

# Management and Utilisation of Resources in the Kundasang Area

-An Interdisciplinary Field Study of Tourism, Water  
Management and Agricultural Development  
in Sabah, Malaysia



SLUSE joint basic course report - December 1998

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## Acknowledgements

The Sabah group would like to take this opportunity to thank the following persons and institutions for their valuable advice and for their fruitful contributions which made this field trip successful .

Firstly we would like to express our gratitude to our four supervisors : Professor Murtedza Mohamad , Associate Professor Abdul Rashid Abdullah, Associate Professor Torsten Müller and Assistant Professor Peter Oksen for their invaluable help and inspiration.

Our dear friends and fellow Malaysian students : Ms. Sim Siong Fong, Ms. Jessie Sabastianus, Ms. Olivia Jikus and Ms Lizanah Mohd. Wasly have had major impact on this field study and on the final report and we therefore thank all of them from the bottom of our hearts.

We are very grateful for the help from Phillip Chung, the group manager and the rest of the staff at KPD, who contributed with important advise and information, as well as supporting us with logistics

From Sabah Parks we would like to thank Erik Wong, Janili Nais and Mr. Wahab who kindly briefed us with information. Also we wish to thank the interpreters from Sabah Parks, Yassin, Dumi and Efendi for their effort in the field.

From Kinabalu Gold Resort we would like to thank Richard Lingam and the rest of the staff for valuable help regarding information and collection of questionnaires. Furthermore they supported us technically.

Last but not least we would like to extend our thanks to the Assistant District Officer in Ranau, Ejvind Koefoed (COWI) in Kota Kinabalu and The Department of Chemistry in Kota Kinabalu for analysing our water samples, and the willingness of the local people who made this study a valuable and treasurable experience.

The Sabah Group

## Abstract

The findings in this report are based upon 10 days of field work in the Kundasang Area in Sabah, where three groups conducted a survey of agriculture, tourism and water. The methods used reflected the interdisciplinarity of the survey, and included qualitative as well as quantitative methods.

The study area is special in several ways. The warm temperate climate and the physical settings are suitable for temperate vegetable production. Further, the Mt. Kinabalu National Park is a major tourist attraction and about 220,000 people per year visit this area to enjoy the nature. Due to the optimal settings a high potential for further development lies within the agricultural and tourism sector. Constraints like water supply, land tenure and labour have been identified as limiting factors for expanding the tourist industry and increasing agricultural production.

In the agricultural sector there is still unutilised land that can be used for vegetable production. The farmers perception of the major constraint for increased utilisation of land is the availability of labour. The shortage of labour is partly caused by new immigration laws that prevent the farmers to hire Indonesian labour. Also there seems to be an unwillingness among the local people to work in the agricultural sector. The tourist sector does not experience any labour shortage.

Water shortage is experienced during the dry season which is partly due to the gravity fed water distribution system. The system has reached its limit and cannot supply the outer kampongs with water. To forth come this constraint many farmers have built illegal pipelines. Unclear circumstances of which authority that has to enforce the rules have made it possible for the farmers to construct these pipelines.

Only Bumiputra are allowed to apply for land in the area, but the access to new land is difficult because most land has already been applied for and registered. The land tenure prevents non-Bumiputra from buying land which acts as a constraint for further expansion of the agricultural and tourism sector, because non-Bumiputra generally have the capital needed. However, landowners are encouraged to participate in joint ventures that can promote the expansion of tourism within the existing land tenure laws.

From a national perspective it is considered that the economic impact of foreign tourists is preferred because they contribute with foreign currency to the state economy. Nevertheless, the survey revealed that the Malaysian tourists contribute more to rural development through a higher expenditure compared to foreign tourists.

