Environmental Impact Assessment for Developing Countries in Asia

Volume 1 - Overview

Bindu N. Lohani
J. Warren Evans
Robert R. Everitt
Harvey Ludwig
Richard A. Carpenter
Shih-Liang Tu

Citation: Lohani, B., J.W. Evans, H. Ludwig, R.R. Everitt, Richard A. Carpenter, and S.L. Tu. 1997. Environmental Impact Assessment for Developing Countries in Asia. Volume 1 - Overview. 356 pp.

Table of Contents

List of Tables

Table:

List of Figures

Figure:

List of Boxes

Box:

List of Abbreviations and Acronyms

ADB	Asian Development Bank
EcE	Economic-cum-Environmental Development Planning
EcoRA	Ecological Risk Assessment
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EMO	Environmental Management Office
EMP	Environmental Management Plan
EPA	Environmental Protection Agency (in the United States of America)
EPB	Environmental Protection Bureau (in the PRC)
ERA	Environmental Risk Assessment
GIS	Geographic Information Systems
HEP	Habitat Evaluation Procedures
HES	Habitat Evaluation System
IAA	International Assistance Agency
IEE	Initial Environmental Examination
IFI	International Financial Institutions
ha	Hectares
MTD	Maximum Tolerated Dose
NGO	Non-governmental Organization
OEPP	Office of Environmental Policy and Planning, Thailand
PRC	People's Republic of China
RA	Risk Assessment
SEI	Significant Environmental Impacts (ADB)
TOR	Terms of Reference
VEC	Valued Ecosystem Component
WHO	World Health Organization

1.0 Introduction

Our understanding of the connections between human life and other elements of nature is limited. We also have the power to destroy the natural systems that sustain us. Our capacity for destruction is illustrated through the deterioration of the ozone layer, through the extinction of species, and through mass deforestation and desertification. In many parts of the world, economic development projects directed at improving levels of material comfort have had unintended detrimental effects on people and natural resources. Water, land, and air have been degraded to the point where they can no longer sustain existing levels of development and quality of life. With inadequate environmental planning, human activities have resulted in the disruption of social and communal harmony, the loss of human livelihood and life, the introduction of new diseases, and the destruction of renewable resources. These and other consequences can negate the positive benefits of economic development. Economic development in developing countries has been focused on immediate economic gains-environmental protection has not been a priority because the economic losses from environmental degradation often occur long after the economic benefits of development have been realized.

The past failure of development planning processes to take adequate account of the detrimental impacts of economic development activities led to the advent of *environmental impact assessment (EIA)* processes. EIA was first employed by industrialized countries in the early 1970s. Since that time, most countries have adopted EIA processes to examine the social and environmental consequences of projects prior to their execution. The purpose of these processes is to provide information to decision makers and the public about the environmental implications of proposed actions before decisions are made.

1.1 Environment and Development in Asia

Asia is experiencing faster economic growth than any other region of the Earth. It is also home to most of the world's poorest people. Poverty forces people to overexploit natural resources, leading to degradation of the very forests, soil, and water upon which they depend. This perpetuates their poverty. Economic growth may alleviate poverty and lead to a higher quality of life of properly planned, it may also reduce pressure on the environment and stem to environmental degradation. However, unregulated and unplanned economic growth can have the opposite effect. Pressure on the environment may be increased, environmental degradation may occur at greater rates, and the sustainability of ecological and economic systems may be compromised. Figure 1-1 shows the interconnections between environmental degradation, poverty, and unregulated development (Jalal, 1993).

Sustainable development is the result of carefully integrating environmental, economic, and social needs to achieve both an increased standard of living in the short term, and a net gain or equilibrium among human, natural, and economic resources to support future generations. In dealing with the environmental problems of Asia as well as the promotion of sustainable development, two characteristic features of the region should be noted. First, the region contains some of the world's most ecologically productive and sensitive areas, including tropical forests, mangroves, small islands, and coral reefs. Second, both lack of development and the development process itself have caused — and continue to cause — environmental degradation. Poverty is still rampant. The region is home to over 80% of the more than one billion absolute poor in the world (people who earn less than a dollar per day). This poverty exerts tremendous pressure on the region's resources. Existing development processes continue to place a low priority on environmental concerns, viewing them as unaffordable.

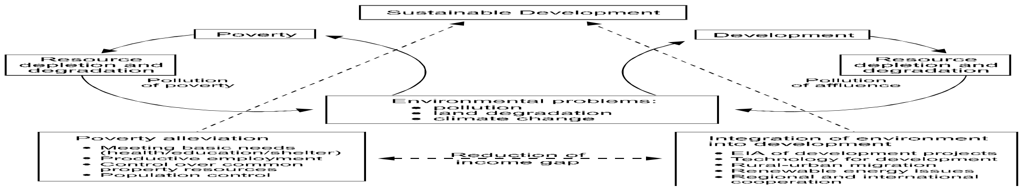


Figure 1-1: Environment and development (*source:* adapted from Jalal, 1993).

To meet the development challenge for Asia — poverty alleviation through environmentally sound development — a number of very significant and constraining problems must be overcome. These problems include land degradation and depletion of natural resources; human settlements unfit for living due to inadequate shelter, sanitation and water supplies; soil, water, and air pollution; and global issues like global warming, ozone depletion, and loss of biodiversity. Population pressure, lack of development, and the development process itself are all contributors to the existing environmental situation. Figure 1-2 illustrates the relative significance of these issues in selected developing countries in Asia.

Deforestation has reached alarming levels. Between 1980 and 1990, the average rate of tropical deforestation in the region was 5 million ha per year. At this rate, an additional 50 million ha, or about 16% of the region's remaining tropical forests, will be lost by the year 2000. Fifteen billion tons of sediment per year are estimated to be carried away by rivers due to land erosion in the region. Desertification affects more than 860 million ha of land and 150 million people in the region. Over-exploitation of groundwater has caused water yield losses, land subsidence, saltwater intrusion, and groundwater pollution in more than one third of the countries in the region (Jalal, 1993).

Region/Country (ranking)	Deforestation[a]	Land and soil resource problems[b] (desertification)	Urban congestion and pollution	Pesticides and fertilizers	Water resource problems[c]	Industrial pollution	Marine and coastal resource degradation[d]	Waste disposal[e]	Acid rain	Rising sea level
South Asia										
Bangladesh	medium	low	medium	medium	high	low	low			high
India	high	high	high	medium	high	high	medium	low	medium	low
Myanmar	medium	medium		low						low
Nepal	high	high	low	low	low		n/a			n/a
Pakistan	medium	high	high	medium	medium	low	low	low		low
Sri Lanka	high	medium	low	low	medium	low	high			low
China, People's Republic of	high	low	high	medium	low	high	low	low	high	medium
Southeast Asia										
Indonesia	high	medium	high	medium	high	medium	medium	low		medium
Lao PDR	high	medium			medium		n/a			n/a
Malaysia	high	low	medium	low	low	medium	medium			low
Philippines	high	high	high	medium	medium	medium	medium	low		medium
Thailand	high	medium	high	medium	high	medium	medium	low	low	medium
Viet Nam	high	medium		low	medium		medium			low
Pacific Islands	medium	medium			medium		high	high		high

a Includes industrial wood production, fuelwood collection, watershed degradation, and loss of biological diversity.
b Includes desertification, salinization, soil erosion, and other forms of land degradation such as water logging.
c Includes water shortages, groundwater depletion, flooding, and water pollution.
d Includes driftnet fishing, coral mining, and coastal development.
e Includes dumping of industrial and toxic waste.

Legend
high priority — low priority — medium priority — n/a not available

Figure 1-2: Relative significance of resource and environmental issues in selected developing countries in Asia (*source:* adapted from Jalal, 1993).

Rapid urbanization presents one of the most serious environmental and social challenges in Asia. The number of megacities comprising more than four million people quadrupled between 1950 and 1990, and environmental problems have grown along with those cities. Adequate shelter is also sorely lacking. Standard dwellings constitute only 17% of the region's shelter stock. Basic sanitation is needed in both urban and rural areas. Deforestation is a growing problem where wood is used for cooking. The application of agrochemicals in the region increased from 22 million tons in 1977 to 46 million tons in 1987, and pesticide consumption is growing at the rate of 5–7% per annum.

Pollution is widespread. Few countries of the region meet the recognized criteria for safe drinking water. Existing air pollution is being aggravated by increases in the use of low quality petroleum and coal for transportation and energy. Consequently, ambient levels of suspended particulates and other forms of pollution in most large Asian cities far exceed recommended public health criteria. The amount of toxic and hazardous material discharged into the ambient environment is also rapidly increasing. Urban populations are being exposed to unquantified or qualified levels of toxic pollutants because of industrial growth.

1.2 EIA and Development Planning

EIA has an important role to play in resolving these environmental problems through its ability to contribute to environmentally sound and sustainable development. Developing countries in Asia have recognized the importance of incorporating EIA processes into development planning. Development planning takes place at a number of different scales (Figure 1-3), and environmental concerns need to be considered at each one of them (Table 1-1).

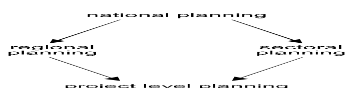


Figure 1-3: Development planning hierarchy (*source:* adapted from Asian Development Bank, 1993a).

The aim of national planning is to set broad economic, environmental, and social development goals for the country's continuing development. At this level, mechanisms employed include the formulation of a national conservation strategy, environment and natural resources management plans, state-of-the-environment reports, environment and natural resources profiles for developing countries and incorporation of environmental and natural resources considerations in economic planning and national development plans. These activities are specific elements of the overall national environmental policy.

Regional planning defines broad land use allocations for a geographic region, normally at the subcountry level. At the regional level, the approach should integrate environmental concerns into development planning. Such an approach is referred to as *economic-cum-environmental (EcE) development planning* (Asian Development Bank, 1993a). This approach facilitates adequate integration of economic development with management of renewable natural resources to achieve sustainability. It fulfils the need for macro-level environmental integration, which the project-oriented EIA is unable to address effectively. Such regional plans can set the context for project-level EIA. In considering regional plans, the environmental impacts of alternatives need to be assessed.

At the project planning level, EIA is the primary tool for integrating environmental considerations into project design and execution. Project proponents and regulatory agencies prefer to consider the environmental impacts of a single project. Ideally, EIA at the project level should take place in the context of regional and sectoral level planning; if this is not feasible, the scope of EIA reports may have to consider broad land use issues. In addition, if environmental effects are considered only at the project level, decision makers will have difficulty taking account of *cumulative environmental effects*. These are impacts which may appear minor for any one project, but which become significant when groups of related projects are considered together. The absence of regional and sectoral planning increases the time and cost involved in the preparation of the EIA report and project approval.

Table 1-1: Integration of environmental concerns into development planning (*source:* adapted from Asian Development Bank, 1993a).

Level	Integration of Environmental Policies and Procedures	Environmental Assessment Planning or Management Techniques Used
National	Environmental policy included in national action plan	• Environmental profiles • International Assistance Agency Country Programming
Regional	Economic-cum-environmental development	• Integrated regional development planning • Land use planning • Environmental master plans
Sectoral	Sectoral review linked with other economic sectors	• Sector environmental guidelines • Sector review strategy
Project	Environmental review of project activities EIA procedures	• EIA • Environmental guidelines

Sectoral planning focuses on the needs of individual development sectors (for example, energy, transport, and forestry). At the sectoral level, environmental guidelines and sectoral reviews and strategies should be formulated and integrated into various sectoral plans. This will help to address specific environmental problems that may be encountered in planning and implementing sectoral development projects. Sectoral plans, however, must also consider the relationships between sectors to avoid land use and infrastructure conflicts.

EIA, EcE, and sectoral planning are important mechanisms by which environmental factors are included in the development planning process level. EcE and sectoral planning evaluates development from the national or sub-country perspective, whereas the EIA is project oriented. When EcE or sectoral plans are available they simplify the EIA process. If they are not available (as is often the case), the project EIA must attempt to evaluate the regional and national implications of the project.

The integration of environmental considerations within the planning process has evolved similarly in both developing and industrialized countries. In Asia, the Asian Development Bank (ADB) and other institutions are currently assisting developing countries to establish, formulate, and apply regional EcE development plans and project EIA planning tools and methodologies. As such, EIA is being used as a tool for influencing development decisions not only in industrialized countries, but in developing countries as well.

1.3 EIA Inputs to the Project Cycle

Increasingly, Asian countries are enacting laws requiring EIAs for all major projects. Indeed, in many countries EIA must be an integral part of the feasibility study. Where these laws are enforced, they can be a powerful means of directing development towards sustainability. Another major trigger for EIA is project financing. In many cases, a review of the project's EIA is a mandatory requirement of financing. Few lending institutions and investors, whether international financial institutions or private sources of capital, are willing to risk their funds on projects which do not meet environmental standards. These conditions have resulted in a careful integration of environmental review procedures with various stages of the "project cycle."

A generalized project cycle can be described in terms of six main stages: 1) project concept; 2) pre-feasibility; 3) feasibility; 4) design and engineering; 5) implementation; and 6) monitoring and evaluation. EIA has a role to play at each stage in the cycle, as shown in Figure 1-4. Most EIA activities take place during the prefeasibility and feasibility stages, with less effort devoted to implementation, monitoring, and evaluation stages. In general, EIA should enhance the project and augment the project planning process.

Early in the project cycle, the EIA process involves site selection, screening, initial assessment, and scoping of significant issues. EIA must be an integral part of the project feasibility study. A project's feasibility study should include a detailed assessment of significant impacts, including gathering of baseline information; the prediction and quantification of effects; and review of the EIA by a review agency (by public and independent experts; see Chapter 12). Subsequent to these initial steps, environmental protection measures are identified, environmental operating conditions are determined, and environmental management plans (see Chapter 10) are established. At the last stage in the feasibility study, the monitoring needs are identified, and the environmental monitoring program (see Chapter 9) and the environmental management plan are formulated.

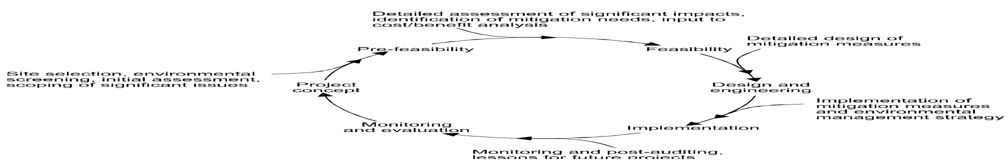


Figure 1-4: EIA inputs to the project cycle (*source:* adapted from Asian Development Bank, 1993b).

The *environmental management plan* is put into effect during the implementation of a project (including construction, operation, maintenance, and ultimate abandonment of a facility). This plan must include *mitigation measures* to reduce the environmental impacts that are generated throughout implementation. Environmental monitoring must be designed to provide information on the activity's actual impacts, compliance with environmental operating conditions, and the effectiveness of environmental mitigation measures. The evaluation of monitoring results is necessary to ensure that environmental objectives are achieved — and, if necessary, that project modifications or remedial measures are undertaken to address unforeseen impacts. Resources for the design and implementation of effective monitoring programs have often been inadequate. As a result, follow up work to ensure that the EIA recommendations are actually carried out has rarely been completed. Many national environmental agencies and international assistance agencies (IAAs) such as the ADB recognize the importance of follow-up evaluations, and are now increasing requirements to ensure funding for the implementation of environmental management plans and monitoring programs.

1.4 Outputs of the EIA Process

The main goal of EIA is to influence development decision-making by providing sound information on environmental impacts and the means for preventing or reducing those impacts. Three major outputs of the EIA process provide the primary means for integrating the results of a specific EIA into the development planning decision process and the concurrent environmental regulatory process: an identification and analysis of the environmental effects of proposed activities (including their probability of occurrence); an environmental management plan which outlines the mitigation measures to be undertaken; and an environmental monitoring program which outlines the data that must be collected in conjunction with the project. All three outputs are required for the EIA process to be effective. In some jurisdictions, the documentation for the EIA process requires that three separate documents be prepared, one for the impact assessment, one for the environmental management plan, and one for the environmental monitoring program. In others, all three are presented as part of the EIA document.

Environmental management is usually integrated into the project management system associated with the construction, operation, and maintenance of the project. Environmental monitoring is normally considered one of the responsibilities of the environmental management system. When successfully integrated with the environmental management system for the project, environmental monitoring can provide valuable feedback about the effectiveness of environmental protection measures. Where monitoring shows that environmental protection measures have been ineffective, corrected action should be undertaken.

1.4.1 Analysis of Environmental Effects

EIA analysis has three sequential phases — identification, prediction, and assessment. Identification involves characterizing the existing physical, social, economic, and ecological environment and identifying components of a development project which are likely to impact that environment. The impacts may be described according to the geographical extent and time period over which they are expected to occur. During the prediction phase, the project impacts are quantified using standards and by comparison with the findings of other projects. Basically, the predictive function of an EIA is to forecast the nature and extent of the identified environmental impacts, and to estimate the likelihood of the occurring impacts. The assessment phase judges the importance or significance of the predicted impacts. The results of the assessment phase, in terms of the beneficial and adverse impacts of the proposed project and its development alternatives, are communicated to decision makers. Population groups that may be directly or indirectly affected by the project are identified. The assessment determines costs and benefits to user groups and the population affected by the project. It also specifies and compares trade-offs between various alternatives.

Methods and techniques for identifying and predicting environmental impacts will be presented in later chapters. Box 1-1 presents a summary of the results of an analysis of environmental effects for the Cikampek-Padalarang Toll Road Project in Indonesia.

Box 1-1: Results of an analysis of the environmental effects of a highway project in Indonesia (*source:* Government of the Republic of Indonesia, 1992a).

The Ministry of Public Works of the Republic of Indonesia commissioned an EIA for the Cikampek-Padalarang Toll Road Project. The road was planned as a 56 km long, dual 2-lane carriageway connecting the Jakarta-Cikampek and Padalarang-Cileunyi toll roads, with the goal being to complete the linkage of Jakarta and Bandung by good quality highways. A 50% reduction in travel time between the two cities was expected. Significant socioeconomic benefits to the region were anticipated, including increases in the development of industrial complexes along the corridor, increased tourism, and improved communication. Negative socioeconomic impacts include the appropriation of land, the weakening of existing community linkages through relocation, and the suppression of agricultural land. Compensation was unlikely to be sufficient to maintain preproject living standards for those who were relocated. Numerous families would likely have experienced significant reductions in income. To counterbalance these negative effects, there was to be a bias in construction work hiring in favor of local people, especially those who were subject to relocation or land-take.

Adverse environmental impacts predicted for the construction phase included increased erosion and landslipping. Impacts associated with increased traffic were anticipated on the existing main road because it was the only access for construction vehicles. Impacts on the flow regimes of natural watercourses, village water supply pipelines, and irrigation works were also expected. Deep cuttings were anticipated to affect standing water levels in wells. A variety of mitigations were incorporated into the project design to address these issues.

Increased noise due to traffic along the highway corridor was the principal negative impact anticipated for the operation phase. Noise barriers were to be erected where this issue proved to be problematic. The rate of accidents involving pedestrians was anticipated to be lower on the new road than on the existing road.

This example provides details of the operational phase of the project. Impacts were determined to fall into six categories: noise;

Box 1-1: Results of an analysis of the environmental effects of a highway project in Indonesia (*source:* Government of the Republic of Indonesia, 1992a).

social; water resources, air quality; traffic; and erosion and slope stability. A study of these impacts was carried out, and is discussed below.

Noise:
The planned highway was to pass through residential areas which were very quiet at night. A preliminary study was carried out using a methodology described in the UK Department of Transport manual on the calculation of traffic noise. Predictions were made for the level of traffic expected 20 years after the opening of the highway, and noise levels were calculated for those cross sections where the highway passed through or close to settlement areas. There were no data on the tolerance of Indonesian people to noise, and no guidelines on acceptable residential noise levels. Both Indonesian industrial noise limits and UK residential noise limits were used to estimate the requirements for sound insulation, and to identify the locations where noise barriers should be installed. The study estimated that a total of 8.7 km of noise barriers would be required to keep levels in settlements below the UK limit of 68 dBA. Provided the noise barriers were installed, no significant noise impacts were anticipated.

Social Impacts:
Social impacts included the interference of the highway with pedestrian traffic routes. Extensive study was undertaken to determine the appropriate placement and number of pedestrian crossing points, which were to take the form of bridges. Some were planned to accommodate normal vehicle traffic, whereas others were designed for light vehicles only, according to preproject usage. All pedestrian bridges were planned to accommodate the passage of animals. Culverts under the highway were also planned to allow the passage of pedestrians, animals, drainage, and irrigation canals. Since a large number of crossings were provided, significant negative social impacts were judged unlikely in the operation phase.

Water Resources Impacts:
The study of the impacts on water resources was broken down into increases in flood flows and impact on water quality. While the impervious highway surface would increase run-off during and after rain, the steep gradients of the small watercourses which drain the highway would make significant flooding as a result of the highway highly improbable.

Pollution resulting from normal traffic on the highway surface would be washed into the rainwater. Dilution and oxidation would occur in the drainage streams. The receiving waters are relatively highly polluted, and the increase in pollution due to highway-derived contaminants was expected to contribute relatively little to the pollution load. The possibility of installing oil and grease separators was investigated and rejected on the grounds that they do not function well under the high flow conditions frequently experienced in this region. No statistics were available on the likelihood of highway spills. A reduced rate of spills was expected because of the better road conditions on the new highway. The study, however, also anticipated that spills would contribute to water pollution from highway run-off. Mitigation would depend on appropriate spill response through trained mobile highway patrols. A rapid response unit at the toll road headquarters was planned.

Air Impacts:
Air pollution from vehicle exhaust was not expected to become a serious problem since the terrain is very open in this area. World Health Organization (WHO) guidelines for air quality were unlikely to be exceeded, and no significant impacts were expected.

Traffic Impacts:
The impact on traffic during the construction phase was expected to be an increase in congestion, particularly at the entry and exit points, and the presence of maintenance vehicles, machinery and staff on the road. Traffic congestion was to be controlled in part by the installation of traffic lights. Traffic control measures including advance warning of road work, speed restrictions, and lane closures were to be used to prevent accidents during road maintenance.

Erosion and Slope Stability Impacts:
Erosion was expected to continue past the construction phase on embankments and cut slopes, especially where vegetation cover was incomplete. Minor landslips were expected in these areas after heavy rainfall, especially in the early stages of operation as new vegetation became established. Routine maintenance was to include inspection of earthworks and drainage systems, and remedial action was to be taken as soon as erosion or slippage became apparent. No significant impact was expected.

1.4.2 Environmental Management Plan

Environmental protection measures are taken to: 1) mitigate environmental impacts; 2) provide in-kind compensation for lost environmental resources; or 3) enhance environmental resources. One of the goals of the EIA process is to develop an implementable set of environmental protection measures. These measures are normally set out in an environmental management plan. A well structured environmental management plan usually covers all phases of the project from preconstruction to decommissioning and addresses all major environmental issues or impacts identified during the EIA process. The plan outlines environmental protection and other measures that will be undertaken to ensure compliance with environmental laws and regulations and to reduce or eliminate adverse impacts. The plan defines:

- the technical work program to mitigate this plan, including details of the required tasks and reports, and the necessary staff skills, supplies, and equipment;
- a detailed accounting of the estimated costs to implement the plan; and
- the planned operation or implementation of the plan, including a staffing chart and proposed schedules of participation by the various members of the project team, and activities and inputs from various governmental agencies.

A detailed description of environmental management plans, their preparation and execution is presented in Chapter 10. Box 1-2 summarizes the environmental management plan for the Cikampek-Padalarang Toll Road Project in Indonesia.

Box 1-2: Example Environmental Management Plan (*source:* Government of the Republic of Indonesia, 1992b).

As required by the Indonesian EIA (AMDAL) process, the Ministry of Public Works of the Republic of Indonesia commissioned an environmental management plan as part of the EIA for the Cikampek-Padalarang Toll Road Project. This plan covered the toll road right of way as well as ancillary construction areas such as quarry, borrow and spoil disposal sites and access roads, base camps, plant yards, etc. The management plan included sections on project approach, preconstruction phase issues, construction phase issues, operation and maintenance phase issues, and implementation of environmental management requirements. In each section, measures relating to environmental management were detailed. Technical, economic, and institutional approaches were used for environmental management. These approaches were described in great detail in the management plan and are summarized below.
Technical approaches included:

- selection of a route corridor and final alignment within the corridor to minimize impacts associated with housing and agricultural land;
- siting and hydraulic design of cross drainage works to minimize upstream and downstream flooding;
- design of embankments and cuttings to incorporate features such as drainage works to minimize erosion and landsliding;
- siting of noise barriers to minimize traffic-generated noise impact where the highway traverses or passes close to settlement areas;
- design of the highway vertical and horizontal alignment to minimize the quantity of spoil generated; and
- siting of pedestrian crossing points in all locations where crossings are required to maintain access to schools, mosques, agricultural land, and other communities together with design of appropriate structures, taking into account such future needs as could reasonably be foreseen.

Economic approaches included:

- financial compensation for land and property lying on the right-of-way according to established Government procedures;
- payment of compensation by the concession company for temporary use of land in connection with the development of borrow and spoil disposal sites; and
- maximization of employment of local human resources by the contractor and concession company during the construction and operation phases respectively, with those losing housing, agriculture, and employment being given preference.

Institutional approaches included incorporating various measures in the construction contract documents to control potentially damaging activities by the contractor, and developing appropriate enforcement procedures. Some of the social impacts associated with the construction phase could be controlled by improved communications with the affected communities.

1.4.3 Environmental Monitoring Program

Environmental monitoring involves the systematic collection of data to determine 1) the actual environmental effects of a project; 2) the compliance of the project with regulatory standards; or 3) the degree of implementation of environmental protection measures and success of the environmental protection measures. The information generated by monitoring programs provides the feedback necessary to ensure that environmental protection measures have been effective in helping achieve an environmentally sound project.

An *environmental monitoring program* plan outlines the monitoring objectives; the specific information to be collected; the data collection program (including sampling design); and the management of the monitoring program. Program management includes assigning institutional responsibility, defining reporting requirements, ensuring enforcement capability, and confirming that adequate resources are provided in terms of skilled staff, equipment, training, and funds.

A detailed description of environmental monitoring plans, their preparation and execution is presented in Chapter 9. Box 1-3 summarizes the environmental monitoring plan for the Cikampek-Padalarang Toll Road Project.

Box 1-3: Example Environmental Monitoring Plan (*source:* Government of the Republic of Indonesia, 1992c).

The Ministry of Public Works of the Republic of Indonesia commissioned an EIA for the Cikampek-Padalarang Toll Road Project. An environmental monitoring plan was prepared as part of an overall quality control measure to ensure that environmental protection measures as detailed in the environmental management plan were adopted, and to make sure that any enforcement measures needed were carried out. In addition, the plan aimed to assess the effectiveness or necessity of the environmental management measures in practice; to provide information on which to base additional environmental protection measures where necessary; and to provide feedback on the magnitude and nature of actual impacts. Monitoring was to include all areas covered in the environmental management plan as well as communities outside the right-of-way which would experience social impacts as a result of the movement of displaced people.

The monitoring plan included sections on impacts from each of the four project phases (preconstruction, construction, operation, and maintenance), and on the implementation of environmental monitoring.

The monitoring plan recognized that adverse social impacts associated with the land-take were likely to be the most important category of impacts associated with the project. Detailed social studies of eight sample settlement areas were the basis for the assessment of these impacts. Project implementation, however, had already proceeded to the point that many of the recommendations for mitigating these impacts through land acquisition, resettlement, and restoration of incomes were already underway before the environmental management plan was prepared. Monitoring was unlikely to significantly improve environmental management in this project, but could help in management planning of future toll road projects.

During the preconstruction phase notice boards were constructed to provide affected communities with information concerning the project. These notice boards were monitored to establish whether or not people were receiving up-to-date and relevant information about the project. The success in replacing public facilities such as mosques, schools, and health facilities that had to be demolished was also monitored.

Construction phase monitoring was extensive and detailed. In addition to a plan for monitoring related to the deployment of heavy plant, equipment, and materials, it included monitoring of general measures relating to environmental management (including waste disposal, public nuisance, and conservation of cultural, archaeological and fossil resources), the deployment of the contractor's work force, the base camp, land clearance, general haulage, construction of earthworks, construction of base courses and surfacing, quarry and borrow areas, spoil disposal, and the construction of bridges and other major structures.

Monitoring in the operation and maintenance phase was to be focused on noise, social aspects, erosion and slope stability, waste, and traffic.

Implementation of the monitoring plan was organized by construction phase. Organizational aspects, executive responsibilities, procedures, and financial aspects are also determined.

1.4.4 The Environmental Management Office

The implementation of the environmental management plan requires that an *Environmental Management Office* be established as a part of project management. While environmental officers may have various titles (for example, environmental coordinator or environmental supervisor), their responsibilities are clear — to see that the environmental management plan and environmental monitoring plan are carried out. Box 1-4 describes the environmental management unit established for the Cikampek-Padalarang Toll Road Project. Chapter 10 provides a more detailed explanation of the functions and responsibilities of the Environmental Management Office.

Box 1-4: Example Environmental Management Unit (*source:* Government of the Republic of Indonesia, 1992c).

A small environment management unit (EMU) was created for the construction of the Cikampek- Padalarang toll road. The EMU was managed by a senior environmental specialist (the Environmental Supervisor) who had responsibilities for those aspects of construction that had environmental implications. The cost estimate for environmental management during the construction phase was 206,000,000 Indonesia Rupiahs (approximately US$ 100,000 in 1992). For the first two years of the toll road operation and maintenance the environmental management will remain with the EMU under the direction of the Environmental Supervisor. After two years, responsibilities for environmental management will be transferred to the Maintenance Manager. The Maintenance Manager may from time to time contract environmental specialists to help with specific problems. Costs associated with the operation and maintenance phase (25 years) are 196,000,000 Indonesia Rupiahs (approximately US$ 100,000 in 1992).

Environmental monitoring during construction and operation will be the responsibility of the EMU during the early years, then the Maintenance Manager in subsequent years. Incremental costs for environmental monitoring over and above the costs for environmental management were estimated at 31,000,000 Indonesia Rupiahs (approximately US$ 15,000 in 1992). These costs assume that monitoring will only be necessary during the first five years of operation.

1.5 Challenges for the Practice of EIA in Developing Asia

Developing countries in Asia have generally incorporated EIA into development planning processes. EIA implementation in Asia faces severe limitations, however, including: 1) insufficient procedural guidance; 2) inadequate baseline data upon which to base analyses; 3) the cost of EIA study preparation; 4) potential delays in project implementation; 5) the lack of expertise for assessing impacts; 6) inefficient communication of EIA results to decision makers; 7) lack of inter-agency coordination; 8) limited capacity for review of EIA reports; and 9) insufficient commitment to follow up on the implementation of environmental protection and monitoring requirements. Of these constraints, one of the most significant is the lack of effective communication of EIA results and recommendations to decision makers. This may be the result of a lack of EIA skills in staff of national EIA agencies — if they had the skills, they likely would discover a way to get their findings to decision makers. Another serious shortcoming which often negates high quality EIA is the insufficient commitment to follow up; resulting in no action in spite of the EIA findings and recommendations.

Developing countries often have limited technical and social databases for making impact projections. As a result, extensive baseline data must be collected. This is perhaps the single most expensive and time-consuming endeavor in the conduct of an EIA. The expense can be considerably reduced, while maintaining quality and accuracy, if the essential baseline data/information is available. In the absence of baseline data, project-level EIAs should not be substituted for higher level environmental planning (that is, regional development planning, sectoral development planning) because these plans do not adequately address the needs of specific projects.

Comprehensive environmental planning generates information that becomes critical to the rational use of renewable natural resources. Regional and sectoral development planning, national and regional conservation strategies, and environmental profiles provide much of the baseline information for EIA. An EIA may then be used to correct environmental deficiencies at the project level.

Since developing countries face a shortage of EIA experts, relevant capacity building in Asia is a priority. Increasing needs for EIA and environmental management programs should provide employment opportunities and career prospects in the field. IAAs such as the ADB and the World Bank are providing technical assistance to help build EIA capacity.

The lack of inter-agency coordination is another problem. Many agencies are involved at various stages of development projects and EIA assignments — often with no clear demarcation of responsibilities. Thus in addition to general guidelines for the preparation of EIA reports, there is also a need for specific guidelines for development sectors. Such guidelines should be comprehensive, thorough, and relevant to the specific needs and realities of each developing country. Greater discussion of sectoral guidelines is presented in Section 3.1. The EIA guidelines should also provide for monitoring programs that determine the effectiveness of environmental protection measures incorporated into development activities. The primary factor in the successful use of EIA is the capability of project proponents and the national environment agency to initiate and coordinate environmental management efforts, competently review reports to ensure that environmental plans and management measures are adequate for their intended purposes, and ensure that the EIA findings are considered by the country's decision makers. Successful environmental management is much more likely when project proponents and environmental agencies clearly understand their respective responsibilities. To accomplish these tasks, EIA training programs should be initiated whenever possible for proponents and review agencies.

1.6 References and Further Reading

Asian Development Bank. 1993a. Guidelines for Integrated Regional Economic-cum-Environmental Development Planning, Volume I: Guidelines. Asian Development Bank, Manila, Philippines, 125 pp.

Asian Development Bank. 1993b. Environmental Assessment Requirements and Environmental Review Procedures of the Asian Development Bank. Office of the Environment, Asian Development Bank, Manila, Philippines. March 1993, 44 pp.

Government of the Republic of Indonesia. 1992a. Cikampek-Padalarang Toll Road Project, Environmental Impact Analysis. Ministry of Public Works, P.T. Jasa Marga (Persero), Directorate General of Highways, Indonesian Highway Corporation #Y02121-66, 133 pp.

Government of the Republic of Indonesia. 1992b. Cikampek-Padalarang Toll Road Project, Environmental Management Plan. Ministry of Public Works, P.T. Jasa Marga (Persero), Directorate General of Highways, Indonesian Highway Corporation #Y02121-66, 80 pp.

Government of the Republic of Indonesia. 1992c. Cikampek-Padalarang Toll Road Project, Environmental Monitoring Plan (RPL). Ministry of Public Works, P.T. Jasa Marga (Persero), Directorate General of Highways, Indonesian Highway Corporation #Y02121-66, 44 pp.

Jalal, K.F. 1993. Sustainable Development, Environment and Poverty Nexus. Occas. Pap. No. 7. Economics and Development Resource Centre, Asian Development Bank, Manila, Philippines. December 1993. 24 pp.

2.0 Institutional Aspects of Environmental Impact Assessment in Asia

The performance of environmental impact assessment (EIA) in developing countries in Asia over the past 25 years can hardly be considered satisfactory, in spite of the considerable effort devoted to improving cost effective EIA methods and techniques (Ebisemiju, 1993). Considering the severe limitations on EIA implementation present in Asia, significant achievements have nonetheless been made. To evaluate progress toward more effective EIA processes in developing countries in Asia, basic institutional aspects that contribute to the effectiveness of an EIA process must be understood. This chapter examines:

1. the legal mandate for EIA;
2. the steps in the EIA process;
3. the roles and responsibilities of various groups in the EIA process;
4. human resource requirements for EIA;
5. financial requirements for EIA;
6. public participation in EIA;
7. the role of environmental standards in EIA;
8. the need for guidelines and procedures in EIA;
9. the special EIA requirements of International Financial Institutions (IFIs); and
10. constraints to the implementation of EIA in developing Asia.

2.1 Legal Mandate

The strength of the legal mandate for EIA institutions is a measure of the level of a country's commitment to an effective EIA system. Most developing countries in Asia have an established framework for environmental protection and environmental management (Asian Development Bank, 1992). The laws, regulations, policies, and agencies that define each country's institutional framework are designed to contribute to the conservation and protection of the environment. Many institutions are concerned with pollution prevention and the protection of air and water quality. Others are concerned with conservation, protected areas, and the protection of biodiversity. Still others, including EIA institutions, regulate, enforce, and coordinate resource use and development activities (Asian Development Bank, 1992).

A number of high-level environmental agencies have been established in Asian developing countries. For example, in the Republic of Korea, the Environmental Administration is a central agency dealing with environmental matters in general and with pollution in particular. It has statutory authority to implement government policy through local government, and is responsible for improving environmental quality in general and setting specific environmental quality standards for development projects. In India, the environmental agency reports directly to the Prime Minister. Singapore has a separate ministry which deals with environmental matters, while Indonesia, Laos, Malaysia, Nepal, Philippines, Sri Lanka, Thailand, and Viet Nam each have a ministry that deals with environmental matters in connection with other related issues such as population (Nepal), transport (Sri Lanka), science and technology (Lao People's Democratic Republic, Malaysia, Thailand, Viet Nam), and natural resources (Philippines, Bangladesh). The Cook Islands has a Directorate of Conservation and Papua New Guinea has a Ministry for Environment and Conservation.

Most Asian developing countries have some form of environmental legislation. Invariably, it includes a statement on policy, goals, objectives, and priorities. In some cases, it covers several aspects of environment; in others it merely establishes the enabling acts and defines the scope and functions of the central environmental agency, or provides for a statutory environmental review procedure. The various types of legislation may be classified as follows (Asian Development Bank, 1992):

1. environmental problems covered by comprehensive environmental legislation, as in the Republic of Korea, Pakistan, Philippines, and Viet Nam (see Box 2-1);
2. environmental problems covered by comprehensive environmental legislation and supplemented by legislation in sectoral areas, as in the People's Republic of China (PRC), Indonesia, Malaysia, Sri Lanka, and Thailand;
3. sectoral legislation dealing with specific environmental problems, as in Bangladesh; Fiji; PRC; Hong Kong, China; India; Papua New Guinea; and Singapore;
4. limited sectoral legislation, as in Nepal and some South Pacific developing countries; and
5. legislation extremely limited, as in Bhutan, Maldives, and some South Pacific developing countries.

Traditional areas of environmental concern, like air and water quality, forestry, wildlife, land use, and sociocultural needs, are generally well covered by existing legislation. More recent areas of concern, including the disposal, recycling and reuse of domestic wastes, threats to coastal environments, the use of hazardous chemicals, and mining, are usually lacking coverage (Asian Development Bank, 1992).

In some cases, IFIs provide countries with assistance in strengthening environmental management legislation and capabilities. One such example is an ongoing Asian Development Bank (ADB) Technical Assistance (TA No. 2531-BHU) which is helping Bhutan to strengthen its EIA capabilities and to prepare environmental and sectoral EIA guidelines.

2.1.1 Enforcement of Environmental Legislation

Environmental law and the practice of environmental protection in developing countries is often described as rule-oriented and poorly implemented and enforced. The reasons for this include fragmentation of the legal basis for action, lack of coordination between environmental and sectoral government agencies, and deficiencies in personnel skills and material requirements. Improvement of these conditions lies not only in better legislation, but also in education, planning, budgeting, and reordering of national priorities.

Although legislation often plays a major role in environmental improvement, nothing guarantees that the intent of the legislators will be implemented in practice. Environmental legislation is often not expressed in regulations, enforcement, control, and decrees or guidelines for implementation. Effective implementation of the law requires:

- promulgation of executory regulations;
- organization of new institutions where necessary;
- effective operation of management and enforcement;
- definition of appropriate conditions for the issuance of licences;
- setting of environmental quality standards;
- recruitment and training of personnel;
- provision of material means and equipment; and
- allocation of appropriate budgets.

Box 2-1: Environmental legislation in Viet Nam.

The legal framework for environmental management in Viet Nam is based on the National Environmental Protection Law (NEPL) approved by the National Assembly on December 27, 1993. The NEPL is enabling legislation intended to establish the basic tenets of environmental management by setting the course for environmental policy and regulatory development. It lays down a framework intended to improve national, provincial and local organizational efficiency, and to raise environmental awareness in all levels of society to safeguard human and environmental health and to promote sustainable development. The NEPL designates the Ministry of Science, Technology and Environment (MOSTE) as the institution responsible for implementation of the NEPL at the national level; the Departments of Science, Technology and Environment assume this responsibility at the provincial level. This legislative mandate is crucial for two reasons. First, it is legislated, that is, it derives from an enactment of the National Assembly, the most important political institution in the country. Second, the NEPL belongs to the new generation of Vietnamese laws that are more comprehensive and precise than their predecessors.

The National Environment Agency (NEA) within MOSTE has overall responsibility for state environmental management, including:

1. promulgating and organizing the execution of legal documents on environmental protection, and promulgating a system of ental standards;
2. formulating and directing the implementation of an environmental strategy and policies on environmental protection, and plans for g environmental degradation, deterioration, pollution, and accidents;
3. establishing and managing facilities for environmental protection and facilities relating to environmental protection;
4. organizing, developing and managing systems for environmental monitoring, including periodically evaluating the actual state of onment, and forecasting environmental changes;
5. evaluation of reports on environmental impacts resulting from new projects and existing facilities;
6. issuing and revoking certificates based on compliance with environmental standards;
7 inspecting, controlling and supervising the observance of the NEPL, presiding over disputes and complaints relating to ental protection, and dealing with breaches of the NEPL;
8. training of personnel in environmental science and management, and educating, popularizing and disseminating knowledge on ental protection and the NEPL;
9. organizing research and development activities and the application of scientific technological advances in the field of environmental ı; and
10. developing international relations in the field of environmental protection.

The framework for environmental assessment is laid out in:

- Government Decree No. 175/CP- Providing Guidance for the Implementation of the Law on Environmental Protection (October);
- MOSTE Instruction No: 715/QD-MTg- Guidance on Setting Up and Appraising the Report of Environmental Impact Assessment to : Foreign Investment Project (April 3, 1995);
- MOSTE Instruction No. 1420/QD-MTg- Guidance on Environmental Impact Assessment For Operating Units (December 26,
- MOSTE Decision No. 1806/QD-Ttg- Promulgation of the Regulations and Organization of Appraisal Council on Environmental ssessment and Issuing Environmental License (December 31, 1994); and
- MOSTE Decision No. 1807/QD/MTg- Regulations on Organization of Appraisal Council on Environmental Impact Assessment ıd Issuing Environmental License (December 31, 1994).

These decrees and instructions outline the contents and formats for EIA reports and define the procedures for their subsequent review and appraisal.

Human resource development should encompass training in environmental planning and management; training in enforcement procedures; and the provision of monitoring equipment and support in its use, maintenance, and repair. Without these measures, the intent of the environmental legislation will remain largely ineffective.

To date, the priority of decision makers in developing countries has been short term economic sustainability (Ludwig, 1993). Short term economic sustainability does not take account of the environmental consequences of economic development. Until decision makers are able to reorient their priorities towards long-term economic sustainability, which depends on a sustainable flow of resources for the environment, commitments to protect and enhance the environment will remain insufficient. The ADB's Klang Valley Environmental Improvement Project (Asian Development Bank, 1987a) provides one example of an estimate of the degree of enforcement of environmental legislation. This study compiled all existing environmental legislation and regulations for Malaysia. The study estimated that the overall average level of enforcement was about 20%, a figure considered to be relatively high for an Asian developing country.

2.1.2 Environmental Impact Assessment: Legislative Versus Administrative Arrangements

Two approaches, legislative and administrative, have been used to introduce EIA into the development planning process. Legislation is used to create a clear and unambiguous mandate to ensure and enforce consideration of environmental matters in development decision making. Legislation regarding the use of EIA varies from countries which have specific EIA legislation to those which have no specific EIA legislation (see Table 2-1). The latter countries rely instead on general environmental protection legislation to help mitigate adverse environmental impacts.

Administrative approaches usually take the form of executive orders, policy statements, national conservation strategies, or environmental action plans. Effective administrative procedures for EIA force project proponents to comply with procedures in a meaningful way. Project proponents generally resist taking EIA seriously because it may increase project cost, it reduces their autonomy and it provides information to potential project opponents. EIA procedures that do not have sanctions for noncompliance are often met with token compliance or less. In many countries, the EIA requirements are rigorous but unenforceable.

Development programs or projects with potentially significant environmental impacts are often reviewed by government departments responsible for environmental matters such as natural resources management and conservation. Because many departments do not possess any statutory guidelines or mandated power, such review procedures are often ineffective. Review processes are therefore being transferred to specific interdepartmental committees and, in some instances, to environmental ministries or other statutory agencies/boards.

Table 2-1: Institutional arrangements and environmental agencies for EIA in selected Asia-Pacific developing countries (*source:* adapted from Smith and van der Wansem, 1995).

Country	Main Oversight Agency	Legislative and Administrative Documents	Date of Enactment
Bangladesh	Department of Environment within the Ministry of Environment and Forests	• Constitutional Provision for Conservation	1972
		• Guidelines for Private Appraisal in Water Sector	1991
		• Guidelines for EIA in Water Sector	
		• National Environment Policy and Action Plan	1992
		• Guidelines for People's Participation in Water Sector	1992
		• National Environmental Guidelines for Industries	1993
		• No specific EIA legislation, however there was a Declaration that Environmental Impact Assessments should be carried out for all major development projects	pending
		• Environment Protection Act	1995
		• National Environmental Management Action Plan	1995
Cambodia	Ministry of Environment	• Law on Environment Protection and Natural Resource Management	1996
People's Republic of China	National Environmental Protection Agency at various levels (no committee review)	• Constitutional Provision: Article 11	1978
		• Environmental Protection Law (Articles 6, 7)	1979
		• Marine Environmental Protection Law	1982
		• Management Guidelines on Environmental Protection of Construction Projects of the P.R.C.	1986
		• Regulations for Engineer Design on Environmental Protection Construction Projects	1987
		• Management Procedure for Environmental Protection of Construction Projects	1990
		• Constitutional Provision: Articles 9, 10, 22, 26	1993
		• Management Guidelines on Strengthening Loan Projects for EIA	1993-95
India	Department of Environment within the Ministry of Environment*	• Administrative Instructions Established	1973
		• Constitutional Provision: Articles 48A and 51A(g)	1977
		• Department of Environment (Protection) Act No. 29	1986
		• Specific legislation is planned	
Indonesia	BAPEDAL (Environmental Impact Management Agency) within the Ministry of the Environment (uses two EIA review commissions)	• Constitutional provision: Article 33(3)	1945, 1973
		• Articulation of a National Environmental Policy, as part of the general Guidelines of the State Policy (GBHN)	1978
		• Creation of the State Ministry of Population and Environment (KLH)	1982
		• Act No. 4 Basic Provisions for the Management of the Living Environment (Article 16)	1986
		• Government Regulation No. 29: required implementation, as of 5 June 1987, of an AMDAL (EIA) System	1987
		• Ministerial Decrees Nos. 49-53: General AMDAL guidelines promulgated by KLH	1990
		• Presidential Decree No. 23, creating new agency BAPEDAL	
		• Government Regulation No. 51, repealing Nos. 29 and 49-53, only addresses applicability parameters	1993
Lao PDR	Science, Technology and Environment Office	• No EIS legislation to date	
Malaysia	Department of Environment (DOE) within the Ministry of Science, Technology and	• Implicit reference in Constitution	
		• Environmental Quality Act	1974
		• Environmental Quality Act Amendment	1985

Country	Main Oversight Agency	Legislative and Administrative Documents	Date of Enactment
	Environment **	• Environmental Quality (Prescribed Activity) (EIA) Order • Environmental Quality Act Amendment	1987 1996
Nepal	Environmental Impact Study Project (EISP), Department of Soil and Watershed Management, Ministry of Population and Environment	No formal procedure for EIA of selected projects	
Philippines	Environmental Management Bureau of Department of Environment and Natural Resources	• Presidential Decree (PD) 1151 Philippine Environment Policy • PD 1586 Establishing the Environmental Impact Statement (EIS) System • Rules and Regulations to Implement the EIS System	1977 1978 1985
Sri Lanka	Central Environmental Authority within the Ministry of Transport, Environment and Women's Affairs	• National Environmental Act • Coast Conservation Act • Government Notification 772/72 • Government Notification 859/14 • EIA Guidelines • Provincial Statutes; e.g., Northwestern Province Environmental Statute No. 12 of 1990	1980 1981 1993 1995 1993/95
Thailand	Ministry of Science, Technology and Environment***	• Environmental Quality Act	1992
Viet Nam	National Environment Agency in the Ministry of Science, Technology and Environment	• Environmental Protection Law	1994

* uses an environmental appraisal committee
** EIA Review Committee within DOE for preliminary EIAs and an EIA ad hoc panel for detailed EIAs
*** with three departments on environment (Office of Policy and Planning, Pollution Control Department, Department of Environmental Quality Promotion)

2.2 Environmental Impact Assessment Process in the Asian Context

From a procedural perspective, EIA is a multi-step process by which a wide range of issues are taken into account to determine whether and/or under which environmental constraints a project should be undertaken. The effectiveness of the EIA system is dependent on the specific steps involved in reviewing project proposals. In general, the major steps in the EIA process (Figure 2-1) are: 1) screening; 2) scoping or preparation of an Initial Environmental Examination (IEE) report; 3) preparation of an EIA report; 4) review of the EIA report; 5) approval of the EIA report with terms and conditions; and 6) environmental management. In some jurisdictions there is an additional step called post audit and evaluation. Post audit is usually undertaken sometime after the project is operational.

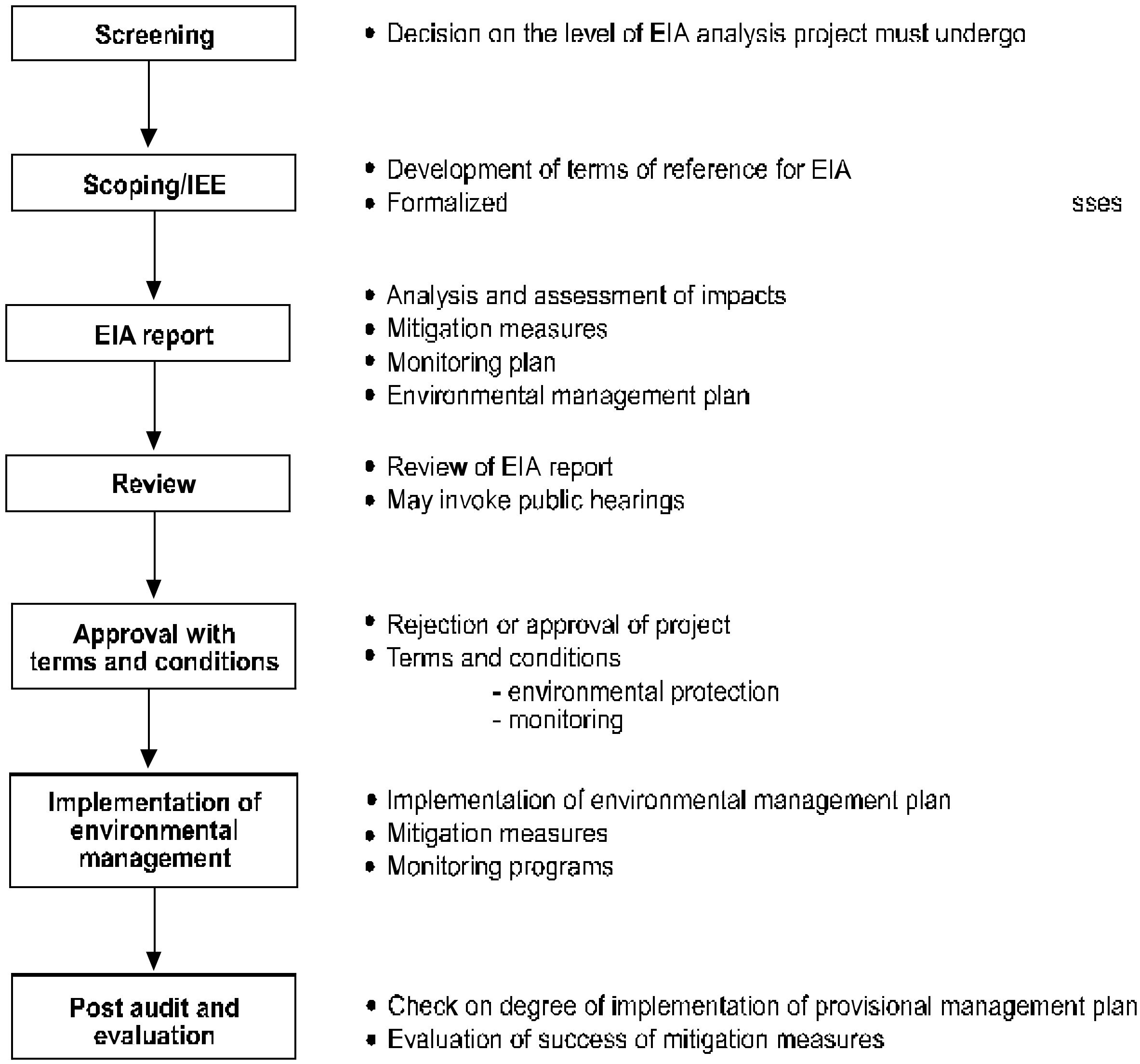


Figure 2-1: Major steps in the EIA process.

2.2.1 Screening

Screening is the process undertaken to decide which level of environmental review a project requires. In some countries, it is simply a decision as to whether an EIA is required or not using prescribed lists or criteria. For the most part, the screening criteria for determining the level of review required are relatively well defined. In some cases there is considerable discretion in determining whether or not an EIA should be carried out. For example, in the Philippines, projects considered environmentally critical or proposed for an environmentally critical area must undergo an EIA (Box 2-2). The ADB uses a threefold categorization: an EIA, an IEE, and no EIA (Box 2-3). The World Bank has a similar system.

Box 2-2: Screening criteria for the Philippines.

Philippine regulations require the preparation of an Environmental Impact Statement (EIS) for environmentally critical projects and a Project Description (PD) for projects which impact environmentally critical areas. In 1979, the EIS system was institutionalized by virtue of the Presidential Decree 1586.

Environmentally critical projects under Philippine regulations include:

- heavy industries;
- resource extraction; and
- infrastructure projects.

Environmentally critical areas under Philippine regulations include:

- national parks, watershed reserves, wildlife reserves and sanctuaries;
- areas set aside as aesthetically potential tourist spots;
- habitats of endangered or threatened species of indigenous Philippine wildlife;
- areas of unique archaeological or scientific interest;
- areas frequently visited and/or hard hit by natural calamities including: typhoons, tsunamis, earthquakes, storm surges, and floods;
- areas with critical slopes;
- areas defined as prime agricultural land;
- aquifers;
- water bodies;
- mangrove swamps; and
- coral reefs.

Box 2-3: Screening in multilateral lending agencies.

Asian Development Bank Project Categories

The ADB categorizes projects into three groups, each of which requires a different level of environmental review. For projects that are being considered for funding by the ADB, every effort should be made to adhere to ADB procedure from the earliest project development stages. The categorization procedure is explained in Section 21 of the ADB's Operations Manual entitled "Environmental Considerations in Bank Operations" (also in Asian Development Bank, 1993b).

Project Category A: Projects in this category typically require an EIA. The project type, scale, and location determine this designation. The potentially significant environmental issues for these projects may lead to changes in land use, as well as changes to the social, physical, and biological environment. The ADB suggests that an environmental specialist's advice be sought to determine the scope of the EIA necessary for compliance with the ADB's environmental policies. Bank personnel are involved in this category of project from early field reconnaissance through EIA review.

Project Category B: This category is for projects that require an IEE, but not an EIA. Often the only difference between projects in this category and those in category A is the scale. Large power plant projects fall under category A; medium-sized power plant projects are in category B. The environmental impacts from these projects are generally less severe than those of projects in category A, and these projects are not located in environmentally sensitive areas. Mitigation measures for these projects are more easily prescribed. The Bank suggests that an environmental specialist will be required to assist in formulating the Terms of Reference for the IEE so that the IEE report will comply with Bank policies.

Project Category C: This category is for projects that typically do not require an environmental assessment. These projects are unlikely to have adverse environmental impacts.

World Bank Project Categories

The categorization procedure in use at the World Bank is explained in the World Bank's Operational Manual under Operational Directive 4.01 (original OD 4.00 is reproduced in Volume 1 of World Bank, 1991 and updated to OD 4.01 in World Bank, 1993) The World Bank's categorization procedure differs from that of the ADB in that the IEE is part of the project screening step, so although Category B projects require an environmental assessment reduced in scale from that of an EIA, an IEE is not mentioned. The categories are defined below.

Project Category A: Projects in this category typically require an EIA. The potential significant environmental issues for these projects may lead to significant changes in land use, as well as changes to the social, physical, and biological environment. This category is identical to Category A of the ADB.

Project Category B: This category is for projects that usually require an environmental review but at a level of effort less than that of an EIA study. This category is basically the same as the ADB's Category B.

Project Category C: This category is for projects that typically do not require an environmental assessment. These projects are unlikely to have adverse environmental impacts. This is the same as the ADB's Category C.

2.2.2 Scoping to Determine the Terms of Reference for EIA

Scoping is the process of determining the issues to be addressed, the information to be collected, and the analysis required to assess the environmental impacts of a project. The primary output of scoping is the terms of reference (TOR) required to conduct an EIA and to prepare the EIA report. Most EIA administrative agencies in Asia approve the TOR for the EIA, but few agencies prepare them. The task of preparation is left to the proponent who normally contracts a team of EIA practitioners (EIA Team) to prepare the TOR. These are then submitted to the review agency. For example, in the PRC, the local Environmental Protection Bureau (EPB) is responsible for scoping but often does not have the capacity to develop TOR for EIAs; they rely heavily on EIA practitioners to do this. The TOR developed by the EIA team are then reviewed by the EPBs with the help of outside experts. Without sectoral guidelines, the EIA team has much latitude in the development of the TOR. In the absence of public participation, the scope and quality of the EIA are dependent on the interplay of experts hired by the review agency and the EIA team. The EIA team must work within the proponent's budget. The work proposed by the EIA team is always influenced by the training and capabilities of its members. For example, a group of engineers and physical scientists is less likely to recommend comprehensive biological surveys than a group of biologists. Sectoral guidelines developed by an independent group of experts are needed to counter these tendencies.

In some developing countries, the TOR are developed from general guidelines. These guidelines often require baseline data that has little relevance to the situation at hand. This leads to an EIA report with extensive superfluous baseline information, little analysis of impacts, and a standard set of mitigation measures. In the absence of clear guidelines, the TOR for a study are developed by the EIA practitioners undertaking the work. These practitioners must negotiate the TOR with the review agency in each case.

Initial Environmental Examination

In some EIA processes, scoping is conducted in the context of an *initial environmental examination*. After a project has been screened and found to have potentially significant environmental impacts, an IEE is undertaken to determine the probable environmental impacts associated with the project and ascertain whether a full-scale EIA is required. The IEE is usually conducted with a limited budget, and is based on existing information and the professional judgment of people who are knowledgeable about impacts from similar projects. The three primary objectives of the IEE are to:

1. identify the nature and severity of specific, significant environmental issues associated with the project;
2. identify easily implementable mitigative or offsetting measures for the significant environmental issues. If the IEE shows there are no significant environmental issues which need further study, then the IEE serves as the final EIA Report; and
3. develop the TOR for the full-scale EIA study should more detailed assessment be needed, or any special topic reports which may be required instead of, or in addition to, the full-scale EIA.

The IEE process involves identifying potentially significant environmental issues, and resolving those issues which are easily mitigated. Conducting an IEE ensures a focused TOR for a full-scale EIA because it identifies the issues requiring resolution and provides background information on them. The objectives of the IEE may be met without extensive financial and human resources, thereby increasing efficiency. The most crucial requirements for IEE execution are excellent judgment and appropriate experience, since evaluations and decisions are based on limited information. Competent EIA practitioners need to be involved in the IEE phase because the decisions made at this stage affect the composition and scope of the EIA performed on a project. A poor IEE report could result in failure to recognize significant environmental impacts, but a good report can result in efficient resolution of significant environmental issues.

2.2.3 Full-Scale EIA

A project must undergo a *full scale EIA* if it is explicitly prescribed by law (or regulation) or if the IEE results indicate that an EIA is required. A full-scale EIA normally involves a rigorous study whereby new environmental information is collected. A number of environmental experts are generally required. A full-scale EIA may also undergo or involve elaborate review procedures and requirements for public consultation. A detailed EIA report is required as part of a full-scale EIA. EIA reports are generally prepared by EIA practitioners. Depending on their capability, the available budget, and the time frame, they produce reports of varying quality. In most cases, consultants follow the guidelines developed by the review agency and/or the international assistance agency (IAA) (if any). These guidelines specify what is to be included in the EIA report. Because the scope of the TOR is often too broad for the available time and money, EIA reports do not always provide an in-depth analysis of the critical issues.

The Ideal Terms of Reference

The Project on Coherence of Environmental Assessment in International Bilateral Aid (OECD, 1994) developed procedural guidelines that include a framework TOR for environmental assessment of development assistance projects (Table 2-2). The guidelines were prepared for use by desk officers and environmental specialists of bilateral aid agencies, other operational staff of in-country units (embassies, posts, or missions), and implementing agencies within developing countries. The framework TOR are, however, also applicable to the environmental assessment requirements of multilateral institutions (for example, the ADB and the World Bank). These TOR are a useful standard. They illustrate the importance of clear, detailed TOR for EIAs prepared in developing countries in Asia. They represent the ideal — it is very doubtful that any EIA prepared to date has ever included all information listed in the framework TOR.

The framework TOR outline the requirements for two qualitatively different types of information: 1) detailed project justification; and 2) detailed environmental assessment information.

Detailed project justification includes information on:

- the problem or development goal;
- the proposed solution;
- cooperation amongst donors, lenders, and the developing country;
- the objectives of the assessment;
- legal and policy considerations;
- the institutional capacity;
- alternatives to the project and within the project;
- institutional cooperation; and
- public involvement.

The provision of this information is normally the responsibility of the bilateral or multilateral agency and the implementing agency in the developing country. In the case of a bilateral development project or a multilateral bank loan, this information is to be collected during the early stages of project formulation prior to the conduct of the feasibility study. In the case of a project being undertaken without international assistance, this information will be produced by the national economic planning agency.

Detailed environmental assessment information includes:

- a project description;
- a description of the environment;
- information quality;
- positive impacts;
- negative impacts on
    - natural resources
    - human resources
    - resettlement and compensation
    - cumulative impacts
    - trans-boundary impacts
    - impact significance;

- mitigation measures;
- an environmental management plan; and
- an environmental monitoring program/plan.

Most of this information is to be provided by the project proponent or the EIA practitioners who are responsible for the environmental assessment. It is the basic information that is required to prepare an EIA report. At a minimum, an EIA report should have the following contents:

Executive Summary

1. Introduction
2. Description of the Project
3. Description of the Environment
4. Anticipated Environmental Impacts and Mitigation Measures
5. Alternatives
6. Environmental Monitoring
7. Additional Studies
8. Environmental Management Plan and Environmental Management Office
9. Summary and Conclusions
10. Annexes

A detailed presentation of the contents of the EIA report is presented in Chapter 11.

Table 2-2: Framework terms of reference for environmental assessment of a development project (*source:* adapted from OECD, 1994).

Information		Basic Requirement	Responsibility
A.	Introduction		
1.	Background	Introduce the project and most critical environmental issues involved	- all
B.	Context		
2.	The Problem	Summarize the basic development issues or problem being addressed by the proposed activity (e.g., pollution, flooding, drought, erosion, energy shortage, poor health, inadequate infrastructure)	- bilateral agency - multi-lateral agency - country project implementing agency
3.	The Proposed Solution	Summarize the way in which the proposed activity is expected to resolve the issues, or solve or alleviate the problem with the emphasis on sustainability	- bilateral agency - multi-lateral agency - country project implementing agency
4.	Cooperation Amongst Jurisdictions	Summarize agreement or arrangements between the donor(s) or lenders and the recipient country under which the EIA is being conducted	- bilateral agency - multi-lateral agency - country project implementing agency
5.	Objectives of the Assessment	State clearly the objectives of the assessment and the relationship of the results to project planning, design, implementation, and follow-up.	- bilateral agency - multi-lateral agency - country project implementing agency
C.	Institutional Setting		
6.	Legal/Policy Base	Summarize the legal, policy and procedural basis for the EIA in the recipient country and the donor country	- bilateral agency - multi-lateral agency - country project implementing agency
7.	Institutional Capacity	Summarize and provide an appraisal of the strengths and limitations of the recipient country in the various fields of environmental protection and management	- bilateral agency - multi-lateral agency - country project implementing agency
D.	Alternatives		
8.	Alternative to the Project		
8a.	Policy Interventions	Assess the potential for achieving the basic developmental objective at the policy level	- bilateral agency - multi-lateral agency - country project implementing agency
8b.	Other Projects	Assess the potential for achieving the basic development objective by implementing other projects which are substantially different than the one proposed.	- bilateral agency - multi-lateral agency - country project implementing agency
9.	Alternatives within the Project	Evaluate potential alternatives for key aspects of the proposed project (e.g., options for siting, waste management, energy conservation, and pollution control technology).	- bilateral agency - multi-lateral agency - country project implementing agency
E.	Institutional and Public Involvement		
10.	Institutional Cooperation	Show clearly how the proposed project conforms with the overall development strategy and the priorities of the recipient country.	- bilateral agency - multi-lateral agency - country project implementing agency
11.	Public Involvement	Show how affected groups and non-governmental organizations in the recipient country, and the interested publics in the recipient country, will be given the opportunity to participate in the assessment process.	- bilateral agency - multi-lateral agency - country project implementing agency

Information	Basic Requirement	Responsibility
F. Required Information and Data		
12. Description of the Project	Describe the project (design, location, layout, size, capacity, activities); inputs (land, raw materials, energy) and outputs (products, by-products, wastes).	- project proponent or EIA consultants responsible for EIA Report Preparation
13. Description of Environment	Identify study boundaries and provide baseline data on relevant (as determined from scoping results) physical, ecological, social, economic, cultural, and demographic conditions within those boundaries.	- project proponent or EIA consultants responsible for EIA Report Preparation
14. Information Quality	Assess the quality of all information, identify data gaps, and summarize limitations placed on the assessment from such deficiencies.	- project proponent or EIA consultants responsible for EIA Report Preparation
G. Analysis of Impacts		
15. Positive Impacts	Predict how the lives of affected people will be improved and any enhancement of natural systems resulting from project implementation.	- project proponent or EIA consultants responsible for EIA Report Preparation
16. Negative Impacts		
16a Natural Resources	Predict any significant reduction in the quality of air, water and soil and loss of biodiversity.	- project proponent or EIA consultants responsible for EIA Report Preparation
16b Human Resources	Evaluate the risk of significant deterioration in the health or well-being of the affected people.	- project proponent or EIA consultants responsible for EIA Report Preparation
16c Relocation and Compensation	Evaluate plans for involuntary resettlement and describe measures taken to minimize the need for relocation.	- project proponent or EIA consultants responsible for EIA Report Preparation
16d Cumulative Impacts	Evaluate the incremental contribution to long term degradation of local natural and systems.	- project proponent or EIA consultants responsible for EIA Report Preparation
16e Trans-Boundary Impacts	Evaluate the potential for impact on neighboring countries and the potential effects on the global commons.	- project proponent or EIA consultants responsible for EIA Report Preparation
16f Impact Significance	Define the meaning of "significant" and assess the "significance" of the expected impacts.	- project proponent or EIA consultants responsible for EIA Report Preparation
H. Mitigation and Monitoring		
17. Environmental Management Plan	Provide a detailed plan covering mitigation of predicted impacts, management of residual impacts, resettlement and compensation schemes, decommissioning, and training programs.	- project proponent or EIA consultants responsible for EIA Report Preparation
18. Environmental Monitoring Program/Plan	Provide a comprehensive and detailed plan covering the environmental and social variables to be monitored, the location and timing of sampling and the use to be made of the monitoring data.	- project proponent or EIA consultants responsible for EIA Report Preparation
I. Conclusions and Recommendations		
19. Project Decisions	Indicate the extent to which the proposed project conforms with the general principles of sustainable development.	- bilateral agency - multi-lateral agency - country project implementing agency - project proponent or EIA consultants responsible for EIA Report Preparation
20. Technical Matters	Summarize the design and operational changes considered critical to improving the environmental acceptability of the project.	- project proponent or EIA consultants responsible for EIA Report Preparation
21. Non-Technical (Executive) Summary	Summarize in non-technical terms, the key findings and recommendations of the assessment, including the main economic benefits, significant environmental effects and proposed mitigation measures.	- project proponent or EIA consultants responsible for EIA Report Preparation

Information	Basic Requirement	Responsibility
J. Additional Information		
22. Organization	Provide information on the assessment team, the overall approach, the organization of component studies, the schedule, the budget and the independent review.	- project proponent or EIA consultants responsible for EIA Report Preparation
23. Additional Studies	Provide information on the results of additional studies done to support the EIA (e.g., environmental risk assessment, environmental economic analyses)	

2.2.4 Review Process

Different jurisdictions use different arrangements for the review of projects (Table 2-3). Often EIA reports are reviewed by a review agency or by a special "Standing Committee" or "Commission" established to review projects in a given sector. In most cases, a technical evaluation of the EIA report is made by specialists. This technical evaluation provides the basis for the review. The output of the review is either a rejection of the project, or an approval report outlining terms and conditions under which the project may proceed. These terms and conditions are attached to any licence, permit, or certificate issued by the approval authority. IAAs like the ADB and the World Bank also use experts for the review and evaluation of EIA reports submitted to them as part of their environmental assessment requirements.

Table 2-3: Example institutional arrangements for review of project proposals (*source:* Smith and van der Wansem, 1995).

Country	Main Oversight Agency	EIA Preparer	Public Participation	Coordination with Local Authority	Penalty for Violation
Bangladesh	Ministry of Environment and Forests	Project Proponent	No	No	No
People's Republic of China	National Environmental Protection Agency	Project Proponent	Yes, but no public hearings	Yes	Yes
India	Department of Environment within the Ministry of Environment	Project Proponent	Limited	Yes	No
Indonesia	BAPEDAL Environmental Impact Management Agency within the Ministry of the Environment	Project Proponent	Limited	Yes	No
Lao PDR	If EIS conducted, Ministry of Agriculture and Forestry				
Malaysia	Department of Environment within the Ministry of Science, Technology and Environment	Project Proponent	Yes	Yes	Yes
Philippines	Environmental Management Bureau of Department of Environment and Natural Resources	Project Proponent	Yes	Yes	
Thailand	Ministry of Science, Technology and Environment	Project Proponent	Yes	Yes	

Viet Nam	National Environment Agency within the Ministry of Science, Technology and Environment	Project Proponent	No	Yes	No

2.2.5 Approval Process - Attaching Terms and Conditions

In most cases, the results of an EIA review are provided to the agency that is responsible for ultimately approving the proposed project. In many jurisdictions, project approval also depends on approval from the EIA agency. One output of the EIA review process is the terms and conditions that are attached to approvals. These terms and conditions define the environmental protection measures that must be integrated into a project. The terms and conditions may also specify environmental monitoring that must be undertaken in conjunction with the project. For example, in the PRC, EPB (National Environmental Protection Agency for large projects) staff must inspect construction projects to ensure that the environmental protection measures are installed and operable prior to giving final clearance to the project.

2.2.6 Environmental Management and Monitoring

Environmental management is that part of project management that is responsible for implementation of mitigation measures and environmental monitoring. The *environmental management plan* (see Section 1.4.2) outlines the mitigations and other measures that will be undertaken to ensure compliance with environmental laws and regulations, to reduce or eliminate adverse impacts, and to promote feasible environmental enhancement measures. The *environmental monitoring plan* (see Section 1.4.3) outlines the objectives of the monitoring; the specific information to be collected; the data collection program, including sampling design; and monitoring program management. Environmental management includes assigning institutional responsibility, reporting requirements, enforcement capability, and ensuring that adequate resources are provided in terms of funds, skilled staff, equipment, and supplementary training.

The details of preparing environmental management plans are presented in Chapter 10. The details of preparing an environmental monitoring program are discussed in Chapter 9.

2.2.7 Post-Audit and Evaluation

Most EIA processes recognize the need for follow-up and evaluation. Follow-up is required to determine whether the environmental protection measures and monitoring programs that were conditions of project approval have been undertaken as required. Further follow-up is required to determine if the environmental protection measures were successful and if the monitoring data have been analyzed and acted upon. Box 2-4 illustrates the ADB's approach to EIA follow-up and evaluation.

Box 2-4: Post evaluation procedures of the Asian Development Bank.

A review mission is dispatched periodically to undertake discussions with concerned executing agencies to determine the degree to which environmental mitigation measures earlier agreed upon by both the borrower and the Bank have been implemented. It is the task of the review mission to verify that environmental safeguards built into the project design are satisfactorily implemented by the borrower/executing agency during the construction and operation of the project. For example, industrial project problems may occur during operations due to insufficient maintenance or non-use of pollution control devices and facilities. For infrastructure projects, such as roads, railways, and ports, the critical stage is often during construction. Independent third party monitoring of environmental aspects may be considered as part of the overall project plan.

The ADB's post-evaluation reports and project performance audit reports include a final assessment of the degree to which the projects satisfied the proposed environmental requirements, the effectiveness of mitigatory measures and institutional development, and whether any unanticipated effects occurred as a result of project activities. The Environment Division of the ADB prepares an annual report, *Post-Project Appraisal: Projects Requiring Environmental Analysis*. The report reviews and assesses, for each project, the: 1) beneficial and detrimental environmental impacts of the project; 2) location and design/operational alternatives considered and reasons for final choice; 3) environmental protection measures adopted and the effect of such measures upon project costs and on the economic evaluation of the project; and 4) environmental aspects of the project in relation to overall cost-benefit analysis.

2.3 Roles and Responsibilities of Groups Involved in the EIA System

There are many actors in the EIA process. Each has an important role to play (Table 2-4). An effective EIA system gives each actor ample opportunity for participation.

Table 2-4: Roles and responsibilities by EIA process stage.

	Actor				
EIA Process Stage	**EIA Administrative Agency**	**Proponent**	**EIA Practitioners**	**Other Government Agencies**	**Public and Interest Grou**
Screening	Screen project	Provide necessary information	Assist proponent and review agency by providing technical information and advice	Raise issues and concerns Provide review comments	
Scoping/IEE	Approve TOR Review IEE	Provide TOR Provide IEE	Prepare TOR Review TOR Prepare IEE Review IEE	Raise issues and concerns Provide review comments	Participate in consultative a
Full Scale EIA	Approve TOR	Provide EIA	Prepare EIA	Raise issues and concerns Provide review comments	Participate in consultative a
Review	Review EIA		Review EIA	Provide review comments	
Approval	Approve EIA Attach terms and conditions		Advise review agency on appropriate terms and conditions	Approve project	
Environmental Management		Implement environmental protection measures and monitoring	Conduct monitoring	Implement monitoring	
Post Audit and Evaluation	Evaluate project	Provide necessary information			

2.3.1 EIA Administrative Agency

The *EIA administrative agency* has responsibility for efficient operation of the EIA process. This encompasses a number of tasks, including screening of projects and provision of general procedural advice to the project proponents throughout the EIA process. In cases where an IEE or full-scale EIA is required, the EIA agency will approve the TOR for the EIA report. The EIA agency manages the review of the EIA report and is responsible for any approvals or recommendations associated with the EIA. In most jurisdictions, the EIA agency is responsible for verifying that environmental protection measures are properly implemented.

In addition to their responsibilities for day-to-day operation of the review process, the administrative agency must provide formal procedural guidance to proponents and EIA practitioners who will be participating in the EIA process. Procedural guidelines outline the basic requirements of compliance with the EIA rules and regulations. Many EIA agencies have recognized the need for such technical guidance. Sectoral guidelines outlining environmental issues, potential environmental impacts, and suggestions for mitigation are often developed by these agencies.

2.3.2 Project Proponent

The *project proponent* is the entity with overall responsibility for the project. The proponent may be a private sector developer, a government agency, a joint venture, or some combination of these. The proponent is responsible for providing the scientific and technical information necessary at all stages of the EIA process. Proponents usually contract outside experts skilled in EIA to assist them in this task. The proponent is also responsible for providing access to information about the project activities and the environmental setting of those activities. The level of detail required varies with the type of report. Initial project screening requires the least detailed information. A scoping/IEE report requires a higher level of detail, and a full EIA will generally require field work to gather sufficient data for an adequate assessment of the potentially significant environmental impacts of the project. During a full-scale EIA, the proponent normally commissions a study to gather the required information. As the EIA will be conducted as an integral part of the feasibility study, much of EIA team's data needs may be provided by other members of the project team.

In the review process, the proponent must be available to answer questions about the project, its potential impacts, and the proposed environmental protection measures. The proponent is responsible for the implementation of mitigation measures and may be required to conduct environmental monitoring.

2.3.3 Environmental Practitioners

Environmental practitioners act for the proponent, the EIA agency, and governmental project implementing agencies. Environmental practitioners can be drawn from private consultancy practices, project proponent personnel, government utilities and infrastructure development agencies, scientific and technical institutes, and academia. They have considerable influence on the scientific and technical aspects of the EIA review process. Over time, practitioners have accumulated considerable procedural knowledge. This knowledge is applied to help proponents satisfy the requirement of the EIA process and develop guidelines for impact assessment.

In many jurisdictions, EIA practitioners provide advice to the EIA agency throughout the process. Few EIA agencies have the necessary technical and scientific expertise on staff to deal with the broad range of environmental issues they face. Where possible, they supplement their staff by hiring outside practitioners to help with project screening, reviewing TOR, and reviewing EIAs. The sectoral standing committees and commissions set up as review bodies may also be supported by independent practitioners.

Proponents rely heavily on practitioners to prepare TORs; conduct environmental studies; design mitigation measures; and prepare EIA reports, environmental management plans, and environmental monitoring programs.

2.3.4 Other Government Agencies

EIA is usually conducted in conjunction with the project approval process. Responsibility for granting final project approval may lie with a planning agency or an economic development agency. This agency normally is involved throughout the EIA process. At the beginning of the project approval process, the agency ensures that the project proponent is aware of the requirements of the EIA process, and may refer the proponent to the EIA administrative agency. In most provinces of the PRC, for example, once the Planning Commission registers a project, it notifies the relevant EPB. In some cases representatives from the EPB attend a meeting convened by the Planning Commission at the beginning of the fiscal year to discuss proposed projects for the year. In Hainan province, the Planning Commission will not register a project until it receives notice from the Department of Environment and Resources that the project is undergoing an environmental assessment.

The planning or economic development agency is also involved in environmental management and monitoring planning. It can play an important role in ensuring the appropriate environmental protection measures are incorporated into the feasibility study.

Once the EIA administrative agency has completed its review, the agency responsible for approval takes the decision or recommendations of the EIA administrative agency into account in its decision making process. The degree of cooperation and interaction between the two agencies determines the degree to which potential environmental impacts are taken into account in the final project approval.

Other government agencies are often charged with management and/or protection of environmental resources, social development, public health, and economic development. If a project will have an impact on one or more of these sectors, the agencies responsible should have an opportunity to raise issues and provide input into the EIA process. These agencies are often contacted by the EIA team during the preparation of the EIA report, and should be represented in the EIA review panel/committee.

2.3.5 The Public

Most development projects affect a wide range of people with varied interests. Public participation is required to allow the affected people to identify significant environmental and social issues. An effective EIA process takes issues raised by the public into account in the project design, or addresses the issues through appropriate environmental protection measures. Many development projects have failed because their designs did not address local needs or were not appropriate to the socioeconomic context of the locality. Although most developing countries have no formal requirements for public participation, communities are sometimes consulted by the EIA team during its preparation of the EIA report. While this practice of community consultation is relatively new, it is assuming increasing importance and is thus becoming more prevalent.

2.3.6 International Assistance Agencies

Most projects funded by loans from IAAs must undergo an EIA. All IAAs operate on the principle that responsibility for the preparation and review of the EIA rests with the recipient country. In some cases, however, the IAAs will provide technical assistance for the EIA pursuant to local EIA laws and regulations. Such help may include screening the project; conducting the IEE; preparing the TOR; retaining a consultant to conduct the EIA studies and prepare the EIA report; reviewing the EIA report; and attaching terms and conditions to the approval. In other cases, the IAA will leave the recipient country to do the EIA, but will require that the completed EIA meet its requirements. The IAA then reviews the EIA report, approves or rejects the funding proposal, and attaches terms and conditions if approved. After the project is in operation, the IAA may conduct a post project evaluation.

In general, the IAAs tend to require higher standards for EIA than do many developing countries. The IAA standards for EIA are often useful goals for the evolving EIA processes in developing countries. An important aspect of the EIA team's work is to find a balance between the standards of the IAA and the standards of the developing country.

2.3.7 Academic Institutions

Universities and other academic organizations can assume several roles in the EIA process. They may assemble teams to perform EIAs because they have access to different disciplines on their faculties. The same advantage gives them a role in reviewing EIA drafts; more importantly, they usually have an independence from the project that is difficult to find in other sources of reviewers. Universities should be the main source of training for EIA practitioners. They should also bring new analytical methods, such as GIS and computer-assisted risk assessment, into practice.

2.4 Human Resource Requirements

The capabilities of the people involved influence the effectiveness of the EIA. Trained and experienced people are necessary to make the EIA process work effectively. Training programs have not kept pace with the rapid development of new procedures and practices for EIA. The number of skilled EIA professionals in Asia is severely limited, and human resource development is the top priority.

Senior officials responsible for the overall direction of the process need to develop an understanding of: a) the functions of an EIA process; b) the essential skills needed for EIA practitioners; c) the level of procedural and technical guidance required for efficient operation of the process; d) the appropriate quality standard for EIA reports; e) the importance of ensuring monitoring and compliance after acceptance of the EIA; and f) the role of EIA in development planning.

EIA agency staff need skills in project screening; reviewing IEEs; developing EIA TOR; reviewing EIA reports; reviewing project compliance with environmental management plans; and designing environmental monitoring programs. It is desirable that agency staff collectively have expertise in physical sciences, environmental engineering, ecological sciences, and social sciences.

The EIA practitioner deals primarily with the provision of scientific and technical information. It is important to have a broad range of scientific training represented on teams of EIA practitioners. Because most approaches to the assessment of environmental impacts are interdisciplinary by nature, team members must also have the ability to look beyond their own discipline. Practitioners must develop a good understanding of the EIA process and its goals. It is important for them to understand how their information is used within the EIA process. Practitioners must know how to critique their own EIA reports, develop environmental management plans, and design environmental monitoring programs.

To effectively advise the EIA administrative agency on aspects of the EIA process, EIA practitioners must be able to:

- develop clear TOR;
- review TORs prepared by other EIA practitioners;
- guide the EIA team to develop a TOR that is relevant to the environmental issues that must be addressed;
- judge the quality of EIA analyses and reports prepared by other practitioners when acting as technical reviewers of EIA reports; and
- judge the environmental soundness of a given project when acting as EIA Committee members.

2.5 Financial Resource Requirements

While skilled people are a crucial part of an effective EIA process, the quality of EIA studies and reports is also highly influenced by the resources available to the EIA practitioner. An effective EIA process forces proponents to provide sufficient financial resources to ensure the production of an EIA report that meets quality standards.

EIAs require time and money. EIA studies vary in scope, quality, and levels of expertise used in their preparation. The cost of the studies depends on the quality of the advice provided to decision makers through individual assessments and their intended use in project design, implementation, and management. While the costs of preparing an EIA report sometimes appear high, they are actually small when compared with the overall project costs. Generally, EIA budgets range from 0.1% to 1% of the overall project cost. These funds would produce a "minimum adequate product" for most developing countries. For example, in Thailand, the costs have ranged from US$ 1,000 for IEE-level studies to over US$ 800,000 for detailed EIAs. The expenditures in Thailand for water resources development project EIAs range between 0.01% to 0.16% of the total project cost. Similar figures for industrial development projects range from 0.048% to 0.14% of the total cost.

In the Philippines, the Forest Management Bureau estimates that mitigation measures required for timber concessions are about 1% of the total investments. The Department of Public Works and Highways reports that EIA level studies for urban highway projects require about 10% of the cost of the feasibility studies (or 0.001% of total project costs, excluding costs associated with acquiring land for the right of way), with the total cost for EIA studies ranging between US$10,000 and US$60,000.

Most IEEs in Thailand have taken a few months to prepare. The time spent on preparation depends on the type of project and the analyst's qualifications and experience. While checklists and matrices seem to be the most suitable methods because of their low resource demand, expert judgement is often required in choosing the appropriate method. In the Philippines, the Forest Management Board has completed 72 IEE-level studies, requiring about one person month each. This level of effort is typical for most sectors in the Philippines.

2.6 Participatory Development and Public Participation

2.6.1 Participatory Development

Participatory development is a process through which stakeholders influence and share control over development initiatives and the decisions and resources that affect them (Asian Development Bank, 1996). Participatory development processes (World Bank, 1996):

- identify strengths and weaknesses of existing policies and service and support systems; that is, the stakeholders jointly conduct the analysis and diagnosis;
- decide and articulate what is needed; that is, the stakeholders jointly set objectives;
- decide in pragmatic terms, directions, priorities, and institutional responsibilities; that is the stakeholders jointly create a strategy; and
- develop and oversee development of project policies, specifications, blueprints, budgets, and technologies needed to move from the present to the future; that is, the stakeholders jointly formulate project tactics.

Participatory development processes are relatively new. These are being used by bilateral and multi-lateral agencies to increase the sustainability of the development projects. Participatory development processes strive to increase the "sense of ownership" in the projects' beneficiaries by increasing the participation of a large number and a wide range of stakeholders in project planning and implementation. In the past, EIA processes were often the only forum for affected peoples to participate in project planning phases. Today they offer a vehicle for participatory development. Chapter 7 provides more detail about the participatory development process.

2.6.2 Public Participation

In the EIA context, *public participation* is defined as a two-way communication between the project EIA team and the targeted and/or affected peoples. The goals of public participation are to promote public understanding and acceptance by minimizing perceived impacts of the project through education and open discussion. In return, public feedback can be used as constructive input into improving the project design. This definition stresses the importance of communication to both the community and the project itself.

Public participation has become a mandatory component of EIAs for most projects supported by multilateral development banks. This is largely the result of pressure from citizens groups that have complained that community resources were being affected by projects, without public notice or consultation. It is for this same reason that many countries routinely incorporate public participation into their EIA procedures, even if multilateral institutions are not involved (see Table 2-3).

Educating the public about a project is an essential first step for all public participation programs. An uninformed public cannot make educated decisions about a project. Basic data on the type, size, and location of the project should be publicized. Additional data and analysis regarding the expected significant socioeconomic and environmental issues related to the project should be made readily available to interested parties who are affected by the project.

It is important for project proponents to realize the benefits of public participation are not one-sided. The objectives of public participation encompass benefits to the community as well as to the project. The primary result of a public participation program is that the concerns of the community are acknowledged and addressed. Such open involvement tends to increase public acceptance of a project, and increase the likelihood of a project's sustainability over the long term. A major component of public participation is educating people about the project and its likely effects on their lives. If uninformed, the public will often react negatively towards a project. Good ways to avoid confrontation are to keep people fully informed and to seek their help in resolving contentious matters which concern them. Projects pushed ahead in spite of public opposition often fail, at considerable cost to all parties involved. Public participation also may be used to help quantify the value of non-market resources, such as religious or historic sites, scenic and recreational areas, endangered species, etc.

Project proponents are sometimes reluctant to communicate openly regarding significant socioeconomic and environmental issues. They may fear that public awareness of a project's potential negative impacts will increase opposition to the project. In fact, the opposite is often the case. Lack of clear communication between those implementing a project and those affected by it creates feelings of alienation in the community and heightens public concern. The demonstration of good faith by the project proponents in representing all aspects of the project through a public information programme can actually help reduce public opposition.

The specific concerns of the public regarding a project should be addressed in detail in every EIA. Since certain topics are not openly discussed in some societies, it may require some effort to ascertain exactly what the root issues are. If the trust of the community representatives and open dialogue is to be established, it is critical that the approach taken by project spokespersons toward community representatives be cooperative, and not condescending or dictatorial.

Public participation goes beyond simply defining the public's concerns. Solutions to the major issues should be developed though joint efforts so that they will be acceptable to both the project proponents and the public. Community representatives may suggest measures to mitigate disruptive socioeconomic effects from the project, and may also assist in the development of appropriate environmental protection measures.

Fifteen years of EIA experience in the Philippines has shown that many problems associated with the EIA process are traceable to lack of adequate communication and understanding, as well as an inadequate appreciation of the social, cultural and political factors that affect EIA implementation. Environmental impact assessment can only be effectively carried out with the participation of the key players or stakeholders. Lessons learned in the Philippines (Guerrero et al., 1994) include the following:

- Consultation must occur early in the process. Potentially affected parties must be informed and involved at the inception of a project. The best time to involve the public is at the planning stage.
- Public meetings must be conducted to find out local views and concerns so that these can be incorporated into the project plan. It is inadvisable to delay public meetings or wait until complaints or negative feelings have been aired, as this causes hearings to become confrontational, and conflict resolution becomes more difficult.
- Sensitivity to the needs of local people is needed.
- Dialogue is important. Decision makers should listen to the public, be open-minded about their suggestions, and be sensitive to feedback from those whose perspectives, values and experience differ from theirs.
- Indigenous peoples' beliefs and values must be respected and efforts made to preserve their cultural integrity.

Many local and international nongovernment organizations (NGOs) have become interested and active in environmental issues over the past several decades. They help educate the public regarding environmental issues, lobby for more stringent environmental laws and regulations, and conduct campaigns against projects which they deem environmentally dangerous. This has given them an adversarial image in many cases. NGOs, however, can be called upon in some instances to assist with a variety of efforts, including environmental training, the development of appropriate ambient and discharge standards, and even monitoring projects for compliance with standards. The opportunities to work with, and receive assistance from NGOs should not be overlooked, especially in developing countries where appropriate environmental technology, funds, and trained personnel are often in short supply.

2.7 Environmental Standards

Predicting changes in environmental conditions is one thing, evaluating the significance of the changes is quite another. Environmental standards are necessary to provide a scale against which the environmental changes (positive or negative) associated with a project may be measured. The EIA process is more objective where the assessment of the significance of impacts may be defined by comparing the expected changes in environmental parameters with the desired environmental quality standards. The effectiveness of the EIA process in protecting the environment is, of course, highly dependent on the degree of environmental protection offered by the standard.

Ambient environmental standards generally define the prescribed limits to which levels of environmental resources may be permitted to fall, or the upper limits to which pollutants may be allowed to reach in the environment. Ambient standards may define the degree of environmental quality which must be maintained in an environmental resource to support its continued beneficial human use (see Box 2-5 on water quality standards in Indonesia). While often set to protect human health, ambient standards may also be set to ensure long-term sustainability of an environmental resource. For example, minimum quality standards may be set for ecologically sensitive areas (ADB, 1989).

Box 2-5: Water quality standards in Indonesia (*source:* Taylor and Sukarsono, 1991).

Water quality standards in Indonesia are divided into two categories:

1. National Water Quality Standards (NWQS), and
2. Local Water Quality Standards (LWQS).

National Water Quality Standards

National Water Quality Standards represent the numerical concentration or narrative statement recommended to support and maintain a designated water use. These national standards are derived using the information found in the water quality criteria. The standards give the concentration of chemicals which, if present in water at that concentration, will not harm fish or plant crops or humans drinking the water. If the chemicals are present in concentrations above those given in the standards, they will have detrimental effects such as slowing down the growth rate, stopping reproduction or possibly killing the organism. The standard can also be a narrative statement. National Water Quality Standards do not take local water quality into consideration.

Local Water Quality Standards

Local Water Quality Standards are the numerical concentration or narrative statement which have been established to support and protect the designated uses of water at a specified area. These Local Water Quality Standards are developed for a specific part of a river, lake, or river basin. Local standards include the information which is present in the National Water Quality Standards, the local water quality conditions — for example, whether the water is hard or soft, to what purpose it is used — the socioeconomic conditions, and the needs and characteristics of the region (such as whether it is heavily industrialized or if the land is forested or used for agriculture). A Local Water Quality Standard for a particular parameter may be different from the National Water Quality Standard for that same parameter. The concentration may be either higher or lower, depending on local conditions. If the water body has a number of uses, the Local Water Quality Standards applied to it are for the most sensitive use.

Discharge standards for emissions and effluents from projects define the maximum acceptable quantity of pollutants which may be discharged into the ecosystem, area or region. Discharge standards are set for specific pollutants, and often are stated as concentrations, or as discharge rates to incorporate the time dimension. They are usually specific to an area or ecological zone, and may be set for specific industries. Box 2-6 provides the effluent quality standards for existing sugar industry operations in Indonesia.

Project specific discharge standards should be based on the amount of a pollutant that may be discharged without causing violation of ambient standards for environmental resources. For this to be done, the receiving environment for the pollutant must be characterized in terms of existing levels. Predicted changes in concentrations resulting from the additional discharge should be compared against ambient standards. Chapter 4 presents methods and procedures for predicting changes in environmental quality.

Box 2-6: Effluent quality standard for the Indonesian sugar industry (*source:* BAPEDAL, 1991).

Maximum Effluent Flow of 40 m^3 per ton of sugar product		
Parameter	**Maximum Concentration**	**Maximum Pollution Load**
BOD_5	100 mg/l	4.0 kg/ton
COD	250 mg/1	10.0 kg/ton
TSS	175 mg/1	7.0 kg/ton
Sulfide (as H_2S)	1.0 mg/1	0.04 kg/ton
pH	6-9	—

Notes:

1. Except pH, maximum concentration of each parameter in the aforementioned table shall be stated in milligram per liter of waste water.

2. Maximum pollution load of each parameter in the aforementioned table is stated in kg parameter per ton of sugar product.

All environmental standards should be considered as tentative. Standards are set based on current knowledge, environmental conditions, living standards and technologies. As these conditions change, it may become necessary to revise the standards. A specific case of changing standards occurs where development already has resulted in excessive degradation of the environment and standards are introduced to reverse the effects. Often, it is neither practical nor possible to introduce and enforce standards which would immediately rectify the situation, as doing so could force many projects to cease operation. Instead, progressive standards may be introduced with a specified timetable for implementation so that polluters have time to plan and prepare for the gradual modification of their operations to reduce effluent without severe economic hardship.

Where neither ambient nor discharge standards exist, there is the risk of uncontrolled ecological disruption and environmental degradation — which in turn will reduce the quality of life for all inhabitants of the affected area. At the least, temporary minimum standards should be set by the EIA team and then modified as appropriate. One alternative is to begin with a minimum standard of environmental protection measures for all projects regardless of their type, size or location. As they are developed, subsequent ambient and discharge standards may supersede the standard environmental protection measures.

2.7.1 Meeting the Standards with an Environmental Management Plan

Discharge standards define the conditions under which a project may or may not discharge effluent into the environment, and thus the type and amount of treatment required for the effluent. For a project to meet the appropriate discharge standards, an environmental management plan is prepared as part of the full-scale EIA. The EIA itself should include a review of existing standards and recommend needed changes. The environmental management plan provides detailed design criteria for specific mitigation measures to be implemented. The *environmental management office* will track the effectiveness of the mitigation measures at meeting the discharge standards.

The cost of installing and operating treatment facilities can be a very significant item in the total project budget, and must not be overlooked in the project's financial feasibility study. The choice of a project location can also be influenced heavily by environmental standards. Choosing a site to minimize the investment requirements for effluent treatment can reduce overall project costs. Industrial projects are often grouped together to take advantage of cost-reducing centralized effluent treatment and disposal facilities. Where there has been considerable development prior to the introduction of environmental standards, retrofitting projects to meet the standards can be even more costly than incorporating treatment facilities into new projects.

2.8 Guidelines and Procedures

To increase the effectiveness of the EIA process, EIA agencies must provide formal procedural and technical guidance to proponents and EIA practitioners. *Procedural guidelines* outline the basic requirements and steps required for compliance with the EIA process rules and regulations. They usually provide information on the contents and format of EIA reports. Many advanced EIA agencies have recognized the need to provide technical guidance. *Sectoral guidelines* outlining environmental issues, potential environmental impacts, and suggested mitigations have been developed by these agencies (Asian Development Bank, 1987b; 1988; 1993a; 1993b). Section 3.1 provides a more detailed discussion of sectoral guidelines.

The sectoral guidelines aim to assist project developers, government agencies, and consultants concerned with environmental protection in developing countries to plan and carry out EIAs for development projects. They are designed for the limited budget and technical skills typical of developing countries. The guidelines furnish information which can help national environmental protection agencies convince government decision makers of the importance of environmental parameters in development planning. Sectoral guidelines also suggest means for making this possible by providing appropriate TOR. Sectoral guidelines usually do not refer to specific details; they cover only aspects of general interest to EIA practitioners (for example, environmental impacts associated with the project type, methods of assessment, etc.).

2.9 Special Considerations for International Assistance Agencies

International assistance agencies, and especially multilateral development banks, play a key role in supporting many development initiatives in developing countries. Recently, these agencies have come under intense pressure from a variety of sources to require that every project they support be environmentally sound. In order to meet the resultant preconditions for project assistance, it is incumbent upon developing country governments to continue to develop their environmental protection policies, procedures, and technical and enforcement capabilities.

2.9.1 International Lending Agency IEE Procedures

Asian Development Bank

The ADB has a formal IEE process for projects prepared by its staff. IEEs are conducted for projects which have passed through the Bank's initial project screening phase (ADB, 1993b). The Bank has prepared sector-specific guidelines which assist its staff in preparation of the IEE (Asian Development Bank, 1987b; 1988; 1993a). The three general sectors are industry and power, infrastructure, and agricultural and natural resource development. These sectoral guidelines are further supplemented by other guidelines dealing with special aspects of EIA (for example, environmental risk assessment, health risk assessment, economic evaluation of environmental impacts). The ADB also provides guidelines for the incorporation of social dimensions into projects.

The general purpose of the guidelines is to facilitate the work of the ADB staff in the incorporation of environmental considerations into the project preparation process. These guidelines have been widely distributed and are used by EIA practitioners in many Asian developing countries. As a result, Bank staff are in a better position to: 1) prepare the Bank's project covenants on necessary environmental constraints; 2) strengthen the overall project context through improvement of aspects relating to environment, including public health, control of pollution emissions, preserving valuable ecosystems, and improving quality of life; and 3) include and estimate the cost of mitigation measures, monitoring programs, and the environmental management plan.

The guidelines use the checklist approach. A checklist covers the typical impacts which could be caused by the project, on an item-by-item basis, based on experience with previous projects. IEE guidelines have been prepared for three different sectors, covering 20 different types of projects. The project classifications are as follows:

Infrastructure: Airports, Highways and Roads, Ports and Harbors, Sewerage and Excreta Disposal, and Urban Development;

Agriculture: Irrigation, Fisheries and Aquaculture, Watershed Natural Development, Forestry, Land Clearing, Coastal Resources Zone Management; and

Industry: Industries, Cement Manufacturing, Fertilizers, Power Mining, Thermal Power, Hydropower, Power Transmission Lines, and Oil and Gas Pipelines.

In addition, every IEE Sector Guideline volume contains a section entitled “Guideline Annexes For All Types of Projects.” This section provides general policy for all types of projects and should be used in conjunction with the project-specific guidelines. Topics covered are the following:

1. Environmental Constraints for Major Development Projects;
2. Resettlement;
3. Post-Construction Environmental Monitoring Program;
4. Control of Pollution Emissions and of Hazardous Materials;
5. Encroachment into Forests and Swamplands;
6. Effects and Abatement of Noise and Vibrations;
7. Dams and Reservoirs;
8. Environmental Standards;
9. Operation and Maintenance Problems; and
10. Critical Parameters for Overall Project Review.

The guidelines available for special aspects of EIA, and for the incorporation of social dimensions into projects include:

- Economic Analysis of Environmental Impacts;
- Environmental Evaluation of Coastal Zone Projects;
- Environmental Risk Assessment;
- Guidelines for Integrated Regional Economic-cum-Environment Development Planning;
- Health Impact Assessment of Development Projects;
- Handbook for Incorporation of Social Dimensions in Projects; and
- Mainstreaming Participatory Development Processes.

These guidelines may be helpful for any IEE team, and are especially useful for projects to be funded by the ADB.

World Bank

The World Bank combines project screening and the IEE into what is called the World Bank Screening Stage. The first step is to categorize a project according to its potential environmental impacts. The next step is the environmental screening phase which identifies the key environmental issues, the type of environmental analysis recommended, and a preliminary schedule for conducting the analysis. The information is incorporated into an initial executive project summary and reviewed. After the review, decisions are made concerning the type, timing, and major issues for environmental review.

The World Bank has incorporated its guidelines for the production of environmental assessments into a three-volume set entitled, *"The Environmental Assessment Sourcebook"* (World Bank, 1991). The guidelines are organized into three sectors:

1. agricultural and rural development sector;
2. infrastructure sector; and
3. energy and industry sector.

The guidelines begin with general considerations pertaining to EIAs in the sector covered and discussions of particularly relevant topics. The balance of each chapter covers specific types of projects, chosen primarily because they have potentially significant environmental issues. For each type, the project is briefly described, potential impacts are summarized, and special issues that should be considered in an EIA are noted. Possible alternatives to the project are outlined, management and training needs are discussed, and monitoring requirements are described. Each review concludes with a table of potential impacts and the measures which can be used to mitigate them. Sample TOR for the various project types are collected in one section in each chapter.

The guidelines note that not all projects will require an EIA. Alternative approaches that focus on a narrower range of issues are acceptable for many types of projects, especially those of smaller scale and those not located in environmentally sensitive areas. These projects may have environmental issues that can be resolved in environmental assessment studies of a reduced scope, similar to that of an IEE. Project types that may follow this alternative approach include:

1. integrated pest management programs for many agricultural projects which do not involve major irrigation or land development;
2. specific environmental design criteria and pollution standards for small or medium scale industrial plants; and
3. specific environmental design criteria and construction supervision programs for small scale rural works projects.

The World Bank guidelines, like those of the ADB, are valuable tools in assessing the environmental impacts of projects at many stages of the review process. Projects being funded by the World Bank, especially, will benefit from implementation of the approaches to review suggested steps in the guidelines.

2.10 Constraints to Implementing Environmental Assessment Procedures in Developing Countries

The legal, administrative, institutional, and procedural frameworks for EIA often constrain the implementation of EIA in developing countries. Many EIA agencies are subsidiary units of an environmental ministry or agency. In the Philippines, for example, the EIA Division is part of the Environmental Management Bureau of the Department of Environment and Natural Resources. In Sichuan province of the PRC, EIA is the responsibility of the Environmental Management of Exploitation and Construction Division of the provincial Environmental Protection Bureau in the Sichuan Construction Commission. The relatively low status of these agencies in the bureaucracy makes it difficult for them to have sufficient influence to ensure effective implementation of the EIA process.

