DRAFT (18 September 2006)

MRC Environmental Risk Assessment Training Program

Chau Doc/Takeo Case Study
Workshop 2: Risk Analysis Stage 1

Cambodian Consultants: Mr Lak Leng, Dr Chrin Sokha, Ms Nhim Sophea, Mr Nom Sophearith, Dr Chea Tharith

Vietnam Consultants: Mr Mai Thai An, Dr Tran Mai Kien, Mr Tran Minh Khoi, Dr Duong Hong Son, Mr Doan Van Tien, Ms Pnam Ngoc Xuan

Mentor: Professor Barry Hart

4-8 September 2006

1. Introduction

The report contains a summary of the activities and outputs from the Chau Doc/Takeo Case Study Workshop 2 undertaken 4-8 September in Takeo, Cambodia.

The full program is outlined in Appendix A.

The Environmental Risk Assessment process being followed is shown in Figure 1. Different stages being undertaken as follows:

- Workshop 1 Problem formulation
- Workshop 2 Introduction to risk analysis (both qualitative and quantitative) – including an introduction to Bayesian Network models
- Workshop 3 Risk analysis for present and future scenarios
  Management and planning implications of the results
- Workshop 4 Complete final report with conclusions and recommendations
  Final presentation of results by each team

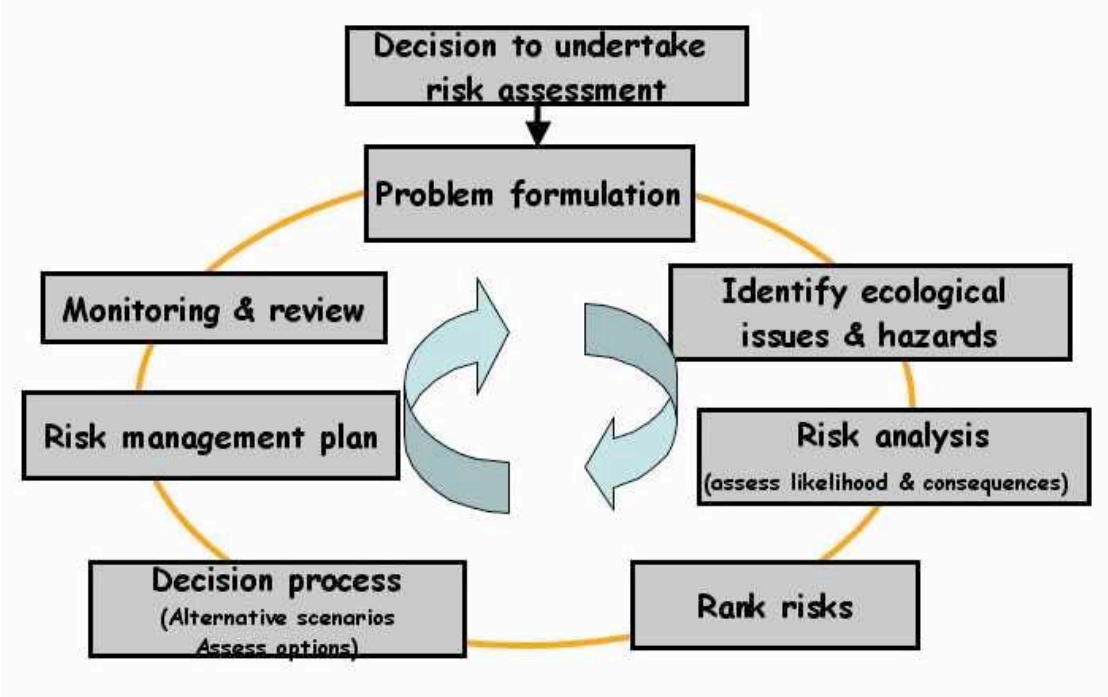

Figure 1: Environmental risk assessment process

2. Summary of problem formulation stage

2.1 Overall risk assessment objective

To determine the potential risks to four important environmental values[1] due to human activities[2] in the study region now and over the next10 years.

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[1] Cage aquaculture fish production, the health of the Bassac River ecosystem, the health of the human population and rice production.

2.2 Study region

- Figure 2 is the system (big picture) conceptual model developed by the participants during Workshop 1.
- During Workshop 1, participants undertook a field visit around the Chau Doc region to familiarise themselves with the various activities in this region (see Chau Doc/Takeo Workshop 1 Report).
- During Workshop 2, participants took a boat trip to view the flooded regions of Takeo Province. We visited the village of Bourei Cholsar, where we meet with the deputy regional leader and discussed a number of aspects of the region. The size of the flooded area was impressive.

2.3 Scope of the project

Spatial

- See Figure 2 for scope - broadly from 20km north of Takeo to 50km south of Chau Doc and about 20km west of the Bassac to 10 km east of the Mekong.
- Subsequently each team further considered the region of study to take account of the area of highest risk for their issue.