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## APPENDIX

# 1 List of abbreviations

<b>ADO</b>	Assistant District Officer
<b>BOD</b>	Biological Oxygen Demand
<b>CDO</b>	Community Development Officer
<b>DID</b>	Drainage and Irrigation Department
<b>DO</b>	Dissolved Oxygen
<b>DR</b>	Direct Ranking
<b>EIA</b>	Environmental Impact Assessment
<b>FAMA</b>	Federal Agricultural and Marketing Authority
<b>JKKK</b>	Jawankasa Komajuan dan Kesolamatan Kampung
<b>KK</b>	Kota Kinabalu (The capital of Sabah)
<b>KGR</b>	Kinabalu Gold Resort
<b>KPD</b>	Korporasi Pembangunan DESA ( Rural Development Corporation)
<b>LFA</b>	Local Farmers Association
<b>MPN</b>	Most Probable Number
<b>MTPB</b>	Malaysian Tourist Promotion Board
<b>NP</b>	National Park
<b>NTFP</b>	Non Timber Forest Products
<b>PMR</b>	Pair wise Matrix Ranking
<b>PRA</b>	Participatory Rural Appraisal
<b>RM</b>	Ringgit (Malaysian currency)
<b>STPC</b>	Sabah Tourism Promotion Co-operation
<b>TOL</b>	Temporary Occupancy Licence
<b>WHO</b>	World Health Organisation

## 2 The SLUSE concept

SLUSE (Sustainable Land USE and natural resource management) is a consortium of Danish universities. SLUSE was established in the spring of 1998 by three universities, Roskilde University Centre (RUC), The Royal Veterinary and Agricultural University (KVL) and University of Copenhagen (KU).

The aim of SLUSE is to enhance interdisciplinarity in the studies of sustainable land use and natural resource management and at the same time develop the co-operation between the three universities. An important aspect of the concept is the interaction between different scientific approaches to give an in-depth understanding of environmental related issues. Students with a relevant bachelor degree within natural and social science can apply for participation in the SLUSE education.

To give the students the chance of a hands on experience a three week field course is compulsory for students joining the SLUSE education. The field course is integrated in a one semester *Basic Course* on sustainable land use and natural resource management. The field trip took place in the period from the 7<sup>th</sup> to the 18<sup>th</sup> of October 1998. This period was spent partly doing field work in a predefined study area partly researching at a university. At the end of the field course a debriefing note on the field stay was prepared in order to present the preliminary results. This report presents the results of the field work. However, it should be stressed that the participants have gained much more than this report will reveal.



## 3 Introduction

### 3.1 The study area

The study area is situated on the island of Borneo in the Malaysian state of Sabah. More specifically it is the village of Kundasang, in Ranau District, and the surrounding areas including Mt. Kinabalu National Park. This area is located on the south eastern flanks of Mount Kinabalu, which is the highest mountain in South East Asia (4101 m.a.s.).

The area is generally very hilly, with slopes ranging from 5-60 % at an average of 20% (Lim, 1995). Lying at an altitude of 1200-1800 m.a.s. the area is characterised as having a temperate climate. The hottest month is May the coolest is January with mean daily maximums of 25.7 °C and 22.6 °C respectively. Mean night temperatures are between 16.6 °C in June and 14.6 °C in February (SLUSE handout, 1998). Because of the "shadow" effect of Mt. Kinabalu the area has the lowest recorded average rainfall in Sabah. Potential evaporation of 1248 mm leaves only 1001 mm available for runoff and infiltration and therefore the area is the driest in Sabah. Soil conditions vary and include Lithosols, Acrisols, Cambisols, Gleysols and Podzols (SLUSE handout, 1998). The natural vegetation is mountain rain forest. This vegetation is conserved within Mt. Kinabalu National Park which was gazetted in 1964 and covers an area of 700 sq. km (AUR, 1984).

The Kundasang area comprises approximately 20 villages, *kampongs*, which are spread over the entire area (see appendix 1). Infrastructure consists of a few paved roads in the area close to Kundasang town and unpaved roads in the more remote areas; all kampongs can be reached by road with a four wheel driven vehicle. The kampongs consist of one-family houses built close together. Most households consist of 6 - 8 people.

The number of persons living in the Kundasang area is estimated to be 6000-8000. Most of the people are Dusuns, an indigenous ethnic group, but there are many Chinese, Indonesian and Malay settlers (AUR, 1984).

Malaysia's multi-ethnic population is categorised by the government into two types, the *Bumiputra* and *non-Bumiputra*. The former term, Bumiputra, which literally means "sons of the soil" refers in Sabah to the Malays and the various indigenous ethnic groups, such as Dusun. The term non-Bumiputra refers to those of immigrant descent, mainly Chinese and Indians. (Prof. Mohamad, pers. comm.)