Highly trained technically competent people are required to operate and manage an EIA process. Even ideal institutional arrangements will be ineffective if human resources are inadequate. Many people are trained in physical and engineering sciences, however, few of these people have any training in environmental protection. Consequently, there is a shortage of qualified environmental engineers, ecologists and socioeconomists in many parts of PRC. EIA practitioners in the PRC have identified the lack of people trained in ecological and socioeconomic impact assessment as major weaknesses in impact assessment. For example, many people involved in EIA in the PRC are trained in the physical sciences or engineering. Most of the institutes in the PRC that prepare EIAs have only one or two staff with an environmental science background and no staff with ecological or social science training.

EIA teams charged with the preparation of an EIA require expertise in project management and environmental engineering. The project manager must be an expert in EIA methodology and have an understanding of all the environmental aspects involved. The project manager must also be capable of producing a work plan designed to integrate activities and work products of the numerous EIA specialists. An environmental engineer is needed to ensure environmental protection measures are incorporated into the project design to make it environmentally sound. It takes an engineer to understand how to modify the design to reach the environmental goals. Many EIA teams in developing countries lack critical expertise in both of these disciplines — creating a large barrier to the implementation of an effective EIA process.

In some countries, however, the quality and quantity of environmental professionals is relatively high. In Thailand, the Environmental Impact Evaluation Division of the Office of Environmental Policy and Planning (OEPP) has well educated and trained staff. The Division is required to prepare a preliminary review of Final EIA reports within 30 days of their receipt, and acts as the Secretariat to five Technical Review Committees (organized by sector) which have another 15 days to review the EIA once received from the OEPP. Failure to review the EIA within the defined timeframe is treated as a *de facto* authorization to the permitting agency to issue a permit. The tight time schedules apply to all private sector projects regardless of project size or complexity. The time pressures are regarded by the private sector as an important safeguard against project delays. However, the OEPP regards the time frame as unrealistic for complex projects. The pressure on the EIA Division to quickly review the detailed EIA reports means that only one team member has time to conduct a thorough review. The quality of the review thus depends on the experience and expertise of the OEPP reviewer.

In making general observations about EIA in the Philippines, Ross (1994) stated: 1) the EIA process is seen as a bureaucratic requirement needed to obtain project approval; 2) political interference determines the outcomes of some environmental reviews; 3) questionable practices by public servants serve to discredit the process; and 4) the treatment of projects in environmentally critical areas is less than satisfactory. All four of these are common to many developing countries. The view that EIA is simply another bureaucratic requirement to obtain project approval is widespread. In many countries, there is a process for environmental review of project proposals, but the people responsible often lack the necessary skills to effectively carry out the reviews. Unfortunately, the goals of the EIA process are not always well understood by decision makers, project proponents, and in some cases, the EIA administrative agency staff. This leads to political interference and indiscretion on the part of EIA agency staff.

Ludwig and Castro (1995) found the Philippine National Power Corporation's new policy and program a notable exception. The basic concept behind the new policy is that the host communities, whose resources are used by the project, are entitled to a fair share of the benefits. This means that the project is expanded to include additional components to fill "critical community environmental gaps." Filling of these gaps is necessary to: 1) furnish host communities affected by the project with immediate improvements towards a minimum acceptable quality of life, and 2) furnish other improvements to help host communities maintain long term social and economic sustainability. Environmental Impact Assessment is seen as being of great importance in implementing the new policy. In addition to delineating the environmental protection measures, the EIA includes a socioeconomic study which serves to identify the critical community environmental gaps. Project components for filling these gaps can then be formulated.

Except for the limited amount in Thailand and the Philippines, public participation is largely absent from the practice of EIA in most developing countries. There are many political, institutional, and economic reasons that prevent the development of public participation programs that are characteristic of the EIA process in developed countries. In some countries the government is unwilling to have any form of public debate or scrutiny of its development policy. In other countries, while there are no formal prohibitions, there are no mandatory requirements for public participation. In most countries, affected interest groups do not have sufficient resources to participate effectively in the EIA process. Restricting the ranges of issues and interests reinforces the tendency for EIA to remain a bureaucratic requirement.

The quality of EIA reports is highly variable. Similarly, the scientific and technical information upon which environmental assessment decisions are being made is often inadequate. In a recent review of EIAs submitted to the ADB, EIAs were evaluated for both their compliance to the Bank's prescribed format and the substance of the information provided. The results revealed that EIAs were generally weak in: 1) assessment of ecological impacts; 2) analysis of alternatives; 3) economic analysis of environmental impacts; and 4) public participation. Finally, the environmental management plans proposed for implementation of the recommendations of the EIA report were usually inadequate both in terms of the institutional arrangements proposed and the funding allocated.

There are very real constraints on the availability of environmental information to be used in an EIA report. Time and budgets often do not allow for extensive new data collection and there is considerable reliance on existing and secondary data. In spite of this, most EIAs provide considerable background information on the environment. The problem is that they often provide little else. Where they are most obviously lacking is in the assessment or prediction of impacts and in the provision of details of appropriate mitigation measures.

2.11 References and Further Reading

Asian Development Bank. 1987a. Klang Valley Environmental Improvement Project. Prepared by Engineering Sciences and SEATEC International for the Asian Development Bank. Asian Development Bank, Manila, Philippines.

Asian Development Bank, 1987b. Environmental Guidelines for Selected Agricultural and Natural Resources Development Projects. Asian Development Bank, Manila, Philippines.

Asian Development Bank, 1988. Environmental Guidelines for Selected Industrial and Power Development Projects. Asian Development Bank, Manila, Philippines. 154 pp.

Asian Development Bank. 1989. Minimum Quality Criteria for Ecologically Sensitive Areas. ADB Environment Paper No. 4. Asian Development Bank, Manila, Philippines. 96 pp.

Asian Development Bank. 1992. Environmental Legislation and Administration: Briefing Profiles of Selected Developing Member Countries of the Asian Development Bank. ADB Environment Paper No. 2. Asian Development Bank, Manila, Philippines. 59 pp.

Asian Development Bank, 1993a. Environmental Guidelines for Selected Infrastructure Projects. Asian Development Bank, Manila, Philippines. 128 pp.

Asian Development Bank, 1993b. Environmental Assessment Requirements and Environmental Review Procedures of the Asian Development Bank. Office of Environment, Asian Development Bank, Manila, Philippines. 44 pp.

Asian Development Bank. 1996. Mainstreaming Participatory Development Processes. Asian Development Bank, Manila, Philippines. 19 pp.

BAPEDAL Environmental Impact Management Agency. 1991. Decree of the State Minister for Population and Environment Number: KEP-03/MENKLH/II/1991.

Ebisemiju, F. 1993. Environmental impact assessment: making it work in developing countries. Journal of Environmental Management, 38: 247-273.

Guerrero, Sylvia H., Alexander G. Flor, Heinz Kroske, and Marlito L. Cardenas. 1994. Public Participation in EIA: A Manual on Communication. Environmental Management Bureau and the MADECOR Environmental Management Systems Inc., College Laguna, Philippines. 98 pp.

Ludwig, Harvey F. 1993. Sustainability - What is it? What does it mean? Asian Society for Environmental Protection (ASEP) Newsletter, December 1993.

Ludwig, Harvey F. and Humbelina Castro. 1995. Sharing of project benefits for hydropower projects in upland regions of the Philippines. P. 4, 12 in Asian Society for Environmental Protection (ASEP) Newsletter, March 1995.

OECD. 1994. Towards Coherence in Environmental Assessment, Volume II. Procedural Guidelines, Results of the Project on Coherence of Environmental Assessment for International Bilateral Aid. Submitted by Canada to the DAC Working Group on Development Assistance and Environment, 1994.

Ross, W.A. 1994. Environmental impact assessment in the Philippines: progress, problems, and directions for the future. Environmental Impact Assessment Review, 14: 217-232.

Smith, D.B. and Mieke van der Wansem. 1995. Strengthening EIA Capacity in Asia. A Synthesis Report of Recent Experience with Environmental Impact Assessment in Three Countries: The Philippines, Indonesia, and Sri Lanka. Prepared for the World Resources Institute. 100 pp.

Taylor, Margaret C. and Sri Hudyastuti Sukarsono. 1991. Development of Water Quality Standards: An Indonesian Study. Environmental Management Development in Indonesia Project (EMDI). Jakarta and Halifax. 117 pp.

World Bank. 1991. Environmental Assessment Sourcebook. World Bank Technical Paper. No. 139. World Bank Environment Department, Washington, DC. Three volumes.

World Bank. 1993. Environmental Assessment Sourcebook Update Number 1. The World Bank and Environmental Assessment: An Overview. World Bank Environment Department, Washington, DC. April 1993. 4 pp.

World Bank. 1996. The World Bank Participation Sourcebook. Environment Department Paper 019. World Bank, Washington, DC. 259 pp.

3.0 Methods for Environmental Impact Assessment

Changes in the practice of Environmental Impact Assessment (EIA) and advances in information technology have greatly expanded the range of tools available to the EIA practitioner. For example, map overlay methods, originally pioneered by McHarg (1971), have evolved into sophisticated Geographic Information Systems (GIS). Expert systems, a branch of artificial intelligence, have been developed to help in screening, scoping, developing terms of reference (TOR), and conducting preliminary assessments. These systems use comprehensive checklists, matrices, and networks in combination with hundreds of impact rules developed by EIA experts. The global embrace of sustainable development has made the analysis of costs and benefits an integral part of EIA. This has forced the expansion of factors to be considered in traditional cost benefit analysis. The following chapters describe some of these more specialized approaches and methods that have evolved to meet the changing needs of EIA: 1) predictive methods (Chapter 4); 2) environmental risk assessment (Chapter 5); 3) economic analysis (Chapter 6); and expert systems (Chapter 8).

This chapter describes some of the simplest techniques and methods for EIA, and gives information to help choose the most appropriate method for a given situation. *Ad hoc methods* (section 3.1) are useful when time constraints and lack of information require that the EIA must rely exclusively on expert opinion. *Checklists and matrices* (section 3.2) are good tools for organizing and presenting information. *Sectoral guidelines* are becoming widely accepted as an appropriate technique for conducting initial environmental analysis. Section 3.3 presents an overview of the sectoral guidelines developed by the Asian Development Bank (ADB), the World Bank, and the Economic and Social Commission for Asia and the Pacific (ESCAP). The *systematic sequential approach* (SSA) (Section 3.4) provides a proven approach to “thinking through” the causal chain: activity - changes - impacts - mitigation. *Networks* (Section 3.5) are a formalized way of representing these causal chains. *Simulation modeling workshops* (Section 3.6) are techniques for taking network representation of impacts and building simple conceptual models. In developing the simulation models, the conceptual models are translated into mathematical and computer language. Through the use of dynamic simulation, the impacts over time can be projected. *Spatial analysis methods* (Section 3.7) allow for the presentation of the spatial pattern of environmental impacts through map overlays. GIS is routinely used for analyzing and displaying spatial impacts. *Rapid assessment techniques* (Section 3.8) have been designed to cope with need for quick assessments to deal with rapid changes in many parts of the developing world.

The Role of Expert Judgement

Most methods and techniques for identifying, measuring, and assessing impacts rely on expert judgement. In fact, many checklists, matrices, and models used in EIA represent decades of experience accumulated by numerous experts. The experts themselves are heavily involved in all aspects of the assessment — they are used to help identify the potential for significant impacts, plan data collection and monitoring programs, provide their judgement on the level of significance for specific impacts, and suggest ways of reducing or preventing impacts.

Choosing a Method

EIA methods range from simple to complex, requiring different kinds of data, different data formats, and varying levels of expertise and technological sophistication for their interpretation. The analyses they produce have differing levels of precision and certainty. All of these factors should be considered when selecting a method.

The EIA practitioner is faced with a vast quantity of raw and usually unorganized information that must be collected and analyzed in preparation of an EIA report. The best methods are able to:

- organize a large mass of heterogenous data;
- allow summarization of data;
- aggregate the data into smaller sets with least loss of information; and
- display the raw data and the derived information in a direct and relevant fashion.

The needs of the target audience should also be considered when choosing a method. At preliminary stages, proponents need to have clear information about alternatives, research needs and feasibility. Appropriate methods, skillfully applied, can save time and money, and can generate valuable support for a proposal. At later stages of comprehensive EIAs, decision makers include those with a mandate to approve and set the conditions for going ahead with a development. For an informed decision to be made, the decision makers need to understand the nature and extent of potential impacts and the trade offs involved.

Whatever methods are chosen, the focus of impact assessment has evolved from generating a list of potential impacts on selected environmental components. Today's methods consider the environment to be a dynamic, integrated group of natural and social systems. Impacts occur over time and space. Some impacts are immediate while others are delayed. Some impacts occur as a direct result of an activity; others occur as secondary or higher order impacts resulting from changes in other environmental components.

In selecting assessment methods, it helps to understand two perspectives underlying the utility of EIA. From the first perspective, EIA is a technique to analyze the impacts of project activities, and is a complex and complicated procedure. The complexity is increased by the diversity of the disciplines involved — social, physical, and biological. This perspective holds that scientific experts should be responsible for conducting and reviewing EIAs, and that the maximum possible quantification should be accomplished. This element of decision-making should be incorporated into the EIA process. From a second perspective, EIA is primarily an opportunity to allow groups that are potentially affected — populations, development agencies, and project proponents — to participate in the decision-making process. This perspective suggests that:

- decision making should not be restricted to scientific opinions alone, but should also reflect social and cultural viewpoints; and
- a key role of EIA is to identify and communicate potential impacts to the concerned people and encourage rational discussion.

Appropriateness of Methods for Developing Countries

Table 3-1 lists criteria for selecting methods at several stages of the assessment process. No single method will meet all the necessary criteria. The objective is to select an array of methods that collectively will meet assessment needs. Of the variety of techniques and methods available, only a few are applicable to developing countries. The latter are described here. Most have been used in developing countries, although not all widely so. In most cases, we present detailed examples of their use. A critique of each method is also made, based on the criteria defined in Table 3-1. This critique includes an assessment of the method's appropriateness for use in developing countries. It is generally assumed that developing countries have limited financial resources, technical expertise, and baseline data. Because of the pressure for rapid economic development, the methods used in developing countries must be effective in a relative short time frame. Many argue that developing countries cannot afford to use sophisticated methods because they are too expensive. It is suggested that they will only be used if funding from international assistance agencies (IAA) is available. This is only partly true. Often the application of the sophisticated methods requires input from international EIA experts. If this is the case, the labor costs associated with a method may make it expensive. There are, however, plenty of examples of EIA practitioners in developing countries using sophisticated mathematical models for air and water quality assessment in the environmental assessment of large energy and infrastructure projects. For example, the National Power Corporation in the Philippines uses air dispersion models for the assessment of environmental effects of thermal generating stations. Similarly, most of the scientific and engineering institutes in the People's Republic of China (PRC) that have Class A licenses for EIA have strong capability in computer modeling for EIA.

We use the cost/effectiveness criteria (Table 3-1) as the primary determinate of the appropriateness of the methods for application in developing countries.

Basic Terminology

Some basic terminology has been adopted to aid in the presentation and comparison of methods:

An *activity* is the basic element of a project or plan that has potential to affect any aspect of the environment. Projects are composed of activities. Activities are often called actions.

An *environmental component* is a basic element of the physical, biological, social, or economic environment. Environmental components receive environmental impacts from activities. Environmental components can be aggregated into super-components or desegregated into sub-components. Most methods define a hierarchy of components (e.g., physical may be split into atmosphere, water, soils, etc. and atmosphere might be split into air quality, meteorology, climate, etc.).

An *environmental change* is the measurable change in physical and biological systems and environmental quality resulting from a development activity.

An *environmental impact* is an estimate or judgement of the significance and value of environmental effects on physical, biological, social or economic environment.

A *component characteristic* is a qualitative description or a quantitative measurement of a component.

A *factor* is the basic element of analysis used in any method. In most methods, factors relate to some form of environmental impact.

A *factor index* is a numerical value (e.g., from 0 to 1) representing impact or level of importance associated with a factor. Factor indices are used in all methods that use rules for aggregating impacts associated with individual factors into a grand index.

A grand index is a single numerical value calculated by aggregation (usually by linear combination) of factor indices. In most methods, the grand index is calculated by the summation of weighted factor indices.

Table 3-1: Objective criteria for selecting an EIA method.

Key Area of the Assessment Process	Criteria	Criteria Description
Cost /Time Effectiveness Criteria	Expertise Requirements	Simple enough to allow the available manpower with limited background knowledge to grasp and apply the method without difficulty.
	Data Requirements	Does not require primary data collection and can be used with readily available data.
	Time Requirements	Can be completed well within the time requirements for the EIA review.
	Flexibility	Flexible enough to allow for modifications and changes during the course of the study, especially if more detailed study is required.
	Personnel Level of Effort	Can be performed with limited manpower and budgets.
Impact Identification	Comprehensiveness	Comprehensive enough to contain all possible options and alternatives; able to give sufficient information about the impacts to enable effective decision-making.
	Indicator-based	Able to identify specific parameters with which to measure significant impacts.
	Discriminative	Requires and suggests methods for identifying project impacts as distinguished from future environmental changes produced by other causes.
	Time Dimension	Can identify impacts on a temporal scale.
	Spatial Dimension	Can identify impacts on spatial scales.
Impact Measurement	Commensurate	Uses a commensurate set of units so that comparison can be made between alternatives.
	Quantitative	Suggests specific and measurable indicators to be used to quantify relevant impacts.
	Measures Changes	Provides for the measurement of impact magnitude as distinct from impact significance.
	Objective	Is based on explicitly stated objective criteria.
Impact Assessment	Credibility	Provides sufficient depth of analysis and instills confidence into the users and the general public.
	Replicability	Analysis can be replicated by other EIA practitioners.
	Significance-based	Can explicitly assess the significance of measured impacts on a local, regional, and national scale. Explicitly states criteria and assumptions employed to determine impact significance.
	Aggregation	Aggregates the vast amounts of information and raw data.
	Uncertainty	Accommodates a degree of uncertainty. Identifies impacts that have low probability of occurrence but a high potential for damage and loss.
	Alternative Comparison	Provides for a comparison of impacts of project alternatives. Clearly portrays the impacts on the environment with and without the project.
Communication	Communicability	Provides a sufficiently detailed and complete comparison of the various project alternatives available. Requires and suggests a mechanism for public involvement in interpreting the impacts and their significance Provides a mechanism for linking and assessing impacts on affected geographical or social groups. Provides a description of the project setting to help users adequately understand the whole picture.

Key Area of the Assessment Process	Criteria	Criteria Description
	Summary Format	Summarizes the results of the impact analysis in a format that will give the users, who range from the public to the decision-makers, sufficient detail to understand and develop confidence in the assessment. Provides a format for highlighting the key issues and impacts identified in the assessment.

3.1 Ad Hoc Method

Ad hoc methods are not really methods as they do not structure the problem so it is more amenable to systematic analysis. A good example of an ad hoc method is a team of experts assembled for a short time to conduct an EIA. Each expert's conclusions are based on a unique combination of experience, training and intuition. These conclusions are assembled into a report. Sometimes this is the only required or possible approach. In other instances, when more scientific methods are available, it is not sufficient to rely on ad hoc methods.

Table 3-2 gives the results of using the ad hoc method to compare alternative reservoir arrangements. Broad qualitative information about factors useful in the comparative evaluation of alternative development actions is presented. The information is stated in simple terms that are readily understood by the lay person. No information about the cause-effect relationship between project actions and environmental components is provided. The actual impacts on specific environmental components likely to be affected by the project or those that may require further investigation are not identified. The method merely presents the pertinent information without resorting to any relative weighting of importance.

This method is very easy to use, but does have a few drawbacks (Lohani and Kan, 1983):

- it may not encompass all the relevant impacts;
- because the criteria used to evaluate impacts are not comparable, the relative weights of various impacts cannot be compared;
- it is inherently inefficient as it requires sizeable effort to identify and assemble an appropriate panel of experts for each assessment; and
- it provides minimal guidance for impact analysis while suggesting broad areas of possible impacts.

The problem with the exercise of expert judgement in an ad hoc manner is that it is characterized by a process of assessment that can never be replicated, thus making it difficult to review and critique the conclusions in the EIA. Environmental impact assessment usually requires the collection and analysis of considerable information about the economic, social, and biophysical environment. Methods are needed to organize this information for analysis and presentation — ad hoc methods fail to do this in any meaningful way.

Table 3-2: Illustration of the ad hoc method for comparing alternative reservoir arrangements (*source:* Lohani and Kan, 1983).

Items	Alternatives		
	A	B	C
Number of reservoirs on river system	4	1	0
Combined surface area, ha	8500	1300	-
Total reservoir shoreline, km	190	65	-
New irrigation areas, ha	40000	12000	-
Reduced open space because of project and associated population increases, ha	10000	2000	-
Inundated archaeological sites, nos.	11	3	-
Reduced soil erosion, relative magnitude	4x	1x	Nil
Enhanced fisheries, relative magnitude	4x	1x	Nil
Provision of flood control measures	Yes	Yes	No
New potential malarial areas, relative magnitude	4x	1x	Nil
Additional employment potential, number of persons	1000	200	-

Box 3-1: Evaluation of ad hoc method.

Key Area of the Assessment Process	Criteria	L denotes Criteria Completely Satisfied P denotes Criteria Partially Satisfied N denotes Criteria Not Satisfied
Cost / Time Effectiveness Criteria	1. Expertise Requirements	L
	2. Data Requirements	L
	3. Time Requirements	L
	4. Flexibility	L
	5. Personnel Level of Effort	P
Impact Identification	6. Comprehensiveness	N
	7. Indicator-based	N
	8. Discriminative	N
	9. Time Dimension	N
	10. Spatial Dimension	N
Impact Measurement	11. Commensurate	N
	12. Quantitative	N
	13. Measures Changes	N
	14. Objective	N
Impact Assessment	15. Credibility	P
	16. Replicability	N
	17. Significance-based	N
	18. Aggregation	N
	19. Uncertainty	N
	20. Alternative Comparison	P
Communication	21. Communicability	P
	22. Summary Format	N

Are these applications appropriate for developing countries? Yes, but they should be supplemented by other methods to analyze, organize and present the results of the assessment. Ad hoc methods, usually the collective opinion of a group of experts, are used throughout the EIA process. Often panels of experts are asked to help develop TOR for EIA reports. Experts are almost always consulted during the review of the EIA report. In most cases, the analyses that support the preparation of the EIA report should be undertaken using systematic methods. Experts need to be able to back up their conclusions.

3.2 Methods for Organizing and Presenting Information

Checklists and matrices are commonly used to organize and present information. Many of the more sophisticated methods and techniques often use checklists and matrices as a starting point for analysis.

Information Presented in Checklists and Matrices

All checklists and matrices have boxes or cells that must be filled with information about the nature of the impact. Depending on the method, this information can be descriptive or evaluative (Table 3-3). The simplest methods merely determine the possibility or potential existence of an impact, while others, like weighting-scaling checklists, make judgements about the magnitude and importance of the impact.

Table 3-3: Information presented in checklists and matrices.

Impact Characteristic Identified or Evaluated	Descriptive or Evaluative Measure	Type of Scale	Determined By	Used By Method
Existence	yes or no	nominal	Expert Judgement	Simple Checklist
Duration	short term or long term	nominal	Expert Judgement	Descriptive Checklist (Oregon Method) (Smardon et al., 1976)
Reversibility	reversible or irreversible	nominal	Expert Judgement	Descriptive Checklist (Oregon Method) (Smardon et al., 1976)
Magnitude	minor, moderate or major	ordinal	Expert Judgement	Descriptive Checklist (Oregon Method) (Smardon et al., 1976)
	1 to 10, with 1 representing small, 5 representing intermediate, 10 representing large	interval	Expert Judgement	Leopold Matrix (Leopold et al., 1971)
Causal relationship	direct, indirect, or synergistic	nominal	Expert Judgement	Descriptive Checklist (Oregon Method) (Smardon et al., 1976)
Importance	1 to 10, with 1 representing low, 10 representing high	interval	Subjective Judgement	Leopold Matrix (Leopold et al., 1971
	0 to 1000, where the sum of the importance weights is equal to 1000	interval	Subjective Judgement	Battelle Environmental Evaluation System (Dee et al., 1972)
Environmental Impact Units (EIU)	0 to 1, with 0 representing poor quality, 1 representing very good quality	interval	Value Functions based on expert or subjective judgement	Battelle Environmental Evaluation System (Dee et al., 1972)
Benefit/Cost	+ for benefit - for cost	nominal	subjective judgement	Fisher and Davis (1973)
Significance	no impact insignificant impact significant impact mitigated impact unknown impact	nominal	subjective and expert judgement	H.A. Simons (1992)

3.2.1 Checklists

Checklists are standard lists of the types of impacts associated with a particular type of project. Checklists methods are primarily for organizing information or ensuring that no potential impact is overlooked. They are a more formalized version of ad hoc approaches in that specific areas of impact are listed and instructions are supplied for impact identification and evaluation. Sophisticated checklists include: 1) scaling checklists in which the listed impacts are ranked in order of magnitude or severity, and 2) weighting-scaling checklists, in which numerous environmental parameters are weighted (using expert judgement), and an index is then calculated to serve as a measure for comparing project alternatives.

There are four general types of checklists:

1. ***Simple Checklist:*** a list of environmental parameters with no guidelines on how they are to be measured and interpreted. Table 3-4 illustrates a simple checklist that identifies the potential impacts of the Huasai-Thale Noi Road Project in Thailand.

2. ***Descriptive Checklist:*** includes an identification of environmental parameters and guidelines on how to measure data on particular parameters.

3. ***Scaling Checklist:*** similar to a descriptive checklist, but with additional information on subjective scaling of the parameters.

4. ***Scaling Weighting Checklist:*** similar to a scaling checklist, with additional information for the subjective evaluation of each parameter with respect to all the other parameters.

Table 3-4: Simple checklist developed for the Huasai-Thale Noi Road Project (*source:* National Environment Board, 1980).

	Nature of Likely Impacts									
	Adverse						**Beneficial**			
Items	**ST**	**LT**	**R**	**IR**	**L**	**W**	**ST**	**LT**	**SI**	**N**
Aquatic Ecosystems		x		x	x					
Fisheries		x		x	x					
Forests		x		x	x					
Terrestrial Wildlife		x		x		x				
Rare & Endangered Species		x		x		x				
Surface Water Hydrology		x		x		x				
Surface Water Quality		x								
Groundwater	*	*	*	*	*	*	*	*	*	*
Soils										
Air Quality	x				x					
Navigation		x			x					
Land Transportation								x	x	
Agriculture							x			x
Socioeconomic								x		x
Aesthetic		x			x					

Legend

x	indicates potential for type of impact	ST	denotes Short Term	LT	denotes Long Term
R	denotes Reversible	IR	denotes Irreversible	L	denotes Local
W	denotes Wide	SI	denotes Significant	N	denotes Normal

* denotes Negligible

Varying levels of information and expertise are required to prepare checklists. Simple checklists may require only a generalized knowledge of the environmental parameters likely to be affected, and access to an information base. Alternatively, simple checklist methods can be used to summarize the results of an EIA. Scaling weighted checklists are likely to require more expertise to prepare.

There are several major reasons for using checklists:

- they are useful in summarizing information to make it accessible to specialists from other fields, or to decision makers who may have a limited amount of technical knowledge;
- scaling checklists provide a preliminary level of analysis; and
- weighting is a mechanism for incorporating information about ecosystem functions.

Westman (1985) listed some of the problems with checklists when used as an impact assessment method:

1. they are too general or incomplete;
2. they do not illustrate interactions between effects;
3. the number of categories to be reviewed can be immense, thus distracting from the most significant impacts; and
4. the identification of effects is qualitative and subjective.

Box 3-2: Evaluation of Simple Checklists.

Key Area of the Assessment Process	Criteria	L denotes Criteria Completely Satisfied P denotes Criteria Partially Satisfied N denotes Criteria Not Satisfied
Cost / Time Effectiveness Criteria	1. Expertise Requirements	L
	2. Data Requirements	L
	3. Time Requirements	L
	4. Flexibility	L
	5. Personnel Level of Effort	L
Impact Identification	6. Comprehensiveness	L
	7. Indicator-based	N
	8. Discriminative	N
	9. Time Dimension	N
	10. Spatial Dimension	N
Impact Measurement	11. Commensurate	N
	12. Quantitative	N
	13. Measures Changes	N
	14. Objective	N
Impact Assessment	15. Credibility	P
	16. Replicability	N
	17. Significance-based	P
	18. Aggregation	N
	19. Uncertainty	N
	20. Alternative Comparison	P
Communication	21. Communicability	L
	22. Summary Format	L

Are these applications appropriate for developing countries? Yes, but checklists must be specifically developed for application to sector and country conditions. General checklists adopted from other countries and industrial sectors are of limited use.

3.2.2 Scales and Weights

Descriptive checklists are excellent for describing comprehensive lists of impacts, however, they are not able to rank alternatives. Various methods have been developed for the evaluation of alternatives. Before discussing the simplest of these methods (that is, checklists), it is necessary to define the basic steps of methods for evaluating alternatives:

1. determine an appropriate set of environmental factors to be considered (for example, wildlife habitat);
2. determine the environmental impact index for each factor;
   2.1 define the units of measurement for each environmental factor (e.g., hectares preserved),
   2.2 collect the data on the environmental factor (e.g., 10000 hectares preserved),
   2.3 decide on a common interval scale for each environmental factor index (e.g., 0 to 1),
   2.4 convert the data for the environmental factor to environmental factor index (this is usually done by normalizing all values over a maximum or minimum value);
3. determine a weight for each environmental factor; and
4. decide on the method of aggregation across all factors (usually additive).

Consider the two factors and two alternatives example in Table 3-5. The two factors are wildlife habitat (measured in hectares preserved) and employment increase (measured in jobs). In the hypothetical example for two alternatives, data has been provided. In the example, the environmental factor data has been scaled to an index (0 is worst and 1 is best). Scaling was done by dividing the factor data by the maximum values for both alternatives. The example shows two methods of aggregation:

1. Simple addition of factor indices, which assumes all factors are equally weighted. In this case alternative two is preferred.
2. Weights of .20 on wildlife habitat and .80 on employment, respectively. In this case, alternative one is preferred to alternative two.

Table 3-5: Two alternative examples to illustrate weighting and scaling techniques.

Factors	Weights	Alternative One			Alternative Two		
		Raw Data	Scaled	Weighted	Raw Data	Scaled	Weighted
Wildlife Habitat Preserved (ha.)		5000			10000		
Employment Increase (jobs)		5000			3000		
Wildlife Habitat Index	1		0.5			1	
Employment Increase Index	1		1			0.6	
Wildlife Habitat Weighted Index	0.2			0.1			0.2
Employment Increase Weighted Index	0.8			0.8			0.48
Grand Index		n/a	1.5	0.9	n/a	1.6	0.68

Each weighting and scaling checklist technique will differ from others in terms of the assumptions it makes with respect to: 1) environmental factors to be considered; 2) techniques for constructing the index; 3) methods for determining weights on each factor; and 4) methods used to aggregate across all factors.

The four most common types of scales encountered in EIA methods are (Westman, 1985): 1) nominal, 2) ordinal, 3) interval, and 4) ratio (see Table 3-6). Most descriptive information is categorical data measured on nominal scales. Evaluative information is normally measured on ordinal, interval, or ratio scales. The choice of scale is extremely important. Only interval and ratio scales can be used to aggregate information on individual environmental factors into an overall grand index. Regardless of which scale is used, it must always be carefully defined. Recent court challenges to the EIA process in Canada have criticized EIA methods that use terms like "moderate" or "medium". One judge concluded that impacts classified as moderate and medium are in fact considered to be significant impacts as defined by legislation (Locke and Matthews, 1994).

Table 3-6: Types of scales commonly used in EIA methods (*source:* Westman, 1985).

Scale	Nature of Scale	Examples	Permissible Mathematical Transformation	Measure of Location	Permissible Statistical Analysis
Nominal	Classifies Objects	Species Classification, coding soil types	One-to-one substitution	Mode	Information Statistics
Ordinal	Ranks Objects	orderings: - minimum to maximum - worst to best - minor to major	equivalence to non-monotonic functions	median	Non parametric
Interval	Rates objects in units of equal difference	time (hours), temperature (degrees)	linear transformation	arithmetic mean	Parametric
Ratio	rates objects in equal difference and equal ratio	height, weight	multiplication or division by a constant or other ratio scale value	geometric mean	Parametric

Many applications of EIA methods are flawed because practitioners often construct quantitative representations of ordinal data. They then wrongly assume that they can aggregate ordinal data into a grand index. For example, instead of asking an expert to assign the magnitude of impact as low, medium, or high, the practitioner might ask for magnitude on a scale from 1 to 10 where 1 is low, medium is 5 and 10 is high. While this is now numerical data, it is still represented on an ordinal scale and should not be aggregated. To construct an interval scale special care must be taken. In the context of constructing environmental quality indices, Dee et al. (1972) suggested the following procedure:

1. Collect information on the relationship between the factor and the quality of the environment.
2. Order the environmental factor scale (normally the x-axis) so that the lowest (or worst) value for the environmental factor corresponds to zero in the environmental quality scale (normally the y-axis).
3. Divide the environmental quality scale into equal intervals ranging between 0 and 1, and determine the appropriate value of the factor for each interval. Continue this process until a reasonable curve may be drawn.
4. Steps 1 to 3 should be repeated independently by various experts. The average values should produce the group curve. If factors are based on value judgements alone, a representative cross-section should be used.
5. If there are large variations among the different experts, a review may be performed.
6. Steps 1 through 5 should be repeated by various groups of experts to test reproducibility.

This technique can be used to construct a graph that represents the relationship between the factor index and an environmental variable. The example graph (Figure 3-1) shows the relationship between the factor index and amount of forest land protected.

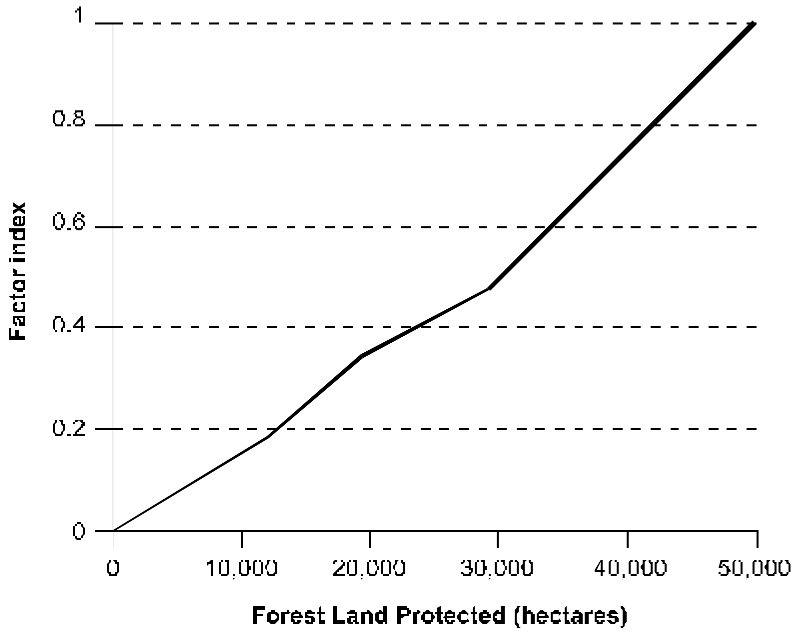


Figure 3-1: Factor index for forest land protected.

Canter (1977, 1996) and ESCAP (1990) describe a number of examples and applications of weighting-scaling checklists. In some applications, with skilled personnel, these methods may be appropriate. Because of inherent difficulties in developing factor indices and the potential for misuse of these methods, however, we do not recommend their use in developing countries.

Box 3-3: Evaluation of weighting scaling checklists.

Key Area of the Assessment Process	Criteria	L denotes Criteria Completely Satisfied P denotes Criteria Partially Satisfied N denotes Criteria Not Satisfied
Cost / Time Effectiveness Criteria	1. Expertise Requirements	N
	2. Data Requirements	P
	3. Time Requirements	P
	4. Flexibility	L
	5. Personnel Level of Effort	P
Impact Identification	6. Comprehensiveness	P
	7. Indicator-based	N
	8. Discriminative	N
	9. Time Dimension	N
	10. Spatial Dimension	N
Impact Measurement	11. Commensurate	P
	12. Quantitative	N
	13. Measures Changes	N
	14. Objective	N
Impact Assessment	15. Credibility	P
	16. Replicability	N
	17. Significance-based	N
	18. Aggregation	P
	19. Uncertainty	N
	20. Alternative Comparison	L
Communication	21. Communicability	P
	22. Summary Format	L

Is this application appropriate for developing countries? Not recommended. Few practitioners apart from the originators of these methods take the methodological care needed to determine scales and weights.

3.2.3 Matrices

Matrix methods identify interactions between various project actions and environmental parameters and components. They incorporate a list of project activities with a checklist of environmental components that might be affected by these activities. A matrix of potential interactions is produced by combining these two lists (placing one on the vertical axis and the other on the horizontal axis). One of the earliest matrix methods was developed by Leopold et al. (1971). In a Leopold matrix and its variants, the columns of the matrix correspond to project actions (for example, flow alteration) while the rows represent environmental conditions (for example, water temperature). The impact associated with the action columns and the environmental condition row is described in terms of its magnitude and significance.

Most matrices were built for specific applications, although the Leopold Matrix itself is quite general. Matrices can be tailor-made to suit the needs of any project that is to be evaluated. They should preferably cover both the construction and the operation phases of the project, because sometimes, the former causes greater impacts than the latter. Simple matrices are useful: 1) early in EIA processes for scoping the assessment; 2) for identifying areas that require further research; and 3) for identifying interactions between project activities and specific environmental components. However, matrices also have their disadvantages: they tend to overly simplify impact pathways, they do not explicitly represent spatial or temporal considerations, and they do not adequately address synergistic impacts.

Matrices require information about both the environmental components and project activities. The cells of the matrix are filled in using subjective (expert) judgement, or by using extensive data bases. There are two general types of matrices: 1) simple interaction matrices; and 2) significance or importance-rated matrices. Simple matrix methods simply identify the potential for interaction (see Table 3-7). Significance or importance-rated methods require either more extensive data bases or more experience to prepare. Values assigned to each cell in the matrix are based on scores or assigned ratings, not on measurement and experimentation. For example, the significance or importance of impact may be categorized (no impact, insignificant impact, significant impact, or uncertain). Alternatively, it may be assigned a numerical score (for example, 0 is no impact, 10 is maximum impact).

Table 3-7: Simple environmental impact matrix for the Phoenix Pulp Mill (*source:* Lohani and Halim, 1983).

Environmental Components	Project Activities								
	Plant Construction	Farming of Kenaf	Use of Pesticide Fertilizer	Transport of Raw Materials	Water Intake	Solid Waste	Effluent Discharge	Emissions	Employ-ment
Surface Water Quality			x			x	x		x
Surface Water Hydrology					x				
Air Quality				x				x	
Fisheries			x				x		
Terrestrial Wildlife Habitat	x								
Terrestrial Wildlife	x								
Land Use Pattern		x							
Highways/Railways				x					
Water Supply			x				x		
Agriculture		x							
Housing									x
Health						x	x	x	
Socioeconomic									x

Leopold Matrix

Leopold et al. (1971) designed a matrix with a hundred specified actions and 88 environmental components (Table 3-8). Each action and its potential for impacting each environmental item is considered. The magnitude of the interaction (extensiveness or scale) is described by assigning a value ranging from 1 (for small magnitudes) to 10 (for large magnitudes). The assignment of numerical values is based on an evaluation of available facts and data. Similarly, the scale of importance also ranges from 1 (very low interaction) to 10 (very important interaction). Assignment of numerical values for importance is based on the subjective judgement of the interdisciplinary team working on the EIA study.

The matrix approach is reasonably flexible. The total number of specified actions and environmental items may increase or decrease depending on the nature and scope of the study and the specific TOR for which the environmental impact study is undertaken. This is one of the attractive features of the Leopold Matrix. Technically, the Leopold Matrix approach is a gross screening technique to identify impacts. It is a valuable tool for explaining impacts by presenting a visual display of the impacted items and their causes. Summing the rows and columns that are designated as having interactions can provide deeper insight and aid further interpretation of the impacts. The matrix can also be employed to identify impacts during the various parts of the entire project cycle — construction, operation, and even dismantling phases.

Table 3-8: Actions and environmental items in the Leopold Matrix (*source:* Canter, 1977).

Actions		Environmental Items	
Category	**Description**	**Category**	**Description**
A. Modification of regime	a) Exotic fauna introduction	A. Physical & chemical characteristics	
	b) Biological controls		
	c) Modification of habitat		
	d) Alteration of ground cover	1. Earth	
	e) Alteration of groundwater hydrology		a) Mineral resources
	f) Alteration of drainage		b) Construction material
	g) River control & flow modification		c) Soils
	h) Canalization		d) Land form
	I) Irrigation		e) Force fields & background radiation
	j) Weather modification		f) Unique physical features
	k) Burning	2. Water	
	l) Surface or paving		a) Surface
	m) Noise & vibration		b) Ocean
			c) Underground
B. Land transformation & construction	a) Urbanization		d) Quality
	b) Industrial sites & buildings		e) Temperature
	c) Airports		f) Recharge
	d) Highways & bridges		g) Snow, ice & permafrost
	e) Roads & trails	3. Atmosphere	
	f) Railroads		a) Quality (gases, particulates)
	g) Cables & lifts		b) Climate (micro, macro)
	h) Transmission lines, pipelines & corridors		c) Temperature
	I) Barriers including fencing	4. Processes	
	j) Channel dredging & straightening		a) Floods
	k) Channel retaining walls		b) Erosions
	l) Canals		c) Deposition (sedimentation, precipitation)
	m) Dams & impoundments		d) Solution
	n) Piers, seawalls, marinas & sea terminals		e) Sorption (ion exchange, complexing)
	o) Offshore structures		f) Compaction & settling
	p) Recreational structures		g) Stability (slides, slumps)
	q) Blasting & drilling		h) Stress-strain (earthquakes)
	r) Cut & fill		I) Air movements
	s) Tunnels & underground structures	B. Biological conditions	
C. Resource extraction	a) Blasting and drilling	1. Flora	
	b) Surface excavation		
	c) Subsurface excavation & retorting		a) Trees
	d) Well dredging & fluid		b) Shrubs
	e) Dredging		c) Grass
	f) Clear cutting & other lumbering		d) Crops
	g) Commercial fishing & hunting		e) Micro flora
			f) Aquatic plants
D. Processing	a) Farming		g) Endangered species
	b) Ranching & grazing		h) Barriers
	c) Feed lots	2. Fauna	I) Corridors
	d) Dairying		
	e) Energy generation		a) Birds
	f) Mineral processing		b) Land animals including reptiles
	g) Metallurgical industry		c) Fish & shellfish
	h) Chemical industry		d) Benthic organisms
	I) Textile industry		e) Insects
	j) Automobile & aircraft		f) Microfauna
	k) Oil refining		g) Endangered species
	l) Food		h) Barriers
	m) Lumbering		
	n) Pulp & paper		

Actions		Environmental Items	
Category	**Description**	**Category**	**Description**
	o) Production storage		
E. Land alteration	a) Erosion control and terracing	C. Cultural factors	
	b) Mine sealing and waste control		
	c) Strip mining rehabilitation	1. Land use	a) Wilderness and open spaces
	d) Landscaping		b) Wetlands
	e) Harbor dredging		c) Forestry
	f) Marsh fill and drainage		d) Grazing
			e) Agriculture
F. Resource renewal	a) Reforestation		f) Residential
	b) Wildlife stocking and management		g) Commercial
	c) Groundwater recharge		h) Industry
	d) Fertilization application		l) Mining and quarrying
	e) Waste recycling		
G. Changes in traffic		2. Recreation	a) Hunting
	a) Railway		b) Fishing
	b) Automobile		c) Boating
	c) Trucking		d) Swimming
	d) Shipping		e) Camping and hiking
	e) Aircraft		f) Picnicking
	f) River and canal traffic		g) Resorts
	g) Pleasure boating		
	h) Trails	3. Aesthetic &	a) Scenic views and vistas
	l) Cables and lifts	human interest	b) Wilderness qualities
	j) Communication		c) Open-space qualities
H. Waste	k) Pipeline		d) Landscape design
replacement &			e) Unique physical features
treatment	a) Ocean dumping		f) Parks and reserves
	b) Landfill		g) Monuments
	c) Emplacement of tailings, spoils and overburden		h) Rare and unique species or eco-systems
	d) Underground storage		l) Historical or archaeological sites and objects
	e) Junk disposal		j) Presence of misfits
	f) Oil well flooding		
	g) Deep well emplacement		a) Cultural patterns (lifestyle)
	h) Cooling water discharge	4. Cultural status	b) Health and safety
	l) Municipal waste discharge		c) Employment
	j) Liquid effluent discharge		d) Population density
	k) Stabilization and oxidation ponds		
	l) Septic tanks, commercial and domestic		a) Structures
	m) Stack and exhaust emission	5. Manufactured	b) Transportation network (movement, access)
	n) Spent lubricants	facilities and	c) Utility networks
I. Chemical treatment		activities	d) Waste disposal
	a) Fertilization		e) Barriers
	b) Chemical deicing of highways, etc.		f) Corridors
	c) Chemical stabilization of soil		
	d) Weed control		a) Salinisation of water resources
J. Accidents	e) Insect control (pesticides)		b) Eutrophication
		D. Ecological	c) Disease-insect vectors
	a) Explosions	relationships	d) Food chains
	b) Spills and leaks		e) Salinisation of surficial material
K. Others	c) Operational failure		f) Brush encroachment
			g) Other
		E. Others	

Box 3-4: Evaluation of Matrix Methods.

Key Area of the Assessment Process	Criteria	L denotes Criteria Completely Satisfied P denotes Criteria Partially Satisfied N denotes Criteria Not Satisfied
Cost / Time Effectiveness Criteria	1. Expertise Requirements	P
	2. Data Requirements	L
	3. Time Requirements	P
	4. Flexibility	P
	5. Personnel Level of Effort	P
Impact Identification	6. Comprehensiveness	L
	7. Indicator-based	N
	8. Discriminative	N
	9. Time Dimension	N
	10. Spatial Dimension	N
Impact Measurement	11. Commensurate	N
	12. Quantitative	N
	13. Measures Changes	N
	14. Objective	P
Impact Assessment	15. Credibility	P
	16. Replicability	N
	17. Significance-based	N
	18. Aggregation	P
	19. Uncertainty	N
	20. Alternative Comparison	N
Communication	21. Communicability	L
	22. Summary Format	L

Is this application appropriate for developing countries? Yes, but matrices should be specifically developed for application to sector and country conditions. Matrices force EIA practitioners to think systematically about the interactions between project activities and environmental components.

3.3 Sectoral Guidelines

New EIAs should build on what has already been learned. While each situation requires a unique assessment plan, after almost three decades of EIA practice there is much knowledge of impacts that can be transferred from past assessments to new projects. EIA practitioners have collected past experience and best practice examples into various handbooks and guidelines. Sectoral guidelines are perhaps the most useful and widespread of these tools for assisting in the preparation of EIAs. Most EIA agencies in developing countries have recognized the importance of producing country and sector specific guidelines for EIA. These guidelines normally contain a comprehensive listing of:

1. project types covered by the guidelines;
2. activities that fall within each project type;
3. environmental components that may possibly be affected by the project activities;
4. significant issues that must be addressed in project planning;
5. suggested mitigation measures that might be incorporated into the project; and
6. recommended monitoring requirements.

These guidelines often use checklists and matrices to organize and present specific information. In most cases, the guidelines leave the choice of the prediction and assessment method up to the individual practitioner.

3.3.1 When to Use Sectoral Guidelines

Project planning and management is generally undertaken along sectoral lines. This pattern reflects the structure of governments, industrial agencies, and international financial institutions (IFI) which are organized by sectors (for example, energy, transportation, agriculture). Sectors are also convenient ways of classifying and organizing our knowledge about the environmental impacts of development activity. Generic EIA guidelines have proven to be of limited use.

Most jurisdictions have adopted EIA guidelines for each sector. The purpose of these guidelines is to facilitate the incorporation of environmental protection into project preparation and appraisal. Experience throughout the world has shown that, through proper design and planning, adverse environmental consequences of development projects can be eliminated or reduced to acceptable levels. The guidelines are used to determine whether or not a particular project can be expected to result in significant environmental impacts, and if so, what needs to be done to ensure that these impacts will be mitigated in the project plan. Guidelines often contain advice on how to develop the TOR for EIA studies to support preparation of EIA reports.

In practice, sectoral guidelines:

1. are most useful in the early stages of an environmental assessment when TOR for the EIA are unavailable or are being prepared;
2. help with impact identification and in the development of detailed TOR for conducting an EIA;
3. provide guidance on how to present information in the proper format to aid in review; and
4. provide useful information against which to evaluate the actual results of the EIA.

3.1.2 Existing Guidelines

Several organizations, including some of the IFIs and bilateral aid agencies, have developed sets of environmental guidelines. Hundreds of guidelines exist; a comprehensive listing is available from the International Institute for Environment and Development (1995). Although these guidelines have been designed to help their staff design and appraise projects, they are also very useful to EIA practitioners in that they represent the accumulated wisdom on the known impacts of particular categories of development projects. These guidelines can be either generally applicable to EIAs conducted for projects funded by that organization, or specific for a given project type. Typically, both types of guidelines are necessary for the evaluation of any particular project. These guidelines are available from the publications departments of the funding organization. Since they reflect the policy of an organization, they are typically updated on a regular basis and are not reproduced here. Rather, this chapter aims to provide an introduction to the use of sectoral guidelines.

Usually the guidelines developed for use by IFIs or by bilateral agencies are designed for use in the developing country context. They may, as a result, be considerably less extensive than those employed in industrialized countries.

Asian Development Bank

The ADB has developed environmental guidelines for selected projects in agricultural and natural resources development (Asian Development Bank, 1987), infrastructure (Asian Development Bank, 1993a), and industrial and power development (Asian Development Bank, 1993b). These guidelines were produced to enable ADB project staff to incorporate environmental considerations during project preparation. They help project staff to:

1. prepare ADB loan convenants for the project on necessary environmental constraints;
2. strengthen the overall project context through improvements in aspects relating to environment (for example, public health, control of pollution emissions, preservation of valuable natural ecology, and improvement of the quality of life); and
3. include and estimate the cost of mitigation measures, monitoring programs, and the environmental management plan.

The ADB guidelines have broad applicability outside the Bank itself and are in use in most of the ADB's developing member countries.

The ADB guidelines help determine whether the proposed project can be expected to have significant environmental impacts (SEIs). If SEIs might occur, the Guidelines recommend the preparation of a brief Initial Environmental Examination (IEE). The IEE will make a preliminary evaluation of each potentially significant environmental impact of the proposed project, determining whether the project merits further detailed study. If there is no need for further study, the IEE itself becomes the completed EIA for the project and no follow-up EIA is required.

The ADB requires an IEE to be undertaken by its project staff in the early stages of project preparation. An IEE must always meet the requirements for EIA stipulated by the relevant country's environmental (or equivalent) agency; in countries where there are no specific EIA requirements, use of the Guidelines helps ensure that an acceptable assessment of the project is undertaken and that the project includes the necessary mitigation measures to meet that country's environmental protection standards.

Completing the Initial Environmental Examination

The Guidelines contain:

1. a checklist associated with a project type (for example, Table 3-9); and
2. A description of the significant environmental issues associated with a project type (for example, Table 3-10).

The first step in completing the IEE is to complete the environmental checklist (see Table 3-9). This checklist identifies and briefly describes all significant environmental issues which may result from the type of project under consideration. Each of the probable significant environmental issues should be assessed to determine whether it merits more detailed evaluation; that is, whether an EIA is needed. If there is no need for follow-up EIA (all items are checked in the D1 Column of the checklist table), the IEE serves as the completed EIA. If items are checked in Column D2 but not in Columns D3 or D4 of the checklist table, the needed follow-up work can usually be done by an individual consultant. If items are checked in Columns D3 or D4, a complete EIA will be needed.

If a full EIA is needed, TOR must be developed. The ADB guidelines provide a sample TOR for the EIA. A detailed discussion of the TOR for and the content of an EIA report is provided in Chapter 11.

The completed checklist, along with the TOR (when necessary), often serves as the completed IEE. In the ADB system, the completed IEE is sent to the ADB's environment specialists, the executing agency and the concerned national environmental administrative agency. If appropriate, the ADB will require that an EIA be part of the overall feasibility study. The TOR for the EIA includes the information in the checklist table, and: 1) the type and level of professional skills needed in person-months for both local and international consultants; and 2) the estimated cost of the EIA.

Table 3-9: Part of the IEE Checklist of Dams and Reservoirs (*source:* Asian Development Bank, 1993).

IEE Checklist (Reservoir)

Dams and Reservoirs

CHECKLIST

1. This lists all significant environmental effects known to have occurred in past dams/reservoir/hydropower projects in developing countries

2. This is arranged to permit: i) ready screening out of non-pertinent items by checking the column "No Significant Effects," and ii) ready grading of significant environmental effects by degree of effect.

3. The checking process of (2) above furnishes the information needed for preparing the IEE.

Table 1: Checklist of Environmental Parameters for Dams and Reservoirs/Hydropower Projects

For ______________________________(Name of Project)

Actions Affecting Environmental Resources and Values (A)	Damages to Environment (B)	Recommended Feasible Protection Measures (C)	IEE (D)			
			No Significant Effect (D1)	Significant Effect		
				Small (D2)	Moderate (D3)	Major (D4)
A. Environmental Problems Due to Project Location						
Resettlement	Serious social inequities	Carefully planned resettlement program, including "hard" budget				
Encroachment into precious ecology	Loss of ecological values	Careful planning, plus offsetting measures				
Encroachment on historical/cultural values	Loss of these values	Careful planning, plus mitigation measures				
Watershed erosion silt runoff	Shortened reservoir life	Watershed management program				
Impairment of navigation	Economic loss	Careful planning, plus mitigation measures				
Effects on groundwater hydrology	Economic loss	Careful planning, plus mitigation measures				
Migrating valuable fish species	Decrease in fish species catch	Furnish fish traps				
Inundation of mineral resources	Loss of these values	Mines before inundation, if feasible				
Other inundation losses	Depends on type of effect	Careful planning /design /O&M/ monitoring				

Table 3-10: Environmental problems due to project location (*source:* Asian Development Bank, 1993).

1. Resettlement: Resettlement of population in inundated area. This problem, discussed in Annex III/2, has often been serious in past projects because of failure to include sufficient funds in the project core budget to cover appropriate resettlement costs, including rehabilitation, etc.
2. Encroachment into watershed: The access roads built for the project and the new lake will often "serve to accelerate inroads into the watershed by farmers, hunters, timber exploiters, etc., thereby accelerating losses in forests and wildlife.
3. Encroachment on historical/cultural monuments/areas: This must be carefully evaluated and, if precious items are believed to exist in the area to be inundated, a program for finding and salvaging these should be undertaken prior to inundation.
4. Watershed erosion/silt run-off: If the existing condition of erosion/silt run-off in the watershed is sufficient to jeopardize the life of the dam by an excessive filling rate, consideration must be given to expanding the project to include a watershed reforestation and/or regreening program (to be included in the project's core budget).
5. Impairment of navigation: Will the dam itself impair downstream navigation and, if so, what provisions may be made to offset this loss?
6. Impairment of groundwater hydrology: Will the reservoir result in waterlogging in the vicinity and, if so, how can damages be feasibly offset ?
7. Migrating valuable fish species: Will the dam obstruct valuable migrating fisheries and, if so, how can these losses be offset?
8. Inundation of mineral resources: Will the reservoir cause loss of valuable mineral resource development potentials?
9. Other problems from flooding of inundated area: This usually eliminates productive farmlands or forest, displaces and endangers wildlife in the area, displaces the existing riverine fisheries, greatly alters the hydrologic regime, and may induce earthquake hazards.

World Bank Sourcebook

The World Bank Environmental Assessment Sourcebook (1991) is a three volume document designed to assist all those involved with environmental assessment, including practitioners themselves, project designers and World Bank task managers. Practitioners conducting assessments for borrowing governments need to know Bank policy on the subject under consideration and which aspects of the projects are of particular concern to the Bank. Project designers need to know applicable Bank requirements and the environmental implications of their design choices. In addition, they need to understand the objectives of the practitioners. The Sourcebook provides these two groups of users with both specific information and a common ground for discussion. TMs are responsible for ensuring that borrowers fulfill Bank requirements for environmental review (including EIA). The Sourcebook provides them with assistance for these advisory tasks, through discussions of fundamental environmental considerations; summaries of relevant Bank policies; and analyses of other topics that affect project implementation. Additional audiences that might find the Sourcebook of interest are other economic development and finance agencies, practitioners for non-Bank projects, environmentalists, academics and NGOs.

The Sourcebook focuses on those operations with major potential for negative environmental impacts (for example, infrastructure, dams and highways). The book is large, and no user will ever have need of all sections. As such, the Table of Contents is the most efficient entry point. The first volume deals with World Bank policies and procedures and cross-sectoral issues. The Bank's EIA requirements and environmental review process, from screening at the time of project identification through to post-completion evaluation, are presented. A standard format for an EIA Terms of Reference is also provided. Two issue chapters deal with ecological, social, and cultural topics likely to arise in environmental assessment. Three "methods" chapters deal with economic evaluation of environmental costs and benefits, institutional strengthening, and financial intermediary lending. An additional chapter deals with community involvement and the role of NGOs in environmental review.

Sectoral guidelines for agriculture and rural development projects; population, health and nutrition; transportation; urban development; water supply and sewerage; energy and industry are contained in the second and third volumes. For each of the sectors, the Sourcebook provides both general considerations pertaining to environmental assessment in the sector in question and discussions of particularly relevant topics (for example, the energy and industry chapter contains a section on plant siting, and the agriculture sector includes a section on integrated pest management and use of agrochemicals). The balance of each chapter covers specific types of projects, chosen primarily because they have potentially significant environmental impacts. For each type, the features of the project that have environmental significance are described, potential impacts are summarized, and special issues to be considered in an EIA are noted. Possible alternatives to the project are outlined, and discussions of management and training needs and monitoring requirements are added. Each review concludes with a table of potential impacts and the measures which can be used to mitigate them. Sample TOR for the various project types are collected in one section in each chapter.

Regularly distributed "updates" provide users with information on a variety of topics. Often updates are issued to replace older policies and procedures; in other cases, they might be issued to provide details of a new technique or technology, or an emerging issue of concern.

ESCAP

In addition to general EIA guidelines for planners and decision makers published by ESCAP in 1985, the Commission has developed more recent sectoral guidelines for projects involving water resources development, transport development, industrial development, and agricultural development. The ESCAP guidelines' primary audience is government agencies concerned with environmental protection in developing countries. The guidelines are designed to assist developing country personnel, in the case that they are providing the bulk of input, in planning and conducting EIAs.

Generally, the sectoral guidelines have a clearly defined scope of application. In the case of the Guidelines for Water Resources Development (ESCAP, 1990), for example, the scope is limited to projects making use of fresh water resources — marine waters are not considered. The specific objectives of the above mentioned guidelines (and the others are similar) are to: a) summarize the general assessment methodologies presented in pertinent references; b) fill a gap existing in other references, namely identification of data collection and evaluation methodologies for assessing the quality and quantity of key parameters; and c) present the typical impacts and pathways related to water resources development projects, based on literature references and five special case studies (from Indonesia, Thailand, Philippines, and Lao PDR). The guidelines also outline the fundamental approach for EIA, guiding the user through the EIA process in the context of water resources developments, and touch briefly on four resources required for EIA: specific resource measurement methods, financial resources (costs of EIA studies), human resources, and time.

Sample TORs for EIAs for water resource projects are included. Potential environmental impacts and management requirements (including some mitigation measures) of water resource development projects are summarized, based on the findings of more detailed reports. For ease of use, these summaries are broken down by project type (for example, dams/reservoirs, irrigation, hydropower, channelization, dredging and filling, and groundwater manipulation). Table 3-11 illustrates how the guidelines deal with issues relating to dredging and filling operations.

The guidelines outline six methodologies designed specifically for water resources development projects: the ADB checklist (see Table 3-9); the Battelle system, an environmental evaluation system developed by Battelle Northwest Laboratories for the U.S. Bureau of Reclamation (Dee et al., 1972); the water resources assessment methodology (WRAM) developed by the U.S. Army Corps of Engineers; water resources development matrices; water resources development networks; and Adaptive Environmental Assessment and Management (AEAM) (see section 3.6 for more details on simulation modeling workshops and the AEAM process).

Table 3-11: Extract from Chapter II (Environmental Impact and Management Requirements of Water Resources Development Projects) of the ESCAP sectoral guidelines for water resources development.

F. Dredging and filling

1. *Ecology controversy*

Dredging and filling operations have developed into one of the most controversial of all civil engineering activities as related to effects on natural ecosystems including fisheries and all other types of aquatic biota. This is because of the recognition that the swamps and other shallow water areas often used for dredging/filling are often the zones where the aquatic ecology is most productive. Thus it is the general consensus today that shallow aquatic zones which are probably the reproduction zones for important fisheries (including shellfish) should not be dredged nor filled except under very carefully controlled conditions, based on scientific surveys and valuations, which will serve to protect the natural ecological system.

2. *Environmental effects*

The major adverse impacts of dredging result from disturbance of the natural aquatic ecosystem, hence the potentials for damaging the natural wildlife (including fin-fish, shellfish, waterfowl, endangered species of plants, etc.) can be very great. Evaluation of these possible effects require field investigations to establish the without-project status of the key species present and their relationship to environmental factors such as depth, nature of the benthos, etc., so that it can be shown that the proposed action will not result in adverse impacts on values which need to be protected. On the positive side, dredging can be very helpful: a) in improving navigation; b) in furnishing sand and aggregate essential to construction based on use of concrete; and c) indirectly furnishing filling materials which contribute to land reclamation projects.

Filling operations, lke dredging, can raise havoc with the natural ecosystem unless properly controlled: hence the same precautions should be employed as for dredging. The positive benefits of filling are essentially from: a) enabling highways/railways to pass over low-lying areas; b) reclamation of land needed for urban development including housing industries, airports, schools, and other public institutions; and c) disposal of solid wastes (including land reclamation).

3. *Environmental management measures*

Because of the major environmental losses due to dredging and filling operations in the past, a large scale research and development programme was undertaken by the United States Army Corps of Engineers. The result of the program was the development of criteria and guidelines for dredging and filling which results in minimum adverse impacts and provides for mitigating measures. These guidelines are provided in Reference 15.

Box 3-5: Evaluation of sector guidelines.

Key Area of the Assessment Process	Criteria	L denotes Criteria Completely Satisfied P denotes Criteria Partially Satisfied N denotes Criteria Not Satisfied
Cost / Time Effectiveness Criteria	1. Expertise Requirements	P
	2. Data Requirements	L
	3. Time requirements	L
	4. Flexibility	L
	5. Personnel Level of Effort	L
Impact Identification	6. Comprehensiveness	P
	7. Indicator-based	P
	8. Discriminative	P
	9. Time Dimension	N
	10. Spatial Dimension	N
Impact Measurement	11. Commensurate	N
	12. Quantitative	N
	13. Measures Changes	N
	14. Objective	P
Impact Assessment	15. Credibility	P
	16. Replicability	P
	17. Significance-based	N
	18. Aggregation	P
	19. Uncertainty	N
	20. Alternative Comparison	P
Communication	21. Communicability	L
	22. Summary Format	L

Is this application appropriate for developing countries? Yes, but it requires environmental specialists with the expertise to interpret and adapt the guidelines to the specific situation. Sector guidelines are best used as initial assessment tools to lay the groundwork for more detailed EIAs.

3.4 The Systematic Sequential Approach

Prepared formats such as checklists, matrices and sector guidelines are most useful during the initial stages of EIA. Along with other information, checklists and matrices can help with the identification of issues and impacts, as well as helping to develop the TOR for further studies. Care must be taken with prepared formats as they may contain information that is out of date or inappropriate for the jurisdiction or the environmental setting. In these cases, use of the checklist or matrix may result in EIA documents that may be misleading, incomplete or place the emphasis on the wrong causal relationships. Once the initial assessment is completed, more systematic and scientific approaches should be used to conduct the detailed EIA.

The *systematic sequential approach* (SSA) of assessment is a “scientific thinking through” of the potential impacts on the environment with and without the project. SSA aims to understand how environmental, social, and economic systems are interrelated, and how they will react to human disturbances. SSA views EIA as a continuing source of information throughout the project cycle. During the planning stages, broad economic goals and objectives are seen to give rise to planned projects (Figure 3-2). In the SSA approach, project activities are linked to changes in the environment. During the EIA, predictions of these environmental changes must be made using various methods and techniques. Not all predicted environmental changes are considered to be potential impacts. Levels of significance of environmental change must be decided upon, then assigned to impacts. The assessment of significance is usually based on the values ascribed to environmental components, as well as the degree of change. Once the assessment of potential impacts has been completed, mitigative measures are prescribed to prevent, reduce, or otherwise ameliorate the potential impacts. These measures will often alter the project design. They may lead to project relocation, changes in industrial processes, introduction of pollution abatement technology, and other measures. As the project moves toward implementation, an environmental management plan must be put in place to ensure that planned mitigative measures will be implemented. This plan also specifies monitoring that must take place to determine actual impacts and to evaluate the effectiveness of mitigation measures.

Once the project begins operation, the project activities lead to actual changes in the environment and actual impacts. Monitoring systems designed during the EIA provide the basic information that allows for detection of changes in the environment. Based on monitoring information and on the evaluation of the actual impacts and the effectiveness of mitigation measures, the project implementation activities may be altered. In the long term, monitoring result may lead to revised economic development goals and objectives (Figure 3-2).

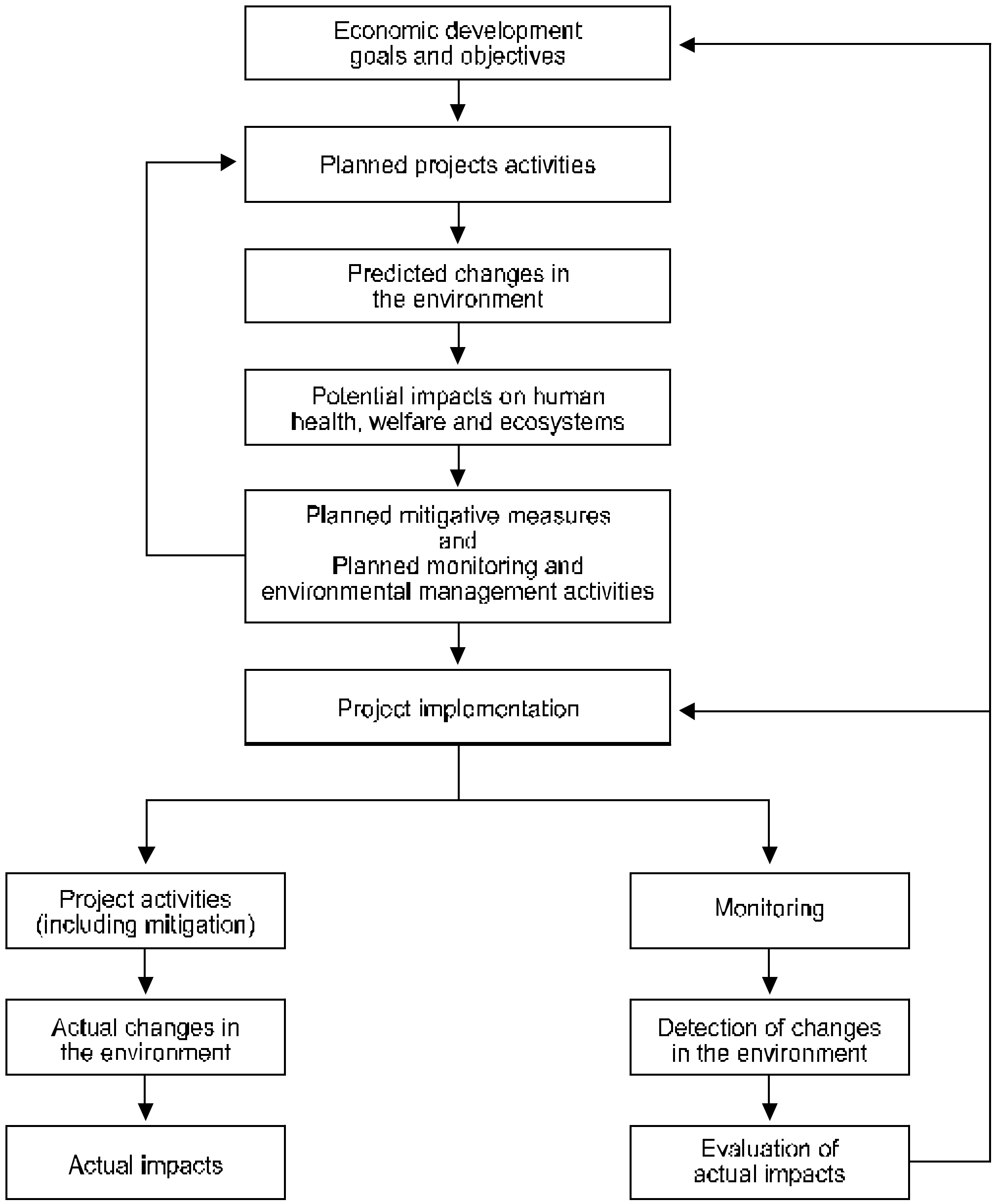


Figure 3-2: Overview of EIA information in the project cycle.

This section focuses on constructing the causal chain: activity - changes - impact - mitigation. The four basic steps are:

1. For each reasonable project alternative (that is, technology, size, site, etc.), identify and describe the major project activities during construction, operation, and other phases.

ACTIVITIES LEAD TO CHANGES

2. Predict significant changes in the natural environment, and when uncertain, their likelihood of occurrence, and magnitude or severity (Risk Assessment).

CHANGES LEAD TO IMPACTS

3. Changes, *per se*, are not impacts. Ask the question, "Who cares, and why?" about each change in the environment. The answers are impacts on human health, welfare, and ecosystems.

IMPACTS LEAD TO MITIGATION

4. Where it seems likely that the impact is adverse and unacceptable, devise mitigative measures and project changes to prevent and/or ameliorate the impacts; and plan monitoring to assure the implementation of the measures and to determine whether other unforeseen impacts occur.

The SSA requires the development of conceptual models that represent the causal chain: activity - changes - impact - mitigation. For example, Table 3-12 illustrates the activities, changes, impacts, and mitigation measures for agriculture projects. Often the best way to represent these causal chains is as network diagrams. The network diagrammatic representation of the causal chain that begins with application of inorganic fertilizers (from Table 3.12) is presented in Figure 3.3. In this case, the application of the fertilizer set in motion a series of direct and indirect changes in the environment. The application first increases the nutrients nitrogen and phosphorus in the soil. Some fraction of these nutrients is carried into water bodies by run-off. Once in the water, the nutrients become available to plants, both algae and aquatic macrophytes. This leads to increased growth and biomass in the water bodies, which may ultimately reduce dissolved oxygen concentrations. Decreased dissolved oxygen concentrations may lead to reduced fish populations, fish size, and fish flesh quality, which may reduce fish harvests and the economic value to the fishery.

Table 3-12: Causal chains: activity - changes- impact - mitigation for agriculture projects (*source:* Asian Development Bank, 1983).

Development Activity	Change in Natural System	Impact on Human Health and Welfare	Mitigation Measures to be Evaluated
AGRICULTURE			
1. Use of chemical pe	• loss of valuable nontarget organisms pollinators) • disruption of natural predator- prey -pa relationships • pest resistance	• loss of wildlife through food chain conc chemicals • cost of using more pesticide or more e new chemicals • fish kills • worker intoxification	• biological pest control • restricted use of chemicals • changes in cropping systems
2. Use of inorganic fe	• physical and chemical changes in sc • water contamination from runoff	• eutrophication leading to aquatic weed damage to fisheries, and degraded wa	• vegetation strips as traps between fields a waterways for silt and nutrients • more precise application of fertilizer • use of natural fertilizers where possible
3. Monoculture croppi systems	• changes in soil and topography • simplification of ecosystems	• vulnerability to pests • loss of wildlife	• preservation of diversity in patches and r of natural vegetation • mixed cropping pattern
4. Irrigation	• salinization • waterlogging • return water contamination	• spread of disease vectors • loss of arable land • fisheries degraded	• alternative crops that require less water • careful management of water to avoid ov

Development Activity	Change in Natural System	Impact on Human Health and Welfare	Mitigation Measures to be Evaluated
5. Rainfed agriculture	• soil erosion • leaching of soil nutrients • reduced infiltration	• sedimentation damage in reservoirs ar estuaries • decreasing productivity • accentuated peaks in water yield	• soil conservation actions - structural and
6. Indiscriminate land	• soil compaction • erosion of marginal lands • loss of forest shade and forage • conversion to grasslands	• decreased productivity • sedimentation damage • short-lived pastures	• land capability assessment and allocatior sustainable use
7. Concentrated feedir animals	• concentration of animal wastes • water contamination	• eutrophication • odor nuisance • opportunity for recycling as fertilizer	• oxidation ponds • alternative protein sources from wild popu

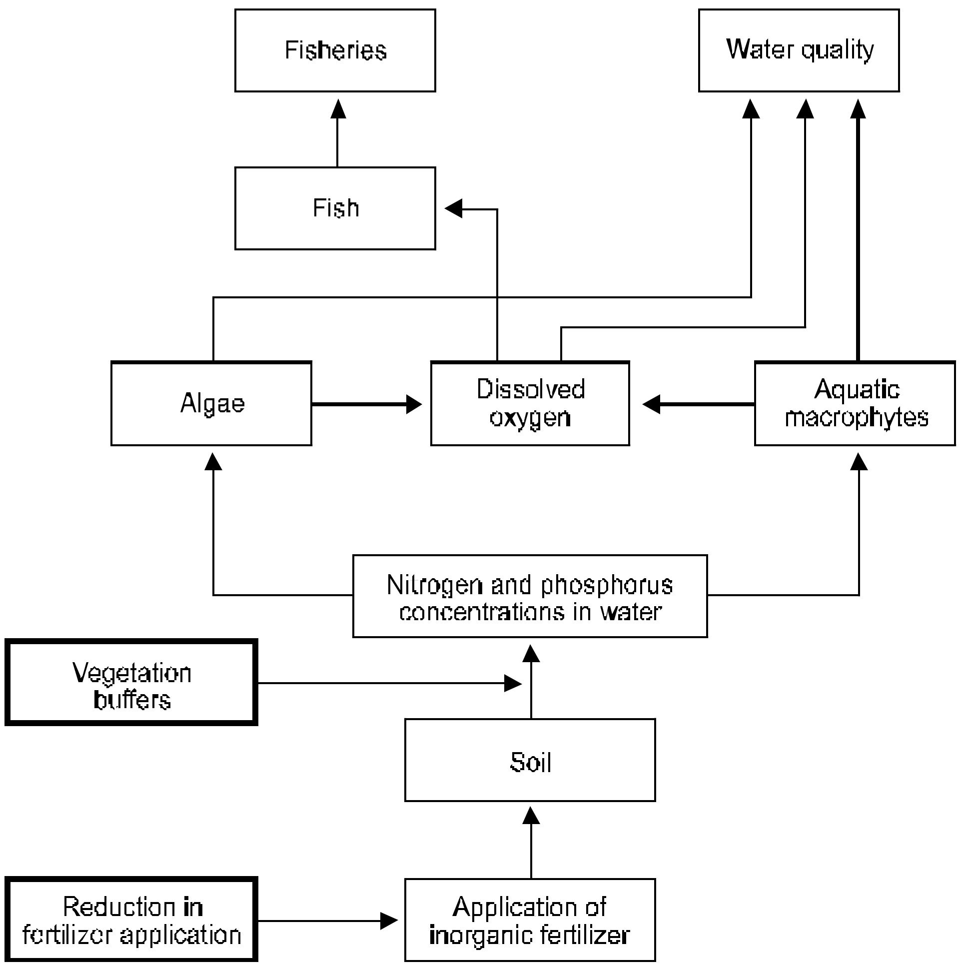


Figure 3-3: Network diagram of the causal chain that begins with application of inorganic fertilizers.

3.5 Networks

Development of the conceptual models that represent potential impact pathways as causal chains is at the essence of the application of the SSA. As illustrated by the examples presented in the previous section, network diagrams are one of the best ways of representing these causal chains. Network diagrams (Figure 3-4) provide a means for displaying first, secondary, tertiary, and higher order impacts. To develop a network, a series of questions related to each project activity (such as what are the primary impact areas, the primary impacts within these areas, the secondary impact areas, the secondary impacts within these areas, and so on) must be answered. In developing a network diagram, the first step is to identify the first order changes in environmental components. The secondary changes in other environmental components that will result from the first order changes are then identified. In turn, third order charges resulting from secondary changes are identified. This process is continued until the network diagram is completed to the practitioner's satisfaction. The network helps in exploring and understanding the underlying relationships between environmental components that produce higher order changes that are often overlooked by simpler approaches.

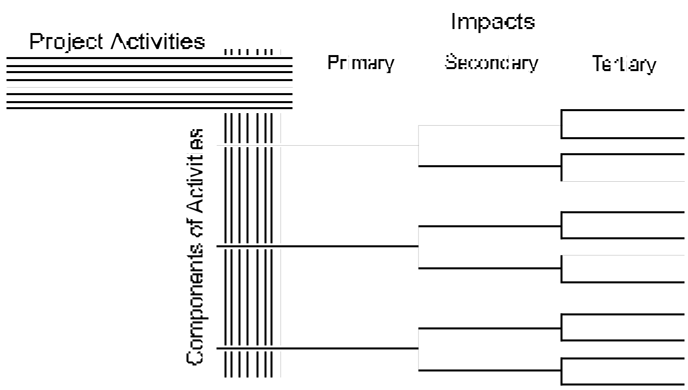


Figure 3-4: Conceptual model of impact networks.

From Matrices to Networks

The stepped matrix technique, developed by Sorenson (1971) to display the possible consequences of land use in the California coastal zone, illustrates how the matrix approach can evolve logically into network diagrams. The stepped matrix approach was applied to the Nong Pla Reservoir (Figure 3-5). To interpret the results for the Nong Pla Reservoir:

1. Enter the matrix in Figure 3-4 at the upper left-hand corner under the heading Project Elements.
2. Read to the right. A causal factor that may result in an impact is shown as "Dam and Reservoir"
3. Read downwards until either a (☆), (★), (☐) or (☐) is encountered.
   (☆) represents a major positive impact
   (★) represents a minor positive impact
   (☐) represents a major negative impact
   (☐) represents a minor negative impact
4. Reading downwards from "Dam and Reservoir," a (★) is encountered. This indicates a minor positive impact of "Dam and Reservoir" on "Surface water - hydrology."
5. Reading to the right, the initial impact on "Surface Water" is listed as "more water storage"; changes "more nutrient enrichment" and the possible final impact "disturbed aquatic habitat."

Causal Factor

Project Element: Water Resources Development — Dam and reservoir; Irrigation System

Altered Element	Initial	Changes	Final
PHYSICAL RESOURCE Surface water hydrology	more water storage	more nutrient enrichment	disturbed aquatic habitat
	less water flow	more salinity	disturbed coastal zone characteristics
Surface water quality	more phosphate	more nutrient enrichment	more productivity
	more pesticides and fertilizer utilization	more residual pollution	more toxic accumulation in food chain
Ground water hydrology	—	—	—
Ground water quality	—	—	—
Soils	flooded area		loss of agriculture
	intensive land use	soil loss	loss of soil fertility
Geology/seismology	—	—	—
Erosion sedimentation	more sedimentation trapping	less storage capacity dam	less dam life
	more bank erosion	more turbidity	less water quality
Climate	changed relative humidity	changed microclimate	changed rainfall
ECOLOGICAL RESOURCE Fisheries	more productivity	more job opportunity	more income
	less fish migration	less fish population	less income
Aquatic biology	less riverine habitat	less species in reservoir	less species diversity
	less nutrient	less primary productivity	less aquatic population
Terrestrial wildlife	—	—	—
Forest	loss of deciduous forest		change in climate
HUMAN USE VALUE Agriculture irrigation	loss of agricultural area		less job opportunity
	more irrigated water		more crop production
Aquaculture	more job opportunity	more income	more standard of life
Water supply	more water supply	more consumption	good public health
Navigation	—	—	—
Power	—	—	—
Recreation	more recreation resources	more tourism development	more job opportunity
Flood control	reduce flood hazard		reduce flood damage
Dedicated area use			
Industry	more industrial water supply	more industrial development	more income
Agro-industry	more industrial water supply	more industrial development	more income
Mineral development	—	—	—
Highways/railways	more road network	more communication	better socio-economics
Land use	less agriculture	less product	less income
	more agriculture	more production	more income
QUALITY OF LIFE VALUE Socio-economics	more income	better standard of living	better social welfare
Resettlement	more emigration	more social instability	more social problems
Cultural/Historical	—	—	—
Aesthetic	—	—	—
Archaeological	—	—	—
Public Health	more mosquito breeding ground	more haemorrhagic malaria fever	worse public health
	all-year-round water supply	more water consumption	better public health
Nutrition	more protein source	better nutrient status	better health
	more purchasing power for food		better health

Figure 3-5: Stepped matrix for Nong Pla Reservoir.

Figure 3-6 illustrates the network diagram for a dredging project (Sorensen, 1971, in Canter, 1996); Figure 3-7 illustrates the network diagram for a pulp mill using Kenaf (Lohani and Halim, 1983); Figure 3-8 illustrates the stepped matrix for the Pattani multipurpose project in Southern Thailand.

Networks or systems diagrams overcome the limitations of matrices by accommodating higher order impacts. They are also far better at explicitly identifying the causal basis for impacts. In addition, they are well suited to identifying the interaction between a number of activities, components, and a single target resource. As an assessment tool, they are capable of making qualitative predictions of the cumulative impact of a number of activities on a single target resource. However, they neither formally integrate over the spatial and temporal dimensions, nor do they integrate across target resources. While networks and systems diagrams can be communicated well and are easy to develop using expert judgement, scientific documentation of complex systems diagrams require a considerable amount of human and financial resources.

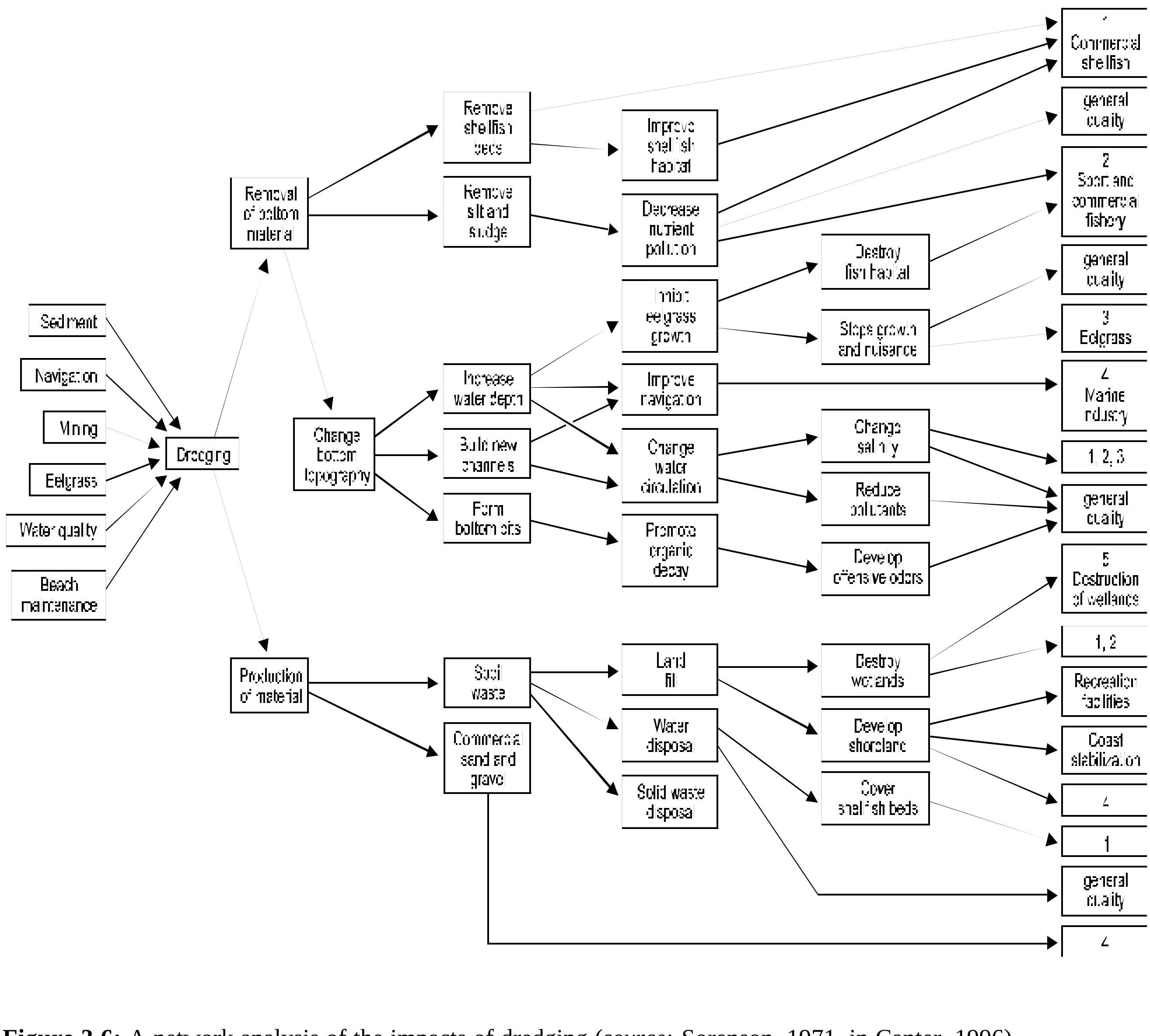


Figure 3-6: A network analysis of the impacts of dredging (*source:* Sorenson, 1971, in Canter, 1996)

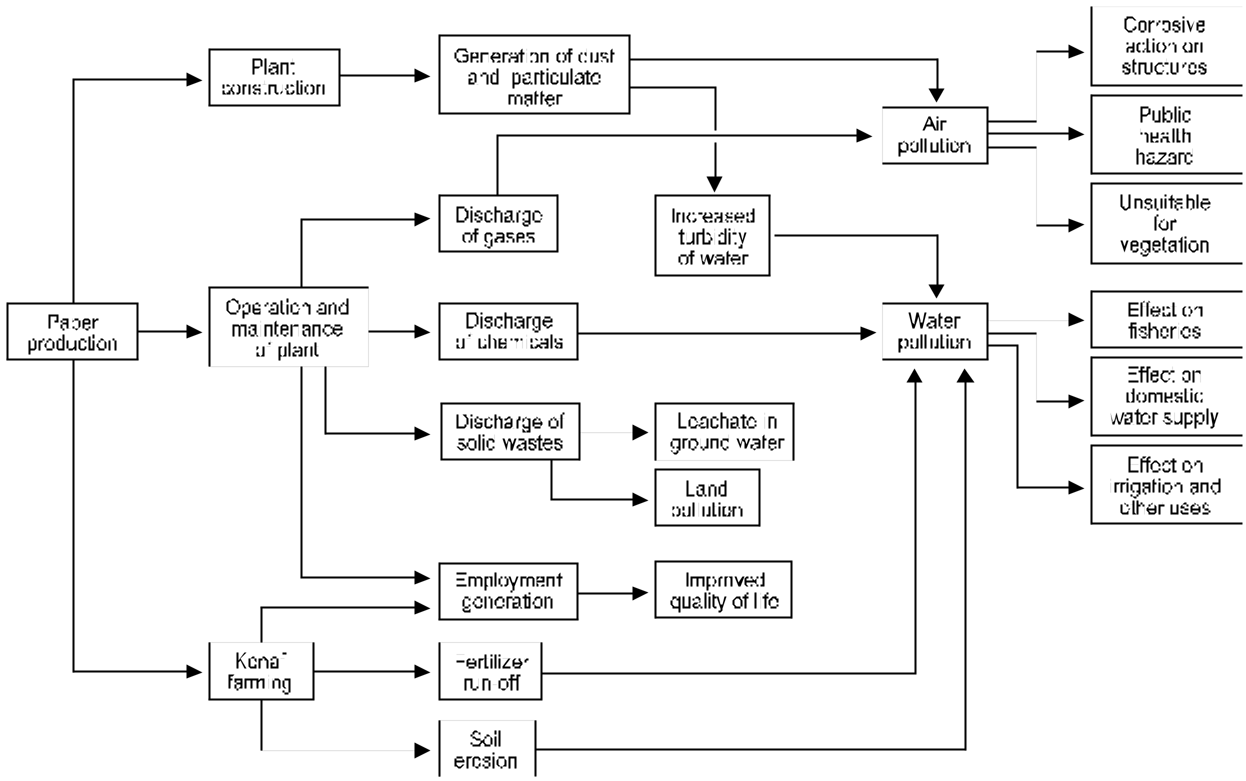


Figure 3-7: Network of pulp mill impacts (*source:* Lohani and Halim, 1983).

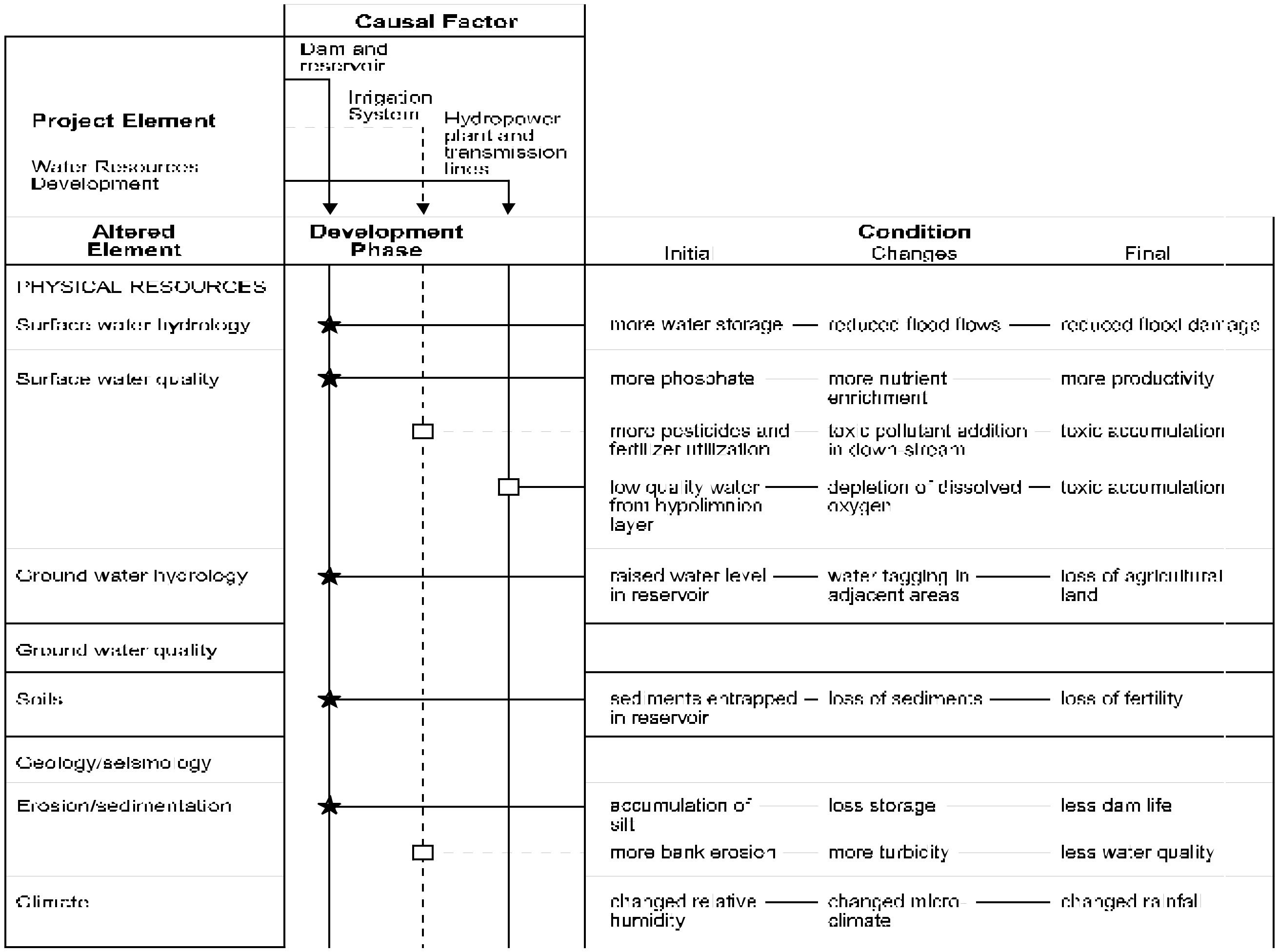


Figure 3-8: Stepped matrix for Pattani Multipurpose Reservoir Project.

Impact Hypotheses

Network diagrams have been used by ecological modelers as a means of representing the conceptual structure of models. In the context of EIA, one group of modelers used a sophisticated network or system diagram to represent *impact hypotheses* (Everitt et al., 1986). Impact hypotheses are explicit statements that causally relate project activities to environmental components.

This approach was combined with a descriptive matrix for an IEE of the environmental and socioeconomic impact of a proposed pulp and paper mill and eucalyptus plantation development in Thailand (H.A. Simon Ltd. Consulting Engineers, 1992). The purpose of the IEE was to identify all of the potential environmental and socio-economic effects of the proposed project, prescribe mitigation measures not included in the project description, and determine the level of further assessment required.

The IEE of the proposed project proceeded with the following major steps:

1. Review of the project description, which consists of the activities that will occur inside and outside the mill in the manufacture of pulp and paper, and review of the development and operation of the eucalyptus plantations that will supply the mill with wood.
2. Review of information on the environmental and socioeconomic setting of the project area, which included review of the current issues surrounding the project.
3. A visit to the proposed mill and plantation sites to gather information on the project and proposed site from local residents and the proponent.
4. Information synthesis and screening of the potential environmental and socioeconomic effects of project. Development of the TOR for an EIA of the project.

The IEE focused on the project description and the environmental and socioeconomic setting of the affected area. The following major parts of the proposed project were assessed for potential effects: 1) the construction phase of the mill site; 2) the proposed facilities and methodology for the disposal of mill effluent, including air emissions; and 3) the development and operation of the eucalyptus plantations. The environmental and social components which were assessed are those prescribed by the Office of the National Environmental Board (ONEB) of Thailand for environmental assessment. The parameters of the ONEB are aggregated into the following major categories: Physical Resources; Ecological Resources; Human Uses; and Quality of Life.

The constituent activities of the three major components of the project were systematically assessed using expert judgement for their potential impact on each parameter of the ONEB. Each potential impact was rated as either “no impact,” “insignificant impact,” “significant impact,” “mitigated impact,” or “unknown impact.” The rating assigned to the categories was determined by the relationship between the activity and the parameter, the existence of mitigation measures in the project description, and by the completeness of available information on the activity and parameter. A cross-impact matrix (Table 3-13) was used to summarize the information.

The potential impacts of the project (that is, each combination of project activity and environmental parameter of the impact matrix) were classified into one of five possible categories:

1. No Impact: The potential impact of project activity will be assessed as NO IMPACT if the project activity is physically removed in space or time from the environmental parameter.

2. Significant impact: An impact is said to be SIGNIFICANT if the project activity has potential to affect an environmental parameter. To determine whether a given impact is significant the following criteria are used:
   i. spatial scale of the impact (site, local, regional, or national/international);
   ii. time horizon of the impact (short, medium, or long term);
   iii. magnitude of the change in the environmental parameter brought about by the project activities (small, moderate, large);
   iv. importance to local human populations (for example, fish for consumption, drinking water, agricultural products);
   v. national or international profile (for example, tropical rainforests, and any rare or endangered species); or
   vi. if being altered from its existing or predevelopment status will be important in evaluating the impacts of development and in focusing regulatory policy (for example, fish populations).

3. Insignificant Impact: If an impact occurs but does not meet the criteria for significance it is assigned the category INSIGNIFICANT.

4. Unknown Impact. The potential impact of a project activity will be assessed as being UNKNOWN if:
    i. the nature and location of the project activity is uncertain;
    ii. the occurrence of the environmental parameter within the study area is uncertain;
    iii. the time scale of the effect is unknown;
    iv. the spatial scale over which the effect may occur is unknown; or
    v. the magnitude of the effect cannot be predicted.

5. Mitigated Impact: The potential impact of a project activity on an environmental parameter is said to be MITIGATED, if:
    i. there is potential for a significant impact; and
    ii. the proposed mitigation measure will prevent the impact or reduce the impact to acceptable levels.

The provision of the "unknown" category in an IEE is important as it facilitates the identification of all aspects and potential impacts of a project that require further study. Inclusion of this category prevents miscategorization of potential effects due to a lack of information. Because specific details of the outside activities of the construction and operation of the pulp and paper mill were not specified and had to be inferred, there are more potential impacts that are classified as "unknown" than expected.

A major objective of environmental assessment is to prescribe ways in which project effects can be minimized through mitigation measures during the development and operation phases of the project. Because environmental screening normally occurs early in the developmental stages of the project when many of the design and operational details of a project are not firm, mitigation options for a potential effect often cannot be prescribed within the desired levels of confidence.

All IEEs conducted using this method reveal some potential project impacts that would not be significant, and other impacts that would be very significant. The latter impacts require closer scrutiny. To facilitate this, impact hypotheses are constructed for each major potential impact. Impact hypotheses (see, for example, Figure 3-9) were constructed for those potential major impacts of the project categorized as "significant," "mitigated," or "unknown." For each impact hypothesis, the following information is presented:

1. a detailed description providing a statement for each linkage in the impact hypothesis (see, for example, Table 3-14);
2. Documentation of evidence for and against the statements in the hypothesis;
3. Listing of potential or proposed mitigation measures; and
4. Listing of further studies and monitoring requirements.

The analysis of the impact hypotheses provides the information base upon which the TOR for the full EIA of the project is derived.

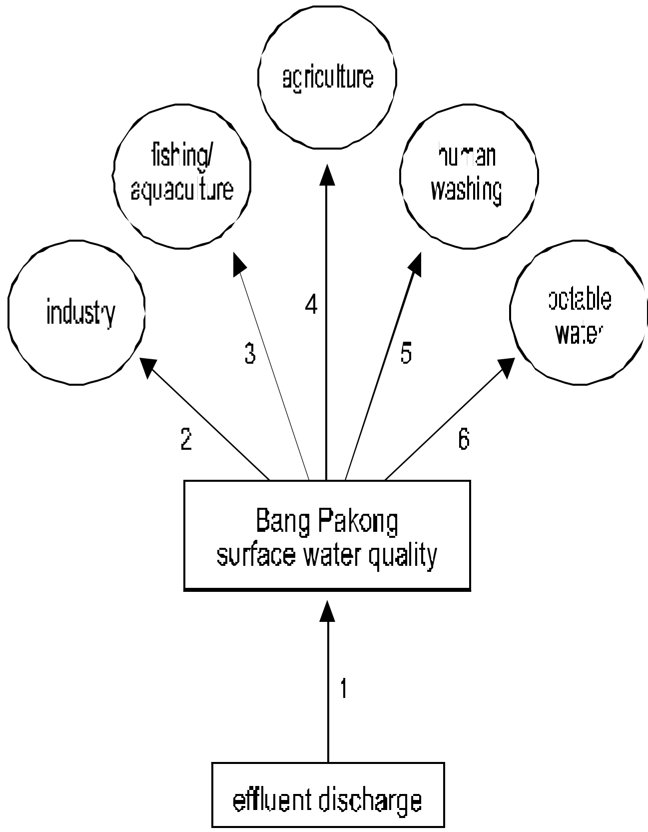


Figure 3-9: Impact hypothesis: Discharge of mill effluent in the Bang Pakong River will affect human uses of the river (*source:* H.A. Simons Ltd., Consulting Engineers, 1992).

Table 3-13: Partial cross impact matrix for the IEE of a pulp and paper mill in Thailand (*source:* H.A. Simons Ltd., Consulting Engineers, 1992).

	Physical Resources										Ecological Resources			
	Surface water hydrology	Surface water quality	Ground water hydrology	Ground water quality	Climate	Air quality (smog, noise)	Soils	Land capability	Mineral resources	Geology & seismology	Aquatic biota	Forests & vegetation	Terrestrial wildlife	Rare & endangered species
Mill Site Construction														
Procurement	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Labor Recruitment	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Road Construction	M	M	I	I	N	I	I	I	N	I	M	I	I	I
Pulp & Paper Mill														
Earthworks	M	M	I	I	N	I	U	I	N	I	M	I	I	I
Pipelines	I	I	I	I	N	I	I	I	N	N	I	I	I	I
Liquid & Solid Disposal	I	U	I	U	N	U	I	U	N	N	U	I	I	I
Reservoir														
Earthworks	M	M	I	I	N	I	U	I	N	I	M	I	I	I
Diking	I	I	I	I	N	I	I	I	N	I	I	I	I	I
River Pumping	U	I	I	I	N	I	I	I	N	N	M	I	I	I
Stream Damming	M	I	I	I	N	I	I	I	N	I	M	I	I	I
Effluent Lagoon														
Earthworks	I	M	I	I	N	I	U	I	N	I	M	I	U	I
Diking	I	I	I	I	N	I	I	I	N	I	I	I	I	I
Landfill Site														
Earthworks	I	M	I	I	N	I	U	I	N	I	M	I	U	I
Mill Site Operation														
Pulp & Paper Mill														
Hiring and Training	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Transport of Material	I	I	I	I	N	S	I	I	N	I	I	I	I	I
Wood Storage	N	M	N	M	N	I	M	I	N	N	M	I	I	I
Air Emissions	N	I	N	I	I	S	I	I	N	N	I	I	I	I
Effluent Storage	I	M	M	M	I	S	M	M	N	I	M	I	I	I
Effluent Discharge	I	S	I	U	N	U	I	I	N	N	S	I	I	I

	Physical Resources										Ecological Resources			
	Surface water hydrology	Surface water quality	Ground water hydrology	Ground water quality	Climate	Air quality (smog, noise)	Soils	Land capability	Mineral resources	Geology & seismology	Aquatic biota	Forests & vegetation	Terrestrial wildlife	Rare & endangered species
Effluent Irrigation	I	U	S	S	N	U	S	S	N	N	U	I	I	I
Sanitary Disposal	I	U	I	U	N	I	U	U	N	N	I	I	I	I
Solid Disposal	I	U	I	U	N	I	S	S	N	N	I	I	I	I

Table 3-14: Statement of the impact (*source:* H.A. Simons Ltd., Consulting Engineers, 1992).