Temporal

Three time periods will be investigated:

- present
- short term – 5 years
- medium term – 10 years.

Future scenarios

The future scenarios to be considered at Workshop 3 are listed in Section 5.

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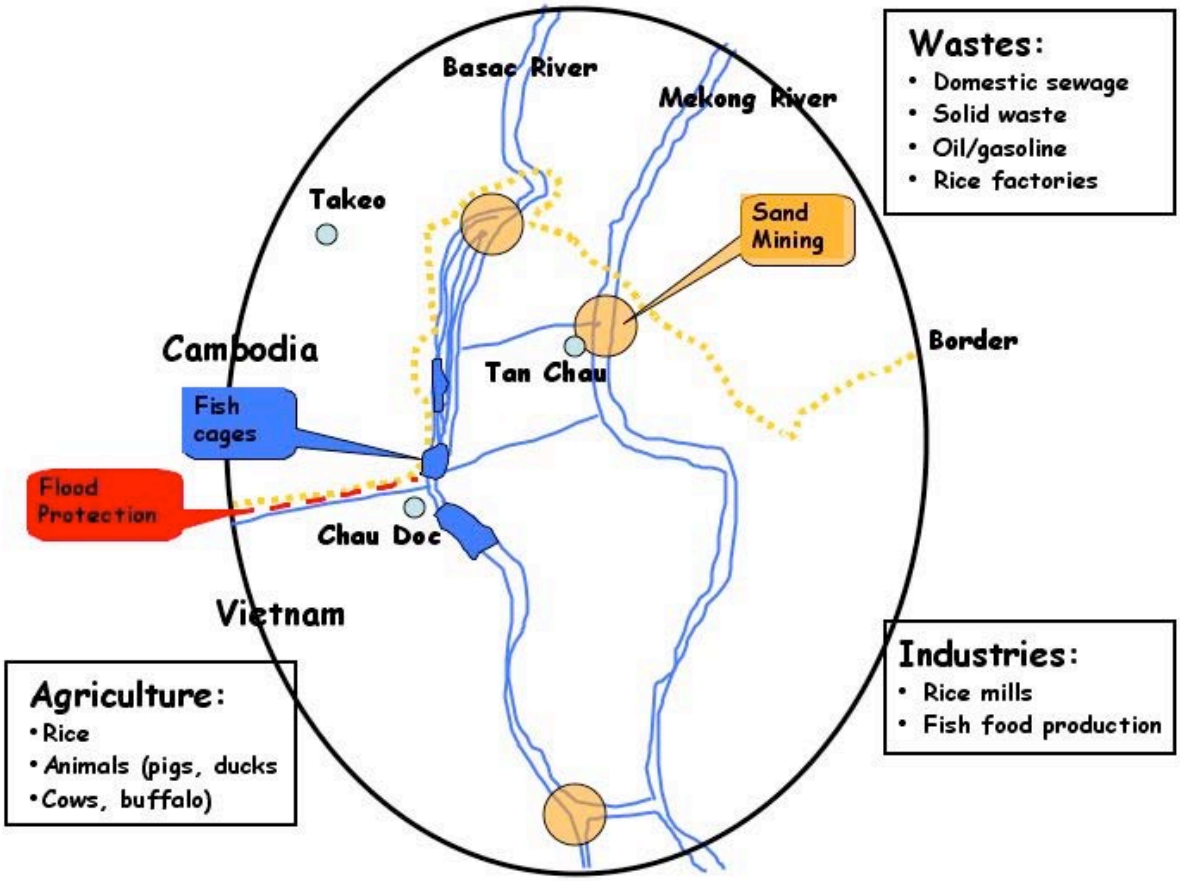
[2] Wastes from humans, agriculture, aquaculture, water transportation; major land use changes; changed flow regimes (e.g. due to Chinese dams); climate change.



2.4 Issues for study

It was agreed that the environmental management goal for the study region was to maintain and protected the following environmental values:

- Maintain *adequate cage aquaculture fisheries production* in the Bassac River in region of Chau Doc,
- Protect *human health* in the study region by maintaining adequate drinking water quality & preventing contamination of food (particularly fish and other aquatic foods),
- Maintain a *healthy ecosystem in the Bassac River* (including fish migration) in the study region and also maintain *healthy wetland ecosystems* around Takeo,
- Maintain *adequate rice production* in the study region.

2.5 Hazard/threat analysis

The following major hazards (threats) were identified:

- *Domestic wastewater* discharged from Chau Doc (population ca. 114,000) to the Bassac River. These effluents include: untreated sewage, septic tank effluent and stormwater. Possible adverse effects due to these wastewater discharges may occur in the vicinity of the city and further downstream. The risk assessment will determine the extent of possible downstream effects.
- *Agricultural* runoff to the Bassac River is thought to occur from the agricultural areas in Takeo Province (Cambodia) and An Giang Province (Vietnam). This

runoff may contain pesticides and herbicides, nutrients, suspended sediment and organic matter, and are a risk to the river and wetland ecosystems.