Most of the land within the Kundasang area, apart from the land belonging to Kinabalu National Park, is of Native Title. This land can be transferred only between the local indigenous people, that is, the Sabahan Bumiputras, not even to Bumiputras from other States. However, a small percentage of the land has now been converted to Commercial Land and this can be transferred to anybody, irrespective of ethnic background. Some of the land belongs to the State, which can be allocated to people like hotel operators on a temporary basis (Prof. Mohamad, pers. comm.).

A relatively large area of the land outside Kinabalu National Park is used for agricultural purposes. The physical settings make the area a highly suitable place for temperate vegetable production, comparable to the Cameron Highlands in Peninsular Malaysia. Vegetable production is a very intensive system which demands a high level of irrigation as well as high inputs of pesticides, fertiliser and labour. The level of mechanisation is low and most work is done by hand.

The most important agricultural agency, Korporasi Pembangunan DESA (KPD), or Rural Development Corporation is a project implementing agency under the Sabah Ministry of Agriculture and Fisheries. It was established in 1976 as a social corporation. KPD aims at eradicating rural poverty and increasing agricultural production within the Kundasang area (Gunting & Khoo, 1989). By promoting activities in agriculture the goal is to make farmers self-sufficient.

Furthermore, KPD supplies the farmers with fertilisers, pesticides and seeds. The farmers have to pay for these services through monthly payments. KPD also manages the water supply system for households and irrigation. Recently KPD has set a goal for the water supply in which the following objective is stated: *The system should be able to provide adequate and timely water supply, so that farmers can increase their produce and in turn their income* (KPD, pers. comm.). To fulfil this goal an extension and upgrading of the water supply has been implemented in the area.

Apart from agriculture, tourism is an important economic activity within the Kundasang area. Mt. Kinabalu National Park is one of the major tourist attractions in Sabah and about 200.000 people visit the park every year (Appendix 2). Most tourists come to enjoy the cool climate and natural beauty and approximately 15% of the visitors climb the mountain. In 1984 a golf course was established to attract a more diverse group of tourists (AUR, 1984). Within the past 5 years, there has been a rapid increase in the number of hotels and resorts in the study area.

This is mainly due to a major renovation and improvement of the paved road to the National Park which in turn has increased the number of tourists in the area.

### 3.2 Project presentation

The thrust of the development plans for the Kundasang area is on promoting tourism and increasing agricultural production (AUR, 1984). It is therefore but logical that the focus is on these two sectors: *tourism* and *agriculture*. Considering the fact that both tourism and vegetable production are highly water-demanding, it becomes indispensable to include *the water resource* as the third aspect of the study. The working questions and the common objective of this report will be presented in the following.

The Kundasang area is considered by the state government to be an area of potential for development within the agricultural sector. The former Chief Minister has been quoted for the following statement:

*"I want to see this area terraced, farm roads established, farms irrigated with sprinklers and vegetables covering these hills in green"*

The former Chief Minister, 1976 (KPD, pers. comm.).

Given the optimal physical conditions it can be questioned why vegetables are not covering the hills to a greater extent. This has led to the following working question raised by the **agriculture subgroup** :

? **What are the problems as perceived by the farmers to increase agricultural production in the Kundasang area ?** → Why? (Why not economic, political, biophysical...)

Whatever the farmer perceives as a problem in increasing agricultural production is considered. Regarding agricultural production, only vegetable production is dealt with in recognition of the fact that this is the main agricultural activity in the area. Increase in agricultural production includes both an increase in output per unit area and increase by expansion of the cultivated area.

There is likewise a potential for further development of the tourism sector due to the numerous natural attractions within the area, among which Mt. Kinabalu is the greatest. In the Sabah Tourism Master Plan of 1996 the Kundasang area is regarded as one of the most promising locations for expansion of the tourism industry in Sabah.

The State Government claims that the tourism industry is a major contributor to development of rural areas. The **tourism subgroup** therefore, wants to investigate the economic impact generated through employment within the tourist sector, as well as the expenditure of the different categories of tourists. This has led to the following working question:

**What is the economic impact of tourism on tourist related businesses in the Kundasang area, and is it a major contributor to rural development?**

Other impacts of tourism such as environmental and social impacts and the economic multiplier effect will not be assessed.

