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.

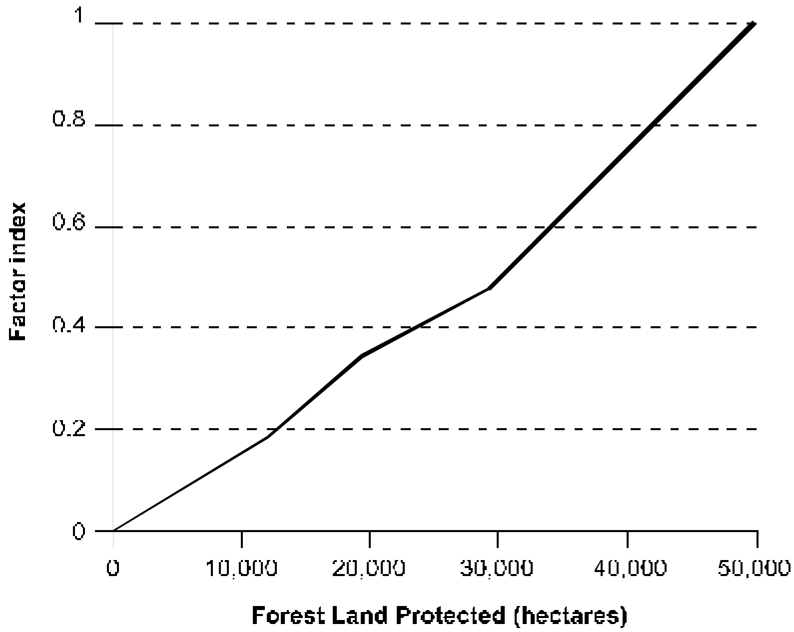

Figure 3-1: Factor index for forest land protected.

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		I) 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
	I) 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		I) 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
	I) 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).

