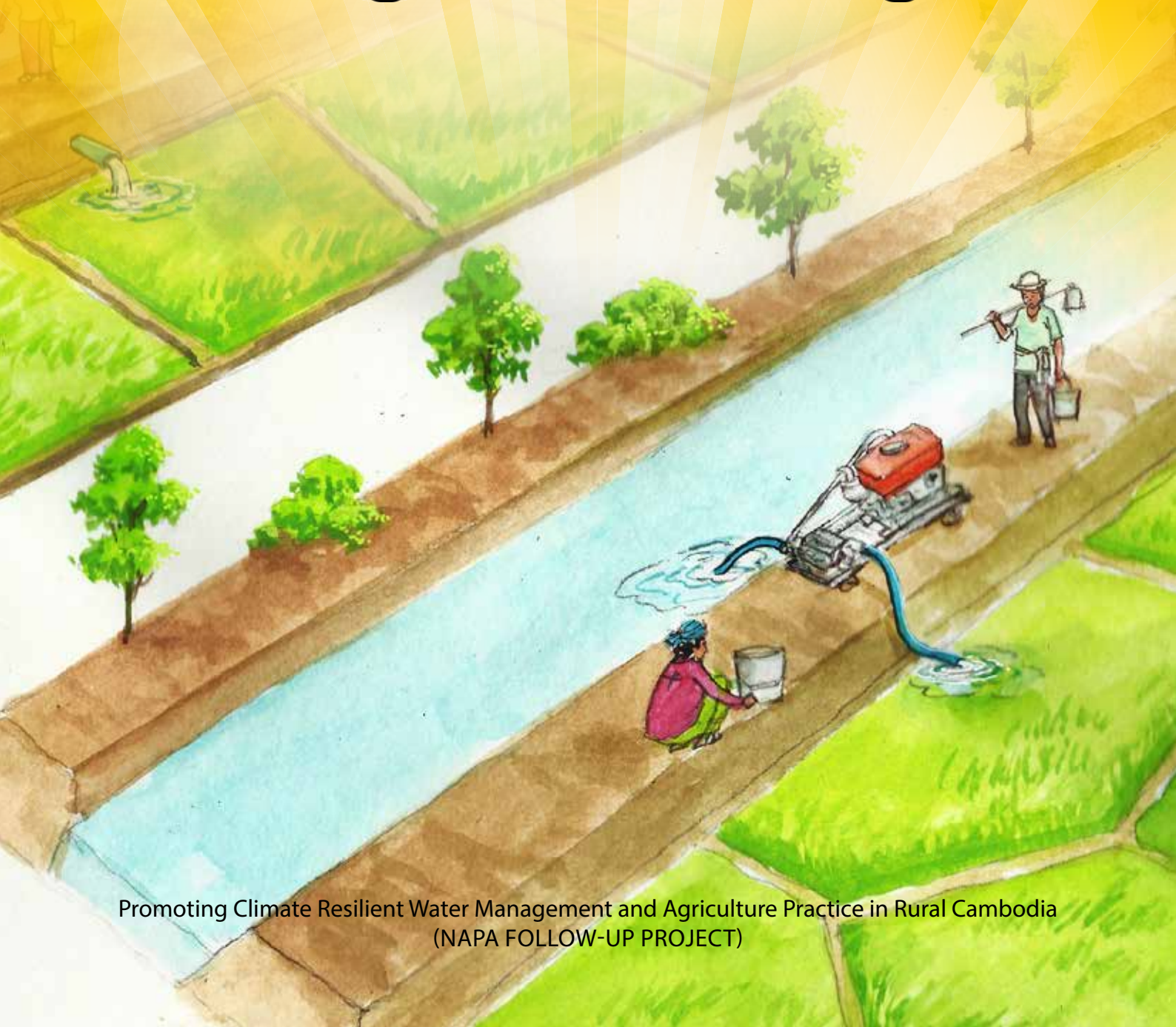




# Climate Resilient Irrigation Training



Promoting Climate Resilient Water Management and Agriculture Practice in Rural Cambodia  
(NAPA FOLLOW-UP PROJECT)

### For more information

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# PREFACE

Cambodia releases small amount of greenhouse gases into the atmosphere but Cambodian people is one of the most vulnerable people to climate change. 80% of people in the rural area whose livelihood is depending on agriculture, non-timber forest products and fishery are vulnerable to climate change. Irrigation system helps farmers who depend on the rain to do agriculture activities. Thus, building irrigation system resilient to climate change is crucial.

With funding support from United Nations Development Programme (UNDP), Global Environment Facility (GEF) and government of Canada, Project Support Unit of the Ministry of Agriculture, Forestry and Fisheries collaborates with irrigation specialists to produce a manual about climate resilient irrigation system to pilot in the target areas of the project Promoting Climate-Resilient Water Management and Agricultural Practices in Rural Cambodia (NAPA Follow-up).

This training manual points out the current implementation and strategy in promoting climate-resilient irrigation based on the community approach to build climate-resilient water management.

The manual has six units:

- Unit 1: Climate change and the meaning of climate resilience
- Unit 2: Water resources and use in rural Cambodia
- Unit 3: Water balance and the impact of climate change
- Unit 4: Technologies for water management
- Unit 5: Integrated water management as a response to climate change
- Unit 6: Developing integrated water management plans for communities

These units help the facilitator of the project, non-government organizations in particular the sub-national team understand and use it as a training materials to train stakeholders at the community level such as local authority, farmer water user community (FWUC) and water user group (WUG) to promote the understanding on community climate-resilience, ensure resilience in water management and reduce the risk resulted from climate risk.

The facilitator can use this manual based on the situation and requirement. The experience from NAPA FU was included as a case study and example, thus, the case study and example does not yet represent the overall experience in Cambodia. However, the Project Support Unit team hope that the lessons consolidated for this first publication are useful for the facilitator and stakeholders.

On behalf of the Project Support Unit, I would like to sincerely thank Julian Hilton Abrams, Hok Kimthourn, Project Manager and Keo Sovanthapheap, Board Member and representative from the Ministry of Water Resources and Meteorology, representative from the Ministry of Environment, Ministry of Women's Affairs, National Committee for Sub-national Democratic Development, NGO Forum, Cambodia Climate Change Network, and advisor and team of NAPA Follow up project who contributed in this training manual.

Phnom Penh, 1 March 2015



**Mam Amnot**

Secretary of State  
Ministry of Agriculture, Forestry and Fisheries  
and Project Director, Project Support Unit

# CLIMATE CHANGE AND THE MEANING OF CLIMATE RESILIENCE

## UNIT SUMMARY

In this unit, trainees will review the expected impacts of global climate change in Cambodia, together with the degree of uncertainty of the projected changes. Because of the uncertainty and the long time-scales involved, specific technical “fixes” cannot provide the whole response to climate change. Climate resilience is seen as the capacity of communities, farms and households to adapt to the impacts of climate change as these arise. Building this capacity is a long-term process and has three dimensions: institutional capacity (the ability to take appropriate decisions and implement them); technical capacity (understanding of and ability to use appropriate technologies) and capital assets (the long term, sustainable build-up of infrastructure and other assets that contribute to climate resilience).

## KEY MESSAGES

1. Climate Change is likely to have important effects on Cambodia's weather
2. Because Cambodian livelihoods are dependent on the weather, this will have important impacts on Cambodian people's lives.
3. There is nothing directly Cambodians can do to stop climate change – they can only “learn to live with it.”
4. The most important changes in Cambodia's weather will include higher temperatures and shorter wet seasons. There may be an increase in the number and severity of natural disasters including floods and droughts.
5. Although the general direction of climate change can be predicted, the exact size and timing of effects cannot be predicted. This is because of uncertainties about human behaviour (climate change mitigation policies) and because of uncertainties about the global and local weather systems.
6. Therefore, we should not look for projects that will stop the effects of climate change. Instead, we should try to build Climate Resilience, which we can define as:
 

*“The capacity of communities, farms and households to adapt to the impacts of climate change.”*
7. Building climate resilience will take a long time. Three types of capacity are likely to be needed: institutional, technical and capital assets.

## LESSON CONTENT

### THEME 1. WHAT IS CLIMATE CHANGE?

Climate change is the changing in the weather patterns resulted from the changing of the nature or human activities and this change is in the long run from 20-30 years onward.

Since the industrial revolution over 200 years ago, human activities have come to affect the climate in serious and immediate ways—the increasing emission of greenhouse gases into the atmosphere are intensifying a natural phenomenon called greenhouse effect.

The surface of the Earth is kept warm by energy from the sun. Most of the energy from the sun bounces off the surface of the Earth and back into space again. Some of the energy is trapped by gases in the Earth's atmosphere.

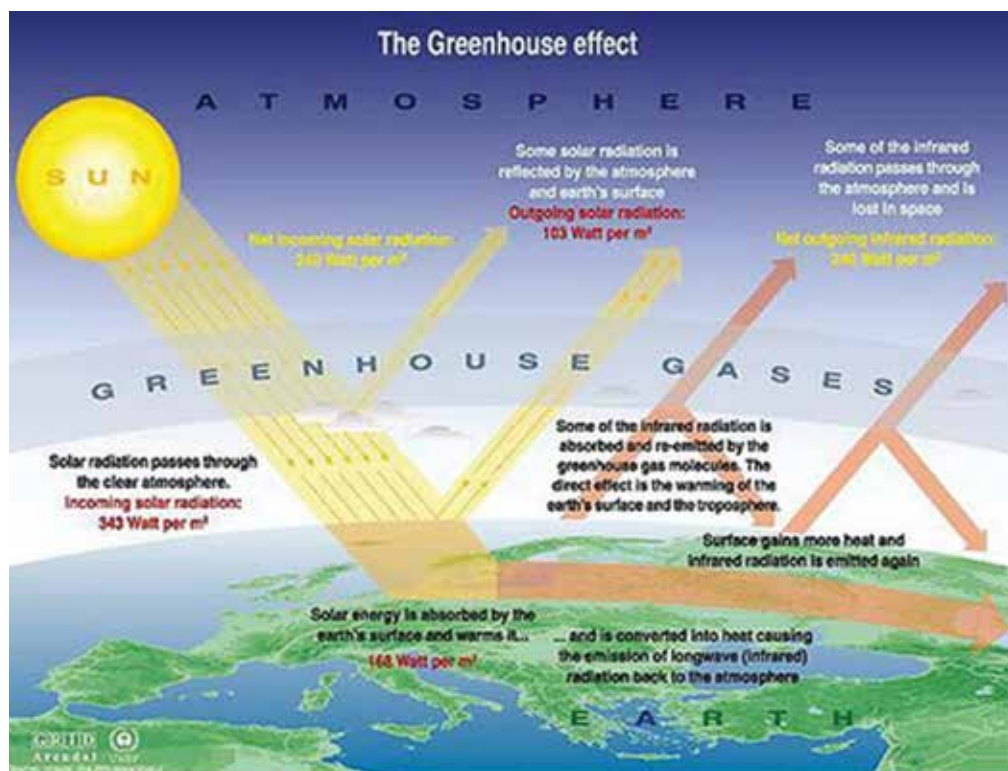
Carbon dioxide ( $\text{CO}_2$ ) is the most important of these gases. The proportion of carbon dioxide in the Earth's atmosphere is very small – about 391 parts per million (0.04%). If there was no carbon dioxide, the Earth would very cold. If the amount of carbon dioxide increases, the earth gets warmer.

Plants grow by trapping carbon dioxide from the atmosphere using the energy of the sun. When people or animals eat the plants, the carbon dioxide goes back into the atmosphere. When people cut down trees to burn for fuel, the carbon dioxide goes back into the atmosphere. However this carbon dioxide was only taken out of the

atmosphere a short time ago. People used wood for fuel for thousands of years without making much difference to the carbon dioxide in the atmosphere.

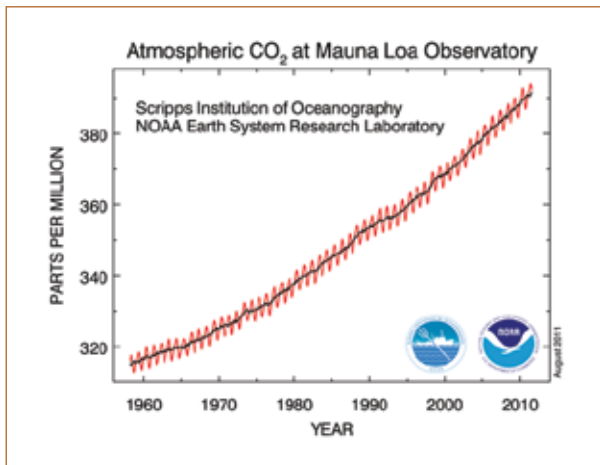
About two hundred years ago people started using coal and oil for fuel. Coal and oil were formed by taking carbon dioxide out of the Earth's atmosphere during a time that lasted for hundreds of millions of years. By burning coal and oil people are putting carbon dioxide back into the atmosphere very quickly. The amount of carbon dioxide in the Earth's atmosphere 200 years ago was about 270ppm. Now it is about 391 ppm<sup>1</sup>. That makes the Earth's "blanket" thicker and the result is likely to be that the Earth will get warmer. Most scientists agree that the earth will get warmer as a result.

The science of global warming is very complicated. Most scientists agree that more carbon dioxide will make the Earth warmer, but nobody can be certain how fast it will get warmer or how much. However, there is already evidence that the Earth has started to get warmer : average temperatures have risen about 0.5 degrees centigrade in the last hundred years. Most scientists expect a bigger increase in the next hundred years.



1. [http://climate.org/climatelab/carbon\\_dioxide](http://climate.org/climatelab/carbon_dioxide)

## THEME 2. HOW WILL CLIMATE CHANGE AFFECT CAMBODIA?



The UNDP Climate Change Country Profile for Cambodia<sup>2</sup> estimates that:

- By 2060, average temperature will increase by between 0.7°C and 2.7°C
- By 2090, average temperature will increase by between 1.4°C and 4.3°C
- By 2060, between 14% and 49% of days would be like a very hot day now.
- By 2090, between 20% and 68% of days would be like a very hot day now.
- The number of hot days will increase most in June, July and August.
- The number nights that will be like a very hot night now, will increase more than the number of hot days.

- Days that would be considered “cold” now will become very unusual.
- By 2090, rain in June, July and August will increase by between – 11% to + 31%
- By 2090, rain in September, October and November will increase by between -8% to +42%.
- However, rain in December, January and February will decrease by between -54% to + 36%.

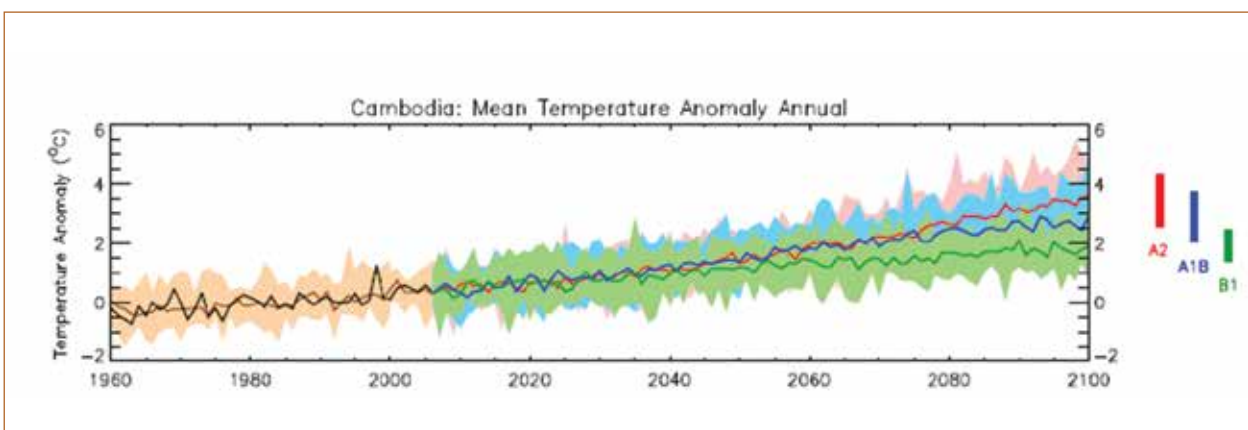
Overall, the amount of rain will increase, but more rain will fall in the wet season and less rain in the dry season. The wet season will be shorter and the dry season will be longer. A bigger percentage of all rain will fall in heavy storms.

By 2090, sea level will rise by between 0.18m and 0.56m.

These climate changes will take place over a long time. Not many of us in this training are likely to be around to check the temperature in 2090!

