Chapter 7

INTEGRATED LAKE AND RESERVOIR MANAGEMENT

This chapter is intended for more senior-level reservoir managers and researchers dealing with the integration of water quality management concerns into overall environmental management planning. Some less scientific and technical aspects of these topics, along with some other topics, are discussed in Chapter 8. This chapter focuses on both the near future and the prospective development of reservoir management beyond the present dominant management style based on making independent decisions for each problem and the different aspects of each problem.

A working definition of integrated management is: *The management of a system of functions under single general control in a way that seeks to simultaneously maximize the combined benefits from the individual functions.* From this definition, it follows that the ultimate goal of integrated management is more effective resource management, which considers the simultaneous consideration of formerly separate resource development problems. Integrated management can be regarded as the coordinated control, direction or influence of all human activities in a defined environmental system to achieve and balance the broadest possible range of short- and long-term objectives (Mitchell, 1990; Cairns, 1991; Harper and Fergusson, 1995; Nienhuis et al., 1998; International Environment Technology Center, 1999).

There are many aspects of integrated management. These are divided in this chapter into several topics to enable a structured representation. The goals of integrated management are presented first, followed by suggestions for their practical realization. Several structural topics are then presented, followed by associated political and technical problems.

The importance of clearly setting the goals for management activities is stressed in Section 7.1. Different aspects of the practical realization of the goals stated cannot be underestimated (Section 7.2). Section 7.3 gives an overview of different levels and subjects of integration to be considered, some of which are detailed in the following sections. The subjects internal to water management in the stricter sense are the integration of water quality and water quantity, because water quality is strongly related to water quantity and conflicts can be expected between these two components (Section 7.4). Water uses and management from the perspective of specific uses can conflict with the available natural resources, and integration has to respect both in seeking a compromise solution (Section 7.5).

The subjects more external to the water environment are environment and technology, and partnerships between societal components. Environment technology needs to respect the limitations of the natural environment. Thus, both must find integrative, mutually-friendly ways to interact (Section 7.6). It is important that all community groups, not just managers, are aware of the associated problems, and cooperate on developing joint goals in partnership (Section 7.7). The particular instruments for achieving integrated management are of both a political and legal character (Section 7.8) and a technical nature (Section 7.9).

7.1 GOALS OF INTEGRATED MANAGEMENT

The goals of integrated water quality management are summarized in Table 7.1.

Decision makers and land managers must base their actions to protect aquatic resources on scientifically-sound policy to the maximum extent. It is expected that ecological research and management programs based on partnerships between science, policy and management will contribute to the solution of critical problems.

7.2 PRACTICAL REALIZATION OF INTEGRATED MANAGEMENT

As suggested by one experienced manager, the following integrated management guidelines should be followed (Tyson, 1994):

- Development of methodologies for integrated river basin management that include land-use management and water planning,
- Improvement of the volume and accuracy of national and global assessment of water resources,
- Development, promulgation and implementation of new, innovative approaches to water supply and sewage treatment,
- Development, promulgation and implementation of waste minimization and recovery techniques,
- Development of low-tech, low-cost treatment options,
- Increased application of use-related receiving water standards,

Table 7.1. Summary of the goals of integrated water quality management (modified from Lindstrom and Rebescu, 1994)

- Making better provision for the conservation, allocation, use and quality of water
- Protecting human health
- Promoting soil conservation and preventing damage by flood and erosion
- Providing and controlling multiple uses of water and drainage of land and integrating them with conservation programs
- Ensuring adequate account was taken of the needs of citizens and industry
- Enabling water-related recreation
- Protecting all aquatic life, fisheries and wildlife
- Preserving aesthetic and scenic values
- Protecting and recovering of vegetation
- Providing adequate monitoring and use of databases, particularly for early warning of difficulties
- Ensuring long-term protection of aquatic resources
- Achieving cost effectiveness

- Development and application of economic evaluation tools to both environmental costs and benefits,
- Informing, educating and training professionals and the public.

Howard et al. (1995; also see Rast and Holland, 1988; Rast et al., 1989) have provided direction on how to achieve these general guidelines, as follows:

- Identification of drainage basin wide issues, and short- and long-term development of suitable strategies for the identified issues.
- Prioritization of sub-catchments for action, and identification of areas where maximum benefit can be derived, using criteria such as fitness for use, development status and maintenance of integrity of potable water supply.
- Identification of specific areas and variables of concern, and giving priority to those areas containing the most significant sources of pollution and those that threaten the health of people and communities.
- Prioritizing pollution sources according to the magnitude of their contribution and the possibility of managing the problem, with specific site inspections and meetings to prioritize these sources (this process may be steered by a sub-catchment advisory committee).
- Screening the types of control options and proposing strategies, including control at the sources, control in the delivery process (e.g., wetlands, pollution traps), and control of the water users by provision of alternative water sources.
- Screening practices, and ranking and developing the action plan.
- Implementing actions, under the assumption that the organizations responsible for implementing the various components of the plan are already supportive of the proposals.
- Monitoring the results and revising the strategy as necessary; Water Quality Indices and Biotic Indices are useful management tools and useful tools for conveying this information in a "user-friendly" manner (the experience gained also may be used to revise the action plans and assist with formulation of new strategies).
- Auditing the action plans, since it is essential that implementation of actions is audited to ensure that they take place at the correct place and correct time within the agreed budgets.