Hypothesis 9: **Discharge of mill effluent in the Bang Pakong River will affect human uses of the river.**

Link 1: Pulp and paper mill effluent will degrade water quality in the Bang Pakong River for a certain distance downstream of the discharge diffuser.

Link 2: Degraded river water quality will negatively affect industries (e.g., whisky factory) that rely on the river as a source of process water. Existing water treatment activities by downstream industrial users will become more expensive, causing their production cost increase.

Link 3: Lower river water quality will have detrimental effects on fisheries and aquaculture that depend on the Bang Pakong River. Fish will become tainted, which will lead to reduced food supply, reduced income, and possible human health implications.

Link 4: River water polluted by the pulp and paper mill will have negative effects on agricultural operations that use river water for irrigation. Food crops will become contaminated, which will lead to reduced food supply and/or farm income.

Link 5: People who use contaminated river water for bathing and washing will develop rashes and skin disorders, or will be forced to seek other sources of washwater.

Link 6: Mill effluents discharged into the river will cause a degradation of drinking water supplies. Water treatment activities for downstream municipalities will become more complex and expensive.

Box 3-6: Evaluation of network methods.

Key Area of the Assessment Process	Criteria	L denotes Criteria Completely Satisfied P denotes Criteria Partially Satisfied N denotes Criteria Not Satisfied
Cost / Time Effectiveness Criteria	1. Expertise Requirements	P
	2. Data Requirements	L
	3. Time requirements	L
	4. Flexibility	L
	5. Personnel Level of Effort	L
Impact Identification	6. Comprehensiveness	N
	7. Indicator-based	L
	8. Discriminative	P
	9. Time Dimension	N
	10. Spatial Dimension	N
Impact Measurement	11. Commensurate	N
	12. Quantitative	N
	13. Measures Changes	N
	14. Objective	P
Impact Assessment	15. Credibility	P
	16. Replicability	P
	17. Significance-based	N
	18. Aggregation	P
	19. Uncertainty	N
	20. Alternative Comparison	N
Communication	21. Communicability	L
	22. Summary Format	P

Is this application appropriate for developing countries? Yes, but it requires environmental specialists with expertise in the first and higher order relationships of project activities and environmental components.

3.6 Simulation Modeling Workshops

System ecologists have developed an approach to EIA and management commonly referred to as *Adaptive Environmental Assessment and Management* (AEAM). AEAM uses interdisciplinary workshops composed of scientists and environmental managers to construct simulation models to predict impacts (Holling, 1978). Simulation models are usually expensive, time consuming to construct, and used only when there is sufficient funding and expertise available. Several simple models have been developed which can be used to predict changes in specific environmental resources. This approach broadens the potential of simulation models to evaluate the impacts of alternatives and is considered beneficial for project planning.

The AEAM approach uses short-term interdisciplinary teams interacting through modeling workshops to predict impacts and evaluate alternatives including management measures. The assessment is built around a small core group of people who interact with a wider set of relevant experts during a series of short-term, intensive workshops. These workshops provide a common meeting ground and aid in the integration of the information provided by people from different fields of expertise and management. The development of simulation models forces specialists to view their area of interest in the context of the whole system. It leads to clear-cut problem definition and existing data evaluation, and allows formulation of some initial predictive assessment schemes and sequences in analysis.

For such simulation models to be developed through the series of workshops, unambiguous information must be available. In the workshop environment, the interdisciplinary team is required to be explicit about its assumptions. The consequent objectivity exposes critical conceptual uncertainties about the behavior of the system under study, and more importantly, identifies the research needed for the proper prediction of impacts in the context of the interdisciplinary effort.

The use of AEAM was demonstrated for the Nam Pong environmental management research project by the Committee for the Coordination of Investigations of the Lower Mekong Basin (Interim Mekong Committee, 1982a). The steps in constructing the simulation models were:

1. determining actions, including those development activities that have the potential to impact upon the environment as well as management and regulatory actions that restrict or control human activity (Table 3-15);
2. determining indicators — those measures of the environmental and social systems that are indicative of the degree of change or impact of actions (Table 3-16);
3. determining the spatial extent and resolution (Figure 3-10) of the study area;
4. determining the planning horizon and time step (Figure 3-11);
5. selection of the submodels (Figure 3-12);
6. developing the looking outward matrix (Table 3-17);
7. programming the submodels;
8. integrating the submodels;
9. scenario development; and
10. gaming with the model to examine scenario results.

In the Nam Pong Model, four submodels were defined to aggregate the many model components into groups or related components (Figure 3-12). The components used were identified as part of the definition of the problem in terms of actions, indicators, and the spatial and temporal frameworks. The components chosen for each of the four submodels coincided with the major scientific, social, and economic disciplines represented by participants in the workshop.

Steps 1 to 5 are usually conducted by all participants in the workshop to be sure that each discipline and interest is represented in the model. The sixth step, constructing the "looking outward matrix" is also conducted in a plenary session of the workshop. This is one of the most important phases in the workshop exercise. The "looking outward" process is designed to develop an interaction matrix between the various submodels. The looking outward matrix is similar to a component interaction matrix. Discussions and refinements during the Nam Pong workshops resulted in the final "looking outward" matrix shown in Table 3-17.

With the completion of the looking outward matrix, development of the conceptual submodels begins. The goals and responsibilities of each group are stated, and each group is required to explicitly identify the information required to make predictions on the nature, scale, and magnitude of change the respective subsystems will undergo over time.

In the Nam Pong application four groups of interdisciplinary experts developed submodels for their respective subsystems. These were later linked together and run under a variety of possible scenarios to ascertain the numerous management options and hypotheses on the system.

Table 3-15: Actions discussed and implemented in Nam Pong Model (*source:* Interim Mekong Committee, 1982b).

Submodel	Actions Considered Relevant	Actions Selected for Model
Water	Set operating rule curve Set flood control rule curve	Set rule
Fishery	Enhance stock Aquaculture (fish farming) Regulate fisheries Specify fishing season	Stock reservoir Fish culture Restrict number of fishermen Restrict fishing season
Land Use	Zone land Regulate land tenure Regulate deforestation Regulate legal forestry Regulate forest planting Promote fertilizer use Accelerate dry season cropping Promote crop diversification	Regulate deforestation rate Regulate forestation Accelerate dry season cropping
Socioeconomic	Resettle population Control migration by incentives Establish new industries Increase efficiency of labor Supply services: power roads health education	Increase effectiveness of family planning Establish new industries (Sugar refinery)

Table 3-16: Indicators discussed and implemented in Nam Pong Model (*source:* Interim Mekong Committee, 1982b).

Submodel	Indicators Considered Relevant	Indicators Selected for Model
Water	Quantity of water for irrigation Power generated Area damaged by flood Water quality Sedimentation in reservoir	Reservoir inflow Reservoir level Reservoir outflow Reservoir storage Power generated Area flooded Water demand Water shortage
Fishery	Fish harvest Catch per effort Biomass of fish Species composition of fish Successional stage of fish	Number of fishermen Fishing income Fish harvest Catch per effort Biomass of each generic group
Land Use	Forest area Yield per area subsistence crop Yield per area market crop Dry season growing area Irrigated area	Sedimentation rate Area of each land-use type Yield of each land-use type Erosion and sedimentation
Socioeconomic	Population Average per capita income Income distribution Quantity and quality of domestic water Health Education Mortality rate	Net income Income by profession Income per capita Population distribution (spatially and temporally)

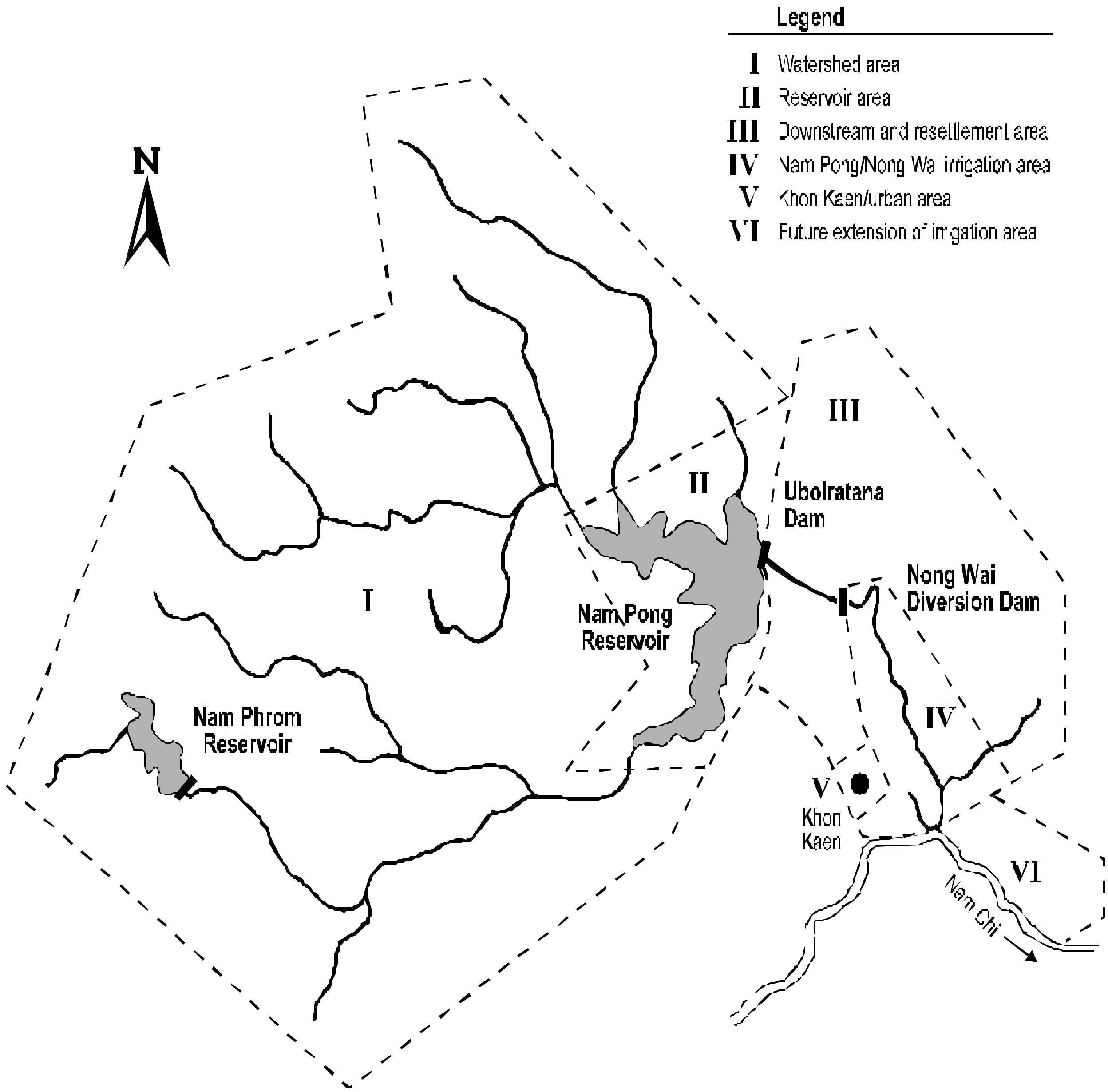


Figure 3-10: Spatial extent and subdivisions for the Nam Pong Model (*source:* Interim Mekong Committee, 1982b).

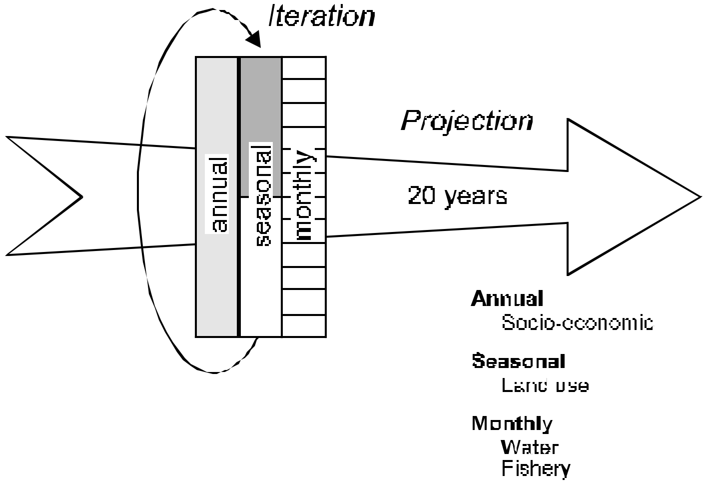


Figure 3-11: Temporal horizon and length iteration intervals for the Nam Pong Model (*source:* Interim Mekong Committee, 1982b).

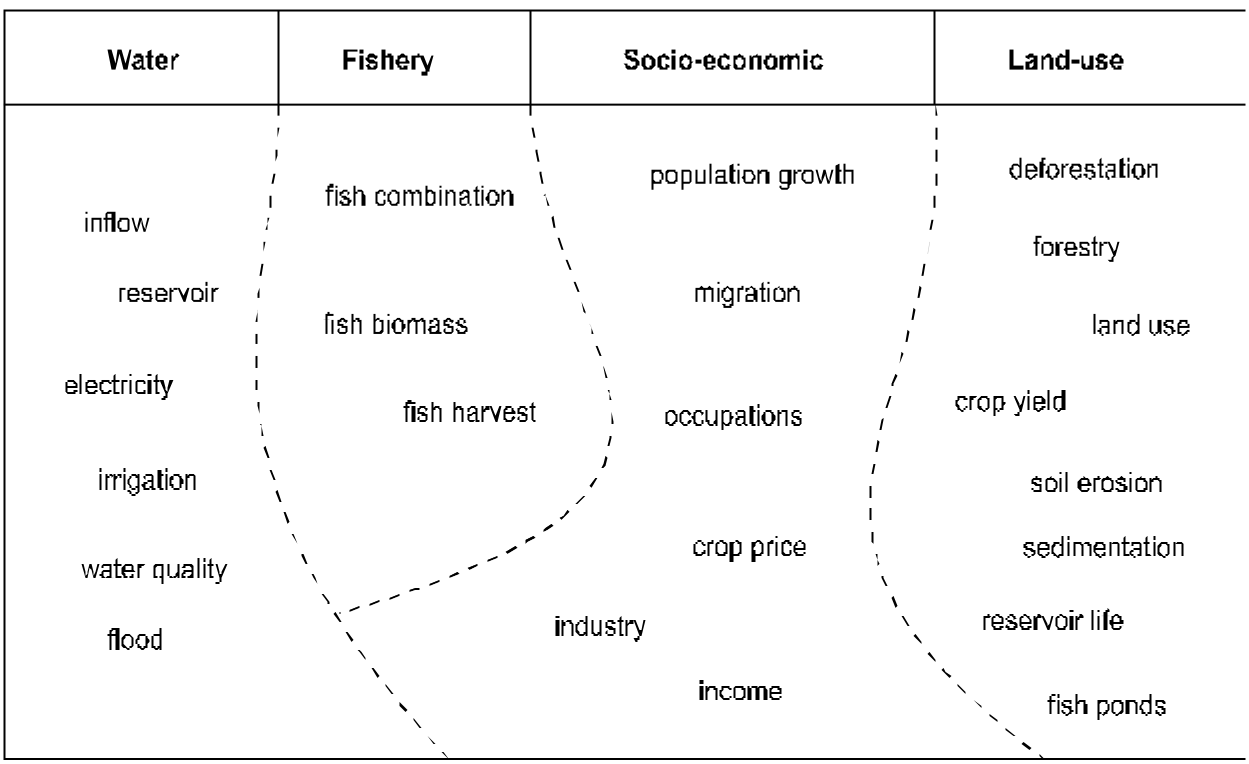


Figure 3-12: Allocation of model components to submodels (*source:* Interim Mekong Committee, 1982b).

Table 3-17: Final looking outward matrix for the Nam Pong application (*source:* Interim Mekong Committee 1982b).

To From	Water Submodel	Fish Submodel	Land Use Submodel	Socioeconomic Submodel
Water		Reservoir water level (m MSL) Reservoir surface area (km^2) Turbidity Inflow ($10^6 m^3$)	Flooded area (km^2) Water shortage ($10^6 m^3$) Inflow ($10^6 m^3$)	
Fishery			Drawdown area (km^2)	Fish harvest (ton) Number of commercial fishermen
Land use	Water demand for irrigation ($10^6 m^3$)			Crop production (ton) Cultivated area (km^2)
Socio-economic	Water demand for industry and domestic uses ($10^6 m^3$)		Population change	

Workshops often conclude with a discussion of needed model refinements and the requirements of information identified. Subsequent workshops are held at a later date after model refinement. New data obtained in the meantime may be used to refine and develop the model to enhance its predictive capabilities (Interim Mekong Committee, 1982b). Such workshops also form the backbone of long term, in-depth analyses in which alternative predictions are made, tested, and alternative management and development schemes are evaluated. But the limiting factor is that the models will only be as accurate and comprehensive as the data available.

Box 3-7: Evaluation of Simulation Modeling Workshops.

Key Area of the Assessment Process	Criteria	L denotes Criteria Completely Satisfied P denotes Criteria Partially Satisfied N denotes Criteria Not Satisfied
Cost / Time Effectiveness Criteria	1. Expertise Requirements	N
	2. Data Requirements	N
	3. Time requirements	N
	4. Flexibility	L
	5. Personnel Level of Effort	P
Impact Identification	6. Comprehensiveness	P
	7. Indicator-based	L
	8. Discriminative	L
	9. Time Dimension	L
	10. Spatial Dimension	L
Impact Measurement	11. Commensurate	L
	12. Quantitative	L
	13. Measures Changes	L
	14. Objective	P
Impact Assessment	15. Credibility	P
	16. Replicability	L
	17. Significance-based	P
	18. Aggregation	L
	19. Uncertainty	P
	20. Alternative Comparison	L
Communication	21. Communicability	L
	22. Summary Format	L

Is this application appropriate for developing countries? The first steps in developing the conceptual model are appropriate for developing countries. However, the development of an application specific computer simulation model is not recommended because of high costs and the high level of expertise required. The development of an application specific computer simulation model should be used only in cases where existing predictive computer models are not well suited to the EIA.

3.7 Spatially Based Methods

3.7.1 Overlays

Shopley and Fuggle (1984) credited McHarg (1969) with the development of map overlays. An overlay is based on a set of transparent maps, each of which represents the spatial distribution of an environmental characteristic (for example, susceptibility to erosion). Information for an array of variables is collected for standard geographical units within the study area, and recorded on a series of maps, typically one for each variable. These maps are overlaid to produce a composite (see Figure 3-13). The resulting composite maps characterize the area's physical, social, ecological, land use and other relevant characteristics, relative to the location of the proposed development. To investigate the degree of associated impacts, any number of project alternatives can be located on the final map. The validity of the analysis is related to the type and number of parameters chosen. For a readable composite map, the number of parameters in a transparency overlay is limited to about ten. These methods are used in at least two ways in impact assessment. One way is to use before and after maps to assess visually the changes to the landscape. The other way is to combine mapping with an analysis of sensitive areas or ecological carrying capacity. When used in this latter way, constraints on the level of development are set on the basis of limits determined by the location of sensitive areas and by assessments of carrying capacity. These methods are spatially oriented and are capable of clearly communicating the spatial aspects of cumulative impacts. Their limitations relate to: 1) lack of causal explanation of impact pathways; and 2) lack of predictive capability with respect to population effects. However, some sophisticated versions can make predictions about potential habitat loss.

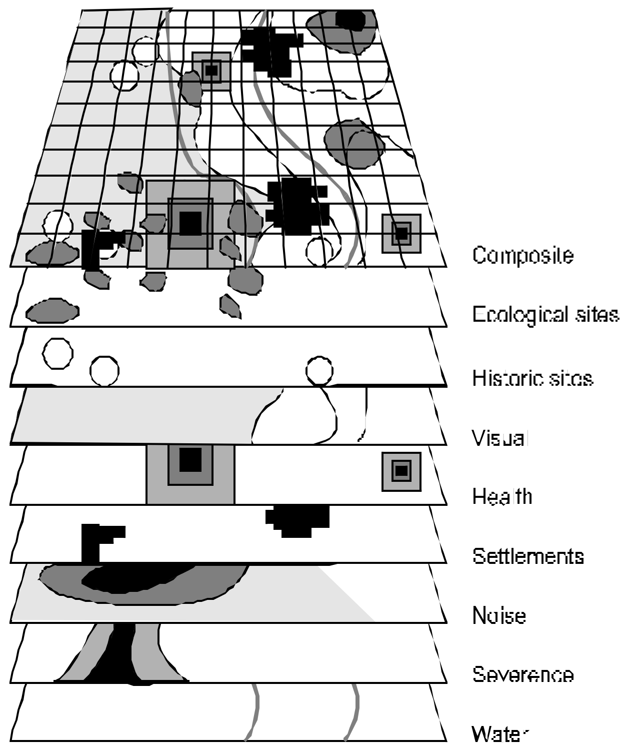


Figure 3-13: Example of overlay method (*source:* Wathern, 1988).

Essentially, the overlay method divides the study area into convenient geographical units based on uniformly spaced grid points, topographic features, or differing land uses. Field surveys, topographical land inventory maps, aerial photography, etc., are used to assemble information related to environmental and human factors within the geographical units. Factors are composed by assembling concerns that have a common basis, and regional maps are drawn for each factor. Through the use of overlays, landuse possibilities and engineering feasibility are visually determined (McHarg, 1968).

The scale of the maps can vary from large-scale (for regional planning purposes) to small-scale identification of site specific features. Overlays also are used in route selection for linear projects such as roads and transmission lines. Their use facilitates screening of alternative routes at an early stage, reducing the amount of detailed analysis required by eliminating some routes early on.

For optimal results data for various characteristics must be of comparable quality; if the data base for one characteristic is weaker than for the others it will be under-represented through this method.

McHarg (1968) demonstrated this technique with specific orientation towards highways. His method consisted of transparencies of environmental characteristics overlaid on a regional base map. Eleven to sixteen environmental and land use characteristics were mapped. The maps represented three levels of environmental and land use characteristics based upon "compatibility with the highway." The approach seems most useful for screening alternative project sites or routes before a detailed impact analysis is completed. The method has also been used for evaluating development options in coastal areas and for routing pipelines and transmission lines.

3.7.2 Geographic Information Systems

Traditionally, the overlays have been produced by hand. As a result of recent developments, Geographical Information Systems (GIS) are becoming popular in situations where the computer technology and trained personnel are available. Computers also are used routinely to do cluster analyses of complex overlays.

A significant application of GIS is the construction of real world models based on digital data. Modeling can analyze trends, identify factors that are causing them, reveal alternative paths to solving the given problem, and indicate the implications or consequences of decisions. For example, GIS can show how a natural resource will be affected by a decision. Based on satellite data, areas that suffer most from deforestation may be identified and analyzed on the basis of overlaying data on soil types, the species required, the likely growth and yield, and the impact of regulatory measures applicable to the area (Asian Development Bank, 1991). The timing, types, and scale of timber management practices needed may then be indicated, specifying the consequences. In agriculture, the potential loss of natural vegetation to expanded rice cultivation can be quantified, based on economic evaluation. Where conventional change detection techniques do not yield satisfactory results, a GIS approach can indicate the change in quantitative terms (for example, in new area development). The impact of development plans on the environment can be assessed by integrating data on land use with topographic and geologic information. Similarly, satellite imagery can periodically be used to update maps of irrigated land. The spectral features of irrigated and non-irrigated fields can be combined with other data on the fields to derive estimates of demand for irrigation water and devise land management plans. GIS can be used to assess the risk of drought in choosing areas for rainfed crops. In fisheries, based on past trends of population dynamics in a given area, long-term consequences of restocking programs on the environment may be indicated. GIS is also used in determining optimal routes for communications, irrigation, and road maintenance. Network modeling to connect various data bases can also be done.

Another important application of GIS is in statistical analysis of features (for example, the area of forest water body or the length of rivers, canals, and roads). An area can be statistically described, for example, by soil type. The length of a road can be classified in terms of its condition. It is also common to delineate what is known as "buffer zones" around points, lines, or polygons to indicate selected areas for special attention. For example, the land surrounding a reserve forest can be studied for determining the most appropriate land use. The "buffer zone" could be overlayed with an ideal land capability layer to choose the best possible use.

A "ranking method" can be used to evaluate lands suitable for cultivation of particular crops. The method involves the use of several thematic maps from satellite data as well as non-image data. For example, land resources can be evaluated for paddy field development. Data on land conditions, land productivity, and soil moisture conditions need to be collected and evaluated so that suitable areas for paddy cultivation can be identified.

GIS is a powerful management tool for resource managers and planners. Its applications are limited only by the quality, quantity, and coverage of data that are fed into the system. Some of the standard GIS applications are integrating maps made at different scales; overlaying different types of maps which show different attributes; and identifying required areas within a given distance from roads or rivers. For instance, by overlaying maps of vegetation and soils, a new map on land suitability can be generated and the impact of proposed projects can be studied. The farm-to-market transport economics can be considered in determining the planting of specific areas on a commercial scale. Similarly, the most favorable zones for the development of shrimp farming outside mangroves can be located.

Box 3-8: Evaluation of Spatially Based Methods.

Key Area of the Assessment Process	Criteria	L denotes Criteria Completely Satisfied P denotes Criteria Partially Satisfied N denotes Criteria Not Satisfied
Cost / Time Effectiveness Criteria	1. Expertise Requirements	L
	2. Data Requirements	P
	3. Time requirements	L
	4. Flexibility	L
	5. Personnel Level of Effort	P
Impact Identification	6. Comprehensiveness	N
	7. Indicator-based	P
	8. Discriminative	N
	9. Time Dimension	P
	10. Spatial Dimension	L
Impact Measurement	11. Commensurate	L
	12. Quantitative	L
	13. Measures Changes	L
	14. Objective	L
Impact Assessment	15. Credibility	L
	16. Replicability	L
	17. Significance-based	N
	18. Aggregation	P
	19. Uncertainty	N
	20. Alternative Comparison	P
Communication	21. Communicability	L
	22. Summary Format	L

Is this application appropriate for developing countries? Yes, especially simple map overlay techniques where there is existing map-based information.

3.8 Rapid Assessment of Pollution Sources

In the early 1980s, the World Health Organization (WHO) developed a manual for rapid assessment of sources of land, air, and water pollution (WHO, 1982). The rapid assessment procedure has been found useful in developing countries in the design of environmental control strategies using relatively modest financial and human resources (Economopoulos, 1993a). Part I of the latest revision of the procedure (Economopoulos, 1993a) updates the rapid pollution assessment factors and introduces air, water, and solid waste inventory and control models. Part II (Economopoulos, 1993b) provides guidance on how to assess current air and water quality and how to identify land pollution problems. It also describes how to formulate alternative control strategies and how to evaluate their effectiveness.

3.8.1 Rapid Assessment Procedure

The rapid assessment procedure allows for quick estimation of releases of pollutants to the environment. The basic concept is illustrated in Figure 3-14. The procedure uses information on existing pollution sources for a given study area. Inputs include the quantities of consumption and outputs of various industrial and urban processes, industrial production figures, fuel usage, number of motor vehicles, number of houses connected to sewers, etc. These data are multiplied by predetermined waste load factors to provide estimates of the generated loads for each pollution type. The generated loads provide a worst case estimate of the amount of pollutant that is being released to the environment. The next step is to identify the type of pollution control being used and estimate its effectiveness in reducing the level of pollutant. This allows for an estimate of the release to the environment to be made.

Economopoulos (1993a) lists those activities for which waste load factors and control models have been developed (Table 3.18). The activities are classified using the UN SIC system to make it easy to refer to the national statistics of a country to get data the level of industrial activity. The list of industrial sources and processes (Table 3.18) accounts for most of the industrial pollution sources. This list may be used as a guide to identify major pollution sources during the initial phases of the inventory work.

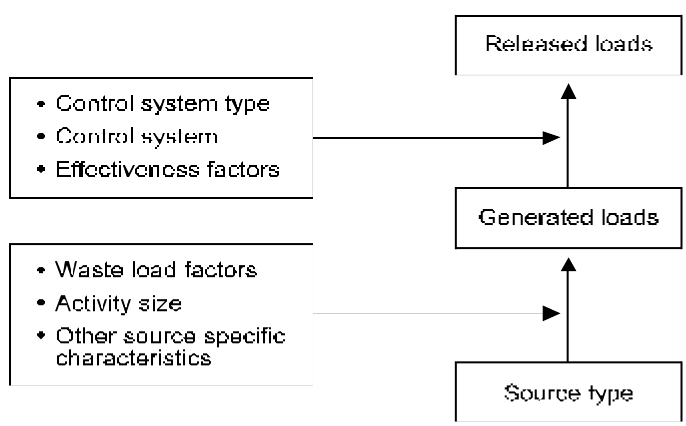


Figure 3-14: Estimating pollution loading using the rapid assessment procedure.

Table 3-18: List of activities included in the air, water, and solid waste inventory and control models, classified under the SIC system, UN (*source:* Economopoulos. 1993a). The _ indicates that the relevant industry or process is included in the appropriate air, water or solid waste inventory and control models of Sections 3.2.2, 4.2.2 and 5.2.2 respectively.

	Emissions	Effluents	Solid Wastes
0 Activities not Adequately Defined			
Consumer solvent use	_		
Surface coating	_		
1 Agriculture, Hunting, Forestry and Fishing			
11 Agriculture and hunting			
111 Agriculture and livestock production	_	_	_
12 Forestry and Logging			
121 Forestry	_		
2 Mining and Quarrying			
21 Coal mining	_		_
22 Crude petroleum and natural gas production	_		
23 Metal ore mining	_		_
29 Other mining	_		_
3 Manufacturing			
31 Manufacture of food, beverages & tobacco			
311/2 Food Manufacturing			
3111 Slaughtering, preparing and preserving meat	_	_	_
3112 Manufacture of dairy products		_	
3113 Canning and preserving fruits and vegetables		_	_
3114 Canning, preserving and processing of fish	_	_	_
3115 Manufacture of vegetable and animal oils and fats		_	_
3116 Grain mill products	_	_	
3117 Bakery products		_	
3118 Sugar factories and refineries		_	
3121 Food products not elsewhere classified	_	_	_
3122 Alfalfa dehydrating	_		
313 Beverage industries			
3131 Distilling, rectifying and blending spirits		_	_
3132 Wine industries		_	
3133 Malt liquors and malt	_	_	
3134 Soft drinks		_	
32 Textile, wearing apparel and leather			
321 Manufacture of textiles			
3210 Manufacture of textiles		_	
322 Manufacture of wearing apparel, except footwear			
3211 Spinning, weaving and finishing textiles	_		_
3214 Carpet and rug manufacture			_
323 Manufacture of leather and products of leather			
3231 Tanneries and leather finishing		_	_
34 Paper and paper products, printing and publishing			
341 Manufacture of paper and paper products	_	_	_
342 Printing, publishing and allied industries	_		_
35 Manufacture of chemicals, and chemical, petroleum, coal, rubber and plastic products			

Code	Industry	Emissions	Effluents	Solid Wastes
351	Manufacture of industrial chemicals			
3511	Basic industrial chemicals except fertilizers	_	_	_
3512	Manufacture of fertilizers and pesticides	_	_	
3513	Resins, plastics and fibers except glass	_	_	
352	Manufacture of other chemical products			
3521	Manufacture of paints, varnishes and lacquers	_		_
3522	Manufacture of drugs and medicines		_	_
3523	Manufacture of soap and cleaning preparations	_	_	
3529	Chemical products not elsewhere classified	_	_	
353	Petroleum refineries	_	_	_
354	Manufacture of miscellaneous products of petroleum and coal	_	_	_
355	Manufacture of rubber products			
3551	Tire and tube industries		_	_
36	*Non-metallic mineral products, except products of petroleum and coal*			
361	Manufacture of pottery, china and earthenware	_		
362	Manufacture of glass and glass products	_	_	
369	Manufacture of other non-metallic mineral products			
3691	Manufacture of structural clay products	_		
3692	Cement, lime and plaster	_		
3699	Products not elsewhere classified	_		
37	*Basic metal industries*			
371	Iron and steel basic industries	_	_	_
372	Non-ferrous metal basic industries	_	_	_
38	*Fabricated metal products, machinery and equipment*			
381	Fabricated metal products, except machinery	_	_	_
384	Manufacture of transport equipment			
3841	Ship building and repairing			_
4	**Electricity, Gas and Water**			
41	Electricity, gas and steam			
4101	Electricity, light and power	_	_	_
6	**Wholesale and Retail Trade**			
61	Wholesale trade	_		
62	Retail trade	_	_	
63	Restaurants and hotels			
631	Restaurants, cafes and other eating and drinking		_	
632	Hotels, rooming houses, camps and other lodging		_	
7	**Transport, Storage and Communication**			
71	Transport and storage			
711	Land transport	_		
712	Water transport	_		
713	Air transport	_	_	
719	Services allied to transport			
7192	Storage and warehousing	_	_	
9	**Community, Social and Personal Services**			
92	Sanitary and related community services	_	_	_
93	Social and related community services		_	
931	Education services		_	
932	Medical, dental and other health services			_

		Emissions	Effluents	Solid Wastes
94	Recreational and cultural services		_	
95	Personal and household services			
952	Laundries, laundry services and cleaning	_		

3.8.2 Waste Load Factors

Waste load factors have been developed for air, water, and solid waste. For air emissions, Economopoulos (1993a) presents tables of estimated per unit loading for TSP, SO_2, NO_x, CO, and VOC for the activities listed in Table 3.18. Example air emission load factors for natural gas sources are given in Table 3-19. For liquid wastes, Economopoulos (1993a) presents tables of estimated per unit loading for BOD_5, TSS, Tot N, Tot P, and other pollutants (Phenol, Sulfide, Chromium, and Oil) for the activities listed in Table 3.18.

Example liquid waste load factors for petroleum refineries are presented in Table 3-20. For solid wastes, Economopoulos (1993a) presents tables of estimated per unit loadings for inorganic, oily, organic, putrescible, low hazard, and infectious wastes. Example solid waste load factors for petroleum refineries are given in Table 3-21.

Table 3-19: Natural gas - model for air emissions inventories and control (*source:* Economopoulos, 1993a).

Major Division 4. Electricity Gas and Water

SIC# 410 Electricity Gas and Steam

Process	Unit (U)	TSP kg/U	SO_2 kg/U		NO_x kg/U		C0 kg/U	VOC kg /U
Gaseous Fuels Natural Gas								
Utility Boiler	1000 Nm^3	0.048	15.6	S	8.8	f	0.64	0.028
	T	0.061	20	S	11.3	f	0.82	0.036
Industrial Boiler	1000 Nm^3	0.048	15.6	S	2.24		0.56	0.092
	T	0.061	20	S	2.87		0.72	0.l18
Domestic Furnaces	1000 Nm^3	0.048	15.6	S	1.6		0.32	0.127
	T	0.061	20	S	2.05		0.41	0.163
Stationary Gas Turbines	1000 Nm^3	0.224	15.6	S	6.62		1.84	0.673
	T	0.287	20	S	8.91		2.36	0.863

Notes: A is the percent ash content of combustible by weight
S is the percent Sulfur content of combustible by weight
N is the weight percent of Nitrogen in the fuel
Typical Sulfur content of Natural Gas is 0.000615%.

Table 3-20: Petroleum Refineries - model for liquid waste inventories and control (*source:* Economopoulos. 1993a).

Major Division 3. Manufacturing

Division 35. Manufacture of Chemicals and of Chemical, Petroleum, Coal, Rubber, and Plastics Products

SIC # 353 Petroleum Refineries

Process	Unit (U)	Waste Volume m^3/U	BOD_5 kg/U	TSS kg/U	Tot N kg/U	Tot P kg/U	Other Pollutants	Load kg /U
Topping Refinery	1000 m^3 of crude	484	3.4	11.7	1.2		Oil	8.3
							Phenol	0.034
							Sulfide	0.054
							Cr	0.007
Cracking Refinery	1000 m^3 of crude	605	72.9	18.2	28.3		Oil	31.2
							Phenol	4.0
							Sulfide	0.94
							Cr	0.25
Petrochemcial Refinery	1000 m^3 of crude	726	172	48.6	34.2		Oil	52.9
							Phenol	7.7
							Sulfide	0.086
							Cr	0.234
Lube Oil Refinery	1000 m^3 of crude	1090	217	71.5	24.1		Oil	120
							Phenol	8.3
							Sulfide	0.014
							Cr	0.046
Integrated Refinery	1000 m^3 of crude	1162	197	58.1	20.5		Oil	74.9
							Phenol	3.8
							Sulfide	2.0
							Cr	0.49

Table 3-21: Petroleum Refineries - model for solid and hazardous waste inventories (*source:* Economopoulos. 1993a).

Major Division 3. Manufacturing

Division 35. Manufacture of Chemicals and of Chemical, Petroleum, Coal, Rubber, and Plastics Products

SIC # 353 Petroleum Refineries

Process	Unit (U)	Inorganic kg/U	Oily kg/U	Organic kg/U	Putrescible kg/U	Low Hazard kg /U	Infectious kg/U
Topping Refinery	1000 m^3 of crude		1311				
Low Cracking Refinery	1000 m^3 of crude		1675				
High Cracking Refinery	1000 m^3 of crude		3303				
Lube Oil Refinery	1000 m^3 of crude		6140				

Note: The major problem is oily sludges which are often contaminated by heavy metals.

3.8.3 Use in EIA

The rapid assessment procedure may be used to assess the environmental impacts of developments. The use of waste load factors enables prediction of the approximate pollutant loadings generated by a new development project. This, in conjunction with knowledge about existing pollutant concentrations, allows a preliminary assessment of the degree to which the project would adversely affect the prevailing conditions of the proposed site. On a local basis, rapid assessment studies can provide the following contributions to environmental management agencies (WHO, 1983):

- define high priority control actions;
- organize effective detailed source survey programs;
- organize appropriate environmental monitoring programs;
- assess and evaluate the impacts of proposed pollution control strategies;
- assess impacts of new industrial development projects; and
- help site selection and determination of proper control measures.

Application of the Rapid Assessment Procedure to the Ha Long Bay Water Pollution Study

The rapid assessment procedure was recently used to estimate water pollution loadings into Ha Long Bay in Quang Ninh province in Viet Nam. A pollution inventory was developed for defined pollution sources areas in Ha Long City and environs, including Hong Gai estuary (Table 3.22). For each pollution source area, the loadings of key pollutants either provided the point sources or had to be estimated using the rapid assessment procedure. The pollution loading are used as input to a simple hydrographic water quality model that is being calibrated for Ha Long Bay. The model makes predictions of key pollutants (Table 3.23). Various pollution control strategies can be evaluated by altering the estimated releases of pollutants and assessing the changes in water quality that result.

Table 3-22: Key land based pollution sources and pollutants Ha Long City and environs.

Source	Pollutant	Included in Rapid Assessment Waste Load Factor Tables?
Domestic sewage	fecal bacteria and nutrients	yes
Coal mining	suspended solids	no
Upland erosion	suspended solids	no
Land reclamation	suspended solids	no
Brick yards	suspended solids	no
Saw mills	suspended solids	no
Fish plants, beer manufacturing, domestic waste	BOD	yes
Shrimp farming	BOD	no
Shipping and tanker port	Oil and Grease	no
Livestock production	BOD	yes
Restaurants	BOD	yes

Table 3-23: Pollutants included in hydrographic and water quality model.

BOD	DO	TSS
Tot P	PO_4	Tot N
NO_3	Oil	Metals
Fecal Coliform		

Box 3-9: Evaluation of Rapid Assessment of Pollution Sources.

Key Area of the Assessment Process	Criteria	L denotes Criteria Completely Satisfied P denotes Criteria Partially Satisfied N denotes Criteria Not Satisfied
Cost / Time Effectiveness Criteria	1. Expertise Requirements	L
	2. Data Requirements	P
	3. Time Requirements	L
	4. Flexibility	L
	5. Personnel Level of Effort	P
Impact Identification	6. Comprehensiveness	N
	7. Indicator-based	P
	8. Discriminative	N
	9. Time Dimension	N
	10. Spatial Dimension	N
Impact Measurement	11. Commensurate	L
	12. Quantitative	L
	13. Measures Changes	L
	14. Objective	L
Impact Assessment	15. Credibility	L
	16. Replicability	L
	17. Significance-based	N
	18. Aggregation	P
	19. Uncertainty	N
	20. Alternative Comparison	P
Communication	21. Communicability	L
	22. Summary Format	L

Is this application appropriate for developing countries? Yes, this method is a valuable tool for obtaining estimates of aggregate pollution loadings for a study area. It can be used to evaluate alternative control strategies through comparison of changes in pollutant loadings. It does not, however, make estimates of the impacts on key human and ecological components.

3.9 Summary

This chapter reviewed some of the basic methods available to conduct environmental assessments. Checklists and matrices are good tools for organizing and presenting the large amount of information that must be processed in EIAs. Matrices also help to represent the interactions between project activities and environmental components. Sectoral guidelines help bring collective experience with environmental impacts of specific project types to bear during initial assessments. They normally contain a comprehensive listing of: 1) project types covered by the guidelines; 2) activities that fall within each project type; 3) environmental components that may possibly be affected by the project activities; 4) significant issues that must be addressed in project planning; 5) suggested mitigation measures that might be incorporated into the project; and 6) recommended monitoring requirements. The SSA shows how to systematically conduct the EIA using this information. It relies on development of conceptual models of causal chains: activity- environmental change- impact - mitigation. Network diagrams are one of the best ways of representing these causal chains. These networks help in visualizing and understanding the basic relationships between environmental components that may trigger higher order impacts. Computer simulation modeling workshops can be used to develop conceptual models and network diagrams. In some cases, computer models may be developed during these workshops. Pollution and pollution control is one of the major problems in developing countries. The rapid assessment procedures provide a method for developing pollution inventories and recommending pollution control strategies.

Most methods are best used during the impact identification stage of EIA. To be effective they must be used with other tools or rely expert judgement. In the next chapter, we discuss a number of predictive tools that are useful in EIA.

3.10 References

Asian Development Bank, 1983.

Asian Development Bank, 1987a. Environmental guidelines for selected agricultural and natural resources development projects. Asian Development Bank, Manila, Philippines.

Asian Development Bank, 1993a. Environmental guidelines for selected infrastructure projects. Asian Development Bank, Manila, Philippines.

Asian Development Bank. 1993b. Environmental Guidelines for Selected Industrial and Power Development Projects.

Asian Development Bank. 1991. Remote Sensing and Geographical Information Systems for Natural Resource Management. Asian Development Bank Environmental Paper No. 9. 202 pp.

Canter, L. 1996. Environmental Impact Assessment. 2nd edition. McGraw-Hill Book Company, New York, NY.

Dee, N., J. Baker, N. Drobny, K. Duke, T. Whitman, and P. Fahringer. 1972. An Environmental Evaluation System for Water Resource Planning. Water Resource Research, Vol. 9, pp. 523-535.

Economopoulos, Alexander P. 1993a. Assessment of Sources of Air, Water, and Land Pollution: A Guide to Rapid Source Inventory Techniques and Their Use in Formulating Environmental Control Strategies. Part One: Rapid Inventory Techniques in Environmental Pollution. World Health Organization, Geneva.

Economopoulos, Alexander P. 1993b. Assessment of Sources of Air, Water, and Land Pollution: A Guide to Rapid Source Inventory Techniques and Their Use in Formulating Environmental Control Strategies. Part Two: Approaches for Consideration in Formulation of Environmental Control Strategies. World Health Organization, Geneva.

Everitt, R.R., D.A. Birdsall, and D.P. Stone. 1986. Beaufort Environmental Monitoring Program *in* Lang, R. (ed.). Integrated Approaches to Resource Planning and Management. University of Calgary Press, Calgary AB.

ESCAP (Economic and Social Commission for Asia and the Pacific). 1990. Environmental Impact Guidelines for Water Resources Development. ESCAP Environment and Development Series, United Nations, Nev; York.

Fisher, D. and G.S. Davis. 1973. An approach to assessing environmental impacts, J. Environ. Manage. 1: 207-227.

Golder, J., R.P. Ovellete, S. Saari, and P.N. Cheremisinoff. 1979. Environmental Impact Data Book, Ann Arbor Science Publications Inc., Ann Arbor,MI.

H.A. Simons Ltd. Consulting Engineers. 1992. Pulp and Paper Mill Feasibility Study: Phase I: Wood Supply, Environmental Screening, Site Assessment. Prepared for Advance Agro Group, Thailand.

Holling. C.S. (ed.). 1978. Adaptive Environmental Assessment and Management. John Wiley and Sons, Chichester.

Interim Mekong Committee. 1982a. Environmental Impact Assessment - Guidelines for Application for Tropical River Basin Development, Mekong Secretariat, ESCAP, Bangkok.

Interim Mekong Committee. 1982b. Nam Pong Environmental Management Research Project - Final Report for Phase III: Part 1- An Integrated Simulation Model for Resource Management, Mekong Secretariat, ESCAP, Bangkok.

Interim Mekong Committee. 1979. Environmental Management and Water Resource Development in the Nam Pong Basin of Northeastern Thailand, Mekong Secretariat, ESCAP, Bangkok.

International Institute for Environment and Development. 1995. Directory of Impact Assessment Guidelines. IIED, London, UK.

Leopold, L.B., F.E. Clarke, B.B. Manshaw, and J.R. Balsley. 1971. A Procedure for Evaluating Environmental Impacts, U.S. Geological Survey Circular No. 645, Government Printing Office, Washington, D.C.

Lohani, B.N. and N. Halim. 1983. Recommended Methodologies for Rapid Environmental Impact Assessment in Developing Countries: Experiences Derived from Case Studies in Thailand, Workshop on Environmental Impact Assessment, Guangzhou, People's Republic of China.

Lohani, B.N. and S.A. Kan. 1983. Environmental evaluation for water resources in Thailand. Wat. Resource. Develop.1(3): 185-195.

McHarg, I., 1971. Design with Nature. Doubleday and Company, Inc., Garden City, New York, NY.

McHarg, I. 1969. Design with Nature. Natural History Press. New York, NY.

McHarg, I. 1968. A Comprehensive Highway Route Selection Method, Highway Research, Research No. 246, pp. 1-15.

NEB. 1979. Manual of NEB - Guidelines for Preparation of Environmental Impact Evaluation. National Environment Board, Bangkok.

NEB. 1980. Initial Environmental Examination of Hausai-Thale Noi Road (No. 4150) Project, NEB 0504-79-4-004, National Environment Board, Bangkok.

Shopley, J.B. and R.F. Fuggle. 1984. A Comprehensive review of current environmental impact assessment methods and techniques. J. Environ. Manage. 18:25-47.

Smardon, R.C., J.R. Pease, and P. Donheffner. 1976. Environmental Assessment Form, Environmental Impact Assessment: A Framework or Local.

Sorensen, J.C. 1971. A Framework for Identification and Control of Resource Degradation and Conflict in The Multiple Use of the Coastal Zone, Master's thesis, University of Berkeley.

Wathern, P. 1988. An introductory guide to EIA. *In:* P. Wathern (ed.). Environmental Impact Assessment: Theory and Practice. Unwin Hyman, Boston, MA. 332 pp.

Westman, W.E. 1985. Ecology, Impact Assessment and Environmental Planning. John Wiley & Sons, Toronto, Ont.

World Bank. 1991 World Bank Environmental Assessment Sourcebook. World Bank. Washington D.C.

WHO. 1982. Rapid Assessment of Sources of Air, Water and Lead Pollution, WHO Offset Publication No. 62, World Health Organization, Geneva.

WHO. 1983. Selected Techniques for Environmental Management Training Manual, World Health Organization, Geneva.

4.0 Approaches to Impact Prediction

The scientific and technical credibility of an environmental impact assessment (EIA) relies on the ability of the EIA practitioners to estimate the nature, extent, and magnitude of change in environmental components that may result from project activities. Information about predicted changes is needed for assigning impact significance, prescribing mitigation measures, and designing and developing environmental management plans and monitoring programs. The more accurate the predictions, the more confident the EIA practitioner will be in prescribing specific measures to eliminate or minimize the adverse impacts of development projects.

Most of the EIA methods described in Chapter 3 focus on clearly identifying impact pathways. They rely on underlying conceptual models linking project activities to changes in environmental components. In using these methods, predictions of the degree of change may be qualitative or quantitative. Qualitative approaches depend heavily on expert judgement; quantitative approaches rely on mathematical models developed by experts. This chapter discusses some of the technical and scientific methods available to predict environmental changes. It focuses on quantitative models for prediction.

4.1 Predictive Methods

In their review of EIA methods, Canter and Sadler (1997) provide a listing of prediction techniques applicable to different aspects of EIA (Table 4-1). Canter (1996) provides an excellent overview, based on American experience, of many of these prediction techniques. In many EIA applications, these basic prediction techniques are actually combined. This is particularly true when using computerized modeling software for specific applications, as the application of a computer model usually requires collection of environmental information to set baseline values for the model's variables and to determine the values for model's parameters.

Table 4-1: Prediction techniques applicable in EIA (*source:* adapted from Canter and Sadler, 1997).

Air	1. emission inventory 2. urban area statistical models 3. receptor monitoring 4. box models 5. single to multiple source dispersion models 6. monitoring from analogs 7. air quality indices
Surface Water	1. point and nonpoint waste loads 2. QUAL-IIE and many other quantitative models 3. segment box models 4. waste load allocations 5. water quality indices 6. statistical models for selected parameters 7. water usage studies
Ground Water	1. pollution source surveys 2. soil and/or ground water vulnerability indices 3. pollution source indices 4. leachate testing 5. flow and solute transport models 6. relative subsurface transport models
Noise	1. individual source propagation models plus additive model 2. statistical model of noise based on population 3. noise impact indices

Biological	1. chronic toxicity testing 2. habitat-based methods 3. species population models 4. diversity indices 5. indicators 6. biological assessments 7. ecologically based risk assessment
Historical/Archaeological	1. inventory of resources and effects 2. predictive modeling 3. prioritization of resources
Visual	1. baseline inventory 2. questionnaire checklist 3. photographic or photomontage approach 4. computer simulation modeling 5. visual impact index methods
Socioeconomic	1. demographic models 2. econometric models 3. descriptive checklists 4. multiplier factors based on population or economic changes 5. quality-of-life (QOL) indices 6. health-based risk assessment

A large selection of computer software is available for use in EIA. Most programs are for specific applications; many are available free of charge from government agencies and may be downloaded from the Internet. This chapter lists many of the models that are available, and provides addresses for accessing the models on the World Wide Web.

4.2 Models and Modeling

Modeling is a step by step process by which models are developed and/or applied. The three most common types of models used in EIA are physical models, experimental models, and mathematical models.

4.2.1 Physical Models

Physical models are small-scale models of the environmental system under investigation on which experiments can be carried out to predict future changes. Two types of physical models are discussed here: illustrative or visual models, and working physical models (ERL, 1984).

Illustrative/visual models depict changes to an environmental system caused by a proposed development activity using pictorial images developed from sketches, photographs, films, "photo montages," three-dimensional scale models, and by digital terrain models or digital image processing systems. Figure 4-1, sketch of a dam site, exemplifies an illustrative/visual model.

Working physical models, on the other hand, simulate the processes occurring in the environment using reduced scale models so that resulting changes can be observed and measured in the model. Such models, however, cannot satisfactorily model all real-life situations; faults may occasionally arise as a result of the scaling process. Figure 4-2 shows a three-dimensional physical model of an industrial plant site.

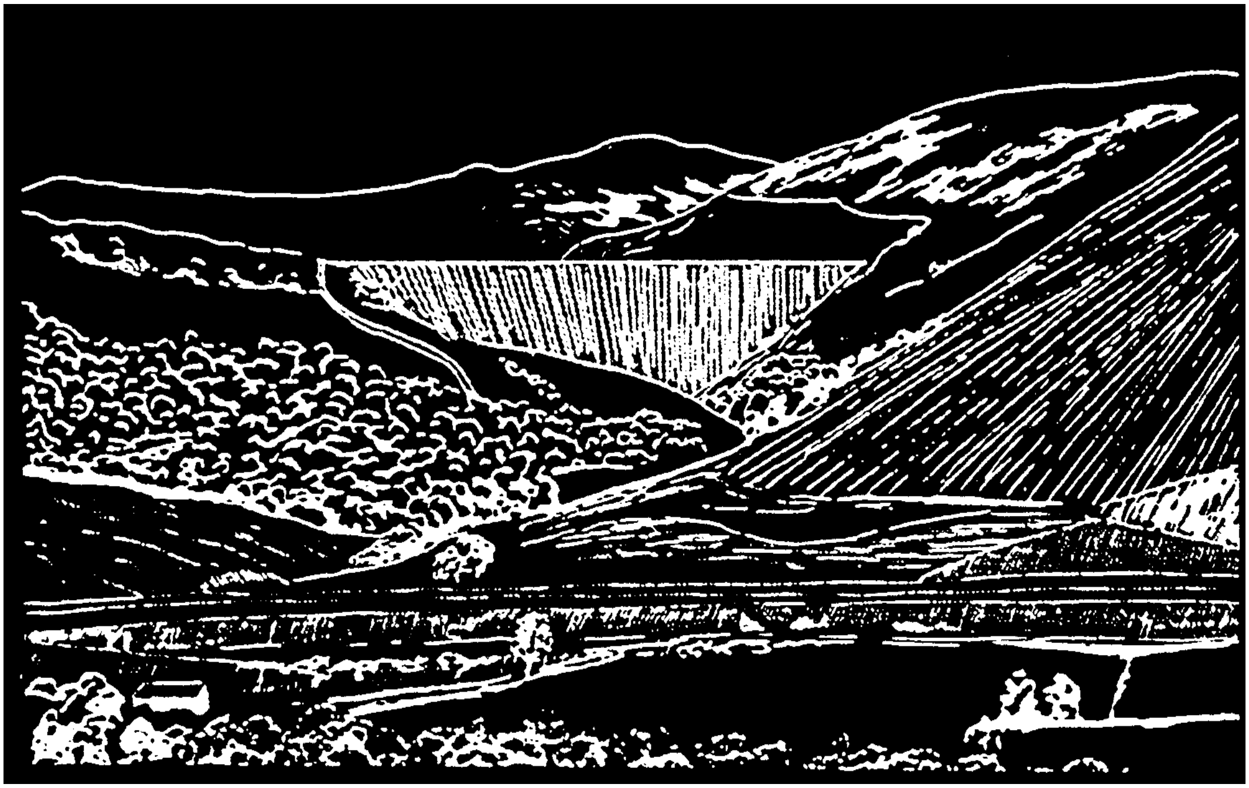


Figure 4-1: Sketch of a dam (*source:* ERL, 1984).

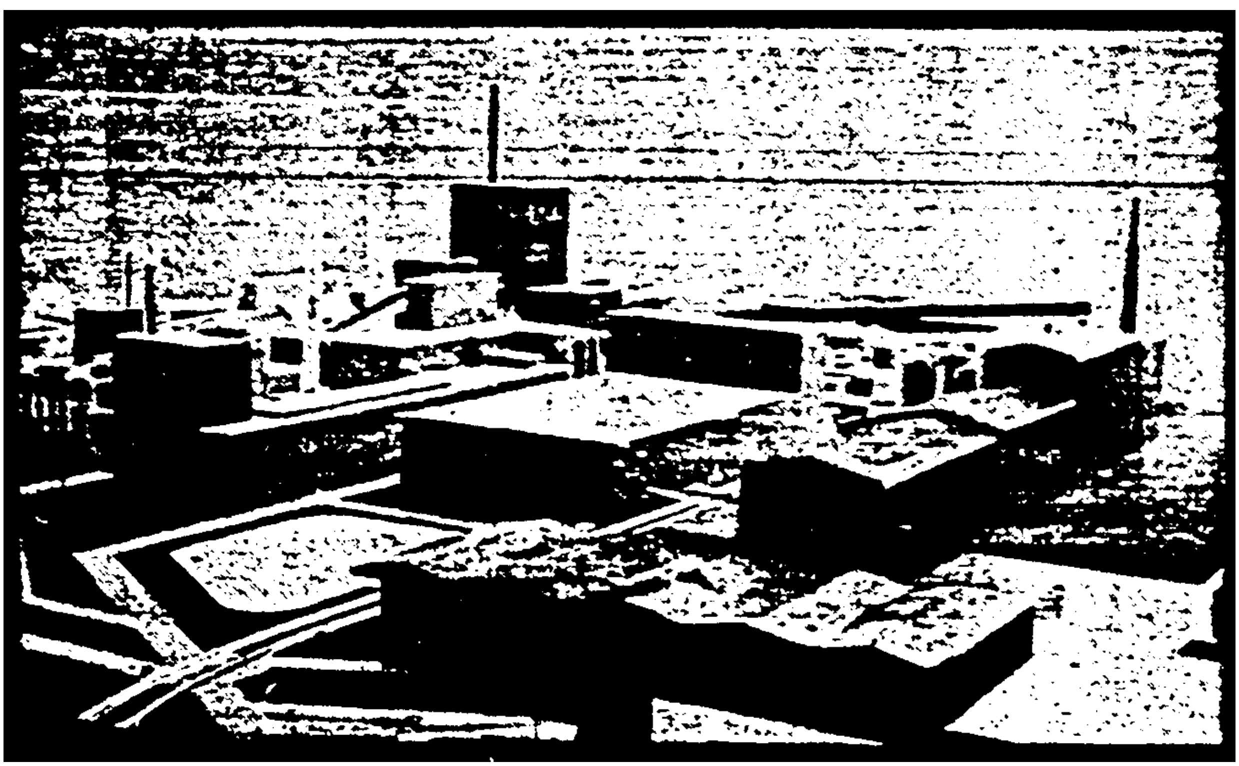


Figure 4-2: Three-dimensional physical model of an industrial plant (*source:* ERL, 1984).

Steps in Physical Modeling

The basic steps in developing physical models are:

1. Define the environmental system to be modeled, the system's salient features, and the effect requiring prediction.
2. Select a suitable existing model facility or construct a special facility. Activities may include photographing the proposed site, and then sketching a new storage terminal on the photographs to determine the visual effect of the development, or using an existing wave chamber to predict water and sediment movements in an estuary after the construction of a new dock.
3. If no appropriate model or facility exists, one may be constructed — for example, one could construct a model of the mentioned estuary, simulating hydrological conditions in the estuary (for example, flows, density, currents, waves, etc.), using an existing chamber facility. In such a case, data on morphology, hydrological conditions, and sediment movements in the estuary should be collected in order to construct a model with similar conditions.
4. Test the validity of the model by comparing its behavior with observations in the field. Adjust the model as necessary after observations.
5. Simulate the source and the conditions in the surrounding environment using appropriate methods and observe or measure the relevant changes in the model. Extrapolate the observations or measurements to predict the effects in the real environment.
6. Interpret the results, taking into account simplification of the real world made by the model.

Resource Requirements

In some cases, physical modeling exercises may be carried out in existing facilities of public and private organizations. If such facilities do not exist and funding permits, facilities may be constructed for prediction purposes. This is, however, rarely possible. Many illustrative models require less effort and expense than working physical models, although the more sophisticated computerized visual simulation models available are substantially more costly. Technical expertise and large quantities of data are required to construct working physical models that adequately simulate the behavior of the real environment. Validation and interpretation of the results of modeling may also require time and technical expertise.

4.2.2 Experimental Models

Scientific data from laboratory or field experiments provide basic information on the relationships between environmental components and human activities. Research results are used to construct empirical models that can infer the likely effects of an activity on an environmental component. Examples of experiments in which the environmental system is modeled and tested in the laboratory include toxicological tests on living organisms using polluted air, water, food, etc.; micro-ecosystem experiments; and pilot-scale plant tests.

Examples of experiments in which tests are carried out in the actual environment include *in situ* tracer experiments to monitor the movement of releases into the environment; controlled experiments in small parts of potentially affected ecosystems; noise tests to determine levels of disturbance; and pumping tests on groundwater.

Steps in Experimental Modeling

The basic steps in experimental modeling are:

1. Define the environmental system to be modeled, the system's salient features, and the effect requiring prediction.
2. Select a suitable experimental approach and define the specific method to be employed. Experimental activities may range from a simple laboratory determination of the level of a specific contaminant in a river and its consequent effects on fish behavior, to an *in situ* tracer experiment approach to predict the dispersion of a pollutant from a proposed sea outfall.
3. Collect the data needed to set up the experiment. To predict the effect of a pollutant on fish behavior, it might be necessary to gather data on river flow and present water quality to simulate the river. Sample fish may be caught and used in the laboratory experiment. Moreover, to predict dispersion of a pollutant in sea water using tracer elements, data should be collected on water movements and location of sensitive receptors to determine appropriate monitoring points.
4. Carry out the experiment, and observe and measure the relevant change in the system. For example, effects of different pollutant concentrations on the fish should be observed and measured. The concentration of tracer elements in the sea outfall should likewise be measured to determine their dispersion.
5. Extrapolate, whenever necessary, from the observations and measurements to predict the effects of the activity in the real environment. In the above two examples, this may necessitate estimating the approximate dose-effect relationships between the fish species and the pollutant, and determining dilution factors to predict the dispersion of the pollutant in sea water.
6. Interpret the results, taking into account the possible differences between experimental and actual circumstances. For instance, in the fish experiment, the absence of uptake by other organisms and the consequent reduction of dissolved oxygen in the experiment and its implication as to the accuracy of the predictions should be discussed. In the same manner, the real life contribution of such factors as decay in sunlight, different densities, and absence of biodegradation (which are controlled in the tracer experiment to predict the dispersion of a pollutant in sea water) should be accounted for and discussed in the assessment.

Resource Requirements

Experimental modeling requires substantial amounts of money, effort, time, and expertise in specialized fields.

4.2.3 From Conceptual Modeling to Computer Modeling

The first step in developing a predictive model is to construct a conceptual model. Most of the methods discussed in Chapter 3 (for example, networks and impact hypotheses) are based on conceptual models. To develop a quantitative predictive model, one must first represent conceptual models as mathematical equations. Once the conceptual models are represented in mathematical language, they are amenable to computation and computerization. For example, dispersion modeling is one of most commonly used techniques for predicting changes in air quality associated with emissions of pollutants. Relatively well established models (for example, the US Environmental Protection Agency's (EPA) computerized air quality models) are used throughout the world. These models are based on mathematical equations that represent a simplification of basic physical processes occurring in the atmosphere. They take, as input, 1) emission of pollutants (or loadings); 2) basic meteorological data; and 3) background concentrations of pollutants. They produce, as output, estimates of pollutant concentrations. These estimates are usually provided graphically as isopleths (contours lines of equal concentration) plotted around the source point.

4.2.4 Mathematical Models

Mathematical models use mathematical equations to represent the functional relationships between variables. In general, sets of equations are combined to simulate the behavior of environmental systems. The number of variables in a model and the nature of the relationships between them are determined by the complexity of the environmental system being modeled. Mathematical modeling aims to limit, as much as possible, the number of variables and thus keep the relationships between variables as simple as possible without compromising the accuracy of representation of the environmental system.

$$C_1 = \frac{Q_o C_o + Q_e C_e}{Q_o + Q_e}$$

An example of a mathematical model is a simple water quality mixing model which is based on the simplest of mass balance equations. The water quality model below assumes continuous discharge of a conservative contaminant into a stream.
where:

C_1 is the downstream concentration;
C_o is the upstream concentration;
C_e is the effluent concentration;
Q_o is the upstream flow; and
Q_e is the effluent flow.

This model may be used to predict changes in downstream effluent concentrations in response to pollutants loading by changing the values of effluent concentration (C_e) and the effluent flow (Q_e).

Types of Mathematical Models

Mathematical models can be described according to the following features:

1. *Empirical or internally descriptive:*
   - *empirical* because they can be derived solely on the basis of statistical analysis of observations from the environment to find the "best fit" equation (empirical models are sometimes called “black box” models); or
   - *internally descriptive* because equations are based on *a priori* understanding of the relationship between variables. The equations therefore represent some theory or assumption of how the environment works.

2. *Generalized or site-specific:*
   - *generalized*, as they can be applicable to a range of different environment allocations which meet certain specific characteristics; or
   - *site-specific*, as they can be developed or applied only to a specific environmental location.

3. *Stationary or dynamic:*
   - *stationary*, if conditions in the model are fixed over the period of the prediction; or
   - *dynamic*, if the predictions are made over a period of time in which conditions in the environment change.

4. *Homogeneous or non-homogeneous:*
   - *homogeneous*, as they can assume that conditions at the source prevail throughout the area over which predictions are made; or
   - *non-homogeneous*, as environmental conditions affecting the predicted outcome vary with distance from the source.

5. *Deterministic or stochastic:*
   - *deterministic*, as input variables and relationships are fixed quantities and the predicted outcome from a given starting point is a single, unique value; or
   - *stochastic*, as simple variables and parameters may be described probabilistically. These models reflect the natural variations occurring in the environment and results are presented as a frequency distribution of probable outcomes rather than as a single value.

Steps in Mathematical Modeling

There are seven steps in mathematical modeling, although not all seven must be applied in every modeling case.

1. Define the environmental system to be modeled, the system's salient features, and the effect requiring prediction (for example, the prediction of maximum concentration of a water contaminant in an area downstream from its point of discharge).
2. Select an appropriate pre-defined model or develop a new model (for the above example, a pre-defined model may be used to predict the downstream concentration, or in the absence of a pre-defined model, it may be necessary to formulate a suitable new model).
3. Collect the necessary data from existing sources or by monitoring and surveying (for the above example, data on the input variables (upstream concentration, discharge concentration, upstream flow and discharge flow) can be collected through actual monitoring and surveying).
4. If necessary, define the model parameters for the particular application, using either standard values or experimental data (calibration). For example, to predict the average annual and maximum concentration of a pollutant emitted from a single tall stack in an open rural area, a set of atmospheric dispersion parameters should be defined for the different classes of meteorological conditions using standard empirical formulae applicable to tall stacks in open rural areas.
5. Test the validity of the model for the intended use by comparing its behavior with observations from the field.
6. Apply the model to predict the future condition of the environment.
7. Communicate the model results and assumptions to the nonspecialist. All relevant variables, relations, assumptions, and factors omitted from the analysis should be identified and their implications for the results discussed.

Resource Requirements

Mathematical models require varying amounts of resource inputs. A simple model, such as the river dilution model used in the above example, may require minimal input data and simple manual calculation, while a complex Gaussian plume model may require sophisticated computer techniques and demand considerable resources of input data, time, and expertise.

Assuming that an existing software program may be used, the costs of using the model may be limited to preparing the input data and to labor costs for technical staff or outside experts to run the model and interpret the results.

4.3 Predicting Quantitative Environmental Changes

Predictive methods for estimating quantitative changes in the environment have been commonly applied to physical systems (air, water, noise), have had some application to ecological systems, and have had limited application to social systems. Predictive models are used in EIA in two distinct ways: 1) comparison of model results with environmental standards; and 2) the evaluation of project alternatives (de Broissia, 1986). This section presents the basic scientific and technical concepts underlying quantitative models and their application in the EIA context. Where possible, experience in using the models in a developing country context is highlighted in an attempt to assess the appropriateness of applying the models in developing Asia.

4.3.1 Air Quality

Conceptual Model

Atmospheric changes are generally caused by the release of reactive substances into air by stationary or mobile sources, and by changes in surface morphology (for example, the construction of large buildings, clearance of vegetation, forestation, and creation of water impoundments). Possible environmental changes range from first order (immediate impact) effects of changes in concentration of substances in the air to higher order (longer-range and secondary impacts) effects of physical and chemical changes on climate (for example, turbulence effects, haze, microclimates over water, heat emission effects, greenhouse effect); to the deposition of substances on soils, water, materials and vegetation; to effects of deposited substances on materials (for example, soiling, corrosion); to effects of changes in climate and air quality on visibility in the atmosphere). Figure 4-3 summarizes the cause-effect network for atmospheric effects.

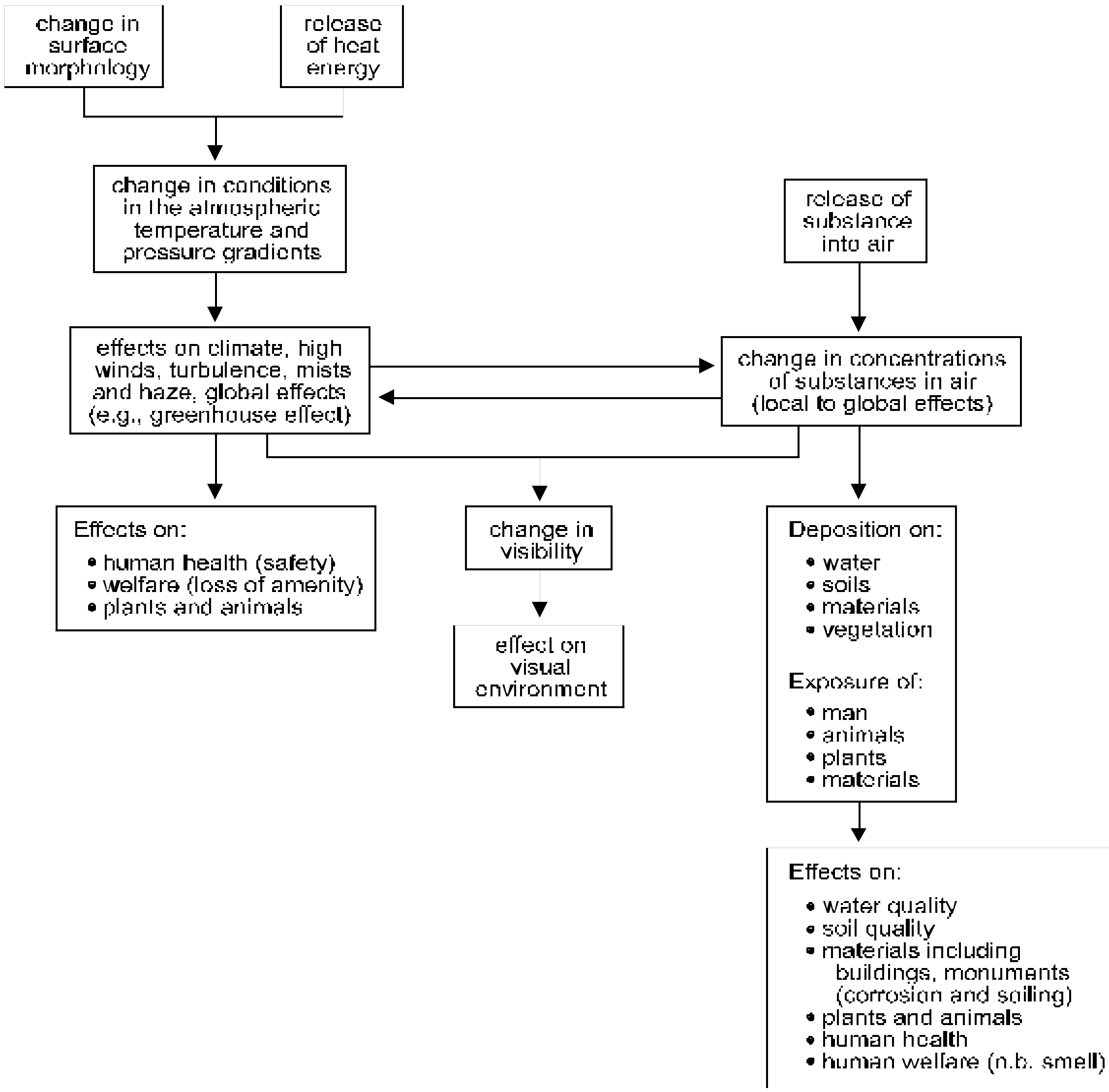


Figure 4-3: Summary cause-effect network for atmospheric effects (*source:* ERL, 1984).

Basic Concepts

There are basically three aspects of air quality problems that are amenable to quantitative prediction. In order of increasing complexity, they are:

1. estimating rates of release of pollutants;
2. predicting atmospheric concentrations of pollutants; and
3. predicting deposition rates on pollutants on soil, water, and vegetation.

Predictions of concentrations and deposition rates are often needed as inputs into other predictive models to determine the potential for secondary and higher order impacts.

Estimating Releases

In all cases, it is necessary to estimate the rates of release of pollutants. Rates of release of substances may be available from design data or from data of similar activities in operation. If this information is not available, rates of release can be calculated using emission factor models. These models assume that the rate of release is directly proportional to the level of implementation of the activity, an assumption represented by the following general equation:

$$R = E\,A$$

where:

R is the rate of release (quantity/unit time);
E is the emission factor (quantity/unit activity); and
A is the rate of activity (unit activity/unit time).

The basic information needed about the release of substances from an activity will include the nature of the substances released, the timing and location of releases, and the quantity of substances released per unit time and/or per unit area. For certain types of pollutants, emissions may be directly assessed against legal standards and guidelines without resorting to predicting their effect on air quality. The criteria against which emissions can be evaluated include:

- standards for emission quality (concentration of substance);
- standards for rate of emission (per unit time or unit activity);
- policy objectives requiring no deterioration from conventional practice; and
- policy objectives requiring achievement of the best practicable control.

The rapid assessment procedure (discussed in section 3.8) illustrates how this approach may be used in developing countries to estimate emissions.

Canter (1996) describes the U.S. EPA approach to compiling an emission inventory for use in an EIA. In summary, this approach has the following basic steps:

1. classify all pollutants and pollutant sources that will derive from the proposed project, considering all stages of the project;
2. identify and compile information on emission factors for each source of each of the pollutants;
3. determine appropriate unit production information for each source;
4. calculate the release rate for each source (unit production multiplied by emission factor); and
5. sum each of the specific pollutant emissions from all sources.

The predicted increases in pollutant emissions due to the project are compared against the existing inventory of pollutants to estimate the percentage increase in the overall emissions inventory. The percentage change is then assessed to make a determination of the significance of the increase of emissions. These interpretations can be based on: 1) the existing air quality; 2) the quantity of emissions and size of the percentage change; 3) the period of the percentage change; 4) the potential for visibility reduction; and 5) any local receptor sensitive to damage from the pollutants (Canter, 1996).

Predicting Changes in Concentrations

The assessment of air quality impacts usually focuses on determining concentrations of air pollutants. Predicted concentrations are often compared against national or local air quality standards or objectives. Much of the pre-project air quality data collection is directed at determining pollutant concentrations at different times, at different locations, and the variations in concentration in time and in space. This information not only determines a baseline for comparison against changes, but also provides background information for predictive models.

In cases where there is concern for higher order effects, predictions of pollutant concentrations are necessary inputs into predictions of deposition rates; exposure to flora, fauna, and man; and changes to local climate and visibility.

Dispersion Models

Air quality dispersion models are among the most widely used predictive tools used in EIA in both developed and developing countries. Dispersion models have evolved to the state where their predictions take into the following atmospheric processes:

- plume rise;
- advection transport by wind;
- vertical, lateral, and horizontal diffusion caused by turbulence;
- reflection from the ground and from the top of the mixing layer;
- physical-chemical transformation of pollutants in air, including radioactive decay, photochemical reactions, and aerosol formation;
- gravitational settling of particulate pollutants;
- dry deposition, that is, uptake of substances onto soil or other surface material by chemical, biological, or physical processes occurring at the interface;
- wet deposition, that is, rain-out and wash-out of substances onto the surface;
- behavior of plumes in response to variations in the land surface;
- entrainment of plumes in the lee of buildings;
- variations in atmospheric diffusion conditions with height above the surface;
- variations in emission rate and/or in meteorological conditions over the period of prediction;
- variations in meteorological and/or topographical conditions with distance from the source; and
- random variation in environmental conditions and emissions.

The data required for dispersion models include source data, meteorological data, topographical data, dispersion parameters, deposition rate parameters, and reaction rate parameters. These data may be obtained from secondary sources, however field studies may need to be conducted to obtain meteorological and topographical data and to calibrate and/or validate the model. Various models can be derived to represent specific atmospheric processes of interest to a certain study. The most commonly used models are the Gaussian plume dispersion models which enable one to predict ground level concentrations of pollutants several kilometers from the source.

Predicting Deposition on Plants, Soils, Water, and Materials

Different types of models may be employed for the three deposition processes, namely:

- gravitational settling affecting dust and aerosols;
- wet deposition affecting water soluble pollutants such as NO_x, SO_x, NH_3, Cl, F, etc. and particulates which may form condensation nuclei and which may combine with rainfall; and
- dry deposition affecting chemically, biologically and physically reactive pollutants absorbed by or into soil, vegetation, materials, and water. (Air pollutants affected by dry deposition include gases such as SO_2, F, Cl, CO, CO_2, NO_2, NH_3, aerosols, ozone, PAN [peroxyacetyl nitrate -- a product of photochemical pollution], and fine particulates.)

Simplified semi-empirical equations are available for calculating gravitational settling and wet and dry deposition. Gravitational settling can be calculated using an empirical settling velocity dependent on the spectrum size and density; it is proportional to the ground level of concentration. It can be represented in dispersion models by tilting the plume downwards.

A simplified model for long-term deposition of particulates, assuming that the total emissions are deposited evenly over a specified area near the source, is given by the equation:

Install Equation Editor and double-click here to view equation.

where:

F is flux or deposition (kg/m^2/yr);
E is emission rate (kg/yr); and
A is surface area (m^2).

Dry deposition rates may be calculated by assuming that the vertical flux is proportional to the ground level concentration and by using an empirical dry deposition parameter:

$$F = V_d C$$

where:

F is vertical flux (ug/m^{2}s);
V_d is deposition velocity (m/s); and
C is ground level concentration (ug/m$^{3)}$.

Wet deposition rates may be calculated by assuming that vertical flux is proportional to the mathematical integral of the concentration over the plume height. Expert advice is needed to identify appropriate areas in gravitational settling models to determine and identify appropriate values for deposition parameters in modeling wet and dry deposition. When wet and dry deposition models are incorporated within dispersion models, the reduction in concentrations in the plume (caused by deposition) may be accounted for by reducing the source strength (that is, the emission rate) accordingly.

Predicting Effects of Deposition - MAGIC Model

The Model of Acidification of Groundwater In Catchments (MAGIC) is a lumped parameter model of intermediate complexity that was originally developed to predict the long-term effects (decades or centuries) of acidic deposition on responses in annual surface water chemistry (Thornton et al, 1990). MAGIC requires input data on annual precipitation volume, time averaged annual concentrations for chemical constituents in deposition, watershed attributes (for example, catchment area, stream length), soil physical and chemical variables, lake and stream physical attributes and discharge rates and initial lake and stream water chemistry conditions.

MAGIC may be used with a dispersion model that provides a spatial pattern of deposition over time. MAGIC was used to help design and implement an investigation of acid deposition in Northern Thailand. This investigation was conducted as a follow-up on the EIA of Mae Moh mine, Mae Moh power plants units 1-11, Lampang power plant units 1-8 and a water supply system (Schultz International Limited, 1993).

Predicting Soiling and Materials Damage Caused by Exposure to Air Pollution

Empirical models may be used whenever available. Where applicable, experiments may also be set up to determine the extent of damage. Generally, however, damage to materials by soot, smoke, and dust as well as metal corrosion by air pollutants may be predicted from historical evidence and by expert advice.

Predicting Effects on Visibility in the Atmosphere

Empirical models have been developed to predict the effects of air pollution on visibility. These models relate concentration of specified substances (notably smoke, $N0_x$, NH_4SO_4, and NH_4NO_3 aerosols) to the distance of maximum visibility. Historical evidence and expert advice may also provide inputs for predicting effects of air pollutants on visibility.

Areas of Application

The U.S. EPA has developed standardized dispersion models that have been adopted by many countries and many EIA practitioners (Tables 4-2 and 4-3). These models are available from the U.S. EPA and may be downloaded from their home page (*www.epa.gov*) on the Internet.

The choice of model for a given application will be based on:

- need for accuracy in prediction;
- type of emission — point, area, line, module, hot or cold intermittent, or continuous;
- meteorological conditions in the receiving area (wind turbulence, stability, inversions, mixing layer height, rainfall);
- topographical conditions in the receiving area;
- location of receptors;
- nature of effects on receptors; and
- nature of substance emitted.

Table 4-2: Air quality modeling software available from the Support Center for Regulatory Air Models - U.S. EPS Office of Air Quality Planning and Standards (*source:* Internet - *www.epa.gov/scram001*).

Model	Description
BLP Buoyant Line and Point Source Dispersion	BLP is a Gaussian plume dispersion model associated with aluminum reduction plants.

Model	Description
Model	
CALINE3 California Line Source Model	CALINE3 is a line-source dispersion model that can be used to predict carbon monoxide concentrations near highways and arterial streets given traffic emissions, site geometry, and meteorology.
CDM2 Climatological Dispersion Model	CDM2 is a climatological dispersion model that determines long-term quasi-stable pollutant concentrations.
COMPLEX I	COMPLEX I is a multiple point-source code with terrain adjustment representing a sequential modeling bridge between VALLEY and COMPLEX II.
CRSTER	CRSTER estimates ground-level concentrations resulting from up to 19 co-located elevated stack emissions.
EKMA	EKMA was developed for relating concentrations of photochemically formed ozone to levels of organic compounds and oxides of nitrogen.
ISC2 Industrial Source Complex Short-Term2 and Industrial Source Complex Long-Term2	ISC2 is a steady-state Gaussian plume model which can be used to access pollutant concentrations from an industrial source complex.
LONGZ-SHORTZ	LONGZ-SHORTZ is designed to calculate the long and short-term pollutant concentrations produced at a large number of receptors by emissions from multiple stack, building, and area sources.
MPRM 1.2 Meteorological Processor for Regulatory Models	MPRM 1.2 provides a general purpose computer processor for organizing available meteorological data into a format suitable for use by air quality dispersion models. Specifically, the processor is designed to accommodate those dispersion models that have gained EPA approval for use in regulatory decision making.
MPTER	MPTER is a multiple point-source Gaussian model with optional terrain adjustments.
PTPLU	PTPLU is a point-source dispersion Gaussian screening model for estimating maximum surface concentrations for one-hour concentrations.
RAM	RAM is a short-term Gaussian steady-state algorithm that estimates concentrations of stable pollutants.
RTDM Rough Terrain Diffusion Model	RTDM is a sequential Gaussian plume model designed to estimate ground-level concentrations in rough (or flat) terrain in the vicinity of one or more co-located point sources.
TOXST/TOXLT Toxic Modeling System Short Term and Long Term	TOXST/TOXLT are designed to assist in the evaluation of acute health hazards that may result from short- and long-term exposure to air pollutants.
UAM Urban Airshed Model	UAM is a three-dimensional grid based photochemical simulation model for urban scale domains.
VALLEY	VALLEY is a steady-state, univariate Gaussian plume dispersion algorithm designed for estimating either 24-hour or annual concentrations resulting from emissions from up to 50 (total) point and area sources.
WRPLOT	WRPLOT is an interactive program that generates wind rose statistics and plots for selected meteorological stations for user-specified date and time ranges. The wind rose depicts the frequency of occurrence of winds in each of 16 direction sectors (north, north-northeast, northeast, etc.) and six wind speed classes for a given location and time period.

Table 4-3: Models available from the U.S. EPA Office of Research and Development (*source:* Internet - *www.epa.gov/scram001*).

Model	Description
APRAC-3	APRAC-3 contains the emission factor computation methodology and treats traffic links in the primary network with low vehicle miles traveled as area sources.
CTDMPLUS	CTDMPLUS is a refined air quality model for use in all stability conditions for complex terrain applications.
CTSCREEN	CTSCREEN is the screening mode of CTDMPLUS. Refer to CTDMPLUS above for all document information for this model.
HIWAY-ROADWAY	HIWAY-ROADWAY are two models which compute the hourly concentrations of non-reactive pollutants downwind of roadways and predict pollutant concentrations within two hundred meters of a highway respectively.
INPUFF	INPUFF is a Gaussian integrated puff model which is capable of addressing the accidental release of a substance over several minutes or of modeling the more typical continuous plume from a stack.
MESOPUFF	MESOPUFF is a Lagrangian model suitable for modeling the transport, diffusion and removal of air pollutants from multiple point and area sources at transport distances beyond 10-50 KM.
MPTDS	MPTDS is a modification of MPTER that explicitly accounts for gravitational settling and/or deposition loss of a pollutant.
PAL Point, Area and Line Source Algorithm Model	PAL is a short-term Gaussian steady state algorithm that estimates concentrations of stable pollutants from point, area and line sources.
PBM Photochemical Box Model	PBM is a simple stationary single-cell model with a variable height lid designed to provide volume-integrated hour averages of 0_3 and other photochemical smog pollutants for an urban area for a single day of simulation.
PEM Pollution Episodic Model	PEM is an urban scale air pollution model capable of predicting short-term average surface concentrations and deposition fluxes of two gaseous or particulate pollutants
PLUVUE	PLUVUE is a model that predicts the transport, atmospheric diffusion, chemical conversion, optical effects and surface deposition of point-source emissions.
SDM Shoreline Dispersion Model	SDM is a multipoint Gaussian dispersion model that can be used to determine ground-level concentrations from tall stationary point source emissions near a shoreline environment. SDM is used in conjunction with MPTER algorithms to calculate concentrations when fumigation conditions do not exist.
TUPOS	TUPOS is a Gaussian model that estimates dispersion directly from fluctuation statistics at plume level.
Guidance Documentation	Guidance on the Application of Refined Dispersion Models for Air Toxics
Guidance Documentation	Evaluation of Dense Gas Simulation Models.

Summary of Air Quality Models Used in Developing Country EIAs

Examples of the use of air quality models in developing country EIAs are relatively easy to find. The most common applications are for thermal power plants and linear developments such as highways.

Industrial Source Complex Short-Term Model (ISCSTM): The ISCSTM model was used in the Mangalore Thermal Power Plant project air quality analysis for receptors up to distances of 20 to 25 km. It is capable of predicting for both simple terrain (below the top of the stack) and complex terrain. It calculates hourly concentrations based on hourly meteorological parameters. These are processed into non-overlapping, short-term and annual averaging periods. It contains both rural and urban model options.

PTPLU (from the UNAMAP series of US EPA) and ISC2 (Industrial Source Complex): The Nong Chok Gas Turbine Power Plant Block 1-4 used PTPLU to do their air quality screening. They also used ISC2 (Industrial Source Complex), an EPA steady state Gaussian plume model, designed for regulatory use in urban areas. This model was also used to measure ground level concentrations of pollutants from the South Bangkok Combined Cycle Block-2. This latter EIA developed its own model for thermal plume modeling.

Complex-I (EPA): Complex-I was developed specifically to treat dispersion from point sources involving complex terrain, where sections of land areas surrounding the source may have elevations as high or even higher than the emitting stack. This model was used in the Suralaya Steam Power Station Expansion, Indonesia.

CAL3QHC (EPA): CALC3QHC is used to predict pollutant concentration near roadway intersections. It was used to predict CO concentrations for the Thonburi Road Extension Project, Thailand.

AIRDISP (Developed by ELSAMPROJEKT A/S in Denmark) and SCREEN (EPA): Both of these Gaussian dispersion models of the point source type used for determining maximum concentrations and its distance from the source were used in the Masinloc Coal Fired Thermal Power Plant project, Philippines. The most important difference between the models is the number of parameters included in the modeling technique applied. The AIRDISP model is the most advanced, taking local meteorological data as well as terrain levels within the area covered by the calculation into account; this is not possible with the SCREEN model. Calculations of one-hour maximum concentrations for SO2, NO2 and particles were made with both models, and where comparisons can be made directly, the results are almost identical. SCREEN is a relatively simple model which is normally used for an initial judgement of pollution sources and which generally calculates very conservatively. It is only capable of handling one emission source per calculation. In a case of more than one source, the worst case source is selected as representative. The AIRDISP model was used for stack height dimensioning until the mid-1980s and was required in connection with regulatory use. It uses basically the same techniques as SCREEN, but is more advanced in several fields. It makes it possible to use frequency distribution of local meteorological data divided according to wind direction, wind speed, and stability class. Terrain levels are included in the model and stated as receptor heights in the entire area covered by the calculation. Finally, it is possible to include more than one source (up to 5) which are assumed to be located in the same geographic point.

VALLEY (EPA) and IMPACT: These models were used in the air quality assessment at Mae Moh. The VALLEY algorithm is a steady-state, univariate Gaussian plume dispersion algorithm designed for estimating either 24 hour or annual concentrations resulting from emissions from up to 50 (total) point and area sources. Calculations of ground level pollutant concentrations are made for each frequency designed in an array defined by six stabilities, 16 wind directions, and six wind speeds for 112 program-designed receptor sites on a radial grid of variable scale.

HIWAY (EPA), California Line Source Model, and CALINE2: These are vehicular pollution models used in Malaysia. HIWAY computes the hourly concentrations of nonreactive pollutants downwind of roadways. It is applicable for uniform wind conditions and level terrain. Although best suited for at-grade highways, it can also be applied to depressed highways (cut sections).
CALINE4 (EPA): CALINE4, a line source Gaussian dispersion model in wide use throughout the world, was used for the Bangkok Elevated Road and Train System. It employs the mixing zone concept to characterize pollution dispersion over the roadway, including both thermal and mechanical turbulence.

MOBILE4 (EPA): MOBILE4 was used to determine road vehicle emission rates for the Bangkok Elevated Road and Train project. It calculates emission factors for hydrocarbons, CO, and nitrogen oxides from gasoline-fueled and diesel-fueled highway motor vehicles, based on eight individual vehicle types in two classes of regions (high and low altitude). Estimates depend on various conditions, including ambient temperature, speed, and mileage accrual rates.

4.3.2 Surface Waters

Conceptual Model

Surface waters include rivers, streams, canals, ditches, lakes, reservoirs, lagoons, estuaries, and coastal waters. Impacts on surface waters are usually caused by physical disturbances (for example, the construction of banks, dams, dikes, and other natural or man-made drainage systems), by changes in climatic conditions, and by the addition or removal of substances, heat, or microorganisms (for example, the discharge of effluents and deposition of air pollutants into water). These activities and processes lead to first order effects as manifested by changes in surface water hydrology, changes in surface water quality, and consequently to higher order effects reflected by changes in sediment behavior, changes in salinity, and changes in aquatic ecology. The summary cause-effect network for surface waters is presented in Figure 4-4.

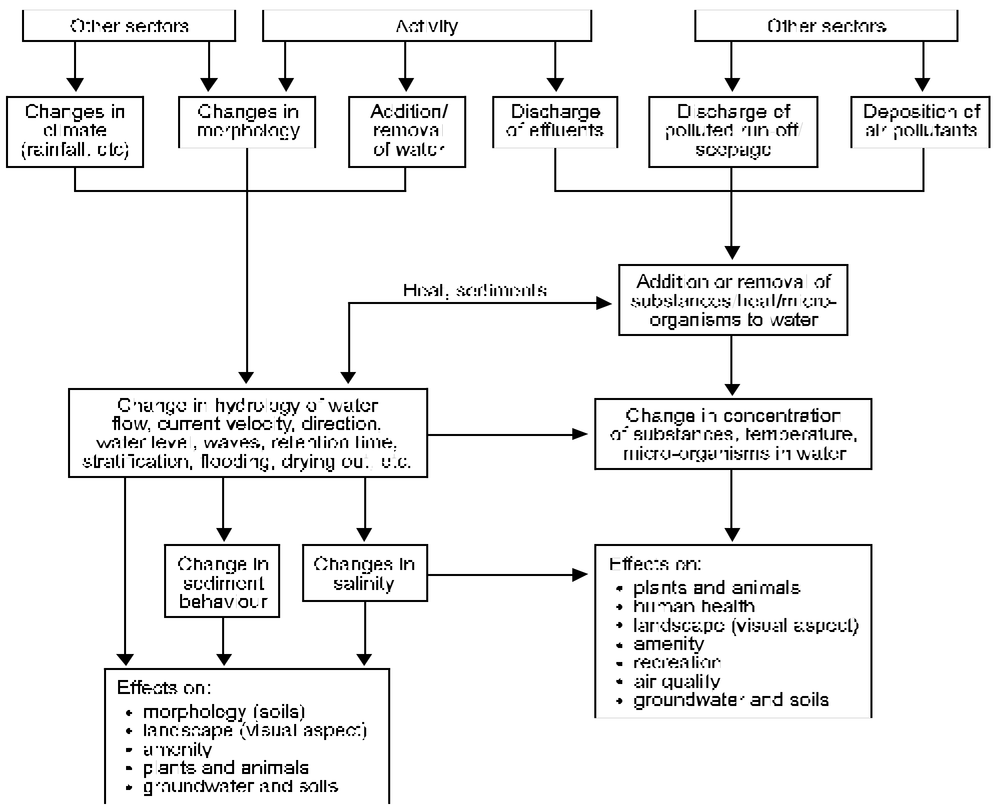


Figure 4-4: Summary of cause-effect network for surface waters (*source:* ERL, 1984).

Basic Concepts

Discharges of Effluents

The calculation of discharges follows the same principles used in calculating releases of emissions to the air discussed under atmospheric impacts (section 4.2.1). Estimates of discharges of pollutants may be available from design data, standard predefined values, monitoring similar operations elsewhere or pilot testing. If this information is not available, it can be calculated using discharge factor models. These models assume the rate of discharge is directly proportional to the level of implementation of the activity. Predictions of effluent discharges into surface waters are based on information on the rate of flow of the discharge, the concentrations of substances present in the discharge, the temperature of the discharge, and the timing and location of discharges.

Data on discharges of effluents may be directly used for comparison of alternatives by comparing the data with existing discharge standards for different types of effluents and receiving water. Estimates of effluent discharge may also be used as inputs into models for predicting effects on hydrology and water quality.

The rapid assessment procedure (discussed in section 3.8) illustrates how this approach may be used in developing countries to estimate effluent discharges.

Run-off Over Land

Run-off into surface water can be predicted by standard mathematical models, experts, and field tests using tracers to determine movement of the run-off and its appearance in surface water bodies. The interest for predicting run-off over land in EIA studies is based mainly on its effects to the hydrology and water quality in receiving water bodies. Special interest may be focused on the run-off of pesticides, fertilizers, and other materials toxic to water bodies used for domestic, agricultural, and recreational purposes.

Mathematical models are available for predicting run-off for:

- permeable or impermeable surfaces;
- sewered or unsewered areas;
- short-term or long-term predictions; and
- quantity or quality, for example, pesticides, sediments, biological oxygen demand, nutrients, dissolved minerals, bacteria, etc.

Run-off models use the same principles to describe the balance between hydrological inputs and outputs to surface run-off (precipitation minus evapotranspiration, infiltration, and storage equals run-off). The basic model may be manipulated to include variables describing relevant processes (for example, erosion, sedimentation, wash-off of chemicals, adsorption, biodegradation, etc.), in which case they can also be integrated to water quality models for the receiving surface waters.

These models require a high level of expert assistance as they need extensive calibration and verification for use in specific areas. Input requirements also include substantial information on rainfall, air temperature, drainage network configuration, soil types, ground cover, land use, and management measures.

Some simple applications of run-off models and their underlying assumptions include:

- prediction of traffic pollutant loads washed off road surfaces through sewers after prolonged dry periods (the accumulated load is assumed to be washed off in the first heavy rainfall and enters surface waters); and
- prediction of the run-off of a conservative pollutant applied within a catchment area (the total amount applied is assumed to be uniformly diluted in the total run-off from the catchment).

Flow Models

Knowledge of water flow is a prerequisite to any water quality modeling. In freshwater systems, hydrological and hydrodynamic models have been developed for use in environmental assessment. In marine systems models have been used to predict currents and water level in coastal and estuarine environments. Many hydrological models are available to calculate time varying flow rates (m^3/sec) in rivers, lakes, and manmade reservoirs. These models are often constructed based on historical data collected at hydrometric monitoring stations.

Hydrodynamic models are based on special cases of the general three-dimensional Navier-Stokes water movement equations. Depending on the nature of the water body, the equations may be reduced to one or two dimensions by depth averaging or cross-section averaging. Large water bodies may be divided into segments and modeled in terms of flows across the boundaries between the segments. Standard computer models are available for relatively simple models, although because of its inherent complexity, mathematical hydraulic modeling requires specialist inputs. The models may also be linked to models for predicting sediment behavior, salinity, temperature, water quality, and surface water movements. Data needed for calibration, validation, and application of mathematical hydraulic models include the system geometry, data on inflows and outflows (time series), initial hydrological conditions, bottom conditions, water levels, and wind conditions.

Oxygen Sag Curve - Streeter Phelps Equation

Models for predicting changes in organic materials usually consider changes in dissolved oxygen resulting from increased demands for oxygen from bacteria during decomposition and supply of oxygen from natural re-aeration. The classical example is the Streeter-Phelps equation that represents the oxygen sag curve The oxygen sag curve (Figure 4-5) illustrates how the oxygen concentration © changes with time and distance downstream of a discharge point. The Streeter-Phelps equation actually represents the dissolved oxygen deficit, (C_s - C) as a function of demand for oxygen and natural aeration, where C_s is the oxygen saturation concentration.

The basic equation is:

$$D_t = \frac{K_1 L_o}{K_2 - K_1} e^{-K_1 t - K_2 t} + D_o e^{-K_2 t}$$

where:

D_t is the dissolved oxygen (DO) deficit at t;
L_o is the BOD concentration at the discharge point immediately after mixing (t=0);
D_o is the initial DO deficit at the point of waste discharge;
t is the time or distance downstream;
K_1 is the parameter of deoxygenation; and
K_2 is the reaeration parameter.

Other processes that affect BOD and resulting dissolved oxygen concentrations, and that can be integrated in this model include algal and plant respiration, benthal oxygen demand, photosynthesis, and nitrogenous oxygen demand.

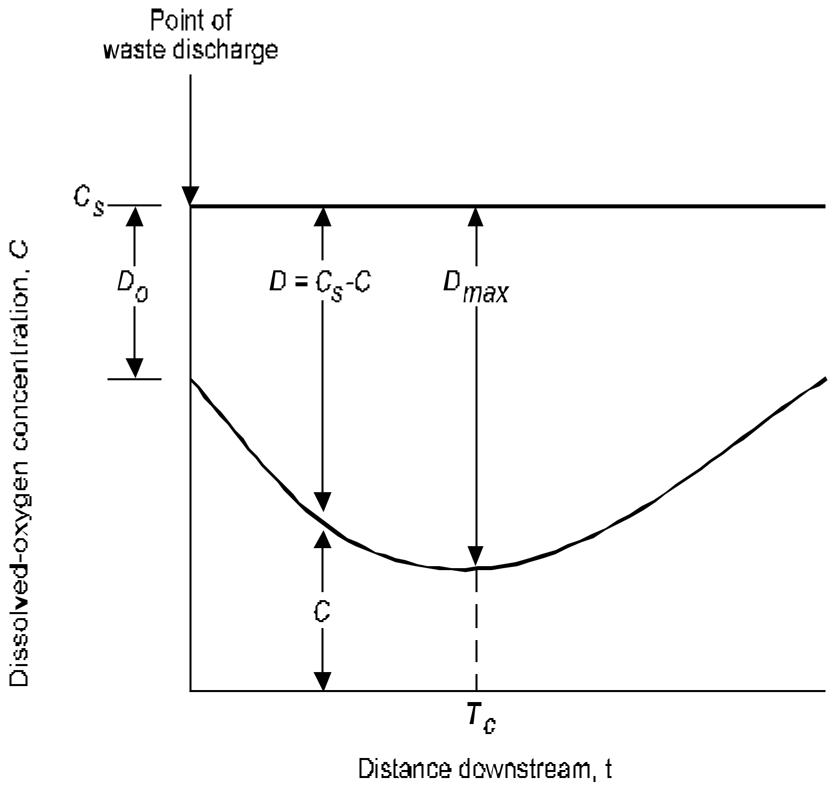


Figure 4-5: Oxygen sag curve obtained from the Streeter-Phelps Equation (*source:* Canter, 1996).

Water Quality - The Mass Balance

The basic concept that underlies most water quality models is that of mass or material balance (Figure 4-6):

$$I + D + F + J = X + R + T$$

where

- I is the inflow into the compartment (mass/time);
- D is the discharge into the compartment (mass/time);
- F is the formation due to biochemical activity in the compartment (mass/time);
- J is the transfer from other compartments (mass/time);
- X is the outflow from the compartment (mass/time);
- R is the degrading reaction (mass/time); and
- T is the transfer to other compartments (mass/time).

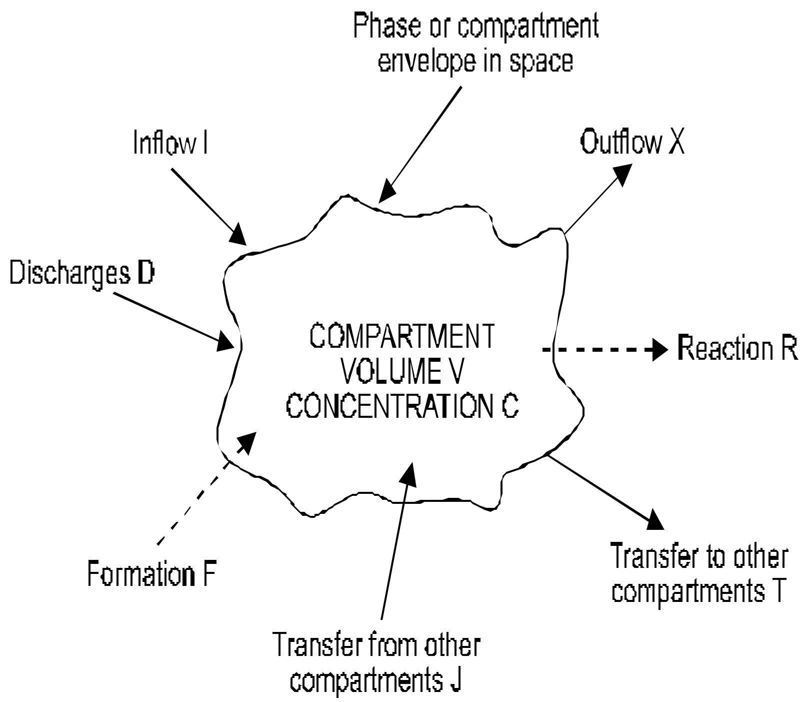


Figure 4-6: Mass balance equation for a compartment (*source:* Mckay and Peterson, 1993).

