Assessment of Available Low cost Monitoring Systems for the Watershed in the Lower Mekong Basin

Report

Prepared by
Benjamin Bhakdi

Vientiane, August 2006

MRC-GTZ Cooperation Programme
Agriculture, Irrigation and Forestry Programme
Watershed Management Project (WSMP)

Index

Introduction 1
1 Strength and Weaknesses in Low Cost Monitoring 2
2 Expected scope and limits 8
3 Low Cost Monitoring Practices Available 11
3.1 Stream Detectives – Green World Foundation 11
3.1.1 Indicators developed 11
3.1.2 Goal of monitoring program 12
3.1.3 History 12
3.1.4 Costs involved in routine measurement 12
3.1.5 Intended User group 12
3.1.6 Facilities needed 12
3.1.7 Suitability for low cost water quality assessment for WSMP 13
3.2 Stream Watch Australia 13
3.2.1 Indicators Developed 13
3.2.2 Goal of monitoring program 14
3.2.3 History 15
3.2.4 Costs involved in routine measurement 15
3.2.5 Intended User group 15
3.2.6 Facilities needed 15
3.2.7 Suitability for low cost water quality assessment for WSMP 15
4 Monitoring tools for MRC 16
4.1 Water Quality Standards in the LMB 16
4.2 Resources needed for proposed monitoring programme 16
4.3 Hidden Costs in LCMS 17
4.4 Factors limiting LCMS 19
5 Points of Interest for Implementation 22
Literature 25

Tables and Figures

Tab.1: Facilities and trainings needed for implementation of LCMS 5

Fig. 1: Three pillars of a functional monitoring system 18
Fig. 2: Monitoring scheme 24

Acronyms

AIFP	Agriculture, Irrigation and Forestry Programme
EC	Electrical Conductivity
EP	Environment Programme
GTZ	German Technical Cooperation
LMB	Lower Mekong Basin
LCMS	Low Cost Monitoring System
MRC	Mekong River Commission
WHO	World Health Organisation
WUP	Water Utilization Programme
WSMP	Watershed Management Programme

Introduction

Water quality monitoring is a tool to analyze the condition of water systems, to provide the basis for detecting trends and to provide the information enabling the establishment of cause-effect relationships. Important aspects of a monitoring system are the interpretation and reporting of the data resulting from monitoring and the making of recommendations for future actions.
Thus there is a logical sequence consisting of three components: monitoring, followed by assessment, followed by management. In addition, there is also a feedback loop created because management inevitably requires compliance monitoring to enforce regulations, as well as assessments at periodic intervals to verify the effectiveness of management decisions (WHO, 1991). To conduct water quality monitoring the following points have to be incorporated:

- □ Define the status of water quality;
- □ Identify and quantify trends in water quality;
- □ Define the cause of observed conditions and trends;
- □ Identify the types of water quality problems that occur in specific geographical areas;

and

- □ Provide the accumulated information and assessments in a format that resource management and regulatory agencies can use to evaluate alternatives and make the necessary decisions.

When setting up water quality monitoring plans it must be considered that implemented technologies and budgets can be covered by existing frameworks and regulations. Whereas capacity building and potential increases in future budgets should be incorporated in the mid and long term planning, current settings should be the baseline for all short term monitoring efforts. Over optimistic planning all too often ends in projects which have to be abandoned. Water management plans should start at a small and affordable scale and improve monitoring scale and technologies over time. In this respect not only can the management gradually become better, but also the people involved in the monitoring can develop better skills and understanding of the processes. Even in highly industrialised countries like the United States it was shown that participatory watershed planning is a tricky business because of the sophisticated structures and multiple user groups involved in the planning process and the often high expectations on the watershed management plan. Therefore watershed management planning is always associated with the risk of implementing impossible expectations:

> The greatest challenge associated with watershed planning is to ensure that the recommendations called for within a plan are implemented and that the plan does not sit on a shelf gathering dust in some office. (US EPA 1997)

The main goal of this paper is to evaluate Low Cost Monitoring Systems which suit the limited financial budget for watershed management in the four riparian countries Lao P.D.R, Thailand, Cambodia and Vietnam and is feasible for the use by local communities.

1 Strength and Weaknesses in Low Cost Monitoring

What should a LCMS be able to do?

A Low Cost Monitoring System should full fill different aspects:

- □ It should be able to monitor trends of water quality
- □ Be fit for a decentralized approach and therefore
- □ Be ready for use by local rural communities
- □ Deliver reliable information to the communities
- □ Be precise enough to allow a estimation of the state of the water
- □ Require low technical implementation costs and maintenance costs
- □ Should provide comparable information throughout the Lower Mekong Basin

What can a LCMS do if implemented correctly?

The implementation of a Low Cost Monitoring System (LCMS) for monitoring of water quality in the Lower Mekong Basin (LMB) has to consider a number of issues related to the scope and limits a LCMS inevitably encounters.

The information obtained by a LCMS is limited to its scope of monitoring parameters, which it is calibrated on. Although this holds true for all monitoring systems the parameters measured have to be even more defined and optimized to environmental and budgetary necessities. The opposing demands encountered in the planning process, i.e. `How much do we want to monitor? And how much money do we want to spent?´ define the range of monitored parameters. It is important at this planning level to understand how much we really need to monitor to reach our goals.

The most obvious strength of a LCMS is the direct involvement of those who are directly affecting water quality and quantity, while also being directly affected by the water quality and quantity in the watershed. The information delivered to communities and decision makers about their own region or an extensive area like the Lower Mekong Basin (LMB) respectively may be more substantial than other approaches because of the involvement of local communities. The educational impact this may have on the population could contribute to a change in water use and in effect to this a better use and/or protection of existing water resources on a community level. In short, this approach could lead to a better management of water resources within the watershed directly affecting the people who use the water and who are affected by water quality. Through the direct involvement of all members concerned with the water resources this final stage of a "perfect" participatory approach would need little or no external capital investment with a community consciously managing the water resources in there catchment.