There is also a lot of uncertainty. For example, the model shows that temperature will increase, but the amount could be quite small or very large. Probably we would not notice an average increase of 0.7°C much, but we would notice 4.3°C a lot. The amount of rain is expected to increase, but there is a possibility it could decrease.

❖ ***Class discussion: Should we be worrying about uncertain events that may take place after most of us are dead?***



2009 National Report

2. <http://country-profiles.geog.ox.ac.uk/index.html?country=Cambodia>

### THEME 3. HOW WILL CLIMATE CHANGE AFFECT A RURAL CAMBODIAN HOUSEHOLD?



#### Family A is a farm family living in rural Cambodia.

Family A has six people in it:

- Father A, who is 55 years old.
- Mother A, who is 50 years old.
- Young A, who is Father and Mother A's son and is 25 years old
- Miss A, who is Father and Mother A's daughter and is 22 years old.
- Miss A who is Young A's wife and is 20 years old.
- Baby A, who is Young A and Miss L's baby and is one year old.

Father and Mother A have lived in the same village all their life. There was no school when they grew up but Father A learned to read and write a little at the pagoda. They have always lived by farming.

The A family has one hectare of rice field that is located 500m from the river bank. The rice field is sometimes flooded by the river. They grow a traditional slow-maturing rice variety. They usually get about 1.8 tonnes of paddy, which is enough for the rice they need to eat and to sell a little. They have 0.2 hectares of land around their house, where they keep pigs and chickens and Mother A grows vegetables. They can earn money by selling vegetables in the wet season and by selling chickens.

The village land where the house stands is a little higher than the rice fields. Normally it does not flood. However the old people remember one time when there was a big flood in the village. That time, peoples' houses were damaged, many animals were drowned and the road connecting the village to the market was destroyed.

Young A helps his parents on the farm and sometimes he goes to work as a labourer for other farmers in the district. One time he went away to Thailand to work there for a few months. Young A tries to raise pigs but he has not been very successful yet because the pigs keep getting sick. He thinks he will learn more and then be able to raise pigs successfully in the future. Young A is always trying to think of ways of making more money. He has suggested that they should stop growing rice and plant cassava instead, because he has heard that it is easy to grow and the price is very high.

Miss A does not live at the house. She is in Phnom Penh, working in a garment factory. The money she earns is very useful for the family. However her parents would like her to come back to the village and get married.

The A family grows rice in the wet season. Normally there is enough rainwater for rice to grow. However sometimes if there is a drought they have to hire a pump to pump water from the river, 500m away.

The A family gets water from a shallow well. The well provides enough water for their household and they can use it to grow a small amount of vegetables in the dry season. However, recently some families in the village have made deeper wells and started to use pumps to take water from the well, to irrigate vegetables and fruit trees. The villagers have noticed that the wells sometimes become dry. Recently Father A and Young A had to dig their well deeper.

## Class Discussion:

- If climate change happened now (i.e. if all the changes expected by 2090, happened immediately) what would be the effect on the family A?
- Would the impacts be the same on all members of the family? Would women be affected differently from men?

### Impacts may include:

- Rice crop failure because of temperature and / or pests
- Need to pump much more water from the river because the wet season ends earlier.
- Well becomes dry in the dry season so harder to keep animals and grow vegetables.
- Floods destroy rice crop.
- Village land floods, killing animals and destroying house. Road to market is destroyed by flooding.

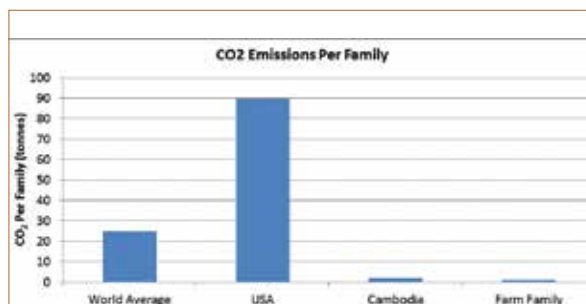


*Climate Change impacts*

## THEME 4. WHAT CAN WE DO TO STOP THE EFFECTS OF CLIMATE CHANGE?

Scientists believe that climate change is caused by human actions: mainly, by burning of fuels that increase the amount of CO<sub>2</sub> in the air.

If climate change is caused by human actions, it can be reduced or stopped by human actions.



Actions to reduce or stop climate change are called mitigation<sup>3</sup> actions. Mitigation actions that have been proposed include:

- reducing the amount of energy that we use, so we use less coal and oil;
- using different sources of energy (for example, solar power) that don't release CO<sub>2</sub>;
- trying to remove CO<sub>2</sub> from the atmosphere by natural means such as growing more trees, or by non-natural means such as storing CO<sub>2</sub> in underground tanks;
- Some scientists have proposed other ways of cooling the Earth's atmosphere directly.

The total amount of CO<sub>2</sub> released into the atmosphere by human actions each year is about 30,000 million tonnes. Cambodia emits about 4.6 million tonnes, or 0.02% of the total. The average household in Cambodia contributes about 1.6 tonnes (the amount for an average American family is around 90 tonnes)<sup>4</sup>. The amount for the family A is much smaller as their house has no electricity and they only have a small motorbike for travelling.

Therefore, there is not much that Cambodia, or the family A, can do to stop global warming (though preserving Cambodia's forests would help, as well as being good for Cambodia).

If the family A cannot stop climate change, they will have to learn to live in a climate that is different from the one that they are used to. This is called "Adaptation."

3. IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Mitigation. <http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-spm.pdf>

4. Data on CO<sub>2</sub> emissions from World Bank: World Development Indicators

### **Definition of “Adapt” from the Merriam-Webster’s Learners’ Dictionary\***

1: to change your behaviour so that it is easier to live in a particular place or situation  
“When children go to a different school, it usually takes them a while to adapt. // These fish all adapt easily to colder water. She has adapted to college life quite easily”

2: to change (something) so that it functions better or is better suited for a purpose

“The teachers adapted the curriculum so that students of all abilities will benefit from it. // The camera has been adapted for underwater use. // The clock was adapted to run on batteries.”

❖ *Does the Khmer word used for “Adaptation” have the same meaning?*

\* <http://www.merriam-webster.com/dictionary/adapt>

### **GROUP TASK**

The trainees split into groups of about 5 or 6 people.

Look at the list of impacts of climate change on Family A (made during the class discussion).

#### **For each impact:**

- If this impact happened immediately, what could the family do to adapt?
- If this impact happens over a long time (50 years) how will the family adapt?
- What can the Government do to help the family adapt?

## **THEME 5. WHAT IS CLIMATE RESILIENCE?**

### **Definition of “Resilient” from the Merriam-Webster’s Learners’ Dictionary\***

1: able to become strong, healthy, or successful again after something bad happens

2: able to return to an original shape after being pulled, stretched, pressed, bent, etc.

❖ *Does the Khmer word used for “climate resilient” have the same meaning?*

\* <http://www.merriam-webster.com/dictionary/resilient>

- For each action proposed: what would be the effect if the action is implemented, but the expected climate change impact never happens (for example, if the family buys an air-conditioner, but the weather never gets any hotter).
- Can the family (or the government) take all the proposed actions? If not, which ones should they take first? Why?

Each group will present their findings.

Then, the facilitator will sum up. The most important point is that adaptation is difficult unless we know what we have to adapt to. Some adaptation measures will produce good results even if the climate does not change: we can call these “no regrets” or “win-win” measures. But some measures might be too expensive to take until we know how the climate will change.

An example of resilience: earthquake resilience; Japan and Haiti. Why is one more resilient than the other?

*In 1995 the city of Kobe in Japan was hit by an earthquake of magnitude 7.0. The earthquake killed more than 6000 people and caused damage costing more than \$US 100 billion, or 2.5% of Japan's GDP. In the worst affected areas, more than half the houses were destroyed. However, houses built after 1981 (when new standards were introduced) were not damaged much.*

## **Some societies are highly resilient to natural disasters**



*Kobe, Japan, in 1995*



*This factory was fully operational 8 days after the Kobe earthquake*

*By August 1995 the sewerage system of the city was working again and the evacuation centres (where people who had lost their houses were living) were closed.*

*By 1996, the factories around Kobe reached 98% of their output before the disaster.*

*By March 1998 all the debris from the earthquake had been removed.*

### **The Haiti Earthquake, 2010**

*In January 2010 Haiti (a poor country with weak governance, located on an island near America) was hit by an earthquake of about the same size as the Kobe earthquake.*

*Estimates of the number of people killed range from 40,000 to over 300,000.*

*People and governments around the world contributed money to help Haiti recover from the disaster: by May 2010 the amount promised was equal to \$US 37,000 for each family that was left homeless. However, six months after the earthquake, only 2% of the debris had been cleared. Many roads in the capital city were still impassable, and 1.6 million people were living in evacuation camps in very bad conditions. Since then, recovery efforts have continued at a very slow pace.*

It is obvious that Japan was more “resilient” to an earthquake disaster than Haiti. What are the reasons for this?

❖ **Class Discussion:** *Both Japan and Haiti have a long experience of earthquake disasters. Why is Japan able to recover from disasters so much more quickly than Haiti?*

## SUMMING UP

We can consider “resilience” as meaning “having the capacity to adapt.

Three things can contribute to climate change resilience:

- Institutional capacity
- Technology
- Capital assets

Illustrations of each one relating to rural climate resilience in Cambodia

- **Institutional capacity:** Climate change will put stress on water resources (for example, Family A find their well becoming dry because other families are using pumps). Water should be managed carefully and used for the most important uses first. This needs institutions: for example a Water Users Community, to decide how much water each family can use.
- **Technology:** Learning new agriculture techniques, such as growing fast-maturing rice using methods that use less water, can help Family A adapt to climate change.
- **Capital assets:** a new irrigation system, a stronger road and perhaps flood defences would help protect Family A from the effects of climate change.

All these kinds of capacity building will take a long time. Because we cannot predict the exact results of climate change, we should focus now on building climate resilience: building the capacity to adapt to climate change. The rest of this training is focused on building climate resilience in one sector: water management.



# WATER RESOURCES AND USE IN RURAL CAMBODIA

## UNIT SUMMARY

Cambodia's aggregate water resources are very large – Cambodia is a wet country. Water arrives “free” from the sky and in the rivers and groundwater and everybody can take as much as they want – so why is water management an issue? Training participants will learn to see that making water available at the time and place and with the quality that is needed always has a cost. The cost is composed of capital and recurrent costs and may be paid “in cash” (example: an urban water bill) or “in kind” (example: the labour needed to draw water from a well). Often, the poor pay more than the rich (example: cost of water delivered by water cart compared to cost of PPWSA<sup>5</sup> water).

Participants will be introduced to model and real examples that will be used throughout the training: an idealised farm household and the actual examples of Bos Leav and O Khsan. Participants will calculate the “cost of water” for the idealised farm using technologies that are common in rural Cambodia, and the “value of water” (the maximum that it would be worth paying for the water) in a variety of alternative uses.

## KEY MESSAGES

1. Cambodia has enough water for all its needs. However, the water is not always at the right place, at the right time, or in the right quality that is needed.
2. Water is an economic resource. There is always a cost associated with making water available when, where and in the quality that the user needs.
3. Water for different uses has different costs.
4. Water for different uses has different economic values.
5. Poor families often pay more for water than rich ones do.

## LESSON CONTENT

### THEME 1: CAMBODIA'S WATER RESOURCES

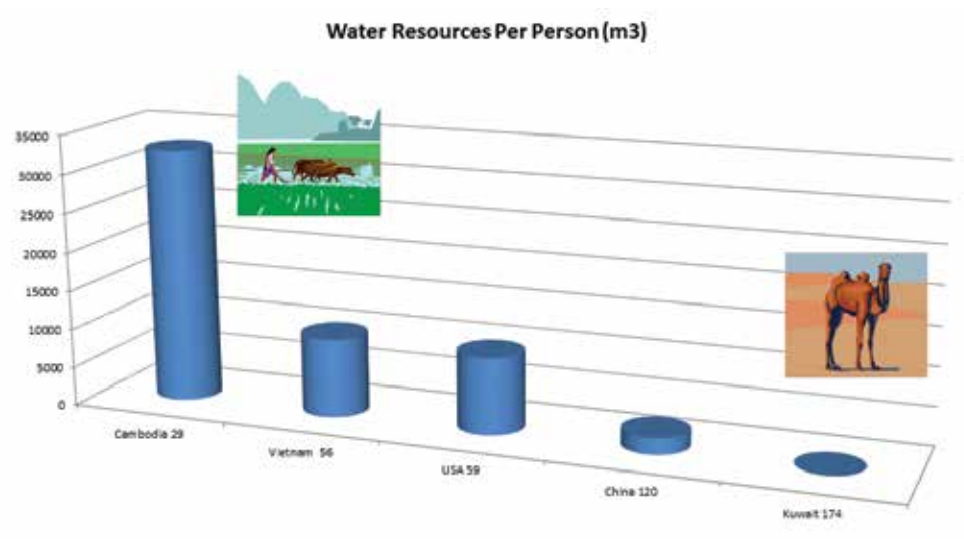
If water was money, Cambodia would be one of the richest countries in the world. FAO calculates that Cambodia's total renewable water resources amount to 32,695 cubic metres per person per year. That is the 29<sup>th</sup> largest amount for any of 174 countries for which data are available<sup>6</sup>.

#### By comparison:

- The world average renewable water resources is 24,776m<sup>3</sup> per person
- French Guiana (the “water-richest” country) has 609,091m<sup>3</sup> per person (it's quite wet there)

5. Phnom Penh Water Supply Authority

6. Water resources data from FAO Aquastat: [http://www.fao.org/nr/water/aquastat/countries\\_regions/cambodia/index.stm](http://www.fao.org/nr/water/aquastat/countries_regions/cambodia/index.stm)



- Vietnam (56<sup>th</sup>) has 10,151 m<sup>3</sup> per person
- The United States (59<sup>th</sup>) has 9,847 m<sup>3</sup> per person
- China (120<sup>th</sup>) has 2,112 m<sup>3</sup> per person
- Kuwait (174<sup>th</sup> place) has just 6.85 m<sup>3</sup> per person

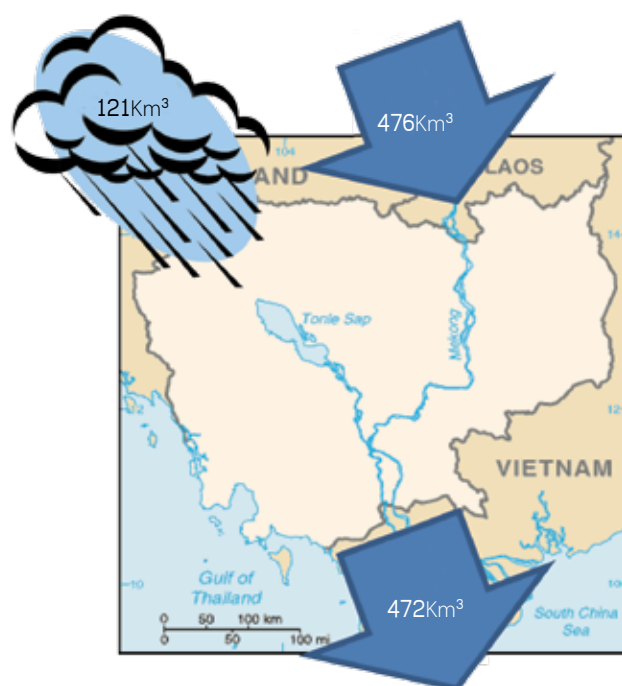
- However: about 471.5 km<sup>3</sup> flows out through the rivers. NB that water flowing out of Cambodia down the Mekong becomes part of Vietnam's "renewable resource."

In this unit we will discuss how water has a money value. We will also look at why, in that case, Cambodia is not a rich country.

- Cambodia's renewable water resources are calculated as 476.11 km<sup>3</sup>.
- Of this, 355.5 km<sup>3</sup> enters by the Mekong and smaller rivers
- Rainfall minus evaporation is about 120.6 km<sup>3</sup>
- Groundwater flows (water flowing into the country through the ground) add about another 5 km<sup>3</sup>

Average rainfall in Cambodia is about 1400 mm per year (a mm of rainfall means 1 litre of rainwater falling on 1 square metre of ground). The average rainfall is quite close to the amount of rain needed to grow one crop of rice<sup>7</sup>.

Most provinces of Cambodia have a little bit less than the average rainfall (1200 – 1500 m<sup>3</sup> per year), while the coastal provinces (Koh Kong and Sihanoukville) and Ratanakiri have quite a lot more<sup>8</sup>.