A volume of space is identified and one or more compartments (for example, air, water, biota) defined. A simple mass or material balance equation is then written for this volume. The mass balance equation states the change in inventory (amount present in the compartment) of a chemical is equal to inputs minus the outputs. The mixing model discussed earlier (section 4.1.4) is perhaps the simplest mass balance model. Canter (1996) describes the mass balance formulation of dissolved oxygen including transport exchanges with air (atmospheric exchange), and biota (production of oxygen due to photosynthesis and respiration (in water column and sediments)).

In cases where there is only one compartment (for example, water) the model may be easily defined. In more complex models, a number of compartments may be present. McKay and Peterson (1993) describe a six compartment model of air, water, fish, soil, bottom sediments, and suspended sediment for estimating the fate of trichloroethylene (Figure 4-7). To describe the fate of trichloroethylene requires estimation of the transfer rates of some fifteen physical, chemical, and biological processes, including rates of sedimentation, run-off from soil, evaporation, reaction, and advective flows.

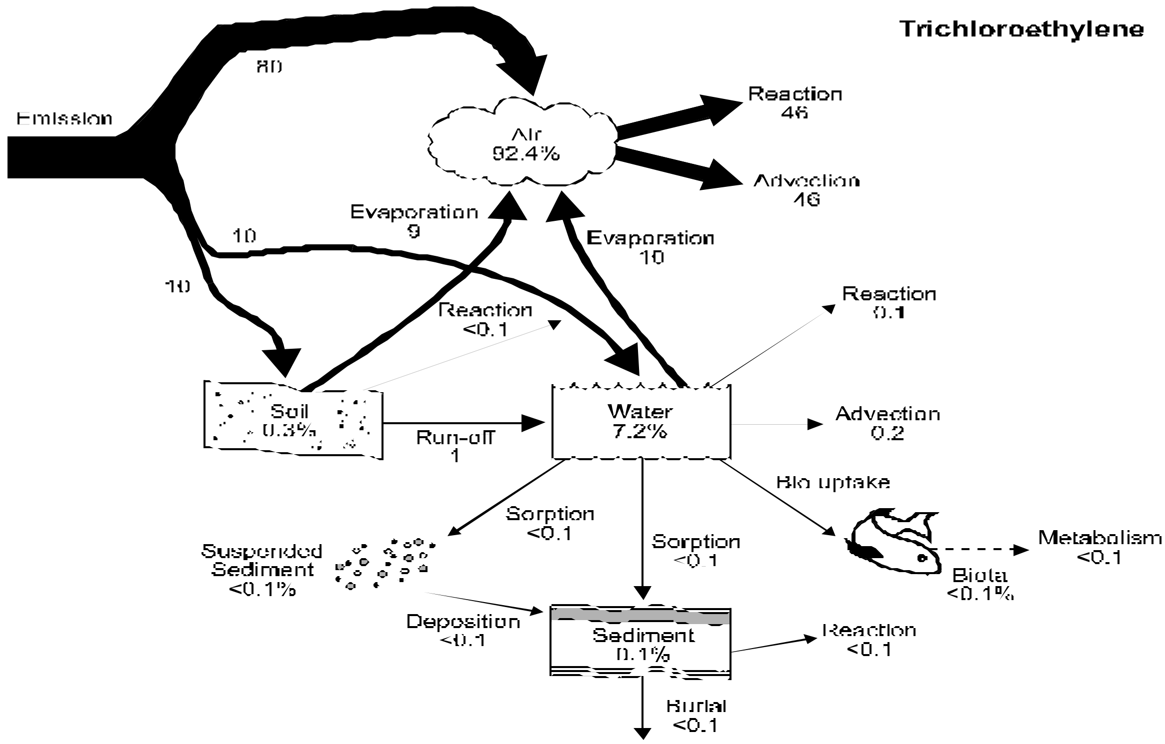


Figure 4-7: Example mass balance diagram for the fate of trichloroethylene (*source:* Mackay and Peterson, 1993).

The definition of the model and estimation of the various rates for the model's processes is only the first step. The next step is to define the various discharges to the system which may come from various industrial and municipal sources, spills, and applications of chemicals (for example, pesticides).

The final step is to define and estimate the transport rates between various media. This is important because a chemical discharged into one media (for example, soil) may be relatively stable, but when conveyed to another media (for example, air), it may be subject to a large reaction rate. For example, a chemical's lifetime in the environment may then be controlled, not by how fast it will react in soil, but by how fast it can evaporate from the soil to the atmosphere (McKay and Peterson, 1993).

In EIA, in the simplest cases, the concern is often limited to the chemical discharges associated with a specific project (for example, the effluent discharge from a pulp and paper mill). A mass balance model can be used to estimate the changes in chemical concentrations within environmental components of concern.

Erosion and Sedimentation

Processes like soil erosion are highly correlated with underlying features of the landscape. These processes have been used as the basis for the universal loss soil equation (USLE). Westman (1985) summarizes the work of many researchers in his presentation of the soil loss equation.

The simplest representation of the universal soil loss equation is:

$$A = 88.27 \times R \times K \times LS \times C \times P$$

where

- *A* is the average annual soil loss (tonnes/km^2 per year);
- *R* is a measure of rainfall intensity; and index value related to the maximum 30 minute rainfall intensity per storm (cm/hr) average over all storms;
- *K* is the soil erodibility factor; an index from 0.001 (non erodible) to 1 (erodible) based on soil texture, structure, organic matter content, permeability (available for US soils from Soil Conversation);
- *LS* is the slope length factor - where S is the slope angle (% of 45 degrees) and L is the length of the slope (m). The factor LS is expressed as a ratio of the erosion from that experienced on a slope of 9% and the length of 22m. The ratios are available from standard slope charts;
- *C* is the vegetative cover and management factor - ranges from .001 for a well managed woodland to 1.0 for no cover;
- *P* is the erosion control or management practice factor - ranges from .001 for effective contouring, terracing, and other erosion control for tilled land to 1.0 for the absence of erosion control.
- 88.27 is a conversion factor to convert units of A (tons/acre/year) original formulation to metric units tonnes/km^2 per year.

The USLE is often used to calculate the sediment yield or sediment input into a given water body (for example, a lake or reach of river).

Models for movement of sediment within a water body concentrate on two processes: bed transport or sediment transport. The processes are the primary influence sediment behavior and can be expressed mathematically as a function of stream velocity. Bed transport is normally modeled as a function of stream bed condition and stream velocity. Sediment transport is normally modeled as a function of a sediment concentration (integrated over the full water depth) and stream velocity. Models may treat the two processes separately or simultaneously. Depending on the nature of the water body, sediment behavior may be modeled in one, two, or three dimensions. The models may also be integrated with hydraulic models to predict hydrological effects.

Areas of Application

Surface water models are applied to make predictions of dissolved oxygen, temperature, instream flows, suspended sediment, salinity and nutrients. Most models useful for impact assessment contain a number of basic processes. For example, the U.S. Department of Agriculture's (USDA) Simulator for Water Resources in Rural Basins-Water Quality was developed to simulate hydrological, sedimentation, and nutrient and pesticide transport processes in a large, complex rural watershed.

Box 4-1: The USDA's Simulator for Water Resources in Rural Basins-Water Quality (SWRRBWQ) (*source:* General Sciences Corporation, 1993).

The SWRRBWQ model operates on a continuous time-scale and allows for subdivision of basins to account for differences in soils, land use, rainfall, etc. It can predict the effect of management decisions on water, sediment, and pesticide yield with reasonable accuracy for ungauged rural basins throughout the United States.

SWRRBWQ includes five major components: weather, hydrology, sedimentation, nutrients, and pesticides. Processes considered include surface run-off, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, sedimentation, and crop growth. A weather generator allows precipitation, temperature, and solar radiation to be simulated when measured data is unavailable. The precipitation model is a first-order Markov chain model, while air temperature and solar radiation are generated from the normal distribution. Sediment yield is based on the Modified Universal Soil Loss Equation (MUSLE). Nutrient yields were taken from the EPIC model (Williams et al., 1984). The pesticide component is a modification of the CREAMS (Smith and Williams, 1980) pesticide model. SWRRBWQ allows for simultaneous computations on each subbasin and routes the water, sediment, nutrients, and pesticides from the subbasin outlets to the basin outlet.

Canter (1996) provides a number of examples of computer based water quality that are in use in the United States (Table 4-4). Most of these models were developed and are maintained in the US Army Corps of Engineers Waterways Experimental Station Environmental Laboratory. Information can be obtained from the World Wide Web (*www.wes.army.mil/el/elmodels/index.html*).

Table 4-4: Examples of computer-based water quality models (*source:* Canter, 1996).

Model name	Description	Major features	Data requirements	Output
CE-THERM-1	1-D vertical reservoir model for temperature	Temperature, total dissolved solids (TDS), suspended solids (SS) coupled to density Specify outflow ports or ports based on temperature objective Reregulation pool, pumped-storage, and/or peaking hydropower options	Inflow rates and constituent values Outflow rates, operations Structural configuration and hydraulic constraints of outlets Initial constituent profiles Morphometric data Meteorological data Process and rate coefficients Release flow and temperature targets if using outflow-port decision routine	Vertical profiles and outflow values for constituents over time (printed and/or plotted) Statistics of predicted and observed values Flux information Operations schedules for multilevel outlet configurations
CE-QUAL-R1	1-D vertical reservoir model for water quality	All CE-THERM-R1 features Allows simulation of most major physical, chemical, and biological processes and associated water quality constituents Simulates anaerobic processes Monte Carlo simulations	Same as CE-THERM-R1 plus additional water quality data and coefficients	Same forms as CE-THERM-R1
CE-QUAL-W2	2-D longitudinal, vertical hydro-dynamic and water quality model for reservoir, estuarine, and other 2-D waterbodies	Solves 2-D hydrodynamics Head of flow boundary conditions Allows multiple branches. Simulates temperature, salinity, and up to 19 other water quality	Basically same as CE-QUAL (THERM)-R1 Tidal boundary conditions for estuarine applications Morphometric data, including widths for each cell	Velocities and water quality constituents at all points on 2-D grid (printed) 2-D vector plots and 2-D constituent concentration contour or shading plots

Model name	Description	Major features	Data requirements	Output
	waterbodies	variables		Time-series data and plots Statistical output Restart files for subsequent hot restart simulations
SELECT	1-D vertical steady-state model of selective withdrawal from a reservoir	Computation of withdrawal zone distribution from a density-stratified reservoir Release temperature, density, conservative constituents computed Multiple outflow types (spillway, water quality gate, flood-control outlet, etc.) handled internally User specifies ports operating or selects ports internally based on quality objective (e.g., temperature) Reaeration of hydropower and flood-control releases	Reservoir profiles for temperature (density) and conservative constituents Outflow rate, operation Structural configuration and hydraulic constraints or outlet(s) Quality targets if deciding port operation	Vertical profile of withdrawal zone Release qualities Appropriate port operations to meet quality targets
STEADY	1-D longitudinal steady-state stream temperature and DO model	1-D steady state Steady flow Allows branches, loops, and lateral inflows and withdrawals Flow can be piecewise nonuniform	Flows, depths, and velocities Average equilibrium temperature and heat-exchange coefficient Inflow temperature and DO Rate coefficients	Printed output for predicted temperature and DO at each node
CE-QUAL-RIV1	1-D dynamic flow, time-varying stream hydraulic (RIV1H), and water quality (RIV1Q) models	Simulates dynamic (highly unsteady) flows Simulates up to 10 time-varying water quality constituents Allows branching systems Allows multiple control structures Stream, structural, and wind reaeration options Direct energy balance or equilibrium temperature approach for temperatures	Physical data, cross-section geometry, elevations, and locations of nodes; lateral inflows and tributaries; control structures Initial conditions Boundary conditions for flow and water quality Rate coefficients and other parameters Meteorological data or equilibrium temperatures and exchange coefficients	Hydraulic information and water quality constituent values printed for all nodes at specific print intervals Time-series plots of selected variables at selected nodes
HEC-5Q	Reservoir system simulation/optimization model for multiple water-resource purposes including water quality, water supply hydropower and flood control	Balanced reservoir system regulation determination Optimum gate regulation for multiple water quality constituents	Inflow quantity and quality Initial water quality conditions System configuration and physical description Reservoir regulation manual operation criteria System diversions Water quantity and quality targets at system control points	Reservoir and river water quality profiles Reservoir and river discharge rates, elevations and travel time

Summary of Use in Developing Countries

AIT2: AIT2 provides two-dimensional modeling of currents and water levels in estuaries and coastal waters. It has been widely used, including for the Ao Phai project in Thailand, the Keppel Channel in Singapore, and the Upper Gulf of Thailand.

Cornell Mixing Zone Expert System (CORMIX) (EPA): The CORMIX model was used for the assessment of potential thermal and chemical impacts resulting from wastewater discharges from the proposed Mangalore power facility. CORMIX is a series of software subsystems for the analysis, prediction and design of aqueous discharges into water bodies and streams. It was developed for the EPA and is a recommended analysis tool in guidance documents on the permitting of industrial discharges to receiving waters.

4.2.3 Soils and Groundwater

Conceptual Model

The integrity of soils and groundwater can be altered by a variety of physical disturbances, including the addition/removal of soil and/or water, compaction of soil, changes in use of land or ground cover, changes in water hydrology, changes in climate (temperature, rainfall, wind), and the addition or removal of substances or heat (for example, discharge of effluents into groundwater, discharge of effluents or disposal of waste onto land, leaching of contaminants into groundwater, changes in quality of surface water, and deposition of air pollutants on land). The effects of these vary from first order effects of leaching into soil and groundwater to changes in groundwater regime, soil structure (including erosion and subsidence), soil quality or temperature, and groundwater quality or temperature. A summary of these effects are presented in Figure 4-8.

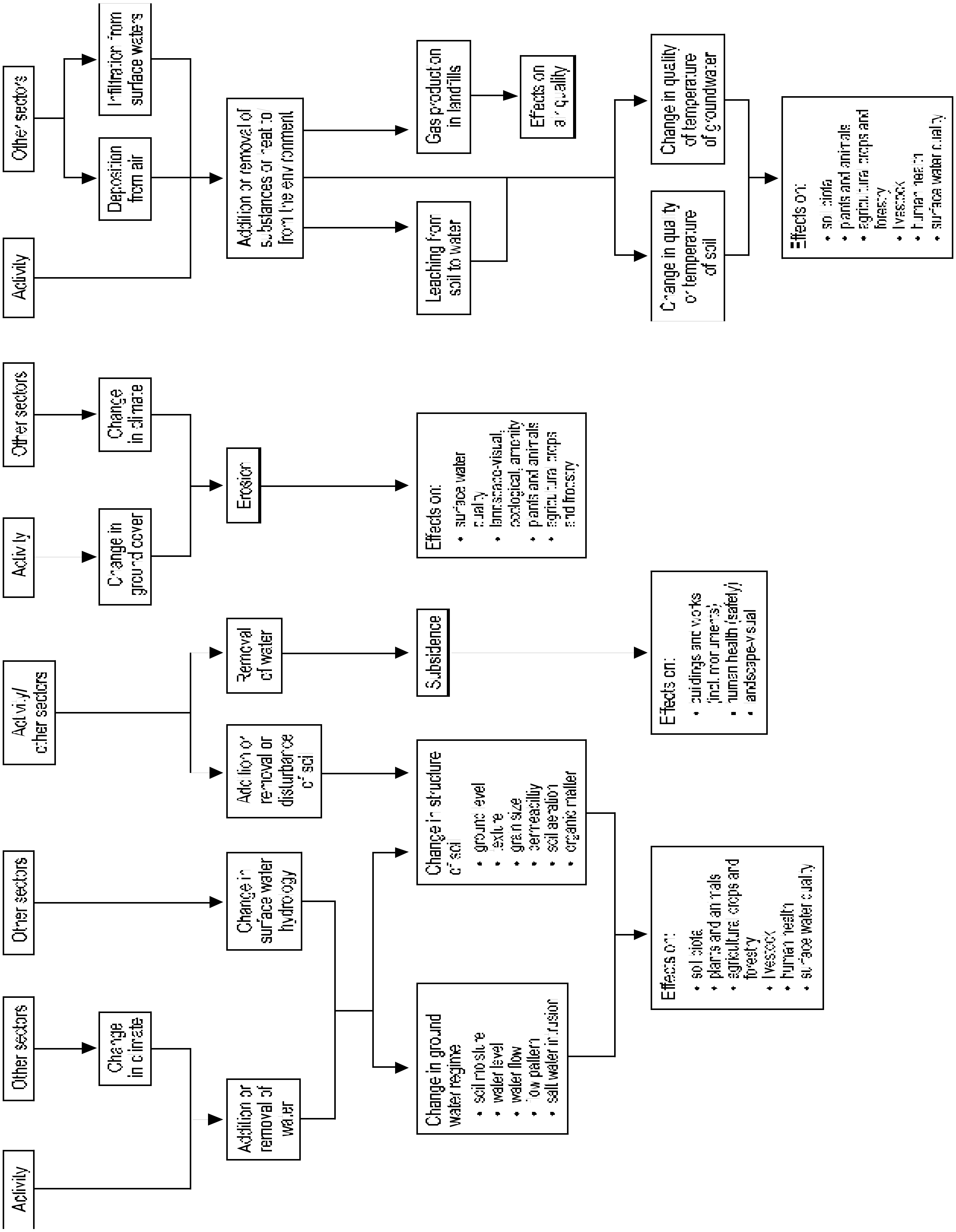


Figure 4-8: Summary of cause-effect network for soils and groundwater (*source:* ERL, 1984).

Basic Concepts

Leaching Into Soils and Groundwater

The volume of leachate percolating through a site can be predicted using mathematical models such as the water balance method in sites above the water table. The water balance method calculates leachate flow by balancing flows into and out of a site as follows:

where

- I is the inflow volume;
- O is the outflow volume;
- S is the storage volume; and
- ? S is the change in the storage volume.

In the unsaturated zone:

where

- P is the precipitation volume;
- Vd is the volume of liquid disposed;
- L is the leachate volume;
- Evt is the volume lost to evapotranspiration;
- Evd is the volume of the liquid disposed lost to evaporation; and
- R is the runoff volume.

For predicting long-term effects, the change in storage can be assumed to be zero, evapotranspiration can be based on existing data or experiments, while run-off can be calculated using an empirical model based on surface conditions and slopes.

Darcy's Law

Darcy's Law is the basis for most models of groundwater flow in sites below the water table. The method describes the flow of groundwater through a saturated porous medium. Flow is dependent on the change in head with distance (that is, the hydraulic gradient) and the permeability of the medium. It is expressed mathematically as:

$$Q = KA\left(\frac{dH}{dL}\right)$$

where:

- Q is the flow (m^3/day);
- K is the permeability (m/day);
- A is the cross-sectional area (m^2); and
- dH/dL is the hydraulic gradient (that is, the change in the water table elevation per unit change in the horizontal direction).

Changes in Groundwater Flow

The effects of physical disturbances and discharge of liquid effluents on groundwater include changes in the availability of soil moisture for soil microorganisms and plants, reducing the available yield for abstraction which can lead to saltwater intrusion to underground water sources or a change in the hydrology of surface waters. Mathematical models are primarily based on analytical or numerical solution of equations for conservation of mass using Darcy's law. The groundwater system can be divided into one, two, or three segments depending on the directions of flows within the system. The flows into and out of each segment are then balanced using Darcy's equation.

Changes in Groundwater Quality

The behavior of nonconservative pollutants can be simulated by superimposing models of chemical conversion, biological breakdown, system process, etc. Tracer experiments may be used to predict dispersion of pollutants in groundwater.

Changes in Soil Structure

Changes in soil structure are caused by agricultural practices, ground conditions, surface water conditions, and by removal of subsurface soil or water. The effects of these changes can manifest on soil microorganisms, plants and animals, crops and livestock, groundwater and surface water hydrology and quality, visual landscape and amenity, and the integrity of buildings and other civil engineering works. Erosion resulting from changes in ground cover, management practices, rainfall and run-off, and wind exposure can be predicted by the universal soil loss equation.

Effects on Soil Quality

In order to determine the effects on soil quality of contaminants, it is necessary to establish the chemical composition, quality, and amount of substrate in the various soil strata; absorption and adsorption onto soil particles; uptake by plants; transport through the soil; and the chemical and biological conversion of substances. Models have been developed to:

- simulate individual processes occurring in soil;
- describe behavior of substances in soil such as nitrogen, phosphorous, and pesticides (laboratory experiments using column tests and lysimeters may also predict the behavior of substances in soil);
- predict the behavior of liquids which are immiscible with water (for example, mathematical models for oil spills on land which simulate the behavior of oil on the surface and in the unsaturated zone and its dispersion above the groundwater table);
- simulate the behavior of gases in soil; or
- predict dispersion of heat released by pipelines or cables, or discharged in effluents.

Areas of Application

Table 4-5 lists some of the software the International Groundwater Modeling Center (IGWMC) at the Colorado School of Mines has to offer, as well as some free, public domain software. Detailed descriptions of most programs (as well as model demos) can be found on the Center's website under the IGWMC Software listing.

Table 4-5: Examples of groundwater models available from the Colorado School of Mines' International Groundwater Modeling Center (*source:* Internet - *www.mines.edu.igwmc*)

Model Name	Model Description
FLOWPATH	A DOS-based two-dimensional finite difference model for steady state flow in confined and unconfined aquifers. It includes an elaborate, user-friendly graphic interface, and extensive graphic display of results. The model is widely used, among others, for well head protection studies.
HYDRUS-2D	A sophisticated Windows-based two-dimensional finite element model for transient unsaturated flow and solute transport. It includes an elaborate, user-friendly graphic interface, and extensive graphic display of results. The program includes modern numerical routines securing efficient and stable solutions for highly nonlinear problems.
INFINITE EXTENT	A program for aquifer test analysis with on-screen, manual curve matching, and automatic parameter evaluation. The program includes type curves for confined, leaky-confined and unconfined cases.
MICRO-FEM	A finite element model for simulation of transient quasi-three-dimensional flow in aquifer systems. This model, widely used in northern Europe, includes elaborate grid design, parameter allocation result analysis options, as well as extensive graphics.
ModelGIS	A modeling system operating in the ARC/INFO Environment under Unix. It includes MODFLOW and MODFLOWT.
MODFLOWT	A three-dimensional finite difference contaminant transport modeling which fully integrates with MODFLOW.
RPTSOLV	A Windows-based finite element model for pumping test analysis in fractured rock
SUPERSLUG	A Windows-based program for slug analysis
STEPMASTER	A Windows-based program for step-drawdown tests.
THCVFIT	A simple interactive DOS program for aquifer test analysis using the HEIS method.
TWODAN	A DOS-based multi-functional analytic element model for two-dimensional steady-state flow with a user-friendly graphic interface and extensive graphic display of results. Well-suited for well-head protection studies.
The United Nations Ground Water for Windows (UN-GWW)	This demo is split up in 4 self-extracting files. It shows in slide show form the hydrogeological and geochemical database options, its extensive graphic display options, as well as options for aquifer test analysis.
UNITS	A DOS-based groundwater units conversion (Shareware)
Visual MODFLOW	A MODFLOW-based modeling environment with extensive GUI and support for MT3D and other MODFLOW related programs.
ZBSoft	A three-dimensional flow and contaminant transport modeling based on the Zheng-Bennett text book on this topic.

4.2.4 Biological/Ecological Resources

Basic Ecological Concepts

Models of biological and ecological resources should be directed at predicting effects on valued ecosystem components.

Conceptual Model

Some development activities have direct impacts on biological systems. For example, clearing of land for infrastructure will destroy vegetation and displace animals. Introduction of contaminants may cause direct mortality of plants and animals. However, in many cases it is changes in the physical environment caused by development that often lead to secondary or high order changes in plants and animals. For example, changes in downstream flow as a result of an upstream dam on a river may change the productivity of fish population. Alternatively, industrial pollution may be transported downstream and move through the food chain and ultimately contaminate the fish and wildlife populations that depend on the river. A simplified conceptual model of potential effects on biota is presented in Figure 4-9.

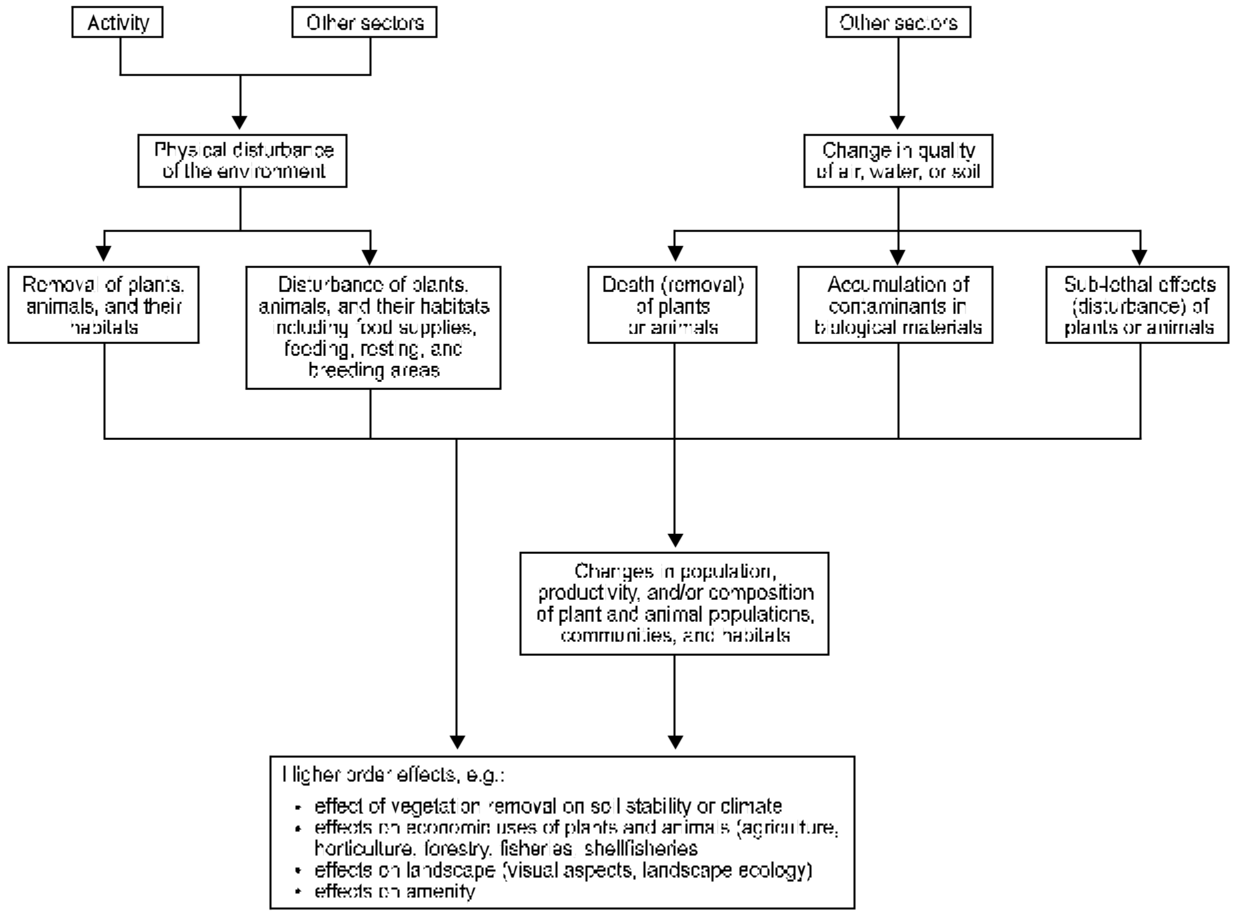


Figure 4-9: Summary of cause-effect network for biota (*source:* ERL, 1984).

While our understanding of ecological systems is increasing, our ability to predict changes in biological and ecological resources is less developed than for physical resources. In this chapter, we present few simple concepts to help in predicting effects on biota. Unfortunately, however, there are few good examples in Asian EIA practice of using predictive tools for assessing impacts on biota. It should be noted that the assessment of biological impacts is becoming increasingly more important as EIAs shift beyond their early focus on controlling pollution.

Basic Concepts

Physical Disturbance

Prediction of changes in physical disturbance of plants and animals usually requires that simple maps of the spatial distribution and abundance of the biota be prepared. The simplest predictive techniques are based on overlaying the project facilities location plan (buildings, roads, staging areas, etc.) over maps of the existing environment. Today, this is often done using geographical information systems (c.f. chapter 3). For vegetation, this technique provides a simple prediction of the area lost. For animals and animal communities, this technique is extended using the "zone of influence" concept (see Figure 4-10). The zone of influence may extend far beyond the site of the physical disturbance. For example, in the case of noise from a road or facility the zone of influence may extend hundreds of meters from the source.

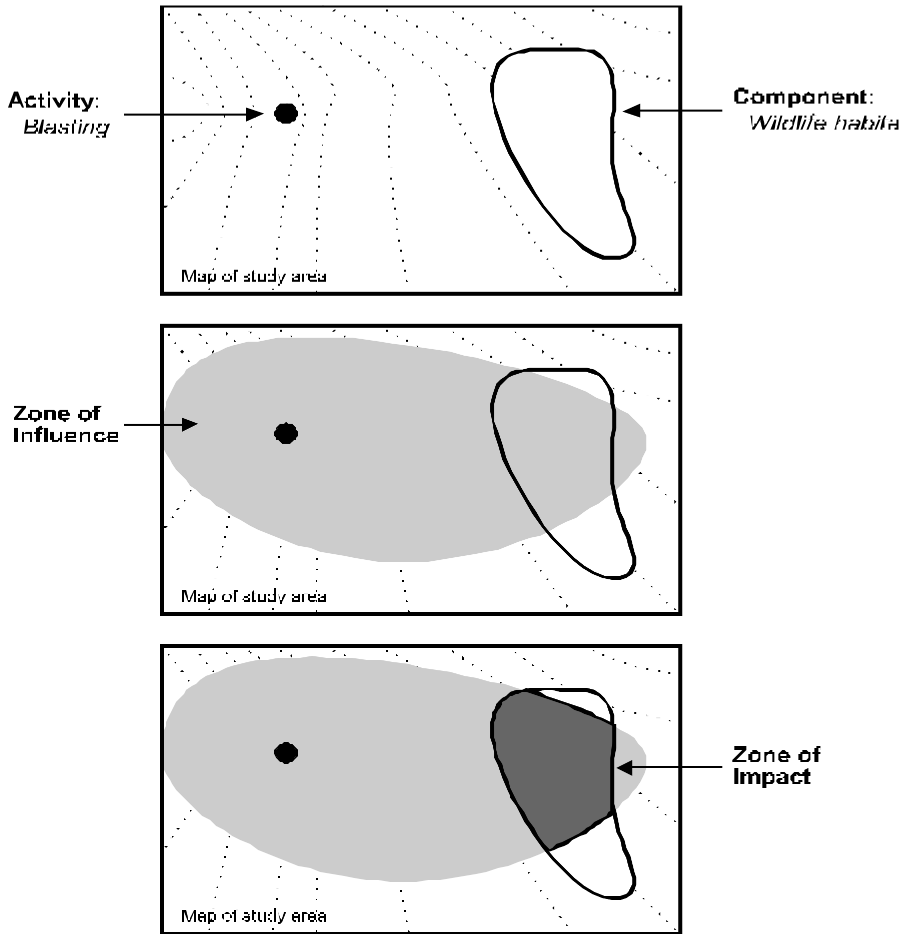


Figure 4-10: Simple illustration of zone of influence.

Habitat Alienation

In the terrestrial environment, the destruction of vegetation and loss of soil usually results in reduction of habitat for animals. The relationship between the extent of the physical disturbance on the area and the amount of habitat lost or degraded is non-linear. Small changes in critical areas can make large areas unsuitable as animal habitat. This is because animal habitat is usually a combination of the basic necessities for an animal: food, water, cover, and other resources. Some habitats are critical for survival, for example, wetlands that act as staging areas for wildlife migration, or mangroves ecosystems that provide breeding areas for aquatic organisms.

Canter (1996) describes two habitat-based methods used for prediction of biological impacts: the Habitat Evaluation System (HES) used by the US Army Corps of Engineers in the evaluation of water resource project in the lower Mississippi; and the Habitat Evaluation Procedure (HEP) developed by the US Fish and Wildlife Service. HEP, originally developed for use in evaluating water resource projects has been applied in many other contexts. Most habitat based methods involve the use of expert judgement to construct simple indices of habitat quality based on key ecosystem variables. In most cases, the habitat quality indices must be redeveloped for each assessment.

These methods are best used to compare the merits of alternatives. They provide neither an absolute measure of impact, nor the degree of significance of the impact.

Box 4-2: Habitat Evaluation Procedures software (*source:* Internet - *www.mesc.usgs.gov/hep/hep.htm/*)

The philosophy behind the Habitat Evaluation Procedures is that an area can have various habitats, and that these habitats have different suitabilities for species that may occur in that area. Further, we assume that the suitabilities can be quantified (via Habitat Suitability Indexes) and that the different habitats have measurable areal extents. The overall suitability of an area for a species we postulate can be represented as a product of the areal extents of each habitat and the suitability of those habitats for the species. If this is true, we may further postulate that as habitat changes through time, by natural or human-induced processes, we can quantify the overall suitability through time by integrating the areal extent-suitability product function over time. Thus, we can quantitatively compare two or more alternative management practices of an area with regard to those practices affecting species in that area. For example, we can judge the effects of logging, mining, cattle grazing, versus no use. Furthermore, HEP allows us to quantify the effects of mitigation (not so great a negative impact) or compensation (improve another like area to make up for lost habitat in the impacted area).

This is an important tool for land use managers, as they can quantify the effects of alternative management plans over time, and provide for mitigation and compensation that can allow fair use of the land and maintain healthy habitats for affected species. The HEP accounting program uses the area of available habitat and Habitat Suitability Index (HSI) to compute the values needed for Habitat Evaluation Procedures (HEP) as described in the Ecological Services Manual (ESM 102) and the HEP training course NR561 [Habitat Evaluation Procedures]. The compiled program requires two floppy disk drives or a hard disk, and 64 kilobytes of RAM.

Changes in Animal Populations

In many cases, the primary concern is with impacts on fish and wildlife populations. This is because these populations often have economic and social importance or are protected by national legislation or international treaties. Population dynamics models are often developed to predict changes in animal populations. The basic model equation (Walters, 1986) is:

$$N_{t+1} = s_{at} N_t + s_{jt} R_t$$

where

- N_t is the population size at specific time t in the annual cycle;
- R_t is the recruitment to the population during the time cycle between t and t+1;
- s_{at} is the survival rate of animals (N_t) from t to t+1; and
- s_{jt} is the survival rate of new recruits (R_t) during the time cycle between t and t+1.

This simple equation allows for the projection of how the population will change over time. Each of the basic components of the equation (that is, recruitment and survival rates) are usually modeled as functions of other ecological parameters and outside interventions. For example, one model of recruitment in a fish population might have recruitment as a function of the population size, fecundity (eggs/female), available spawning habitat, net migration, and water quality. Similarly the survival rates may be a function of population size, harvesting, habitat, and water quality.

In conducting an EIA, one first predicts the changes in those factors upon which recruitment and survival are dependent. Once estimates of recruitment and survival parameters are calculated, the model may be applied to predict changes in population. Walters (1986) provides an excellent description of how to develop the basic model, estimate parameters, and test its accuracy in prediction.

Areas of Application

Table 4-6 provides examples of computer models available for prediction of impacts on habitat.

Table 4-6: Software for programs for habitat evaluation from United States Geological Survey Midcontinent Ecological Sciences Center (*source:* Internet - *www.mesc.usgs.gov/swprods/html*)

Software	Description
HEP Habitat Evaluation Procedures	The HEP accounting program uses the area of available habitat and Habitat Suitability Index (HSI) to compute the values needed for Habitat Evaluation Procedures (HEP) as described in the Ecological Services Manual (ESM 102) and the HEP training course HEP500 [Habitat Evaluation Procedures]
HSI Habitat Suitability Index	The HSI software is a system of programs that uses mathematical models to compute an HSI value for selected species from field measurements of habitat variables. The development and use of HSI models are described in the Ecological Services Manual (ESM 103) and the HEP Training Course HEP 500 Habitat Evaluation Procedures.
PHABSIM	The Physical Habitat Simulation System. This extensive set of programs is designed to predict microhabitat conditions in rivers as a function of streamflow and the relative suitability of those microhabitat conditions to aquatic life. The appropriate use of this set of programs is taught in IF310, [Using the Computer-based Physical Habitat Simulation System (PHABSIM)].
TSLIB The Time Series Library	TSLIB programs provide for data entry, analysis, and display of daily or monthly flow or habitat values. Some programs are useful for integrating microhabitat and macrohabitat, and some are of value in the analysis of water operations systems. Many of the concepts of time series analysis are taught in IF250 [Theory and Concepts of the Instream Flow Incremental Methodology].
SNTEMP Stream Network Temperature Model	SNTEMP predicts the water temperature in streams and rivers from data describing the stream's geometry, meteorology, and hydrology. It handles a dendritic network of streams through time and space. SNTEMP is taught in IF312 [Stream Temperature Modeling]. See More About SNTEMP and SSTEMP.
SSTEMP Stream Segment Temperature Model	SSTEMP is a scaled down version of SNTEMP suitable for single (to a few) reaches and single (to a few) time periods. SSTEMP is taught in IF312 [Stream Temperature Modeling]

4.2.5 Ecotoxicology - Impacts of Pollutants on Biota

The dose of a chemical to an organism is a function of both the concentration of the chemical in the immediate environment and the duration of exposure of the population to that concentration. The two factors interact in multiplicative way; hence the dose of a chemical received by an organism is defined (Westman, 1985) as: *dose* is equal to the concentration of chemical times duration of exposure at concentration.

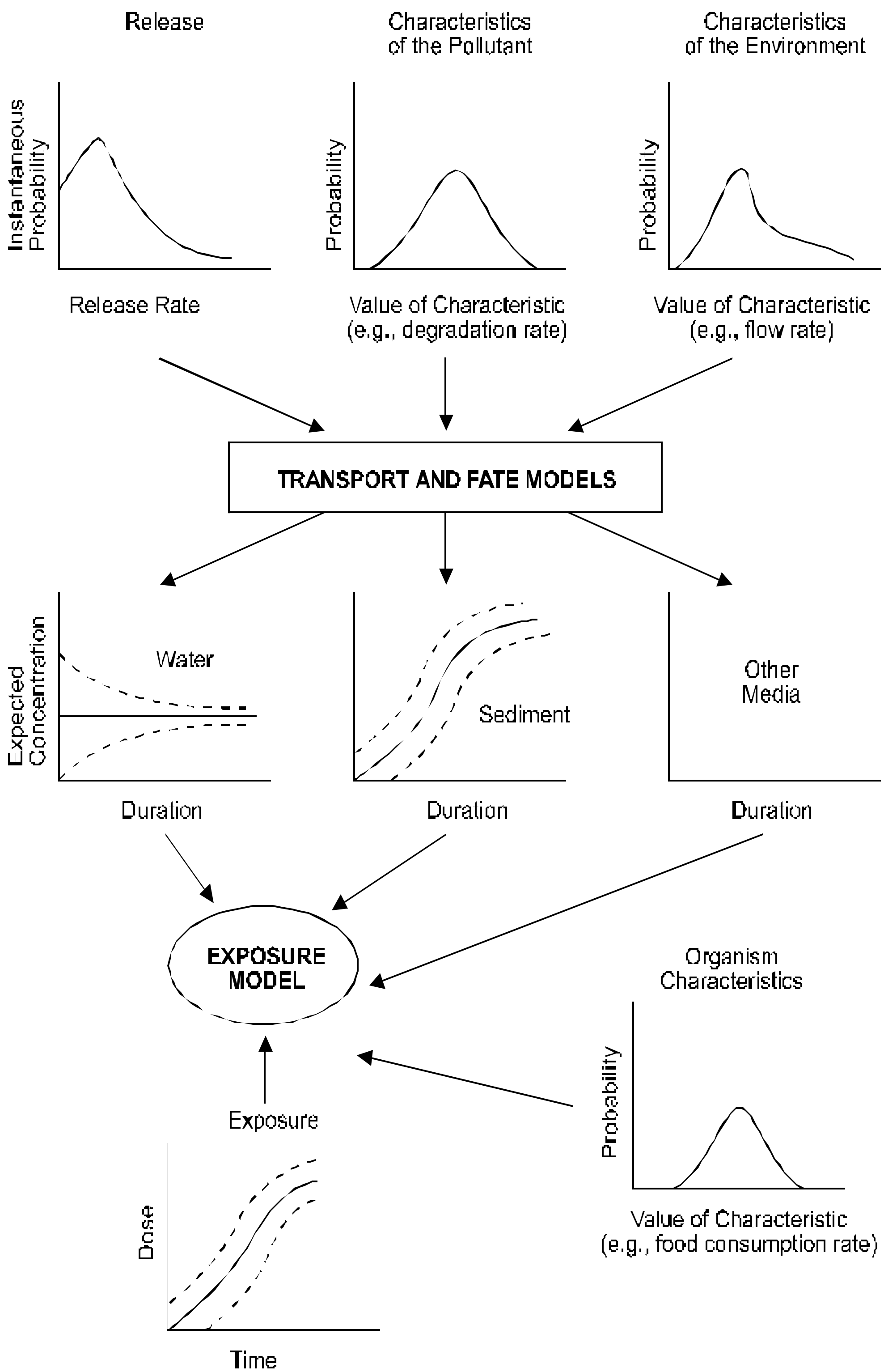


Figure 4-11: The exposure assessment process (*source:* Suter, 1993).

Exposure

Exposure has been defined as contact with a chemical or physical agent. It is the process by which an organism acquires a dose (Suter, 1993). The estimation of exposure of a target organism requires an exposure scenario that answers to four questions (Suter, 1993):

1. given the output of fate models (see section 4.2.2 on mass balance equation for water quality), which media (ecosystem components) are significantly contaminated;
2. to which contaminated media are the target organisms exposed;
3 how are they exposed (pathways and rates of exposure); and
4. given an initial exposure, will the organism modify its behavior to modify exposure pathways or rates (attraction or avoidance)?

Table 4-7 identifies some of the major exposure pathways, while Figure 4-12 provides an example of exposure pathways for two target species: mink, a small carnivorous mammal and the great blue heron, a large piscivorus bird.

Table 4-7: Exposure pathways.

Media	Pathways	Comment
Air - gases and aerosols	Respiration	Assuming accurate fate model estimates, exposure is relatively predictable based on assumptions of homogenous distribution in air.
Water - soluble chemicals	Respiration	Assuming accurate fate model estimates, exposure is relatively predictable based on assumptions of homogenous distribution in water.
Sediment (solids and pore water)	Benthic animals absorb chemicals, respire pore water or free water, and ingest sediments, sediment associated food or food from the water column. Plants rooted in the sediment may take up material from sediments, surface water and air	Processes are very complicated and usually simplifying assumptions are required
Soil (solids, pore water, and pore air)	Organisms in soils may absorb material from soil, pore water, pore air, ingest soil, soil - associated food.	Processes are very complicated and usually simplifying assumptions are required
Ingested Food and Water	Consumption by fish and wildlife	Assume that test animal consumption rates in laboratory for a given availability of food or water are the same as those occurring naturally in the environment
Multi Media	More than one of above pathways	It is often possible to assume one pathway is dominant. In some cases, it will be necessary to estimate the combined dosage.

Behavioral responses of organisms may modify subsequent exposure. Animals commonly avoid contaminated food or media, however there are cases where animals are attracted. Due to lack of behavioral information, most assessors normally assume that behavior does not modify exposure (Suter, 1993).

Because of the complexity involved, most EIA practitioners will have to rely on existing computer software models (for example, the EXAMS model described in Box 4-3) to provide estimates of exposure.

EXAMS provides a means of rapidly evaluating the fate, transport, and exposure concentrations of synthetic organic chemicals--pesticides in aquatic ecosystems. To date there has been little usage of exposure models in EIA. Three possible reasons can be suggested: 1) there has been little emphasis on assessing the exposure of biota to pollutants; 2) EIA practitioners are unaware or unskilled in the use of the tools and techniques for exposure assessment; and 3) the basic baseline data to parameterize the models is unavailable and too costly to obtain.

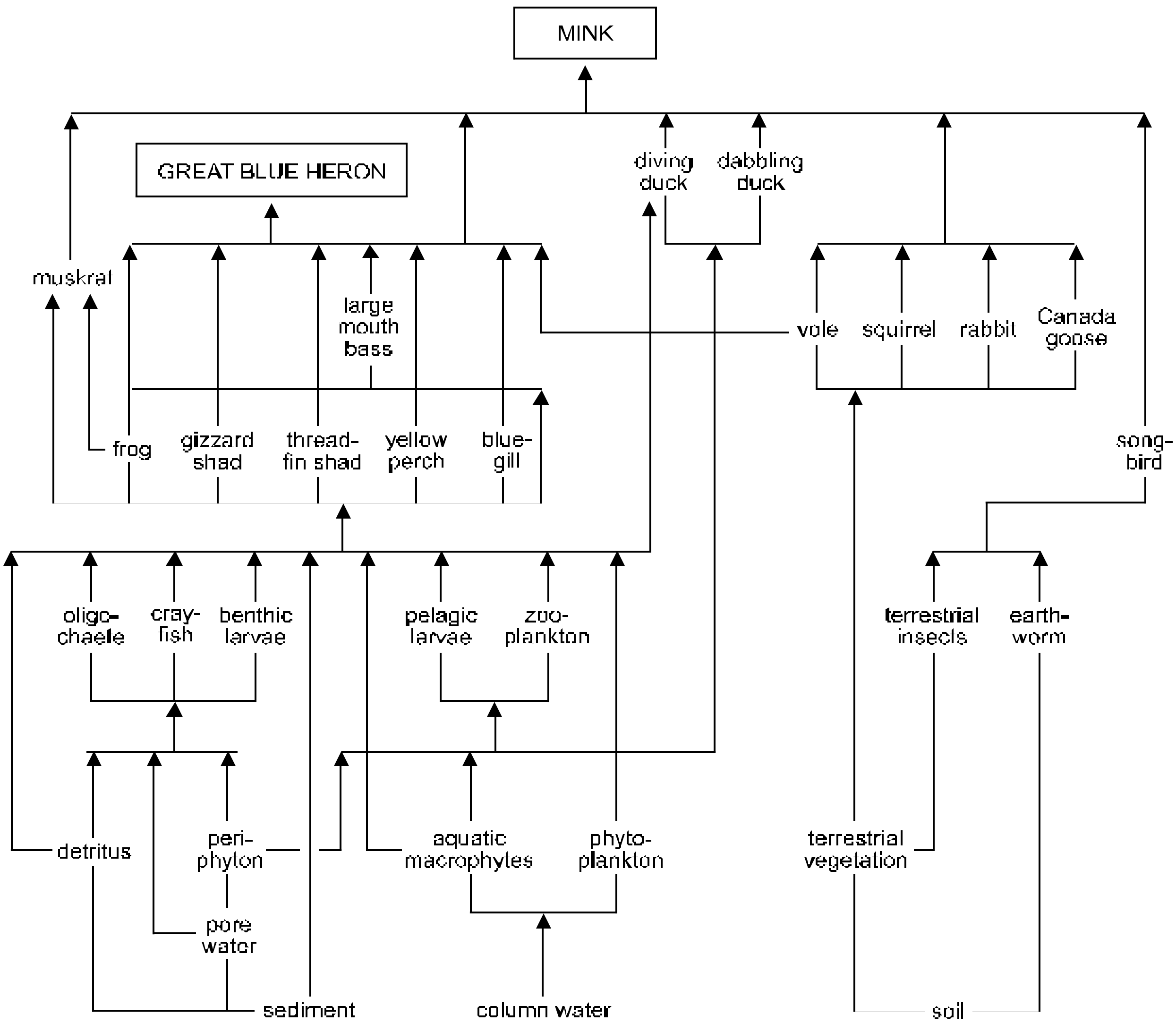


Figure 4-12: Example of exposure pathways (*source:* Suter, 1993).

Box 4-3: The EXAMS Model System (*source:* Center for Exposure Assessment Modeling (CEAM)).

The Exposure Analysis Modeling System, first published in 1982 (EPA-600/3-82-023), provides interactive computer software for formulating aquatic ecosystem models and rapidly evaluating the fate, transport, and exposure concentrations of synthetic organic chemicals--pesticides, industrial materials, and leachates from disposal sites. EXAMS contains an integrated Database Management System specifically designed for storage and management of project databases required by the software. User interaction is provided by a full-featured Command Line Interface, context-sensitive help menus, an on-line data dictionary and Command Line Interface users' guide, and plotting capabilities for review of output data. EXAMS provides 20 output tables which document the input data sets and provide integrated results summaries for aid in ecological risk assessments.

EXAMS' core is a set of process modules that link fundamental chemical properties to the limnological parameters that control the kinetics of fate and transport in aquatic systems. The chemical properties are measurable by conventional laboratory methods; most are required under various regulatory authority. When run under the EPA's GEMS or pcGEMS systems, EXAMS accepts direct output from qsar software. EXAMS' limnological data are composed of elements historically of interest to aquatic scientists worldwide, so generation of suitable environmental datasets can generally be accomplished with minimal project-specific field investigations.

EXAMS provides facilities for long-term (steady-state) analysis of chronic chemical discharges, initial-value approaches for study of short-term chemical releases, and full kinetic simulations that allow for monthly variation in mean climatological parameters and alteration of chemical loadings on daily time scales. EXAMS has been written in generalized (N-dimensional) form in its implementation of algorithms for representing spatial detail and chemical degradation pathways. This DOS implementation allows for study of five simultaneous chemical compounds and 100 environmental segments; other configurations can be created through special arrangement with the author.

EXAMS provides analyses of:

Exposure: the expected (96-hour acute, 21-day and long-term chronic) environmental concentrations of synthetic chemicals and their transformation products,

Fate: the spatial distribution of chemicals in the aquatic ecosystem, and the relative importance of each transformation and transport process (important in establishing the acceptable uncertainty in chemical laboratory data), and

Persistence: the time required for natural purification of the ecosystem (via export and degradation processes) once chemical releases end.

EXAMS 2.96 includes file-transfer interfaces to the PRZM terrestrial model and the FGETS bioaccumulation model.

Effects

Effects assessment is the process of determining the relationship between exposure and its effects on the target organism. Most effects assessments are based on toxicity tests. Suter (1993) outlines the basic steps in the effects assessment (Figure 4-13):

1. toxicity tests are conducted to determine the effects of various combinations of exposure concentrations and the duration on the frequency or severity of the responses of concern, such as increased mortality and decreased fecundity;
2. statistical models are fit to the test data and an exposure — the response model is selected to represent the toxicological responses in the effects models;

3. effects models are generated that represent the relationship between the test results and the target organisms; and
4. the test results and data concerning relevant population and ecosystem processes are used to parameterize the effects model which is then used to derive a function relating the level of effects on the target organism to the exposure.

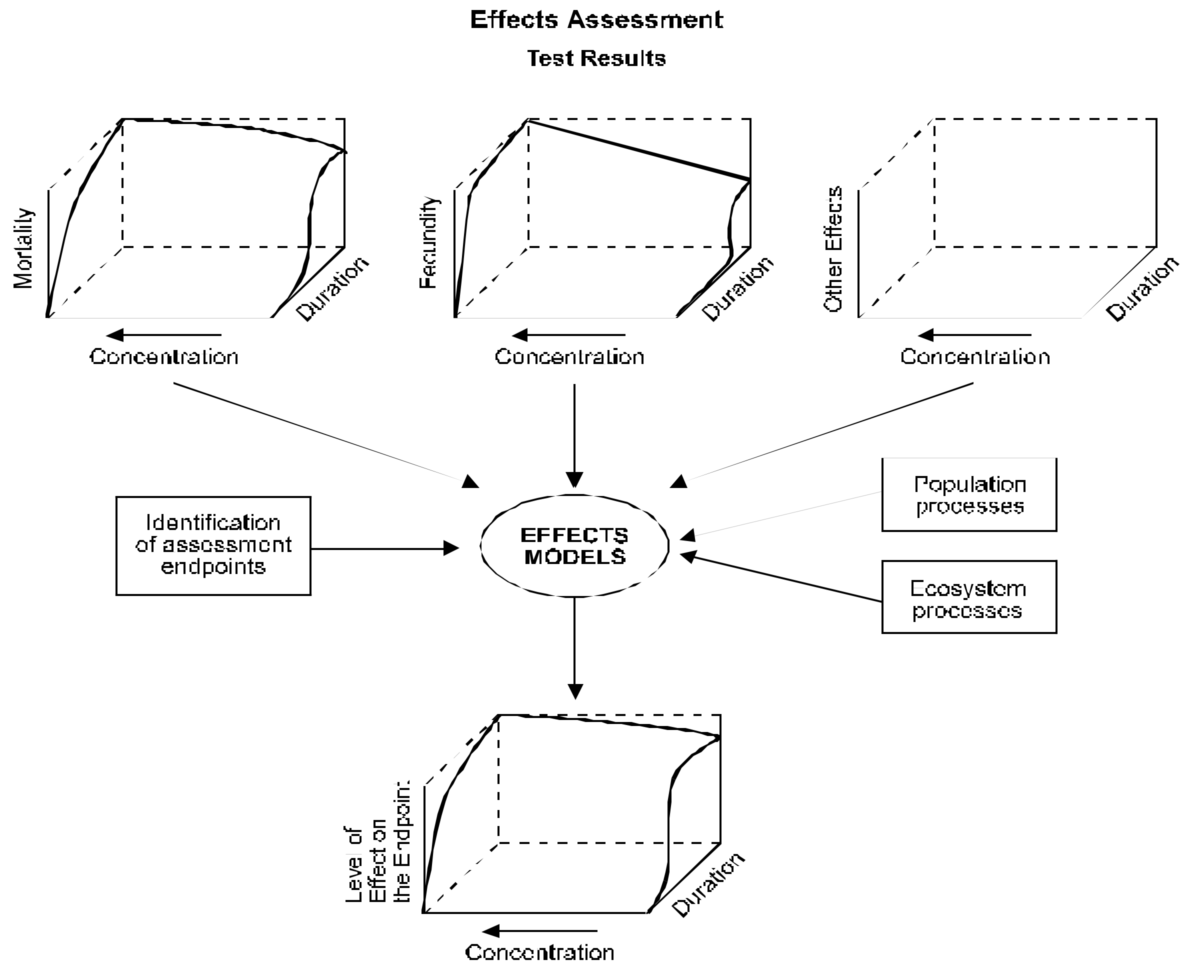


Figure 4-13: Process of effects assessment (*source:* Suter, 1993).

Dose - Response Functions

The most common model to test results is the dose-response function. The pattern of response with increasing dose is assumed to be S-shaped (Figure 4-14). This function assumes that there is no threshold below which there is no response.

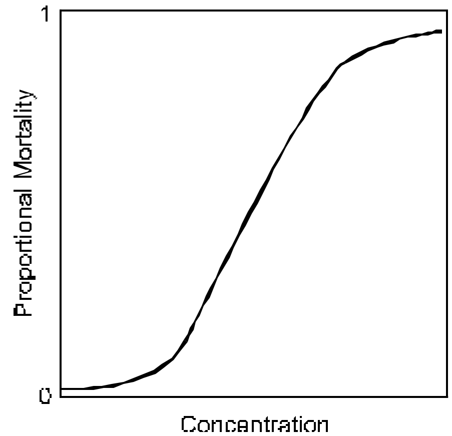


Figure 4-14: A typical S-shaped dose-response curve (*source:* Suter, 1993).

Comparison Against Environmental Standards

The final step is to assess the significance of the predicted effect on a target organism. Exposure assessments allow us to predict the changes in environmental contaminants, but do not provide the means of evaluating the significance of the changes. Effect assessments provide us with information on the magnitude of the effect on target organisms.

The practical difficulties in determining effects models for the target organisms that may be of particular concern to a given EIA, often force the EIA practitioners to ignore biochemical aspects of the environment. Simple physical models that make predictions of chemical concentrations based on transport and dilution are often the best tool available in practice. These predictions of concentrations are usually compared against the published environmental standards without regard to the actual effects on target organisms. The implicit assumption is that if environmental standards are met, the environmental effects are not significant. This assumption is untested and mounting evidence of environmental degradation seems to suggest otherwise.

Areas of Application

Table 4-8 provides examples of models available for exposure assessment in aquatic systems.

Table 4-8: Center for Exposure Assessment Software. DOS releases of selected CEAM software are available through the World Wide Web (*source:* Internet - *ftp.epa.gov/epa_ceam/wwwhtml/software.htm*).

Model Name	Description
CEAM information system Version 3.21 - May 95	The Center for Exposure Assessment Modeling (CEAM) of the U.S. EPA serves as the focal point for ORD's multimedia exposure assessment modeling and ecological risk assessment activities. The CEAM Information System (CEAMINFO) is a collection of reference and information documents and/or files that summarize CEAM mission, activities, documentation, software products, assistance, support, and software product distribution.
CORMIX model Version 3.20 - Dec 96	Cornell Mixing Zone Expert System (CORMIX) can be used for the analysis, prediction, and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. The major emphasis is on the geometry and dilution characteristics of the initial mixing zone -- including compliance with regulatory constraints -- but the system also predicts the behavior of the discharge plume at larger distances. The system consists of three subsystems: CORMIX1 for submerged single port discharges, CORMIX2 for submerged multiport diffuser discharges, and CORMIX3 for buoyant surface discharges. Further information is available from Cornell University concerning technical support available to users for the CORMIX model system, version 3.20, dated December 1996.
EXAMS model Version 3.20 - Dec 96	The Exposure Analysis Modeling System (EXAMS) provides interactive computer software for formulating aquatic ecosystem Models and rapidly evaluating the fate, transport, and exposure concentrations of synthetic organic chemicals--pesticides, industrial materials, and leachates from disposal sites. EXAMS contains an integrated Database Management System (dbms) specifically designed for storage and management of project databases required by the software.
FGETS model system Version 3.0.18 - Sep 94	Food and Gill Exchange of Toxic Substances (FGETS) is a FORTRAN simulation model that predicts temporal dynamics of fish whole body concentration (ug chemical/(g live weight fish)) of nonionic, nonmetabolized, organic chemicals that are bioaccumulated from either: (a) water only - the predominant route of exchange during acute exposures, or (b) water and food jointly - characteristic of chronic exposures.
FEMWATER model Version 1.00 - Jul 93	Three-Dimensional Finite Element Model of Water Flow Through Saturated-Unsaturated Media (3DFEMWATER) and Three-Dimensional Lagrangian-Eulerian Finite Element Model of Waste Transport Through Saturated-Unsaturated Media (3DLEWASTE) are related and can be used together to model flow and transport in three dimensional, variably-saturated porous media under transient conditions with multiple distributed and point sources/sinks.. 3DFEMWATER is designed to simulate the movement of moisture through variably saturated porous media. 3DLEWASTE is designed to simulate solute transport through variably saturated porous media.
HSPF model Version 11.00 - Apr 97	Hydrological Simulation Program - FORTRAN (HSPF) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF incorporates watershed-scale ARM and NPS models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. HSPF simulates three sediment types (sand, silt, and clay) in addition to a single organic chemical and transformation products of that chemical.
MINTEQ model Version 3.11 - Dec 91	MINTEQA2, a geochemical equilibrium speciation model for dilute aqueous systems, is an update of MINTEQ that was developed by combining the fundamental mathematical structure of MINEQL with the thermodynamic data base of WATEQ3. MINTEQA2 can be used to calculate the equilibrium composition of dilute solutions in laboratory or natural aquatic systems. It can be used to calculate the mass distribution between dissolved, adsorbed, and multiple solid phases under a variety of conditions.
MMSOILS model Version 4.00 - Jun 97	The Multimedia Contaminant Fate, Transport, and Exposure Model (MMSOILS) estimates the human exposure and health risk associated with releases of contamination from hazardous waste sites. The methodology consists of a multimedia model that addresses the transport of a chemical in groundwater, surface water, soil erosion, the atmosphere, and accumulation in the food chain. The human exposure pathways considered in the methodology include: soil ingestion, air inhalation of volatiles and particulates, dermal contact, ingestion of drinking water, consumption of fish, consumption of plants grown in contaminated soil, and consumption of animals grazing on contaminated pasture. The intended use of the exposure assessment tool is for screening and relative comparison of different waste sites, remediation activities, and hazard evaluation. The methodology can be used to provide an estimate of health risks for a specific site.

Model Name	Description
MULTIMED model Version 1.01 - Dec 92	The Multimedia Exposure Assessment Model (MULTIMED) for exposure assessment simulates the movement of contaminants leaching from a waste disposal facility. The model consists of a number of modules which predict concentrations at a receptor due to transport in the subsurface, surface air, or air. To enhance the user-friendly nature of the model, separate interactive pre- (PREMED) and post-processing (POSTMED) programs allow the user to create and edit input and plot model output.
MULTIMDP model Version 1.00 - Oct 96	The Multimedia Exposure Assessment Model (MULTIMED) for exposure assessment simulates the movement of contaminants leaching from a waste disposal facility. The MULTIMED model has been modified (MULTIMDP) to simulate the transport and fate of first- and second-generation transformation (daughter) products that migrate from a waste source through the unsaturated and saturated zones to a downgradient receptor well.
PRZM2 model Version 2.00 - Oct 94	Pesticide Root Zone Model - 2 (PRZM2) links two subordinate models, PRZM and Vadose Zone Flow and Transport (VADOFT) to provide a deterministic simulation of the fate of agricultural pesticides in the crop root and underlying unsaturated zone. PRZM2 can simulate multiple pesticides or pesticide parent-daughter product relationships, and estimate probabilities of concentrations or fluxes in or from various media to perform exposure assessments. PRZM/VADOFT codes are linked in PRZM2 using an execution supervisor that can build loading modules tailored to site-specific situations.
PLUMES model Version 3.00 - Dec 94	PLUMES includes two initial dilution plume models (RSB and UM) and a model interface manager for preparing common input and running the models. Two farfield algorithms are automatically initiated beyond the zone of initial dilution. PLUMES also incorporates the flow classification scheme of the Cornell Mixing Zone Models (CORMIX) with recommendations for model usage, thereby providing a linkage between the systems. PLUMES models are intended for use with plumes discharged to marine and some freshwater bodies. Both buoyant and dense plumes, single sources, and many diffuser outfall configurations can be modeled.
PATRIOT model Version 5.10 - Oct 93	Pesticide Assessment Tool for Rating Investigations of Transport (PATRIOT) provides rapid analyses of ground water vulnerability to pesticides on a regional, state, or local level. PATRIOT assesses ground water vulnerability by quantifying pesticide leaching potential in terms of pesticide mass transported to the water table. It integrates a tool that enables analysis of pesticide leaching potential with data required for area-specific analysis anywhere in the U.S. PATRIOT is composed of: 1.pesticide fate and transport model (PRZM2), 2.comprehensive database, 3.interface that facilitates database exploration, 4.directed sequence of interaction that guides user in providing necessary information to perform alternative model analyses, and 5.user-selected methods of summarizing and visualizing results.
QUAL2EU model Version 3.22 - May 96	The Enhanced Stream Water Quality Model (QUAL2E) is a steady state model for conventional pollutants in branching streams and well mixed lakes. It can be operated either as a steady -state or dynamic model and is intended for use as a water quality planning tool. The model can be used to study impact of waste loads on instream water quality and identify magnitude and quality characteristics of non-point waste loads. The Enhanced Stream Water Quality Model with Uncertainty Analysis (QUAL2EU) is an enhancement to the QUAL2E model that allows the user to perform uncertainty analysis.
SWMM model Version 4.30- May 94	Storm Water Management Model (SWMM) - comprehensive computer model for analysis of quantity and quality problems associated with urban runoff. Both single-event and continuous simulation can be performed on catchments having storm sewers, or combined sewers and natural drainage, for prediction of flows, stages and pollutant concentrations. Extran Block solves complete dynamic flow routing equations (St. Venant equations) for accurate simulation of backwater, looped connections, surcharging, and pressure flow. Modeler can simulate all aspects of the urban hydrologic and quality cycles, including rainfall, snowmelt, surface and subsurface runoff, flow routing through drainage network, storage and treatment.
SMPTOX3 model Version 2.01- Feb 93	U.S. EPA regulatory programs have sponsored development of an interactive computer program for performing waste load allocations for toxics -- Simplified Method Program - Variable Complexity Stream Toxics Model (SMPTOX3). It predicts pollutant concentrations in dissolved and particulate phases for water column and bed sediments and total suspended solid. Separate simulation routines are provided for model calibration, waste load allocation, and sensitivity analysis.
WASP model Version 5.10 - Oct 93	The Water Quality Analysis Simulation Program (WASP) is a generalized framework for modeling contaminant fate and transport in surface waters. Problems studied using WASP framework include biochemical oxygen demand and dissolved oxygen dynamics nutrients and eutrophication, bacterial contamination, and organic chemical and heavy

Model Name	Description
	metal contamination. Two WASP models are provided: Toxics, TOXI5, combines kinetic structure with WASP transport structure and simple sediment balance algorithms to predict dissolved and sorbed chemical concentrations in the bed and overlying waters; dissolved oxygen /eutrophication, EUTRO5, combines kinetic structure with WASP5 transport structure to predict DO and phytoplankton dynamics affected by nutrients and organic material.

4.2.6 Sound and Noise

Conceptual Model

Sound is measured in terms of its intensity and frequency with decibel (dB) and hertz (Hz) as their units of measurement respectively. Noise is defined as unwanted sound. Sound and noise may be emitted to the environment from stationary sources (industry, equipment), road traffic and railways, aircraft operations, and blasting. The emissions can result in changes in ambient sound and vibration levels as well as noise levels which may adversely affect health and well being of people living and working in the vicinity of the noise source (Figure 4-15). While there are potential noise impacts on wildlife, this discussion focuses on the effects on people.

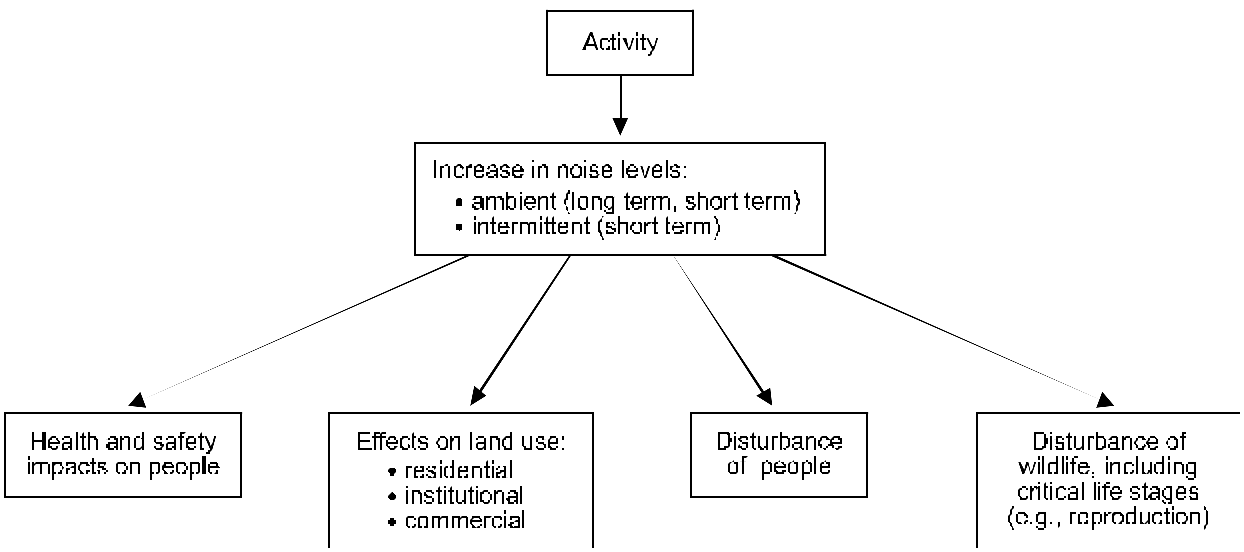


Figure 4-15: Summary cause-effect network of noise impacts.

Empirical models are available to measure sound and noise emissions from roads (considering vehicle type, speed, and road gradient), stationary equipment and plants (considering plant equipment size, power rating. rotation speed, and plant area) and for complex sources like airports. These models are usually integrated with ambient sound and noise models.

Basic Concepts

Noise Measures

Noise is comprised of small, very rapid fluctuations in air pressure to which the ear is quite sensitive. Sound pressure levels are measured on a logarithmic scale in decibels (dB). On this scale 0 dB is the approximate threshold for human hearing and 120 dB is the approximate threshold for pain. Not all sounds at the same decibel levels are perceived to be equally loud as the human ear is less sensitive to some frequencies as others. Also people perceive noise to be more intrusive the longer it persists, the more often it is heard, and the time of day it is heard. A number of descriptors for noise have been developed to account for these factors, including (US Department of Transportation, 1978):

1. Equivalent Sound Level (L_{eq}) - the constant sound level which, in a given situation and time period, conveys the same sound energy as does the actual time varying sound in the same period. The equivalent sound level is the same as the average sound level.
2. Perceived Noise Levels (PNL) - a sound level in decibels by adjusting 1/3 octave band measured levels to correspond to a subjective impression of noisiness.
3. Effective Perceived Noise Level (EPNdB) - a measure to estimate noisiness of a particular sound. It is derived from instantaneous perceived noise level values by applying correction factors for pure tones and the duration of the noise.
4. Sound Exposure Levels (SEL) - the level (dB) of sound experienced of a given time period.
5. Single Event Noise Exposure Levels (SENEL) - the level (dB) of sound experienced during a single event (for example, passage of an aircraft).
6. A- Weighted Sound Levels - the measurement of sound approximating the auditory sensitivity of the human ear (that is, efficient at medium and speech range frequencies). It is measured by an electric weighting network that is progressively less sensitive to sounds below 1000 hertz and is the human ear.

Table 4-9: Measures of noise exposure (*source:* US Department of Transportation, 1978).

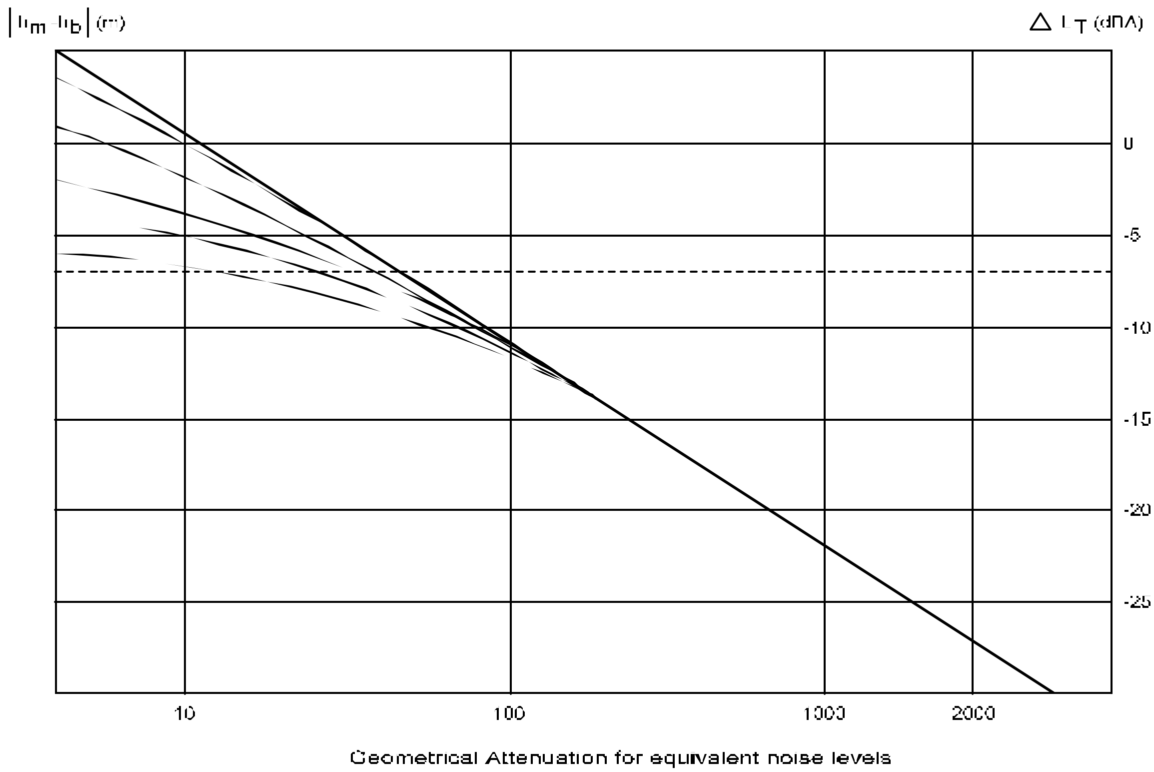
Factor	Noise Exposure Forecasts (NEF)	Day-Night Average Sound Levels (Ldn)	Composite Noise Ratings (CNR)	Composite Noise Equivalent Levels (CNEL)	Time Above Threshold (TA)
Basic measure of single event noise	EPNdb	SEL	PNL	SENEL	L_{eq}
Method of accounting for the duration of single event	Summation of energy above a threshold	Summation of energy above a threshold	None	Summation of energy above a threshold	Summation of energy above a threshold
Time periods during which single events are considered more intrusive	Night (22:00-07:00)	Night (22:00-07:00)	Night (22:00-07:00)	Evening (19:00-22:00) Night (22:00-07:00)	None
Weighting applied to more intrusive events	Night - 12dB	Night - 10dB	Night - 10dB	Evening - 5dB Night - 10dB	None
Summation of contributions of single events to estimate exposure	Logarithmic	Logarithmic	Logarithmic	Logarithmic	Simple Additive

Factor	Noise Exposure Forecasts (NEF)	Day-Night Average Sound Levels (Ldn)	Composite Noise Ratings (CNR)	Composite Noise Equivalent Levels (CNEL)	Time Above Threshold (TA)
Areas of Application	Aircraft Noise	Any Source	Aircraft Noise	Aircraft Noise	Any Source

Noise Exposure Models

The choice of the appropriate measure is related to the specific situation. The Ldn was specifically developed to consider the environmental effects of noise for any source and may be used to compare the noise environment for different situations. For example, the Ldn might be used to compare the noise exposure associated with an existing highway to that of a new airport.

For roads, models are available which have theoretical basis and which are calibrated in the field. There are models for urban roads, waterways, and suburban roads. The models simply apply a variable number of correcting factors, for example, traffic, road, environment, etc., to the curbside emission level to predict its attenuation in the acoustic environment. The commonly used noise scales in road models are the L_{eq} and L_{10} values as they are related to noise conveyance. Figure 4-16 is a sample graph for the attenuation of noise (L_{eq}) with distance from a road.



Correction ΔL_T of the basic value with regard to the perpendicular distance 'a' (m) from receiver to the centre of the road as well as the difference in levels h_m-h_b (m) between receiver and road embankment

a = perpendicular distance between reciever and road centre (m)
h_m = height of receiver (m)
h_b = height of embankment (m)

Figure 4-16: The attenuation of noise (L_{eq}) with distance from a road (*source:* ERL, 1984)

Models for railway environments have the same format as road models, that is the trackside emission level is corrected to predict the attenuation of sound over distance, although fewer correcting factors are applied. Both noise scales and indices are used.

Because of the complexities in aircraft operations, airport models are computerized (for example, the US Federal Aviation Authority's integrated noise models). Most of the noise exposure indices (NEF, Ldn, CNR, SENEL and TA) are used in airport models. The corrected noise exposure level, noise exposure forecast, and composite noise ratings are widely used in military airport studies. Time exposure units (for example, TA65-time above 65dB) and total acoustic energy unit (for example, corrected noise exposure level) are used in aircraft assessment.

Comparison Against Acceptable Levels of Noise

The final step is the prediction of the effect on the target organism, in this case, people. It is not practical to develop dose-response functions for people similar to ecotoxicological effects model. However, land use compatibility guidelines have been developed for acceptable levels of noise (Figure 4-17). These are based on the experience and perceptions of people in the United States. Developing countries may choose to develop other guidelines.

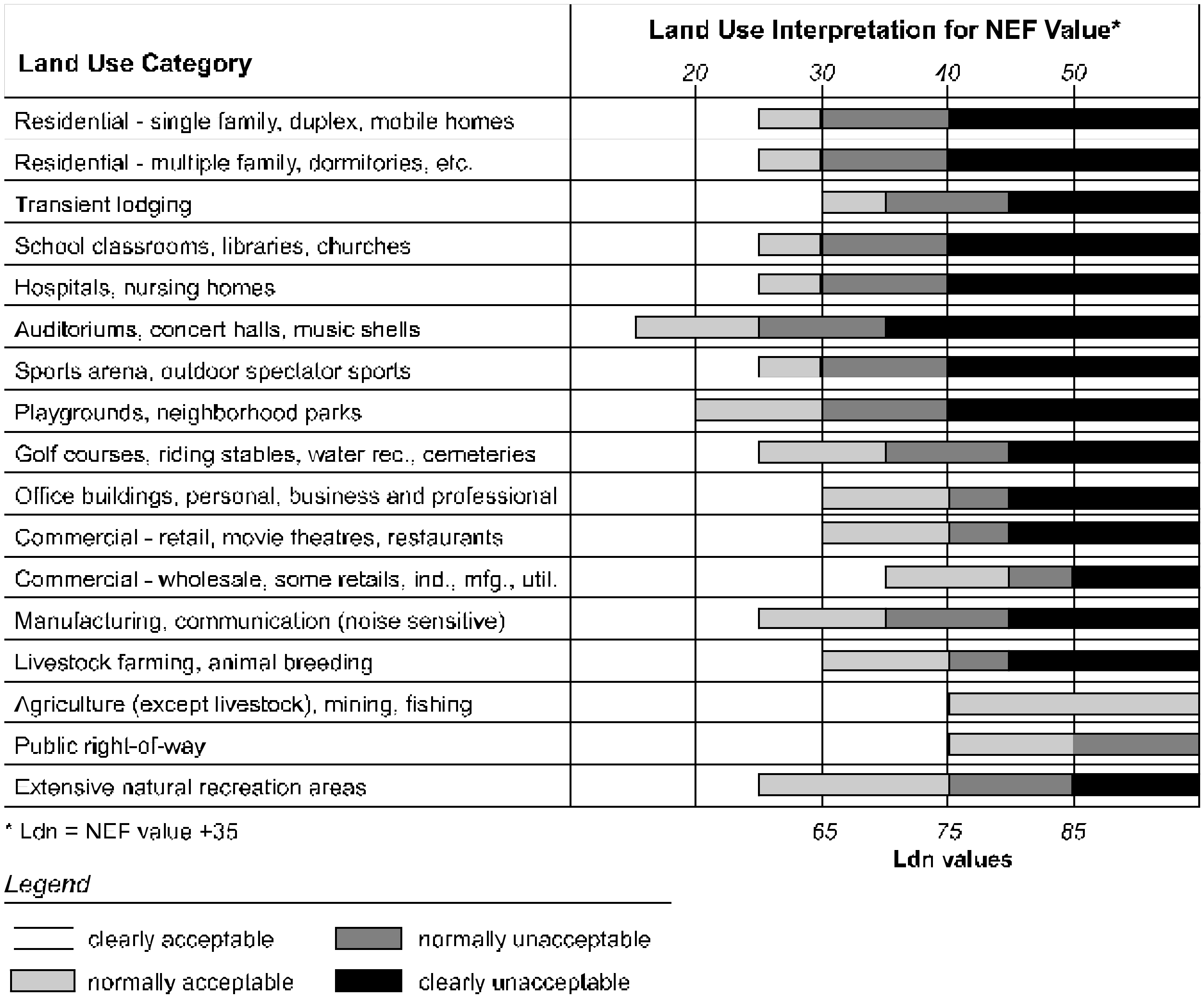


Figure 4-17: Land use compatibility guidelines for noise environment.

Summary of use of Noise Models in Developing Countries

STAMINA: STAMINA was developed for the Thonburi Road Extension Project in Thailand to forecast traffic conditions

NOISECALC: The New York State Department of Public Service's NOISECALC computer program was used to predict noise impacts associated with the Mangalore Thermal Power Station project.

JICA Noise Model: The Masinloc Coal Fired Thermal Power project analysis used a noise model developed by JICA based on a report undertaken for the Coal-Fired Thermal Electric Development Project in Luzon Island in 1990. The model considered the attenuation by distance, the effects of the barrier, and adsorption in the air. All noise sources are assumed to be point noise sources with no directivity.

4.3 References

Canter, Larry W. 1995. Cumulative effects and other analytical challenges in NEPA. draft paper, University of Oklahoma, Norman Oklahoma.

Canter, Larry W. 1996. Environmental Impact Assessment. second edition. McGraw Hill Publishing Company, Inc., New York, NY. 660 pp.

Canter, Larry W. and Barry Sadler. 1997. A Tool Kit for Effective EIA Practice — Review of Methods and Perspectives on their Application. A Supplementary Report of the International Study of the Effectiveness of Environmental Assessment. Environmental and Ground Water Institute, University of Oklahoma, Institute of Environmental Assessment, UK and the International Association for Impact Assessment.

Center for Exposure Assessment Modeling (CEAM). n.d. EXAMS Model System Abstract. National Exposure Research Laboratory - Ecosystems Research Division Office of Research and Development U.S. Environmental Protection Agency. Athens, Georgia.

de Brossia, Michael. 1986. Selected Mathematical Models in Environmental Impact Assessment in Canada. Canadian Environmental Assessment Research Council. Hull, QC. 34 pp.

ERL (Environmental Resources Limited). 1984. Prediction in Environmental Impact Assessment, a summary report of a research project to identify methods of prediction for use in EIA. Prepared for the Ministry of Public Housing, Physical Planning and Environmental Affairs and the Ministry of Agriculture and Fisheries of the Government of Netherlands.

General Sciences Corporation. 1993. SWRRBWQ Windows Interface User's Guide: DRAFT. Office of Science and Technology, Standards and Applied Science Division, U.S. Environmental Protection Agency. Washington, DC.

Mckay, Donald, and Sally Peterson. 1993. Mathematical Models of Transport and Fate. in Ecological Risk Assessment. ed. Glenn W. Suter II. Lewis Publishers, Ann Arbor, MI. 538 pp.

Nicks, A.B., C.W. Richardson, and J.R. Williams. 1990. Evaluation of the EPIC Model Weather Generator. EPIC - Erosion/Productivity Impact Calculator Model Document. USDA. ARS. Technical Bulletin Number 1768: 105-124.

Schultz International Ltd. 1993. An investigation of acidic deposition in Northern Thailand Draft Final Report. Prepared for the Electrical Generating Authority of Thailand. Schultz International, Vancouver BC.

Suter, Glenn II. 1993. Exposure. in Ecological Risk Assessment. ed. Glenn W. Suter II. Lewis Publishers, Ann Arbor, MI. 538 pp.

Thornton, Kent W., David Marmorek, Patrick Ryan, Kim Heltcher, and Don Robinson. 1990. Methods for Projecting Future Changes in Surface Water Acid-Base Chemistry. Acid Deposition: State of Science and Technology, Report 14. National Acid Precipitation Assessment Program. Superintendent of Documents, Government Printing Office. Washington, DC. 162 pp.

U.S. Department of Transportation. 1978. Environmental Assessment Techniques - Notebook 2 of Guidance Notebooks for the Environmental Assessment of Airport Development Projects. U.S. Government Printing Office, Washington, DC.

Walters, Carl. 1986. Adaptive Management of Renewable Resources. Macmillan. New York. 374 pp.

Westman, Walter E. 1985. Ecology, Impact Assessment, and Environmental Planning. John Wiley & Sons, New York, NY. 532pp.

Williams, J. R., A. D. Nicks, and J. G. Arnold. 1985. Simulator for water resources in rural basins. J. Hydr. Eng., ASCE 111(6): 970-986.

5.0 Risk and Uncertainty in Environmental Impact Assessment

Many kinds of uncertainty are present in economic development; for example, financial risk analysis (such as, return on investment) has long been a part of management information. Environmental Impact Assessment (EIA) provides the scope and much of the data for explicitly dealing with uncertainties relating to environmental risks. This chapter reviews the nature of scientific uncertainties about the environment, and then provides an introduction to the concept of, and methods for, *Environmental Risk Assessment* (ERA). Rather than being a separate assessment, ERA is an extension of EIA, undertaken when uncertainties are large and important to project success.

The two major categories of risk are those to human health and those to ecosystem integrity. They are sufficiently different that this chapter deals with them individually. Because of the emphasis in U.S. law, human health risks from cancer are relatively well quantified compared with those from other diseases — this warrants yet another separation of methodologies. A primary use of ERA results, discussed here, is the comparison of risks, their monetary costs, and the costs of emergency response or avoidance. Remaining issues in the improvement of ERA are reviewed in each section.

5.1 The Nature of Uncertainty

Science is the activity of understanding the regularities of the universe and revealing the simple laws that produce them. Prediction (for example, EIA) to guide human actions is also a primary goal of science, however uncertainties interfere, causing what occurs to differ from what was expected. Scientific truth is always somewhat uncertain, and information is characterized by kinds and degrees of doubt, change, and availability.

Ecological uncertainty is of two basic kinds: what is not known at all, and errors in what is known. The latter type is a quantitative departure from the truth, and can sometimes be expressed statistically as a distribution of a number of repeated measurements around a mean value. Other forms of quantitative uncertainty are incomplete data, “anecdotal” data which is not gathered with a statistical design, inappropriate extrapolation, and temporal and spatial variability of the measured parameter. Most important environmental problems, however, suffer from true uncertainty — that is, indeterminacy, or events with an unknown probability. Surprise is a manifestation of uncertainty that, by definition, cannot be predicted. Totally unanticipated rapid and adverse changes in ecosystems may arise from apparently unrelated policy or social events. Long-term effects sometimes become evident only much after the original cause, and explanation may be confounded. For example, surprising consequences in ecosystem behavior are likely as a result of rapid climate change, carbon dioxide fertilization, and enhanced UV radiation. Ocean warming may bring larger and more frequent typhoons, previously unexperienced by tropical coastal zones. Rare stochastic events such as large meteor impacts, major earthquakes, and large volcanic eruptions provide another source of surprise. Multiple causes and nonlinear response are also sources of “unknowable” outcomes.

Box 5-1: Chemical Time Bombs.

One example of surprise is the potential for "chemical time bombs." Long lasting chemicals such as heavy metals and refractory organic compounds may not be toxic or bio-available in the chemical combination or form in which they first are introduced into the biosphere. They are thus ignored in conventional ecotoxicology. Accumulating in soils, sediments and groundwater, they can undergo transformations due to changes in land use, climate, acidification, redox potential, and cation exchange capacity. The responses of biota to these pollutants is time-delayed and nonlinear. ERA can provide an estimate of these risks.

Uncertainties have relative importance, depending on their size. Stochasticity is the variation in response of an ecosystem due to random, uncontrollable factors such as weather, and not to the stressor being studied. If stochasticity is large, a smaller degree of error in measurement is not of much help, and the predictive power of the EIA/ERA is limited.

Another source of uncertainty is bias resulting from measurement and sampling errors of the parameters in a model. These may be reduced at some cost. Field operations, especially in developing countries, make improvements difficult (see section 5.1.2).

Box 5-2: Sources of Uncertainties.

Uncertainties arise from:

- lack of theory, explanatory paradigms, and basic understanding;
- inadequate monitoring of parameters of environmental conditions;
- sampling and analytical errors;
- lack of baseline environmental data at a project site;
- models that do not completely correspond to reality because they cannot consider all variables and must be simplified;
- the novelty of technology, materials or siting;
- inherent variation and stochastic events in complex natural systems; and
- control and replication problems in ecological research.

Box 5-3: Types of Uncertainty Suggesting the Need for ERA.

- Potential for leaks and spills
- Accident rate
- Errors in human behavior
- Weather and storm events
- Movement and fate of pollutants in the environment
- Dose/response relationships based on animal studies
- Equipment and structural failure rate

5.1.1 Natural Variation

A familiar source of uncertainty is natural variation. Any "signal" that a change in condition is due to human action is often hidden in the "noise" of natural changes in the value measured. For example, no statistically significant change in the volume of water discharged by the Amazon River, or the amount of sediment delivered from the deforested Rondonia region, has yet been detected. In this case, a signal that deforestation has altered the hydrologic cycle or soil erosion rate in that basin is obscured by the high natural variability of rainfall. El Niño events explain most of the occasional trends in the “noise” evident in the hundreds of river gauging stations. Scientific research cannot decrease natural variability, but can certainly improve our ability to detect the cause-effect signal.

5.1.2 Biophysical Measurements in the Field

Collecting statistically reliable data in the field in developing countries over a long period of time can be problematic. Access to remote sites may be disrupted during rainy seasons. Political unrest, corrupt officials, and guerilla activities intimidate researchers. Vandalism and theft deplete project equipment and supplies. Heat and humidity, unreliable electric power, poor or nonexistent repair and maintenance facilities, and untrained manpower reduce the effectiveness of sophisticated instruments.

Natural variation in rainfall, soil characteristics, crop yields, biomass productivity, and pest population dynamics are a reality in EIA. The range of natural variability is usually between 100% and 1000%. Spatial variation can be reduced by sampling a larger area or by using larger representative plots, more sample points, or more transects. Temporal variation can be reduced by sampling more frequently or over longer time periods. Both types of variation can be reduced by using a composite sample or by concentrating sampling in the area or period of greatest variability. The detection of a change in one of these parameters due to some management practice or action depends on the magnitude of the change compared with the magnitude of the natural variation — the signal to noise ratio. If this ratio is not greater than one, the large number of replicate samples required to give a 95% confidence level is often too expensive or time consuming to be obtained.

Walters and Holling (1990) explain the necessity for continuous EIA and adaptive ecosystem management:

> Almost by definition, the impacts will be the consequence of disturbances that are unlike any natural system has yet experienced. . . . [T]he post-project system is a new system, and its nature cannot be deduced simply by looking at the original one. If the project planning and development sequence fundamentally incorporates adaptive assessment throughout all of its stages, then the ecological response of both the old and the new systems will be studied. . . . [A]ssessment merges into environmental management. . . . Environmental assessment should be an ongoing investigation into, not a one-time prediction of, impacts (emphasis in the original).

5.1.3 Data Quality

The category of uncertainty that can most readily be reduced has to do with data quality. Determining which parameters are most relevant to decisions affecting sustainability should focus on field investigations. Better monitoring program design can make data collection more efficient and cost-effective; more use can be made of prior similar studies and existing information. Decision makers should be involved in data quality management in order to express their acceptable decision error rate, that is, the probability of making an incorrect decision based on data that inaccurately estimate the true state of nature. Acceptable data quality depends on the decision for which it is to be used and the comfort level demanded by the decision maker.

Accuracy is a combination of precision (standard deviation) and systematic errors (bias in measurements). Other elements of quality are mean square error, representativeness, comparability and completeness. Practical management decisions dictate the required degree of certainty. For example, if soil building processes at a site suggest a tolerable soil loss rate of 7 +/- 3 tons/hectare/year, and soil erosion measurements under the existing agricultural practice predicted in an EIA are 20 +/- 7 tons/ hectare/year, then a clear signal of unsustainability is given, even with the uncertainty. Institutional aspects such as budget disruptions and policy changes may also affect data quality by preventing time series from accumulating. All of these quality aspects are, however, amenable to standardization and control.

Box 5-4: Statistical Analysis.

The null hypothesis is that human intervention (for example, a development project) causes no effect on the environment. A type I error is to reject a true null hypothesis. A type II error is to accept a false null hypothesis. When uncertainty prevents both types of error from being avoided, science traditionally prefers to minimize the risk of making a type I error. For example, if a development or regulatory agency makes a type I error (that adverse change has occurred when none has), unnecessary protective or corrective expenses may be incurred. More dangerous, however, is the usual total disregard of variance and the presentation of a single (expected, or mean) value as a "go - no go" advisory from the impact assessor. This is misleading at best, and quite often will be disputed by subsequent events, earning the assessor the future distrust of the decision maker. Uncertainty must be embraced and preserved by the analyst and communicated clearly to the manager. Statistical "power" of a hypothesis test is the probability of avoiding the type II error; that is, accepting the null-no effect when change has occurred. In contrast with the more familiar "confidence," or the probability of avoiding the type I error (rejecting the null when in fact there has been no change), power is seldom considered in designing monitoring programs. If the size of an impact is small relative to natural variability, it will be difficult to detect with any degree of confidence. The probability of correctly concluding that change has occurred is equally as important as knowing the confidence level, and may be preferred from an ethical standpoint.

Incidentally, the so-called 95% confidence limit — often the minimum statistical significance required for scientific data to be taken seriously — needs to be understood by scientists and their clients for what it is: an artifact of arithmetic in normal distributions of sets of repeated measurements. The probability is 0.95 that the next measured value will lie in an interval on the distribution between 1.96 standard deviations on either side of the mean. 95% of samples taken in the same way will yield confidence intervals that contain the true mean. The coincidence of this interval being about ~2 standard deviations, and the "comfort" that decision makers seem to feel in being right 19 times out of 20, has given a false authority to this arbitrary formulation that is now widely accepted as a standard of certainty. Some bench mark is required for expediency, however, and this one is useful.

Hypothesis Testing: Let us try to apply these arguments to EIA. Say that a parameter of environmental change or damage (D) exists such that an acceptable development project or practice produces $D \leq 0$. The null hypothesis is thus $D = 0$. A "truth table" like that below may be constructed.

	State of Nature, Truth:	
	Null is true- no damage- Project is acceptable	**Null is false- damage- Project is unacceptable**
EIA Conclusion:		
Do not reject null - Project is acceptable	No Error	Type II Error
Reject null - Project is unacceptable	Type I Error	No Error

Whether a management practice at a site is acceptable or not is akin to the question of safety, and safety (a negative concept - the absence of harm) is not provable in a statistical study. The EIA should not reject the null hypothesis if it is true. The difficulty arises because the rejection of a hypothesis is a strong statement, while evidence that favors the null hypothesis is regarded as confirmatory evidence but not proof. The EIA finding that the project is acceptable really means that there is no evidence to indicate otherwise, and the finding should be viewed with some suspicion. Calculating the power, or probability of a type II error takes more data gathering, and is much more difficult to do, than calculating the confidence, or probability of a type I error. In contrast to confidence, power does depend on the magnitude of the hypothesized change to be detected — the larger the change, the larger the power. Increasing the number of sampling stations and frequency of sampling can also increase power, but at some cost in time and effort. Analysis of variance in typical environmental problems shows that the number of samples required to give a power of 0.95 increases rapidly if changes smaller than 50% of the standard deviation are to be detected. Thus, the desired emphasis on avoiding type II error must be balanced against other opportunities to use limited scientific resources to reduce uncertainty in achieving sustainability.

5.2 Risk Assessment Deals Explicitly With Uncertainty

Risk assessment (RA) is the scientific method of confronting and expressing uncertainty in predicting the future. Risk is (has the dimensions of) the chance of some degree of damage in some unit of time, or the probability of frequency of occurrence of an event with a certain range of adverse consequences. These probabilistic expressions, as opposed to a single (mean or expected) value, are what distinguish RA from mere impact assessment. The irreducible uncertainties leave uncertain the calculated absolute value of a risk, often by as much as an order of magnitude or more. Risk itself, therefore, should be expressed and communicated as a mean plus its standard deviation, in addition to any upper bound or worst case calculation that may be used for purposes of conservative policy.

Environmental risk assessment is the process of evaluating the likelihood of adverse effects in, or transmitted by, the natural environment from hazards that accompany human activities. Some of the major hazards associated with development projects are listed in Table 5-1. The effects from hazards may be on human health, economic welfare, quality of life, and *valued ecosystem components* (VECs). The severity, or distribution of the range of magnitude of the adverse effect (damage), is also evaluated.

Table 5-1: Major hazards associated with development projects.

Type of Project	Hazard					
	Toxic Chemical	Flammable or Explosive Material	Highly Reactive or Corrosive Metal	Extreme Conditions of Temperature or Pressure	Large Mechanical Equipment	Collision
Refinery/Petrochemical	X	X		X		
Pesticide Manufacturing	X					
Fertilizer (N&P)	X		X	X		
Pulp and Paper	X					
Thermal Electric		X		X	X	
Oil and Gas Transport		X		X		X
Heavy Chemicals	X		X			
Light Chemicals	X	X				
Smelting	X		X	X	X	
Cement		X		X		
Railroad	X	X			X	X
Highway	X	X				X
Hazardous Waste	X	X	X			
Ports and Harbors	X	X	X		X	X
Dam and Reservoir				X	X	

In its rigorous form, ERA deals with the excess risk — that anthropogenic risk in addition to normal existing risks from natural variation and natural events. ERA also is limited to residual risk from the project being assessed, assuming all existing installations are meeting environmental regulations. Natural disasters are recognized as interacting with anthropogenic hazards to sometimes increase the risk from the latter, but natural disasters are not usually the focus of ERA.

Ecological Risk Assessment (EcoRA) is a subset of ERA. It deals with the condition of ecosystems rather than human health or individual organisms. The site, or ecosystem occurrence in geophysical terms, is analogous to the person in human health ERA. EcoRA has a host of special problems (for example, choosing assessment endpoints) that are well recognized and that add to the uncertainty of the results.

The communication of ERA results should take the form of decision analysis, that is, what options are available and, for each option, what are the risks, costs, and benefits, and how are these distributed within society. Proper comparison and communication can change laypeople's misperceptions of risks so participatory decision making may proceed on a more rational, less emotional basis.

EIA is a prediction based on quantification of cause-effect relationships. The opportunities for variability of data, only partial understanding of development activities and their consequences, and future surprises are obvious. These uncertainties may not, however, be properly communicated to the decision maker since the language of EIA often expresses an "if, then" finding without explicitly addressing the probabilities that are implied. The EIA may use the average (mean) or expected value, or alternatively, a worst case value. The implied choice may be conservative or optimistic, and is usually internally inconsistent. The use of mean values for measurements of effects, when the actual data are widely scattered and/or skewed from a symmetrical bell-shaped pattern, is also misleading. The correct and appropriate way to characterize data is to describe the statistical distribution of a range of values and the confidence with which that range is held to be true. ERA makes it practical to carry throughout the problem analysis, following the rules of probability theory, an expression of the likelihood of all possible values of each parameter. ERA is also known as Probabilistic Risk Assessment and Probabilistic Quantitative Risk Assessment. ERA informs managers and decision makers about the frequency and severity of those adverse consequences to the environment caused by their activities or planned interventions. If these officials are not comfortable with the predictions, changes (for example, using a different site or alternative technology, implementing risk management or emergency response capability) can be made to mitigate or eliminate the impact and to reduce the risk.

Box 5-5: History of Environmental Risk Assessment.

Technological risks began to be specifically analyzed during World War II in military operations research and thereafter in the nuclear energy and space exploration fields. The concern was mainly with infrequent but catastrophic events. Since then, the number of severe industrial accidents that have captured headlines has increased. At the same time, environmental concerns have become a central theme in public policy discussions. Factory explosions, oil tanker spills, chemical tank car derailments, and petroleum product fires have generated a public demand for prevention and a profound concern for victims and damage to the natural environment. Official responses have included:

1980- The Scientific Committee on Problems of the Environment (SCOPE) of the International Congress of Scientific Unions ished the landmark report “Environmental Risk Assessment” (Whyte and Burton, 1980).

1982- The European Economic Community issued the so-called Seveso Directive on potential industrial hazards, following a ous dioxin release incident in Italy.

1984- The World Bank, after the Bhopal, India methyl isocyanate disaster, issued guidelines and a manual to help control major ard accidents (World Bank, 1985a, 1985b).

1987- The Organisation for Economic Cooperation and Development (OECD) compiled a report on risk assessment in the OECD ntries with sections on the nuclear industry, chemicals, petroleum processing, transportation of hazardous materials, and dam-reservoir ects (Hubert, 1987).

1987- The much referenced [Brundtland] Report of the World Commission on Environment and Development called for “further elopment of technology/risk assessment methodologies ...” in pursuing sustainable development.

1990- The Asian Development Bank published “Environmental Risk Assessment: Dealing with Uncertainty in EIA.” (Carpenter et 1990).

1992- Over fifty commercial banks signed a statement that, as part of their credit risk procedures for both domestic and international ing, they would recommend EIA and ERA.

Box 5-6: Uses of ERA in development planning and management.

- Land Use Planning
  - Zoning, restrictions, or exclusion distances to separate industry from residential areas
  - Siting of industrial park components; for example, landfills, incinerators
  - Transportation routing
- Pollution Control Regulations
  - Standards setting
  - Design of monitoring systems
  - Strategies for cleanup of existing hazards
- Allocation of Money and Effort for Risk Reduction
  - Emergency plans
  - Inspection schedules
  - Screening chemicals to set priorities
  - Addressing traditional vs. modern technological risks
  - Training
- Comparing alternative development pathways
  - Import vs. local manufacture
  - Different technologies or raw materials to yield the same goods and/or services

ERA is expensive and so is performed as a part of the EIA process only when uncertainties are large and important for prudent decision making. There should be just one environmental assessment report. Figure 5-1 provides a generic illustration of probabilistic concentration of a toxic material that is the consequence of a hypothetical scenario. When the concentration can be estimated with little error (small standard deviation from the mean), the mean may be used to decide whether it exceeds the maximum allowable level; but when the error in the estimate is large, a statistical expression is necessary to convey the risk of exceeding the maximum allowable level.

A hazard is a danger, peril, source of harm, or an adverse impact on people or property. Risk is an expression of chance, a function of the likelihood of an adverse impact and the magnitude of its consequences.