A participatory approach does also limit the precision and liability of data acquired. Data collected and processed by non professionals will not stand legal trials which might arise in precarious situation, such as pollution by dams or industries. They would therefore have a limited use in a legal environment. It has to be acknowledged that, unless intensive training and certification of selected community members would be implemented, data acquired from community monitoring will only serve the understanding of the state of the environment. This point is of course only relevant if situations arise which may affect legal issues, such as impacts of a dam construction on water quality issues which are monitored by communities. A highly intensive training and monitoring of the performance of those involved in watershed monitoring would in turn result in a higher capital investment which would be counter productive of the LCM approach.

To integrate local communities in water quality monitoring, it is mandatory to develop indicators which are easily understandable, accessible and which are resistant to large errors in the sampling process. These key requirements are not easily matched especially when a pure bio-indicator based monitoring system is implemented as has been seen as most holistic solution for water quality monitoring in the LMB (see BHAKDI 2005). Collecting scientifically prove bio indicators requires disciplined sampling procedures to match required standards.

There has been a long history of refining bio-indicators to a workable monitoring system. Each of today's bio-monitoring systems requires extensive sampling and scientific evaluation which can not be expected from non professionals. Furthermore it is not seen as being feasible to expect community members who receive little or no payment for their work and have other more vital tasks to perform in their working hours (such as farming, earning additional income…) to conduct a full (professional) bio-indicator assessment. This factor will always be the main restrictive factor in LCMS. In conclusion bio-indicators for LCMS have to be as simple as possible, but still provide enough information to allow a sufficient estimation of water quality and trends in a given water body.

The integration of easy to measure physico-chemical parameters into the monitoring routine could provide a good control of bio-indicators. Especially if the bio-indicators are set to measure parameters like oxygen content of the water and therefore relate the use of oxygen to organic pollution. The routine measurement of Oxygen in set time spans would help to see how good the bio-indicators correlate. Collecting data such as Oxygen, pH, Conductivity, Oxidation Reduction potential, Phosphate and Nitrate load would improve the knowledge about the state of the water. However, this approach is associated with a higher capital investment and maintenance due to the analytical instruments required. To use water quality instruments an in depth training and monitoring for use and calibration of the instruments would be required. Therefore may the use of this approach be prohibitively expensive for a basin wide use unless proved to be cost efficient. This approach could be tested in the Pilot Areas.

An advantage of the participative approach is the possibility for awareness rising through community participation. The fact that data have to be obtained by local people will add additional positive impact to the monitoring programme. Training of participants of the monitoring programme will also open up opportunities to educate people about environmental issues. With the implementation of a bottom-up approach (communities monitor their own waters and report to MRC or national authority) instead of a top-down approach (MRC is monitoring and implementing) watershed management plans may be integrated more efficiently.

To optimize the output of a LCMS local knowledge should be used as well. Degradation processes and water volume trends are usually known by local rural communities which are closely "monitoring" water quality and quantity issues through non scientific methods for irrigation and use aquatic invertebrate resources for consumption. In an ideal participative monitoring process there should be room to collect and evaluate this local knowledge. This contribution could be especially useful in an environment like the LMB, because knowledge about previous or "natural" water quality is not easily available.

A view on the basic necessities of a practical monitoring programme

If a practical water quality monitoring programme is to be implemented certain frameworks have to be analysed and respected. The three pillars of a monitoring system are the following:

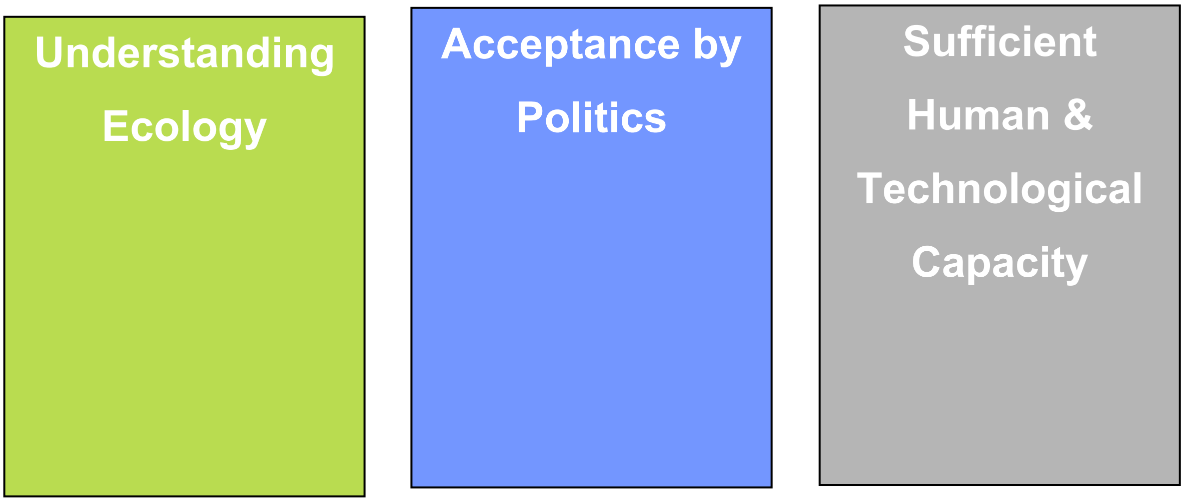

Fig. 1: Three pillars of a functional monitoring system

The first and most obvious pillar is the sufficient understanding of the ecology of the stream system. This includes a basic understanding of the biota, the natural chemical composition of the system, physical parameters and natural variations of all of the above mentioned. It is important to note that for a functional monitoring system a minimum understanding of all aspects above is necessary. If they are not known measurements may lead easily to the wrong conclusions and wrong management practices.