- There are a very large number of *aquaculture cages* in the Bassac River and also in some canals for producing large quantities of fish. It is known that these contribute organic pollution to the Bassac River.
- *Water transport* – a large number of small and large boats use the Bassac River in the study region. We will assess the risk to the river ecosystem, aquaculture and human health from possible spills of chemicals and oil from these ships, and spills of gasoline from the many gas stations located on the river.
- *Reservoirs* are being built upstream in the Chinese section of the Mekong River, and these have the potential to significantly alter the river flows in the study region, and to increase the risks to the ecological health of the river and to the fisheries production.

3. Details of the issues to be assessed

3.1 Team 1 - Fisheries production – cage aquaculture

Mr Doan Van Tien (Coordinator)

Mr Nom Sophearith

Ms Pnam Ngoc Xuan

Statement of the issue

This part of the case study will assess the risk to cage fish aquaculture activities in Chau Doc and Takeo.

There are many fish aquaculture cages located along the Bassac River near Chau Doc (See Workshop 1 Report) and a smaller number around Takeo[3]. The production of fish in these cages is very important to both the local economy and to the health of the local people (important source of protein). There are a number of potential threats to these activities including: adverse effects caused by waste from towns and villages, factory wastes, aquaculture wastes, agricultural runoff, sedimentation and acidic runoff[4].

Team 1 will investigate the toxic and stress effects and increased incidence of fish diseases on aquaculture fish production (yield) that may be caused by these threats.

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3 Estimates of these numbers will be obtained.

4 From both acid sulfate soils and acid rain.

Assessment endpoints

Will be the maintenance of both fish production (measure by yield) and fish health (measured by the incidence of disease).

Scope of the assessment

This assessment will focus on:

- the area about 20 -25 km around the Bassac River on Vietnam site (An Phu and Chau doc District) and Cambodia (Takeo province), and will
- the dry and wet season, and the transition period between the dry season and the rainy season.

The assumption is that this is the area and the times when the risk is likely to be greatest.

Threats & Hazards

The major threats to cage aquaculture were identified as:

- *Hazards causing fish toxicity* – mainly ammonia from sewage discharges, heavy metals (Hg, Cd, Pb, Cu, Zn) in waste discharge from agriculture, domestic sewage, oil leaching from boats and gas stations, and pesticides from agricultural runoff.
- *Hazards causing stress to fish* – reduction in dissolved oxygen (DO) concentration due to organic matter (BOD) from domestic and agricultural runoff, elevated TSS concentrations and reduced pH from acid runoff.
- *Hazards causing fish disease* - bacteria, parasites and viruses from water waste and aquaculture discharges.

Cause-effect conceptual model

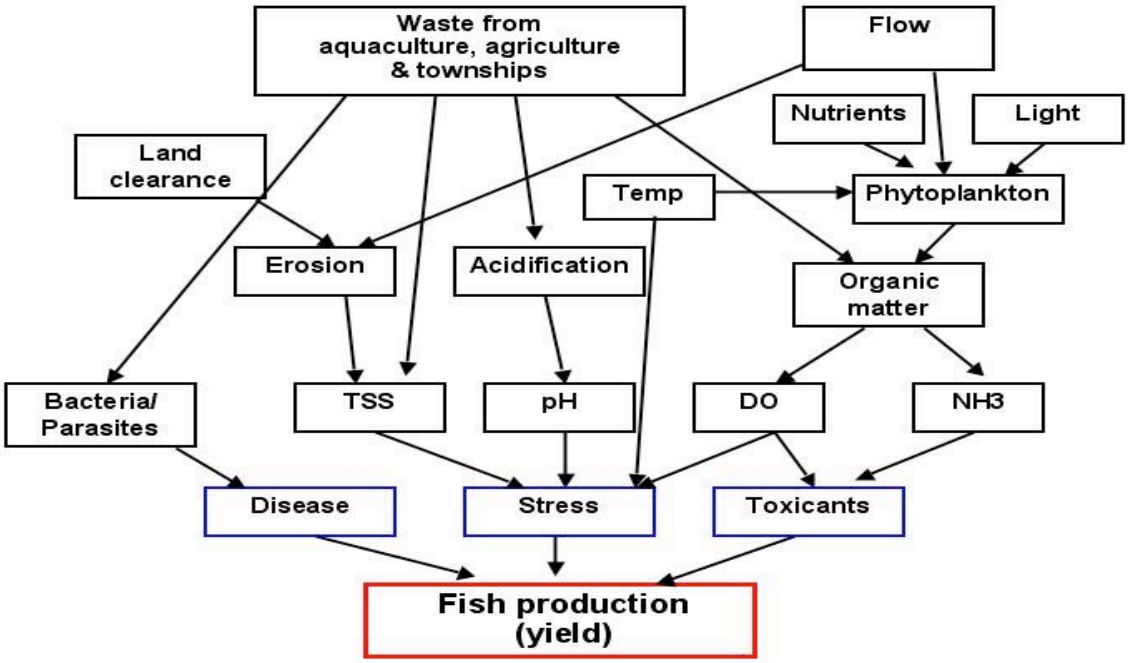

Figure 3: Team 1 conceptual model

Information obtained

See Team 1 Workshop 2 report.