7.3 LEVELS AND SUBJECTS OF INTEGRATION

As the name suggests, integration is the basic premise of the management approach discussed in this chapter. It is necessary to consider several elements of integration:

- Water systems have space scales. They range from global environment concerns, the country that decides about the economic conditions, laws and general rules of water quality management, through the drainage basin affecting the water quality of lakes and reservoirs, up to our main objects. Integration of these scales is necessary.
- Time scales of management actions span from the immediate hourly and daily regulation actions, through weekly and monthly decisions, up to decisions of an investment character and long-term sustainability planning. Because these decisions are interrelated, integration of time scales is the goal.

- Water quality is highly dependent on water quantity, and management of these two aspects must be integrated.
- Most lakes and reservoirs are now used simultaneously for multiple purposes (navigation, recreation, drinking water supply, hydroelectricity, etc.; see Chapter 2, Section 2.1). Integration of conflicting uses is not a simple task.
- Water represents only one natural resource, and water management presents only one branch of the economy. As an example, industry is dependent on water, and water is used and polluted by industry. Modern agriculture is the largest consumer of water, and agricultural pollution represents a major pollution source. Thus, decisions made in an integrated way help optimize these different aspects of the economy.
- Ecological aspects are increasingly becoming a focus of interest to citizens in developed countries. Thus, merging ecology, economy and technology is an urgent goal of integration.
- Partnerships with the local population, its political representatives, industry and other enterprises, and scientific institutions.
- Finally, from the more theoretical perspective, three basic levels of integration can be distinguished: Normative, strategic and operational. One level cannot be successfully solved without integration with the others.

A typical feature of management, but also of other activities and branches of economy, is their hierarchical character. Hierarchy distinguishes various levels, some overlying and some underlying. In decision-making, hierarchy means not only that the overlying levels coordinate several units at a lower level (called top-down effects). It also means that the lower-lying levels insert an effect (feedback) up the hierarchy (bottom-up effects). In a reservoir system, for example, the decreased water quality in one reservoir must be understood at the level of a reservoir system, as a signal to decrease the water supply from this reservoir and instead supply the population from another reservoir. Due to these two-sided effects, it is not important if we consider the lower or at the upper levels as the basic units. It will depend on our position in the hierarchy: If we are members of a water quality laboratory, the most important will be this level. Our activities will be driven by decisions made at a higher level, but our interests will mainly be in the feedback to the nearest, higher level: Only we can give hints for the need for the laboratory, for new methods to be used, for actions recognized as important from our analyzes. Any feedback can be positive or negative. Positive feedback between levels or elements of a hierarchy means that the development or increase of the element from which the feedback originates supports its further development or increase. In controlled systems, the negative feedback is very important, an example being a drinking water treatment plant, when the filling of a tank leads automatically to a decrease of its inflow.

Interactions in any hierarchy are mutual, and in democratically-organized systems the bottom-up effects are quite strong. The consequence of the interrelations is also a feature called multiple feedback, with the consequence that a change at one decision level may have some unexpected consequences at remote hierarchy levels. The borders of the levels are not impermeable, and the detailed definition of the levels depends on local physical, economic, social and political conditions. This is related to one characteristic of large systems; namely, their openness to energy, matter and information.

7.4 INTEGRATION OF WATER QUALITY AND WATER QUANTITY VARIABLES

The water quality of streams is highly dependent on flow rates, in both a positive and negative way. For diffuse (nonpoint) sources of water pollutants, water quality deteriorates with increasing water flows; for point sources, the opposite is true. In reality, however, there typically is a mixture of different types of pollutant sources, and the measured values of water quality parameters can exhibit a wide range, preventing the recognition of clear trends from either pollutant source.

The picture also is obscured by a hysteresis effect, which is caused by different types of dependency between water quantity (flow rate) and water quality, when the water level is rising at the beginning of a flood, and when the water level is falling after the onset of a flood (Fig. 7.1).

The existing data suggest there is a recent trend to an increasing occurrence of floods. A direct historical observation from Germany indicates a general linear rise in flood peak values, associated with increased imperviousness of the drainage basin area. An increasing flood trend also is evident on the basis of records of damage due to floods in the United States (Naiman et al., 1995). This trend has two underlying reasons:

- The extent of flooding is increasing,
- An increasing number of, and more costly, constructions are situated near rivers, so that the same intensity of floods can produce more damage.

