Chapter 2
An Adaptive Ecosystem Management Approach to the Problem Situation

An Adaptive Ecosystem Approach to Rehabilitation and Management of the Cooum River Environmental System in Chennai, India

by

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Introduction

As outlined in the introductory chapter, this research is oriented toward support for rehabilitation and management efforts for the Cooum River in Chennai, India. It employs an ecosystem approach which draws primarily upon theory and methods provided by Adaptive Environmental Assessment and Management (AEAM) (Holling 1978; Walters, 1986; Lee, 1993; Gunderson *et al.*, 1995a). Operational aspects of this approach from adaptive management include (1) participatory workshops oriented toward problem definition, system identification, determination of goals and objectives, and the generation of management alternatives, and (2) the development of a system model of the Cooum River and its environs to be used for scenario analysis and system exploration. A geographic information system (GIS) was integrated into the system modelling component of this process.

Also, this particular application of the ecosystem approach is heavily influenced by Soft Systems Methodology (SSM) (Checkland, 1981; Checkland and Scholes, 1990a) which provides cognitive and methodological tools to deal with human activity systems. The overall approach and its context fall within the domain of 'Post-Normal Science' (Funtowicz and Ravetz, 1994), or science for the investigation and solution of policy issues having to do with the environment.

Before discussing the application of these methods in the Chennai context, and presenting of the results of this research, it is appropriate to provide some context and background for the approach itself. Thus, it is the purpose in this chapter to provide a brief overview of alternative approaches to environmental planning, the nature of environmental problems, and the ecosystem approach. Adaptive management (including the integration of Geographic Information Systems into the system modelling component), and Soft Systems Methodology also are described in detail.

The Nature of Environmental Problems

Environmental planners and managers deal with problems which are complex, ill-structured, plagued with uncertainty, and extremely political (Bardwell, 1991:603). Environmental problems have physical, social, economic and political implications, and may be seen as problem situations occurring due to a "mismatch" between socio-economic systems and physico-ecological systems (Bowonder, 1987:81-82)[1]. The nature and extent of problems are typically contested by various parties and the basic facts, data and forecasts associated with a problem may be in doubt. Environmental quality itself is a highly subjective and multi-dimensional concept. It may be perceived differently by various cultures, sub-cultures, institutions, socio-economic groups and individuals (Hackett, 1993:118-119; Feijoó and Momo, 1991:163; Bowonder, 1984:216).

Environmental problems are also characterized by the order and association of elements of the situation within an interconnected system. There is an underlying, albeit illusive, structure to the problem situation which gives pattern and organization to the whole. *Simply organized* problems, characterized by separability, reducibility and one-dimensional goal structures, are easily bounded and managed systematically. *Unorganized complexity* may be addressed with statistical techniques. However, there are relatively few cognitive or practical tools for coping with

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[1]Bowonder describes this "mismatch" as occurring because the evolution of human systems occurs much more quickly than that of natural systems. Physico-ecological systems cannot adapt to the considerable changes socio-economic systems have undergone over the past several hundred years. The responses of natural systems to large-scale changes (the introduction of chemical wastes, for example) are not at the same speed as those of the input changes. This situation, and the lack of strong feedbacks between natural and human systems, result in rapid non-sustainable development (1987:81-82).

Table 2.1: Distinguishing properties of problems of organized complexity.

Category	*Property*
Ability to formulate the problem	Such problems have no definitive solution.
Relationship between problem and solution	Every formulation of the problem corresponds to a statement of solution and *vice versa*. Understanding the problem is synonymous with solving it.
Testability	There is no single criteria system or rule that determines whether the solution to this type of problem is correct or false. Solutions can only be good or bad relative to one another.
Finality	There is no stopping rule for such problems. There is always room for improvement. Political consequences are played out indefinitely.
Tractability	There is no exhaustive, enumerable list of permissible operations to be used in the solution of problems of organized complexity.
Explanatory characteristics	These problems have many possible explanations for the same discrepancy. Depending on the explanation one chooses, solutions take on different forms.
Level of analysis	Each of these sort of problems can be considered as a symptom of another problem. It has no identifiable root cause; since curing symptoms does not cure problems, one is never sure the problem is attacked at the proper level.
Reproducibility	Each problem is a one-shot operation. Once a solution is attempted, you can never undo what you have already done. There is no trial and error.
Replicability	Every problem is essentially unique.
Responsibility	The problem solver has "no right to be wrong." He or she is morally responsible for what is being done and must share the blame when things go wrong. However, since there is no way of knowing when a wicked problem is solved, very few people are praised for grappling with them.

Source: Mason and Mitroff (1981:10-12), after Rittle (1972).

organized complexity[2] (Mason and Mitroff, 1981:5-9). Properties characterizing problems of organized complexity are presented in Table 2.1.

Funtowicz and Ravetz (1994) provide further insight into situations of organized complexity. Referring to ordinary *versus* emergent complexity (both of which fall with the category of organized complexity, above), they note that *ordinary complexity* "involves structure and self-organization" and has a simple teleology (such as growth or survival) (Funtowicz and Ravetz, 1994:569-570). While it is possible, through the application of systems concepts and methods, to explain situations

[2]Environmental problem situations, those of organized complexity, are also known variously as *wicked, turbulent, ill-structured, fuzzy, soft, messy* or *real-world* problems (for examples see Rittle, 1972; Checkland, 1976; Trist, 1980; Mason and Mitroff, 1981; Morley, 1986; Bardwell, 1991).

involving organized complexity in a functional and mechanistic manner, *emergent complexity*[3] cannot be fully explained in this way. In situations involving emergent complexity, "some at least of the elements of the system possess individuality, along with some degree of intentionality, consciousness, foresight, purpose, symbolic representations and morality." This is the complication added by the activity of human beings.

Such characteristics of real world problem situations – situations of organized (and emergent) complexity – imply that broad participation of directly or indirectly affected parties is required in the problem-solving process, and that decisions must be based on information collected on a wide spectrum and from a large number of diverse sources (Mason and Mitroff, 1981:13). In addition to being participatory, interdisciplinary and comprehensive, environmental management should be flexible enough to allow for the individual nature of each problem (Bardwell, 1991:610).

Mitchell (1991:268-272), referring to problems of resource management and development, summarizes these characteristics in four categories. Thus, (1) such a situation will be multi-dimensional (having environmental, social/cultural and economic dimensions), (2) the components of the system will be interrelated and complex, (3) there will be uncertainty due to lack of information and understanding of the system, and (4) the problem situation will involve multiple (often conflicting) interests and participants. Any successful approach to environmental management will have to address all four of these fundamental issues.[4]

In response to these issues, Mitchell stated that a balanced perspective emphasising

[3] In the systems literature, *emergence* usually refers to a property of a whole entity or system which is not evident in any of its component parts individually. Funtowicz and Ravetz (1994) are here using the term in a somewhat different manner.

[4]The description of the Cooum River problem situation presented in Chapter 1 demonstrates these four characteristics. For example, climatic characteristics, topography, tidal processes and coastal currents all play a role in the situation, as does poverty and slum formation, commercial and industrial activity, income distribution and water supply. These and many other components are interrelated, but the nature of the relationships are often not well understood or identified. Relationships that are known are described with sparse data of poor quality. Stakeholders include government agencies (*e.g.*, the TNSCB, CMDA, Chennai Corporation, PWD, CMWSSB), private interests (consultants, polluting and other affected business), NGOs (such as Exnora, WAMP and INTACH) and various individuals and groups of citizens.

sustainability and compromise is required and that a systems approach (particularly an "ecosystem approach") should be employed in managing the natural environment. Also, the process must handle uncertainty through flexibility and adaptiveness (*i.e*., responsiveness to new information and changing goals) and should be participatory, such that parties with a legitimate interest in the problem situation are involved in the determination of both the ends and means for environmental management (Mitchell, 1991:272). As will be discussed below, these are all characteristics of adaptive management. Mitchell's prescription for '*BEAT*ing' conflict and uncertainty (*B*alanced perspective, an *E*cosystem approach, *A*daptiveness, and participatory, cooperative *T*eamwork) provides a useful framework to present the characteristics of adaptive management. This will be undertaken below, following a brief introduction to Environmental Management and the Ecosystem Approach.

Environmental Planning

Environmental planning may be defined as, "an activity undertaken by individuals and organizations dealing with problems arising at the society-environment interface and devising courses of action to solve these problems" (Briassoulis, 1989:381). A variety of approaches have been taken to planning and management of the environment. This research makes use of an ecosystem approach and, in particular, adaptive environmental management to support environmental management of the Cooum River in Chennai, India. The question arises, however, 'Is application of this approach appropriate in the Chennai situation?'

Various other approaches to dealing with environmental problems have been pursued and should be considered. Some of the most prominent of these are briefly reviewed below. These may be considered 'ideal types' and it will be seen that the approach employed in this work displays characteristics of several of them.

A common approach to environmental planning and a logical extension of the traditional comprehensive planning model is *Comprehensive/Rational Planning* or *Synoptic Planning.* In its application to environmental problems, this approach has the basic premise that all things in nature are spatially and temporally interconnected (Briassoulis, 1989:384). It is also rooted in economic rationality which assumes that, given sufficient information, individuals are able to identify and systematically evaluate goals, values and objectives, and will make economically optimal decisions in choosing among them (Mitchell, 1997: 85). This approach tends to be quantitative but permits multiple iterations, feedback and elaboration of subprocesses (Hudson, 1979:388-389).

The comprehensive rational approach is characterized by (Briassoulis, 1989:384):

1. "Objective and exhaustive analysis of the environmental and socioeconomic conditions of an area along the lines of a systems analytic framework borrowing basic concepts from ecology."

2. Identification and generation of alternative solutions to the problem.

3. Selection of the best solution based on objective scientific criteria.

In this process a core group of experts is placed in the primary planning role (with the assumption that they are working in the public interest).

The comprehensive rational approach is the dominant approach in environmental planning (Briassoulis, 1989:384; Mitchell, 1997:84). It tends to have a bias, however, toward (often absent) centralization of control and power for its implementation, and assumes public, not pluralist interests (Hudson, 1979:389; Briassoulis, 1989:385). This approach does not include mechanisms for inter-jurisdictional cooperation, or to deal with pressure politics of interest groups. Also, science is not always as objective as commonly believed. Scientists may be sponsored by one or more interests in the situation, biases are built into scientific approaches themselves (Hudson, 1979: 394), and individuals may make decisions on the basis of incomplete information and non-economic criteria.

Another holistic model is the *Integrated Approach* which improves on the comprehensive approach primarily by narrowing the perspective to characteristics and interactions of a selected number of critical components of an environmental system. This more focussed approach makes planning and management more feasible in terms of the skills and capabilities of resource managers (Mitchell, 1989:305). Projects which employ an integrated approach that seeks only to identify and understand those components of a system that are most important in the problem situation are also likely to be completed within a more reasonable time frame than would be the case if a comprehensive approach were applied (Mitchell, 1997:57). The integrated approach also emphasises context. Considerations such as the state of the natural environment, prevailing ideologies, economic conditions, administrative and financial arrangements (Mitchell, 1990:8) are, for example, important in judging the feasibility of potential interventions in a system.

In practice, environmental planning often uses an *Incremental Planning* approach. In some instances, this is a crisis management approach. An "inevitable consequence of the world of politics," incremental planning is often employed when a problem has reached crisis proportions before it is addressed in "a disjointed, uncoordinated, piecemeal fashion“ (Briassoulis, 1989:385). However, the incremental approach is also seen by some as a practical and consistent approach in environmental planning. Charles Lindblom (1959), a prominent advocate of the incremental approach, indicated that for complex problems, the exhaustive consideration of all alternatives, values and goals required by the comprehensive/rational approach is impossible. In practice, decision-makers simplify complex situations by restricting themselves to successive limited comparison of relatively few values and options (Lindblom, 1959:84-85). Options are chosen which do not stray too far from the experience of the past and important possible consequences of policy options are often ignored. This reduces uncertainty and complexity for the decision-maker. The approach is politically pragmatic, dealing well with problems of ideological consensus and with fragmentation and imbalances of power and authority among jurisdictions and interest groups. However, this incremental, distributive planning mode works against holistic, environmentally sound solutions (Hudson, 1979:389; Briassoulis, 1989:386).

In contrast to incremental planning, *Transactive Planning* is process-oriented, where the focus is on the effect of planning on people, and not only on achieving specific planned targets (Hudson, 1979:389; Mitchell, 1997:89). This type of approach is characterized by participation, flexible and evolving plans, decentralized planning institutions and the transfer of control over social processes to the public. This approach is strong in the human dimension (psychological, social and institutional processes which facilitate growth and learning between planners and constituencies) but is not very feasible in centralized and bureaucratic environments (Hudson, 1979:392-393).

Transactive planning is a participatory planning model which attempts to find "win-win" solutions in common with interested parties and affected groups. Participation lends legitimacy to solutions. This is expected to increase the ease of implementation and enforcement of solutions (Briassoulis, 1989:388). Unfortunately, while consensus might be reached in relation to small-scale, local problems having limited scope and modest costs, the participatory approach is much less suited to large-scale problems where more ideological disagreement is evident.

On the other hand, when environmental problems are hotly contested, broad in scope, or solutions imply long-term commitment of resources, an advocacy approach to the situation (based in the adversarial tradition of the legal profession) may develop (Hudson, 1979:389-390). This reflects the philosophy that one cannot plan for multiple interests and that solutions to environmental problems reflect the perspective and interests of those served (Briassoulis, 1989:387). Aside from the danger of these solutions being environmentally unsound, this approach risks impasse.