3.2 Team 2 - Human health

Dr Tran Mai Kien (Coordinator)
Mr Lak Leng
Dr Duong Hong Son

Statement of the issue

This part of the case study will assess the risk to human health from water-related factors in the Chau Doc and Takeo regions.

In the study region, it is generally only those people in the larger townships (Chau Doc, Tan Chau, Takeo) that have treated drinking water available to them. Most of the villagers living along the Bassac River and canals use water from the river/canal without treatment.

Additionally, sanitation is poor with domestic sewage generally delivered directly to the waterways from which drinking water is sourced. It is only in the larger townships that any sewage treatment occurs, and then only in septic tanks many (most) of which are poorly maintained.

Thus the part of the case study will focus on water-born diseases and potential human toxicity due to contaminated food.

Assessment endpoints

Will be the number of communicable diseases (with a focus on water-born and water related diseases) related to:

- The digestive system (e.g. dysenteria, diarhea, typhoid fever, parasites),
- Other systems (e.g. malaria, systosomia, tuberculoses, dermatitis, STD (including HIV/AIDS), gynaecological diseases).

Team 2 will also investigate the development and use of a general health index (see conceptual model – Figure 4).

Scope of the assessment

This assessment will focus on the Chau Doc district in the context of the An Giang province in Vietnam and the Takeo province in Cambodia.

Threats & Hazards

Two types of water-related threats to human health have been identified:

(a) By mechanism

- Drinking,
- Eating (Food quality with cumulative effects of toxicology through food-chain mechanism),
- Contact with contaminated water (e.g. domestic water use, air-dissemination),
- Poor behaviour (related to health culture & education),
- Water-related accidents (e.g. accidents associated with water transportation, extreme floods or erosion may cause death or injuries).

(b) By agent

- Biological (e.g. pathogenic bacteria and viruses),
- Chemicals (e.g. toxic heavy metals),
- Organics (e.g. pesticides).

Cause-effect conceptual model

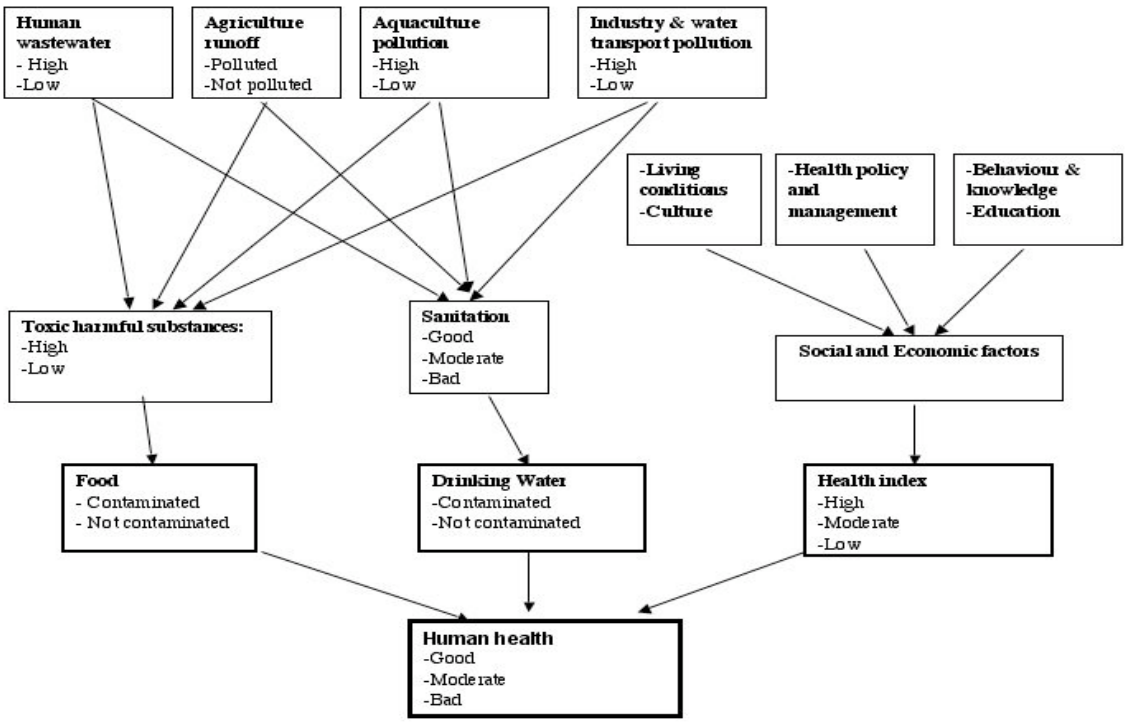

Figure 4: Team 2 conceptual model

Information obtained

See Team 2 Workshop 2 report.