7. FAO Aquastat

8. For regional rainfall data see National Institute of Statistics: Statistical Yearbook 2008

## THEME 2: WATER USE IN CAMBODIA

### 1. How Much Water Does Cambodia Use?

Of the Cambodia's estimated 476.11 km<sup>3</sup> of annual renewable water resources;

| Volume of Water Used in Cambodia <sup>9</sup> |                                |
|-----------------------------------------------|--------------------------------|
| Type of Use                                   | Volume Used (km <sup>3</sup> ) |
| Agriculture                                   | 2.053                          |
| Municipal                                     | 0.098                          |
| Industry                                      | 0.033                          |
| Total                                         | 2.184                          |

The total water use is about 0.5% of the total renewable resource. Agriculture accounts for about 94% of the water that is used.

### 2. How Much Water Does the Family A Use?

The family have 1.2 ha of land (1 ha of rice land and 0.2 ha of house plot and vegetable garden)



Rainfall in their province is 1500mm per year

So  $1.5 \times 1.2 \times 10,000 = 18,000\text{m}^3$  of water fall as rain on their land every year.

The family can also get water by pumping from the river, or by drawing water from their well.

### How much water does the family need<sup>10</sup>?

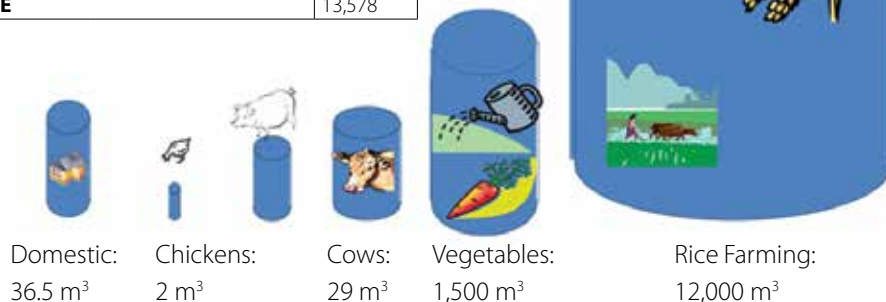
- To grow one rice crop on 1 ha of land needs about 12,000m<sup>3</sup> of water
- To grow vegetables on 0.2ha of land for 6 months each year needs about 1500m<sup>3</sup> of water.
- The family uses about 20 litres per person per day for household use. There are five people actually living in the house (Miss A is in Phnom Penh) so domestic use is about 100 litres per day or 36.5m<sup>3</sup> per year.
- The family has two cows, which each drink 40 litres per day,  $40 \times 365 / 1000 = 29.2\text{ m}^3$
- The family has three pigs, which each drink 10 litres per day  $= 30 \times 365 / 1000 = 10.95\text{ m}^3$
- The family has 10 chickens, which each need 0.5 litres per day, so  $10 \times 0.5 \times 365 / 1000 = 1.825\text{m}^3$

So the total amount of water the family uses is only about 75% of the water falling as rain onto their land. If they need more water, they can take it out of the river or pump it from the well.

Note that water used for rice growing is about 90% of the total in this calculation. In most families it would be more than 90%, because 0.2ha is a very large vegetable plot.

**For a typical Cambodian farm family, water used for growing rice is much more than all other uses combined.**

| Annual Water Use for Family A |                       |                                |               |
|-------------------------------|-----------------------|--------------------------------|---------------|
| Use                           | Size                  | Water Need                     | Total Use     |
| Rice field                    | 1 ha                  | 1 crop = 12,000 m <sup>3</sup> | 12,000        |
| Vegetable                     | 0.2 ha, 6 mths/yr     | 5mm per day                    | 1,500         |
| Domestic                      | 20 l / pers / day     | 5 pers x 365 days              | 36.5          |
| Cows                          | 40 l / cow / day      | 2 cows x 365 days              | 29.2          |
| Pigs                          | 10 l / pig / day      | 3 pigs x 365 days              | 10.95         |
| Chickens                      | 0.5 l / chicken / day | 10 chickens x 365 days         | 1.825         |
| <b>TOTAL ANNUAL WATER USE</b> |                       |                                | <b>13,578</b> |



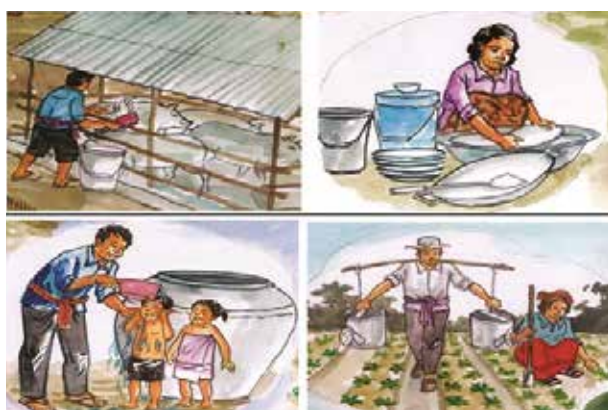
9. Data from FAO Aquastat

10. For data sources see Annex: Training Materials Data Table

## THEME 3: NEED FOR WATER MANAGEMENT IN CAMBODIA

We have seen that Cambodia is very rich in water. We have seen that the family A get more water falling on their land as rain every year, than they need for all their water uses.

So is there any need to manage water resources in Cambodia? Why not just let everybody take as much water as they want, because there is plenty for everybody? We don't manage the air, we just let people breathe it, so why not the same with water?



Daily water consumption

| Annual Water Use for Family A |                   |                                |               |
|-------------------------------|-------------------|--------------------------------|---------------|
| Use                           | Size              | Water Need                     | Total Use     |
| Rice Field                    | 1 ha              | 1 crop = 12,000 m <sup>3</sup> | 12,000        |
| Vegetables                    | 0.2 ha, 6 mths/yr | 5mm per day                    | 1,500         |
| Domestic                      | 20l/pers/day      | 5 pers x 365 days              | 36.5          |
| Cows                          | 40l/cow/day       | 2 cows x 365 days              | 29.2          |
| Pigs                          | 10l/pig/day       | 3 pigs x 365 days              | 10.95         |
| Chickens                      | 0.5l/chicken/day  | 10 chickens x 365 days         | 1.825         |
| <b>TOTAL ANNUAL WATER USE</b> |                   |                                | <b>13,578</b> |

### ❖ Class discussion: Why does Cambodia need to manage water resources?

Although Cambodia has plenty of water on average, the water is not always in the place where it is needed, when it is needed:

- 90% of the water falls in the wet season. That means that there is not enough water to grow crops in the dry season, unless irrigation is used;
- Sometimes there is too much water, causing floods

that damage infrastructure and crops;

- Even in the wet season, there can be dry spells that damage crops. The amount of rain in each month varies from year to year, so farmers do not know when is the best time to plant.
- People traditionally drink water from rivers, ponds and shallow wells. But these water sources can easily become contaminated, so that the water quality is not good enough for people to drink.
- In some areas, the groundwater has arsenic in it, so that it is poisonous to anybody who drinks it for a long time.

When water falls from the sky as rain or flows into the country in the river we can say it is free. But when we need to get water to a place where we want to use it, when we need it and in the quality that we need, we often have to pay.

## THEME 4: COST OF WATER

We pay directly for water for many kinds of use. Some examples:

- Half a litre of quality mineral water, on a restaurant table in Phnom Penh, costs perhaps \$US 0.5 (for some brands, in some restaurants, it can be much more). \$US 200 / m<sup>3</sup>
- The cost of "ordinary" drinking water in a shop is usually about \$US 0.05 for ½ litre. \$US 20 / m<sup>3</sup>.
- Phnom Penh Water Authority has a complicated charging system with price increasing depending on the amount used. However, a typical bill for 119m<sup>3</sup> cost 127,850 riel, or about \$US 0.25 / m<sup>3</sup>.
- In rural districts with no wells, water sellers often charge 2000 riel (\$US 0.50) for a 200 litre drum of water. \$US 2.50 / m<sup>3</sup>.

### How much do the family A pay for water?

- For water falling as rain, they don't pay anything.
- When they have to pump water from the river, they have to hire a pump<sup>11</sup>. The cost is
  - o To hire the pump: 2000 riel
  - o Fuel used in 1 hour: 0.5 litres (their land is very far from the river)
  - o Price of fuel is 3,500 riel per litre.
  - o So total cost per hour is 2000 + 0.5 x 3,500 = 3,750 riel, or about \$US 0.90
  - o Amount of water pumped in 1 hour is 20m<sup>3</sup>

11. Pumping cost data based on survey of farmers in Bos Leav, Kratie, March 2011

- o So the cost of water to the family is \$US 0.90 / 20 = \$US 0.045 / m<sup>3</sup>.
- How much does water from the family well cost?
  - o Mother A or the daughter-in-law of family A go to the well to collect water. The well is 50m from the house. One trip from the house to the well and back, they have to walk 100m. They walk at about 3km / hour so walking 100m takes them about 2 minutes.
  - o Taking the water from the well takes another 2 minutes.
  - o Each time, they can get about 15 litres of water (they use 2 x 10 litre buckets, but they usually spill some water)
  - o So to get 1 m<sup>3</sup> of water would take 4 x 1000 / 15 = about 270 minutes. That is 4 hours and 30 minutes, or about half a day's work.
  - o If Mother A or the daughter-in-law go to work for other people they can earn about \$US 3 per day.
  - o **So we can say the labour they use collecting water from the well is worth about \$US 1.50 per m<sup>3</sup> of water – less than the cost of buying it from a water seller, but much more than the cost a rich family pays in Phnom Penh.**

**More generally, we can say that the cost of any kind of water is made up of:**

- The **capital cost**: the cost of the installation (for example, a well) that is needed to supply the water.
- The **recurrent cost**: the cost of fuel, labour or other things that we need to use every time we take water.

If we want to calculate the total cost of water, we have to have a way to add the capital cost together with the recurrent cost.

**One way to think about this problem is:**

Suppose a farmer borrows the money to buy a pump. The pump costs \$US 500. The pump will work for 10 years, so he has to pay back all the money in that time. He has to pay 2% per month (24% per year) interest on the

loan. How much will the annual payment be on the loan?

There is a formula for this calculation, called the amortization formula. It is slightly complicated:

$$A = P [ i + (1+i)^N ] / [(1+i)^N - 1]$$

- A = the annual payment amount
- P = the loan principal (the amount borrowed)
- i = the interest rate per year
- N = the number of years the loan has to be paid back in (= the life of the pump in this case).

Luckily this formula is built into Microsoft Excel so it is easy to calculate<sup>12</sup>. In the example, the payment would be \$US 135.80 per year.

Suppose the farmer uses the pump to pump 10,000 m<sup>3</sup> of water each year. The recurrent cost of pumping (mainly the fuel) is \$US 0.025 per cubic metre. The fixed cost will be \$US 135.80 / 10,000 = \$US 0.01358. So the total cost of pumping will be about \$US 0.03858 / m<sup>3</sup> in this example.

**Group Exercises: Calculate the cost of water from:**

1. A rainwater harvesting system that costs \$US 250 to install, and provides 50m<sup>3</sup> of water every year. Assume it can be used for 15 years. The maintenance cost is 5% of the capital cost, every year. Use interest rate 12% per year;
2. A pump borehole that costs \$US 1,500 to install. It provides 100 litres of water per family for 20 families every day (for recurrent costs, see the calculation for the A family well). Assume the well can be used for 10 years but there are maintenance costs of 10% every year. Use interest rate 12% per year;
3. A drip irrigation system that costs \$US 100 to install. It can be used for 3 years. The benefit to the farmer is it saves 50% of the water she uses on her vegetable garden. Before she installs the drip system, she is using 200 m<sup>3</sup> of irrigation water every dry season (so the saving is 100m<sup>3</sup>) Use interest rate 12% per year.

12. The formula in MS Excel is "PMT(i,N,C)" where i = interest rate in each period, N = number of periods and C = the capital amount. NB this returns a negative answer; to calculate a payment amount use "=PMT(i,N,C)"



**រដ្ឋាករទឹកស្វយ័តក្រុងភ្នំពេញ**  
Phnom Penh Water Supply Authority

ឈ្មោះ: ហុយ គីង  
Name:

ថ្ងៃបង្កើតបញ្ជី: 30/05/11  
Billing Date:

លេខផ្លូវ: 376  
Street N°:

លេខផ្ទះ: N# 52 E0  
House N°:

លេខសំគាល់: 03 04 34 1710 1  
Delivery Point Code:

លេខវិក្កយបត្រ: PPWSA1106102078  
B/N°:

P1 5 P2

អត្រា: 01 - 03  
Tariff:

រយៈពេលពី: 26/03/11  
Period From:

រយៈពេល: 25/05/11  
To:

| ធាតុកា/Motor    | អំពូលទឹក/Current Reading                 | អំពូលចាស់/Previous Reading               | ការប្រើប្រាស់ទឹក/Consumption |
|-----------------|------------------------------------------|------------------------------------------|------------------------------|
| លេខ: KE99077345 | កាលបរិច្ឆេទ: 25/05/11<br>លេខអង្កេត: 6354 | កាលបរិច្ឆេទ: 25/03/11<br>លេខអង្កេត: 6235 | 119                          |

| បរិក្ខារ/Description |                                       | បរិក្ខណៈ/Quantity       | តម្លៃមធ្យម/Unit Price | ទឹកប្រាក់/Amount |           |
|----------------------|---------------------------------------|-------------------------|-----------------------|------------------|-----------|
| 71110-000            | ដំណើរការប្រើប្រាស់ទឹក កំរិត ១         | METERED CONSUMPTION-TR1 | 14 M3                 | 550.00           | 7,700.00  |
| 71110-000            | ដំណើរការប្រើប្រាស់ទឹក កំរិត ២         | METERED CONSUMPTION-TR2 | 16 M3                 | 770.00           | 12,320.00 |
| 71110-000            | ដំណើរការប្រើប្រាស់ទឹក កំរិត ៣         | METERED CONSUMPTION-TR3 | 70 M3                 | 1,010.00         | 70,700.00 |
| 71110-000            | ដំណើរការប្រើប្រាស់ទឹក កំរិត ៤         | METERED CONSUMPTION-TR4 | 19 M3                 | 1,270.00         | 24,130.00 |
| 73020-000            | ដំណើរការថែទាំប្រព័ន្ធប្រព្រឹត្តិការណ៍ | METER MAINTENANCE       | 2 M                   | 750.00           | 1,500.00  |
| 40000-000            | វិភាគទឹកប្រព័ន្ធប្រព្រឹត្តិការណ៍      | SEWERAGE CHARGE         | 10 %                  | 1,485.00         | 11,485.00 |
| 71710-000            | ទឹកប្រាក់ប្រព័ន្ធប្រព្រឹត្តិការណ៍     | ROUNDING OF WATER BILL  | 1                     | 15.00            | 15.00     |



ប្រាក់កម្រៃប្រើប្រាស់ទឹក: 0.00

សូមបង់ប្រាក់ទឹកនៅ: រដ្ឋាករទឹកស្វយ័តក្រុងភ្នំពេញ (រាជធានីភ្នំពេញ ០៨:០០ - ១៦:០០)

| ការបង់ប្រាក់/Payment                            |                       |                                    | ទឹកប្រាក់ប្រើប្រាស់ទឹក/Amount Charged | 127,850.00 |
|-------------------------------------------------|-----------------------|------------------------------------|---------------------------------------|------------|
| បង្កើតបញ្ជី/Cashier                             | កាលបរិច្ឆេទ: 25/05/11 | ទឹកប្រាក់ប្រើប្រាស់ទឹក/Amount Paid | ទឹកប្រាក់ប្រើប្រាស់ទឹក/Amount Charged | 127,850.00 |
|                                                 |                       |                                    | ទឹកប្រាក់ប្រើប្រាស់ទឹក/Amount Charged | 0.00       |
| សូមបង់ប្រាក់ទឹកនៅ: រដ្ឋាករទឹកស្វយ័តក្រុងភ្នំពេញ |                       |                                    | ទឹកប្រាក់ប្រើប្រាស់ទឹក/Amount Charged | 127,850.00 |
|                                                 |                       |                                    | ទឹកប្រាក់ប្រើប្រាស់ទឹក/Amount Charged | 127,850.00 |

សូមបង់ប្រាក់ទឹកនៅ: រដ្ឋាករទឹកស្វយ័តក្រុងភ្នំពេញ (រាជធានីភ្នំពេញ ០៨:០០ - ១៦:០០) 14/06/11

អាសយដ្ឋាន: N° 45 Street 106 Sangkat Srah Chok, Khan Daun Penh, Phnom Penh

ទូរស័ព្ទ: 023 420 541  
ទូរស័ព្ទ: 023 724 616



**រដ្ឋាករទឹកស្វយ័តក្រុងភ្នំពេញ**  
Phnom Penh Water Supply Authority

119 M3

ឈ្មោះ: ហុយ គីង  
Name:

លេខសំគាល់: 03 04 34 1710 1  
Delivery Point Code:



រយៈពេលពី: 26/03/11  
Period From:

រយៈពេល: 25/05/11  
To:

ថ្ងៃបង្កើតបញ្ជី: 30/05/11  
Billing Date:

លេខវិក្កយបត្រ: PPWSA1106102078  
B/N°:

| ការបង់ប្រាក់/Payment |                       |                                    | ទឹកប្រាក់ប្រើប្រាស់ទឹក/Amount Charged | 127,850.00 |
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| បង្កើតបញ្ជី/Cashier  | កាលបរិច្ឆេទ: 25/05/11 | ទឹកប្រាក់ប្រើប្រាស់ទឹក/Amount Paid | ទឹកប្រាក់ប្រើប្រាស់ទឹក/Amount Charged | 127,850.00 |
|                      |                       |                                    | ទឹកប្រាក់ប្រើប្រាស់ទឹក/Amount Charged | 127,850.00 |

## THEME 5: VALUE OF WATER

We have seen that water from different sources can cost very different amounts of money.