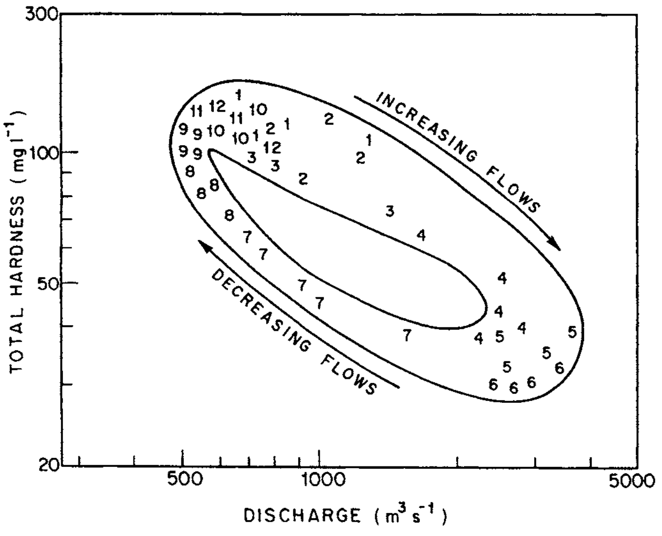

Fig. 7.1. Hysteresis effect of water quality variables during floods.

In regard to the increased density of population and more costly buildings, an increasing number of legislation and other measures are being taken in the United States to prevent construction in areas subject to flooding. Although no direct figures are available, American experts are suggesting that the increasing costs are at least partly compensated for by these measures. The extent of floods seems actually to have risen since 1990. The dominant cause is an improper management approach taken toward water budgets and water retention capacities of the involved areas. The water retention capacities are continuously decreasing due to many factors, including increasing desertification due to deforestation, increasing erosion leading to filling of water retention areas, increased evapotranspiration due to intensive agriculture, drying of wetlands, stream and river channelization, and excessive amelioration. The predominant flood protection measure is to build higher levees often constructed close to the riverbed, which further decreases the area's retention capacity, increasing the extent of downstream flooding. Floodplains capable of retaining large volumes of water, and which reduce water flow velocity, are being lost. Greater extents of impermeable surfaces are being created, preventing the percolation of water into the soil and increasing the surface runoff.

Because of the feedback between increasing channelization and imperviousness and increasing floods, an upward spiral is being created: More channelization produces greater flooding which, in turn, results in increased channelization.

To correct this self-perpetuating cycle, a change in human attitudes regarding flood protection is needed, directed toward maximizing the water retention capacity and perviousness of the surface areas, rather than simply increasing the degree of channelization and the height of levees.

One solution to this problem for cities is the construction of large underground reservoirs. This is being done, for example, in Brazil, whereby the water runoff from some cities is being controlled and the pollution input to rivers is being reduced.

In the above examples, the interests of water quality and water quantity are coherent—the decrease in floods is positive from both aspects. In other instances, however, the interests might be contrary, particularly for reservoir management. Flushing water of poor quality from reservoirs might be in the interest of those responsible for water quality management, while the retention of the water might be the preferred option from the perspective of water quantity. To reduce the reproduction of coarse fish in a reservoir or regulated lake, with the goal of improving water quality (see Section 4.3.1—*Biomanipulation*), a decrease in the water level might be required, whereas those responsible for water quantity might be very interested in retaining water entering the lake during the spring runoff period for later periods of summer drought. Selective water releases from the bottom of a reservoir can be used to rid a waterbody of anoxic hypolimnetic waters, but this also may cause a downstream water quality problem in the form of releasing cold water unsuitable for downstream recreation, as well as losing water storage capacity.

Erosion is an important variable to consider in regard to certain kinds of pollution, particularly phosphorus. Water pollution related to phosphorus is greatly increased as a result of erosion of soil particles onto which phosphorus is bound. This also causes the loss of productive agricultural soil.

Deforestation on a massive scale in certain regions not only creates major changes in water flows, but degrades water quality. It acts on water flows in two ways: It decreases low flows from a given region due to desiccation of the region, thereby decreasing the water retention capacity. It simultaneously increases the high flows, in that most of water falling on the land surface as precipitation flows immediately out of the region, not being retained by the vegetation. Floods increase and water quality deteriorates. Such changes are most dramatically observed in dry regions and less developed countries, where both water shortages and damages due to floods are greatly increasing. However, changes also can be severe even in hydrologically-balanced and well-developed regions, an example being the 1997 and 2002 floods in Central Europe. The water quality decreases during low flows because of a decreased dilution of effluents, and also during floods because of an increased load of suspended materials, the washing out of pollutants, a decay of inflowing organic materials, flooding drinking water sources and deteriorating groundwater.

7.5 INTEGRATION OF NATURAL RESOURCES AND VARIOUS WATER USES

Figure 7.2 suggests that water is only one basic resource for human activities and that, simultaneously, all resources comprise various aspects of management. The figure also illustrates that, in this partial matrix of the whole integration problem, two directions of integration can be considered: Integration of different functions or management aspects for each resource separately (Fig. 7.2A), and integration of individual functions across various resources (Fig. 7.2B).

