

Environmental Approaches during Planning and Construction Stages of Hydropower Projects in Mexico

María Antonieta Gómez-Balandra¹, María del Pilar Saldaña-Fabela¹,
Rosa Dina Llerandi-Juárez²

¹Hydrobiology and Environmental Assessment Department, Mexican Institute of Water Technology, Morelos, Mexico

²Discipline of Compensations, Resettlements and Ecology, Federal Commission of Electricity (CFE), Mexico City, Mexico

Email: magomez@tlaloc.imta.mx

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Abstract

During the Environmental Impact Assessment procedure (EIA) for hydropower projects, apart from the compliance with environmental standards and regulations, important environmental and ecosystem changes are foreseen from planning and construction stages. In Mexico, the EIA and environmental standards are being systematically applied and fulfilled at planning and construction stages for hydropower projects. These are mainly related to control air emissions, solid and hazardous wastes, water discharges and deal with protected species. In addition, due to land use changes, forestry compensation procedures have already been established. To comply with project approval conditions, an Environmental Management Plan (EMP) is carried out during construction; it includes mitigation measures, standards, regulations and approval conditions resulting of project review and in some cases requests from the public audience. Monitoring is carried out in the area of influence that is in the works and where it is expected that natural processes are modified. However, indicators to track these changes are minimal. This paper analyzes the regulatory and organizational frameworks to address environmental management during the planning and construction of hydropower facilities in Mexico and gives recommendations to expand the scope of the supervision and management of ecosystem changes.

Keywords

Environment, Hydro, Project, Requirement, Mexico

1. Introduction

The construction of hydropower projects is becoming more complex and challenging since developers must take into consideration multiple issues related to technical constraints, water availability and competition among water users. Besides, environmental compliance is becoming more integrated and socio-cultural demands more explicit [1]-[6].

Mexico has issued a large number of environmental criteria and standards to regulate activities and economic development since 1994. Some regulations are specific for each sector for example industry, transport, etc. while most are of general application to environmental protection, pollution control and compensation for loss of natural assets and land use change.

In Mexico, different institutions have been responsible for environmental management and protection since the beginning of the 70's decade to date. But it is since 1994 with the North American Free Trade Agreement when a comprehensive environmental legislation, regulations and standards have been issued at federal and state level, so hydroelectric projects should meet environmental procedures and regulations.

Due to the nature of hydroelectric projects, especially large dams, the environmental impact assessment procedure (EIA) is compulsory at the early planning stage. However, as in many countries, this is performed when the project technical and economic studies are advanced. Therefore, EIA is seen more as a license as a structured evaluation that could last at least two or three years, depending on the environmental resources involved [7] [8]. Besides, many projects are evaluated at specific site and not in a regional context. In some recent exercises of early planning, there is a search for matching at basin scale lesser environmental impact with greater energy generation and connectivity [9] [10].

At project level, detailed information is required and its area of influence to evaluate their impacts and planned activities. Thus, specific environmental studies are commissioned to different institutions and universities and their results integrated in the Environmental Impact Statement (EIS) [11] [12]. Nevertheless, there is lack of skills and base studies to integrate data to analyze impacts and design its mitigation and follow up in the long term [13].

At the same time, it is compulsory to follow a land use change procedure, and integrate detailed information on forest to be impacted both by the main civil works and reservoirs into a justificatory technical report DOF—Diario Oficial de la Federación (Code of Federal Regulations) [14]. Its resolution is related to offset forest and biodiversity.

The Ministry of Environment carries out a consultation process with institutions and, when it is requested, a public audience with interested parties. Their concerns and recommendations are integrated in the final resolution or environmental license for the project.

This resolution outlines the project approval conditions that proponent must meet through the Environmental Management Plan (EMP), which comprises specific studies and several programs to deal with environmental management and monitoring. A bond and semi-annual report must be submitted to the Ministry of Environment. Besides, it is compulsory to accomplish other federal, state and municipal standards and regulations which apply to small civil works. Large hydro companies worldwide have integrated regulatory issues and some best practices mainly into construction handbooks as part of the Environmental Management System [15], IHA [5] which becomes the basis for compliance with ISO 14,000. Nevertheless, it is not compulsory in general, to monitoring or following up changes in ecosystems to understand complex and large scale relationships [16]. Cumulative and synergistic impacts are more recently considered to be compensated in the same or a parallel basin [17].

During the tender process, the regulatory requirements are established as clauses of contracts under supervision of the local Residence of The Federal Commission of Electricity (CFE) till construction ends.

