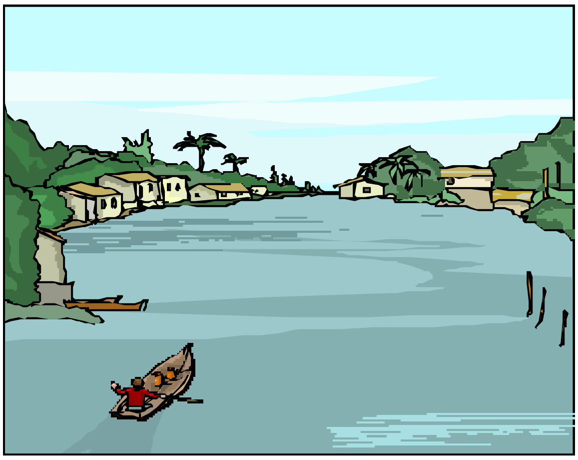
BASELINE MONITORING

Baseline monitoring is conducted to establish existing environmental conditions and to provide background data for future comparisons. It is critical to both environmental impact assessment (EIA) and ecological risk assessment (ERA). Baseline monitoring typically examines physical, chemical, and biological variables in an ecosystem. Monitoring programs can be conducted over a relatively short duration (i.e., less than a year), or can be multi-year programs designed to pick up seasonal trends and natural variation in an ecosystem.



The hypothetical KL pulp and paper mill example introduced earlier will be used throughout this lesson in detailing aspects of baseline monitoring.

Defining Program Objectives

The first step of any baseline monitoring program is to clearly define the objectives of the program. This step is very important and will help with the study design. Defining program objectives often involves communicating with responsible government agencies and other interested stakeholders in identifying and prioritizing management concerns. This input can be used to refine the monitoring program and provide expectations of the type of information required as well as indications of how the information generated will be used in decision making.

The KL mill example provides an opportunity to demonstrate the formulation of program objectives. In this example, baseline monitoring for the proposed mill expansion is planned for only the aquatic environment. The objective of this baseline monitoring program would be determined in consultation with the government agency responsible for permitting, ideally with some public input, and would likely be:

"To characterize the aquatic environment upstream and downstream of the mill prior to construction and expansion"

Fulfilling this specific objective would provide baseline data that can be compared with data collected during and after the mill expansion to determine the nature and extent of impacts on the receiving aquatic environment (i.e., the Mekong River).

Study Design

With the monitoring program objectives clearly defined, it is then possible to design a baseline monitoring study. The study design includes two key tasks: identifying appropriate monitoring sites and selecting monitoring variables. To complete these tasks, it may help to review previous studies conducted in the same area. In some cases, existing data may already exist on the baseline environmental conditions, with no further field sampling required. However, baseline data is often quite limited in the riparian countries of the Lower Mekong Basin (LMB) and likely will need to be collected prior to approval of any large-scale project such as the mill expansion.

When designing the baseline monitoring study, proper planning can result in a more efficient program with significant long-term savings. In the absence of proper planning, the following may occur:

- Environmentally important variables are omitted
- Data do not address the objectives or answer the research questions
- Data are of poor quality and therefore not reliable or credible.

Site Selection

There are a number of factors to consider when selecting sampling sites. Sites should be easily identified for repetitive sampling as well as simple to access. It is also important to select sites that contain similar habitat characteristics (e.g., bottom characteristics, depth, flow, canopy cover) to minimize natural variability between sites.

In areas where a proposed development will occur, baseline monitoring sites should be located in both reference (i.e., unimpacted) and potentially impacted areas. For example, baseline monitoring completed for the hypothetical KL mill should be conducted at stations upstream and downstream from the mill's effluent discharge. When selecting these upstream and downstream sites, the zone of effluent mixing (i.e., the vertical and horizontal range of the discharge) needs to be identified. There are two reasons for this:

1. To ensure that the potentially impacted sites will be located within the zone of effluent mixing
2. To ensure that the reference stations are well beyond any potential zone of impact.

The zone of effluent mixing is usually determined using a 'plume delineation study', which measures the zone of effluent mixing and characterizes the effluent plume. Plume delineation studies are conducted by measuring the concentration of tracers (e.g., known chemicals or added dyes) in the effluent or through predictive models. Tracers are easily measured substances that are either part of the effluent or are added to it and can be monitored to measure the extent of the discharge. Because plume delineation cannot be done until after the proposed mill expansion, predictive models would likely be used in this situation to simulate the effluent discharge. Models might be based on the existing effluent plume, which can be investigated and documented, plus the corresponding expected increase in effluent discharge volume. Once the zone of effluent mixing is characterized, the study area can then be divided into reference and impact areas.