The first approach has dominated until now; there are usually "barriers" of responsibilities between individual resource management sectors. Forestry and agriculture, which

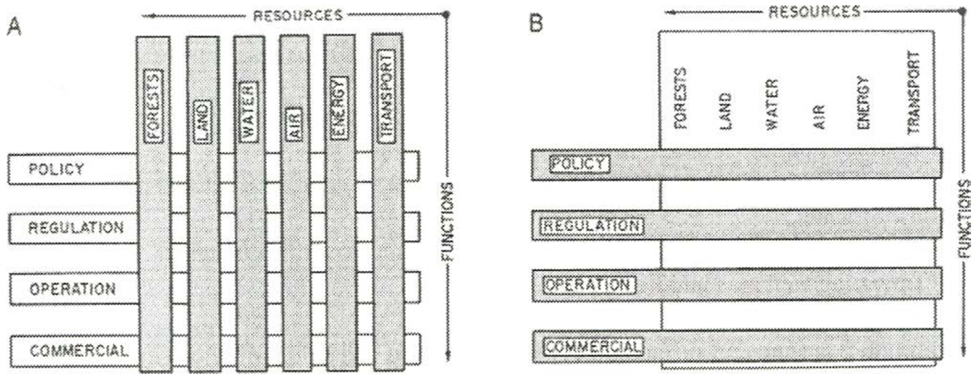

Fig. 7.2. Integrated management of environmental problems. A—Integration of functions for each resource separately. B—Integration of functions across different resources. The approach sub B seems more efficient, but is rarely realized (from Mitchell, 1990).

Table 7.2. Conflicting water uses

• Hydroelectricity Production ⟺ Drinking Water Supply
• Drinking Water Supply ⟺ Recreation
• Agricultural Irrigation ⟺ Industrial Supply
• Nuclear Power (Cooling) ⟺ Recreation

have activities tightly coupled to water quality and water quantity concerns, are the responsibility of separate ministries in many countries.

An example of the advantages of the across-resource approach was provided by the recent multimedia approach to radon pollution in the United States. During comparative evaluation of the alternatives of decreasing the exposure of the population to radon, it was recognized that if the U.S. Environmental Protection Agency substituted indoor air radon reductions for reductions of radon concentrations in drinking water, the agency could save 80% of the costs, or nearly five times as many lives (Greenwald, 1977).

There are many conflicting water uses (Table 7.2). Energy generation and industry have the highest water demand. Energy policy, however, often consider water availability only as a constraint, not being concerned about the consequences of the quantities of water evaporated for water quality (increased concentration of pollution due to less dilution, thermal pollution, use of polluting substances in the power plant, etc.).

The water quality consequence of decreased water usage and decreased hydraulic loads of wastewater treatment plants is that less capacity for purification is needed. If wastewater treatment capacity is constructed on the basis of predictions that do not consider savings and decreased water needs, the water released will be of better quality. However, money can be wasted which could otherwise be used for more appropriate water quality improvement measures.

Agriculture is considered one of the most conservative enterprises. Its effects on water resources are enormous, and can take many forms:

- Changing the water budget of an area via the different crops being cultivated,
- Creating conditions for extensive erosion,
- Constructing excessive under-draining systems that dry the area and accelerate the outflow of water,
- Applying unnecessary fertilizers subsequently washed out into streams,
- Converting wetlands into fields,
- Applying toxic chemicals for crop protection,
- Polluting ground and surface water by concentrated cultivation of domestic animals.

And water is not the only part of the environment that is affected. Air can be saturated with some greenhouse gases, and soils can become exhausted, compacted and polluted. Water quality managers must be patient in explaining the consequences of such agricultural practices, which will ultimately damage the farmers themselves.

7.6 MERGING ENVIRONMENT AND TECHNOLOGY

As the population density increases, our environment is rapidly deteriorating, with increasing Gross National Products leading to increased production of goods and increasing consumption. The relationships between the degree of population density and the Gross National Product are well documented for a number of compounds. They are clearly evident if one visits some of the most populated regions, for example, and sees not only the heavily-deteriorated environment, but also its consequences for the state of the health and the psychological state of the population.

The science that deals with the interrelations of the nonliving and living (biotic) parts of the environment is ecology. Nowadays we often use the term ecology in a much broader sense than for a scientific discipline alone—we speak of ecology as meaning any degree of care about the environment, sometimes even in a pejorative sense (e.g., care regarding some unimportant, or even dangerous organisms). The human environment, however, is the subject of our interest. Those "unimportant" animals are only a part of this environment in regard to its general state. They are not only important for their beauty and function in nature (mostly not well known), but particularly because they reflect the state of the human environment. If everything around us gets eradicated, and we are the part of this environment, when will the time come that we also start to become eradicated?