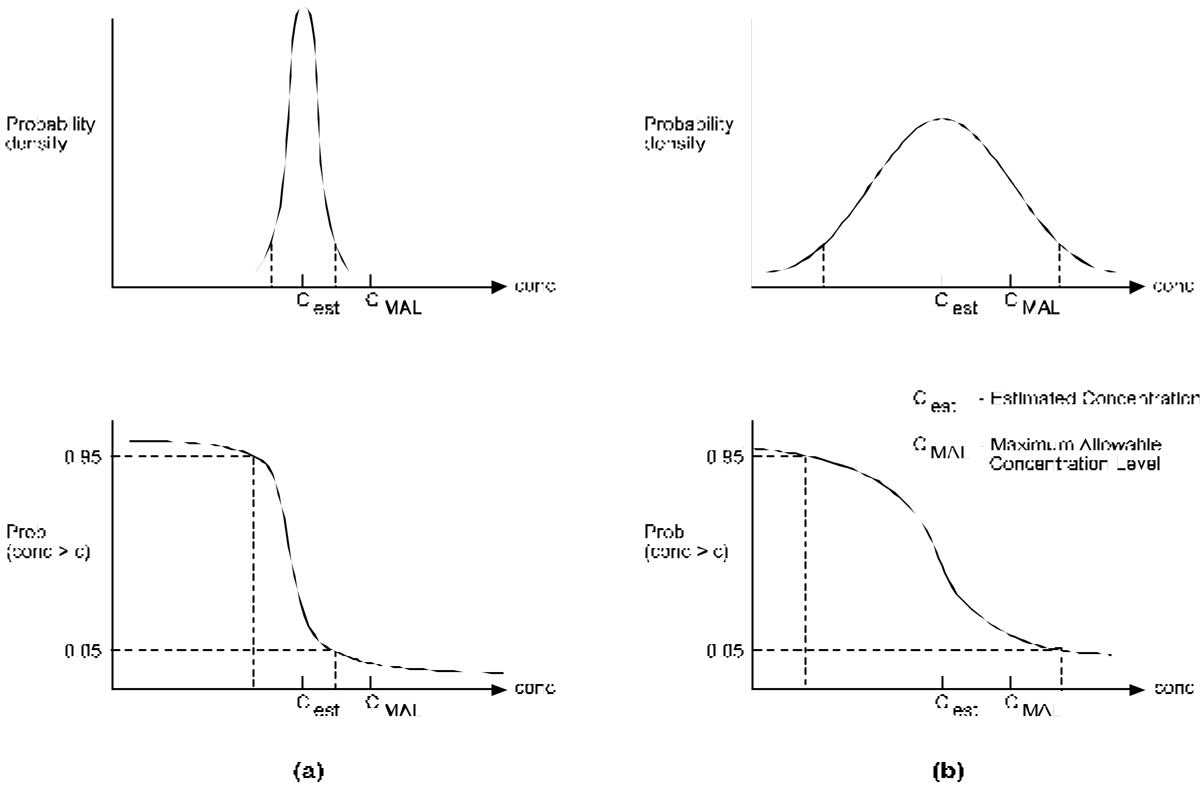


Figure 5-1: Generic illustration of probabilistic concentration of toxic material that is the consequence of a hypothetical scenario. In a) uncertainty is small and an EIA is adequate; in b) uncertainty is large and ERA should be considered to aid in decision-making. Upper curves are probability density functions (the area under the curve between the horizontal axis coordinates is the probability that the actual parameter value lies between those coordinates), and the lower curves are the probability distributions (the vertical axis coordinate for the curve is the probability that the actual parameter value is greater than the horizontal axis coordinate). (*source:* Carpenter et al., 1990).

Box 5-7: Screening.

While when to do ERA is a matter of judgement, some typical hazards to the environment (and their subsequent impacts) suggest the need for ERA. These include:

- toxic, flammable, or explosive materials (while most ERAs of development projects deal with hazardous materials, the screen test here f the chemical is present at any one time, and how hazardous is it, usually in terms of toxicity to humans (see Table 5-2));
- large and complex mechanical equipment or controls;
- extreme conditions of temperature or pressure;
- transportation accidents;
- natural disasters interacting with technological installations; and
- large, rapid changes to valuable ecosystems.

Table 5-2: Chemicals requiring priority attention in developing countries.

Metals:	Cadmium, Chromium (Hexavalent), Lead, Mercury
Pesticides:	DDT, Arsenicals, Paraquat
Solvents:	Trichloroethylene, Perchloroethylene, Benzene
Cyanide (metal processing wastes)	
Polychlorinated Biphenyls (PCB)	
Volatile Organic Compounds (VOC):	Chloroform, Carbon Tetrachloride
Highly Toxic Organic Intermediates:	Aniline, Phosgene
Bulk Chemicals:	Chlorine, Ammonia

5.3 Performing ERA

ERA addresses four questions:

- What can go wrong to cause adverse consequences?
- What is the probability of frequency of occurrence of adverse consequences?
- What are the range and distribution of the severity of adverse consequences?
- What can be done, at what cost, to manage and reduce unacceptable risks and damage?

EIA should answer the first question, and give at least a qualitative expression of the magnitude of the impacts. The major additional consideration in ERA is the frequency of adverse events. Risk management is integrated into ERA because it is the attitudes and concerns of decision makers that set the scope and depth of the study. ERA attempts to quantify the risks to human health, economic welfare, and ecosystems from those human activities and natural phenomena that perturb the natural environment.

The five step sequence in performing ERA is:

1. hazard identification - sources of adverse impacts;
2. hazard accounting - scoping, setting the boundaries of the ERA;
3. scenarios of exposure - how the hazard might be encountered;
4. risk characterization - likelihood and severity of impact damage; and
5. risk management - mitigation or reduction of unacceptable risk.

5.3.1 Step 1 - Hazard Identification

This step, which is akin to the qualitative prediction of impacts in EIA, begins to answer the question "What can go wrong?" It lists the possible sources of harm, usually identified by experience elsewhere with similar technologies, materials, or conditions. This is, in fact, a preliminary risk assessment, immediately useful to managers in appraising the project or activity upon which they are embarking.

Hazardous chemicals are a major topic for ERA. Elaborate screening procedures have been devised to judge when a chemical merits full investigation (Carpenter et al., 1990). The U.S. Environmental Protection Agency (EPA) and the World Bank issue threshold guidelines based on frequently revised lists of highly toxic chemicals. These thresholds indicate the amounts of each chemical, if present at any one location, that trigger risk assessment and emergency planning. Similar quantity-related guidelines are issued for highly reactive and flammable materials.

5.3.2 Step 2 - Hazard Accounting

In the second step, ERA a) considers the total system of which the particular problem is a part, b) begins to answer questions about the frequency and severity of adverse impacts, and c) sets the practical boundaries for the assessment. Much of the hazard accounting will be covered during the scoping of the EIA. For example, a hazardous chemical may pose a risk in any stage of its life cycle, that is, from mining/refining or synthesis through manufacturing, processing and compounding, to storage and transportation, to use and misuse, and finally, to post-use waste disposal or recycling.

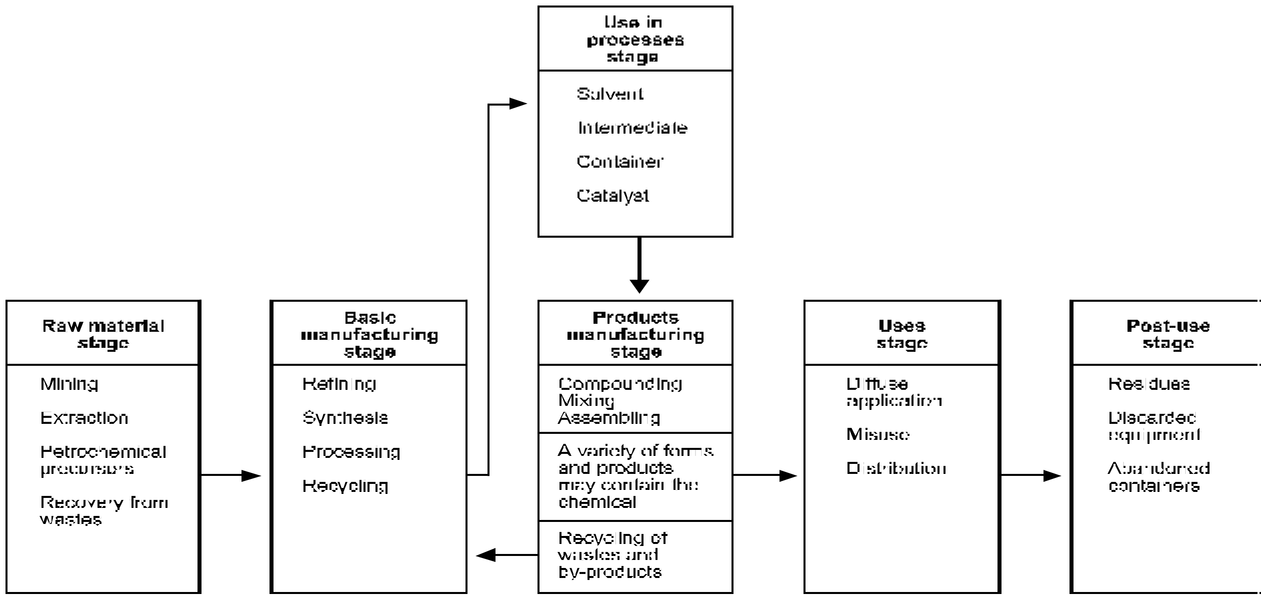


Figure 5-2: Generic flow cycle for hazardous chemicals. Any of the stages may involve suboperations of packaging, storage and transportation (*source:* Smith et al., 1988). During the hazard accounting step, it is decided which parts of the flow cycle are appropriate to be included in the ERA (dependant on the management questions being asked).

Risk managers must state their concerns and indicate possible linkages of operations to mitigation measures. Some of the scoping choices to be made are:

- geographic boundaries;
- time scale of impacts;
- stages of the causal chain of events;
- phase or phases of the technological activity;
- whether to include routine releases or just accidents;
- whether to include workers or just the general population;
- definitive end points for health or ecosystem effects; and
- cumulative effects and interactive risks that result from other projects.

The scope should include the social and natural systems around a project, not just a single pollutant path. For example, it would be wrong to assess the risk posed by small concentrations of halomethanes produced incidentally to the chlorination of drinking water without comparison of the risks to the same public from not killing the pathogenic organisms with chlorine.

The time covered should include all phases of an activity where risk is important, not just the operational period. Construction, maintenance and dismantling may pose special hazards. For example, it is well known that the Chernobyl nuclear reactor was being tested, and normal safety systems were disabled, at the time of the disaster. Toxic effluents such as heavy metals may circulate for a long time and nuclear wastes may have half lives of thousands of years. It is common practice to look at least one lifetime (about 75 years) into the future. The important point is that the time horizon should be consciously chosen and recorded as one of the assumptions of the ERA.

A causal chain for a risk may stretch from an original decision to satisfy some wants and needs, through the choice of technologies, to adverse events, to exposure conditions, and finally to health impacts. In a sense, the Bhopal accident originated with India's desire to be self sufficient and to invite the local manufacture (incidentally by a multinational concern) of pesticides necessary for the protection of food crops. Such a comprehensive analysis of all related human activities is difficult and infrequently attempted.

5.3.3 Step 3 - Scenarios of Exposure

No exposure means no risk, so experiential or imaginative constructions (models) are made of how the hazard might be encountered. For the environmental pathway, the bodily dose/response calculation is only one step. Knowledge of earlier parts of the exposure sequence can reveal chances to reduce risk. For example, a toxic chemical may ultimately poison people when inhaled, but ERA seeks information on:

- the type, amount, location, and storage conditions of the chemical (an inventory);
- releases to the environment, whether deliberate or accidental;
- how people are exposed and for how long;
- ambient concentrations;
- the actual bodily dose; and then
- the physical condition of specific victims that might affect how they respond.

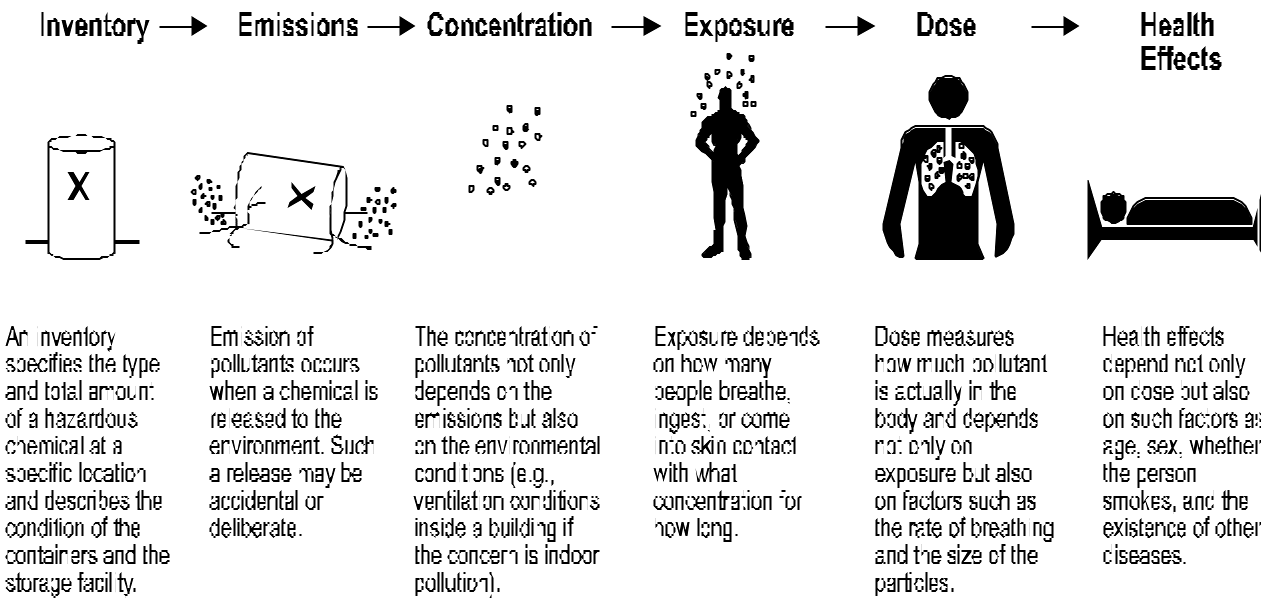


Figure 5-3: The relationship between quantity, emissions, environmental considerations, human exposures, doses, and health effects. At each step, different units and techniques of measurement are used with differing degrees of reliability and specificity. A complete understanding of the risk represented by a pollutant and the potential ways to manage it would entail exploring all the links shown. In practice, lack of data, time or money substantially limit the direct relationship with human health (*source:* Carpenter et al., 1990).

Reasonable sequences of events and environmental pathways by which the source of harm could impact health and welfare, including the condition of ecosystems, are devised. For example, a toxic chemical might move from any point in its life cycle through air, water, plants, animals, or soil to cause an exposure by skin contact, inhalation or ingestion (see Figure 5-4).

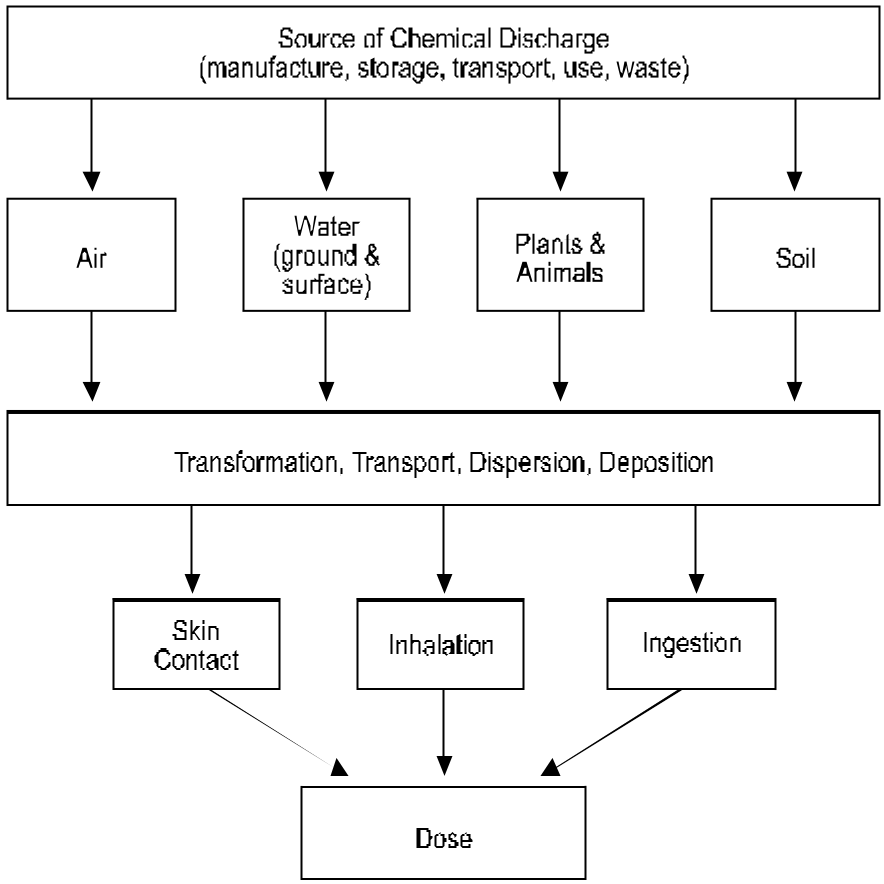


Figure 5-4: Exposure pathways (*source:* Carpenter et al., 1990)

Accident scenarios and their likelihood are analyzed with methods that evolved from the nuclear energy industry. Hazard and Operability Studies (HazOps) investigate deviations from the intent of engineering design. A multidisciplinary team identifies all credible accident scenarios using detailed design information, operating characteristics, and actual operating experience with engineering components and systems.

The Fault Tree procedure begins with an accident and determines with "reverse analysis" the equipment failures or events that could have led to it. The Event Tree procedure begins with a component failure and follows a "forward analysis" to determine if a major accident could result. Figure 5.5 illustrates the differences between the two approaches and also how they can be used in a complementary manner. Maintenance of publicly available data bases on industrial accidents is carried out by the European Economic Community, the U.S. EPA, and the American Institute of Chemical Engineers.

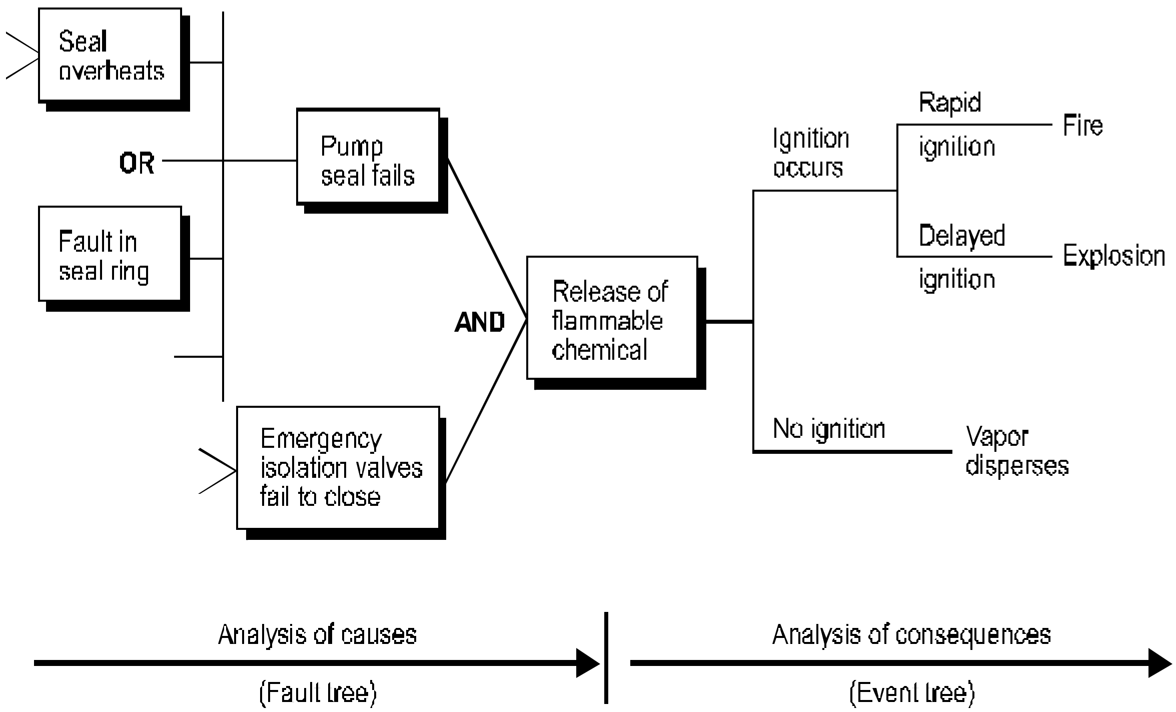


Figure 5-5: Event and fault trees are approaches to schematically breaking down complex systems into manageable parts for which failure rates or other risk-related data can be found. It is thus possible to construct some idea of the failure rate and resultant risk of a large, complex, and new entity, such as a chemical plant, even if no data about its performance exist. This example shows the differences between the two approaches and also how they can be used in a complementary manner (*source:* Smith et al., 1988).

Fault Tree Analysis

During hazard analysis the sequence of events which could lead to hazardous incidents is set out. The likelihood of the incident is then quantified. Fault tree analysis plays a key role in this part of the risk assessment.

Fault tree analysis is normally used to evaluate failures in engineering systems. The analysis provides a graphical representation of the relationships between specific events and the ultimate undesired event (sometimes referred to as the "top event"). For example, the ultimate undesired event might be a large fire for which the preceding events might be both spilling a large quantity of flammable liquid and introducing a source of ignition. Fault tree analysis allows systematic examination of various materials, personnel, and environmental factors influencing the rate of system failure.

The method also allows for the recognition of combinations of failures, which may not otherwise be easily discovered. The fault tree analysis is sufficiently general to allow both qualitative and quantitative estimates of failure probabilities within the analysis. A typical fault tree is given in Figure 5-6. Figure 5-7 is an example of a fault tree applied to biotic systems.

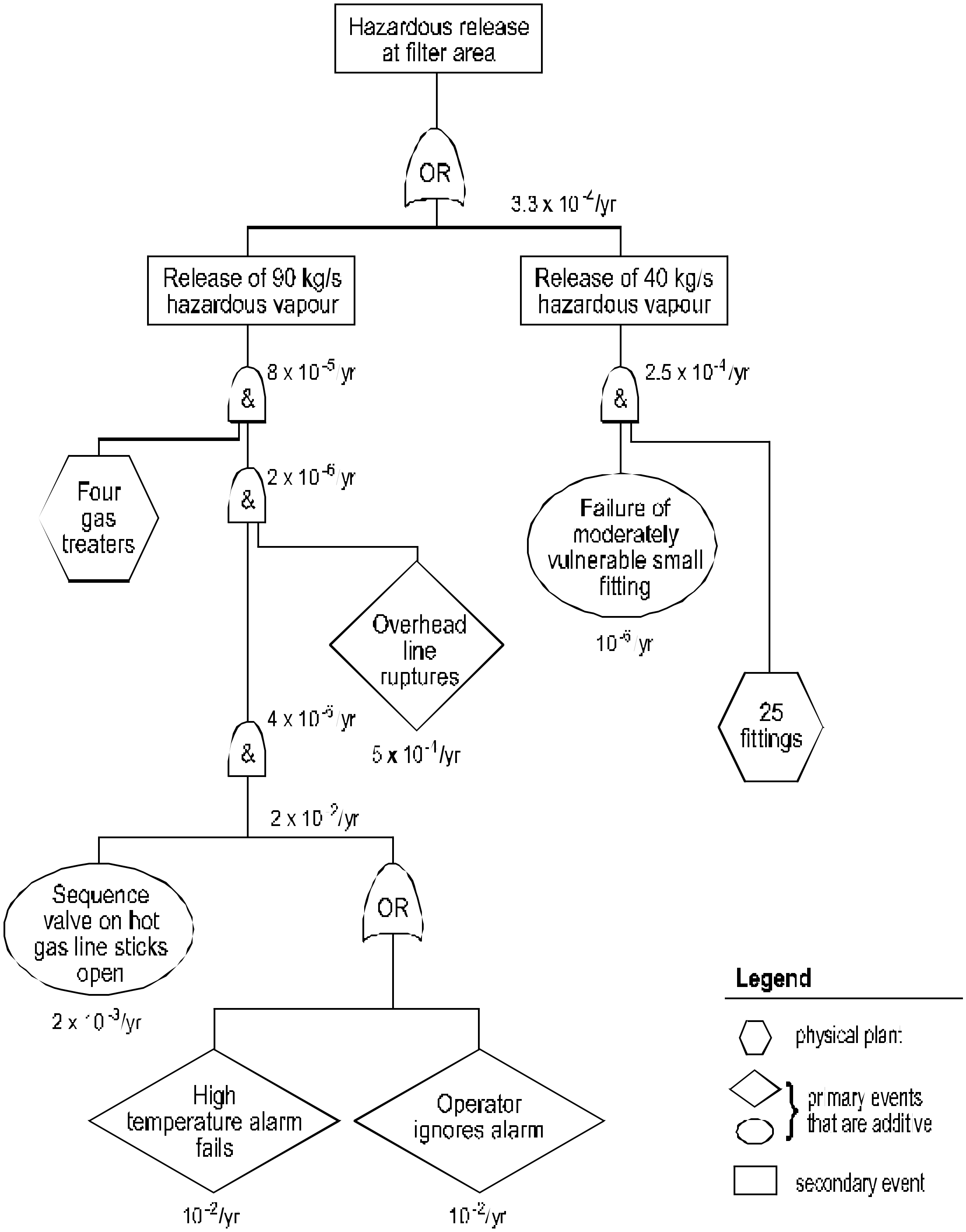


Figure 5-6: A fault tree.

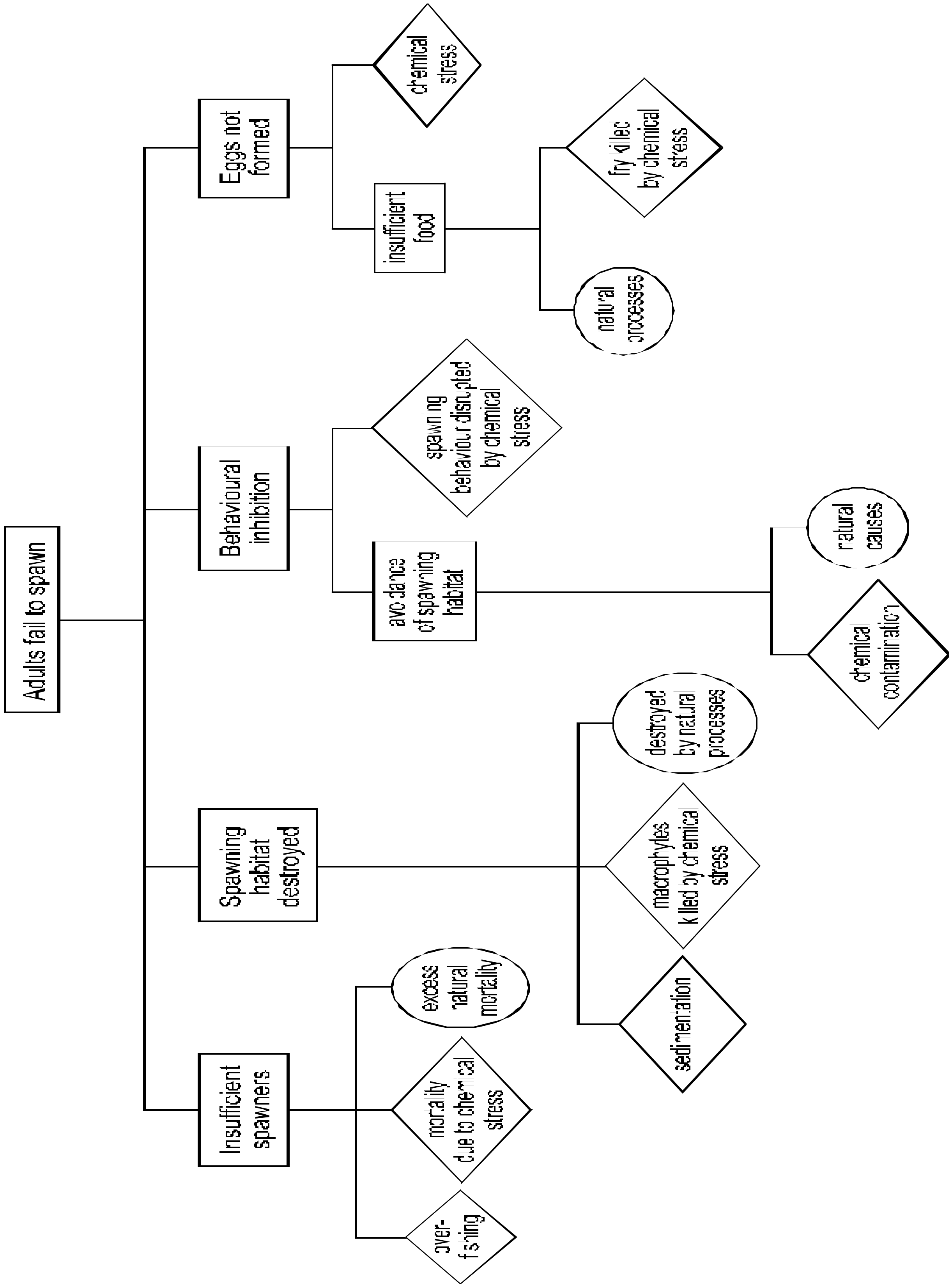


Figure 5-7: A fault tree analysis applied to biotic systems (*source:* Barnthouse et al., 1986).

Development of Fault Tree Logic

An initial step in fault tree analysis is to organize the fault tree study according to the particular risk assessment being carried out. For a particular hazardous event, it is important that the analysis be broad enough to include all identifiable initiating events yet it must also retain a balanced depth. These concepts are examined below.

Initiating events fall into three broad categories — operator error, equipment failure, and external events. Generally, the analysis of operator error and equipment failure receives thorough attention and can be considered one of the more reliable stages in risk assessment. The main difficulty is consideration of external events — events which, although external to the plant or operation under consideration, nevertheless have an impact upon it. They range from catastrophic natural events such as earthquakes or floods to less severe events such as lightning strikes. Local events, such as incidents at a nearby process unit and loss of main power, are also included.

Simple external events are often missed. For example, there may be no analysis of "release of hydrogen" if there is no realization that a hydrogen pipeline located beside a main road will be exposed to vehicular impact. Thus, whenever possible, the assessor should visit the site under consideration to ensure that the more obvious initiating events have been taken into account. Visits to similar plants can help in the assessment of new designs.

Quantification of Fault Trees

Once the various initiating events have been identified, the risks of occurrence of hazardous events must be quantified. Ideally, the assessor identifies the various initiating events, consults a list of probabilities, and inserts the numbers into the calculations. In practice, the assessor identifies the events, finds the best data available, ponders the question "What seems reasonable?," comes to an "expert judgment," and inserts the numbers into the calculations.

One uncertainty which should be resolved at an early stage is the degree to which the numbers are based on historical data rather than expert judgment. It is, therefore, important that the source for each number is clearly set out to enable some judgment to be made of its reliability. This balance between historical data and judgment depends very much on the installation/operation under consideration. In some cases there will be a wealth of operational experience available for a substantial database; in other cases historical data will be lacking — however, even for relatively untried operations, data for the initiating events (for example, valve failure) can often be readily transferred from other fields of experience. Failure rate data shown on fault trees should be supported by a narrative to justify particular values.

Obvious guidelines for checking the quantification of fault trees can be formulated. The simplest is that if the predicted overall likelihood of a major accident far exceeds historical experience then one should either look carefully at the assessment for any special hazardous features of the operation or question the reliability of the figures used. Conversely, low likelihood figures (say, less than 10^{-6} yr^{-1}, one chance in a million per year) should be regarded with suspicion either because some initiating events could have been missed or because some of the figures used are "optimistic."

For a hazardous event to happen, a precursor event often must occur with a failure of operator response (for example, the operator does not act in time to avert the accident, or protective equipment does not operate on demand). A common fault in hazard analysis is to ascribe a high probability for accident prevention once the precursor event has occurred. This often reflects a lack of thought about what personnel will do under conditions which pose a grave threat to their personal safety. Even if "emergency shutdown buttons" are sited close to highly reactive chemical processes, they may not be activated once the chemical process starts to go out of control, especially if personnel panic and rush away from the area.

Uncertainty in Hazard Analysis

The major uncertainties in hazard analysis are the ability of the analyst to include all important initiating events and the reliability of the figures used to quantify likelihood. Several points should be noted concerning these uncertainties, including:

1. The *magnitude of the final likelihood figures* for hazardous events provides an immediate indication of whether all initiating events have been considered. As a broad generalization, if the predicted likelihood of a hazardous event, to which many different initiating events may contribute, is much below 10^{-6} yr^{-1}, the chances are some initiating events have been missed. This is based on practical observation in Western Europe of the likelihoods of failures of well-engineered structures and of major natural disasters. This is not to say, however, that events with lower predicted likelihoods should be excluded from analysis.

2. The *probability distribution* associated with particular events is a second concern. Say a bank of data on equipment failures gives a statistical confidence that a particular failure rate is $2 \pm 0.5 \times 10^{-4}$ yr^{-1}. One could therefore use a figure of 2×10^{-4} yr^{-1} with confidence in a "best estimate" approach and 2.5×10^{-4} yr^{-1} in a conservative approach. Clearly the results of both approaches would be similar.

3. *Precision and accuracy* is the third concern. It should be clear by now that results of the form 2.56×10^{-3} yr^{-1} immediately convey a lack of appreciation of the uncertainties inherent in quantification. In short, precision of better than a few percent is worthless. In terms of overall accuracy, one should be wary of claims that an accuracy of much better than an order of magnitude has been achieved.

4. There is the issue of "*operator error*," for which data do exist. A routine error rate of one in 1000 is often used for situations where it does not apply. For example, an operator and a supervisor are claimed to have a combined probability of failure of 10^{-6} (1/1000 x 1/1000). This is spurious since the two are not independent; the supervisor will tend to assume that the operator is competent and so will not be expecting errors. A combined failure probability of 10^{-4} (1/1000 x 1/10) is more realistic. Also, operator error rates under abnormal conditions can be much higher than one in a 1000.

5. Finally, one must consider the operability of protective instrumentation and equipment. A proper design philosophy is that control and protective items should be independent. Thus, instruments which control the temperature of a reaction should not be used to sound the alarm for "high" temperature since one initiating event, temperature control failure, will also fail the warning system.

It is important when quantifying the hazard to ensure that the events which are being awarded independent probability/likelihood values are in fact independent. Another fault encountered is the evaluation of complex protective instrumentation, which incorporates several redundant systems to give a high reliability, in which no allowance is made for "common mode failure." Such failures include a loss of main power or pneumatic pressure which could disable the entire protective system.

5.3.4 Step 4 - Risk Characterization

Methodically observing or estimating the likelihood of occurrence and the severity of impacts for each scenario can produce curves as illustrated in Figure 5-8, plotting the probability of frequency of adverse events of a given severity vs. the severity per event (for example, the number of fatalities). Known as F/N curves, they present the "how often" and "how bad" aspects of risk. As shown in Figure 5-9, the integral under the curve is not the whole story. Hypothetical project (or technology) A has a lower mean risk than does B (for example, spill and fire from a tank truck in transit), but A also has a larger probability of a catastrophic accident (for example, explosive dispersion of a toxic material in a highly populated area). There is no objective way to combine these two criteria and different societies or individuals will make different choices between the two. However, the explicit depiction of risk is valuable information.

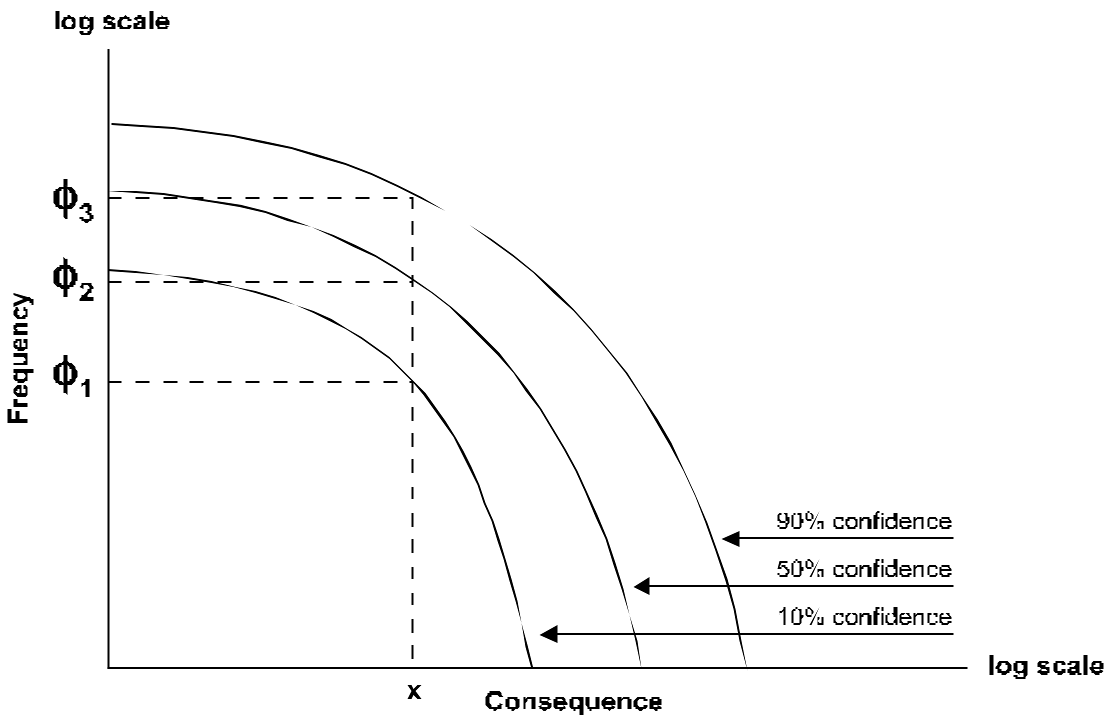


Figure 5-8: Risk is a function of frequency of occurrence of adverse events and the magnitude of their consequence. Note that while risk deals with uncertainty, there is also uncertainty in the expression of risk due to the variability of data used to estimate frequency and severity.

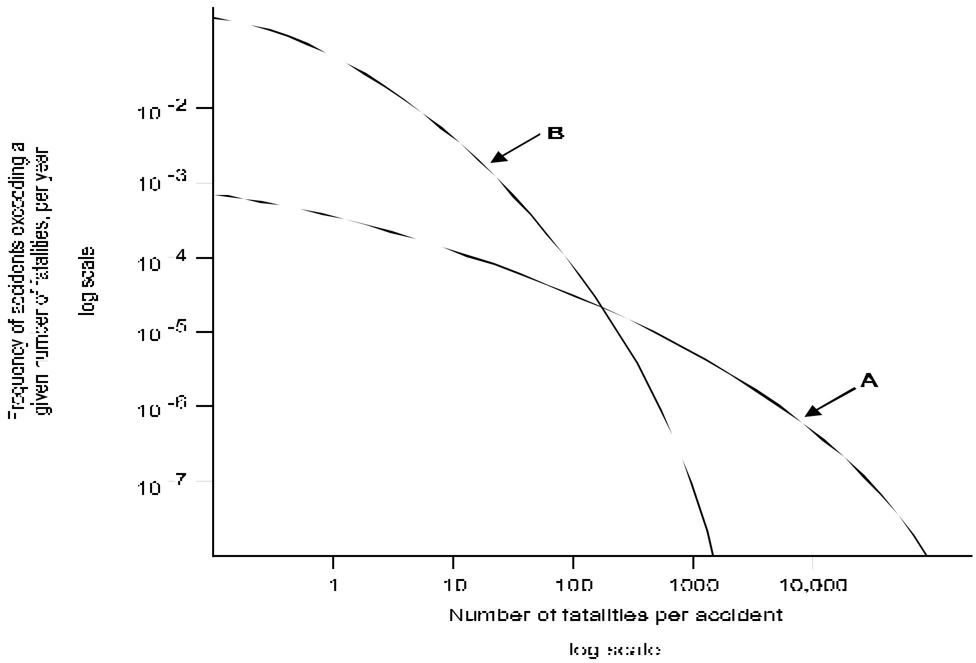


Figure 5-9: Risk distribution for two hypothetical alternative industrial facilities. Plant A has lower mean risk (expected value of damage) than Plant B. Plant A, on the other hand, has considerably larger probability (although still small) of causing a large accident that kills many people. There is no objective way to combine these two criteria (expected value and distribution), and different groups of people will make different choices (*source:* Carpenter et al., 1990).

Risk may also be indicated by the breadth and shape of the distributions or probability densities of the severity values (see Figure 5-10). If the standard deviation is small and the distribution approximately log-normal (bell-shaped), the mean can adequately represent the impact. If the standard deviation is large and there is a pronounced positive skew (tail) with low frequency but high severity outcomes, an expression of this risk and a more thorough investigation are warranted.

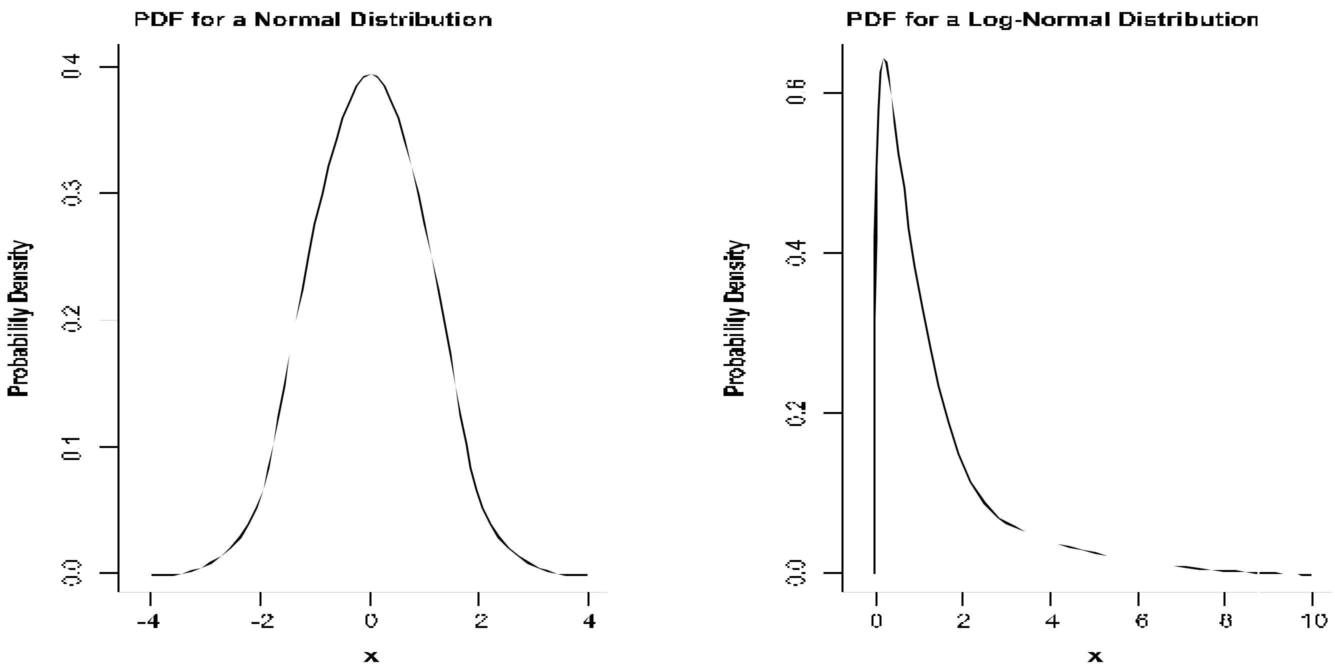
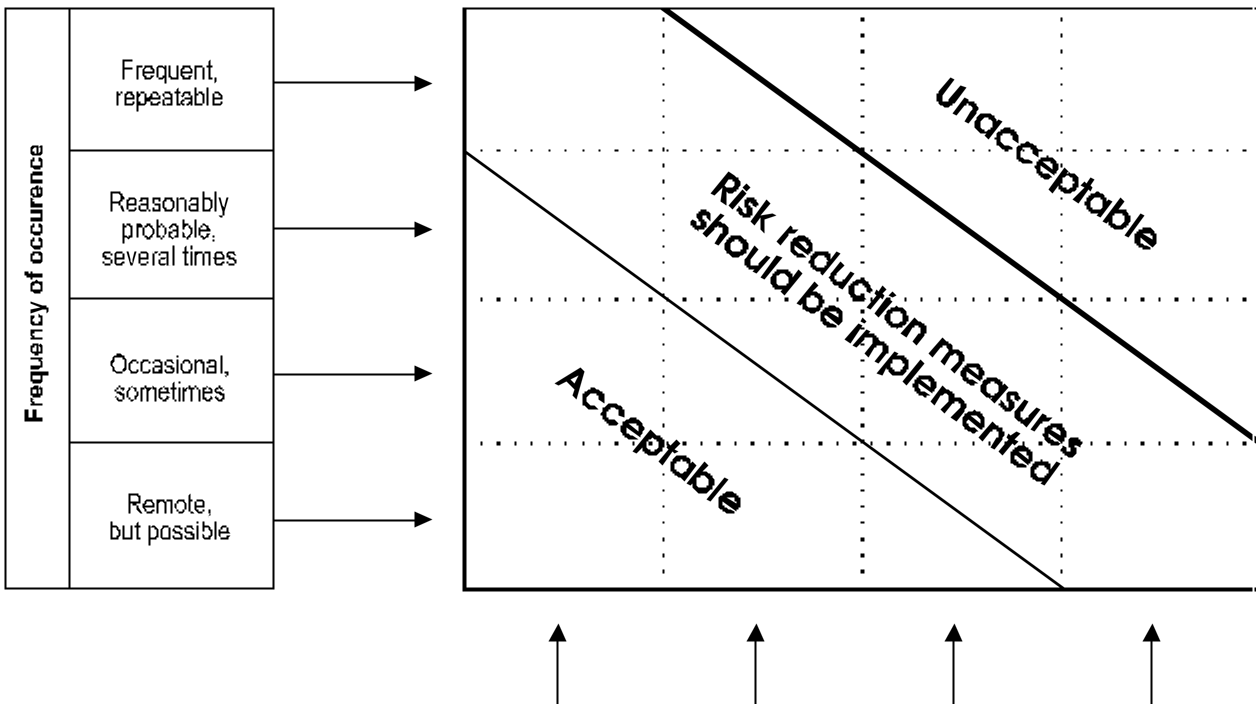


Figure 5-10: Plots of Probability Density Functions (PDF) (*source:* U.S. Environmental Protection Agency, 1997). The probability that a variable will have a value within a small interval around x can be approximated by multiplying f(x) (that is, the value of y at x in a PDF plot) by the width of the interval.

Even a qualitative presentation of risk is useful (see Figure 5-11). It is obvious that whenever frequent occurrence is combined with catastrophic or critical severity, the risk must be reduced if the project is to proceed. Occasional or infrequent adverse events that have only negligible or marginal consequences may be acceptable because of the benefits of the project or activity. See Section 5.6 for an application using expert judgment to express relative risk when quantification is not possible.



		Range of Consequences and Damage			
		Negligible	**Marginal**	**Critical**	**Catastrophic**
Industrial and Community Facilities	**Disruption**	<1 day for repair	A few days required for repair of facilities	Loss of facilities for >1 month	Widespread destruction of property; total loss of some facilities
	Monetary	<$100,000 damage	$100,000 to $1 million damage	$1 to 10 million damage	>$10 million damage to property
Human Health and Safety		Minor illness or injury: ≤ 12 months lost work time	≥12 months lost work time from illness or injury	Death or severe illness or injury to ≥1 person(s)	Death to >10 persons; severe injury/illness to >100
Pollution Damage to Ecosystem		Slight, quickly reversible damage to few species/ ecosystem parts	Temporary, reversible damage. Reversion to earlier successional stage	Loss of keystone species and wide-spread habitat destruction	Complete, irreversible and immediate destruction of all life

Figure 5-11: Risks may be categorized on the basis of their frequency of occurrence and severity of consequences or damage (*source:* Carpenter et al., 1990).

Risk characterization facilitates the judgment of risk acceptability. Risks to health are typically characterized in terms of:

- exposure period;
- potency of a toxic material;
- number of persons involved;
- quality of models;
- quality of data, assumptions, and alternatives;
- the uncertainties and confidence in the assessment; and
- appropriate comparisons with other risks.

Useful risk characterization expressions include:

- probability of the frequency of events causing some specified number of prompt fatalities (for example, equipment failure releasing toxic gas that kills ten or more people is estimated to occur every fifty years);
- annual additional risk of death for an individual in a specified population (for example, one in a million);
- number of excess deaths per million people from a lifetime exposure (for example, 250 people in the exposed population);
- annual number of excess deaths in a specific population (for example, living within a certain distance from a hazard); and
- reduction in life expectancy due to chronic exposure, or chance of an accident.

Figures 5-12 through 5-14 are examples of different means of characterizing risk.

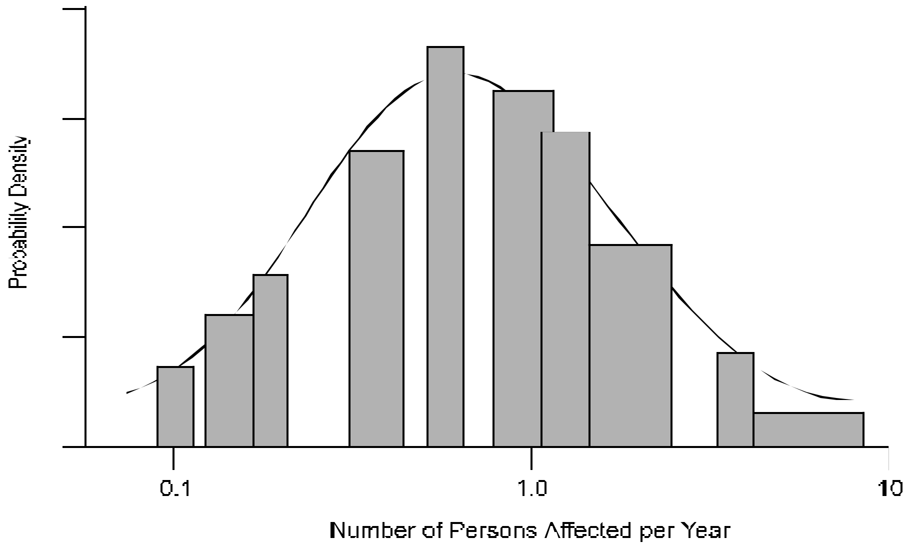


Figure 5-12: Hypothetical estimate of probability density function for number of persons affected per year from accidental releases of toxic gas stored at an industrial facility. Each bar represents a scenario within the range on the horizontal axis indicating the estimated ranges of adverse effects per year for that scenario. The area of the bar is the estimated probability that the scenario will occur in any given year. Note that scenarios may overlap and that gaps will occur (*source:* Carpenter et al., 1990).

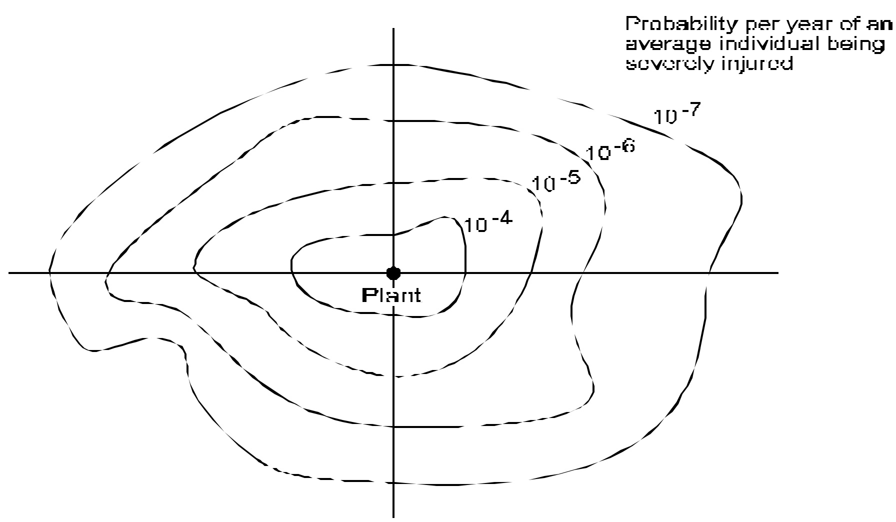


Figure 5-13: Probability per year of an average individual being severely injured.

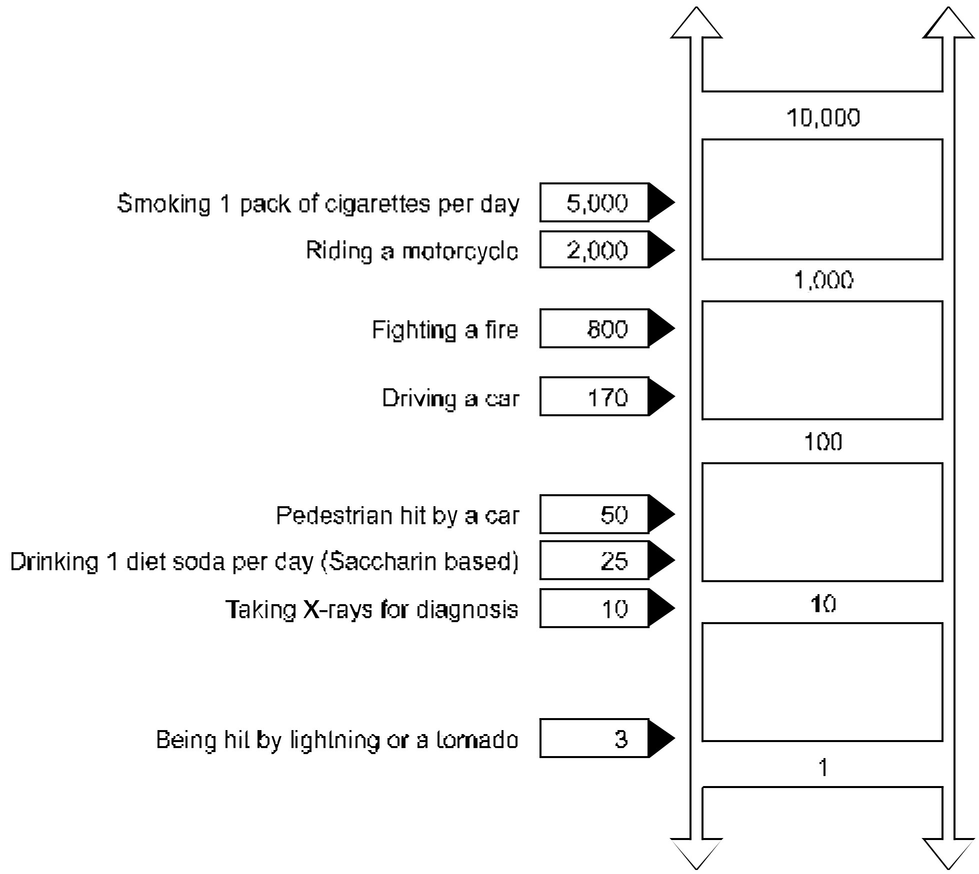


Figure 5-14: Health risk ladder.

Box 5-8: The psychology of risk acceptability.

Risk comparisons must be carefully chosen because risk acceptability decreases markedly when:

- risks are involuntary or controlled by others;
- the consequences are feared and delayed;
- the benefits and risks are inequitably distributed;
- the project is unfamiliar and involves complex technology;
- children are threatened; and
- basic human needs (clean air, drinking water, food) are at risk.

Whyte and Burton (1980) suggest the following comparisons to interpret the findings of ERA (see Figure 5-15):

- elevation of the risk above the natural background level;
- risk of alternative actions to achieve the same goal;
- other familiar risks; and
- benefits of continuing the project and taking the risk.

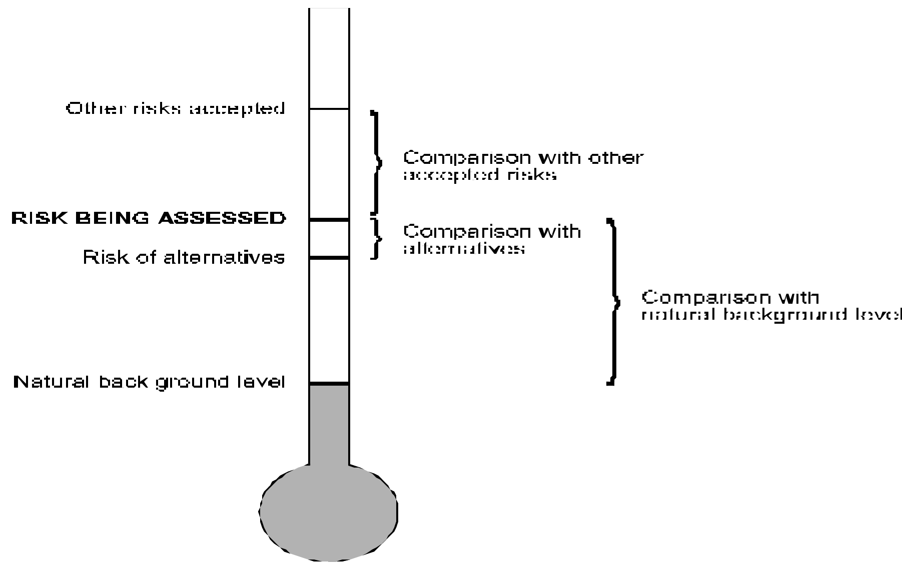


Figure 5-15: Alternative yardsticks for measuring risk (*source:* Whyte and Burton, 1980).

5.3.5 Step 5 - Risk Management

The communication of ERA results should take the form of decision analysis; that is, what options are available, and for each option what are the risks, costs, and benefits, and how are these distributed within society. Proper comparison and communication can actually change laypeople's misperceptions of risks so participatory decision making may proceed on a more rational, less emotional basis. Risk management is the use of ERA results to mitigate or eliminate unacceptable risks. It is the search for alternative risk reduction actions and the implementation of those that appear to be most cost-effective. Most human activities are undertaken for obvious and direct benefits and risks are intuitively compared with these benefits. Avoiding one risk may create another (risk transference); net risk is a consideration facilitated by ERA. There are strong reiteration and feedback between risk management and hazard accounting because a) changes in the scope of the ERA may be necessary to fully answer the questions of management, and b) relatively simple changes in the project may alter the hazard and reduce risk (for example, different siting).

5.4 Human Health Risk Assessment Methods

5.4.1 Exposure and Dose

From the scenarios of exposure it is possible to estimate the amount of a toxin that affects any one person or a population. The procedure varies with the mechanism of exposure; that is, ingestion in food or water, inhalation, or through the skin. For example, the concentration of a toxin in air is calculated as mg/m^3, or it may be converted to an inhaled dose, mg/kg/day, by dividing by 70 kg (an assumed body weight) and multiplying by 20 m^3/day (an assumed human inhalation rate). Published reference concentrations or daily doses are then used for comparison with the measured values to estimate risk. Oral exposure for drinking water is measured in mg/kg/day of intake, and the risk is compared with animal-derived data for a safe concentration (or reference intake that is safe). The concentration in the drinking water supply is measured in mg/l, and then compared with a safe concentration which is calculated as follows:

safe concentration (mg/l) = reference intake dose (mg/kg/day) x 70kg / 2 *l*/day

2*l*/day is assumed to be the amount of water a person uses. All of these individual assumptions need to be adjusted for specific groups and life styles.

Similarly, diet patterns can yield estimates of a dose by studying the amount of a certain food that is eaten and the concentration of the contaminant in that food. Reference safe concentrations (RfC) and doses (RfD) are available from the World Health Organization. The risk assessor must carefully link exposure pathways and personal habits to estimate a dose and consequently a risk of daily continuous or one time exposure.

5.4.2 Cancer

The U.S. EPA has sponsored the development of methods for estimating the additional risk of an individual contracting cancer from exposure to some human-introduced carcinogen in the environment. Several hundred chemical compounds have been tested in animals. The procedure is to expose a group of test animals to high (maximum tolerated) dosage levels (by inhalation, ingestion, or skin absorption) of the suspected carcinogen for a period of time (usually the animal's normal lifetime). Post mortem inspection of each test animal is made for tumors or malignant neoplasms.

The percentage (probability) of animals developing cancer at each dosage level is recorded. The slope of this curve is then extrapolated to the low doses expected to be encountered by human beings who may be exposed to the chemical. Various assumptions are made as to the shape of the extrapolated dose-response curve as it approaches zero dose and zero response (for example, whether a threshold exists or not). The slope becomes a unit cancer risk factor, or potency, expressed in terms of $(mg/kg/day)^{-1}$, or risk per unit dose (risk per mg/kg/day). For example, the route specific unit risk for inhalation exposure equals risk per concentration unit in air equals risk per $microgram/m^3$. The assessor measures the actual concentration at the point of exposure and then calculates the risk from potencies published by the U.S. EPA's "Health Effects Assessment Summary Tables," or by international groups such as the World Health Organization.

5.4.3 Dose x Potency = Risk

When the unit cancer risk factor is multiplied by a dose to an individual, expressed as mg/kg/day, the units cancel and the resulting number is the additional risk to the individual (chance or probability) of contracting cancer during a lifetime of exposure at that dose level to the toxic agent in question. This is an excess risk over the sum of all other risks of contracting cancer (one in three). If, for example, a lifetime exposure of a person to a carcinogenic material in the environment is calculated to yield an added risk of 1×10^{-4}, then the new total cancer risk for that person is 0.3334. This is a small additional risk, but it is important to determine. Individuals are exposed to many natural and artificial carcinogenic substances, some of which are highly potent. Many naturally occurring substances in food are more carcinogenic than are the contaminants from industrial chemicals (Ames and Gold, 1990). It is assumed that risks are additive unless there is strong evidence for synergism or antagonism. Some exposures of the general public are involuntary (for example, polluted air) and not avoidable by individual choice. Such risks, no matter how small, are generally not acceptable because they are perceived to be unaccompanied by any benefit, and people often feel helpless to avoid them.

The expressed risk of contracting cancer is not the same as the risk of death. All cancers are not ultimately fatal. Toxic substances cause tumors at various sites in the body and different cancers have different mortality rates. About 50% of cancer patients survive at least five years. One of four deaths in the U.S. is caused by cancer; thus the overall risk of death by cancer there is 0.25. Developing country statistics may be somewhat different. The World Health Organization is helping other nations in beginning to assemble locally applicable data. Most developing country people will soon live in megacities, and, as a result, their health problems will change (that is, diseases such as cholera, malaria and tuberculosis will be exacerbated by heart disease, AIDS and cancer). A major health hazard will be the epidemic of smoking-related diseases in PRC and other developing countries. This is expected to account for 10% of all deaths and disabilities by the year 2020 (World Health Organization, 1996).

Another useful way of expressing risk is the annual cancer incidence due to exposure to some specific carcinogen; that is, the additional number of new cases of cancer in a population each year. This carcinogen-specific incidence depends on the number of people exposed to varying concentrations of that carcinogen. The U.S. EPA (1990) has made estimates for the American population for a number of cancer-causing agents.

5.4.4 Noncancer Diseases

Risks of contracting diseases other than cancer from exposure to toxic agents in the environment are also estimated using a potency factor called a reference dose (RfD) or reference concentration (RfC); that is, the maximum daily exposure unlikely to cause deleterious health effects. The RfD is derived from animal test data as described earlier. Because of the variety of effects short of death that are associated with diseases other than cancer, morbidity categories also are established for comparing health effects:

- Observable - these effects are detectable but may not show a disability (for example, in the level of an enzyme or low weight gain in infants).
- Serious - development or behavioral abnormalities and/or dysfunction of an organ.
- Catastrophic - prompt death or shortened life, severe disability.

An average reasonable exposure scenario (not a worst case) for the general population is usually chosen for the risk characterization. In some instances, a specially identified subpopulation may be exposed differently and its risk assessed separately. An exposure from a maximum plausible accident may sometimes be included to test the sensitivity of a scenario.

5.5 Comparative Risk Analysis

All societies have become aware that there are more requests for government actions and expenditures for public health and safety than there are revenues to pay for them. Some method of allocating available resources, not only money but also personnel and management attention, is essential. Since health and safety are sensitive political issues, choices and priority decisions are often made in response to alarming events and perceived risks. Decisions in these circumstances can result in wasted resources, unjustified fears, and social disruption. The products of ERA have been presented and used in several ways. In 1990, the U.S. EPA published "Reducing Risk: Setting Priorities and Strategies for Environmental Protection." Here, the idea of comparing similar risks, again on the basis of more-or-less absolute calculated values, was efficiency in government. The goal is to get the most risk reduction per dollar through risk-based strategic planning.

Although this could work fairly well for comparing sources of one kind of risk — say cancer — it is less useful in allocating priorities among different diseases or between health and ecosystems risks.

Another, older, use of the term *comparative risk assessment* involves the comparison of quite varied risks to human health. These are usually risks evaluated from empirical statistics. Lists are presented, of increasing or decreasing order, comparing risks to longevity as dissimilar as going skiing, being unmarried, and eating peanut butter. This misapplication of RA was recognized as long ago as 1980; compared risks must be strictly similar.

Comparative risk assessment is now seen as a tool for more rational and effective environmental management. A risk-based strategy can show which actions will result in the most risk reduction per unit expenditure and which uncertainties are most important for additional scientific study.

5.5.1 Criteria for Comparative Ranking of Health Risks

The large uncertainties in risk assessment preclude reliance on the absolute quantitative risk numbers that are generated. For example, a scenario may produce an estimated exposure dose to a population, which, when multiplied by a unit cancer risk factor, infers that 100 excess cancer cases may be expected due to a specific carcinogen. This is based on the so-called "95% confidence limit, upper bound" estimate, which contains various conservative assumptions, so that it is certain not to be exceeded in more than one in 20 incidences.

Carrying through all uncertainties might produce a wide calculated range (from example, from two to two hundred cases), that also might not be normally distributed; perhaps having a median value of ten, but with a tail of low frequency/high consequence events. The 100 value is far to the high side of the distribution of possible values. It alerts users of the ERA to remotely possible, very bad news, but does not remind them of the usual outcome. This highlights the need to provide both values.

If consistent assumptions and models are carefully used for different scenarios, carcinogenic substances, and populations, a comparison among the similarly calculated risks is a valid way of ranking risks. Uncertainties tend to cancel out. There can be confidence in estimating the relative future risk of a project scheme that is revised in order to reduce risk. A difference of at least an order of magnitude (for example, a hundred versus ten calculated cases) is significant management information. All else being equal, more risk-reduction attention should be devoted to the scenario that yields a calculated hundred cases than to the scenario that yields ten. If the difference is less than a power of ten, other factors in the environmental problem analysis may dominate the choice of action to be taken.

Despite these limitations, it is necessary to loosely anchor comparative (higher or lower) risk rankings to an absolute scale. This can avoid absurdities such as a) ranking a risk of 10^{-8} excess cancer cases as higher than a risk of 10^{-9} when both are *de minimus* (trivial), or b) arguing whether to reduce a 10^{-3} risk or a 10^{-2} risk when both need urgent attention.

Throughout the world, different communities have adopted generally similar absolute values for acceptable risks to human life from involuntary, technology-caused, anthropogenic hazards. Lifetime excess risks greater than 10^{-4} (one in 10,000) for the individual are considered high and unacceptable. Excess risks less than 10^{-6} (one in a million) are low and acceptable — *de minimus* in legal terms — "the law does not deal with trivialities." As a reference, the risk of being struck by lightning is about one in a million in the U.S. For excess risks of between 10^{-6} and 10^{-4}, decisions as to whether to take reduction action are based on additional considerations such as direct project benefits or costs of avoidance.

For non-cancer disease risks, the ratio of the exposure dose to the reference dose determines acceptability because the latter is set by definition presumably to prevent the risk of unacceptable health damage, that is, < 10^{-4}. If the ratio is < one, the risk is acceptable. The likelihood of exposure and the type of endpoint (morbidity or death) considered by the RfD are also factors in acceptability.

5.5.2 Risk - Cost - Benefit

The effectiveness and efficiency of risk management depend on deploying limited resources where they are most needed. Comparing risks and the costs of their reduction is a valuable decision tool. For example, hazardous waste sites are perceived by many citizens as posing a high health risk, and large expenditures are made to clean them up. Yet, when quantitative probabilistic risk assessment is performed on these sites they usually turn out to be relatively low threats. This is because, in most cases, the chance of exposure is slight due to isolation from drinking water supplies and prevention of access. In contrast, the risk from indoor air pollutants is found to be relatively high and worthy of greater reduction efforts than the public might demand. People spend most of their time indoors, often in poorly ventilated areas, exposed to vapors of hazardous household products, to second hand tobacco smoke, and, in some locations, to radon.

Finding a small residual risk does not mean the management activities that have brought the risk down should be decreased, although they should be reviewed for cost effectiveness. It is the further expense of reducing the small residual risk that is subject to question. For example, in the case of public water supply in most Western countries, the low risk is testimony to good sanitation and water treatment practices. But, often proposed drastic and expensive measures necessary to remove trace amounts of pesticides that may pose only a small residual risk should be judged against other opportunities for protecting public health.

Cost effectiveness may be illustrated by calculation of the cost per life saved. For example, the banning by law of unvented kerosene fueled space-heaters cost $100,000/premature death averted, whereas regulations keeping petroleum refinery sludge out of land fills cost $27.6 million/life saved (Ahearne, 1993).

5.5.3 Guidelines for Comparison

The following guidelines can help bring consistency to the ranking exercise. A periodic comprehensive comparison of all major hazards in a governmental jurisdiction can lead to improved budget allocation and administration of risk reduction efforts. Where quantitative, probabilistic risk assessment is possible, comparison is straightforward. Where only qualitative information is available, a group consensus among technical professional experts is attempted.

Considering the uncertainties of ERA, an ordinal ranking would be inappropriate, and is unnecessary. Three levels of risks are sufficient to suggest priorities for governmental attention. Environmental health problems (sources of hazard) are assigned to comparatively higher, medium, or lower risk levels, but are not ranked within each level. The demarcations are not “bright lines,” and scientific uncertainties enter into the judgment of comparative risk. In general, where available data indicate that two risks are about the same calculated magnitude, the more certain of the two would be given the higher priority for attention.

This guideline recognizes that health protection standards can vary in absolute risk by as much as four orders of magnitude. Also, some regulations include consideration of the cost and feasibility of risk management. The laws mandating these standards usually specify that human health is to be protected with an adequate margin of safety. Therefore, whenever governmental regulations, environmental quality standards, or exposure limits are based on risk and deemed to be complied with, the risk must, *ipso facto*, be placed in the lower category for comparison purposes. If there is evidence of noncompliance, the risk is then based on a much higher exposure.

The factors considered in health risk ranking for cancer are: a) the excess risk of contracting cancer for an individual in the general public (or in a specially exposed population) from lifetime exposure to the estimated reasonably expected concentration of a carcinogen in the environment; b) the excess annual incidence of cancer in the general population; and c) the degree of epidemiological association of an environmental contaminant with an excess incidence of cancer.

To warrant a higher priority ranking, the risk of cancer to an individual should be: a) greater than $1x10^{-5}$ (one in 100,000); b) the predicted excess annual incidence in the U.S. population should be greater than 2,500 cases; or c) the epidemiological association should be strong. A medium ranking would result a) if the annual incidence was increased by more than 250 cases; or b) the individual excess risk in the general population was between $1x10^{-6}$ and $1x10^{-5}$; or c) the individual risk in a special population was $1x10^{-4}$ or greater. A lower ranking would be given where a) health protection regulations are met; or b) the individual lifetime excess risk was less than $1x10^{-6}$.

The factors considered in health risk ranking for noncancer diseases are: a) the ratio of the estimated reasonable average exposure dose to the reference dose or reference concentration; b) the morbidity category for the toxic agent; and c) the proportion of the population exposed.

For noncancer diseases to warrant a higher priority ranking, a) the ratio of dose to reference dose should be greater than one; b) the morbidity category should be catastrophic; with c) the general population consistently exposed. A medium ranking would result if a) the dose/RfD was greater than one; but b) the morbidity category was serious but not life threatening, or only specially exposed populations were at risk, or the exposure was sporadic. If the dose/RfD is a) less than one (that is, regulations are met); or b) if the morbidity category is only "observable," then the risk is ranked at the lower level.

Developing member countries may use the western statistics cited in this manual as a starting point for comparative risk analysis, but should begin compilation of their own data. For example:

- Typical values related to exposure of individuals to toxic materials must be established for different populations and cultures. These include body weight, daily intake of air and water, the composition of diets, and patterns of time spent at various locations.
- Perceptions of risk vary among cultures and with the degree of economic development. Risk management must consider perceived risks as well as objective or real risks. Knowledge about local citizens' concerns should be systematically collected by surveys, interviews, and observation.
- General risk statistics for each region and culture should include major causes of death by age group. Accidental death causes are particularly important for risk comparisons and for judging priorities in allocating mitigation efforts. Traffic accident records for major roads and rail lines are necessary for risk assessment of transportation developments.

5.5.4 Issues in Environmental Health Risk Assessment

Animal testing of potential carcinogens. The transferability of animal response data to humans continues to be a matter of scientific controversy. More important, the use of a high, "maximum tolerated dose" (MTD) has raised the question as to whether an observed tumor is a) the consequence of carcinogenicity; or b) the rapid cell division that occurs as the animal attempts to repair the general toxicity damage of the test. A two-stage model of carcinogenicity separating preneoplastic changes from cancer induction is gaining favor. Although MTD may continue to be one level of testing, a lower level may be necessary too. Additional lower levels might require unacceptably greater costs in using more animals and time to obtain statistically significant findings. Thus, the fundamental basis for estimating the potency of chemical hazards is now being debated.

Overly conservative exposure assumptions. The use of the 95% "upper bound" of statistical distributions and "worst case" (often inconsistent) scenarios is challenged as unwarranted and philosophically pessimistic. Even more, these assumptions are seen to be potentially counter productive because they may shift limited risk reduction efforts from some significant risks to small, but exaggerated risks. Risk management is, in this view, a zero sum game and transfers among risks are inevitable. Being overly conservative inhibits optimization of risk management. The mean values should be carried and presented throughout an ERA to show more about the magnitude of the uncertainties, just as the low probability-high consequence information is necessary when there is evidence of abnormal distribution.

Risk communication, perception, and acceptability. The public appears to expect and demand zero risk along with the benefits of a highly technological civilization and burgeoning economy. Risk professionals must patiently do more and provide better explanation of the probabilistic nature of science and the realities of risk in our complex civilization. The unwillingness to consider taking even infinitesimal and vague levels of involuntary risk must somehow be overcome in a participatory democratic way. The correct choice of familiar risks with which to compare new risks is all important. Risk cost-benefit analysis should be further developed as a presentational technique for the results of ERA.

Biomarkers. Sophisticated microbiological techniques are being developed to ascertain effects of toxic substances on fundamental processes such as enzyme production and cell level behavior in humans and animals. These indicators may offer short cuts to predicting health impairment, but the skills and equipment required for these analyses are formidable.

5.6 Ecological Risk Assessment (EcoRA)

The American National Research Council, in its 1993 report "Issues in Risk Assessment," notes:

> "Ecological risk assessments have no equivalent of the lifetime cancer-risk estimate used in health risk assessment. The ecological risks of interest differ qualitatively between different stresses, ecosystem types, and locations. The value of avoiding these risks is not nearly so obvious to the general public as is the value of avoiding exposure to carcinogens . . . the function of risk assessment is to link science to decision-making, and that basic function is essentially the same whether risks to humans or risks to the environment are being considered."

The objective of ERA as applied to ecosystems is usually comparative and qualitative because of the lack of data on stress/response. It is useful to decision makers to a) rank a comprehensive set of environmental problems (stressors on VECs at specific sites) relative to one another, using broad levels of risk; and b) target risk reduction actions toward those geographical areas or ecosystem sites that are of greatest value and at greatest risk. There is not yet any widely applicable, established procedure for EcoRA.

In general, information is gathered about a) hazards or sources of harm; b) stressors and their pathways to target organisms; c) adverse responses of species and communities; and d) measurable changes in the condition (integrity, resilience, productivity, health, sustainability) of the ecosystem (see Figure 5-16). The last set (d) is termed an endpoint attribute similar to mortality or morbidity in humans.

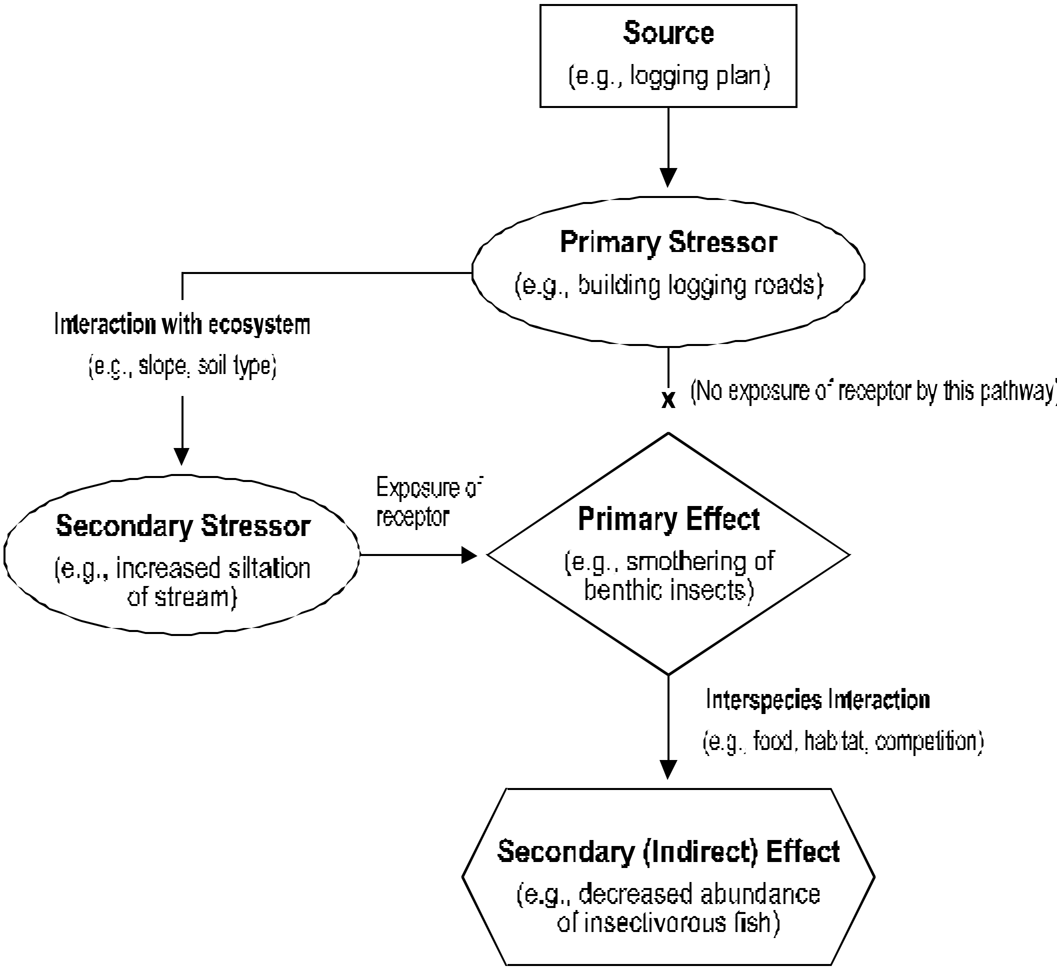


Figure 5-16: Conceptual model for logging (*source:* U.S. Environmental Protection Agency, 1997).

5.6.1 Ecosystem Integrity, Resilience, Biodiversity, Health, and Sustainability

There are several concepts of ecosystem condition that are used in ERA as equivalents to morbidity in human health risk assessment. Searching any comprehensive literature data base for the keywords ecosystem (or biological) integrity, ecosystem resilience, and ecosystem health will reveal the confusion that attends these terms. The International Union for the Conservation of Nature is a source of ecosystem information relevant to developing countries.

Much current emphasis in land management is on biodiversity. By managing for ecosystem integrity and resilience, that is, for the maintenance of ecosystem services rather than just species, both productive uses and biodiversity are achieved.

Integrity of ecosystems remains a vague concept, difficult to quantify, and is rejected as a management goal by some ecologists. Metaphorical integrity is the most common usage; that is, conveying the idea that an ecosystem with integrity is, in a general sense, acceptable.

The following ideas on ecosystem integrity are adapted from Regier et al, 1994.

"An ecosystem with integrity:

- is an ever changing set of organisms, within adapting populations of evolving species, and with a capability for creativity;
- contains organisms that purposely modify their surroundings, but not so as to impair self-organizing capabilities;
- contains some larger and longer lived organisms that cumulate, integrate, and regulate many features of the system;
- processes energy and information from outside the system in a trophic network so as to increase energy and information per unit of biomass;
- exhibits interactions through organization within a complex spatio-temporal domain so that relatively persistent structures are overlain with transient, perhaps cyclical processes;
- achieves organizational flexibility and redundancy to cope with inevitable surprises that are simplifying in the short term but complicating in the long term;
- interrelates dynamically, across fuzzy boundaries, with adjacent ecosystems;
- is a self-organizing dissipative system compromising between the Second Law of Thermo-dynamics and the biological imperative of survival and sustained identity."

This is an elegant expression of the concept of integrity but its relevance to the practical definition of sustainability and calculation of risk is not clear.

Resilience is a promising approach to objective integrity, the ability to recover from a specified stress. It is a context-dependent measurement; the meanings of recover and stress must be clear and testable in scientific experiments. Ecosystems are not a static integration of structure and functions. They continually evolve and change; this is the source of their resilience, which is the desired valuable behavior. Resilience may be gauged and interpreted by examining trends such as:

- the ecosystem has not changed, at a given stress level, from an original satisfactory natural condition;
- the ecosystem changes but returns to the original condition, even under continued stress (how much change? how long to return? is it stable on return?);
- the stress is reduced or removed and the ecosystem returns to the original condition (how much change? how long to return? is it stable on return?); and
- the ecosystem changes permanently (collapses? resumes original natural evolutionary pathway? takes new but derivative evolutionary pathway? takes catastrophically different evolutionary pathway).

A site with high "biological integrity" is, supposedly, able to withstand natural or human disturbances. The components of an Index of Biological Integrity are species abundance counts and ratios, water quality, habitat structure, flow regime, energy source, and biotic interactions. This is essentially a resilience measurement and, although valuable in EcoRA, does not relate directly to productivity or sustainability. Some quantitative indices purporting to measure integrity are solipsistic, self-referential, and constitute a pseudo-science exercise.

Indicators of integrity that could be quantified and monitored include:

- general indicators like primary productivity, nutrient cycling, species diversity, population fluctuations, pest prevalence, spatial patchiness;
- threats, like increases in human population density, consumption rates of water, energy, renewable and non-renewable resources, wastes, infrastructure; and
- improvements in integrity, including increases in production, recycling, conservation and citizen involvement.

Sustainable development has multiple meanings with diverse roots in ecology (both "deep" and conventional), resources, carrying capacity, anti-technology, and ecodevelopment. Operational definitions and indicators of implementation achievement are required if sustainable development is to be anything more than an attractive, but empty, phrase. Most natural scientists who are managing ecosystems such as agriculture are sceptical about their capability to measure sustainability. Sustainability occurs where the productive potential of a managed ecosystem site will continue for a long time under a particular management practice. The utility, capacity, or potential of these natural systems for producing goods and services, is what is to be continued, and even enhanced.

Munn (in Regier, 1994) offers a view of integrity more consistent with this definition of sustainability:

"An ecosystem with integrity should exhibit such properties as:

- strong, energetic processes, not severely constrained;
- self-organizing in an emerging, evolving way;
- self-defending against exotic organisms;
- reserve capabilities to survive and recover from occasional severe crises; attractiveness, at least to informed humans;
- productive of goods and services valued by humans."

Ecosystem health is an attractive metaphor if it is not confined to an analogy to human "vital signs." Ecosystems are more complex than organisms. The November 1995 (vol.4, no.4) issue of Environmental Values is devoted entirely to ecosystem health. Therein, Baird Callicott makes the case, "Ecosystem health — or normal occurrence of ecological processes and functions — is an objective condition of ecosystems, although the concept of ecosystem health allows some room for personal and social determination or construction."

5.6.2 Ecotoxicology

Where chemicals have been tested against animals or plants for exposure-response, a risk assessment procedure similar to that for human health is used. For example, the concentration of a toxin in water to a fish species that kills 50% of the population (LC50) is akin to a maximum daily intake (MDI) in that it may be adopted as an end-point to be avoided. The risk is then evaluated as acceptable when the "quotient" of actual measured concentration to LC50 is less than one. These single chemical-single species consequences seldom reflect the real world where several chemicals stress several species simultaneously. Figure 5-17 shows how many different concentration levels of exposure (EC) can be examined. This is useful when the risk assessment outcome is not based on exceedence of a toxicity benchmark level.

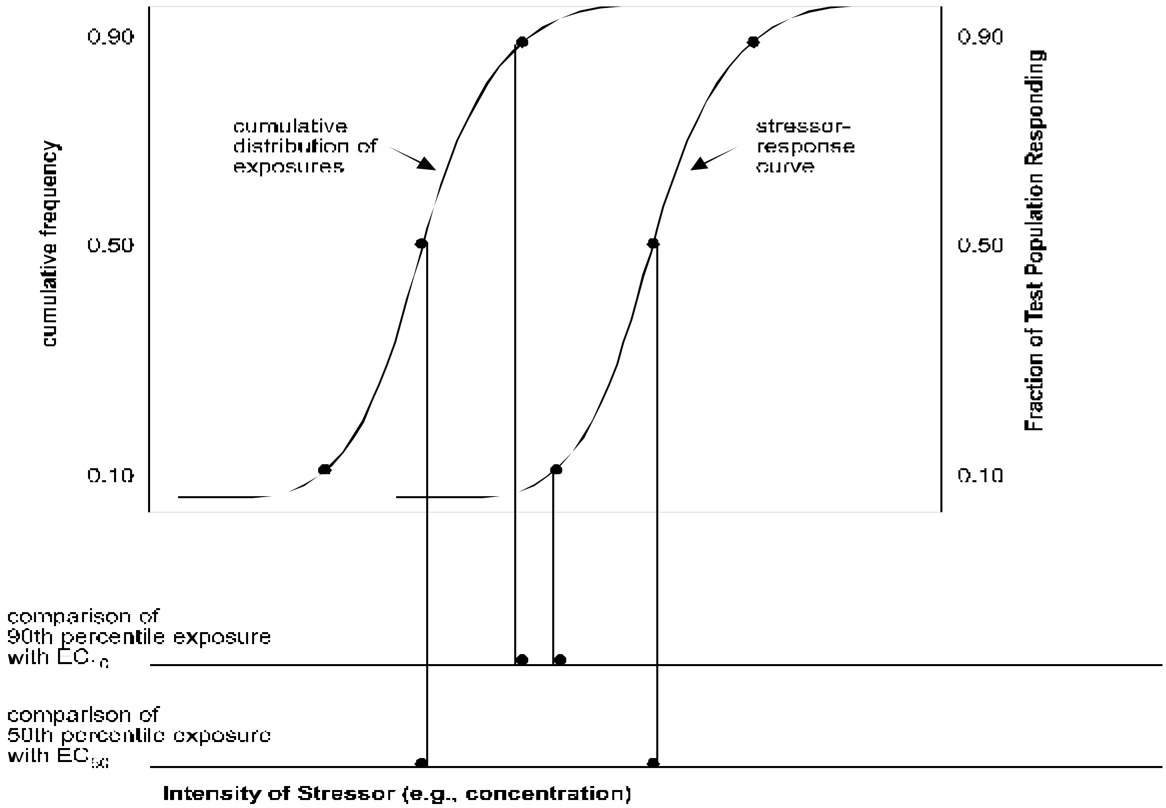


Figure 5-17: Risk estimation techniques: a stressor-response curve vs. a cumulative distribution of exposures (*source:* U.S. Environmental Protection Agency, 1997).

Models may make use of laboratory data to quantify biological and ecological processes and impacts, primarily at the species and community levels. This can be useful at site specific locations, but extrapolating the results to ecosystem and regional levels is more difficult, especially if two or more ecosystems and stressors are involved. A standard water column model comprising many biogeophysical parameters is used at Oak Ridge National Laboratory, "...to extrapolate the results of laboratory toxicity data into meaningful predictions of ecological effects in natural aquatic ecosystems." (Bartell et al., 1992).

Other methods evaluate structural and functional changes at the ecosystem and regional levels and are most easily applied where there is large-scale homogeneity in both the ecosystem and the stressor that affects it. Conversely, these methods break down when a region is a mosaic of many stressors and ecosystems. Normally there is a lack of sufficient data from a broad region to allow quantification. Figure 5-18 is the classical stressor-response relationship, but even a qualitative estimate of the relationship is useful (for example, the dose at which about 50% of the organisms are killed).

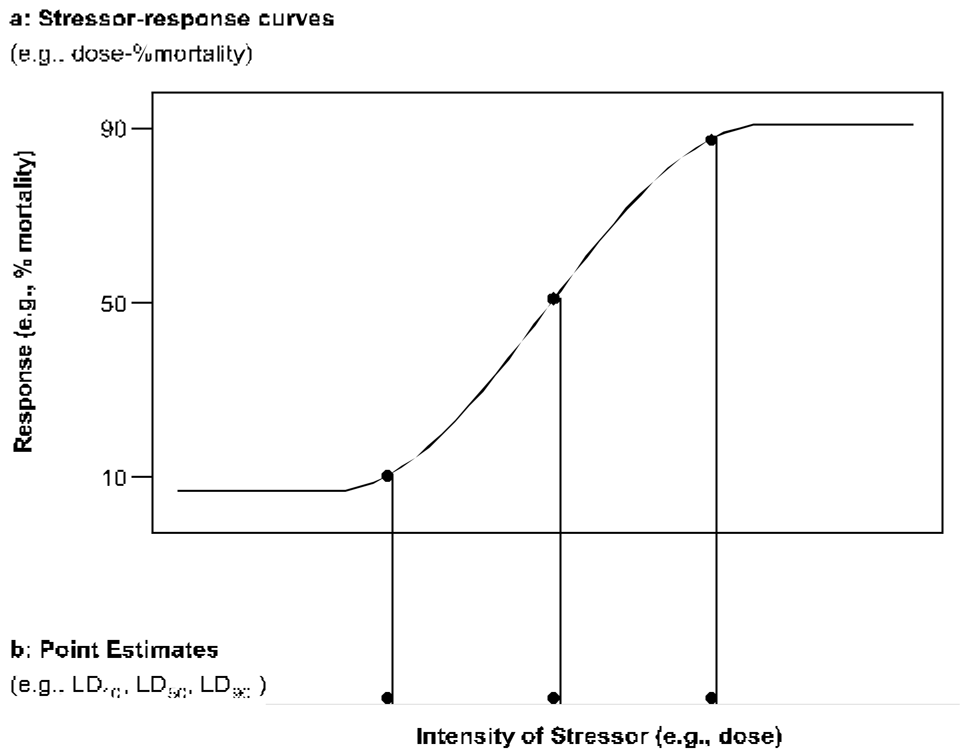


Figure 5-18: A simple example of a stressor-response relationship (*source:* U.S. Environmental Protection Agency, 1997).

5.6.3 Qualitative Comparative EcoRA

Decision makers, politicians, and nonscientists have a need for practical comparative ecological risk assessments. Comparative EcoRA need not be quantitative; it may be preferable to keep it qualitative. A combination of best judgment of ecologists and professional land/water managers with on-site experience, and systematic evaluation of risks from available information is pursued. Effective communication to decision makers is accomplished through use of maps, simplified scoring systems, clearly defined evaluative criteria, and a manageable set of ecological stressors. Defining the specific problem areas and classifying the ecosystems of the study region are important early steps in this approach to comparative EcoRA.

Health risk assessments (with heavy emphasis on public health) differ from ecological risk assessments in several significant ways. For ecosystems, the ERA must consider effects beyond just individual organisms or a single species. No single set of ecological values and tolerances applies to all of the various types of ecosystems. Stressors are not only chemicals or hazardous substances. They also include physical changes and biological perturbations. For public health purposes all humans are treated equally; with ecosystems, some sites and types are more valuable and vulnerable than others. Accommodating these factors complicates comparative ecological risk assessments and renders them more subjective.

5.6.4 Qualitative Methodology

Risks to ecosystems are based on the values (intrinsic and anthropocentric) of actual individual sites and the probability that stressors from human activities will significantly degrade these values in the near future. Uncertainties about value, frequency of adverse impacts, and severity of response to stress are identified and evaluated as a part of the ERA. The ability of the ecosystem occurrence (site) to recover is also considered.

Just as the individual human being is the focus of health risk assessment, the individual ecosystem site is evaluated in ecological risk assessment. Ecosystems are bounded biotic communities in interaction with their physical surroundings of energy, air, water, minerals, and soil (and also other ecosystems). Usually, an ecological risk assessment treats only natural, more or less intact, ecosystems that are lightly managed or essentially undeveloped. Urban and agricultural areas that are substantially modified, intensively managed, and where economic value dominates all others are considered dedicated.

5.6.5 Procedure for Ranking Risks

1. *Establish an Ecosystem Classification* **-** Define and select a manageable number of ecosystem types that are a) identifiable (mappable) through currently available databases and reports, and b) categorized by biophysical properties (climate, rainfall, topography and elevation, vegetation, geology and geomorphology, hydrology, soils, etc.). Examples of marine and terrestrial ecosystem types are: coral reef, freshwater stream, wetland, lowland dry scrub, montane wet forest, and sub alpine dry grassland.

2. *Inventory and Map the Ecosystem Occurrences (Sites)* **-** Gather data about the location, extent and status of resources, degree of disturbance, and level of protection. Previous research and monitoring, and personal interviews may suffice for the inventory but new field studies are often necessary.

3. *Develop Criteria of Value for Each Ecosystem Type* **-** For each of the different ecosystem types, determine individual criteria for the components of value. Valued components include economic productivity, recreation, biodiversity, and cultural/aesthetic significance. Criteria include wetland classifications, the presence of endangered species, rarity, the ratio of native to alien species, and tourism visitor counts. Seek out previous valuation studies, measurable attributes, and changes to those attributes which degrade the resources.

4. *Estimate the Value of Each Ecosystem Occurrence* - Assign numerical scores to each value component at each site on the basis of a simple scalar using quantitative measurements of the criteria (where available) and professional judgments. The certainty of the score of each value component is recorded. Sum the component scores for an overall value score.

5. *Develop a List of Stressors* **-** Determine which consequences of, and perturbations from, human activities may plausibly cause unwanted, negative impacts on the natural ecosystems. Examples of stressors are alien species, toxic chemicals, excessive nutrients, erosion/sedimentation, water diversion, fire, and human crowding.

6. *Gather Data on Stressors and Estimate the Risk from Each* **-** Collect information on past, present and near-future human activities that affect the specific ecosystem sites chosen for the study. Environmental experts and site managers estimate the frequency (F) of occurrence and severity (S) of damage from stressors to each site with which they are familiar. The uncertainty of the estimates is also recorded. Scalars are used to roughly quantify these judgments and the product, F x S = R, becomes a risk score for that stressor at that site.

7. *Map the Information* - Manually create map overlays or use computerized geographic information systems to display all data relevant to risk at each site. Data to be displayed may include location and site boundaries, values, stressors, risk scores, and geographic attributes such as present land use, native forest distribution, rare or endangered species habitat, historic/cultural sites, alien species distribution, public recreation areas, and concentrated fisheries.

8. *Rank Sites Comparatively According to Risk* - Compare a site's overall priority-for-attention score, which is the product of a site's value score and total risk score. Scores should differ by at least 20% of their absolute value to be regarded as different in priority.

9. *Rank Stressors and Ecosystem Types* - Compare the stressors as to importance in a region, and compare different ecosystem types as to degree of risk. Remedial actions can be guided by learning which stressors are widely felt and which ecosystem types are most susceptible to damage. These relative rankings can be used to inform public debate, set budget allocations, focus administrative attention, and establish site specific priorities for remediation, restoration, or protection. Since uncertainties are explicitly recognized and preserved in the assessment, areas where further research and monitoring would be worthwhile to decision makers are also illuminated. A multiple site comparative ERA can also reveal which stressors are the most common and damaging, which activities generate the most stress, and which types of ecosystems are most vulnerable.

5.6.6 Ecological Risk Assessment: A Hawaiian Case Study

A study of the well-known area of Hanauma Bay on Oahu, a prime tourist destination that is designated an underwater park with no fishing allowed, is briefly presented here to illustrate the method for ranking risks. Value components were rated on a three level scalar: 1 = low, 2 = medium, and 3 = high. Certainty about all ratings was indicated by a two level scalar: 1 = poor and 2 = satisfactory. The scores for Hanauma Bay were:

Component	*Value*	*Certainty*
Biodiversity	3	2
Recreation	3	2
Economic Productivity	3	2
Cultural/aesthetic	3	2

The total value score is 12, with uniformly satisfactory certainty. This is the highest possible value score and is to be expected for this bay and its fringing reef. Stressors or sources of harm were identified as toxic chemicals, excess nutrients, erosion/sedimentation, and human crowding. A panel of environmental scientists familiar with Hanauma Bay was convened to rate the likelihood and severity of these stressors causing adverse impacts to the values of the bay.

A six level scalar for frequency (F) of occurrence was used: 1 = remotely possible, 2 = plausible, 3 = likely in the near future, 4 = occasionally, 5 = ongoing, and 6 = progressively increasing.

A six level scalar for the severity (S) of damage was used: 1 = minor loss with rapid recovery, 2 = partial loss with recovery, 3 = partial loss with long time recovery, 4 = major loss with long recovery, 5 = total loss with eventually some recovery, and 6 = irreversible loss of the unique resource.

Each expert independently rated the stressors on the site and the results were then discussed by the group. A consensus was reached on the following ratings:

Stressor	*Frequency*	*Severity*	*Certainty*	*FxS*
toxic chemicals	2	3	satisfactory	6
excess nutrients	5	4	poor	20
erosion/sedimentation	4	2	satisfactory	8
human crowding	6	4	poor	24

The F x S scores (only the top three stressors for any site) were totaled to yield a risk score of 52. This was multiplied by the value score of 12 to yield a priority-for-attention score of 624. The average of all priority scores in the study was 300, indicating Hanauma Bay clearly warranted prompt action. The agencies with jurisdiction decided to close the park one morning each week, to pump all sewage out to a collector sewer and close all septic tanks, to ban feeding of fish, to begin a good-behavior education program for visitors (for example, explaining the negative impacts of walking on the reef), and to increase monitoring and research at the site in order to reduce uncertainties about the impacts and their synergism

In many of the site rating meetings, the experts were divided into two teams and their results compared. The method appears to have a replicability of about ± 10 % of the priority score, and so it was decided to ignore differences in risks of < 20 % in assigning overall action priorities. Despite the qualitative nature of this risk assessment, it has been well received and found useful by government agencies, opinion leaders, environmental groups, and in public forums on future planning for Hawaii.

5.6.7 Issues in Ecological Risk Assessment

1. *Endpoints.* In dealing with ecosystems there is no equivalent to the premature death of an individual human being that so dominates health risk assessment. Species extinction is analogous, but whole communities of many species and their surroundings are of interest. Most risks have to do with the probability of observing an unwanted effect as a result of exposure to a toxic chemical (Bartell et al., 1992). An endpoint, however, must specify a measurable effect that is relevant to society's concerns. The measurement problem is often complicated by uncertainty. For example, it may be impractical, because of the large number of observations required for statistical significance, to determine the decrease in biomass of a species population more closely than 25-50%, whereas a decrease of 10-15% might be serious from an ecological viewpoint. The important endpoint might be the disruption of an ecosystem function that was controlled by a diverse group of organisms. Work underway at Oak Ridge National Laboratory in aquatic systems is promising but focuses on only one of the many types of ecosystems to be assessed.

2. *Single species, single chemical data.* Laboratory experiments to determine exposure-response relationships are usually restricted to one or a few species and one or a few suspected toxic materials; in the real world, pollutants are more often a mixture of chemicals, and many species, even entire ecosystems, are at risk. Further, the mixture usually varies over time and space so that estimating actual exposure levels is even more difficult. Research is proceeding on bioassays using actual polluted water, and on the fundamental chemistry and toxicology of the most toxic constituents of pollutant mixtures (Bartell et al., 1992).

3. *Recoverability.* It is important to risk managers to know the extent to which a damaged ecosystem may recover, with or without assistance. Different species show different behavior. Recovery is also related to the endpoint chosen. There may be no recovery because ecosystems can have more than one stable state. Where native communities are displaced by alien species, as in Hawaii, recovery is unlikely. Modeling of recovery is being investigated at Oak Ridge National Laboratory.

4. *Scale.* The spatial and temporal scales that can be practically covered in an ERA are much smaller than those of interest to managers. Extrapolation from observed areas and times to regional scale and long times requires models. These are not yet reliable, due in part to the inadequacy of ecological theory.

5. *Uncertainty.* In addition to measurement uncertainties, ecosystems appear to be self organizing and non-deterministic. This “true uncertainty,” where even the probability of an event is uncertain, cannot be reduced by more effort. Ecosystems are extremely complex; according to some leaders in the field, they evolve in unpredictable, near chaotic fashion.

6. *Validation of predictive tools.* The lack of long term monitoring and research has hampered the improvement of models. More retrospective examination of environmental management actions is needed to establish confidence and to reject misleading relationships.

5.7 Risks to Economic Welfare

Ecosystems have economic value because people derive utility from their use or their existence. A healthy ecosystem generates market values by providing goods and services, while also providing nonmarket values such as clean air, soil and water quality, flood protection, biological diversity, recreational and educational opportunities, aesthetics, and quality of life. Although some of these economic values are nonmonetary, they are nonetheless important. Pollution, resource extraction, overuse, and alien species invasion can degrade an ecosystem and reduce its economic value.

International concern for the health of the global environment has been growing and attention has focused on tropical forests and fragile island and marine ecosystems. Market values for timber and nontimber forest products, particularly foods and medicines, are used to quantify and monetize the values and damages to existing ecosystems. Analyses of the services provided by the environment, such as soil stabilization, watershed protection, climate regulation, and flood protection, are far less developed. A more detailed discussion of economic evaluation of environmental impacts is presented in Chapter 6.

Recent work in risk to economic welfare because of environmental degradation has indicated the importance of conserving biodiversity by demonstrating the contribution that biological resources make to social and economic development (and losses to society when they are damaged). The dollar value of biological resources may be estimated using actual, option, and existence values.

Dixon and Hufschmidt (1986) illustrate the use of benefit-cost analysis and other techniques in a number of case studies, including assessment of water resources and watershed protection, and lake and marine bay fisheries projects. Aesthetic vistas, clean air view distances, and presence of wilderness or specific flora and fauna are far more difficult to value and are often discussed in qualitative terms or estimated with existence valuation methods.

Economic studies on environmental quality specifically in tourist destination areas addressed three major issues: 1) the impacts of pollution on tourism-related economic values; 2) environmental degradation caused by tourism; and 3) ecotourism. Evaluation has been more qualitative than quantitative because of difficulties in monetizing the large number of services provided by the natural environment.

