Ministry of Mines and Energy
Secretariat of Energy Planning and Development

Manual for Hydropower Inventory Studies of River Basins

2007 edition

CEPEL
Grupo Eletrobrás

PROJETO ESTAL
Ministério de Minas e Energia

Portuguese Edition (December 2007)

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PREFACE

The publication of this Manual for Hydropower Inventory Studies of River Basins is part of a broader resumption of planning by the Ministry of Mines and Energy, as part of its responsibility in the government for devising policies for the energy sector, in line with the guidelines laid down by the National Council for Energy Policies (CNPE).

This Manual is the outcome of the work undertaken in a broad-based review and update of the previous manual published in 1997 by ELETROBRÁS. It reflects current Brazilian experience in Inventory Studies of river basins and the changes that have taken place over the last ten years in the country's electricity sector, especially with regard to legislation, the environment, water resources and institutional changes.

The review of the Manual was initiated in 2004 by the Ministry of Mines and Energy, which subsequently contracted Electric Energy Research Center (CEPEL) to coordinate and consolidate the work under its supervision. The project also received support from the World Bank in the form of an Energy Sector Technical Assistance Loan (ESTAL). A working group was set up of professionals with technical expertise from different companies with experience in Inventory Studies, as well as representatives from sector associations.

One important new ingredient in the latest edition of the Manual is the inclusion of Integrated Environmental Assessments as part of a broader approach addressing issues of sustainable development. In addition, the methodology takes account of the multiple uses of the waters in the river basins under study, in line with the National Plan for Water Resources.

It is, then, with great satisfaction that the Ministry of Mines and Energy presents electricity sector agents with this new Manual for Hydropower Inventory Studies of River Basins, an up-to-date tool that incorporates the latest concepts, methodologies and technical advances produced in Brazil and internationally for assessing hydropower potential. It will surely prove fundamental for the planning and development of new hydropower projects in Brazil, and become an essential reference in the fulfillment of the country's energy requirements for the medium and long term, as set forth in the 2030 National Energy Plan.

Finally, the Ministry of Mines and Energy takes this opportunity to express its gratitude for the collaboration of the institutions involved in this process, which put every effort into ensuring its success by lending the expertise of their most highly qualified technical personnel, representatives of Brazil's acknowledged competence in studies and designs for hydropower projects.

Brasília, December 2007

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Appendices
Bibliography
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1. Hidroeletricidade. 2. Energia elétrica. 3. Bacias hidrográficas. I. Centro de Pesquisas de Energia Elétrica (Brasil). II. Título.

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PREFACE TO ENGLISH LANGUAGE VERSION

The Portuguese language 2007 edition of this Manual for Hydropower Inventory Studies of River Basins (*Manual de Inventário Hidrelétrico de Bacias Hidrográficas)* was launched in December 2007 after two years of work by a multidisciplinary team coordinated by the Electric Energy Research Center (CEPEL) and made up of professionals from the Brazilian electricity sector and other sectors that interface with hydropower development in Brazil. At that time, it was understood that this Manual was important for inventory studies in Brazil because it would present the latest concepts, methodologies and technical advances from Brazil and abroad for use in assessments of hydropower potential.

Since 2008, several inventory studies have been carried out or reviewed based on the 2007 edition of the Manual and using the SINV computer system for the energy and socioenvironmental studies. The SINV computer system, developed by CEPEL, was updated during the review of the Manual. The utilization of the Manual and the SINV system assures quality and homogeneity in the results of studies of this nature, while also simplifying the analysis required at the approval stage.

The Ministry of Mines and Energy's decision to invest in the translation of the Manual into English came in response to the several presentations given of the results of inventory studies at national and international forums and the use of this Manual in inventory studies of bi-national river basins. It also aims to help divulge the country's efforts towards developing its hydropower potential in a sustainable way and show the technical, institutional and legal advances of the Brazilian electricity sector. Given the technical nature of the project, the Ministry again contracted CEPEL, this time to coordinate the translation.

Around the world, the sustainable development of hydropower is also being used to foster social and economic development, especially for local communities, and as an important tool in the fight against global warming. Given that Brazil's environmental legislation is one of the most stringent in the world, the approach the country is adopting to face the challenge of continuing to expand its energy and electricity matrices based on renewable resources is to take socioenvironmental issues into account from the very earliest planning stage. The basic approach in hydropower inventory studies of river basins is, then, to find a balance between cost-effective energy production and socioenvironmental considerations, while also taking account of multiple water uses.

By bringing out an English translation of the 2007 edition of the Manual for Hydropower Inventory Studies of River Basins, the Ministry of Mines and Energy intends to offer the international community a basic reference to be considered in the portfolio of possible energy solutions in developing countries, which should be of particular interest to multilateral financing and development organizations.

The use of this Manual will highlight opportunities for the sustainable development of hydropower. This involves taking account of environmental issues, and enhancing synergies between hydropower development, efficient water use, local and regional social and economic development, improved access to clean energy, job creation and reduced emissions.

Brasília, June 2010

Márcio Pereira Zimmermann
Minister of State of Mines and Energy
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WORKING GROUP

This Manual is the outcome of a review process that started in 2005 when CEPEL (Electric Energy Research Center) was contracted by the Ministry of Mines and Energy by means of the World Bank's Energy Sector Technical Assistance Loan (ESTAL). The review is based on the 1997 manual published by Eletrobrás (*Manual de Inventário Hidrelétrico de Bacias Hidrográficas*).

In order to coordinate the review process, a Working Group was set up, made up of a Core Group, an Executive Group and an Advisory Group. The members of the Core Group were representatives from the Ministry of Mines and Energy (coordinator), CEPEL (Executive Secretary), Eletrobrás (*Centrais Elétricas Brasileira*) and EPE (Energy Research Company). The aim of this group was to assist the ministry in its decision-taking processes.

The brief of the Executive Group was to undertake an analysis of the 1997 manual and propose improvements. As such, it was subdivided into five theme-based groups: institutional, engineering studies, energy studies, water resource studies and socioenvironmental studies. Professionals from different companies from the electricity sector with experience in Inventory Studies were invited to sit on these subgroups, as well as representatives from ANEEL (National Electricity Agency), the Ministry of the Environment, ANA (National Water Agency) and other environmental and water resource entities.

The Advisory Group was formed in order to obtain contributions from sector associations, universities and consultants specialized in Inventory Studies.

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ABBREVIATIONS USED

Abbreviation	Name or explanation in English	Name in Portuguese
ABNT	Brazilian technical standards association	Associação Brasileira de Normas Técnicas
ANA	National Water Agency	Agência Nacional de Águas
ANEEL	National Electricity Agency	Agência Nacional de Energia Elétrica
ART	Document that defines the limits of the professional services to be rendered by members of CREA and by what entity they will be rendered	Anotação de Responsabilidade Técnica
BNDES	National Development Bank	Banco Nacional de Desenvolvimento Econômico e Social
CEPEL	Electric Energy Research Center	Centro de Pesquisas de Energia Elétrica
CMSE	Brazilian Electricity Sector Monitoring Committee	Comitê de Monitoramento do Setor Elétrico
CNI	National Confederation of Industries	Confederação Nacional da Indústria
CNRH	National Council for Water Resources	Conselho Nacional de Recursos Hídricos
COCAR	Cartography Committee, Ministry of Planning, Budgets and Management	Comissão Nacional de Cartografia Ministério do Planejamento, Orçamento e Gestão
CONAMA	National Council for the Environment	Conselho Nacional do Meio Ambiente
CONCAR	National Cartography Council	Conselho Nacional de Cartografia
COPEL	Paraná Energy Company	Companhia Paranaense de Energia
CPRM	Department of Mines and Energy mineral research entity (Geological Survey of Brazil)	Companhia de Pesquisa de Recursos Minerais
CREA	Regional Council for Engineering, Architecture and Agronomy	Conselho Regional de Engenharia, Arquitetura e Agronomia
CUR	Reference Unit Cost	
DEA	Distributed Environmental Assessment	
DERs	Highway departments (states)	Departamento de Estradas de Rodagem
DHN	Brazilian Navy Department of Hydrography and Shipping	Diretoria de Hidrografia e Navegação
DNIT	National Department for Infrastructure and Transportation	Departamento Nacional de Infra-Estrutura e Transporte
DNPM	National Department of Mining	Departamento Nacional da Produção Mineral
DSG	Brazilian Navy Geographical Survey	Diretoria de Serviço Geográfico
EAP	economically active population	
EAR	residual stored energy	Energia Armazenada Residual
EIA	Environmental Impact Assessment	Estudo de Impacto Ambiental
EMBRAPA	agricultural research company	Empresa Brasileira de Pesquisa Agropecuária
EPE	energy research company	Empresa de Pesquisa Energética
FCP	Ministry of Culture foundation for African-Brazilian affairs	Fundação Cultural Palmares
FGV	social science research and education entity	Fundação Getúlio Vargas
FUNAI	entity that divulges information about Brazilian indigenous peoples	Fundação Nacional do Índio
GIS	geographic information system	
GTON	North Region Technical Group	Grupo Técnico Operacional da Região Norte
HDI	Human Development Index	
IA	Negative socioenvironmental index of a cascade option on the environmental system	
IAC	Negative socioenvironmental index of a cascade option on each synthesis component in the study area	
IAE	Positive socioenvironmental index of a cascade option relating to each element	
IAp	Positive socioenvironmental index of a cascade option on the environmental system	
IBAMA	Brazilian Environmental Institute	Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis
IBGE	Brazilian Institute of Geography and Statistics	Instituto Brasileiro de Geografia e Estatística
IEA	Integrated Environmental Assessment	
INCRA	institute for land reform	Instituto Nacional de Colonização e Reforma Agrária
INMET	meteorology institute	Instituto Nacional de Meteorologia
INPE	institute for space research	Instituto Nacional de Pesquisa Espacial