### Does water have the same value in every use?

Suppose the family A is short of water. They don't have enough water to meet all their needs. Which kinds of water use should they reduce first?

❖ **Class discussion.** *Reach a consensus on a ranking of water uses – which ones to reduce first. (Presumably “water for drinking” is the highest value use).*

### Concept of value added.

#### Example

- The family A harvest 1.8 tonnes of paddy rice from their farm. The rice is worth \$US 200 per tonne, so the total value of their production is \$US 360.

- The total cash inputs the K family have used to grow the rice (seed, fertiliser, pump fuel etc but not including their own labour), is \$US 150.
- The Gross Value Added is \$US 360 – 150 = \$US 210.

If it needed 12,000 m<sup>3</sup> of water to grow the rice, we can say the value added per cubic metre of water was \$US 210 / 12,000 = \$US 0.0175 per cubic metre. NB that this is less than the cost of pumping – if the family had to pump all the water for the crop, it would not be worthwhile to grow the rice.

In principle, we could calculate a “value added per m<sup>3</sup> of water” for water in any of the other uses. Probably this value would be higher in the other uses, because the amount of water used is much less.

If there is a shortage of water, we should use the water for the “highest value use” first.



# WATER BALANCE AND THE IMPACT OF CLIMATE CHANGE

## UNIT SUMMARY

In this unit participants will review how different uses of water may lead to conflict and how an integrated response is needed to ensure that water is managed and allocated in an equitable manner. Worked examples will demonstrate how climate change may “tip the balance” with the result that some water users no longer have enough for their needs.

If climate change causes a shortage of water, there are two possible responses:

- Increase the size of the water source (for example, make the reservoir bigger); or
- Use the water more efficiently (grow more rice using the same amount of water).

## KEY MESSAGES

1. Climate change may result in shortages of water. Communities will need to learn to manage water resources more efficiently.
2. Different users have different needs that may conflict with each other.
3. The first step in water use planning is to calculate the size of the resource, and the amount of water that different users need. This is called a Water Balance calculation.
4. Having a good plan for water management is no use unless we can implement the plan effectively. Efficient management of water resources will need both the technology for water management and the institutions that can take decisions on how to use water efficiently.

## LESSON CONTENT

### THEME 1: BALANCING THE NEEDS OF DIFFERENT USERS

In the previous unit we looked at how one family might need to decide between different priorities for water use. In this unit we will study about how to plan the use of water, taking into account the needs of many different

users and the natural environment. Climate change will make water management more important than it is now. Communities that have a capacity to manage water efficiently will become more resilient to climate change.

#### Example: The O Khsan Reservoir

O Khsan is a reservoir in Teuk Krahorm Commune, Choam Ksant District of Preah Vihear.

There was a traditional earth dam in this place before the Pol Pot time. The local people used the dam to store water for their cows and buffaloes, for fishing and for growing rice and vegetables around the reservoir.



*O khsan reservoir*



The dam was improved during the Pol Pot time. It continued in use until 2009, when it was damaged by a flood caused by Typhoon Ketsana.

In 2010, Ministry of Water Resources and Meteorology repaired and improved the dam. Now there is a spillway to let floodwater pass and a gate that can be used to release water into an irrigation canal. With help from the NAPA FU project, PDoWRAM plan to improve the canal so that farmers can get irrigation water.

Some important points about the O Khsan scheme are that:

- there are villages close by the reservoir area. Because people live near the reservoir, there are many different uses for the water.
- traditionally, the reservoir was not used much for rice irrigation, except for some fields around the edge of the reservoir. Domestic water use, cattle, vegetable growing and fishing were probably more important uses than rice irrigation.
- Traditionally, farmers in this area only grew the rice that they needed to eat. There was no way to export any surplus rice because the road was so bad. Now there is a good road it is easy to sell surplus rice for export. For this reason, farmers may look for new fields to expand their rice growing.

- The area of rice fields that can be irrigated from the reservoir is quite small at present. However, there is a lot of land that could be developed for rice growing, if enough water is available. PDoWRAM expect the rehabilitation of the canal will result in rice growing on maybe another 20 ha - 50 ha of land.
- Tourism is another possible use of the reservoir. The reservoir is quite easy to get to by road and it could be developed for various kinds of tourist business. However, tourists like to see reservoirs full of water, not empty after the water has been used for irrigating rice.
- A request has been made for permission to grow lotus in the reservoir area.

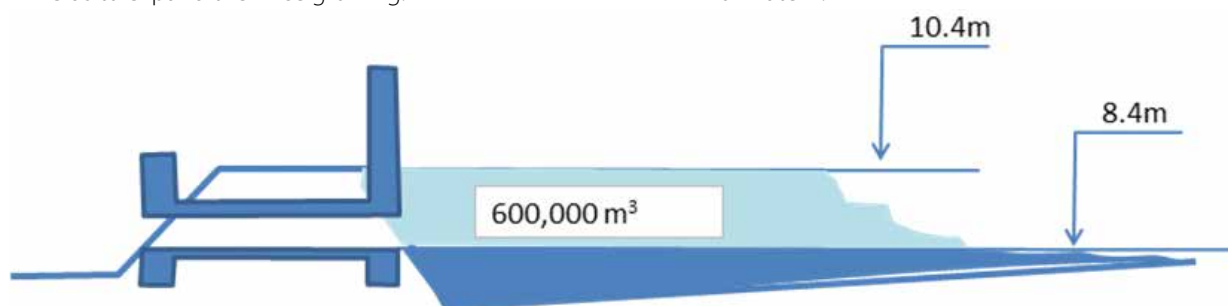
In 2011, MoWRAM have repaired the reservoir to a high standard. The reservoir will keep more water than before and the water flowing into the canal can be controlled by the gate. However, so far there is no plan for how to use the water.

### Step 1: How much water is available?

We will keep this calculation simple by assuming that the reservoir is full at the end of the wet season.

The amount of water available is the amount in the reservoir, that can be released into the canal. That means the water above the level of the gate and below the level of the spillway. (Actually, there is still quite a lot more water that can be pumped out of the reservoir, but for this exercise we will consider the "resource" as the amount that can be released into the canal.

- The crest level of the spillway is about 10.4m elevation.
- The invert of the gate is about 8.4m elevation
- The total area of the reservoir when it is full is about 50ha (500,000m<sup>2</sup>)
- The area of the reservoir at the low water point is about 20 ha (200,000m<sup>2</sup>)
- The volume of water stored and available for use is about  $2 \times (200,000 + (500,000 - 200,000)/3) = 600,000$  m<sup>3</sup> of water<sup>13</sup>.



13. This calculation would be correct if the reservoir was circular with all sides sloping equally towards the middle. To make an accurate calculation we would need to survey the bottom of the reservoir.

These calculations are summarised in the table below

| Estimated Water Use at O Khsan Reservoir |       |                           |                              |
|------------------------------------------|-------|---------------------------|------------------------------|
| Use                                      | Size  | Water Need                | Water Volume                 |
| Old Rice fields irrigated from the canal | 20 ha | 3000 m <sup>3</sup> / ha  | 60,000 m <sup>3</sup>        |
| New Rice fields irrigated from the canal | 20 ha | 3000 m <sup>3</sup> / ha  | 60,000 m <sup>3</sup>        |
| Rice fields irrigated from the reservoir | 5 ha  | 3000 m <sup>3</sup> / ha  | 15,000 m <sup>3</sup>        |
| Rice fields inside the reservoir area    | 5 ha  | 12000 m <sup>3</sup> / ha | 60,000 m <sup>3</sup>        |
| Vegetable crops                          | 5 ha  | 7500 m <sup>3</sup> / ha  | 37,500 m <sup>3</sup>        |
| <b>TOTAL AMOUNT OF WATER NEEDED:</b>     |       |                           | <b>227,500 m<sup>3</sup></b> |

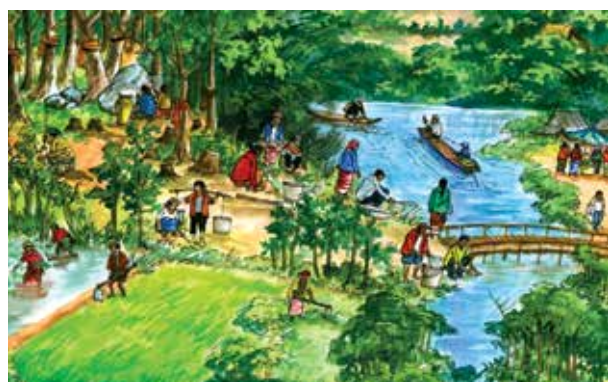
However, during the dry season about half of this water will be lost through evaporation into the air and seepage into the ground, so the amount actually available for use is probably around 300,000m<sup>3</sup>.

### Step 2: Who needs this water?

For this exercise, we will assume that the main water users who want to take water out of the reservoir are:

- Farmers growing rice on existing fields that are irrigated from the canal: 20 ha
- Farmers who want to clear new fields that will be irrigated from the canal: 20ha
- Farmers who grow rice in fields around the reservoir (but are not flooded by the reservoir): 5ha
- Farmers who want to grow a recession rice crop inside the reservoir area on fields that are flooded when the reservoir is full: 5ha
- Vegetable growers around the reservoir area: 5 ha

Other water users: domestic water users, fishermen, cattle owners, lotus growers etc. will not take large amounts of water out of the reservoir, but they may want to keep some water in the reservoir (for example, if there is more water there will be more fish).



### Step 3: How much water might they need?

Suppose the amount of water needed to grow a rice crop on 1ha of land is 12,000m<sup>3</sup>. (This is a reasonable estimate, including water that is lost in the canal and by seepage

into the ground).

The farmers irrigating from the canal and around the reservoir transplant their rice in July –August and harvest in November-December. They get most of their water from rain. However there will be about one month after the end of the wet season when they take water from the canal.

**We will assume these farmers need to get 25% of their water for rice growing from the reservoir, so 3000m<sup>3</sup> per hectare**

**Farmers in the reservoir** area cannot plant until the water level starts to go down. They will plant in November-December and harvest in March-April, so they will not get any water from rain. They will need 12,000m<sup>3</sup> / ha.

Vegetable growers need about 5mm of water per day (50m<sup>3</sup> per ha) for about 50 days for each vegetable crop. If they grow 3 crops in a season they will use 7,500m<sup>3</sup> per ha.

So it appears that on this (very approximate) calculation there is a rough balance between the amount of water available and the amount of water needed.

Obviously this is a very simple way of doing the calculation and there are many more factors to consider. The answer is not exact, but it does show that O Khsan reservoir is about the correct size for its intended purpose (the calculation could tell us if the reservoir was much too big or much too small). The community will find out through experience how much water is available and whether there is a shortage or a surplus.

***Class Discussion:** if the community finds out that there is a surplus of water (so that at the end of the dry season there is still some water stored in the reservoir) what would be the best way to use the water?*

## THEME 2: ADDITIONAL STRESS CAUSED BY CLIMATE CHANGE

Now, we will try to consider what effect will climate change have on the water balance at the O Khsan scheme.

One of the most important effects of climate change, for agriculture, will be that the wet season will get shorter. Therefore, the farmers at O Khsan would need to start using water from the reservoir earlier, and use it for longer.

To look at the effect of this, we will assume that climate change causes the wet season to end one month earlier than at present (at the end of September instead of the end of October). We will assume that the farmers continue growing rice in the traditional way. Now:

- more water will be lost through evaporation and seepage: we will assume the amount lost will become 350,000 m<sup>3</sup>
- farmers growing wet season rice need to use more irrigation water, so now they need 4,000 m<sup>3</sup> / ha of water from the reservoir, instead of 3000m<sup>3</sup> / ha;
- Vegetable growers will need to irrigate their vegetables for longer: assume 8,000m<sup>3</sup> per year instead of 7,500m<sup>3</sup>.

### Group Task

#### Each group should:

1. Re-calculate the "water balance calculations" assuming that the wet season ends in September instead of October.
2. Make suggestions on how the farmers could adapt their agriculture techniques to save water;
3. Make suggestions on how the community could decide which water users have the highest priority, if there is a shortage.

## THEME 3: IMPROVING EFFICIENCY OF WATER USE

If climate change causes water shortages (for example, because more irrigation water will be needed from the O Khsan scheme), there are two possible approaches:

- Try to store more water; or
- Use the water that is stored already, more efficiently.

It would be very difficult to increase the amount of water stored at O Khsan. One way would be to make the spillway higher, but that would cause flooding in the village. Another way (suggested by the villagers) would be to excavate the reservoir to make it deeper, but this would be very expensive (it would cost at least \$US 1.00 to increase the capacity of the reservoir by 1m<sup>3</sup>; but the extra value of rice crop from 1m<sup>3</sup> of water is probably less than \$US 0.05 / m<sup>3</sup> (see Unit 2).

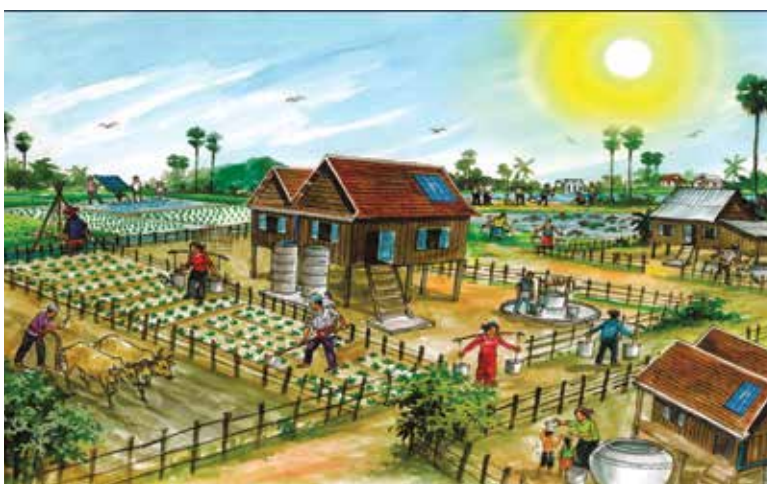
### The Bos Leav Scheme

Most of the land in Bos Leav Commune, Chetr Borei District, Kratie floods every year when the Mekong river rises. The farmers grow rice in the dry season after the flood has gone down.

The area of the Bos Leav irrigation scheme has a number of natural lakes that fill up in the floods every year. The capacity of the lakes has been increased by construction of several small dams that form a line across the area. The dams were constructed in the Pol Pot time. In 2008 the dams were repaired and some canals constructed with help from a Japanese organisation. However the dam is damaged every year by floodwater and the canals are not in good condition.

Most of the farmers in the Bos Leav scheme area need to use pumps to irrigate their rice fields. However, some farmers are too far from the lakes or have land that is too high. Other farmers have low land that stays flooded after the end of the wet season. These farmers sometimes open the water gates to lower the level of water so they can grow rice.

Climate change is likely to increase shortages of water at Bos Leav. The dry season will be longer and hotter and so there will be more need for water from the reservoirs. The amount of water available may decrease as more water will be lost through evaporation.



*The sustainable usage of water*

Like at O Khsan, it would be very difficult to increase the amount of water stored at Bos Leav. That is because, if we make the dam higher, it will help some farmers (who have the higher fields) but it will have a bad impact on the farmers with the lowest fields, in the area north of the reservoir.