The impacts of pollution on tourist areas are well demonstrated in a U.S. Department of Commerce study (1983) of the Amoco Cadiz oil spill in Britanny, France. Major losses in tourist industry revenues and consumer welfare due to oiled beaches were recorded. Tourists today are far more environmentally aware (and concerned) than their predecessors, and are demanding higher standards of environmental quality. Tour operators now call for boycotts of degraded sites in favor of other destinations. Ecotourism (environmentally conscious visitors to unique or outstanding natural areas) is a small but growing sector of the tourism market that is increasing the value of biological diversity, endangered species, and naturally functioning ecosystems. Successful ecotourism depends on a high-quality environment, however, tourism development itself may degrade those qualities. The problem of maintaining a balance between tourism and long-term environmental health (the issue of carrying capacity) was documented by the OECD (1980), where environmental deterioration in Majorca, Spain, caused a shift of tourists to other destinations.

5.7.1 Valuation Methods for Economic Damage to Ecosystems

The literature on economic valuation techniques for environmental degradation is large and applied theory is continually evolving. For comprehensive overviews of techniques, the reader is referred to reviews on contingent valuation and comprehensive summaries of techniques by the OECD (1989) and Dixon et al. (1994). Economic damages represent the monetary value of environmental impacts from residual pollution problems. Direct ecosystem values include production (for example, fishery, forestry, agriculture), commercial services, and unpriced amenities. Other values are indirect or involve potential use (option value) or nonuse (existence value) of ecosystems. Where ecosystem damages cannot be valued in monetary terms, damages should be discussed qualitatively.

The primary method for valuing productivity losses from environmental degradation is change in productivity. The method calculates the difference in production, valued at market prices, from a natural system with and without degradation. The resource restoration cost method calculates actual or predicted expenditures to restore the damaged resource to its former condition.

The loss in income method can be used to estimate welfare damages to commercial firms affected by environmental degradation. This method calculates the difference in the net income of commercial enterprises with and without resource degradation.

The most generally applicable method of valuing such amenity losses is contingent valuation. This approach involves direct questioning of consumers to ascertain the willingness of individuals to pay for environmental improvements or, alternatively, their demand for compensation for environmental losses.

Travel cost and property value are two other methods of estimating amenity values. The travel cost approach uses information on differences in travel costs and visitation rates from different communities to estimate a demand curve for a recreation area. The property value method uses multiple regression analysis to estimate how proximity to amenities such as good beaches or urban parks influences surrounding property values.

Indirect ecosystem values often benefit society at large rather than individuals or businesses. For example, the indirect ecosystem values of watersheds and wetlands include regulation of freshwater supplies, nutrient cycling, protection of soils, maintenance of atmospheric quality, and climate control. Option value measures the willingness of individuals to pay in order to retain the option of having future access to a species or resource. Existence value is the value people attach to the existence of species or habitat that they may have no intention of ever using or visiting, but get satisfaction in knowing that they exist.

Contingent valuation is commonly used by economists to estimate indirect, option, and existence values. Contingent ranking is a related approach, but provides an ordinal ranking rather than cardinal values.

Many of the valuation methods mentioned have theoretical and practical limitations and require careful interpretation. However, uncertain scientific knowledge about what services ecosystems provide and how ecosystem services are affected by stressors is probably a more serious problem when performing economic welfare analysis. Uncertainties in cause-effect relationships and quantification of impacts preclude useful economic valuation in many instances of ecosystem degradation from human activities.

5.7.2 Issues in Risks to Economic Welfare

Nonmarket and even nonuse values are important to this element of ERA, but the social science research techniques to establish the monetary worth of such amenities are still being developed. The dilemma of increasing tourism revenues, rising visitor counts, and environmental stability that allows continued economic benefits presents one of the major issues for future research in risks to economic welfare. Contingent valuation surveys and interviews are dependent on how questionnaires are phrased and administered. Also, the willingness to pay is affected by the ability to pay, meaning that socioeconomic factors must be taken into account. The subjective nature of this field is an obstacle to its utility.

5.8 Summary

Environmental Risk Assessment is developing rapidly and there is no one clearly superior approach to its performance. Adherence to probability theory is the one essential in adding this explicit presentation of uncertainty to the management information package begun about 20 years ago as EIA. If policies and action programs are to be effective and efficient, the frequency and severity of adverse impacts should be investigated and interpreted for decision makers and the interested public.

Health risks and ecosystem risks differ substantially in the endpoints chosen for risk characterization (the individual compared to the biological community), and in the uncertainties accompanying experimental data. Human health risk assessment is far more advanced in methodology. However, both are dominated by concern with toxic chemicals. Both require close communication between environmental scientists and risk managers. A common but flexible framework for hazard identification, exposure pathway analysis, and hazard accounting is useful because the underlying treatment of uncertainty and the decision process is the same for both.

A major application of ERA is in allocating limited budgets and setting priorities for risk reduction programs. Therefore, the economic valuation of damages from adverse events and the cost of reducing or avoiding the risks is essential. Public acceptability of risks is assisted by ERA if proper comparisons are made with the benefits of technological activities, the risks of alternative economic development strategies, and familiar risks in other parts of a modern lifestyle. ERA can help correct misperceptions of risk and avoid unnecessary public anxiety. Environmental risk assessment is maturing as a practical and valuable addition to the set of management and policy tools needed in a complex world.

Acknowledgment

Much of this chapter is based on Carpenter, R.A., 1995. Environmental Risk Assessment. A chapter (pp. 193-217) in Vanclay, F. and D. Bronstein, Eds., Environmental and Social Impact Assessment, Wiley, Chichester. The sections on health and ecosystem risk assessment are based on the report of the Hawaii Environmental Risk Ranking study (Carpenter et al., 1992), which is copyrighted by the East-West Center. Excerpts are used with their permission. The introduction, scope, and definition sections are drawn, in part, from the book on Environmental Risk Assessment prepared for the Asian Development Bank (Carpenter et al., 1990).

5.9 References and Further Reading

Ahearne, J. 1993. "Risk analysis and public policy" in *Environment*, 35(2): 16.

Ames, B. and L. Gold. 1990. "Too many rodent carcinogens" in *Science*, 249 (31 Aug.): 970-1.

Barnthouse, L.W., G.W. Suter, S.M. Bartell, J.J. Beauchamp, R.H. Gardner, E. Linder, R.V. O'Neill, and A.E. Rosen. 1986. User's Manual for Ecological Risk Assessment. Environmental Sciences Division Publication No. 2679. Oak Ridge National Laboratory, Oak Ridge, TN.

Bartell, S., R. Gardner, and R. O'Neill. 1992. Ecological Risk Estimation. Lewis Publishers, Ann Arbor, MI.

Carpenter, R., C. Claudio, L. Habegger, and K. Smith. 1990. Environmental Risk Assessment: Dealing with Uncertainty in EIA. ADB Environmental Paper No. 7. Asian Development Bank, Manila.

Carpenter, R., N. Convard, S. Edgerton, J. Maragos, K. Smith, W. Mitter and others. 1992. Report of the Hawaii Environmental Risk Ranking Study. Department of Health, State of Hawaii, Honolulu, HI.

Dixon, John A., Louise Fallon Scura, Richard A. Carpenter, and Paul B. Sherman. 1994. Economic Analysis of Environmental Impacts, second edition, Earthscan, London in association with the Asian Development Bank and the World Bank.

Dixon, J. and M. Hufschmidt, eds. 1986. Economic Valuation Techniques for the Environment: A Case Study Workbook. The Johns Hopkins University Press, Baltimore, MD.

Hubert, P. 1987. Risk Assessment and Risk Management for Accidents Connected with Industrial Activities. Organisation for Economic Cooperation and Development (OECD), Paris.

National Research Council (U.S.). 1993. Issues in Risk Assessment. National Academy Press. Washington, DC.

Organization for Economic Cooperation and Development. 1980. The Impact of Tourism on the Environment. OECD Publications, Paris.

Organization for Economic Cooperation and Development. 1989. Environmental Policy Benefits: Monetary Valuation. OECD Publications, Paris.

Regier, H., J. Kay, and B. Bandurski. 1994. An Ecosystem in a State of Integrity. In Woodley, S., J. Kay, and G. Francis, eds. Ecological Integrity and the Management of Ecosystems, St. Lucie Press, Boca Raton, FL.

Smith, Kirk R., Richard A. Carpenter, and Susanne Faulstich. 1988. Risk Assessment of Hazardous Chemical Systems in Developing Countries. Occasional Paper No. 5. East-West Environment and Policy Institute, Honolulu, HI.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. 1983. Assessing the Social Costs of Oil Spills: The Amoco Cadiz Case Study. Washington, DC.

U.S. Environmental Protection Agency. 1997. Guidelines for Ecological Risk Assessment. Washington, DC.

U.S. Environmental Protection Agency. 1990. Reducing Risk: Setting Priorities and Strategies for Environmental Protection. EPASAB-EC-90-021, Washington, DC.

Walters, C. and C.S. Holling. 1990. "Large-scale management experiments and learning by doing" in *Ecology*, 71: 2060-2068.

Whyte, A.V. and Ian Burton. 1980. Environmental Risk Assessment. SCOPE #15. New York: John Wiley and Sons.

World Bank. 1985a. Guidelines for Identifying, Analyzing, and Controlling Major Hazard Installations in Developing Countries. Office of Environmental and Scientific Affairs, Washington, DC.

World Bank. 1985b. Manual of Industrial Hazard Assessment Techniques. Office of Environmental and Scientific Affairs, Washington, DC.

World Health Organization. 1996. The Global Burden of Disease. Geneva.

6.0 Economic Analysis

Traditionally, the Environmental Impact Assessment (EIA) was meant to be an independent report related to the environmental impacts of the development project. The assessment had minimal links with economic analysis. There have been considerable discussions among various stakeholders involved in project processing, financing and implementation on how to measure the economic importance of expected environmental impacts. This section focuses on the emerging role of economic evaluation of environmental impacts, specifically on how to use such information in environmental assessment. A brief summary of the principal methods available for placing monetary values (costs and benefits) on environmental impacts, a taxonomy of valuation methods, and steps involved in economic evaluation of environmental impacts are also presented.

6.1 Role of Economics in Environmental Impact Assessment

The economic analysis of development projects has had a relatively long history. Initially, environmental impacts were deemed external to development projects, and hence were excluded from economic analysis. Subsequently, it became the practice to describe environmental impacts quantitatively. Since the mid-1980s there has been a growing interest in placing monetary values on environmental impacts and combining these values into overall project analysis work. In this regard, the Asian Development Bank's (ADB) "Economic Analysis of the Environmental Impacts of Development Projects" (Dixon et al., 1988) can be considered an excellent example. Despite this, until the mid-1990s the analysis described in the publication was rarely applied to actual projects. In 1996, the ADB published "Economic Evaluation of Environmental Impacts: A Workbook" as a follow-up to the 1987 work. It provides the practitioner with a step-by-step valuation procedure. Another publication, the ADB's latest "Guidelines for the Economic Analysis of Projects" (Asian Development Bank, 1997), documents how the economic values of environmental impacts can be integrated into project analysis.

The role of environmental economics in an EIA can be divided into three categories, namely: 1) the use of economics for "benefit-cost analysis" as an integral part of project selection; 2) the use of economics in the assessment of activities suggested by the EIA; and 3) the economic assessment of the environmental impacts of the project.

Environmental economics can aid in the selection of projects in that benefit-cost analysis can be used in the prescreening stage of the project, and the environmental components can be brought into the process of presenting various options and selecting among them. Doing so eventually leads to a project selection process which takes the environment into consideration. In the second role, the economic assessment is focused on the cost assessment of environmental mitigation measures and management plans suggested in the EIA. The economic analysis in the EIA may include a summary of the project costs and how such cost estimates would change due to the activities proposed under the EIA. This component can be considered as an accounting of the environmental investment of a project. The third role, which is the economic assessment of the environmental impacts of a project, is geared towards seeking the economic values (of both costs and benefits) of the environmental impacts. These impacts are neither mitigated, nor taken into account in traditional economic analysis of projects. They should be identified by the EIA and sufficient quantitative and qualitative explanations should be given in EIA documents. The economic evaluation of environmental impacts is related to project intervention, however, methodological difficulties and the traditional thinking that environmental impacts are external to the project have prevented its incorporation into the overall economic analysis of the project.

To illustrate the functions of environmental economics in EIA, consider the case of a power plant. Power can be generated using various forms of energy, including coal, hydropower and geothermal sources. If, in the prescreening, environmental economics is used to identify environmental costs and benefits among the options and is used to select the project, then the first function of environmental economics has been used. Hence, a coal-fired power plant may have been selected and the environmental components may have already been recognized through the preliminary accounting of likely benefits and costs. If the power plant installs an electrostatic precipitator to reduce total suspended particulate emissions, that is a mitigation measure. As such, its costs should be included in the project cost estimates. If the economic assessment was conducted without including the cost of environmental mitigations, it would be biased with the actual cost of the project estimated at a lower figure. Thus, it is important to provide a summary of both the project costs and the related environmental costs in the EIA report — doing so provides insight about the additional costs that a project proponent would incur to correct the environmental damages caused by the project.

On the other hand, the previously mentioned coal power plant may have many other environmental impacts; some may be mitigatable, others not, yet each has a distinct economic value. For example, the generation of CO_2 and the emission of additional gases is an inevitable function of coal burning. One may not be able to directly compensate for such emissions, but there are activities which may reduce the damages caused by them. For instance, although not a mitigation measure, it is clear that the introduction of an afforestation program will result in more trees, thereby increasing the potential of forests to absorb CO_2. Now suppose the new power plant uses state of the art technology in power generation; as a result, the power authority can close some of the old and inefficient power plants. If this is possible, environmental benefits besides those directly associated with the project operations may be obtained. Economic analysis of such environmental impacts can help the project analyst to express the economic benefits of the project in a more complete manner.

In summary, the use of economic analysis in EIA can aide in assessing the proposed project more objectively. If the EIA exercise is used as a planning tool in an iterative manner, it is possible to reduce the negative environmental impacts and capture more positive environmental components if the economic analysis of such impacts is possible with every iteration. The result of integrating economic analysis of environmental impacts can be very useful in enhancing the quality of a project.

6.2 Steps in Economic Valuation of Environmental Impacts

Economic analysis of environmental impacts is important in project preparation to determine whether the net benefits of undertaking the project are greater than the alternatives, including the non-project scenario. Project alternatives often vary in their economic contribution and environmental impacts. Economic assessment of different alternatives in the early stages of project planning should provide important inputs to improve the quality of decision-making. The economic analysis of the environmental impacts of the selected projects also allows for a more complete assessment of the project's costs and benefits. A general procedure that can be followed in economic analysis of environmental impacts is presented in Figure 6-1 (adapted from Asian Development Bank, 1996).

Screen 1 of Figure 6-1 indicates that in the case of internal or mitigated impacts, there is no need to look for an extensive monetization of environmental impacts. They are already treated as part of the project. However, one has to assure that they are properly costed or valued in economic terms and appropriately incorporated into the economic cost benefit streams of the project. As explained earlier, this is the first part of the economic analysis section of the EIA report. A good EIA report should include a section on all economic aspects of the project, including the results of a cost benefit analysis of the overall project after incorporating the internal or mitigated impacts.

Screens 2 and 3 reflect instances when qualitative assessment and documentation is important. Screen 4 refers to the second component of the economic analysis of the EIA which gives an assessment of environmental impacts that can be quantified. At a minimum, the following six tasks need to be completed in the economic analysis of environmental impacts:

1. determine the spatial and conceptual boundaries of the analysis;
2. identify environmental impacts and their relationships to the project;
3. quantify environmental impacts and organize them according to importance — the impacts described qualitatively, if they cannot be expressed in quantitative terms;
4. choose a technique for economic valuation;
5. economic valuation (place monetary values) of environmental impacts identified; and
6. set an appropriate time frame and perform the extended benefit cost analysis.

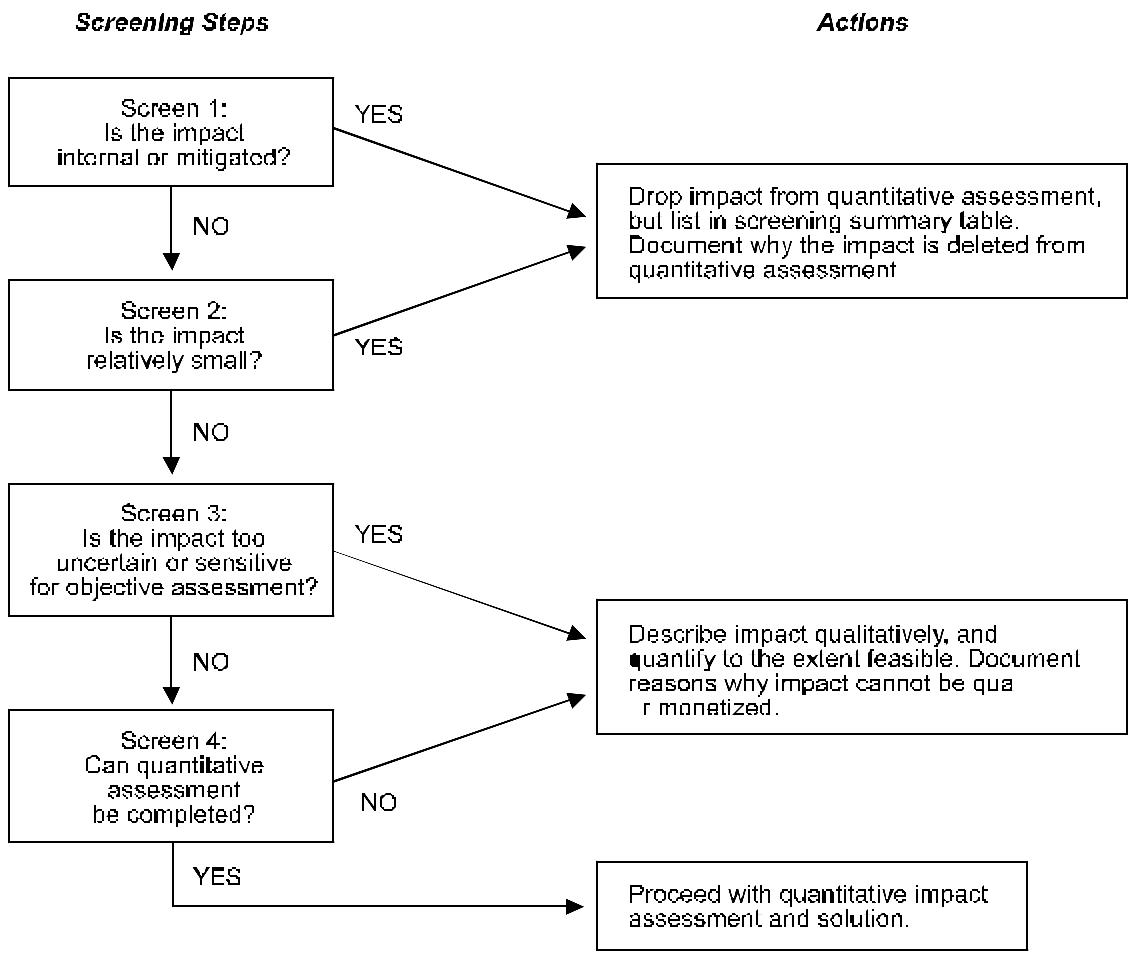


Figure 6-1: The impact screening process.

The boundary of the economic analysis refers to the conceptual and physical limits of the analysis. It may consider on-site and off-site environmental impacts that are consequences of project activities. Another consideration is the type of goods and services that should be included in the analysis. The complexities of a project's environmental impacts may cause some difficulty in establishing the spatial and conceptual boundary of the economic analysis. The rule is to start the analysis with directly observable and measurable impacts.

A successful EIA report should provide the required information for economic analysis of the environmental impacts. Necessary output of Tasks 1, 2, and 3 show a list of all possible environmental impacts of the project. Thus, the EIA should identify and completely document all impacts, providing sufficient quantitative and qualitative descriptions. This list becomes the basis for the economic valuation carried out in Task 5.

Valuing environmental impacts in monetary terms is the most difficult part of the economic analysis. This necessitates the use of valuation techniques (discussed in the remainder of this chapter) appropriate to the environmental impacts being investigated. Choosing the appropriate valuation techniques is itself a difficult task, requiring expert judgment from economists and environmental specialists.

6.3 Methods for Economic Valuation of Environmental Impacts

The remainder of this chapter deals with the various techniques that may be used to determine the monetary values of environmental impacts. The methods in which market prices are used are fairly standard and straightforward approaches that rely largely on changes in physical production or on direct cash expenditures. Other approaches use surrogate markets. The valuation flowchart presented in Figure 6-2 provides a good starting point towards understanding the valuation aspect of economic analysis. Environmental impacts can be divided into three categories. The first two categories are those that cause measurable changes in the production of a specific good or service, and thereby affect: 1) human welfare, and 2) human health. The third category is those that cause changes in the quality of the environment. Figure 6-2 provides a classification system for alternative valuation methods.

Table 6-1 presents applications of economic valuation methods to specific environmental impacts of different types of projects. Readers are advised to refer to the table as each valuation technique is discussed in section 6.7 (Dixon et al., 1988; Carpenter and Maragos, 1989).

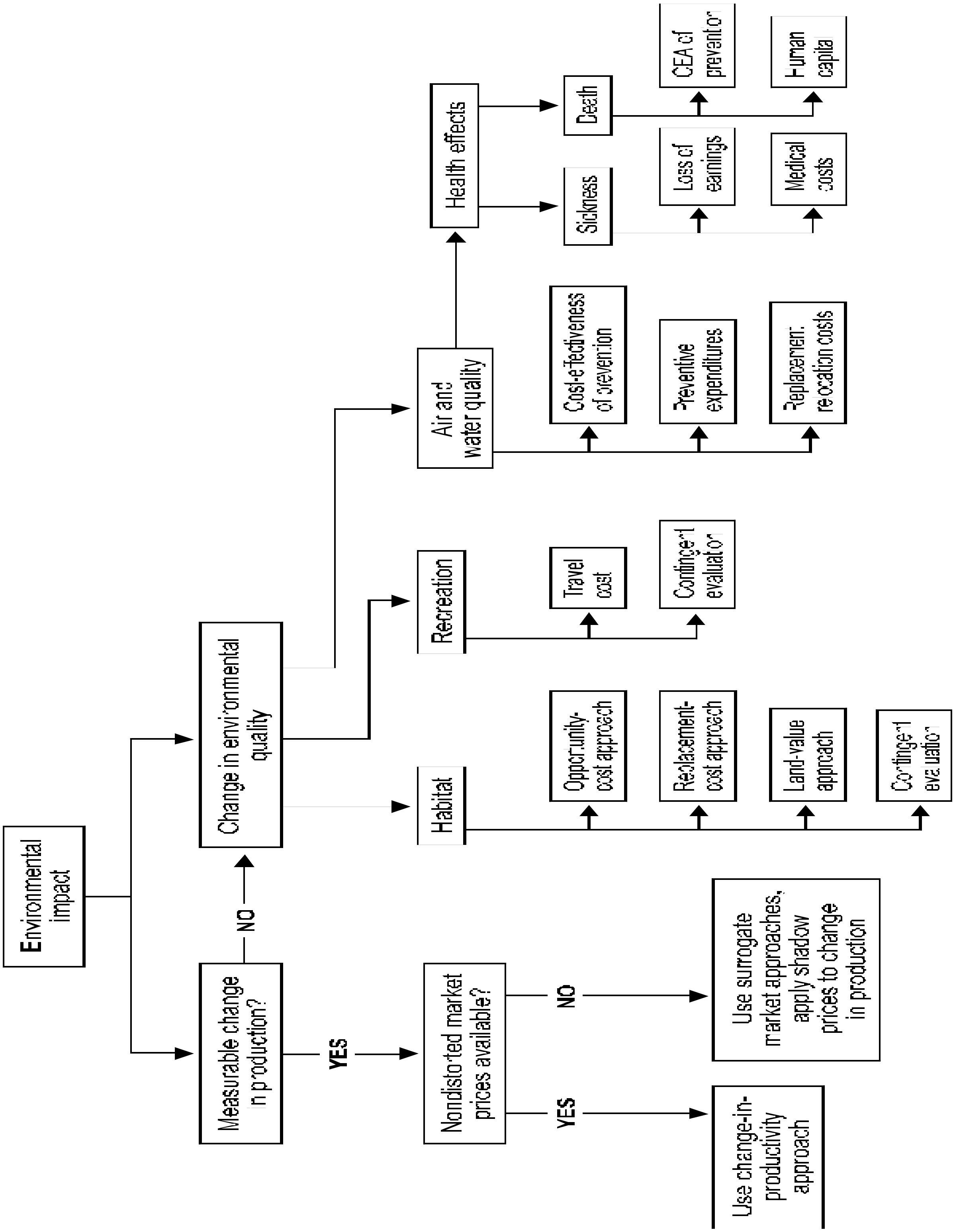


Figure 6-2: A simple valuation flowchart (*source:* Dixon and Bojo, 1988).

Table 6-1: Examples of development projects, possible environmental impacts, and measurement and valuation techniques (*source:* Dixon et al., 1988; Carpenter and Maragos, 1989).

Type of Project	Environmental Impacts	Measurement and Valuation Techniques (comments)
Agriculture, Forestry and Fisheries Development		
Hill forest development	Project will increase fuelwood and fodder production and protect critical watershed	• Change in productivity of forests and agricultural land • Opportunity cost of dung as fertilizer to value benefit of alternative fuel
Fisheries development	Project contributes to over exploitation of shrimp resources	• Change in productivity of fishery due to overfishing
	Project vessels competing with artisanal fishermen – project catch not fully incremental	• Loss of earnings of artisanal fishermen must be subtracted from project – catch projections
	Evidence of overfishing inshore	
Brackish-water shrimp culture	Removal of mangroves for construction of shrimp ponds	• Change in productivity of fishery due to mangrove removal
Livestock development	Effects on forests and rangeland of overgrazing	• Change in productivity of forests and rangeland • Opportunity cost of dung as fertilizer
Irrigation		
Low lift pump maintenance	Shallow flooded areas over drained resulting in lack of water for surface water irrigation in dry season	• Change in productivity due to moisture deficit in dry season
Irrigation and settlement	Project located in watershed in good condition; there should therefore be low sedimentation rate	• (Watershed management covenant in loan agreement to assure that increased development resulting in increased sedimentation would not affect project's future operation)
Outfall drain	Project should have positive environmental impacts by correcting waterlogging and soil salinization problems	• Change in productivity from better growing conditions • Cost effectiveness of alternative rehabilitation designs
Infrastructure		
Road development in hilly area	New cuts in embankments not stabilized with vegetation, causing potential for soil erosion and landslides	• Change in productivity due to soil erosion and sedimentation • Loss of property due to landslides
Urban water supply	Project contributed to increased waste-water volume without providing adequate sewerage facilities	• Loss of earnings directly due to flooding or indirectly from increased incidence of waterborne disease • Loss of property due to flooding • Willingness to pay
Provincial cities water supply	Watershed denudation in the upper recharge area of the project affects project performance	• (The broader issue of management of watershed on which the project depends should have been given consideration)
Water supply	Water diverted from downstream users by artificial well recharge in river bed	• Change in productivity of downstream water users • Willingness to pay
Low-income urban housing	Increased air pollution due to use of underfloor heating systems burning soft-coal briquettes	• Cost effectiveness of alternative heating designs • Loss of earnings from increased respiratory diseases
Industry and Power		
Gas turbine generation	Design as peak-load facility to run on gas; no air quality control included in design; was used as base-load facility run on oil; air quality adversely affected by emissions	• Cost effectiveness of alternative designs to decrease emissions

Type of Project	Environmental Impacts	Measurement and Valuation Techniques (comments)
Palm oil processing plant	Untreated effluent of biological oxygen deficiency (BOD) of 20,000 mg/l discharged into river	• Change in productivity in inland fishery due to water pollution • Cost effectiveness of alternative water treatment designs • Loss of earning from increased health problems due to use of polluted water
Tin mining	Environmental aspects given due consideration with respect to waste tailing disposal, water storage pond dike burst prevention and prevention of malarial-mosquito breeding	• (Project accounted for major potential environmental problems. Negative environmental impact should be minimal)
Hydropower development project	Service roads gave access which promoted deforestation resulting in changes in hydrological patterns, soil erosion, siltation, and flooding	• Change in productivity of forests, agricultural land and downstream fishery; reduction in useful life of downstream hydropower facility • Loss of earnings as a direct result of flooding or indirectly from increased incidence of disease
Hydropower development project	Run-of-river power facility located in catchment with heavy development pressure resulting in increased extreme river flow rates and heavy siltation loads	• (Project design and estimates of project's useful life should account for surrounding environmental conditions which will affect project operation even though not a direct consequence of project) • Preventive expenditures made to reduce downstream consequence of deforestation

6.4 Taxonomy of the Valuation Methods

There are many methods available for economic valuation of environmental impacts. Table 6-2 presents a brief summary of such methods classified according to the human behavior and the nature of the market situation.

Table 6-2: Different methods available for economic valuation of environmental impacts.

	Actual Market-based Information	Indirect Market-based Information	Hypothetical-based Information
Actual Behavior	• change in production • effect on human health • preventive cost	• travel cost • wage differences • property values	• created or simulated market
Potential Behavior	• replacement cost • shadow price	• surrogate goods • opportunity cost	• contingent valuation • bidding games

6.5 Guidelines for Economic Valuation of Environmental Impacts

The methodology of valuing costs and benefits of environmental changes is still evolving. In this respect, some general guidelines for conducting economic analyses of the environmental impacts of development projects should be observed in order to carry out any useful analysis. These are, from the Asian Development Bank's *Guidelines for Economic Analysis of Projects* (Asian Development Bank, 1987):

1. Start with the most obvious and easily valued environmental impacts. First select the effects that have directly measurable productivity changes that can be valued by market prices (for example, changes in fish or crop production due to a diversion of water for a hydroelectric power project).
2. Always look at both the benefit and cost sides. A clear distinction should be made between benefits (costs avoided) and costs, as these will be the reference from which changes are measured. For instance, the value of a regulation structure should include, from the cost side, the capital operations and maintenance costs; and from the cost avoided side, the benefits of reduced flooding downstream.
3. Economic analysis should be done in a "with- and without-project framework." Project alternatives should also be considered.
4. All assumptions in the economic analysis should be stated clearly.
5. When market prices cannot be used directly, surrogate market prices should be used.

The time horizon for the economic analysis may coincide with the economically and technically viable project life span. Where the effects on the environment are expected to persist beyond the project's life span, however, the time horizon of the analysis should be likewise extended. There are two ways to accommodate an extended time horizon. The first is to extend the cash-flow analysis for a number of years specific to the project under consideration. The second is to add a capitalized value of net benefits or costs at the normal end of the project period. This approach implicitly assumes that the impact on the environment extends to infinity (Carpenter and Maragos, 1989).

6.6 Issues in the Incorporation of Environmental Values into Benefit Cost Analysis

The evolutionary nature of the process of valuing environmental impacts requires that three important conceptual issues be addressed. To reiterate previous sections, these issues are: i) the need to choose valuation techniques; ii) the definition of analysis boundaries; and iii) the selection of an appropriate time horizon.

Aside from these issues, designwise, economic analysis has a series of limitations when incorporating the environmental values into benefit cost analysis. Economic analysis does not address the effects of the project on **income distribution**. Projects which will benefit wealthy individuals at the expense of poor individuals may be undesirable on distributional grounds, even if they show high benefit/cost ratios. If analysts are careful, however, they can incorporate distributional impacts into the economic analysis by assigning different weights to the different income groups.

Another issue in the economic analysis is **intergenerational equity**. Future generations might have fewer resources available than they would have had without the project, resulting in a high benefit-cost ratio. One way of addressing this issue is directly related to the choice of discount rate. A high discount rate will favor projects with immediate net benefits, while a low one will have fewer restrictive effects on projects with long-term negative benefits and will give more weight to negative future impacts. The environmental impacts of a project could be highly affected by this issue, as some of the environmental issues may have impact over a long period.

Economic analysis also has to deal with **risk** and **uncertainty**. Natural events such as drought, floods, earthquakes, and plant and animal diseases may seriously affect projects. To handle this problem, expected values are used as alternative values for variables (that is, prices, quantities whose precise value cannot be known in advance). By using a single number, this "expected value" method of accounting for risk and uncertainty does not indicate the degree of uncertainty or the range of values which might actually be expected. Sensitivity analysis can also be used to handle risk and uncertainty in projects. Here, the use of optimistic and pessimistic values for different variables can indicate which variables will have the most pronounced effects on benefits and costs.

Another important issue in the economic analysis is the **accounting of the irreversible damage** projects have on available natural resources. Decision makers must give special attention to irreversible impacts since these may have significant consequences in the future. Irreversibility can be accounted for in the economic analysis by the opportunity-cost approach since it indirectly provides information on the cost of preservation. In general, however, the rule should be that if the costs of retaining an option that would otherwise be foreclosed are relatively low then the decision maker should weigh the possibility of retention. To address this issue, caution should be made in the choice of projects, by wisely using nonrenewable resources and implementing projects which promote sustainable use of renewable resources. The welfare of both current and future generations can be enhanced.

Economic analysis is also limited by **ethical and moral considerations in the valuation of human lives**. Although methods have been devised to evaluate project activities which will affect human health, one cannot readily reply to questions on how much compensation an individual will accept for the loss of his life. Ethically, no project proponent could brazenly show willingness to buy/pay for human lives that might be affected by the project.

Economic valuation will also have limits if the resources in question are imbedded in the people's **cultural traditions and value systems**. This is specifically true for cultural, historical, and aesthetic resources where the people's perception of losses of these resources depends a great deal on their cultural and historical attachment to them. People may be unwilling to accept any level of compensation, no matter how high, if they have strong emotional, cultural, or traditional ties to the resources. Conversely, although people may be willing to pay to preserve or retain a resource, they might be constrained by income.

6.7 Methods for Economic Valuation of Environmental Impacts

There are many methods available for economic valuation of environmental impacts. The valuation to be undertaken and the appropriate methods to be chosen depend on the data availability and other circumstances related to the project. The following section provides a brief description of the more important methods available for valuating environmental impacts. Though inexhaustive, it will familiarize the reader with a range of valuation techniques.

6.7.1 Changes in Productivity

Techniques using changes in productivity as the basis for measurement are direct extensions of traditional benefit-cost analyses. Physical changes in production due to environmental impacts are valued using market prices for inputs and outputs, or, when distortions exist, appropriately modified market prices. The monetary values thus derived are then incorporated into the economic analysis of the project.

To use these techniques, the following steps must be taken:

1. identify the changes in productivity caused by the environmental impacts both on-site and off-site;
2. assess the effects on productivity "with the project" and "without the project." The latter option is used to specify the change the project will cause and to clarify the degree of damage or the damage avoided by the project; and
3. make assumptions about the time over which the changes in productivity must be measured, the "correct" prices to use, and any future changes expected in relative prices.

The lost earnings and medical costs that result from environmental damage caused by a project or the comparable savings which would accrue from preventing that damage are the basis for valuation. This technique is known as the **loss of earnings**, human capital or forgone earnings approach.

The loss of earnings approach may be used when:

1. a direct cause-and-effect relationship can be established and the etiology of the disease is clearly identifiable;
2. the illness is of short-duration, not life-threatening, and has no major long-term effects; and
3. the precise economic value of earnings and medical care is known.

In addition to using this technique in health-related morbidity or mortality, it may also be used to measure loss of (income) earnings caused by exogenous reductions in productivity.

6.7.2 Market Prices

Some techniques use market prices to evaluate actual project costs. They do not attempt to estimate a monetary value for the benefits produced by the project. The project output or product is described in qualitative or physical terms and potential benefits must be determined to justify the costs involved.

To determine the importance individuals attach to impacts on the environment, the preventive expenditure approach examines actual expenditures. The demand for the mitigation of environmental damage may be seen as a surrogate demand for environmental protection. Obviously, individuals will commit their resources only if their subjective estimate of the benefits is at least as great as the costs. An indirect measure of individual perception of these costs can then be derived by looking at the amount of resources allocated to avoiding them. Since an individual's willingness to incur costs is constrained by his/her ability to pay, however, this approach only provides a minimum estimate of the benefits achieved. The assumptions implicit in this kind of analysis are:

1. accurate data on the costs of mitigating expenditures are available; and
2. there are no secondary benefits associated with the expenditures.

The **opportunity cost** approach is based on the concept that the cost of using resources for unpriced or unmarketed purposes can be estimated by using the forgone income from other uses of the resource as a proxy. Rather than attempting to measure directly the benefits gained from preserving a resource, that which is given up for the sake of preservation is measured. Where the opportunity cost of preservation is low, a decision is usually made to conserve the resource in its natural state.

Possible situations where this approach may be valuable include alteration of tropical rainforests, establishment and protection of wildlife sanctuaries, preservation of cultural or historical sites and natural vistas. The approach can also be used to determine where major infrastructure projects or industrial facilities will be sited. Where alternative locations exist, the approach helps to clarify the additional costs of preserving one area versus another. Similarly, this technique can be used to value the effect of the different technological options on the environment.

6.7.3 Surrogate Market Prices

Surrogate market techniques are approaches which use actual market prices to value an unmarketed quality of the environment (for example, clean air, unobstructed views, pleasant surroundings, etc.). The basic assumption is that the purchasers' valuation of the environmental qualities at issue is the price differential arrived at after all variables except environmental quality have been controlled.

Property Values

The basic assumption in using this approach is that the buyers' attitudes toward an attribute of a property (physical, aesthetics, environmental) is reflected by their willingness to pay for the property. For instance in deciding to buy a new house, one would expect its value to be equal to its construction costs plus an appropriate mark-up. In reality, however, decisions to buy a house are influenced by a wide range of attributes, only some of which are physical.

The property value approach is designed to control certain variables so that any remaining price differential can then be assigned to the unpriced environmental "good." Similarly, environmental "bad" can be measured using this technique, or with a drop in property value due to increased noise, air pollution, or view obstruction. For example, benefits from an urban flood control project could in part be estimated by examining price differences between housing units located in a flood-prone district and similar housing in less frequently flooded areas.

Wage Differentials

The wage differentials approach rests on the theory that in a perfectly competitive equilibrium, the demand for labor equals the value of the marginal product of the worker and the supply of labor varies not only with wages, but also with working and living conditions. A higher wage is thus needed to induce workers to work in polluted areas or to undertake risky occupations. Workers are presumed to be able to work freely among jobs, and therefore to be able to choose particular jobs in particular areas at certain wages which will maximize their utility.

Differences in wage levels for similar jobs may be viewed as a function of different levels in the attributes of a job relating to working or living conditions. If such a relationship between wage levels and attributes could be estimated, implicit prices could be determined. Assuming constant implicit prices (reflecting marginal willingness to pay or the acceptance of lower or higher wages for lower or higher levels of the particular attribute), benefits could be estimated for improvements in levels of attributes. Common attributes affecting wage differentials are risks to life and health, and the presence of urban amenities.

Travel Cost

The travel cost approach is based on the simple premise that observed behavior can be used to estimate a value for an unpriced environmental "good" by treating increasing travel costs as a surrogate for variable admission prices. This approach is widely used to determine values people place on recreational facilities. Usually such goods are provided either free of charge or for a nominal admission fee. The value of the benefits or utility derived from the park, however, is often much larger than the fee, with the difference being the consumer's surplus. To estimate the total amount of a consumer's surplus, one must derive a demand curve from the actual use of the park.

6.7.4 Replacement Cost

The basic premise of the replacement-cost approach is that the costs incurred in replacing productive assets damaged by a project can be measured. These costs can be interpreted as an estimate of the benefits presumed to flow from measures taken to prevent that damage from occurring. The rationale for this technique is similar to that for preventive expenditures except that the replacement costs are not a subjective valuation of the potential damages. Rather they are the true costs of replacement if damage had actually occurred. The approach may thus be interpreted as an "accounting procedure" used to work out whether it is more efficient to let damage happen and then to repair it or to prevent it from happening in the first place. It estimates the upper limit of the value of the damage but does not really measure the benefits of environmental protection *per se*.

The assumptions implicit in this type of analysis are:

1. the magnitude of damage is measurable;
2. the replacement costs are calculable and are not greater than the value of the productive resources destroyed, and therefore it is economically efficient to make the replacement; and
3. there are no secondary benefits associated with the expenditures.

Relocation Costs

This variant of the replacement-cost technique uses the actual costs of relocating a physical facility to evaluate the potential benefits (and associated costs) of preventing the environmental change which would necessitate the relocation. A case in point is the construction of an oil palm mill which would discharge waste water into a nearby stream. Of the various environmental costs associated with this discharge, one might need to relocate a domestic water supply intake which is downstream from the mill.

Shadow Projects

The shadow-project technique was developed in an attempt to estimate the cost of replacing the entire range of environmental goods and services threatened by a project.

The assumptions implicit in this analysis are that:

1. the endangered resource is scarce and highly valued;
2 the human-built alternative would provide the same quantity and quality of goods as does the natural environment;
3. the original level of goods and services is desirable and should therefore be maintained; and
4. the costs of the shadow project do not exceed the value of the lost productive service of the natural environment.

6.7.5 Contingent Valuation Methods

Contingent valuation methods are survey-based methods which may be used to value the environmental impacts of development projects when no data are available on market or surrogate market prices. Some of these methods may not be applicable in the analysis of many projects in developing countries, however they are nevertheless valuable tools in some cases concerning such diverse goods and services as species preservation; historical or cultural phenomena; genetic diversity; preservation of open spaces, unobstructed views; or public access to amenity resources.

Bidding Games

In a bidding game, individuals are asked to evaluate a hypothetical situation and to express their willingness to pay or to accept compensation for a change in the level of provision of an environmental "good" or service (for example, access to parks, clean air or water, or unobstructed views). Respondents' willingness to pay rather than to do without the "good" may be summed up to provide an estimate of aggregate willingness to pay. There are two types of bidding games: single bid games and iterative bid games.

Single bid games ask respondents the maximum price they would be willing to pay for an environmental "good" such as clean water or to quote the minimum amount of compensation they would accept for doing without that "good." The responses are then averaged and extrapolated to come up with the aggregate willingness to pay or an aggregate level of compensation.

In the *iterative (or converging) bid games,* individuals are asked whether they would pay a given amount for the environmental "good" or service. The amount is then varied iteratively until a willingness to pay or a minimum willingness to accept compensation is reached.

Take-it-or-Leave-it Experiments

This method is best illustrated by an experiment asking different groups of respondents if they would be willing to accept $10, $20, or $50 for a decrease in air quality. Each respondent is given only one amount to respond to. The various amounts are randomly distributed over the entire surveyed population. For each given amount, the proportion of respondents who would and would not accept the offer can be determined. The answers are then analyzed to come up with the average consumer's willingness to pay, which in return is multiplied by the number of people affected to arrive at the aggregate willingness to pay.

Costless Choice

The costless choice method involves asking participants to choose from two or more alternatives, each of which is desirable and will cost nothing. The choice might be between a certain amount of money or some unpriced environmental "good" (for example, a reduction in air or noise pollution). If the individual chooses the environmental "good" rather than the money, the minimum value of the environmental "good" to that individual is established. If the money were chosen, then it would be established that the individual thought the "good" to be worth less than that certain amount.

6.7.6 Cost-Effectiveness Analysis

Although cost-effectiveness analysis is not a straightforward valuation technique, it can nonetheless be useful. This approach focuses entirely on meeting a predetermined standard or goal given limited resources (for example, limited funds, inadequate data, or insufficient knowledge of the nature and link between environmental damage and human health and welfare). After considering all the alternatives, cost effectiveness analysis is used to determine the most effective way to meet a goal. The major difference between cost-effectiveness analysis and other approaches is that no attempt is made to monetize the benefits. It is thus a highly useful approach for projects with benefits that are difficult to measure in monetary terms.

The first step in cost-effectiveness analysis is to fix a target. In the environmental field it may be a certain ambient quality or an emission standard for industrial facilities. Once a target is chosen, cost-effectiveness analysis is carried out by examining the various options by which the target can be achieved. This may involve analyzing the capital and operating costs of different pollution control technologies. The basic goal, however, is to identify the least-cost alternative which will achieve the goal selected.

Since cost-effectiveness analysis does not give an estimate of benefits that can be derived from meeting a given standard or goal, it is possible that even the most cost-effective (least-cost) option of meeting a strict standard is still too expensive. This would suggest that standard should be relaxed — cost-effectiveness analysis can help point this out too.

6.7.7 Benefits-Transfer-Method

The Benefits-Transfer-Method (BTM) is a method of estimating the value of environmental impacts by adapting values reported in other studies, preferably in a similar location under comparable circumstances, through primary research. Although the BTM is a secondary valuation technique, it is very practical because it saves budget and time requirements for data gathering and analysis work.

In general there are four basic steps in obtaining BTM values. The first is to select literature in order to obtain values and estimates of environmental benefits and damages. These values then need to be adjusted, in order to fit the bio-physical baseline and socio-economic and monetary information of the current project. The adjusted values are then multiplied by the number of affected individuals to get the total values per unit of time. Finally, the total discounted values of environmental impacts are calculated over the time period which impacts are expected to occur.

Although the method is straightforward, sound judgement must be used or else the calculated values may be totally inapplicable to the project being evaluated. If BTM is to be used, it is important to properly evaluate the appropriateness of the value because a wide range may be found in the literature due to the differences in estimation procedures. It is also important to make necessary modifications in the values to account for differences in the primary study site and the new study site. If the values from a developed country are to be extrapolated to a developing country (which is often the case), the major differences in personal income, property rights, land prices, institutions, cultures, climates and natural resources should be considered.

6.8 References and Further Reading

Asian Development Bank. 1996. Economic Evaluation of Environmental Impacts: A Workbook. Parts I and II. Environment Division, Office of Environment and Social Development, Asian Development Bank, Manila, Philippines. 303 pp.

Asian Development Bank. 1987. Guidelines for Economic Analysis of Projects. Asian Development Bank internal document, Aug. 1987. Manila, Philippines. 172 pp.

Carpenter, R.A. and J.E. Maragos (eds). 1989. How to Assess Environmental Impacts on Tropical Islands and Coastal Areas. South Pacific Regional Environment Programme (SPREP) Training Manual. Sponsored by Asian Development Bank. Prepared by Environment and Policy Institute, East-West Center, Honolulu, HI. 345 pp.

Dixon and Bojo, J. 1988.

Dixon, J.A., R.A. Carpenter, L.A. Fallon, P.B. Sherman, and S. Manipomoke. 1988. Economic Analysis of the Environmental Impacts of Development Projects. Earthscan Publications Ltd., London. 134 pp.

7.0 Social Assessment

Evaluation of the social implications of a project is tightly linked to the scrutiny of that project's social and economic objectives. Social assessments must go well beyond determining a project's adverse impacts. As a methodology, social assessment refers to a broad range of processes and procedures for incorporating social dimensions into development projects. In some jurisdictions and agencies, the social assessment is conducted in conjunction with the environmental impact assessment (EIA); in others, it is conducted separately. In both cases, the social assessment influences project design and the overall approval of the project.

Many of the methods and techniques discussed in this chapter have evolved in the context of international development assistance provided by bilateral agencies and the multilateral development banks. As such, they focus on people as beneficiaries. They also consider people as vulnerable groups that may be adversely affected by the project. Important distinctions are made between those who will benefit and those who may be harmed. The social assessment aims to determine the social costs of the project and the degree to which the benefits of a project will be distributed in an equitable manner. Social assessments are necessary to help ensure the project will accomplish its development goals (for example, poverty reduction; enhancement of the role of women in development; human resources development, including population planning; and avoiding or mitigating negative effects on vulnerable groups, and protecting these groups).

By addressing the specific development goals in the assessment of development projects, developers, lenders and governments can help ensure that project benefits are realized and negative social impacts are minimized. Various methods and approaches have been developed to consider social dimensions, including:

- social analysis;
- gender analysis;
- indigenous peoples plans;
- involuntary resettlement plans;
- cooperation with non-governmental organizations;
- use of participatory development processes; and
- benefits monitoring and evaluation.

7.1 Social Assessment and the Project Cycle

Chapter 1 illustrated the EIA inputs into the project cycle. As with environmental considerations, the need to analyze the social factors which influence (and are influenced by) a project continues throughout the entire life of a project. The major activities involved in incorporating social dimensions into the project are summarized in Table 7-1. The project preparation stage, in particular the preparation of the feasibility study, is the focus of many social assessment activities. It is thus imperative that those tasked with preparation of the feasibility study are given clear, focused terms of reference and specific guidance on how to carry out the necessary analyses to ensure social dimensions are adequately addressed.

Table 7-1: Social dimensions activities undertaken during the project cycle.

Project Stage	Activities Undertaken
Project Concept & Pre-feasibility	• identification of social dimensions and associated processes that may be important in the project • selection of key elements of social analysis • identification of initial potential social issues and impacts • initial Social Assessment
Feasibility Study	• social analysis • involuntary resettlement planning • indigenous peoples planning • gender analysis • poverty impact analysis • benefit monitoring and evaluation planning
Project Implementation	• arrangements for resettlement • information dissemination on role of beneficiaries • ongoing stakeholder consultation • strengthen beneficiary organizations • improving absorptive capacity of target groups • mitigating adverse effects on vulnerable groups
Monitoring	• monitoring of social indicators developed during the project design • review missions to assess social dimensions and associated processes • progress reporting by the executing agency (for example, beneficiary participation by number, gender, income group; participation by adversely affected groups; formation of beneficiary groups (numbers by gender and income class))

7.2 Conducting a Social Assessment

The basic steps for incorporating social dimensions into a project are (Asian Development Bank, 1994):

1. Social Analysis
   a) identifying the client population
   b) assessing needs
   c) assessing demand
   d) assessing absorptive capacity
   e) conducting gender analysis
   f) assessing adverse impacts on vulnerable groups
      - poverty impact assessment
      - indigenous peoples
      - involuntary resettlement;
2. Targeting;
3. Designing Participatory Development Processes;
4. Formulating Delivery Mechanisms; and
5. Benefit Monitoring and Evaluation.

7.2.1 Basic Steps

Social analyses are becoming a requirement of most assessments undertaken in developing countries. These analyses involve three principal steps: initial issue identification; preliminary assessment of all issues; and detailed social analysis of the potential for the major impacts. Initial issue identification may be carried out in an ad hoc or informal way, by seeking expert opinion, and by public involvement. The key to success is to incorporate a range of perspectives in the process. Since the widest range of social, economic, cultural, resource use and infrastructure effects occur at the local level, local people generally identify most potential effects and are key to the identification of issues. The success of a social analysis can be enhanced by taking the following measures:

- involve a qualified social impact specialist with a solid background in social sciences;
- incorporate some form of participatory development process;
- hire local experts;
- use local knowledge as well as scientific data; and
- use realistic assumptions for development practices such as construction practices rather than ideal or worst case.

Identifying Client Groups

Client groups are those groups that will either benefit or be adversely affected by the project. The first step in any social analysis is to gather baseline information on client groups. As not all project beneficiaries will have the same needs and demands, the population may have to be divided into sub-groups. A basic profile for each sub-group should be developed. This profile should include:

- the number in each sub-group,
- differentiation by gender,
- number of single-headed households,
- household size,
- occupations,
- income and asset levels,
- levels of education and access to education,
- health problems and access to health services,
- social organization and group formation, and
- ethnic or cultural distinctions.

This information should describe the socioeconomic traditions of the client group which affect life-styles, beliefs and patterns of use of facilities to be affected by the project. It is not always necessary to conduct detailed socioeconomic surveys to gather this information. In fact, current practice is usually to conduct participatory rural appraisals as part of the participatory development activities associated with the project (see section 7.2.3).

Client Needs

Once the baseline information on the client group has been identified, the social assessment team should assess the expressed need of client groups in relation to the benefits to be provided by the project. In assessing client needs, the social analysis team should:

- describe the quantity and quality of related facilities available to each of the sub-groups, including any problems of access, cost, quality, etc. and the level of service to be provided to each subgroup under the project;

- assess the priority given by the expected clients to acquiring the facilities to be established by the project in relation to their willingness to allocate their resources (for example, time, capital, effort) for the acquisition of such facilities — if the facilities are a priority, determine the clients' preference with respect to type, quality, and cost of project; and
- determine the potential to maximize the project's benefits through the addition of project components designed specifically to ensure benefits flow to affected people.

Client Demands

Once the client's needs have been identified, the social assessment team should:

- assess the client group's demand for the project, for example, by assessing present expenditures and efforts by clients to access such facilities through formal, informal, or traditional means;
- for each client group, assess the client's ability and willingness to pay for access to the project; and
- assess the project's potential to change the demand for the project (for example, through better client-provider relations).

The Nong Khai-Udon Thani Water Supply and Sanitation Project's (Thailand) assessment of clients needs and demands (Box 7-1) identified four client groups, and found that each one had different needs and demands for water.

Box 7-1: Assessing clients' needs and demands - Nong Khai-Udon Thani Water Supply and Sanitation Project (*source:* Pro-en Consultant and Management Co. Ltd., 1996).

During the course of the social assessment, the social assessment team identified four client groups: 1) piped water users, 2) non-piped water users owning their own land, 3) non-piped water users not owning their own land; 4) industries (factories and services industries). The groups were further sub-divided to those living in Nong Khai, Udon Thani and the Highway corridor. The social assessment was undertaken to examine the attributes of the potential beneficiaries. Each group was assessed as to its ability to access the project, their willingness to pay, and the positive and negative social impacts of the project.

The assessment determined that the ability of domestic users to benefit from the project would depend on whether they could connect to a piped water supply and whether they could afford to pay monthly water supply charges. Based on sample results, 90% of piped water users in Udon Thani, 70% of users in Highway corridor, and 50% of the users in Nong Khai were willing to pay for an improved system. Of those currently without piped water, 80% of Udon Thani potential users and 75% of Highway Corridor users would be willing to pay for a piped water supply. Sample data for Nong Khai was insufficient for analysis, but it is likely the percentage of users willing to pay is similar to that of the Highway Corridor.

Absorptive Capacity

Absorptive capacity is the capacity of the client group to reap the benefits from the project and/or adapt to the adverse impacts associated with the project.

The social analysis should:

- examine the variations in existing knowledge, attitudes, and practice which may influence the extent and manner in which the project may be used;
- describe the behavioral changes which may be required for clients to use and sustain the benefits which may be provided through the project; and
- assess their ability and willingness to make these changes in terms of their motivation to change, including aspirations, level of knowledge, skills and experience, social cohesion of the client groups, and constraints.

Many projects concerned with forestry enhancement and watershed rehabilitation have to be concerned with increasing the absorptive capacity of target beneficiaries (for example, see Box 7-2). Potential beneficiaries are often poor with low cash income, little education, and are in poor health. They are likely dependent on a natural resource base which has been degraded through unsustainable practices.

Box 7-2: Assessing absorptive capacity - forestry sector and watershed rehabilitation projects in Viet Nam.

Viet Nam is conducting a number of forestry sector and watershed rehabilitation projects, with the aid of foreign donor assistance. These projects are part of Viet Nam's strategy to address the problem of deforestation. Decline in forest cover has reduced the value of remaining timber stands, resulted in soil loss and loss of soil fertility, reduced biodiversity, and impaired the watershed hydrological functions, thereby threatening downstream water supplies and increasing risks associated with flooding. Past forestry practices and timber harvesting by state forest enterprises have been a major source of forest decline. In addition, deforestation and environmental degradation is continuing through practices of shifting cultivation and illegal logging. Increasing population pressures are such that lowland agricultural systems are unable to provide for all. This has forced movement and resettlement (aided by Government policy) of ethnic minorities and lowland immigrants into the upland watersheds. Unfortunately, the movement of people has not been accompanied with the introduction of economically viable agroforestry systems and appropriate land use practices. Most villagers are aware of the risks of natural resource degradation. Their unsustainable use of the forest stems from their poverty, scarcity of land and low agricultural productivity. Minority peoples clearly see the need for forest protection and they traditionally use the forest as a natural reservoir of resource in times of scarcity.

The immediate beneficiaries of the projects (people in the villages) wish to increase their standard of living through production of income generating crops. There are a number of critical factors needed to ensure that the benefits will flow to the people in the project areas. The first is the creation of security of land tenure. The projects will hasten the process of land allocation and the creation of rights for individual households to use forest land. In some communes, this process of allocation of forest land is well advanced. The second important factor is the availability of credit to allow for improvements to the land. This will allow the individual farmers to invest in new crops and other improvements to land. The third factor is the knowledge of cropping systems and farm economics to make effective use of the land and funds for investment. *Unfortunately, the knowledge of the project beneficiaries is very low. In fact, the education level is also very low - restricting the capacity of the beneficiaries to absorb new knowledge and take advantage of the project benefits. It is very important to transfer knowledge to farmers as early as possible in the project through improved extension services including training of extension workers, model farms, television, and other education and awareness programs.*

Gender Issues

The social analysis must include an examination of gender issues, including:

- an assessment of differences in values, roles, and needs of men and women in terms of the impact of these factors on decisions to use the project; and
- an assessment of the access of men and women to the project, and to related training and employment opportunities — including identification of constraints (for example, time, finances, transportation, literacy, health, social, cultural, legal or religious constraints) faced by women or men in gaining access to the project.

Gender analysis is discussed in more detail in section 7.3.3

Potential Adverse Impacts

The assessment of potential adverse impacts should include:

- identification of those groups which may be adversely affected by the project, including groups who may be required to relocate, or groups adversely affected by loss of income, loss of traditional lands and cultural property and possible exposure to health hazards (for example, noise or air pollution, traffic hazards, etc.);
- determination of the possibility of conflict over rights to key resources such as water;
- determination of how pricing policies would affect the distribution of and access to project benefits by poor clients, including an assessment of the ability of client groups who are defined as too poor to afford a basic level of service to access the project, and identification of financing measures which are affordable for the poor groups on a sustainable basis;
- determination of any significant changes in affected groups' life-styles;
- identify and assess options for avoiding, mitigating, or compensating groups which may be adversely affected; and
- consult with affected groups to obtain feedback through such means as community dialogues, public hearings, referendum, formation of multipartite negotiating, or monitoring teams concerning the proposed solution.

7.2.2 Targeting

To ensure benefits flow to the intended members of the client group, the following should be considered in the project design and implementation:

- determine whether there are groups of people who are not in the targeted client group but may wish to co-opt the project (for example, at Nam Pong in Thailand, the new reservoir attracted Vietnamese who moved in and became "middlemen" — Thai fishermen caught fish in the reservoir, but middlemen took the main profits);
- identify the possible methods, opportunities, or extent to which people in this group might co-opt these services;
- if the preceding analysis shows there is a likelihood that people who are not in the target group would be motivated and able to co-opt the project, then new targeting and monitoring mechanisms should ensure that the services are provided to the persons outside of the target group.

- if the project has potential for maximizing the access of poor people to a project (as a result of the goal of enhancing income-generating or income-enhancing opportunities), identify measures or processes which specify poverty reduction objectives; and
- if the project has potential for poor people to access the project, identify measures which would ensure that the poor will have maximum access.

7.2.3 Participatory Development Processes

"Through participation we lost control of the project and in doing so gained ownership and sustainability, precious things in our business" — World Bank Task Manager

Participation is a process through which stakeholders influence and share control over development initiatives and the decisions and resources that affect them (Asian Development Bank, 1996). Participatory development processes (World Bank, 1996):

- identify strengths and weaknesses of existing policies and service and support systems; that is, the stakeholders conduct the analysis and diagnosis collaboratively;
- decide and articulate what is needed; that is, the stakeholders jointly set objectives;
- decide in pragmatic terms, directions, priorities, and institutional responsibilities; that is the stakeholders jointly create a strategy; and
- develop and oversee development of project policies, specifications, blueprints, budgets, and technologies needed to move from the present to the future; that is, the stakeholders jointly formulate project tactics.

Participatory development processes may be used throughout the project cycle; they usually facilitate or complement the social and related analysis that must be done. There is no single approach or methodology that is to be followed. The World Bank Participation Sourcebook (World Bank, 1996) provides a number of case studies, provides an overview of the basic methodologies, outlines the basic practices, and provides guidance on how to conduct a participatory development process. Box 7-3 summarizes a case study of participatory development in India based on Forest Protection Committees composed of villagers who band together to care for the forest.

Box 7-3: Andhra Pradesh Forestry Project (World Bank, 1996).

Forest Protection Committees (FPC) are groups of local people who form themselves into one village-wide organization to negotiate with one voice with the Forest Department. Members of a FPC take on the duties of keeping the forest free from poachers and take on some forest husbandry responsibilities in exchange for legitimate access to harvesting timber and non-timber forest products. The Forest Protection Committee approach originated and has been successfully applied in West Bengal. Through this approach government foresters shift from a policing role to a social role that provides income to forest dwellers and regenerates the forest.

Introduction of the FPC approach into Andhra Pradesh began in 1991. As a part of the project preparation, a participatory planning workshop was held to bring various government stakeholders together to collaboratively identify institutional changes needed to support participatory forestry. During the workshop a stakeholder analysis was conducted. This identified up to sixty different groups, including villagers from adjoining forests, rural women, cattle owners, tribes, and the Forestry Department. A problem tree and corresponding objectives tree were collaboratively developed (see Figures 7-1 and 7-2). The objectives were converted into a corresponding set of actions (Table 7-2). A separate NGO workshop was held with the Forestry Department and broad range of NGOs.

The introduction of the FPCs met some resistance in the Forestry Department, but eventually it was accepted and became a core element in the Andhra Pradesh Forestry Project.

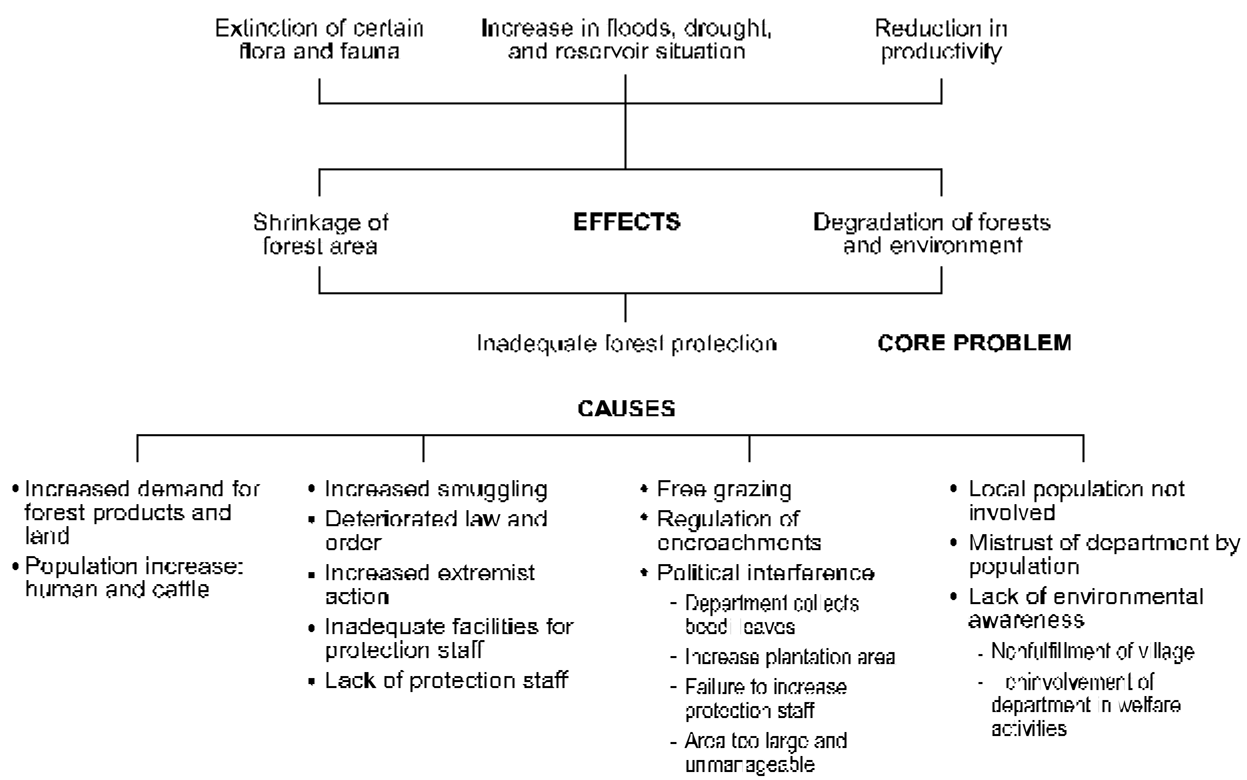


Figure 7-1: Problem tree for forest protection, Andhra Pradesh Forestry Project in India (*source:* World Bank, 1996).

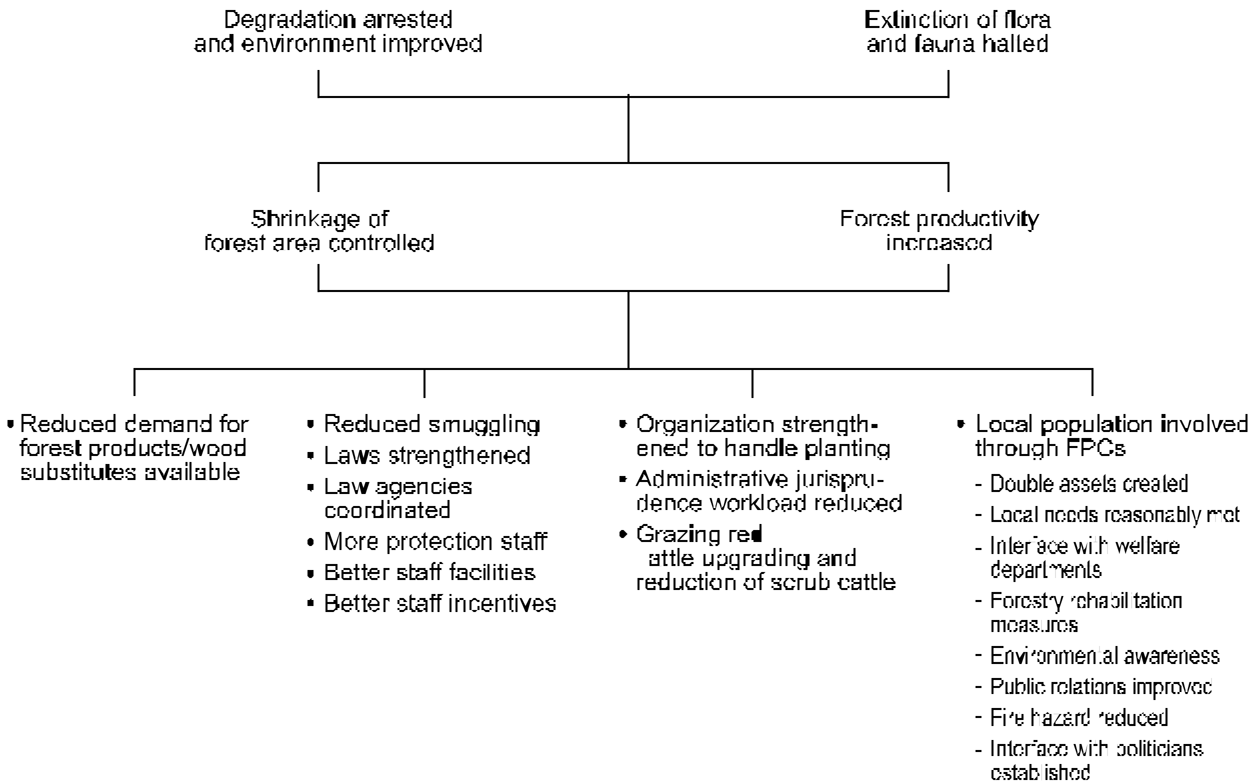


Figure 7-2: Objectives tree for forest protection, Andhra Pradesh Forestry Project in India (*source:* World Bank, 1996).

Table 7-2: Forest protection options arising from a participatory planning workshop, Andhra Pradesh Forestry Project in India (*source:* World Bank, 1996)**.**

Involvement of the Local Population in Forest Protection	• rehabilitation of headloaders (firewood poachers) in plantation activities • participatory management by the villagers • reforestation of encroached areas under the concept of FPC by actively involving the encroachers themselves • training of villagers and farmers in the development of protected forests
Meeting Local Needs Reasonably	• opening up local fuelwood depots, bamboo depots, and small timber depots • supply of bamboo to local artisan at subsidized rates • raising fodder plots in the forest adjoining the villages
Interface with Welfare Departments in Welfare Activities	• participation in the implementation of welfare in tribal areas

Cooperation with Non-Governmental Organizations

Non-governmental organizations (NGOs) possess knowledge and expertise they have developed from direct involvement, especially operational NGOs and NGOs working at the community level. Effective NGOs can help identify, understand and articulate the problems and needs of the beneficiary community. NGO input is especially important in addressing social concerns such as involuntary resettlement, indigenous peoples and women in development. NGO participation in projects can help strengthen accountability and transparency in project activities.

7.2.4 Delivery Mechanisms

An evaluation of the capacity of the executing agency to deliver the project should be made. This should include an assessment of:

- the ability of the executing agency to provide the project to the prospective clients in ways which are commensurate with the client's ability to use it — consider the agency's mandate and commitment of leaders, resources, management systems, procedures, experience of the agency with similar projects, and its attitudes towards participatory approaches;
- the approaches used by the organization for attaining the social goals of the project;
- training needs in social dimensions for those involved in project implementation;
- the major channels for spreading information for both literate and illiterate people, and through different local languages;
- any political constraints or tensions which may interrupt access to the project;
- the acceptability of project outreach staff to each client subgroup; and
- the need for NGOs to assist as intermediaries within the client subgroups, including definition of the roles which the NGOs may perform, and identification of criteria for selecting NGOs or other intermediaries who may be involved.

7.2.5 Benefit Monitoring and Evaluation

Benefits monitoring should be incorporated in the environmental monitoring plan. The benefits monitoring plan should:

- identify a few indicators of the achievement of the project output(s), purpose(s), and goal(s) for each component;
- assess existing management information systems in terms of their adequacy in guiding the operation of the project for maximum effect;
- specify indicators to monitor and evaluate the delivery and distribution of benefits to the client groups identified, and to identify adjustments required during implementation to meet the needs of client groups more effectively; and
- specify indicators to monitor and evaluate project operation and maintenance.

7.3 Vulnerable Groups

7.3.1 Involuntary Resettlement Planning

In developing countries, the scale of development-related population displacement has grown rapidly in the past few decades due to the accelerated provision of infrastructure and growing population densities. The displacement toll of the 300 large dams that, on average, enter into construction every year is estimated to be above four million people. The urban development and transportation programs being started each year in developing countries are estimated to displace some additional six million people. Over the past decade, it is estimated that about 80-90 million people have been resettled as a result of infrastructure programs for dam construction, urban development and transportation development (World Bank, 1994).

The costs of inadequate resettlement can be very high, resulting in increased poverty for large numbers of people. This is especially serious since many of those affected are already very poor. They tend to live in disadvantaged areas where infrastructure is lacking and social services are very limited. The remote locations of many dam sites are often inhabited by indigenous people, ethnic minorities or pastoral groups. This heightens the need for sound policies and effective implementation.

Impacts

Involuntary resettlement consists of two closely related yet distinct processes: displacing people and rebuilding their livelihood. These processes are among the most difficult in development work. The complexity of involuntary resettlement and the enormous diversity of project situations make achieving good resettlement a formidable task. Recognizing the intrinsic difficulty of resettlement is the prime step for addressing this task seriously.

When people are displaced, production systems may be dismantled, kinship groups are scattered, and long-established residential settlements are disorganized. People's lives are affected in very painful ways. Many jobs and assets are lost. Health care tends to deteriorate. Links between producers and their customers are often severed, and local labor markets are disrupted. Informal social networks that are part of daily sustenance systems — providing mutual help in child care, food security, revenue transfers, short-term credit, labor exchanges, and other basic sources of socio-economic support — are dissolved. Local organizations and formal and informal associations disappear because of the dispersion of their members. Traditional community and authority systems can lose their leaders. Symbolic markers, such as ancestral shrines and graves, are abandoned, breaking links with the past and with peoples' cultural identities.

The cumulative effects can tear apart the social fabric and local economy, and is profoundly disruptive to large numbers of people. The main risk is impoverishment — through landlessness, joblessness, food insecurity, deteriorating health, or the loss of access to community assets. This is why carrying out resettlement adequately is an impoverishment prevention and poverty reduction task. Mitigation measures must be adopted to ensure that project-induced displacement and resettlement do not make people worse off.

Moving people involuntarily also raises legal issues. The potential for violating people's individual and group rights makes compulsory relocation unlike any other project activity. The fact that projects frequently are delayed by courts, and that compensation levels are often raised significantly on appeal, reflects the recognition in legal systems that people cannot be arbitrarily displaced without just compensation, regardless of national need. When resettlement processes are carried out in a lawful manner that fully respects people's rights, opposition to projects by adversely affected people is reduced (although not eliminated) and overall project implementation is likely to unfold more effectively. Resettlement that reflects the needs and rights of affected persons is not just compliance with the law, but also constitutes sound development practice.

A Framework for a Resettlement Action Plan

A plan of action, or a resettlement action plan (RAP), is necessary to re-establish the social and economic productivity of the displaced communities. The basic framework for RAPs is well described in Asian Development Bank (1997). A well crafted plan (see Table 7-3) will have:

- a statement of objectives and an overview of the national and donor policy context;
- a description of the project design and scope of resettlement which includes a description of efforts to minimize resettlement;
- a special analysis of how the project will affect vulnerable groups;
- basic information on the impact of land acquisition and losses to potentially affected persons (PAPs) and a clear definition of eligibility and entitlement considerations;
- a description of resettlement site development and income restoration programs;
- the institutional framework for resettlement implementation, including the mandate and staffing for a resettlement agency, needs for capacity building and training, and roles of NGOs and PAPs in resettlement activities;
- a description of the participatory development approach to consultation and community involvement;
- a budget, including land acquisition and resettlement costs, allocation and timing, and funding sources and approvals; and
- the monitoring and evaluation system, including monitoring indicators, reporting system, monitoring program participants and impact evaluation.

Resettlement action plans are often focused on the issues associated with land ownership and identification of who is entitled to compensation as a result of the project. The Kali Gandaki "A" Hydroelectric Detailed Design Study - Acquisition, Compensation and Rehabilitation Program provides a good example of the compensation for land acquisition. This project also has a good rehabilitation and resettlement plan that will strengthen capacity and offer special assistance to women and other vulnerable groups. It provides for:

- rehabilitation grants for housing rental allowance, travel to district headquarters, land registration fees, and compensation for fruit trees and standing crop;
- creation of a micro-enterprise revolving fund ($50,000 US);
- creation of preferential hiring;
- training opportunities for women and other disadvantaged groups; and
- other measures including tree planting, regional forester and watershed stabilization specialist, assistance in improving agricultural production, construction and operation of a fish hatchery, rural electrification, and community forests.

Table 7-3: Resettlement Action Plan Outline (*source:* Asian Development Bank, 1997).

I. Objectives of Resettlement and Policy Framework
- describe the purpose and objectives of resettlement
- national and local land and compensation laws that apply to the project
- description of donor policies and how these will be achieved under the project
- statement of principles and legal/policy commitments from the borrower/executing agency

II. Project Design and Scope of Resettlement
- detailed description, including maps, of the scope of resettlement and how resettlement relates to the main investment project
- describe alternative options, if any , considered to minimize resettlement
- details of special consideration given to how the project will impact indigenous people and other vulnerable groups, including women
- responsibility for resettlement planning and implementation

III. Socio-economic Information and Entitlements
- impact of land acquisition on potential affected peoples
- identify all losses to resettlers and host communities
- details of common property resources
- cut-off dates of eligibility
- new eligibility of policy and Entitlement Matrix

IV. Resettlement Site Development and Income Restoration
- location, quality of site, and development needs
- layout, design and social infrastructure
- safeguarding income and livelihoods
- income restoration programs
- gender issues and other vulnerable groups
- integration with host communities

V. Institutional Framework for Resettlement Implementation
- mandate of resettlement agency
- establishing a resettlement unit and staffing
- technical assistance for capacity building
- role of NGOs and PAPs organizations in resettlement
- grievance redress committees

VI. Consultation and Community Participation
- identification of project stakeholders
- mechanisms for participation
- participatory resettlement management
- institutions in participation
- NGOs as a vehicle for participation

VII. Resettlement Budget and Financing
- land acquisition and resettlement costs
- budgetary allocation and timing
- sources of funding and approval process

VIII. Monitoring and Evaluation
- establishing a monitoring and evaluation system
- monitoring and reporting
- NGO/PAPs participation in monitoring and evaluation
- resettlement impact evaluation

Box 7-4: Kali Gandaki "A" Hydroelectric Detailed Design Study - Acquisition, Compensation and Rehabilitation Program.

The project includes a dam and reservoir site, a power plant site and the transmission line alignments and access road. Two separate acquisition, compensation, and rehabilitation programs (ACRP) were developed; one for the access road and one for the facilities. The Access Road ACRP implemented compensation for PAPs: a total of 333 people were compensated, of which 84 were considered to be seriously affected (SPAP). The Facilities ACRP identified 284 PAPs, of which 65 are deemed SPAPs.

Land Take and Affected Persons for the Facilities ACRP

Site	Temporary & Permanent Land Take (ha)	SPAPs	PAPs	Total PAPs
Dam & Reservoir	89.62	14	133	147
Power Plant	36.95	9	86	95
Transmission Line	1.75	42		42
TOTAL	128.32	65	219	284

The Facilities ACRP has an estimated total cost of 12,156,400 Nepalese Rupees (NRs) for land acquisition and NRs 7,908,850 for other compensated impacts (that is, structures, infrastructure and relocation) to compensate people for project related losses.

Visits to the project areas by non-project personnel in September, 1995 and comments from residents at the Public Consultation meeting held in February, 1996 suggest that residents of local communities who received compensation through the Access Road ACRP were generally satisfied with the process and the compensation. Residents are in support of the Project. Their primary concerns, which the implementation of the Facilities ACRP should be careful to address, are compensation of Guthi (trust) land, fair and equitable compensation rates, job training for local residents, support programs for PAPs and SPAPs, and methods for encouraging local participation.

Phases of the ACRP

Study Phase

- analysis of cadastral survey that required identification of land parcels, establishment of land ownership and types of land
- check of PAPs names for the records of the District

Survey

- survey of conducted of PAP households
- survey of fodder and fruit trees, affected houses and cowsheds
- assessment of the number of PAPs and SPAPs
- valuation of land and other assets
- proposal prepared for compensation rate, its structure and a payment schedule

Implementation Phase

- preparation of a primary investigation report to be submitted to Government
- publishing of PAPs' names in the National Newspaper with the parcel number and areas to be acquired
- preparation of the compensation recommendations
- meetings held with the Compensation Fixation Committee
- make offers of compensation
- make decision regarding the ACRP implementation including the complaints of PAPs

This project has a "good practice" rehabilitation and resettlement plan providing for: rehabilitation grants for housing rental allowance, travel to district headquarters, land registration fees, compensation for fruit trees and standing crop; creation of a micro-enterprise revolving fund (US$ 50,000); creation of preferential hiring; training opportunities for women and other disadvantaged groups; other measures including tree planting, regional forester and watershed stabilization specialist, help in improving agricultural production, construction and operation of a fish hatchery, rural electrification, community forests.

7.3.2 Indigenous Peoples Planning

Indigenous peoples are amongst the most vulnerable of all groups. They are often disadvantaged in many ways, including through poverty, low levels of education, poor access to medical care, and isolation from the mainstream economy. Indigenous peoples may have distinct languages, cultural behaviors and mistrust of outsiders. They need to treated differently than other target groups — in many cases, a separate indigenous peoples plan should be prepared.

The key elements in the preparation of an indigenous peoples plan are:

- consideration during project design of the needs and wishes of indigenous peoples, local patterns of social organization, cultural belief, ancestral domain, and traditional land and resource use;
- studies to identify potential adverse effects on indigenous peoples and identification of measures to mitigate these effects;
- measures to strengthen the capacity of social, legal, and technical skills of staff in those government institutions mandated to care for indigenous peoples;
- involvement of existing institutions (local organizations and NGOs) with experience in working with indigenous peoples;
- support for agricultural and agri-forestry systems that are well adapted to needs, environments, and capability of indigenous peoples; and
- promotion of self-reliance and avoidance to increasing the dependency of indigenous peoples on the project.

The Cordillera Highland Agricultural Resource Management Project (Asian Development Bank, 1995) prepared an indigenous cultural communities development strategy to ensure that five ethno-linguistic groups in the project area will receive culturally compatible social and economic benefits (see Box 7-5).

Box 7-5: Indigenous Peoples Plan for the Philippines Cordillera Highland Agricultural Resource Management Project (Asian Development Bank, 1995).

The activities included in the plan are:

Community Mobilization
Socioeconomic profiles of the *barangays* will be undertaken to assist targeting project beneficiaries. Beneficiaries will be trained in participatory planning. Barangay needs and priorities will be assessed. A natural resource management plan will be prepared, and the community will assist in project implementation and monitoring.

Natural Resource Management Including Reforestation
Environmental awareness training will be provided and will form the basis for implementation of community based reforestation, forest management, forest protection, and land-use planning. The project aims to generate employment for the poor, who will be responsible for planting and maintaining reforested areas. Traditional methods of preventing erosion and sustainable land management will be encouraged.

Strengthening of the Institutions Responsible for the Issuance of Land Tenure Security
The ancestral and land tenure programs of the Department of Natural Resources (DENR) and Department of Agrarian Reform (DAR) will be made more accessible to indigenous people. DENR, DAR, and local government units (LGUs) will be trained. They will work closely with indigenous communities to implement an information dissemination campaign on ancestral domain and land claim options. In addition to the capacity building in DENR and DAR it is estimated that Certificates of Ancestral Domain Claim will be issued for approximately 150,000 ha with subsequent specific tenurial instruments such as Certificates of Ancestral Land Claim being granted for 480 ha and Certificates for Land Ownership Award being granted for 26,450 ha.

Rural Infrastructure Development
This component consists of rehabilitation of farm-to-market roads, domestic water supply, and community irrigation systems. These are priority needs that the communities identified and must be addressed to enhance the socioeconomic well being of the communities.

Provision of Support Services for Agricultural Development
These services, consisting of agribusiness, extension, adaptive research, and rural financial services, are aimed at assisting farmers to develop new market outlets, adopt improved technologies, and seek new investment options. Savings groups will be formed among the poorer segment of communities to enable them to access formal credit sources to finance priority needs and begin income generating activities.

Gender Specific Activities
Women's roles in the communities will be enhanced to further develop their potential by ensuring equitable access to and control over project resources. Specific activities directed at women include training and organization of women by the community mobilization officer, valued added processing by women, and access to financing for small scale livelihood activities. The project will also incorporate gender sensitive reporting, gender sensitive training for staff, and inclusion of women's issues and concerns in the Barangay natural resource management plans.

7.3.3 Gender Analysis

The term "gender" refers to the social facets of culture, religion, and class which condition the way in which masculine and feminine roles and status are constructed and defined in each society. Gender relations are dynamic and changing over time in response to varying socioeconomic conditions and ideological circumstances. As gender (the social differentiation between women and men) is socially and culturally constructed, gender roles can be transformed by social changes (Moser, 1993)

Failure to recognize the importance of gender in international assistance to developing countries has often resulted in men being the major beneficiaries of the development projects. Women often gained very little benefit and, in some cases, conditions for them worsened. In almost all developing countries, women are in a much lower position than men, especially in power relations — this can usually be attributed to culture (especially religion) and traditions. Although women must fulfil many duties, both at home and in the community, they rarely have the right to decide or to take part in decision making processes or contribute to solving problems that directly affect them. This not only disadvantages women, it also reduces development efficiency because it does not fully utilize the knowledge and capacity of women. The elimination of inequality between men and women through the process of *gender and development* aims at integrating women more fully into the development process as participants as well as beneficiaries (Hoa, 1996).

The basic rationale for gender analysis in project planning is:

- women and men have different economic capacities and some work done by women (for example, housework) is not easily quantified, although this work will be costly to replace;
- women tend to have less control than men over resources;
- women play a multitude of social and economic roles and may have limited time available to participate in the project or partake of the project benefits; and
- acceptable social behavior in some cultures may limit women's ability to participate effectively and take part in decision-making.

Gender responsiveness in project planning is tightly linked to participatory development processes and targeting women and men as separate groups. Gender considerations can be incorporated into project planning and design by ensuring that (Connor, 1996):

- gender dis-aggregated data is collected and analyzed;
- consultations include women and, depending on the cultural context, these consultations may have women facilitators consulting with women, separate from men;
- participatory development processes are directed at creating socially acceptable ways for women to become an integral part of decision making;
- strategies of participation in the projects, and management of project impacts is targeted on both men and women; and
- monitoring and evaluation programs should include specific indicators relating to women and include women in the collection and interpretation of monitoring data.

Box 7-6: Promoting participation of women in the Bangladesh Forestry Sector Project (Asian Development Bank, 1996)

In Bangladesh, the continued pressure on forest land for conversion into agricultural lands, for timber and fuelwood, and non timber forest produce has led to drastic reductions of forest areas in the country. The Bangladesh Forestry Sector Master Plan (FSMP) states that "women and poor people who do not have land based sources of livelihood will be employed on priority basis in nurseries, plantation, forest management, harvesting, and industrial work." Women's participation in public programs has traditionally remained limited by social norms and religious practices.

Key Issues for Women's Participation in Forestry

- species preference and requirements of non-timber forest produce need to be fully taken into account in forestry planning;
- poor women are important stakeholders in the protection and maintenance of common property forest resources because they depend on them for subsistence;
- women's work schedules and availability must be taken into account when planning forestry activities to ensure that they can be easily involved;
- access to land and land rights is crucial for women. Women need to be given opportunities to access khas lands for afforestation;
- rural poor women have proven more creditworthy than their male counterparts. Ensuing access to institutional credit for planting and land improvement may bring high returns and increases household incomes;
- training programs for women are needed to increase their skills and knowledge of silvicultural practices; and
- women need access to high quality seed and seedlings.

Project Activities for Women

The Bangladesh Forestry Sector Project will provide equal opportunities for women to participate in a culturally compatible manner, with access to project outputs through:

- the provision of single or joint rights to use forest land and other land being brought under Project activities;
- specific rights-to-use for women of matrilineal ethnic minorities participating in Project activities;
- specific targeting of female-headed households and other disadvantaged women;
- expanded opportunities of women to participate in community decision making, planning, and management of Project activities through their membership of local community organizations; and
- training of women in group formation and in improved nursery and plantation techniques.

This project also includes an Ethnic Minorities Development Plan which uses participatory processes to facilitate full and equitable participation of ethnic minorities with respect for dignity, human rights, and cultural uniqueness. The objectives of the Plan are to ensure that ethnic minorities receive culturally compatible benefits and to avoid adverse effects.

7.3.4 Human Health Impacts Analysis

Health impact assessment procedures have evolved independently in several development sectors, including irrigated agriculture, multipurpose reservoirs, water supply and chemical manufacture. The methods and procedures used and the problems encountered share many similarities. Examples of potential health impacts associated with irrigation, industry, fisheries and aquaculture, watershed development, forestry, land clearing and rehabilitation, dams and reservoirs, coastal zone development, thermal power, mining and mineral processing, electricity oil and gas distribution lines, airports, highways and roads, ports and harbors, and urban development are provided in Appendix I. (Asian Development Bank, 1992).

In the water supply and sanitation sector, the World Health Organization (WHO) has published procedures for analyzing non-functioning or under-utilized systems and for evaluating the positive health impacts of fully functioning systems (WHO, 1983a,b). In this sector, health impacts generally refer to the intended health improvements which are assumed to derive from safe water supply and sanitation. Sanitary engineers are quite well versed on health hazards of all types.

Vector Borne Diseases

One important group of health risks, vector-borne diseases, has received considerable attention in development sectors associated with water resources, such as irrigation and reservoirs. There have been many reviews (Oomen et al., 1988, Service, 1989). Such developments change the distribution and flow of surface waters, creating a favorable habitat for vector breeding. Human exposure to biting insects or contaminated waters provides the conditions necessary for an increased health risk. Expensive mitigation measures take the form of vector control through chemical application of environmental modification.

An important component of environmental management occurs at the design stage. Decisions about infrastructure, location and resettlement could help reduce vector populations or prevent exposure. This, in turn, requires a health impact assessment procedure. One such procedure was published as *Guidelines for Forecasting the Vector-borne Disease Implications of Water Resources Development* (Birley, 1991). It covers the sub-sectors of irrigated agriculture and multipurpose reservoirs, and assists the user to identify:

- the specific vector-borne disease hazards which occur regionally and in different habitats;
- the vulnerable communities; and
- the capabilities of the health service to monitor, safeguard, and mitigate.

These three components of the assessment were then combined into a statement of health risk.

A recent report advocated rapid assessment for identifying environmental and health hazards in irrigation schemes. A set of vector-borne disease hazards were identified and a simple questionnaire was devised to determine whether the adverse effects (health risks) appeared sufficiently serious to warrant the project manager seeking specialist advice (Bolton et al., 1990). Although the distinction between health hazard and health risk is well established in the chemical sector, it has not been in common use elsewhere.

Box 7-7: An example of vector borne disease hazards (*source:* Macdonald, 1991 in Asian Development Bank, 1992)

The linkage between housing and health is widely recognized but hard to evaluate. The City Corporation of Yangon (Rangoon) built low-cost satellite towns on reclaimed swampy land to accommodate large numbers of squatters. Although protected from flooding by bunds and sluice gates, the ground became waterlogged during the rains. The surface drains were inadequate, mosquitoes bred heavily, and *bancroftian filariasis* transmission was soon established. Multi-storied blocks of flats were also constructed with good internal plumbing but not connected to the city sewage system. Pools of polluted waste water were formed and mosquitoes proliferated.

In the chemical industry sector there are procedures for determining modes of failure and the associated health hazards. There are two main issues: poisoning by routine or accidental exposure to toxic chemicals; and traumatic injury from fire, explosion, radiation, or corrosive action.

Over 60,000 chemicals are in common use and adequate information about toxicity and reactivity is not available for all of them. A meeting in 1986 established principles and objectives for health and safety assessments (WHO, 1987). Health impact assessment was viewed as a component of EIA. The three main tasks of health impact assessment were listed as: identification of hazard, interpretation of health risk, and risk management.

7.4 References and Further Reading

Asian Development Bank. 1997. Handbook on Resettlement - A Guide to Good Practice. Second Draft. Office of Environment and Social Development, Asian Development Bank. Manila, Philippines. 84 pp.

Asian Development Bank. 1996. Mainstreaming Participatory Development Processes. Office of Environment and Social Development, Asian Development Bank. Manila, Philippines. 19 pp.

Asian Development Bank. 1995. Report and Recommendation of the President to the Board of Directors on a Proposed Loan to the Republic of Philippines for the Cordillera Highland Agricultural Resource Management Project.

Asian Development Bank. 1994. Handbook for Incorporation of Social Dimensions in Projects. Social Dimensions Unit, Asian Development Bank. Manila, Philippines. 105 pp.

Asian Development Bank. 1993. Guidelines for Social Analysis of Development Projects. Asian Development Bank, Manila, Philippines.

Asian Development Bank. 1992. Guidelines for Health Impact Assessment of Development Projects. Office of the Environment, Asian Development Bank. Manila, Philippines.

Asian Development Bank. 1991a. Guidelines for Incorporation of Social Dimensions in Bank Operations. Draft. Asian Development Bank, Manila, Philippines.

Asian Development Bank. 1991b. Guidelines for Social Analysis of Development Projects. Asian Development Bank, Manila, Philippines.

Asian Development Bank. 1991c. Environmental Planning and Management and the Project Cycle. Environment Paper No. 1. Asian Development Bank. Manila, Philippines.

Asian Development Bank. 1986. Economic Analysis of the Environmental Impacts of Development Projects. Asian Development Bank, Manila, Philippines.

Birley, M.H. 1991. Guidelines for Forecasting the Vector-Borne Disease Implications of Water Resources Development (2nd edition). World Health Organisation, Geneva, Switzerland

Bolton, D., A.M.A. Imevbore, and P. Fraval. 1990. A Rapid Assessment Procedure for Identifying Environmental and Health Hazards in Irrigation Schemes. (OD 120). Hydraulics Research, Wallingford.

Branch, K., D. Hooper, J. Thompson, and J. Creighton. 1984. Guide to Social Assessment: A Framework for Assessing Social Change. Westview Press, Boulder, CO.

Briones, N. and W. Lagunilla. 1992. Socioeconomic Analysis of the Environmental Impacts of the Antamok Gold Project's Open-Pit Mining in Benguet, Philippines. Environmental and Resource Management Project. Philippines.

Burdge, R.J. 1994. A Community Guide to Social Impact Assessment. Social Ecology Press, Middleton, WI.

Burdge, R.J. and R.A. Robertson. Social impact assessment and the public involvement process. Environ. Impact Assess. Rev. 10: 81-90.

Canter, L.W. 1977. Environmental Impact Assessment. McGraw-Hill, New York, NY.

Canter, L.W. 1995. Environmental Impact Assessment. McGraw-Hill, New York, NY.

Carley, M.J. and E.S. Bustelo. 1984. Social Impact Assessment and Monitoring: A Guide to the Literature. Westview Press, Boulder, CO.

Cernea, M.M. 1988. Involuntary Resettlement in Development Projects. Policy Guidelines in World Bank-Financed Projects. World Bank Tech. Pap. No. 80. World Bank, Washington, DC.

Connor, Kerry M. Connor. 1996. Public Participation in the EIA Process: Theory and Process (Draft). Annex 5 in Interim Report submitted to Asia Development Bank on T.A. 2351-THA Strengthening the Environmental Impact Assessment Process in Thailand by Seatec International, Bangkok Thailand, September 1996.

Craig, D. 1990. Social impact assessment: politically oriented approaches and applications. Environ. Impact Assess. Rev. 10: 37-54.

D'More, L.J. 1978. An overview of SIA. In: F.S. Tester and W. Mykes (eds.). Social Impact Assessment: Theory, Method and Practice. Detselig, Calgary, AB. pp. 366-373.

Derman, W. and S. Whiteford (eds.). 1985. Social Impact Analysis and Development Planning in the Third World. Westview Press. Boulder, CO.

Dietz, T. and C.M. Dunning. 1983. Demographic change assessment. In: K. Finsterbusch, L.G. Llewellyn and C.P. Wolf (eds.). Social Impact Assessment Methods. Sage Publications, Beverly Hills, CA. pp. 127-150.

Finsterbusch, K. 1976. Methodology for Social Impact Assessment of Highway Locations. Maryland State Highway Administration, Brookland, MD. pp. 10-13.

Finsterbusch, K. and C.P. Wolf. 1977. Methodology of Social Impact Assessment. Community Development Series, Vol. 32. Dowden, Hutchinson and Ross, Stroudsburg, PA.

Finsterbusch, K., L.G. Llewellyn, and C.P. Wolf (eds.). 1983. Social Impact Assessment Methods. Sage Publications, Beverly Hills, CA.

Freudenberg, W.R. 1986. Social impact assessment. Annu. Rev. Sociol. 12: 451-478.

Gagnon, C., P. Hirsch, and R. Howitt. 1993. Can SIA empower communities? Environ. Impact Assess. Rev. 13: 229-253.

Grossman, W.D. 1994. Socio-economic ecological models: criteria for evaluation of state-of-the-art models shown on four case studies. Ecol. Model. 75/76: 21-36.

Halstead, J.M., R.A. Chase, S.H. Murdock, and F.L. Leistritz. 1984. Socioeconomic Impact Management: Design and Implementation. Westview Press, Boulder, Colorado.

Hindmarsh, R.A., T.J. Hundloe, G.T. McDonald, and R.E. Rickson (eds). 1988. Papers on Assessing the Social Impacts of Development. Institute of Applied Environmental Research, Griffith University, Brisbane.

Hoa, Pham Thi Mong. 1996. Gender and Development. Invited paper at Environmental Management Seminar - Viet Nam Canada Environmental Project. Hanoi, Viet Nam.

Interorganizational Committee on Guidelines and Principles for Social Impact Assessment. 1995. Guidelines and principles for social impact assessment. Environ. Impact Assess. Rev. 15: 11-43.

Jalal, K.F. 1993. Sustainable Development, Environment and Poverty Nexus. Occas. Pap. No. y. Economics and Development Resource Centre, Asian Development Bank, Manila, Philippines. 24 pp.

Kim, S.H. and J.A. Dixon. 1986. Economic valuation of environmental quality aspects of upland agricultural projects in Korea. In: J.A. Dixon and M.M. Hufschmidt (eds.). Economic Valuation Techniques for the Environment: A Case Study Workbook. Johns Hopkins University Press, Baltimore, MD.

Krawetz, N.M. 1991. Social Impact Assessment: An Introductory Handbook. Dalhousie University, Halifax, NS.

Leistritz, F.L. and S.H. Murdock. 1981. Socioeconomic Impact of Resource Development: Methods for Assessment. Westview Press, Boulder, CO.

Liestritz, F.L., B.L. Ekstrom, R.A. Chase, R. Bisset, and J.M. Halstead. 1986. Social Impact Assessment and Management: An Annotated Bibliography. Garland Publishing, New York, NY.

Liestritz, F.L., R.C. Coon, and R.R. Hamm. 1994. A microcomputer model for assessing socioeconomic impacts of development projects. Impact Assess. 12(4) 373-384.

McDonald, G.T. 1990. Regional economic and social impact assessment. Environ. Impact Assess. Rev. 10: 25-36.

Macdonald. 1991.

Moser, Caroline O.N.. 1993. Gender Planning and Development: Theory, Practice and Training. London: Routledge.

Murdock, S.H. and F.L. Leistritz. 1980. Selecting socioeconomic assessment models: a discussion of criteria and selected models. J. Environ. Manage. 10: 241-252.

Murdock, S.H. and F.L. Leistritz. 1983. Computerized socio-economic assessment models. In: K. Finsterbusch, L.G. Llewellyn and C.P. Wolf (eds.). Social Impact Assessment Methods. Sage Publications, Beverley Hills, CA.

Oomen et al. 1988.

Pro-en Consultant and Management Co. Ltd. and Team Consulting Engineers Co. Ltd. 1996. Nong Khai - Udon Thani Supply and Sanitation Project - T.A. No. 2292 -THA Feasibility Study. Producted for Asian Development Bank. Manila, Philippines.

Ross, H. 1990. Community social impact assessment: a framework for indigenous peoples. Environ. Impact Assess. Rev. 10: 185-193.

Service. 1989.

Westman, W.E. 1985. Ecology, Impact Assessment and Environmental Planning. John Wiley & Sons, Toronto, ON.

WHO. 1983a. Maximising Benefits to Health: An Appraisal Methodology for Water Supply and Sanitation Projects (ETS/83.7). World Health Organisation.

WHO. 1983b. Minimum Evaluation Procedure (MEP) for Water Supply and Sanitation Projects (ETS/83.1, CDD/OPR/83.1) World Health Organisation.

WHO. 1987. Health and Safety Component of Environmental Impact Assessment (15). World Health Organisation.

Wildman, P.H. and G.B. Baker. 1985. The Social Impact Assessment Handbook: How to Assess and Evaluate the Social Impact of Resource Development of Local Communities. Australian Social Impact Publications, Sydney.

World Bank. 1994. Resettlement and Development: The Bankwide Review of Projects Involving Resettlement 1986-1993. Environment Department. Washington, DC.

World Bank. 1996. World Bank Participation Sourcebook. Environment Department. Washington, DC.

8.0 Application of Expert Systems

The various methods, approaches and techniques presented in chapters three to seven for identifying, measuring, and assessing impacts all have two aspects in common. First, they are designed to deal with the considerable amount of information that must be processed and analyzed as a part of an environmental impact assessment (EIA). Second, they rely on expert judgement.

The challenge of collecting, processing, analyzing, and reporting information can be partially met by use of various computer and information technologies. The use of predictive computer models (Chapter 4) is becoming more prevalent. The use of geographic information systems (GIS) (Chapter 3) for handling spatial data is also becoming more frequent where there are adequate personnel skills and financial resources to acquire the necessary data. In most cases, however, environmental problem solving is conceptual and cannot always be reduced to quantitative analysis (that is, modeling). Often, available information is incomplete, subjective, and inconsistent.

Experts are heavily involved in all aspects of the assessment. Many checklists, matrices, and models used in EIA are accumulations of the experience of many experts gathered over many years. Experts are used to help identify the potential for significant impacts, plan data collection and monitoring programs, provide judgement on the level of significance for specific impacts, and suggest ways of reducing or preventing impacts. The discussion, in Chapter 2, of constraints on implementing EIA processes in developing countries concluded there is a critical lack of environmental scientific expertise to help government, industry, and development banks apply existing knowledge to meet the EIA requirements. When there are a large number of projects to consider, contracting outside experts for each one is not always practical, and EIAs may be undertaken by those lacking either sufficient training or time to make sound decisions.

Expert systems are promising technologies that manage information demands and provide required expertise. They thus seem well suited to many of the tasks associated with EIA. Additional advantages of using expert systems for EIA are:

1. expert systems help users cope with large volumes of EIA work;
2. expert systems deliver EIA expertise to the non-expert;
3. expert systems enhance user accountability for decisions reached; and
4. expert systems provide a structured approach to EIA.

Because the application of expert system technology to EIA is relatively new, one might consider the technology as “too” advanced and not appropriate for developing countries. This is not true, and expert systems are slowly being disseminated throughout developing countries in Asia and the Pacific.

Before discussing the current application of expert systems in developing Asia and the Pacific, it is necessary to better describe the technology itself and discuss its present and potential application to EIA.

8.1 Terminology

Developers of expert systems strive to provide systems with the ability to:

1. mimic the reasoning capability of human experts;
2. deal with incomplete and imprecise knowledge;

3. explain and provide a rationale for conclusions;
4. provide alternate options for consideration;
5. provide wider distribution and access to scarce expert knowledge; and
6. provide systematic and consistent application of knowledge.

Reasons for developing and implementing expert systems vary, but are most often characterized by one or more of the following:

1. human expertise is lost due to retirement, transfer, etc.;
2. average practitioners perform inconsistently;
3. tasks are not repetitive (algorithmic), but require extensive thought each time; and
4. human experts are scarce, and a *knowledge bottleneck* exists.

Expert systems technologies have bewildered many outsiders (such as engineers and technical specialists who do not specialize in artificial intelligence). This is, in part, because of the use of complex terminology and unclear definitions. To establish a common base of understanding, some definitions are suggested here (Finn, 1989):

Artificial Intelligence: The sub-field of computer science concerned with understanding the concepts and methods of human reasoning, and the application of this understanding to the development of computer programs that exhibit intelligent behavior.

