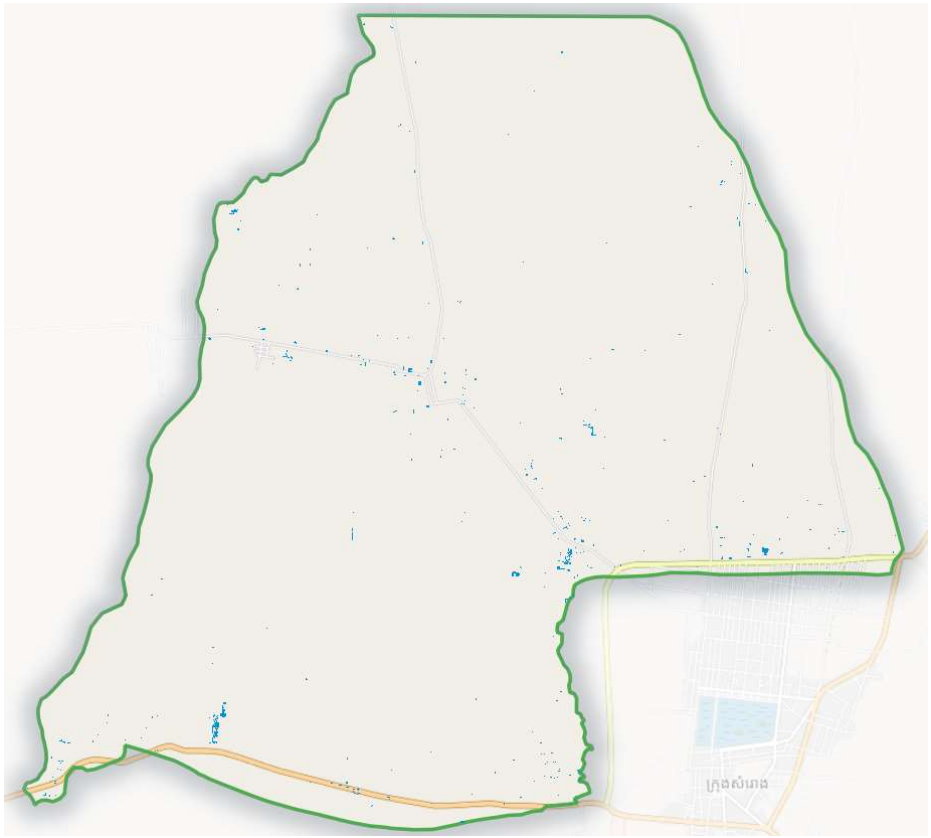


Figure 12: Very High-Resolution Water Mask over Bansay Reak area (blue) background : OSM

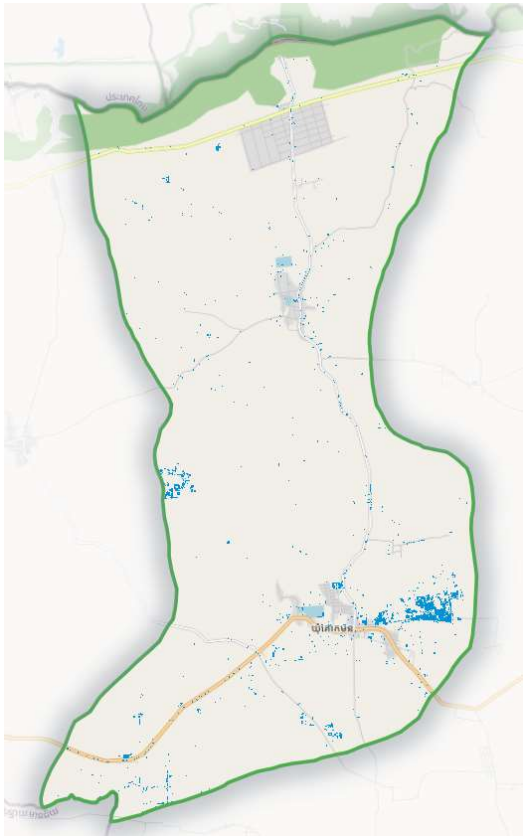


Figure 13: Very High-Resolution Water Mask over Kouk Mon area (blue) background : OSM

Cost Benefit Analysis:

Based on the two AoIs of Service 2, representing a total of 388km², we will try in this Cost Benefit Analysis to extrapolate the cost for a production at Service 1 area level and National level. First of all, the VHR EO data availability is the key to a large-scale production. In Service 2 AoIs demonstration case, we found multiple coverage of VHR imagery during the year, but unfortunately, only for dry season. The cloud coverage during the rainy season is too important to have a "usable" EO data to detect water features. Based on VHR imagery as soon as possible after the wet season (in our case December and January), we produce semi-automatically a water feature map. All the pre-processing (EO data preparation), classification (object-based approach) and postprocessing (filtering, formatting) are automatic steps. The ground truth collection, based on photointerpretation and usage of ancillary data, and manual enhancement are a manual part. In case of large-scale production, the ground truth data collection could be drastically reduced by mutualising the training for homogeneous area (same date of VHR coverage and same type of water features). The manual enhancement step is the only step that is linearly increasing with the size of the area to be produced. However, based on our experience on the service 2 area, we can conclude that even without manual enhancement, the results are pretty good. Omissions and commissions are due to lack of SWIR bands in VHR imagery, information useful to compute NDWI and to help water detection.

Based on Service 2 experience and the original financial proposition for EOC0010, we provide an estimation of the production of "Water Mask" based on VHR imagery for Service 1 area and at National scale (see Table 10).

Table 10: Cost Benefit Analysis: cost estimation for Service 1 area and National area.

Activities		Service 2 (388km²)		Service 1 (18.995km²)		National (181.035km²)	
		Quantity	Cost	Quantity	Cost	Quantity	Cost
EO data	VHR cost (unit km²)	400	3 200 €	19000	152 000 €	181000	1 448 000 €
Coordination		10	1 300 €	245	31 850 €	467	60 710 €
Development	Method	40	4 000 €	20	2 000 €	30	3 000 €
	Prototype	70	7 000 €	10	1 000 €	10	1 000 €
	Validation	35	1 750 €	10	500 €	10	500 €
Production	GT preparation	5	250 €	122,5	6 125 €	233,5	11 675 €
	EO data preprocessing	1	50 €	24,5	1 225 €	46,7	2 335 €
	Classification / postprocessing	2	100 €	49	2 450 €	93,4	4 670 €
	Manual enhancement	20	1 000 €	980	49 000 €	9340	467 000 €
	Validation	2	200 €	98	9 800 €	467	46 700 €
Total		185	18 850 €	1314	255 950 €	10230,6	2 045 590 €

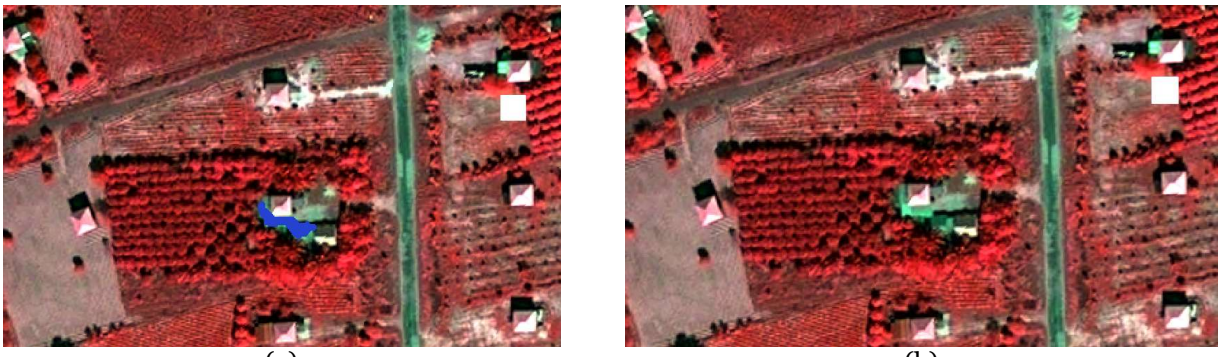
3.2.4 Usage, Limitations and Constraints

The provided water features maps for the AoIs should allow users to have an exhaustive inventory of small water features (bigger than 100m²).

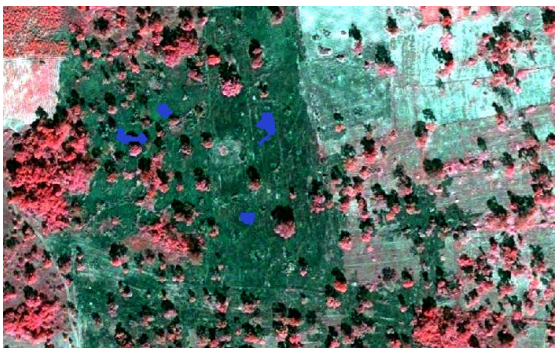
Due to the fact that this 2 AoIs are in a region mainly covered by clouds in wet season, it was decided with GIZ to produce the water feature maps using the closest data after the wet season, in our case, in December 2018 and January 2019. The water feature maps delivered is thus not representative to all the water features that could appear during the wet season, only a basis on water presence.

Due to the lack of some spectral information in VHR EO data (compared to Sentinel-2 for example), water detection is less perfect, and some confusion could occur, for example with building, inundated fields and roads (see **Error! Reference source not found.**). However, the final accuracy for both AoIs are significantly above the thematic accuracies requested.

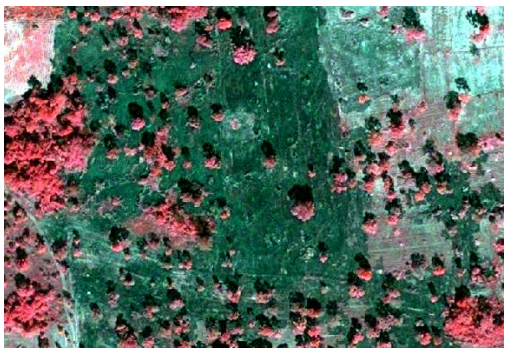
Figure 14: Illustration of omissions and commissions before manual enhancement step



(a) (b)



(c)



(d)

water mask in blue over VHR imagery (a) and (c) and respectively only the VHR image in (b) and (d).

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APPENDIX B: ANALYSES - WATER AREA VALUES BY MONTH

Water extents in km² by months for both provinces for the entire 3-year-series.

Kampong Thom		
Date	*Pixels*	*Area (km2)*
May 2017	4935714	**493.6**
June 2017	5794544	**579.5**
July 2017	7558079	**755.8**
August 2017	11239691	**1124.0**
September 2017	11952568	**1195.3**
October 2017	11871853	**1187.2**
November 2017	11192768	**1119.3**
December 2017	9490275	**949.0**
January 2018	7132465	**713.2**
February 2018	5664745	**566.5**
March 2018	5101400	**510.1**
April 2018	4673195	**467.3**
May 2018	4696757	**469.7**
June 2018	5536156	**553.6**
July 2018	7528438	**752.8**
August 2018	12442056	**1244.2**
September 2018	15116963	**1511.7**
October 2018	14521850	**1452.2**
November 2018	12862870	**1286.3**
December 2018	8851680	**885.2**
January 2019	6120121	**612.0**
February 2019	5072746	**507.3**
March 2019	4663472	**466.3**
April 2019	4389472	**438.9**
May 2019	4188638	**418.9**
June 2019	4318005	**431.8**
July 2019	4187694	**418.8**
August 2019	6295395	**629.5**
September 2019	12072662	**1207.3**
October 2019	12830763	**1283.1**
November 2019	9018986	**901.9**
December 2019	6120993	**612.1**
January 2020	4931097	**493.1**
February 2020	4455094	**445.5**
March 2020	4038272	**403.8**
April 2020	3673014	**367.3**
May 2020	3477198	**347.7**
June 2020	3627490	**362.7**
July 2020	3625140	**362.5**

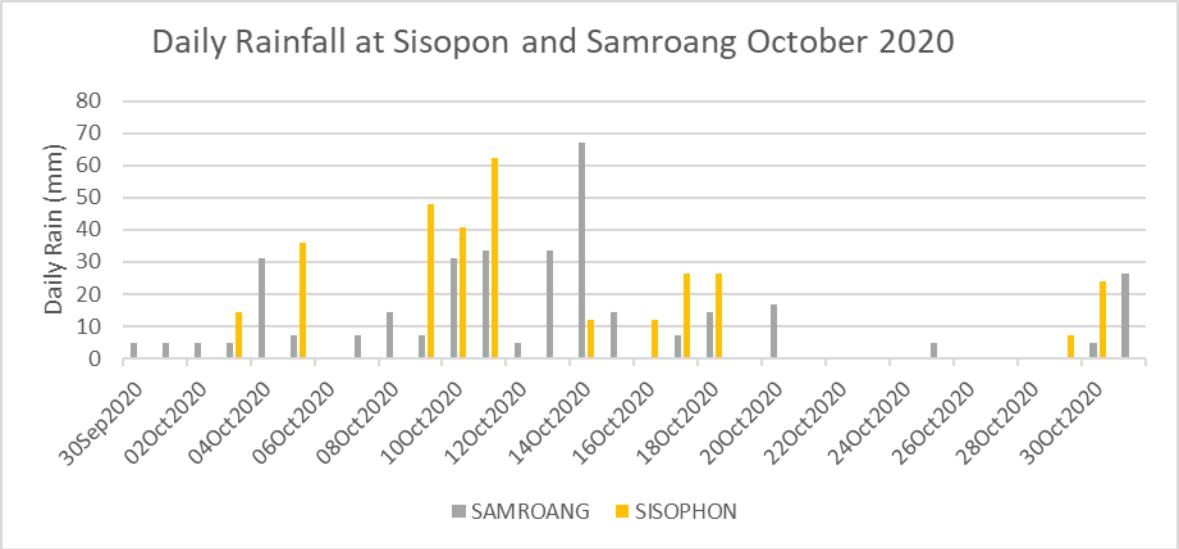
Oddar Meanchey		
Date	*Pixels*	*Area (km2)*
May 2017	315514	**31.6**
June 2017	418978	**41.9**
July 2017	408091	**40.8**
August 2017	489490	**48.9**
September 2017	557403	**55.7**
October 2017	583200	**58.3**
November 2017	491846	**49.2**
December 2017	422674	**42.3**
January 2018	419874	**42.0**
February 2018	420339	**42.0**
March 2018	462541	**46.3**
April 2018	370051	**37.0**
May 2018	369688	**37.0**
June 2018	379803	**38.0**
July 2018	433850	**43.4**
August 2018	466749	**46.7**
September 2018	573149	**57.3**
October 2018	551627	**55.2**
November 2018	454511	**45.5**
December 2018	412883	**41.3**
January 2019	391726	**39.2**
February 2019	480818	**48.1**
March 2019	425670	**42.6**
April 2019	381115	**38.1**
May 2019	343108	**34.3**
June 2019	376143	**37.6**
July 2019	357124	**35.7**
August 2019	351586	**35.2**
September 2019	789358	**78.9**
October 2019	689822	**69.0**
November 2019	577547	**57.8**
December 2019	456664	**45.7**
January 2020	482873	**48.3**
February 2020	541753	**54.2**
March 2020	394958	**39.5**
April 2020	376106	**37.6**
May 2020	415895	**41.6**
June 2020	438856	**43.9**
July 2020	467362	**46.7**

Annex E. Floods of October 2020

Annex E Flooding in Banteay and Oddar Meanchey October 2020

1.1 Flooded Areas

Flooding in Banteay and Oddar Meanchey October 2020 following sustained but not exceptionally high rainfall recorded.at various raingauges such as Sisopohon shown below.



Flooding also occurred in Aranyprathet and various other locations in Thailand. In the study provinces the flooding was significant in Banteay Meanchey at Sisopon, Poipet and Thma Puok, all areas identified previously. In Oddar Meanchey there was less flooding and only limited damages.

The satellite images available (Sentinel) were analysed by the project and statistics calculated of areas affected for Banteay Meanchey. This can be compared with the statistics published by Humanitarian Response Forum at the time[1]. There are differences between the two sources but not more than different processing and different images would indicate.

As shown in the subsequent figures, satellite imagery of 14,16,20, 22 and 26th of October was analysed and flood inundation areas calculated. Banteay Meanchey has significantly higher flood areas than Oddar Meanchey and much larger areas of crop and number of people affected. It is notable that the imagery available from Sentinel satellites add greatly to the temporal variation in flooding that can be detected than was possible 5 years previously.

[1] Cambodia Humanitarian response forum https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/hrf_sitrep_no6_26-oct-20.pdf

	Banteay Meanchay October 2020 Flood Inundation				
	14th	16th	20th	22nd	26th
Inundation (km^2)	711	1,023	950	1,643	1,311
Inundation (%)	11	16	15	26	21

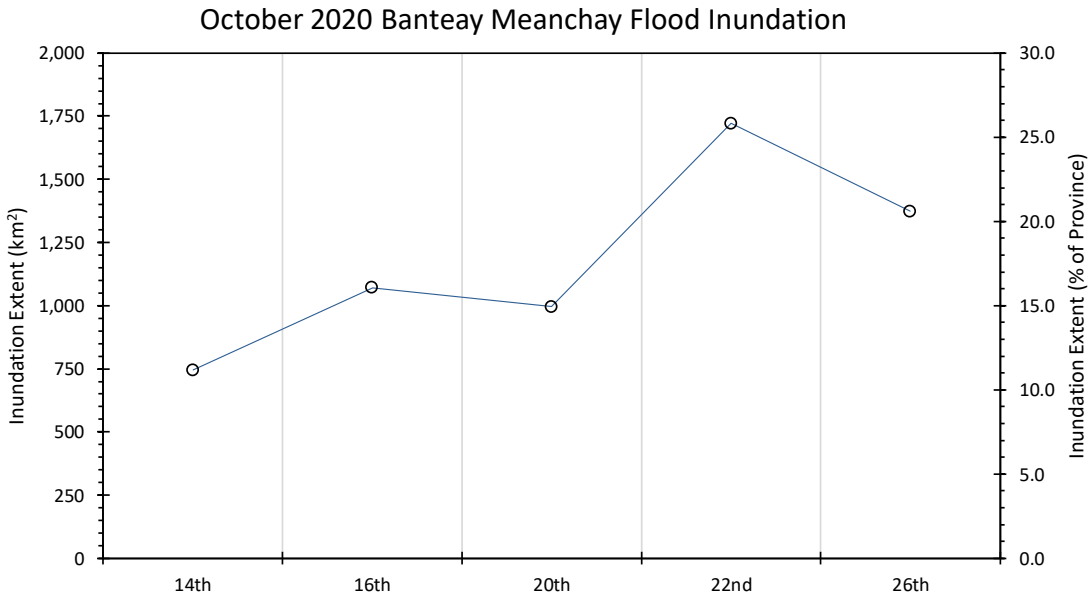


Figure 1 Flood Areas in Banteay Meanchey 14-26 October 2020 from analysis of Sentinel 1 satellite imagery

Table 1 Areas of Inundation (km2) in each province by land cover class for different dates of Sentinel Sattelite imagery

Land Type	Inundation Banteay (km^2)					Inundation Oddar (km^2)		
	14th	16th	20th	22nd	26th	16/17	22/23	26/17
Field Crop	1.9	3.7	2.5	12.2	6.6	2.256	2.115	1.735
Paddy Field	646.8	940.1	881.5	1521.3	1210.1	7.623	8.316	3.794
Urban Area	5.7	10.2	6.6	19.8	12.1	0.410	0.411	0.454
Water Body	21.8	27.2	20.8	30.8	27.2	1.295	1.332	1.354
Total	679.7	985.4	915.2	1590.0	1261.5	17.2202	18.5891	13.8134

According to HRF6 Banteay Meanchey was one of the most affected provinces and suffered 23 deaths and 75,000ha of crop affected as recorded up to 26 October. It is likely that with the difficulty of access this will be an underestimate but is reasonably consistent with the areas affected calculated in Table 1.

FLOOD IMPACT BREAKDOWN BY PROVINCE*

Province	Households affected	Households displaced	Deaths	Houses affected	Health centres affected	Schools affected	Length of road affected (meter)	Agricultural land affected (hectare)	Report date by PCDM
Battambang	66,088	4,592	-	66,067	-	316	1,188,703	164,116	21-Oct
Banteay Meanchey	41,927	5,437	23	41,927	8	191	74,996	75,620	26-Oct
Pursat	29,172	1,911	6	24,772	3	26	336,588	47,190	26-Oct
Kampong Thom	11,709	-	6	11,709	1	92	87,989	11,481	22-Oct
Phnom Penh	5,587	1,593	-	4,965	-	-	10,000	1,350	21-Oct
Kandal	6,538	129	-	2,558	5	22	142,761	10,604	26-Oct
Svay Rieng	3,480	36	-	1,196	1	1	16,760	2,504	26-Oct
Kampong Speu	2,421	212	-	1,697	-	1	16,229	3,196	26-Oct
Pailin	1,310	253	1	1,227	-	2	55,670	4,784	21-Oct
Stung Treng	1,226	57	1	861	1	3	71,950	1,209	26-Oct
Takeo	1,948	-	-	1,948	-	3	102,221	1,868	21-Oct
Siem Reap	3,680	29	1	2,280	2	15	36,436	1,302	21-Oct
Preah Vihear	365	46	-	345	-	-	3,480	2,986	26-Oct
Oddar Meanchey	421	4			1	14	4,650	1,544	21-Oct
TOTAL	175,872	14,299	38	161,552	22	686	2,148,433	329,754	

*Data presented above is the latest available from Provincial Committees for Disaster Management. Due to the time lag in reporting and rapidly evolving situation the flood impact data is subject to change each day.

1.2 Satellite Imagery

Visible range satellite sensed imagery suffers from having areas obscured by clouds so radar based imagery such as Radarsat and Sentinel 1 is more suitable for analysis although until recently it was of low resolution spatially and temporally.

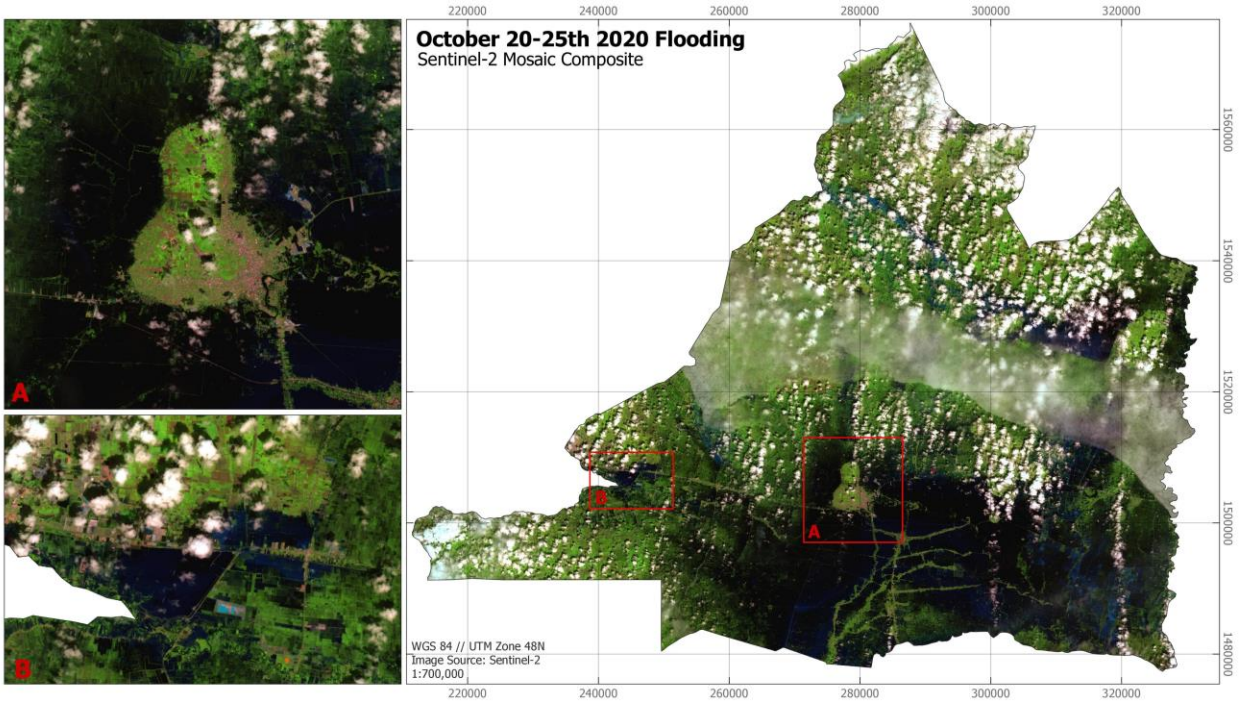
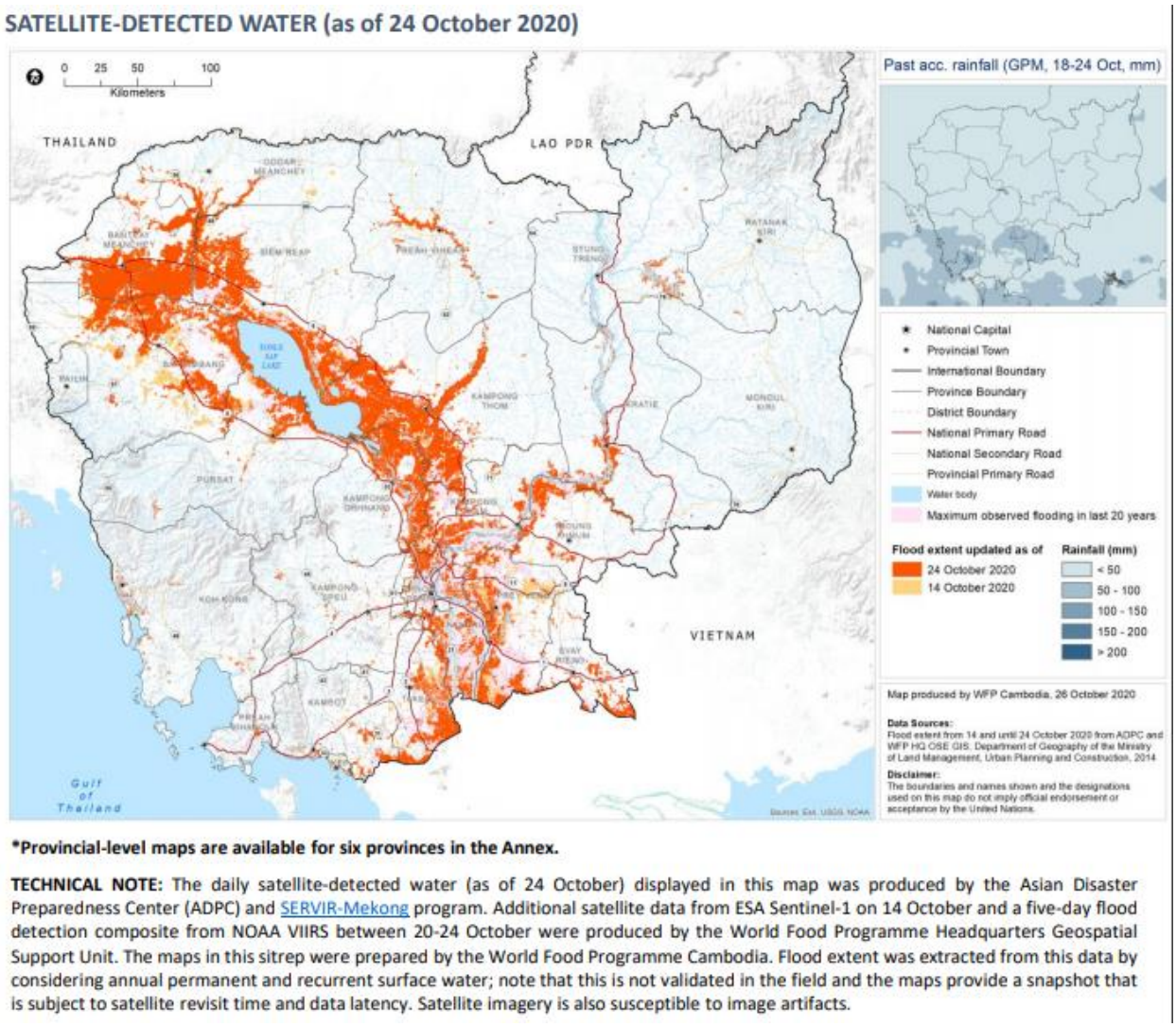


Figure 2 Visible range satellite imagery (Sentinel 2)



***Provincial-level maps are available for six provinces in the Annex.**

TECHNICAL NOTE: The daily satellite-detected water (as of 24 October) displayed in this map was produced by the Asian Disaster Preparedness Center (ADPC) and SERVIR-Mekong program. Additional satellite data from ESA Sentinel-1 on 14 October and a five-day flood detection composite from NOAA VIIRS between 20-24 October were produced by the World Food Programme Headquarters Geospatial Support Unit. The maps in this sitrep were prepared by the World Food Programme Cambodia. Flood extent was extracted from this data by considering annual permanent and recurrent surface water; note that this is not validated in the field and the maps provide a snapshot that is subject to satellite revisit time and data latency. Satellite imagery is also susceptible to image artifacts.