The farmers sometimes have to pump water into the canals. However, because the canals are earth canals and not in very good condition, a lot of this water (maybe 20% -40%<sup>14</sup>) will just seep back into the ground again before it reaches the fields. So a lot of water is wasted and the farmers spend money for pumping water that never gets to their fields.

At Bos Leav, there is enough water to grow a rice crop on all the rice fields, and there may be enough water to grow a second crop on some fields. However, we need to use water effectively. This will need

- Better technology to control the flow of water (keeping the water in the places where it is needed)
- Better technology for taking the water to the fields – one option is constructing concrete canals that do not leak water;
- Strong institutions to manage the water and stop some farmers from wasting water that other farmers need.



The irrigation from canal

# TECHNOLOGIES FOR WATER MANAGEMENT



## UNIT SUMMARY

This unit will be divided into two sub-units: technology for improving climate resilience in rice irrigation and community-based technology for water for horticulture and household use. Participants will be encouraged to compare technologies using a common standard of costs and benefits.

Three areas will be examined: improving durability, particularly resistance to flood damage; the advantages and disadvantages of seeking to increase reservoir storage capacity as a response to climate change; and technologies to improve water use efficiency in transmission and in the field.

Community-based technologies examined and compared will include rainwater harvesting, pond and well construction, potential use of solar and wind power and on-farm improvements such as drip irrigation.

## UNIT 4.1: CLIMATE ADAPTIVE TECHNOLOGIES FOR RICE IRRIGATION

### THEME 1: IRRIGATION FOR ADAPTATION TO CLIMATE CHANGE

#### KEY MESSAGES

1. Cambodia's irrigation infrastructure is characterised by a number of key weaknesses
2. Although the government has invested heavily in water sources and main canals (making more water available) there is a need to improve distribution networks (secondary and tertiary canals)
3. Rice irrigation uses water very inefficiently. Technologies that can improve the efficiency of water use include lined or concrete canals for distribution.
4. Systems that provide the farmer with "free" water may not be the most economic and do not provide the farmer with incentives to use water efficiently.

As a result of climate change, Cambodia will have more rain, but the rain will fall in a shorter wet season. There will be more intense storms and bigger floods (see Unit 1). This will cause more damage to the irrigation systems, unless the design of the systems is improved.

Reservoir dams almost always need spillways (like the one in the photograph) to allow flood waters to pass without damaging the dam. Spillways are designed based on the maximum flood size that is expected to happen, with the climate we have today. But the spillway may last for 50 years or more. After 50 years, the climate may have changed. Should we try to build spillways bigger so that they will be big enough for the floods that may happen after climate change?

**Class discussion:**  
**Advantages and disadvantages of designing spillways for future climate conditions.**

Because the wet season will be shorter, Cambodian farmers will become more reliant on water from reservoirs to irrigate their crops. As we saw in Unit 3; there are two ways to make more water available:

- Increase the size of the water resource: for example, by building more reservoirs;
- or
- Use the water from the reservoirs more efficiently: grow more rice for each cubic metre of water.

The NAPA and other plans for climate-change adaptation investments include a number of proposals for new reservoirs or repairs to existing reservoirs. If these reservoirs are built successfully, they will increase the climate resilience of the local communities. However, there are some disadvantages of building reservoirs:

1. They are expensive to build;
2. Because Cambodia is a flat country, reservoirs use a lot of land. For example, the reservoir at O Khsan has a total area of about 50 hectares, and we calculated in Unit 3 that the total area of fields it can irrigate is also about 50 hectares. So, for one hectare of irrigated rice land, we need to use 1 hectare for reservoir<sup>15</sup>.
3. Very often there are already farmers growing rice in the reservoir area. According to the law, the reservoir area is State land, but the farmers may have been there a long time. Even if the farmers have no right to be there, we have to subtract the value of their crop from the benefits of the reservoir scheme.

**Water Use Efficiency.**

Irrigation efficiency means the amount of rice that can be grown with one cubic metre of water, or the volume of water needed to grow one tonne of rice.



*O Khsan reservoir without spillway*



*O Khsan reservoir with spillway*



The amount of water taken from the irrigation reservoir to grow one tonne of rice<sup>16</sup> might be about 4,000 m<sup>3</sup>. Where does this water go to<sup>17</sup>?

- Evapo-transpiration (making the rice plant grow): 1,700 m<sup>3</sup>
- Evaporation from the field directly into the air: 500 m<sup>3</sup>
- Water seeping into the soil from the rice field: 800 m<sup>3</sup>
- Water seeping into the ground from the canal: 1000 m<sup>3</sup>

So (in this example) only about 40% of the water taken out of the reservoir is actually used by the rice plant to grow.

Most of the canals on Cambodia's irrigation systems are very inefficient. They are earth canals with no lining, and a lot of water just seeps back into the ground. In our example, 25% of the reservoir water is lost this way, but in the proportion can be 50% or more in some cases.

The canals have very few gates and check structures, so it is not easy to control the flow of water in the canal. The canals are like a tap that can only be turned "full on" or "full off." If the farmers can control the flow of water so that the fields get just the correct amount of water, they can use water more efficiently. They can grow more rice with the same amount of water.

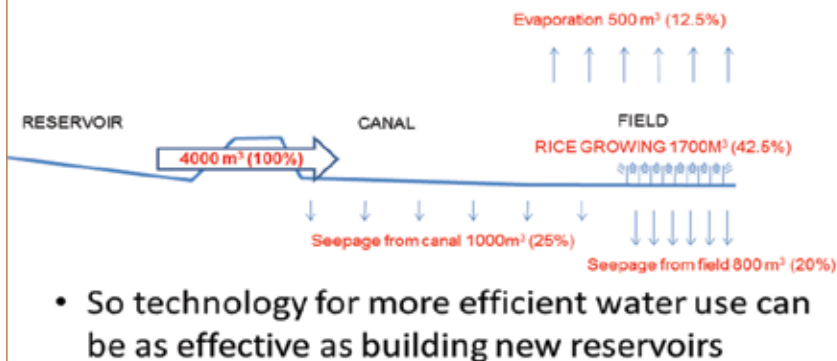
Techniques farmers can use to improve water efficiency at field level include:

15. The area of the Kamping Puoy Reservoir in Battambang Province, irrigated is about 4,800 ha.

16. Based on 12,000m<sup>3</sup> per ha for a crop of 3 tonnes / ha

17. Based on output of FAO-Cropwat software for rice growing in medium soil type in Cambodian climate. Canal losses based on Indian Practical Civil Engineer's Handbook.

## Only about 40% of the water released from the reservoir is actually used to grow rice



- Broadcast planting (instead of traditional transplanting) uses about 25% less water;
- Alternate wetting and drying: Flooding the field, then allowing it to dry, then flooding it again, uses less water than keeping the field flooded all the time.
- Land levelling: if the field is not completely level, water will be wasted because the farmer has to apply too much water in one part of the field to have enough water in another part;
- Changing ploughing methods can reduce seepage losses.

However, none of these methods will help save water unless the farmer can control the amount of irrigation water applied to the field.

Compared to a traditional earth canal, a concrete canal like the one in the picture has many advantages:

compared to 10m – 20m for an earth canal carrying the same water;

- We can easily design the canal to cross over drainage channels, letting floodwater flow away underneath the canal without damaging it;
- Any gates and check structures the canal needs will be very small, for they just fit inside the concrete channel.

However, it is much more expensive to build a concrete canal compared to an earth canal. A concrete canal like the one in the picture would probably cost \$US 60,000 for one kilometre. One kilometre of earth canal to carry the same water, would cost perhaps \$US 10,000. If we include check structures and gates for the earth canal, the cost might be \$US 20,000 /km, so still only one-third of the cost of the concrete canal.

Suppose the concrete canal irrigates 60 ha of rice. It

- No water is lost through seepage (if the canal is in good condition);
- The canal cannot be damaged by erosion;
- Because the canal cannot be damaged by erosion, we can design it to make the water flow faster than in an earth canal. Then, the canal will not become full of silt;
- The maintenance costs of the canal are very low;
- The canal needs very little land – it is only about 1m wide

## A technology for water-efficient irrigation: Concrete Canals



Traditional earth canal at Stung Phe, Kampot province



Concrete canals at O Krasar, Kep province

needs 10,000m<sup>3</sup> of water to irrigate 1 ha rice so the total water flowing in the canal is 600,000m<sup>3</sup> per year.

In an earth canal, perhaps 25% the water would be lost through seepage. So the amount of water taken out of the reservoir would be 800,000 m<sup>3</sup> per year and 200,000m<sup>3</sup> of this water would be lost before it reached the field. Therefore with the concrete canal we save 200,000m<sup>3</sup> of water to use to irrigate additional fields. We can say the benefit of the concrete canal (from increased water use efficiency) is 200,000m<sup>3</sup> of water per year.

How much does this water cost? We can calculate the cost as the payments on a loan to build the canal, paid back over the life of the canal (say, 10 years).

Using the amortization formula (Unit 2) we find that

$$A = P [i + (1+i)^N] / [(1+i)^N - 1]$$

- P = \$US 40,000 (the extra cost of the concrete canal)
- i = 12%
- N = 15 years
- A = \$US 5,873

So the cost per cubic metre of water saved is \$US 5,873 / 200,000 = \$US 0.029 / m<sup>3</sup>. That is quite a low cost compared to the “cost of water” we calculated for various water sources in Unit 2. Of course, this calculation does not take into account the other benefits of the concrete canal.

## Pumping Versus Gravity Flow

Many irrigation canals are designed so that water can flow directly to the fields from the canal by gravity flow. For this to happen, the level of water in the canal has to be at least 100mm higher than the ground level in the fields.

Of course, farmers like gravity flow systems because they do not have to use pumps. The farmer does not spend money on pump fuel so he is happy.

However, experience in Cambodia is that even happy farmers are not very willing to pay Irrigation Service Fees for the irrigation water they get. Because there is no money to maintain the canals, they often become



damaged until they can no longer command the fields by gravity. Then, the farmers have to use pumps to irrigate their fields.

Canals that provide water by gravity flow are more expensive to build and more expensive to maintain than low-level canals that the farmer has to pump.

## Which is the Better System: Cost-Benefit Analysis

An example calculation of the benefits of each canal system is shown in the table below.

Based on these figures we can calculate the net benefit (the farmers' benefit minus the maintenance costs and the pumping costs) for each canal, each year:

- Gravity flow canal:  $(50 \times 110) + (20 \times 500) - 2,000 = \$US 13,500$  per year
- Pumped canal:  $(50 \times 110) + (20 \times 500) - 100 - (50 \times 40) - (20 \times 300) = \$US 8,600$  per year.

So the gravity flow canal has a higher cost but provides a bigger benefit to the farmers. How can we decide which is “better?”

One way is to use a cost-benefit analysis technique called “Internal Rate of Return” This is rather like calculating an annual profit from an investment. We can calculate Internal Rate of Return using a formula in Microsoft Excel<sup>18</sup>. We enter the capital cost of the project as a minus amount in Year 0 and the annual benefit in each of Years 1 to 15.

So, calculating by this method, the pumped canal provides a higher return on investments than the gravity flow canal.

18. The Excel formula for IRR is “=IRR(MyRange)” where MyRange contains the net benefit in each year during the lifetime of the scheme. At least one value in MyRange (usually the first year, when the capital cost is incurred) must be negative.

## Which is the Better System: Cost-Benefit Analysis

|                                        | Gravity Flow Canal | Pumped Canal  |
|----------------------------------------|--------------------|---------------|
| Cost of Construction (per km)          | \$US 20,000        | \$US 7,500    |
| Cost of Maintenance (per km, per year) | \$US 2,000         | \$US 100      |
| Wet Season Fields Irrigated            | 50 ha              | 50 ha         |
| Dry Season Fields Irrigated            | 20 ha              | 20 ha         |
| Benefit to Farmer WS                   | \$US 110 / ha      | \$US 110 / ha |
| Benefit to Farmer DS                   | \$US 500 / ha      | \$US 500 / ha |
| Farmers' Pumping Cost WS               | 0                  | \$US 40 / ha  |
| Farmers' Pumping Cost Dry Season       | 0                  | \$US 300 / ha |

| Year         | 0          | 1         | 2         | 3         | ...       | 15        | IRR % |
|--------------|------------|-----------|-----------|-----------|-----------|-----------|-------|
| Gravity Flow | - \$20,000 | \$ 13,500 | \$ 13,500 | \$ 13,500 | \$ 13,500 | \$ 13,500 | 67%   |
| Pumped       | - \$ 7,500 | \$ 8,600  | \$ 8,600  | \$ 8,600  | \$ 8,600  | \$ 8,600  | 92%   |

*Class discussion: Comment on this finding. What other advantages or disadvantages could there be for each type of canal?*

## UNIT 4.2 COMMUNITY-BASED TECHNOLOGIES FOR WATER MANAGEMENT

### KEY MESSAGES

1. There are a number of technologies available for community based water management. Some of these technologies are new, others are very familiar in Cambodia
2. All these technologies have some useful applications. However, we must take into account the costs and the appropriate uses of each technology.
3. Farmers will not adopt a technology if it is not economic – that is, if the cost of water using the new technology is higher than the cost of water using the old technology.

### LESSON CONTENT

#### THEME 1: WHAT DO WE MEAN BY COMMUNITY BASED ADAPTATION MEASURES

Next, we will look at a number of technologies we can call “Community Based Adaptation Measures.” These are technologies for small-scale water management by households and local communities. We will see that in general, these technologies are not suitable for rice irrigation because the scale is too small or the costs

are too high. However, these technologies can be an important part of building climate resilience if they are used for the appropriate purpose.

We will look at a number of different technologies. We will try to compare the technologies by calculating a “cost of water” from each technology.

We will look at two types of small-scale water source:

1. Ponds
2. Rainwater Harvesting

We will look at two types of “new” technology for pumping water.

3. Wind Pump
4. Solar Pump

We will also look at one “old” technology: diesel pumps; and ask if there are ways that they can be made more efficient.

#### 1. Ponds

Ponds are a very familiar technology in Cambodia. In the past they have been used for many different purposes:

- domestic water supplies;
- water for animals;
- water for vegetable gardens;
- fish raising.

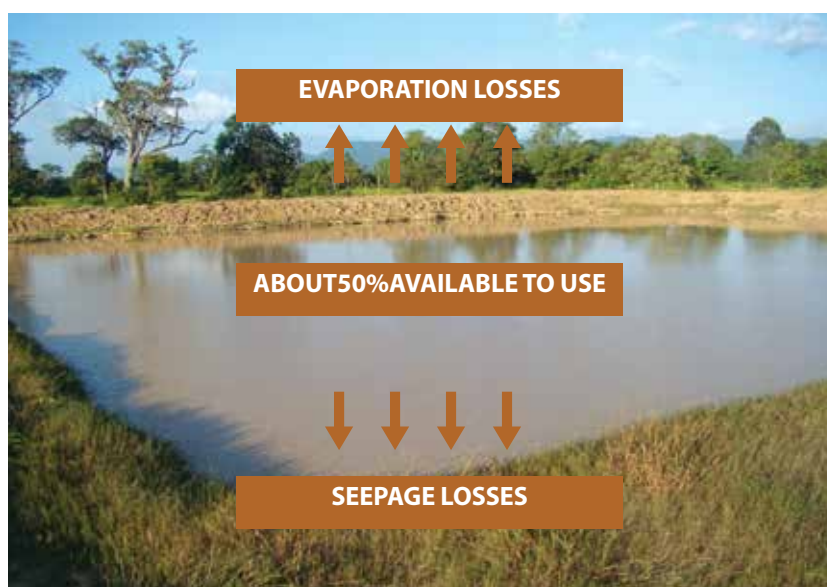
Ponds are not a very good type of domestic water supply, because they can easily become contaminated. However, they can be very useful as a water source for vegetable gardens or for fish raising.

## How much water does a pond provide?

The simplest way to calculate this is to assume that the pond is full at the end of the wet season.

Then, probably about half of the water stored in the pond at the end of the wet season will be lost through seepage into the ground and by evaporation (minus any rain that falls in the dry season).

So the water provided will be about half the volume of the pond, each year.