The environmental planning approaches reviewed above are taken mainly from the experience of planning for environmental problems in the developed countries. The main form of environmental planning that has occurred in developing countries is the rational/comprehensive form. However, as in the more developed countries, this often evolves into adversarial or incremental forms of planning. For example, Khator and Ross (1991), in a study of water pollution policy in India, found that Indians typically take the incremental approach to environmental problems.

It should also be noted that these planning approaches are extremes and are often combined with other approaches. The *Mixed Scanning Approach* developed by Etzione (1967), for example, combines aspects of incremental and rational comprehensive approaches, attempting to build on their strengths while minimizing their weaknesses. It does this by combining "higher order, fundamental decision-making with lower order, incremental decisions that work out and/or prepare for the higher order ones" (Entzioni, 1986:8).

Many planning activities in developing countries, which attempt to employ the above planning approaches in various combinations have been increasingly viewed as unsuccessful. Rondinelli (1993b:3-4) provides some explanation of their failure. Referring to development assistance activities, he notes that high levels of uncertainty, complexity and risk make development planning and management in the third world more difficult in several ways. It is;

> a) More difficult and complex to state goals and objectives precisely, because development problems were not well defined or understood, "solutions" were not always clear or easily transferable; impacts of interventions could not always be predicted; and the objectives of multiple participants and stakeholders in the projects were not always consistent.
>
> b) More difficult to assess the feasibility of potential interventions through projects and programs because of the lack of complete knowledge of the dimensions of the problem or the most appropriate and effective interventions.
>
> c) More difficult and less effective to pre-design projects or programs in too much detail. Simply designing projects by the donor's standards and criteria was insufficient for ensuring effectiveness or sustainability. Participation by host country governments and beneficiaries became more critical.
>
> d) More difficult to keep the design and implementation phases of the project strictly separated under conditions of complexity and uncertainty because activities would have to be adjusted as they were carried out as more was learned about the local conditions in developing countries.
>
> e) More difficult to apply standard appraisal criteria such as financial rates-of-return or social cost-benefit analysis or predetermined technical standards because of the donors' inability to predict human reactions to interventions with any degree of certainty, and because the implementation of projects was not always completely under the donor's or even the host government's' control.

Rondinelli (1993b:4) concludes that,

> "...development projects that are really experiments in problem-solving and or in pursuing opportunities for economic and social change must be supported by management systems that encourage and reward experimentation, innovation, and adaptation."

An *Adaptive Approach* to planning and management is one such system. This is a major theme in environmental management and is a characteristic of many ecosystem approaches. Such an approach provides a general framework for the work undertaken in this program of research. Also, as already noted, this work draws heavily upon *Adaptive Environmental Assessment and Management (AEAM)*. These are detailed later in this chapter.

An Ecosystem Approach Framework

Environmental problem situations are characterised by high levels of uncertainty, disputed values, conflicting interests, and the inability to replicate interventions in evolving systems. It seems that any attempt to support decision making in this context, employing exclusively the approaches, methods and techniques of science from the logical-positivist tradition, are likely to be frustrated. Funtowitz (1999) notes that;

> In addition to its traditional achievements of discovery and application, science now has a new challenge. This is to contribute to the proper management of the natural environment, on which we all depend. Science for the environment is used for the resolution of policy issues. In this context, research lacks the supports of the controlled environment of the traditional laboratory and the simple goals of R&D. Scientific problem-solving becomes "post-normal".

Kay *et al.* (1999:16-17) noted that in this post-normal mode, decision making becomes a matter of "finding our way through a partially undiscovered country rather than charting a scientifically determined course to a known point." Furthermore, within this context, science must inform decisions that are "...in the end, an expression of human ethics and preferences, and of the socio-political context in which they are made." This requires an approach to environmental concerns that is able to deal with uncertainty, operate in situations in which decision stakes are high, accommodate new information and changing goals, and guide courses of action which take into account the conflicting interests and values of multiple stakeholders. While some of these requirements are met by one or another of the approaches to planning described above, none of these fit this role better than an ecosystem approach to scientific inquiry.

The ecosystem approach, as employed here, does not reject traditional science. Rather, it integrates it into a more holistic means of inquiry. Ecosystem approaches recognise that problem situations can be usefully conceptualized as systems of inter-related elements and actors. The identification of system characteristics such as structure and processes, various levels of hierarchy (subsystems, wider systems), emergent properties, communication and control mechanisms and feedback loops, can be a powerful aid in the understanding of environmental problem situations. The ecosystem approach draws upon systems-based approaches and collaborative processes to develop a qualitative understanding of the problem situation, including its cultural and political context. This understanding, or conceptual model of the 'system', is used to selectively direct further (likely traditional scientific) inquiry in the situation to develop knowledge about key actors, components and interrelationships. In this sense, the approach is similar to integrated models of planning described above.

Further discussion of the ecosystem approach is presented below in the context of adaptive management, so additional description of such an approach at this point is not required, except to present an overall ecosystem approach schematic or framework. Such a heuristic framework for an ecosystem approach has been developed by Kay and Boyle, (1999) and published in Kay, *et al*. (1999). A version of this provides a guide for the research undertaken here (Figure 2.1).

The main components of this framework are the generation of an understanding or 'system description' of the socio-ecological system(s) pertinent to the problem situation, the generation of alternative scenarios representing desirable and feasible possible future states of the system, the choice of a 'vision' of the future organization of the system (from possibilities generated in describing the system) to be encouraged in the real world, the design of an adaptive program to achieve that vision, and ongoing adaptive management of the situation. Operation of the framework is unlikely to be a linear process. For example, development of a system description includes the simultaneous development of an understanding of desirable and feasible alternative states (visions) of that system. Alternative scenarios for desirable and feasible configurations of the system may be a product of the development of such a system description, and not a distinct 'stage' in the sequence. Also, the whole of the framework is intended to be iterative, being subsumed in a process of ongoing adaptive management (illustrated by the 3 circles of governance, management and monitoring at the base of Figure 2.1). The schematic indicates that the primary influences to operationalize the framework come from systems approaches and collaborative processes. Specific methods and techniques are not prescribed. The choice of these should be sensitive to the context in which they are applied.

This research operates those parts of the framework having to do with the development of a system description and generation of management scenarios. (Other parts Figure 2.1, therefore, deserves some attention. Kay *et al*. (1999:17) noted that the framework "presumes that decisions about environmental issues involve mapping out a vision of how the landscape of human and natural ecosystems should co-evolve as a self-organizing entity to meet human preferences." The upper

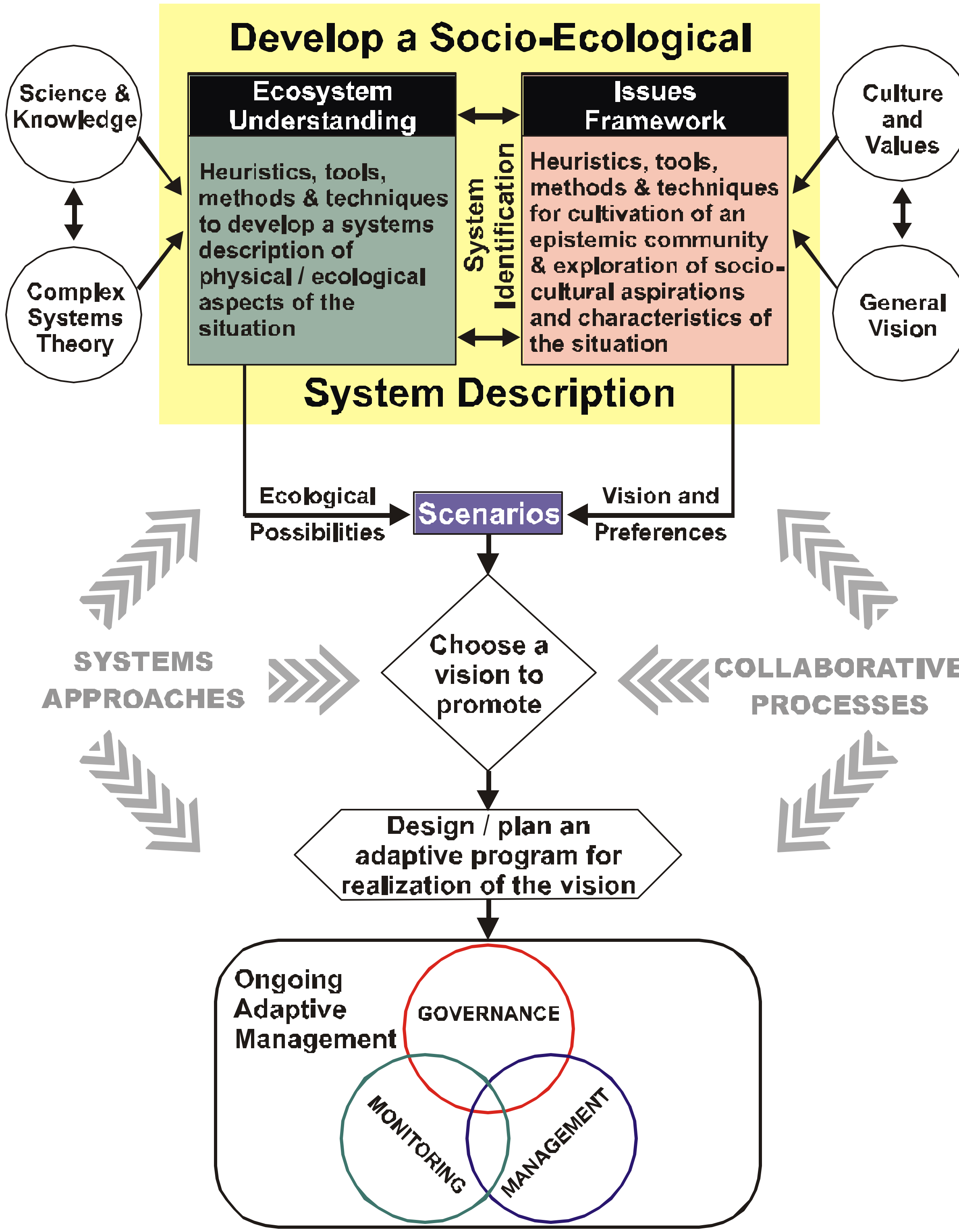

Figure 2.1: An ecosystem approach framework. (Adapted from Kay and Boyle, 1999 and Kay *et al*, 1999:739, in consultation with James Kay).

portion of the of the approach are beyond the scope of this work). The upper part of the schematic presented in schematic is about developing an understanding of those systems: how they are structured and how they function, what future states of the system are possible, which of these are desirable to encourage, and which of these are feasible to promote. The box in the upper left of the diagram represents the development of an understanding of the situation in systems terms and is informed by systems theories and scientific knowledge in general. The box in the upper right represents activities directed toward generating an understanding of the social, cultural, political and institutional context of the problem situation, the incorporation of perspectives and values of pertinent stakeholders, the influence of societal goals, the development of a 'vision' of how the system should evolve, and the promotion of collaboration, communication and cooperation among actors in the situation.

Together, these activities generate a description of a socio-ecological system within which management activities will occur. The development of this description informs the generation of scenarios that represent future states of the system. These scenarios are a selected set of those that are ecologically possible, and are both desirable and feasible to implement within the cultural, economic and political context of the problem situation.

Note that within this process there is flexibility as to how to go about activities such as defining the problem situation, identifying pertinent systems and generating scenarios. Tools are chosen according to the context for the particular situation to which the ecosystem approach is applied. This is a characteristic of pragmatic or eclectic science discussed in the introductory chapter. For this research, heuristics, methods and techniques associated with Adaptive Management and Soft Systems Methodology were employed. These were applied within a participatory process to generate a common understanding of the socio-ecological system(s) associated with the Cooum River problem situation. The main vehicle for this was two workshops, as described in the Adaptive Management literature, and which drew on tools and theory provided by the SSM community. In this application, alternative desirable and feasible future states for the socio-ecological system were explored with the aid of computer based, (GIS supported), scenario analysis.

Adaptive Environmental Management

Overview

In planning and managing for environmental problems, a framework suitable for dealing with complexity and uncertainty is crucial. One such approach is *Adaptive Environmental Assessment and Management (AEAM)*.[5] This is a systems-based (ecosystem) approach designed to deal with uncertainties inherent in environmental change. It makes use of existing data and brings together scientific experts, planners and policy makers in workshops to make use of best-available knowledge and to design interventions in the system in such a way as to generate knowledge and facilitate learning (Grayson, *et al*., 1994:246; Holling, 1978:8). This approach is anticipatory, developing solutions based on predictable future events, and flexible, allowing for changes in goals, revised predictions and new evidence. It is a continuous process of learning. There is also a strong emphasis on communication and participation in AEAM and the approach, as theorized and described in the core literature, can be seen as a marriage of soft and hard approaches to science in pursuit of social learning for sustainable ecosystem management.

Adaptive management first appeared in the Gulf Island Recreation Land Simulation study in 1968 as an attempt to "bridge gaps among scientific disciplines, technical experts, and policy designers" (Gunderson, *et al.*, 1995b:490). Following this, in the mid-1970s, the basic concepts of adaptive environmental assessment and management were developed by an interdisciplinary team of biologists and systems analysis, led by Canadian ecologist C.S. Holling, working at the International Institute of Applied Systems Analysts (IIASA) in Laxenburg, Austria (Lee, 1993:54). These ideas and their application have been published in scientific journals, reports and books. The heart of this effort is a series of four main books entitled *Adaptive Environmental Assessment and Management*, edited by C.S. Holling (1978), *Adaptive Management of Renewable Resources* by Walters (1986), *Compass and Gyroscope: Integrating Science and Politics for*

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[5]Adaptive Environmental Assessment and Management is also often referred to as Adaptive Environmental Management, Adaptive Resource Management, Adaptive Environmental Assessment, and Adaptive Management. These terms are used interchangeably here.

the Environment by Lee (1993), and *Barriers and Bridges to the Renewal of Ecosystems and Institutions*, edited by Gunderson, Holling and Light (1995a).