To meet the challenge of providing adequate water supply for irrigation and consumption, KPD has to cope with impacts on both the quantity and the quality of the water resource. Describing the present condition of the resource, the users opinions and the institutional arrangement gives a picture of the constraints and opportunities of today. This, in turn, can identify the capability of the water supply system to cope with the future. The **water subgroup** investigate this by analysing the technical and institutional aspects of the water supply system. This has led to the following working question:

**How is the water supply system in the Kundasang area capable of coping with changes affecting the water resource ?**

Neither the natural factors influencing the water resource, such as the water retention capacity of the soils, nor the impact of economic matters and state water policies on the management of the water supply system will be analysed.

In summary, the Kundasang area is characterised by a potential for development of the agricultural and tourism sector. However, the water resource, as well as other important resources, may turn out to become limiting factors under pressure of increasing tourist and agricultural activities.

Together the three subgroups, the **Sabah Team**, have defined a common objective, formulated in the following question:

**What are the opportunities and constraints for further utilisation of the resources in the Kundasang Area ?**

The findings from each subgroup have been integrated in a common discussion concerning the further utilisation of resources. In this context, tourism is considered as a resource, along with water, land, and labour.

Except for the results of each subgroup which are presented individually, the entire report has been written as a common report by the team as a whole.

## **3.3 Project design**

### **3.3.1 Preparation**

Before the field trip in October 1998 the Sabah team was given a general introduction to the study area of Kundasang and some key areas of interest were identified by the supervisors. These key areas were used as guidelines for problem identification. During this process three subgroups were formed, as presented in the previous section. Since interdisciplinarity is fundamental to the SLUSE concept it was a criteria used in the formation of sub groups. Furthermore, a common theme for the Sabah team was chosen in order to integrate the three subjects of interest and assure a holistic approach to natural resource management and land use.

The subgroups prepared themselves by gathering information on the Kundasang area. Recent literature and statistics specific for the study area proved to be very difficult to obtain from Denmark and detailed maps were even harder to get. The working questions of each subgroup were developed on the basis of the limited amount of information about the study area and thus, the questions were more influenced by assumptions than actual knowledge. This, to some extent, explains the revisions of the working questions, which was needed as the field work progressed. The revisions will be described later in this chapter.

### **3.3.2 Subgroups and teamwork**

As the field course progressed it became evident that a better understanding of natural resource management and land use would be gained not only by discussing a common theme, but also by integrating the working processes. To be able to do this it was important that the subgroups co-operated. The supervisors catalysed this subgroup-subgroup interaction by conducting meetings for the whole team every night. At these meetings the subgroups presented their findings of the day and it became clear that much of this information, though collected with a specific working question in mind, was also relevant for the other groups and should be shared.

For the preparation of the debriefing note the division of the Sabah team into subgroups was discontinued and the note was written by the team in pleno. The note was structured as a discussion of issues central to the common theme and to answering the working questions of the subgroups. The Sabah team realised that much was gained by working in this way and therefore it was decided that this approach would be used in major parts of this final report. This way of working ensures interdisciplinarity not only in conducting the field study, but also in analysing the results.

### 3.3.3 Revision of working questions

#### Water group

The water group assumed that the management of water as a resource was inadequate and that it was necessary to look into this management to fully understand the reasons for the water scarcity in the area. Apart from addressing the quantity of available water, an investigation of the water quality was wanted because water quality is essential to the well-being of the local people. Furthermore the water quality could be affected by the different activities in the area, especially the highly intensive vegetable production. The working question turned out to be a good guideline for the field work.

One of the initial ideas was to investigate the power relations within policy making. During the field work it turned out that the rationales behind the policy making was not immediately identifiable. Therefore the emphasis of the investigation was shifted towards different unique issues in the Kundasang area which were of importance to the water management. These were primarily legal issues and the complexity of the institutional framework.

#### Agriculture group

Before arriving to the study area the agriculture group assumed that a shift from shifting cultivation towards permanent vegetable production had recently occurred within the region, reflecting a process of agricultural intensification. The group intended to classify the farmers according to their degree of intensity.

Furthermore, it was believed that each farmer had undergone substantial changes in his farming method, reflecting this continuous intensification process. It turned out however, that it was not possible to distinguish among the degree of intensification of the different farms. All the farmers in the sample were more or less on the same level of intensity and any variation was too small to use as a classification parameter.

The focus on intensification as a continuous process was therefore misleading. Emphasis had to be switched from focus on changes in intensity of production to focus on the current situation of production. The aim was still to analyse the problems the farmers face in increasing their agricultural production both through an intensification of production and by expansion of the cultivated area.