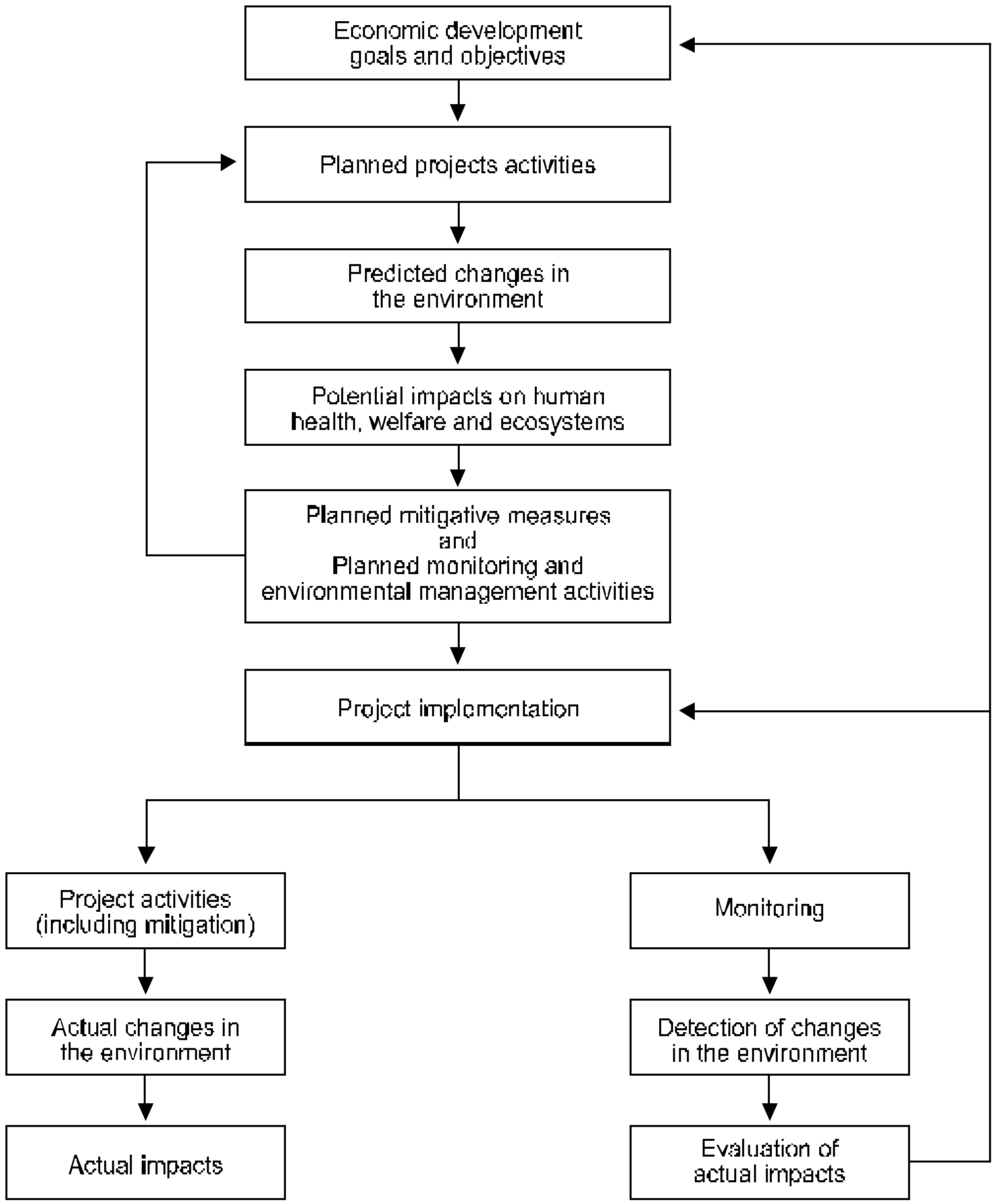

Figure 3-2: Overview of EIA information in the project cycle.

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

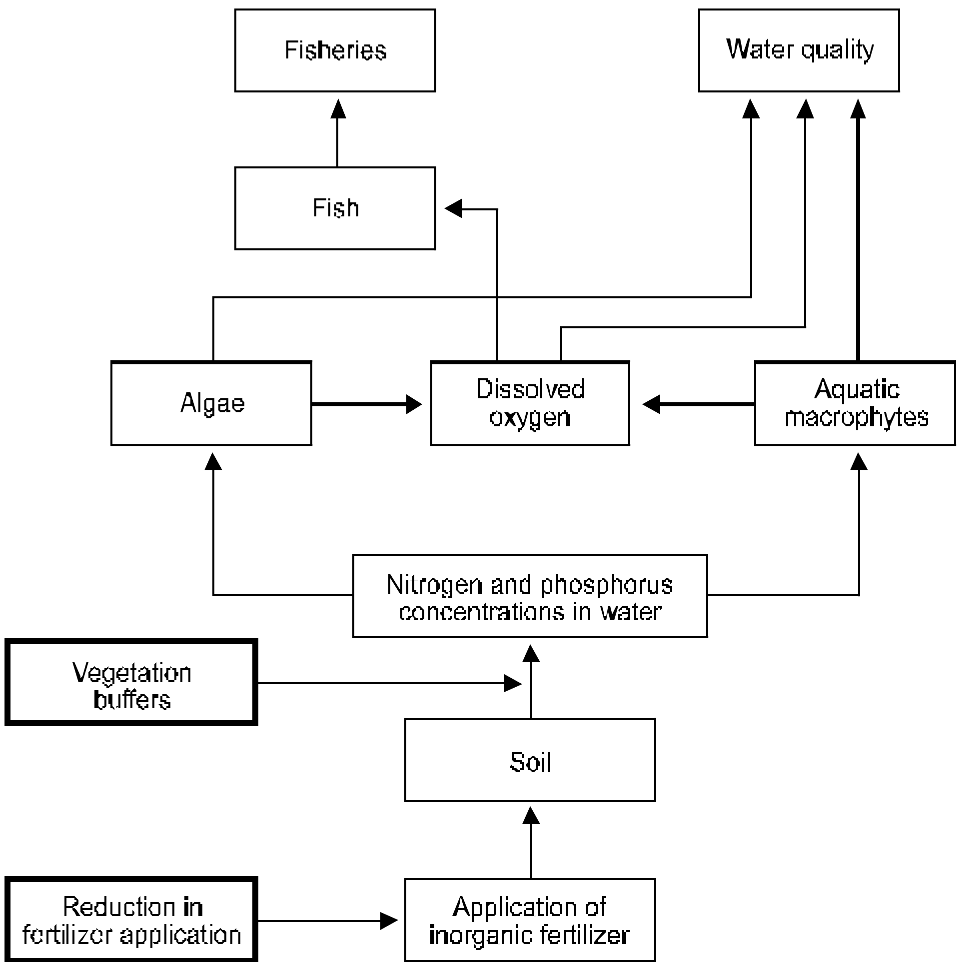

Figure 3-3: Network diagram of the causal chain that begins with application of inorganic fertilizers.

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.

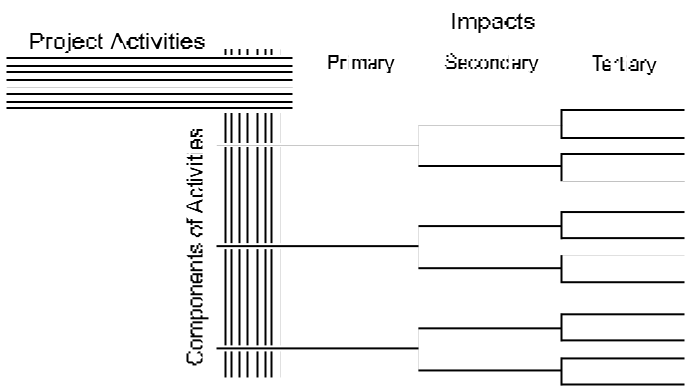

Figure 3-4: Conceptual model of impact networks.