Although some of the concepts associated with adaptive environmental assessment and management have evolved as practitioners learned from applying the approach to various situations, the underlying premise has endured. AEAM is rooted in the understanding that we have incomplete knowledge of the complex and evolving systems in which we intervene and that management of these systems is an ongoing learning process in which we will probably never achieve full knowledge and complete understanding (Holling, 1995:13; Walters, 1986:8). However, this should not stop resource managers from intervening in a situation in which lack of intervention is clearly costly or damaging. Instead, intervention should be designed as experiments so that knowledge about systems is maximized and learning occurs from unexpected events. Thus, the adaptive approach actively operates the learning cycle for the purpose of generating reliable knowledge, which is necessary for sustainable development to occur (Lee, 1993:54). This is what makes the approach adaptive. New information from the experience of intervening in (and monitoring) the system informs continued management of the system, the experience of which generates new knowledge – and so on.

Adaptive environmental assessment and management has been applied to a wide range of situations. Some of these applications are presented in Table 2.2 and Table 2.3. These tables serve to demonstrate the range of problems which adaptive management has been used to address. The Environmental and Social Systems Analysts (ESSA, 1982:24) categorized these applications into *environmental impact assessment, research planning,resource management and policy,* and *project integration and synthesis*.[6]

As the focus of this work is on applications of AEAM to environmental management, the interest here is in ESSA's third category. Within this category, adaptive management programs fall

[6]ESSA's final category, *project integration and synthesis*, in some ways applies to all AEAM projects (1982:29). That is, it refers not just to integration of information through modelling, systems analyses, *etc.*, but also to integration between institutions, people and disciplines that is necessary for an interdisciplinary, participatory and cooperative approach .

Table 2.2: Some major AEAM applications. (Year is initial year of project).

User	*Project*	*Year*	*Location*
Environment Canada	Eastern Spruce Budworm Research and Management policy planning	1972	Fredricton, NB
Austrian Man and Biosphere program and IIASA	Environmental and Social Consequences of Development in the Alpine Village of Obergurgl	1974	Obergurgl, Austria
Arctic Project Office NOAA	Ecological Processes Study – Barrier Island Lagoon	1976	Barrier Islands, AK
Cdn. Dept. of Fisheries & Oceans	Management of West Coast Salmon	1976	Vancouver, BC
U.S. Fish and Wildlife Service	Charles M. Russell Refuge	1978	C.M. Russell Refuge, MT
Environment Canada	Porcupine Caribou Herd	1978	N. Slope AK, Yukon
U.S. Geological Survey	Truckee-Carson River Quality Assessment	1978	Reno, NV
B.C. Council of Forest Industries	The Assimilative Capacity of Aquatic Environments for Pulp Mill Effluent	1979	Vancouver, BC
Alberta Oil Sands Environmental Research Program	An Adaptive Environmental Assessment Approach to the Effect of Development of Alberta Oil Sands	1979	Ft. McMurray, AB
California Water Policy Center (USFWS)	Sacramento-San Joaquin Water Management System – Integrated Management	1979	Sacramento, CA
U.S. Forest Service	Western Spruce Budworm Research Planning	1980	Portland, OR
Mekong Secretariat, U.N. Bangkok, Ford Foundation	Application of AEAM to the Nam Pong Environment Management Research Project	1980	Bangkok, Thailand
B.C. Hydro and Power Authority	Mackenzie Delta Modeling for Environmental Studies of Liard River Hydro-electric Development	1980	Mackenzie Delta, NWT
NOAA/OCSEAP/BLM	Research Planning– effects of Bering Sea Petroleum Development on King and Tanner Crab populations	1980	Bering Sea
Ontario Ministry of Municipal Affairs and Housing	Integration of the Lakeshore Capacity Study	1980	Toronto, ON
Nat'l Power Plant Team (USFWS)	Acid Precipitation -- Research Needs	1980	Ann Arbor, MI
Cooperative Agreement between Assistant Secretary for Fish, Wildlife and Parks & Governor's Office, ND	Wetland Preservation and Protection in North Dakota	1980	Bismark, DA
Wyoming Game and Fish Dept.	Resource Development & Management, Jackson Hole	1981	Jackson Hole, WY
Petro Canada	Development and Application of a Site Selection Methodology for an LNG Facility on the BC coast	1981	Calgary, AB
Environment Canada	Beaufort Sea Hydrocarbon Development	1981	Beaufort Sea
Great Lakes Fisheries Commission	Training in Adaptive Environmental Assessment	1981	Sault Ste. Marie, MI
Biological Services Program, U.S. Fish and Wildlife Service	Development of the Beluga Coal Resource in Alaska	1981	Cook Inlet, AK
Environmental Protection Agency	Potential Impacts of Drilling Muds and Cuttings on the Gulf of Mexico Marine Environment	1981	Pensacola, FL
U.S. Bureau of Land Management	Saval Ranch Project – Research Planning and Management of Alternate Cattle Grazing Schemes	1981	Elko, NV
Environmental Protection Agency	Environmental effects of Developments in Mobile Bay	1981	Mobile Bay, AL
B.C. Ministries of Forests and Environment	Research Planning for the Integrated Wildlife Intensive Forestry Research Program	1981	Victoria, BC
Ontario Ministry of Natural Resources	Application of AEAM to Fisheries Management and Acid Rain Research: Algonquin Assessment Unit	1981	Toronto, ON
Canadian Department of Fisheries and Oceans	Research Needs and Data Base Management for Acid Rain Studies in Eastern Canada	1982	Toronto, ON
U.S. Forest Service	Development of Integrated Management Model of Forest, Fisheries, Wildlife Resources in SE Alaska	1982	Juneau, AK

Source: After ESSA, 1982: 12-13.

Table 2.3: Further examples of adaptive management programs.

Project	*Year*	*Reference*
Wildlife management and monitoring on the Galápagos Islands	1998	Gibbs *et al*., 1998
Sustainable Land Management for the Murray Darling Basin, Australia	1998	CSIRO, 2000
Endangered species management: adaptive disease management of White Sturgeon in Kootenai River, B.C.	1995/ 1991	LaPatra, *et al*., 1999
Adaptive management for water quality in the Latrobe River Catchment, Victoria, Australia	1994	Grayson *et al*., 1994
Restoration of upland habitat for nesting ducks and other birds in the Canadian Prairies	1993	Clark and Diamond, 1993
Wood duck nest box programs in Montezuma National Wildlife Refuge	1993	Semel and Sherman, 1993
Adaptive management and regulation of waterfowl harvests in the US	1993	Williams and Johnson, 1995; Johnson *et al*., 1993
Adaptive experimentation for the effects of forest fragmentation on boreal birds in northern Alberta	1993	Schmiegelow and Hannon, 1993
Goshawk Management on Arizona's Kaibab Plateau	1992	Dewhurst *et al*., 1995
Management of antlerless elk harvests in Idaho	1992	Gratson *et al*., 1992
Adaptive forest management for plants and animals of the Ozark forest	1990	Kurzejeski *et al*., 1993
Management of rabies disease and urban skunk populations	1987	Schubert *et al*., 1998
Adaptive management in the US National Estuary Program	1987	Imperial *et al*., 1993
Adaptive management of salmon and power generation in the Columbia River Basin	1984/ 1980	Lee, 1989; Lee and Lawrence, 1986; Volkman and McConnaha, 1993
Adaptive management of water quality and living resources habitat in the Chesapeake Bay and its catchment basin	1983/ 1977	Hennessey, 1994
Adaptive management of sockeye salmon in Rivers Inlet, B.C.	1979	Walters *et al*., 1993
Great Lakes Program	1972	Francis and Reiger, 1995; Imperial *et al*., 1993

into two types according to the overall goals. First, some projects address management of a valued biological resource . Such programs are implemented to prevent deterioration, or maximize sustainable harvests of a singular renewable resource. Examples of this type of application are the Rivers Inlet Sockeye Salmon project in British Columbia in the 1980s (Walters *et al.*, 1993) and the Columbia River Basin project (Lee and Lawrence, 1986; Lee, 1993), both of which targeted salmon stocks. Also in this category are plans for adaptive management of waterfowl harvests in the U.S. (Williams and Johnson, 1995) and of forest habitat for the preservation of the northern Goshawk in the Kaibab National Forest of the United States.

Other adaptive environmental management schemes have broader goals to improve environmental quality or ecosystem health in general. Projects which fall into this category include the Chesapeake Bay Program (Hennessey, 1994; Costanza and Greer, 1995) concerned with the viability of the ecosystem consisting of the Chesapeake Bay estuary and its drainage basin, water quality issues in the Latrobe River in Victoria, Australia (Grayson *et al*., 1994), management of the Florida Everglades for multiple uses such as agriculture, urban land use and water supply (Light, *et al*., 1995) and sustainable land management at the catchment and regional scale for the Murray Darling Basin, Australia (CSIRO, 2000).

In reviewing the literature, however, one finds that the distinction between targeting an ecosystem and targeting a particular biological resource *within* an ecosystem is merely a matter of starting points. For example, managers of projects with sustainable yield goals must define habitat and manage ecosystems, while those starting with ecosystem level objectives must identify key species and their habitats as indicators of ecosystem health. Whatever the starting point, it is the ecosystem which is managed.

The following four sections lay out the characteristics of AEAM following the framework presented by Mitchell (1991). Here a distinction has been made between characteristics of adaptive management approach and its components. *Characteristics* are understood to be theoretical aspects which underpin the approach. *Components* are technical tools associated with the adaptive management, such as workshops and simulation modelling, (which are described following a discussion of characteristics of AEAM).

Characteristics of Adaptive Environmental Assessment and Management

Ecosystems: A Systems Perspective

The concept of *"system"* is a heuristic device to aid understanding of the real world by structuring complex situations as an organized whole consisting of inter-related elements (Flood and

Carson, 1993:7).[7] An *ecosystem* is a type of system, commonly defined as a collection of biological and ecological interacting components, their interactions and their physical environment (Allen, *et al*., 1993:17-18). These interactions comprise ecosystem *process*, the functioning or operation of an ecosystem. The regularity and persistence of these interactions define ecosystem *structure*.[8] A representation of the structure of a system emerges from defining and bounding a problem situation in which key variables and relationships are exposed. The interactions of these sets of variables (processes) emerge in part because they operate at similar speeds, having for example, common turnover times and rates of matter-energy processing. Ecosystem structure can be defined according to processes which operate at similar speeds and with a distinct spatial scale (Allen *et al*, 1993:19).

Ecosystems are evolutionary in that they follow a cycle which is the manifestation of four evolving functions: *exploitation, conservation, release* and *reorganization* (Figure 2.2). There are nested sets of such cycles, as presented in Figure 2.3, each operating at a distinct spatial scale and with its own temporal attributes (Holling, 1995:23).

Adaptive management employs two key concepts related to the above information. First, ecosystem structure can be defined by relatively few variables. An important part of AEAM is discovering, defining, monitoring and managing these key variables (Holling, 1990:74). Second, because of complexity and uncertainty, ecosystem structure is not always correctly defined. Key variables or their interactions may be poorly understood or overlooked altogether. Practitioners of adaptive management should accept this possibility and be prepared to deal with resulting surprises by flexibility in defining ecosystem structure (*e.g.*, as regards spatial or temporal scale).

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[7] Defining systems characteristics include hierarchical organization (subsystems and wider systems), emergent properties (the whole being greater than the sum of its parts), and flows of materials, energy or information between elements, which constitute their inter-relationships. Flood and Carson (1993) provide a good introduction to systems science for those interested in further reading.

[8] Another way of thinking of processes is as activities that occur within a system, whereas the structure of the system provides a framework within which the processes occur, and defines how the elements are related to each other (Flood and Carson, 1993:13). Checkland (1981:316-317) associates processes with elements characterized by continuous change, whereas structure is provided by elements that change only slowly or occasionally.

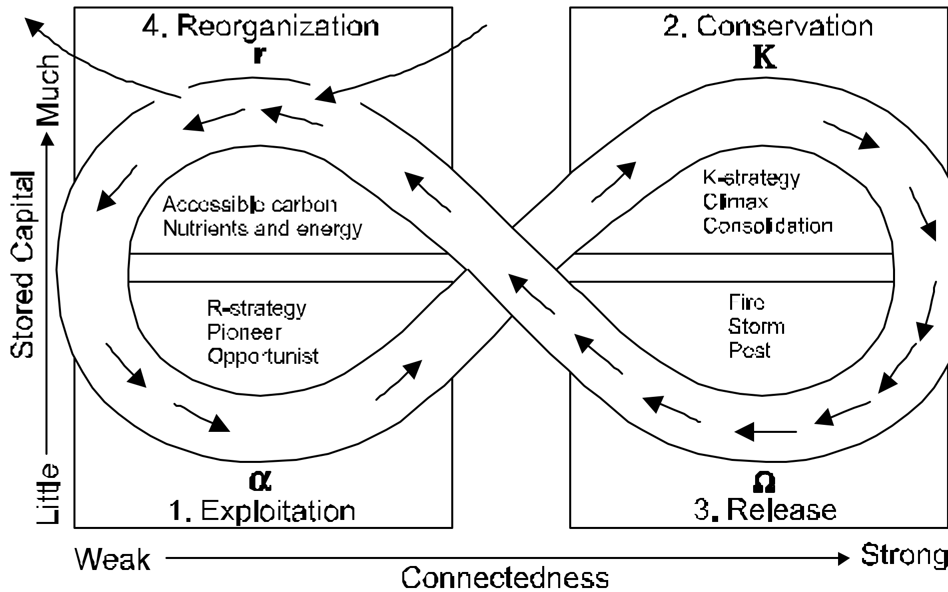

Figure 2.2: The four ecosystem functions and the flow of events between them. The arrows show the speed of that flow in the ecosystem cycle, where arrows close to each other indicate a rapidly changing situation and arrows far from each other indicate a slowly changing situation. The cycle reflects changes in two attributes; that is: (1) the Y axis -- the amount of accumulated capital (nutrients, carbon) stored in variables that are the dominant keystone variables at the moment -- and (2) the X axis -- the degree of connectedness among variables. The exit from the cycle indicated at the left of the figure suggests the stage where a flip is most likely into a less or more productive and organized system (*i.e.,* devolution or evolution as revolution). Source: Holling, (1995):22, Figure 1.2.

