Preamble

This paper is addressed to ICOLD members and all others associated with dams. It is intended to enhance their awareness of the environmental issues of dam engineering by defining ICOLD's position on the subject.

ICOLD attaches great importance to the environmental and social aspects of dams and reservoirs, and wants them to be addressed with the same concern which has made the question of dam safety a predominant concept pervading all its work.

In addition to the three classical criteria of technical, economic and financial feasibility, dam projects have to satisfy a fourth and particularly stringent criterion, namely social and political acceptance. Today the decisive factor for such acceptance, ranking on a par with dam safety, is compatibility with the environment.

Thus, ICOLD will bring all its influence to bear on its members to encourage and assist them with regard to environment-conscious planning and construction, adequate environmental impact assessments, and the implementation of mitigating measures. However, ICOLD cannot enforce this policy as an organization, nor can it criticize or comment on individual projects in its member countries or others, much as it disapproves ill-advised projects which can only jeopardize the generally good reputation of modern dam engineering. Instead, ICOLD will focus on positive examples to show what good dam engineering, is by presenting selected case studies which cover a wide range of projects and project settings, and which deal in depth with their specific problems and the successful strategies adopted to solve them. When such successful projects have been given due prominence, no planner will be able to avoid having his own projects measured by them and judged accordingly.

1. What's it all about?

All dams and reservoirs as many other human activities, become a part of their environment which they influence and transform to a degree and within a range that vary from project to project. Frequently seeming to be in opposition, but not necessarily irreconcilable, dams and their environment interrelate with a degree of complexity that makes the task of the dam engineer particularly difficult. The solution must be to find the golden mean by striking a balance between divergent, and sometimes contradictory goals.

We need dams and the many benefits which their reservoirs offer all over the world, by storing water in times of surplus and dispensing it in times of scarcity. Dams prevent or mitigate devastating floods and catastrophic droughts. They adjust natural runoff with its seasonal variations and climatic irregularities to meet the pattern of demand for irrigated agriculture, power generation, domestic and industrial supply and navigation. They provide recreation, attract tourism, promote aquaculture and fisheries, and can enhance environmental conditions. Thus, dams and reservoirs have become an integral part of our engineered infrastructure, of our man-made basis of survival. Still more dams will be needed in the future for the adequate management of the world's limited, unevenly distributed and in many places acutely scarce water resources (see also **Annex A**). But more and more we also recognize an urgent need to protect and conserve our natural environment as the endangered basis of all life. And there is also a social side to the comprehensive conception of environment: the people, their land and settlements, their economy and traditions. The impact of dams and reservoirs on this environment is inevitable and undeniable; land is flooded, people are resettled, the continuity of aquatic life along a river is interrupted, and its runoff modified and often reduced by diversions.

Thus, dam engineers find themselves confronted with the basic problems inherent in the transformation of the natural world into a human environment. In our never ending quest to provide a growing number of people with a better life, the need to develop natural resources, including water, means that the natural environment cannot be preserved completely unchanged. But great care must be taken to protect the environment from all avoidable harm or interference. We must cooperate conscientiously with nature's inherent fragility as well as its dynamism without ever overtaxing its powers of regeneration, its ability to adapt to a new but ecologically equivalent equilibrium. And we must ensure that the people directly affected by a dam project are better off than before.

The contribution of dam engineers to the development of water resources is based on proven technology, as our profession's track record of over 39 000 [According to the criteria of the ICOLD World Register, dams higher than 15 m (or higher than 10 m but with more than 500 m crest length, or more than 1 million m 3 storage capacity, or more than 2 000 m 3 /s spilling capacity)] large dams clearly shows. This technology continues to benefit from ongoing refinement and a steady growth of knowledge and experience, in particular with regard to its social and environmental consequences. Guided by the concept of sustainable development, ICOLD will make every effort to make the contribution expected of a leading professional organization to the further improvement of dam engineering. This contribution will reflect increased environmental sensitivity as well as the traditional technical excellence.

