ENVIRONMENTAL MONITORING BASICS

The vast marine, coastal and freshwater ecosystems of the Mekong River Basin (MRB) have exceptional capacities to cleanse themselves of pollutants. However, the absorptive and healing capacities of many receiving water bodies are being exceeded in the face of ever-increasing pollutant loads being discharged into these ecosystems. Continued population growth, urban and industrial development, and poor sewerage infrastructure will continue to threaten the sustainability of the aquatic environment.

As environmental protection becomes a higher priority in the MRB, policy alone will not be sufficient to ensure sustainable development. Some practical, scientific tools will be necessary to gauge the health of valued ecosystems in the Basin and to guide management actions. Environmental monitoring is one of the most important tools available for detecting improvements or further degradation in select ecosystems or in the Basin as a whole.

Environmental monitoring is essentially a range of activities undertaken to provide management information about environmental conditions or contaminants. It is conducted to assess the status of the environment and to protect against potential damage by anthropogenic activities, such as waste disposal or logging. More specifically, monitoring is used to:

- Identify and quantify existing problems and provide early warnings of potential future problems
- Evaluate the effectiveness of pollution abatement programs and other regulatory and/or management actions
- Assess compliance with environmental regulations or criteria
- Enhance general knowledge on aquatic (both freshwater and estuary) systems and environmental health
- Inform decision making regarding environmental degradation
- Rank or prioritize pollution problems so that resources (i.e., available funding and trained persons) can be focused on the most important problem.

THE COSTS OF MONITORING

Perhaps a more appropriate issue to consider should be the cost of NOT monitoring. If governments choose not to monitor, many social and economic costs can result, including:

- Economic consequences. Correcting problems after environmental degradation has occurred is ultimately much more costly than monitoring. In addition, degraded habitats will never fully return to a pristine condition. Better to prevent than repair.
- Social consequences. Public health problems can develop. Groundwater or surface water pollution can cause disease, or render a drinking water supply unusable.

TYPES OF MONITORING PROGRAMS

Several issues need to be considered in designing on appropriate monitoring program. For example, the specific environmental problem needs to be defined. Clear objectives on how to assess the severity of the problem must also be defined. Or, environmental managers may choose to monitor an ecosystem to determine 'normal ranges' of nutrients, water level fluctuations, wildlife migrations, or sedimentation quantities.

For example, a baseline study is used to establish existing environmental conditions. In comparison, a compliance monitoring program compares field measurements to regulatory values or criteria. Some types of different monitoring programs are described in Table 1.

MONITORING STRATEGY

The first steps in developing a monitoring strategy are the identification and preliminary characterization of stressors, the ecosystem potentially at risk, and possible ecological effects. Performing this analysis is an interactive process that contributes to the development of a conceptual model.

Stressors can be a variety of organic and inorganic chemicals, like pesticides or PCBs. Biological stressors can include excess nutrients from farming activities. Physical stressors could be habitat destruction, warm water discharges, or sedimentation from deforestation. Characterization of potential stressors helps to define the resources at risk, as well as ecological effects that may result.

Table 1 Characteristics of different types of monitoring programs

PROGRAM TYPE	NUMBER, TYPE OF VARIABLES/ TOOLS	SPATIAL SCALE	TEMPORAL SCALE		INTENSITY, TYPE OF DATA ANALYSIS
			FREQUENCY OF MEASUREMENT	DURATION	
BASELINE	Many variables Physical, chemical, biological	Intermediate	Low - medium	1 year(s)	Low-medium Descriptive, summary
COMPLIANCE	Few variables Usually chemistry, toxicity tests	Small	Medium - high	Variable (often long)	Medium intensity Descriptive, summary, hypothesis testing
IMPACT ASSESSMENT/ HYPOTHESIS TESTING	Few to many variables Physical, chemical, biological, toxicity tests	Intermediate	Low-medium	1 year(s)	High intensity Hypothesis testing
STATUS	Few variables Physical, biological, chemical, toxicity tests	Large (regional)	Low (usually single survey)	Short	Low-medium intensity Descriptive, summary
TREND	Few variables Usually physical, chemical	Variable	Low (annual) to medium (seasonal)	Long (10 years)	Low-medium intensity Descriptive, summary, time series

Stressor characteristics include:

- Type – chemical, physical or biological
- Media – water, sediment, body tissue
- Intensity – concentration or magnitude
- Duration – short or long-term
- Frequency – single event, episodic or continuous
- Timing – occurrence relative to biological cycles
- Scale – spatial similarities and extent.

If the stressors are identified first, such as increased sedimentation due to land clearing, information on the spatial and temporal distribution of the stressors can be helpful in identifying the resources at risk. If effects to resources are identified first, such as dwindling fish numbers, the effects can directly indicate ecological components that may be considered in the monitoring program.

Once the stressors and resources at risk are known or suspected, development of a conceptual model can begin. The conceptual model is just a qualitative description of how the various ecological components interact with the stressors, and the accompanying effects.

Boundaries

Boundaries of monitoring programs determine the type of questions that can be answered. They can be:

- Social or economic
- Temporal or spatial
- Ecological – derived from physical, chemical or biological processes
- Technical – determined by limitations of available equipment
- Administrative or political.

Hypotheses

The types of responses expected from exposure to the stressor(s) will determine the sampling design and the measurement variables.

If predictions are clearly stated, monitoring objectives can be established and testable questions (i.e., hypotheses) can be developed as a basis for the next step sampling.