2. Approach

With the main objective of reviewing the environmental management at planning and construction stages to enforce the incorporation of ecosystem assessment and monitoring at the operation stages, this paper analyses the more recent experiences from La Yesca and El Cajon projects. The main activities carried out to integrate the present analysis were:

- 1) Review of Mexican environmental regulations associated to hydropower projects based on the work performed by different areas of the Federal Commission of Electricity (CFE).
- 2) Geographical scope for environmental impact assessment and follow up of different hydropower projects.

- 3) Analysis of the organizational framework established for two last hydropower projects built in Mexico to discuss the level of attention to environmental issues.
- 4) Review of ecosystem approaches and monitoring.

3. Results

3.1. Review of Mexican Environmental Regulations

A hydropower project is regulated in accordance to its activities during site preparation, construction and operation. Thus, since the initial geological exploration there is a standard that regulates project activities [18]. This establishes the environmental protection specifications for direct mining exploration activities in agricultural, livestock areas, and in areas with dry and temperate climates with desert scrub, tropical deciduous forest, conifers or oaks. It is requested an Environmental Impact Statement (EIS) should be submitted too to get a resolution for those activities. **Figure 1** points out environmental approaches conducted at each stage of hydro projects development in Mexico.

At identification stage, potential sites are selected under maximum generation criteria, but considering environmental and social concerns, such as biodiversity and resettlements, among others to give a hierarchical order. During prefeasibility, of a reduced number of potential projects, studies on environment and social issues are carried out or contracted with universities to be included in the Environmental Impact Statement (EIS). In the feasibility stage EIS is integrated and presented to the Ministry of Environment. Once resolution is obtained and conditions of approval, these are included in the bidding process through an Environmental Management Plan to be accomplished during construction. In some cases a bail is required to assure the compliance with mitigation measurements. At the construction end closing this bail is revoked and only few monitoring activities and mitigation measurements continue into operation phase.

At present the main standards to be met by any hydropower project are listed in **Table 1**. These must be declared in Chapter 3 of the environmental impact statement (EIS), indicating the relationship between activities and project standards and how to achieve them.

Environmental Impact Assessment

The EIA process is compulsory for dam projects, reservoirs, diversion and flood control structures with a capacity of 1 million cubic meters or larger. The requirements of an Environmental Impact Statement (EIS) are in general:

- A. Information about project, proponent and consultant.
- B. Project description.

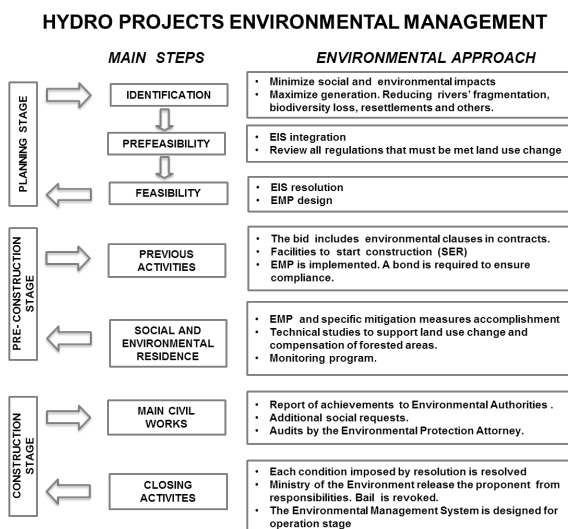


Figure 1. Environmental management plan for hydro projects in Mexico (modified from [19]).

Table 1. Main national standards for hydropower projects.

Official Mexican Standard	Environmental Protection
NOM-001-SEMARNAT-1996	Wastewater discharges to water bodies
NOM-004-SEMARNAT-2002	Sludge and bio-sludge disposal
NOM-041-SEMARNAT-2006	Vehicular emissions (oil)
NOM-043-SEMARNAT-1993	Solid particles from fix sources
NOM-045-SEMARNAT-2006	Vehicular emissions (diesel)
NOM-080-SEMARNAT-1994	Noise by mobile sources
NOM-081-SEMARNAT-1994	Noise by fix sources
NOM-052-SEMARNAT-2005	Hazardous wastes
NOM-059-SEMARNAT-2010	Native and protected species
NOM-017-STPS-2008	Personal equipment
NOM-031-STPS-2011,	Security and health at work

C. Applicable laws and regulations on environmental matters and with the land use regulation.

D. Description of the environmental system and problems detected in the area of influence.

E. Identification, description and assessment of environmental impacts.

F. Preventive and mitigation measures.

G. Environmental forecasts and assessment of project alternatives.

H. Data, methods and results.

I. Information.

During the EIS integration is necessary to review the scope of laws and its regulations (including updates) such as the general or federal laws for:

- Ecological Equilibrium and Environmental Protection,
- Sustainable Forestry Development,
- Wildlife,
- Prevention and Integrated Waste Management,
- National Waters,
- Archaeological Zones and Monuments.