3.3 Team 3 - Ecological health – Bassac river & Cambodian wetlands

Dr Chrin Sokha (Coordinator)
Dr Chea Tharith
Mr Mai Thai An

Statement of the issue

This part of the case study will assess the risk to the ecological health of (a) the Bassac River around Chau Doc and (b) the wetlands around Takeo.

The ecological health of these water bodies is extremely important because of the fish they produce and the ecosystem services they provide – particularly the capacity to 'treat' much of the wastewater that enters them from domestic sources, aquaculture and agriculture.

In addition to degradation in quality due to many sources of pollution, the riverine ecosystem may also be under threat because of possible upstream flow changes. Equally, the wetlands in southern Cambodia are being destroyed due to clearing of inundated forest regions to make way for more rice fields.

Assessment endpoints

Will be:

(a) the maintenance of fish (and macroinvertebrate) species composition in the Bassac River,

(b) the maintenance of fish (and phytoplankton & zooplankton) species composition in the study wetlands.

Scope of the study

The specific study area for the Bassac River will be from the border to 20 km downstream of Chau Doc, while the wetlands study area will be in Cambodia from Takeo township to the Vietnam border.

The focus will also be on the dry season when pollutant concentrations are expected to be highest, and on the dry-wet season transition period when most land-based pollutants will be washed into the wetlands and the Bassac River.

The assumption is that this is the area and the times when the risk is likely to be greatest.

Threats & Hazards

Bassac River	**Wetlands**
• water pollution	• water pollution
• reduction of water flow	• reduction of water flow and change of flow regimes
• pollution from water transportation	• destruction of inundated forests for farming and fuel wood
• bank erosion and sedimentation	