Figure 3 Satellite Image published by Cambodia Humanitarian Response Form, Notes on data sources as shown

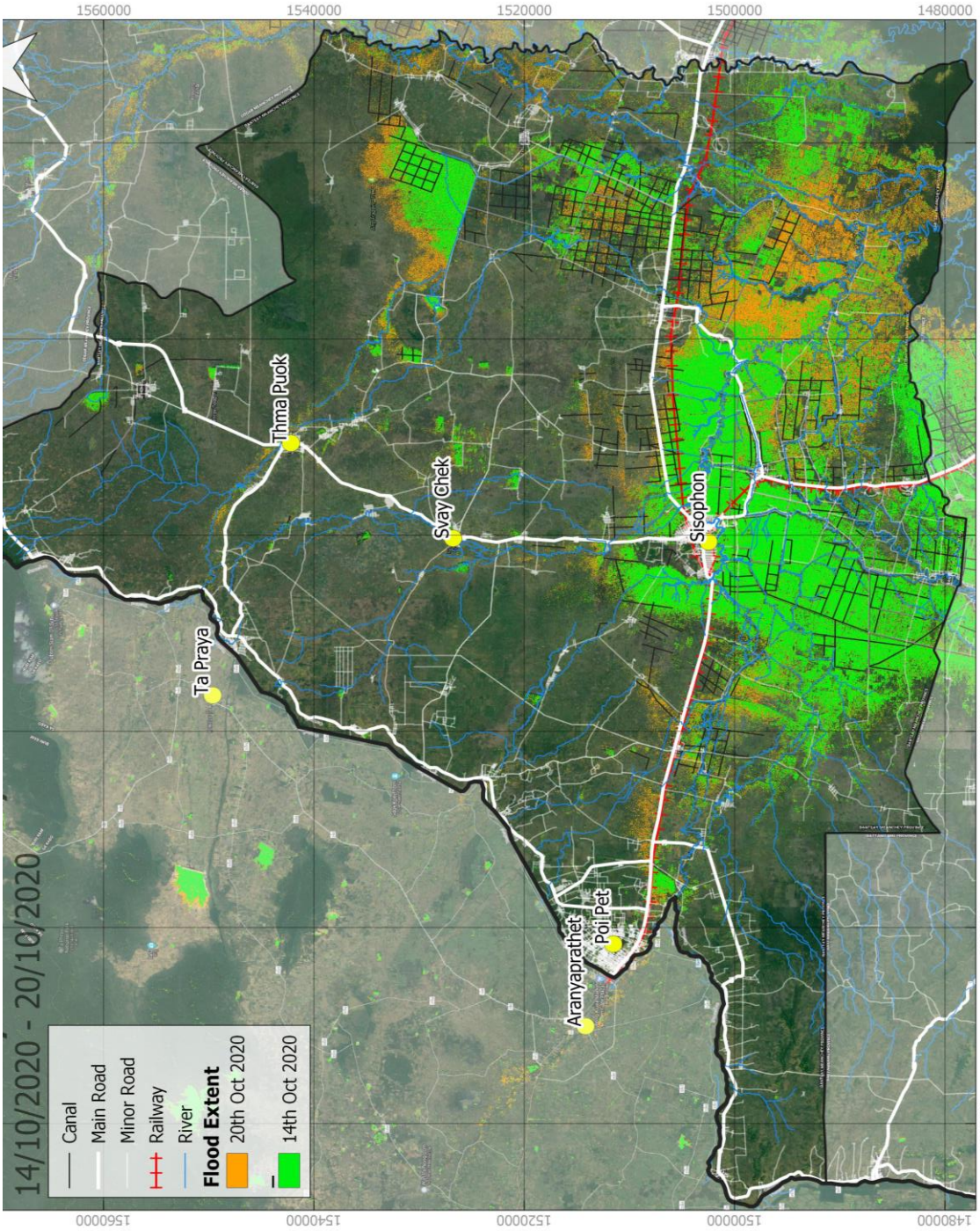


Figure 4 Bantey Meanchey Satellite detected flood extent 20 and 26 October

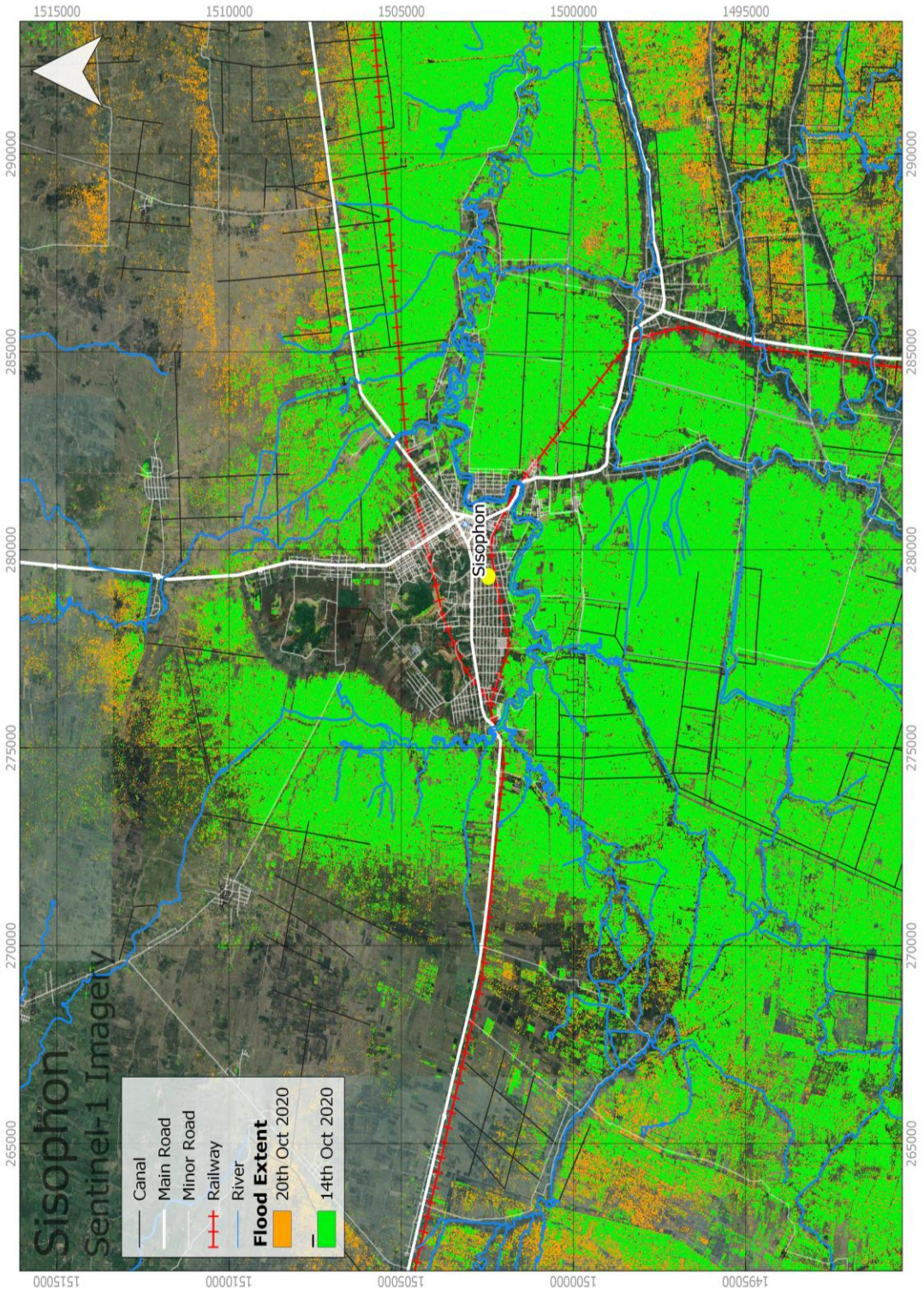


Figure 5 Flooded Area Sre Sisopon 14-20 October Sentinel 1 Imagery

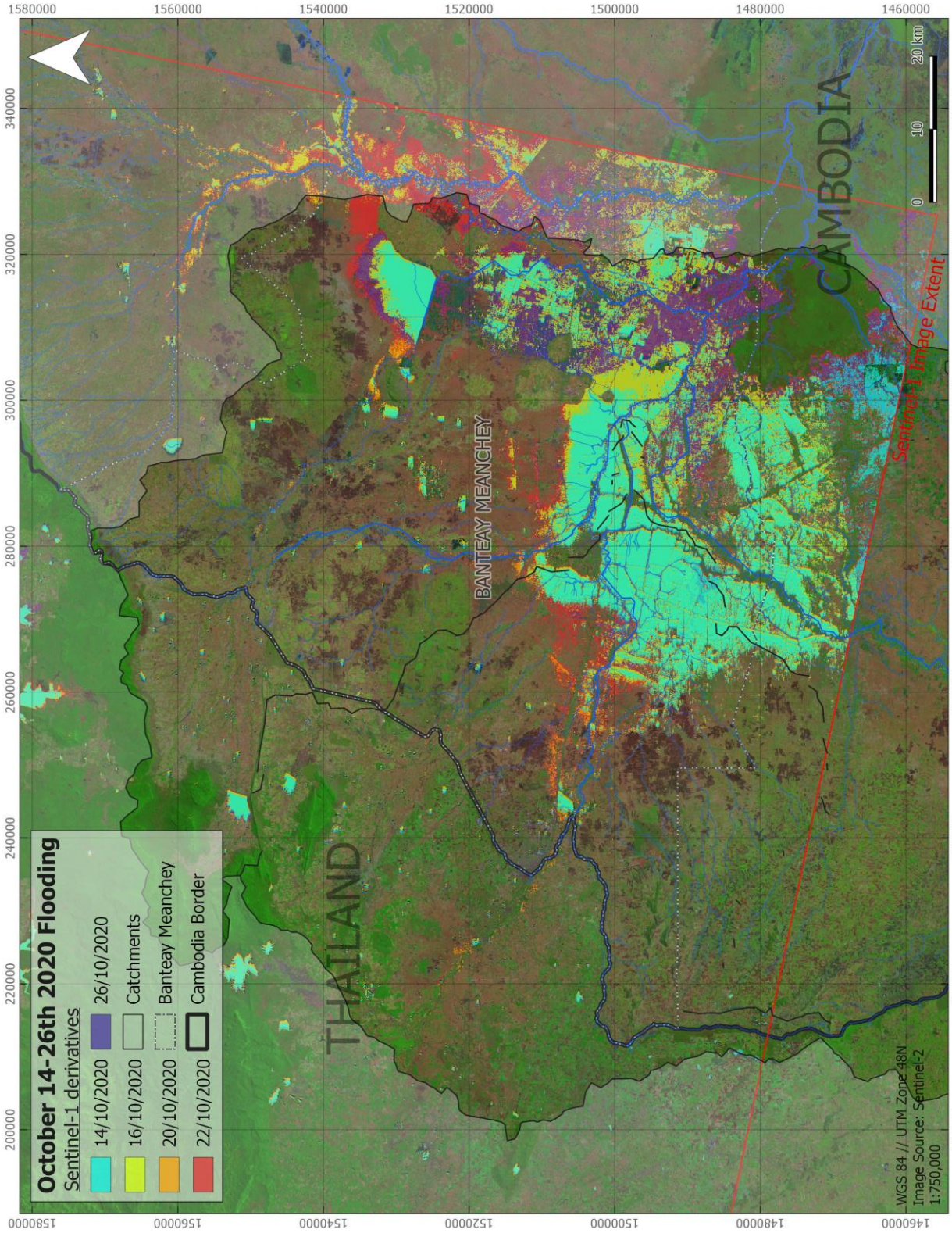


Figure 6 Flooded area Bantey Meanchey, Oddar Meanchey and Thailand 14-26 October 2020

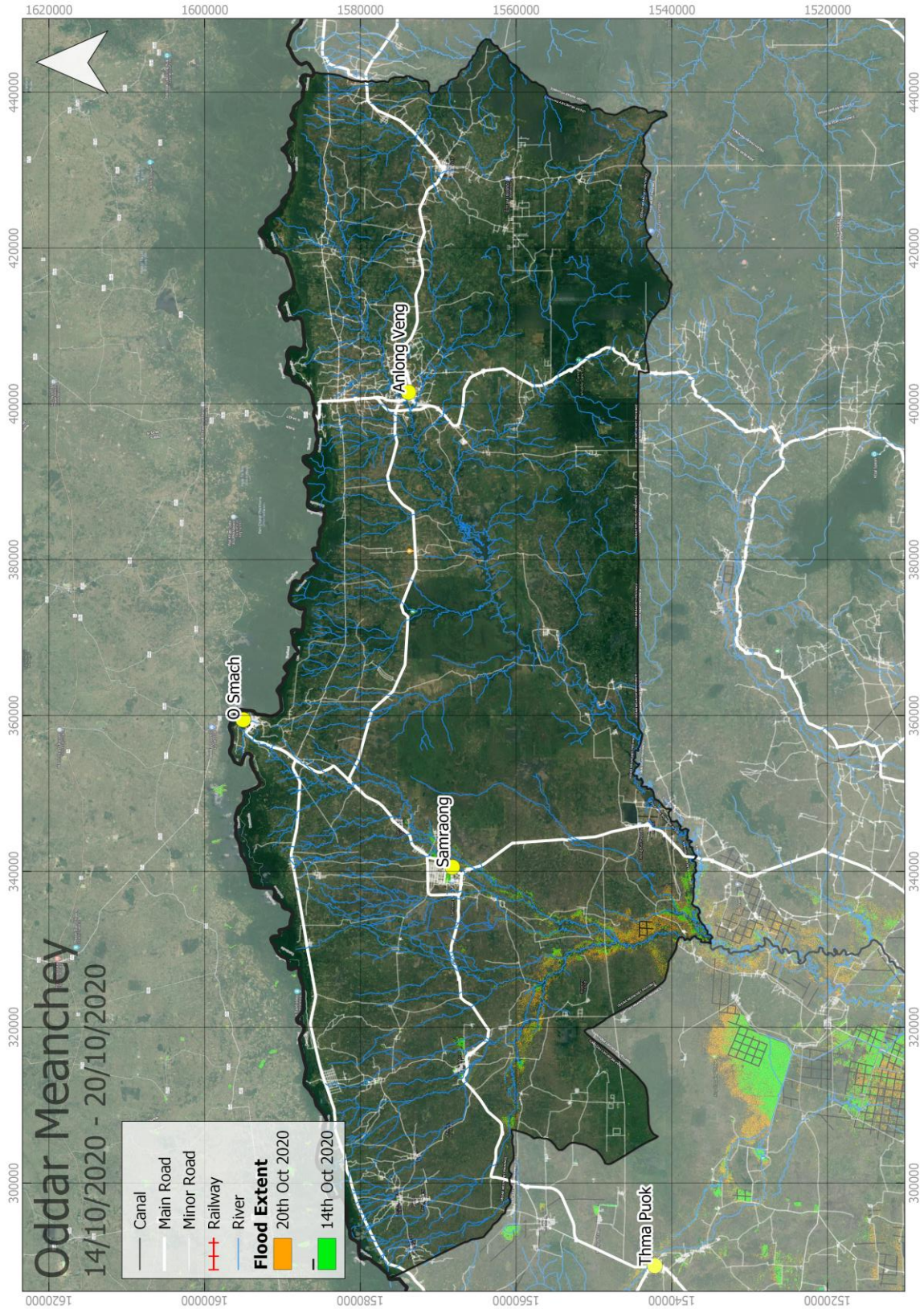


Figure 7 Flooded Areas Detected in Oddar Meanchey (only west part had available images)

Figure 8 Drone photographs in area of Banteay Meanchey University 27 October

- Rescue boats at Banteay Meanchey Provincial Office, Sisopon
- Extensive flooding of rice fields

Information on the flood warning in Thailand was obtained from telemetric data as below. It can be seen that at Wathana Nakhon there was heavy rainfall on 17 October and warnings issued in the morning. The river at Aranyaprathet was rising and warning given at 23:15 then by 9:32 on 18 October evacuations were ongoing in Aranyaprathet.

! List of responsible agencies, Sor Por. 6, Tonle Sap River Basin, Sa Kaeo Province, number of notifications 30 times

order	A date	Detail	Alarm type	Rainfall while warning	Amount of water level while warning	Rain 15 minutes	12 hrs rain	Rain 24h	48h of rain	Water level
1	18-10-2020 09:32	Evacuation report with high water level, Ban Dan station, Ban Dan sub-district, Aranyaprathet district, Sa Kaeo province (STN1003)	Water level	3.5	4.71	0.0	3.5	12.0	12.0	4.63
2	17-10-2020 23:15	Alarm alert with high water level, Ban Dan Station, Ban Dan Subdistrict, Aranyaprathet District, Sa Kaeo Province (STN1003)	Water level	2.5	3.74	0.0	2.5	34.0	34.0	3.71
3	17-10-2020 10:16	Alerted by rainfall, Baan Sap Somboon Station, Sare O District, Watthana Nakhon District, Sa Kaeo Province (STN1002)	Rain	112.5	0	5.0	74.5	83.0	83.0	-
4	17-10-2020 09:38	Notification of rainfall surveillance at Baan Sap Somboon Station, Serror District, Watthana Nakhon District, Sa Kaeo Province (STN1002)	Rain	84.5	0	8.5	63.0	63.5	63.5	-
5	16-10-2020 21:49	Notification of rainfall monitoring at Ban Be Grim Station, Klong Thap Chan Sub-district, Aranyaprathet District, Sa Kaeo Province (STN1004)	Rain	82.5	0	6.5	11.0	15.5	15.5	-
6	16-10-2020 19:36	Notice of surveillance with high water level, Ban Dan Station, Ban Dan Subdistrict, Aranyaprathet District, Sa Kaeo Province (STN1003)	Water level	48.5	2.38	5.0	48.5	64.5	64.5	2.31
7	19-09-2020 00.52	Notification of rainfall surveillance, Ban Watthana Nakhon Station, Watthana Nakhon Sub-district, Watthana Nakhon District, Sa Kaeo Province (STN1000)	Rain	83	0	1.0	89.0	92.5	92.5	-
8	18-09-2020 23:37	Alerted by rainfall, Baan Sap Somboon Station, Sare O District, Watthana Nakhon District, Sa Kaeo Province (STN1002)	Rain	98	0	3.5	90.0	92.0	92.0	-
9	18-09-2020 22:31	Alerted by rainfall, Baan Sub Max Station, Nong Nam Sai Sub-district, Watthana Nakhon District, Sa Kaeo Province (STN1001)	Rain	97.5	0	1.0	89.5	91.5	91.5	-
10	18-09-2020 21:50	Notification of rainfall surveillance at Baan Sub Max Station, Nong Nam Sai Sub-district, Watthana Nakhon District, Sa Kaeo Province (STN1001)	Rain	86.5	0	9.5	84.5	85.5	85.5	-
11	18-09-2020 21:45	Notification of rainfall surveillance at Baan Sap Somboon Station, Serror District, Watthana Nakhon District, Sa Kaeo Province (STN1002)	Rain	83.5	0	3.5	74.0	75.5	75.5	-
12	23-09-2562 19:57	Alarm alert with high water level, Ban Dan Station, Ban Dan Subdistrict, Aranyaprathet District, Sa Kaeo Province (STN1003)	Water level	0.5	3.03	0.0	0.5	33.0	33.0	3.03

Figure 9 Flooding in Aranyaprathet Thailand on 18 October (https://forum.thaivisa.com/topic/1188233-sa-kaeo-province-devastated-by-flooding-especially-downtown-aranyaprathet/)

Annex F. Focus Group Interviews completed in Cambodia Provinces Banteay and Oddar Meanchey with Farmer Water Groups and Agricultural Cooperatives

ANNEX F Focus Group Interviews in Cambodia Provinces Banteay and Oddar Meanchey with Farmer Water Groups and Agricultural Cooperatives

Note All interviews were conducted in Khmer language during February 2020, here the transcripts have been translated into English language as faithfully as possible using contemporary recordings.

Part 1 – Vulnerability Assessment for selection of target districts

Part 2 – Transcript of Focal Group Interviews (Translated to English)

Part 3 – Summary of Focal Group findings and recommendations

1.1 Part 1 Vulnerability Assessments to select Focal Group Districts

The choice of target groups for interview were based on a vulnerability assessment in terms of access to water resources and the effect this has on the livelihoods of agricultural communities.

Certain indicators will be used to assess vulnerability in the Cambodian provinces, the intention was to compare this with the Thai provinces allowing for comparison and lessons learned for improved water management and access to be made. Unfortunately it was not possible to complete similar interviews in Thailand due to the Covid outbreak although field visits were made as reported in the next Annex.

Studies will be carried out at the district level. Suggestions from local government will be used, alongside and flood and drought risk areas identified through modelling and analysis together with IDPoor data.

1.2 Locations

The locations for vulnerability assessments carried out within the Cambodian provinces were based on a physical and social factors: high flood and drought risk areas identified through modelling and analysis as described in the main report including IDPoor status and suggestions from district authorities.

It is most appropriate to collect information and data from several districts that overlap in terms of the above factors. The methods used, if successful can then be used to model scaling-up projects whereby more districts and communes can be targeted conduct a large-scale vulnerability assessment of the projects.

1.3 Oddar Meanchey

The map in figure 1 supplied by OMC PDWRAM presents the areas worst-affected areas by flood and drought in the last year. From the map and meetings the flooding was worst in the districts: Chong Kal (specifically Amok), Trapaeng Prasat (specifically Ou Svay), Anlong Vaeng and Samraong. For drought, the districts were identified as: Samraong, Chong Kal and Banteay Ampil.

A note on crops and market access in OMC: Through correspondence with the head of the Provincial Derpartment for Agriculture, Forestry and Fisheries (PDAFF). A major issue within the province for agricultural communities is access to markets. Due to the reliance on wet rice, cassava cultivation is a top priority, and currently the market access for the crop is limited. In addition, cashew crops are also said to have been harvested but with no market to sell the produce. The PDAFF representative also mentions the various ways that farmers adapt themselves to water shortages such as digging wells and not cultivating dry rice. It is

therefore important to account for these value chain limitations when making recommendations for the future adaptation of agriculture.