On the other hand, project must consider water availability issued for basins through the national standard [20] by the National Commission of Water (Conagua). Once obtained a positive environmental resolution of the EIS, water can be requested and allocated for the projects. For forest compensation, the general structure and content of a Technical Justificatory Study required by the National Forestry Commission (Conafor) is as listed below:

- 1) Uses intended to give to the acquired or expropriated land.
- 2) Location and area of property or set of properties, where forest is going to be lost, through geo-referenced maps.
- 3) Description of physical and biological elements of the hydrological-forest basin where the project site is located.
- 4) Description of project's site conditions including the purpose for which it is intended, climate, soil types, average slope, landform, hydrography and vegetation and fauna types.
- 5) Estimation of volume by species of forest or raw materials resulting from the change in land use.
- 6) Time and ways of implementing land use change.
- 7) Vegetation left or to be established to protect fragile lands.
- 8) Prevention and mitigation measures of impacts on forest resources and wildlife, applicable during different developmental stages of land use change.
- 9) Environmental services under jeopardy by the proposed change of land use.
- 10) Technical, economic and social justification to motivate exceptional authorizations of land use change.

- 11) Inscription data of the person who made the study and its implementation.
- 12) Established criteria in land's ecological regulation programs in different categories.
- 13) Economic Estimation of biological resources to be protected in the area subjected to land use change.
- 14) Cost estimation of restoration activities due to land use change.

3.2. Review of Geographical Scope

Projects must be in accordance with compulsory and guiding instruments for conservation, in the first category: the Ecological and Territorial Ordinance Program and its environmental management units under different conservation and land use criteria. Other policy and regulatory instruments are the Management Plans of Natural Protected Areas; Ramsar sites and its protection criteria, etc.

Examples of guiding instruments are: the Priority Areas for conservation both terrestrial and hydrological ecosystems to improve biological corridors or connectivity. At the same level are sites of importance to birds promoted by the National Commission of Biodiversity.

Therefore, a Regional Environmental System (ERS) is required for each hydropower project as a polygon to be overlapped with the described compulsory and guiding instruments. The Ministry of Environment has developed public tools as SIGEIA (<http://www.semarnat.gob.mx/sigeia> Geographical Information System for Environmental Impact Assessment) to overlap project areas or ERS with GIS layers containing geographical boundaries of compulsory regulations like land use ordinances and protected areas restrictions. Similarly ERS can be compared with guide maps on priority terrestrial or hydrological areas for conservation or biodiversity protection [21].

The ERS comprises impacted surfaces by civil works, activities, and reservoir plus an influence area by the project operation downstream. In areas where land uses change a specific permit and resolution are needed. Thus, part of the basin catchment area and downstream are indicated as area of influence where natural processes are going to change. In the ERS the natural processes and ecological structures modified by project must be analysed such as hydrological alterations, nutrients and sediment transport changes, water quality, biological corridors and forest communities, among others. According to the EIA process, all these issues are to be followed and monitored during construction and operation but indicators are scarce or not monitored.

For El Cajon and La Yesca dams located in the Santiago River Basin Northwest Mexico in a cascade scheme (Figure 2), its influence area was different since El Cajon considered only surfaces to be part of the project like the reservoir and civil works area. Whereas La Yesca ERS had an artificial limit consisted in a topographical change at the plateau elevation. This ERS followed the contour around reservoir. In comparison ERS's for El Cajon and La Yesca were 4206.90 ha and 65,000 ha respectively, including part of the Bolaños river basin.