2. Sustainable Development of Water Resources

Increased awareness of the natural environment and its endangered situation is one of the most important developments of the late twentieth century. The United Nations "Declaration on the Environment" and the Club of Rome's message on the "Limits to Growth" left their mark on our thinking in 1972, followed in 1987 by immediate and worldwide agreement on the convincing concept of "sustainable development" as propagated in the Brundtland Report

of the United Nations on "Our Common Future". In 1992, the United Nations Conference on Environment and Development (UNCED) put the issue into a global perspective and drew up a comprehensive action program in Agenda 21.

Like many other international organizations dedicated to the engineering of water resources development (see **Annex B**), especially leading financing institutions such as the World Bank, ICOLD fully supports these concepts and principles and adheres to them as basic guidelines for its own work. Attention to the social and environmental aspects of dams and reservoirs must be a dominating concern pervading all our activities in the same way as the concern for safety. We now aim at balancing the need for the development of water resources with the conservation of the environment in a way which will not compromise future generations.

In search of this balance, ICOLD members should be guided by the following aspects of environmental policy:

a) Concern for the environment, including both natural conditions and social aspects, must be manifest from the first planning steps, throughout all phases of design and implementation, and during the entire operating life of a project.

Dam promoters must be aware of the fact that although dams are the most important means of making surface water available at the place and time of demand, there are also other, non-structural means of increasing water utilization which can be applied in addition to dams or as an alternative, such as the tapping and recharging of groundwater or desalination of seawater.

Furthermore, with resources increasingly limited or difficult of access, more thought must be given to demand-side management, to achieving better results with less water input by increasing the efficiency of water use in irrigated agriculture and industry, by reducing losses in supply systems, by the treatment and recycling of waste water, and by the conservation of water and energy.

Hence, during the initial stages of planning a dam project, the question should be studied whether alternative solutions exist that could possibly fulfil the various purposes of the dam project at lower long-term costs to society and the environment.

b) In the past it has been the hallmark of our very best engineers to see the natural environment as one of their responsibilities too, which is why many dams and reservoirs harmonize so well with their environment.

Today, however, the enormous increase in human knowledge, including that in the field of environmental science, means that a whole team of specialists is needed to access and utilize that knowledge for a water resources development project.

c) The larger the project, the greater the effects on the natural and social environment to be expected, and the wider the scope of the multidisciplinary, holistic studies which they require. Large-scale development demands integrated planning for an entire river basin before the implementation of the first individual project(s). Where river basins are part of more than one country, such planning presupposes international cooperation.

d) Projects must be judged everywhere and without exception by the state-of-the-art of the technologies involved and by current standards of environmental care. The scope for reducing any detrimental impacts on the environment through alternative solutions, project modifications in response to particular needs, or mitigating measures should be thoroughly investigated, evaluated and implemented.

A comprehensive Environmental Impact Assessment, since 1971 mandatory in a growing number of ICOLD member countries, ought to become standard procedure everywhere as part of project conceptualization, that is well before final design and the start of construction.

Countries still lacking in expertise or the legal framework and administrative structures should receive assistance from countries where the relevant legislation is more advanced and the necessary practical experience has been gained with regard to the extent of the investigations required, the methods and procedures to be employed, and the conclusions to be drawn from the results. Special attention should be paid to any effects on biodiversity or the habitat of rare or endangered species.

e) The decision on what is usually a very considerable investment for a dam project must be based on an unequivocally realistic economic analysis, especially in the case of a large project in a developing country which would tie down a major share of its financial resources for many years. Any tendency to overstate the benefits and understate the costs must be strictly avoided. This also requires taking the impacts on the natural and social environment into account. In spite of proposals put forward by international financing institutions and a growing literature on the subject, some such impacts are difficult to quantify or plainly defy expression in monetary terms. In such cases, they must be incorporated in the decision making process at a higher level of judgment than is implied by a merely numerical cost-benefit analysis, and the dam promoter should explain how such non-quantifiable impacts affect his decision.

An important item on the benefit side is the useful life of the reservoir. Hence, actually available live storage volume must be estimated according to reliable data on the transportation of solids according to realistic assumptions on

reservoir sedimentation processes and the effect of mitigating measures. Sedimentation control in the reservoir by sediment flushing, sluicing or dredging must be supported by erosion control in the watershed in order to prolong reservoir life as far into the future as possible.