In most cases, technology is the main way we produce food, clothes and the many goods that we need. And humans seem to need more and more, meaning more clothing, more cars, more traveling, etc. Unfortunately, the way we use technology is the main cause for global environmental deterioration. During every phase of the technological process, byproducts with negative consequences are created. Pollutants are emitted to the air and water, reaching in this way also to the soil. Wastes are accumulating either immediately during the technological production process, when products are transported and sold to consumers, after they have been unpacked, and after the products lose their functionality.

Merging of these two seemingly-conflicting perspectives is not easy. Although we seek measures for a clean environment, we also perform activities that inevitably lead to pollution (e.g., we need industry and agriculture to feed and clothe ourselves). Requests for recreation are often conflicting: On the one hand, we desire to visit pleasant, quiet environments and, on the other hand, recreation often represents a destructive force to the environment.

Is there a way to cope with the opposing demands of the technology and the environment? In fact, merging of the two can be facilitated by means of ecotechnology (see Chapter 4). Ecotechnology provides us with an approach to decrease the damage due to the environment. We cannot stop creating pollution. It is as unavoidable because dissipation is one of the basic laws in nature; energy and other resource losses accompany every process. We respire and burn part of our food for our life processes, releasing the waste products into the environment in the form of heat, urine and feces. With the consumption of energy in the form of coal, gas or electricity, we convert part of it from high, useful quality to heat as a waste product. Highly-organized organic materials (e.g., the numerous plastic materials) are decomposing into often-toxic rubbish and wastes. These processes are inevitable.

What we can do is to minimize these losses by saving, by using less, by reusing, and by finding ways to produce less wastes. Nature is capable of digesting or otherwise neutralizing certain quantities of waste products, so we can try to maintain and even increase this capacity. Indeed, we can learn from nature in many ways: There are many natural products from the plant and animal kingdom we do know and use, and knowledge of the laws of natural ecosystems enables us to imitate the efficient ways that nature can work. Nature is the only system from which we can learn how to cope with the complexity of interrelations, how to deal with very complex natural systems, and how to optimize the existence of the human race. We can learn intensively from nature. Many new branches of science and technology are created (e.g., cybernetics and its many derivatives, increasing the speed of ships and airplanes, building resistant constructions, producing new medicines). This is *ecotechnology* in the broader sense, directed to these aims; that is, to a merging of the environment with progressive technology.

7.7 PARTNERSHIP

What is meant by partnership? The overriding goal here is to join the relevant stakeholders, and harmonize as much as possible the various interests in a drainage basin with respect to its water resources. Based primarily on the program implemented in the Lobo/Broa Reservoir drainage basin in Brazil, the following main roles must be developed to facilitate a long-term program in river basin management (Table 7.3). Building an appropriate integration among users of river basin water resources is fundamental for water quality management. A first component of this partnership is *university and/or local research institutes*. The research system provides the basic information, organizes and improves the data bank, proposes specific monitoring actions, and represents the continuity factor allowing for identification of problems and long-term planning and management.

Private sector. The private sector also has a key role in this partnership. It can develop joint ventures and consortia with universities regarding the implementation of new and innovative environmental technologies. It can contribute with funding of specific projects for which incentives by the public sector can be promoted. A recent World Bank study on Environmentally Sustainable Development showed that clean water and sanitation facilities for approximately two billion people are urgently needed (World Bank, 1993). Sustainability criteria for water resource systems have been discussed in detail by a working group of the International Hydrological Program of UNESCO, with contributions from the Task Committee of the Division of Water Resource Planning and Management of the American Society of Civil Engineers, with the results being presented by Loucks and Gladwell.

Public and private sectors should be actively engaged in providing "environmental jobs" for the local community (e.g., reforestation, lake shore cleaning, waste recycling). The "water industry" can proportionate several employment opportunities for the local community.

Table 7.3. Main partnership roles for river basin management (from Tundisi and Straškraba, 1995)

University:
- Theoretical background and data bank
- Economic evaluation of ecosystem and sub-system functions and processes
- Monitoring perspectives, technological and scientific development
- Alternatives for management and ecotechnological approaches
- Evaluation of costs of environmental disruption and costs to repair damage

Public sector:
- Application and decisions on new ideas and methods for environmental planning and management
- Legal actions (ombudsman for environment)
- Consortia of municipalities and integrated management
- Integration with the private sector

Private sector:
- Technological applications and joint ventures with universities and the public sector
- Financing of environmental projects
- Participation in wastewater treatment projects, recovery of ecosystems, watershed protection
- Consulting (environmental engineering, applications of ecotechnology)
- The "water industry"

Community participation:
- Re-direction of development with a realistic view of the problem and the use of resources
- Decodifier of scientific information (e.g., school teachers training programs)
- Participating in the use and application of ecotechnology
- Participating in monitoring and environmental projects
- Initiating legal actions

Community participation. The confrontation between development and conservation is due partly to the excessive centralization of authority, and the attitude of governments toward the use of resources. The local community may have other designs and aspirations for the use of the water resources in a drainage basin. One of the greatest benefits of decentralization is the possibility to include the views of the community in the development of the river basin management strategies and in environmental planning. Thus, community participation has the important objective of critiquing, re-directing and offering alternatives to development plans. Without this participation, any regional development plan with an environmental background will fail, and the term "sustainable development" will only be rhetoric (Biswas, 1988). The effectiveness of the conservation, recovery and planning programs can be significantly increased with public participation. This includes not only the representatives in the public sector, but also direct participation by non-governmental organizations (NGOs) and conservation societies (Tundisi, 1986; Tundisi and Straškraba, 1995).