Among the problems expected to be mentioned by the farmers was soil erosion, and the group was prepared to undertake an investigation of this. As soil erosion however was not mentioned

very often by the farmers this topic was abandoned.

### **Tourism group**

The tourism group wanted to categorise the tourists according to two parameters, namely nationality and preferences. This was done in order to examine different expenditures among the categories. E.g. it was expected that a golf player would spend more money than a mountain climber. A clear pattern between preferences and tourist expenditure were not revealed in the study. Therefore the group only examined the expenditure between nationalities, more precise foreign and Malaysian tourists. The group was also interested in evaluating the park in monetary terms. Unfortunately, it turned out that some essential information was confidential and therefore not accessible. Because of this the working question was revised to concentrate fully on the economic impact of tourism on local tourist related businesses.



## 4 Choice of methods

Traditionally there has been a distinction between the research methods used in natural and social science mainly determined by the objects studied. When choosing methods for this field study it had to be taken into consideration that the issues studied were to be dealt with in an interdisciplinary way. This meant that it was not feasible to make a distinction between the methods of natural and social science when trying to overcome the traditional boundaries. Both natural and social science have used quantitative and qualitative methods. The natural scientist has used quantitative measurement techniques for gathering data whereas the social scientist has used questionnaires. The natural scientist has used qualitative methods such as descriptions based on visual assessment, whereas social science uses qualitative interviews.

The overall aim of the quantitative methods is to collect information and thereby produce general and formalised knowledge, whereas the overall aim of the qualitative methods is to obtain a deeper understanding of unique relations. The former thus seeks to explain a given situation or a given problem whereas the latter seeks to understand a given situation or a given problem (Andersen, 1990).

During our field work qualitative as well as quantitative methods adopted from social sciences have been used. An example of a qualitative method is the semi-structured open ended interview. A quantitative method adopted from social science is the questionnaire which was used by one of the subgroups. Methods adopted from natural sciences were limited to quantitative methods such as measuring the water velocity at specific locations.

Hence quantitative and qualitative methods are complements and not necessarily in competition with one another and therefore an optimal research design can be reached if a combination of the methods is used. Our interdisciplinary approach of studying natural resource management has been to combine the quantitative and qualitative methods in order to obtain a more holistic understanding of the natural resource problems.

Therefore a distinction between the methods of natural and social science has not been considered relevant within this report and the argumentation for our choice of methods, as well as the evaluation of the choice of methods, has been done through a discussion of quantitative and qualitative methods together with the techniques of Participatory Rural Appraisal (PRA). The different qualitative methods used by the three groups were semi-structured interviews with open-ended and closed questions and topic focussed interviews. The ranking technique of Participatory Rural Appraisal (PRA) was used. The quantitative methods used were ques-

tionnaires with closed questions and water sampling. The agricultural group primarily used semi-structured interviews, while the tourism group mainly conducted questionnaires and semi-structured interviews. The water group used the qualitative methods and the PRA techniques mentioned above and collected water samples.

In the following section the criteria for choosing the respondents and the choice of methods is discussed.

#### **4.1 Sampling**

In order to obtain a broad picture and to avoid obvious biases, various criteria were set for choosing the respondents. Geographical distribution, (wealth) and social status were the most important criteria considered. Head of the households, owners, and managers were preferred as respondents but if they were not present, a substitute with knowledge of the relevant topic was sought.

To investigate whether the water quality and quantity were acceptable according to WHO standards, five different sampling locations were chosen of which four were located at KPD intakes (Mesilau East, Mesilau West, Mantaki & Kamowanan rivers) and Naradaw river. The locations are plotted on the map in appendix 1. The measurements at the intakes should give indications of the water quality in Kundasang. Down stream of Kundasang an impact on the water quality could be expected, therefore the runoff from Kundasang, Naradaw river, was chosen as an additional test location. Three water samples were taken from each location on three different dates. The reason for taking three samples at each place was to get a chance of seeing the variations at the locations.

The E.coli and coliform tests were taken at four different locations. The places were: Before the treatment plant, after the main storage tank, at a household near Kundasang and at Naradaw river. These different locations were chosen to get an idea of how the quality of the water varies within the distribution system. The location situated at the Naradaw river was chosen according to the above stated reasons.

Regarding questionnaires only few collecting places were chosen within the national park. Questionnaires were collected at the Park Information Center, the mountain huts (Laban Rata) and the Park restaurant. These collecting places were characterised by a high density of tourists.