The second pillar is the acceptance by politics. This is in the first place quite an obvious point regarding the general approval or denial of the implementation of the monitoring system. More difficult may be the support for or blocking of the implementation of the system. In any case may the close cooperation with the national agencies facilitate the implementation. As mentioned before in this paper while implementing the monitoring system it is mandatory that feedback loops are in place to provide assistance to the villages who may find impairments of water quality and react within a minimum time frame. One problem which may be encountered on a regional scale is the fear of national governments to be compared to other national governments. It is therefore recommended to contain the different results of the pilot areas within the national line agencies and government institutions. It is obvious that this promise has to be met by MRC. Once systems and monitoring practices are in place and first positive results are achieved governments may probably open up themselves and proudly present their successes in Watershed Management. This might even be a good incentive to promote sustainable management of water resources.

The third pillar is the availability of human and technical capacity to conduct water monitoring and training, provision of analytical facilities and technical equipment. Each riparian country has its own distinct level of technological equipment and will therefore need an individual evaluation and adaptation on the LCMS. In all implemented monitoring systems a larger proportion of the budget should be dedicated to human capacity building and improvement of technological – laboratorial equipment. The sustainability of an implemented monitoring system will in the long run rely on these human resources and well trained laboratorial staff. The adoption of a internship programme and support programme within the human capacity building programme of MRC would be a crucial step for the successful implementation of a LCMS.

When all three pillars of this framework are fulfilled the LCMS would have the best foundation for a successful implementation. In each field may come up a variety of other aspects. They should be integrated into the process of optimization of the complete monitoring system.

The positive effects of LCMS are:

- The wide range of communities which would potentially be involved which would enable data collection from a wide area of the total basin.
- The information obtained through activation of local community resources are not “hidden” – the data are processed through the community and therefore already provides information to the people immediately concerned with their environment.

- The data from the location can be complimented with local knowledge which potentially increases the information value.
- If the right incentives are given to people – along with the empowerment of local communities by providing them tools for monitoring and a functional reporting system the monitoring might be managed in such a way that important trends in the watershed will be reported reliable to the responsible authority.
- Independent results could be obtained from different communities in the watershed. This would hold especially true for watersheds with a high strain on land and water resources, because intensive land use usually concurs with high population density. If the LCMS approach would be implemented, different villages participating in the water quality monitoring would provide different independent monitoring results.

An important requirement in LCMS is the availability of standardized indicators which are tailored to the use by communities with low technical facilities. This will require the advice of aquatic biologists in the planning phase and successive calibration sessions to verify the proper function of the indicators.

The focus of a LCMS should be on the education and training of local personnel in order to apply the LCMS in their respective eco-region and analyse the data obtained from the different monitoring session bearing in mind the limitations of the data. A crucial issue is to create the motivation and the right incentives for a continuous and high quality monitoring in the community. For example, this could include education and training in health issues especially affecting small children and elderly people. In this way community members are better motivated to participate in the programme.

The final stage of the LCMS should be developed in such a way, that local communities can use the technology with confidents and be able to acquire outputs which both directly benefit the community due to improved quality of life and provide information to decision makers on the local and national scale with useful information about the state of the watersheds in their community, district or country. The collected information will finally provide the first comprehensive overview about the state of the waters in the LMB.

2 Expected scope and limits

Observe changes in the environment

As with any other monitoring system, a LCMS has to be applied correctly and within its scope and ability to monitor changes with respect to the scale of change. The question of scale is often overlooked in environmental monitoring (PERRY & VANDERKLEIN 1996). It is important to understand that the observed change by a community or by several communities is probably on the scale of a Sub-Catchment level or Catchment level. Because effects of scale matter to the decision makers (i.e. is it necessary to intervene? Is it a threat to the Mekong River as the main receiving water course in the LMB?) there need to be an evaluation based on which scale this change is taking place and how far down stream this trend is impacting. It must be remembered that the main task of the MRC is to manage the Mekong river system, not the sub-catchments of a watershed. This implies also that a change in water quality in the upper reaches of a watershed which might be neutralized by the time the water reaches the outlet of the watershed may not fall within the management duty of the MRC, whereas a heavy impact on water quality in the upper reach which has a profound impact on water exiting the watershed will and has to be monitored by MRC. The difficulty is that light impacts in the upper watershed potentially have a long term effect on the receiving water system and could therefore fall into the responsibility of the MRC's current mandate. A possible solution which would help to decide if a reported trend in water quality is important to the MRC management goals would be to evaluate the numbers of communities within the respective watershed which reported the trend and where these communities are located within the watershed. The evaluation of the sampling results of these communities would than allow an estimation how far reaching this trend is and if it is possible to contain the (negative) impact within the watershed or if the impact might have external effects.

The discussion of geographical locations of sampling stations is a very important topic in monitoring issues. As the discussion above shows communities within a watershed will have different importance to the MRC monitoring objectives. Obviously sampling results of communities at or close to the outlet will have a higher significance for the MRC water management goals in the initial stages of the monitoring system than upstream communities in the watershed. Although it is necessary to prioritise the findings within a watershed regarding the geographical location it has to be understood that results from the upper parts of a watershed have to be evaluated as well. Findings in upstream communities have a high significance for the communities within the watershed regarding the local impact of water quality impairment or diminished/increased flows - even if the Mekong River will not be impacted. Therefore it is mandatory from an ethical point of view and also for keeping up the motivation of communities to continue monitoring to respond to findings, no matter where they occur.