Multipurpose benefits which do not produce revenues for financing the project must nevertheless be taken into account in assessment of a project or a comparison with alternatives. Such comparison includes the environmental advantages of hydropower over thermal generation.

f) Involuntary resettlement must be handled with special care, managerial skill and political concern based on comprehensive social research, and sound planning for implementation. The associated costs must be included in the comparative economic analyses of alternative projects, but should be managed independently to make sure that the affected population will be properly compensated. For the population involved, resettlement must result in a clear improvement of their living standard, because the people directly affected by a project should always be the first to benefit instead of suffering for the benefit of others [For that reason, under a law dating back to 1916, communities in Switzerland are entitled to considerable annual payments and quotas of free energy for granting the rights to hydropower development on their territory]. Special care must be given to vulnerable ethnic groups.

g) Even if there is no resettlement problem, the impact of water resources development projects on local people can be considerable during both construction and operation. All such projects have to be planned, implemented and operated with the clear consent of the public concerned. Hence, the organization of the overall decision-making process, incorporating the technical design as a sub-process, should involve all relevant interest groups from the initial stages of project conceptualization, even if existing legislation does not (yet) demand it.

Such concerted action requires continuous, comprehensive and objective information on the project to be given to governmental authorities, the media, local action committees or other non-governmental organizations, and above all to the directly or indirectly affected people and their representatives. In this information transfer from planners to the public, dam engineers must contribute, through their professional expertise, to a clear understanding and dispassionate discussion based on facts and not on irrational ideas of the positive and negative aspects of a project and its possible alternatives. Dam promoters must act as mediators and educators with the aim of becoming good neighbours and not intruders.

h) A complete post-construction audit of an entire project or at least a performance analysis of major impacts should be carried out in order to determine the extent to which the environmental objectives of the project or of certain mitigating measures are being achieved. The results of such analyses should be published as a contribution to our knowledge on such matters, and for application to future projects.

i) As soon as a project becomes operational, its impact on the environment should be assessed at regular intervals, based on data and sources resulting from adequate pre-construction monitoring. Depending on the individual situation, certain critical parameters should be monitored as a basis for a subsequent performance analysis of the project, resulting in a better understanding of its interactions with the environment.

j) In this context, there is also a need for more ecological research on dams and reservoirs which have already seen many years of service. Mistakes and shortcomings could be avoided, many of the recurring controversies relating to the ecological impacts of new dam projects could be prevented and the problems involved could be clarified and solved more easily, if our latent store of long-term experience with the operation of so many dams and reservoirs were to be collected, processed, evaluated and published in the framework of research projects based on carefully directed investigations. Such research projects would also provide and enhance the basis for a general policy of intensified collaboration with environmental scientists.

3. The Role of ICOLD

The International Commission on Large Dams (ICOLD) was founded in 1928 to provide a forum for discussion and for the exchange of knowledge and experience in dam engineering for engineers and others concerned with the development of water resources. Its objectives are to encourage improvements in dam engineering in all its aspects, and in all phases of the planning, design, construction and operation of dams and associated works.

At Congresses and Symposia as well as in specially appointed Technical Committees, the Commission gathers relevant information, and addresses questions concerning technical, environmental, social, economic and financial aspects of dam development, with particular emphasis on overall safety and compatibility with the environment, and then disseminates the results to its members.

With a present total of 85 member countries, ICOLD leads the profession in ensuring that dams are built and operated safely, efficiently, economically, and with a minimum environmental impact. For more than 20 years, ICOLD has been particularly concerned to enhance the profession's awareness of the social and environmental aspects of dams and reservoirs, and to broadening its perspective in such a way that these aspects receive the same attention and conscientious treatment as the technical aspects. As early as 1973, this concern was expressed as follows [I. Chéret, General Report on Question 40, 11th Congress on Large Dams, Madrid, 1973]: "The real problem to be solved is the question whether dams are useful or detrimental, whether they improve our environment as a whole and man's well-being or whether they spoil it, and appreciating in each case whether they should be built or not, and according to what characteristics."

To reflect the growing concern for the environment, a Committee on the Environment was formed in 1972 and has been renewed four times since. In a number of Technical Bulletins [See **Annex C)**] this Committee has addressed many environmental problems related to dams, including socio-economic, ecological and geophysical effects as well as water quality. In June 1980, ICOLD published a comprehensive matrix in Bulletin No. 35 as a guideline for the identification and evaluation of all conceivable effects of individual dams on the specific parts of their environment. Since 1973, environmental issues related to reservoirs have been the subject of papers, communications and discussions at eight ICOLD Congresses [See **Annex D)**].