At present with more digital data and powerful tools available ERS's are outlined following limits of sub or

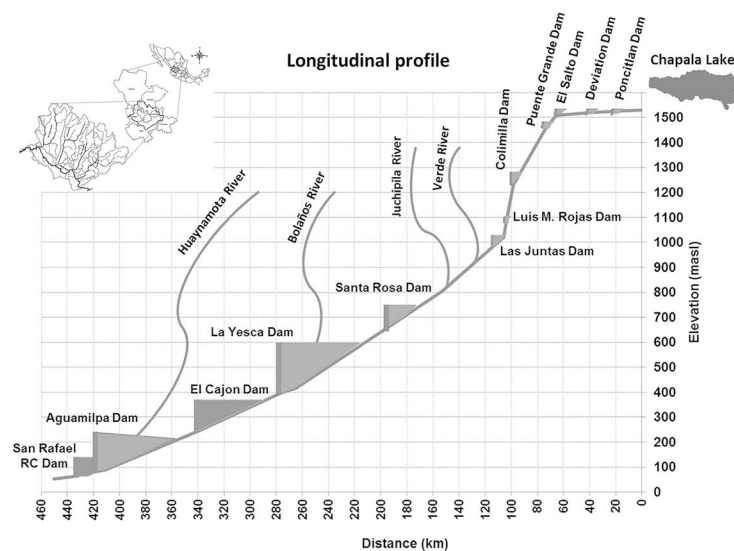


Figure 2. Cascade system in the Santiago river.

micro basins in order to better understand natural process in the watershed, reservoir and downstream. Other important features taken into consideration are changes in vegetation and altitude, as well limits of territorial legal ordinances. In the case of recent studies for new projects one example is the ERS of the Paso de la Reina project defined under these criteria (Figure 3).

The scope of the Technical Justificatory Study considers the loss of environmental services (mainly carbon capture and groundwater recharge) and forest cover to be compensated through the National Forestry Commission. For La Yesca project, in the corresponding reservoir and civil work, vegetated areas were approximately 2000 ha, forest to be compensated.

In the whole ERS of 65,000 ha, the expected impacts were analyzed including changes in surface hydrology, groundwater, topography, demography, environmental and social aspects with data integrated into the EIS but not into a GIS. For Paso de la Reina Project all the information was integrated into a GIS.

Environmental Management Plan

Even though the EIA process is requested by law since 1988 in Mexico, only in recent years it has becoming compulsory to include the Environmental Management Plan (EMP) as a framework to accomplish regulations and implement mitigation measurements. After the EIS resolution a period of time is given to implement the EMP. Its main objectives are twofold since it can follow mitigation measures and regulation achievements as well as monitoring specific indicators during project construction (Figure 4).

3.3. Analysis of the Organizational Framework

The organizational structure within the CFE to address environmental issues considers departments of environmental protection and archaeological advisors, both in technical and operational areas shown in Figure 5. These areas support projects once environmental, socio and technical-economic issues are fulfilled at prefeasibility stage.

Specifically for El Cajon and La Yesca projects in the Santiago River prefeasibility studies were done by the North Pacific Centre for Preliminary Projects supported by the headquarters (Coordination of Hydroelectric Projects). The Finance and Inversion area is in charge of the bidding process.

Socio-Environmental Residence

Once the bid succeeded and is formalized, a local Socio-Environmental Residence is established, under the General Construction Residence (Figure 6). Its main objectives are to accomplish the approval conditions included in the Environmental Management Plan (EMP) which includes a monitoring program. The Social-Environmental Residence in La Yesca had five areas to: 1) mapping and databases, 2) environmental issues, 3) social and agencies liaison, 4) property rights acquisition and 5) social and infrastructure compensation. At this resi-

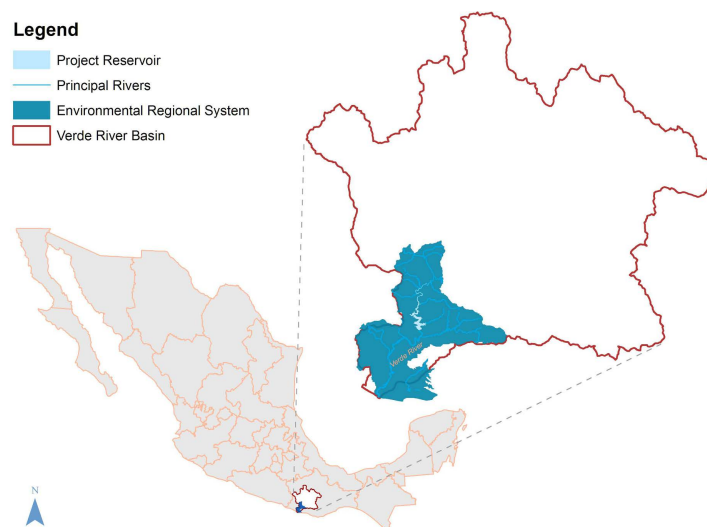


Figure 3. ERS Paso de la reina project.