In watersheds which are not significantly degraded the monitoring of upstream waters may serve as an early indicator of significant change in the entire watershed due to the important role of upstream land use to the water quality and quantity in the flow regime of rivers. This is because upstream catchments in the LMB are usually characterized by steeper slopes, fewer settlements, higher rainfall and less intensive land use. These settings may increase the significance of upstream watershed monitoring during the rainy season, when a large volume of the surface water will originate from the areas with the steeper slopes, whereas low laying lands may contribute more to groundwater infiltration. The fact that water volumes do multiply more than sixty times in the streams during the rainy season as measured in Nam Ton Pilot Area may illustrate the importance of the differentiation of the flow in dry and wet season which will not only influence the significance of flow related pollution dilution, but may make bio monitoring practically impossible during high flow months, due to the strong currents and inaccessibility of the indicator species. In addition, remote areas often have valuable natural resources such as timber which attract exploitation. In the long term all communities will have the same significance for monitoring watersheds since a sound management of water resources can only take place if the needs of all communities are respected and the whole watershed is monitored – from the springs until the outlet.

The role of national authorities

> …getting the local government involved is often a missing piece. Given the fact that local government controls land use and has access to funding and decision-making authority,… [we] believe [that] they are critical players in making the watershed approach a reality. (US EPA 1997)

Reports have to be standardized with a number of objectively acquired data. Once a report is handed in from a community, officials should follow up on the findings by the local people and double check to verify if the reported indicators are correct. This interaction between local communities and local authorities is the key step in the monitoring program because it allows the findings to be reported to the public and responsible institutions which represent the first level of control. Hence this interaction needs special attention because the communication needs to run smoothly and without restriction or misunderstanding. Special training sessions have to be implemented for reporting skills and confidence building. In particular local authorities should take part from the beginning in implementing the community monitoring network while receive training on how to evaluate data and discover potential fraud. In this way both sides can become familiar with the procedures so that the Low Cost Monitoring System can evolve into just that – a system which requires minimum control and follow up by higher administrative levels and therefore becomes most cost effective.

A trigger monitoring system

The implementation of a LCMS without a formal integration into a more sophisticated water quality monitoring system will quickly reach its limits. To make the implementation of the LCMS sustainable within the in parts rapid development of the region it should be seen as part of a monitoring scheme which incorporates low cost-low resolution as well as high end-high resolution approaches[1]. LCMS will stand at the base of this monitoring system and provide a wide coverage of background monitoring within the LMB. If water quality or quantity problems are identified by the participatory approach further monitoring levels will be activated. Higher levels of the monitoring system will include local authorities, national authorities and special "task forces" for In Depth Analysis of sophisticated problems which can consist of specialists form different institutions. Each level of the monitoring system will intensify the water quality assessment and provide a better understanding of the situation.

By implementing a multi-level monitoring system as shown in Fig. x a successive capacity building in the water quality management sector could take place. Each monitoring level has in its own way a high importance and is tailored to the problems most probably occurring in the watersheds of the LMB including pollution sources such as faecal pollution, eutrophication, pesticides and others. Because some problems will occur more often than others in the LMB each monitoring level will only gradually be activated to find answers to the observed trends of water quality over a time span. The objective of a multi-level monitoring approach is to minimize costs by

[1] The term resolution is meant to be the number of sampling locations and their density within the stream system

only applying the level of monitoring technology and staff which is appropriate or necessary.

Inevitably the time needed for finding the cause of the problem might be lengthened if all levels of the monitoring system have to be applied. By adapting the monitoring scheme to rapidly assess the most common problems in water quality degradation on a watershed level it is expected to be economically feasible be able to better serve the needs in the LMB for water quality monitoring.

It must be understood that this system can be only a temporary, transitional system, if a continuous monitoring is to take place. This is because monitoring is a continuous process, whereas the proposed system is a compromise of monitoring and rapid assessment due to financial restrictions. It is assumed here that the continuous monitoring by communities will be limited. This could be proofed wrong by trial in the Pilot Areas.

The monitoring draft pays tribute to the changes in land use of the LMB, and will most probably be more rapid and affordable, than the implementation of a complete professional monitoring network.

3 Low Cost Monitoring Practices Available

3.1 Stream Detectives – Green World Foundation

3.1.1 Indicators developed

The Stream Detective Manual developed by the Green World Foundation gives a wide number of bio indicators to conduct water quality assessment. The indicators were developed for the watersheds in Central and Northern Thailand with emphasise on the Ping River. The indicators including 54 Invertebrates including Mayfly Nymphs, Stonefly Nymphs, Cased Caddisfly Larvae, Dobsonfly Larvae, Prawns and Shrimps, Dragonfly Nymphs, Damselfly nymphs, Mussels and Cockels, Snails, Non Biting Midge Larvae, Aquatic Segmented Worms, Crabs, Water Bugs, Water Beetles, Water Beetle Larvae, Aquatic Moth Larvae, Fly Larvae, Flatworms and Leeches, 25 fish species and 36 stream bank animals including otters, fish eating birds, waterside birds, common birds found near water, amphibians and waterside insects are used to define water and stream habitat quality. The collected species are statistically evaluated by the diversity not regarding their abundance in the stream.

The physical habitat of the stream is analysed by inventorying the stream depth and width of the stream, its flow pattern, the abundance of different stone sizes and the abundance of organic debris.
The chosen indicators and the monitoring concept targets the organic pollution of the river and does indicate species, particular oxygen sensitive species.

3.1.2 Goal of monitoring program

The focus of the Stream Detective Manual is on environmental education. The scope of the indicators given in the book gives evidence about the change of the stream between chosen sampling intervals and estimates the current condition in the stream primarily concerning organic pollution. The monitoring programme should give the participants a better understanding and observation skills for estimating environmental degradation. The resolution of the indicators in terms of gradual quality change within a river is not quantified. The water quality is classified based on a six tier scale termed “outstanding, excellent, good, average, poor, very poor”.

3.1.3 History

The Stream Detective approach is already in use by high schools and communities in the Ping River Catchment in Eastern Thailand. The first version of the Stream Detective Package was released in 1999. Data about successful monitoring results were not accessible.