Development of partnerships in drainage basin management is a long term process that must progress on the basis of two basic assumptions:

- A systemic and articulated approach to the problem, with the drainage basin as the basic management unit (i.e., an ecosystem approach).
- A better quality of life, with sustainable development as the main goal.

The scientific community can take the lead in the process of integrated drainage basin water resource management. To do so, however, the scientific community will have to think and act strategically, which involves six key elements, as follows:

- Any strategy must be guided by a clear vision. In this case, the vision is one of people working together to achieve something that would be impossible to achieve by those same people working alone or in isolation. Intense communication must be part of this vision.
- It must be recognized that strategy describes activities that involve an extended time horizon, including the time it takes to carry out the activities and the time it takes for their impacts to become apparent.
- Although the consequences of pursuing a given strategy may not become apparent for a long time, their eventual impact can be significant.
- An effective strategy usually requires concentrating activity, efforts or attention on a narrow range of pursuits. Focusing on these chosen activities implicitly reduces the resources available for other activities. One of the key areas upon which to concentrate is that of overcoming barriers to communication. This is an area in which chief executives should be most active. These barriers manifest themselves in many forms (e.g., psychological, organizational, technical, disciplinary).
- Most strategies require that a series of certain types of decisions be made over time. These decisions must follow a consistent pattern and be supportive of one another.
- A strategy embraces a wide spectrum of activities, ranging from resource allocation processes to day-to-day operations. The need for consistency over time in these activities also requires that all levels of an organization act to reinforce the strategy. The key is adequate communication (e.g., see World Lake Vision Committe, 2003).

Integration of scientific reasoning into management decisions is made easier by the application of mathematical models, particularly Decision Support Systems (DSS) (see Chapter 5). DDS represent tools that facilitate the making of decisions on the basis of the summarized scientific knowledge. The name stresses that DSS are devoted to *support* decisions, rather than providing them; they provide the manager with the analysis of the problem, using the expert and scientific knowledge condensed into the DSS. For decisions that involve simultaneously considering multiple criteria, the use of multi-criterion optimization is necessary (e.g., Bogardi and Bardossy, 1987).

7.8 POLITICAL AND LEGAL ISSUES

Lake and reservoirs are complex ecosystems, and their effective management implies the involvement of many organizations, institutions, NGOs and individual citizens. Thus, an effective integrated lake and reservoir management strategy requires that these entities have a wide understanding of the problems and their implications for society. It does not imply that the various groups involved in the preservation of lakes and reservoirs agree on all details in the management plans—on the contrary, it is always very fruitful that a wide spectrum of viewpoints are represented in the discussion phase, before a final strategy is selected. However, it is of great importance that all parties accept the dimensions of the problem in space and time, which implies that the entire drainage basin area should be considered, and both the short- and long-term effects discussed.

The complex nature of lake and reservoir management problems often requires a complex set of solutions. There is usually not a simple solution to these problems, but rather a spectrum of cooperative solutions, which can only be found when the spatial dimensions of the problems are accepted. Thus, a wide spectrum of the techniques selected from those presented in Chapter 4, and applied to the entire drainage basin area of a lake or reservoir, will in practice encompass the optimum solution.

Proper management plans that focus on long-term preservation and protection are the most cost-efficient solutions to lake and reservoir environmental problems, since pollution abatement is expensive and many pollutants can accumulate in these aquatic ecosystems. Unfortunately, politicians often have an effective time horizon of only four to six years, because they are typically elected only for terms of this length. In contrast, the perspective of effective lake and reservoir management must be viewed within time intervals that can extend to several decades or more. What is required, therefore, is a profound understanding by politicians and communities of the need to accept a long-term preservation strategy as an alternative to a short term strategy (i.e., just solve the most pressing problems now). The latter strategy is often cheaper on a short-term basis, but ultimately expensive over the long term, and may result in additional obstacles to implementing the best solution.

A common understanding of the core problems, and their significance for society among the politicians and all citizens in a community, is the appropriate basis for making proper environmental decisions. An approach used in Scandinavia, whereby an ombudsman for the environment is nominated, may be a proper idea to adopt in many cases, since it would work to ensure that politicians make decisions on behalf of citizens, rather than on behalf of economic special interests.