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."

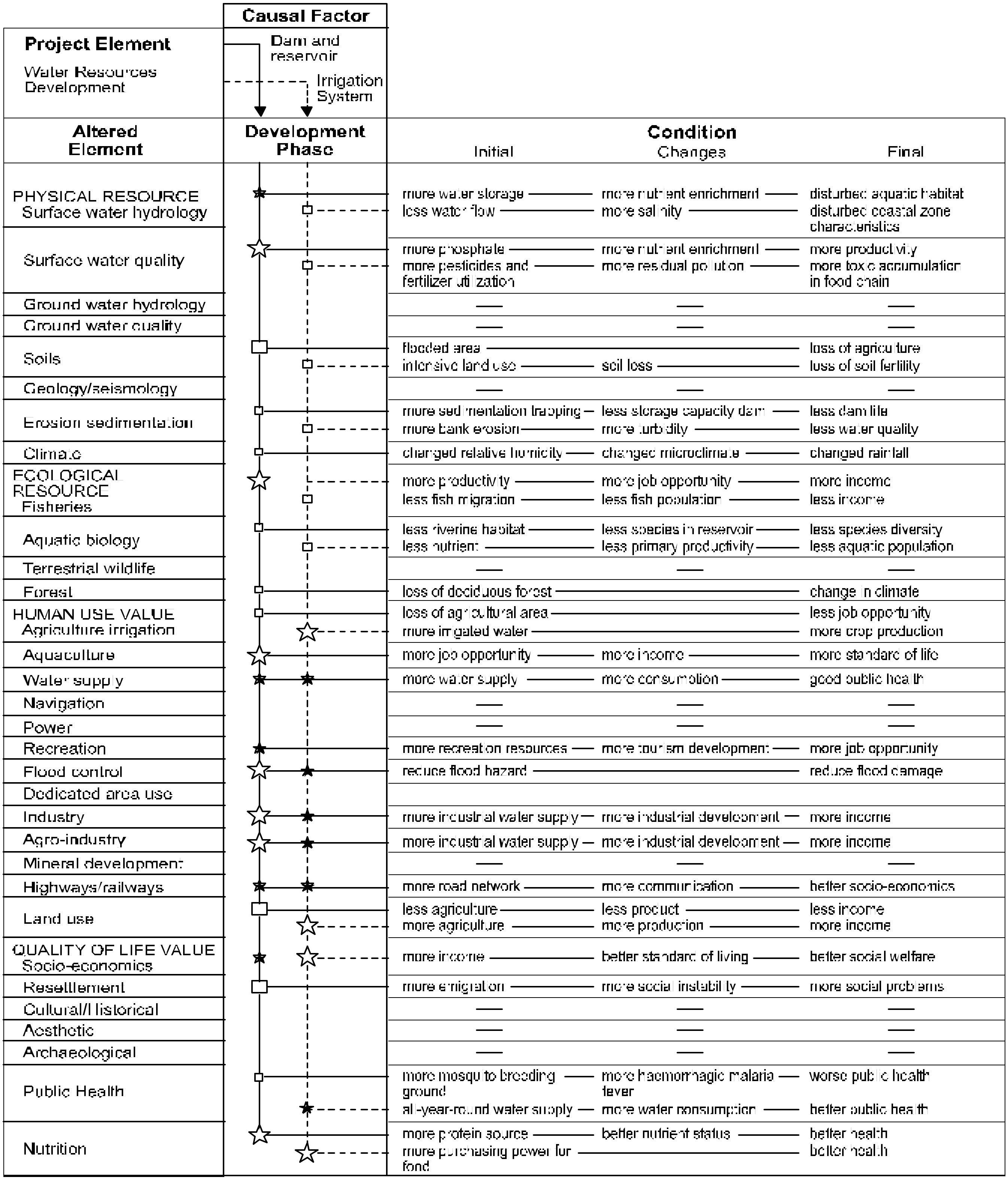

Figure 3-5: Stepped matrix for Nong Pla Reservoir.

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.