## APPROXIMATE GARDEN SIZE AND COSTS FOR PONDS

| Length<br>m | Width<br>m | Depth<br>m | Volume<br>m <sup>3</sup> | Water<br>Available<br>m <sup>3</sup> | Area of<br>Garden <sup>19</sup><br>m <sup>2</sup> | Example    | Approx.<br>Cost <sup>20</sup> |
|-------------|------------|------------|--------------------------|--------------------------------------|---------------------------------------------------|------------|-------------------------------|
| 10          | 5          | 2          | 50.67                    | 25.33                                | 35                                                | 7m x 5m    | \$ 100.00                     |
| 20          | 10         | 3          | 366.00                   | 183.00                               | 244                                               | 12m x 12m  | \$ 500.00                     |
| 50          | 25         | 4          | 3,885.33                 | 1,942.67                             | 2,500                                             | 25m x 100m | \$ 3,000.00                   |

Suppose the pond is used for watering vegetables. Using the same estimate as in Unit 3, a vegetable garden producing three crops of vegetables in the dry season will need about 7,500m<sup>3</sup> of water hectare, or 0.75m<sup>3</sup> per square metre.

Based on this, the following table shows the size of vegetable garden that can be watered with ponds of different sizes.

So a pond costing about \$US 100 to excavate will provide enough water for a small vegetable garden for household consumption. A large pond costing \$US 3,000 will provide enough water for a commercial vegetable garden of 0.15ha, or for household gardens for about 50 families.

On the same calculation, a pond providing enough water for 0.5ha of rice field (needing 6000m<sup>3</sup> of water) would

probably need to be about 80m x 40m x 5m deep and would cost about \$US 10,000. The investment is about \$US 20,000 per hectare, or about ten times as much per hectare MoWRAM estimates for canal irrigation schemes<sup>21</sup>.

## Rainwater Harvesting

Rainwater harvesting just means catching and storing rainwater. Many different technologies are used around the world but the one that is most familiar in Cambodia is roof-rainwater harvesting. Water falling on the roof is trapped and stored in a jar or tank.

Many families in Cambodia use rainwater harvesting. However the main cost of the system is the cost of the tank to store the water. For this reason, only a minority of families install systems that can provide enough water to use through the dry season.

19. Garden areas that can be irrigated from each pond are based on a dry season irrigation requirement of 7,500m<sup>3</sup>/ha or 750 litres/square meter of garden. See Training Materials Data Table for source.

20. Costs based on data for pond excavations from C/S Fund Project Implementation Database

21. MoWRAM uses budget estimates of \$1,500 to \$2,000 per hectare for irrigation rehabilitation. Source: World Bank Public Expenditure Review 2011 for Agriculture, Irrigation and Rural Roads.



### How big a tank does a family need, to have water all through the dry season?

If we calculate for a family of five people using the rainwater only for their domestic water needs, we can assume they need about 100 litres of water every day<sup>22</sup>.

For the six dry months November –April, they will use about 18,000 litres of water.

They may not need a tank of 18,000 litres size, because some water will fall on their roof in the dry season.

Probably a tank of 10,000 litres would ensure the family has a water supply all through the year.

However, a 10,000 litre tank is not cheap – a concrete tank of this size would cost about \$US 1,000, while a plastic water tank of 10,000 litres costs about \$1,200.

For watering vegetables, a pond would normally be a less costly solution than rainwater harvesting.

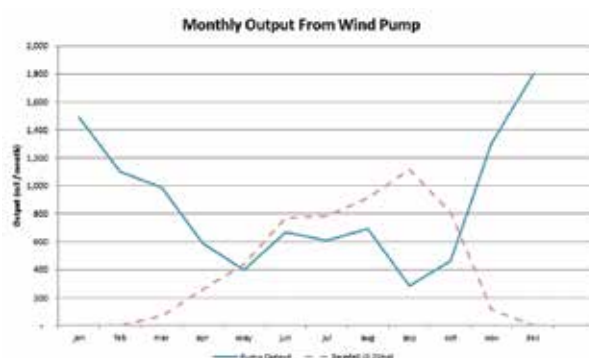
## Wind Pumps

Wind pumps have been used in many different countries in the world – in China and in the Netherlands, and more recently in the United States of America, for example. However they have not been common in Cambodia, partly because Cambodia is not a very windy country.

Recently, some companies and NGOs have tried to introduce wind pumps into Cambodia. The advantages of a wind pump are clear: the technology is very simple, and the energy source is free. Using a standard formula (from FAO<sup>23</sup>), and wind speed data from NASA<sup>24</sup>, we can calculate approximately how much water a wind pump in a good location in northern Cambodia, lifting water from a well with the water table 5m below the ground, might pump in 1 year.

We can see that the months with less wind, and so less

| Costs of Wind Pump Set-Up <sup>25</sup> |                  |
|-----------------------------------------|------------------|
| Part                                    | Approximate Cost |
| 4m CDI wind pump                        | \$ 1,800         |
| Borehole                                | \$ 500           |
| 100 m <sup>3</sup> tank                 | \$ 3,250         |
| Miscellaneous                           | \$750            |



### Expected Monthly Output from Wind Pump<sup>26</sup>

Pump Output calculated for a 4.0 m diameter wind pump operating with 7m dynamic head in northern Cambodia. Effective rainfall is calculated for a 0.5 hectare vegetable patch.

22. See Index: Training Materials Data Table

23. FAO Irrigation and Drainage Paper 43: Water Lifting Devices. <http://www.fao.org/docrep/010/ah810e/AH810E00.htm>

24. <http://eosweb.larc.nasa.gov/sse/>

25. Wind pump cost quoted on CDI website:XXX. Other costs area approximate.

26. <http://cambodia.picosol.nl/en/solar-pump-system-layout>



output, are in the wet season when there is no need for water from the pump. Based on this calculation, one 4m wind pump would probably provide enough water for 0.75 ha of vegetables.

However, the total amount of water pumped is not the only important figure. For a vegetable grower, the water must be available every day, not just on the days when the wind blows. Because the wind is not very reliable in Cambodia, the system will need a tank big enough to hold water for several days.

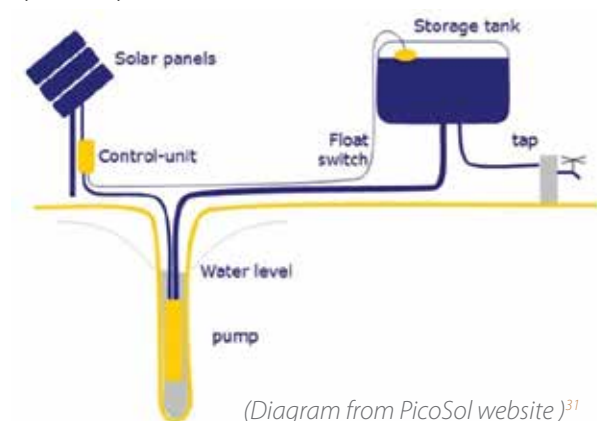
For 0.75ha of vegetable garden, a tank of 100m<sup>3</sup> would be needed to hold four days' supply of water (assuming that only 0.5ha of vegetables are actually growing on any particular day, the water need is about 25m<sup>3</sup> per day). A tank of this size is quite expensive – it would be the most costly part of the system, as shown in the table.

## Solar Pumps

Solar pumps are a much newer technology than wind pumps, because they depend on solar panels for the power source. The pump itself is an electric pump, but it must be a special type because the amount of power will vary a lot.

Compared to wind pumps, solar pumps have one big advantage in Cambodia: the sunshine here is much more reliable than the wind. Therefore, a solar pump set will not need such a big tank as a wind pump set.

## System lay-out



Solar water pumping system in Bos leav commune, Kracheh province

| Cost of Solar Pump Set-Up |                  |
|---------------------------|------------------|
| Part                      | Approximate Cost |
| Solar Panel 300 Wp        | \$ 1,800         |
| Controller                | \$ 50            |
| Borehole                  | \$ 500           |
| 50 m <sup>3</sup> tank    | \$ 2,000         |
| Pump                      | \$ 2,000         |
| Miscellaneous             | \$1,150          |
| <b>Total</b>              | <b>\$ 7,500</b>  |

For the same situation as the wind pump set, a solar pump set would probably cost slightly more: Note that as well as being used for vegetable gardens, solar pumps or wind pumps could potentially be used for domestic water supplies in a village. Instead of constructing many wells at different places around the village (so people have water close to their homes) it would be possible to construct one well with a wind pump or a solar pump, a high tank and a pipe system to take water to different parts of the village.

### Group Exercise: Calculating the Cost of Water

Each group will calculate internal rate of return on investment (IRR) in one of the following technologies:

- Pond
- Rainwater harvesting
- Wind Pump
- Solar Pump

(more data for the calculations will be supplied during the lesson)

### An old technology: Diesel Pumps

The “cost of water” from any of the technologies we have just looked at : ponds, rainwater harvesting, wind pumps or solar pumps; is much higher than the cost of pumping water from a river or a borehole using a diesel pump.

For this reason, it is not realistic to expect that Cambodian

farmers will invest their own money in wind pumps or solar pumps in the near future. They will use this technology if someone else pays the capital cost, but they will not buy it for themselves.

Diesel pumps also have the big advantage that the farmer can move the pump around and can switch it on and off whenever he likes – he does not have to wait for the wind to blow or the sun to shine.

However, diesel pumps are not seen as “clean” technology because they burn diesel fuel and so they contribute to the cause of climate change by emitting carbon dioxide (though actually the amount is rather small, compared to the amount of CO<sub>2</sub> produced by cars belonging to climate change projects, for example).

Diesel pumps are not very efficient. Only about 10% of the energy in the diesel fuel, is converted into pumping energy. The diesel pumps used by Cambodian farmers are probably much less efficient than this. The pumps are normally described as “15hp” pumps but a calculation of the output shows it is probably less than 5hp<sup>27</sup>. An engine will not work most efficiently when it is only working at a small part of its maximum power.

Nobody has studied this problem, but it is possible that by using more efficient pumps, and by using them in more efficient ways, Cambodian farmers could save money, improve climate change resilience – and reduce CO<sub>2</sub> emissions.



*The use of old pumping machine for irrigation*

27. Based on data collected at Bos Leav, Kratie in March 2011 and on standard engine efficiency calculations

*An increase in overall fuel efficiency of 10% in a diesel pump used to pump 30,000 cubic metres per year would save 75 litres of fuel and reduce CO<sub>2</sub> emissions by about 200 kg. The farmer will save about \$US 50 per year in fuel costs. This is probably quite similar to the saving the farmer would make if he installed a wind pump or a solar pump to pump part of the water for his rice field.*

# INTEGRATED WATER MANAGEMENT AS A RESPONSE TO CLIMATE CHANGE

## UNIT SUMMARY

In this unit participants will be introduced to the concept of integrated water resource management. The relevant provisions of the Water Law will be reviewed. Different approaches to the allocation of water will be discussed, including a “water pricing” approach and a “allocation” approach.

Participants will review the vital role that institutions have in management of water resources. The basic institutional framework in Cambodia will be examined and its strengths and weaknesses discussed. The need for improved cross-sectoral integration and for capacity to allocate water use rights (as opposed to a focus on operation and maintenance of infrastructure) will be identified.

Participants will review what institutions exist at present in their home provinces for integrated water management, and how effectively these function.

The proposals recently developed by CDRI for integrated water resource management at Provincial level will be reviewed.

## KEY MESSAGES

1. Water use in one sector in one province can affect water resources in another sector or in another province.
2. Integrated Water Resource Management means making the most efficient use of water resources taking the needs of all sectors and the natural environment into account.
3. There are different ways of allocating water resources. One way is “water pricing” where the user who can pay the highest price, gets the most water. Another way is “allocation” where a management institution decides how much water each user gets.
4. A good plan for water resources is only useful if there is a strong institution to implement the plan.

5. FWUC need to develop a capacity to manage water and enforce community decisions, not just to maintain infrastructure.
6. Recently, CDRI developed a proposal for integrated water resource management committees at Provincial level.

## LESSON CONTENT

### THEME 1: INTEGRATED WATER RESOURCE MANAGEMENT<sup>28</sup>

In the previous units we have talked about how farms and communities may need to choose priorities for water use. Climate change will cause more severe shortages

28. [http://en.wikipedia.org/wiki/Integrated\\_Water\\_Resources\\_Management](http://en.wikipedia.org/wiki/Integrated_Water_Resources_Management)

of water in the dry season and the need for water management will be greater.

Water management is not just a matter for one sector. For example, if farmers pump water from wells for irrigation, the groundwater table goes down and there is a shortage of water for domestic use. This is already happening in some areas of Cambodia and is a common problem in other countries.

Water flows across administrative boundaries. For example, if all the water in the Stung Sen was used for agriculture in Preah Vihear, there would be a shortage of water in Kampong Thom.

River water and groundwater are not completely separate resources. Rivers are fed mainly by groundwater flows. If we pump water out of the river, the groundwater level will go down, and if we pump water out of the ground, the river level will go down.

### **Integrated Water Resource Management (IWRM) means<sup>29</sup>:**

*“a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.”*

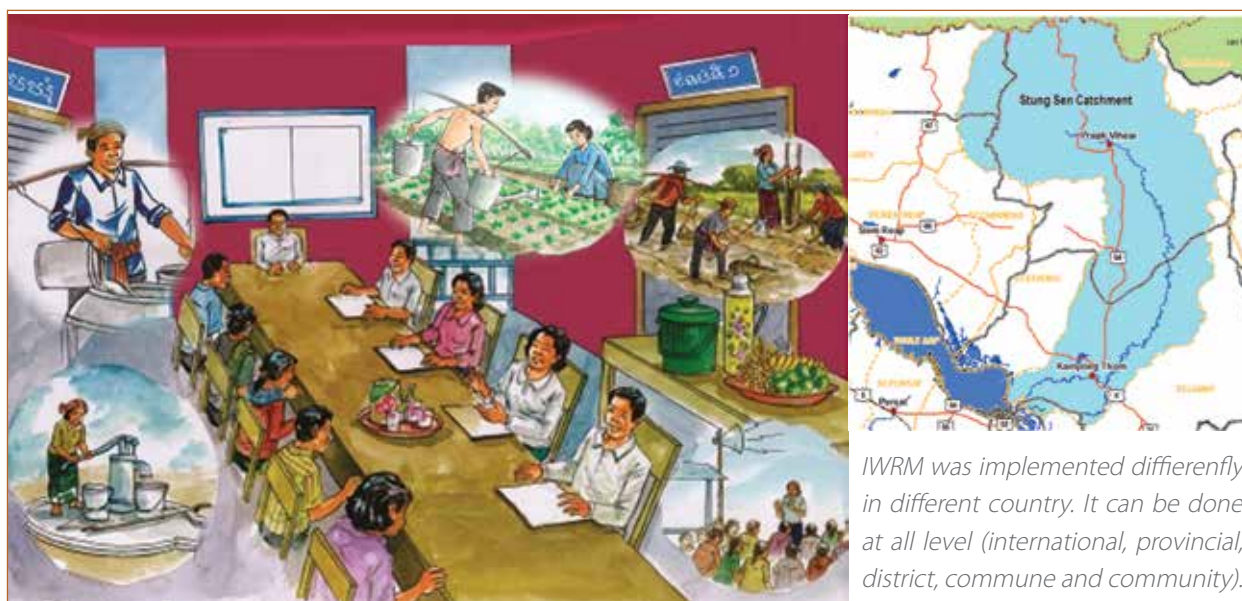
IWRM means planning for the whole water resource and for the needs of all water users. In IWRM, the natural environment is considered as one of the water users.

*“An IWRM approach is an open, flexible process, bringing together decision-makers across the various sectors that impact water resources, and bringing all stakeholders to the table to set policy and make sound, balanced decisions in response to specific water challenges faced.”*

In the Dublin Statement<sup>30</sup> on Water and Sustainable Development (1992) the following principles were agreed:

1. “Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
2. “Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels.
3. “Women play a central part in the provision, management and safeguarding of water.
4. “Water has an economic value in all its competing uses and should be recognized as an economic good, taking into account of affordability and equity criteria.”

IWRM institutions usually have representatives from different types of water user – for example, agriculture, industry, domestic water supplies.