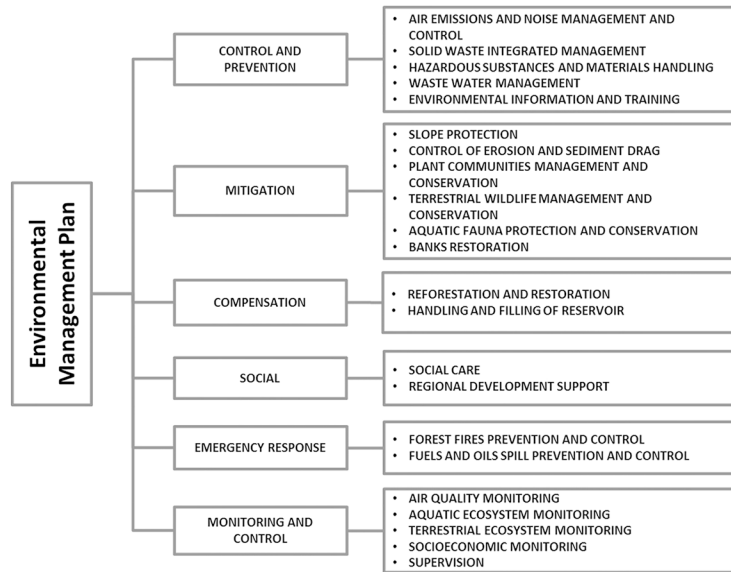


Figure 4. Environment management plan structure.

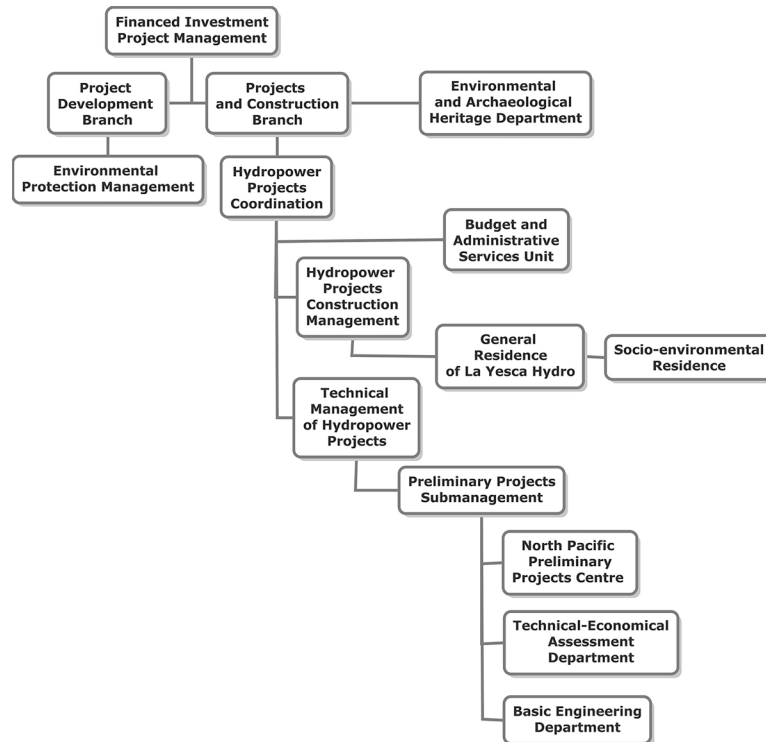


Figure 5. CFE organizational structure for environmental management.

dence 78 field and office employees were assigned.

3.4. Review of Ecosystem Approaches and Monitoring

As large dams' impacts are analyzed in their natural context including its position in the basin, the ecosystems fragmentation is an important issue for aquatic and terrestrial communities. Therefore, preserving or promoting environmental flows, sediment transport and hydro-geomorphology features that mimic habitats under an adap-

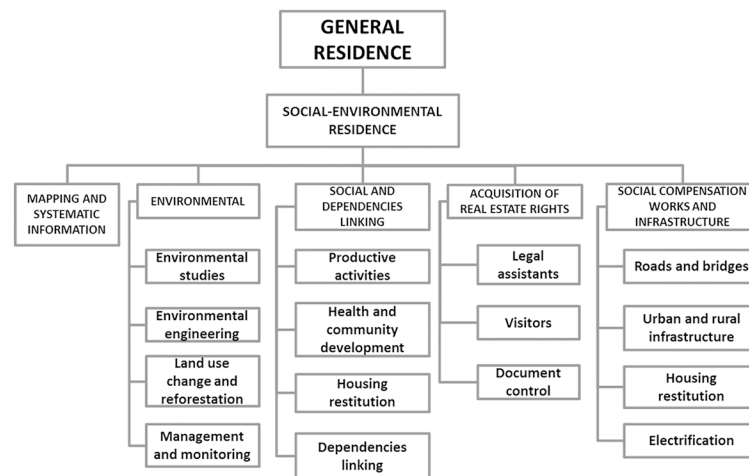


Figure 6. Social and environmental residence structure.