Expert System: A computer program that performs difficult, specialized tasks at the level of a human expert. Because of the reliance of these programs on varied types of knowledge, these programs are also known as Knowledge-Based Systems.

Heuristic Knowledge: Judgmental knowledge underlying expertise — often consisting of *rules-of-thumb* acquired through personal experience. This heuristic knowledge is usually implicit, not necessarily being explicit even to the expert.

Domain Knowledge: The term *domain* refers to the specific area of application, such as pump failure diagnosis, or chemical analysis. Domain knowledge is that knowledge which is specific to the domain, rather than general knowledge, or common sense knowledge.

Knowledge Base: That part of the program in which the knowledge is stored, using some method of representation, such as rules.

Inference Mechanism: Also known as the "Inference Engine," this controls the reasoning operations of the expert system. This is the part of the program that deals with making assertions, hypotheses, and conclusions. It is through the inference mechanism that the reasoning strategy (or method of solution) is controlled.

8.2 Expert Systems Fundamentals

The general structure of an expert system (Figure 8-1) can be described in terms of six main components:

1. The external data acquisition systems, which provide the input data for the specific application. These systems may be manual (that is, data must be collected and entered by hand) or automated (for example, remote sensing);
2. the knowledge base, which is a collection of domain specific knowledge usually represented as rules based on IF-THEN logic;
3. external application programs, with which the system exchanges information and data. For example, computer simulation models may provide quantitative estimates of air and water quality parameters or GIS may provide spatial data on the location and characteristics of key environmental components. Reports from expert systems may be exported to common wordprocessing or database software programs;
4. the user, who controls the system, inputs information, selects options, and generates reports;
5. the user interface, which is the means by which the user communicates with other components. Most user interfaces are menu driven and have a number of display and reporting features; and
6. the inference engine, which is the reasoning mechanism that manipulates the rules in the knowledge base to provide conclusions. These specific conclusions depend on the information supplied by the user, external data acquisition systems, and external programs.

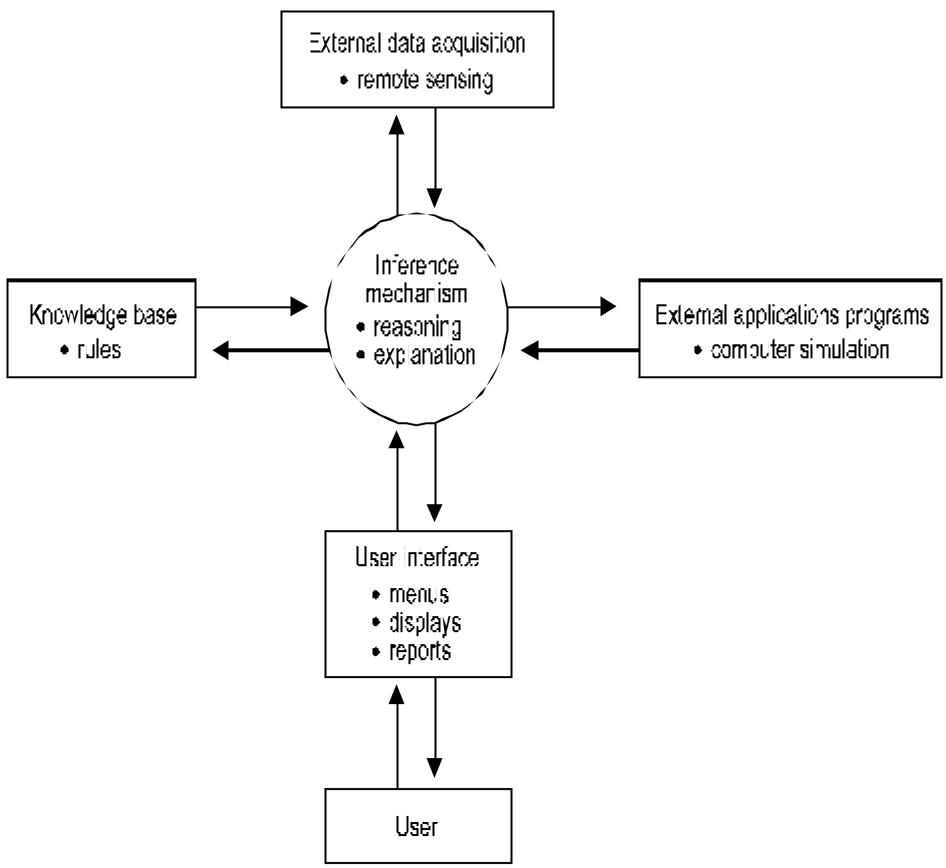


Figure 8-1: General structure of expert systems.

Knowledge bases in expert systems are based on collections of rules. These rules are constructed by codifying the experience and knowledge of a group of experts. These rules are often represented in the following form:

IF	<a set of conditions is true>
THEN	<certain conclusions can be drawn>

For example:

IF	there is a discharge of a pollutant
and	the loading of the pollutant is a relatively large volume
and	the discharge is into a water body
THEN	the water body's water quality will significantly decline
and	IF the water body's ambient water quality is within environmental standards
THEN	ambient water quality will decline below environmental standards.

Note that the rules are represented in natural language (in this case English). One benefit of this natural representation of rules is that knowledge bases can be developed rapidly without the need to perform extensive programming. Another benefit is that once a knowledge base has been developed, it is relatively easy to maintain. Adding, modifying, or deleting rules does not usually require making extensive system changes. The end-user also benefits by this natural-language format since questions are posed in language which can be colloquial and familiar to the users. Typically, answers are selected from *menus*, rather than users being required to type full sentences.

Another feature of expert systems is their ability to perform some form of explanation, or justification. This means that once a conclusion is reached, the end-user may ask the expert system to explain its answer, and the system will step back through its solution procedure, or explain its answer in some other way. It is possible to perform this function because the separation of inference and application allows for the development of application-independent tracing or explanation mechanisms. In addition, many systems allow users to pause in the midst of a solution procedure and examine the system's current knowledge about the problem at hand, and its current reasoning path.

8.3 Applications of Expert Systems to EIA

Gray and Stokoe (1988) reviewed a number of expert systems and decision support tools in environmental assessment and natural resource management. They found only a few examples of systems applied specifically to EIA, however they found many more applied to natural resources management. Systems were identified for forestry, hazardous wastes, risk assessment, weather forecasting and a number for specialized applications that were difficult to categorize. Page's (1989) comparative analysis of environmental expert systems in Canada and the then Federal Republic of Germany also revealed only a small number of applications specifically directed to EIA. He found a number of systems that applied to natural resource management. Page's review revealed that most of the systems were either in a prototype or demonstration stage. His study found a number of promising directions in the environmental expert systems being developed, namely:

1. more "intelligent" (that is, AI-based) user interfaces, employing colored graphics, object oriented techniques, window systems, flexible help functions on different user levels, explanation facilities and eventually performing some natural language processing;
2. "Intelligent" user access support and orientation on environmental databases (for example, literature of chemical substances), as well as more efficient database search techniques;
3. training and instructional systems allowing for an efficient transfer of environmental expert knowledge; and
4. straightforward diagnostic/interpretation expert systems for well-bounded domains, which are well understood in AI, and where powerful tools are already available, as problem solving aids (for example, in early stages of the EIA process).

Hushon (1990) identified sixty-eight applications of expert systems to a wide range of environmental problems. Again, very few of those identified were useful as EIA tools. By the early 1990s, a number of expert systems for environmental assessment had been developed or were in the prototype phase. Geraghty (1993) reported on eleven expert systems for environmental assessment, of which the majority were in the prototype phase. Most recently, Beanlands (1994) prepared a bibliography listing expert system applications specific to EIA.

Although the theoretical benefits of expert systems for EIA have been known for some time, to date there are still only a small number of these systems. A number of limitations to using expert systems for EIA help to explain this dearth:

1. the high level of effort required to develop the knowledge base, rule base, and/or geographic setting within the expert system;
2. the frequent need to customize expert systems for each organization (thus making them impractical for simple one time applications);
3. the training and computer hardware that must be available to the EIA team so they can adequately use the expert system; and
4. the lack of suitability of such systems for performing algorithmic problem solving tasks.

8.3.1 Applications of EIA Expert Systems in Developed Countries

This section and the next (8.3.2) present brief descriptions of selected expert systems for EIA. It is important to note that there are very few fully operational systems, and thus, many of the systems described below are research prototypes that have not been applied to real world situations. It is unclear whether any prototypes will become fully operational expert systems — this is due, in part, to the previously mentioned limitations of expert systems, and the inability to accurately predict technological breakthroughs and large funding commitments that are required to develop each expert system to a fully operational phase.

SCREENER™

SCREENER is a computer assisted environmental expert system that screens projects for potential environmental impacts. The user selects from a menu of options both the proposed activity and the environmental features where the activity will take place. The program receives this information and refers to its knowledge and rule bases to assign a code that describes the potential impact of the activity in the environment designated by the user (1 - no impact; 2 - insignificant impacts; 3 - mitigable impacts; 4 - unknown impacts; 5 - significant impact). Based on the code, SCREENER recommends the level of environmental impact assessment required for the project. SCREENER also provides the user with suggested mitigation measures to help prevent or reduce environmental impacts. In Canada, SCREENER has been implemented at about forty sites by Canadian government departments. SCREENER was based on the DOS operating system and has been replaced by the Calyx™ technology for Windows.

Calyx™

ESSA Software Ltd. (“ESSA”), through its Calyx™ group of products (“Calyx”), provides a suite of decision support software tools. The Calyx group of products are PC-based, with applications that allow decision makers (usually project managers) the ability to assess likely environmental and socio-economic impacts of their activities before they happen. With Calyx, users can devise several different scenarios for projects, compare their environmental impacts and recommended mitigations, and reach a conclusion about the most acceptable solution. From entering the characteristics of the project site and the project activities, to printing the final reports, Calyx takes users step-by-step through the process.

The core technology and knowledge base associated with its expert system is adaptable to many applications. The first applications involve the analysis, classification, and mitigation of various environmental and land management issues and their impacts. Specifically, software applications have been created for the design and operation of military-bases and power projects, while additional applications are available for international financial organizations and government agencies for the review & analysis of a variety of issues associated with infrastructure development projects.

ESSA Software has released two applications of its knowledge-based software to date: Calyx EA (Environmental Assessment), and Calyx-ADB (Asian Development Bank). A third application, Calyx RM (Range Management), is currently being evaluated and beta tested by key clients in the military both in Canada and Australia, and is scheduled for general release in late 1997. Initial development on a fourth product (Calyx EA-Power) is under way with CH2MHill Ltd., a large U.S.-based international engineering firm, with a client in Russia. A final product, Calyx - Emergency Preparedness, is currently under development at this time.

The version of Calyx developed in conjunction with the Asian Development Bank for application in ASEAN countries is described in detail in section 8.3.2.

In contrast to stand-alone, special-purpose software tools currently available in the market, Calyx offers several unique characteristics, including the ability to successfully integrate relational databases, GIS-based information, and other software models and applications into its software.

ORBI

This expert system for EIA was developed by the Universidade Nove de Lisboa for the Portuguese Department of Environment (Geraghty, 1993). It is written in Prolog with a natural-language interface

(Portuguese). This is one of the few expert systems for EIA which currently has such a facility. This facility makes using and communicating with the system more straightforward and easier than with the usual expert system shells or programing languages, as the user can program and update the system in the user's own language rather than using computer code.

The system consists of four separate programs: the first is in BASIC for digitizing a subject region (a region is broken down into a locational grid); the second is for receiving and storing the digitized information; the third is for knowledge updating; and the fourth comprises two modules in Prolog (the first is a natural-language interface, and the second is an evaluation and explanation module; each of which runs independently of the other).

ORBI has expertise in several disciplines, including geology, hydrology, ecology, and microclimate. The system makes judgments about the suitability of a particular subject region for uses such as industry, agriculture, and recreation. Quantified values are obtained via inferencing rules that indicate the suitability of the environmental assets available relative to development requirements (for example, intensive agriculture). ORBI can produce graphic output in the form of maps, via a plotter.

IMPACT: An Expert System for Environmental Impact Assessment

IMPACT is an environmental analysis screening tool for the U.S. Department of Energy's Savannah River Site in South Carolina (Geraghty, 1993). It uses a simplified GIS approach to assess several types of impacts, including proximity effects, air and water pollution, and groundwater effects (Loehle and Osteen, 1990). Objects such as wetlands or wildlife habitat are represented by circles that cover the area of concern; they are stored as an x-y pair and a radius. This simplified approach is possible because the problem of concern was screening for possible impacts, thus false alarms (warning of an impact when none is likely) are acceptable. Each object has a characteristic influence zone extending out from its boundaries. Any activity within this zone generates a warning of possible impact. The rule base for IMPACT consists of: 1) the radii of zones of influence for each object type; 2) the manner in which objects interact (for example, wells do not adversely affect roads, but waste sites affect wells); and 3) specific regulatory provisions such as necessary permits. The program communicates its results by producing a written tabular report. IMPACT has been tested by its developers on a number of situations. It continues to undergo testing to improve its efficacy (Geraghty, 1993).

8.3.2 Applications for Developing Countries

Calyx-ADB

Calyx-ADB was specifically designed to assist EIA practitioners in the Association of Southeast Asian Nations (ASEAN) countries. The software, developed during an Asian Development Bank regional technical assistance project, is based on Calyx EA, a computer system developed for environmental applications by ESSA Software Ltd. of Vancouver, Canada. Calyx-ADB provides assistance in: 1) screening, 2) scoping the terms of reference for EIA studies and reports, 3) identifying key issues and impacts to consider during the review of EIA reports, and 4) developing monitoring requirements and mitigation measures to attach to approvals. In addition, the system provides information on environmental standards, mitigation measures, guideline documents, and laws and regulations. The information and knowledge on environmental impacts and mitigation measures contained in the system are based on experience gained in EIA throughout the ASEAN region. Calyx-ADB was developed over a two year period by ESSA Technologies Ltd. of Vancouver, B.C. in conjunction with international and local experts in EIA.

The regional technical assistance project was implemented within four countries in the ASEAN region: Indonesia, Malaysia, Philippines and Thailand. The implementing agencies are:

- Indonesia - Badan Pengendalian Dampak Lingkungan (BAPEDAL)
- Malaysia - Department of Environment
- Philippines - Environmental Management Bureau, Department of Environment and Natural Resources
- Thailand - Office of Environmental Policy and Planning, Ministry of Science, Technology and Environment.

Each of the countries has slightly different needs for computerization of their EIA procedures and practices. To make the system useful in each of these countries and within the Asian Development Bank itself, the system was designed to accommodate these different institutional requirements.

The overall objective of the project was to design, develop, test, and implement a computer-based system for EIA in support of environmental assessment activities in the Bank's developing member countries (DMCs) in the ASEAN. The specific objectives were to: 1) to produce a computer system to increase the effectiveness of the preparation and review of EIA through systematic scoping for environmental impact assessment; 2) to produce software to facilitate the determination of appropriate terms and conditions to be attached to approvals of EIA reports; 3) to test/demonstrate the system in each of the four developing member countries, as well as at the Asian Development Bank; and 4) to increase accessibility to existing information on environmental standards and guidelines for EIA. The first version of the system covers four sectors: Irrigation, Urban Wastewater and Water Supply, Power, and Transportation.

The major components of the ADB expert system are shown in the context diagram (Figure 8-2). The diagram shows the EIA tasks for which the system provides assistance and the end users. In addition to these tasks, the complete Calyx-ADB allows knowledge engineers and database administrators to maintain system knowledge bases and databases.

To date over 150 copies of the software have been distributed throughout Asia and the Pacific (including Bhutan, Nepal, Tonga as well the original four ASEAN countries). Over 150 people have been trained in the use of Calyx-ADB. In Thailand, the Environmental Impact Evaluation Division of the Office of Environmental Policy and Planning used Calyx-ADB as training tool to provide in-depth training on EIA. Current proposals provide for the introduction of Calyx-ADB into Viet Nam, Cambodia, Lao PDR, and Myanmar.

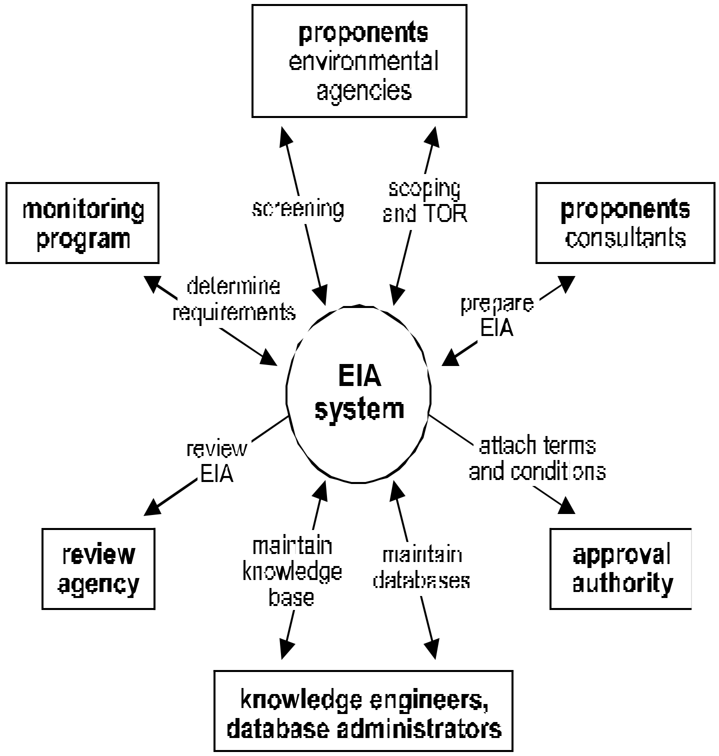


Figure 8-2: Context diagram for the Calyx-ADB computerized EIA system.

MEXSES: Mekong Expert System for Environmental Screening

MEXSES is a prototype expert system for environmental screening developed primarily for implementation by the Mekong Secretariat. The system is a computer program available from the International Institute for Applied Systems Analysis (Fedra, 1991). It draws on a number of established EIA techniques in an attempt to combine the most appropriate elements into one comprehensive and intelligent, knowledge-driven framework and easy-to-use tool. The system manages a database of project assessments and a geographical database of maps and geo-referenced data (Figure 8-3). MEXSES is designed for early assessment and screening of projects. It allows for evaluation of a project in terms of its potential environmental impacts at any early stage with a minimum of project specific information. The prototype draws on extensive knowledge and databases on project characteristics based on generic profiles and a hierarchial classification scheme. The prototype's knowledge base is limited to a few examples of checklists and rules for one problem class (that is, Dams and Reservoirs). MEXSES did not proceed past the prototype stage.

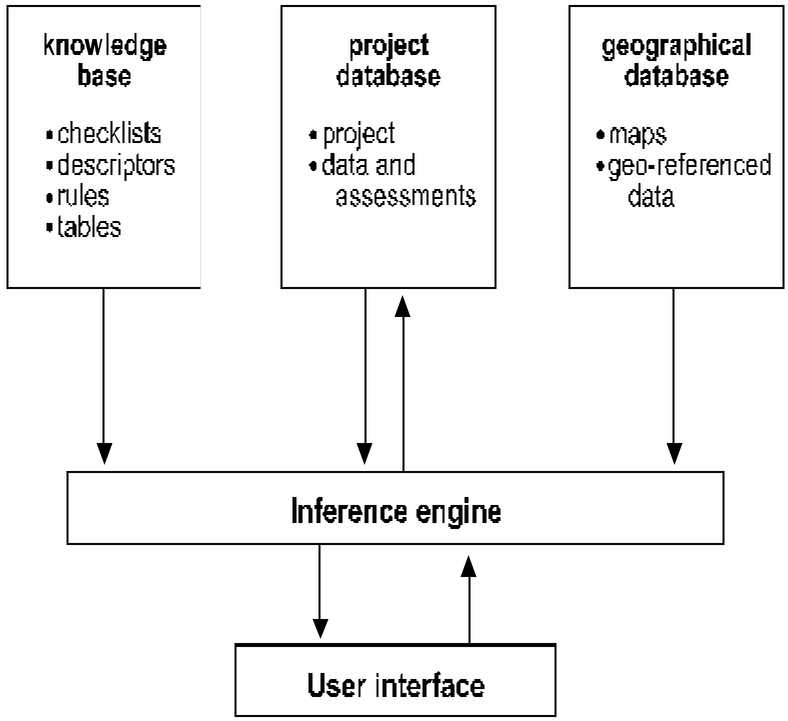


Figure 8-3: The basic structure and components of MEXSES.

8.3.3 Other EIA Decision Support Tools for Developing Countries

The system was developed as a component of the Australian-assisted Natural Resources Management and Development Project of the Department of Environment and Natural Resources. Its principal aim is to help strengthen the Philippine Government's EIA system by allowing quick retrieval of relevant information needed by project proponents, decision-makers, and compliance monitoring teams.

The computer-assisted EIA system is currently being pilot-tested in Cebu Province for two types of environmentally critical projects — sand/gravel quarrying and aquaculture. The system is characterized by the flow chart depicted in Figure 8-4. The system's four main features are:

1. the "Guidelines Routine;"
2. the "Assessment Routine;"
3. the "Review Routine;" and
4. the "Document Monitoring Routine."

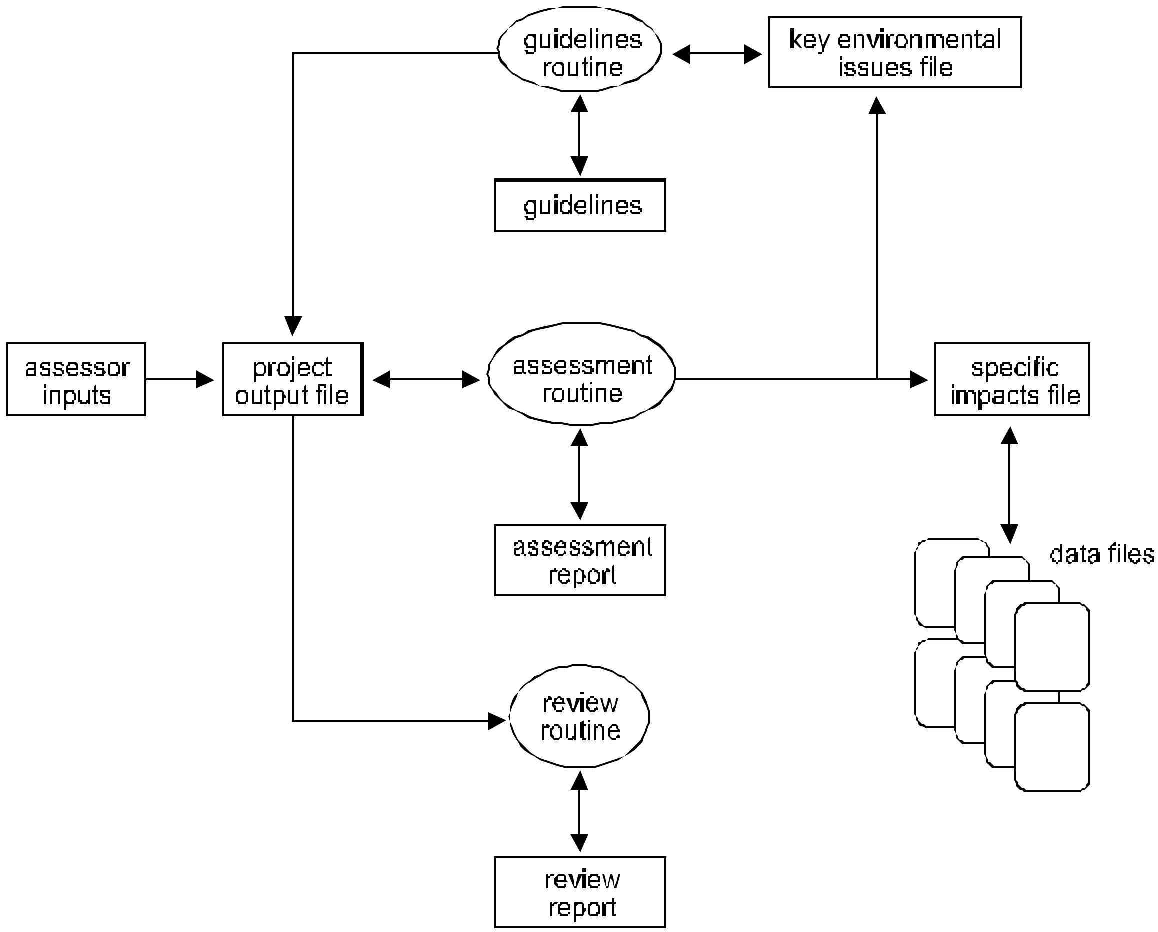


Figure 8-4: The basic organizational structure of the computer assisted EIA system.

The "Guidelines Routine" enables the user to print the scoping guidelines needed to direct project proponents in the preparation of EIA project documents for a specific project. The "Assessment Routine" includes three database files — the main file which is the assessment file, the reference file (issues file) which contains the environmental issues, and the reference file (impacts file) for the environmental impacts. The "Review Routine" provides a text editor to help the EIA Coordinator to consolidate the preliminary assessments made by the project evaluator. The text editor can generate a formatted review containing relevant issues and recommendations that should be addressed by the EIA Review Committee for final decision-making. It will access the project output file and process the project along with the assessor summaries to produce a review report. The "Document Monitoring Routine" generates reports useful in monitoring the processing status of the EIA project documents.

EIAMAN: Computerized Environmental Management System

EIAMAN is an operational prototype program for evaluating and managing development in the Marshall Islands (Carter, 1995). EIAMAN provides a filing and retrieval system for all documents associated with any development project proposed to the Marshall Islands Environmental Protection Agency. The program has a number of desirable features:

1. it provides easy access to important reference documents during the evaluation of a project;
2. it may be used to prepare documents that would serve as important elements of the EIA report;

3. it helps the user conduct a preliminary proposal evaluation;
4. it helps the user conduct scoping; and
5. It makes recommendations on additional studies that may be required.

The knowledge base is organized in terms of checklists for key environmental factors. It incorporates many social, biological, and political considerations, but is quite limited with respect to physical considerations. The user interface is simple to use. It allows the user to:

1. enter information about the preliminary proposal;
2. review the preliminary proposal;
3. conduct scoping;
4. propose additional studies be conducted; and
5. prepare appropriate EIA documentation.

The user interface also manages the interaction with various spreadsheets, memoranda, and documents that are produced by the system.

Summary of Applications

Expert systems are computer programs that perform difficult, specialized tasks at the level of a human expert. They have been implemented in a variety of applications, including games (for example, chess) and public works projects (for example, wastewater engineering). The heuristic reasoning capabilities of expert systems technology seem well suited to many of the tasks associated with undertaking an EIA, however, to date, only a few such systems have been developed. Most of these are in the prototype phase. Some of those systems developed are fully operational at a large number of sites (Table 8-1). Until now, the development of expert systems in developing countries has been funded by International Assistance Agencies, in particular, the Asian Development Bank. While there is interest in EIA expert systems in developing countries, the degree to which these systems will be adopted is uncertain. The degree to which expert systems will be used depends on whether or not practitioners in developing countries can acquire the necessary skills to effectively use the systems.

Table 8-1: Summary of selected expert systems for EIA.

Name	Description	Use in Developed Country	Use in Developing Country
SCREENER™	EIA screening tool	fully operational in forty federal government sites in Canada	
Calyx EA	determines potential environmental effects of projects (no GIS)	operational system being tested in Canada by two government agencies.	complete system being tested in a number of South Pacific island states.
Calyx GIS	determines potential environmental effects of projects using GIS	Calyx GIS prototypes being tested by federal governments of Australia and Canada	
ORBI	expert system for EIA that produces graphic outputs	used by Portugal's federal Department of Environment	
IMPACT	EIA screening tool	operational system being tested by U.S. Department of Energy at the Savannah River Site	
Calyx ADB	determines potential environmental effects of projects		complete system being tested in Bhutan, Nepal, Viet Nam, Thailand, Philippines, Indonesia, Malaysia
MEXSES	EIA screening tool		prototype system developed for the Mekong Secretariat
Computer Assisted EIA	information retrieval system		prototype being tested in Cebu Province of Philippines
EIAMAN	provides filing and retrieval systems for all development project documents		prototype being used in Marshall Islands

8.4 Anatomy of an Expert System

To provide a more in depth understanding of workings and capabilities of expert systems, this section presents a detailed look at the Calyx-ADB expert system for EIA. ***The illustrative examples presented are often simplifications of the information contained in a Calyx-ADB knowledge base. Knowledge bases are constantly being updated as new knowledge is gained and the current knowledge base for Calyx-ADB may contain different information.***

Calyx-ADB has seven core components (Figure 8-5):

1. a knowledge base that is a collection of domain-specific information;
2. databases that provide information about specific environmental components;
3. databases that contain information on laws, regulations, and environmental standards;
4. an inference engine, which implements problem solving strategies to utilize the knowledge base and derive new conclusions;
5. a user interface that controls and guides the practitioner-machine dialogue, including an explanation component that can, on request, explain the system's inference procedures;

6. a reporting system to present the conclusions of the expert system; and
7. output databases that store the results of EIA tasks performed by the system.

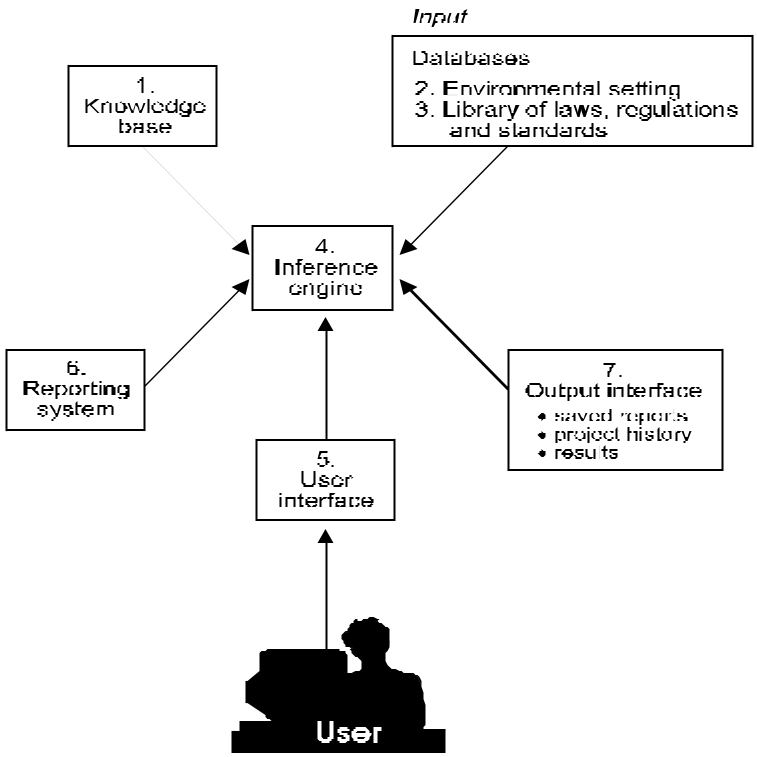


Figure 8-5: Components of ADB expert system.

8.4.1 Knowledge Base

The computerized expert system for EIA developed for the ADB (ESSA Technologies Ltd., 1996) uses a sophisticated knowledge representation system. The system requires information about the project activities and the environmental setting. Each rule states the conditions under which a project activity will have a degree of impact on an environmental component.

Elements of an Impact Rule

The generic elements of a rule (Table 8-2) are:

1. *activity*: which is the basic element of a project or plan that has potential to affect any aspect of the environment. Projects are composed of activities;
2. *activity characteristics*: which define the magnitude, duration, intensity, or extent of an activity;
3. *component*: which is a basic element of the physical, biological, social, or economic environment. Environmental components receive environmental impacts from activities;
4. *component characteristics*: which define the susceptibility, sensitivity, or vulnerability of a component to an impact;
5. *impact mode*: which defines the mechanism by which the impact may occur;

6. *relationship*: which defines the spatial and temporal relationship between the activity and the component; and
7. *site characteristics*: which define characteristics of the site that may influence the nature and degree of impact.

In terms of the IF-THEN format, a rule may be stated:

IF	the activity occurs
and	the activity has certain activity characteristics
and	the component exists
and	the component has certain component characteristics
and	the activity and component have a specific spatial and temporal relationship
and	certain site characteristics exist
THEN	the activity will have a degree of impact on a component acting through the mechanism defined by the impact mode

For example,

Activity:	IF emissions occur
Activity Characteristic:	and the emissions are in large volume
Component:	and an airshed for a population center exists
Component Characteristic:	and the population is very large
Relationship:	and the emissions occur upwind of or into the airshed of the population center
Site Characteristic:	and the atmosphere conditions at or near population are subject to inversions
First Order Impact:	THEN there is potential for significant impacts on air quality in the airshed through increasing concentration of pollutants.

Table 8-2: Generic elements of a rule.

Element	Description
Activity	• project activity; only one identified per rule • e.g., blasting/drilling, asphalting/paving, truck traffic/hauling
Activity Characteristic	• attribute(s) of the project activity; one or more may be identified • e.g., volume, toxicity, areal extent, frequency, duration
Component	• environmental component; only one identified per rule • e.g., terrestrial birds, trees, soil, rivers, aboriginal peoples
Component Characteristics	• attribute(s) of the environmental component; one or more may be identified • e.g., root depth, life stage, rare/endangered, flow rate
Impact Mode	• mode of potential impact; only one may be identified per rule • e.g., contamination, erosion, destruction, change in behavior
Relationship	• descriptor of spatial or temporal relationship between impact mode and component; one or more may be identified • e.g., on/in, up slope of, upwind of, near, coincident with, adjacent to
Site Characteristic	• other characteristics that may be necessary to include in a rule, but describe something about the site or location rather than about the activity or component; one or more may be identified • e.g., heavy rainfall, in a valley, subject to earthquakes • the information on site characteristics will be part of the setting information, and will be identified on a setting-specific or location-specific basis

Triggering Higher Order Rules

First order rules describe the direct impacts of a project on a component. The knowledge base contains higher order rules to ensure that higher order impacts are identified. The structure of first order and higher order rules is almost identical. The only difference is in the initiator portion of the rule: for first order impacts, it is an activity, and for higher order rules it is a component that has been affected by a previous impact and the mode of that impact. Higher order rules are similar to the cells of component interaction matric es (described in Chapter 4). For example, a higher order rule may describe the relationship between changes in air quality and health of residents in a nearby city.

For example,

Mode/Component:	IF air quality in the airshed is reduced through pollution
Component Characteristic	and ambient air quality was within acceptable limits
Component:	and there are local residents
Relationship:	and local residents reside in the area that defines the airshed
Higher order impact:	THEN there is potential for significant impact on the health of local residents.

Linkages to Other Databases

In the ADB knowledge base, the rulebase is linked to three other main databases (Figure 8-6): 1) information requirements; 2) monitoring requirements; and 3) mitigation measures. The information requirements database contains a description of the information that must be gathered to conduct the assessment. This information is made available during scoping to help define the terms of reference. The monitoring requirements database contains suggestions on data that should be collected to monitor project impacts. The mitigation database contains recommended mitigation measures that will prevent or reduce project impacts. Both the monitoring requirements and mitigation measures are available to help the user in specifying terms and conditions of approvals.

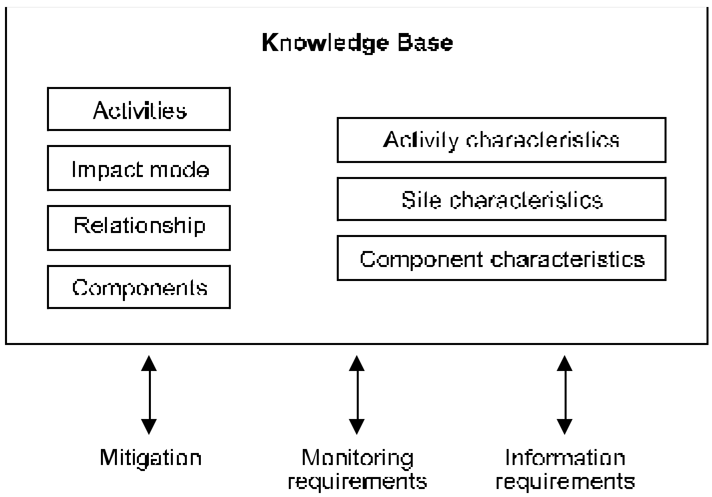


Figure 8-6: Major databases in the ADB knowledge base.

Box 8-1: Information requirements for the first order rule: *Site clearing and preparation damages/destroys terrestrial flora*.

adjacent to: Determine the proximity (distance) from the various project activities to the various environmental components.

ecologically sensitive: Determine whether there are any ecologically sensitive areas present. Such areas include: protected forest land, wildlife sanctuaries, national forest land, wetland (Thailand has a Wetland Directory), mangrove, sites of high biodiversity (e.g., areas that may contain herbal medicines), sites containing rare/endangered species, national parks, watershed classification areas, and areas of genetic importance for particular species (e.g., gold teak in Thailand).

area cleared: Determine the length of time (in months) that any portion of the area will be without vegetation, and the total area to be cleared at any one time.

Information Requirements

During the scoping stage of EIA it is often necessary to determine the information required to conduct the assessment. In Calyx-ADB, most elements in an impact rule are linked to specific information requirements. Consider the first order rule:

IF	site clearing and preparation occurs
and	the area to be cleared is large
and	terrestrial flora exist
and	the terrestrial flora are adjacent to the site clearing
and	the site is characterized as ecologically sensitive
THEN	there is potential for significant impact on terrestrial flora through damage and destruction by site clearing and preparation.

Each of the rule elements (that is, activity characteristic, component characteristic, site characteristics, and relationship) is linked to specific information requirements. The expert system will let the user know about these information requirements whenever *Site clearing and preparation* is identified as one of the project activities, and specific *terrestrial flora* is identified or if the user is uncertain about the presence of *terrestrial flora* (Box 8-1).

Mitigation Measures

Each of the impact rules in the knowledge base is linked to one or more mitigation measures. For our example impact rule, *Site Clearing and Preparation damages/destroys terrestrial flora*, one mitigation measure is:

> *Shifting flora from the project site*: Check for the presence of any rare and endangered species. Record the number of different species present. Where possible relocate rare and endangered species If this is not possible avoid areas where the species are present and prevent access.

The system will present the user with this mitigation option whenever there is potential for an impact on rare and endangered terrestrial flora.

Monitoring Requirements

Each of the impact rules in the knowledge base is linked to one or more monitoring requirements. For our example impact rule, *Site Clearing and Preparation damages/destroys terrestrial flora*, one monitoring requirement is:

> *Protection of trees during construction*: Check for the presence of any rare and endangered species as well as protected species. Monitor the number of different species present before and after the project in the area. Such monitoring should be done once in a year during the first five years and later can be done once in every five years.

In developing terms and conditions for approval, the system will present this monitoring requirement as one of a number of suggested monitoring requirements.

8.4.2 Knowledge Acquisition

The rules in the knowledge base are representations of expert judgement. In the Calyx-ADB system, this expert judgement was acquired in three ways: 1) interviews with individual experts; 2) interdisciplinary workshops focusing on industrial sectors; and 3) review of numerous environmental impact statements and other documents. The task of developing the knowledge base is referred to as "knowledge engineering."

Procedure for Knowledge Acquisition

Issues are broad statements about the potential of a project to generate environmental impacts. For example, an issue statement might relate to effects of wastewater of thermal generation stations on human health (Box 8-2). A number of rules are required to represent issues in the knowledge base.

Box 8-2: Wastewater from thermal power stations — statement of issue.

There are generally three kinds of wastewater from thermal power plants:

1. Domestic wastewater from the canteens, dormitories, and offices, which can be categorized as high BOD wastewater. In the case that the sewer system is a combined one, rainwater may dilute the wastewater, causing it to bypass the system into the receptors outside the plant. Treatment is by biological process (i.e aeration, activated sludge treatment).
2. Spent water from processes. This includes the boiler water, cleaning water, cooling tower water. The water is characterized by high mineral content or high grease and oil content. Nitrogenous compounds (i.e hydrazine used for antifouling) may be found. Treatment is by chemical precipitation and oil and grease removal.
3. Once-through water for cooling for the power plant, which will have about +9 ºC added to the existing water temperature. The volume is enormous, about 7-12 m^3 for a 300 MW power plant. The characteristics are the same as at intake, except that the living organisms are likely to perish from temperature shock. Heat dissipation when released to receiving body of water is required to minimize impact to the living organisms.

The wastewater issue can be significant only in the following cases:

1. The project design does not include provision for needed treatment facilities (for reducing contaminant levels and for effective heat dissipation method for cooling water).
2. Faults in the design and operation of the treatment plants (under capacity, bypassing in the case of combined sewers, etc.) which can be evaluated by wastewater treatment experts.
3. There are sensitive receptors downstream:

3.1 The receiving body of water may be too small, such that the effluents from the power plant can effect the characteristics of the)D, COD, temperature, chemicals).

3.2 Inadequate dispersion, such as the still water in lakes and lagoons, rivers with low current speed or with tidal effects that alternate rections often.

3.3 Uses of the water downstream which require exceptionally good quality of water, such as aquaculture, recreation, potable water

In developing Calyx-ADB, the first step was to define a preliminary set of issues that might arise in the conduct of an EIA for projects in the power, urban water supply and wastewater, irrigation, and transportation sectors. These issues were developed by preliminary review of EIA documents and written submissions by domain experts. The next step was to define a set of rules for each issue. In working with experts and/or EIA documents, knowledge engineers first tried to obtain answers to the questions listed in Table 8-4. The answers to these questions were recorded in special rule templates. The information from rule templates was entered into a Knowledge Acquisition Tool (KAT™). KAT™ allows easy entering and editing of all elements of the knowledge base. KAT™ is used to generate the knowledge base in a format that may be used in computer systems.

Table 8-3: Basic questions asked by knowledge engineers.

1. **Under what conditions will a significant impact occur?**

   In answering this question, knowledge engineers are expected to identify the activity, component, impact mode, relationship(s) and attributes(s) for each impact (preferably from the existing lists, but adding new ones if needed). This information should be recorded on the rule templates. Once the conditions for a significant impact are identified, determine the conditions under which the impact might be insignificant (as opposed to there being no impact at all). For ex ample, would it be insignificant if the degree of impact were smaller? If the component were less susceptible/vulnerable? The conditions for an insignificant impact should be documented at the bottom of the rule template.

2. **What information will be needed to assess the significance of the impact?**

   This is a double-check to ensure that all the conditions for an impact are identified; it may also provide a useful list of information requirements.

3. **What mitigation measures will prevent or reduce this impact?**

   The mitigation keywords should be written on the rule templates, and then the complete mitigation information should be filled out on the mitigation templates (or entered directly into the Knowledge Acquisition Tool). The minimum information we need for the mitigation is the name or keyword of the mitigation, a description of the mitigation, the reference for the mitigation, and the activities and/or components and/or impact modes to which it applies. *For every mitigation you list on the rule templates, there must be a detailed entry in the mitigation templates.*

4. **If the project were to proceed, what monitoring will be required?**

   These monitoring requirements may be to track project impacts, track the success of mitigation measures, or both. If the monitoring requirements refer specifically to the mitigation measures, this information should be entered into the mitigation template for that mitigation.

8.4.3 Environmental Setting Databases

The system requires information about: 1) the project activities; 2) the environmental setting (including all biophysical, social, and economic components); and 3) the relationship between the project activities and the environment. For Calyx-ADB, activities lists have been developed for four sectors: urban wastewater/water supply, irrigation, power, and transportation. The activities lists are similar to those developed for various checklist and matrix methods. Sets of characteristics that might be necessary to further describe these activities have also been developed. For example, the activity "Application of herbicides" has the following characteristics:

toxicity (strong, moderate, weak)
quantity (large, medium, small)
frequency (high, medium, low)

The significance of the impact will be affected by the values chosen for each of the activity characteristics.

Environmental Settings

In very sophisticated computer systems, environmental information may be gathered by automated systems through remote sensing or by linking to already existing GIS data. In most systems, however, it must be entered by the user. In Calyx-ADB, the information must first be gathered by the user. During the session with the system, the user inputs the necessary information through the user interface. A hierarchy of environmental components has been developed to guide the user. This hierarchy contains all of the environmental, social and economic components that might be affected by a project. Table 8-4 illustrates the component hierarchy for physical resources. The complete hierarchy is presented in Table 8-6. A set of characteristics that might be necessary to further describe these components has also been developed. For example, the component “canals” has the following characteristics:

dissolved oxygen concentration (well above 4 mg/l, at or just above 4mg/l, < 4 mg/l)
public water supply (yes, no)
source for domestic/industrial water (yes, no)
used for fisheries (yes, no)
used by wildlife (yes, no)
size (small, large)
N content (high, low)
P content (high, low)
flow rate (slow, fast)
volume of water (low, high)
BOD (above standards, below standards)
suspended solids (above standards, below standards)
fecal coliform (above standards, below standards)
provides aquifer recharge (yes, no)
normal iron concentration (yes, no)

Note that some characteristics (for example, *dissolved oxygen concentration*) are expressed as quantitative ranges, while others (for example, *used for fisheries*) are expressed as qualitative choices. In some cases, the characteristics in the expert system are represented as qualitative choices (for example, *flow rate*) where normal EIA data collection practices will provide quantitative data for the parameter values. In these cases, the user must exercise their judgement in making the qualitative choices.

The significance of the impact will be affected by the values chosen for each of the characteristics. It is not necessary for the user to specify all the values for the characteristics. In cases where information is missing or unknown, the system simply assigns a greater range of uncertainty with respect to the significance of the impact.

All information on components and their characteristics and the relationships between components is stored in an environmental setting database. Separate databases may be created for each specific environmental setting.

Table 8-4: Component hierarchy for physical resources.

Physical Resources	**Atmosphere**	air quality micro-meteorology climate
	Groundwater	aquifers wells groundwater springs
	Surface Water	canals estuaries lakes/reservoirs rivers streams
	Hydrology	hydrological regime
	Land Resources	aquifer recharge areas aggregate resources floodplains barren land coastline/shoreline geology/seismology landforms/topography mineral resources soil river beds river banks

8.4.4 Library Databases

Calyx-ADB contains a hypertext library that lets the user view information on laws, regulations, EIA procedural guidelines, and environmental standards for Indonesia, Malaysia, Philippines, Thailand, and the Asian Development Bank.

8.4.5 Inference Engine

The inference engine is a computer software that manipulates the rules in the knowledge base to provide conclusions based on the information provided as input. The inference can provide answers to a question like:

1. What are all the potential impacts associated with hydroelectric dams?

If this question is asked in Calyx-ADB, hundreds of potential impacts will be presented. A more focused question might be:

2. What are the impacts of reservoir impoundment on people currently living in or near the reservoir area?; or
3. How will alteration of downstream flow affect drinking water quality?; or
4. What mitigation and monitoring is required to ensure that water quality remains within acceptable standards?

While the inference engine is highly efficient at manipulating the knowledge base, it relies on the user interface to tell it what to do.

8.4.6 User Interface

The user interface controls the interaction (in computer terms — the dialogue) between the user and the inference engine. Most expert systems are designed for a specific task or to help the user solve a particular problem. The user interface must guide the user through the performance of the tasks. For example, if a user wishes to develop a terms of reference for an EIA, the user interface must ensure that: 1) all necessary input is provided by the user; 2) necessary linkages to the inference engine to get the appropriate information are made; and 3) the information is assembled into a format suitable for reporting.

EIA Tasks Performed

Calyx-ADB has been designed to help with: 1) screening; 2) scoping; 3) assessment; 4) review of EIA reports; and 5) determining appropriate mitigation and monitoring requirements.

Screening

Screening is the process of deciding upon the level of environmental review required. In some countries, it is simply a decision as to whether an EIA is required or not. Prescribed lists or criteria are used to determine whether a project requires an EIA. In Calyx-ADB, screening criteria for the four countries and the Bank are contained within the system. The screening criteria are divided into two lists: 1) project criteria which relate to the magnitude and nature of the projects; and 2) site criteria which relate to the sensitivity of the environment to potential impacts. The user simply selects from the list and the screening is completed.

Scoping to Determine the Terms of Reference

As defined in Chapter 2, the scoping or IEE stage is the process of determining the issues to be addressed, the information to be collected, and the analysis required to assess the environmental impacts of a project. The primary output of scoping is the terms of reference for the information and analysis required to conduct an EIA and the preparation of an EIA report. In the Calyx-ADB system, the user provides available information about the project and the environment. Based on this information, the system provides a listing of:

1. issues that should be considered;
2. information that will be required to resolve the issues;
3. recommendations on mitigative or offsetting measures to be considered; and
4. recommendations on monitoring requirements to be considered for the project.

Assessment

In conducting the assessment, Calyx-ADB uses the inference engine to determine the significance of the environmental impacts. Based on information about the project activities, activity characteristics, components, component characteristics, relationships, and site characteristics, the inference engine determines a level of significance for each rule in the knowledge base. The system also identifies mitigation measures for each of the impacts and asks the user to choose those mitigations that will be incorporated in the project design.

Review of EIA Reports

The review of EIA reports is normally done by a review agency or by a special Standing Committee or Commission established to review projects in a given sector. In most cases, a technical evaluation of the EIA report is made by specialists. This technical evaluation provides the basis for the review. To assist in the technical evaluation, the Calyx-ADB system provides a checklist of the important elements that should be considered in the review of the EIA report. The review checklist generated by Calyx-ADB is based on the Terms of Reference for the EIA.

Mitigation and Monitoring Requirements

One output of the EIA review process is the terms and conditions that are attached to approvals. These terms and conditions define the environmental protection measures that must be integrated into a project. The terms and conditions may also specify environmental monitoring that must be undertaken in conjunction with the project. Calyx-ADB provides a draft of these terms and conditions for incorporation into project approval reports.

8.4.7 Reporting System

Before the results of an expert system can be of any use, it must be able to provide reports in an easily understandable format. Many matrix and checklist techniques have been adopted for organizing the output from expert systems. Experts systems that are linked to GIS can provide sophisticated map overlays indicating areal extent of impacts.

The reports in Calyx-ADB have five main blocks:

1. **registration blocks:** which contain specifics of the project, the agency preparing the report, any registration numbers, dates, etc.;
2. **person responsible blocks:** which contain names, addresses, and contact details for those people responsible for preparation of the report;
3. **comment blocks:** which represent user supplied comments
4. **report type fixed information:** which contain additional information that is specific to that report type or jurisdiction.
5. **the main body of the report:** which is generated by the system for a specific project. Depending on the report, one or more blocks of the following information will be included:
   - i. Information Requirements;
   - ii. Mitigation Measures (TOR);
   - iii. Monitoring Requirements (TOR);
   - iv. Activities and Activity Attributes;
   - v. Components and Component Attributes;
   - vi. Impacts Summary;
   - vii. Impacts Detailed;
   - viii. Issues Summary;
   - ix. Issues Detailed;
   - x. Screening Conclusion;
   - xi. Mitigation Recommended; and
   - xii. Monitoring Recommended.

Illustrative Example: Scoping of a Hydro Project

In our example, Calyx-ADB was used to develop the terms of reference for the Initial Environmental Examination of a hydro-electric project. Calyx-ADB's scoping module was used to generate a report on the recommended terms of reference (Table 8-5). The terms of reference presented in Table 8-5 has been condensed and is only a partial representation of the information that was provided by Calyx-ADB. Calyx-ADB has used a report template for the major headings in the terms of reference report. The information presented in *italics* in Table 8-5 is generated from the Calyx-ADB knowledge base by the inference engine.

Table 8-5: Sample scoping report produced by the Calyx-ADB computerized EIA system.

TERMS OF REFERENCE FOR
INITIAL ENVIRONMENTAL EXAMINATION

Project Registration

Assessment Number: 1
Project Title: *Hydro Project*
Project ID: 1
Project Location: *South East Asia*
Project Description: *An example hydroelectric project to illustrate reporting features of Calyx-ADB. Actual output condensed for presentation purposes*.
Size of the Project:
Project Proponent: *A large independent power producer*.

Terms of Reference

The initial environmental examination should have the following contents:

A. INTRODUCTION (½ page)

1. This section should include the purpose of the report, extent of the IEE study and brief description of any special techniques or methods used.

B. DESCRIPTION OF THE PROJECT

2. This section should include the type and the need for the project, location,, size or magnitude or operation and proposed schedule for implementation.

Project Activity Information
Specific information about the following activities is required to conduct the assessment.

Reservoir impoundment

Determine the surface area, the depth and the size of the reservoir, the amount of shallow water that it will contain, and the degree of fluctuation in surface level that is expected (particularly between wet seasons and times of drought). Also determine if the reservoir will result in reduced fluctuation levels in downstream waters.

Determine the expected reduction in flow in the watercourse being diverted to fill the reservoir, and/or in the watercourse being impounded, during the period in which the reservoir is being filled.

C. DESCRIPTION OF THE ENVIRONMENT

3. This section should include the physical and ecological resources, human and economic development and quality of life values.

Environmental Components Information
Specific information about the following types of components is required to conduct the assessment.

Physical Resources

<u>Surface Water</u>
<u>rivers</u>
Determine the flow rate of the watercourse, during both the wet and the dry seasons.

Determine whether the water is used for domestic (e.g., drinking water, washing water), agricultural (e.g., irrigation) or industrial purposes (e.g., pulp and paper mills, textiles, food processing require high amounts of water). Also determine whether it is a source of water for local wildlife.

Determine whether the water contains normal concentrations of iron or normal salinity, and whether the dissolved oxygen concentration is above or below 4mg/L.

Ecological Resources
<u>fish</u>
Determine whether any of the species in the area are protected by law or regulation. Lists of protected species can be obtained from government wildlife or environment agencies. .

Determine whether any of the species in the area are of commercial value (harvested for sale in the marketplace). Information on whether a particular species is of commercial value can be obtained from the government wildlife, fishery or environment agencies.

Determine whether any of the species in the area is used for traditional purposes by the local people.

Determine the presence of fish species that migrate, or change habitat to other areas during different stages of its life cycle.

Determine whether the habitat in the area for local aquatic bird and animal species is critical for their survival. Critical habitat includes breeding areas, spawning grounds, feeding areas and migration corridors.

D. SCREENING OF POTENTIAL IMPACTS

4. This section should screen out "no significant impacts" from those with significant adverse impacts and should discuss the appropriate mitigation measures, where necessary.

Issues to be Addressed:

<u>reduced downstream aquatic habitat and restricted human use of river</u>
Reservoir filling can cause a short-term stoppage or significant decrease in river flow downstream of the dam. The reduction in flow can also occur in a source river if the reservoir being created is not in that river. Such dewatering can significantly affect downstream aquatic biota, and human uses of the river, such as water supply, recreation, navigation, and aquaculture.

<u>water quality degradation in/below reservoir</u>
Reservoir impoundment may lead to increased iron concentrations, increased heavy metal concentrations, increased salinity, increased turbidity, temperature changes in the water, and/or reduced dissolved oxygen concentrations in the reservoir. The kind of effect depends on the geology of the reservoir catchment, the nature of the reservoir (e.g., flushing rate, shape and depth). Reduced dissolved oxygen may result from eutrophication of the reservoir which may be the outcome of land uses in the watershed above the reservoir. If the reservoir water is used as a source for drinking or irrigation water, then the contamination will be significant. Contamination may also be

observed in the rivers and canals downstream of the reservoir. Again if these are used for drinking or irrigation significant problems may result. If the reservoir has reduced oxygen levels this may negatively affect fish populations. Conversely altered temperature and nutrient levels may lead to an increase in some fish populations.

E. MITIGATION

Mitigation
Information about the following potential mitigation measures to prevent, reduce, or ameliorate impacts is required to conduct the assessment.

Create artificial rapids downstream
Increase oxygen levels downstream by creating artificial rapids. This will increase the mixing of water and air, and thereby increase oxygen levels in the water.

Develop new spawning sites/stock fry
New natural spawning sites will be developed using diversion canals and permanent water depressions in the project area to make up for the loss of fish due to the construction of dams and/or reservoirs. Also pond fisheries, paddy fisheries through the incorporation of ring canals at the periphery of individual fields, and public stocking of canals will be studied and encouraged. If suitable areas can be identified then cage culture projects will be encouraged.

Fill reservoir during wet/rainy season
Reservoir filling should occur during the rainy season to minimize the impact of water shortage downstream, and should not reduce the downstream flow by more than 10%. This applies both to the watercourse on which the reservoir is located, as well as to the watercourse serving as the source of the impounded water (if the two watercourses are different).

F. INSTITUTIONAL REQUIREMENTS AND ENVIRONMENTAL MONITORING PROGRAM

5. This section should describe the institutional capability (both hardware and software needs) and the monitoring or surveillance program and submission of progress reports.

Monitoring Requirements
Information about the following potential monitoring requirements associated with potential impacts is required to conduct the assessment.

Monitor spawning habitat and fish yields
Monitor the area of spawning ground available to fish before and after the project. Also monitor the fish yields from the reservoir which would give an approximate idea of the fish population in the water.

Sample water quality parameters (DO, temp)
Sample the temperature of the receiving waters upstream, at the discharge point, and at several points downstream (location to be determined by the results from thermal plume modeling). Sample the water at 1 m depth for standard water quality parameters, as well as for microorganisms (zooplankton, phytoplankton). Sample the water downstream, if used for agriculture, for DO levels. Also, take sediment samples of the benthic community to monitor any changes in species composition or abundance.

Monitor river flow below impoundment
Monitor the flow rate of the watercourse below the reservoir (and below the diversion for filling the reservoir, if this is happening on a different watercourse) and compare the data to the flow rates in that watercourse prior to the impoundment.

G. FINDINGS AND RECOMMENDATIONS (1 or 2 pages)

6. This section should include an evaluation of the screening process and recommendations should be provided whether significant environmental impacts exist needing further detailed study or EIA. If further additional study is needed, then this section will include a brief terms of reference (TOR) for the needed follow-up EIA, including approximate descriptions of the work tasks, professional skills required, time required, and estimated cost.

H. CONCLUSIONS (½ page)

7. This section should discuss the result of the IEE and justification, if any, of the need for additional study or EIA.

PERSONS RESPONSIBLE

These terms of reference report was prepared by:
Name: *John Doe*
Title: *Environmental Specialist*
Agency/Division: *Consultant*
Telephone: *555-1234*
Fax: *555-1233*
Signature:
Date:

Name: *Jane Ray*
Title: *Project Manager*
Agency/Division: *International Power Inc.*
Telephone: *555-2345*
Fax: *555-3456*
Signature:
Date:

8.4.8 Output Databases

The results of the screening, scoping, assessment, review, and define appropriate conditions for mitigation and monitoring are stored in output databases. The user has direct access to report files which can be imported in third party word processing packages. In addition, all the information entered by the user, and record of all the EIA tasks performed to date is stored in a project file. The user can easily load previous work and complete or revise an EIA.

Table 8-6: Component hierarchy used in the ADB expert system.

Physical Resources

Atmosphere
air quality
micro-meteorology
climate

Groundwater
aquifers
wells
groundwater springs

Surface Water
canals
estuaries
lakes/reservoirs
marine waters
rivers
streams

Hydrology
hydrological regime

Land Resources
aquifer recharge areas
aggregate resources
floodplains
barren land
coastline/shoreline
geology/seismology
landforms/topography
mineral resources
soil
river beds
river banks

Ecological Resources

Aquatic Flora
emergent vegetation
free floating-vegetation
submerged vegetation

Aquatic Fauna
aquatic mammals
aquatic birds
aquatic reptiles/amphibians
aquatic invertebrates
benthic organisms
fish

Terrestrial Flora
crops
grasses/herbs/ferns
lichens/moss
shrubs
trees

Terrestrial Fauna
terrestrial mammals
terrestrial birds
terrestrial reptiles/amphibians
terrestrial invertebrates

Ecosystems
freshwater ecosystem
marine ecosystem
terrestrial ecosystem
wetland

Socio-Economic Resources

Land Use
agricultural land use
aquaculture land use
commercial land use
forestry land use
industrial land use
institutional land use
mining land use
recreational land use
residential land use
transportation land use
buffer zone
native land
planned development areas
parks and sanctuaries
potential mining areas

Built Environment
dams
dikes
bridges
buildings
communication structure
marine structures
transmission structure
hydro power facility
flood control system
oil/gas lines
electricity lines
telephone lines
roads/railways
sewerage system
trails
waste disposal sites
water supply system
water intake structure
infrastructure

Services
communication services
water supply
education
electricity
emergency response
firefighting
flood control/drainage
gas
general social services
government
green space
health services
irrigation water
law enforcement
mass transit
navigation
provision of goods and services
sewage treatment
solid waste disposal

Table 8-6: (continued).

Economy	Human interests/values	
employment	aesthetics	commercial resource users
inflation and property value	businesses	recreational resource users
local tax revenues	community structure	traditional resource users
personal income	family structure	current resource users
business income	social well-being	farmers
regional income	human health	religious groups
distribution of income	human safety	special status groups
regional economic activity	mobility	people
standard of living	archeological feature	population distribution
	religious features/cemeteries	local residents
	traditional/historic/cultural features	land owners
	tradition and culture	land prices/value
	artists/artisans	personal property
	commuters	water resource users
	developers	workers

8.5 References and Further Reading

Beanlands, G.A. 1994. The Application of Expert Systems to Environmental Impact Assessment. Annotated Bibliography. GEBEC Consultants, Halifax.

Bielawski, L. and R. Lewand. 1991. Intelligent Systems Design. John Wiley & Sons, Inc.: Toronto. 302 pp.

Carter, R. 1995. Review of EIAMAN Program Version 1.0. Report Prepared for Asian Development Bank, Manila. 32pp.

ESSA Technologies Ltd. 1996. RETA 5544: Development of Computerized EIA Systems, Final Report. Submitted to Asian Development Bank by ESSA Technologies Ltd. Vancouver, BC. 23p, and appendices.

Fedra, K. 1991. A computer based approach to environmental impact assessment. In: A.G. Colombo and G. Permazzi (eds.). Proceedings of the Workshop in Indicators and Indices for Environmental Impact Assessment and Risk Analysis, pp. 11 - 40.

Finn, G.A. 1989. Applications of expert systems in the process industry. In: G.G. Patry and D. Chapman (eds.). Dynamic Modeling and Expert Systems in Wastewater Engineering. Lewis Publishers, Inc. Chelsea, MI. Chapter 6, pp. 167-192.

Geraghty, P.J. 1993. Environmental assessment and the application of expert systems: an overview. J. Environ. Manage. 39: 37-38.

Gray, A. and P. Stokoe. 1988. Knowledge-based on Expert Systems and Decision Support Tools for Environmental Assessment and Management: Their Potential and Limitations. School for Resource and Environmental Studies. Dalhousie University, Halifax, Nova Scotia.

Hushon, J.M. 1990. Overview of environmental expert systems. In: J.M Hushon (ed.) Expert Systems for Environmental Applications. American Chemical Society.

Loehle, C. and R. Osteen. 1990. IMPACT: An expert system for environmental impact assessment. AI Applications in Resource Management 4: 35-43.

Page, B. 1989. An Analysis of Environmental Expert System Applications with Special Emphasis on Canada and the Federal Republic of Germany. Bericht Nr. 144/89, Fachberiech Informatik, Universitat Hamburg. Hamburg, Federal Republic of Germany.

Table of Contents

9.0 Environmental Monitoring Program

Environmental monitoring provides feedback about the actual environmental impacts of a project. Monitoring results help judge the success of mitigation measures in protecting the environment. They are also used to ensure compliance with environmental standards, and to facilitate any needed project design or operational changes.

The importance of monitoring can be illustrated by using a hypothetical example of a wastewater treatment plant. The plant may have been built according to the Environmental Management Plan specified in the Environmental Impact Assessment (EIA). However, due to lack of funds, bad management, or insufficient skills, the plant is functioning poorly. Without monitoring, the impacts caused by the poor functioning could continue indefinitely. With monitoring (and response by the appropriate regulatory agency), the problems can be recognized and resolved. For example, assume that the wastewater treatment plant described above is operating as originally planned. The receiving body of water, for instance a river, was assumed to have sufficient capacity to assimilate wastewater that had received only primary treatment. If, however, a large amount of water is abstracted upstream of the wastewater treatment plant, the assimilative capacity of the river will be reduced. The monitoring program would show the water quality had deteriorated and that secondary treatment was required. (This situation could be avoided by proper regional environmental planning.)

A monitoring program, backed up by powers to ensure corrective action when the monitoring results show it necessary, is a proven way to ensure effective implementation of mitigation measures. By tracking a project's actual impacts, monitoring reduces the environmental risks associated with that project, and allows for project modifications to be made where required. An excellent example of an effective monitoring program is the irrigation component of the Tarim Basin Project in the PRC. Previous irrigation facilities in the area did not include appropriate drainage, and severe soil salinization occurred, resulting in large reductions in crop yields. The Tarim Basin Project, which was initiated in 1992, provides adequate drainage to prevent additional salinization, and to reverse some of the damage already done. The need to obtain firm data on the extent of the problem during project operation was recognized. A detailed, continuing monitoring program to evaluate the actual project impacts, and to initiate research and development work to optimize the irrigation techniques, was specified in the EIA.

9.1 Implementing an Environmental Monitoring Program

9.1.1 Environmental Monitoring Defined

In general, environmental monitoring programs will collect data for one or more of the following purposes (Everitt, 1992):

1. to establish a baseline; that is, gathering information on the basic site characteristics prior to development or to establish current conditions;
2. to establish long term trends in natural unperturbed systems to establish natural baselines;
3. to estimate inherent variation within the environment, which can be compared with the variation observed in another specific area;
4. to make comparisons between different situations (for example, pre-development and post development; upstream and downstream; at different distances from a source) to detect changes; and
5. to make comparisons against a standard or target level.

Compliance Monitoring

Compliance monitoring is a commonly practiced form of environmental monitoring. The purpose of compliance monitoring is to ensure that the quality or quantity of an environmental component is not altered by a human activity beyond a specified standard of regulation level. An example of compliance monitoring is a sampling program conducted by either industry or government to ensure that concentrations of a contaminant do not exceed a specified level either in the effluent or in the receiving waters. Implicit in compliance monitoring is the assumption that if the characteristic being monitored is within acceptable limits, then the effects will be within acceptable limits. *Compliance monitoring is not concerned with determining actual effects.*

Environmental Effects Monitoring

When the objectives of the monitoring program require that actual effects be determined, environmental effects monitoring is required.

Environmental effects monitoring has been defined as the repetitive measurement of environmental parameters to test specific hypotheses of the effects of human activity on the environment (LGL Ltd. et al 1984). Conover (1985) added to this definition the notion that environmental monitoring measures changes for the purpose of establishing cause-effect relationships. This manual adopts the following definition of environmental monitoring:

> *Environmental effects monitoring is the repetitive and systematic measurement of the characteristics of environmental components to test specific hypotheses of the effects of human activity on the environment. Environmental monitoring is undertaken primarily to determine the environmental effects of human activities, and secondarily to increase understanding of cause-effect relationships between human activity and environmental change.*

The implications of this definition are that:

1. environmental monitoring programs should involve repetitive sampling over a number of years;
2. environmental monitoring programs should be scientifically rigorous and be based on testable hypotheses;
3. sampling programs designed to test the hypotheses should be such that the results may be used to detect temporal trends and/or spatial differences; and
4. environmental monitoring programs should attempt to establish empirical links between human activities and their effects on the environment.

Environmental Effects Monitoring in Environmental Impact Assessment

Environmental effects monitoring programs provide the necessary information to:

1. verify the accuracy of EIA predictions; and
2. determine the effectiveness of measures to mitigate adverse effects of projects on the environment.

Feedback from environmental monitoring programs may be used to:

1. determine whether more or less stringent mitigation measures are needed; and
2. improve the predictive capability of EIAs.

Improving the Predictive Capability of Environmental Impact Assessments

In recent years, the effectiveness of EIA studies has come under serious challenge, and repeated calls have been made for a new, more scientifically sound approach to forecasting environmental effects. Unfortunately, despite the large number of impact predictions that have been formulated, few attempts have been made to test previous predictions (Marmorek et al., 1986; Munro et al., 1986; Bernard et al., 1989). As a result, many inaccurate predictions are probably being propagated in ongoing EIA processes.

Environmental monitoring programs capable of detecting environmental effects are essential if we are to learn from experience. In addition to enhancing the predictive capability for assessing potential effects, information generated from environmental monitoring programs can benefit future EIA activities by providing for better monitoring plans.

Assessing the Effectiveness of Mitigation Measures

Without monitoring there is no mechanism for evaluating the success of the mitigation measures undertaken. Environmental monitoring provides important information that allows for more effective planning and an adaptive response based on an assessment of the effectiveness of mitigation measures. Normally a number of environmental operating conditions are laid down upon granting of project approval. These, along with any conditions set out in permits and licences, become part of the overall environmental management regime for the project.

Environmental monitoring is required to assess whether the various mitigation measures are effective in attaining the goals of environmental protection. Without an environmental monitoring program, it is not possible to determine whether the environment is being protected or not. The absence of such a program also leaves the EIA process without a mechanism for evaluating its performance against its goals. Environmental monitoring can help to:

1. describe the extent of environmental effects and resource losses;
2. provide scientific information about the response of an ecosystem to a given set of human activities and mitigation measures; and
3. provide data for use as a part of environmental auditing of environmental management practices.

9.1.2 Monitoring Program in the EIA Methodology

Environmental monitoring must be an integral part of all phases of the project cycle. By providing information about the current status of our environment, environmental monitoring programs provide information feedback on the actual effects of human activities on the environment, and of the effectiveness of prescribed mitigation measures to protect the environment. This feedback is essential to ensure that those who plan development and those who manage environmental resources are supplied with information upon which to base their decisions and follow up activities (Everitt, 1992). This is critical if we are to learn from one project to the next. Information generated from environmental monitoring will increase the scientific understanding of environmental impacts, thereby permitting increasingly better EIA of future projects.

The role of environmental monitoring programs in EIA can be seen by examining the three major information feedback loops they provide (Figure 9-1):

1. *Within project corrections (loop 1-2-3-1)*. Mitigation measures are implemented as specified by project planning and the EIA. These measures, together with the project activities, lead to actual effects (Figure 9-1: link 1). Environmental monitoring provides information on the actual effects (link 2), which can be used by management to modify how they execute the project (link 3). Information through this loop continues because adjustments to project management can lead to new environmental effects.

2. *EIA process helps monitoring design which in turn provides information to the EIA process (loop 4-5-6-7)*. Scoping and analysis of issues in the early stages of the EIA process helps define the monitoring program plan (Figure 9-1: link 4), and then, the monitoring program (for example, baseline monitoring) (link 5). Initial monitoring data guides the impact assessment (link 6), which in turn can be used to revise the monitoring program (link 7).

3. *Environmental monitoring programs provide information for follow up activities (loop 8-9)*. Environmental monitoring data provides the information upon which environmental follow-up programs can evaluate the success of mitigation measures and determine the accuracy of impact predictions (Figure 9-1: link 8). Once the evaluation is complete this information will lead to better design of mitigation measures, more effective EIA procedures, increased predictive capability, and improved monitoring programs for future projects (link 9).

9.1.3 Objectives of Project Based Environmental Monitoring Programs

Two phases of monitoring are undertaken. The first is baseline monitoring (or surveys), which takes place during the EIA phase (or earlier). Baseline monitoring records the status of the environment prior to project implementation. Requirements for baseline data are normally outlined in the terms of reference for the EIA. The second stage, which is the focus of this chapter, is monitoring undertaken in the project design, construction, and operation stages.

Both compliance and environmental effects monitoring are required. The objectives of project-based monitoring programs are to: 1) ensure compliance with the mitigation measures (including off-setting and enhancement measures) identified in the EIA; and 2) determine the project’s actual environmental impacts so that modifications can be made to the project or the project’s mitigation measures, if necessary (Asian Development Bank, 1994). Most monitoring is directed towards these objectives.

The goal of the environmental management plan is to ensure that all necessary corrective actions, both mitigative and off-setting, are carried out to counter any adverse environmental impacts, and that enhancement measures are used where feasible and practical. One of the goals of the monitoring program is to actually observe and analyze the project’s impacts, thereby providing information to help in re-designing mitigation measures to reduce the risks associated with a project.

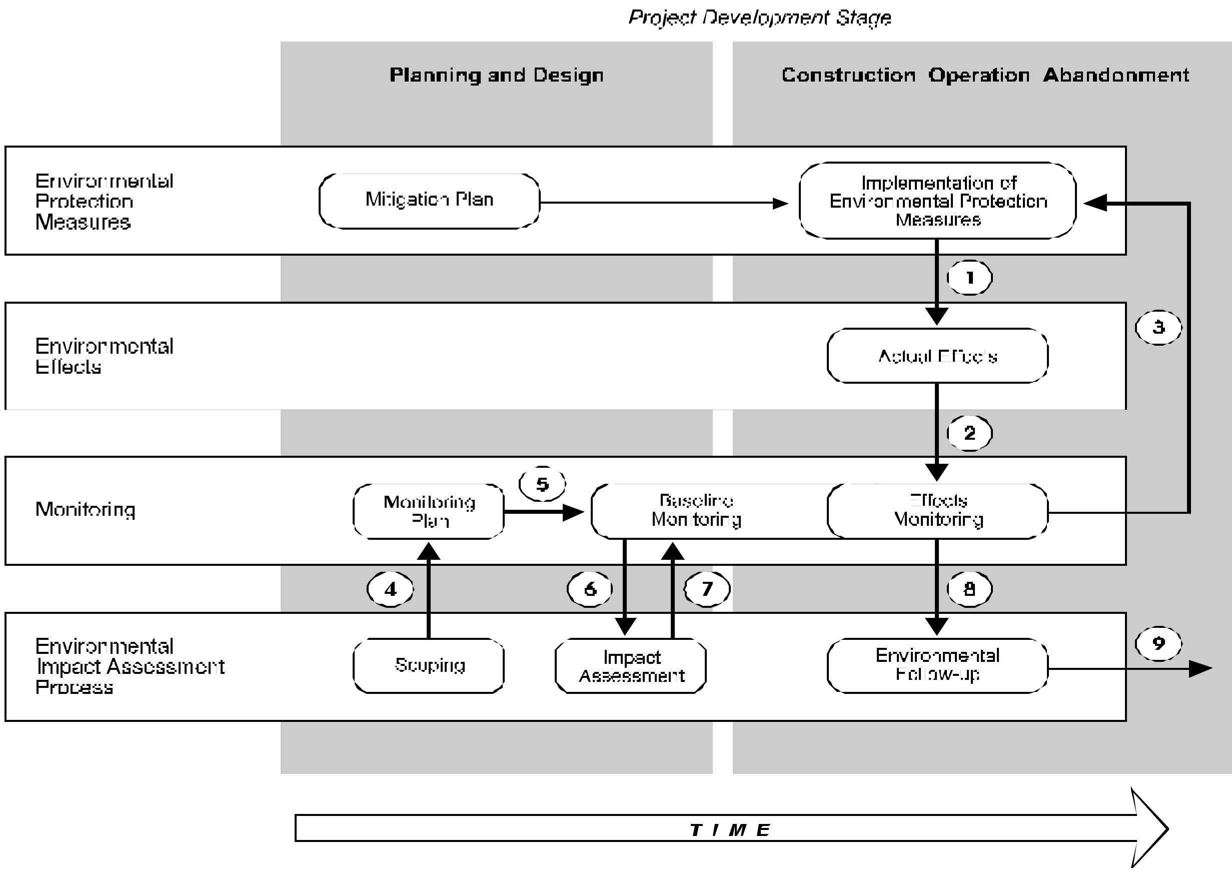


Figure 9-1: Monitoring provides important information feedback for more effective planning for environmental protection (*source:* Everitt, 1992).

Compliance and effects monitoring occurs during the project construction, operation, and abandonment stages. The resources and institutional set-up should be available for the monitoring at these stages. All large-scale construction projects will require some construction stage monitoring. To control the environmental hazards of construction as specified in the EIA, a monitoring program should be established to ensure that each mitigation measure is effectively implemented. There are numerous potential areas for monitoring during operations.

Two questions must be asked regarding each mitigation measure: 1) is it necessary to include monitoring provisions to ensure that the mitigation measure will be successfully implemented (constructed and operated) as outlined in the EIA; and 2) is there a chance that the actual impacts will be different from the predicted impacts, and are the associated risks great enough to warrant a monitoring program to track the actual impacts and make modifications to the project if required? If the answer to either of these questions is yes, then a monitoring program for the mitigation measures needs to be developed.

Institutional Requirements

In addition to devising a monitoring program, it is also necessary to work out a plan for its implementation. This includes assigning institutional responsibility, reporting requirements, enforcement capability, and ensuring that adequate resources, in terms of staffing and skills, equipment, training, and budget, are provided. A monitoring program that does not have a management component will have little chance of success. Often an environmental management office (see Chapter 10) must be included in the overall project management structure. The organization responsible for monitoring must have sufficient staffing and skills, training, equipment, and funds to carry out the required monitoring tasks.

9.1.4 Cost Justification for Monitoring

The EIA report should show clearly how the recommended monitoring will enhance, rather than detract from, the project's economic and environmental objectives. The proposed monitoring program should include its own benefit/cost analysis to ensure the monitoring program will bear critical scrutiny whenever cost-sensitive project review officials evaluate the program.

A monitoring program should be the least cost alternative to achieve the stated monitoring objectives, and should be included in the core project funding. It is crucial to include the monitoring program budget in the project core budget. Experience has shown that it is extremely difficult to go back and obtain more funds for monitoring after the core budget has been approved. Most developing country EIAs in the past did not arrange for such funding, and in most cases, the recommended and approved monitoring was not implemented.

9.1.5 Reporting and Enforcement Capability

Should the data analyses indicate that corrective actions are needed, information collected through the monitoring program must be transmitted to an organization that has the power to take appropriate action. The institutional arrangements for monitoring, including who should receive the results and analysis, and who is responsible for taking corrective actions, should be specified in the EIA. Enforcement capability implies that some government organization has the power to compel the implementing organization to abide by the terms of the original project agreement. This usually implies either legal or financial power. Since it is often difficult to obtain legal power to enforce the conditions in the EIA, it may be more effective to apply financial pressure. For example, if the resettlement program for a reservoir project was not proceeding as outlined in the EIA, further funding for the construction of the dam could be withheld until compliance was achieved.

9.1.6 Monitoring Requirements For Effective Pollution Control

Environmental monitoring is absolutely essential to the success of any program aimed at controlling environmental degradation, including environmental pollution control. Four elements are needed to achieve effective control: 1) appropriate environmental standards; 2) enforceable legislation and regulations; 3) enforcement capability; and 4) adequate monitoring to obtain the data required by the regulatory agency to enforce the regulations in the courts. Without monitoring there can be no awareness of noncompliance.

Most developing countries have enacted pollution control regulations, but lack the monitoring capabilities necessary to enforce them consistently. Some developing countries have carried out pilot monitoring projects, mostly in the fields of water and air pollution control. The programs have been sponsored by various international assistance agencies and implemented by the national environmental protection agencies. Designed to demonstrate proper use of monitoring, and to train staff in appropriate environmental monitoring technologies, the intent of these pilot monitoring projects was that they would be followed up by continued monitoring financed locally. Most of the projects have been unsuccessful because the sponsors and developing countries alike did not realize the complexities of planning and conducting a meaningful environmental monitoring program. To be sustainable, a national environmental monitoring program requires a sound foundation of technical, institutional, economic, and financial structures.

9.2 Designing Environmental Monitoring Programs

There are many institutional, scientific, and fiscal issues that must be addressed in the implementation of an environmental monitoring program. Careful consideration of these issues in the design and planning stages will help avoid many of the pitfalls associated with environmental monitoring programs. Completion of the following tasks will lead to an effective environmental monitoring program.

9.2.1 Analysis of Significant Environmental Issues

At the outset of planning for an environmental monitoring program, the manager of the program may not know exactly what should be monitored, when monitoring should begin, where it should occur, which techniques should be employed, and who should take responsibility for its conduct. Because there are usually a number of subjective decisions to be made, it is important to start with an analysis of environmental issues. The scoping phase of EIA is designed to identify and focus the major issues. Scoping should provide a valuable source of information on the concerns that need to be addressed by the monitoring program (see Chapter 11). Practical experience with environmental monitoring programs in developed countries shows there is a wide range of public and professional concerns that are industry specific. Broad participation by a range of interests will likely be required. Stakeholders that should be considered include government environmental and regulatory agencies, environmental interest groups, local communities, industry, and the professional community (Everitt, 1992).

9.2.2 Formulation of Specific Objectives

It is often necessary to formulate broad objectives for an environmental monitoring program. For example, suppose the objective is to protect the environmental quality of an estuary but most of the concerns relate to a fishery, fish populations and fish habitat that may be affected by effluent from an industrial outfall. In the design of the monitoring program more specific objectives must be developed. For example, the:

General Objective: *to protect the environmental quality in the estuary*

could lead to the:

Specific Objectives: *to determine amount of degradation of fish habitat associated with the industrial effluent;*

to determine population trends in fish populations; and

to determine losses to the fishery.

9.2.3 Formulation of Specific Questions — Defining Assessment Endpoints

Effects monitoring programs work best when the scientific method guides data collection, analysis, and interpretation. Formal hypotheses of the effects of a project help link the subjective issues and objectives to the more objective field sampling and data analyses. Prior to defining a hypothesis, a question to be answered must be formulated. The answers to these questions are the assessment endpoints. Assessment endpoints are information a decision or policy maker might wish to know about the status of valued environmental components (VECs).

Environmental monitoring programs collect data on *environmental indicators*, to provide information for the evaluation of *assessment endpoints*, which reflect *environmental values* (Figure 9-2).

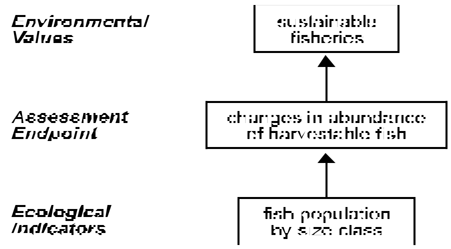


Figure 9-2: The relationship between environmental values, assessment endpoints and environmental indicators in environmental monitoring (*source:* Everitt, 1992).

Environmental values are the qualities or quantities we desire in our environment. The environmental values are what we ultimately are trying to protect, or are striving for, with respect to the environment. Examples of environmental values are contaminant-free fish, or sustainable fisheries.

Environmental monitoring programs must have clearly defined assessment endpoints. Assessment endpoints are expressions of the environmental values that are to be protected (Suter, 1990). An assessment endpoint is generally the answer to a question regarding the environment effects that was posed at the beginning of the environmental monitoring programs. If the question was embodied in a formal hypothesis, the assessment endpoint is the rejection or acceptance of the hypothesis. Without assessment endpoints, environmental monitoring programs may be terminated prematurely or be continued longer than necessary.

Assessments often fail because the endpoints lack unambiguous operational definition. A complete operational definition of an assessment endpoint requires a subject (for example, a rare and endangered species) and a characteristic of the subject (local extinction or percentage reduction in range) (Suter, 1990).

The choice of VECs is related to the perceived significance of the environmental components (Everitt, 1987). In general, the significance or importance of environmental components may be based on: 1) legal status (for example, rare and endangered species); 2) political or public concerns (for example, resource use conflicts); 3) scientific judgement (for example, ecological importance); or 4) commercial or economic importance. In addition to their economic, social, political or ecological significance, chosen components should: 1) have unambiguous operational definition; 2) be accessible to prediction and measurement; and 3) be susceptible to hazard.

In many cases, VECs can be directly measured (for example, extent of habitat for an endangered species), however in other cases, direct measurement is impossible or impractical. The chosen measurement endpoints or environmental indicators must correspond to, or be predictive of assessment endpoints (see box 9-1 and 9-2).

Environmental indicators must be: 1) measurable; 2) appropriate to the scale of disturbance/ contamination; 3) appropriate to the impact mechanism; 4) appropriate to temporal dynamics; 5) diagnostic; and 6) standardized; as well as have: 1) a low natural variability; 2) a broad applicability; and 3) an existing data series.

Box 9-1: Environmental indicators correspond to assessment endpoints.

People wish to be assured that fish is wholesome and free from contamination. This environmental value might be reflected in environmental monitoring programs that determined assessment endpoints that show that the body burdens of chemical *x* in fish increased after an industrial plant became operational, or that fish harvests (consumption) did not decrease despite the discoloration of fish flesh from accumulation of chemical *x*.

Environmental indicators corresponding with these assessment endpoints are the concentration of chemical *x* in a sample of fish, and the size class structure of the population of fish that have accumulated chemical *x*.

For example, key questions associated with the objectives defined above might be:

1. *will or has fish habitat in the estuary been degraded as a result of the human activity?;*
2. *are fish populations declining, increasing, or stable?*
3. *are current levels of fish harvests sustaining the local fishery?*

The VECs in the key questions are fish habitat, fish populations, and fish harvests.

Box 9-2: Criteria for Choosing VECs for Assessment Endpoints.

The following criteria are useful when choosing assessment endpoints:

- predictable and measurable
- legal, political, economic, ecological relevance
- unambiguous operational definition
- sensitive to human activity

Box 9-3: Monitoring programs require specific objectives, specific questions, valued environmental components and environmental indicators.

Suppose the objective is to protect the environmental quality of an estuary but most of the concerns relate to a fishery, fish populations and fish habitat that may be affected by effluent from an industrial outfall.

General Objective:

- *to protect the environmental quality in the estuary*

Specific Objectives:

- *to determine the amount of degradation of fish habitat associated with the effluent*
- *to determine population trends in fish populations*
- *to determine losses to the fishery*

Valued Environmental Components

- *fish habitat*
- *fish populations*
- *fish harvests*

Specific Questions – Assessment Endpoints

1. *will, or, has fish habitat in the estuary been degraded as a result of the human activity?*
2. *are fish populations declining, increasing, or stable?*
3. *are current levels of fish harvests sustaining the local fishery?*

Environmental Indicators

1. *fish population by size class;* and
2. *area of contaminated fish habitat.*

9.2.4 Construct Simple Conceptual Models of Impact

It is desirable to have simple conceptual models of the mechanisms by which impact might occur. In addition to being useful in determining which variables to monitor, these models are extremely valuable in communicating the rationale for monitoring. One of the best ways to represent a conceptual model is with an impact hypothesis (see Chapter 4). An impact hypothesis is simply a statement of our understanding of the mechanism of the potential effect of the particular activity. Mechanisms of effect can be physically, ecologically, physiologically, and behaviorally based. For example, the three questions above can be embodied within an impact hypothesis that incorporates the environmental components: the fishery, fish, and fish habitat (Figure 9-3).

The hypothesis exemplified in Figure 9-3 describes the cumulative effects through time of industrial effluent on fish harvesting. An elaboration of the hypothesis in Figure 9-3 that would exemplify a spatially cumulative effects hypothesis would be inclusion of the effects of other human activities (for example, fishing pressure, erosion from forestry activities, and acidic precipitation) on fish harvesting. In practice such multi-activity hypotheses are not testable as a whole, but need to be disaggregated into component activities. An example of a hypothesis of an immediate and direct effect drawn from Figure 9-3 could be the effects of industrial effluent on bottom substrate.

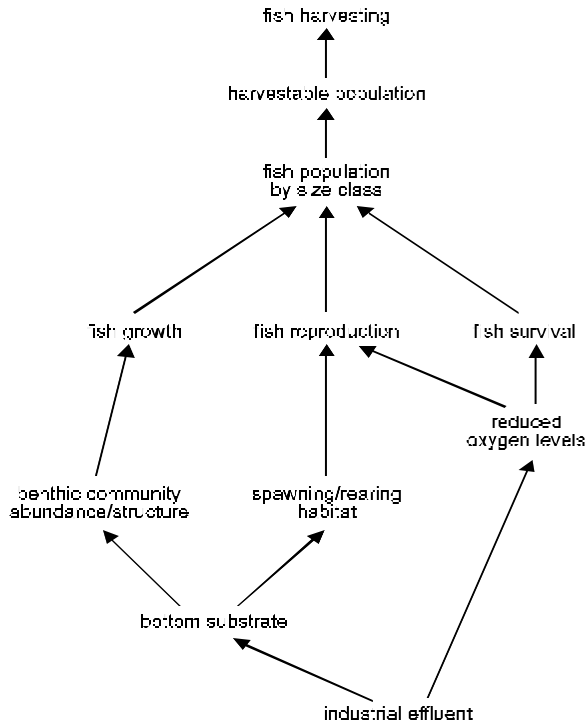


Figure 9-3: Example impact hypothesis of the cumulative effects through time of industrial effluent on fish harvesting (*source:* Everitt, 1992).

9.2.5 Selecting Environmental Indicators

After the impact hypothesis is defined, monitoring effort can be concentrated on the specific environmental indicators of impact. It is necessary that the indicators chosen be relevant to the impact mechanisms, be indicative of the VECs of interest, be measurable, and be appropriate to the spatial and temporal scale of disturbance/contamination (see Box 9-4). Where possible, standardized indicators with existing data series should be chosen. Other desirable characteristics of environmental indicators include: 1) low natural variability; 2) broad applicability; 3) being diagnostic with respect to the potential cause.

Two environmental indicators relevant to our example are:

1. *fish population by size class;* and
2. *area of contaminated fish habitat.*

The complexity of most ecosystems makes it impractical to measure environmental indicators corresponding to all the desired VECs. A smaller, more manageable set of environmental indicators must be chosen. In selecting indicators it is desirable to identify those which reflect the response of other indicators. This form of correlation amongst the responses of indicators can expedite effects evaluation in environmental monitoring because the response of one indicator can be taken as being representative of the response of other indicators. For example, if a particular color of fish flesh is specific to chemical X, then fish color observation alone, instead of time and resource consuming tissue residue analyses, could be used as the indicator of chemical accumulation in fish. However, in most cases the development of multiple lines of evidence of effects is still necessary in environmental monitoring (Cairns, 1990).

Box 9-4: Criteria for Selecting Environmental Indicators.

The following criteria are useful in selecting environmental indicators:

- measurable
- indicative of VEC
- sensitive to VEC
- standardized
- appropriate to the scale of disturbance/pollution
- low natural variability
- appropriate to the impact mechanism
- broad applicability
- appropriate to temporal dynamics
- existing data series
- diagnostic with respect to the potential cause

9.2.6 Establish an Information Management System

An information system for receiving, storing, retrieving, manipulating and disseminating data must be in place in the monitoring program. Because monitoring requires that repetitive measurements be made, the information management system needs to be capable of processing time series data for reports based on the analytical framework required for interpreting monitoring results. In the absence of existing data collection programs, baseline data will have to be collected as part of the initial stages of the environmental monitoring program.

Define Data Analyses Prior to Data Collection

The data analyses to be conducted are dictated by the objectives of the environmental monitoring program. The statistical methods used to analyze the data should be described in detail prior to data collection. These methods should be chosen so that uncertainty or error estimates in the data can be quantified. Example statistical methods useful in an environmental monitoring program include: 1) frequency distribution analysis; 2) analysis of variance; 3) analysis of covariance; 4) cluster analysis; 5) multiple regression analysis; 6) principal components analysis; 7) time series analysis; and 8) the application of dynamic systems models (Green, 1979).

Reporting

A critical component of environmental monitoring is the reporting phase. A report that documents the environmental monitoring from rationale to results and interpretations must be prepared. It should include recommendations, where appropriate, for more or less stringent mitigation measures, or improvements in the effectiveness of EIA procedures. In addition to documenting present environmental monitoring, information in the environmental monitoring report is also used to assist in the development of future environmental monitoring programs.

9.2.7 Development of a Rigorous Sampling Design

There is a need for more consistent, systematic, and statistically valid approaches to sampling. Green (1987) provides a set of guidelines for statistical design in research and monitoring:

1. Clearly formulate the question. Rephrase as a null hypothesis (see also Box 5-4) and an alternative hypothesis.
2. There should be a control. If it is an observational study over space and time, try to have both a spatial and temporal control (reference site).
3. Have replicate samples within treatments, areas, etc.
4. There should be a balanced (equal) and random (or at least unbiased) allocation of samples with respect to the variables of interest (see #8).
5. Do some preliminary sampling (a pilot study) so that steps 6-9 can be done.
6. Evaluate the sampling method for consistency (lack of bias) over the entire universe that will be sampled.
7. Estimate necessary sample number (or adequacy of feasible sample number), and optimum sample unit size.
8. If there is a large scale spatial pattern, consider a stratified sampling design. To estimate spatial distribution allocate samples evenly over the area; to estimate abundance allocate samples proportional to estimated abundance.
9. Decide how to handle problems in data: transform it? use nonparametric statistics? use simulation, randomization or jackknife? use sequential sampling? apply corrections for bias?
10. Stick with the results (that is, let the hypotheses be falsifiable).

Formulate Statistical Hypotheses

Statistical hypotheses (see Box 9-5) will have to be formulated as a part of the statistical design of the data analyses.

Box 9-5: Example statistical hypotheses.

Hypothesis 1:

Ho: Fish habitat in the effluent-exposed area is as productive as non-exposed area.
Ha: Fish habitat in the effluent-exposed area is not as productive as non-exposed area.

Hypothesis 2:

Ho: There is no change in the fish community in the effluent-exposed area.
Ha: The fish community in the effluent-exposed area has changed since effluent discharge began.

Hypothesis 1 implies that sampling will have to be stratified spatially; Hypothesis 2 implies that time series information will be required.

9.2.8 Establish Rigorous Quality Assurance Quality and Quality Control

The accuracy and precision of data generated by a monitoring program can only be assessed if a good quality assurance and quality control program is in place. The objectives of the quality assurance and control programs are to:

1. generate quality analytical data using standardized and accepted sampling techniques;
2. capture natural spatial and temporal variability in environmental indicators;
3. be sensitive to sampling and analytic error;
4. be sensitive to sample contamination, and to extreme values due to natural or special source conditions;
5. ensure complete documentation and defensibility of all data; and
6. expedite data evaluation and acceptance.

A successful environmental monitoring program requires field and laboratory staff trained in sample collection and sample processing procedures. If appropriately trained staff are not available, the available staff should be sent to a commercial or government laboratory for detailed instruction in the methods required. Specific protocols for: 1) sample collection and storage; 2) sample shipments; and 3) testing laboratories should be provided in the overall design.

9.2.9 Prepare a Cost Estimate for the Entire Monitoring Program

There are at least six major cost elements associated with monitoring programs (in addition to overall administration and coordination costs):

1. program design costs;
2. field sampling programs;
3. laboratory analyses;
4. operation and maintenance costs associated with information management;
5. quantitative analysis and reporting; and
6. communication and liaison.

A cost estimate for each of these program elements should be provided in detail at the outset of the monitoring program.

9.2.10 Periodic Program Review

The environmental monitoring program must continue through time as prescribed by the objectives and endpoints of the program. Explicit in an environmental monitoring program is periodic program review to ensure that the data being collected and the information being provided to decision makers is still relevant, and of maximum utility. Systematic review of the program will allow for new scientific understanding to be incorporated into the program, conceivably leading to additions, deletions, and modifications to impact hypotheses and to the sampling programs.

9.3 Examples of Monitoring from Developing Country EIAs

Samut Prakarn Wastewater Management Project, Thailand

This Asian Development Bank funded project has a long history — dating back to the early 1980s — of planning and environmental analysis. Initially the concept was to build an industrial pollution control facility for a relatively small area of high density industrial development in Samut Prakarn, south of Bangkok (see Chapter 16 in the case studies volume for a more detailed review of this project). Environmental analysis took place over the period from the early 1980s until the project was approved in 1985. Decisions on the need to invest in the project and on the scope of the project were based on two main sources of information: 1) monitoring by the Thai government which indicated continuing environmental degradation, and 2) a periodic review of the alternative approaches to dealing with the water pollution problem. A technical assistance study determined that both a cost comparison and an environmental comparison of the alternative approaches to wastewater management were needed.

The EIA consisted of a two-staged approach. An initial environmental examination (IEE) was used to evaluate thirteen options (including a no-action option) for wastewater management. The IEE results were combined with the results of the cost comparison to identify the optimum approach to wastewater management. The preferred alternative is two large centralized collection and treatment schemes, servicing industry as well as community or domestic wastewater. The IEE also outlined the detailed analysis required for the highest priority alternative. A subsequent EIA of this alternative was undertaken as a part of the feasibility study.

As a follow-up to this EIA, an environmental monitoring program with the following two objectives was designed:

- to monitor changes in key environmental elements so any long-term adverse impacts caused by project interventions can be predicted in a cost-efficient and timely manner; and
- to provide a tool for decision-making on whether any project modifications or mitigation of adverse impacts are necessary.

Monitoring programs included:

1. unit operations and processes, of the collection, transfer, treatment and disposal facilities of the project, and their relevant health and safety features.
2. beneficiaries, including industries, commercial establishments and households. Apart from gathering data that are necessary for assessment of impacts on communities and beneficiaries, this type of monitoring can also help increase awareness of users and enhance the public-relations strength of the project. Whether the project achieves overall environmental improvement benefits will depend largely on the attitudes and awareness of beneficiaries.
3. Chao Phraya and khlong water quality. The current Pollution Control Division monitoring program is sound in its methodology and approach. Its areal coverage is to be expanded to provide a more meaningful picture of the entire project area.
4. human use values, with a focus on agriculture and both freshwater and brackish/coastal aquaculture. As mentioned above, concerned relevant sector agencies could participate in the monitoring program, perhaps with minor modifications to their current effort.
5. special ecosystems, with a focus on the mangrove forest areas, the marine environment and the Bang Krachao area.

Tarim River Basin Comprehensive Water Resources Development Project

The Tarim project, including a detailed EIA, was completed in 1991 under the direction of the Xinjiang Provincial Water Conservancy Bureau (Gunaratnam, 1992). The monitoring program specified in the EIA for comprehensive water resource development in the Tarim River Basin of Xinjiang Province, northwestern PRC, includes all parameters relating to irrigation, drainage, land reclamation, and regreening for anti-desertification (Table 9-1). Full scale monitoring was initiated in 1992. Financing for monitoring was included in the project loan.

A primary goal of the project was to increase the area under irrigation. The danger of salinization due to improper application of water and insufficient drainage was addressed in the EIA, however the factors affecting the actual extent of salinization are extremely complicated and could not be assessed until irrigation actually began. The project hence included a monitoring program to determine the extent of salinization and to take corrective actions where necessary as part of the environmental management plan (EMP).

Table 9-1: Monitoring parameters for the Tarim River Basin Project (*source:* Asian Development Bank, 1994).

Resource	Parameter or Unit of Measurement
Socio-economic	
Crop yields	bushels, bales, kilos or output
Animal productivity	kilos produced per year
Family income	income per household per year
Public health	doctor visits per capita specific cases by disease per capita
Status of relocated families	homelessness per capita persons per household
Water Resources	
Water resource balance	groundwater depth surface water levels flow rate
Water distribution to three areas	flow rates through each of the supply canals
Water quality: salinity	total dissolved solids
Ecology	
Effectiveness of regreening program (lower Tarim Basin)	ratio of ground area covered by plants to total surface area
Effects on wetlands	abundance of 4 indicator plant species

Xiaolangdi Dam and Reservoir Comprehensive Water Resources Development Project

The Xiaolangdi Project is a US$1.3 billion project to stop the continuing serious flooding hazards in the Lower Yellow River Basin which is inhabited by 70 million people. In addition, the project has large-scale irrigation and hydro-power components, plus numerous additional components of lesser scale as needed for comprehensive water resources development. These include measures to minimize or offset environmental hazards, and environmental enhancement measures. The project EIA team was converted into the Project's Environmental Management Office, and was given the responsibility to implement and coordinate a comprehensive environmental monitoring plan. Funding is included in the project loan.

The EIA covered all environmental aspects. The assessment singled out four issues of significance: 1) dam stability and safety; 2) resettlement; 3) cultural heritage; and 4) public health. These issues became the focus of the environmental management plan and subsequent monitoring activities. The institutional arrangements for the environmental management plan and environmental management office for the project are described in Chapter 10.

During the pre-construction phase, environmental monitoring involved environmental surveillance and inspection during the preparation of the construction site and monitoring activities related to resettlement. During the construction and operation phase, the monitoring system is designed to: 1) ensure that contractors and operators properly carry out mitigation measures; and 2) evaluate the adequacy of the environmental management plan. Monitoring programs are designed to observe actual effects; and in the event there are unacceptable adverse effects, recommend corrective action.

9.4 Post Audit and Evaluation

Post project evaluation procedures are becoming a more common practice, particularly with International Financial Institutions. For example, after the completion of project construction, the Asian Development Bank sends a review mission to undertake discussions with concerned executing agencies to determine the implementation of environmental mitigation measures earlier agreed upon by both the borrower and the Bank. It is the task of the review mission to verify that environmental safeguards built into the project design are satisfactorily implemented by the borrower/executing agency during the construction and operation of the project. The Asian Development Bank's post-evaluation reports and project performance audit reports include a final assessment of the degree to which the projects satisfied the proposed environmental requirements, the effectiveness of mitigatory measures and institutional development and whether any unanticipated effects occurred as a result of project activities. These reports are often prepared within a year or two of the completion of construction. As such, they cannot identify long term adverse effects or failures in mitigation measures that may occur later in the project's life.

Post audit and evaluation of environmental management plans and monitoring programs provides us with a way to learn from experience. Monitoring results are an important source of information to verify the accuracy of EIA predictions. Systematic evaluation of monitoring results allows EIA practitioners to understand strengths and weaknesses in existing approaches. This understanding will naturally lead to better techniques and approaches to impact assessment. Monitoring information is essential in helping us determine the effectiveness of mitigation measures. Without essential feedback provided by monitoring programs on "what works" and "what does not work," each new project will be designed like the last one. There will be little opportunity to learn from our mistakes and to apply new and better mitigation techniques.

Post evaluation reports like those prepared by the Asian Development Bank are a useful source of information, however, one further step is required. We must ensure that we learn from experience. From time to time, there needs to be a formal and systematic post hoc evaluation of the effectiveness of our environmental protection efforts on development projects. The results need to be gathered together and disseminated, widely and rapidly.

9.5 References and Further Reading

Asian Development Bank.. Forthcoming (draft, May 1994). Asian Development Bank Environmental Impact Assessment Training Program. Office of the Environment, Asian Development Bank.

Bernard, D.P., Donald B. Hunsaker Jr., and D.R. Marmorek. 1989. Tools for improving predictive capabilities of environmental impact assessments: structured hypotheses, audits, and monitoring. Paper prepared for The Scientific Challenges of NEPA: Future Directions Based on 20 Years of Experience. Ninth Oak Ridge National Laboratory Life Sciences Symposium, Knoxville, TN, 24-27 October 1989.