Kay *et al* (1999) describe another important set of characteristics of complex systems (such as ecosystems and human systems) – self-organizing behaviour. A simplified description of self-organization in open systems is that stable structures emerge in systems to dissipate flows of exergy[9] through the system. Such stable structures may, for example, be populations of aerobic bacteria or fish in a river such as the Cooum, having associated processes such as decomposition of organic nutrients, reproduction, digestion and other metabolic processes. If flows of exergy through a system are maintained within certain limits, a stable and coherent behavioural state can develop. Within this state space the system will be resilient. The system acts as if it is attracted to this

[9]High quality energy with regard to its ability to do work.

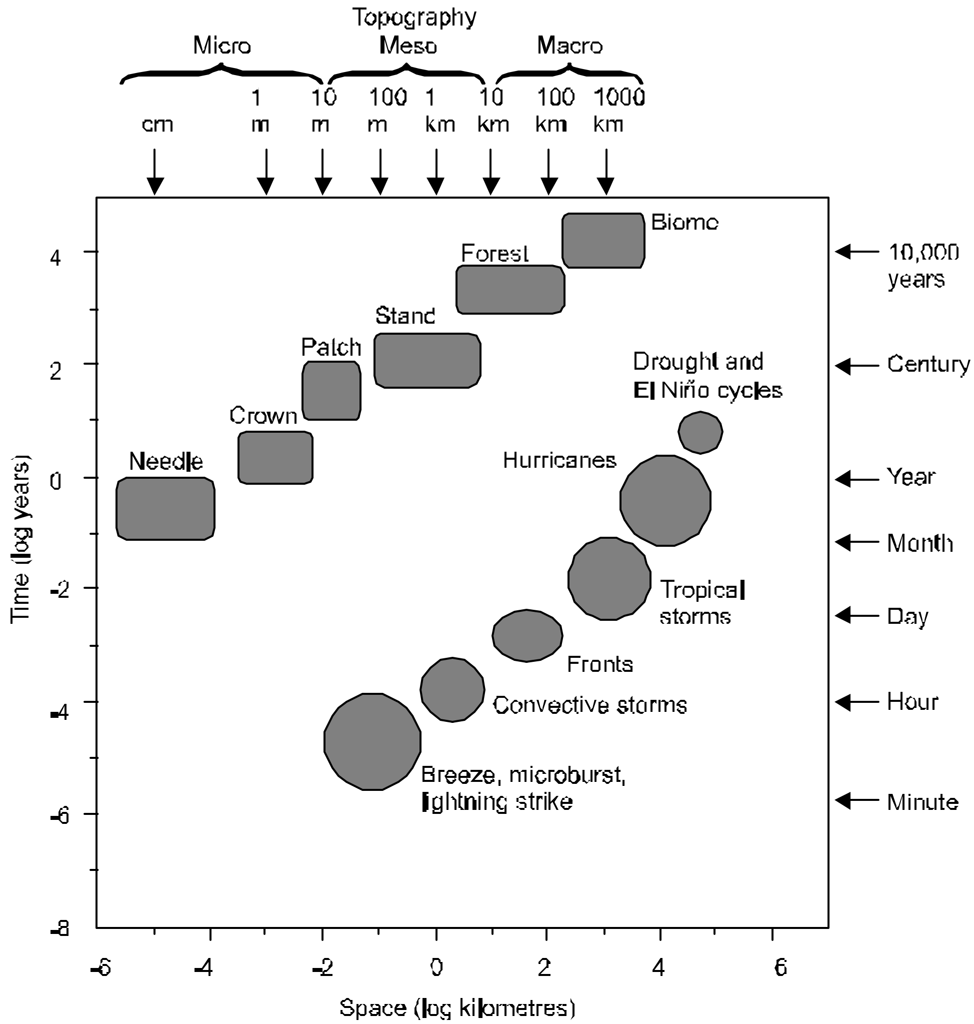

Figure 2.3: Space/time hierarchy of the boreal forest and of the atmosphere.
Source: Holling, 1995:23, Figure 1.3.

domain of behaviour, or *attractor state* (Kay *et al*, 1999:725). However, changing flows of exergy in the system can move the system away from equilibrium, and if a critical (catastrophe) threshold is reached, the system will spontaneously reorganize (or 'flip') to an new domain of coherent behaviour. For example, with large increases in domestic wastes (organic nutrients), the Cooum River system flipped from a system characterized by processes of aerobic decomposition of organic nutrients, to one in which anaerobic bacteria undertook decomposition of nutrients. Many other structures and processes in the system also changed, for example, fish species were no longer part of the system.

Thus, complex self-organizing open systems can have alternate stable states. This implies that if one can understand the cluster of important feedback loops and autocatalytic processes[10] that lead the system to organize within a particular domain of behaviour, such alternative states, if perceived as desirable, can serve as objectives for management. Propensities can be either reinforced or undermined so that particular configurations of the system (attractor states) are encouraged and others discouraged.

Although ecosystems have in the past usually been defined in biophysical terms, it is now commonly acknowledged that ecosystems are more than biophysical elements and their interactions. There are also human actors within such a system. Politics, management, multiple and conflicting uses, morals, intentions, societal goals and values overlay, are intertwined with and provide a context for the elements, interrelationships and operation of natural systems. It is, therefore, useful to conceive of ecosystems as consisting of both societal/cultural components and actors, and biophysical ones. Lee (1993:11) recognises this added complexity by referring to *large ecosystems.* He points out that "what makes the ecosystem "large" is not acreage but interdependent use; the large ecosystem is socially constructed." In a similar vein, this research will sometimes refer to such systems as *socio-ecological systems* so as to avoid the strong exclusively physical and biological connotations that the term *ecosystem* often evokes, and to emphasise the human components, including economic, political and cultural aspects, in the conception of ecosystems

One implication of this understanding of ecosystems is that it is not only the natural environment that should be the target of ecosystem management. As Kay (1994:68) pointed out, it is human interactions with the natural environment, not the environment itself, that need to be managed. If this line of thought is pursued, considerations of sustainability (in support of long term use of the natural environment), and participation in the management process (to accommodate the perspectives and activities of multiple stakeholders in the situation) arise. These issues correspond to Mitchell's "Balance" and "Teamwork" criteria, and are discussed below.

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[10]Kay *et al* (1999:725), after Popper, labelled such feedback loops and processes *propensities* of the system, the cluster of these being its *canon*.

It is important to keep in mind that systems (ecosystems, large ecosystems, socio-ecological systems) are mental constructs – models or simplifications of reality to structure our understanding of the world.[11] Even though we often reify the concept, we should remember this to maintain flexibility in learning (which involves re-conceptualization) about a system. One way to do this is by recognizing the role of perspective in conceptualization of the system. This implies that, since a system is a conceptual construct, there can be better or worse 'systems' defined to aid our understanding of the real world. Indeed, multiple 'systems' can be defined to describe the same real world situation. Allen, Bandurski and King (1994:6) acknowledged this crucial concept by recognizing that different *types* of systems can be defined with regard to a single situation. The type of system is based on criteria or standards derived from one's perspective:

> Independent of scale, there are criteria that set the bounded system away from its background. The bounded system is the foreground and its boundary is a reflection of the type of system it is. One has to look at the appropriate scale to see an object, but which object one sees in the foreground at a certain scale comes from the standards that prescribe the type of system.

One's perspective, experience or interest in the situation, therefore, will influence the conceptualization of the system. Given the same information and situation, different people might decide to draw the boundaries of what they consider to be 'the system' differently, *i.e.*, they might have different conceptions of what are the main components and interactions in the system as opposed to what is considered to be the environment of the system. For example, to an engineer at the Tamil Nadu Slum Clearance Board, a slum settlement along a river bank might be seen as a problematic situation in itself. However, to a slum dweller this may very well be perceived as the

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[11] There is a common confusion with the use of the word 'system.' In every-day usage, the word is often used to refer to a real thing or situation. However, in systems thinking (as in General Systems Theory and its descendent Complex System Theories, which underpin the concept of 'ecosystem'), a 'system' is a conceptual construct or tool which is mapped onto a real world situation. Systems concepts such as hierarchy and emergent properties are used to organize our observations of the workings of the real world and to define a model representing our understanding of the structure and functioning of part of the real world. We refer to this model as the 'system'. This entails a necessary simplification of the real world.

The confusion comes because not only do we refer to this conceptual construct which represents part of the functioning of the real world as "the system," but we also tend to apply this label to the actual real world situation itself. We should keep the concepts separate because we may incompletely or incorrectly understand the real world situation, and thus have an inadequate concept of the system. It is much easier to accept changes to our definition of the system, (especially if these involve drastic re-scoping and changes of scale), if we think of it as merely a conceptual map to aid in the understanding of the real world, and not as if it were a real thing in itself.

solution to a problematic situation. Conceptualizations of the same situation in the real world, built upon these two widely varying perspectives and sets of experience, are likely to be radically different. Similarly, human and bio-physical perspectives will generate different representations of a system. In Chennai, for example, one might draw important elements such as the river course and stormwater drainage system, and processes such as precipitation and tidal mixing to the foreground in the definition of the system. Another perspective might emphasis population, slum formation and the production of waste. The challenge is to integrate the different perspectives (Kay, 1997:67).

Recognition of the importance of system type implies that in managing an ecosystem a system definition/conceptualization must be undertaken for each relevant perspective, or else that a common understanding of 'the ecosystem' must be arrived at which incorporates the perspective of key stakeholders and actors in the situation. AEAM attempts to address this aspect of the management problem through stakeholder participation in a series of workshops and by stakeholder contributions to the development of simulation models which represent a common understanding of the ecosystem. These components of AEAM are discussed below.

Adaptiveness: Embracing Uncertainty

Walters (1986:162) describes three types of uncertainty which are usually distinguished in regard to natural systems. The first is background variation or "noise." This is not considered to affect management decisions except to obfuscate underlying trends and to necessitate monitoring and means of adjustment to changes in the environment of the system. Second, there exists statistical or "parametric" uncertainty. This is uncertainty about what has been defined as 'the system' for purposes of the management problem at hand. In particular, this is uncertainty about "what equations to use, how to estimate parameter values from noisy data, and how to assign probabilities to various hypotheses expressed as alternative equations and/or parameter values" (Walters, 1986:162). Finally, there is uncertainty in the definition of the structure of the system. Here the concern is that key variables and relationships may have been missed out. This implies that large and unexpected surprises in the functional responses of the system to management interventions may occur if its structural representation is incomplete.

An important principle of adaptive management is a recognition that all three kinds of uncertainty will always be present. Adaptive management attempts to use techniques that reduce uncertainty while also benefiting from the unexpected. In this way, surprises become opportunities to learn rather than failures in predictive models (Lee, 1993:56; Holling, 1978:9).

The three types of uncertainty, above, are an artificial partition of a continuum. For example, in defining a problem, distinctions must be made between system parameters and background variation, (*i.e.*, drawing a boundary between the system and its wider environment). This is largely a matter of temporal and spatial scale (Walters, 1986:163). The ability to match appropriate scales to the problem, and to understand processes that occur between scales, is crucial to successful adaptive management (Gunderson, *et al*., 1995b:531). Barriers to success include an orientation to past values and assumptions, and the inability to translate values and measures across scales, (*i.e*., to recognize processes operating at broader scales and to expand space and time scales, redefining the scope of the problem without losing touch with “local and fast dimensions”) (Gunderson, *et al*., 1995b:528).

Walters (1986:163-164) found it heuristically useful to divide the process of adaptive management into three phases based on levels of uncertainty associated with environmental management problems. These are the *preadaptive phase*, the *adaptive phase* and the *certainty-equivalent* phase. The first phase is *preadaptive* because managers have little or no data on the response of the particular system with which they are dealing. Therefore, management decisions must be based on whatever existing data are available and the experience with “similar” situations in other systems. Choosing between management options may be difficult during this phase due to lack of information. However, almost any intervention in the system will increase knowledge and reduce uncertainty for management of the system in the future. Thus, recognizing uncertainty, AEAM uses management as a tool to reduce it (Williams and Johnson, 1995:431). The key policy issue in this phase is how much to invest in monitoring systems in pursuit of knowledge of system responses to development (Walters, 1986:163).

As knowledge about the system accumulates, managers can generate hypotheses, in the form of alternative models, to describe how the system will respond to various interventions. This is the *adaptive phase*. The key policy issue at this stage is "whether to act informatively with respect to hypotheses that imply opportunities for improved performance by moving outside the range of experience available" (Walters, 1986:163). During this phase, surprise remains unexceptional. This emphasises the importance of continual monitoring of key indicators.