## **4.2 Qualitative methods**

Before arriving to the study area, little was known about the actual conditions and therefore the issues of interest had to be identified before they could be investigated. The reason for choosing qualitative methods was because they allow for an identification of not previously known issues. Furthermore they give the opportunity for an in depth understanding of these issues by asking additional questions.

### **4.2.1 Semi-structured interviews**

Semi-structured interviews can contain both open-ended and closed questions. When asking open-ended questions the respondent is encouraged to answer in a full sentence rather than in a few words. If the question is put in a way the respondent does not fully understand the use of keywords can be helpful to keep the interview on track. As the sequence of questions is not predetermined it allows the interviewer to choose the questions randomly.

Semi-structured interviews with closed questions can be useful when the interviewer needs basic knowledge which is often used for classification purposes. This type of interview is less dependent on the skills of the interviewer than other qualitative interviews such as topic focussed and informal interviews, because the interview guide helps the interviewer proceed on the preferred topics. Furthermore, when specific information is needed the interview guide ensures that the same topics are covered in each interview which allows for data-comparison. At the same time the interview guide makes it possible for different interviewers to ask the same questions and thereby keep some consistence in the topics covered. The above mentioned characteristics are the main reason why all three subgroups used semi-structured interviews.

### **4.2.2 Topic focussed interviews**

The reason why some subgroups also chose topic focussed interviews was that the actual discussion would be in focus and it would be more open. In the topic focussed interview the respondent is given the opportunity to select the relevant issues and information within the topic. Another advantage is that the interview is less formal and the respondent will be more comfortable and thereby be more open towards the interviewer. The distinction between the two types, semi-structured and topic focussed, is a difference in the flexibility of the respondent's answer.

The weakness is that the interviewer can forget important questions because there is no clear defined questions. In an informal interview the interviewer might get information which is less

relevant for the topics chosen. Another disadvantage is, that to keep up the informal conversation the interviewer might not be able to take notes.

#### **4.2.3 Participatory Rural Appraisal (PRA)**

PRA is an approach consisting of a set of methods which focus on the knowledge and participation of local people. The concept and strength of PRA is that local people through field learning experiences become aware of and share their knowledge. During the fieldwork two different PRA methods were practised; matrix scoring and pair wise matrix ranking (PMR). These two methods were chosen to give an overview of the diverse opinions among the respondents.

Matrix scoring is considered to be a variation of direct ranking (DR). In the matrix scoring the respondent can choose between a score from one to five for each object. The objects are scored against one another and thereby the relative importance between the objects is revealed. The matrix scoring was used by the water group in order to reveal some sensitive information which otherwise would be difficult to obtain.

In the PMR the respondent has to make a definite choice between two objects at a time. By comparing the objects pair wise the procedure of ranking can be simplified (Mikkelsen, 1997). All the objects are listed and tested against each other in a triangular matrix. The advantage of using PMR is that the respondent only has to consider the ranking of two objects and therefore the choices reflects the immediate preferences of the respondent. Therefore the PMR is assumed to be a more reliable, unbiased and accurate ranking method, especially when a large number of objects are being evaluated. The agriculture group used this method to what the farmers considered as the major constraints in relation to increasing the agricultural production.

### **4.3 Quantitative methods**

Two of the subgroups used quantitative methods in their data-collection. Questionnaires were used to gain knowledge about the expenditure of tourists. Water analysis was conducted in order to test the water for factors influencing the quantity and quality.

#### **4.3.1 Questionnaire with closed questions**

Structured questionnaires with closed questions were used in order to collect information from many respondents in a short period of time. One advantage of conducting questionnaires is that data is comparable, so that calculations, statistics, and generalisations

of the information will be possible. One weakness of this method is that the interviewer is distanced from the study object, which might result in misunderstandings and language barriers cannot be overcome. The intention of conducting a survey with a structured questionnaire was to estimate the expenditure of the tourists visiting the national park and the surroundings and to be able to differentiate these tourists into different categories. In order to make it clear for the respondent which type of response was sought, closed questions with predetermined values and categories for expenditure and purpose of stay, were set. To minimise the time spent by the respondent, the questionnaire was structured to fit one page, with a total of twelve questions. In the beginning of the field stay pilot-questionnaires were handed out in order to examine if the results were useful. Some misleading questions and improper price indexes were corrected until a satisfactory output was obtained.