tive management are of paramount importance [16] [22]. Even though at present regulations in Mexico have advanced integrating these issues only on environmental flows but considering this kind of management (standard of reference NMX-AA-159-SCOFI-2012) [23].

As worldwide in Mexico, wildlife and aquatic biodiversity depend on these natural processes which have been impacted by regional cumulative impacts, including [24]-[28]. In response to these issues, some provisions are being taken by CFE to incorporate these criteria for site selection at early planning stages.

In addition, environmental flow strategies are being included in the hydropower operation to resemble natural variability even though with a loss in power generation, because of a technical regulation to promote environmental flows were issued in September 2012 [23]. An adaptive approach to make the project profitable and preserve aquatic ecosystem is under discussion for new projects and its implementation will be a real challenge for CFE or any other electricity public or private company [29] [30]. Even more nowadays with the Mexican energy reform and openness to public inversion in this field.

Our Environmental Federal Law issued in 1988 with its several amendments (last during this year) initially considered topics such as ecosystem functionality. At present more complex topics have been included like ecological integrity (structure and functioning), load capacity and ecosystem services to be evaluated by projects.

For assessing ecological integrity there are not available official data since biodiversity information is mainly processed like inventories rather than habitat functionality and species needs. In regards to methods there are few examples of application in this topic and other like environmental services payment by large hydro projects. Nevertheless, some consultants and academic institutions have developed specific studies in these topics and they have been included in the EIS reports, at least as frameworks or initial approaches for their analysis.

In Mexico many impacts of large dams are classified as significant due to the Law definition of significance “alteration in ecosystems on its natural resources or health that create obstacles for the development of man, other life forms and in the continuity of natural processes”. Therefore, recognition of residual or cumulative impacts during operation is important to promote specific assessments and mitigation of changes or losses such like: [25] [28] [31] [32].

- Water quality changes in the reservoir and downstream impacts.
- Reservoir surface area as quantity of riparian and terrestrial flooded habitat, including habitat losses for wildlife.
- River channel inundated or dewatered impacting aquatic habitat downstream.
- Riparian and terrestrial diversity loss.
- Catchment connectivity at basin-scale to leave free streams of different hydrological order.
- Hydrologic and sediment regimes due to flow modification and the barrier effect of dam.
- Residence time change and water quality release downstream.
- Native biodiversity, introduction or potential growth of invasive species in the reservoir.

In regards to these issues, in Mexico there are isolated case studies or specific evaluations done by universities without implementation, nor follow-up of indicators. In the near future it is expected to adopt a systematic

approach of these topics with universities participation and at regional scale with proven approaches or methods within the regulatory system of Mexico.

4. Conclusions and Recommendations

Due to advances in environmental management required by the Ministry of Environment to deal with air emissions, wastewater discharges, solid and hazardous wastes, noise and other issues. Nowadays, these conventional impacts can be overcome and managed properly during planning and construction stages.

For that reason, the stress of Mexican law to submit an environmental impact study for review and approval is more about the significant impacts that affect the structural and functional characteristics of ecosystems and cause cumulative effects. However, for practical reasons, EISs are more focused on conventional or controlled impacts.

Developing strategies and data for a more complex approach are needed to research and follow changes in environmental conditions, for example, not only on environmental flows but hydro-sedimentary process, connectivity, biological networks and relationships between cycles of dry and floods seasons.

These issues need more comprehensive assessments, rather than just the information to be included in an EIS which takes one or two years at most and in some cases it is required as additional information to be compiled in short terms according to legal deadlines. For that reason, encouraging the participation of institutions and universities with research programs and projects is an urgent need, as well as promoting sectorial programs to produce data and regional integrated assessments to building capacities.

It is also important to demonstrate the dams' positive and negative impacts by following regional strategic indicators to be included in the hydrological and hydraulic policies and plans in Mexico. Even more at present, when institutions are changing and other stakeholders are going to be part of hydraulic development in the country.

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