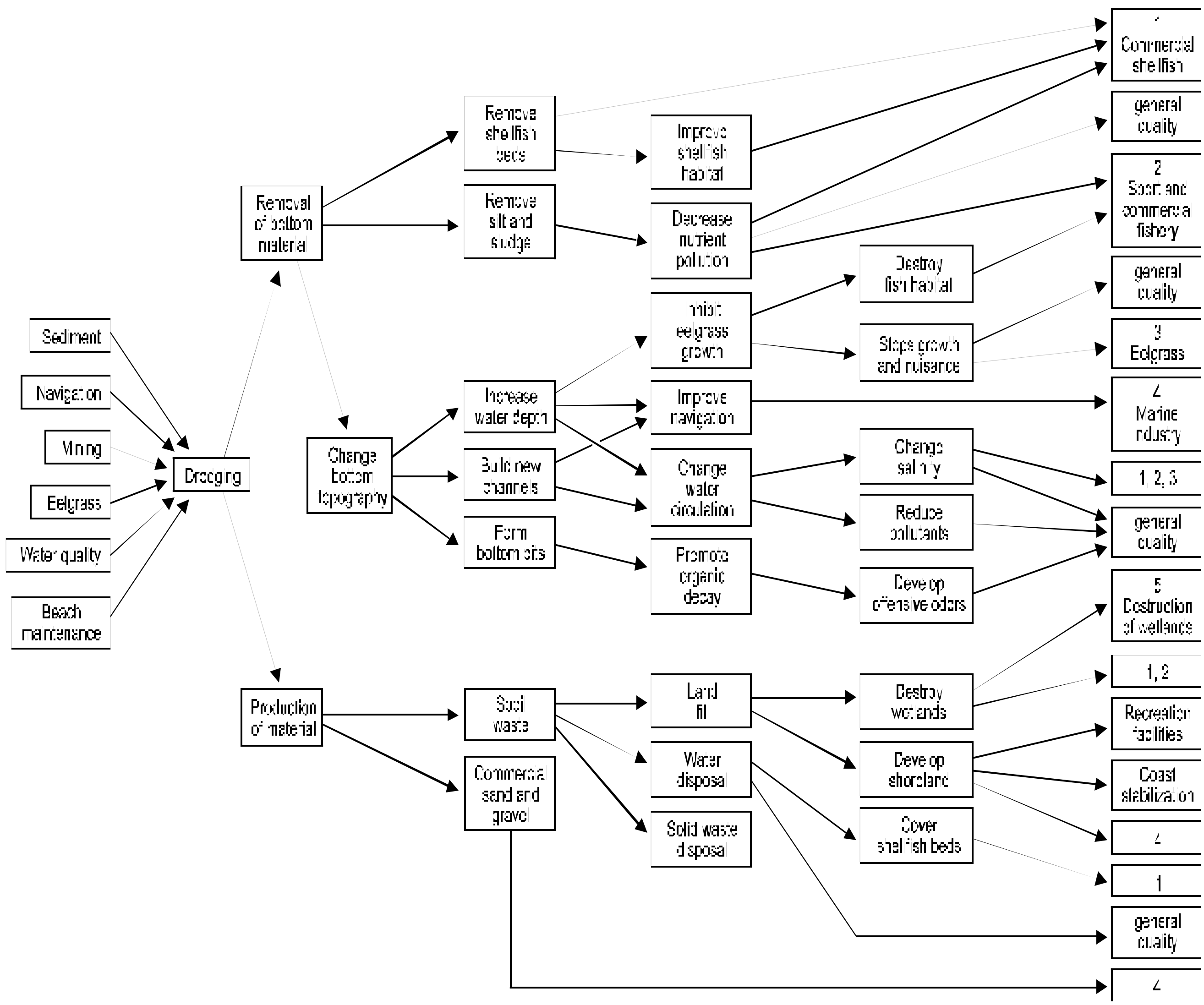

Figure 3-6: A network analysis of the impacts of dredging (*source:* Sorenson, 1971, in Canter, 1996)