Abbreviation	Name or explanation in English	Name in Portuguese
INPRA	socioenvironmental research institute	Instituto Internacional de Pesquisa e Responsabilidade Socioambiental Chico Mendes
IPARJ	Rio de Janeiro based institute for anthropological research	Instituto de Pesquisas Antropológicas do Rio de Janeiro
IPEA	entity that carries out economic research	Instituto de Pesquisa Econômica Aplicada
IPHAN/MinC	Ministry of Culture heritage protection agency	Instituto do Patrimônio Histórico e Arqueológico Nacional
ISA	socioenvironmental NGO	Instituto Socioambiental
ISS	Tax on Services	Imposto sobre Serviços
LI	Installation License	Licença de Instalação
LP	Preliminary License	Licença Prévia
MAPA	Ministry of Agriculture, Fisheries and Supplies	Ministério de Agricultura, Pecuária e Abastecimento
MCidades	Ministry of Cities	Ministério das Cidades
MDA	Ministry of Agrarian Development	Ministério do Desenvolvimento Agrário
MDIC	Ministry of Development, Industry and Foreign Trade	Ministério do Desenvolvimento, Indústria e Comércio Exterior
MDS	Ministry of Social Development and Fight against Hunger	Ministério do Desenvolvimento Social e Combate à Fome
MI	Ministry of National Integration	Ministério de Integração Nacional
MMA	Ministry of the Environment	Ministério de Meio Ambiente
MME	Ministry of Mines and Energy	Ministério das Minas e Energia
MT	Ministry of Transport	Ministério dos Transportes
MTur	Ministry of Tourism	Ministério do Turismo
NA	water level	Nível d’água
OEMAs	state environmental entities	Órgãos Estaduais de Meio Ambiente
ONS	entity responsible for coordinating and controlling the operation of electricity generation and transmission facilities included in the SIN	Operador Nacional do Sistema Elétrico
OPE	Standard Eletrobras Cost Estimate	Orçamento Padrão da Eletrobrás
OTEP	technical education and research organizations	Organizações Técnicas de Ensino e Pesquisa
PBA	Basic Environmental Plan (part of installation licensing process)	Plano Básico Ambiental (parte do processo de obtenção da Licença de Instalação)
PCA	Environmental Control Plan (part of operational licensing process)	Plano de Controle Ambiental (parte do processo de obtenção da Licença de Operação)
PIE	Independent Electricity Generator	Produtor Independente de Energia Elétrica
PNRH	National Plan for Water Resources	Plano Nacional de Recursos Hídricos
PPA	Multi-Year Plan	Plano Plurianual
PRH	Water Resources Plan	Plano de Recursos Hídricos
RAIS	annual list of information on society	Relação Anual de Informações Sociais
RIMA	Environmental Impact Report	Relatório de Impacto Ambiental
SBE	Brazilian Society of Speleology	Sociedade Brasileira de Espeleologia
SEAP	Department of Aquaculture and Fishing	Secretaria Especial de Aqüicultura e Pesca
SEMA	state departments of the environment	Secretarias estaduais de meio Ambiente
SEPPIR	Department for Racial Equality	Secretaria Especial de Políticas de Promoção da Igualdade Racial
SERH	state departments of water resources	Secretarias Estaduais de Recursos Hídricos
SIN	National Interconnected System	Sistema Interligado Nacional
SINDUSCON	civil construction industry union	Sindicato da Indústria de Construção Civil
SIPAM	Amazon protection system	Sistema de Proteção da Amazônia
SisEvapo	system for evaluating net evaporation from reservoirs	Sistema de Avaliação da Evaporação Líquida dos Reservatórios
SISNAMA	National system for coordinating environmental actions	Sistema Nacional do Meio Ambiente
SIUC	information system on conservation units run by IBAMA	Sistema de Informações de Unidades de Conservação/IBAMA
SPHAN	precursor of IPHAN	Serviço de Patrimônio Histórico e Arqueológico Nacional
SRHU/MMA	Department of Water Resources	Secretaria de Recursos Hídricos
TAR	reference power rate	Tarifa Atualizada de Referência
UNDP	United Nations Development Programme	
WHO	World Health Organization	

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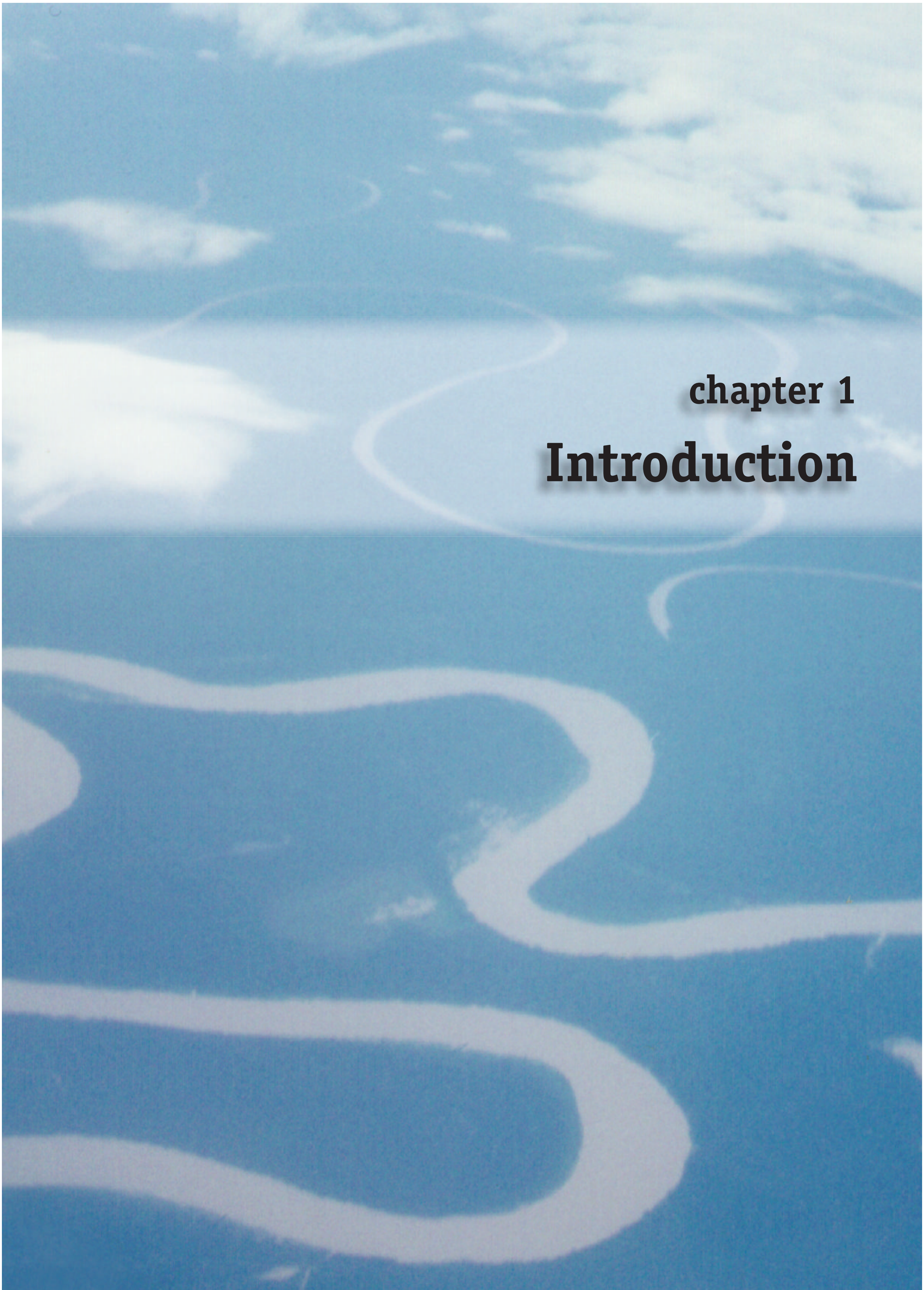
CHAPTER 1