Cairns, J., Jr. 1990. Prediction, validation, monitoring, and mitigation of anthropogenic effects upon natural systems. Environmental Auditor 2(1): 19-25.

Conover, S.A.M. 1985. Environmental effects monitoring and Environment Canada: a synthesis of the findings of four workshops. In: B. Sadler (ed.). Audit and Evaluation in Environmental Assessment and Management: Canadian and International Experience: Volume II Support Studies. Proceedings of the Conference on Follow-up/Audit of EIA Results. Organized by the Environmental Protection Service of Environment Canada and The Banff Centre, School of Management, October 13-15, 1985, pp. 408-434.

Everitt, R.R. 1992. Environmental Effects Monitoring Manual. Prepared for the Federal Environmental Assessment Review Office and Environment Canada, Environmental Assessment Division, Inland Waters Directorate. Ottawa, ON.

Everitt, R.R. 1987. Determining the Scope of Environmental Assessments. Report prepared for the Federal Environmental Assessment Review Office. Vancouver, BC.

Gunaratnam, Daniel, 1992. Engineering-cum-environmentalism: case study of the Tarim River Basin in China. ASEP Newsletter, September 1992.

Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. John Wiley & Sons, New York, NY. 257 pp.

Green, R.H. 1987. The Fundamental Principals of Research and Monitoring Program Design in Relation to the BEMP Process and the Design of Systematic Aerial Surveys for Whales. Appendix B. In: Beaufort Environmental Monitoring Project 1986-87 Final Report. Northern Affairs Program Environmental Studies Report No. 52. Indian and Northern Affairs Canada, Ottawa, ON.

LGL Ltd., ESL Environmental Sciences Ltd., Arctic Laboratories Ltd., and Atlantic Oceanics Co. Ltd. 1984. Effects Monitoring Strategies and Programs for Canada's East Coast. Prepared for Environmental Studies Revolving Funds (EMR), Canada Oil and Gas Lands Administration.

Marmorek, D.R., D.P. Bernard, R.R. Everitt, N.C. Sonntag, G.D. Sutherland, A. Sekerak, R. Eccles, A. Chiasson, and M. LeBelle. 1986. Predicting environmental impacts of hydroelectric developments in Canada. Prepared for the Canadian Electrical Association. 140 pp. and appendices 2,3,4.

Munro, D.A., T.J. Bryant, and A. Matte-Baker - Naivasha Consultants 1986. Learning from experience: a state-of-the-art review and evaluation of environmental impact assessment audits. Background paper prepared for the Canadian Environmental Assessment Research Council. Hull, QC.

Suter, G.W., II. 1990. Endpoints for Regional Ecological Risk Assessments. Environmental Management, 14(1): 9-23.

10.0 Environmental Management Plan and Office

A primary goal of Environmental Impact Assessment (EIA) is to develop procedures to ensure that all mitigation measures and monitoring requirements specified in the approved EIA will actually be carried out in subsequent stages of project development. These mitigation measures and monitoring requirements are normally set out in an Environmental Management Plan (EMP). A well structured EMP usually covers all phases of the project, from preconstruction right through to decommissioning. The Plan outlines mitigation and other measures that will be undertaken to ensure compliance with environmental laws and regulations and to reduce or eliminate adverse impacts. Specifically, the EMP outlines:

- the technical work program to carry out the EMP, including details of the required tasks and reports, and the necessary staff skills, supplies, and equipment;
- a detailed accounting of the estimated costs to implement the EMP; and
- the planned operation or implementation of the EMP, including a staffing chart and proposed schedules of participation by the various members of the project team, and activities and inputs from various governmental agencies.

The main mechanism for implementation of the EMP is the establishment of an Environmental Management Office (EMO). The EMO is to be established, with sufficient staffing and budget, as part of the project proponent's Project Management Office. Environmental staff in this office work alongside the construction and operation personnel to ensure that the measures and requirements outlined in the EMP are actually carried out. The establishment and funding of an EMO is essential insurance for environmentally sound projects.

10.1 Implementing an Environmental Management Plan

Implementation of the EMP requires that:

1. the detailed final design (plans and specifications) for the project incorporates all mitigation measures specified in the approved EIA. This is facilitated if the EIA is conducted as an integral part of the project feasibility study;
2. the contract for construction of the project includes all mitigation measures to be implemented. The mitigation measures should be sufficiently detailed that the construction contractor, in preparing his bid, will be clearly aware that he will be required to comply with these mitigation measures;
3. the construction contractors' performance is duly monitored for compliance with the EMP by competent environmental construction inspectors furnished by the EMO. This means implementation of the construction stage portion of the Environmental Monitoring Program specified in the EIA;
4. on completion of construction, inspection takes place to check that the works, as built, meet all significant environmental requirements before the project is officially accepted;
5. the operations stage monitoring program is implemented as specified in the EMP; and
6. there is effective reporting by the EMO, through the Project Management Office, to show that the EMP is being properly managed.

10.1.1 Modifications in Detailed Final Design

In developed countries, laws and regulations require that mitigation measures specified in the EIA be incorporated into the detailed final design of the plans and specifications. These requirements are duly enforced. In many developing countries, it has been difficult to ensure the mitigation measures are incorporated in the final design. Numerous projects have been constructed without proper attention to the specified mitigation measures. The EMO staff are responsible for working with the project design engineers to ensure the mitigation measures are incorporated into the detailed design; as such, the description in the EIA of the required mitigation measures must be sufficiently detailed to permit the design engineers to understand exactly what is needed. It is thus preferable for the EIA to be an integral part of the overall feasibility study — thereby allowing for mitigations to be routinely included by the design engineers.

10.1.2 Construction Contractors' Contract Requirements

Past experience has shown that many construction contractors do not fully understand their obligations with respect to mitigation measures. Often, they do not make adequate provision for this work during bid preparation, and they find themselves without sufficient monies to carry out the works needed to implement mitigation measures. This makes them reluctant to comply with the requirements of the EIA and EMP. It is important that the construction contract include provisions to ensure: 1) the construction contractor clearly understands mitigation requirements, 2) environmental construction inspectors from the EMO monitor the contractor's performance in this regard; and 3) the mitigation measures are specified in sufficient detail that the contractor can make reasonable estimates of actual costs (see Box 10-1). Staff from the EMO must work and cooperate with the design engineers to gain agreement on final contract details.

Box 10-1: Mitigation measures must be of sufficient detail to guide construction contractors and allow for realistic cost estimates.

Mitigation Measure	Contract Requirements
resurfacing of exposed areas	provide estimate of actual area to be resurfaced
prevent soil erosion operations so as not to incur damages to adjacent properties and downstream waterways	require that dikes or other erosion control structures must be built and provide examples of acceptable structures
eliminate objectionable noise nuisances to neighboring properties	specify allowable noise limits
will control dust nuisances	specify dust control is to be undertaken

10.1.3 Environmental Supervision of Construction

Environmental construction inspectors from the EMO must work alongside and together with the engineering construction supervisors to ensure the specified mitigation measures are carried out. The environmental construction inspectors must keep daily log books of their work and observations for this purpose. This is a common practice for engineering construction supervisors. Environmental construction inspectors should prepare periodic reports (weekly and monthly) to the EMO. These reports should document instances of inattention to mitigation measures and suggest needed improvements in the mitigation measures. Copies of this report should be provided to the chief engineering construction supervisor.

The EMO should cultivate appropriate working relationships between the engineering construction supervisors and the environmental construction inspectors. General agreement should be made on reporting procedures. Usually the construction contract will give legal authority to the engineering construction supervisor to supervise the work; in such cases, the instructions from the environmental construction inspector to the construction contractor may need to be transmitted via the engineering construction supervisor. When problems are identified by environmental construction inspectors, it is essential that the EMO act quickly to ensure that the construction contractor take corrective action.

10.1.4 Environmental Acceptance of Completion of Construction

Environmental Management Office staff should participate in the inspection of completed construction works to ensure that the mitigation measures have been completed as related to environmental requirements. Where possible, final payment to the construction contractor should be withheld until the EMO certifies concurrence with mitigation measures proposed in the EIA and EMP.

10.1.5 Monitoring During Operations Stage

Staff from the EMO are responsible for ensuring the operations stage monitoring program is successfully implemented. Part of this responsibility includes ensuring proper report preparation and distribution. This includes periodic reports as well as special reports needed for managing special environmental problems which may arise. Monitoring is necessary to ensure that the mitigation measures specified in the EIA are effectively implemented. It is also necessary for identifying any significant environmental deficiencies in the project plan. Quantified descriptions of deficiencies in the project facilities and operational procedures should be prepared. Recommendations for corrective action should include firm justifications based on the monitoring observations.

10.1.6 Opportunities for Environmental Improvements

The EMO’s monitoring operations, at both the construction and operational stages, should identify potential modifications to the overall project plan to enhance environmental protection. Many development projects present opportunities for add-ons not directly related to the primary project objective. Often valuable environmental benefits can be realized for a small incremental cost.

10.2 Environmental Management Office

The EMO should be established by the Project Management Office as soon as possible, preferably in time to manage planning and carrying out of the EIA, and certainly prior to implementation of construction. Should it not be possible to establish the EMO until after completion of the EIA, consideration should be given to use of the EIA team to serve as the interim environmental management office pending official establishment of the EMO.

A budget (covering the project’s design life period) for the EMO should be an integral part of the project’s core budget. It should include funding for the EMO staffing, environmental construction inspectors, and monitoring done by other agencies on behalf of the EMO. The budget should cover both the construction and operational stages, as well as facilities and support. For major projects, the EMO staff should include a professional engineer (usually as the full-time EMO Chief), an ecologist, a sociologist, and an economist.

10.2.1 Reporting by Environmental Management Office

The EMO is to prepare and distribute, through the Project Management Office, periodic reports. These monthly and annual reports on its operations should be of sufficient detail to allow both public and private sectors to evaluate the environmental soundness of the project. The report should provide information on both the project plan and operations, including attention to needed corrective measures. Generally these reports should be distributed by the Project Management Office to concerned government agencies (including the environmental agency) and to other concerned agencies, including those participating in project funding.

The EMO, based on the information from its various activities, is in an excellent position to assist in preparing post evaluation and auditing reports which may be required by the multi-lateral development banks (for example, the Asian Development Bank and the World Bank).

10.3 Environmental Review Panel

In the event of major projects, it may be desirable for the project proponent to establish an Environmental Review Panel which meets periodically (for example, semi-annually) to guide the EMO operations. The Panel would prepare reports on each visit (say ten days per visit for major projects); these reports would include a description of observations, findings, and recommendations for improvements. Such a panel is not only valuable for guiding the EMO operations to suit the project proponent's needs, but also for ensuring optimal cooperation with all agencies who have significant concerns about the project's environmental effects.

10.4 Difficulties in Implementing the Environmental Management Plan and the Environmental Management Office

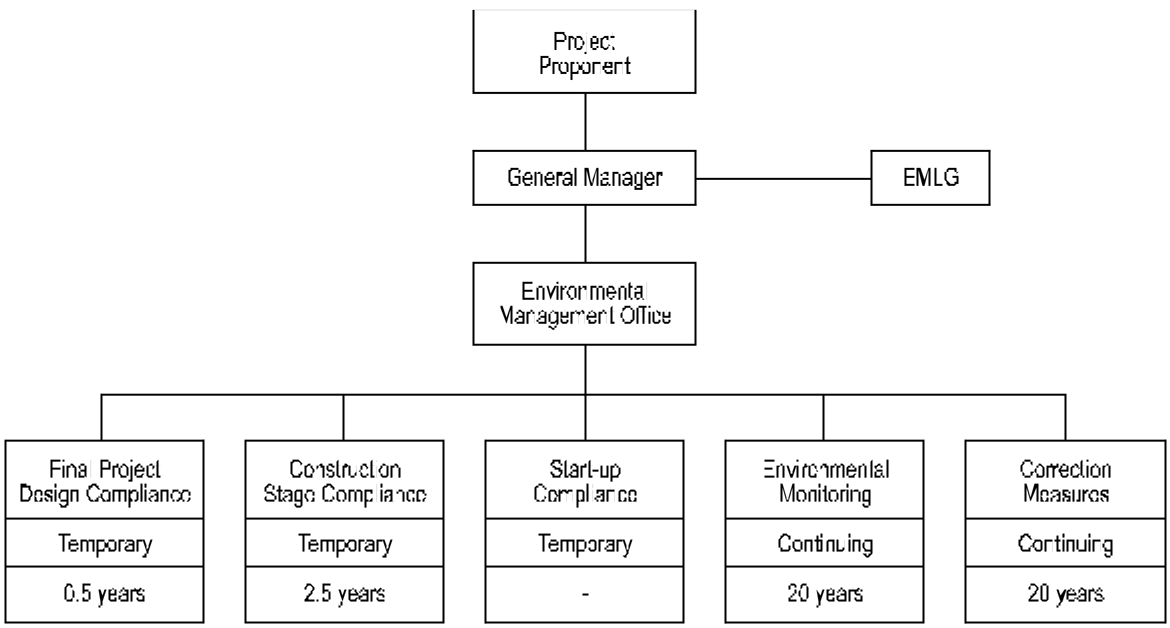
Those responsible for managing development projects in developing countries may not readily be receptive to the need for an EMP and the creation of an EMO. Some decision makers and developers lack proper understanding of the necessity and benefits of environmentally sound design and effective mitigation measures. Others are reluctant to commit the financial resources necessary to hire staff and operate an EMO. Many wish to minimize the costs associated with implementation of the mitigation measures and monitoring requirements. These costs are really quite small relative to overall project costs, yet are usually essential in terms of achieving an environmentally sound and sustainable project.

10.5 Generic Environmental Management Plan and Environmental Management Office

The generic EMP and EMO (Figure 10-1 and Tables 10-1 and 10-2) are representative summaries of an approach being utilized for major water resource development projects in PRC. Similar approaches can used for any type of project.

The basic functions (Table 10-1) that must be discharged to implement the EMP change as the project moves through its various phases. During the pre-construction stage, the focus is on establishing the EMO, ensuring the final design incorporates the appropriate mitigations, and finalizing construction contract requirements for mitigation and monitoring. During construction, the focus is on ensuring the construction contract requirements are fulfilled. These requirements include basic health and safety requirements as well as ensuring the project works and mitigation measures are environmentally sound. During operations, the monitoring programs begin in earnest and the role of the EMO shifts to identifying problems and recommending corrective actions. Throughout implementation of the EMP there are a number of functions that must be discharged. These include liaison with environmental agencies, preparation and distribution of periodic reports, preparation of press releases, public participation and consultation, and benefit cost analysis of the EMP.

The staff of the EMO (Table 10-2) will include a chief engineer, an assistant chief engineer, an ecologist, a socio-economist, an economist, consultants, and inspectors. The level of effort required from these individuals changes throughout the project. The estimates of level of effort (Table 10-2) are based on: 1) a 0.5 year pre-construction period; 2) a 2.5 year construction period; and 3) a 20 year operational period. The estimates do not include the costs of monitoring or training, but do include the costs of supervising monitoring and training. The estimates also do not include the level of effort for the Expert Panel which includes four local professionals plus two foreign experts. The Panel meets every six months, for a total of six meetings from start to end of the construction period. These estimates are based on the approach being taken in the People's Republic of China for large water resource developments. The required level of effort for projects in other sectors and jurisdictions may be very different.



Notes:

1. The time frames shown above were selected for illustrative purposes. These time-frames must be tailored to match the particular project.
2. Final design for the project including contract documents, plans and specifications must include the EPMs specified by the EIA.
3. Provisions for the construction stage must include construction supervision for environmental matters as well as the usual construction supervision for engineering activities.
4. On completion of construction, a trial run will be conducted to be sure than EPMs have been implemented effectively.
5. Operational phase monitoring will be done to ensure that the project is being operated in compliance with the constraints intended to protect the environment, and to provide feedback necessary to identify and correct residual problems or to take advantage of enhancement opportunities.
6. Approval of officials will be gained so that required engineering or institutional correction measures can be carried out.

Figure 10-1: Implementation of an Environmental Management Plan.

Table 10-1: Example environmental management functions and Environmental Management Office work load.

Work Items		Frequency / Timing	Annual Level of Effort (Person Months)
1	**Pre-construction (PC)**		
1.1	Establishment of Environmental Management Liaison Group and Environmental Management Office	as soon as possible	6
1.2	Ensuring that final designs incorporate mitigation measures	during preconstruction	6
1.3	Ensuring that contractor's contract includes mitigation measures	during preconstruction	6
1.4	Planning of construction stage Environmental Management Office program	during preconstruction	2
1.5	Beginning implementation of training program	during preconstruction	6
1.6	Planning for use of Expert Panel on Environment	during preconstruction	2
		Total	28
2	**Construction Period (CP)**		
2.1	Complete environmental training program	start of construction	2
2.2	Implement use of environmental construction inspectors and use of environmental inspection reports for controlling the construction contractor's operations	start of construction	72
2.3	Medical screening and facilities for construction works	start of construction	2
2.4	Water supply, sanitation, housing for construction camps	start of construction	2
2.5	Insecticide spraying of construction camp buildings	start of construction	1
2.6	Ensuring health and safety of tunnel construction workers	start of construction	2
2.7	Ensuring carrying out of mitigation measures of resettlement program (housing, water supply, sanitation, etc.)	start of construction	1
2.8	Checking on disease rates in construction camps and in service areas/vicinity for hemorrhagic fever, malaria, encephalitis	start of construction	2
2.9	Rat control measures at construction camps	start of construction	2
2.10	Check on adequacy of disposal of tunnel excavation materials	start of construction	2
2.11	Other mitigation measures	start of construction	4
2.12	Planning and implementation of special studies shown needed by items above	during construction	2
2.13	Assisting in establishment of institutional system for integrated water and waste management and reuse for optimal use in target areas, including permit systems	during construction	4
2.14	Assistance to institutional system of 2.13 in planning and implementation of water use, waste management, and water reuse facilities	during construction	4
2.15	Use of expert panel on environment	during construction	4
		Total	118
3.	**Operation Stage**		
3.1	Implementation of monitoring program	start of operation	36

Work Items		Frequency / Timing	Annual Level of Effort (Person Months)
3.2	Based on results of 3.1, plan and implement necessary connections for project facilities and for operation/ management of project facilities	during operation	2
3.3	Based on results of 3.1, plan, recommend, and implement desirable environmental enhancement facilities/programs	during operation	2
3.4	Formulate and implement needed additional training	during operation	1
3.5	Formulate and implement needed additional special environment studies	during operation	1
3.6	Continuation of 2.13	during operation	2
3.7	Continuation of 2.14	during operation	2
		Total	46
4.	**Continuing Activities**		
4.1	Liaison with environmental agencies, provincial agencies, local agencies	continuing	6
4.2	Preparation and distribution of periodic Environmental Management Office reports	semi-annual plus specials	3
4.3	Preparation and use of media releases	continuing	3
4.4	Public participation and consultation	continuing	6
4.5	Estimation of the cost and benefits of environmental management plan	annual	2
4.6	Overall administration of environmental management office	continuing	12
		Total	32

Table 10-2: Estimated staffing requirement for the Environmental Management Office.

Item / Professionals	Pre-construction (half-year)	Construction Period (2.5 years)		Operation Period (20 years)	
	Total Months	Annual Months	Total Months	Annual Months	Total Months
Chief Engineer	6	12	30	12	240
Asst. Chief Engineer	6	12	30	12	240
Ecologist	6	6	15	6	120
Socio-Economist	6	8	20	6	120
Economist	2	4	10	2	40
Consultants	2	4	10	4	80
Inspectors	0	72	180	36	720
Sub Total	**28**	**118**	**295**	**78**	**1560**

10.6 Xiaolangdi Project

An EMP was prepared for the Xiaolangdi multipurpose dam and reservoir project on the Yellow River at Xiaolangdi in Henan Province of the People's Republic of China (Ludwig et al, 1994). The Xiaolangdi Project, under construction (circa 1997), is a major project with the primary objectives of flood control, sediment control in the Yellow River channel, power production, and water supply. The EIA took six years and involved a team from the Yellow River Conservancy Commission (YRCC) supported by eighty-eight Chinese experts. An international Panel of Experts was appointed to provide advice on dam design and safety factors.

The EMP provided for the establishment of an EMO to lead and coordinate the implementation of all mitigation measures and monitoring requirements (section 9.3 provides more information about the monitoring program). The responsibilities of the EMO include: 1) management of periodic monitoring for assessing actual effects; 2) planning and implementing corrective measures; 3) providing periodic reports and, as needed, special reports for distribution to concerned government agencies and the World Bank. The work of the EMO is funded by the core project funding.

The EMP includes a number of major sub programs (Table 10-3).

- seismic monitoring program;
- resettlement program;
- protection of cultural relics;
- sanitation and anti-epidemic program;
- monitoring of hydrology, sediment, meteorology, and water quality;
- management of the construction area;
- reservoir clearing;
- special studies; and
- environmental library, consultants, and technical exchanges.

Most of these programs will be implemented by agencies other than the EMO, however, it will have major responsibilities to monitor and report on the performance of these programs. For example, the YRCC Hydrographic Bureau will be responsible for monitoring of hydrology, sediment, meteorology, and water quality, while the EMO will monitor their performance, evaluate the monitoring results, and, if necessary, recommend corrective action.

Table 10-4 illustrates the staffing requirements and responsibilities for the EMO. The staff are organized into five sections: 1) chief engineer's office; 2) deputy chief engineer's office; 3) management section; 4) monitoring section; and 5) administrative section.

The total budget (Table 10-5) for the EMP is 132 million Chinese Yuan (approximately $US 16 million in 1994). While not specifically included in the EMP, environmental enhancement programs for recreational development and aquaculture were identified in the EIA. An additional investment of 8,130,000 Yuan for recreational development and 850 million Yuan for downstream aquaculture is required to maximize the benefits from the Xiaolangdi reservoir.

Table 10-3: Summary description of Xiaolangdi Environmental Management Plan.

	Task Description	Implementor	Monito
e	organize and monitor implementation of environmental protection activities	Yellow River Water and Hydropower Development Corporation (YRWHDC)	National Environme Protection Agency, Water Resources
ng	1. organize and monitor implementation of environmental protection activities 2. monitor the region 35 km upstream and 10 km downstream of the dam 3. prepare monthly seismic reports, and to expeditiously report unusual events to the n makers	Reconnaissance Planning and Design Institute under YRCC	Environmental Mar Office (EMO) under
	1. complete EIA of resettlement area 2. organize and implement environmental aspects of resettlement planning 3. write up quarterly report on resettlement progress 4. do annual socioeconomic environmental evaluation in the host area 5. conduct environmental management of development projects	local resettlement offices, environmental protection bureaus (EPBs), experts employed by EMO	EMO under YRWH
cs	1. organize and monitor implementation of environmental protection activities 2. prepare quarterly reports	provincial cultural relics bureaus	Nation Cultural Rel EMO under YRWH
nic	1. give annual physical examinations to construction workforce and to 1-10% of people in affected areas 2. monitor epidemic situations, rats, mosquitoes, diet, hygiene 3. control rats and mosquitoes to prevent malaria, encephalitis and hemorrhagic fever 4. distribute vaccines to susceptible communities	reservoir anti-epidemic station, and station at province, prefecture, and municipal levels	EMO of YRWHDC
	1. monitor reservoir and downstream hydrology 2. monitor reservoir and downstream sediment 3. conduct meteorological monitoring 4. analyze water quality and bottom sediment	YRCC Hydrographic Bureau	EMO under YRWH
on	check on contractors' implementation of environmental protection rules	local EPBs, EMO of YRWHDC	EMO under YRWH
	clear the reservoir area	Resettlement Offices	EMO under YRWH
	1. Study of surface and ground water balance 2. Study of downstream aquaculture 3. Planning of recreation development 4. Feasibility study of reservoir navigation 5. EIA for irrigation areas	YRCC, relevant authorities of Henan Province	EMO under YRWH
	1. set up an environmental library 2. employ expert consultants as required 3. technically train staff of EMO and EIA Team	EMO under YRWHDC	YRWHDC

Table 10-4: Staffing and responsibilities of Xiaolangdi Environmental Management Office.

Sub-Division	Man-Month / Year	Person	Main Tasks
Director	12	1	overall responsibility, representative on Environmental Management Leading Group
Chief Engineer	12	1	1. Assisting Director in preparing and reviewing Environmental Management Office technical reports 2. Responsible for annual technical reviews and appraisal

Management Section	6	0.5	1. Long-term planning of mitigation measures, annual work plans
	6	0.5	2 Assisting Planning and Financial Department in allocating money in EMMs.
	24	2	3. Checking and monitoring implementation of mitigation measures
	12	1	4. Coordination between resettlement agencies, local environmental protection bureaus and cultural relics bureaus
	12	1	5. Controlling environmental protection at site, monitoring and checking contractors' implementation of environmental provisions
	12	1	6. Preparing quarterly and annual reports on performance of mitigation measures
Monitoring Section	12	1	1. Responsible for implementation and coordination of environmental monitoring programs
	12	1	2. Statistics and analysis of monitoring results, recommending how to control unfavorable impacts (in consultation with management section)
	12	1	3. Preparing annual monitoring reports on XLD Project
Administrative & Foreign Affairs Section	18	1.5	1. Management of library and technical files including translation as necessary
	6	0.5	2. Technical training and international liaison, accessing funding for environmental work form various sources
	6	0.5	3. Preparing bulletin on XLD environment
	18	1.5	4. Daily affairs of Environmental Management Office (secretarial, etc.)
Total	**180**	**15**	

Not all the costs will be part of the implementation of the EMP. Other agencies will also have significant disbursements. For example, an additional 105 million Yuan is required for environmental aspects of the resettlement plan, and another 18,660,000 Yuan will be spent on protection of cultural relics.

Table 10-5: Cost estimate (millions of Yuan) for the Xiaolangdi Environmental Management Plan.

Item	Total (10^6 Yuan)	Capital Construction (10^6 Yuan)	Equipment (10^6 Yuan)	Implementation & Operation Cost (10^6 Yuan)
1. Seismic Monitoring	7.10	0.73	2.05	4.32
2. Resettlement Management	1.07			1.07
1) Impact Assessment	0.61			0.61
2) Management & Monitoring	0.46			0.46
3. Salvage of Cultural Relics	17.16			17.16
4. Sanitation & Anti-epidemic	4.24	0.27	0.30	3.67
5. Monitoring of Hydrology, Sediment, Meteorology & Water Quality	71.62	9.05	16.25	46.32
6. Reservoir Clearing	10.85			10.85
1) Optimization	0.04			0.04
2) Reservoir Clearing	10.81			10.81
7. Environmental Management Office (including library)	4.65	0.50	0.60	3.55
8. Technical Exchanges & Training	0.50			0.50
9. Special Studies	0.65			0.65
10. Advice by Experts	2.43			2.43
11. Sub-total of items 1-10	120.27	10.55	19.20	90.52
12. Contingency (10%)	10.03			
13. Total for EMP Implementation (items 1-12)	132.30			
14. Recreation Development	8.13			
15. Downstream Aquaculture	850.00			

Table 10-6 shows an example table of contents of a report prepared by the EMO's Expert Panel for the EMO of the Xiaolangdi project, based on a periodic inspection/review of the EMO's environmental monitoring during the construction stage. A brief excerpt from the report (Box 10-2) illustrates the type of conclusions and recommendations contained in the report.

Table 10-6: Example table of contents for a report by the Environmental Management Office of the Xiaolangdi project.

Report of Xiaolangdi Expert Panel on
Visit to Zhengzhou of 3 to 11 September 1995 (3rd Panel Meeting)
For Review of Environmental Management Offices Construction Stage Monitoring

Table of Contents

Box 10-2: Excerpt from Expert Panel Report - Xiaolangdi project. The text has been edited for readability and to remove direct references to specific individuals.

4.3.15 Conclusions and Recommendations (Progress Report /4/Section 3)

4.3.15.1 Progress Report /4/Section 3 (ii)

This discussion notes that the overall construction program managed by XECC treat environmental protection lightly. This is precisely why environmental monitoring of the construction operation is so important.

Item (ii) of progress report 4/Section 3 notes that the Environmental Handbook (Reference 2) is to be distributed to all construction zone staff so that they will pay conscientious attention to environmental protection in their future work. The Handbook should indeed be distributed to officials concerned with dam construction (and also to those concerned with Resettlement), but this should not be interpreted to mean there will be compliance, compliance can be expected only with use of enforcement procedures noted in Section 4.2.

4.3.15.2 Progress Report 4/Section 3 (iv)

This statement is not consistent with progress report 4/Section 2.5 (which indicates that all is OK).

4.3.15.3 Progress Report 4/Section 3 (v)

See Section 4.2 (a)(b)(c).

5. Management Information System (Environmental Aspects)

This is missing in progress report 4. Please include this in future progress reports.

6. Recommendations for Preparation of Future Progress Reports

Based on all of the discussion above, Annex A has been prepared to serve as a guideline for preparation of future progress reports.

7. Recommendations for Future Visits by Environmental Panel

(a) One day of the field visit should be allocated for a classroom meeting at the dam site of the Environmental Panel with Environmental Management Offices group of Environmental Inspectors, plus others, for detailed discussion of the work of the Environmental Inspectors. This should include I) presentation by each Environmental Inspector to describe his own work, with typical copies of his routine reports, ii) presentation on effectiveness of relationships with the Engineering Supervisor of Construction, and iii) presentation on technical problems.

(b) The next field visits to the construction zone should include inspection of points of discharge of sewage effluent to waterways and of the refuse disposal site.

© The Environmental Panel and the Resettlement Panel both need to focus their field visits to Resettlement communities on Resettlement communities which have been completed, including infrastructure, and which are occupied and being lived in.

(d) One full day should be allowed by Environmental Expert to prepare his final draft report (same for the Resettlement Expert) and the next day for translation, with the following day for discussion of the draft (Panel Member to read Chinese draft at the beginning of the third day, to set the stage for discussion of the draft).

8. Next Panel Meeting

This is scheduled to begin 14 April, 1996.

10.7 Summary and Conclusions

The implementation of an EMP and EMO is relatively new in EIA for developing countries, having evolved in the early years of the 1990s. This evolution happened because it was found that, in many past projects, the EIA requirements were not actually achieved in the project's final design, construction and operation. It is now recognized that an EMP implemented through an EMO is essential for ensuring environmental soundness in developing country project planning and implementation. The benefits are great compared to the relatively low cost.

10.8 References and Further Reading

Ludwig, H.F., D. Gunaratnam, and Z. Yuming. 1994. Environmental impact assessment for Xiaolangdi Yellow River multi-purpose economic-cum-environmental improvement project. The Environmentalist, 14(3): 1-12.

11.0 Preparing an Environmental Impact Assessment Report

This section outlines the structure of an Environmental Impact Assessment (EIA) report. It provides a framework for applying the methods and approaches detailed in previous chapters. With the guidance given in this chapter, the EIA practitioner can proceed in a step-by-step fashion to prepare an EIA report.

At a minimum, an EIA report should contain: 1) an introduction; 2) a project description; 3) a detailed description of the environment; 4) an assessment of environmental impacts and mitigation measures; 5) an environmental management plan; and 6) an environmental monitoring plan. In many jurisdictions, the EIA report also contains an evaluation of alternatives, environmental economic analyses including a cost-benefit analysis, and a description of the public participation program. For example, Box 11-1 provides the suggested format for an EIA report for the Asian Development Bank (Asian Development Bank, 1993).

Box 11-1: Suggested Format for an EIA Report for the Asian Development Bank.

Introduction
Description of Project
Description of Environment
Anticipated Environmental Impacts and Mitigation Measures
Alternatives
Cost-Benefit Analyses
Institutional Requirements and Environmental Monitoring Program
Public Involvement
Conclusions

11.1 Terms of Reference

Requirements for the preparation of an EIA report should be clearly outlined in a terms of reference (TOR), which should be prepared for the specific project to be assessed. The EIA report should be prepared by the proponent to the requirements of the review authority that will examine the report. If the report is not suitable for review and evaluation, the review bodies will not be in a position to a) decide whether the project should be permitted to proceed, and b) if it does proceed, set appropriate terms and conditions to ensure an environmentally sound project.

Chapter 2 emphasized the importance of scoping to develop the appropriate TOR. The effectiveness of EIA is compromised whenever time and money is spent searching for sophisticated answers to unimportant questions. It is also compromised whenever important issues are neglected through failure to consider a broad range of interests in the early stages of the EIA. Scoping has the objective of identifying the right questions to ask during the conduct of an environmental assessment.

11.1.1 Scoping Defined

Scoping is a process of interaction between interested public, government agencies and proponents to determine the important issues and alternatives that should be examined in EIA (U.S. Council on Environmental Quality, 1981).

Scoping is the process of determining the issues to be addressed, the information to be collected, and the analysis required to assess the environmental impacts of a project. (ESSA Technologies Ltd., 1994).

Scoping is a process within which various methods are applied to:

- identify concerns of the public and scientists about a proposed project or action;
- evaluate these concerns to determine the key issues for the purposes of the EIA (and to eliminate those issues which are not significant); and
- organize and communicate these to assist in the *analysis of issues* and the ultimate making of decisions (Federal Environmental Assessment Review Office, 1987).

There are two key concepts in these definitions:

- consultation with stakeholders to identify issues and concerns; and
- evaluation and priorization of issues.

The Asian Development Bank uses an initial environmental examination (IEE) to implement scoping for development projects. As defined in Chapter 2, the primary objectives of the IEE are to:

1. identify the nature and severity of specific, significant environmental issues associated with the project;
2. identify easily implementable mitigations for the significant environmental issues; and
3. produce a detailed terms of reference should further EIA studies be needed.

The TOR should provide those preparing the EIA report with explicit direction on preparing the EIA report. It should be specific about the information requirements and level of detail to be included in each major section of the report.

11.2 Contents of the EIA Report

This section outlines the basic components or sections that should be included in an EIA report. A recommended table of contents for an EIA report is presented in Box 11-2.

Box 11-2: Table of Contents for an EIA Report.

Executive Summary
1. Introduction
2. Description of the Project
3. Description of the Environment
4. Anticipated Environmental Impacts and Mitigation Measures
5. Alternatives
6. Environmental Monitoring
7. Additional Studies
8. Environmental Management Plan and Environmental Management Office
9. Summary and Conclusions
10. Annexes

11.2.1 Executive Summary

An executive summary should be prepared. This critical document summarizes the significant findings of the EIA report. The executive summary must describe each significant environmental issue and its resolution in sufficient detail so that the reader can understand its importance and scope, as well as the appropriateness of the approach taken to resolve it. The executive summary should be a clear presentation of the critical facts that make up each issue, and the resolution of the issues. Whenever possible, the summary should make use of base maps, tables and figures. Information should be condensed into succinct, but meaningful presentations. It must be able to stand alone as a document.

11.2.2 Introduction

The introduction section of the EIA usually should include the following:

i. Purpose of the report, including a) identification of the project and project proponent; b) a brief description of the nature, size, and location of the project and of its importance to the country; and c) any other pertinent background information.
ii. Stage of project preparation.
iii. Extent of the EIA study, including scope of study, magnitude of effort, and person or agency performing the study.
iv. Brief outline of the contents of the report, including mention of any special techniques or methods used for identifying issues, assessing impacts, and designing environmental protection measures.
v. Background references.
vi. Acknowledgments.

A review of relevant studies and examples of environmental impacts of similar projects should also be presented.

11.2.3 Description of the Project

The project description should be based on the project feasibility study. Not all the detailed engineering information needs to be included as much of it is unnecessary for the environmental review. The project description should present a condensed description of those aspects of the project likely to cause environmental effects. The project should be described in terms of its basic activities, location, layout, and schedule (in terms of the project life cycle). This project description section of the report should furnish sufficient details to give a brief but clear picture of the following:

i. Type of project.
ii. Need for the project.
iii. Location (use maps showing general location, specific location, project boundary and project site layout).
iv. Size or magnitude of operation, including any associated activities required by or for the project.
v. Proposed schedule for approval and implementation.
vi. Description of the project, including drawings showing project layout, components of project, etc. Schematic representations of the feasibility drawings which give the information important for EIA purposes should be produced to provide reviewers a clear picture of the project and its operations.
vii. Description of mitigation measures incorporated into the project to meet environmental standards, environmental operating conditions, or other EIA requirements.

Any new and untested technology should be highlighted and an assessment of the risk of technological failure included.

11.2.4 Description of the Environment

Study Area

A clear delineation of the study area is important to define the area within which impacts must be considered. The additional description of the study area that will be required for the EIA is dependent on the types of resources located in the area, and upon the magnitude of the anticipated impacts. The area to study must be large enough to include all valued environmental resources that might be significantly affected by the project.

Establish a Baseline

Once the study area is well defined, studies to gather the baseline conditions for valued environmental components must be developed. Many jurisdictions have developed standard checklists that allow for consistent terminology in organizing the data assembled for environmental components. The system used in Thailand is presented in Table 11-1. In general, it is necessary to provided sufficient information to give a brief but clear picture of the existing environmental components and values. These components and values include, to the extent applicable (but are not necessarily limited to):

i. **Physical components:** topography, soils, climate, surface water, groundwater, geology/ seismology.
ii. **Ecological components:** fisheries, aquatic biology, wildlife, forests, rare or endangered species, wilderness or protected areas.
iii. **Human and economic development:** population and communities (numbers, locations, composition, employment, etc.), industries, infrastructural facilities (including water supply, sewerage, flood control/damage, etc.), institutions, transportation (roads, harbors, airports, navigation), land use

planning (including dedicated area uses), power sources and transmission, agricultural development, mineral development, and tourism components.

iv. **Quality of life values:** socioeconomic values, public health, recreational components and development, aesthetic values, archaeological or historical treasures, and cultural values.

Table 11-1: Classification of environmental components used in EIAs in Thailand (*source:* adapted from the National Environment Board, 1979).

	National Environment Board Parameters	
Physical Resources	Surface Water Hydrology	Air Quality
	Surface Water Quality	Soils
	Ground Water Hydrology	Land Quality
	Ground Water Quality	Mineral Resources
	Climate	Geology / Seismology
Ecological Resources	Forest, Vegetation Cover	Aquatic Biology
	Terrestrial Wildlife	Fisheries
	Endangered Species	
Human Use Values	Agriculture	Industries
	Land Use	Highways, Railways
	Flood Control	Navigation
	Water Supply	Housing
	Power	Sanitation
Quality of Life Values	Aesthetics	Public Safety
	Cultural	Socio-Economic
	Archaeological	Recreation
	Public Health	Dedicated Use Areas

It is not necessary to gather information on all the components listed in such environmental component checklists. The baseline studies should concentrate on identifying those environmental components that may be significantly impacted by the project.

Base Maps

Many environmental components can be best represented as spatial data through various types of maps. In addition to the basic physical features and infrastructure of the study area, it is valuable to have maps identifying vegetation types/communities, animal habitat, and major population centers.

11.2.5 Anticipated Environmental Impacts and Mitigation Measures

A thorough treatment of project issues, their impacts on valued components and recommended mitigation measures to minimize impacts are the core of a successful EIA. One approach is to present this information in terms of the various stages of the project: preliminary design, final design, construction and operation. This methodology ties the impacts on the components to the stage(s) of the project during which they are triggered. Addressing impacts through the associated project stage indicates clearly which aspects of the project will require mitigative actions in the form of design changes, and matches the decisions regarding mitigation with the project implementation schedule.

Item-by-Item Review: This section of the report should evaluate the expected impact (quantified to the degree possible) of the project on each component or value and, in the case of applicable sectoral environmental guidelines, wherever any significant impact is expected (this would include environmental risk assessment, where appropriate). Environmental impacts to be investigated should include those due to project location; those caused by possible accidents; those related to design; and those resulting from construction, regular operations, final decommissioning or rehabilitation of a completed project. Where adverse effects are indicated, discuss measures for minimizing and/or offsetting them. Opportunities for enhancing natural environmental values should be explored. Both direct and indirect effects should be considered, and the region of influence indicated. As required, the impact on the global environment should be described.

This analysis is the key presentation in the report — if not sufficiently complete, it may be necessary to delay the project until the analysis can be completed. It is necessary to present a reasonably complete picture of both the human use and quality of life gains to result from the project due to the utilization, alteration, and impairment of the natural components affected by the project, so that fair evaluation of the net worth of the project can be made.

Irreversible and Irretrievable Commitments of Components: The EIA report should identify the extent to which the proposed project would irreversibly curtail potential uses of the environment. For example, highways that cut through stream corridors, wetlands, or a natural estuary can result in irreversible damage to these sensitive ecosystems. Other impacts that may be irreversible include alteration of historic sites, and expenditure of construction materials and fuels. Projects through sensitive areas like estuaries and marshes may permanently impair the natural ecology of the area, while elimination of recreation areas and parklands can precipitate drastic changes in an area's social and economic character.

Effects During Project Construction: The construction phase of the project usually involves environmental impacts that will cease at completion of construction. These impacts may be significant, particularly when construction occurs over a number of years. These impacts and the mitigation measures proposed to reduce or prevent them should be discussed separately in the report.

In Chapter 1, EIA analysis was defined as having three sequential phases — identification, prediction and assessment. Identification involves characterizing the existing baseline environment and components of a development project which are likely to impact the environment. Many of the methods discussed in Chapter 3 along with scoping techniques are well suited for impact identification. During the prediction phase, the project impacts are quantified using standards and by comparison with the findings of other projects. Basically, the predictive function of an EIA is to forecast the nature and extent of the identified environmental impacts, and to estimate the probability that the impacts will occur. The methods described in Chapter 4 are designed for the prediction phase of EIA. During the assessment phase, the importance or significance of impacts is evaluated. The assessment should include consideration of the proposed mitigation measures that have been incorporated into the project design. Overall assessment of significance is based on the net impact assuming the proposed mitigation measures will be effective in minimizing adverse effects.

Assessment of Significance

As part of the International Study on the Effectiveness of Environmental Assessment sponsored by the International Association of Impact Assessment, the Canadian Environmental Assessment Agency, and Australian Environmental Protection Agency, Hilden (1995) prepared a review of the practice of assessing the significance of environmental impacts. He found that significance criteria could be used throughout the different stages in the EIA process, and he concluded that an assessment of significance at different stages in the EIA process based on clear guidelines and criteria could be highly effective in assisting practitioners in assigning significance.

Canter (1996), in his description of the prediction and assessment of impacts on the environment, provides specific guidance on and examples of how to assess significance for: 1) air; 2) surface water; 3) soil and groundwater; 4) noise; 5) biological environment; 6) cultural (architectural, historical and archaeological) environment; 7) visual environment; and 8) socioeconomic environment.

Criteria for Determining Significance

Determination of the significance of the anticipated impacts of proposed projects is a key component of the EIA process. While considerable expert judgement is exercised in the assessment of significance, there are few guidelines that can be followed in performing such an assessment. Definitions of significance and/or significant impacts are now included in EIA guidelines or regulations of many countries and international organizations (Canter and Canty, 1993). Some criteria for determining adverse impacts include:

- loss of rare or endangered species;
- reductions in species diversity;
- loss of critical/productive habitat;
- transformation of natural landscapes;
- toxicity impacts on human health;
- reductions in the capacity of renewable resources to meet the needs of present and future generations;
- loss of current use of lands and resources for traditional purposes by aboriginal persons; and
- foreclosure of future resource use or production.

The significance of adverse impacts depends on magnitude, geographic extent, duration and frequency, irreversibility, ecological context, social context, and economic context. Likelihood is determined by probability of occurrence and scientific uncertainty.

Major questions that need to be asked and answered in assessing significance are (Asian Development Bank, 1994):

1. Will the project create unwarranted losses in precious or irreplaceable biodiversity or other resources?
2. Will the project induce an unwarranted acceleration in the use of scarce resources and favor short-term over long-term economic gains?
3. Will the project adversely affect national energy to an unwarranted degree?
4. Will the project result in unwarranted hazards to endangered species?
5. Will the project tend to intensify undesirable rural-to-urban migration to an unwarranted degree?
6. Will the project tend to increase the income gap between the poor and affluent sectors of the population?

Additional questions that might require consideration are:

7. Will the project contribute to global effects (for example, increasing carbon dioxide, ozone depletion, climate change)?
8. Will the project have effects on national financing (for example, domestic hydropower projects reducing dependence on imported oil)?

The criteria for evaluating a project's environmental issues are listed below. The application of these criteria is somewhat subjective and will require justification in the EIA report. These criteria must be evaluated simultaneously as they are interrelated.

1. **Importance:** The value that is attached to a specific environmental component in its current condition.
2. **Extent of Disturbance:** The area affected by the disturbance which is anticipated to occur from the project.
3. **Duration and Frequency:** The amount of continuous time the disturbance-causing activity will occur and the frequency of occurrence.
4. **Risk:** The probability of an unplanned incident caused by the project that would result in significant adverse impacts.
5. **Reversibility:** The ability of the environmental components to recover their value after a disturbance has occurred.

Assigning Significance

Most EIA reports assign a significance to potential impacts. H.A. Simons Ltd. Consulting Engineers (1992) used a five-fold classification for assessing the impacts of a pulp mill project in Thailand (see details of the classification system in section 3.5). The potential impacts of this project, that is, each combination of project activity and environmental parameter of the impact matrix, were classified into one of five possible categories:

1. No Impact;
2. Significant Impact;
3. Insignificant Impact;
4. Unknown Impact; or
5. Mitigated Impact.

Mitigation Measures

The EIA report should provide a detailed description of recommended mitigation measures. Where appropriate, alternative means of mitigating the impacts should be presented. Each mitigation measure should be described in terms of:

1. the impacts it is designed to mitigate;
2. an assessment of its likely effectiveness in terms of reducing or preventing impacts;
3. its next best alternative;
4. its cost; and
5. the implementation plan for putting the measure into practice.

11.2.6 Alternatives

If the proposed project is expected to cause serious losses of natural environmental components and/or serious health effects, the EIA report should include consideration of both alternative projects or approaches which could achieve the same or equivalent results and the advantages/disadvantages of the alternatives from the point of view of environmental protection. Consideration of multiple alternatives can greatly increase the cost of the EIA report and great care should be undertaken in developing the TOR for this part of the EIA. Ideally, the TOR should spell out the alternative to be evaluated and identify the environmental and social factors upon which it is to be evaluated. In some cases, the TOR may also identify project-related economic factors to take into consideration. A method to be used to evaluate alternatives may be detailed in the TOR. In general, the TOR requirements should include: 1) a summary of adverse impacts of each alternative; 2) the mitigation measures proposed for each alternative; and 3) a discussion with respect to whether the proposed project alternative minimizes the environmental impact and is within acceptable environmental impacts limits.

EIAs address at least two alternatives (with and without the project); they can include multiple alternatives (usually limited to three to five alternatives). A number of factors are usually considered in evaluating alternatives. For example, an assessment of a highway project may include consideration of different routes, different traffic capacities, or various ways of scheduling construction. Depending on the project need, available budget and the TOR, it may be necessary to consider alternate modes of transportation (for example, railroads). In general, alternatives for projects may involve: 1) site selection; 2) design alternatives for a given site; 3) construction, operation, and decommissioning alternatives for a design; 4) project scale; 5) phasing alternatives for large staged projects; and 6) timing alternatives for project construction, operation, and decommissioning (Canter, 1996). The factors considered and degree of scrutiny depends on the time and budget available. Few EIAs consider all alternatives to same degree.

11.2.7 Environmental Monitoring Program

The technical aspects of monitoring the effectiveness of mitigation measures must be described in the environmental monitoring section of the report (Asian Development Bank, 1994). The description of the monitoring program should include:

1. a technical plan which spells out in detail: 1) the methodologies for measurement, 2) the required frequency of measurements, 3) the planned location of measurements, 4) data storage and analysis, 5) reporting schedules, and 6) emergency procedures; and
2. detailed budgets and procurement schedules for the 1) necessary equipment and supplies, and 2) technical and administrative manpower.

11.2.8 Additional Studies

This section contains a description of other major studies undertaken in support of the preparation of the EIA. For example, in early chapters, we presented material on public participation, environmental economics, and environmental risk assessment. If formal studies on these subjects have been undertaken as part of the EIA, these need to be included.

Public Participation

Public participation in the EIA process is a practice that has been adopted by many national governments and is required by international assistance agencies including the multi-lateral development banks. For these governments and agencies, the completed EIA must include documentation on the affected people's responses to the project. The determination of public response to a project may include an initial educational campaign using mass media or public forums to describe the project, followed by a structured poll or survey of people's attitudes. The extent of public education about the project, and the level of public participation required in the EIA, depend upon the magnitude of the impact, the size of the affected population and the requirements of the approving authority (government and/or lending agency). The TOR for an EIA requiring public participation must describe how the issue will be addressed, including the media to be used and the fraction of the population contacted by the educational program and survey.

This section of the EIA report should include:

- summary issues identified by stakeholders;
- the TOR for the EIA public meetings and participation;
- list of persons receiving this and previous draft reports;
- compliance with coordination and regulatory requirements;
- public hearings, press releases, notifications; and
- a summary of the principal community/interest group concerns.

Environmental Economics

Economic analysis of environmental impacts provides one means of quantifying the severity of the impacts. The net environmental benefit or loss provided by a project can be evaluated if monetary values may be assigned to environmental and social components. Project options may be compared by their net economic impact. Economic analysis may also be used to develop equitable impact mitigation measures. For example, if a project is anticipated to cause negative impacts to a component such as fisheries, resulting in quantifiable loss of income to local fishermen and subsequent losses of income to fish marketers or processors, an appropriate mitigation measure may be the development of aquaculture at a scale that would at least offset the economic losses from the original fishery.

Economic analysis of the projects should include the present value of all benefits and all costs compared in the form of internal rate return on investment, and net present value. Cost-effectiveness of mitigating measures may have to be presented separately.

The net of economic cost and benefit impacts may be totaled by component, by implementation phase of the project, and for the project as a whole. If there are several project alternatives being considered, the net economic cost or benefit may be an important deciding factor in choosing the appropriate alternative. If there are no means of quantifying the value of a component, the importance of the component must be described in such a way that the severity of impact may be evaluated.

If a cost-benefit analysis has been undertaken, the EIA report should spell out the factors taken into account and define the key assumptions. These assumptions include: 1) setting the discount rate if applicable; and 2) specifying any constraints on costs.

Environmental Risk Assessment

An environmental risk assessment may be a necessary part of the EIA if there is considerable uncertainty about the likelihood or the magnitude of environmental impacts. The data collected during basic EIA studies provides much of the information needed for explicitly dealing with the uncertainties relating to environment impacts. There are two major categories of risk: 1) those to human health, and 2) those to ecosystem integrity. The primary goal of environmental risk assessment is to evaluate risks, their monetary costs, the costs of emergency response and/or avoidance of risk.

Environmental risk assessment studies require a high degree of scientific and mathematical rigor and may be costly if not properly planned.

11.2.9 Environmental Management Plan and Environmental Management Office

The environmental management plan (EMP) is needed to ensure that the mitigation measures specified in the EIA will actually be complied with when the project is approved for implementation (Asian Development Bank, 1994). The administration of an EMP may require the establishment of an Environmental Management Office to house monitoring staff after the closure of the EIA office. Funding to cover the costs of establishing and operating an appropriate Environmental Management Office to administer the EMP should be guaranteed in the basic project budget.

The EIA report should include a description of the administrative aspects of ensuring that mitigative measures are implemented and their effectiveness monitored after approval of the EIA. These details are the subject of the environmental management plan. They include: 1) checking the final design documents to ensure they incorporate the management measures; 2) monitoring the construction and interacting with the contractor to ensure an understanding of compliance with the constraints involved with the environmental protection or mitigation measures during construction; and 3) following construction, continued monitoring during project operations to ensure that the project meets its environmental goals, and to initiate needed modifications to the project design or operations for this purpose.

11.2.10 Summary and Conclusion

The EIA report should present the conclusions of the study, including: a) the overall net gains which justify implementation of the project; b) explanation of how adverse effects have been mitigated; c) explanation of use or destruction of any irreplaceable components; and d) provisions for follow-up surveillance and monitoring. Simple visual presentations of the type and magnitude of the impacts may aid the decision-maker.

11.2.11 Annexes

A number of annexes are normally included as part of the EIA report. These annexes provide important detailed information that is not appropriate for presentation in the main body of the EIA report. These annexes may include:

- terms of reference for the EIA;
- abstracts or summaries of relevant background documents;
- tabular and graphical summaries of data;
- a list of contacts and meetings; and
- a list of data sources.

11.3 Managing the Preparation of the EIA

11.3.1 The EIA Work Plan

The EIA work plan is the management outline of the EIA. It breaks the significant environmental issues into tasks, assigns the tasks to EIA team members, describes the qualifications required of each team member, schedules the completion of tasks, and budgets each task according to its schedule. Each of the functions of the work plan is essential for the proper execution of the EIA process. The work plan is as important as the technical components for the completion of a successful EIA report (Asian Development Bank, 1994).

Typical work plan tasks are listed in Table 11-2. The tasks relate primarily to the performance of items contained in the project description, description of the environment, anticipated environmental impacts and mitigation measures, environmental monitoring plan and environmental management plan chapters of the suggested EIA format. The scheduling of the interim, draft final and final reports also is critical. The preparation of the executive summary must also be planned, ideally as a distinct plan item.

Table 11-2: Listing of typical work plan tasks (*source:* Asian Development Bank, 1994).

	EIA Work Plan	
1	**Work Plan Tasks to be Specified in Terms of Reference**	
	1.1	Assemble, review, and evaluate background information
	1.2	Confirm the proper delineation of the study area
	1.3	Develop environmental base maps for the study area
	1.4	Quantify baseline component data for each significant environmental issue
	1.5	Quantify impacts for significant environmental issues
	1.6	Develop feasible mitigation measures
	1.7	Collaborate with the feasibility study team on mitigation measures
	1.8	Carry out all related tasks described in the EIA format
	1.9	Prepare project reports (interim, draft, and final)
	1.10	Review report submittals with government regulators
2	**Task Scheduling:** Each task must be scheduled using a critical path defining interrelated or dependent action items.	
3	**Budget:** Each task must be budgeted in time and monetary units	
4	**Staff Requirements:** A list of staff and their qualifications required to complete the tasks must be included in the work plan.	

EIA Team Personnel

Most EIA reports are prepared by a team of environmental specialists drawn from various disciplines. In general, each team should have at least one qualified environmental engineer, social scientist, biologist, and physical scientist. All teams should be directed by an EIA Team Leader who has a good understanding of the administrative, procedural, and technical requirements of the country's EIA process. Experience with the type of development and its associated environmental impacts is also required.

The EIA team must include personnel with the managerial and technical expertise required to perform the work required by the EIA. The management skills are provided by the Project Manager and Deputy Manager, with planning and technical assistance provided by the Project Planner or Technical Analyst. Ideally the management team will have an extensive background in EIA work, but if this expertise is lacking in the management staff it can be provided by hiring an EIA expert. Project delays due to incomplete EIAs can be expensive, and have the potential to jeopardize funding from an international assistance agency. Staffing decisions should be based on the need to provide the skills required to complete the report. Table 11-3 deals with the staffing requirements of the EIA team.

Selection of the environmental specialists is based on the natural and human resources in the study area which may be affected by the project. As an example, a dam and flood control project may require the skills of a water resources engineer or hydrologist, an aquatic ecologist or fisheries specialist, an agricultural specialist, a socioeconomist, and an expert in resettlement. The personnel selection will be different for each project based on the components in the study area and the type and magnitude of project.

Task Schedule

EIA tasks must be scheduled so the subject items can be completed within the overall time frame of the EIA and feasibility study. The general concept of task scheduling represented in Figure 11-1 is complicated by the interlinking of tasks. For example, the models in Task 3 may require the data assembled during Task 2 as input prior to its inception. Often the work of one environmental specialist is dependent upon information from another specialist. For example, to evaluate fisheries impacts in a lake which is enlarged and deepened for water supply purposes, the fisheries specialist will need information regarding water quality impacts, provided by the water resource specialist or hydrologist. If the fisheries specialist cannot begin evaluations until the hydrologist has completed a task, this must be taken into account in overall planning. This interdependency of tasks is a result of the interconnected nature of components and requires careful task planning.

The EIA Budget

The EIA budget is a natural outgrowth of the task scheduling and staffing processes. The budget should be tied to the completion of tasks such as submittal and acceptance of interim, draft final, and final reports. For tasks which extend beyond the time frame of the EIA process (for example, the EMP), sufficient budget and payment scheduling must be provided.

Table 11-3: EIA team staff requirements (*source:* Asian Development Bank, 1994).

1. Project Manager

Qualifications

- √ Extensive EIA project management experience
- √ Experience on EIA projects of similar magnitude
- √ Good communication and organization skills
- √ History of completing projects on time and within budget
- √ Prior EIA expert experience, if possible

2. Deputy Project Manager

Qualifications

- √ Project management experience
- √ Experience in the local or regional area
- √ Familiarity with the local situation
- √ Excellent written and oral communication skills
- √ EIA experience or knowledge

3. Project Planner / Technical Analyst

Qualifications

- √ Knowledge of the project type – design, planning, and operations
- √ Understanding of EIA process and objectives
- √ Extensive background in project planning

4. Environmental Specialists

May include

- √ Physical scientists
- √ Biological and ecological scientists
- √ Social scientists
- √ Economists
- √ Engineers
- √ Other Specialists

5. EIA Expert

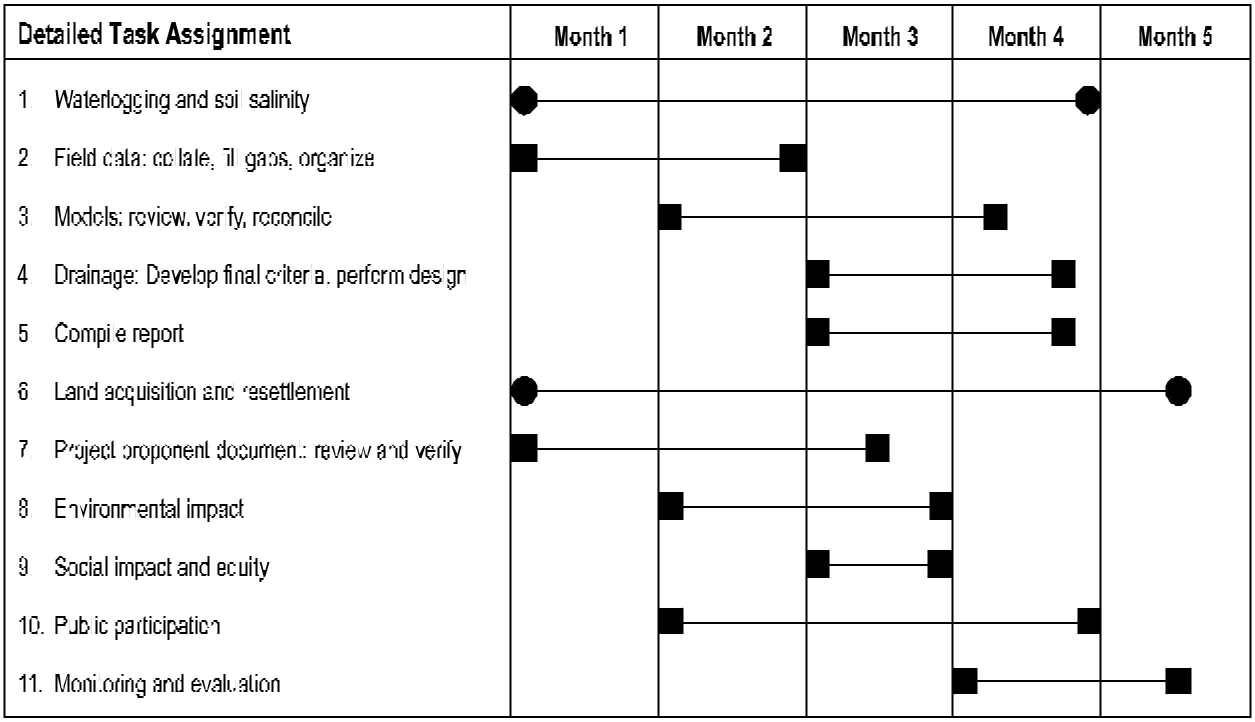


Figure 11-1: Work plan task schedule example (*source:* Asian Development Bank, 1994).

11.4 References and Further Reading

Asian Development Bank. 1993. Environmental Assessment Requirements and Environmental Review Procedures of the Asian Development Bank. Office of the Environment, Asian Development Bank. March 1993, 44 pp.

Asian Development Bank. 1994. Asian Development Bank Environmental Impact Assessment Training Program. Office of the Environment, Asian Development Bank. May 1994.

Canter, L.W. 1996. Environmental Impact Assessment. Second Edition. McGraw Hill, New York, NY. 660 pp.

Canter, L.W and G.A. Canty. 1993. Impact significance determination- basic considerations and sequenced approach. Environmental Impact Assessment Review 13: 275-297.

ESSA Technologies Ltd. 1994. Preliminary Design and Project Charter for ADB RETA 5544: Computerized EIA System. Report prepared for the Asian Development Bank. Manila, Philippines.

Federal Environmental Assessment Review Office. 1987. Determining the Scope of Environmental Impact Assessments. Prepared by ESSA Environmental and Social Systems Analysts Ltd. Vancouver, BC.

H.A. Simons Ltd. Consulting Engineers. 1992. Pulp and Paper Mill Feasibility Study: Phase I: Wood Supply, Environmental Screening, Site Assessment. Prepared for Advance Agro Group, Thailand.

Hilden, M. 1995. Evaluation of the significance of environmental impacts. Theme paper prepared for EIA Process Strengthening Workshop, April 4-7, 1995, Canberra, Australia as part of International Study on the Effectiveness of Environmental Assessment sponsored by the International Association of Impact Assessment, the Canadian Environmental Assessment Agency, and Australian Environmental Protection Agency. 11 pp.

National Environment Board. 1979. Manual of NEB - Guidelines for Preparation of Environmental Impact Evaluation. National Environment Board, Bangkok, Thailand.

Thompson, M.A. 1990. Determining impact significance in EIA: a review of 24 methodologies. Journal of Environmental Management, 30: 225-250.

U.S. Council on Environmental Quality. 1981. Memorandum: Scoping Guidance. U.S. CEQ, Washington, DC. 19 pp.

12.0 Reviewing and Evaluating an EIA Report

12.1 Introduction

An Environmental Impact Assessment (EIA) report is normally reviewed once it has been completed, before being submitted to the decision making authority. The main purpose of the review is to verify that the information and conclusions presented in the EIA report are sufficient for informed decision making. In most countries the formal review is undertaken by a governmental environmental review agency. The results of the review are then passed on to another agency for ultimate approval of the development project.

In spite of the important role that EIA information plays in project approval processes, the quality of EIA reports is highly variable. The scientific and technical information upon which environmental assessment decisions are being made is often inadequate. In a recent review of EIAs submitted to the Asian Development Bank (ADB, 1993), reports were evaluated for both their compliance with the Bank's prescribed format and the substance of the information provided. This review showed that EIA reports submitted to the ADB still require improvement.

Two primary reasons for poor quality EIA reports are lack of qualified environmental experts, and insufficient time and money. An additional cause is inadequate terms of reference (TOR) for the EIA study. Perhaps the main reason why poor quality EIA reports are still being prepared, however, is the lack of concerted effort by government environmental agencies to force improvements. Review authorities are not very rigorous in their review of EIA reports. This is evident in that there are few systematic approaches for review and evaluation. Problems in EIA reports are often identified during the review stage, however information on how to correct these problems and thus improve future reports is not being passed on to the consultants and academics who prepare them. Hopefully, the requirements of review authorities will become more stringent and the capabilities of reviewers will improve. This will lead to gradual improvements in EIA report quality.

This chapter outlines the main considerations in a proper review and evaluation of an EIA report. It follows Sadler (1996) in using the triple A-test of appropriateness (coverage of key issues and impacts), adequacy (of impact analysis), and actionability (does the report provide the basis for informed decision making?).

12.2 Review Criteria

An EIA report should satisfy three criteria:

1. completeness and conformance with the TOR for the EIA;
2. accuracy and veracity as defined by general acceptable scientific criteria (for example, quality assurance and quality control procedures for analysis of sampling data) and use of acceptable methods for the assessment of environmental impacts; and
3. clear description of environmental impacts, recommended mitigation measures, environmental monitoring plan, and environmental management plan.

12.3 EIA Report Quality Control

The EIA should be critiqued internally before being released for formal review by the EIA review authority. This critique should be undertaken to ensure the environmental assessment is complete, and that all tasks in the TOR have been performed satisfactorily. If the critique indicates that some requirements have not been met, they should be clearly defined for additional attention. The output of the critique is a written set of instructions on the additional work to be done by the EIA team. The critique is the quality control step for an EIA report. This is a critical step in the EIA process, as the outcome may affect the environmental acceptability of the proposed project.

The purpose of the critique is to ensure the final EIA reports sent to governmental agencies and other funding agencies for review and approval are complete, and present as accurate a picture as possible of the likely environmental effects of the project. The critique confirms that all significant issues have been addressed and that provisions for the management of these issues are contained in the EIA report. The critique ascertains that all tasks listed in the TOR for the EIA have been performed, especially the special requirements of any involved international assistance agencies.

A team of environmental and technical specialists normally assists with the critique of the EIA. The most practical approach to critiquing is first to examine the EIA report's Table of Contents to check that all the items required by the TOR are included. Each report section should then be reviewed to ensure it has been adequately handled; the TOR should be used for this purpose. In the People's Republic of China, quality control of the EIA is a specific step in the EIA process (Box 12-1).

Box 12-1: Critiquing EIA in the People's Republic of China

Once the EIA practitioners have completed the EIA report, it is reviewed prior to submission to the National Environmental Protection Agency or the Provincial Environmental Protection Bureau. This review may be undertaken by the staff or consultants of the project proponent. In some cases, special groups within environmental research institutes have been sent up to ensure quality is maintained in all EIA reports.

12.4 Formal Review of the EIA Report

Formal review of the EIA report is undertaken by a review authority that is part of the EIA administrative agency. In many cases, a technical review by agency staff occurs prior to the formal review by the review authority.

12.4.1 Two Approaches to Review

The review occurs at two distinct levels, both of which are required. There is also much interaction between levels (Schibuola and Byer, 1991). The first level is a systematic review of each major step or aspect of the EIA. Methods and approaches used are critiqued both on technical grounds and based on what is expected. The TOR may be used to define what is expected. Review at this level may be made on: 1) conformance and completeness as defined by the TOR; 2) accuracy and veracity as defined by general acceptable scientific criteria (for example, quality assurance and quality control procedures for analysis of sampling data); and 3) use of acceptable methods for assessment of environmental impacts.

The first level of review requires a standard (that is, the ideal EIA report) for comparison. While the TOR come closest to defining what should be in the ideal EIA, they are only useful if properly prepared — if the terms of reference are inadequate and imprecise, they will not serve as useful guide for the reviewer. It is, in fact, difficult to see how an EIA can be systematically evaluated without a well defined TOR for the EIA report. With knowledge of the TOR, the reviewer can easily search through the EIA to determine its completeness and conformance to the TOR. The Calyx-ADB expert system described in Chapter 8 uses this approach. Based on the TOR generated by the system, a review checklist is prepared that may be used to evaluate the EIA report.

The second level of review, which probes deeper into the EIA, does not rely on an objective standard for evaluation. It does rely on common sense, world knowledge, and understanding of the context and setting for the EIA. For example, a reviewer may notice, that in the analysis of alternatives, the preferred alternative is the one that was preferred by the proponent prior to conducting the environmental assessment (Schibuola and Byer, 1991). If the level one review indicates the methods used or the veracity of the results is in question, this knowledge may cause the reviewer to argue that the EIA is biased in favor of the proponent's preferred alternative.

12.4.2 Section-by-Section Review of the EIA Report: A Checklist

This section, organized according to the table of contents for a typical EIA report as presented in Chapter 11, provides a list of what to look for in each section of the EIA report.

Executive Summary

- ✓ an adequate summary of the significant findings of the EIA report
- ✓ a sufficiently detailed description of how significant environmental issues will be resolved — enough to allow the reader to grasp its importance and scope, as well as the appropriateness of the approach taken to resolve
- ✓ a presentation of the study's conclusions
- ✓ effective, simple visual presentations of the type and magnitude of the impacts

Introduction

- ✓ the project rationale
- ✓ methods used to identify, predict and assess impacts
- ✓ a review of similar projects
- ✓ the purpose and overview of the report

Project Description

- ✓ a listing of project activities that are likely to cause significant impacts to environmental resources
- ✓ a listing of mitigation measures to be incorporated into the project
- ✓ the location, scale, and scheduling of activities
- ✓ potential accident or hazard scenarios covered in the risk assessment are based on the characteristics of the project and the history of accidents at similar types of facilities
- ✓ information should match the expected operations according to the feasibility study

Description of the Environment

- ✓ a description of the environmental components that may be significantly affected by the project
- ✓ an explanation of the derivation of environmental indicators chosen to represent environmental components
- ✓ base maps for spatial data (Base maps are an extremely valuable tool to orient the intended audience of the EIA report with regard to the distribution of the various resources, and their proximity to the project site. The map legends must be clear for each resource, and the maps easy to read and accurately scaled. All of the major topographical and land use features in the project area should be included on the maps. A common mistake in many developing country EIAs is to use the feasibility study maps. Feasibility study maps contain much information that is superfluous for EIA purposes. Experience has shown that the presence of carefully planned environmental base maps is a good indicator of the quality of an EIA report (Ludwig *et. al.*, 1988).)
- ✓ baseline values, or some other appropriate form of quantitative and qualitative information, for resources that may be affected either directly or indirectly by project activities (Baseline values are important because they represent the pre-existing conditions that the environmental protection measures identified in the EIA are intended to preserve — to the extent possible, within economic-cum-environmental development constraints.)

Anticipated Impacts

- ✓ a description of the major issues
- ✓ documentation of the cause and effect relationships between planned project activities and the environmental components
- ✓ identification of secondary or higher order effects, with clearly defined pathways of impacts from higher order effects
- ✓ impact prediction includes a number of stated assumptions that affect the predicted impacts, their probability of occurrence and degree of impact
- ✓ methods used to predict impacts
- ✓ an assessment of the significance of predicted impacts
- ✓ methods or approaches to assigning impact significance
- ✓ justification for the choice of methods used to predict environmental impacts (This can be based on a review of the previous use of the model, which can be substantiated by a review of relevant published scientific and technical articles and reports.)

Mitigation Measures

- ✓ a description of all the environmental protection measures considered to mitigate or offset damaging environmental impacts from project activities
- ✓ a description of the costs and benefits for each recommended environmental protection option developed to resolve a significant environmental issue, as well as a comparison of each option to the other options; the justification for a recommended option must include an explanation of how its cost was weighed against the projected reduction in value of the environmental resource
- ✓ appropriateness and cost effectiveness of environmental protection measures
- ✓ a description of the technology used in each environmental protection measure, including information regarding its prior effective use, the range of environmental conditions under which it is effective, and the level of skill required to operate or maintain the technology

- ✓ a time schedule for implementation of the environmental protection measures, showing that they will be in use before the project impacts are felt
- ✓ a drawing or table that illustrates how the mitigation measures address the significant environmental issues

Alternatives

- ✓ an acceptable evaluation method
- ✓ a definition of environmental factors
- ✓ a comprehensive listing of environmental factors considered
- ✓ an acceptable range of alternatives
- ✓ a defined method of scaling
- ✓ a defined method of weighting
- ✓ a defined method of aggregation
- ✓ a correctly applied method
- ✓ explicitly stated assumptions
- ✓ uncertainty considered

Environmental Monitoring Plan

- ✓ monitoring objectives (that is, is monitoring linked to determine actual effects and effectiveness of environmental protection measures)
- ✓ well specified questions to be addressed by the monitoring program
- ✓ clearly defined measurable environmental indicators
- ✓ a sampling design (frequency, intensity) sufficient to provide the information necessary to answer questions
- ✓ analytical system quality assurance and quality controls are effective
- ✓ information for reporting monitoring results in place

Additional Studies: Environmental Economics

- ✓ evaluation method acceptable
- ✓ environmental factors defined
- ✓ environmental factors comprehensive
- ✓ methods for valuation of environmental components described
- ✓ methods applied correctly
- ✓ assumptions explicitly stated
- ✓ uncertainty considered

Additional Studies: Public Participation

- ✓ strategy and approach
- ✓ chronology of individuals and groups consulted
- ✓ descriptions of methods used to consult with public

- ✓ summary of information obtained during consultations and how it was used in preparation of the EIA report

Environmental Management Plan and Environmental Management Office

- ✓ detailed descriptions of the environmental protection measures, the monitoring program, and a variety of other required follow-up activities
- ✓ monitoring requirements
- ✓ staffing requirements
- ✓ budgets and schedules
- ✓ administrative arrangements
- ✓ administrative mechanisms for enforcement and taking corrective action are in place

Summary and Conclusions

- ✓ net benefits which justify the project
- ✓ explanation of how adverse effects have been mitigated
- ✓ explanation of use or destruction of any irreplaceable components
- ✓ provisions for follow-up surveillance and monitoring

Annexes

- ✓ quality of relevant background documents
- ✓ quality assurance of data presented
- ✓ assessment of people contacted
- ✓ reliability of data sources

12.5 Problems in Conducting EIA Reviews and Evaluations

The expertise required for EIA review is essentially the same as that required for preparing the EIA report. While it is desirable that the first stage of the review be done by technical staff in the EIA administration agency, in most developing countries, the EIA administrative agency is short on the necessary environmental expertise required to conduct the review. The usual solution to this problem is to furnish these skills to reviewers in the EIA administrative agency through either training or use of advisory committees composed of academics or consultants from the private sector. In Thailand, where advisory committees are used (see section 2.10), experience has shown that the advisory committee members themselves (despite the high status in the developing country) may lack sufficient expertise.

There are very real constraints on the availability of environmental information to be used in an EIA report. Time and budgets often do not allow for extensive new data collection and there is considerable reliance on existing and secondary data. In spite of this, most EIAs provide considerable background information on the environment. The problem is that they often provide little else. Where they are most obviously lacking is in the assessment or prediction of impacts and in the provision of details of appropriate environmental protection measures.

12.6 References and Further Reading

Asian Development Bank, 1993. Environmental Assessment Requirements and Environmental Review Procedures of the Asian Development Bank. Office of Environment, Asian Development Bank, Manila, Philippines. 44 pp.

Ludwig, H.F., *et. al.* 1988. Environmental Technology in Developing Countries. South Asian Publishers, New Delhi, India.

Ross, W.A. 1994. Environmental impact assessment in the Philippines: progress, problems, and directions for the future. Environmental Impact Assessment Review, 14: 217-232.

Sadler, Barry. 1996. Environmental Assessment in a Changing World: Evaluating Practice to Improve Performance. Final Report of the International Study of the Effectiveness of Environmental Assessment. Minister of Supply and Services (Canada), Ottawa, ON.

Schibuola, S. and P.H. Byer. 1991. Use of knowledge based systems for the review and evaluation of environmental impact statements. Environmental Impact Assessment Review, 11: 11-27.

13.0 Future Trends in Environmental Impact Assessment in Asia

The practice of environmental impact assessment (EIA) is evolving. Major problems exist, and many question its overall effectiveness. The recently completed International Study of the Effectiveness of Environmental Assessment focused on ten organizing themes (Table 13-1). The Effectiveness Study was based primarily on developed country experiences in North America and Western Europe, however, these ten basic themes have much in common with many of the emerging trends in the development of EIA principles, procedures, and practices in developing Asia.

13.1 Examining the Foundations

Most countries in Asia have established EIA processes. Some countries have considerable experience with EIA. The early focus in the region was on controlling pollution and restricting industrial development that was clearly detrimental to human health and the natural environment. Today, environmental assessments must deal with a wide range of environmental, economic, social, and cultural issues. As living standards increase, people are demanding better environmental quality and a greater say in development decisions. In addition to considering a broad range of issues, EIAs are becoming more inclusive with respect to the participation of interested stakeholders. Most national governments are thus being forced to reexamine the basic principles embodied in their EIA processes. This reexamination is creating increased impetus to ensure that EIA processes are effective.

The biggest single constraint on the effectiveness of EIA is the timing of the assessment in the development project cycle. In spite of attempts to ensure that EIA information reaches decision makers early in the development planning cycle, many EIAs occur only after major decisions (for example, site selection and investment) have been made. As a result, any EIA findings that may result in delays, major project modification, or outright cancellation are difficult to accept.

The practice of EIA is not without other shortcomings. For example, EIA has not been very useful in addressing environmental degradation caused by the development or continued operation of small- and medium-scale industrial production. Similarly, it has not been very effective in planning rural development/agriculture projects. To apply EIA in the planning of small-scale/dispersed developments, governments need to (i) strengthen the regional environmental planning practices and enable institutions responsible for monitoring regional developments to use EIA for regional as well as project specific developments, and (ii) strengthen industrial permit systems and enable environmental agencies to use EIA as one of the key permitting parameters for new as well as existing industries.

13.2 Sustainability

EIA has been accepted as an essential tool for implementing the principles of sustainable development. In this light, there is an increasing trend to assess the sustainability of projects. In some cases, this is merely an extension of traditional approaches (for example, a raw material supply analysis for a pulp and paper mill, a water supply analysis for a new industrial park). In other cases, it may mean incorporating an examination of the capacity of a water body or an airshed to provide a sustainable flow of economic, social, and environmental benefits to people.

Table 13-1: Frames of reference for initial review of trends and innovations (*source:* Sadler, 1995).

Organizing Theme	Level and Focus of Review	Key Issues
A. Foundations	***Adequacy of EA Systems***	***What is the Role of "Second Generation" EA?***
I) Guiding Values and Principles	• purpose and orientation of EA • basic requirements for all effective processes • key values, objectives and principles of approach • procedural and methodological implications	How are the functions of EA changing? To what extent do the purposes and assumptions that guided the design and institutionalization of the process still hold? What are the characteristics of effective EA process and practice? How are / might they be expressed in law, policy and institutional arrangements?
B. New Dimensions	***Scope of EA Process***	***Where is EA Going?***
ii) Application of Sustainability Concepts	• nature and implications of sustainability concepts • translation into operational guidelines and rules of thumb • incorporation into EA policy and practice • adjustments to procedures and methods	What is the value and relevance of sustainability concepts, such as biodiversity, natural capital and intergenerational equity? How might these be substantiated and applied in EA? What accompanying process adjustments may be necessary, e.g., to significance criteria, impact analysis and mitigation?
iii) Strategic Environmental Assessment (SEA)	• rationale and potential of SEA • linkages to project EA and other policy and planning instruments • recent approaches and arrangements for the conduct of SEA • institutional and methodological constraints and opportunities	What institutional frameworks are in place for applying SEA? How is the conduct of SEA similar to or different from project EA? Which methods and procedures are employed and what are their strengths and weaknesses? What are requirements for, and barriers to, an effective process?
iv) Cumulative and Large Scale Effects	• definitions and requirements for addressing cumulative effects • project oriented versus ecosystem approaches • frameworks for planning and monitoring • relationships to product assessment life cycle analysis and environmental audits	What is the status of the theory and the practice of assessing cumulative and large scale effects? How are incremental, regional or global changes addressed in EA processes? Which procedures and methods are employed and with what results? Where might immediate improvements be made to our approaches?
C. Process Strengthening	***Elements of Approach***	***How Can EA Methods and Procedures Be Improved?***
v) Relationship to Decision Making	• utility of inputs to decision making process • importance of evaluation of alternatives • EA documentation and quality review • implementation of terms and conditions	How is EA related to types and levels of decision making? To what extent does this process focus on the justification for and to a proposal? How useful for decision making are EA reports in clarifying the pros and cons of proposed action? What changes might improve their relevance for this purpose?
vi) Integrated Approaches to Impact Analysis	• "best guess" science paradigms and practices • traditional knowledge • user-friendly tools, techniques and information technologies • relationship of socio-economic, biophysical, health and risk components	How well does impact assessment serve decision making under conditions of uncertainty? Which approaches and instruments are or can be applied for "policy integration" of cross-media and cross-domain impacts? How can we best deploy scientific analysis and interest-based negotiation to integrate knowledge and values in the form of advice to decision makers? What tool kits are available to facilitate problem solving by local communities and groups?
vii) Public Participation and Dispute Settlement	• conflict resolution in the EA process • provisions for public scrutiny and involvement • forms of participation and negotiation • relationship to decision making powers and responsibilities	What are the roles and scope of public participation in EA? What procedures are followed to ensure openness and fairness of processes? Which methods are employed and with what results? Are mediation and other alternative dispute resolution procedures being used and with what success?

Organizing Theme	Level and Focus of Review	Key Issues
viii) Follow-up and Post Project Analysis	• requirements for follow up to EAs • experience with effects monitoring and impact management • use and results of EA audits • ex-post review for process development	What is the scope of EA review and follow-up? Which types of follow-up procedures are employed and with what results? How are the results incorporated into impact management, future project cycles, and EA policy and practice?
ix) Total Process Management	• managing for quality, integrity and innovation • coordination of EA processes with other policy, planning and regulatory instruments • coherence of EA systems, including protocols and procedures for transboundary EA • information and communication media	How can the cost-effectiveness of EA processes be improved? How is EA linked to other processes, such as sustainability strategies, land use planning and pollution control? What measures are followed to harmonize EA systems, nationally and internationally? How can administrators best communicate with EA users, including decision makers and the public?
x) Capacity Building	• needs and demands • training, networking and cooperation • research, development and pilot projects • EA skills and competencies for the 21st century • international standards	What are the needs of industrial and developing countries, and how do they vary regionally and by country? What is the actual and potential contribution of EA training to professional and institutional strengthening? How might cost-effective support and cooperation be established? What are the priorities for EA research and development?

Inclusion of sustainability criteria often forces examination of the very difficult questions of the maintenance of biodiversity and ecosystem integrity. For example, the development of tourist facilities and aquaculture facilities in the coastal zone has often been at the expense of mangrove and other coastal ecosystems that have provided a sustainable flow of benefits to coastal peoples over countless generations.

EIA is expected to play an increasing role in ensuring that projects meet sustainability criteria. To achieve this, EIA of the future must take a lead planning role in orienting industry, tourism, urban infrastructure and other developments toward cleaner production, waste minimization, and pollution prevention. The analysis should compare proposed processes to alternative, cleaner technologies. Similarly a life cycle analysis should be incorporated in the EIA and impacts should be evaluated for alternatives. It will be appropriate for EIA reports of the future to evaluate requirements for selected projects to meet ISO 14000; to recommend self monitoring potentials and integrate such with recommended command and control monitoring; and to recommend voluntary compliance alternatives. It is likely that these approaches to environmental management will be realized in developing countries only if industry/developers take the lead. This possibility will become more likely if the project EIA quantifies the benefits and prescribes the steps and inputs required.

13.3 Strategic Environmental Assessment

Strategic environmental assessment has been defined as:

> The formalized, systematic and comprehensive process of evaluating environmental impacts of a policy, plan, or program and its alternatives, the preparation of a written report on the findings, and the use of the finding in publicly accountable decision making (Therivel, 1995).

The European Commission is scheduled to publish a draft of its directive on strategic environmental assessment. This directive applies to plans and programs "which are being adopted as part of the land use decision making process for the purpose of setting the framework for subsequent development consent decisions which will allow developers to proceed with projects" (Explanatory Memorandum accompanying the draft Directive). The proposed directive provides a procedural framework for carrying out a strategic environmental assessment of plans and programs. An environmental statement containing the following items is required:

1. contents of the plan;
2. environmental characteristics of any area to be significantly affected by the plan/program;
3. any existing environmental problems relevant to the plan/program;
4. likely significant direct and indirect environmental effects of implementing the plan/program on people, biota, soil, water, air, climate, landscape, material assets, and cultural heritage;
5. alternative ways which have been considered for achieving the objectives, and the reasons for not adopting the alternatives;
6. measures to prevent, reduce, and where possible offset significant adverse environmental effects;
7. difficulties encountered in carrying out the environmental assessment; and
8. a non-technical summary of the environmental statement.

Strategic environmental assessment is a response to the recognition that project-focused EIAs are not adequate for all levels of decision making. Many of the new approaches to EIA are designed to extend beyond its more traditional project focus. These new approaches include:

- ***Class Assessments,*** which cover the common impacts of similar projects that are unlikely to vary with location. For example, dredging in riverine environments will generate similar impacts in many different rivers and estuaries. The EIA for any particular project may draw upon a generalized impact analysis. As experience has grown, the efficiency of class assessments has increased with their use.
- ***Programmatic EIAs,*** which address the impacts of large scale projects at many sites (e.g., strip mining of coal in a region of generally homogeneous terrain). An overall assessment may suffice for many individual project localities.
- ***Sectoral EIAs***, which highlight the impacts of development in an industrial sector by comparing different technologies that may eventually be chosen. For example, if the initiating project is a highway, the sectoral approach would assess alternative transportation modes (e.g., light rail transit) to accomplish the same goal.
- ***Regional Master Planning,*** which is the most attractive level for managing the environment. In this case, an entire river basin, a watershed, an air quality district, a managed ecosystem, a coastal zone, or an island is analyzed for the probable environmental impacts of all types of economic development. Current and future pollution controls are estimated. Vulnerable and valuable natural areas are marked for conservation. Industrial parks are sited in appropriate areas where wastes and infrastructure can be concentrated for the most cost-effective management. In the context of regional master planning, ecologically sensitive areas should be identified, research begun on the major ecosystems, cumulative effects of past, current and future development analyzed, and rough carrying capacity established. To fund such studies of these natural systems, contributions are solicited from all development interests. Programs are coordinated and organized by the local government.
- ***Development Strategies***, which require environmental assessments because they select technologies, and set priorities and timetables for large financial investments. For example, in considering whether to exploit some natural endowment of mineral resources, potentially great environmental consequences should be assessed at the outset. The usefulness of comprehensive assessment can also be illustrated by examining the effects of our strategy of dependence on large

hydro power projects around the world — including the effects of displacing many persons from reservoir zones.

- ***National Budgets***, which should have specific reference to environmental protection expenditures and environmental degradation costs. The availability of full environmental cost accounting is growing and is based on the same quantitative bio-geophysical indicators and measurements as are generated in the basic EIA. So called "green report cards" are being considered by both the Organization for Economic Cooperation and Development and the World Bank for noting the environmental management performance of various countries.

Methods and procedures for conducting EIAs for these higher levels of decision making are not well developed. Few of the large body of EIA practitioners that are well qualified to conduct project level assessments can claim expertise in the various facets of strategic environmental assessment.

13.4 Cumulative and Large Scale Effects

Cumulative impact assessment (CEA) allows for interest in the valued environmental resources, not simply the impacts of a single project. The problem with CEA is how to practically limit the scope of its application. In the absence of guidance on how to bound the CEA, the EIA practitioner will claim to have inadequate resources and will thus limit their assessment to the project direct impacts.

Examples of cumulative effects problems encountered in developing Asia are:

- long range transport of air pollutants;
- urban air quality and airshed saturation;
- mobilization of persistent or bio-accumulated substances;
- climate change;
- habitat alienation;
- habitat fragmentation;
- reduction in soil quality and quantity;
- reduction in ground water supplies and ground water quality;
- effects associated with agricultural, silvicultural, and horticultural chemicals;
- increased sediment, chemical, and thermal loading of freshwater and marine water;
- accelerated rates of renewable resource harvesting;
- long term containment and disposal of toxic wastes; and
- productive land loss due to infrastructure development.

Consideration of the potential of new projects to exacerbate these problems has not been effectively integrated into EIAs in developing Asia. This is partly because “cumulative effect” is one of the most confusing of all EIA concepts. Cumulative effects are difficult to analyze and there are few agreed upon methods for their assessment.

Canter (1996), following the United States' approach, defines cumulative impact as:

> "the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non federal) or person undertakes such other actions. Cumulative impacts can result from individually minor, but collectively significant actions taking place over a period time."

Another view (Sonntag *et al*, 1986) states: "Cumulative effects can be characterized as impacts on the natural and social environments which: 1) occur so frequently in time or so densely in space that they cannot be assimilated; or 2) combine with effects of other activities in a synergistic manner"

Most EIA practitioners and EIA processes in Asia are not well suited to the assessment of cumulative effects. It is, however, anticipated that much greater consideration of concepts such as "sustainability," "assimilative capacity," "ecological thresholds," and "carrying capacity" will be used in future EIAs. There will likely also be much greater understanding of the need to place EIA of individual projects in the context of regional planning.

13.5 Decision Making

There is every reason to believe that the results of the EIA process will have increasing influence over development decision making. National governments and international assistance agencies (IAAs) are increasingly recognizing the environmental costs associated with failure to account for the environmental impacts of projects. EIA processes have been criticized for lack of effectiveness by many quarters. In most cases, the response has been to strengthen the legal, regulatory, and institutional capability of EIA agencies.

Most development assistance, whether multilateral or bicameral, is now subject to the environmental assessment requirements of the donor's jurisdiction. In addition, some countries (e.g., The Netherlands) are implementing procedures within their embassies to assess the environmental impacts of all their activities in developing countries. Developing countries, while actively encouraging foreign and domestic investment, are very conscious of ensuring that investors incorporate environmentally sound technologies into their projects. Procedures and practices at two major decision points in the EIA processes are constantly changing. The trend toward improvements in 1) screening and scoping; 2) EIA report quality and EIA review; and 3) environmental monitoring will continue.

13.5.1 Screening and Scoping

Screening is necessary to avoid overwhelming the EIA administrative agencies with unnecessary assessments. Screening helps limit the number of projects that require detailed scrutiny within the EIA process. Screening criteria have been developed based on experience with the environmental impacts of various types of projects gained over many years. These criteria will continue to be refined to ensure increased efficiency in defining the EIA requirements of development projects. The EIAs of those projects that do require more detailed environmental assessments will be better prepared. Greater emphasis during the scoping stage is being placed on the terms of reference for the EIA being jointly developed by the EIA administrative body, the project proponent, and the EIA practitioners.

13.5.2 EIA Report Quality and EIA Review

Better terms of reference will increase the likelihood that high quality EIA reports are prepared. The scientific and technical quality of impact analysis will naturally increase as the capability of the EIA practitioners increases. Increased participation by the public and other stakeholders in the EIA process will also raise the quality of EIA reports. Public participation, however, is likely to have a more dramatic effect on the nature of EIA review. There will be increased demands for accountability of EIA reviewers, EIA administrative agencies, EIA practitioners and proponents alike. This will increase the care and attention taken in the scrutiny of EIA reports.

A related problem is the institutional weakness of governments (and institutions such as IFIs) to efficiently and accurately determine prescriptions for environmental management and monitoring which are affordable, achievable and meet environmental quality management needs. It may be that the routine review process does not take advantage of local government knowledge or selected individuals' expertise. Future changes to the EIA process should include improvements to ensure key individuals or institutions are included in this aspect of the review process.

13.5.3 Monitoring

Current problems with the use of EIA for environmental planning have little to do with shortcomings in the planning approach and more to do with the reliance on monitoring and enforcement by governments to see that recommended mitigation/management measures are effectively implemented. The EIA report can address this shortcoming by including an assessment of the capabilities of designated responsible parties to implement the measures. Where there are risks of noncompliance, the EIA should recommend alternative implementation measures (e.g., giving responsibility through contracts to independent parties).

The most widely recognized weakness in the EIA process is the apparent inability of governments and IFIs to follow approval of project EIAs with monitoring. The EIA could include an institutional evaluation of the capabilities of the approving agencies to monitor the implementation of mitigation and/or management measures and recommend how a) to strengthen their capacity to do so, or, b) probably more realistically, how to achieve the measures through alternative approaches (again through contracting or other alternatives).

13.6 Improvements in Methods and Approaches

13.6.1 Best Practices

Developing Member Countries (DMCs) must build their own databases and make use of past EIAs. Usually, past EIAs are not available to those preparing subsequent ones; sometimes they are treated as confidential. In addition, some map-based data are only available for military purposes. Continued efforts to develop and make accessible libraries, inventories and databases of best EIA practices will lead to increased capability of EIA professionals in DMCs.

13.6.2 Sectoral Guidelines

In the short term, improvements to EIA methods and approaches will focus on developing technical guidance for the preparation of environmental assessments. Sectoral guidelines help proponents more clearly understand the scope and required level of detail for EIA reports. The trend is toward each country preparing its own set of guidelines for each sector; certainly most ASEAN countries are moving this way (e.g., Malaysia is well advanced in guideline preparation). IAAs like the Asian Development Bank (ADB) have also developed sectoral guidelines for most major project types. Other countries will benefit greatly from adapting these guidelines and preparing guidelines in their own languages suitable to their own special needs.

13.6.3 Disciplinary Guidelines

Sectoral guidelines will be complemented by disciplinary methodological guidelines. These will also be provided in each DMC. Guideline development will be coordinated by national working groups composed of selected experts from throughout each country. Initial work on national guidelines should concentrate on the following: 1) ecological impact assessment, 2) social impact assessment, 3) environmental economic analysis, 4) regional development impact assessment, 5) public consultation, and 6) environmental risk assessment.

13.6.4 Environmental Information Systems

There will be increased use of information technologies in all aspects of environmental assessment. There are some redirections required for EIA to optimize availability of "new" technologies and environmental management practices. For regional environmental management, EIA must take better advantage of GIS-based planning and monitoring systems. Remote automatic monitoring systems should also be considered at the project level and linked to national or regional monitoring systems. Other examples include use of CD-ROM technologies to deliver EIA knowledge through training, EIA tracking systems for managing the administrative aspects of the EIA process, computer models to help provide more rigorous predictions of impact, and expert systems to provide EIA procedural and technical knowledge to a wide range of EIA stakeholders.

13.7 Public Participation and Dispute Resolution

Public participation is becoming increasingly more important in EIA processes in Asia. A recent ADB technical assistance project, "Strengthening Environmental Impact Assessment in Thailand," was tasked with both incorporating public participation requirements into the environmental assessment process and developing guidelines for public participation. The approach taken in the guidelines is consistent with the participatory development approaches being used by IAAs in project design, development, and implementation.

13.8 Follow-up and Post Project Analysis

Post audit and evaluation of environmental management plans and monitoring programs provides a means to learn from experience. Systematic evaluation of monitoring results allow EIA practitioners to understand strengths and weaknesses in existing approaches. This understanding will naturally lead to better techniques and approaches to impact assessment. Monitoring information is essential in helping to determine the effectiveness of mitigation measures. Without the essential feedback on "what works" and "what does not work" provided by monitoring programs, each new project will be designed like the last one. There will be little opportunity to learn from previous mistakes, and to apply new and better mitigation techniques.

In the future, increased emphasis will be placed on post-approval monitoring and post-project evaluation procedures, particularly within IFIs. In some DMCs, however, it will not be practical to incorporate strict provisions for post approval monitoring into the EIA process for some time. The costs and staffing needs for such a program may not currently be justifiable. Initially, educational programs will be needed to increase awareness of the role that post-project approval monitoring can play in the EIA process. As a first step, it will be desirable to provide training in environmental effects monitoring programs, including the design of such programs.

Post evaluation reports like those prepared by the ADB (see Chapter 9: Environmental Monitoring Program) are useful sources of information. Nonetheless, one further step is required. We must ensure that we learn from experience. From time to time, a formal and systematic post hoc evaluation of the effectiveness of environmental protection efforts on development projects must be undertaken. The results must be assembled and then disseminated, widely and rapidly, by an independent body. For example, the International Association of Impact Assessment or some other professional society should be mandated to conduct retrospective appraisals and report on the results.

13.9 Capacity Building

Capacity building in the context of EIA is far more difficult than most donor agencies realize. Current approaches to capacity building are being re-evaluated, yet there remains a great emphasis on training courses and seminars. These are very visible, but unfortunately, unless they are extraordinary well designed, many of these do not achieve tangible results. The focus on increasing the skills of those involved in EIA is correct, but the mechanism of delivery is often inappropriate. The best training programs are those developed in consultation with the EIA professionals in the country. Training materials should always be translated into the national language. In doing so, a set of teaching materials and a cadre of trainers is left behind. This provides the basic capital necessary to undertake training but does not provide for the operating funds. The next step is to provide the financial resources to deliver the training programs. The best programs are those that are able to access a substantial counterpart contribution and commitment. Future training courses will be increasingly well targeted at the four main groups that require training: those that manage the EIA process, those that prepare EIA reports, those that review EIA reports, and proponents who are responsible for environmental planning, assessment and management of their developments.

Guideline development (see section 13.6) is another major focus of capacity building. Here the trend is toward sectoral and jurisdictional guidelines. The trend is also to have these sectoral guidelines developed by a team or committee of national and international experts. The international experts bring a broad perspective and the latest knowledge, while the national experts best understand the local needs and context. Guideline development is often complemented by case studies. These case studies provide practical experience to a small group of practitioners, while allowing for EIA methods to be adapted to the local context.

Capacity building will continue to provide assistance in strengthening the public administration of EIA processes. In addition to increasing the skills of public servants, there will be increased help to develop standard operating procedural manuals, computer-based systems for tracking proposals, and databases for managing information.

13.10 References and Further Reading

Canter, L.W. 1996. Environmental Impact Assessment. McGraw-Hill, New York, NY.

Sadler, Barry. 1997. EIA process strengthening - perspective and priorities. Pages 1-29 in Report of the EIA Process Strengthening Workshop, Canberra 4-7 April, 1995. Published by the Environmental Protection Agency, Canberra, Australia for the International Study of the Effectiveness of Environmental Assessment.

Sonntag, N.C., R.R. Everitt, L. Rattie, D.L. Colnett, C.P. Wolf, J. Truett, A. Dorcey, and C.S. Holling. 1986. Cumulative Effects Assessment: A Context for Further Research and Development. Canadian Environmental Assessment Research Council (CEARC), Hull, QC. 99 pp. and appendices.

Therivel, R. (ed). 1995. Environmental appraisal of development plans 2; 1992-1995. Working paper 160, School of Planning, Oxford Brookes University.

Appendix

Using the Internet as an EIA Resource Tool

As more and more of the world becomes linked by computer and communications technology, the possibilities for using the Internet as a resource for environmental impact assessment (EIA) are growing. The purpose of this appendix is not to explain how to use the Internet, but rather to highlight some of the many types of information accessible through the World Wide Web (WWW). While some potentially useful web site addresses are provided, it is important to note that the WWW is a dynamic, constantly evolving place. As such, the addresses and the information available through the Internet are always subject to change. The best way to appreciate the utility of the WWW is to spend some time getting comfortable with search mechanisms and looking at what is available through various sites.

One of the features of the WWW is the ability to be linked electronically from one site to another. As such, once one finds a site of interest, many more relevant sites may be easily accessible without further searching. The International Association for Impact Assessment's (IAIA) home page, for example, contains an extensive index of useful Internet web sites, with links to most. This index, developed by the Environmental Assessment and Compliance unit of the Canadian International Development Agency, includes sites covering a wide range of EIA-related topics — everything from databases of EIA training courses to predictive models to strategic EIA. Some sites that may be of interest to practitioners of EIA in developing countries in Asia are listed below, along with brief descriptions of the type of information the sites contain.

ACCESS EPA: An Environmental Directory
(http://earth1.epa.gov/Access/)

This site provides a directory of the U.S. Environmental Protection Agency and other public sector environmental information resources. There is an extensive list of environmental topics.

Australian EIA Network
(http://www.erin.gov.au/net/eianet.html)

This is an extensive site managed by Environment Australia's Environmental Protection Group which includes contact names and addresses, case studies; information on EIA training resources (for example, the UNEP EIA Training Resource Manual, the IAIA training course database), EIA in Australia, and legislation and agreements; discussion and policy documents (on such topics as social impact assessment, public participation, strategic assessment, cumulative impact assessment, etc.).

Bibliography of Biodiversity Assessment Methodologies
(http://www.erin.gov.au/life/general_info/biodiv_assess_intro.html)

This site provides a large bibliography of methods for assessing biodiversity.

Canadian Environmental Assessment Agency
(http://www.ceaa.gc.ca)

In addition to information about the Canadian Environmental Assessment Act, this site contains reports of the study on environmental assessment effectiveness and links to numerous other relevant sites.

Ecological Risk Analysis: Tools and Applications
(http://www.hsrd.ornl.gov/ecorisk/ecorisk.html)

Information, provided by the Oak Ridge National Laboratory, which can be used to conduct ecological screening and baseline risk assessments. The site includes a database of benchmarks for aquatic organisms, wildlife, and sediments; guidance documents for performing environmental assessments; and links to other good assessment sites.

Envirolink
(http://envirolink.org/)

This site provides a compilation of comprehensive, up-to-date environmental resources available through the WWW. It has links to sites covering just about any topic related to the environment field, including risk assessment.

Envirosense
(http://es.inel.gov/)

This site is the U.S. Environmental Protection Agency's pollution prevention forum; a repository of information related to pollution prevention, compliance, pollution control technologies, etc. It has numerous databases.

International Association for Impact Assessment
(http://www.ext.NoDak.edu/IAIA/)

This site contains information about the IAIA, selected references on various aspects of EIA, and numerous links to relevant sites, including the Impact Assessment Journal and the IAIA Newsletter.

International Institute for Sustainable Development
(http://iisd1.iisd.ca/)

This homepage has a number of documents relevant to EIA, including an EIA database. It also contains ISO 14,000 information.

U.S. Environmental Protection Agency's Air Pollution Database
(http://www.epa.gov/dics/airs/airs.html)

This is a repository of resources relevant to airborne pollution in various countries. The extensive list of resources includes data from monitoring systems, a list of air pollution point sources, reference data, and a technology transfer network.

U.S. Environmental Protection Agency/Purdue University Software for Environmental Awareness
(http://www.epa.gov/glnpo/seahome/)

More than 40 of the EPA's environmental software programs can be found at this site, as well as an Environmental Assessment Resource Guide (a generic source of information for conducting EIA for many types of projects, this document covers scoping, alternatives identification, impact identification and analysis, mitigation measures, and decision-making) and a Comparative Risk Assessment methodology.

University of Manchester, EIA Centre
(http://art.man.ac.uk/eia/EIAc.html)

This homepage contains EIA newsletters, an EIA leaflet series, discussion papers, lists of the Centre's publications and training activities, and documents regarding developing country initiatives in EIA.

Water Quality Assessment
(http://www.ncl.ac.uk/~nxc/EIA.html)

This site provides an on-line computer modeling program for water quality assessment; it predicts the two-dimensional concentration distribution of pollutants in a river downstream from a discharge point. The model adopts an approximate solution identified as a standard EIA calculation method by environmental authorities in many countries for new and extension construction projects.

World Bank
(http://www.worldbank.org)

A search on environmental assessment retrieves a number of documents, including papers detailing EIA case studies in developing countries.