29. [http://en.wikipedia.org/wiki/Integrated\\_Water\\_Resources\\_Management](http://en.wikipedia.org/wiki/Integrated_Water_Resources_Management)

30. [http://en.wikipedia.org/wiki/Dublin\\_Statement](http://en.wikipedia.org/wiki/Dublin_Statement)



*The Mekong River Basin is defined by the land area surrounding all the streams and rivers that flow into the Mekong River. This includes parts of China, Myanmar and Viet Nam, nearly one third of Thailand and most of Cambodia and Lao PDR. With a total land area of 795 000 square kilometres, the Mekong River Basin is nearly the size of France and Germany together. From its headwaters thousands of metres high on the Tibetan Plateau, it flows through six distinct geographical regions, each with characteristic features of elevation, topography and land cover. It would take 2 days of twenty-four hour driving at 100 km per hour to drive the same distance as the length of the Mekong River (4800 km).*

*From the Mekong River Commission website<sup>31</sup>*

## THEME 2: CAMBODIA LAW AND INSTITUTIONS

Overall management of Cambodia's water resources is governed by the Water Law of 2007<sup>32</sup>. Under the Water Law:

1. All water resources are the property of the State;
2. Ministry of Water Resources and Meteorology is responsible to manage water resources in cooperation with other concerned Ministries;

3. Citizens are entitled to use water for essential purposes "in a manner that will not affect the legal rights of others." Essential purposes includes domestic use and home gardens but does not seem to include rice irrigation.
4. Large scale water users – including irrigation water users – need a permit issued by MoWRAM. They must pay a water fee.
5. The Water Law establishes the legal basis for the Farmer Water User Communities and states that the FWUC must be registered with the Provincial Departments of Water Resources (PDoWRAM).
6. The Water Law introduces an Integrated Water Resource Management approach.

The policy of MoWRAM for management of irrigation systems is called Participatory Irrigation Management and Development (PIMD). Under PIMD, FWUC are responsible to operate and maintain the canal systems that bring water to the rice fields. FWUC should be financed by Irrigation Service Fees paid by the farmers.

## THEME 3: ALLOCATING WATER USE RIGHTS

Who should have the right to use water, and how much? Some different approaches might be:

1. "Water comes from the sky as rain. It should be free like the air, anybody can use as much as they want."
2. "Any water that is on my land, or in the ground under my land, that is my water. I can use it how I like."
3. "Water should be shared out fairly. First, everybody should have enough to drink. Next, everybody should have enough for other essential uses. Then, the water that is left over should be shared out equally."
4. "Water is an economic good. The way to allocate economic goods efficiently is to sell them in a market"

31. [www.mrcmekong.org](http://www.mrcmekong.org)

32. Water Law 2007

Anybody who has water should be allowed to sell it to anybody who needs it and can pay for it, so the user who can pay the highest price can get the most water."

***Class Discussion: Which of these four statements do you agree with most? (Take a vote).***

All four of the statements we have discussed could be taken as a good description of how water is allocated, in some countries and at some times. In most countries including Cambodia, there is a shortage of water, at some times and in some places, so Statement 1 is not practical. If some people take all the water they want, other people will not have enough.

The Cambodian Water Law says clearly that all water resources belong to the State. That means, that a land owner does not automatically have the right to use any water that is on his or her land, or in the ground under the land. In reality, the Government does not normally try to regulate how citizens use water that is on their land. However, examples where the government might intervene include:

- A farmer constructs a big borehole well and uses it to irrigate his rice fields. He can grow three crops of rice per year. But his neighbours find that the groundwater level has dropped so their wells are dry. They complain to the Commune Chief because they have no water to drink in the dry season.
- A factory uses water to wash its equipment and lets the dirty water, full of chemical pollutants, flow back into the stream that crosses the factory land. Further down the stream, farmers find that the water is poisonous. It makes their animals sick and they cannot use it to irrigate their fields.

In most countries, the approach to allocation of water resources is close to either Statement 3 or Statement 4, or sometimes a mixture of both. We can call Statement 3 an Allocation approach and Statement 4 a Water Pricing approach.

Cambodian policy as expressed in the Water Law is effectively an Allocation Approach. Although the Law provides for a Water Fee, water rights belong to the State so they cannot be bought and sold. Most farmers do not have to pay the full cost of supplying water to their fields (because the Government has paid the capital costs and the FWUC are not strong enough to collect the Irrigation

Service Fees). Because the farmer does not pay for the water, he is not careful to use it efficiently. This creates shortages for other users. Because irrigation water is paid for by the Government, not the farmer, the richest farmers (who have most land) get the most help from the Government and the poorest farmers get the least help.

In a water pricing approach, the State allocates (or sells) water rights to citizens, including farmers. Then, the farmers can either use their water rights, or sell them to somebody else. Australia uses this method for managing water resources. For example:

- Farmer A and Farmer B both have rights to use an equal amount of water.
- However, Farmer A has good land and Farmer B has bad land.
- Farmer A buys water rights from Farmer B. Then, Farmer A uses all the water. Farmer B does not grow any crops, but he gets an income from selling his water rights to Farmer A.

**A water pricing system is difficult to implement in a country like Cambodia because:**

- There is not enough infrastructure to transfer water from one user to another;
- it is difficult to measure the amount of water each user gets;
- users expect to get water for free. They will not be happy if they have to start paying.
- there are no water management institutions that can control the system.

The International Water Management Institute (IWMI) sees water pricing as the best policy in the long term. However it recognises that this would be difficult to achieve immediately:

*At the Kamping Puoy scheme in Battambang, irrigation service fees are set at 40,000 riel per hectare for the dry season crop. This is a low amount compared to the benefit the farmer gets and is not enough to pay the cost of maintaining the scheme. However, the FWUC finds that it is difficult to collect even this fee. Small farmers pay the correct amount, but big farmers – owning 10 hectares or more in some cases, refuse to pay and the FWUC is not strong enough to enforce payment.*



*“In many places, water allocations might be easier to implement than water pricing, particularly in the near-term. However, public agencies in many areas should take a long-term view toward establishing the institutions and investing in the infrastructure needed to support effective water pricing programmes.”*

Water pricing is not realistic in Cambodia now. However, climate change will happen over a long time. By 2060 or 2090, Cambodia may be as developed as Australia is now. The first step is to understand that water is an economic good that has a cost to the supplier and a value to the user. If the cost to the supplier (often, the Government) is more than the value to the user (the farmer) the result will be poor management of water resources and increased vulnerability to climate change.

## THEME 4: EXISTING WATER MANAGEMENT INSTITUTIONS

### Group Task

Each group should:

- Make a list of which institutions are involved in water management in their Province, at Provincial,

District, Commune and Community level. Is there any institutions based on a river basin or catchment, instead of an administrative area?

- How effective are these institutions at managing water? What could be done to improve their effectiveness?
- How is water allocated? What kinds of user get priority, and how is the priority enforced?

At the local level FWUC has responsibility for water resource management. To be able to implement this effectively, FWUC needs capacity to make water use plans, allocate water to each farmer in a fair way, and enforce decisions (stop some farmers from taking more than their share). This function of the FWUC is at least as important as its maintenance function. Unfortunately, FWUC are often seen just as “committees to maintain the canal” and their capacity for water management is very weak.

## THEME 5: A PROPOSAL FOR INTEGRATED WATER MANAGEMENT AT SUB-NATIONAL LEVEL IN CAMBODIA

CDRI have conducted a study into integrated water resource management in Cambodia. Based on discussions with stakeholders, they proposed the establishment

of sub-committees at Provincial level, to be called an Irrigation and Catchment Management Sub-Committee (ICMSC). The ICMSC would:

- Coordinate FWUCs, provincial departments and local authorities and provide inter-disciplinary expertise from different provincial departments, NGOs, donors and external experts in hydrology and IWRM;
- Build a common understanding among stakeholders about IWRM and D&D policy and support the

spatial integration of upstream and downstream communities;

- Promote 'bottom-up' processes for small and medium scale irrigation schemes;
- Provide a forum for funds to be raised;
- Assist in conflict-resolution and enable FWUCs to help farmers plan and coordinate their cropping and harvesting informed by hydrological and social knowledge.

# DEVELOPING INTEGRATED WATER MANAGEMENT PLANS FOR COMMUNITIES

## UNIT SUMMARY

In this final unit the participants will prepare model water resource management plans. One model and two practical examples (Bos Leav and Teuk Krahorm) will be discussed. Participants will identify the different (potentially competing) groups of water users, propose how priorities for water use should be set and discuss technologies and institutions that could contribute to integrated and effective management of the water resource.

## KEY MESSAGES

1. Integrated Water Resource Management should be based on a water resource management plan
2. The plan should identify the size of the water resource and the water needs of different uses, now and in the future
3. The effects of climate change should be considered in the water resource management plan

## LESSON CONTENT

**The key contents of a water resource management plan should include:**

1. Size of the resource: how much water is available for use?
2. Water Users and Water Needs:
  - a. Who are the different water users?
  - b. How much water do they need, and at what time of year?
3. Impact of development: these could include:
  - a. In the future there will be more people, so they will need more water;
  - b. People will increase the amount of water they use, as they get richer;
  - c. New industries or types of agriculture may start in the area and may need water.
4. Impact of climate change:
  - a. What impact will higher temperatures have on water use?
  - b. What impact will shorter wet seasons have?
5. Management Arrangements
  - a. Which institutions are responsible to manage the water resource?
  - b. How will their decisions be enforced?
6. Water Use Priorities: If there is a shortage of water (for instance, because of a drought) which uses should be reduced first?

## Model Irrigation Scheme: O Sar

| Name of                                                                         | O Sar                                                                                                                                                                                                                                                                             |     |     |             |     |                                     |       |      |      |
|---------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-------------|-----|-------------------------------------|-------|------|------|
| Scheme                                                                          |                                                                                                                                                                                                                                                                                   |     |     |             |     |                                     |       |      |      |
| Location                                                                        | O Sar is a community reservoir used for irrigation and fishing. Some rare birds come to breed on the reservoir and this is the basis for a small eco-tourism industry.                                                                                                            |     |     |             |     |                                     |       |      |      |
| General Description                                                             | <ul style="list-style-type: none"><li>Wet season rice irrigation</li><li>Dry season rice irrigation</li><li>Dry season non-rice crop irrigation</li><li>Fishing</li><li>Eco-tourism</li></ul>                                                                                     |     |     |             |     |                                     |       |      |      |
| Present Uses                                                                    | Embankment dam and 2 lines of canal with gates                                                                                                                                                                                                                                    |     |     |             |     |                                     |       |      |      |
| History                                                                         |                                                                                                                                                                                                                                                                                   |     |     |             |     |                                     |       |      |      |
| Command Area                                                                    | Total area that can be irrigated from the canals is 100 ha. Actual cropping at present is: <ul style="list-style-type: none"><li>Wet season rice 100 ha</li><li>Dry season rice 15 ha</li><li>Non-rice crops 15 ha</li></ul>                                                      |     |     |             |     |                                     |       |      |      |
| Farming Systems                                                                 | 1 wet season rice crop planted in August and harvested in December<br>1 dry season rice crop planted in February and harvested in May<br>Dry season non-rice crops grown from November to June                                                                                    |     |     |             |     |                                     |       |      |      |
| FWUC                                                                            | FWUC formed but few activities and little capacity yet                                                                                                                                                                                                                            |     |     |             |     |                                     |       |      |      |
| Water Availability                                                              | Total amount of water stored in the reservoir at the end of October is 1,200,000 m <sup>3</sup> . During the dry season water is lost by evaporation and seepage and some water is gained from rainwater recharge.                                                                |     |     |             |     |                                     |       |      |      |
|                                                                                 | Month By Month Water Losses and Use in Dry Season ( x 1000 m <sup>3</sup> )                                                                                                                                                                                                       |     |     |             |     |                                     |       |      |      |
|                                                                                 |                                                                                                                                                                                                                                                                                   | Nov | Dec | Jan         | Feb | Mar                                 | April | May  | June |
|                                                                                 | Evaporation                                                                                                                                                                                                                                                                       | -50 | -50 | -50         | -55 | -60                                 | -70   | -55  | -50  |
|                                                                                 | Seepage                                                                                                                                                                                                                                                                           | -50 | -50 | -50         | -50 | -50                                 | -50   | -50  | -50  |
|                                                                                 | Recharge                                                                                                                                                                                                                                                                          | +60 | +40 | +10         | +5  | +5                                  | +50   | +100 | +200 |
| Irrigation water needed for each type of crop, x 1000 m <sup>3</sup> / ha / mth |                                                                                                                                                                                                                                                                                   |     |     |             |     |                                     |       |      |      |
|                                                                                 | WS Rice                                                                                                                                                                                                                                                                           | 2   | 1   |             |     |                                     |       |      |      |
|                                                                                 | DS Rice                                                                                                                                                                                                                                                                           |     |     | 2           | 4   | 2                                   | 3     | 2    |      |
|                                                                                 | Non-Rice Crop                                                                                                                                                                                                                                                                     | 1.5 | 1.5 | 1.5         | 1.5 | 1.5                                 | 1.5   | 1    | 0.5  |
| Other needs (minimum volume of water needed in reservoir x 1000m <sup>3</sup> ) | Fishing                                                                                                                                                                                                                                                                           |     |     |             |     | 150                                 |       |      |      |
|                                                                                 | Environment (rare birds)                                                                                                                                                                                                                                                          |     |     |             | 200 |                                     |       |      |      |
| Impact of Climate Change                                                        | <ul style="list-style-type: none"><li>Severe floods delay planting until September</li><li>Wet season ends 1 month earlier. Wet season rice crop will need 2,000m<sup>3</sup> / ha irrigation water per month October – December plus 1000m<sup>3</sup> / ha in January</li></ul> |     |     |             |     |                                     |       |      |      |
| Crop Security                                                                   | Security of the wet season rice crop is the highest priority for the farmers                                                                                                                                                                                                      |     |     |             |     |                                     |       |      |      |
| Benefits                                                                        | Type of water use                                                                                                                                                                                                                                                                 |     |     | Benefit     |     | # HH doing this activity at present |       |      |      |
|                                                                                 | Wet season rice crop                                                                                                                                                                                                                                                              |     |     | \$300 / ha  |     | 120                                 |       |      |      |
|                                                                                 | Dry season rice crop                                                                                                                                                                                                                                                              |     |     | \$250 / ha  |     | 20                                  |       |      |      |
|                                                                                 | Dry season vegetables                                                                                                                                                                                                                                                             |     |     | \$2000 / ha |     | 40                                  |       |      |      |
|                                                                                 | Fishing                                                                                                                                                                                                                                                                           |     |     | \$400 / HH  |     | 10                                  |       |      |      |
|                                                                                 | Eco-tourism                                                                                                                                                                                                                                                                       |     |     | \$1000 / HH |     | 10                                  |       |      |      |

We can show that all the water users at O Sar are roughly in balance. However:

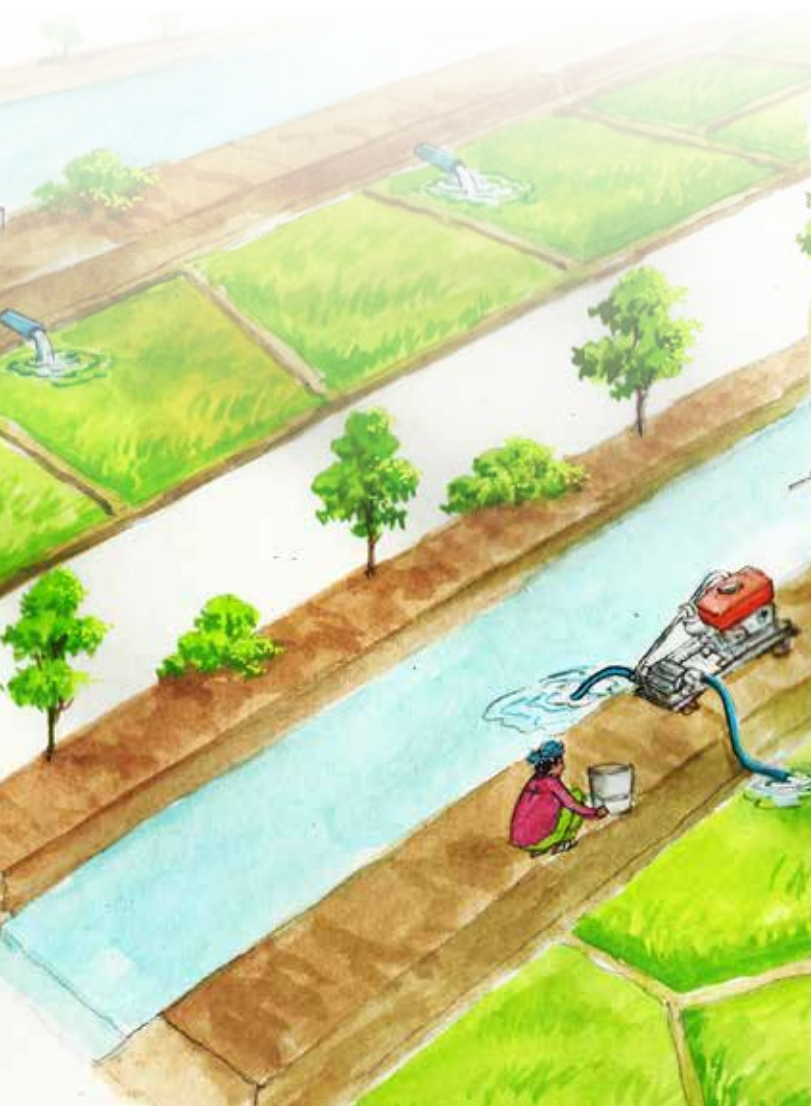
- If any users tries to increase the amount of water use (for example, more households grow dry season rice or more households grow non-rice crops) there will not be enough water.
- If climate change makes the dry season longer, there will not be enough water for all the present uses.