chapter 1

Introduction

CHAPTER 1

1.1 HYDROELECTRIC POWER

Over the years Brazil has adopted a policy of harnessing its hydroelectric potential, which has made it self-sufficient in electricity by drawing on a low-cost renewable source of energy and developing national technology.

As the electricity industry is a major user of water, it has the responsibility and duty to plan the use of this resource as an input for the cost-effective, optimized production of electricity, alongside the other users of water.

This is a topic that is currently legislated and regulated by several government entities and allows for the involvement of different agents. Appendix 1 presents an overview of the issues concerning hydroelectric power and its potential from a Brazilian and international perspective, as well as the institutional context in which hydropower inventory studies are undertaken in Brazil. It also explains certain key issues involved in the relationship between institutions and the legal processes and procedures needed for hydropower generation at this stage of planning. Appendix 1 is organized into the following topics:

- Hydroelectric Power around the World

  This topic presents an assessment of key issues affecting hydroelectric power in the world today. It addresses topics raised by institutions such as the International Hydropower Association, the World Commission on Dams, the World Research Institute and the International Rivers Network, providing an overview of the arguments for and against impoundment. The issues concerning dams around the world are presented in brief, illustrated by a quantitative and qualitative analysis of existing dams designed to show that the issue is not restricted to energy generation alone. In order to inform those people who may be in charge of undertaking Hydropower Inventory Studies about any potential areas of conflict, the main arguments against hydroelectric power on a world level are also presented. There is also a discussion of the impact of large-scale dams, concluding that the issues at stake are not just a function of the scale of a project.

  Some of the international data on hydropower are presented, which show its contribution to the international energy grid. Data are also provided on the world's largest electricity and hydropower producers. The contrasts between the electricity systems in different countries are highlighted, giving special attention to the exceptional make-up of the Brazilian grid. A general picture is also given of the countries with the potential to develop hydroelectric power. A description is provided of some of the features that set hydroelectric power apart from other sources of energy, which can, if developed appropriately, make hydropower plants even more competitive.

- Hydroelectric Power in Brazil

  Brazil's hydroelectric potential and the feasibility of its being harnessed are illustrated in an overview of the different hydroelectric projects classified according to their stage of development, location, scale, river basin and impounded area, drawing on data from SIPOT[1]. A historical view of hydropower projects in the country is given, covering the introduction of the system, the creation of the companies and the overall growth of the electricity industry.

  The current state of the hydropower system in the country is also presented, as well as its prospects for growth and the role of the interconnected transmission system, which links up different river basins in Brazil and is designed to optimize the country's water resources by integrating them through a wide variety of dispatch configurations. This is particularly important for ensuring the feasibility of hydropower projects in the north of Brazil.

1 SIPOT – Information System on the Hydroelectric Potential of Brazil, Eletrobrás. *sipot@eletrobras.com*.

A brief analysis is also made of the impact social and environmental aspects have on hydropower generation in Brazil, based on the Environmental Master Plan (II PDMA) and several changes to the relevant legislation.

- Hydroelectric Power Projects and the Institutional Organization of the Electricity Sector

  This section shows how legislation pertaining to the electricity sector has changed since the first reforms were made in 1995, when acts 9.074 and 8.987 were passed to legislate the granting of electricity contracts.

- Institutional Organization

  This shows the different entities and agents and their respective powers.

- Legislation Pertaining to Harnessing Hydroelectric Potential

  In 1995, Act 8.987 brought in major changes to the way concessions were granted and authorization was given for the rendering of public services. It regulates article 175 of the Federal Constitution of 1988, which states that concessions for public services and works and authorization for public services must be subject to public tender. This item discusses the implications of this change of focus, covering the following topics:

- Concessions for projects in the electricity industry;
- Resolutions for Hydropower Inventory Studies;
- Financial compensation;
- National Policy for Water Resources;
- National Policy for the Environment.

1.2 OBJECTIVE

The aim of this Manual for Hydropower Inventory Studies is to present a set of criteria, procedures and instructions for undertaking Hydropower Inventory Studies of river basins.

The hydroelectric potential of a river basin, as defined in this Manual, corresponds to the potential that can be technically, economically, socially and environmentally harnessed, taking into account the multiple water uses in the river basin under study.

The techniques and methods used for this purpose have been developed and refined in Brazil since the early 1960s. The methods described in this Manual are the result of the experience acquired in hydropower developments in Brazil.

This new edition of the Manual for Hydropower Inventory Studies is based on the 1997[2] edition and includes some additional items:

- methods and criteria for social and environmental studies in compliance with Integrated Environmental Assessments (IEA);
- a chapter dedicated to specific analyses concerning the IEA of the cascade selected in the Final Studies;
- methods and criteria for considering, in the Final Studies, the potential positive socioenvironmental impacts arising from the introduction of the hydropower plants;
- updated methods and criteria for building up the scenario for multiple water use in the light of the National Plan for Water Resources;
- updated procedures for appraising, quantifying and calculating the costs involved;
- updated unit prices;
- altered multi-objective methodology for selecting the cascade in the Final Studies so that positive socioenvironmental impacts can be included;
- updated version of the SINV[3] program, which is used for the energy and socioenvironmental studies in compliance with the procedures in this manual.

2 Manual de Inventário Hidroelétrico de Bacias Hidrográficas, Eletrobrás, 1997.

3 SINV – System used for the socio-environmental and energy studies and for the studies used to select the cascades in hydropower inventory studies, CEPEL, 2007.

1.3 EXPANSION PLANS FOR THE BRAZILIAN POWER SYSTEM

Planning the Brazilian energy sector involves taking decisions about the expansion of the production/generation system, the transportation system, and the storage of energy (at hydroelectric power plants and in fuel stocks). It is by this process that supply is adjusted to the demand forecast in different analyses taking into consideration the country's different sources of energy and fuel imports and exports. Overall, it requires several kinds of studies with different aims and time-frames depending on the specific aim.

In view of the nature of Brazil's electricity system and the rest of the energy sector, its expansion is planned in three distinct stages involving different kinds of studies as set out below.

- **Long-Term Studies** covering up to 30 years, involving analyses of different strategies for developing the country's different energy systems and the future energy supply mix. The priorities are also established for the country's technological and industrial development, as well as a program of engineering studies designed to assess the technical, economic and socioenvironmental feasibility of different energy developments. The findings include recommendations for river basins to be prioritized in Hydropower Inventory Studies, guidelines for short-term studies, and estimates of marginal costs for long-term expansion plans.

  The main variables in these studies are: the prospects for the domestic economy and the respective demands of the energy market; the availability of primary energy sources and the options for importing energy and energy sources; trends in technology development, especially concerning renewable energy sources; the environmental impacts of projects; and conservation and efficiency projects for energy use and production. These studies are carried out every four to five years on average, and their findings serve as an input for energy strategies and policies, which are consolidated in the studies for the National Energy Matrix and the National Energy Plan.

- **Medium-Term Studies** for the electricity sector covering up to 15 years, which include analyses of the different options for expanding power generation and transmission adjusted to the market's energy requirements. These studies are developed for specific planning cases, such as the studies for and design of interconnections between the systems in different regions of the country, the introduction of hydropower from the Amazon to the National Interconnected System, and the calculation of marginal costs for designing hydropower plants. The studies meet the specific expansion needs of the national electricity system.