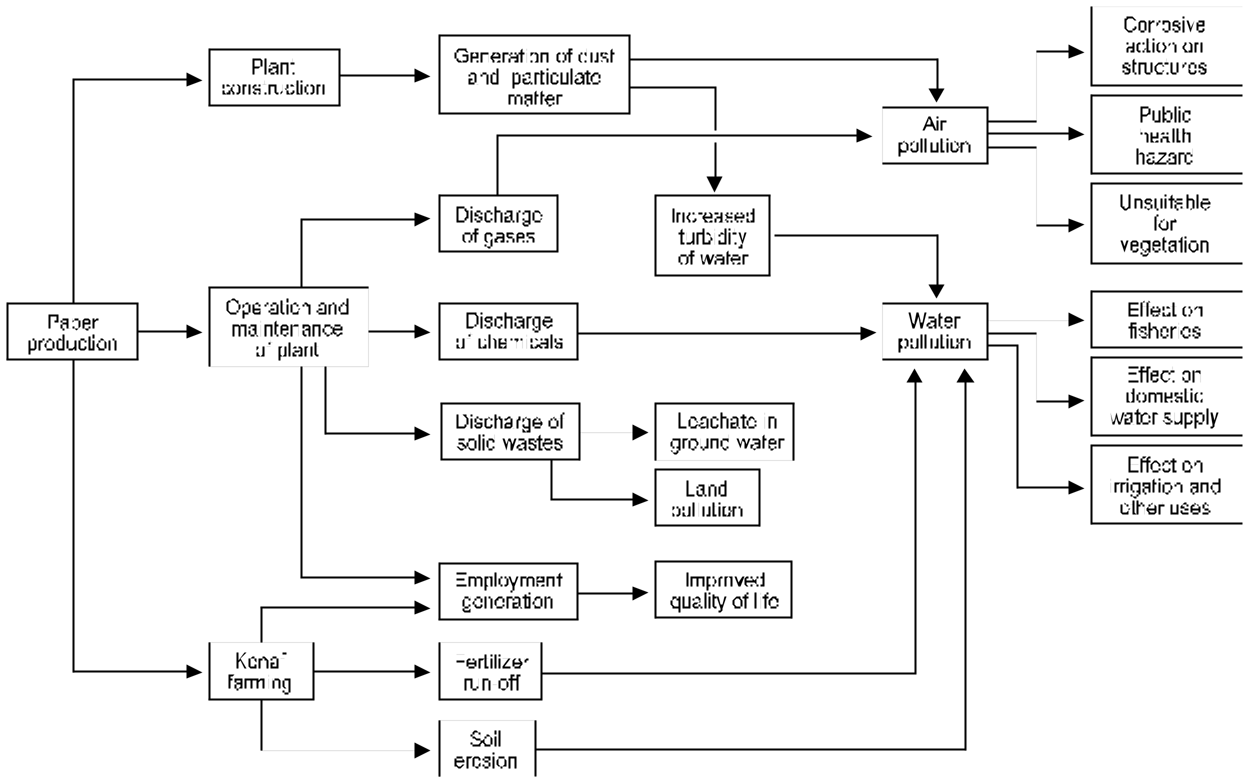

Figure 3-7: Network of pulp mill impacts (*source:* Lohani and Halim, 1983).