Cause-effect conceptual models

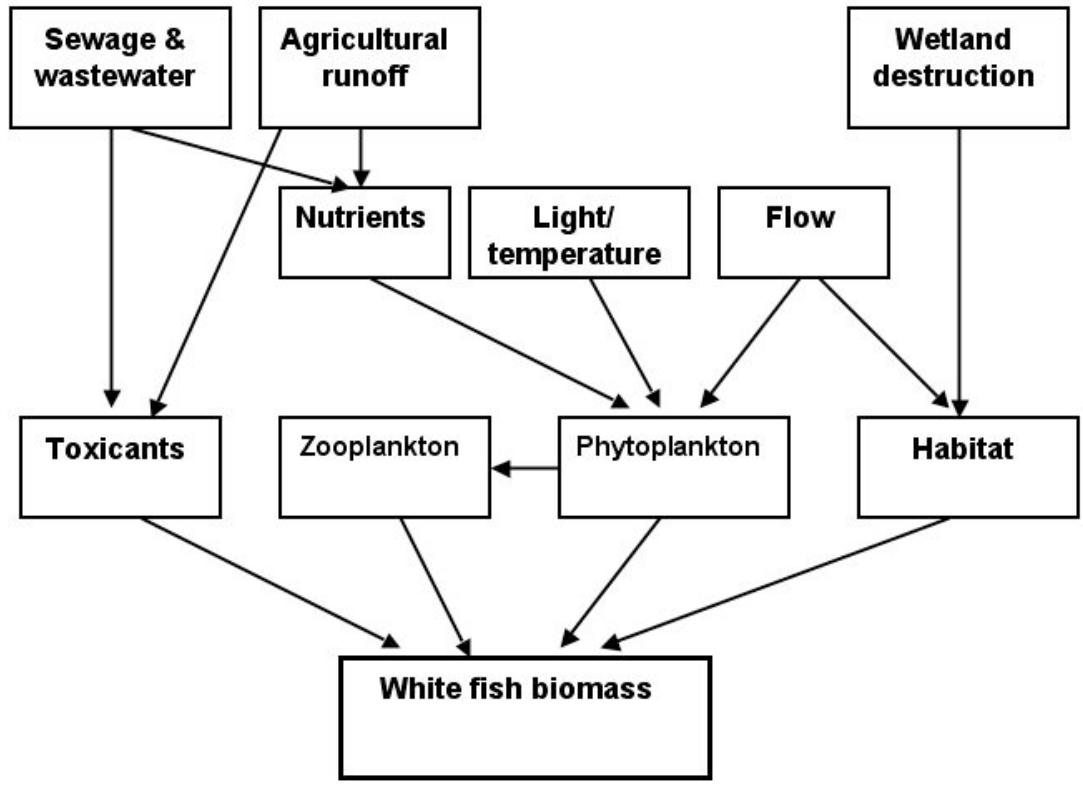

Figure 5: Team 3 conceptual model for wetlands

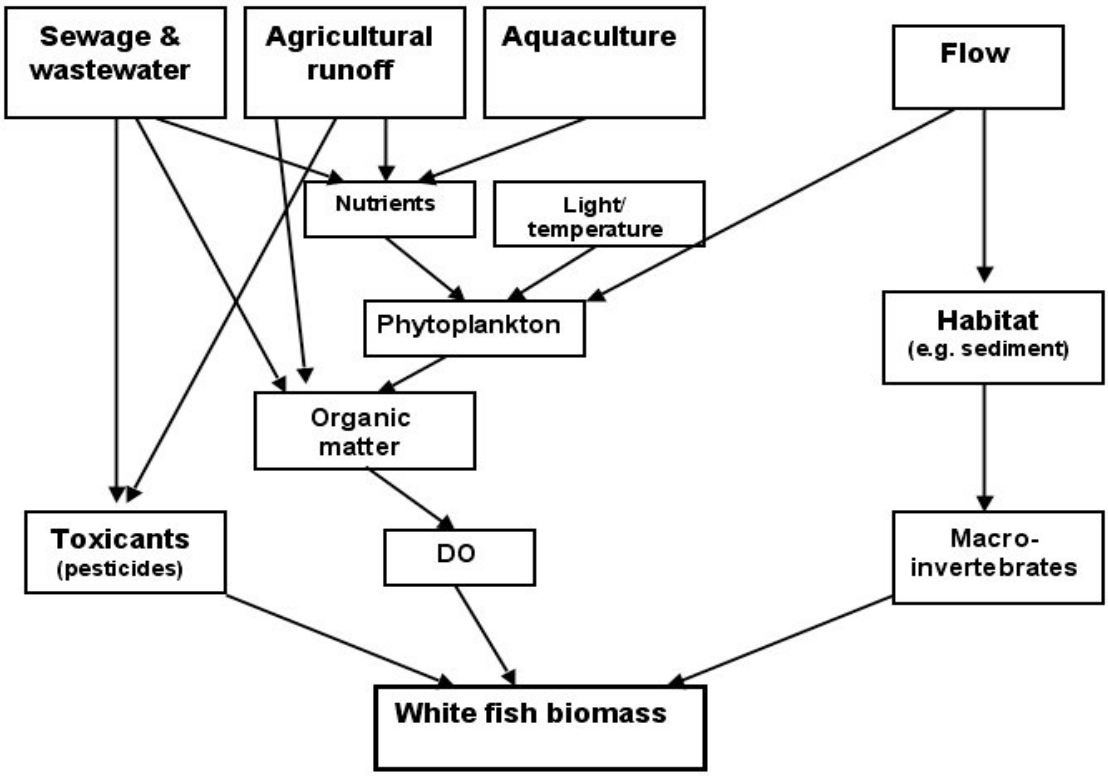

Figure 6: Team 3 conceptual model for Bassac River

Information obtained

See Team 3 Workshop 2 report.

3.4 Team 4 – Agriculture – rice production

Ms Nhim Sophea (Coordinator)

Mr Tran Minh Khoi

Statement of the issue

This part of the case study will assess the risk to rice agriculture in the region close to the Cambodian/Vietnam border.

Rice production is by far the most dominant agricultural activity in this region, and has been for many years. In Vietnam, many areas now have three rice crops per year, with two being normal. In Cambodia, there has been a major expansion in the area devoted to rice production in Takeo Province over recent years, although only one crop per year is harvested (recessional rice production).

Assessment endpoint

Will be a decrease in rice productivity.

Scope of the study

This study will focus on the area spanning about 20 km on both sides of the border between Takeo and Chau Doc, and the time period January to September (with focus on the early flood season).

The assumption is that this is the area and the times when the risk is likely to be greatest.

Threats & Hazards

These will include:

- Flood conditions,
- Pollution particularly pH, oil spills and sedimentation,
- Insects,
- Seed quality.