  The main variables in these studies are the same as those for the short-term studies below.

- **Short-Term Studies** covering at least the next ten years, which present decisions concerning the physical expansion of energy supply, pinpointing specific projects and their time-frame for introduction, with analyses of supply conditions for the market. The physical targets and the expansion programs are established with a view to future auctions for the purchase of energy from new generation developments and future auctions for new transmission facilities. The technical, economic and socioenvironmental feasibility studies required for new generation projects are identified.

  Other sources of energy are also analyzed, taking into consideration the current priority of developing the plan with a focus on energy integration, especially for oil and oil products, liquid fuels, natural gas, renewable energy sources and coal.

  The main variables in these studies are: the demands of the energy market; the criteria for assuring supply and minimizing investment costs; the time-frame for new developments, taking into consideration the engineering and environmental studies involved. These studies are carried out every year and are consolidated in the Ten-Year Expansion Plan.

By this means, the expansion of Brazil's energy system is planned by consolidating these studies on two distinct levels: the Ten-Year Expansion Plan and the National Energy Plan, the latter of which is strategic in nature, providing energy guidelines and policies and setting the groundwork for shaping the Ten-Year Plan.

The quality of the expansion plans depends on the coherence and homogeneity of the respective Hydropower Inventory Studies and the compatibility between them, even when they are carried out by different technical teams.

1.4 STUDIES AND DESIGNS REQUIRED FOR NEW HYDROELECTRIC PROJECTS

The development of new hydroelectric power plants involves five distinct stages (see Figure 1.4.01).

The first of these is the **Estimate of Hydroelectric Potential**, when a preliminary analysis is made of the river basin, looking into its topographical, hydrological, geological and environmental features to identify whether it could be harnessed for power generation. This analysis, which is based purely upon pre-existing data, is office-based and provides a first indication of the potential and estimated cost of developing the river basin, as well as prioritizing topics for the next stage.

The second stage is the **Hydropower Inventory Study**, when different cascades comprising a number of individual projects are devised and analyzed for the river basin. These are then compared to select the one that gives the best relative development cost, energy benefits and socioenvironmental impacts. The analysis draws on secondary data, which are supplemented by field data and involves basic cartographic, hydrometeorological, energy, geological, geotechnical, socioenvironmental and multiple water use studies. Based on this analysis, a number of possible cascades are identified, including their key characteristics, cost/benefit ratios and socioenvironmental indexes. As part of the Hydropower Inventory Study, the projects from the final selected cascade are submitted to an Integrated Environmental Assessment (IEA), which is needed for environmental licensing purposes. These projects are then included in the national list of approved projects, and are available for inclusion in energy expansion plans.

Next is the **Feasibility** stage, which includes more detailed studies to assess aspects of technical, energy, economic and socioenvironmental feasibility, the results of which serve to identify the optimal projects, which are then made available for auction. These studies include field work and calculations of the basic dimensions of the project and reservoir, its area of influence and the local and regional infrastructure needed for it to be built. These also include multiple water use analyses and assessments of socioenvironmental interference. The results of these studies are compiled in an Environmental Impact Assessment (EIA) and an Environmental Impact Report (RIMA) for each project, which are submitted to the respective environmental agencies as part of the application for a Preliminary License.

The next step in developing a project, once a bid process has taken place, is the **Basic Design**. The project analyzed in the feasibility studies is characterized in detail to identify more precisely its technical requirements, the technical specifications for the civil construction and the hydro and electromechanical equipment required, as well as the associated social and environmental programs. A Basic Environmental Plan (Projeto Básico Ambiental) must be prepared on the basis of the recommendations in the EIA before an Installation License can be issued and the construction work contracted out.

The final stage is the **Executive Design**, in which the civil construction and the hydro and electromechanical equipment are defined in detail so that the construction work can be carried out and the equipment assembled. This stage also includes all the steps concerning the impoundment, including the socioenvironmental programs to prevent, minimize or offset any social or environmental damage, after which an Operating License can be applied for.

Once the plant has been built, the reservoir is filled and the plant is commissioned. Once generation begins, the plant is monitored closely to adjust any issues that may be identified. The plant can only enter service once it has received an Operating License.

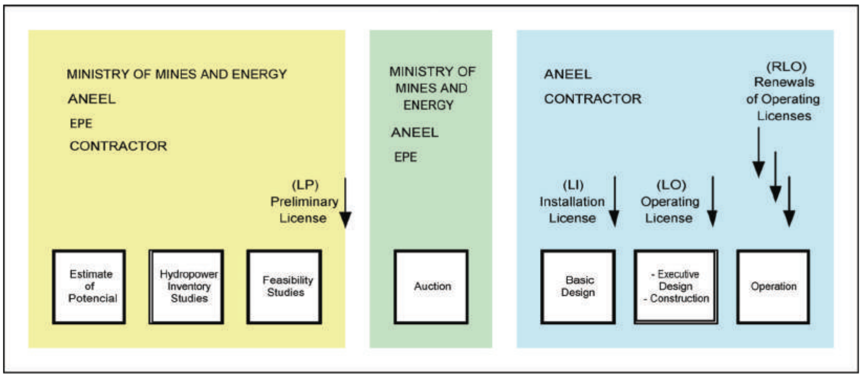


Figure 1.4.01 – Stages of introducing a new hydropower project

1.5 PHASES OF HYDROPOWER INVENTORY STUDIES

Hydropower Inventory Studies are carried out in four phases:

- Planning

  Initially, it is necessary to plan and organize the study, listing the different studies that need to be undertaken and estimating how long they will take and their cost. At the end, a management report is produced that contains the work plan. The flowchart in Figure 1.5.01 contains the activities involved at this stage.

- Preliminary Studies

  Different cascades are proposed and analyzed for harnessing the hydroelectric potential, making a preliminary estimate of their generation potential and costs and any negative socioenvironmental impacts involved, all using secondary data. The aim of the Preliminary Studies is to select the most promising cascades from a socioenvironmental, energy and economic perspective, so that these can then be subject to more in-depth analysis at the next phase. The flow chart in Figure 1.5.02 shows the activities in this phase.

- Final Studies

  The aim of the Final Studies is to establish what construction work and equipment would be required to fully harness the hydroelectric, socioenvironmental and economic potential of the basin.

  The analysis in this phase is in-depth, and takes into account the positive socioenvironmental impacts. There are also supplementary field studies undertaken for the projects included in the cascade options selected in the previous phase. The flow chart in Figure 1.5.03 shows the activities in this phase.

- Integrated Environmental Assessment of the final selected cascade

  The aim of this phase is to supplement and consolidate the socioenvironmental studies for the cascade selected in the Final Studies, highlighting the cumulative and synergistic effects resulting from the negative and positive impacts brought about by the set of projects involved. It is in this phase that the socioenvironmental guidelines are drawn up so that the studies required for designing the projects and future socioenvironmental studies for the river basin can be undertaken, and for the purposes of environmental licensing for the developments. The flowchart in Figure 1.5.04 shows the activities in this phase.