3.1.4 Costs involved in routine measurement

3.1.5 Intended User group

The manual is made for secondary school and was created within the 1999 Education Act of Thailand.

3.1.6 Facilities needed

Trainers and teachers are required to explain and implement the knowledge and procedures to conduct the investigations. For the investigation itself only little equipment is needed. Some bright containers to sort aquatic invertebrates, a magnifying glass and some nets to catch the animals are sufficient. The disadvantage is the large number of people needed to carry out the investigation and to collect sufficient material. In the manual it is recommended to conduct the sampling with at least 20 students.

3.1.7 Suitability for low cost water quality assessment for WSMP

The Stream Detective system is entirely based on bio indicators. Therefore the costs of monitoring in terms of capital investment are low. All indicators are chosen for easy identification and accessibility. Because the focus of the monitoring system is on the educational aspect and the indicators are chosen to determine mainly organic pollution of the rivers, the system is not focused on the abundance of toxicants, pesticides or water volume related changes in the aquatic communities. The assessment of water quality and stream habitat quality is on a basic level. It is expected that the widespread use of this approach could assist the monitoring of water in the LMB. Nevertheless the system must be adapted to the diverse ecoregions in the LMB and maybe simplified for the use by communities. It would be desirable to also implement simple physico-chemical parameters, such as dissolved oxygen, conductivity, pH and ORP in the measurement and give instruments to the local authorities.

3.2 Stream Watch Australia

3.2.1 Indicators Developed

Water Bugs

The Waterwatch Manual gives instructions about how to sort macro invertebrates and their classification into family level. Waterwatch relies on external invertebrate guides to help the group to identify the collected water bugs.

Turbidity

Turbidity is measured with a Secchi disk, turbidity meter or a turbidity tube. Usually the turbidity tube is used for most waters, unless the water is very clear and the human eye can not distinguish the nuances of turbidity and the levelled readings in the bottom of the tube. The Secchi disk is only used in deep standing waters.

Electrical Conductivity (EC)

EC is measured with a conductivity meter. Detailed calibration and calculation procedures for non temperature compensating Conductivity meters are given. There are two different Conductivity meters in use, one with a measuring range of 0-1990µS/cm, one for brackish waters with a range of 0-19900 µS/cm and one 0-50000µS/cm for marine waters.

pH

pH is measured with pH strips with a accuracy of 0,5 or electronic pH-meters. Detailed calibration and application procedures are given in the Waterwatch manual.

Dissolved Oxygen

DO is measured by an electronic Oxy-Meter in the field or by processing the samples with a Winkler Titration in the laboratory after preservation of the sample in the field.

Phosphorus

To measure P the Waterwatch approach uses a Colour Comparator for high concentrations of P (< 0,1mg/l) or a Colorimeter for lower concentrations (>0,1-0,02mg/l). The Colorimeter is relatively expensive to use because of the spectrometer technology. The use of the Colorimeter demands basic laboratory skills and is relatively complicated. A laboratory is required for calibration.

Nitrogen

There are two alternatives to measure Nitrogen contents. The more simple and cost effective one is a Colour comparator, in which the sample is mixed with a reagent and the resulting red colour is compared to a colour wheel. The accuracy for low concentrations is not as good as for medium and high concentrations. For lower concentrations a Colorimeter/Spectrometer method is used. It is more expensive and needs regular maintenance and calibration. It is further recommended to send the samples to a lab if concentrations are expected to be low.

3.2.2 Goal of monitoring program

The goal of the monitoring program of Waterwatch Australia is to provide communities with a tool to monitor catchments. The initiative must come from members of the community. By implementing this de-centralized approach workload is taken from government institutions for field investigation and as a positive side effect the communities are also immersed into the complexity of water management. The tools provided to the community to assess water quality issues is also raising more awareness about environmental issues. The concrete monitoring goals are defined by the groups and reflect their concerns or interests. These can range from a pure interest in background monitoring of the catchment's water quality to profound problems, i.e. caused by a newly installed paper mill, dam, or other constructions. This approach therefore relies on active community participation and problem awareness.

3.2.3 History

Waterwatch Australia is the umbrella organisation for Waterwatch Australia, Stream Watch Australia and Ribbons of Blue. The first project was initiated 10 years ago with the wider programs and significant numbers of participants are now working for Waterwatch since five years. The precision of the measurements rose significantly through trainings and small competition workshops to less than 5% error. It showed that for a community based approach, one of the highest investment costs was quality control and training.

3.2.4 Costs involved in routine measurement

3.2.5 Intended User group

The user groups are diverse and include farmers, school groups, individuals, ex-scientists and industry. Due to the problem oriented approach there was no limitation for interested groups and individuals to participate. In some cases people were actively asked to partake and help government institutions to monitor water quality on private property.

3.2.6 Facilities needed

To implement an approach to monitor water quality such as the Waterwatch approach, calibrating laboratories were needed, together with scientific staff, coordinators and Waterwatch supervisors. For the sampling the above mentioned test kits and test instruments were needed and appropriate reporting standards had to be set up. The coordinator's key function was to conduct data quality control and be directly in touch with the Waterwatch group.

3.2.7 Suitability for low cost water quality assessment for WSMP

The Waterwatch approach is interesting for the WSMP for various reasons. It combines bio-indicators and physico-chemical indicators and therefore monitors a wider scale of factors than the stream detective approach. Expected difficulties are the often problematic handling of sensitive equipment by local communities in the LMB and the often insufficient knowledge about technical maintenance of instruments. Laboratory equipment in particular very much relies on the proper maintenance and calibration for reliable results. Furthermore is the accessibility to water quality laboratories in the LMB often difficult and requires extensive travels. With an implementation of a Waterwatch like approach, an upgrading and training of existing laboratories for calibration of field instruments would be necessary.