In the future, ICOLD will intensify its activities to harmonize the development of water resources with the conservation of the environment and with regard for the people affected by a project. It will advance the growth of our understanding of environmental interactions and progress in the methods available to control them by the collection, analysis, evaluation and publication of actual experience, including the elaboration of guidelines based on such experience. It will encourage the application of environment conscious criteria and objectives, as well as the establishment of an adequate legal and institutional framework tailored to every country's specific conditions and needs. It will provide its members with up-to-date information on the current norms of environmental care and the state-of-the-art in dealing with environmental issues.

In addition, ICOLD will collect and review relevant technical papers, recommendations and instructions issued by other international organizations, and make them accessible to its members. This service will also apply to the official directives for conducting environmental impact assessments in general which have been issued in many countries, and which could serve as examples in others.

Wherever appropriate and mutually beneficial, ICOLD will collaborate with other international organizations and associations. It will assist them in maintaining a vigorous exchange or transfer of technology and knowledge to enable all countries to profit from the current state-of-the-art.

ANNEXES

A) The Role of Dams and Reservoirs

There is no life on earth without water, our most important resource apart from air and land. During the past three centuries, the amount of water withdrawn from freshwater resources has increased by a factor of 35, world population by a factor of 8. With the present world population of 5.6 billion still growing at a rate of about 90 million per year, and with their legitimate expectations of higher standards of living, global water demand is expected to rise by a further 2-3 percent annually in the decades ahead.

But freshwater resources are limited and unevenly distributed. We cannot forever try to meet insatiable demands by continuously expanding a supply that has limits. In the high-consumption countries with rich resources and a highly developed technical infrastructure, the many ways of conserving, recycling and re-using water may more or less suffice to curb further growth in supply. In many other regions, however, water availability is critical to any further development above the present unsatisfactorily low level, and even to the mere survival of existing communities or to meet the continuously growing demand originating from the rapid increase of their population. In these regions man cannot forego the contribution to be made by dams and reservoirs to the harnessing of water resources.

Seasonal variations and climatic irregularities in flow impede the efficient use of river runoff, with flooding and drought causing problems of catastrophic proportions. For almost 5 000 years dams have served to ensure an adequate supply of water by storing water in times of surplus and releasing it in times of scarcity, thus also preventing or mitigating floods. In response to enormously increased demand, more than half of ICOLD's registered 39 000 large dams have been built in the past 35 years. They have become an integral part of our technical infrastructure, and throughout the world they enhance our basis of life by offering many indispensable benefits. Still more dams will be needed in the future for the adequate management of the world's limited, unevenly distributed and in many places acutely scarce water resources.

This applies in particular to the developing regions of the world, which account for 70 percent of the world population, and for no less than 94 percent of annual population growth. One billion people there are suffering from chronic undernourishment or plain starvation, with between 10 and 15 million children dying of hunger every year. About 1.5 billion people have no access to a reliable source of drinking water, and more than two dozen countries have not enough water to sustain their populations properly. Millions die from water related diseases every year. The result is an exodus of the impoverished rural populations to the even greater inhumanity of the vast shanty towns surrounding the big cities. Of the 22 cities which will have more than 10 million inhabitants by the end of this century, 18 will be in developing countries.

In many of these countries, increased food production is only possible through improved or increased irrigation. At the present time, about 250 million hectares of land are under irrigation, growing one third of our food on less than one fifth of the world's total cultivated area, and accounting for almost three quarters of world water consumption. In conjunction with great efforts to develop effective ways of saving water by avoiding losses in the distribution systems, and by applying more skillful irrigation techniques, UNDP (the United Nations Development Program) is aiming at a 3 percent compound rate of growth in irrigated agriculture to meet the needs of an extra one billion people in the next

ten years. Half of them will be city dwellers with a concentrated drinking water requirement. Since the groundwater reservoirs presently tapped to provide about half of irrigation, drinking and industrial water supply are already heavily overdraw in many parts of the world, the only large-scale solution apart from saving water is to increase the share of surface water from storage reservoirs.