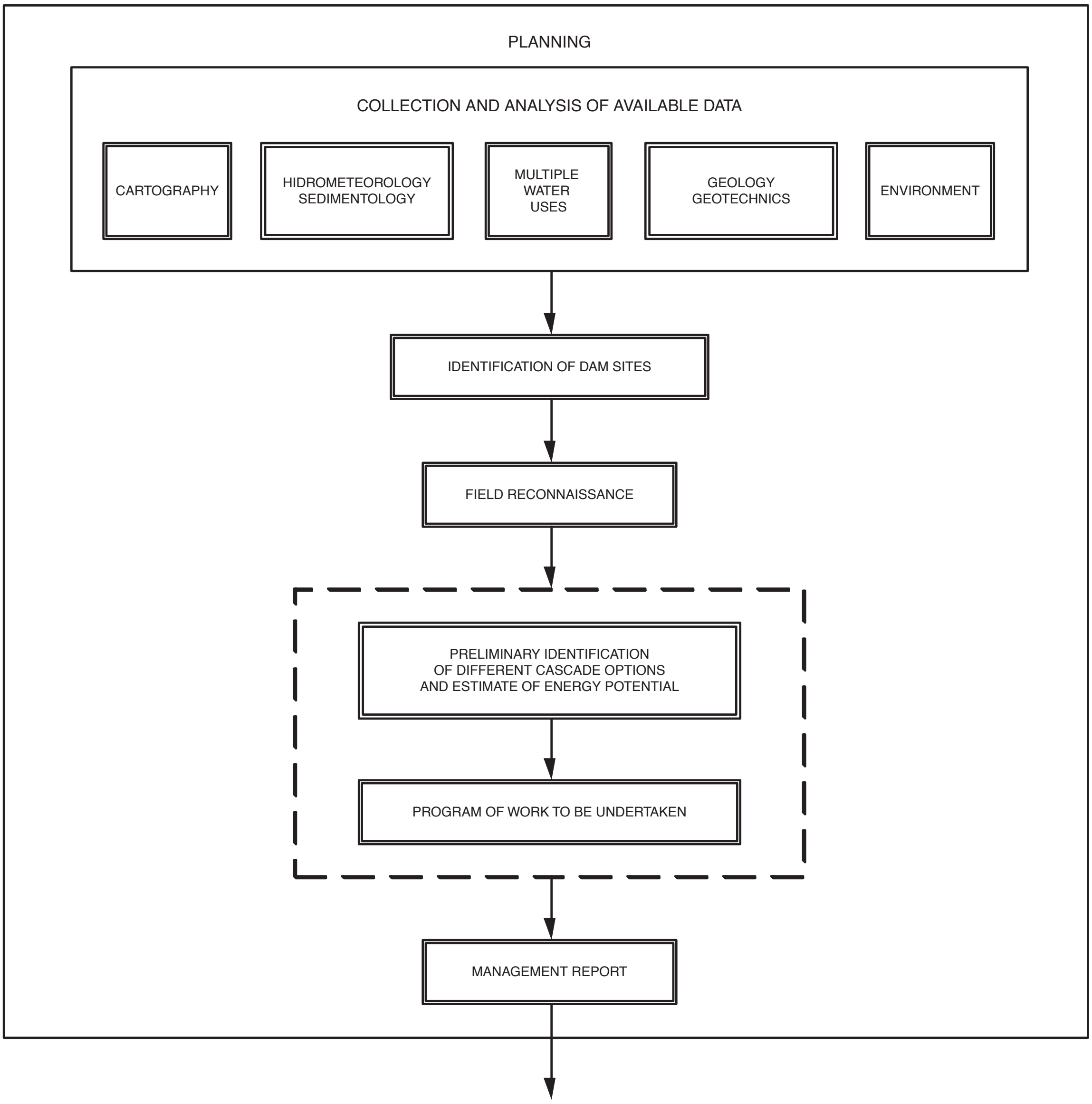


Figure 1.5.01 – Flow Chart of the Planning Phase

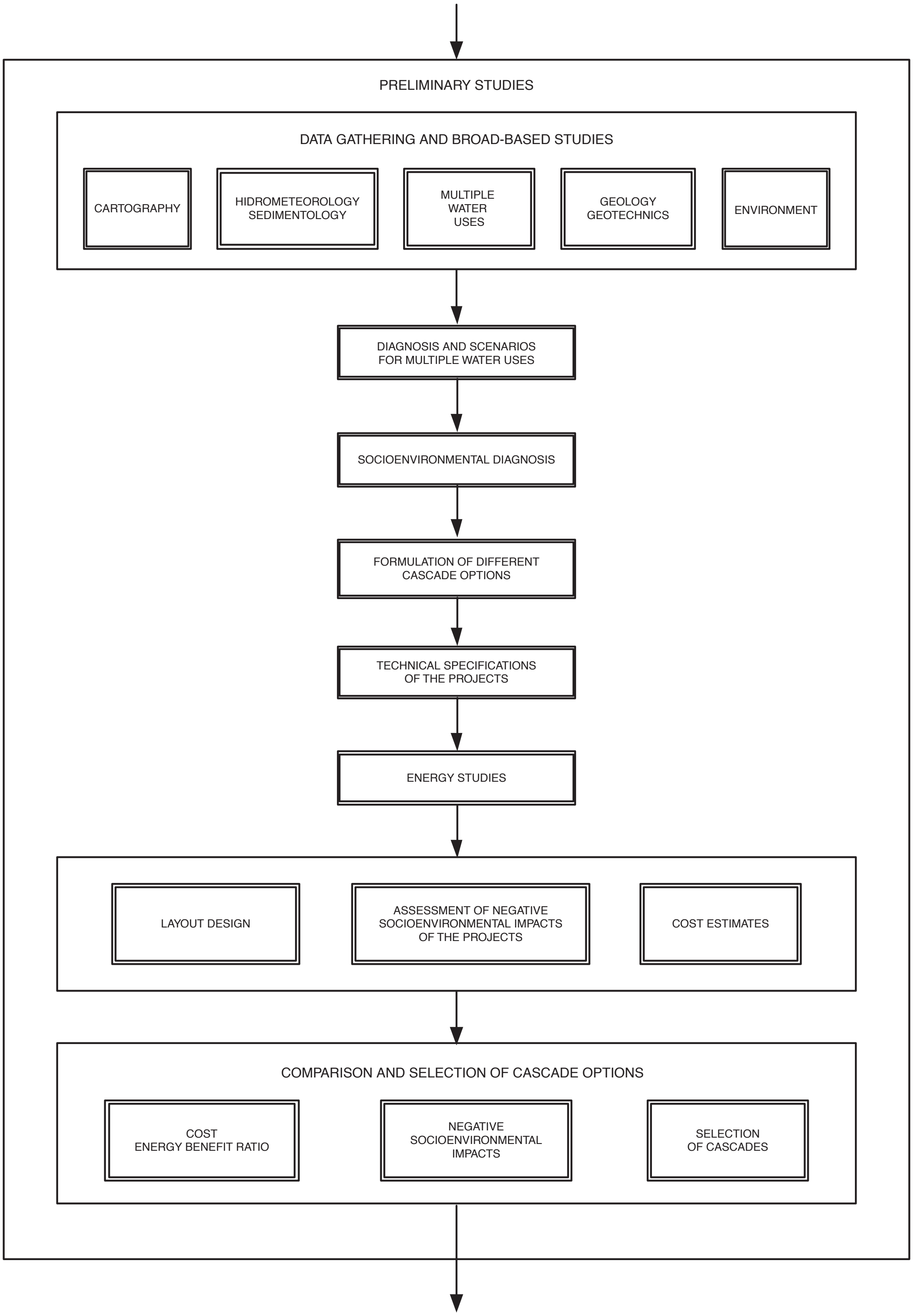


Figure 1.5.02 – Flow Chart of Preliminary Studies

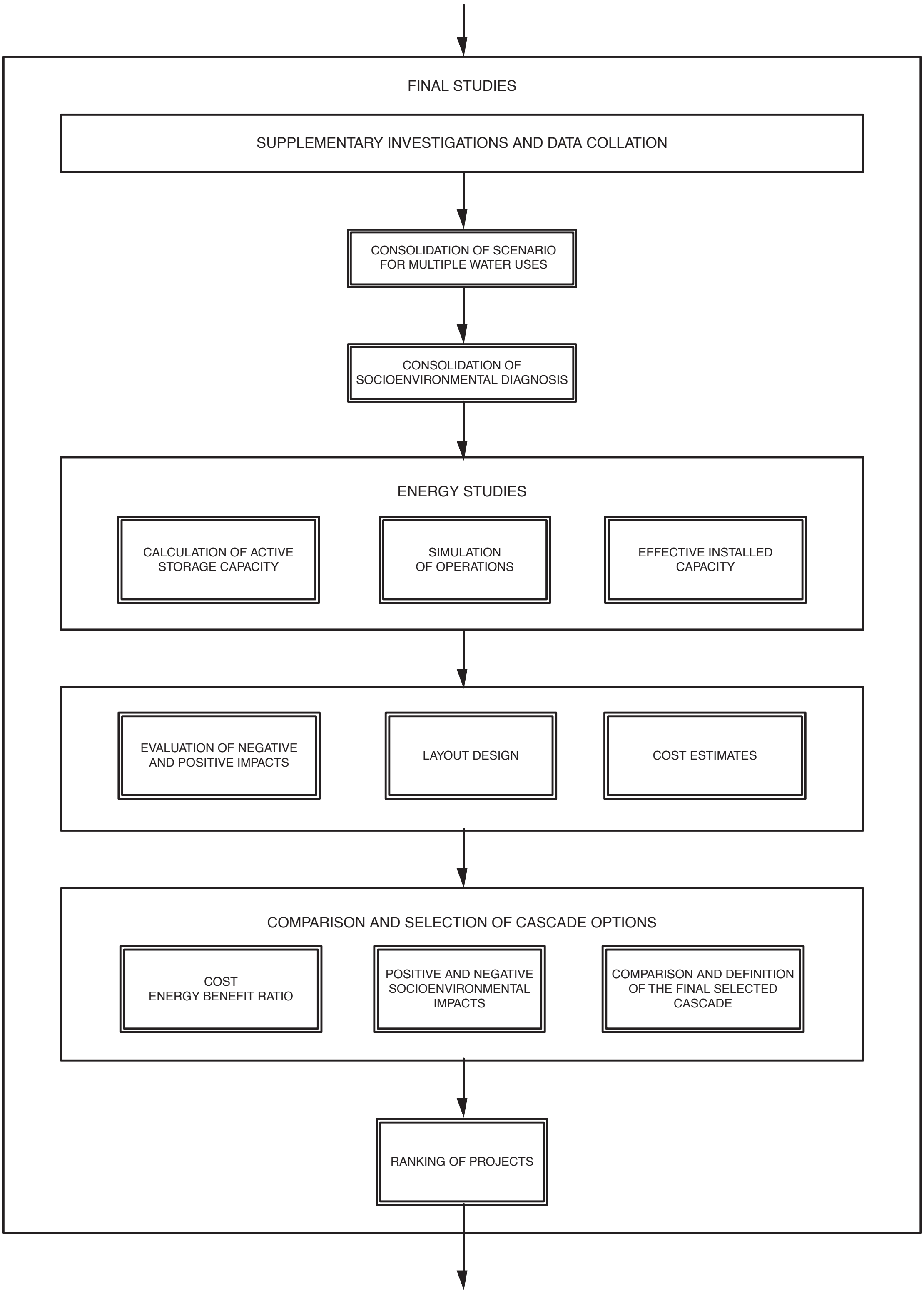


Figure 1.5.03 – Flow Chart of Final Studies

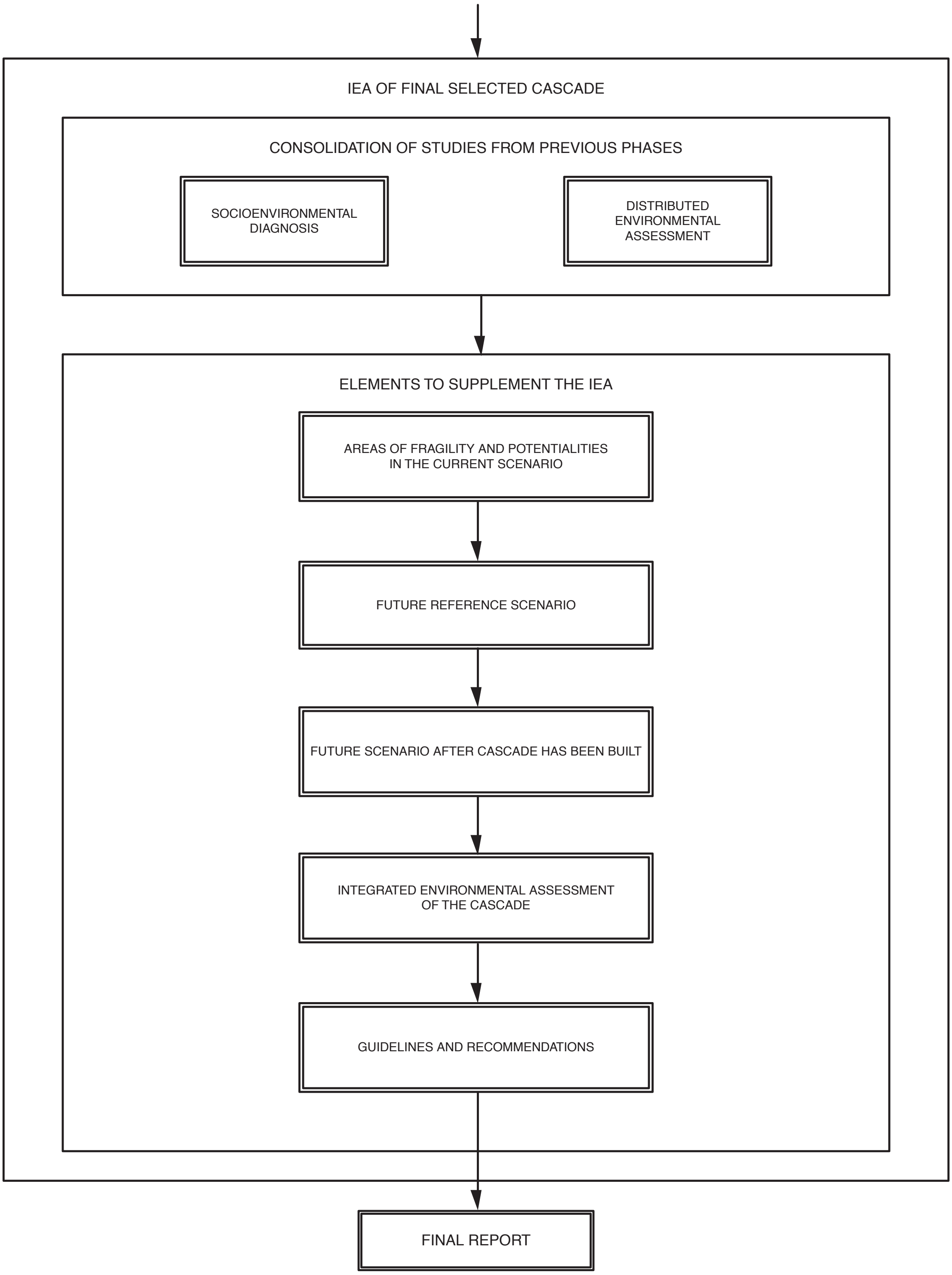


Figure 1.5.04 – Flow Chart for IEA of Final Selected Cascade

1.6 PROCEDURES FOR THE PREPARATION AND APPROVAL OF HYDROPOWER INVENTORY STUDIES

Table 1.6.01 shows the institutional and legal procedures required for preparing a Hydropower Inventory Study.

Table 1.6.01 – Institutional and Legal Procedures for preparing a Hydropower Inventory Study

	Activity	Entity	Regulation	Mandatory
1	Apply to have the Hydropower Inventory Study registered by ANEEL	Main Stakeholder	ANEEL Resolution 393/98 articles 6 and 9	Yes
2	Register the Hydropower Inventory Study	ANEEL	ANEEL Resolution 393/98 art. 6	Yes
3	Notify the Ministry of Mines and Energy (MME) about the beginning of the studies	Main Stakeholder		Yes
4	Notify the other ministries about the beginning of the Hydropower Inventory Study in the river basin	Ministry of Mines and Energy (MME)		Yes
4	Register *Anotação de Responsabilidade Técnica* (ART) with CREA	Professional Responsible	CONFEA Resolution 425/98	Yes
5	Notify ANEEL if the Inventory Studies are abandoned	Main Stakeholder	ANEEL Resolution 393/98 Art 11	Yes
6	Authorize field studies	ANEEL / FUNAI / INPRA / Brazilian Navy / state departments and others		Yes
9	Notify river basin committees, ANA or state water resource and environmental administrators (when applicable) of the beginning of studies	Main Stakeholder	Act 9433/97 and ANEEL Resolution 393/98 Art 13	Yes