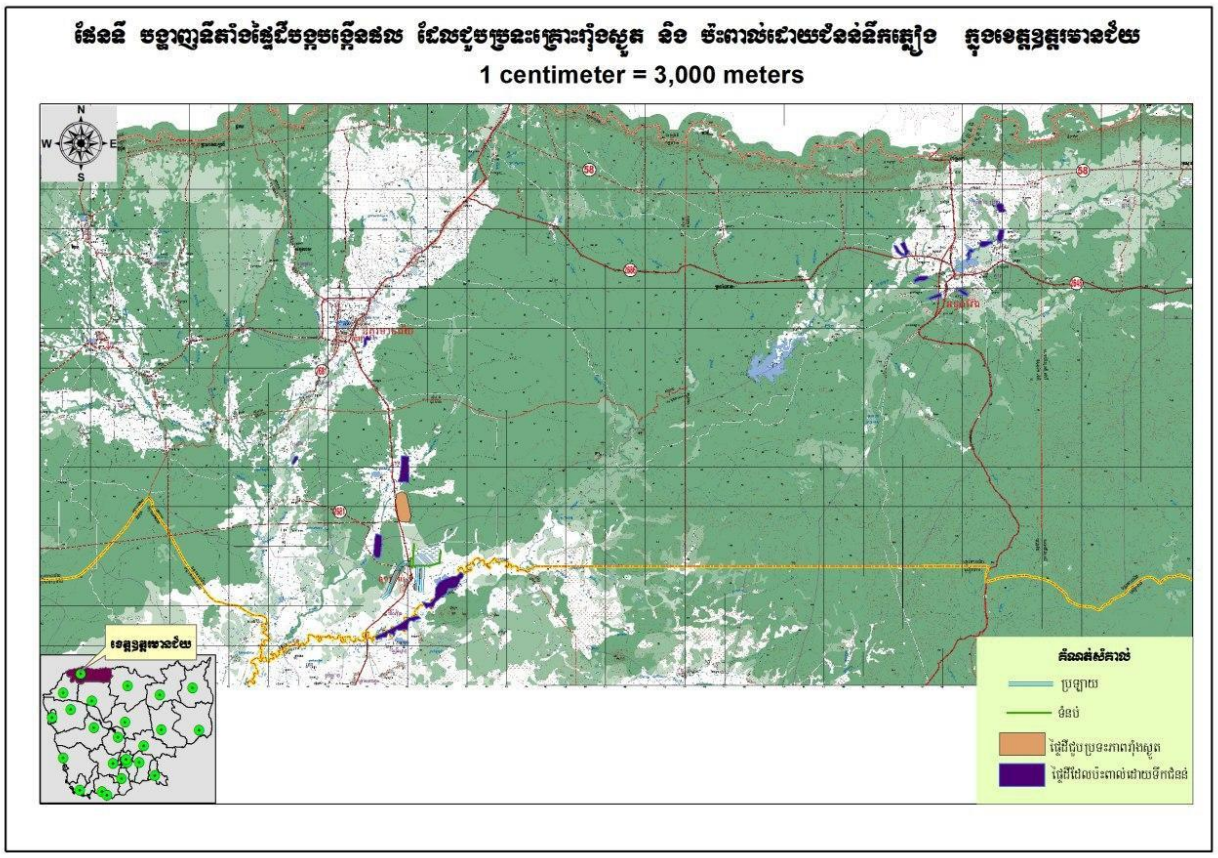


Figure 1: Flood and drought affected areas in Oddar Meanchey Province (2019) Source: PDWRAM. Legend: orange= drought, purple= flood, green= dam, blue= reservoir.

1.4 Banteay Meanchey

The districts identified by BMC PDWRAM and provincial officials in early 2020 as worst- affected by flood in recent years are: Poipet, Malai, Ou chrov, Serei Sisophon and Mongkul Borey. For drought, all former districts were identified in addition to Thmar Puok and Svay Chek. In late 2020 Thmar Pouk was also impacted by flood.

In addition, the PDWRAM 3 year rolling plan for 2019-2021 provides data on household access to clean water across the 9 districts. The 4 districts with the worst access to clean water as of 2018 are: Svay Chek (30.8%), Thma Puok (33.1%), Mongkul Borey (38%) and Preah Netr Preah (42.4%). The local information on flood and drought severity is in general agreement with the modelling and analysis.

IDPoor Indicator

The IDPoor commune comparison can be used to identify areas that are more vulnerable in through a criteria indicating 'poverty'. Agricultural communities often become more economically vulnerable when water supply is limited or unexpected flood and drought events occur; reducing their ability to cultivate crops. Therefore, it

is important to perceive some link between improving water management strategies and IDPoor levels, amongst a range of other factors.

Figure 2 maps the concentration of IDPoor level 1 and 2 households in OMC and BMC by commune. The labelled areas represent the communes with more than 20% of IDPoor 1 and 2 households of the total population. The initiative is not completely representative of vulnerability or poverty within provinces, however it is the most comprehensive database currently available in Cambodia.

Oddar Meanchey IDPoor communes:

- Samroang district: Banseay Reak, Bos Sbov, Koun Kriel
- Anlong Vaeng district: Trapeang Prei
- Trapeang Prasat district: Ph'av

Banteay Meanchey IDPoor communes:

- Phnum Srok district: Spaen Sraeng, Srah Chik
- Preah Netr Preah district: Prasat, Phnum Lieb, Tean Kam, Tuek Chour, Bos Sbov
- Ou Chrov district: Samraong
- Serei Sisophon district: Kaoh Pong Satv
- Thma Puok district: Banteay Chmar, Kuok Katkthen
- Svay Chek district: Sarongk, Svay Chek, Ta Phou, Treas
- Malai district: Boeng Beng, Ou Sampor, Ou Sralau

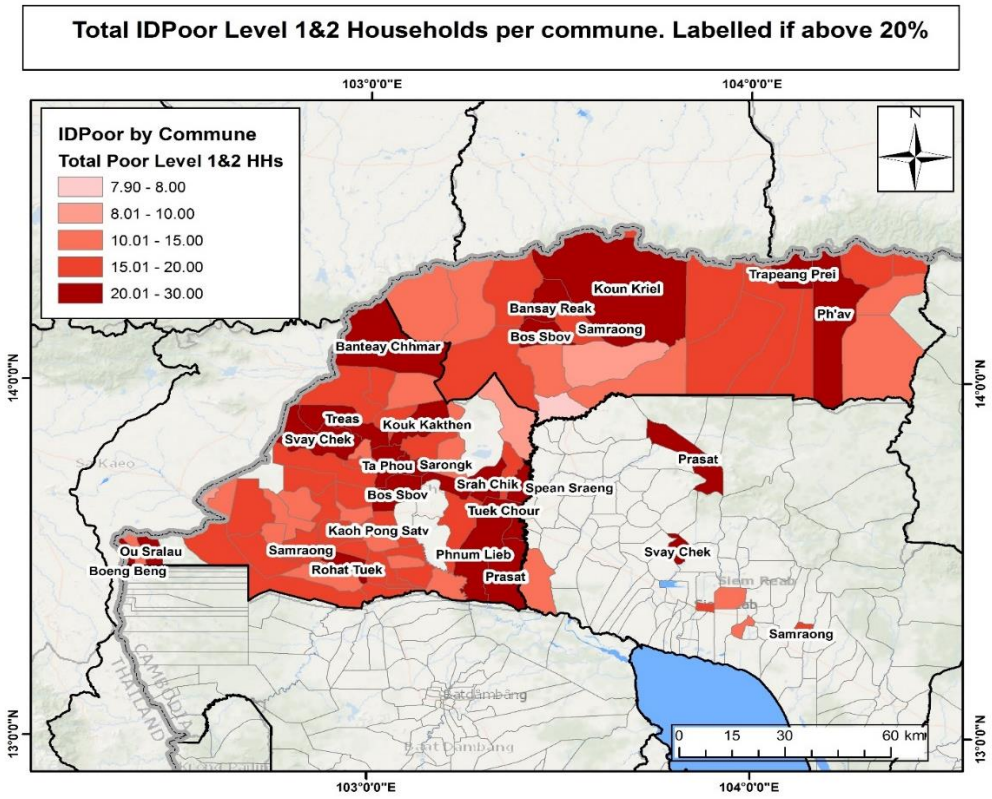


Figure 2: Percentage IDPoor level 1&2 Households in Oddar Meanchey and Banteay Meanchey by commune.

1.5 Communes and farmer groups

Ideally a large a sample of FGD would be conducted but within the project relatively small resources and time were available so al many of the identified hot spot areas as possible were approached and group discussions held with six local groups in each province as shown in Table 1.

Table 1 Local Groups where Focal Group Discussions were held

Province	Oddar Meanchey Village/Commune/District	Organisation		Banteay Meanchey Village/Commune/District	Organisation
OM1	- Kork Morn Samrong	Ou Ankrang FWUC	BM1	Kourk Phnov Banteay Neang Mongkol Borei	Por Pi Derm FWUC
OM2	Kon Kreal Samrong	Tumnup Lork FWUC	BM2	Kork Tunloap Banteay Neang Mongkol Borei	Bantey Neang AC
OM3	Kor Village Chong Kai Chong Kai	Stung Sraeng FWUC	BM3	Srae La' Kouk Romiet Thmar Puok	Kork Romiet FWUC
OM4	Kor Village Chong Kai Chong Kai	Chong Kal FWUC	BM4	- Kouk Romiet Thmar Puok	Kork Romiet AC
OM5	Sambour meas Bansay Reak Samrong Town	Sambour Meas AC	BM5	- Phkaom Svay Chek	Phkaom AC
OM6	Tumnup Chas Beng Samrong	Beng Samaki Akphivot AC	BM6	- Samraong Ou Chrov	Samraong AC
Total 6		FWUC=4, AC=2	Total 6		FWUC=2 AC=4

The discussions were recorded and then transcribed and translated to English for this report. These transcripts are given in the next session followed by a matrix summary of the points raised by participants.

The discussions were led by social scientist Soknea Oun assisted by Lucy Porter with assistance from the GIZ RED team in Siem Reap.

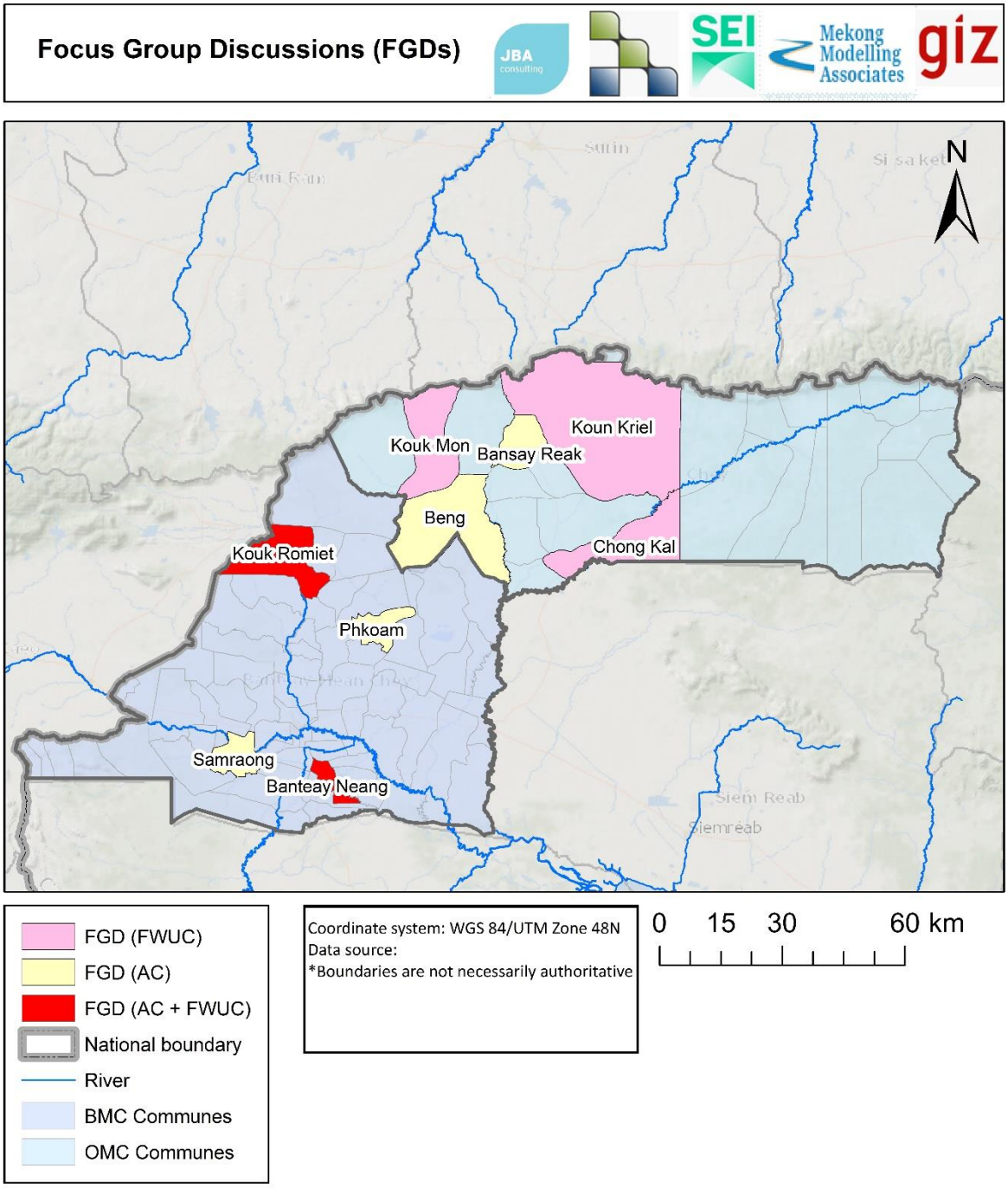


Figure 3 Location of Communes where Focal Group Discussions were held with Farmer Water User Groups and Agricultural Cooperatives

1 OM1 - FGD with Ou Angrang FWUC, Kouk Mon

Date: 25 February 2020
Location: Kork Morn Commune, Samrong district, Oddar Meanchey
FWUC Name: Ou Angkrang
Participants:

1. Mr. Yao Ra (FWUC Chief)
2. Mr. Pi Pear (FWUC Deputy Chief)
3. Ms. Ruth Seu (Member)
4. Ms. Til Saray (Member)

1.6 Water Resource Access:

1. ***How far do you have to travel to the nearest water body?***

To the nearest water body is the ponds which are located in the village, but to get to the reservoir, it is 3km away from my village. Moreover, the ponds in my village are joint ponds which are dug for the community members (1 pond for 25 households). For your information, in our community we have so many ponds as there was an agricultural community in our community, and they had helped built so many ponds in the village; and some ponds were constructed by individuals as they need the soil and leave the pond for villagers. For this whole Kork Morn commune we do not have problem with water shortage for domestic use. However, only a few villages that get access to water but the quality of the water is not so good.

There is a big pond (50m x 50m with 3.5m depth) that CIDO organization helped our community to promote agricultural production. Although the pond is not as big as the reservoir, it is enough to help support the livelihood of the people in a few villages of this commune. CIDO had contributed a lot to this community as they also helped construct the road (1km) in the community as well. But now the project had already been phased out leaving a lot of achievement. Also, there is another pond in his (chief) village which is 180m x 200m with the depth of 4m.

2. ***Overall, how many big water bodies in your community?***

There is this big reservoir that you drove pass and a few big ponds in different villages in the community, including the old ponds constructed in Pol Pot regime but recently is being rehabilitated as well by ADB.

This reservoir is called Ou Angkrang and was built in Pol Pot regime. This reservoir receives the rainfall/water runoff from the Cardamom Mountain. If you come here during the rainy season, you cannot even see the road as it is covered by the flood/water.

Every time during the rainy season, we open the sluice gate and the spillway to release the water from the reservoir; otherwise, the force of the water would damage the structure.

There is another reservoir called Rohal, but it is not as big as this one. However, community members are also relying/depending on that source for water use.

Within 4 villages of this commune, there are 8 big ponds that farmers can store water; and other reservoirs that are being rehabilitated.

3. ***Besides all of these storages, do farmers or community members have other methods to conserve the rainfall/water like the cement barrels or jars?***

Yes, they do. On the average, there are between 5-7 jars that each household possesses. In general, it has been a few years that we do not have problems with water shortage in our community except one village, Neam Thom. In fact, there are ponds in that village as well but due to the poor management of the village chief, they cannot get access to clean water for domestic use sufficiently.

Figure 4. Ou Angkrang Reservoir and its sluice gate (on the right)

4. ***It seems that you have enjoyed the availability in your community for domestic use purposes. How about water for agricultural uses?***

For agricultural production, we cannot compete with other communities as we are located in the upland/uphill area and the soil consumes too much water for crops. It dries too quickly. In fact, while other communities produce 6 tons of wet rice crops, we can hardly do only 2 tons.

As I have joined the tour visit to other FWUC communities in Banteay Meanchey that they cultivate dry rice; I have seen the green rice field after they supply the water into their plots of land and it stays for longer. While the soil in our community would be dry after supplying the water for one to two hours. No matter how hard we try to apply the water, for one hectare of land it can produce at most 3 tons. This is because the soil consumes too much water, especially during the dry season. At the community that I visited, they said that for 1ha of land they use only 12,000 cubic meter of water and they open the gate to supply the water only twice a month. However, in our community we have tried supply the water on regular basis and much more amount of water compared to those communities, but it still does not work.

Based on our experiences, during the dry season we could supply water to only 20ha of rice fields, and the water has been all used up.

Nonetheless, if we grow cassava, we do not need much water to supply and it needs to be planted at the uphill areas. If we do it at the lowland areas, the crops will be rotten.

In our community, farmers cultivate more rice than cassava; probably 3 times more. There is only 10% of farmers here cultivating cassava.

We do only wet rice and it is rainfed which is much better than depending on the water from the reservoir. Previously, it rained in October for almost 10 days by 28th October.

5. ***How do you distinguish between agriculture and domestic water? Are they different supplies? What is the source?***

No, we do not distinguish them. Well, actually people from the village have never used water from this reservoir for domestic use as they can easily access to the water in the ponds located in their villages.

While the water in this reservoir is only used by the community members for washing up the animals or people, or animals for drinking.

6. ***How about the quality of the water? Do you notice if water has ever caused any problems when using for cooking or drinking?***

It seems to be fine as nowadays community members have the water purifiers at home to purify water before drinking. The purifiers are provided by Samaritan's Purse organization that farmers have to pay 20,000 riels for one; and they drink the bottled water not unboiled water like before.

This water is only used for washing the clothes, shower, and cooking. The same as rainfall that we store in the storages that we also need to purify first.

7. ***Do you access groundwater via hand pump, open well or other?***

Yes, we do get the access to open well but the quality of the groundwater is very poor for cooking. As I attended the training, they taught us to store the groundwater in the storage for 24 hours before using; however, it is still not usable due to the arsenic in the water. Farmers do not prefer using groundwater because even used for washing or taking a shower, it makes your hair dry; and if apply on the crops like vegetables it makes the crops grow bad.

8. ***Do you have piped water?***

No, we don't. However, recently there is a private enterprise/company is carrying out a study to setup a clean water station at the downstream of the reservoir. They are now constructing a big pond to store the water in order to supply it through the pipes for community members later.

9. ***In short, do you think the stored water in those storages is enough for your community for both agriculture and domestic use?***

I think for domestic use is fine. However, for agriculture we cannot guarantee as water is short in dry season. For wet rice crop cultivation is fine because we depend on rainfall and water in the reservoir.

In fact, there are a few farmers are cultivating dry rice, but they also experience water shortage during the time of irrigation/harvesting.

10. ***From your experience when are there water shortages?***

Normally, it rains between April or May every year. However, in the last two years when the rain did not come as we expected, we open the sluice gate and released water from this reservoir for farmers cultivating dry rice, and thus it started to be short. However, we still had water remaining not completely dry out because there are many other ponds nearby the reservoir.

Figure 5. Ponds in the Ou Angkrang Reservoir

1.7 Maintenance and management

1. ***Is the irrigation system you manage small, medium, or large scale?***

It is medium scale. This reservoir has the capacity to store million cubic meter of water and 1,335ha of irrigated areas. This reservoir has the length of 3800m long and 1000m width. There are 8 villages that relying on this water source for their domestic uses.

2. ***How often do you decide when to divert and apply water to land? What are your main management strategies to decide when and where water will be directed to?***

During the rainy season before farmers cultivate dry rice, we had more water in the reservoir, and we normally start releasing the water in June, so that they can have enough water in their rice fields until end of October or November. We closely observe on the water level when supplying to their fields and start to drop the gate in October; but not completely close it. Also, we notice that when we realize that the rice fields turn yellow as it filled with sufficient water, we can close the gate.

When farmers need water to apply their lands, they inform to me as a FWUC chief to release the water for them. However, if we encounter any difficulties regarding the obstacles in managing water, we can inform to local authority to seek for assistance or collaboration.

Regarding the procedure to ask for water to apply the lands, farmers can directly contact me through telephone or meet me in person. And the water is always directed to those farmers who need water for wet rice. If any farmers do not water in their rice fields, we can just divert it to those who are in needs.

The same for dry season that our strategy to supply the water is to see that once the fields are filled with sufficient water, we will close the gate.

Based on my bad experience last year with my careless management, I let others open the gate whenever they want the water without monitoring when to close it, as a result, water was also used up from the reservoir. Since then I keep the gate key to myself and I would come to open and close the gate whenever the farmers need it.

Now I am thinking about a new plan that for next season I will inform all farmers whose rice fields are close to one canal that I will open the gate and let the water fill the canal and the farmers have to pump the water from the canal to supply to their fields by themselves.

Currently, we have three main canals. Yet, water is only sufficient and can be filled the canals only during the wet season. If there is this much water for dry season, we would be able to cultivate dry rice.

3. ***What are the main crops that the farmers are cultivating? And that the irrigation systems manage to supply to?***

The first priority crop is rice. On the other hand, for watermelon, we are asked by the owners to supply only little amount of water for them to fill the storage, so that they can apply to the crops by themselves and if they need more water, they have to pump from the nearby water body.

Normally, farmers have to inform the FWUC chief on what crops or how many hectares of land they are cultivating, so that he can inform to both PDAFF and PDWRAM on this progress. In this community, there are 4 hectares of watermelon.

4. ***How do you ensure the irrigation systems are well-maintained?***

To ensure that the irrigation systems are well-maintained, we just have to keep our eyes on the structures and report to PDWRAM when there are damages, they will be the ones to repair it.

5. ***Are there trainings for members of FWUC?***

Yes, there are. They kept coming to provide us trainings like once per month for one-year long. Firstly, when MOWRAM came, they came to select/appoint the committee members for this community. Later, they provided us trainings regarding agriculture, water management, and the use of fertilizers, etc. They provided a lot of good trainings for us; yet the community is not fully self-functioned without their support.

6. ***Is your community able to generate income from collecting the ISF from farmers?***

It is not easy. Before we agreed to collect 5000-10000 riels/ha from farmers in wet season, but due to the fact that farmers could not earn much from their harvest and some farmers did not pay us. So, we did not know what to do to collect the fee from them. We just let them use freely.

7. ***Are there any particularly challenges often faced when governing and managing the irrigation system?***

There are problems as we have not properly managed it and we still need strong support from the government. Despite what conditions are written in the FWUC sub-degree regarding the ISF collection from farmers, we failed to do it. And this is because we do not have a strong management and collaboration with the local authority to be strict on this. As a FWUC chief, I do have the names of farmers who are cultivating dry rice and for how many hectares, so that I can manage regarding the ISF collection in the near future. So far we do not have any problems or disputes between farmers reading water management.

However, we got some complaint during the rainy season as we open the gate and water flows to farmers' fields for too much. Yet, we do so to prevent the damage of the reservoir as there's too much water in it.

1.8 Environmental Challenges:

1. ***Are you aware of the environmental changes?***

We have never had any proper meeting to raise awareness about his, but we know and hear about this through media and the notification from MOWRAM regarding the weather forecasting.

Recently, we also noticed that the weather is sometime too cold, and some other times it is too hot.

Regarding the rainfall pattern, we normally notice that it starts to rain in May. But nowadays no rain until June-July. Also the amount of rainfall is less than before and for shorter period.

It has been 4-5 years that these seasons have been changed.

2. ***What have been the recent effects of flood and droughts on irrigation systems in your area?***

Sometimes, it floods 3 times a year. However, in the last two years there was only one-time flood. Flood starts in early or mid-September. Talking about its impact, flood has never damaged the infrastructure nor households because the flood does not stay long; it flows to other places for a few days as this is upland area. Only cassava crops about 10-20ha that are being impacted by flood. For rice crops, flood makes it grow better.

On the other hand, it has been 3 years in a row that we have experienced drought during July-August as it did not rain at all. And it mainly affected rice crops. From my personal experience, within 3ha of rice fields, I could harvest with only 7 sacks of rice yields.

3. ***Do you have strategies place to mitigate against this change?***

No, we don't. As what I have seen this drought is the result of deforestation. Too many hectares have been destroyed. What is remaining today is just 10% of total forest that I witnessed before. Honestly speaking it is our farmers' mistakes that cleared the forest for agricultural lands, and thus all the forest gone. Despite how hot the weather is, human/farmers here are still able to withstand with such conditions. But they do bring and drink more water. However, the cold season last only 3 days.

1.9 Farming community:

1. ***Do you hold meetings with the rest of the farming community to discuss irrigation system management?***

Before we did with the support from MOWRAM and participants were supported financially, and thus there were more participants taking part. However, after they stopped coming here anymore, when I invited other partners to join without providing them anything, they do not come to the meeting anymore.

However, recently only a few committee members are being invited when the PDWRAM came to visit the irrigation system; not the meeting with other community.

2. ***Do men and women partake in managing the irrigation system?***

Both men and women take part equally in term of managing the irrigation system as long as we inform them or ask them to help. By the way, nowadays there are guards working in the community, and thus we can ask them for help instead of ordinary farmers. Before that when we experienced the damage of the reservoir, we called up everyone in the community to help including women and they were helpful as they cooked and worked with us to repair the structure. In term of meeting participation, there seems to have more women than men as men are busy working at the fields.

1.10 Recommendations:

1. What do you believe is needed to improve water management in your area?

Unless there's more support from government or development partners to help on repairing the broken parts of the systems. Nowadays farmers divert the water from the main canal directly to their rice fields but without proper management as they let the water fill and flow outside of the fields after it is full.

Now for better use of water in the future especially in dry season, I plan that for those whose fields are far from the main canal are not allowed to cultivate dry rice. For those whose fields are close to the main canals, I will only supply the water into the canal and so that they can pump the water to their fields easily.

Nowadays the government also plan to construct the secondary canals to bring water directly to the fields as well, so farmers do not have to pump.

In fact, in our community the problems that we mainly face are that we cannot cultivate rice crops with high yields due to the geographical/topographical conditions, and secondly even when we harvest, we have no access to market to sell our products. I also grow mangos but there's only one market available at Smach and once I harvest and sell there, the price is very cheap as there is surplus of mangos by the time I harvest. Therefore, I decided to stop planting them for sale.