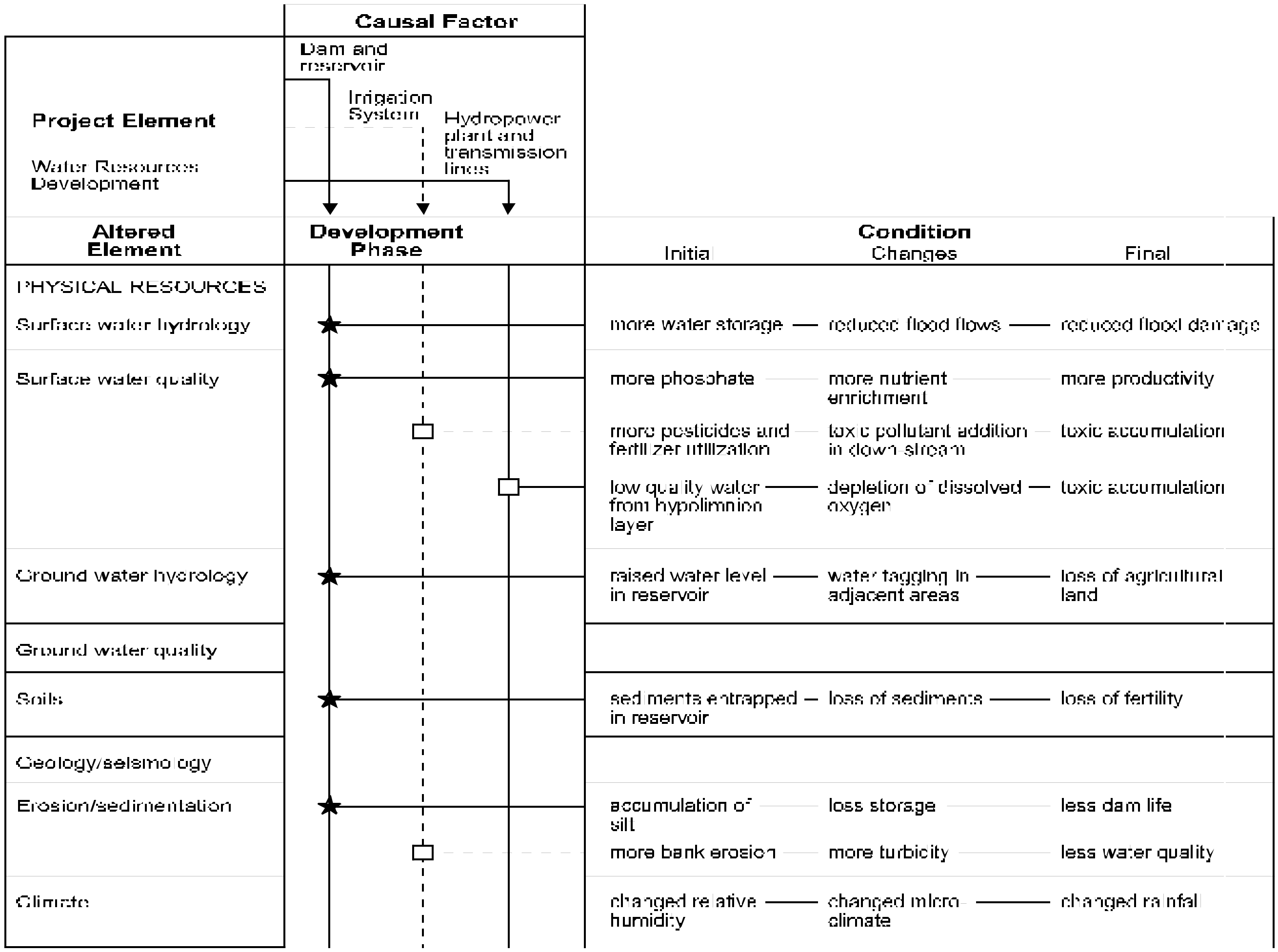

Figure 3-8: Stepped matrix for Pattani Multipurpose Reservoir Project.

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.

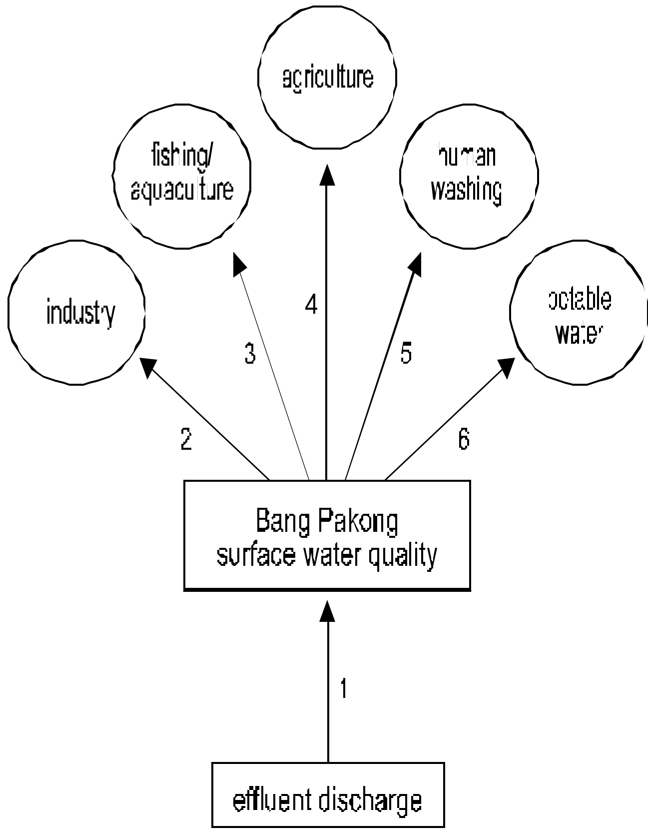

Figure 3-9: Impact hypothesis: Discharge of mill effluent in the Bang Pakong River will affect human uses of the river (*source:* H.A. Simons Ltd., Consulting Engineers, 1992).

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)