4 Monitoring tools for MRC

It must be recognised that both of the above presented monitoring tools rely on previous knowledge of biota and physico-chemical standards in the study area. Both are in many cases not known for the greater part of the LMB. To get this basic knowledge further research should be integrated into the effort to understand the ecology and natural constitution of the waters of the LMB better. After research is conducted about these indicators, bio-indicators can be selected to be used by local communities for water quality background assessment. The Environment Programme of the MRC will play a crucial role in this effort.

4.1 Water Quality Standards in the LMB

Most of the standards agreed on in the Water Utilization Programme of the MRC are indicators which are non controversial and already employed by the national departments responsible for water resource management in the four riparian countries. The direct implementation of the above mentioned bio-indicators into the current indicator program is not possible. The current knowledge of the relationship of physico-chemical indicators and bio-indicators is not sufficient to relate them.

Nevertheless the Stream Detective approach in combination with parts of the Waterwatch approach could be an interesting starting point for LCMS after the following modifications have been made.

4.2 Resources needed for proposed monitoring programme

For the proposed water quality monitoring program existing water quality testing facilities can be used. It is recommended to continuously train laboratory staff and implement a quality control mechanism for the data analysis. As experienced on various field trips handling of technical instruments in particular and sample handling needs intensive training, if local staff has to conduct field surveys unsupervised. In general it should become the long term aim to establish an infrastructure which allows the responsible line agencies to act on their own behalf and conduct field studies. The establishment of an institutional network which can act on the behalf of the MRC with a sufficient data quality in field and laboratory sampling is the mandatory base for any monitoring system. This would require a stronger focus of MRC on the training of laboratory and field staff. In particular Lao P.D.R. and Cambodia should use the opportunity to receive laboratory and field training including quality control procedures.

As discussed above it might be problematic to employ local communities for water quality monitoring, however one possible solution could be to use students at the national universities to conduct field research and monitoring programmes. This would have different positive effects: on the one hand future scientists could be trained based on the required standards and quality project staff would be available for MRC. It could be also an advantage, in the medium and long term process, to integrate an internship program into MRC, which would allow students to gain insight into the work of this organisation. This could take place in the experimental phase of the implementation phase and would allow employing local staff with the goal to educate them in the required field and rise local capacities to a higher standard.

4.3 Hidden Costs in LCMS

There is one distinct problem in all monitoring programs: the need to deliver data precise enough to respond to the required monitoring parameters. As in any field precision does not come along cheap – investments need to be made to improve measurements and data resulting from these measurements. Regardless of low or high cost monitoring programmes basic investments have to be made to achieve the desired data resolution, although on different levels. A high tech approach includes high initial investment costs which are primarily correlated with modern logging technology and remote data transmission via data loggers and phone lines. The sophistication of the equipment will require experts to install and maintain the equipment. As stated in other reports these costs lie around 16.000USD. Additional maintenance costs will add another 3. to 4.000 USD/a, although more costs might arise from training costs and political costs which vary from country to country as well as vandalism of the installed monitoring equipment, although this can be minimized by a wise choice of the monitoring station sites (personnel communication with Peter Clews AHNIP, MRC)

The LCM requires much less capital investment for the technical side of the monitoring programme. However, it must be recognised that a continuing and sophisticated training and quality control programme must be implemented as well and supplement the monitoring efforts throughout the years as was shown in the Waterwatch approach, where precision of measurements reached 95% in 2005 (Waterwatch Report 2005). Nevertheless the improvement of precision went along with the implementation of local Waterwatch coordinators and an elaborate feedback and calibration procedures for community groups with expert water quality laboratories. Research into issues such as data quality of water laboratories and knowledge of water experts will most certainly show that the setup of a network as existing in Australia within the Waterwatch umbrella organisation and cooperation with government agencies would need huge investments into basic facilities and human resources if implemented in the LMB. Although this would be desirable and most probably be a foundation for a sustainable approach it may be unlikely that such investments would be undertaken on a basin wide scale. Table 1 shows the facilities which would need to be implemented or improved. The costs must be estimated.

Tab.1: Facilities and trainings needed for implementation of LCMS

Facility	Task	Costs
Water Quality Lab	Secure supply of chemicals, train staff, implement blind samples for groups, implement timeframes in which groups can send in control samples	Potentially high in Laos and Cambodia. Thailand and Vietnam are sufficiently equipped
Logistics	Communication between HQ and community groups, potentially data base, sample transportation, scheduling of trainings	n.k.
Coordinators	Train the trainer, select a sufficient number of coordinators, skill building of coordinators, secure	n.k

	continuous employment	
Quality Control	Implement six monthly quality control sessions with blind samples from Water quality Lab. Invite test samples to be send back to HQ for error evaluation. Implement procedures for error finding through coordinators	n.k.
Motivation of groups	Initial workshops and village gatherings, explanatory sessions for villagers. Securing continuous participation through i.e. competitions with other Waterwatch groups. Communities need direct feed back for their efforts and need to see action in case of problems occurring.	n.k.

4.4 Factors limiting LCMS

Another factor which should not be neglected is that community participation of developed countries and developing countries is based on very different perceptions of the roles of individuals in society. Communities in developed countries have usually lifestyles which include leisure time and income earning "unproductive" age phases (retirement, child care and educational time frames for children) which allows interested community members to concentrate on "hobbies" such as environmental monitoring and surveying which do not earn income – a concept on which monitoring programmes such as the Waterwatch approach are build on. This also incorporates a sense of responsibility for individuals of their role in the national setting and the will to keep the environment healthy and aesthetical. This attitude is also related to the empowerment and environmental education of individuals within a nation. In contrast to this, rural communities in developing countries such as the Lao P.D.R who also desire a healthy state of the environment may not be able to use the little free time they have to conduct water monitoring. The active participation of communities and what incentives are accepted should be tested in the pilot watersheds. Furthermore is potentially the willingness to contribute free labour to national authorities – as it might be perceived – very limited. A very physical orientated life style, such as farming with low income earnings is in this respect also restrictive to additional tasks which do not earn additional income for the household. The incentive given through a potentially healthy environment without direct benefit for the community is maybe not sufficient. It was shown in other projects in rural India that:

> Active community participation firstly implies that people want the change which is to be introduced and secondly willing and motivated to contribute to and take responsibility for bringing about and managing the changed circumstances. (Hónore 2002, p.83)

Therefore it is most probable that an active community participation can only be achieved if water quality problems occur which have a direct effect on communities in the watershed. This could include health issues such as diarrhoea, child mortality or insufficient water supply for domestic use, irrigation or other uses. Other reasons for an interest in participative water quality monitoring may be disputes between up/down stream villages over water resource issues, such as pollution and over-abstraction of water. To make these arguments more objective and create a sustainable solution to these problems it was shown by communities in Northern Thailand that participation can be highly motivated and can contribute to the cause finding of the problem (Green World Foundation). In this case is the involvement of community members very effective especially because of the increased trust community members have in decisions taken, when data are collected by members of the community and not by outsiders.

In conclusion it can be assumed that within the above mentioned scope participatory LCMS can contribute to the assessment of water quality in the LMB on a broader scale.

Nevertheless if community participation can only be achieved while a problem is already existent, the monitoring system would much rather turn into an impact assessment approach which deals only with assessment of the current status of the stream systems. Nevertheless, if the implementation of the approach in the Pilot Areas proofs to be successful this concept could be the initial setup for a permanent and basin wide monitoring concept.

If monitoring practices are being used by communities out of whatever reason, the data provided should be integrated into existing data bases. If the monitoring approach fails, the assessment of water quality initiated by communities can still be used as a warning system for degraded watersheds in cases where communities are willing to participate. In this case the system could provide a reporting tool to trigger more research into water quality related issues.

Assess degrading or improving water quality trends

The orchestrated implementation of a LCMS in the region will substantially improve the general knowledge about the water quality and environmental. But it will not be sufficient enough to understand why observed trends are the way they are and how these trends can be controlled. To manage natural resources - and this holds also true for water resource management considered here - there will be eventually more financial investment and technology needed to monitor changes continuously and to correctly decide to manage water resources on a watershed and basin scale. The sound understanding of cause-effect relationships and the knowledge about how to measure possible key parameters to observe changes are the most basic requirements for fact based decision making. To address these issues cooperation with universities and research institutions are necessary.

Regarding the limited financial resources in water resource management in the LMB the LCMS could establish itself as the background monitoring system for water and land use changes. Its function could be crucial especially if implemented within a larger scheme of monitoring technologies (see page 14). By developing the right tools for communities to monitor water quality on a basic level and report degradation of water quality to the authorities a very strong incentive could be given to them to continuously monitor their environment because it immediately impacts on their own quality of life and health. Followed by the immersion of communities into environmental monitoring it can be hoped that the existing local understanding of the environment can be improved. This approach would also allow to access local knowledge and integrate it into planning procedures of authorities.

5 Points of Interest for Implementation

As mentioned in the previous chapter a LCMS as a sole monitoring system would quickly reach its limits. It is proposed here that a multi level monitoring system should be implemented. By the integration of the LCMS into sequentially more sophisticated monitoring systems water management could rely on hard data and less guessing.

If LCMS seem to be appropriate for the WSMP in cooperation with the EP and WUP, the following steps would need to be considered:

1. Assess costs and hidden costs for a participatory approach and equipment
2. Definition of bio-indicators for ecoregions in the LMB
    a. Define bio-indicators and desired resolution for water quality assessment and trend evaluation with WUP/EP/WSMP regarding the goal parameters which should be monitored
    b. Implement cooperation with universities
    c. Setup of operational concepts on national and local level for the respective pilot watersheds
    d. Restructure to fit budget constraints
3. Inventory and assessment of existing laboratory facilities and evaluation of quality standards
    a. What improvement is necessary to meet the required standards?
    b. Where is the money best spend – on water quality laboratories associated to ministries or university laboratories
4. Assessment of existing logistical infrastructure to pilot watersheds.
5. Supply of equipment (for bio-monitoring, pH and electronic equipment for Oxygen, Conductivity, ORP)
6. Train the trainers and continued education for the trainers
7. Training of communities
    a. Field training in pilot areas for participating community members
    b. Reporting skills to higher level of authority
8. Calibration of measurements and follow up on volunteering scheme.
9. If needed, set up of qualified individuals who are employed by national line agency
10. Feedback to EP to check up findings in terms of choice of indicators
11. Possibly field assessment with community and EP specialist

12. Adjustment of indicators
13. Feedback of results into the community and consultation with them and implementing appropriate measures to correct water management → positive feedback loop
14. Building up model communities to facilitate involvement of other communities
15. Use pilot watershed for training of reporting and quality control skills of local authorities and national authorities
16. Implementation of national line agencies of MRC as task forces if more detailed water quality assessment is necessary – connecting national agencies with community level assessment for dialog
17. Publish community findings for increased transparency
18. Transfer of system to other watersheds
19. Evaluate findings in terms of:
    a. Data resolution
    b. Quality control
    c. Long term participation of communities
    d. Indicator suitability
    e. Integration possibilities in MRC data base
    f. Number of participating communities
    g. Acceptance by communities
    h. Cost benefit analysis
    i. Positive incentives for communities
20. Introduction of calibration mechanism with test samples of communities analyzed in the reference laboratory on national level.
21. Coordination of procedures and standards on regional level