Reference sites should be located in areas that are not exposed to mill effluent and should include at least one station immediately upstream from the mill's discharge. The distance between the reference site and the first downstream impacted site should be minimal to reduce the possibility of confusion due to contaminants from other sources unrelated to the mill. This reference site does not need to represent pristine conditions, but rather areas with low impacts or minimal disturbance.

Often, more than one reference site may be required to evaluate potential impacts. A second site in the same river reach can be used to provide additional information on natural variability. Extra reference sites can also be selected at the headwaters of a river to obtain true background levels if there are other upstream contaminant sources.

Impacted sites should also be selected at near-field and far-field locations downstream from the proposed project location. Data from these sites can be used to characterize current environmental conditions and assess the extent of impacts following the mill expansion. The near-field sites should be located at the edge of the initial dilution zone within the effluent plume. The initial dilution zone is the area in the immediate vicinity of the mill's effluent discharge as it enters the river. This area is usually characterized by turbulence and does not usually extend more than 5 to 50 m from the discharge point.

Far-field sites should be located further downstream at a sufficient distance away from the discharge to allow for mixing of the effluent and river water.

Figure 1 shows baseline monitoring stations selected for the mill expansion. In this example, predictive models would be used to estimate the effluent discharge. The rationale for selection of each sampling site follows:

- Station R-1 is a reference site. It is located upstream of the mill in a tributary to the Mekong River. There are no upstream contaminant sources, therefore, this site represents the natural background conditions.
- Station R-2 is a second reference site. It is located a small distance upstream of the mill and reflects the background conditions in the river. Unlike Site R-1, this site may be impacted by other upstream discharges (e.g., aquaculture operations, agricultural run-off).
- Station NF is a near-field site. It is located 30 m downstream from the effluent discharge at the edge of the initial dilution zone and will reflect immediate effects in the river.
- Station FF is a far-field site. This station is located approximately 250 m downstream of the effluent discharge and will reflect the effects of the mill's effluent a distance away from the discharge point following dilution and mixing.

Monitoring Variables

As it is not possible to monitor all chemical, physical and biological parameters in an ecosystem, focus must be directed to a few key parameters that will reflect general baseline conditions. Criteria for selecting variables include:

- Relevance to the monitoring objectives
- Sensitivity and response time
- Variability
- Practical issues (e.g., ease of measurement, cost).

Some parameters commonly monitored in baseline monitoring programs include:

Figure 1 Locations of sampling stations for the KL pulp and paper mill

- Soils
- Vegetation
- Aquatic benthos and terrestrial insects
- Water and sediment quality
- Fisheries resources.

While baseline monitoring programs usually focus on chemical and physical parameters, biological variables are often more useful to characterize environmental conditions. Biota integrate disturbances occurring over larger areas. For example, stream organisms can provide a way to evaluate effects of activities throughout an entire watershed. Biota also respond to a wide variety of natural and human-induced environmental influences, such as toxic effluents, nutrient enrichment and physical habitat degradation. Additionally, biota often provide a more sensitive indication of environmental change than analyses of water or sediment chemistry. For example, biological tissue may concentrate contaminants at levels more easily detected than in water or sediment.

A baseline monitoring program for the proposed KL mill expansion would sample variables found in the aquatic ecosystem since this is the receiving environment most at risk. Using the criteria explained earlier, the following variables would likely be selected to characterize the background conditions of the Mekong River: water chemistry, sediment chemistry, benthic invertebrate community and fisheries resources. The rationale for variable selection and choice of sampling methods are explained in the following sections.

Water Chemistry

Water chemistry is a common variable in aquatic monitoring programs and can be used to measure a number of parameters, such as pH, conductivity, total suspended solids (TSS), nutrients, hardness and metals. Analysis of water chemistry for the KL pulp and paper mill example may also include organic compounds, such as resin acids and phenols produced in the pulping process, as well as other parameters important when monitoring pulp mill effluents.

There are a number of reasons water chemistry is commonly monitored as part of baseline monitoring programs. Water samples are easy to collect and analyze. They also provide a good measure of soluble contaminants in an aquatic system. However, there are inadequacies associated with water chemistry. One of the biggest drawbacks is that each water sample represents water quality conditions only at the time of sampling and may not be representative of long-term water quality in the receiving environment.