10	Carry out the Hydropower Inventory Study in accordance with the terms of this Manual and use the SINV system for energy and socioenvironmental studies and for selecting the cascade options	Main Stakeholder		Yes
10.1	Planning			
	Establish procedures for monitoring the studies	MME / EPE	Act 10.847/2004 Art. 4	Recommended
10.2	Preliminary Studies			
	Submit progress report to MME / EPE and ANEEL	Main Stakeholder	Act 10.847/2004 Art. 4 and ANEEL Resolution 393/98 Art. 10	Yes
	Technical meeting to be called by MME for presentation of the results of this stage	MME		Yes
10.3	Final Studies			
	Send the water resource administration body (ANA or state entity) the information about the consumption of water for other purposes and streamflow information for each project site.	Main Stakeholder		Recommended
	Send ANEEL the streamflow information for the project sites for the final cascade selected using the format described in Annex G.	Main Stakeholder		Yes
	Public meeting to be called by MME to present the findings concerning the final cascade selected and the IEA, and its guidelines and recommendations	MME		Yes
11	Submit studies to ANEEL	Main Stakeholder		Yes
12	Notify receipt of studies	ANEEL	ANEEL Res. 393/98 Art. 14	Yes
14	Give approval of studies	ANEEL	ANEEL Res. 393/98 Art. 14	Yes

1.7 SCOPE OF THE MANUAL

This manual provides guidelines for the studies needed for Hydropower Inventory Studies of river basins anywhere in Brazil. In each real situation, the features of the basin in question should be analyzed by adapting the basic methodology to each case as efficiently and pragmatically as possible, taking into account specific features in each case and consulting the government entities responsible for approving the studies.