2 OM2 - FGD with Tumnup Lork FWUC

Farmer Water User Community Focus Group – Summary Notes
Date: 24 February 2020
Location: Kon Kreal Commune, Samrong Town, Oddar Meanchey
FWUC Name: Tumnup Lork FWUC
Participants:

1. Mr. Lan Ny (FWUC Chief)
2. Neth Mount (FWUC 1st deputy chief)
3. Norm Soth (FWUC 2nd deputy chief)
4. Sann Eth (Accountant)
5. Member

The FWUC community consists of 4 different villages namely Thnal Bot, Khtum, Trapaing Veng, and Ta Marn with a total member of 16 (F=1). The FWUC community was officially established and registered in 2017. The Tumnup Lork dam/irrigation system was formerly constructed in 1975 during the Khmer Rouge regime, but was not functioning well until 2016 to be well-functioned after receiving support from the PDWRAM/MOWRAM on rehabilitation. The dam was first rehabilitated with the support from the other farming community, second time by using the commune budget, and third and fourth time was financially supported by MOWRAM.

Figure 6. Tumnup Lork dam

2.1 Water Resource Access:

1. ***How far do you have to travel to the nearest water body?***

The nearest water body is known as Tumnup Lork dam (see Figure 6) which is located in the middle of the community. We cannot estimate how many hectares are the irrigated areas as farmers still enjoy using the rainfall water during the wet season. Therefore, we cannot tell how much land our irrigation system is capable of irrigating. Regarding the capacity of the dam, PDWRAM has recently just come to collect the data on that; therefore, we cannot tell how much the capacity of the dam is.

2. ***How do you distinguish between agriculture and domestic water? Are they different supplies? What is the source?***

We as farmers here heavily rely on this dam as the main source of the water to supply to farmers for both agricultural and domestic uses. Although there is one existing water supplier community, they also get water from this dam to supply to community members for domestic use. And another private company buys water from that community to purify and supply clean water to the community as well. Recently, there's another clean water supplier but their station is still being constructed.

This dam is a natural water body that can only store the water during the wet season as the rain falls because there is no water source of water linked to this dam. And we use the water from the dam to supply water during the dry season.

3. ***Do you access groundwater via hand pump, open well or other?***

There are so many wells and hand pumps, but those cannot provide sufficient ground water for farmers to use.

4. ***Do you monitor or are you aware of monitored ground water level?***

No, we cannot monitor.

5. ***Do you have piped water?***

The piped water is supplied by the water supplier like I mentioned earlier. It is charged 1,500 riels per $1m^3$. Although the water supplier community uses water from our irrigation system, they do not pay the ISF to us as mentioned in the sub-degree and ToR. When we claim for ISF from them, they referred to PDAFF and we were asked to supply them the ToR of FWUC on ISF collection. Despite the fact that we gave them our document, they still refused to pay for it.

6. ***Are there many water storages in the area? What is the main method of water storage? Besides the dam, is there any other storages?***

This irrigation system is long. There are 2 lakes, a number of streams and creeks linked to the dam. Total length of the dam is 2700m long. The capacity of the dam is quite big and enough for usage except the fact that we do not have external source to supply to this dam, and thus it lowers as we use it daily.

We had a tour visit to another FWUC community in Por Pir Derm in Banteay Meanchey through GIZ. Their irrigation system receives water from Kamping Pouy reservoir as it floods. Therefore, they never run out of water in their system.

7. ***How about water storages like jars or barrels? Do farmers own them to store the water? If so, how many of them that farmers have on average?***

Yes, there are. Some households were given those storages through NGOs that came to work in the community. But not all households own them. Each household owns around 4 jars/barrels on average as each one of them contains 1,200L. It depends on how wealthy the family is. Some families are able to build the storage that looks like a pool (cement) to store the water for domestic use.

8. ***Are the storage capacities enough for domestic and agricultural supply? From your experience when there are shortages?***

This natural dam is sufficient to supply water for domestic use. That can be guaranteed. However, during the dry season, it is not enough for agriculture. Water from this dam is classified into 3 categories a) household use b) irrigation during the wet season and c) and to supply to other small ponds or creeks. During the dry season water can be enough only for small vegetable growing or dry rice cultivation, but not for sale.

Based on our experiences, water shortage normally takes place between April-May. Water starts to lower after May. Normally, it starts to rain again in September. However, recently from September 2019, there was no rain until now. Therefore, it affects the agricultural productions of our farmers because our main source of water is also low during this period.

As I noticed, recent 2019 had a longer dry season. However, the hottest period of time in my community was in 2017 which caused many deaths of animals and crops. That was the time that even the dam was dry out. During 2016-17 it was the time that we were rehabilitating the dam, and thus, it did not function well which made the temperature the hottest that even the mango trees died.

9. ***How's the quality of water? How do you observe about the quality of it? Whether it contains sediment or arsenic?***

The water quality is normal. It might smell but it is due to the weeds/grass or other natural plants growing nearby the system. It does not affect the crops when applied. If you talk about the chemical substance inside the water, I don't think we have that problems. Or probably because we do not know about the technical term about it. However, it contains sediment but it is fine to use for cooking.

2.2 Maintenance and management

1. ***Is the irrigation system you manage small, medium, or large scale?***

We are not sure about its classification regarding the scale because the PDWRAM has not mentioned or informed us about this determinant on the size of this irrigation system. But I do not think it is a large one because its capacity can only supply water during the rainy season; not enough for farmers to support their occupation during the dry season.

2. ***Are there any infrastructures to divert water from this dam?***

Yes. In our master plan map, there are 2 main canals (1st main canal stretches for 5200m long, and the 2nd one is 1100m) and a number of tertiary canals to divert the water from this dam to irrigate the land. They are all earthen canals from the old time.

3. ***How often do you decide when to divert and apply water to land?***

During the rainy season we open the gate of the dam daily for one whole season until September or October. We open the gate to release the water to maintain the irrigation system from being damaged by the flood during the rainy season. We cannot tell when exactly that we close the gate as we habitually depend on the actual agricultural production that our farmers have had done. When we notice that rice starts to grow well, we close the gate of the dam. It is not regular on how long we open the gate, because we depend on the weather as well and the amount of the rainfalls.

So far, if there's too much water, we increase the height of the water level to be released. However, during the dry season we close the gate since October until now. Even if we open the gate, the water will not flow downstream because it starts to be low.

4. ***What are your main management strategies to decide when and where water will be directed to?***

For the rainy season, we open the gate of the dam and supply water to farmers in general for whatever crops they are cultivating. Generally, cassava is planted in the upland areas while rice is planted in low land area. Therefore, when we open the gate, it does not affect severely to any kinds of the crops. Specifically, cassava does not need as much as water as rice. If cassava is supplied with too much water, it will damage the crops instead. From our experience, we do not need to get water from this dam to supply cassava because only the rainfall once is sufficient.

5. ***What are the main crops that the farmers are cultivating? And that the irrigation systems manage to supply to?***

The main crops are rice, and cassava, water melon and little bit of vegetables for household consumption and selling in local community. For water melon cultivation, as our irrigation system potential, it can supply water to water melon very little; less than 10 tons as a whole. We do not dare to allow farmers to grow this kind of crop because we are afraid that we will run out of water before they can harvest for the yield.

6. ***How do you ensure the irrigation systems are well-maintained?***

We often fix the system when there are damages. Recently in January we also fixed different parts of the systems as it required. And we keep the maintenance works by using the ISF collected from farmers/FWUC members. Also to avoid flood from happening that may damage the irrigation system, we have to monitor the system regularly by checking the water levels as indicated on the meters as we do not have any warning devices to alert or notify us. Plus, we traditionally use our own observations whether the rain would be coming or not to decide on opening the gate or not. From our experiences during rainy season, we standby every night with other FWUC members to make sure that the water level rises at the level that we can manage to open the gate or not. Also, the meter is used to tell the height of the water levels and this needs to be reported to PDWRAM daily. On the other hand, if the systems are damaged severely, we have to ask for assistance from PDWRAM or MOWRAM.

7. ***Are there trainings for members of FWUC?***

There are so many trainings that PDWRAM/MOWRAM has provided to FWUC members starting from operation and maintenance (O&M) to crop cultivation trainings. The PDWRAM came to provide trainings to our community very often (30 times) and repeatedly taught us about water use and management, as well as seed selection trainings which focus on what type of seeds are capable for the amount of water that our irrigation can supply, etc. Moreover, they also provided us some administrative tasks like writing letters in accordance to the sample of the reports that they require.

8. ***Are there any particularly challenges often faced when governing and managing the irrigation system?***

We have problems in term of governing the irrigation system such as flood protection. As a matter of fact, the body part of the system is quite shallow/low, therefore, it is normally flooded during the rainy season. In the future, it is possible to be damaged. And our community is not capable of fixing it.

Moreover, we also faced some issues with the beneficiaries who do business based on water from this irrigation system and willing not to pay for the ISF. Besides, we cannot determine how many hectares exactly that the farmers own, so that we can collect the fees from them as they lie to us about the total land areas they cultivated. Most importantly, the FWUC committees do not get any financial support or salary to support our work or maintenance. So far, PDWRAM has supported us as much as they can also. We often help the community as much as we can as well, especially with labour when flood comes.

2.3 Environmental Challenges:

1. ***What have been the recent effects of flood and droughts on irrigation systems in your area?***

The effect from flood is not so serious; the water just runs through the system and makes some small holes during the flood. On the other hand, drought does not affect the irrigation system at all. Yet, its hot temperature caused the weeds/grass that we grow to protect the system dead. But when it rains, the weeds/grass grow again; that is fine. In short, if the weeds/grass die, our irrigation system can be affected/broken partially as well.

2. ***How about the damage on crops?***

Back to 2017, it was dry during the dry season when farmers did not do any rice cultivation; therefore, it did not affect their land/crops. And it rained in rainy season as usual.

However, in 2019 it was dry during the rainy season. The dry season was long, but then it started to rain a bit later, and thus the rain made the crops grow well again. And no diseases caused/reported recently.

3. ***How do you ration the water when there is shortage?***

In 2018 during the time that there was water shortage, we allowed farmers to pump the remaining water from the dam to irrigate their small-scale crops at home. As the farmers experienced water shortage earlier, this year they do not grow anything during the dry season because they do not know how to divert/get the water to irrigate their crops. We cannot help them either as our system/dam is lower than the existing canals which cannot bring water to supply those canals for farmers.

Moreover, farmers themselves do not have time to grow other crops besides rice and cassava because once they harvest rice; they start growing cassava and the rice cultivation starts again after they harvest the cassava.

4. ***Are you aware of environmental changes recently?***

In 2019 we announced/shared the information received from MOWRAM/PDWRAM about the environmental change as the dry season is longer than usual; and thus we reminded the farmers to be cautious about crops cultivation and gave suggestions whether we should start growing earlier or listen to announcement from the ministry.

Moreover, we always keep ourselves updated about the weather by listening the news broadcasted through media – radio, and from our traditional observation.

5. ***Do you have strategies place to mitigate against this change?***

We do not really have a strategy regarding the change. However, we only open the gate to supply water when is necessarily needed to prevent water from drying out.

Our existing infrastructures (canals) do not work well during the dry season as the water body is deeper than the canal, and thus when the water starts lower, water cannot flow through the canals; unless we pump. And pumping costs a lot more money on gasoline.

6. ***Do you get any information from the government such as flood and drought warnings?***

From MOWRAM they mentioned about reducing the amount of land cultivation during the time of water shortage. Based on what the government announced, this season almost all crops are not allowed; to prevent from water shortage completely. Or grow any types of crops that consume less water. It is not official announcement/warning to the whole community. It is just a recommendation.

2.4 Farming community:

1. ***Do you hold meetings with the rest of the farming community to discuss irrigation system management?***

Our community has never had any cooperation with PDAFF. We only hold meetings within our FWUC community with the members to discuss on issues related to ISF collection, system maintenance, and gather during the flood event to help with labour.

2. ***Do men and women partake in managing the irrigation system?***

Yes, they do. So far, men and women equally take part in O&M process, especially when there is an emergency. Both men and women help carry the pile of soil, grow the weeds along the system. As I observed women participated more than men as they have more spare time than men do. Besides, both men and women also take part in meetings when we invite them to listen about O&M capacity building.

2.5 Recommendations:

1. ***What do you believe is needed to improve water management in your area?***

I think if the government can help rehabilitate the existing water infrastructure or construct new canals in our area to bring water from the dam newly constructed by Chinese company that would help us in term of managing the use of the water in our dam. We can open or close the water in the dam when is needed; and so we can have sufficient water whole time. I heard this news from PDWRAM but I am not sure what it is officially called. Besides, we want to have infrastructures/weir to keep the water from flowing when water is needed.

3 OM3 - FGD with Stung Sraeng FWUC

Date: 26 February 2020
Location: Kor village, Chong Kal Commune, Chong Kal district, Oddar Meanchey
FWUC Name: Stung Sraeng FWUC
Participants:

1. Mr. Phlun Plorn (FWUC Chief)
2. Mr. Rung Sareut (Deputy Chief)
3. Mr. Puch Kanderng (Accountant)
4. Mr. Seung Theam (Member)

3.1 Water Resource Access:

1. ***How far do you have to travel to the nearest water body?***

In my village, farmers have to travel around 500m to get access to the nearest water body. However, for their rice fields, they are even closer to the water source; maybe 100m to their fields. People can get access to water for domestic use easily. For some villages in the commune can access to the water in the canal for less than 30m; and for those who wish to cultivate their rice, they can pump the water from the canal directly as it is close to their fields. And now currently the government has just started a project to construct secondary canals for all villages in this commune in which one village receives 2km of secondary canals, so that farmers can have water to supply their agricultural products. Nowadays, people in our community do not cultivate dry rice as the water in the canal is only sufficient for domestic use. This canal connects to the water body and brings water to people in Banteay Meanchey instead.

2. ***Based on what you said, this irrigation system is only able to supply water for domestic use only while wet rice cultivation is based on rainfall. Is that right?***

Yes, we heavily depend on rainfall for wet rice cultivation. Water from the canal cannot sufficiently supply to our fields because in fact the current main canal is higher than the rice fields, and thus it cannot bring the water to the fields. That is why we are requesting to construct the secondary canals.

3. ***So far, do you have problem with water quality in your areas? Is the water good enough for cooking?***

No, we do not have any issues with the quality of the water. Nowadays, we can use the water from that canal and put it in the purifier before drinking. Even if used for shower, the water from the canal is not as bad as the ground water from the well.

4. ***How about the groundwater from the wells?***

It is different. Both water from the openwells or pumps when used to take a shower, it makes your hair dry and sticky. Unlike the water from the canal. Moreover, this canal is supplied by the water falling from the mountain in Anlung Veng. As long as the local community members there take good care of the water upstream regarding the environment there, then we here can enjoy the good water as well.

5. ***Despite the quality of the groundwater, do farmers still get access to wells and pump to get the water? Or do they completely stop using it?***

In my village people still access the groundwater from the well and use it. In fact, the quality of the water varies from place to place. The water from my well at home is as clear as a mirror and we can use it for drinking as well after purifying it. Almost every household has access to groundwater through the well as they have to dig about 35m to get water. In some areas farmers dig only 7-8m to get the

groundwater. Diverse topographical and geographical areas provide different quality of water. For example, we used to dig a well up to 80m and no matter how long we try to get the water, its quality is so bad; and thus we decided to fill the hole of that well back.

6. ***As a FWUC committee member, do you monitor the level of groundwater used by the farmers in your community?***

There are many households that get access to groundwater. We cannot tell how much water from the ground is used. Some of us know the numbers of total wells or pumps available in our villages. In my case, there 95 wells from my village. For me there are 6 hand pump wells, 2 open wells, and 7 well pumps and two ponds. However, one of the ponds is too shallow and it is not enough for domestic uses, even its quality is not good for drinking or cooking. We only use it to supply on the crops at home.

7. ***Do farmers in your community have piped water?***

No, we do not. However, recently there's an NGO called Samaritan's Purse has been working in our community and planned to construct/install the clean water station, so that people will have access to clean water through the pipes. Yet, we do not have a proper location for the station yet.

8. ***How about water storages in your community? How do farmers conserve water and allow them to use that stored water later? Is the stored water sufficient for agricultural products or growing vegetables?***

So far we have an old existing dam (constructed in Khmer Rouge Regime) that diverts the water from the stream, so that we can enjoy the water stored there. We do not know exactly about the capacity of the dam but it can store thousand cubic meters of water and it sufficient for 2 whole villages for domestic use for whole year round. Moreover, we have the newly constructed canals and some ponds. Besides, farmers have jars to conserve the water and on average they own 4-7 jars per household.

On the other hand, the stored water is only for adequate for domestic purposes; not for agriculture. Once it rains, it fills all the water storages available in our community.

9. ***From your experiences, when do you normally notice or witness water shortage in your community?***

It depends. Some seasons when there's too much rain, we have sufficient water to use. However, if the rainfall isn't too much, we would experience the water shortage.

Yet in the recent years, the rainfall patterns have changed. Starting from April to May, water shortage starts to be lower. In these last two years, we have encountered difficulty with less rainfall as the changes in climate. Nonetheless, we have access to wells instead which we can rely on when experiencing water shortage. Also, we are less worried about water shortage now as we have (this) new canal to help store water. This canal was constructed in 2013 but still being repaired continuously due to small damages.

During the water shortage period between April-June, we start to conserve the water in the canal and reservoir by not opening the sluice gate to release the water as much as usual.

With the current project from PDWRAM on constructing the secondary canals, we are hoping that the farmers will be able to cultivate dry rice as there will be sufficient water.

10. ***Are there any other crops that farmers are cultivating besides wet rice?***

In my community there are some households growing vegetables for household consumption. Yet, most farmers do cassava farming. Between 80%-100% that farmers do both crops as once they finish/harvest rice yields, they start growing cassava. Comparing between cassava and dry rice, I think farmers would prefer growing cassava because to cultivate dry rice is more difficult to apply the pesticide and supply much more water. While growing cassava, you only need to plant them once and wait for the rainfall to pour on them.

For the cassava production cost is 6-7 million riels per hectare. And every household has at least 2-3ha of cassava. And the process to grow it is much easier than rice. However, for the price of wet rice is almost twice less than cassava.

The productions of wet rice are varied from village to village based on the locations of their rice fields. From my experiences, although we depend on rainfall but in the recent event that not so much rainfall was pouring, I did not have sufficient water to supply my fields. While other farmers whose fields close to the canal/water source, they can pump more water from the canal; and thus their yields are higher.

3.2 Maintenance and management

1. ***Is the irrigation system you manage small, medium, or large scale?***

It is a large irrigation scheme as it supplies the water not only to this province but also to Banteay Meanchey and Siem Reap. The main canal is long but for the length that is under our supervision is 17km long.

2. ***How often do you decide when to divert and apply water to land? What are your main management strategies to decide when and where water will be directed to?***

It has been two years that we release the water from the reservoir and store it in this main canal. However, the water store in this irrigation system is only to supply to farmers for their domestic use. So far the water available in the canal is not sufficient for farmers to irrigate or cultivate their agricultural crops yet. That is why we are trying to get the project to build the secondary canals done as soon as possible for our farmers. To get the water from the canal to use, farmers can go and pump the water directly from the canal to their personal storages for domestic use.

But like I mentioned earlier that farmers in Siem Reap and Banteay Meanchey are the ones who benefit from this canal, and thus they requested to the local authority to open the sluice gate and release the water for them to do the dry rice in their areas. Regarding the level/amount of water when releasing, it is not too much. They open it low. For the authority to open the gate is not under our community, it is given to another FWUC community which located close to the reservoir.

As the water is released to the beneficiaries in Siem Reap and Banteay Meanchey, the farmers there are able to grow dry rice. This irrigation system brings water to Ta Vong and Phnom Srok commune. I have been there; their dry rice crops are very good as fed with enough water.

3. ***Does your FWUC community ration the level of water consumed by the farmers?***

No, we don't. That is also one of our plans that we have been preparing. As long as we have the secondary canals ready and bring enough water to the farmers, we will be able to ration the level of water for them to use.

4. ***How about the fee/charge that farmers pay as they use the water from this irrigation system?***

We have discussed regarding this matter. We agreed that whoever depend on this irrigation system to get water to supply to their fields, we would like to charge them 40,000 riels per hectare within one

season as contribution. However, that ISF does not mean that they have to buy the water. That money collected from the beneficiaries is to conserve when the system needs repair. However, all of this is still the plan. We haven't implemented yet. Hopefully, we can start implementing this by next year.

On the other hand, for the water that they get access to through this canal for their household consumption purpose is not charged as the PDWRAM/MOWRAM had not forbidden us from using it.

5. ***How do you ensure the irrigation systems are well-maintained?***

So far we have not done anything yet. Recently, PDWRAM has provided us trainings regarding O&M. But in reality when needing to repair, it is the responsibility of the government. Our community has not been occupied to repair the system yet. In term of maintenance, we are told to take a good look on the system and report to PDWRAM if there is/are damage(s). Our important job is to keep the environment around the system clean.

6. ***As you mentioned about the trainings with PDWRAM, what are those trainings about that provided to your members of FWUC?***

It was about conserving/managing the water and taking good care of the canal, keeping the environment clean and help each other to maintain the system.

7. ***Are there any particularly challenges often faced when governing and managing the irrigation system?***

As far as our concerns regarding managing this system, it is about keeping the system clean. Despite our efforts to promote clean environment and hygiene, community members still do not follow as they throw the garbage away and into the canal.

Although we are responsible for keeping it clean, the duty of collecting the garbage is not ours. On a regular basis PDWRAM is the one to bring the excavator truck to excavate the garbage.

8. ***Any challenges due to water shortage?***

Well, this year there was a big rain/flood and thus the water is still available in the canal as the reservoir was able to store so much water as well. However, the year before (2018) we encountered worse water shortage as the rainfall for less days.

This year during the water shortage, the PDWRAM was able to bring in 5 electronic pump generators to pump the water from the canal to supply the water to the rice fields for farmers (as per request from the farmers). As a result, the intervention could help make their yields grow better and farmers were able to harvest their yields instead being damaged completely.

3.3 Environmental Challenges:

1. ***What have been the recent effects of flood and droughts on irrigation systems in your area?***

In the recent year (September 2019) there was flood and it damaged a number of areas of the system. It destroyed the concrete embankment of the canal and its bank.

Also in 2013 that there was a big flood. However, for the recent flood it was not that big but it came in a flash. Due to that flood, it destroyed many hectares of the wet rice after the flood had gone. It flooded the fields, and when it's gone, the yields gone bad as well. My crops personally had been completely damaged for not being able to harvest any yields.

Due to the effects of the current flood, 50% of wet rice crop was affected/damaged. However, cassava crops were fine as they were planted on the upland of the area. However, the drought has never affected the system.

As the system is damaged, we reported to PDWRAM to come and repair it because they have technical team to fix the system.

2. ***Are you aware of environmental changes recently? About rainfall pattern?***

This year it rains in a flash but in a short period of time. For dry season, this year is normal. But last year it was hotter than usual. Normally, February to March would bring some rain, but until now it has not been raining yet. The rainy season is short while they dry season is long.

3. ***Do you have strategies place to mitigate against this change?***

I have no ideas of what to do to mitigate this change. However, it is possible if we plant more tree, it would reduce the hot temperature during the hot season. However, for flood event I don't know what we can do to prevent it from happening. During the flood, it had been flooded for whole 2 weeks.

4. ***Do you get any formation or warnings from the government regarding these natural disaster?***

Yes, we do. They always inform/give warning every year through telephone number and also from the media that we can access to that information. From what we can do after receiving information or warnings is to prevent ourselves and be careful during the events – such as to look after our young family members during the flood event. As we are living in the lowland areas, we are always aware and prepared ourselves. Moreover, recently MOWRAM has also connected us to the emergency system. Once there is emergency, MOWRAM will notify those people all at once up to 1,000 people at the same time.

3.4 Farming community:

1. ***Do you hold meetings with the rest of the farming community to discuss irrigation system management?***

The agricultural sector (MAFF) are the ones that have been providing training to us. They have been teaching us about rice crops and the use of fertilizers.

Regarding the meetings with farmers to discuss about irrigation system management, we have never done that. Only the committee members are being summoned when PDWRAM comes. No meeting between FWUC and FWUC before. Only the site visits that we have been involved as organized by MOWRAM, we were brought to see the irrigation systems in Takeo.

2. ***Do men and women partake in managing the irrigation system?***

Due to the fact that we have not broadly promoted about our tasks to women, only men are the ones being actively involved in managing the irrigation system.

3.5 Recommendations:

1. ***What do you believe is needed to improve water management in your area?***

I think for better water management in this community and as I attended the community meeting, we need to have the weirs/structure/sluice gate to get access of the water for each village. For instance, we can plan later to limit on the number of days or duration that we are going to provide the water for Village A for 5 days by closing the sluice gate, and then move to Village B after they have enough. As I saw this as the example from the community in Siem Reap. Moreover, there is also a proposal to the PDWRAM to construct gate at each of the bridge in the community.

4 OM4 - FGD with Chong Kal FWUC

Date: 26 February 2020
Location: Kor village, Chong Kal Commune, Chong Kal district, Oddar Meanchey
FWUC Name: Chong Kal FWUC
Participants:

6. Ho Sangheu (M) FWUC Chief
7. Dann Ourt (F) FWUC Deputy Chief
8. Ann Savart (F) Accountant

4.1 Water Resource Access:

1. ***How far do you have to travel to the nearest water body?***

It is not really far for the farmers to get access to the system. It is about 1km away to the furthest rice fields and some are close to the system which is less than 1km.

2. ***How do you distinguish between agriculture and domestic water? Are they different supplies? What is the source?***

Both are from the same supplier. We heavily depend on the water from the reservoir to supply to the rice fields and daily use. The reservoir was built in 1960s but was rehabilitated in 2015 to function again.

3. ***Do you access groundwater via hand pump, open well or other?***

Yes, we do. But the groundwater from those wells nearby the reservoir is not good in quality. At the moment we get it from the ground, it is okay. However, when kept for a few days in the jar, it turns into red. It is the same for other wells in the villages not only the ones close to the reservoir.

The water from the reservoir itself is also not good. Yet, it is okay to supply for agricultural purposes.

4. ***Do you monitor or are you aware of monitored ground water level?***

There are many households that access to groundwater, but we cannot tell how many of them or how much water they use from the ground. Almost every house has the well as they are given by the NGOs and some households dig it personally by themselves. The canal is connected to the reservoir and thus the quality of the water is the same that it is usable to irrigate the crops without affecting the yields.