Cooperation and understanding are catalysts for the right decisions. However, they also need to work within the framework of clear, detailed and widely-based environmental legislation. Although detailed recommendations on how future environmental legislation should look for developing countries is beyond the scope of this document, a few considerations are discussed in this section, as follows:

- Environmental legislation must consider the specific environment toward which it is aimed. This implies that legislators in developing countries should not imitate the environmental legislation from industrialized countries, because they have a very different environment in the broadest sense of the word. Every country has its own local conditions, which should be considered in the environmental legislation. A minimum standard may be acceptable for all countries. In addition to the minimum requirements, however, such factors as the economic situation of the country, and the geographic, ecological and morphological conditions, should be considered in efforts to intensify the requirements.

- The technological and economic possibilities of the country should be considered in the legislation. Expensive environmental solutions are not necessarily the right answer, for example, for a country for which lower labor costs and more available space suggest the use of soft technology. Many of the techniques mentioned in Chapter 4 offer feasible soft-technological solutions, which could and should be reflected in the environmental legislation.
- Ecological principles should be considered in the legislation, particularly if a wide use of soft technology is foreseen. The legislation that focuses on planning and utilization of natural resources urgently needs ecological considerations to be incorporated, in order to ensure preservation of the environment. Legislation about a buffer zone along rivers and at the shorelines of lakes is an illustrative example of the use of ecological principles in environmental legislation. Legislation on the utilization of recycling principles, and on landscape planning, are other examples in which ecological principles should play an important role.
- The application of green taxes and green auditing also merit mention, since they also should be reflected in environmental legislation. The applied practice of assessing fines for violation of environmental rules/legislation may also play a major role.

Environmental problems are, of course, also complex for politicians. Thus, they should not seek partial solutions, since they are not feasible in such conditions, but rather should utilize the entire spectrum of political instruments to achieve a proper solution to any environmental problem. It implies they should draw properly on the environmental legislation, using it on behalf of the environment, applying green taxes where appropriate, encouraging citizen involvement, and give open information on present and future environmental problems and on the plans for their solution. This is not an easy task. Thus, citizens, the environmental ombudsman and the NGOs of the region must prey relentlessly on the conscience of politicians. The "ping–pong" exchange between politicians and environmentalists is an important democratic process to ensure a proper long-term environmental management, but also requires an open discussion from both sides and a strong involvement on the part of citizens.

The political aspects may be considered an attempt to find an optimal solution or trade-off on the basis of political means. It is an enormous challenge to politicians, particularly when the long-term aspects, as they should be, are included in the considerations. The concept of sustainable development is an attempt to define political goals with respect to all the aspects, and with respect to long-term effects. It is, however, not an easy task to find sustainable solutions to our current problems in concrete situations. With the present population growth in many developing countries, it often is impossible to find solutions for the sustainable development of a region without inclusion of family planning, for example, as a possible tool in environmental management. The need for water supply and safe drinking water, and the impacts on the environment, increases with population density. If the available water resources are not sufficient for the growing population, the only feasible solution is to control the population growth. This is often a very hot political issue in developing countries, but there appears to be no alternative in many of the most threatened regions of the world.

7.9 TECHNICAL ISSUES

It has been emphasized many times throughout this book that it is necessary to utilize the entire spectrum of techniques and other solution possibilities, which may be grouped in five classes:

- Environmental technology or "end-of-pipe" technology,
- Ecotechnology,
- Cleaner technology,
- Environmental legislation,
- Proper long-term environmental planning.

The selection of the right combination of methods and approaches also was previously touched upon in this book. A wide spectrum of environmental models (see Chapter 5) are presently available as powerful instruments in environmental planning. The models answer such questions as: Which reduction of the environmental impact on a particular ecosystem is needed to achieve a given environmental quality within a given period of time? The answer is found by application of models to assess the environmental consequences of various environmental strategies, or else the model is used to examine a certain spectrum of scenarios. With the present state-of-the-art of ecological modelling, the inclusion of political, economic and social aspects into models is in its infancy. Thus, it is also necessary to make a political, economic and a social evaluation of the various solutions found with the models.

The technical costs of a given environmental solution are usually not difficult to estimate. For all the techniques mentioned in Chapter 4, the general basis for assessment of costs has been discussed. It is significantly more difficult to assess what society gains with a cleaner lake, higher biodiversity, more bird life, or better water quality. This problem also is discussed further in the next section. It should be mentioned here, however, that ecological–economic models have been developed. In this context, it is relatively easy to assess the direct costs of various solutions and economic consequences, for example, of the quality of water used for drinking water, or the impacts of the water quality on the fishery. It is considerably more difficult to assess the value of a beautiful natural environment. The recreational value of lake water with a high transparency, for example, can be estimated on the basis of different costs of lake shoreline properties on a clean versus pollution lake. It is understandable that very few models have been able to consider the value of the environment. If the very rapid development of models which we have experienced during the last two decades is taken into account, and the emergence of what is called ecological economy, it will likely be possible within the next decade to more widely use ecological–economic models to assess the best environmental strategy, which would include considerations of the value of a beautiful environment.