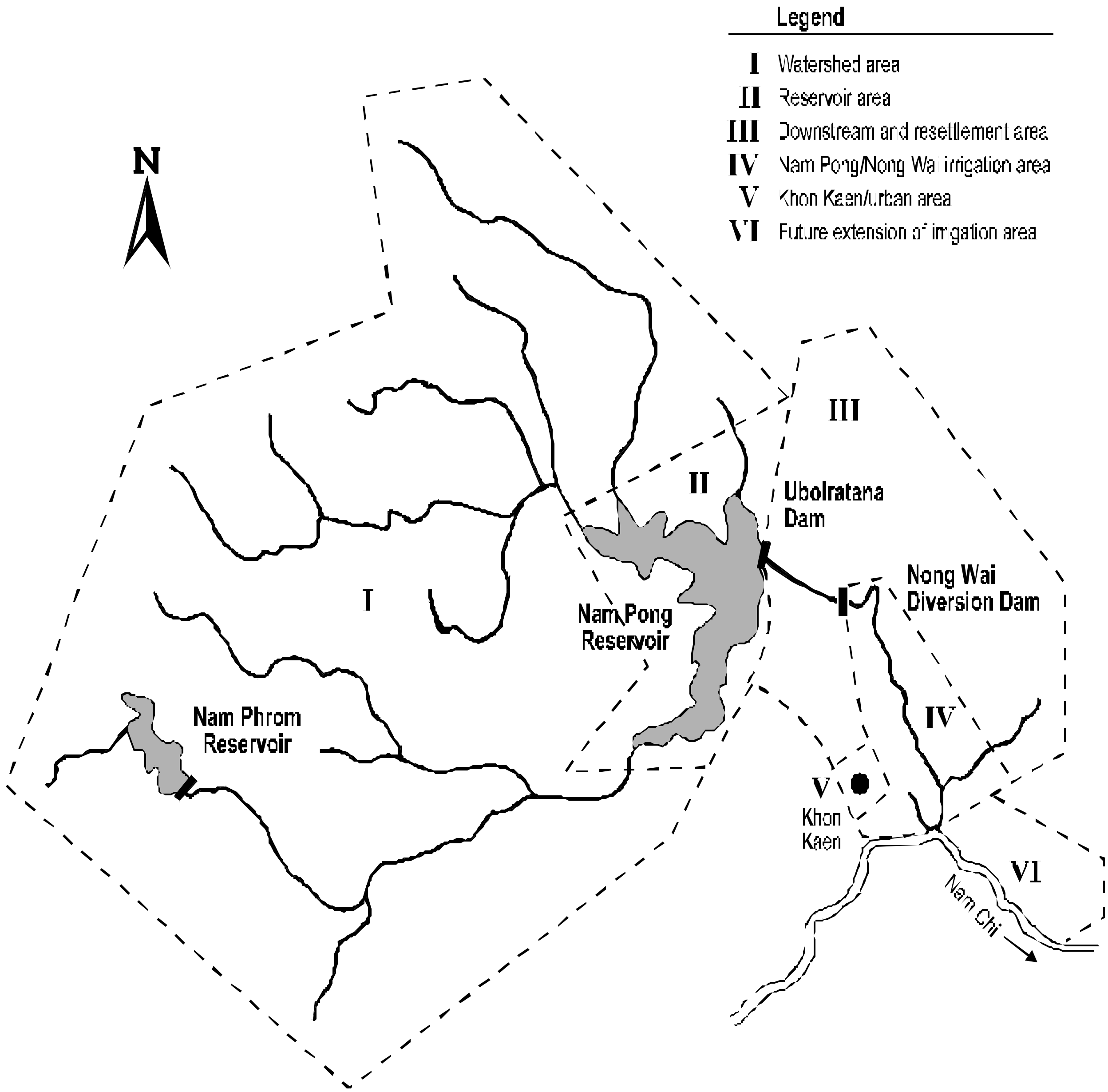

Figure 3-10: Spatial extent and subdivisions for the Nam Pong Model (*source:* Interim Mekong Committee, 1982b).

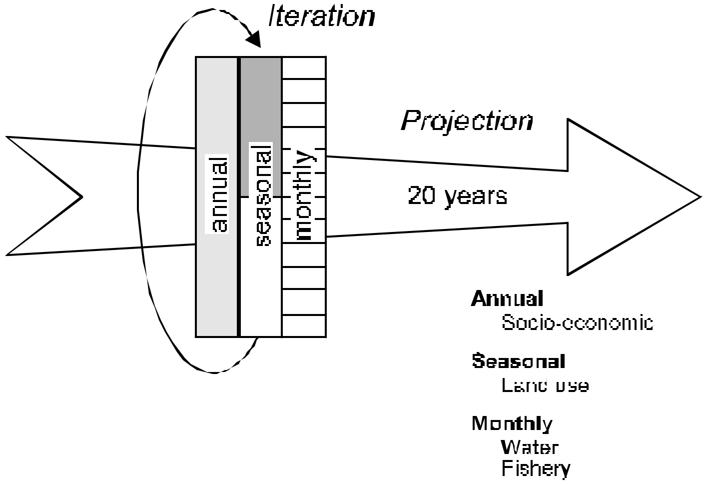

Figure 3-11: Temporal horizon and length iteration intervals for the Nam Pong Model (*source:* Interim Mekong Committee, 1982b).