5. ***Do you have piped water?***

No, we do not. However, recently there's a clean water station is being constructed by the private company and they also access the water from the same reservoir to supply their station.

6. ***Are there many water storages in the area? What is the main method of water storage? Besides the dam, is there any other storages?***

Mostly the community members have water tanks at their houses to conserve the water. The tank is 1.5m x 2.5m wide with 2.5m height. Additionally, they have the concrete sewage pipes at home to store the rain water in which each one of the pipe can store up to 500L. Normally, those farmers who are affordable to buy these pipes have 8 pipes at home.

There are ponds in the community as well; however, its water cannot be used for cooking and it is not sufficient. For drinking water, the farmers have to purchase from the suppliers which costs them 10000 riels per barrel.

7. ***How about water storages like jars or barrels? Do farmers own them to store the water? If so, how many of them that farmers have on average?***

They have jars at home to conserve the rain water. Almost everyone has jars at home between 2-5 jars at least. Of course they use the stored water for cooking and drinking; yet it is not enough. The stored water is only sufficient for about half a month to one month. That is why they have to buy from the local supplier for drinking water.

8. ***Are the storage capacities enough for domestic and agricultural supply? From your experience when there are shortages?***

For agricultural supply, farmers depend on both rainfall and water in the reservoir to cultivate their wet rice. We have never done the dry rice as we do not have enough water to cultivate it ever since. Besides wet rice, farmers do cassava as secondary crops. Yet, we do not know exactly how many hectares farmers are cultivating these two crops. Due to water shortage, farmers cannot grow other vegetables for sale; only for household consumption.

Normally, starting from March to June every year, water starts shortage. Currently, the water in the reservoir is not much available. Also we were told by the PDWRAM to conserve the water available now to prevent from water shortage, and thus dry rice cultivation is not allowed this year.

The reason that we lack of water to supply the agriculture due to the fact that we do not have another source of water to supply to the reservoir as this reservoir depends heavily on the rainfall. In fact this year the water in the reservoir is not full due to little rainfall. A whole commune consisting of 8 villages, all farmers rely on this water body.

9. ***Regarding the government's notification to conserve the water, by when can you release the water for farmers to use?***

Well, we still can use the water and release it to the canal for farmers to supply their crops; just not as much for dry rice; otherwise, it is used up and dried out. To release the gate, we need to ask for the authority to release this. For the water governing/management, I am the one who keeps the key to the gate. Whenever the farmers need water to supply their crops, they inform to me and I will report to PDWRAM and local authority.

10. ***How's the quality of water? How do you observe about the quality of it? Whether it contains sediment or arsenic?***

Yes, the quality is not so good as it contains sediment and it not safe to cook.

4.2 Maintenance and management

1. ***Is the irrigation system you manage small, medium, or large scale?***

The irrigation system that we are responsible for managing is considered as medium. The systems include a reservoir to store the water and a main canal which is 3km long for my responsibility. Moreover, the reservoir is 3km x 3km.

2. ***How often do you decide when to divert and apply water to land? What are your main management strategies to decide when and where water will be directed to?***

In my community, we need to go to see the site directly. When releasing the water, we go to see at the fields of the farmers. When it seems to be enough, we will close the gate. For example, previously the farmers in Chhouk village asked me to open the sluice gate, so that they access water to supply their crops for 7ha. Therefore, I had to go and see by myself of how much water I should have supplied. I did, but I couldn't measure how much was used. I just supplied the water for 2 nights constantly, for what I saw was sufficient for the crops, then I closed it back.

3. ***What are the main crops that the farmers are cultivating? And that the irrigation systems manage to supply to?***

The first priority of the crops that we supply the water to are water melon, maze, and vegetables. For water melon, farmers only need water to be supplied/fulfilled the canal; so that they can pump the water to apply on the crops by themselves. However, for wet rice we only depend on rainfall, and thus we do not need to open the gate to supply their wet rice. Normally, I open the sluice gate to release the water in between May or June as water is needed. Recently, after farmers broadcasted their rice fields, and the paddy did not seem to grow well, I managed to open the gate for them, and they were able to harvest it. Also, for cassava we do not need to open the sluice gate to supply the water to as this crop only depends on rainfall.

4. ***How do you ensure the irrigation systems are well-maintained?***

Based on my experiences to ensure that the irrigation systems are well-maintained, we have explained the farmers about the water use and have good cooperation with local authority very closely. Moreover, we have always solved the problems or challenges faced by the community through the collaboration with commune officials. Most importantly when facing any problems regarding the damage on the system, I always report to the PDWRAM, so that they can provide assistance accordingly.

5. ***What are the issues or challenges you have solved?***

The problem is that farmers have different needs of water. Farmers that are in need of water cannot access to water while those that do not need water have exceedance of water availability. We worked with the local authority to explain the farmers about our irrigation system works that some might have their rice fields located close to the canal and some do not.

6. ***Are there trainings for members of FWUC?***

Yes, there are. Lately, officials from MOWRAM came and provided a training on irrigation system O&M methods and also about income generation for the FWUC.

7. ***So far, has your FWUC generated income to support your community?***

In fact, for the 200ha of dry rice if we have sufficient water to supply to the farmers, we possibly can collect the fee from the farmers. However, we do not have enough water for them to cultivate dry rice yet. For the small farming or small crop cultivation when farmers need water, we have never charged the ISF from them.

So far our community is being financially supported through the contribution from farmers who depend on this irrigation system; yet the contribution is their good will not their obligation. And the budget from their contribution is reserved when the system needs small fixing.

8. ***Are there any particularly challenges often faced when governing and managing the irrigation system?***

Besides from what I mentioned earlier, there are challenges regarding farmers' knowledge. So far there has been a case that farmers broke the system (canal) to pump the water to catch some fishes for selling. Moreover, there is another issue as we recommended farmers to equip the sewage pipe along the canal to divert the water into their rice fields. However, they do not follow. Instead they damaged/cut the canal directly, so that the water runs to their fields without closing it after being filled.

Although we have the rights to fine those vandals, we think that because the limited knowledge of the farmers and our community has just been newly established. Therefore, we did not do anything but explained to them about the effects instead.

4.3 Environmental Challenges:

1. ***What have been the recent effects of flood and droughts on irrigation systems in your area?***

We encountered drought last year in July-August 2019. But then all of a sudden with the flood that rainy season brought in September 2019, it damaged the products of wet rice. As the intervention from PDWRAM during the drought event, we requested to PDWRAM to pump the water from the reservoir to our rice fields, and they did bring 5 electronic water pump machines. Some farmers were able to harvest after that while some could not.

There had been 15 different areas along the main canal being damaged by flood. But after reporting to PDWRAM, they have a quick intervention and help us on time. The reservoir has never damaged as the FWUC committee had a close inspection during the disaster event.

2. ***How about the damage on crops?***

That was a lot being damaged; only wet rice. But I do not know exactly how much damage. Also cassava crops were damaged as well due to the weather that was too hot. And once it rained, it just came in a flash. Thus, it was destroyed and costly because in one hectare farmers were trying many times to grow it. Once harvested, the yield was less than usual and the price was low.

3. ***Are you aware of environmental changes recently?***

Yes. There have been natural disaster events. Since December till this February, it has not rained yet even once. The dry season is longer than usual. Normally, these months would have been raining. Moreover, the rainfall pattern has changed as it rained for less days than usual and the temperature has been hotter and hotter.

4. ***Do you have strategies place to mitigate against this change?***

As recommended by the government to mitigate against this change, we are encouraged to construct more ponds, buy more jars, or tanks.

4.4 Farming community:

1. ***Do you hold meetings with the rest of the farming community to discuss irrigation system management?***

Yes, we do. We have held meetings with nearby communities; once or twice a year. We normally discuss about issues relating to maintenance and management of the water.

2. ***Do men and women partake in managing the irrigation system?***

More women partake in managing the irrigation system, as they take control over the inspection along the canal or the sewage pipes. Both men and women also paid a tour visit to other irrigation systems such as the one in Kampot and Pursat to see how other systems are working/functioning.

4.5 Recommendations:

1. What do you believe is needed to improve water management in your area?

Regarding water governance and management, FWUC must cooperate with the local authority to promote about the benefits of the irrigation systems to the farmers, so that they can help maintain the system. Moreover, we should collaborate with commune chief and PDWRAM regularly on any matters regarding water use in the community. We would like to ask for recommendation and good tips regarding water governance from all partners or government, so that we can improve ourselves. To seek for additional source to supply water to this recent reservoir through main canal. There is a nearby natural reservoir called Ang Phnom Ah Tor which store million cubic meters. Currently, there has been study conducted to bring water from that reservoir to the one in our community. Potentially, if the project is successful, our district will have enough water. That reservoir (Ang Phnom Ah Tor) has supplied water to Banteay Meachey and Siem Reap. Despite the fact that our district is located closely to the source, we cannot access the water from this reservoir.

5 OM5 - FGD with Sambour Meas AC

Date: 24 February 2020
Location: Sambour Mean village, Bansay Reak commune, Samrong town, OMC
AC – Sambour Meas Agricultural Cooperatives
Participants:

1. Pann Leng (M) AC Chief
2. Phonn Sinoun (F) Chief of Monitoring
3. Phorn Sophoeun (M) Village Chief/ Member
4. Seam Savuth (M) Accountant

1. How much land do you cultivate? (hectares)

As the whole community of the AC members, the rice field is 135ha and cassava accounts for 75ha. So far, no cashew planting reported as there is only 1-2ha that farmers have just started growing and have not harvested yet. From farmers' opinion, they want to grow cashew more, but that is just the plan. We have not talked deeply about it yet.

2. Do your family own the land or is it rented? From whom?

Those lands are owned by the AC members personally; not renting from anyone. On average, each member owns 3ha as some members own less than 1ha while others have around 10ha.

3. What crops do you grow?

As always, we have been growing rice and cassava, and have just started growing cashew. For rice, we only grow wet rice ever since because this area lacks of water to cultivate dry rice. We do not even have enough water for drinking. How can we cultivate dry rice? If I dare to grow 1ha of water melon, I am sure that I will not get anything back when harvesting because of water shortage. The water is almost out now. If the rain does not fall by April, we all must have no water to do anything at all.

5.1 Water Resource:

1. From your experience how many times is water applied to cultivate wet rice?

We grow wet rice during the wet season, and thus the crop heavily relies on the rainfalls. What we need to do during the rainy season is to build the dyke ready to store/keep the rainfall water in our rice fields. As always we depend on rainfalls to supply water to wet rice.

2. Is the rainfall sufficient for you to cultivate wet rice?

From 2016-18 the rain water was not enough for rice as it started to shortage by the end of the season – during the time we were about to harvest; and thus it caused the quality of the rice when harvested. However, only just recently in 2019 that rainfall seemed to be pouring down sufficiently for us to irrigate wet rice till end of the season and we were able to increase our yield compared to a few years early.

3. How about cassava? How many times do you apply the water?

In this area when growing cassava, we do not need to apply water on them. Normally, we start growing cassava in between January-February and we harvest it in December or January next year. Once we plant it, we wait for the rain to pour down on it. If no rain, it all goes bad. And if there's too much water/rain, it also damages the crops. Besides, farmers also grow vegetable gardens around their house for household consumption only.

4. ***On average, do you have sufficient water to grow these crops?***

No, we do not. In this area of this community, we do not have a source of water to supply to grow our crops. We only depend on rain. When it rains at the mountain in Thailand, the water flows to our area as well; however, we do not have any structure or weir to stop the water or to store the water during that time. As it rains, the water just flows wasted downhill because we do not have any structures to keep the water. We are close to Surin province of Thailand, but there's no water source from Thailand that we can benefit from.

5. ***How would you describe your access to water resources for a) agriculture and b) domestic use?***

It's very limited for both purposes. Honestly speaking in this area, we cannot use the water from the pond for drinking; we buy bottled water for drinking. Water from the pond is used for domestic use only such as cooking, bathing and washing the clothes. We do not even have access to clean water.

The water that we have access to contains the sediment due to the use of fertilizer during the cultivation period as well as the water flown from other areas to the ponds. The water supplier just pumps the water from those pond and supply/sell to us without having it purified.

Not all farmers drink this bottled water because they are not affordable to buy this water. Therefore, for those poor households they also boil the water they get from the pond.

6. ***How about the quality of the water? Has it been always this poor or just recently?***

It has always been like this ever since the pond was constructed.

7. ***How far do you have to travel to the nearest water body?***

It is between 200-300m to that pond that we get access water. There are three ponds in this community; however, one of them belongs to the school which is only to be used for the school purpose only.

While the other two of the ponds are (30x40m) and (30x20m) big.

8. ***Do you/farmers have strategies to conserve the water?***

Some farmers are able to buy or make water tanks to store the water. But mostly the farmers were supported by an NGO to build those tanks at home. Yet, its capacity to store the rain water is still not enough for using the whole season.

Only the rich people are able to afford the big water tanks/barrels which can store water up to 1000L-2000L; but that tank is so expensive.

9. ***Do you use stored water? From rain?***

Yes, we do. And it is only for domestic use not for agriculture.

10. ***What is the current status of the water infrastructure in the area?***

There is no existing water infrastructure in this area. There are only broken/old canals from the Khmer Rouge regime existed in this community, but it cannot help supply water for farmers at all as the canals do not have any sewage to convey the water to the fields. Once the water flows from the mountain, it goes downstream. There are only a few ponds in the area.

11. Does cooperation occur between the FWUC managing the irrigation systems and the AC's/farmers in general?

There was before. Although they shared their experiences or opinion, we cannot follow them as it is not feasible in our area. For example, even if we dig the pond 3m deep, the soil still absorbs the water and shortages it. We have no solutions. Unlike in other community that they have reservoir to store the water during the dry season.

So far that discussion that we had was with other AC and organization. As they conducted the studies here, and they said it is not feasible reflecting to their budget. Therefore, the project never happens here for help us with the irrigation system.

We also had meetings/discussions with FWUC as well, yet they could only advise us on how to manage the clean water as long as we could find the source of water to supply the irrigation system first. However, our problem is that we do not even have access to unclean water to use yet.

12. Areas for improvement/ recommendation on irrigation systems?

In this area, we need to have a sewage/structure to divert the water; otherwise, it damages the crops. If we build a reservoir, it affects hundreds of hectares of rice fields of farmers. We do not have budget to money to construct it.

Actually there are existing infrastructures from Khmer Rouge regime, but those structures are broken. If we rebuild them at those old places, we will be able to use the water by releasing the water with sluice gate. However, those structures have been completely broken as the water washed them away during the flood. In this area every year during the flood season, you cannot even walk due to the big flood. As the community is located in the uphill area, the flood comes and flows from the mountainous areas downhill.

However, if we have or build the sluice gate to open/close the gate of the water, we might be able to conserve water to use during the dry season. If there's too much water, we can open the gate and release the water to avoid damaging the crops at the other side of the gate. When there's water shortage, we can close the gate and keep the water. The structure should be built between 1-1.5km away from the community to conserve the water that flows from the mountain and Thailand.

If the structure was built, it would supply water to other farmers' land in other villages as well.

13. Is there any nearby water sources around your area?

No, there is not. So many kilometers away from this community, there is no water source as we are geographically located in the uphill area, and thus the water runs downstream from here.

14. Do you access groundwater via handpump, openwell or other?

We do. But the water is not usable as it contains arsenic, and thus we cannot even use it for shower nor drinking. If we irrigate the crops with this groundwater from the well, it will damage our crops too. However, if we only use it for washing the clothes, that is fine.

There are households having wells in the community too; but I cannot tell how many exactly.

There's no clean water supplier selling water in this area. We have to go to Samrong to get clean water. The NGO provided us the water purifier, so that we can use it to purify water for drinking.

5.2 Flood and Drought:

1. Has your land or household been affected recently by flood/drought?

Flood has never damaged any property or crops. Only just this recent year that farmers complained about too much water that destroyed some of their cassava crops. However, the rainfall brought enough water to the rice crops. The yield of the rice crop has increased better off than ever before. In fact, 3ha of land could produce up to 10 tons of rice. I think the reason that cassava crop got damaged because of too much water was probably due to the quality of the soil. Every year the cassava yield gives more production than rice. It's reverse this year. 2017 was the year that flood had damaged the rice crops; and also the infrastructure was flooded but not damaged. Mostly drought happens in August or September until most rice crops were destroyed. In 2018, rice crops were completely damaged, and then it rained at the end of the season which could make the rice grow a bit better for harvesting.

2. ***Is there any changes in rainfall pattern that has affected this?***

Of course there is. You see that since November until now, there's no rain. The small dry season is longer than usual. Moreover, the weather has changed as sometimes it was too hot or too cold.

3. ***Since there's change how have farmers adapted to these challenges?***

As I observe from the way the farmers live in these changing situations in climate, people get sick more than before. a few days ago, the weather was windy and cold that we put on many clothes when getting out, and now it is too hot. Although news broadcasted that there was rain in other areas nearby, it did not rain in my area here.

4. ***Do you get any information from the government such as flood and drought warnings? Or do they inform you about how to mitigate to these changes?***

Yes, we do listen to the news from media.

5.3 Climate Change:

1. ***How about trainings on environmental changes?***

We have received a number of trainings from the PDWRAM on how to adapt to the environmental change as well. However, it does not seem to work out. What they told us was to protect ourselves during the raining season like to not shade under the tree to avoid from the lightening.

2. ***Any strategies in place to mitigate against this change?***

The relevant partner also taught us about conserving the water during the drought to not use them wastefully, or pump the water to catch the fish; however, farmers did not listen to the warnings as they have to make a living and to make ends meet.

5.4 Decision-making/gender

1. ***What are the roles for men and women in relation to agriculture?***

They have involved in various activities equally. For example, as the wife is seed spreading, the husband helps put the fertilizers. Other females help the husband by carrying the seed or fertilizer from the dyke into the rice field for the husband as it is far to get. During the harvesting season, they both help each other and go to the rice miller together. The wife also helps cooking for husband when going to the field as well.

2. ***What about the level of participation of men and women in decision-making activities in the agricultural sector?***

About the level of participation varies from family to family. Some families seek for mutual agreement before making decision. In my case, we have to discuss with each other, especially about the price of the rice that the middleman offer when selling to them, and thus we talk to seek for agreement before we finally decide whether to sell or not. However, from my family experience I let my wife to decide on selling. Overall, we mostly discuss between husband and wife to settle down and equally share our opinion in order to avoid any arguments later.

5.5 Additional discussion:

1. ***How about the market of the rice in your area?***

This year the price has been fallen down. As the yield of the wet rice has increased, the price has decrease sharply. In fact, the price of the recent production was 1kg=800 riels. However, when the yield was low, we were able to sell the production at the price of 1000 riels per kg.

As we kept the rice in stock for longer, it starts to be lighter and thus we must decide to sell to the middleman in order to pay off the debt for the fertilizers and seeds that we bought earlier at the beginning of the season.

Whoever is wealthier, they keep the rice longer, so that the price would go up again. But for the poor, we must sell them to avoid the loss in weights.

2. ***Do you get the access to information about the price market of the communities nearby?***

It is the same as they sell at the same rice miller/middleman. The price offered is different from one miller to another.

Only those farmers/groups of farmers/communities who have been in contract with the private company or enterprise that got to sell their rice crops to them. Other farmers without contract could hardly sell their rice production with the desired price, as they could sell only to the middleman not the company. And the price is set by the middleman after they checked the quality of our rice.

So far as far as I know GIZ has cooperated with PDAFF to help ACs in term of building network between ACs to private company, so that farmers could sell their rice production to specified company with suitable price. By doing so, the networking group/federation will buy rice crops from the farmers in ACs directly rather than selling to middleman.

However, there was internal problems in the recent years that the private company/miller had been sub-contracted to another enterprise and they did not pay for what they bought from farmers. And thus the farmers do not trust the federation anymore.

As our final comment, I would like you to help us promote to other development partners to help construct irrigation systems in our areas/community, so that we have sufficient water to supply our crops to increase the production and have better livelihood.

6 OM6 - FGD with Beng Samaki Akphivot AC

Focus Group Discussion with Agricultural Cooperatives
Date: 25 February 2020
Location: Tumnup Chas village, Beng Commune, Samrong district, OMC
AC – Beng Samaki Akphivot Agricultural Cooperatives
Participants:

5. Yean San (M) AC Chief
6. Moeun Ly (M) Member
7. Sorn Dany (F) Accountant
8. San Poir (M) Secretary

1. ***On average how much land do farmers cultivate? (hectares)***

On average each farmer owns between 2-5ha of land for cultivating. Those lands are personally owned by the farmers; not renting. I personally have 10ha of land as I grow both wet rice and cassava which cassava accounts for 3ha.

2. ***What crops do you grow?***

There are only rice and cassava. Most importantly, only wet rice is being cultivated in this area as water is not sufficient to cultivate dry rice. As a matter of fact, dry rice requires much more water, and thus farmers must encounter water shortage before harvesting. In this community, we have never cultivated dry rice since the reservoir was broken.

There is a big reservoir located nearby the commune as it is known as Sciliem Reservoir. It was built since Khmer Rouge Regime and was broken. Recently it has just been being rehabilitated its main canals by the MOWRAM.

We are not sure how big the reservoir is; maybe 50m x 2km. We are not so sure as only the secretary was joining the process to measure the length of the reservoir. It was planned to conserve the fish by the NGO. It takes about 1km away from this village to the reservoir.

Figure 7. Sciliem reservoir located in Beng commune, was built in Khmer Rouge Regime.

6.1 Water Resource:

1. ***From your experience how many times is water applied to cultivate wet rice?***

Well, wet rice is cultivated based on rainfall. Without the rainfall, there's no water in the rice field.

2. ***Is the rainfall sufficient for you to cultivate wet rice?***

Sometimes, it is enough. But sometimes it does not. In fact, for the last two years (2018-19) rainfall was not enough to cultivate the wet rice as it normally does. The rain has not fallen down since October 2019.

3. ***How about cassava? How many times do you apply the water?***

Cassava crop also depends on the rainfall; yet if it rains too much, it also affects the crop.

4. ***When do you usually start growing cassava?***

Normally, if it initially rains in March, farmers will start growing right away in March. Otherwise, they wait until late May or June. I cannot start growing if it does not rain; otherwise, we will lose the stems that we grow. If we risk to plant when there's no rain, it will be very costly as we have to spend on the stem again and again, fertilizer, and labour.

5. ***How long does it take to harvest the cassava after growing?***

From my experiences if we have enough water at the beginning to start, we can harvest it after 8 months.

6. ***Besides these two crops, are there any other crops that farmers in your community are growing?***

Yes, farmers from her village are growing vegetables such as cucumber, morning glory, mungbean, and Pak Choi for sale, while farmers in my village can only grow vegetables for household consumption.

7. ***On average, do you have sufficient water to grow these crops?***

Those farmers who are living nearby the reservoir have enough water to grow those crops. But not those who live far from it. While in my village, we do not have sufficient water; even water for drinking. We have been trying to dig the well, but no water.

8. ***How would you describe your access to water resources for a) agriculture and b) domestic use?***

For domestic use, I can say water is enough to supply to our people but not for agriculture. We depend on rainfall.

9. ***How about those people living nearby the reservoir? Is there crop being sufficiently supplied with water?***

Although they live close to the reservoir, they are not able to get the water from the reservoir to irrigate their land as it is costly to pump the water to fulfil their fields; the rice fields are far from the reservoir. To be able to pump, we need to motor/machine, wire, access to electricity and labour.

In my village, there are wealthy households which they can afford to pump water into their private ponds for their personal purposes. However, there is no community property to get access to that water yet.

And even some villages do not even have sufficient electricity to use. How can they pump the water?

10. ***How far do you have to travel to the nearest water body?***

It is 1km away to get to the Sciliem reservoir which is the biggest water body here. Other water storages like ponds are located in the village.

11. Is there water in the Sciliem reservoir? And how would you get the water from it?

Yes, there is. However, as the government announced on conserving the water during the drought, now the sluice gate is closed to keep the water in the storage. Based on our experience, last year the water was released until the reservoir dried out, and thus this year they decided to store it.

Recently, people still have water in the ponds and other storages, and thus they have not gone to get access to the reservoir for domestic use. However, there's no irrigation system connected to that reservoir yet because the old main canal has just been rehabilitated.

Figure 8. The main canal is being under construction.

Figure 9. Sluice gate in Sciliem reservoir being closed.

Currently, when the sluice gate is open, it can only release water to supply the pond or creek or the rice fields nearby. However, if you wish to get water for domestic use, you can go and take it by yourself. There's nobody that you need to report to. The key to the sluice gate is given to the village chief in my village.

12. Do you/have there been any issues with water quality? Arsenic?

The water from the pond is not so good as it contains sediments. The quality of the water in this community is still usable for cooking, showering, and washing the clothes. However, for drinking water is commonly bought from the water supplier in the community.

Those suppliers also pump the water from the pond and sell in the village (1000L = 12000 riels). However, the ground water through pumpwell or openwell also make the rice yellow as cooking, and thus people stop using them for cooking anymore.

13. Do you/farmers have strategies to conserve the water?

There are only ponds and creeks in our community where we can rely on for water. Those ponds are 30m x 20m wide and are used to store the rainfall.

There are a few ponds constructed by the government; yet some are not usable as the soil quality is bad and thus the water cannot be used. Yet, in some areas the water in pond is good for people to use. The quality of the water varies due to the topography of the area.

Besides farmers have jars to store the rain water. Each household has between 3-5 jars; yet it is not even for domestic use.

14. Do you use stored water? From rain?

The stored water is only used to do the washing, cooking, and shower. Most people buy clean water sold by the local water supplier for drinking. While others have been using the water they can get from the well located near the reservoir.

15. What is the current status of the water infrastructure in the area?

There is a big reservoir and one main canal (earthen) stretching 5km away. This canal has the potential to supply water to thousand hectares of the irrigated areas during the wet season. The dry season is still not enough because we do not have a big reservoir to store the water.

16. Does cooperation occur between the FWUC managing the irrigation systems and the AC's/farmers in general?

No, it does not. The sluice gate is controlled by the village chief not the FWUC. The AC is located in Tumnup Chas village, while the authority who's in control of the key to the gate is from Sciliem and Kork Kabas village.