The *certainty-equivalent phase* represents a situation in which sufficient information has been generated through experience and experimentation, and adequate understanding of the system has developed so that there is no further advantage in experimentation. Managers should act according to the best available model of the system as if it were based on certain knowledge. However, even allowing the (unrealistic) assumption that all knowledge previously generated pertains to the present state of an ecosystem, (that is, the system does not change over time), the certainty-equivalent phase may never be attained.

These phases in the evolution of the understanding of a situation also assume that the uncertainty to be reduced is either parametric or structural. There is a more fundamental uncertainty to consider in addition to these, which Wynne (1992) refers to as *indeterminancy*.[12] Indeterminancy is uncertainty about whether appropriate questions are being asked, whether problems are addressed with appropriate theoretical and methodological tools and within an appropriate paradigm. Ecosystem approaches have evolved in response to this kind of uncertainty. Recognition of the failure of "normal" positivist/reductionist science to deal adequately with environmental problem situations has led to such innovations as the application of systems concepts and participation of stakeholders in environmental planning and management.

Another useful way to characterize uncertainty is from the perspective of complexity and self-organization of systems (discussed in the preceding section). Kay (2000), for example, describes increasing levels of uncertainty associated with (1) systems whose behaviour can be described by mechanical Newtonian functional relationships, (2) systems characterized by

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[12]Wynne (1992) identifies four types of uncertainty: risk, uncertainty, ignorance and indeterminancy. 'Risk' and 'uncertainty' correspond to degrees of parametric uncertainty discussed above, while 'ignorance' is structural uncertainty.

homeostasis about a single attractor, (3) systems having multiple attractor states where the attractors, and thresholds between them, are known, (4) systems in which the thresholds between attractors are not known, and (5) systems which have unknown attractors. Associated with this increase in complexity and uncertainty is a corresponding decline in the ability of management efforts which are based on anticipatory science to deal with the situation. As uncertainty and unpredictability increase, so does the need for adaptive management.

This implies that anticipatory management becomes less useful as complexity and uncertainty increase. This is an issue for caution in the application of AEAM. Despite the fact that the AEAM approach is explicitly adaptive, its application has traditionally employed anticipatory methods. That is, many of the tools employed by AEAM practitioners are rooted in traditional anticipatory science (*e.g.*, simulation modelling and forecasting) which attempts to predict the response of systems to management interventions. Learning is stimulated by comparison of actual and predicted system responses. These tools, based on the best available knowledge of the current organizational domain of the system, are most useful in the exploration and modelling of that single domain of organization. They will be inadequate to model system behaviour at catastrophe thresholds and within alternative attractor states unless those attractors and their thresholds are also known.

Teamwork: People, Communication and Organization

Adaptive environmental assessment and management is hailed as an interdisciplinary approach, involving policy people, managers, and scientists from various backgrounds. The AEAM process is also billed as participatory, involving multiple and conflicting interests. For adaptive management (and ecosystem approaches in general) to be successful in this way depends on the proper combination of people, communication and organization.

People are the key. For example, successful application of AEAM often depends on the participation of at least one *wise integrator*. This is “an individual with professional understanding who has an intuitive knowledge that the process will help and knows the institutional environment well enough to nurse the process through to completion" (ESSA, 1982:36; also see Gunderson *et al*., 1995b:505). The formation and influence of what Haas (1990) refers to as an *epistemic community* may also play a crucial role in providing insight and bridging conflict in environmental problem situations. Haas (1990:40-42) describes such a community as,

> ...composed of professionals (usually recruited from several disciplines) who share a commitment to a common causal model and a common set of political values. They are united by a belief in the truth of their model and by a commitment to translate this truth into public policy, in the conviction that human welfare will be enhanced as a result.

This informal network of experts or professionals shares a concern with, and a common approach to, the problem. This is the crux of their role in the process. That is, their advice is credible because "their understanding [is] scientific -- that is, open to revision by new information" (Lee, 1993:131).

In Chennai the network of 'credible' and 'legitimate' participants are primarily government planners, scientists and engineers, as well as local and international consultants. The paradigm which this group shares is rooted in normal reductionist science, engineering approaches to problem solving and master planning. NGOs and academic researchers are not seen by this group as making a credible contribution. They often do not share a "common causal model and a common set of political values."

For cooperation and participation to occur, open communication among decision makers, scientists, managers and the public is essential. Holling (1978:120) holds that communication is so important that it requires the dedication of at least as much effort as analysis. The main tool for communication among the various parties in AEAM is through participation in a series of workshops, and in the construction of (and gaming with) a dynamic system model. (Workshops and modelling are further discussed below). Another means of facilitating communication and participation occurs at the organizational level, especially in very large management programs. Practitioners are increasingly realizing the importance of flexibly structuring the organizational and institutional framework of environmental management programs to include all important contributors (Lee, 1993; Hennessey, 1994; Gunderson *et al*., 1995b). Public advisory committees are one way of doing this, and are typical in adaptive management programs.

AEAM has generally been found to be successful, but in those applications which have failed, lack of institutional support has been cited as a major cause (*e.g.*, ESSA, 1982; Rondinelli 1993a, 1993b). ESSA (1982:32) holds that the reason is "institutional inertia" resulting from two main sources:

> (1) Large organizations strongly tend to worship stability and thereby attempt to maintain the status quo. Routine and imitative behaviour (*i.e.*, mimicry) reduces the costs of decision making and creates (in theory) predictability.
>
> (2) Related to the previous point is a lack of entrepreneurial spirit within organizations. Risks are feared and, therefore, immediate success is a requirement for any innovation.

Barriers such as this reflect an investment in, and inertia of, a mechanistic management style (Table 2.4). Rondinelli (1993a, 1993b) holds that, while an adaptive and experimental approach is needed in many developing country situations because of high levels of uncertainty, complexity and risk, the predominance of rigid bureaucracies, centralized and hierarchical control structures, operational biases toward programmed (not process-oriented) management styles, and failure to involve stakeholders in the management process are barriers to its implementation. These may be observed in the Indian context. For example, the Cooum situation is characterized by scarcity and poor quality of data, models of the situation constricted by jurisdictional and disciplinary boundaries, actors within government agencies that are paralysed by perceived lack of power to do so much as share information with other stakeholders, and a public which consistently complains of a closed and exclusive management process.

Such barriers should be expected and will require strategies to avoid or overcome them. For example, Brinkerhoff and Ingle (1989:491) suggest that a 'deliverables' mentality (which is characteristic of rigid bureaucracies and programmed approaches) may be appeased by incorporating short- and medium-term targets within an adaptive program.

Another possible way to overcome such barriers emphasises 'Teamwork' and the importance of key players in the adaptive management process. As discussed above, a respected proponent of the process within the institutional setting, or an objective and credible community of experts which endorses an adaptive ecosystem management approach, may be vital in overcoming

Table 2.4: Characteristics of mechanistic and adaptive management strategies in institutions.

	Management Strategy	
	Mechanistic	***Adaptive***
Environment	Certain	Uncertain
Tasks	Routine	Innovative
Management Processes		
Planning	Comprehensive	Incremental
Decision-making	Centralized	Decentralized
Authority	Hierarchical	Collegial
Leadership style	Command	Participatory
Communications	Vertical, formal	Interactive, formal and informal
Coordination	Control	Facilitation
Monitoring	Conformance to plan	Adjust strategy and plan
Use of formal rules and regulations	High	Low
Basis of staffing	Functions	Objectives
Structures	Hierarchical	Organic
Staff values	Low tolerance for ambiguity	High tolerance for ambiguity

Source: Rondinelli (1993b, Figure 2) after Rondinelli, Middleton and Verspoor, 1990.

institutional inertia.

The analytical approach employed in conventional applications of AEAM, (such as simulation modelling and management intervention formulated as scientific experimentation), can also be a barrier to the success of adaptive management programs. Gardener (1989:352) notes that the sophistication of such methods can compromise the potential for full community involvement in the process. Also, results of scientific studies in adaptive management programs are typically published in technical forums, and written for an academic and technical audience. As such they are not very accessible to the public (Smith *et al.*, 1998:676). Confusion can also be generated, and the perceived objectivity of the management process undermined when scientists (perhaps representing different interests in the situation) disagree on "facts" and assumptions associated with system models (McLain and Lee, 1996:443-444).

Additionally, scientific methods favour information and knowledge that can be quantified, and may exclude other kinds of knowledge (McLain and Lee, 1996:444). This presents a barrier to stakeholder participation and illustrates the danger that potentially enlightening understandings and perspectives of stakeholders in the situation may be ignored.

Such concerns arising from past adaptive management efforts, re-emphasize the earlier statement about the importance of communication. For this reason this research has attempted to avoid the use of scientific jargon in the conduct of workshops, and in the dissemination of information to participants in the program of research and stakeholders in the situation. This work also attempts to incorporate the knowledge of all stakeholders participating in the research in a shared conceptual model of the system, and employs the construction and use of a simulation model to express and explore aspects of that understanding.

Balance: Sustainable Development and AEAM

A central principle of sustainable development is the satisfaction of human needs in the long run (Gardner, 1989:340). This implies that trade-offs must be made between enhancing and preserving the resource base and the pursuit of economic growth. Trade-offs may be brought about, for example, where sustainable activities occur at lower levels or higher costs than previously was the case. Such (perceived) sacrifices will be easier to implement if public participation and communication have generated an awareness and sense of ownership of the problem situation and management program.

In addition, the systems perspective taken by adaptive management is conducive to recognition of environmental constraints on the economic system. The integration of human components and activity with biophysical elements and processes in the conceptualization of an ecosystem promotes the development of strategies to manage human interaction with the natural environment while highlighting the impacts of that interaction. This is in opposition to the historical trend in economic development in which the environment is treated as an external and everlasting source of raw materials and a bottomless sink for waste.

Lee (1993:8) argued that to achieve an environmentally sustainable economy we must enter into a process of social learning. He described social learning as a combination of adaptive management, (especially in the sense of explicitly operating the learning cycle while intervening in ecosystems), and the context of application within bounded conflict, (meaning politics), which result in the construction of institutions that can sustain civilization in the long term. Such institutions are likely to undertake management of ecosystems in the ‘adaptive’ manner described in Table 2.4.

Lee (1993:8) summarised the pertinence of adaptive management and social learning to sustainability nicely:

> Social learning explores the human niche in the world as rapidly as knowledge can be gained, on terms that are governable though not always orderly. It expands our awareness of effects across space, time, and function ... Human action affects the natural world in ways we do not sense, expect, or control. Learning how to do all three lies at the centre of a sustainable economy.

Components of AEAM

Specific analytic techniques employed in adaptive environmental assessment and management depend on the nature of the problem being addressed. However, there are two general procedures which are always present. These are the use of a series of workshops to bring together key actors, and the development of a dynamic system model.

Workshops

Holling (1978:12-13) described adaptive management as a process involving two groups of people: (1) a small core group of analysts and support staff, and (2) key cooperators in the management project. It is the role of the core group to integrate information through the application of systems techniques such as computer modelling and mathematical analysis. This group also coordinates the project, bringing together the second group in a series of workshops which are central to the approach.

The first workshop initiates the problem analysis and usually brings together about 20-25 key actors; (*e.g.*, scientists, managers and policy people), to scope, define and focus the problem (ESSA, 1982:2). This workshop considers all elements of the project. This includes the determination of goals and objectives, the allocation of tasks for subgroups, discussion of key variables, indicators and information needs, possible management actions, the spatial extent and time horizon, and the development of a framework for (and perhaps a crude working version) of a system model (Holling, 1978:51). Less tangible but very important products of this first workshop include facilitation of communication between actors and the creation of an atmosphere conducive to the generation of creative management alternatives (ESSA, 1982:2, 28).

Further workshops address more specific tasks. The participants involved in these workshops (*e.g.*, decision makers, scientists) depend upon the particular stage of the process and the task to be performed. Tasks of secondary workshops may include further definition of management goals, construction and refinement of the dynamic system model, exploration of uncertainties, and the development of alternative management actions. Gaming sessions with public involvement may be organized to facilitate public participation and communication (ESSA, 1982:28). Between workshops, the core group consolidates information by way of model testing, evaluation of management policies, collection of data (Holling, 1978:56).

Models

Associated with the conventional process of adaptive environmental assessment and management is the development of computer simulation models as decision support tools to help develop and explore management options (Holling, 1978:14). This process requires the construction of symbolic models to represent the relationships between components of the system. Simulation comes from subjecting inputs to mathematical and logical operations to predict outputs. The term “dynamic” indicates simulations which are iterative, with each iteration representing a step forward in time and with the model state values changing with each iteration (Hettelingh, 1990:10). “Static” or “steady-state” simulations solve the model equations for a single period.

A major advantage of system modelling is that it creates a simplified laboratory world in which management actions can be tested (ESSA, 1982:43). This helps to alleviate the problem of reproducibility in complex real-world problem situations (as presented in Table 2.1). That is, simulation testing and experimentation can be performed with no irreversible adverse effects to the ecosystem. Extreme management actions and creative alternatives can be explored. In addition, the use of simulation models brings together integrated and inter-disciplinary teams, forces assumptions to be explicitly stated, and highlights further data and analysis needs (Gunderson *et al.*, 1995b:526, 528; ESSA, 1982:43).

Furthermore, computer models accelerate time and compress space, thereby allowing the user to experience results of ‘management interventions’ in the system being modelled. That is, this tool links the system’s dynamics and the users’ perception. Helping the user to experience a broader range of space and time can bridge a major barrier to adaptive management: the inability to recognize processes operating at broader scales and to expand the scope in space and time to match these processes (Gunderson *et al.*, 1995b:528).