Sediment Chemistry

Sediment chemistry is also commonly assessed in aquatic monitoring programs and is primarily conducted when activities are likely to cause erosion or contribute dissolved contaminants that accumulate in sediments over time. Typically, analysis of sediment chemistry includes moisture content, grain size, total organic carbon (TOC), nutrients, and metals.

Analysis of sediment TOC is important in determining the proportion of a particular contaminant that may be available for uptake by aquatic biota, especially in cases where the discharge of a contaminant is short-lived. Some contaminants, like dioxins, readily bind to organic material. River substrates with high total organic carbon are effective 'sinks' for such substances. Hydrophobic (i.e., water hating) substances will be bound in the sediments and, over time, may be buried by subsequent sedimentation, effectively reducing the amount of bioavailable contaminant.

Sediment chemistry is a popular component of baseline monitoring programs for a number of reasons. Sediments integrate contamination over time and provide an indication of long-term change in a water body. Unlike water chemistry, sediment chemistry is less variable and provides a measure of the less-soluble contaminants, such as metals and organics.

Benthic Invertebrate Community

There is a long history of using benthic invertebrates in baseline monitoring programs.

Benthic invertebrates are a popular monitoring variable for several reasons. They are widely distributed, relatively abundant, easy to collect and easy to identify. Diverse and abundant benthic communities are necessary to maintain healthy aquatic populations further up the food chain. Benthic invertebrates are sensitive to change, provide an effective measure of community-level effects and reflect the cumulative effects of past and present conditions. Benthic invertebrates are generally sedentary and therefore represent an appropriate scale for monitoring point-source discharges. Benthic invertebrate samples can be assessed for diversity indices, taxonomic richness, abundance, dominance, and presence/absence of pollution-tolerant taxa.

Fisheries Resources

Fish are also a commonly monitored variable in baseline monitoring programs. Fish are generally sensitive to contamination and reflect environmental effects at many levels (e.g., individual, community, population). Fish are often monitored to supplement benthic invertebrate surveys as they have a longer life cycle and reflect long-term impacts to aquatic biota. Fish are also more mobile than invertebrates and therefore provide an additional level of information on the status of the ecosystem. Monitoring of the fisheries in the reach of the Mekong River affected by the KL mill should include sampling to determine the fish species which frequent this reach of the river, as well as their migration patterns – this information is essential in planning mitigation measures for the proposed mill expansion. In addition, because the mill has been releasing effluent since 1978, fish tissue should be examined for the presence of dioxins.

While there are many positive reasons to include fish in a baseline monitoring program, there are some negative aspects as well. Sample collection may be costly and time consuming. In addition, the scale may be too broad to monitor the mill's sampling point source discharge, especially if large mobile fish are being monitored (e.g., it can be difficult to determine the potential exposure of mobile fish species to the mill's effluent discharge).

Fish survey methodology for large rivers generally focuses on sentinel fish species (e.g., non-mobile fish species resident in the study area) that are present at both the reference and impact stations. At least two sentinel species should be used and at least one should be a bottom feeder, such as the Giant catfish (*Pangasianodan gigas)*. An experienced fisheries biologist should be consulted before selecting species. It is recommended that at least 20 males and 20 females be collected at each station and analyzed for parameters such as length, weight, age, external condition, and fecundity.

Sampling methods should be site-specific and be based on physical and biological principles that affect fish distribution in the river. Some sampling methods include gill nets, seining, and angling.

Gill nets are commonly used for reconnaissance-level inventories of fish in rivers and lakes. Gill nets are suspended in the water column and capture fish that become entangled in the mesh. The correct mesh size should be selected to catch fish of the appropriate species and size and to limit unwanted by-catch.

Seine nets can be used to sample shallow shorelines or intertidal habitat where effluent is discharged into rivers.

Angling is conducted using fishing rod and reel, fishhooks, line, weights, bait, lures, and patience. This method can be used to sample relatively sedentary species and can be very selective so that only the target species is sampled. However, angling can be labor and time intensive and tends to provide data of limited use since the technique is highly biased for size and species.

QA/QC

Quality assurance/quality control is an essential component of all baseline monitoring programs. Quality Assurance (QA) refers to externally imposed management practices that ensure the data is scientifically defensible. Quality Control (QC) is a specific aspect of QA and refers to techniques used to measure and assess data quality. QA/QC essentially is a means of ensuring that data being generated are of acceptable quality, enabling scientifically sound conclusions to be drawn from the data. This is accomplished through overall quality assurance practices, such as staff training, use of standardized methods, as well as quality controls measures.