17. Areas for improvement/ recommendation on irrigation systems?

It is important to rehabilitate the ponds existing in the villages as it is too shallow to conserve water for their agricultural activities. Moreover, for the reservoir we should consider make its height higher to raise the capacity to store the water. I think the most possible and feasible project that can be done and prioritized is to construct and rehabilitate the ponds and creeks.

18. Do you have a piped water supply?

No, we do not.

19. Do you access groundwater via handpump, openwell or other?

Yes, we do. In some areas even we dig the well up to 100m, there's still no water. And the quality of the ground water is not as good as the stored water from rain.

20. Does information sharing occur between the farmers in your province to a) manage the water resources and b) to determine when and which crops are best to cultivate?

Regarding water management sometimes the village chief advises us to use the water carefully. In the last few years, he made announcement about the use of the water to save water as there was water shortage.

During the water shortage, we were advised to cultivate other crops that consume less water unlike rice. However, we can grow or cultivate other vegetables as long as we can get the water to supply them. Although having been advised by the local authority, only those who have been growing vegetables that would continue doing it. Those who have been doing rice and cassava do not shift to grow other crops as recommended.

6.2 Flood and Drought:

1. ***Has your land or household been affected recently by flood/drought?***

Talking about flood, Kork Kabas village is the most affected area in the last few years. Other villages besides Kork Kabas are doing fine during the rainy season; no flood. As the village located in the downhill of the dam, thus it is easily affected by flood.

Last year flood damaged a number of roads infrastructure in the community and a huge rice fields had been flooded. For the village that located close to the dam, the rice production had been almost completely damaged between 50-60ha.

Moreover, during the rainy season the reservoir is partially being affected as well. Therefore, there are still studies being carried out by the government to learn about its capacity.

On the other hand, it has been two years that the rice and cassava production has been affected by drought. However, we do not know exactly about the statistics of the land being damaged. Moreover, when selling the price has been dropped sharply. Rice is 600 riels/kg while dried cassava is 470 riels/kg.

2. ***Is there any changes in rainfall pattern that has affected this?***

Normally, it rains in April-May and a small/short dry season in July for 1-2 months. However, recently it has been dry/ no rain since October till now. Wet and dry seasons have changed unlike usual. It's more drought than rain in the last two years.

3. ***What have you witness as the main effects of recent a) flood and b) drought events on agricultural productions?***

Personally, I normally receive 6-7 million riels from selling rice and the same for cassava, and thus totally I would usually get 14 million after harvesting both crops. However, with the recent natural disaster event, I could hardly earn 4 million riels for both crops. After the recent drought, one hectare of rice or cassava could provide only 1 million riels to farmers. Talking about rice yield, normally in one hectare of rice after harvesting, I would get 20 sacks now I got only 5-6 sacks.

4. ***Since there's change how have farmers adapted to these challenges?***

We do not have any strategies in place. We wanted to mitigate these changes as well by conserving more water; however, the source of the water is far from our fields. If we pump the water, it is even more difficult as it is far and costly. However, we hope that we could have canals with sluice gate properly where we can open and close the gate whenever we need water to irrigate our areas.

5. ***Do you get any information from the government such as flood and drought warnings? Or do they inform you about how to mitigate to these changes?***

The government announces the warnings and shares information about flood and drought every year through the village chief; but no strategies or solutions given to farmers to mitigate these challenges. Just recently that there is a project to rehabilitate the main canal.

6.3 Climate Change:

1. ***Are you currently aware of environmental changes?***

Yes, we are. We normally inform our members about how these changes could cause effects on our livelihood and daily life activities. These changes had caused the farmers/community members with diarrhoea, dengue, and diseases on livestock.

Besides from farming, some families are also raising livestock. However, it is just a small percentage and only for household consumption.

2. ***Any strategies in place to mitigate against this change?***

Regarding livestock raising, we haven't received any technical trainings regarding vaccination or methods of raising them effectively yet because our AC has just newly been established for three years. There has been visits from the PDAFF and other development partners, but no proper trainings provided yet. We have already requested to PDAFF to provide on such trainings, but no approved yet. They only visit the community when there's a local assembly or we are being invited to the PDAFF office sometimes to join a meeting. Besides PDAFF, there are other NGOs like ADDA, READA, and CIDO that have been supporting us.

6.4 Decision-making/gender

1. ***What are the roles for men and women in relation to agriculture?***

Recently, the PDoWA (Provincial Department of Women Affair) has come and created a group of women to produce traditional Khmer costume to generate their income.

Regarding agricultural activities, women in this community do not involve much as there has been the use of the machinery at the field, and thus not so much involvement. However, some families also engage women in these activities like rice broadcasting. Moreover, when making decision about seed selection or selling, women and men take part equally to discuss before deciding.

2. ***Are there committees for men and women within your agricultural communities?***

Our committees have 4 female and 6 male members. However, recently some members have migrated to Thailand for work; and thus the remaining is less than 10 members.

6.5 Questions or suggestions:

Regarding water management, the water availability for agricultural activities is not enough for farmers. Although we have the reservoir to store the water, it is still insufficient for domestic use as the dry season is long as we long for water every day. If the rain does not fall until August, the water in the reservoir now will be dried out. It is important to construct more ponds in the community. Also we have completely no access to clean water. We initially wanted to start the business by generating clean water station in our community, but we did not have enough budget to do so. Another problem that we are facing is the struggle in selling our agricultural products as our AC has not been contracted with any private companies or enterprise to sell our products to yet. Despite being planned and drafted to PDAFF, we have not got any responses from them yet.

7 BM1 - FGD with Por Pi Derm FWUC

Date: 14 February 2020
Location: BMC, Mongul Borei district, Banteay Neang commune, Kourk Phnov village
FGD: FWUC (Por Pir Derm FWUC)
Participants: 4 (F=1)

1. Cheat Hov (M) FWUC Chief
2. Set Run (M) 1st Deputy Chief
3. Vat Channarong (F) Accountant
4. Pin Sokhorn (M) 2nd Deputy Chief

7.1 Water Resource Access:

1. ***How far do you have to travel to the nearest water body?***

We depend on Mongul Borei stream which is originally from Pailin province but there are 3 structures before getting water to our community. There's a main canal which stretches for 2km long and it is located 1100m away from the weir. Total number of secondary canal is 5300m. And there are tertiary canals which provide water directly to the farmers' fields. The farmers only need to pump from the closest canals to supply water to their fields. It is difficult for those whose fields are located around 700-800m from the canal to get water. And very few other farmers have their rice fields located 2km away from the source of water as well.

Well, to elaborate about the water status in this community is that there is no reservoir in this community. All structures receive water from the rainfall to fill in and the stream divert the water into those canals constantly.

The 3 structures we mentioned earlier are located in Ou Doun Poeu, Bavel, and Prey Kpos upstream before the water flows to our community, and thus it is not much water we have. That is our issue as there are larges rice fields at each section where water is diverted, and thus we encounter water shortage when the water flows from upstream is not sufficient for our community.

2. ***How do you distinguish between agriculture and domestic water? Are they different supplies? What is the source?***

As water flows and distributes from the main source, when it is stored and arrives Mongul Borei stream, we let it fully fill the secondary canals before diverting it to other communities besides ours. As the main canal is full with water, we let it flow to the other commune such as Banteay Neang, Srah Rean, and Kork Balang as these three communes rely on the same main canal.

We heavily depend on the water from Mongkol Borei stream for both agricultural and domestic uses.

3. ***Do you get access to groundwater through hand pump, open well or others?***

There are wells and handpumps at the village but owned by each household. Those groundwater is accessed by each household for domestic use only; not for agriculture. Yet, its capacity is still not enough for use. Mostly households use the clean water rather than groundwater. There are between 6-7 wells per village with 50-60m depth. However, in some villages groundwater is not usable after they pumped the wells as the groundwater level is very little. We do not mind whether its quality is good or bad, but there is no water coming out after pumping. Some farmers pump the well in the middle of the rice field, but still not sufficient water for them to use.

4. ***Do you monitor or are you aware of monitored ground water level?***

As FWUC, we cannot monitor the level of groundwater.

5. ***Do you have piped water?***

We do have piped water at every village now which is owned by private company. On average, one household uses up to 15m^3 per month (1m^3x2000r).

6. ***Are there many water storages in the area? What is the main method of water storage?***

We have ponds and lake to store water in the area. Once the main canal is dried out, there is no water in secondary or tertiary canals as well. Yet, so far we have never had experienced water shortage. Just this year (end of 2019) since October, there is no rain.

Besides, there are jars (appr.20 jars) at each house. Normally, there's enough rainfall for use. However, since October till now it rained only once recently.

7. ***Are the storage capacities enough for domestic and agricultural supply?***

Stored water is only available for domestic use unless water is stored in the pond that it is used to irrigate some crops such as corn, mushroom and other vegetables. Farmers here have been growing a number of diverse types of vegetables for sale (at the local market); not just for household consumption.

7.2 Maintenance and management

1. ***Is the irrigation system you manage small, medium, or large scale?***

This irrigation system is determined as medium scale. Under our supervision, the irrigation systems we are managing include one main canal, one secondary canal, and 13 tertiary canals; one weir at the stream and 3 weirs along the main canal.

2. ***How often do you decide when to divert and apply water to land?***

We do not determine when to divert the water. We supply the water based on their needs and seasons. We let the FWUG to manage when farmers need water; and they can just release the sluice gate for farmers to get access to water. Moreover, we notice that if the rain has poured enough for farmers, we do not have to open the gate to supply water for them. There are 20 FWUGs (blocks) that can decide to open or close the gate for farmers.

3. ***What are your main management strategies to decide when and where water will be directed to?***

If the water is sufficient, we supply the water to the neighboring communities/communes to use. However, if the water is not enough, we only supply when farmers request. We do not depend on types of crops to supply the water because all farmers grow rice at the same time and vegetables between Jan-Feb. Since rice requires more water, we supply more to the rice fields because vegetables do not need much water. The most important crop is rice and then corn, beans, long beans, and other vegetables for sale. Nowadays farmers tend to grow vegetables as it generates suitable income for them and high demand from the market. Some farmers bring their products to sell at the market directly, while some others have the middlemen coming down to buy from their farms.

4. ***How do you ensure the irrigation systems are well-maintained?***

To ensure the irrigation system to be well-functioned, we have put it in the 5 years plan of operation and maintenance. When the system is broken down, we contact the PDWRAM. When there is no flood and the yield of the rice is good, we collect the ISF from farmers twice to support the O&M process of the system. We ban the big truck from driving across the system to avoid the damage on the system. Farmers are doing another type of rice which they start growing from this

month of the year and harvest it in August. Then they start doing another one in November. It was fine during the last 5 years. Just recently that we have problem with water shortage.

5. ***Are there trainings for members of FWUC?***

There are trainings on vegetable growing techniques, water management and use, O&M and ISF collection, as well as the dispute resolution. We promote these kinds of activities at the village level through our committee members.

We share the information regarding water management and water use to farmers that to cautiously use the water when there's shortage. However, there are still problems as farmers do not fully comprehend the water management in the community, and thus it leads to dispute between farmers. For instance, those farmers whose rice fields are higher than the others try to pump the water, and it floods those lower rice fields.

6. ***Are there any particularly challenges often faced when governing and managing the irrigation system?***

There are challenges FWUC has faced such as to solve the problem of the farmers. Besides the tertiary canals are shallow, and thus actions to rehabilitate them are needed. To rehabilitate these tertiary canals, we used the budget from the community as we collected ISF from farmers. Sometimes we request more from PDWRAM, and the contributions from farmers.

7.3 Environmental Challenges:

1. ***What have been the recent effects of flood and droughts on irrigation systems in your area?***

In 2013-14, it was flood. However, this area recently experiences drought (Since October till now). The recent drought event has damaged rice and crops; the total agricultural land area is 1066ha. Moreover, it caused water shortage and decline in yield (before 1h=4 tons, now 1h=2.5 tons). Although it caused water shortage, it did not affect the irrigation system at all. Only if there's too much water, that would damage the system.

2. ***How has your management had to change to adapt to this?***

So far, we have requested to PDWRAM in Battambang to have a better water management in term of storing the water when farmers need the water in our commune, we can suggest PDWRAM there to release/divert the water for us who are living down here for domestic use when there's no more rain water.

3. ***How do you ration the water when there is shortage?***

To ration the water when there is a shortage, we turn off the pump machines power by the farmers. However, we cannot ban them completely as they need water to irrigate and cultivate their crops. Therefore, we let them pump completely from the stream/canal. When farmers visually witness that there's no water in the water body anymore, they do not dare to pump anymore. And we as the committees have to ask the PDWRAM in Battambang to release the water for us to use. Before we always had water available in the ponds and lakes. Just this year – with the drought and farmers cultivate large areas of rice, and thus they pumped all the water. Despite the fact that announced and informed farmers in accordance to the "Notification" from government on conserving and carefully using the water, the farmers still did not listen to us because they only wanted their yields to be good and more.

4. ***Are you aware of environmental changes recently?***

I am aware of environmental change and I realize that during the wet season, it starts late and finishes quickly. In September it flooded once last year and now it is different.

5. ***Do you have strategies place to mitigate against this change?***

To mitigate the climate change, we announced to the farmers to not grow rice for the 2nd phase and recommended them to do a short-term rice instead of the long-term one. But that's what we have done, whether they listen to us or not. We do not have any measures to stop them.

6. ***Do you get any information from the government such as flood and drought warnings?***

We did receive warnings and information shared by the government such as MOWRAM and PDWRAM on the nature events; as well as the Notification letter issued by the MOWRAM on preventing from growing rice for the 2nd time.

Normally, rain comes in October till end of November constantly and there were a few times flood. But now only once; and dry since September. In our community, we cultivate rice twice; and now we do not have enough water for the 2nd time cultivation.

7.4 Farming community:

1. ***Do you hold meetings with the rest of the farming community to discuss irrigation system management?***

We have meeting with CIDO organization and the FWUC network. Moreover, there's a meeting at Kampong Thom province that I attended to discuss with other communities with around 30-40 members during the general assembly on better water management.

We have a meeting once a year with the network during the assembly. Each FWUC has to pay to the network once a year as a member (250000 riels/year).

2. ***Do men and women partake in managing the irrigation system?***

Regarding gender, men have been more involved in physical work in the sector. Noticeably, there are also female chiefs at other agricultural communities as well.

Recommendations/Opinions:

-To rehabilitate the tertiary canals to supply water to their rice field.

-without canal, water is useless.

-PDAFF has encouraged us to not use chemical fertilizer; however, the price of the rice without using chemical does not reflect the cost of production.

-cost of rice production is higher than cost when sale. Nowadays a good type of rice can be sold at around $200/ton.

-should set a fixed price for rice to avoid the middleman to get benefits.

8 BM2 - FGD with Banteay Neang AC

Date: 14 February 2020
Location: BMC, Mongul Borei district, Banteay Neang commune, Kork Tunloap village
AC: Banteay Neang AC
Participants: 4 (F=1)
PARTICIPANT INFORMATION:

1. Orn Lay (Head of AC)
2. Song Loung (Member)
3. Kim Bunneour (Member of Monitoring)
4. Si Kimsoun (Deputy head of AC)

1. How much land do you cultivate? (hectares)

In our community, the cultivated land is 10 thousands hectares.
P1: I have 4 rai.
P2: I have 2 rai
P3: I have 2 hectares.
P4: I have 2 rai.

2. ***Do your family own the land or is it rented? From whom.***

We all own the lands. I own the land. But I don't cultivate. I rent to others.

3. ***What crop(s) do you grow***?

We grow rice. We also want to grow vegetables, but there's not sufficient water. Pond water became arsenic, not good quality. For vegetables, we want to grow for consumption.

8.1 SECTION A: WATER RESOURCES:

1. From your experience how many times is water applied to cultivate:

For rice, the water is applied twice in one season. We only cultivate dry rice. We cannot cultivate wet rice because we cannot do it alone. The yield is not good. The pests or insects cut the rice. And other farmers will surround to get all the water. We don't grow cassava or corn or sugarcane here. Some families grow them for consumption only.

2. On average, do you have sufficient water to grow these crops?

The water is insufficient. This year there's shortage of water.

3. How would you describe your access to water resources for a) agriculture and b) domestic use?

We get access to water resource through master canal flew from Angkor Borey river. If there's no water in Mongkul Borey river, we don't have water to use, either. The water resource is very limited. For this year, if we use, it is not even enough for 1 month. Some people pump the water into their own rice field. There's piped water supply for domestic usage for the villages along the main road. But for the villages far from the main road, villagers need to have their own wells. The villagers share the costs for digging wells.

4. How far do you have to travel to the nearest water body?

It is quite far, about 1km. If there's water, it's fine. But sometimes, there's no water.

5. Do you/have there been any issues with water quality? Arsenic?

There's no water quality. For agriculture, it's ok. But for domestic usage, it's not cleaned and safe. It's not like in the past that we could drink directly from the pond. But now, we cannot drink it unless filtered. The bad quality of water has occurred in the last 3- 4 years.

6. Do you have strategies to conserve water?

There're strategies, but other villagers/farmers are anarchic. There's no clear and proper management of the canals. If you want water, you must give money to the person who opens the water gate.

7. Do you use stored water? From rain? How many jars?

P2: We store rainwater in jars. I have about 20 jars. But there was no rain since September.

P1: When there's rain, I have pond and basin for family consumption.

P4: I pump the water from the stream, but I must filter the rainwater with sand and small rocks before using, otherwise it cannot be used.

Farmers think the rainwater is clean and safe. But for educated city people, they know that the water from above and below is not clean.

8. What is the current status of the water infrastructure in the area? (stengths/weaknesses)

Canal can be used to water the crops in the whole village/district, but there has been no rain. Someone closes Kamol river. Even the local authority cannot open it. Kamol river is the water from Angkor Borey river. When we do research, there are some rich people who have hundred hectares of rice field close the water gate to apply to their rice fields, but don't let the water flow to our side.

There's no reservoir. In Pol Pot regime, there was a Banteay Neang reservoir. No one rehabilitated it. It became the private land.

P3: I don't know the capacity of the master canal because nowadays, there's no water. If the commune project to rehabilitate each canal 1 meter, it can be used in the whole commune or district. But most importantly, there's no water.

The master canal flow through these 5 villages: Banteay Neang, Sareing,Ta Lorn, Kork Balaing, Au Prasat. And villagers in these villages try to take the master canal. They are violent.

Areas for improvement/ recommendations:

P3: I have one opinion. I am not so educated, either. The government strategy is to focus on peace, prevent war in the whole country. But they don't pay attention on building and managing the irrigation systems. There should be proper management of the gate of canal. Everyone has the tool to open the canal gate, so anyone can open it. There's no sharing.

9. Does cooperation occur between the FWUC managing the irrigation systems and the AC's/farmers in general?

There's no cooperation. Farmers aren't dare with the government agencies or local authority. The lawmakers come to our community, and farmers listen to them and believe them. The local authority or the government agencies don't care unless there's land dispute in the community. The government can find peace and liberate the country. How can't they build canal? It's because they don't want to.

10. How do you distinguish between agricultural and domestic water? Are they different supplies? What is the source?

For agriculture, we depend on Mongkul Borey river. And for domestic use, we depend on piped supply water, groundwater via wells, and rainwater reserved in jars.

11. ***Do you have a piped water supply***?

There is piped supply. But the supply isn't sufficient. We cannot use this water for cultivation. It costs 50 cents/m^3. The fee to connect piped network is about 300.000 Khmer Riel.

12. Do you access groundwater via handpump, openwell or other?

Yes, a lot of household have access to groundwater. Some areas got water from the ground, some don't. It's about 15-20% of the household in the community has access to handpump. The handpump wells are mostly built by NGOs.

13. ***Does information sharing occur between the farmers in your province to a) manage the water resources you and b) to determine when and which crops are best to cultivate?***

Provincial Department of Agriculture share the methods of cultivation, and also some trainings on what's the best crops to cultivate. However, the water resource is the main problem. Only the high position people can solve this problem. Even if we have water, there's no proper management.

8.2 SECTION B: FLOOD AND DROUGHT:

1. Has your land or household been affected recently by flood and or drought?

Yes, our lands have been affected.

2. What have you witnessed as the main effects of recent a) flood and b) drought events on:

There was flood in 2015-2016. The roads and the rice fields were flooded. Physical infra such as bridge and roads and household were also affected. We cannot determine how much it was affected. Only the local authority has the total data.

There was drought recently. Farmers fell into debt, haven't returned the payment yet. The local authority announced to farmers to not grow rice twice, but even we do it twice, we cannot pay back the debt yet.

Because of the natural disasters like flood and drought, the farmers have fell into debt and hunger. Some people lose houses and lands. Some migrate to work in Thailand as seasonal workers. Some migrate to work there permanently.

P3: I've noticed there's different patterns in rain fall in about 10 years. Cambodia is in tropical region, hot and humid. But now, it's not humid anymore. The soil is so dry.

3. How have farmers adapted to these challenges?

2 families spend their own money to dig wells and connect to electricity to water their cultivation. Other families have no solutions.

4. Do you get any information from the government such as flood and drought warnings?

The local authority informs about flood and drought, but no measures or methods to prevent it.

8.3 SECTION C: CLIMATE CHANGE:

1. Are you currently aware of environmental changes?

Yes, we are aware

2. Do you have any strategies in place to mitigate against this?

P3: We don't have any strategies. As I have observed, the cause is the depletion of forest. There's no water in our river in both dry and rainy seasons.

The relevant government agencies and local authority do not provide any assistance.

8.4 SECTION D: DECISION-MAKING/GENDER:

1. What are the roles for men and women in relation to agriculture?

Women also participate in cultivation process. But mostly men are more involved. men are more involved in choosing seeds, fertilizer, and stuffs. As for selling, it depends on the household. Some women help selling and manage finance. Women help with cooking and chores.

2. Are there committees for men and women within your agricultural communities?

There are no committees. It's just community helping vulnerable farmers/families with low or no interest rate. And our community also provide seeds for them.

3. What is the level of participation of men and women in decision-making activities in the agricultural sector?

On average, both men and women play important roles in decision making. It's 50-50. Some household, women are the lead because their husbands are busy drinking. Women are more participating in selling because they are good at bargaining and negotiation.

Level of participation: 1= very often, 2= often, 3= little often, 4= never

Activity	**Men**	**Women**
Cultivation	1	1
Selling	3	1

8.5 SECTION E: GROUP QUESTIONS AND SUGGESTIONS:

1. Are there any questions or suggestions the group may like to add on the topics discussed here today?

P1: The intention of establishing this community is for agriculture. And to do agriculture, water is the main factor. It's my request to the NGOs, and government to cooperate with the local authority to solve the water issue by building the irrigation system to develop the community and economy and improve the employability for farmers.

P3: I want to add a bit. Farmers depend on agriculture. And agriculture depends on water. I'd like to request to Ministry, Department and Office of Agricultural to inspect the fertilizers with standards. And if the fertilizers are already inspected, please put agricultural stamp on it. Moreover, please find market for farmers. We should close the import of agricultural products from neighbouring countries to promote our own agricultural produce and our local agriculture.
Private companies and department of agriculture raise awareness about fertilizers. In the beginning, it's good. But later without proper inspection and monitoring, the quality is decreased.

9 BM3 - FGD with Kork Romiet FWUC

Date: 13 February 2020
Location: BMC, Thmar Pouk district, Kourk Romiet commune, Srae La'or village
FGD: FWUC (Tumnup Srae La'or FWUC)
Participants: 5 (F=1)

1. Yean Sareth (M) Village Chief and FWUC member
2. Ourn Oeun (M) Secretary
3. Ung Nort (M) Commune council member and FWUC advisor
4. Ben Serey (M) FWUC Chief
5. Bin Orn (F) FWUG chief

9.1 Water Resource Access:

1. ***How far do you have to travel to the nearest water body?***

It is about 1km away to get to the nearest water body (reservoir) which is called Ang Srae La'or (1550m x 1650m). It takes about 10 mns to get there. Another water source is Kourk Prech (1000mx500m) which is 6-7km away from the village which its capacity to supply to the whole village if full.

2. ***How do farmers distinguish water for agricultural and domestic use? Are they from different sources/supplies?***

We supply the water based on their needs. Water is used to cultivate their rice and crops. Nowaday the water from the nearest water body is to cultivate dry rice and water melon which have been grown. For both purposes we rely on the same source of water from the reservoir as it flows to the dam downstream. Firstly, we release the water to flow from the reservoir (Ang Srae La'or) to Srae La'or dam to irrigate or supply to farmers.

3. ***Do you get access to groundwater through pumpwell, openwell?***

There are some wells in the villages to get groundwater; however, they are mostly done by private companies not by commune. The private water suppliers have equipped the pipe and provided the clean water to the farmers/people directly to their houses. They all depend on the water from the reservoir.

FWUC cannot tell how many liters per day the water is used from the ground. Also the piped water is owned by private enterprise and community members have to pay for it which is 3500r/m3 which on average spend around 50000r/month. Some farmers who are affordable can just pump the water directly from the stream to their storages for their usage.

4. ***Are there any storages besides the reservoir you mentioned?***

Addition to the reservoir, there is a pond nearby the pagoda which is 60mx80m. Besides, people are using jars to store water for domestic use. On the average, farmers have 10 jars per household for personal use. The stored water is used for drinking, cooking, and doing laundry.

5. ***In general, is the water sufficient for agriculture and domestic use in your community?***

It depends. Some years there is enough water, some there is not due to the rainfall levels. Some villages cannot get full access to this water due to the lack infrastructure (canal) to bring the water there. It depends whether the storage capacities are enough for farmers to use for either domestic or agricultural supply because they have different experiences in different years. However, recently in 2019 starting from May there is no water/rain. And the quality of the water is only usable for

bathing not for drinking. It had been 5 months that we were having problem with water shortage and its quality. However, it was flooded in July last year. Within the last 5 years, 2019 was the year that we experienced the water shortage quite seriously as the water dried out from the reservoir.

During the water shortage, we still had access to water in the stream and people pump/get that water to conserve in the jar and keep it for a while before using it for cooking or drinking.

9.2 Maintenance and management

1. ***What is the scale of the irrigation system you manage?***

In the village, the irrigation systems available are the medium scale. There are two irrigation infrastructures – Kork Prech and Srae La'or.