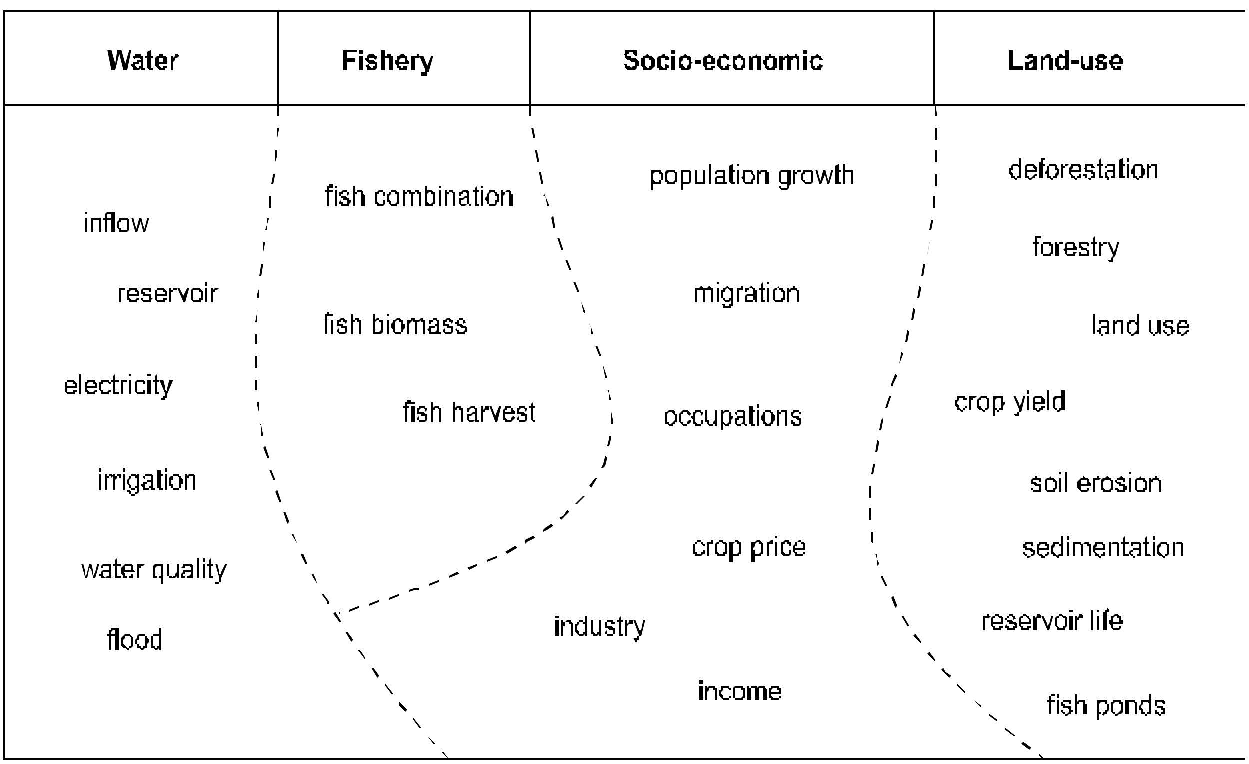

Figure 3-12: Allocation of model components to submodels (*source:* Interim Mekong Committee, 1982b).

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.

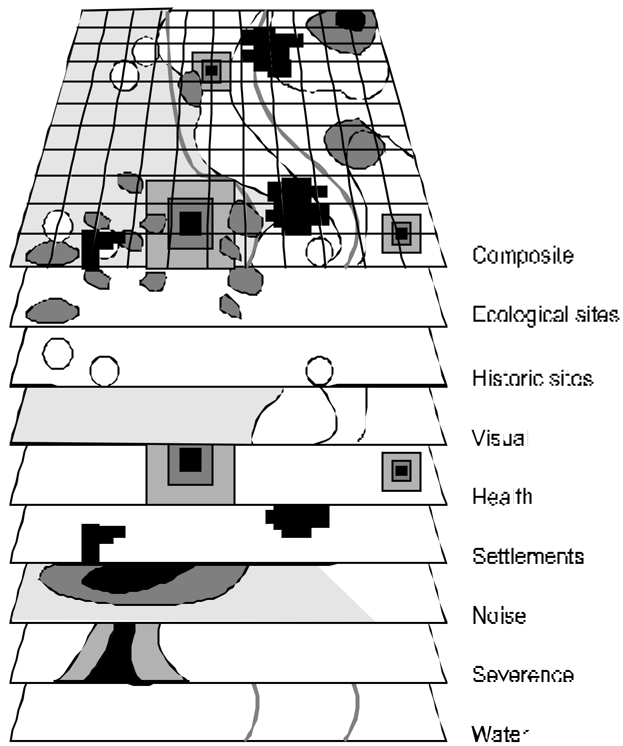

Figure 3-13: Example of overlay method (*source:* Wathern, 1988).

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.

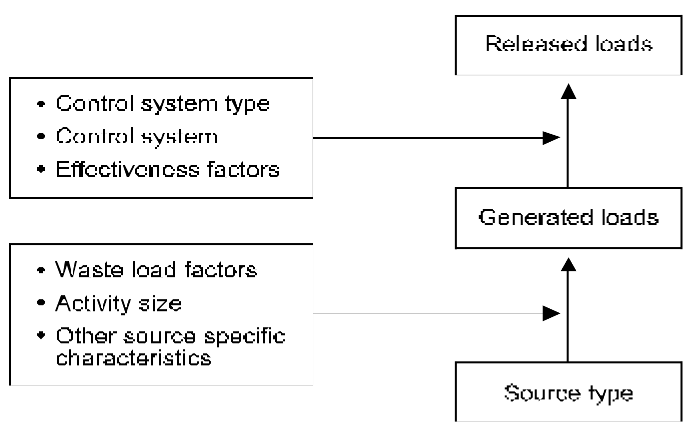

Figure 3-14: Estimating pollution loading using the rapid assessment procedure.

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	Description	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.

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