The involvement of workshop participants in the development of simulation models also ensures that all understand its capabilities and limitations (Grayson, *et al.*, 1994:245), increasing the usefulness of the computer model to non-technical users. The visible results of a running model (in the creation of which both technical and non-technical users have contributed) generates a sense of ownership and acceptance. Graphical presentation of results, user friendly software and ‘hands-on’ gaming increase the utility of the models and the impact of modelling on decision making (ESSA, 1982:43). There is a danger, however, that users of the model will take its results as dependable predictions. To avoid their misuse, care should be taken to ensure that the accuracy of model results is understood. Risks and uncertainties associated with the model should be explained (ESSA, 1982:42).

Table 2.5: Some advantages and disadvantages of simulation modelling

Disadvantages	Advantages
▾ Requires computer facilities	▾ Promotes communication between disciplines
▾ Requires expertise and time for development	▾ User forced to clarify assumptions and causal mechanisms
▾ Results may be too easily believed by decision makers	▾ Any form of relationships can be handled - linear or nonlinear
▾ Results are usually complex (if there are many variables) and are therefore difficult to communicate to decision makers	▾ Can compare alternative management schemes
▾ Fails to allow measures of degree of belief in data or in the assumptions to be reflected in final results	▾ Can include uncertainties of various types
▾ Relations between variables usually assumed constant through time	▾ Graphics output a good way of communicating impacts
	▾ Can utilize information about known processes that have not been investigated for the particular system of study but that have some generality (*e.g.*, predation, population growth)
	▾ Can use detailed information concerning processes in the natural system
	▾ Helps to identify key variables or relationships that need to be investigated or are sensitive

Source: Holling, 1978: after Table 5.5, 79.

Holling (1978) lists disadvantages and advantages of the use of simulation models in AEAM (Table 2.5). Note that many of the advantages correspond to the products of system identification exercises. The *process* of developing a simulation model may be seen as such an exercise. The product of that process, the model itself, is an expression of participants' conception and understanding of the system. (This is a large part of the role that simulation modelling and the development of GIS-based decision support system and database play in this research).

It has been mentioned above that one of the objectives of the first, and possibly subsequent, workshops in the AEAM process is the construction, modification and use of simulation models. Grayson, *et al*., (1994:248) described this process as follows:

1. Definition of the model scope including:
   - possible management actions;
   - indicator variables of the system that will test the efficacy of the management actions;
   - the required spatial scale for the model;
   - the simulation time step and overall period of simulation.

2. Formation of the modelling sub-groups; management actions and indicators are grouped into thematic sub-groups so that sub-models of the various components of the system can be developed and integrated at a later stage. People are assigned to each sub-group on the basis of knowledge and skills and the information requirements of the sub-groups are identified.

3. Development of the sub-models: within each sub-group, existing information is synthesized in order to model the behaviour of the indicator variables and to produce functional relationships between the management actions and the indicator variables. A sub-model of each component of the system is then developed by a modeller assigned to the sub-group.

4. Development of the integrated model: the sub-models are linked to form an integrated model of the system which is then tested and validated by the sub-groups.

5. Gaming: the model is used by the group as a whole to develop management scenarios and to compare the effects of the various management actions.

6. On-going development: the model is a dynamic entity which develops as further information becomes available or as different management options need to be evaluated.

AEAM in a Developing Country Context

Most applications of adaptive environmental assessment and management have been situated in more developed countries (MDCs). This raises a question: Is the approach suitable for less developed countries (LDCs)? Holling (1978) certainly thinks so. His review of the application of AEAM to the development of forestry, agriculture and hydroelectric power generation in the Rio

Caroni basin in Venezuela described the successful development of a rain-vegetation-soil-river simulation model to evaluate alternative intensities and combinations of land use within the watershed using various time horizons (Holling, 1978:246). However, successful modelling is only one component of AEAM, and does not constitute the approach itself. In reference to another project, Holling argued the universality of the adaptive management approach, citing a 2-day workshop for a regional planning project in the Bermejo River basin in Argentina as successfully "reidentifying the issues, promoting integration among disciplines, and producing a more global and coherent view of the problem and its solutions" (1978:19). However, he tells us no more about this project.

Another application of adaptive environmental assessment and management in the developing world was the Nam Pong Environmental Management Research Project. This project saw the successful development and evaluation of a management-oriented model of the Nam Pong River basin through the participation (and training) of Thai scientists in two month-long workshops in 1980 and 1981 (ESSA, 1982:102). It is not known how useful the model has actually been to institutions and managers in subsequent management of the basin.

These few examples hint at the suitability of the adaptive management approach in LDCs, but are far from conclusive. The question remains unanswered, but may be explored through yet another question: How is the context of environmental management in a developing country context different than in developed countries? Here, two categories may be identified: (1) differences in the or ecological setting.

Table 2.6 presents conditions in the first category, the international and historical setting. There are several implications of these for operationalizing adaptive management in developing countries. First, Sanderson noted that management options are more likely to be constrained due to urgent needs to maximize productivity of the system. However, this is no reason that adaptive management should not be attempted. Indeed, not only could AEAM prove useful to identify those options which do remain but, as discussed above, the process attempts to create an atmosphere in which creative management alternatives are generated.

Table 2.6: Differences in the context for environmental management between MDCs and LDCs.

Category	***Explanation***	***Implication for Environmental Management***
Structural Constraints	LDCs' macroeconomic environment is relatively fixed. They are confined in their range of motion by the rules of the international system over which they have little control.	Increased likelihood to be dominated by external management organizations with less "embeddedness" in the local environment. (Technical solutions and expertise, overriding of local knowledge)
International Economic Change	Politics in LDCs are structured by economics at a global scale to a greater degree than are MDCs.	Developing country ecosystems are more vulnerable to external cycles.
Colonial Legacy	LDCs are linked to a development design not of their making and outside of their control.	Imperatives of economic growth result in intensive management of resources, increasing the occurrence of brittleness in systems, surprise and catastrophe.
Persistence of the Current International Structure	The ability of LDCs to avoid the environmentally destructive consequences of the international economic system may depend on their ability to change the rules of the system.	The strategic focus of resource management must include the "overarching macrostructure," a goal undermined by the gap in power between LDCs and MDCs.

Source: Derived from a discussion of the case for developing country exceptionalism (Sanderson, 1995:377-383).

international and historical situation of LDCs, and (2) differences in the internal policy, bureaucratic

Second, the systems being managed in LDCs are likely to be more vulnerable to external shocks. For example, in systems which produce agricultural goods for export on the international market, a sudden increase in the price of beef or drop of grain prices might affect the dynamics of the system. External influences on such a system could be caused by changes in consumptive preferences in developed countries, new technologies, and war. Two aspects of adaptive management make this approach particularly appropriate in such a situation. One way is through a systems perspective. Part of the process of adaptive management is an attempt to bound problems in such a way that such external influences are considered (*i.e.*, defining appropriate spatial and temporal scales). Despite this, unforeseen events do happen. Adaptive management recognises (and expects) that surprises will occur, whether from misunderstanding of the structure of the system, or imposed from the (perceived) environment of the system. Managers and their programs are encouraged to be flexible and adaptive, learning from surprises and incorporating new information by, for example, expanding the scope of their spatial and temporal perspective.

Third, structural constraints in development projects (*e.g.*, as might be imposed by the IMF or World Bank) result in external experts and management consultants being parachuted into a situation often with little appreciation of local conditions and knowledge (Rondinelli, 1993a:96; Sanderson, 1995:380). Lonergan (1993:328) highlighted this problem, stating that along with the normal complex and multidimensional aspects of environmental problems, those in developing nations are also *conditional*,

> ... in that the state of a social system and the relationships which describe that system at any time are unique in time and space; poverty and environmental degradation are historically, socially, and politically, constructed -- only after assessing the significance of these forces can one understand the society and the relationships within.

This aspect of management in LDCs is alleviated by the emphasis on participation in AEAM. This is not merely information dissemination, but actual involvement in activities such as goal setting, and determination and evaluation of management alternatives. When outside management agencies and foreign 'experts' are involved, they should take the role of facilitators. This should mobilize and integrate local knowledge, perspectives and expertise. In the instance where local expertise is lacking, the facilitator's role may also include training (Brinkerhoff and Ingle, 1989:494). Participation has the added advantage of building local capacity.

An important observation regarding the second category (internal differences) is that LDC institutions usually are more heterogeneous than those in MDCs. For example, there is likely to exist multiple means of governance of common pool resources, such as water, and the existence of indigenous institutions and tenure systems (Sanderson, 1995:383). This heterogeneity increases the incidence of politically fractious conflict-beset situations which frustrate efforts to manage fragile ecosystems. An example from India is the situation of squatter settlements (slums) on both public and private land along riversides in Madras. The rights of slum dwellers to occupy the land is officially recognized (Government of Tamil Nadu, 1971). This legal protection for squatters, legitimate claims to the land by the owners, and immediate proximity to a common resource add the complexity of multiple legitimate stakeholders to the situation. Jurisdiction over various aspects of the situation by agencies such as the Public Works Department, the Tamil Nadu Slum Clearance Board, the Chennai Metropolitan Development Authority, the Corporation of Chennai and the

Chennai Metropolitan Water Supply and Sewerage Board further complicate management issues.

Institutional inertia also may be greater in less developed countries. As a result, resource managers find that they are constrained in the approaches they may employ. Rondinelli (1993a:103) stated the problem as:

> What leads to success is the ability of managers to design and manage simultaneously; to test new ideas and methods continuously no matter what the circumstances in which they find themselves. This managerial flexibility, however, is often squashed by officials in the headquarters of international agencies or national ministries who insist on conformance to detailed plans and rigid management procedures.

According to this description, adaptive environmental management is a formula for success, but the implementation of such a program is unlikely in circumstances that demand a programmed approach. It may be possible to change this situation by incorporating some characteristics of a programmed approach into an adaptive management program. For example, Brinkerhoff and Ingle (1989:491) describe a structured flexibility approach that maintains characteristics very similar to those of adaptive management, but (among other things) satisfies the 'deliverables' mentality of inflexible bureaucrats by incorporating short and medium term measurable product or service targets.

Thus, adaptive management has the characteristics to address environmental management problems not only in the developed world but also in developing nations. A systems approach and emphasis on real participation make the approach transferable in the face of greater vulnerability to external influences, restricted management options and potential conflict. The greatest barrier to the implementation of the approach in developing countries may be an inflexible institutional and bureaucratic environment.

The Potential Role of GIS within AEAM

Geographic information systems (GIS) are "a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes" (Burrough, 1986:6). One set of purposes might be the support of the adaptive environmental assessment and management process. In particular GIS has relevance to the system modelling process that is such a central component of the usual AEAM procedure. Steyaert and Goodchild (1994:348) list four aspects for which GIS may make contributions to simulation in environmental management; as a preprocessor of data, storage and management of large spatial databases, analysis of data and model results, and visualization and presentation of simulations. Each of these will be discussed briefly below.

Preprocessing, Data Storage and Management

Large amounts and diverse sorts of data may be required for environmental modelling. Due to the nature of the environmental management problems, much of these data will have spatial characteristics. For example, land use and land cover data, digital elevation models and remote sensing imagery provide useful information to those attempting to model environmental and ecological processes. GIS provides a convenient means of storing and managing such data. Steyaert and Goodchild (1994:348) noted that GIS has automatic 'housekeeping' functions, such as documentation of data layers, and provides uniform access to diverse data that has been integrated into the system.

Basic functions of GIS also lend themselves to the preparation of data for modelling the environment, whether the modelling system is a GIS or an external program. Map digitizing, import and editing (data collection), generalization and re-sampling, projection changes and data extraction (through windowing and other means) are some ways in which GIS can preprocess data (Steyaert and Goodchild, 1994:348). Also significant is the ability to reformat and export data in formats useable to other packages, (especially, in this context, to simulation modelling packages).

Spatial Analysis

Spatial analysis is perhaps the most important contribution that GIS can make to the modelling component of adaptive environmental assessment and management. One opportunity is for GIS is to add a component of 'spatial specificity' to modelling. For example, traditional watershed modelling employs a "lumped-model" or "lumped-systems" approach which averages variables with spatial attributes, such as land use and elevation, within watersheds without consideration of their spatial characteristics (Maidment, 1993:149). In contrast, distributed parameter modelling expressly considers spatially controlling parameters such as soils and land use (Engel, *et al*., 1993:232). Engel, *et al*. stated that this provides for more accurate system simulations, simultaneous simulation of conditions at all points throughout the watershed (allowing the simulation of processes with both temporal and spatial characteristics), and extrapolation of plot-sized studies to the entire watershed. With distributed parameter modelling, for example, a watershed may be divided into a grid of cells, each with topographical and other attributes. Such variables as runoff, erosion and chemical transport can be modelled and, for example, upland areas contributing to potential problems and areas in need of remedial action may be identified (Engel, *et al*., 1993:232).

This cell-based distributed parameter modelling procedure is similar in concept to analysis performed in raster-based GIS. In addition to the performance of such analyses through multiple iterations, GIS has two other potential contributions to distributed parameter modelling. First, analysis in a GIS can 'parametize' the model.[13] For example, Blaszczynski (1992, as reported in Steyaert and Goodchild, 1994:341) derived the parameters required to apply a revised Universal Soil Loss Equation model (*e.g.,* terrain slope length, steepness, land cover and management, runoff and rainfall) in a dynamic model of surface water quality through spatial analysis of terrain, soil survey and land use data in a GIS. At the other end of the process, GIS can be used to analyse the results of the model. For example, the use of Boolean logical operators and reclassification functions would facilitate the identification (and mapping) of the upland problem areas referred to in the above example from Engel *et al*.. Such functions are generic to GIS. In fact, GIS packages usually incorporate sufficient terrain analysis tools (such as the GRASS "Waterworks" package) that together with standard Boolean search and overlay functions, provide all the necessary

[13]"Parametize" "parametized" and "parametizing" are terms that are used throughout this work to refer to the process of developing parameters for input into an environmental model. This process could range from simple retrieval and transport of data to more extensive analysis to arrive at a set of data of the nature and form required by the environmental model.

capabilities for contemporary hydrologic modelling (Steyaert and Goodchild, 1994:339).