*Class discussion: How to decide which users should have priority? How to enforce the decisions that are made?*

### Group Task

Based on the descriptions of the irrigation schemes (this will include data on the size of the water resource available) at Bos Leav and at Teuk Krahorm and on their knowledge, the groups should carry out the following tasks.

1. Identify the different types of water user at the scheme;
2. Identify what existing institutions have a role in water resource management at the scheme, and what arrangements there are for coordination between them;
3. Propose how priorities for water use should be set. Who should have the right to use water, for what purpose? How should decisions such as, when to open and close water gates, be taken?
4. What actions should be taken to improve climate change resilience at the irrigation scheme?
5. What improvements in infrastructure or technology could make water management at the scheme more effective?
6. How could the institutions for water management at the scheme be strengthened, to make water management more effective?



# ANNEX 1: TRAINING WATER USE DATA

| Description                                        | Source                                                                                                                                                                                                                                                                                                              | Unit                | Quantity |
|----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------|
| Quantity of Water Needed to Grow 1 ha of Rice Crop | A reasonable average value. NCDD Technical Manual assumes 1,3500mm (= 1,3500m <sup>3</sup> / ha). The irrigation schedules for Kamping Puoy, Battambang are based on about 1,1000m <sup>3</sup> / ha. Rain would add about 100m <sup>3</sup> /ha in the growing season so 1,2000m <sup>3</sup> / ha is a "good fit" | m <sup>3</sup>      | 12,000   |
| Water Used for Vegetable Growing in the Dry Season | Based on average requirement of 4mm / day over 6 months.                                                                                                                                                                                                                                                            | m <sup>3</sup>      | 7,500    |
| Household daily water consumption                  | Figure used in Rural Water Supply and Sanitation Framework of MRD, 2001: see World Bank WSP 2007 "Measuring Rural Water Supply Access." NB NCDD Technical Manual sets this as a minimum figure.                                                                                                                     | litres / person     | 20       |
| Livestock water consumption: cows                  | Water Requirements of Livestock at:<br><a href="http://www.omafra.gov.on.ca/english/engineer/facts/07-023.htm">http://www.omafra.gov.on.ca/english/engineer/facts/07-023.htm</a><br><br>See also: Davis and Lambert 1995: Engineering in Emergencies (Oxfam)                                                        | litres/ animal /day | 40       |
| Livestock water consumption: pigs                  |                                                                                                                                                                                                                                                                                                                     | litres/ animal/ day | 10       |
| Livestock water consumption: chickens              |                                                                                                                                                                                                                                                                                                                     | litres/ animal/ day | 0.5      |

# ANNEX 2: COST OF WATER

## EXERCICE 1: Rain Water Harvesting Storage

|               |                                              |          |                          |
|---------------|----------------------------------------------|----------|--------------------------|
| Investment    | US\$250                                      | Duration | 10 years                 |
| Incurent Cost | 5% of the capital investment for maintenance | Result   | 100 m <sup>3</sup> /year |

| Amortisation Calculation: Rain Water Harvesting Storage |   |           |                    |                              |           |               |           |
|---------------------------------------------------------|---|-----------|--------------------|------------------------------|-----------|---------------|-----------|
| Calculation of Annual Payment                           |   |           |                    | Illustration of Loan Payment |           |               |           |
|                                                         |   |           |                    | Year                         | Repayment | Interest Rate | Balance   |
| Capital Amount                                          | P | \$ 250.00 |                    | 0                            |           |               | \$ 250.00 |
| Interest Rate                                           | i | 12%       |                    | 1                            | \$ 36.71  | \$ 30.00      | \$ 243.29 |
| Number of Years                                         | N | 10        |                    | 2                            | \$ 36.71  | \$ 29.20      | \$ 235.78 |
|                                                         |   |           |                    | 3                            | \$ 36.71  | \$ 28.29      | \$ 227.37 |
| Annual Payment                                          | A | \$ 36.71  |                    | 4                            | \$ 36.71  | \$ 7.28       | \$ 217.95 |
| Operation Cost                                          |   | \$ -      |                    | 5                            | \$ 36.71  | \$ 26.15      | \$ 207.40 |
| Maintenance Cost                                        |   | \$ -      |                    | 6                            | \$ 36.71  | \$ 24.89      | \$ 195.58 |
| Total Cost Per Year                                     |   | \$ 36.71  |                    | 7                            | \$ 36.71  | \$ 23.47      | \$ 182.34 |
|                                                         |   |           |                    | 8                            | \$ 36.71  | \$ 21.88      | \$ 167.52 |
| Water Benefit                                           |   | 182.50    | m <sup>3</sup> /yr | 9                            | \$ 36.71  | \$ 20.10      | \$ 150.91 |
| Cost per m <sup>3</sup>                                 |   | \$ 0.20   |                    | 10                           | \$ 36.71  | \$ 18.11      | \$ 132.32 |

**Exercise:** Use amortisation formular (use Microsoft Excel) to calculate the cost of 13 m<sup>3</sup>. Intest rate is 12% in one year.

| Internal Rate of Return: Rain Water Harvesting Storage |   |           |                    |                                 |                |               |        |
|--------------------------------------------------------|---|-----------|--------------------|---------------------------------|----------------|---------------|--------|
| Calculation of Internal Rate of Return                 |   |           |                    | Illustration of NPV Calculation |                |               |        |
|                                                        |   |           |                    | Year                            | Annual Benefit | Present Value |        |
| Capital Amount                                         | P | \$ 250.00 |                    | 0                               | \$ -250.00     | \$            | -250   |
| Interest Rate                                          | i | 12%       |                    | 1                               | \$ 67.53       | \$            | 60.29  |
| Number of Years                                        | N | 10        |                    | 2                               | \$ 67.53       | \$            | 58.83  |
|                                                        |   |           |                    | 3                               | \$ 67.53       | \$            | 48.06  |
| Annual Payment                                         | A | \$ 36.71  |                    | 4                               | \$ 67.53       | \$            | 42.91  |
| Operation Cost                                         |   | \$ -      |                    | 5                               | \$ 67.53       | \$            | 38.32  |
| Maintenance Cost                                       |   | \$ -      |                    | 6                               | \$ 67.53       | \$            | 34.21  |
| Total Cost Per Year                                    |   | \$ 36.71  |                    | 7                               | \$ 67.53       | \$            | 30.54  |
|                                                        |   |           |                    | 8                               | \$ 67.53       | \$            | 27.27  |
| Water Benefit                                          |   | 182.50    | m <sup>3</sup> /yr | 9                               | \$ 67.53       | \$            | 24.35  |
| Cost per m <sup>3</sup>                                |   | \$ .20    | \$ 0.37            | 10                              | \$ 67.53       |               | 21.74  |
| Annual Net Benefit                                     |   |           | \$ 67.53           |                                 |                |               |        |
| Net Present Value                                      |   |           |                    |                                 | \$ 131.53      | \$            | 131.53 |
| IRR                                                    |   |           |                    |                                 | 23.82%         |               |        |

## EXERCICE 2: Pump Well

|                      |                                                                                                                   |
|----------------------|-------------------------------------------------------------------------------------------------------------------|
| Investment           | US\$1,500                                                                                                         |
| Operation Cost       | Labor: 1/2 day to fetch 1m <sup>3</sup> of water. Labor cost for US\$3/day.                                       |
| Total Operation Cost | 730m <sup>3</sup> x US\$3/2 = US\$1,095                                                                           |
| Maintenance          | 1% of the capital investment                                                                                      |
| Duration             | 10 years                                                                                                          |
| Result               | Each household fetch 100 liters of water per day. 100 liters/1,000 x 20 households x 365 days = 730m <sup>3</sup> |

**Exercise:** Use the amortisation formular (use Microsoft Excel) to calculate the cost 1m<sup>3</sup> of water from pump well.

| Amortisation Calculation: Pump Well |   |             |                    |                              |           |               |             |
|-------------------------------------|---|-------------|--------------------|------------------------------|-----------|---------------|-------------|
| Calculation of Annual Payment       |   |             |                    | Illustration of Loan Payment |           |               |             |
|                                     |   |             |                    | Year                         | Repayment | Interest Rate | Balance     |
| Capital Amount                      | P | \$ 1,500    |                    | 0                            |           |               | \$ 1,500    |
| Interest Rate                       | i | 12%         |                    | 1                            | \$ 265.48 | \$ 180        | \$ 1,414.52 |
| Number of Years                     | N | 10          |                    | 2                            | \$ 265.48 | \$ 169.74     | \$ 1,318.79 |
|                                     |   |             |                    | 3                            | \$ 265.48 | \$ 158.25     | \$ 1,211.57 |
| Annual Payment                      | A | \$ 265.48   |                    | 4                            | \$ 265.48 | \$ 145.39     | \$ 1,091.48 |
| Operation Cost                      |   | \$ 1,095    |                    | 5                            | \$ 265.48 | \$ 130.98     | \$ 956.98   |
| Maintenance Cost                    |   | \$ 15       |                    | 6                            | \$ 265.48 | \$ 114.84     | \$ 806.34   |
| Total Cost Per Year                 |   | \$ 1,375.48 |                    | 7                            | \$ 265.48 | \$ 96.76      | \$ 637.63   |
|                                     |   |             |                    | 8                            | \$ 265.48 | \$ 76.52      | \$ 448.67   |
| Water Benefit                       |   | 730         | m <sup>3</sup> /yr | 9                            | \$ 265.48 | \$ 53.84      | \$ 237.03   |
| Cost per m <sup>3</sup>             |   | \$ 1.88     |                    | 10                           | \$ 265.48 | \$ 28.44      | \$ -0       |

| Internal Rate of Return: Pump Well     |   |             |                    |                                 |                |               |  |
|----------------------------------------|---|-------------|--------------------|---------------------------------|----------------|---------------|--|
| Calculation of Internal Rate of Return |   |             |                    | Illustration of NPV Calculation |                |               |  |
|                                        |   |             |                    | Year                            | Annual Benefit | Present Value |  |
| Capital Amount                         | P | \$ 1,500    |                    | 0                               | \$ -1,500      | \$ -1,500     |  |
| Interest Rate                          | i | 12%         |                    | 1                               | \$ 270.10      | \$ 241.16     |  |
| Number of Years                        | N | 10          |                    | 2                               | \$ 270.10      | \$ 215.32     |  |
|                                        |   |             |                    | 3                               | \$ 270.10      | \$ 192.25     |  |
| Annual Payment                         | A | \$ 265.48   |                    | 4                               | \$ 270.10      | \$ 171.65     |  |
| Operation Cost                         |   | \$ 1,095    |                    | 5                               | \$ 270.10      | \$ 153.26     |  |
| Maintenance Cost                       |   | \$ 15       |                    | 6                               | \$ 270.10      | \$ 136.84     |  |
| Total Cost Per Year                    |   | \$ 1,375.48 |                    | 7                               | \$ 270.10      | \$ 122.18     |  |
|                                        |   |             |                    | 8                               | \$ 270.10      | \$ 109.09     |  |
| Water Benefit                          |   | 730         | m <sup>3</sup> /yr | 9                               | \$ 270.10      | \$ 97.40      |  |
| Cost per m <sup>3</sup>                |   | \$ 1.88     | \$ 0.37            | 10                              | \$ 270.10      | \$ 86.96      |  |
| Annual Net Benefit                     |   |             | \$ 270.10          |                                 |                |               |  |
| Net Present Value                      |   |             |                    |                                 | \$ 26.13       | \$ 26.13      |  |
| IRR                                    |   |             |                    |                                 | 12.42%         |               |  |

## EXERCICE 3: Solar Pump

|                  |                                                          |
|------------------|----------------------------------------------------------|
| Investment       | US\$7,600                                                |
| Incurrent Cost   | \$ -                                                     |
| Maintenance Cost | US\$50/year                                              |
| Duration         | 10 years                                                 |
| Result           | 15 households use 3,650 m <sup>3</sup> of water per year |

**Exercise:** Use the amortisation formular (use Microsoft Excel) to calculate the cost 1m<sup>3</sup> of water from solar pump.  
Interest rate is 12% per year

| Amortisation Calculation: Solar Pump |   |             |                    |                              |             |               |             |
|--------------------------------------|---|-------------|--------------------|------------------------------|-------------|---------------|-------------|
| Calculation of Annual Payment        |   |             |                    | Illustration of Loan Payment |             |               |             |
|                                      |   |             |                    | Year                         | Repayment   | Interest Rate | Balance     |
| Capital Amount                       | P | \$7,600.00  |                    | 0                            |             |               | \$ 7,600.00 |
| Interest Rate                        | i | 12%         |                    | 1                            | \$ 1,345.08 | \$ 920.00     | \$ 7,166.92 |
| Number of Years                      | N | 10          |                    | 2                            | \$ 1,345.08 | \$ 860.03     | \$ 6,681.87 |
|                                      |   |             |                    | 3                            | \$ 1,345.08 | \$ 801.82     | \$ 6,138.62 |
| Annual Payment                       | A | \$1,345.08  |                    | 4                            | \$ 1,345.08 | \$ 736.63     | \$ 5,530.17 |
| Operation Cost                       |   | \$ -        |                    | 5                            | \$ 1,345.08 | \$ 663.62     | \$ 4,848.71 |
| Maintenance Cost                     |   | \$ 76.00    |                    | 6                            | \$ 1,345.08 | \$ 581.85     | \$ 4,085.48 |
| Total Cost Per Year                  |   | \$ 1,421.08 |                    | 7                            | \$ 1,345.08 | \$ 490.26     | \$ 3,230.65 |
|                                      |   |             |                    | 8                            | \$ 1,345.08 | \$ 387.68     | \$ 2,273.25 |
| Water Benefit                        |   | 4,380       | m <sup>3</sup> /yr | 9                            | \$ 1,345.08 | \$ 272.79     | \$ 1,200.96 |
| Cost per m <sup>3</sup>              |   | \$ 0.32     |                    | 10                           | \$ 1,345.08 | \$ 144.12     | \$ -0.00    |

| Internal Rate of Return: Solar Pump    |   |             |                    |                                 |                |               |
|----------------------------------------|---|-------------|--------------------|---------------------------------|----------------|---------------|
| Calculation of Internal Rate of Return |   |             |                    | Illustration of NPV Calculation |                |               |
|                                        |   |             |                    | Year                            | Annual Benefit | Present Value |
| Capital Amount                         | P | \$7,600.00  |                    | 0                               | \$ -7,600.00   | \$ -7,600.00  |
| Interest Rate                          | i | 12%         |                    | 1                               | \$ 1,620.60    | \$ 1,446.96   |
| Number of Years                        | N | 10          |                    | 2                               | \$ 1,620.60    | \$ 1,291.93   |
|                                        |   |             |                    | 3                               | \$ 1,620.60    | \$ 1,153.51   |
| Annual Payment                         | A | \$1,345.08  |                    | 4                               | \$ 1,620.60    | \$ 1,029.92   |
| Operation Cost                         |   | \$ -        |                    | 5                               | \$ 1,620.60    | \$ 919.57     |
| Maintenance Cost                       |   | \$ 76       |                    | 6                               | \$ 1,620.60    | \$ 821.05     |
| Total Cost Per Year                    |   | \$ 1,421.08 |                    | 7                               | \$ 1,620.60    | \$ 733.08     |
|                                        |   |             |                    | 8                               | \$ 1,620.60    | \$ 654.53     |
| Water Benefit                          |   | 4,380       | m <sup>3</sup> /yr | 9                               | \$ 1,620.60    | \$ 584.40     |
| Cost per m <sup>3</sup>                |   | \$ 0.32     | \$ 0.37            | 10                              | \$ 1,620.60    | \$ 521.79     |
| Annual Net Benefit                     |   |             | \$ 1,620.60        |                                 |                |               |
| Net Present Value                      |   |             |                    |                                 | \$ 1,556.75    | \$ 1,556.75   |
| IRR                                    |   |             |                    |                                 | 17%            |               |

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