Cause-effect conceptual model

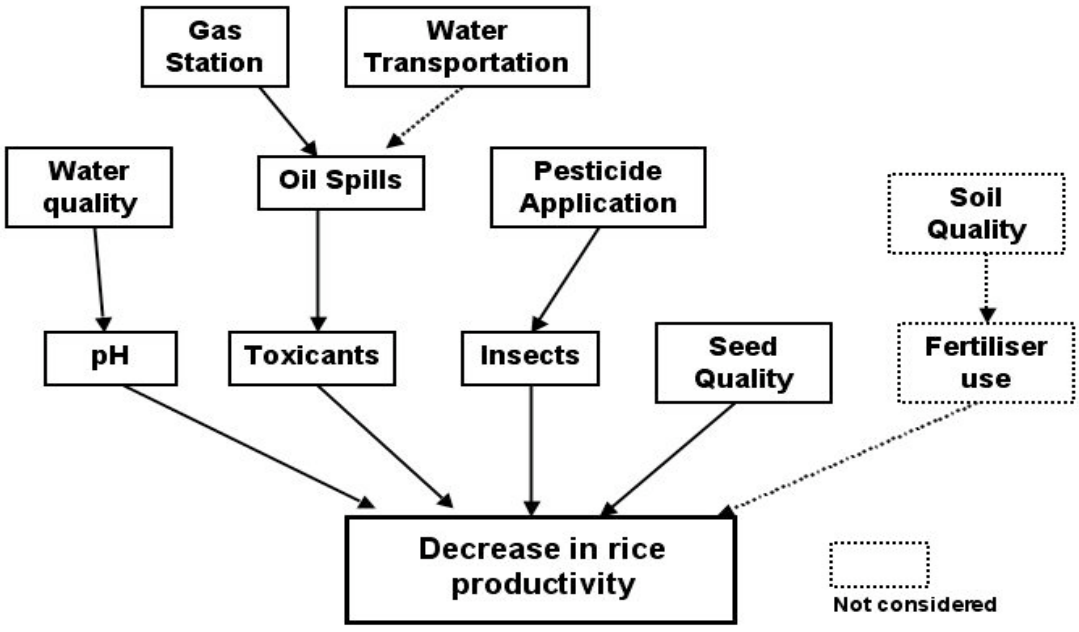

Figure 7: Team 3 conceptual model

Information obtained

See Team 4 Workshop 2 report.

4. Risk analysis stage

Participants undertook three exercises in this stage of the ERA process:

- Qualitative risk analysis,
- Introductions to quantitative risk analysis,
- Introduction to use of Bayesian Network models in risk assessment.

4.1 Quantitative risk analysis

For the qualitative risk analysis, each team was asked to rank the *consequences* and *likelihood* for each issue on a scale from 1 to 5, and then to estimate the relative risk.

Consequences - 1 = insignificant to 5 = serious

Likelihood - 1 = unlikely to 5 = almost certain

The results are shown in Table 1 below, and are interesting for a number of reasons.

- Three teams assessed fish aquaculture as being at highest risk – although interestingly the team who are assessing aquaculture did not rank this issue the highest.
- It was also noticeable that Team 4 who are assessing the risks to rice production scored this issue lowest of any team.
- Apart from the above result, there was little agreement between the teams in their assessment of the five issues.
- In general, the risk rankings were relatively low (excluding aquaculture the rankings ranged from 2 to 10).
- A large number of the rankings for likelihood and consequences were in the range 2-3, suggesting that the teams were lacking in information and preferred the 'middle ground'.

Participants discussed this process and decided the major problems with the approach were:

- difficulties in deciding on the ranking because of a lack of data or information,
- uncertainty in what was meant by the various terms (e.g. unlikely, almost certain, insignificant, serious),
- did not know what information the different teams used to make their assessments (lack of transparency),
- potential for the assessor to bias his/her assessments because no justification was required.

Table 1: Results of the qualitative risk assessment for the Chau Doc/Takeo case study

Issue	Team 1			Team 2			Team 3			Team 4		
	C	L	**R**	C	L	**R**	C	L	**R**	C	L	**R**
Aquaculture	3	2	**6**	4	3	**12**	4	4	**16**	4	3	**12**
Human health	3	3	**9**	4	2.5	**10**	3	2	**6**	3	2	**6**
Wetland health	2	2	**4**	3	2	**6**	2	2	**4**	3	3	**9**
River health	3	3	**9**	3	2	**6**	3	3	**9**	3	2	**6**
Rice production	2	3	**6**	2	2.5	**5**	4	2	**8**	2	1	**2**

C = consequences, L = likelihood, R = risk

4.2 Introduction to quantitative risk analysis

Professor Hart presented the information 'Quantitative risk assessment (see MRC ERA Presentation 4) demonstrating the advantages of more quantitative environmental risk assessments and showing a number of ways this can be achieved.

He indicated that the group would be using a new technique – Bayesian network modelling – for the first time to provide a quantitative assessment of the risks being assessed in each case study.

4.3 Introduction to use of Bayesian Network models in risk assessment

Professor Hart then presented the information 'An introduction to Bayesian Networks' (see MRC ERA Presentation 5a) in three stages:

- An introduction to BN and what they can do,
- Participants completed an exercise to define appropriate states (or categories) for the variables linked directly to the endpoint in their conceptual model,
- Completion of the presentation, showing how BNs can be used in different modes (e.g. prediction, inference, diagnostic, scenario testing).