However, GIS as a stand-alone system is usually not used for environmental simulation modelling. Steyaert and Goodchild (1994:349) reported that simulations written as a series of GIS commands and operations are rare. It is more common that GIS are loosely coupled with modular system simulation software. However, such makeshift systems often result in cumbersome data conversion procedures (Steyaerd and Goodchild, 1994:347). One way that this, and other awkward technical tasks, might be relieved is by programming routines to automatically perform such procedures, and to provide access to these through a task-oriented form or menu driven interface (such as might be created using Arc/Info's Arc Macro Language).

Visualization and Presentation

A final category of the potential contributions of GIS to the AEAM process is the visualization and presentation of simulation results. In addition to standard tabular and graphical reporting functions, cartographic mapping capabilities are an important component of any GIS. Thus, a GIS brings increased capability to present and display results. The importance of this capability is indicated by the persistent reference in the adaptive management literature to the significant communicative role of clear visual presentation of results (*e.g*., Holling, 1978:124; ESSA 1982:43; Walters 1986:59).

GIS appear to be suited to use within the AEAM process. They can benefit the modelling process at all stages, from preprocessing of the data through data management, analysis and modelling to presentation of results. This work employs GIS, as part of a prototype decision support system, to construct and maintain a database of the study area, provide tools for query and visualization of datasets, and through simple analyses and retrieval of data, to parametize an environmental simulation model. This is discussed in detail in Chapter 4, and Appendix II.

Soft Systems Methodology

Overview

Another major influence on the approach taken in this research is the work of Checkland and his colleagues at the Department of Systems and Information Management, University of Lancaster, in attempting to make sense of, and intervene in, human activity systems. Soft System Methodology (SSM) provides a conceptual basis and a set of tools to address problem situations characterized by what Funtowitz and Ravetz (1994) refer to as emergent complexity. Allen, Bandurski and King (1993:45) in their report to the Great Lakes Science Advisory Board, recommended that Checkland's approach be employed in the execution of the general and specific recommendations in their report on the application of the ecosystem approach in the Great Lakes Basin.

Soft Systems Methodology was developed in the 1970s out of the failure of the systems engineering approach (which is used to solve 'hard' engineering type problems) to solve 'soft' human/social problems. 'Hard' problems in this context refer to problems which, although often difficult to understand and deal with, are definable. One can know what the problem is. Soft problems, on the other hand, are less focussed or structured and more 'fuzzy' or 'messy.' Soft problems are more usefully discussed as problematic situations in which the "same" problem may be perceived differently by various people (Flood and Carson, 1993:98). Soft or 'fuzzy' problems are typically encountered when attempting to deal with situations involving human or social 'real-world' situations. Hence, the term 'real-world problem' is often used by practitioners of Soft Systems Methodology. A real-world problem is a problem "which arises in the everyday world of events and ideas, and may be perceived differently by different people. Such problems are not constructed by the investigator as are laboratory problems" (Checkland, 1981:316; also see Flood and Carson, 1993:97-98). Note the similarities between this description of the type of problematic situations toward which SSM is oriented, and the discussion of the nature of environmental problems above.

Thus, soft systems methodology is

> a general methodology which uses systems ideas to find a structure in apparently unstructured "soft" problems, and hence leads to action to eliminate, alleviate or solve the problem, or provides an orderly way of tackling "hard" problems" (Checkland, 1976:52).

An important aspect of Checkland's and others' work at the University of Lancaster is that the development of SSM, which applied systems thinking to ill-structured problems, was undertaken through interactions with real problem situations (Checkland and Scholes, 1990a:16). This type of research, labelled 'action research' in the soft systems literature, uses the experience of the research itself as a research object about which lessons may be drawn (in lieu of classical hypothesis testing). To undertake action research, an intellectual framework (such as hard systems engineering) for understanding the problem situation is adopted. The use of the framework is expected to lead both to insights into the problem situation and to a gradual improvement of the framework itself (Checkland and Scholes, 1990a:16).

The Basic Soft Systems Methodology

The idea that our perceptions of the world inform our conceptualizations of it implies that, as human beings, we endow our world with meaning. This is an important realization central to Soft Systems Methodology. That is, we deal with the "creation of an interpreted world, not merely an experienced world" (Checkland and Scholes, 1990a:2). Further, we can form intentions according to how we interpret the situations we experience, and act on these intentions. Such action is 'purposeful action' which is "deliberate, decided, willed action, whether by and individual or by a group" and taken in response to experience of the world to which humans cannot help but attribute meaning (Checkland and Scholes, 1990a:2). Human beings are continually taking purposeful action related to experiences of situations and the knowledge (interpretation of the real world) generated by such experiences. This experience-based knowledge informs purposeful action which in turn creates new experience of the world, yielding further experienced-based knowledge in a knowledge acquisition cycle which embodies the fundamental possibility of learning (Checkland and Scholes, 1990a:3).

Soft Systems Methodology is a methodology for "formally operating the learning cycle" in which learning from experience is directed to inform purposeful action in real world situations and is intended to improve the problem situation (as perceived by those taking the action) (Checkland and Scholes, 1990a:4). Thus, SSM involves the perception (and interpretation) of a real world problem situation which yields choices of relevant systems of purposeful activity. These conceptualizations are compared to the (perceived) problem situation, leading to debate about purposeful action to improve the situation. This action changes the situation, the perception of which leads to the conceptualization of relevant systems of purposeful activity ... and so on. This basic system of learning is demonstrated in Figure 2.4.

SSM also deals with a specific kind of system, a human activity system. The concept of a human activity system involves a set of interrelated human activities "which combine together to achieve the purpose attributed to the whole. One way to visualize a human activity system is to see it as the expression of a level of order (or purpose) higher than that contained in its component parts" (Woodburn, 1991:30). Thus, a house as a dwelling place, viewed as a system, is not merely a physical structure with people or a family living and performing daily functions and having particular interactions. It has meaning attributed to it by actors or observers of the system – it is a home, (*i.e*., the whole is greater than the sum of the parts).

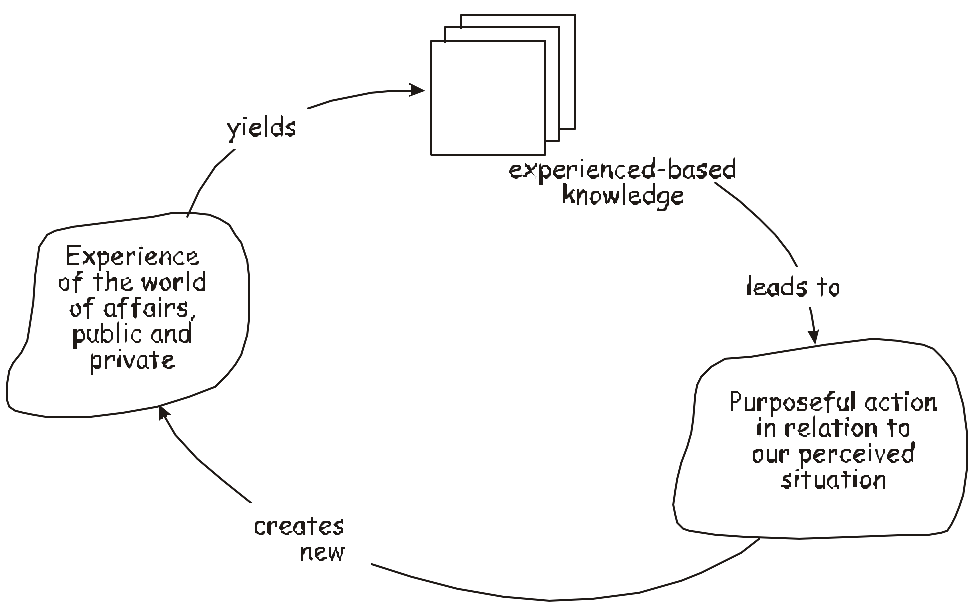

Figure 2.4: The experience-action cycle (Checkland and Scholes, 1990a:3).

The conventional SSM methodology developed by Checkland is described below. This methodology is presented because it is the most common form of the General Soft Systems Methodology. It is important to realize, however, that it is only one way to organize the learning cycle and that adaptation of the methodology may result from the learning experience of applying it, and that backtracking and iteration within the general methodology are a part of the learning process.

Figure 2.5 illustrates Checkland's general soft systems methodology. The basic methodology consists of seven stages; the problem situation unstructured, the problem situation expressed, root definitions of relevant systems, construction of conceptual models, comparison of conceptual models with the problem situation, debate about feasible and desirable change, and action to improve the problem situation. Checkland's seven stages to SSM can be condensed into three general phases. Woodburn (1991:29-30) presents these as:

(a) Building a "rich picture" of the problem situation (stages 1 and 2),
(b) Developing models of relevant human activity systems (stages 3 and 4), and
(c) Using those models to stimulate thinking about organisational change (stages 5, 6 and 7).

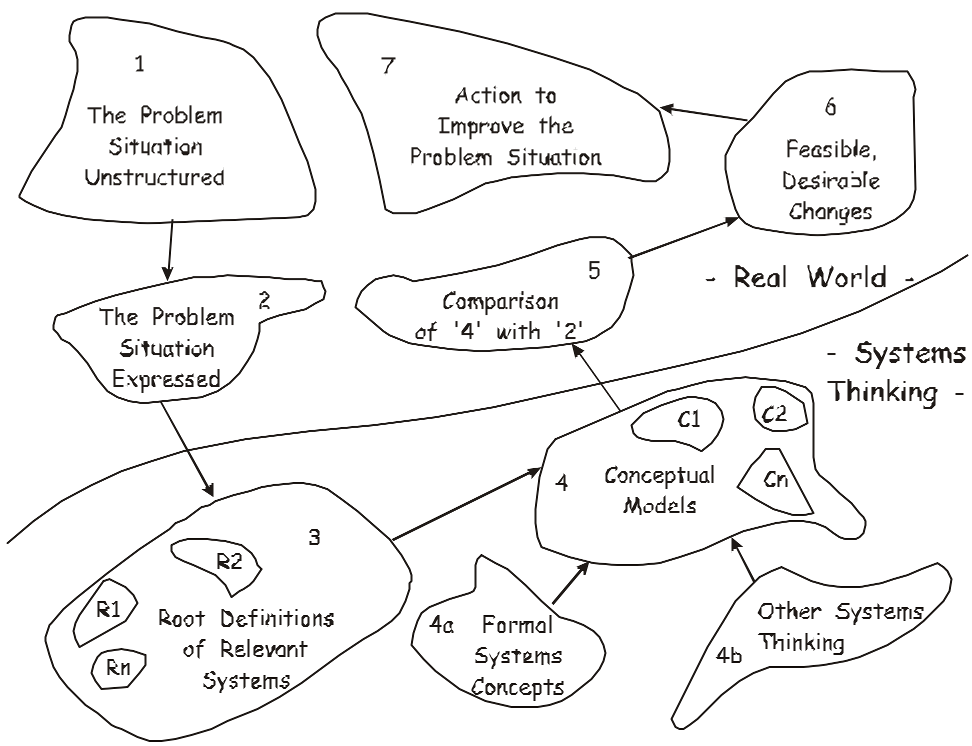

Figure 2.5: The original 7-stage Soft Systems Methodology (Checkland, 1981).

1. The Problem Situation Unstructured

The unstructured problem situation stage deals with the identification of a problem situation as it exists in the real world. This requires that an observer of or actor in the real situation perceives it as problematic. Thus, the identification of a 'problem' situation is always subjective. Once a problem situation is identified, it may be expressed.

2. The Problem Situation Expressed

At this stage a 'Rich Picture' of the problem situation is built. The 'Rich Picture' should be as neutral as possible while recognising the perspectives of various actors. This will lead to the development of non-neutral root definitions and conceptual models of relevant systems, (that is definitions and models base on explicitly recognized perspectives or world views), in the next phase of the methodology.

Expression of the problem situation involves identification, definition and measurement of various actors, components, interactions and relationships within the system. At this point, processes (who is doing what...) structures (within what organizational framework...) and climate (under what cultural norms, values...) may be identified (Woodburn, 1991:29). This is, thus, an analysis phase without necessarily employing systems thinking and concepts. In fact, analysis should not be in systems terms unless the problem situation is relatively unstructured (as there is a danger of becoming misled into identifying organizational groupings) (Checkland, 1976:60).

Rather, analysis needs to be addressed in terms designed to answer the question of "what?" (as opposed to "how") (Checkland, 1976:60). For example, the problem situation will be "turbulent" but elements of structure and process still may be identified. Structural elements are those which are relatively static. They act as a framework within which processes exist. Elements of process, on the other hand are dynamic. Examination of structure may, for example, be in terms of physical layout, hierarchy, reporting structure, patterns of communication (formal and informal), while examination of process may elucidate organizational contexts and basic activities such as planning to do something, doing it, monitoring how well it is done, and external effects, as well as taking action to correct deviations from the plan process (Checkland, 1976:60-61). Diagrams and pictures illustrating the situation are useful at this stage.

One must at some point move from analysis of the situation to the building of conceptual models. There is no rule for knowing when to stop the analysis, but Checkland (1976:61) notes that the analysis should be sufficient when one can answer at least the following questions:

1. What resources are deployed...
   ...in what operational context?
   ...under what planning procedures?
   ...within what structure?
   ...in what environments and wider systems?
   ...by whom?