2. ***How often do you decide when to divert and apply water to land? What are your main management strategies to decide when and where water will be directed to?***

Mostly in one season, sometime we divert and supply the water once per month or per week. It depends on when water is needed by the farmers. FWUC is the one responsible for releasing the water for farmers, yet we do not do it regularly. If there's rain, we do not use much water from the reservoir. Only when there's no rain or shortage, that we use or release the water for people in the community to use. During wet season, we are able to supply the water to farmers while in dry season we can supply very little of the water which is only sufficient for domestic use only; not for agriculture. Farmers come and suggest us to open the gate of the water to supply for them based on the areas for a number of days.

During the rainy season, the water is enough for cultivation. However, we have to open the gate to release the water during the dry season to cultivate dry rice (3-4 ha) and domestic use and small gardening/crops growing.

In fact, if farmers have a big plot of lands which requires large amount of water to supply, they will come and request the committee members to release the water for them. From their suggestion, we have a meeting within the committee members to make decision and then we announce to whole community. For example, when we decide to divert the water to the earth part and for how long – a week and then to the other direction, that we all need to inform the farmers to know in prior.

When and where to divert the water is based on the season, while in fact rice demands most water among other crops (cassava does not require water to cultivate only rely on the rainfall) and then beans and household consumption. PDAFF has suggested to grow water melon in December as it does not consume much water as rice.

3. ***What are the main crops that the farmers are cultivating? And that the irrigation systems manage to supply to?***

The most significant crops that the irrigation systems we manage to supply are wet rice, beans and water melon. However, the water is not enough to supply dry rice.

4. ***How do you ensure that the irrigation systems are well-maintained?***

We use the O&M budget, contributions and ISF from the farmers as well as collecting from those who have the big machines and depending on the water to use this money to repair the systems. The systems are well-maintained unless the farmers fully understand about the policy and works of the FWUC, so that they can participate or contribute more. So far, farmers do not really understand about the effective use of water. For instance, some farmers whose fields are very far from the water source requested us to release the water to their fields, and when the water is not running sufficiently as they need, the disappointment and dispute occurred.

5. ***Are there trainings provided to FWUC members?***

Yes, there are. MOWRAM has conducted a number of trainings on water management and water use for FWUC. Since 2016-2018, MOWRAM was always the one that came and provided the training. There was VSG organization who came to teach farmers about types of crop to grow, pricing, livelihood generation, and hygiene and water use participation from the farmers.

6. ***What are the challenges that the FWUC has experienced?***

The challenges FWUC has faced in governing and managing the irrigation system are: farmers are mad when requesting for water and we cannot fulfil their needs, lack of irrigation systems such as canals, canal construction affects their rice field, FWUC do not dare to ask for the ISF from the farmers as stated in sub-degree.

9.3 Environmental Challenges:

1. ***Are you aware of the environmental changes? What have been the recent effects of flood and droughts on irrigation systems in your area?***

The effects of recent flood have caused the flow in the reservoir which damaged the dam and the farmers were helping to reconstruct it. Flood has damaged a number of cultivated land of about 25 ha of rice and 37 ha of cassava. Infrastructure/ housing has not been severely damaged as before. While during drought, it led to fish and other aquatic animal shortage and almost all types of crops have been completely destroyed. In fact, during the flood time in 2019, it caused the damage in the reservoir, and the FWUC and community members helped each other on time and restore it.

2. ***Do you have strategies place to mitigate against this change?***

Since there's drought, we heavily depend on the rain. So far, we have promoted about this to the farmers and suggested them to use water carefully; not wastefully. FWUC has been aware about the environmental changes through training provided by the NGOs. Normally, it started to rain in April. But now it has been drought/no rain since September 2019 till now. The drought is longer than usual.

The government did announce and share the information on the flood and drought warnings to the community about the climate change through circular. FWUC does not hold a regular or official meetings with other communities unless there are issues or problems happening in the community, that the partners or NGOs would hold a meeting once a month.

Women participate more than men in term of O&M. Within FWUC, there are 19 members with 6 female members.

Suggestions/recommendation/opinion:

Seek for more development partners to help the community, especially the budget to strengthen the capacity of FWUC since ISF is not enough. Also to rehabilitate the irrigation system in the community. Government to help teach the farmers about effective use of water more often. Construct more canals to bring water from the source to nearby village – Ta Song village. Also, there's lack of support to financially help the institution of FWUC.

10 BM4 - FGD with Kork Romiet AC

Date: 15th February 2020
Location: Thmei Village, Kork Romiet Commune, Banteay Meanchey
AC: Kork Romiet Chork Chey

1. How much land do you cultivate? (hectares)
P1: I have 2 rai.
P2: I have 2 hectares.
We cultivate in about the same amount of land.

2. Do your family own the land or is it rented? From whom?
The lands are ours.

3. What crop(s) do you grow?
We grow cassava and wet rice. For rice, we do once a year. Only wet rice can be cultivated here because there is not enough water resource during the dry season. Terrain is for cassava plantation, and lowland is for growing rice. Besides these main crops, we don't grow other crops because there's not enough water to cultivate.

10.1 SECTION A: WATER RESOURCES:

1. From your experience how many times is water applied to cultivate:
Around May, June or July, we must start sowing rice seedlings, even though there's no rain. Otherwise, it'd be too late for wet rice season. For cassava, there's no specific season. It can be grown in any season. Cassava yields in about 8-10 months.

2. On average, do you have sufficient water to grow these crops?
Before, it was enough. But starting from 2018, 2019, there wasn't enough water. If there were enough water in 2019, we would gain some yields. We rely on the rainwater, the pond and water from Thailand. In rainy season, they open their canal. But there's none in dry season. In Thailand, they have irrigation system.

3. How would you describe your access to water resources for a) agriculture and b) domestic use?
It's limited. The water is enough for domestic usage. As for agriculture, we rely on rainwater.

4. How far do you have to travel to the nearest water body?

In this village, there's only this pond, which is the biggest. It's about 100 meters from the village.

5. Do you/have there been any issues with water quality? Arsenic?
There's no safety. It can be used for bath, but not for drinking. For drinking water, we buy from private providers. 1 bottle – 50 cents

6. Do you have strategies to conserve water?

We store water in jars.

7. Do you use stored water? From rain? How many jars?
Each family has around 2-10 jars.

8. What is the current status of the water infrastructure in the area? (stengths/weaknesses)

In our community, there's no water infrastructure like irrigation system or reservoir. There's only ponds. The capacity of pond is about 200.000 m^3. We think it's impossible to have irrigation system because the distance from village to rice field and plantation are pretty far.

9. Does cooperation occur between the FWUC managing the irrigation systems and the AC's/farmers in general?

We've never heard of it before. And we've never had any cooperation with other community or other agricultural groups, either. There's only this community which was established in 2015. In the beginning, we met quite often. There were a lot of meetings on savings strategies. But we haven't met for the last 2-3 years.

10. How do you distinguish between agricultural and domestic water? Are they different supplies? What is the source?

For agricultural, we rely on rain. And domestic wate, we rely on wells and pond.

11. Do you have a piped water supply?

No, we don't have piped water supply.

12. Do you access groundwater via handpump, openwell or other?

Yes, we do have wells.

13. Does information sharing occur between the farmers in your province to a) manage the water resources you and b) to determine when and which crops are best to cultivate?

No, never. We live far away from each other. If we meet sometimes, we only ask each other about how's the rice and cassava. Last year, the authority requested to farmers in our community to share the cost of lifting the canal to fill the water in the pond. But until today, there is no progress. They said the money isn't enough yet.

10.2 SECTION B: FLOOD AND DROUGHT:

1. Has your land or household been affected recently by flood and or drought?

Yes, everyone has been affected.

2. What have you witnessed as the main effects of recent a) flood and b) drought events on:

There was flood around 2013 or 2014. It affected cassava and rice. And it made the crops rotten. The road was also destroyed. We don't have the data of the effects, only the local authority knew about it. Actually, the damage wasn't huge. The farmers affected little. P4: It instead provided a good yield of rice. Because my rice field needed water. The recent drought was in 2019. For drought, it affects a lot. The rice yield was low. Before, per 5-6 hectares, we could get 10-15 tons. After drought, we couldn't even get 3 tons. I am not complaining. I'm just being honest. The cassava was also affected. The money was lost, including labor cost and the cost of fertilizer. The market was also affected. The price went down for both rice and cassava. The quality wasn't good, either. The cassavas were so small. The good quality rice is 8 thai baht per kg. In the beginning of the season, cassavas are 2 thai baht per kg. But the price decreases to about 1.30-1.70 thai baht/kg when it is to seasons. The market price depends on the mouth of the middlemen. The price goes down to 1.30-1.50 thai baht/kg when it's a rich season. The price of dried cassava is 4.1 thai baht or 4.2 thai baht or 4.3 thai baht per kg depends on them. It's hard for the price to go up, but it's so easy for the price to go down. In one day, the price can go down very easily. It totally depends on the middlemen.

3. How have farmers adapted to these challenges?

We haven't really discussed about how to solve the challenges that we faced. Before, during the community meetings, we used to discuss about buying the produce from the farmers. But it wasn't possible.

4. Do you get any information from the government such as flood and drought warnings?

There's announcement from the local authority that this year there'd be drought, so farmers and people should store/conserve the water in the village. We did as informed, but the pond is dried by itself. There's no assistance from the government, just announcement.

10.3 SECTION C: CLIMATE CHANGE:

1. Are you currently aware of environmental changes?

We've heard about it from TV announcement.

2. Do you have any strategies in place to mitigate against this?

We don't know how to mitigate. Planning tree is the only option.

10.4 SECTION D: DECISION-MAKING/GENDER:

1. What are the roles for men and women in relation to agriculture?

P4: In the morning, my husband goes to the rice field to plow. In the afternoon, he takes the seedlings to sow. And I cook and deliver the food for him.

P3: For rice cultivation, mostly men take more roles than women. For cassava, both men and women help each other. For harvesting and selling stages, we both take part in them. Some women take part more in selling, depends on the family. Women don't mind. We do all types of tasks ranging from chores, to harvesting and selling.

Tick where both sexes involved

Activity	**Men**	**Women**
Rice cultivation	☑	
Cassava plantation	☑	☑
Harvesting and selling	☑	☑

2. Are there committees for men and women within your agricultural communities?

No, there aren't any committees.

3. What is the level of participation of men and women in decision-making activities in the agricultural sector?

Women, of course. The level of participation of women is 1, and men is 3. Because men are busy.
Level of participation: 1= very often, 2= often, 3= little often, 4= never

Activity	**Men**	**Women**

Cultivation of rice and cassava	**3**	**2**
Selling the produce	1	1

10.5 SECTION E: GROUP QUESTIONS AND SUGGESTIONS:

1. ***Are there any questions or suggestions the group may like to add on the topics discussed here today?***

We want to request wells per family. But it's difficult as it's quite deep to reach the water resource. But it'd be better to have a basin to store rainwater. We'd like to request for 1 basin per family.

11 BM5 - FGD with Phkaom AC

Date: 15th February 2020
Location: Phkaom Commune, Banteay Meanchey
Participant's information:

1. **Oung Eat (Head of AC)**
2. **Rach Cheat ()**
3. **Siev Yer (Head of Finance)**
4. **Kanharith (Head of Monitoring)**
5. **Seur Seuk (Deputy head of Monitoring)**
6. **Oun Sarouth (Member of AC)**
7. **Nem Chan (Deputy head of AC)**

1. How much land do you cultivate? (hectares)
Each family has about 3 hectares of land for cultivation.
2. Do your family own the land or is it rented? From whom.
It's our own land.
3. What crop(s) do you grow?

We grow rice and cassava. We only grow wet rice because there's no irrigation system. The main crops for each family in our community are rice and cassava.

11.1 SECTION A: WATER RESOURCES:

1. From your experience how many times is water applied to cultivate:

In fact, my community cannot do agricultural intensification. We totally depend on the rainwater. We're not successful in growing rice. We don't have water to pump into the rice field unless there's rain. For cassava, it's like rice. We don't need to apply water. We depend on the nature.

I just start growing vegetables about 1 or 2 rai. It's for consumption and can also supply to nearby communities. There's a river nearby my plantation, so I can pump the water in. But other families haven't started this yet.

2. On average, do you have sufficient water to grow these crops?
On average, our cultivation isn't successful. The yield in 1 hectares is about 1.5 tons. But if there's rain in the beginning of the year, the yield is about 2-3 tons. We've noticed that the yield has decreased for the last 2-3 years, since 2018. For cassava, it's the same. The yield has decreased for the last 2 years. Before we gained 30 tons, but for the last 2 years, the yield halved the yield before, only 15 tons.

3. How would you describe your access to water resources for a) agriculture and b) domestic use?
There's shortage of water resources for both agriculture and domestic use. Here, we don't have water station. We buy water from private providers for domestic use. It's not really clean. We have the big pond, but we don't have water pumping machine to pump the water to each household. We don't have any irrigation systems. We only have the pond, small stream, small dam, and river. The pond is enough for the wet rice, but we don't use it to water the rice. It's just for domestic use. The water from the river is used to water the vegetables.
4. How far do you have to travel to the nearest water body?

It is about 50 meters from the community. The pond is for the domestic use in the village. It cannot be used to water the vegetables.

5. Do you/have there been any issues with water quality? Arsenic?

This year, there're some issues that affect the rice. When the water was pumped into the rice field, it made the rice rotten. The insects were attracted to the uncleaned water and destroy the rice. But not all the rice field were affected.

6. ***Do you have strategies to conserve water?***

For agricultural use, when the rainy season is over, there's no more water. As for domestic use, we use wells. But not all household have wells. The water from the wells is sufficient for domestic use. The water source is shallow. We dig only 15 meters to reach the water source. The quality is ok; it can be used.

7. Do you use stored water? From rain? How many jars?

We have jars to store rainwater or water from private providers. Each family has around 4-5 jars.

8. ***What is the current status of the water infrastructure in the area? (stengths/weaknesses)***
There is no irrigation systems in this community. There are only old streams that our ancestors dug. Areas for improvement/ recommendations: The fund of the commune is very limited. It is used to build the small roads in villages and commune. The project to rehabilitate the canal or stream doesn't work. There is lack of cooperation and assistance from the government and NGOs. We don't know who to contact for help. There's a partner organization that we were in contact to build water station. But at that time, our pond wasn't full enough. However, the Department of Rural Development announced a new project to ensure the sufficient of water by 2023. They don't allow any NGOs to help the community because they think that it's in private form. Other communities already implemented this project.

9. Does cooperation occur between the FWUC managing the irrigation systems and the AC's/farmers in general?
There's no FWUC in our community. Therefore, there's no cooperation between the FWUC and the AC. But the nearby community, there is this organization running.

10. How do you distinguish between agricultural and domestic water? Are they different supplies? What is the source?

The agricultural and domestic water are from different sources. Like I said earlier, for agriculture, we depend on the rainwater. And for domestic use, we depends on the pond, wells.

11. Do you have a piped water supply?
There's no piped water supply in our community.

12. Do you access groundwater via handpump, openwell or other?

Yes, we have access to wells.

13. Does information sharing occur between the farmers in your province to a) manage the water resources you and b) to determine when and which crops are best to cultivate?

In this community, we used to have discussion on finding the markets before the cultivation. If we produce before finding the market, the middleman will try to decrease the price. We're also learning about the production chain to find markets with proper contract for our community. The partner organization helps us to strengthen the understanding of the production chain to prevent price depreciation. When we form a community, we research on the demand of the companies then we produce. We have a meeting plan. In January, we had a meeting on a poultry group. In February, we had a meeting on closing the account and prepare for the annual meeting. In March, we are going to have a meeting to determine the best crop seeds and find the buying partners.

11.2 SECTION B: FLOOD AND DROUGHT:

1. Has your land or household been affected recently by flood and or drought?

Yes, we have been affected. We have witnessed the natural disasters quite often. We also faced storm. In 2018, we faced storm, and a bit drought.

2. What have you witnessed as the main effects of recent a) flood and b) drought events on:

It's hard to describe because we don't have irrigation systems, so the rainwater flows away. Some family has a lot of rice field, but the yield wasn't good. For instance, some years, I cultivated 10 hectares of wet rice, but I only got 200.000 to 300.000. Because we don't have irrigation systems. For draught, we have faced 2 years. The yield decreases. Moreover, it affects the living conditions of the family. They migrate to other neighbouring countries, and some fall into debts.

3. How have farmers adapted to these challenges?

There're no solutions because the farmers are quite traditional. The farmers complain to each other. We used to prepare 3-year workplan; however, our farmers did not have an understanding about it. So, it's like we didn't do anything. When we finished to workplan, we submitted to the Provincial Hall, waiting to hear from partner organization. However, we've never been successful. There was no assistance from government or any organizations.

4. Do you get any information from the government such as flood and drought warnings?

Yes, I got information from the government. They also give the phone number.

11.3 SECTION C: CLIMATE CHANGE:

5. Are you currently aware of environmental changes?

I've heard about it through information spreading through phone.

6. Do you have any strategies in place to mitigate against this?

I don't have any idea. I don't really understand about this issue. No organizations have trained about this issue yet.

11.4 SECTION D: DECISION-MAKING/GENDER:

7. What are the roles for men and women in relation to agriculture?

Regarding this, the participation of men and women in technical meeting is equal. For my community, both men and women participate equally in agriculture. As for selling, women are most likely to take lead because they have techniques to bargain. The gender equality in my community is well balanced. There is no training on this issue, but it is the customary practice from our ancestors.

Activity	Men	Women
Cultivation process to harvesting	☑	☑
Selling the produce		☑

8. Are there committees for men and women within your agricultural communities?

In the committee, there are a greater number of men than women. We don't want men to be in a greater number. It's because of the election. Men stand for election. There are a few women who stand for election, as well. But some women are lack in capacity. There are 2 women of my community in the committee. Nevertheless, in poultry group, the members are all women.

9. What is the level of participation of men and women in decision-making activities in the agricultural sector?

The level of participation of men and women in decision-making activities in the cultivation process is equal. Women are more likely to take up more role in decision-making activities, including cooking. For selling, I'd like to clarify about the custom of this community. Raising poultry, pigs and the rice, it's women's role to decide on whether to sell or not. Raising cows, horses, elephants, motors and cars it's the men who decide on whether to sell.

Level of participation: 1= very often, 2= often, 3= little often, 4= never

Activity	**Men**	**Women**
Cultivation process	1	1
Raising and selling poultry, pigs	4	1
Selling rice	4	1
Raising cows, horses, elephants	1	4
Selling motors and cars	1	4

11.5 SECTION E: GROUP QUESTIONS AND SUGGESTIONS:

10. Are there any questions or suggestions the group may like to add on the topics discussed here today?

Request: We'd like to request for assistance from any NGOs to help rehabilitate the stream. We also want a water station for domestic use. That is a request to the government or any NGOs. Please help spread this request to the government and NGOs. We're facing poverty issue as our community has just started. We're lack warehouse to store agricultural produce and office for community. We'd like to request to build irrigation systems such as master canal or streams. We're lack water resource. Other communities have water resource that's why they are succeeded in cultivating dry rice. We can only do wet rice. I also want to request the organization to speed up the licensing application form for my community from the Department of Agriculture. If we don't have the license, we're worried that we cannot gain the confidence from private sectors or partner organizations.

12 BM6 - FGD with Samrong AC

Date: 14th February 2020

PARTICIPANT INFORMATION:

5. Yem Sokhorn (Head of Community)
6. Eb Yai (Financier)
7. Snga Roul (Monitor)

1. How much land do you cultivate? (hectares)

I have 5 hectares of land (P1). Rice
I also have 5 hectares of land (P2).
I have 10 hectares of land (P3). Rice

2. Do your family own the land or is it rented? From whom.

It's our own land.

3. What crop(s) do you grow?

I grow rice during both dry and rainy season. Other than that, I grow mango for my own consumption. And I also do some fishing along the canal. I produce seed rice.

12.1 SECTION A: WATER RESOURCES:

1. From your experience how many times is water applied to cultivate:

This year, there is not enough water applied to cultivate. Normally, during the season, there is flood, so there is sufficient water applied. When there's sufficient water, I pump the water to wet rice field 2 or 3 times. For this year, I dig the pond to reserve the water. All members do that, but it's not enough for use. For dry rice, I pump the water into the rice field 2 times. This 2 times is when there's some rain also.

2. On average, do you have sufficient water to grow these crops?

There's not sufficient water to grow rice, particularly the cultivation of dry rice. The insufficient of water has happened about 2 or 3 years, and we couldn't get good yield from dry rice cultivation. But as for wet rice, it has been ok. However, this year, we don't have enough water for both dry and wet rice.

3. How would you describe your access to water resources for a) agriculture and b) domestic use?

The water resource is still very limited for agriculture. We do the cultivation depending on the sky.

As for domestic use, we have sufficient water to use. We never lack of water for domestic use.

4. How far do you have to travel to the nearest water body?

The nearest water body is about 4 km from Samrong village.

5. Do you/have there been any issues with water quality? Arsenic?

This year the water quality is strange. When the water touches the rice, it makes the rice rotten quickly. It canot be used, unless filtered.

6. Do you have strategies to conserve water?

We dig ponds and some families use groundwater via openwell.

7. Do you use stored water? From rain? How many jars?

We also store rainwater for domestic use. Each household, there are 5-6 jars.

8. What is the current status of the water infrastructure in the area? (stengths/weaknesses)

The irrigation systems such as canal are not effective for rice. These days, farmers are not knowledgeable about irrigation systems. They fill the lands in the canals, that's why, there's shortage of water resource. And there are disputes to open the canal. And if we want to open canal, we need to spend our own money. The main water resource is from Thailand, from the river near the border called Khai Don and Kanseng reservoir. We mostly receive water from Khai Don river. When they have surplus of water, they will let it flow to us. The old canals should be rehabilitated for agricultural use. Those old canals were built during the Pol Pot regime. We have enough irrigation systems during the Pol Pot regime.

9. Does cooperation occur between the FWUC managing the irrigation systems and the AC's/farmers in general?

There's not FWUC in my community

10. How do you distinguish between agricultural and domestic water? Are they different supplies? What is the source?

For both agricultural and domestic water, we use rainwater, and water flow from Khai Don river.

11. Do you have a piped water supply?

No, there's no piped water supply in my community.

12. Do you access groundwater via handpump, openwell or other?

We access to groundwater via openwell. Sometimes, there's no groundwater if we didn't dig at the right water resource spot.

13. Does information sharing occur between the farmers in your province to a) manage the water resources you and b) to determine when and which crops are best to cultivate?

There's no information sharing between farmers. When there's shortage of water, the farmers request the head of commune to open the water canal.The local authority allows farmers to pump water from canal and river when there's insufficient of water.

12.2 SECTION B: FLOOD AND DROUGHT:

1. Has your land or household been affected recently by flood and or drought?

Yes, our land and household have been affected by flood and drought. The flood occurred in 2011, 2012, 2013. Drought occurred in 2019.

2. What have you witnessed as the main effects of recent a) flood and b) drought events on:

A) During flood, rice was totally destroyed. There were no canals or reservoir to release water. B) For drought, it affects a lot. The commune also has some information about the effects of the drought. We did the dry rice twice, but we couldn't get any yields. For the yield we used to get 4 tons, it decreased to 2 tons.

3. How have farmers adapted to these challenges?

We don't have any solutions as we grow rice, depending on rainwater.

4. Do you get any information from the government such as flood and drought warnings?

We follow the news on weather announcement. We also follow the government announcement through facebook. There are also some warnings, but they never reach us.

12.3 SECTION C: CLIMATE CHANGE:

3. Are you currently aware of environmental changes?

Yes, we are aware of the environmental changes.

4. Do you have any strategies in place to mitigate against this?

The Department of Agriculture prepare the seeds to adapt to the climate change. For us, we are advised to plant a lot of trees. If we have proper irrigation systems by rehabilitating the canals and river, it'd be a lot of help to us.

12.4 SECTION D: DECISION-MAKING/GENDER:

1. What are the roles for men and women in relation to agriculture?

Tick where both sexes involved

Men and women have the same role in agriculture. Women clean/remove grass, clean seeds, and cooking. Men who have more strength, do the plowing; and anything that is heavy. Women are more involved in light tasks.

Activity	Men	Women
Cleaning grass, cleaning seeds, cooking,		☑

Plowing	☑	

2. Are there committees for men and women within your agricultural communities?

Yes. They disseminate information or training relating to agriculture, and bookkeeping, etc. The information sharing/training is once a month.

3. What is the level of participation of men and women in decision-making activities in the agricultural sector?

The level of participation of both men and women is equal. We always discuss with each other in any activity relating to agriculture.

Level of participation: 1= very often, 2= often, 3= little often, 4= never

Activity	**Men**	**Women**
Choosing seeds	1	1
Selling the produce	1	1

12.5 SECTION E: GROUP QUESTIONS AND SUGGESTIONS:

1. Are there any questions or suggestions the group may like to add on the topics discussed here today?

There should be more irrigation systems built in this community to avoid any disputes between the farmers. The local authority must have proper water management and allow the water to be opened. When there's monthly commune meeting, the issue of irrigation systems has never been raised, only the issue on building roads.