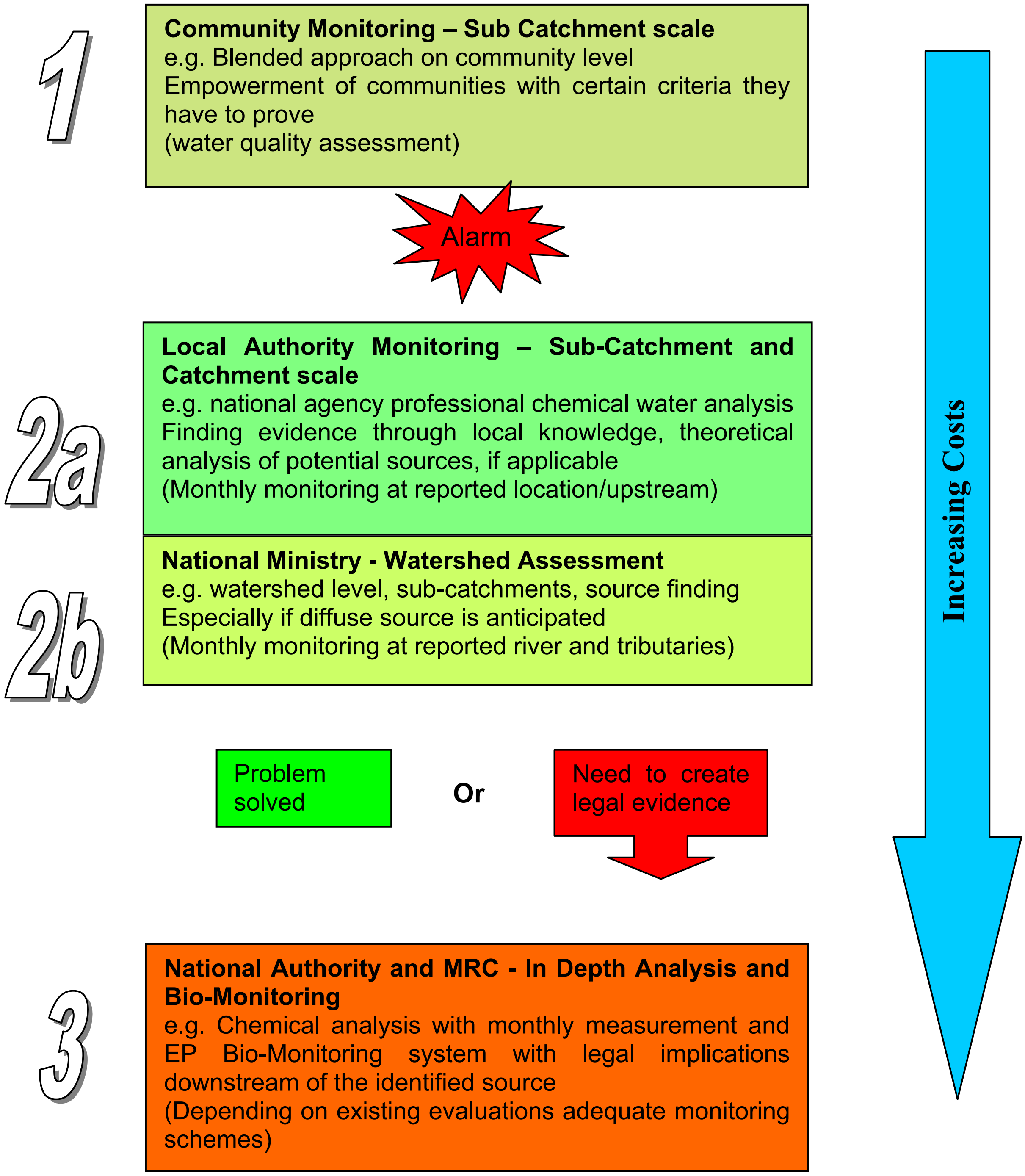

Fig. 2: Monitoring scheme.

The trigger monitoring system relies on community based monitoring as a basic background assessment. The change in aquatic macro-invertebrate communities would trigger a second level of the monitoring system. This could alternatively consist of local authorities and line agencies and ministries at the same level, or both of them separately representing different more sophisticated levels for monitoring. These structural decisions depend on the national existing institutions and possibilities. In any case the last level of monitoring would be represented by the currently appearing bio-indicator system of MRC from the EP. This is because the EP aims to develop a scientifically based bio-indicator system which could be used for legal cases, where the findings might have wider implications.

Literature

BHAKDI, B. (2005): Outline for an Operational Water Monitoring System for Water Quality and Quantity for the two Pilot Watersheds Nam Ton and Siem Reap. MRCS. Vientiane. Lao P.D.R.

GREEN WORLD FOUNDATION: Stream Detectives Manual. Bangkok

CHAPMAN, D. (1996)[2]: *WHO Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring*. E&FN Spon. Cambridge.

HEATHCOTE, I. W. (1998): *Integrated Watershed Management: Principles and Practices.* New York. John Wiley & Sons.

HIGHT, J. AND FERRIER, G. (2006): *Building Capacity to Monitor Water Quality: A First Step To Cleaner Water In Developing Countries*. OECD Trade and Environment Working Paper No. 2006-03

HONORÉ, G. (2002): *Principles and Practices of Integrated Watershed Management in India.* Indo – German Bilateral Project “Watershed Management”. GTZ. New Dehli

PEREZ, C. A.; MILLER, K.; RONCOLI, C. (2003): Directed Readings: *Watershed Management.* Directed Readings Series no. 03-01. SANREM CRSP

TOMICH, T. (2004): *Empowerment Through Measurement*. Policy Briefs 07. ASB Programme, ICRAF, Nairobi

U.S. ENVIRONMENTAL PROTECTION AGENCY (1997): *Top 10 Watershed Lessons Learned.*Washington D.C.

WATERWATCH AUSTRALIA: www.waterwatch.org.au

WHO (2004)[3]: *Guidelines for Drinking Water Quality*. WHO. Geneva. Switzerland.