SAMPLING

Sampling involves the actual selection of measurable variables and collection of field data. Ideally, sampling should help to answer the research questions. Table 2 lists types of measurement variables.

Of course, it is impractical to monitor every contaminant and every biological component of an ecosystem. Both time and financial constraints would just not allow this. Therefore, the selection of appropriate measurement variables requires careful consideration during the early stages of the development of a monitoring program. Selection also depends in part on the nature of the research questions. The variables selected must be accessible for measurement, must be useful for answering the research question and must not be overly expensive to measure.

Table 2 A listing of potential environmental monitoring variables

TYPE OF VARIABLE	FUNCTION
Chemical	Measures contaminants, modifiers, nutrients
Water column	Measures contaminants, modifiers (salinity), nutrients
Tissue	Measures organism exposure
	Measures contamination (for human consumers)
Physical	Contaminants: suspended or deposited solids
	Modifiers: water temperature, sediment grain size
Toxicological	Direct measure of effects (toxicity)
Biological	Direct measure of effects in the ecosystem
Benthic invertebrates	Measure of community-level effects
	Benthos important aquatic prey species.
Fish	Measure of effects at many levels (community, population, organism)

WATER QUALITY ASSESSMENT

So far, aquatic ecosystem monitoring as a whole has been addressed in this lesson. However, water quality assessments are the type of monitoring program most often undertaken in terms of informing management decision making. A water quality assessment requires the gathering of physical, chemical and biological data on water as well as the drawing of conclusions that will be useful to resource management concerns.

The assessment procedure used at various stages is influenced by the following factors:

- The nature of the problem
- The availability and reliability of source data
- The availability and reliability of the methods applicable to assessment and readiness to apply method
- Time and resources available.

The process of determining objectives should start with an in-depth investigation of all factors and activities that exert an influence, directly or indirectly, on water quality. Inventories should be prepared on:

- The geographical features of the study area, including topography, relief, lithology, pedology, climate, land use, hydrogeology, hydrology, etc.
- Water uses, including dams, canals, water withdrawal for cities and industries, agricultural activities, navigation, fisheries, etc.
- Pollution sources (present and future), including domestic, industrial and agricultural, as well as their stage of pollution control and waste treatment facilities.

Water quality assessment is the overall process of evaluation of the physical, chemical and biological nature of the water, whereas water quality monitoring is the collection of the relevant information (the data).

Traditionally, the main reason for assessing the quality of the aquatic environment has been to verify whether water quality is suitable for its intended use, such as drinking or irrigation. In recent years, the use of monitoring has evolved to help determine trends in the quality of an aquatic environment and to assess how that quality is affected by the release of contaminants, other anthropogenic activities, and/or by waste treatment operations.

Monitoring has increasingly been carried out to estimate nutrient or pollutant fluxes discharged by rivers or groundwater to lakes and oceans, or across international boundaries.

There are two different types of monitoring programs, depending on how many assessment objectives have to be met:

- Single-objective monitoring to address one problem area only. This involves a simple set of variables such as: pH, alkalinity and some cations for acid rain; nutrients and chlorophyll pigments for eutrophication; various nitrogenous compounds for nitrate pollution; or sodium, calcium, chloride and a few other elements for irrigation.
- Multi-objective monitoring to cover various water uses and provide data for more than one assessment program, such as drinking water supply, industry, fisheries or aquatic life, thereby involving a large set of variables.

A water quality assessment or monitoring program may focus on the spatial distribution of quality (i.e., high station number), on trends (i.e., high sampling frequency), or on pollutants (i.e., in-depth inventories). Consequently, preliminary surveys are needed in order to determine the necessary focus for a monitoring program.

Monitoring must generate the data needed for meaningful interpretation and management decisions, but should avoid collection of a vast amount of unnecessary data which are costly to obtain, but do not contribute to the required understanding of water quality. Three monitoring phases can be distinguished:

- Simple monitoring based on a limited number of samples, basic analysis or observations, and simple data treatment.
- Intermediate-level monitoring requiring some specific laboratory facilities and more financial support to increase the number of stations, samples, analytical variables, etc.
- Advanced-level monitoring involving sophisticated techniques and highly trained technicians. The analytical facilities can perform any required pollutant determination, with an increasing number of variables per sample, and of samples taken.

BIOLOGICAL INDICATORS

Biological indicators are essentially statistical measures of ecological well-being. The development and monitoring of biological indicators can be an important tool in encouraging the incorporation of environmental information into decision making. Each indicator can provide a picture of the status or trends relevant to one issue. Taken together, a group of indicators can provide an overview of the health of an ecosystem.

Indicators can be used in the following ways:

- To increase awareness of environmental issues
- To monitor the progress of a species or ecosystem
- To identify information gaps
- To set conservation and research priorities.

Desirable indicators are variables that summarize or otherwise simplify relevant information, make visible trends of interest, and quantify, measure and communicate the information. Biological indicators can be critical 'early warning detectors', used to identify trends in time to remedy the problem potentially causing environmental degradation. Some relevant biological indicators for the MRB are listed in Table 3.

Table 3 Potential biological indicators for the MRC

Environmental Value	Indicator
Water Quality	Turbidity
	Fecal coliforms
	pH
	Use of agricultural chemicals
	Land area affected by salinization, heavy sedimentation.
	Biological oxygen demand
Biodiversity	Wood harvesting intensity
	Percent of exotic species relative to native species
	Species with decreasing populations
	Number of protected areas
	Threatened and endangered species as a percent of total native species
	Percent of forest land in monoculture