2. How well is resource deployment monitored and controlled?

In general, the analysis is complete when it is possible to formulate a root definition (as described below). That is, when the function of the analysis phase "to display the situation so that a range of possible and, hopefully, relevant choices can be revealed" has been fulfilled (Checkland in Flood and Carson, 1993:110).

3. Root Definitions of Relevant Systems

At this point, the soft systems practitioner leaves the realm of thinking in real world terms and begins using systems thinking to construct models of relevant human activity systems. The purposefulness of each relevant human activity system may be expressed in a 'root definition' which is a "core description of purposeful activity taken from a specific point of view" (Flood and Carson, 1993:111). A root definition is "a condensed representation of the system(s) in its most fundamental form" and aims to capture insight into the situation (Checkland, 1976:62)

One technique for constructing well-formulated root definitions is to write a statement which reflects the aspects of the mnemonic CATWOE (Checkland, 1979:42). The components of this mnemonic are detailed below:

C	Customer	Who would be victims or beneficiaries of this system?
A	Actor	Who would perform the activities?
T	Transformation	What input is transformed into what output?
W	*Weltanschauung*	What view of the world makes this system meaningful?
O	Owner	Who could abolish this system?
E	Environmental Constraints	What in its environment does this system take as given?

The ‘Customer,’ ‘Actor,’ ‘Owner’ and ‘Environmental Constraints’ components of the CATWOE mnemonic are self-explanatory and will not be expanded upon here. The remaining components, (*i.e*., ‘Transformation’ and ‘*Weltanschauung*’) deserve some illumination. *Weltanschauung* is a German word meaning ‘world view’ and may be translated in this context to mean "what view of the world makes the situation meaningful?" (Flood and Carson, 1993:111). (Figure 2.6). *Weltanschauung* is linked to culture; it is a cultural viewpoint. Every actor or group of actors will have a different *Weltanschauung*. None is "better" than the other, and all are equally valid. A holistic approach, such as SSM, will take different Weltanschauungen into consideration.

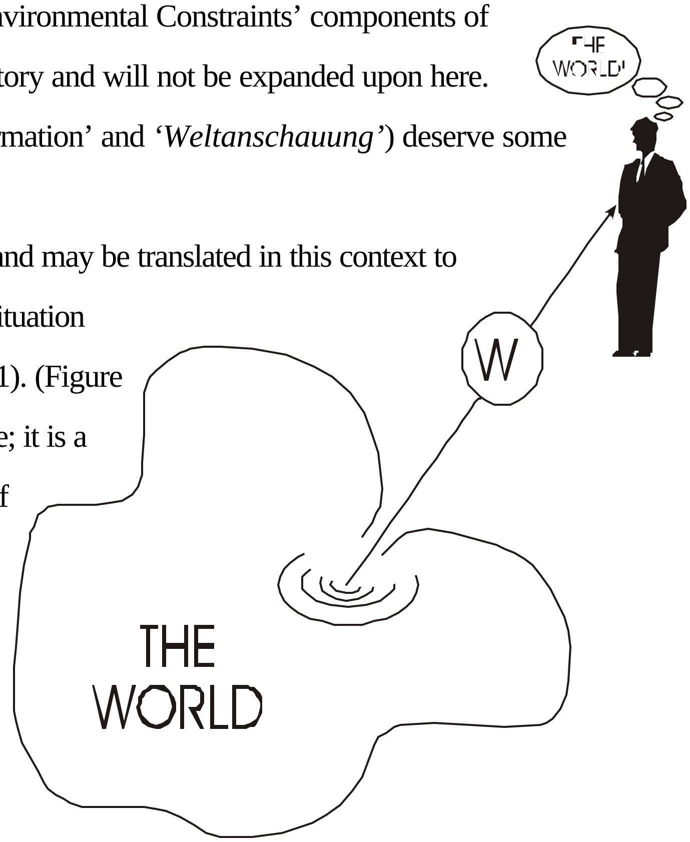

Figure 2.6: Weltanschauung – from CATWOE in Soft Systems Methodology. (Flood and Carson, 1988:120).

A transformation is also involved in a human activity system where the activity of the system transforms some input into an output. Generally, for a physical/abstract input a physical/abstract output is required. In constructing the root definition "it is important that the actual output is directly related to the input, so that the input is still there in some altered form" (Flood and Carson, 1993:112). It is useful to track both physical and abstract inputs. Also, consideration of how the transformation (T) could fail enables managers to think of measurements to monitor and control purposeful activity (Flood and Carson, 1993:113):

1. Measures of Effectiveness:	*e.g*., T is correct/wrong activity to be doing
2. Measures of Efficacy:	*e.g*., the way T is done does/does not work
3. Measures of Efficiency:	*e.g*., T is/is not done with minimum resources (such as time)

It is important to note that measures of performance imply a structure for root definitions (Checkland *et. al.*, 1990:33). That is, statements of root definitions may be cast in the form:

either: do X in order to achieve Z

or: do X by Y in order to achieve Z

There can never be a demonstrably correct root definition because such a definition represents only one particular interpretation (*Weltanschauung*) of a real world situation. There may, however, be a range of possibilities of root definitions from glib and shallow to full of insight (Checkland, 1976:63). The root definition needs to be penetrating, derived from the richness of the analysis and "revealing to those involved in the day-to-day workings of the system concerned" (Checkland, 1976:63). Even an insightful root definition is only one possible interpretation of the purposefulness of the human activity system. It is, therefore, usually rewarding to explore the implications of several root definitions, (*e.g.,* from the perspective of what a participant wants a system to be as well as what an outside observer takes it to be) (Checkland, 1976:63).

4. Conceptual Models

Conceptualization uses systems thinking formally and involves a conscious break from the analysis stage (marked by the root definition). It is "the process of building conceptual models relevant to the problem situation but in a mood of detachment from it, something which can be compared, formally and specifically with the picture built up in the analysis phase" (Checkland, 1976:64). Conceptual models consist of "what the system *must do* in order *to be* the system named in the root definition" (Flood and Carson, 1993:114). A conceptual model here *is not* a representation of the "ideal" system or a representation of what "ought to be" in the real situation. It is a descriptive rather than a prescriptive model.

Checkland (1976:64) notes two main problems with which the researcher or manager is confronted at this stage:

1. finding a way to do the conceptualization, and

2. finding a way to validate the conceptual model which is the outcome.

It was discovered early in the development of soft systems methodology that, in conceptualizing human activity systems, it is useful to link a set of verbs, in the correct sequence, which identify the minimum activities necessary to the human activity system described in the root definition (Checkland, 1976:64). Verbs (or short action-statements) are selected as elements and these verbs/elements are ordered logically, reflecting sequences of activity in the system. These activities are linked by arrows, in a diagram indicating that an activity is 'logically dependent upon' or 'contingent upon' another activity. If an activity yields an output which is a significant input to another activity, then the latter is contingent, or dependent, upon the former (Checkland and Scholes, 1990b:42). Flows through the system which are absolutely essential and are reflected in the root definition may also be illustrated at this primary level of conceptualization.

In the early development of SSM, validation of the conceptualization was undertaken by comparing the conceptualized system with a formal model of a human activity system. As the methodology progressed, however, there was a realization that human activity systems are *abstract conceptualizations* which reflect a particular perception of the real situation and that it is impossible to represent the real world without involving subjective interpretation. Thus, it is inappropriate to attempt to validate these models. There is no such thing as a 'valid' or 'invalid' model, only models which are technically defensible or indefensible (Checkland and Scholes, 1990b:43; also see von Bülow, 1989:39-40).

5. Using Conceptual Models to Stimulate Thinking About Organisational Change

Stages 5, 6, and 7 are here discussed together because of the difficulty of generalizing about these stages of the process. In this phase, a comparison of the conceptual models to each other and to the 'rich picture' built during the analysis stage is intended to generate debate for desirable and feasible change. This comparison may come about in various ways. For example, Checkland and Scholes (1990a:43) noted that informal discussion, formal questioning, scenario writing based on operating models and attempting to model the real world into the structure provided by the conceptual models are all ways of generating debate. The most common practice, formal questioning, may proceed, for example, by asking of each activity in the conceptual model; Does it exist in the real situation? How is it done? and, How is it judged? (Checkland and Scholes, 1990a:43).

Regardless of how the comparison with the real world is undertaken, the aim is not to improve the models but to "find an accommodation between different interests in the situation, an accommodation which can be argued to constitute an improvement of the initial problem situation" (Checkland and Scholes, 1990a:44).

Such a debate, and hopefully the accommodation of interests, leads to the identification of desirable and feasible change. Change may, for example, be desirable on a structural level or an attitudinal level. Ideas for change, however, must be assessed for cultural feasibility and systemic desirability in the context of particular world views (Woodburn, 1991:30). Once the changes are implemented, the procedure does not stop. Soft systems practitioners emphasize that the situation should be under continuous monitoring and control. As Checkland (1976:72) states;

> the whole bias of the methodology is against the notion of once-and-for-all finite tasks and in favour of on-going purposeful maintenance of relationships.

SSM and the Cooum River Environmental Management Research Program

Soft Systems Methodology has been interpreted by some as a prescriptive functional methodology describing a series of stages to be followed (and tools to be applied) to undertake a system study and inform decisions for action in a problematic situation (*e.g.,* Naughton, 1981). This view is representative of the early development of SSM (in the 1970s and early 1980s). This is *not* how SSM was employed in this study. Although a discussion of the early form of the methodology, as above, is heuristically useful, more recent development and applications of SSM have expanded this methodology to be less prescriptive and more flexible. Checkland and Scholes (1990a) describe this dichotomy in the understanding and application of SSM in terms of *mode 1* (prescriptive use of the 7-stage model) and *mode 2* (a more pliant use of SSM to make sense of a problem situation).

By 1994, Krehler (1994:1296) found that many of the applications of SSM being undertaken by the 'inside group' of researchers and postgraduate students at the University of Lancaster (the originating school of SSM) were being undertaken in mode 2. Krehler (1994:1298) stated that mode 2 is used for reflection about the problem situation. It is a means to make sense of the complexity of the situation and the intricate multi-level approach to it (*e.g.*, systemic, systematic, cultural, logical, inclusive of a variety of perspectives). Differences between the two modes as ideal types are outlined in Table 2.7. It is within mode 2 that SSM is employed here.

Table 2.7: Differences between mode 1 and mode 2 of SSM.

Mode 1	Mode 2
Using SSM to do a study	Doing work using SSM
Intervention	Interaction
Mentally starting from SSM	Mentally starting inside the flux[†], providing a coherent way of describing or making sense of it
Stage by stage; logic-driven stream and cultural stream of analysis	SSM as a thinking mode, used in internalized form takes SSM itself as a framework; meta-level[‡] use of SSM compared with mode 1

Source: Kreher (1994):1300 (after Checkland and Scholes, 1990a).
[†]That is, starting with a problematic situation and using SSM techniques and tools as appropriate to organize observation and understanding, and to generate debate about it. More emphasis is placed on understanding the situation, than on prescriptive application of the methodology.
[‡]Use of the approach as a set of guiding principles within which tools and techniques are not prescribed.

Additionally, the 7 stage model and the specific tools used within these stages should not be seen, within mode 2 of SSM, as essential to the methodology. Modifications of the methodology in applications began to appear in the 1980s. For example, Atkinson (1986) selected 5 distinct modified applications of the methodology in a discussion of the emerging plurality of SSM. He concluded that "the actual methodologies used in soft systems projects are contingent upon the *context*, the *use* and the *users* of that methodology (1986:31). More specifically Atkinson

(1986:31) states,

> ...that if [Checkland's] SSM is an 'ideal type' of soft systems methodology, a distillation from a number of such methodologies evolved within a number of projects that, in turn, forms a point of departure from which other methodologies materialise in the context of a particular project and the *Weltanschauungen* of the inquirers themselves.

Thus, this research draws upon SSM to inform the approach to the Cooum River problem situation along the lines of a mode 2 application of the approach. Rather than an application of the 7 stage model, SSM influences this research by guiding inquiry into the Cooum problem as a learning process. The overall framework is influenced by SSM in the description of a socio-ecological system *via* the expression of the problem situation in real-world terms, the use of explicit systems thinking to conceptualize and operate relevant systems, and the use of these to simulate debate about desirable and feasible change. In the working sessions of the workshops SSM contributes conceptual tools and practical techniques, such as the development of a 'Rich Picture' and CATWOE analysis, to explore the Cooum situation – a complex problem situation in which human activity is involved.

Conclusions

This chapter has presented and discussed a general background for the approach and methods employed in this research. In light of characteristics of the problem situation such as complexity, uncertainty, multiple and competing interests in the situation, and the severity of the problem, a sectoral or disciplinary approach to the problem is inappropriate. A holistic approach grounded in systems thinking and which attempts to incorporate participation by stakeholders in the situation has been constructed. It is thought that this approach is more appropriate.

In brief, the approach taken here can be described as an ecosystem approach to the problem of rehabilitation and management of the Cooum River and its environs in Chennai. This draws mainly upon adaptive environmental management to operationalize the ecosystem approach framework, especially with respect to the use of a series of workshops oriented toward problem definition, system identification, the generation of goals and objectives for management of the system, the development of alternative possible management interventions, and scenario analysis using a computer simulation model.

This work is also informed by Soft Systems Methodology. SSM provides conceptual and methodological tools to understand human activity in the problem situation. It provides a way of modelling human activity and guiding learning through the application of the methodology itself. In Chapter 3, the methods and results of the first workshop in the Cooum River Environmental Management Research Program are presented and discussed.