BMC	**Kuok Romiet FWUC -** Srae La'or village	**Kuok Romiet AC**	**Banteay Neang FWUC -** Kourk Phnov village	**Banteay Neang AC**	**Samroang AC**	**Phkoam AC**
Distance to water body	Ang Srae Lor reservoir is 1km away, Kourk Prech reservoir is 6-7km away.	100m from village	100m from village. Depend on Mongul Borei stream.	1km. If there's no water becomes more laborious.	4km from village	50m from village (pond)
Crops	Wet rice, watermelon , beans. Not enough water to supply drry rice.	Wet rice, cassava (yield 8-10mths) Not enough WR for dry rice. Terrain=cassava, lowland=rice. Most farmers own around 2ha.	Crops in order of importance: rice, beans, corn, long beans and veg. Supply more water to the rice fields as veg doesn't need much water.	Rice: only dry as cannot do wet rice 'alone' Bad yield-pests/insects. Try to grow veg but insufficient water. Cassava/cane/corn not grown unless hh. Community= 10,000 ha, individual: 2-4ha.	Dry+ wet rice, mango for hh. 5-10 ha per hh.	Wet rice +cassava. Each family around 3ha.
Water status	Insufficient water, since May 2019. Insufficient for dry rice. Having problems for the past 5 months.	Insufficient water, since around Sept/ Oct 2019 (agri) .	Insufficient, since Oct 2019 only rained once. Heavily depend on water from Mongkol Borei stream. Wells and handmpumps for domestic but most households buy clean water.	Insufficient. Shortage 2020. No rain since sept 2019. No water to fill the canal, or rainwater filling the ponds. Competition over WR. Not enough for 1mth.	Insufficient for dry rice, limited for agri around 2-3years. 2020 not enough rainwater for wet rice. domestic fine	Insufficient. Shortage for agri and domestic. Pond enough for wet rice but needed for domestic. NOW: YIELD=1.5tons/ 1ha. If rain = 2-3. yield declined for both crops
Domestic vs Agriculture	Agri= rainwater/irrigation if available. Domestic= ponds, wells, groundwater, piped. Water body has been used to cultivate dry rice and watermelon.	Agri= rainwater/irrigation if available. Domestic= ponds, wells, groundwater.	Agri= rainwater/irrigation if available. Domestic= ponds, wells, groundwater, piped.	Agri= rainwater/irrigation if available. Domestic= ponds, wells, groundwater, piped.	Agri= rainwater/irrigation if available. Domestic= ponds, wells, groundwater.	Agri= rainwater/irrigation if available from Khai Don. Domestic= ponds, wells, groundwater

BMC	**Kuok Romiet FWUC -** Srae La'or village	**Kuok Romiet AC**	**Banteay Neang FWUC -** Kourk Phnov village	**Banteay Neang AC**	**Samroang AC**	**Phkoam AC**
Infrastructure	Ang Srae La'or resrvoir and dam 1550*1650 m. Kourk Prech (1000mx500m) medium-scale irri systems, groundwater wells, piped water	0 irrigation systems. Rely on rainwater (agri), ponds, wells and water from Thialand (domestic).No piped water . NOTE: distance for irrigation very far from village to field.	Main canal (2km) Monkgul Borei stream fills secondary canals (5300m) then diverted to community, wells (6-7 p/v) and 50-60m deep, piped water. No reservoir in community. 3 structures upstream before the water flows to community - Ou Doun Poeu, Bavel and Prey Kpos.	Canal for crops in whole village/district. Kamol river flows from Angkor Borey - closed, local water authority have issues opening gate. Piped water. Some wells, shared cost. Access to groundwater, 15-20% access to handpump	Canals ineffective for rice, irrigation (farmers not knowledgable) .Main WR from Khai Don river and Kanseng reservoir. No piped water. Groundwater via openwell.	Pond, small stream, small dam and river. No irrigation systems. Only old streams built by ancestors. No piped water. Access to wells.
Maintenance	We manage medium scale irrigation systems (the two reservoirs outlined above). Use O&M budget, ISF from the farmers		5 year 0&M plan. Collect ISF from farmers 2x per season. Ban large trucks from driving across irri systems. Manage - one main canal, one secondary canal, 13 tertiary canal and 4 weirs.			
Trainings	MOWRAM trainings on WRM and use. Crop cultivation, pricing, livelihood generation, hygeine and water use participation (VSG organisation) .	No WRM trainings.	Veg growing, water management, ISF collection, dispute resolution. Farmers do not fully understand WRM which causes disputes.	PDAFF on cultivation methods. No WRM trainings	No WRM trainings.	Organisations helping to strengthen product chain understanding, markets etc. No WRM trainings.
Piped water/ wells	3500riels/m^3 so on average it costs community members 50,000riels/ month. Some farmers can just pump the water directly from the stream to their storages.	No piped water supply.	Yes, on average one houselshold uses 15m^3/month and 1m^3 costs 2000riel.	Yes it is 50 cents/m^3. Costs 300,000riels to connect to the network. Cannot use for cultivation.	No piped water supply.	No piped water supply.

BMC	**Kuok Romiet FWUC -** Srae La'or village	**Kuok Romiet AC**	**Banteay Neang FWUC -** Kourk Phnov village	**Banteay Neang AC**	**Samroang AC**	**Phkoam AC**
Storage	Jars for domestic use - drinking, cooking, laundry (10 p/hh). Open water from resvoir to irrigate. Pond near the pagoda which is 60x80m.	Jars (2-10 p/hh). No reservoir. Pond capacity = 200,000m3.	Pond and lake to store, jars (20 p/hh). Only for domestic use, unless the pond is filled which can be used to irrigat e corn, mushroom and other vegetables.	No reservoir, needs rehabilitating. Jars: up to 20 per hh. Some from pond/basin for hh consumption or pump water from stream and filter.	rainwater, jars (5-6 p/hh). Dig ponds/ groundwater openwell to conserve	Jars for rainwater. (4-5 p/hh). Or water from private providers. Have large pond (but no pumping machine)
Application of water to crops	Seasonal, rice higest demand for supply. Depends when water is needed, can be supplied weekly/ monthly but recently in dry season not able to open gate for agriculture.	Once in May/June/July. Rice most important, cassava is resilient.	Based on needs and seasons, most imp: 1= rice, corn, beans, other veg. Farmers pump from closest canals to their fields, difficult for those with fields >700m from the fields.	Dry rice: applied 2x per season. For agricultural supply, rely on Angkor Borey river. Domestic: piped, groundwater (wells), jars.	Sufficient:pumped 2-3 times. Normally a flood in the dry season, 2020 insufficient	totally depend on rainwater. Water not pumped unless theres rain. Rice not successful. Cassava not needed. Applied for veg.
Communication	Communcic ate with farmers to collect ISF money. No regular meetings unless issues in the community. Farmers can come and request the committee to release water for them.	No cooperation with FWUC. Only within AC, not met for 3 years.	No cooperation with AC. Meet CIDO and FWUC network. Attended meeting in Kampong Thom to dicuss WR with other communities. Meet once a year with FWUC network (250,000riels/year membership).	No cooperation with FWUC. With water, no proper management or discussion from provinical levels.	No FWUC, no communicatio n. In AC, committee meeting once a month.	Lack of communication/ assistance from NGOs and govt. No FWUC so no communication.
Quality	Unsafe for drinking, buy piped water: 3500r/m3 – monthly average spend = 50,000r	Unsafe for drinking - buy	Unsafe for drinking: buy, piped: 15m3 per month (1m3x2000r). 6-7 wells per village with 50-60m depth.	Pond water- arsenic. Agriculture = ok. Domestic= unsafe. Last 3-4 yrs bad quality.	Unsafe for drinking, makes rice rotten unless filtered	Made the rice rotten. Insects then destroyed the rice. Not all fields.

BMC	**Kuok Romiet FWUC -** Srae La'or village	**Kuok Romiet AC**	**Banteay Neang FWUC -** Kourk Phnov village	**Banteay Neang AC**	**Samroang AC**	**Phkoam AC**
Flood	Recently caused reservoir flow damaging dam. Land damaged: 25ha of rice, 37 ha of cassava. 2019 flood damaged the reservoir and the FWUC community members helped each other to fix it.	2013/14 flood: affected cassava and rice, rotten crops. Road damaged.	2013-14 flood.	2015/16 flood: damage road, rice fields and physical infrastructrure. Note: no longer humid, soil is very dry.	Floods: 2011/12/13: destroyed rice, as there were no canals to release the water	(F+D) No irrigation system so describe as the rainwater just flowing away. Yield bad. Some years 10ha cultivated rice, but much less now.
Drought	Drought led to all crops being completely destroyed. +fish and other aquatic animals	2019 : severely affected rice yield . Usually 10-15ton /5-6ha , NOW: less than 3 tons. Cassava affected. Markets affected.	Damaged rice and crops. 1066 ha+ shortages, decline in yield: 1h=4tons NOW: 1h=2.5tons	Drought recently --> farmers fell into debt.	2019: dry rice crop failed 2x with no yield. Decrease: 4tons --> 2 tons	2018/19 faced drought. Decreased yield and affected hh conditions. --> migrations, debt.
Adapation to F+D	Depend heavily on rain, so promoted using the water sparingly. Droughts are longer than usual.	Undiscussed.	Turn off pump, but cannot completely ban for cultivation. Pump from canal instead. Have to ask the PDWRAM in Battambang to release extra water for us.	2 families use their own money on wells, others there are no solutions. Notified by authorities to grow rice once, but even if it is grown twice in debt. Debt, hunger, loss of land.	No adaptations as the rice is grown dependent on rainwater.	None, farmers are traditional. Used to prepare 3yr workplan, but the farmers didn't understand so it was unscussessful.
F + D Warnings	Yes, from govt.	Yes, from govt. but no assistance	Yes, from govt.	Yes, from govt. Farmers do not listen or conserve water as they just want to improve their yields.	Yes, from govt through Facebook.	Yes, from govt. also a phone number

BMC	**Kuok Romiet FWUC -** Srae La'or village	**Kuok Romiet AC**	**Banteay Neang FWUC -** Kourk Phnov village	**Banteay Neang AC**	**Samroang AC**	**Phkoam AC**
Climate Change	Yes, NGO trainings. Normally rains in April, but now there has been no rain since Sept 2019.	Yes. From TV. No mitigation strategies. Planting trees.	Aware. Wet season begins late and finishes early. Ask farmers to grow short-term rice instead of long-term.	Aware. Wet season is starting late and finishing early. No mitigation strategies. Find cause in the depletion of the forest. Have asked farmers to grow short-term rice and avoid growing in the 2nd phase.	Aware. Advised to plant trees.No mitigation strategies in place.	Aware, through media and phone. No strategies in place, don't really understand the issue as organisations have not discussed with them.
Activities/ Gender	Women partipate more than men in O&M.	Men more involved in rice cultivation. Cassava: both. Some women more involved in selling.	Men more involved, due to physicality.	Mostly men (cultivation/seeds/fertlizer)/ Women in some cultivation and selling/finances.	Men and women have the same role in agriculture. Heavy lifting=men, women= light tasks.	Both men and women take part equally. Women are more involved in selling. M+W involved in cultivation to harvest
Committees/ Gender	Over 2x more men in the FWUC.	No committees for men and women. Women more involved in decision-making as men are too busy.	Men more involved in decision-making. No committees.	No committees for men and women. Community just helps vulnerable farmers.50-50 decision-making. Women in selling as husbands drinking/ have skills in negotitation.	Yes, committees. Disseminate information or training relating to agriculture, bookeeping etc once a month. Decision-making equal.	More men than women in the committee. More men stand for election. Some women lack in capacity.
Challenges	Farmer disputes when requesting water and it is unavailable. Lack of irrigation systems such as canals whilst canal constructions affect the rice fields. FWUC afraid of ISF discussions. Lack of financial support.		Farmer disputes. Water low in tertiary channels- need rehabilitation. Don't have enough money to do it ourselves. Mongkul Borei stream originates in Pailin, but 3 structures using water before arriving in BN.	Piped supply insufficient. (50cents/m3). Issues w/ violence between villages taking over master canal.Not informed on measures to help w/ flood and drought. No assistance from govt.		Commune fund low. Project to rehabilitate the canal doesn't work.

BMC	**Kuok Romiet FWUC -** Srae La'or village	**Kuok Romiet AC**	**Banteay Neang FWUC -** Kourk Phnov village	**Banteay Neang AC**	**Samroang AC**	**Phkoam AC**
Suggestions/ Questions	Need more developmen t partners to strengthen budget and capacity as ISF is not enough. Rehabilitate irrigation systems. Govt needed for trainings on water use. Construct canal to bring water from the source to the nearby Ta Song village.	Request wells per hh. Difficult to reach water resource. Better to have basin for water storage. 1 basin per family requested.	Rehabilitate tertiary canals. PDAFF recommend against fertilizer but an alternative is needed. Markets: need fixed price to avoid middle man.	NGOs and govt must cooperate w/ local levels to solve WR issues. Build irrigation systems. Inspect fertlizers/raise awarness.Marke t access needs improvement/se curity.	Old canals need rehabilitating for agriculture (KR built). Irrigation systems needed to avoid farmer disputes. The issue of WR/WRM is never raised, only ever roads so needs more focus for future planning.	Ask for assistance in rehabilitating the stream. Water station for domestic. Facing poverty in community. Lack water resources to cultivate dry rice so main priority. Licences for agriculture.

OMC	**Kon Kreal FWUC -** Tumnup Lork	**Bansay Reak** AC - Sambour Meas	**Beng** AC - Beng Samaki Akphivot	**Chong Kal** FWUC - Kor village	**Chong Kal 2** FWUC - Kor village	**Kork Morn** FWUC - Ou Angkrang
Distance to water body	Tumnup Lork dam, located in the middle of the community	Between 200-300m to a pond. Three ponds in community, one is used exclusively by the school. Ponds 30x40m and 30mx20m.	1km to Sciliem reservoir - other ponds in village	1km to furthest rice fields and some farms are much closer to the system.	Around 500m to water body. Some villages are only 30m away from a canal.	Ponds located in the village, reservoir is 3km away.
Crops	Rice, cassava, watermelon and some vegetables for domestic and local use. Afraid to let farmers grow water melon as it uses a lot of water.	Rice and cassava but also just started growing cashew. Only wet rice. Not enough water for drinking. Cant grow wet rice or water melon. Rice 135ha, cassava 75ha, 1-2ha cashew. Members own 1ha-10ha, on average around 3ha.	Wet rice and cassava (never cultivated dry since since the reservoir was broken - it has been recently rehabilitated). Some farmers growing cucumber, morning glory, mungbean and Pak Choi - others grow vegatables for household consumption. 2-5ha of land per farmer on average.	Water melon, maze and vegetables (apply water). Wet rice and cassava (rainfall fed).	Rice. Vegetables (household consumption). Over 80% also farm cassava. Rice requires lots of water and pesticides whilst cassava is much easier as just relies on rainfall. Cassava = 6-7 million riels per hectare. Price of wet rice is twice as less. Every household has at least 2-3ha of cassava.	Farmers cultivate three times as much rice as cassava. Only 10% of farmers cultivate cassava. We do only rainfed rice so we don't have to depend on the reservoir. There are a few farmers cultivating dry rice but they have been experiencing water shortages at the time of irrigation/ harvesting. Watermelon.
Water status	Not enough water in dry season for agriculture - only for vegetable and rice but not for selling. 2019 long dry season.	Not enough water for drinking. Water almost out now, if the rain does not fall by April we will have no water.	In 2018 and 2019 not enough rain to grow normal amounts of rice. Not even enough water for drinking in some villages. Most villages domestic water is not an issue.		Flood last year filled the reservoir but in 2018 we had a water shortage. PDWRAM brought 5 electronic pumps as requested.	No shortage of water for domestic use. Water is short for agriculture in the dry season.
Domestic vs Agriculture	Relying heavily on Tumnup Lork dam for domestic and agricutural. Many wells and hand pumps for domestic use only.	Very limited for both purposes.	Plenty water for domestic use and we rely on rainfall for agriculture.	Agriculture = rainwater + reservoir levels, lack water for agri because reservoir lacks supply.	Always enough for domestic supply but only enough for agriculture if there is sufficient rain.	Not doing well in agriculture compared to other communities because of our upland topography. Domestic is fine because of many ponds.

OMC	**Kon Kreal FWUC -** Tumnup Lork	**Bansay Reak** AC - Sambour Meas	**Beng** AC - Beng Samaki Akphivot	**Chong Kal** FWUC - Kor village	**Chong Kal 2** FWUC - Kor village	**Kork Morn** FWUC - Ou Angkrang
Infrastructure	2700m long dam - 2 lakes, creeks and streams linked to it. No extrenal source to supply dam so it lowers daily. 2 main canals - one is 5200m, other is 1100m, also a number of tertiary canals (earthen canals from Khmer Rouge)	No existing water infrastructure in area. Only broken/ old canals from the Khmer Rouge regime, canals cannot supply water to fields. Only a few ponds in the area.	Big reservoir and one main canal (5km), not enough storages to hold water for dry rice cultivation. Old main canal has just been rehabilitated and is not working yet.	Reservoir built in the 1960s, rehabilitated in 2015. Canal system. Most houses have a well. Community ponds.	Old Khmer Rouge dam that is sufficient for 2 whole villages domestic use year-round. 4-7 jars per household.	Reservoir - Ou Angkrang (Khmer Rouge) 3800m x 1000m. Reservoir - Rohal (smaller) Big pond (50m x 50m with 3.5m depth) that CIDO built to promote agriculture. CIDO also constructed 1km of road. Another pond - 180m x 200m with 3m depth.
Maintenance	Often fix using the ISF collected from farmers. During rainy season we standby every night to monitor the water level.			Collaborate with commune officials. Report to PDWRAM so they can provide any necessary assistance.	Havent had to repair yet. Will report to PDWRAM is any problems.	Just keep our eyes on it and report to PDWRAM, they will repair it. Havent collected ISF from farmers as they don't earn much and some refuse to pay.
Trainings	Many trainings from PDWRAM (30 times) and MOWRAM. Taught us about water use, management and administration.		No strategies or solutions passed onto farmers.	Lately, officials from MOWRAM came and provided a training on irrigation O&M methods and also about income generation for the FWUC.	PDWRAM provided trainings regarding O&M. Conserving/ managing water, maintaining canals, keeping the environment clean. MAFF have tarined us on different crops and the use of fertilisers.	Trainings once a month for a year now from MOWRAM. Agriculture, water management, fertilisers, etc. Community is not fully self-functioning without their support.
Piped water/ wells	Yes, 1,500riels per m^3. Water supplier uses water from irrigation system but refuses to pay us the ISF as stated in the ToR.	Water contains arsenic so cannot use well water for drinking or showering, only washing clothes. No clean water supplier in area, have to go to Samrong. NGO's have provided water purifiers.	No piped water. In some areas we dig well up to 100m.	No piped water. Groundwater from the wells is not good quality - turns red when kept in a jar.	No piped water. Samiritan's purse (NGO) has planned to install a clean water station, no proper location for it yet.	No piped water. Private company is carrying out a study to setup a clean water station downstream of the reservoir. Company is constructing a big pond to store the water in order to supply it through the pipes later.

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Storage	Each household has 4 jars on average (1,200l each). Some families can build pools with cement.	Capacity to store rain water is not enough for drinking for the whole year. Only the rich can afford the expensive tanks that can store 1000-2000l.	Ponds 30m x 20m wide - some ponds constructed by government. Each household has 3-5 jars. Use this water for washing and cooking.	Water tanks or concrete sewage pipes at houses (store 500l), jars. Stored water only usually lasts a month or so then they have to buy drinking water.	Secondary canals are currently being constructed to provide water for agriculture.	Joint ponds (1 pond for 25 households). Within 4 villages there are 8 big ponds. Each household has 5-7 jars.
Application of water to crops	Open gate of dam from September to October (rainy season), not always regular as depends on rainfall. Cassava is planted in upland areas, cant have too much water	Depend on rainfall for wet rice. Need to build dyke in rainy season to store water. Don't apply water to cassava, rely on rainfall but too much/little it will be damaged.	Wet rice is dependent on rainwater. Not able to get water from reservoir as have to pump it	For water melon farmers need a canal which they can pump from and apply water. Need pumps and electricity to use the water.	Stored water is only adequate for domestic purposes. Water in nearby canals diverted to Banteay Meanchey and Siem Reap where they can grow dry rice.	Located in an upland area so the soil consumes too much water for crops and it dries too quickly. Whilst other communities can produce 6 tons of wet rice crops we can hardly produce 2 tons. Regular application of water does not work. During the dry season we could supply water to only 20ha of rice fields. Farmers have to pump water to grow watermelon.
Communication	No cooperation with PDAFF. Only hold meetings within our FWUC community.	Had meetings with FWUC but advised us on how to manage clean water and we don't have access to any clean water or even unclean water.	No cooperation with FWUC. Sluice gate controlled by village chief and not FWUC.		No meetings with other FWUC's or AC's. Only have meetings organised by PDWRAM or MOWRAM.	People don't want to come to meetings without a financial incentive.
Quality	Normal, does contain sediment but it is okay for cooking.	Cannot drink pond water as it contains sediment and fertiliser. Some poor housholds cannt afford bottled water so they boil the water from the ponds.	Water in pond contains sediments. Groundwater through wells makes rice yellow. Water quality depends on topography	Contains sediment - not safe to cook.	No problem with canal water - we can use the water and put it in the purifier before drinking. Water from the openwells makes hair dry and sticky when shower.	Community members have water purifiers at home that are provided by Samaritan's Purse for 20,000 riels. Quality of groundwater is very poor for cooking and contains arsenic. Even for washing the groundwater makes your hair dry and you cant use it on the crops.

OMC	**Kon Kreal FWUC -** Tumnup Lork	**Bansay Reak** AC - Sambour Meas	**Beng** AC - Beng Samaki Akphivot	**Chong Kal** FWUC - Kor village	**Chong Kal 2** FWUC - Kor village	**Kork Morn** FWUC - Ou Angkrang
Flood	Not serious, water just runs through system and makes some small holes.	Flood has never damaged property or crops. Only this year, water killed cassava crops. In 2017, water damaged rice crops.	Kork Kabas village most affected (located downstream of dam), 2019 - roads damaged, 50-60ha of rice fields damaged, reservoir affected so studies being carried out	Flood in September 2019 - damaged wet rice. 15 different areas along main canal affected but PDWRAM intervened quickly to prevent further damage.	September 2019 flood, destroyed concrete embankment of canal and its bank. Reported to PDWRAM who came to fix it. 50% of wet rice crop was damaged/affected. Big flood in 2013.	Floods have never damaged the infrastructure nor households because the flood does not stay long, it flows to other areas as this is an upland area. 10-20ha of cassava are affected by floods whilst floods are a good thing for rice crops.
Drought	Hot weather kills weeds and grass that are grown to protect the system - can damage irrigation systems. Very hot in 2017, killed many animals and crops.	Most drought in August or September, in 2018 rice were completely damaged.	Been two years since rice and cassava affected by drought. More drought than usual in last two years. Used to get 20 sacks of rice (14 million), now only 5-6 sacks (4 million)	July-August 2019. PDWRAM brought 5 electronic water pump machines. Hot weather damages cassava crops.	Drought has never affected the system.	Experienced drought for 3 years in a row during July-August. Within 3ha of rice fields I could only harvest 7 sacks.
Adapation to F+D	In 2018 when there was a water shortage, farmers pumped out remaining water from dam. Don't grow anything in dry season.	Not use water wastefully, pump water to catch fish. PDWRAM provide some training e.g. don't shade under a tree during rain to avoid lightning.	No strategies. Wanted to conserve more water but its far and costly to pump. Recent project to rehabilitate main canal.	Construct more ponds, buy more tanks and jars.	Not much of an idea. Could plant more trees to reduce temperatures in hot season. Don't know how to prevent flood.	No strategies. Drought is the result of deforestation. Just 10% remains of what existed before. The cold season lasts only 3 days.
F + D Warnings	MOWRAM mentioned reducing land cultivation during water shortage. Government recommends not to grow anything.	Some news from media but farmers don't listen as they have to make a living.	Via village chief every year. No strategies for mitigation. Told to cultivate crops that consume less water but people still use water if they can access it.	Held meetings with nearby communities once or twice a year. Normally discuss about issues relating to maintenance and management.	Warnings from the government by telephone and the media. We are in the lowland area so we always prepare for flood and look after the vulnerable. MOWWRAM can notify over 1,000 people at the same time.	

OMC	**Kon Kreal FWUC -** Tumnup Lork	**Bansay Reak** AC - Sambour Meas	**Beng** AC - Beng Samaki Akphivot	**Chong Kal** FWUC - Kor village	**Chong Kal 2** FWUC - Kor village	**Kork Morn** FWUC - Ou Angkrang
Climate Change	MOWRAM/ PDWRAM explained that would get longer dry seasons. Listen to weather news from media, radio and use observations.	Small dry season longer than usual. Weather is sometimes too hot or too cold.	Diarrohea, dengue and and diseases on livestock. No vaccination training. Have asked PDAFF - other NGO's have helped.	Longer dry season, rainfall patterns changed, temperature getting hotter and hotter.	Rainy season short whilst the dry season is long and hotter.	Hear through media and notifications from MOWRAM. Rain is coming later, less and for a shorter period. Noticed changes in the seasons for the last 4-5 years.
Activities/ Gender	Men and women take part equally. Women maybe participate more than men as they have more time.	Equal - e.g. wife helps with spreading rice whilst husband spreads fertiliser. Disucss between wife and husband to avoid arguments.	Machinery used so not much involvement of women. Some families engage women in rice spreading. Women can make decisions about seed selection/ selling.	More women in charge of managing irrigation system. Men and women went on trip to see other irrigation systems.	Not promoted our tasks to women so only the men are actively involved in managing the irrigation system.	Equal participation. In terms of meetings there seems to be more women as men are busy working in the fields.
Committees/ Gender	Both take part in meetings.		4 females, 6 males. Recent migration to Thailand for work so now less than 10 members.	Meetings with nearby communities once or twice a year.	Committee members summoned when PDWRAM comes. No meeting between FWUC and FWUC before.	When MOWRAM stopped providing financial support to participants, people stopped coming. When PDWRAM come to visit only a few committee members are invited.
Suggestions/ Questions	Construct canals to bring water to reservoir from newly constructed Chinese dam. Want more water to use in dry season.	Should restore Khmer Rouge structures, should build sluice gates. Structure should be built between 1-1.5km away to conserve water that flow from mountains.	Reservoir insufficient for domestic use, need more ponds in community. No access to clean water. Most feasible project is to deepen and rehabilitate the ponds and creeks in the villages.	More cooperation with local authority. Bring water from Ang Phnom Ah Tor reservoir to local reservoir (study conducted). Stores 1 million cubic metres.	Construct more sluice gates to give access to the water for each village. Can plan how long to give each village water for. Saw an example in a community in Siem Reap.	Need help repairing the broken parts of the systems. Farmers are currently diverting water from the canal without proper management. People with fields that are far from the main canal should not be able to cultivate dry rice. We need more secondary canals. We need better access to markets, I grew mangos to sell at Ou Smach but price was too cheap.

Annex G. Proposed Contents of a Provincial Water Management Plan in Cambodia (Khmer Language)

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