Given the foreseeable depletion of fossil fuels, which presently are used to satisfy three quarters of primary energy requirements worldwide, plus the problem of the greenhouse effect and global warming, there is an urgent need to gradually replace them with methods of energy production which do not release CO 2 , (or airborne mercury from coal-fired plants) into the atmosphere and which draw on renewable sources of energy. In the short and medium term, however, the predominant sources of renewable energy that will permit large-scale exploitation will be biomass and hydropower, before new sources like the direct harnessing of the sun's energy by photovoltaics will be ready to make contributions of the same order of magnitude.

Hydropower is solar energy in naturally and ideally concentrated form that can be utilized with the help of a mature and familiar technology with unsurpassed rates of efficiency and without depriving future generations in any way of raw materials or burdening them with pollutants or wastes. In many developing countries, it is the only natural energy resource. With a total annual generation of 2.1 million GWh, hydropower accounts today for 20 percent of electricity production and about 7 percent of total energy production worldwide. Even at a conservative estimate, the total exploitable hydropotential in the world amounts to at least six times as much. Very often, hydropower pays for multipurpose benefits, too. When this is taken into account, and when all environmental and social costs are internalized, hydropower compares favorably with other sources of energy.

Flood control has always been a particularly significant motive for dam construction and frequently its primary purpose. It will continue to be so, as long as about 40 percent of all fatalities from natural catastrophes worldwide are caused by flooding, amounting to a frightening total of nearly 100 000 per year. Compared with the main requirements of irrigation, domestic and industrial water supply, energy production and flood control, the other purposes and benefits of dams such as navigation, fisheries and tourism, improvements to the infrastructure, job creation and on-site training, are of generally minor importance, but must nevertheless not be disregarded or underrated.

B) Some International Associations related to Water Resources Development and Hydraulic Engineering

CIGR	Commission Internationale du Génie Rural
FIDIC	Fédération Internationale des Ingénieurs-Conseils
AIH	Association Internationale des Hydrogéologues
AIRH	Association Internationale de la Recherche Hydraulique
AISH	Association Internationale des Sciences Hydrologiques
IAWPRC	International Association on Water Pollution, Research and Control
IAWQ	International Association on Water Quality
CIID	Commission Internationale des Irrigations et du Drainage
IHA	International Hydropower Association
IWRA	International Water Resources Association
IWSA	International Water Supply Association
AIPCN	Association Internationale Permanente des Congrès de Navigation http://www.pianc-aipcn.org
SIL	Societas Internationalis Limnologiae (Association Internationale de la Limnologie Théorique et Appliquée)
UNIPEDE	Union Internationale des Producteurs et Distributeurs d'Énergie Electrique

WFEO Fédération Mondiale des Organisations d'Ingénieurs

CME Conseil Mondial de l'Eau

C) ICOLD Technical Bulletins related to Environmental Aspects

Bulletin 35 (1980) Dams and the Environment
Bulletin 37 (1981) Dam Projects and Environmental Success
Bulletin 50 (1985) Dams and the Environment - Notes on Regional Influences
Bulletin 65 (1988) Dams and Environment - Cases Histories
Bulletin 66 (1989) Dams and Environment - The Zuiderzee Damming
Bulletin 86 (1992) Dams and Environment - Socio-Economic Impacts
Bulletin 90 (1993) Dams and Environment - Geophysical Impacts
Bulletin 96 (1994) Dams and Environment - Water Quality and Climate
Bulletin 100 (1995) Dams and Environment - Ridracoli: A model achievement
Bulletin 103 (1996) Tailings Dams and Environment - Review and Recommendations

D) Environmental Aspects discussed at ICOLD Congresses and Symposia

1973 The consequences on the environment of building dams (Q.40)
1976 The effects on dams and reservoirs of some environmental factors (Q.47)
1982 Reservoir sedimentation and slope stability - Technical and environmental effects (Q.54)
1988 Reservoirs and the environment - Experience in management and monitoring (Q.60)
1991 Environmental issues in dam projects (Q.64)
1994 Environmental experience gained from reservoirs in operation (Q.69)
1995 Reservoirs in river basin development (Symposium)
1997 Performance of reservoirs (Q.74)