It is recommended that an integrated study be made of each river basin, identifying the potential for regulating its streamflow over several years so as to ensure that its economic-energy efficiency is optimized.

Overall, this Manual can only be used for projects that are greater in size than small hydros (over 30 MW). It should be noted that in river basins which could contain some plants over 30 MW as well as others of a smaller scale, these should all be included in the Hydropower Inventory Study.

When Hydropower Inventory Studies are reviewed and/or updated, all available information should be drawn on, giving special attention to the latest socioenvironmental studies and the expected cost of the projects, using the methods set forth in this Manual.

1.8 CONTENTS OF THE MANUAL

This Manual contains seven chapters, one appendix and seven annexes. In each chapter, the references are included as footnotes. All the references are also listed at the end of each chapter and there is also a selected bibliography.

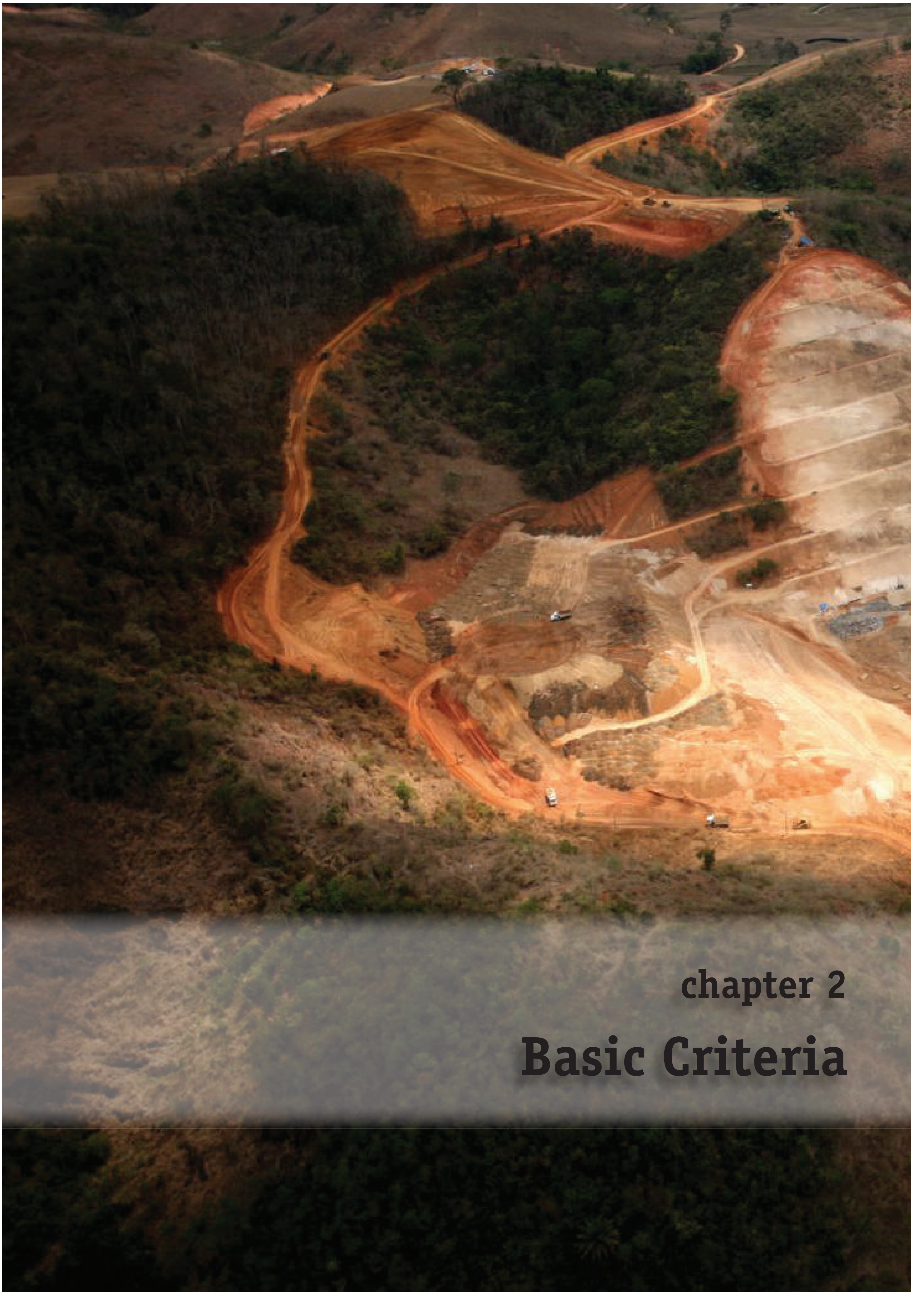
Chapter 1 consists of this introduction and is supplemented by Appendix 1. Chapter 2 sets out the basic criteria, while Chapter 3 gives information on planning Inventory Studies. Chapter 4 contains the procedures for Preliminary Studies, and Chapter 5 contains the procedures for Final Studies. Chapter 6 provides the supplementary procedures for IEA's, and Chapter 7 provides a model for drafting the final report.

Annexes A, B, C, E and G contain lists of the spreadsheets and graphs that are provided in digital format. Annex D sets out the features of the SINV system, version 6.0. Annex F gives a summarized method for IEA's used in three previous Inventory Studies.

1.9 BIBLIOGRAPHY

ELETROBRÁS, *Manual de Inventário Hidroelétrico de Bacias Hidrográficas*, 1997.

MINISTRY OF THE ENVIRONMENT, *Plano Nacional de Recursos Hídricos*, 2006. Available at: http://www.mma.gov.br/port/srh/pnrh.



chapter 2

Basic Criteria

CHAPTER 2

The basic criterion for all Inventory Studies is to maximize economic-energy efficiency, while minimizing negative socioenvironmental impacts and also taking into account any positive socioenvironmental impacts to be gleaned by building hydroelectric projects in the river basin. When these studies are carried out, energy, economic, multiple water use, socioenvironmental and engineering technique criteria must therefore be set.

The energy and economic criteria are directly related to optimizing the hydroelectric potential of the river basin in question, while respecting the portions of head and flow required for other water uses. These criteria will have a direct impact on the goal of maximizing economic-energy efficiency, which, in the comparison of different options, is translated into their respective cost / energy benefit ratios (R$/MWh).

The criteria for multiple water uses involve taking into consideration the other uses of the water resources in the basin, minimizing any conflict and ensuring the efficient use of the water by estimating the amount of head and flow available for electricity generation. As such, a diagnostic study should be prepared during the Preliminary Studies to serve as a source of data for designing a scenario of future multiple water uses for the river basin, which will be used in the Final Studies.

The engineering criteria refer to the use of established solutions in devising the layout of the projects. Users of this manual will have access to a set of information and procedures which will ultimately provide the capacity for the structures to be dimensioned and costs and quantities estimated both simply and quickly. The costs quoted for civil construction and equipment are the mean of the unit prices being charged recently in Brazil. The equipment includes the latest electromechanical technologies.

The criteria of a socioenvironmental nature concern the analysis of the negative and positive socioenvironmental impacts which each cascade option would have on the area under study. The analysis of negative socioenvironmental impacts is necessary to ensure that such impacts are minimized and is instrumental in the selection of the best cascade. The analysis of positive socioenvironmental impacts is a factor that influences the final selection of the best cascade.

The socioenvironmental criteria should be taken into consideration when the different cascades and projects are devised, so that the different cascades can be compared and selected in view of two indexes which express the intensity of the negative and positive impacts individually on the area under study.