The steps involved in building a Bayesian Network model are:

1. Construct the conceptual model,
2. Develop the BN *structure* from the conceptual model,
3. Define appropriate *states* for each variable,
4. Construct the *conditional probability tables* (CPT),
5. *Populate* the variable with information,
6. *Solve* the BN.

Participants focused mainly on steps 1, 2, 3 and 4. The results are provided in the four team reports.

The other steps will be covered in detail in Workshop 3.

5. Future scenarios

The future scenarios over the next 5-10 years that will be considered are listed in the Table below. Also shown is the consultant who will obtain the necessary information before the November 2006 workshop.

Table 2: Future scenarios to be considered in the final risk analysis

Possible Change	Who?
Land use changes Increased rice production is planned for the Takeo Province. The main option will be to increase dry season farming, which will need irrigation (what infrastructure will be needed?) Issues: • Potential further clearing of 'flooded forest' areas to produce additional agricultural land, • Potential increase of agricultural runoff, which may be particularly important in the early wet season. We need information on the likely changes and the possible effects.	Tharith
Flow changes due to upstream development of hydroelectricity dams (in China, Lao, etc) We need information on the possible effects of these dams in the Chau Doc/Takeo region. • Dams will store water, therefore less downstream. This effect will be particularly noticeable during filling (most effect in dry season not wet season) – what effect in study region? • There will be an enhanced fluctuation in daily flow (not expected to be noticeable effect in Chau Doc/Takeo region). • The released water will have changed water quality (e.g. less TSS leading to increased downstream erosion) and lower temperature. • There could be less flooding of the 'flooded forests' in Takeo region. • The dams will stop migration of fish for spawning, but will this affect the study region? The major source of information on these future changes is with the MRCS.	Arounna Son
Climate change We need information on the possible effects in the Chau Doc/Takeo region. Climate change scenarios are available at MRCS, and it may be possible to obtain information from the MRC climate modelling team during the September BN Workshop. The climate change predictions suggest that little change will occur over the next 10 years.	Son

Increased ***urbanisation (including tourists)*** We need relevant information on the possible populations increases and the additional pollution likely to result. • Increased population in Chau Doc and Takeo region • Increased population in Phnom Penh (with & without treatment) – 100-150 km travel to Study Region • Increased prevalence in transmitted diseases (e.g. HIV-Aids) and waterborne disease	Sokha Son Hart Kien
Increased ***cage aquaculture production*** We need relevant information on the possible increases in cage numbers and the additional pollution likely to result for: • Takeo Region • Chau Doc Region • further upstream in Bassac (Kandal Province and An Phu)	Sophearith Xuan/Tien
Increases in ***water transportation*** There are plans to increase the number of large boats using the Bassac to Phnom Penh (rather than the Mekong). Also it is possible that there will be an increased use of water transportation in the Takeo region that could result in increased pollution. The MRC navigation program will have relevant information.	Arounna
Increased ***industrial*** activities It is also possible that there will be increased industrial activity in the study region – particularly in the number of textile and agro-processing industries. We need relevant information on the possible increases in the number and types of industries, and the additional pollution likely to occur.	

6. Reporting

It was agreed that all reporting (reports, email contacts) between team members, coordinators and Professor Hart should go through the MRCS (Arounna), with a copy to the relevant EP coordinator.

7. Role of coordinator

A coordinator has been selected for each Team. The coordinator's tasks are:

- To ensure all work is completed on time.
- To report to Professor Hart and Arounna any problems being experienced (e.g. can't find data, can't access data). Important to report problems EARLY and not wait until the final report is needed.
- To prepare regular short progress report (suggest fortnightly by email).

- To coordinate the preparation of the team report for presentation and discussion at the November 2006 Workshop.
- To be the main contact point for Arounna and Prof Hart.

8. Final report

Two reports will be prepared in February 2007:

- Report 1 will be full technical report.
- Report 2 will be small (2 page) summary report card setting out the main conclusions and recommendation in simple terms.

A broad outline of the structure and contents of the Final Report is provided below.

9. Team workshops & Mentor visits

The project has planned three additional workshops to coincide with important milestones, namely Completion of Phase 1 (and training of modeller in Bayesian modelling), completion of the risk assessment for the present and future scenarios, and preparation and presentation of final report.

- Workshop 1 & site visit (Planning, Problem formulation) Jun 2006
- Workshop 2 & site visit (Completion Phase 1) Sep 2006
- Workshop 3 (Quantitative risk assessment, develop models) Nov 2006
- Workshop 4 (Completion risk assessment, final report) Feb 2006

Prof Barry Hart

9 September 2006

Final ERA Report
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