#### **4.3.2 Water sampling**

When dealing with natural resource management the monitoring of the resource is an obvious approach. Therefore quantitative methods were used for this purpose. The quality and quantity of water was measured with quantitative methods. The more specific parameters and the equipment needed to quantify these parameters are listed in table 1.

The parameters measured with the Horiba multi-electrode and the flow-meter measurements were conducted in situ. The parameters measured with the Horiba multi-electrode. The remaining analysis took place in the temporary field laboratory. The water samples were collected 10-20 cm below the water surface in the middle of the river. All above mentioned parameters were measured according to the instructions following the equipment kits. The flow rate was determined according to the following method. The flow rate was found according to the following.

In order to measure the flow of waters in the rivers width and depth (3-5 intervals) were measured. This made it possible to model triangles at each river bank and a number of squares in the middle of the river bed (see figure 1). The water velocity was measured at the different intervals with the OSS-PC1 propeller in revolutions per minute. When the river profile is known along with the water velocity the water quantity in the river can be calculated. See section 5.4 on water quantity.

Table 1: Parameters measured on the water resource.

Parameters	Equipment
PH	<i>Horiba<sup>R</sup> multi-electrode</i>
Conductivity	<i>Horiba<sup>R</sup> multi-electrode</i>
Temperature	<i>Horiba<sup>R</sup> multi-electrode</i>
BOD <sub>5</sub>	<i>Horiba<sup>R</sup> multi-electrode</i>
Turbidity	<i>Horiba<sup>R</sup> multi-electrode &amp; Nephelometer</i>
Ammonium	<i>Merckoquant Ammonium Test</i>
Nitrate	<i>Merckoquant Nitrate Test, Aquamerck Nitrate Test</i>
Nitrite	<i>Merckoquant Nitrate Test</i>
Phosphate	<i>Merckoquant Phosphate Test</i>
Carbonate	<i>Aquamerck Total Hardness (Gesmathärte) Test</i>
Flow rate	<i>Current meter model OSS-PC1 from Kahl Scientific</i>

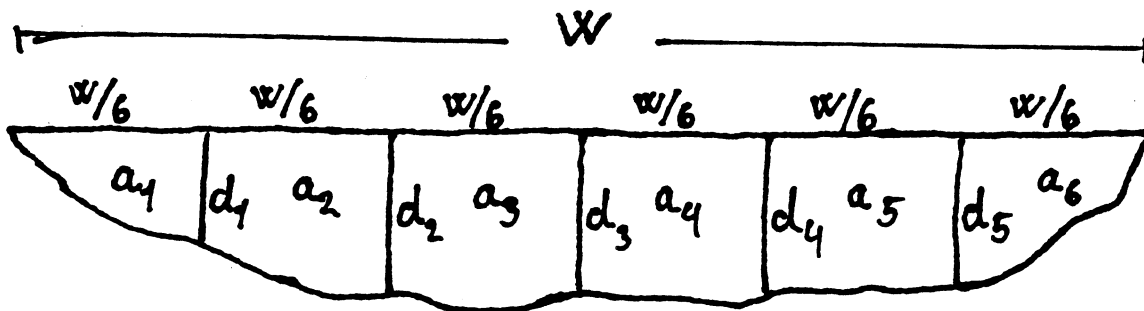


Figure 1: A theoretical illustration showing a riverbed

The Biological Oxygen Demand (BOD) is defined as the quantity of dissolved oxygen (DO) which is able to oxidise the organic compounds with the assistance of micro organisms (Rump & Krist, 1988). The BOD was measured directly as the oxygen loss during a five day period ( $BOD_5$ ). In the five days incubation period the samples were protected against light sources with aluminium foil, to ensure that there was no photosynthetic activity taking place. At the same time the bottles were sealed completely to avoid any contact with oxygen. Therefore the oxygen concentration after five days ( $DO - DO_5 = BOD_5$ ) was the result of biological activity demanding oxygen.

Some tests could not be done in the field laboratory these were the coliform and E. coli tests, the pesticide tests and the heavy metal tests. It was very fortunate that the Department of Chemistry in Kota Kinabalu could find the time to do these analysis. At the same time they tested the water for a lot of the compounds, which were also tested in the field. These tests were more accurate and showed in many cases small amounts of compounds which were not detectable in the field laboratory.