The inclusion of political and social aspects in modelling exercises is presently almost impossible. Social models are generally much less developed than ecological and economic models (compare with Chapter 5). It does not imply that the social aspects of an environmental strategy cannot be considered, but only that the social consequences have to be considered by other methods in efforts to find a trade-off between the two aspects in an environmental plan. Usually it is not too difficult, since the environmental and social benefits often work hand in hand, although the optimal conditions for both aspects considered simultaneously is not necessary the optimum solution for the two aspects considered separately. More often, there are conflicts between the economic and social benefits.

Economic development without considerations of the environmental and social implications often has a negative effect on the environmental and social conditions in a given region. Elimination of the negative effects at a later stage may cost more than the economic advantages gained in the first place. Thus, it is crucial to attempt to optimize the economic, social and environmental aspects by the use of the recommendations given in Chapter 10 and throughout this book. Lacking a proper system analytical tool to find the optimal solution or trade-off between the various aspects and problems, proper planning and a good management strategy presently seem to offer the only feasible solution thus far. In this context, the inclusion of social aspects is expected to play a more important role in the development of management strategies in the future.

Attempts have been made to formulate landmarks to be used in a blueprint directed toward sustainable development (e.g., see László et al., 1988; Rast, 2003). The concepts of ecosystem health and ecological indicators represent such attempts, although much wider experience in the use of the concepts in practical environmental management is needed before final recommendations can be given. For example, the extent to which these concepts consider the long term effects and the social-environmental aspects is still unclear.

Environmental managers want to include more ecological and social considerations in their management strategies. Thus, they have asked the following question to ecologists: How can we measure and express that an ecosystem is ecologically sound, and that it has a positive effect on the health of the population? The doctor of medicine attempts to express the health condition of his patient by the use of such indicators as blood pressure, temperature, kidney function, etc. In the same manner, the environmental manager is searching for ecological indicators that can assess the ecosystem health and its impact on the health of the population. Because an ecosystem is a very complex system, it is not surprising that it is not easy to find good ecological indicators to give the appropriate information on ecosystem health, although many ecologists and system ecologists have worked, and are still working, on this problem.

Costanza (1992) and Costanza et al. (1992) summarize the concept of ecosystem health by

- Homeostasis,
- Absence of disease,
- Diversity or complexity,
- Stability or resilience,
- Vigor or scope for growth,
- Balance between system components.

He emphasizes that it is necessary to consider all, or at least most, of the definitions simultaneously. Consequently, he proposes an overall system health index (HI) as:

$$HI = V * O * R,$$

where: V = system vigor,
O = system organization index, and
R = resilience index.

With this proposal, Costanza probably touches on the most crucial ecosystem properties for assessing ecosystem health.

The concepts of exergy and ecological buffer capacities have been proposed as ecological indicators (Jørgensen, 1995a, 1995b). It can be shown that these two concepts combine the above given definitions. However, several other indicators also have recently been proposed in the environmental literature.

The current collection of lake data by the International Lake Environment Committee (ILEC) and the Global Environmental Monitoring System (GEMS) is very important in this context, since an accurate assessment of ecosystem health can only be made on basis of real data. Moreover, a global overview of ecosystem health requires a global monitoring system. The regional efforts in this direction are also important. The main objectives of the European Environmental Agency in Copenhagen, for example, is to provide information on the environmental status in various parts of the European Union.

More experience is urgently needed before the use of ecosystem health and ecological indicators can be generally recommended. Thus, it would be inappropriate to include them as defining elements in the development of management strategies. The results obtained with the use of these concepts, however, look very promising. It may be important to follow the development of these approaches carefully, and incorporate them in development of management strategies in the future when the concepts have more widely demonstrated their applicability. The relationships between ecosystem health in the sense presented above, and the health and the social conditions of the population, have not yet been subjects of research on a sufficient scale. Prevention, rather than cure, however, is widely discussed also in the pathological literature. Environmental management will be able to play a major role, particularly if more research support will be allocated to study the interrelationships between environment, human health, and social problems.

Based on the above discussions, and an optimistic view (which may or may not be realistic), the following trends in environmental management are expected in the future:

- Consideration of the social problems and aspects related to the environmental management of lakes and reservoirs.
- Wider use of integrated models (i.e., models that consider more than one aspect of a problem). Economic–ecological models probably should be in wide use within a decade, while social–economic–ecological models may not be ready to be applied on a large scale within a time horizon of less than 20 years.
- More application of landmark concepts, such as ecosystem health and integrity, when these concepts have shown their applicability on a broader scale.
- A generally more integrated management that simultaneously considers ecosystem health, human health and the social conditions determined by the environment.
- A more open debate between politicians and citizens in their efforts to find proper solutions to environmental issues.

For developing countries, it is particularly recommended that these trends be followed, because they will provide additional opportunities for assessment of sound environmental management. To this end, developing countries also should be prepared to slaughter, if necessary, some "holy cows", a primary example being the introduction of family planning.

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