As this is a study that is used for sector planning, the main benefit is the generation of electricity, which is achieved by maximizing the economic-energy efficiency of the river basin. However, the analysis of potential positive impacts is also included with a view to elucidating how social and economic development both locally and regionally could be boosted by the introduction of the hydropower projects. This analysis feeds into the subsequent stages of the planning cycle for these projects (Feasibility Studies, Basic Design, etc.) and identifies what coordination needs to be established between different institutions for this potential to be realized.

The positive socioenvironmental impacts are only included in the analysis for the purposes of making the final selection of one cascade in the Final Studies. In the Preliminary Studies, when a number of cascades are shortlisted to be analyzed in greater detail in the Final Studies, the focus should still be on maximizing economic-energy efficiency and minimizing negative socioenvironmental impacts, and any that fail to meet either or both of these criteria should be eliminated.

It should be noted that in order to take full account of these four groups of criteria, the aspects that are included in the cost/benefit indexes as construction costs (control and compensation costs) should not be included in the negative socioenvironmental impact index. In other words, this index should only cover externalities brought about by the negative impacts identified in the study area, such as changes to the way of life of the local people or lost natural habitats.

For the assessments of socioenvironmental criteria and multiple water uses, the local social and economic development trends should be taken into account, as set out below:

- for evaluating multiple water uses in the river basin, forecasts should be prepared on a time frame that is compatible with the National Plan for Water Resources. The future scenario should be comprised of the criteria set out in item 2.2.
- the socioenvironmental assessments undertaken in the Preliminary and Final Studies must take into account the current socioenvironmental situation in the region under study and its development trends as identified in the socioenvironmental diagnostic study, including any regional development policies, plans or programs, be they by federal, state or municipal entities, as well as all water resource plans and any other sector plans or programs.
- in the Integrated Environmental Assessment (IEA) of the cascade selected in the Final Studies, scenarios must be prepared for the future development of the region under study following the guidelines set out in chapter 6 and in compliance with the recommendations in this chapter.

2.1 ENERGY CRITERIA

The evaluation of the energy potential of the cascades under study should take into account the following basic criteria:

2.1.1 Reference System

A reference system is defined as the set of electricity generation plants which the energy benefits of the cascade options under examination should be quantified against. The reference system should be the power system that the projects under study would be connected to and must be defined by the concession-granting authority.

2.1.2 Critical Period

The critical period of a reference system is the period of time from the streamflow records when the reservoirs of the system were fully used, without any deficit, at the beginning of which time they were full and at the end they were totally depleted, without their replenishing completely during the period in question. The critical period to be adopted in the Inventory Studies will be defined by the concession-granting authority. In 2007, when this manual was published, the critical period adopted for the National Interconnected System ran from June 1949 to November 1956 (90 months).

2.1.3 Energy Benefits

When one or a group of hydroelectric power plants are integrated into a system, this brings about three kinds of energy benefits: firm energy, secondary energy and peaking capability.

A system's **firm energy** is the greatest load the system can provide without any deficits occurring under the worst hydrological conditions recorded for the series of natural streamflows.

Secondary energy is the energy that is available only during favorable hydrological periods, and can be used to meet the needs of consumers with intermittent load requirements or to substitute thermal power generation, bringing about fuel savings.

Peaking capability is the maximum amount of energy a system can produce during peak demand periods. It is directly correlated to the plants' installed capacity, so when calculating it, one should also take into account all losses caused by reduced head when reservoirs are depleted and/or the level of the tailrace is high, as well as scheduled and unscheduled shutdowns.

In Inventory Studies, firm energy is the most important variable when analyzing the benefits of any given cascade. In this manual, secondary energy is not taken into consideration at this stage, basically because of the great uncertainty as to its effective use. However, it may be taken into account if the concession-granting authority deems it desirable, in which case the authority will be responsible for determining how it should be calculated. By the same token, in isolated hydrothermal systems, secondary energy may be a decisive factor in correctly dimensioning a hydroelectric project.

Peaking capacity benefits are included indirectly. All projects are pre-dimensioned to have a common reference capability factor (item 2.1.4), which allows the respective energy benefits to be compared consistently from the perspective of the corresponding peaking capacity benefits.

Firm Energy

In Inventory Studies, the firm energy from one hydropower plant or group of plants is the mean energy generated by the plant or group of plants obtained in simulations of the operation of the system during the critical period of the reference system, as described in item 5.3.1. In the Preliminary Studies, rough estimates can be made based on the formulas given in items 4.6.1 and 4.6.2.

Firm Energy Contribution

The firm energy contribution from one hydropower plant or group of plants is the extra firm energy generated when this project or group of projects is added to the others in the river basin. Generally, this increase is the same as or greater than the firm energy of the projects analyzed, since the addition of new projects can sometimes cause the contribution by other plants in the same river basin to rise because of the effects on their regulation reservoirs. Should the water level in the tailrace canal of the project in question be lower than the water level in the reservoir immediately downstream, there may be energy losses for those immediately upstream.

As with firm energy, the firm energy contribution can be calculated by simulating the operation of the system during the critical period of the reference system, as described in item 5.3.1. In the Preliminary Studies, rough estimates can be made based on the formulas given in item 4.6.3.

Minimum Firm Energy Contribution

Before construction work begins, a minimum firm energy contribution must be set for any new project, below which level it will not be included in any cascade option. This minimum will vary according to the region and the reference system, and should be set by the concession-granting authority.

2.1.4 Energy Dimensioning

In the energy dimensioning of projects, the maximum reservoir drawdown must be determined, as must the installed capacity and the reference head. The installed capacity is the combined capacity of all the generators. The reference head is the net head at which the turbines, with their distributors fully open, will supply the installed capacity. Generally speaking, the optimal values for a given project will depend on the cascade it is part of. However, in Inventory Studies there is no need to consider the outcome of the different energy dimensioning activities for a given project in every cascade it is part of; it is enough to carry out the energy dimensioning of the project for the cascade where it will have the highest installed capacity. This approximation can be used when there is no great difference between the different energy dimensions calculated. However, when the energy dimensioning of a given project for two different cascade options gives rise to quite different results, it is recommended that two projects be created and analyzed separately for the same dam site.

Maximum Drawdown

When the hydroelectric potential of a river basin is being harnessed, every effort should be made to ensure that the projects are designed to have some storage capacity so that energy can be generated during drier periods by harnessing the water stored during rainy periods. However, when reservoirs are drawn down too low, there is a loss of head and a resulting drop in generating capacity. A value for maximum drawdown or live storage should therefore be set for each project by a process of optimization, based on the firm energy contribution by the project when it is integrated into the cascade taken as the basis for the energy dimensioning. Even so, special attention should be paid to the reservoir replenishment time, which should not exceed 36 months after the end of the critical period. The procedure for calculating this in the Preliminary and Final Studies is described in items 4.6.6 and 5.3.4, respectively.

Reference Head for Inventory Studies

For the purposes of Inventory Studies, the reference head is taken as the average net head of the project, which is defined as the difference between the mean level in the reservoir and the water level in the tailrace at a flow rate that is 10% greater than the mean flow during the critical period for the reference system, or the maximum normal water level of the reservoir downstream, when this is greater than the previous level, minus hydraulic losses (item 4.6.1). When using energy simulation models, the water level in the tailrace for calculating the reference head is the mean water level in the tailrace of the project throughout the critical period of the reference system.

Reference Capacity Factor (F_k)

When analyzing peaking capacity benefits, the energy calculations for the projects make use of the same reference capacity factor so that the comparisons between the energy benefits of different projects are consistent. This factor represents the ratio between the sum of the firm energy from the projects in the reference system and their respective installed capacity.

The capacity factor can be calculated by the following expression:

$$F_k = f_c*(1-P_p)*(1-r)/(1-P_e) \quad (2.1.4.01)$$

Where:

f_c	load factor of the market to be supplied by the reference system;
P_p	peak power loss factor in the transmission system;
P_e	power loss factor in the transmission system;
r	generation reserve factor of 15%.

In the absence of more reliable information, it is recommended to use F_k = 55%.

Installed Capacity (P_i)

This is obtained by applying the reference capacity factor to the firm energy to be obtained from the project when it is integrated into the cascade option taken as the basis for the energy dimensioning, as shown below:

$$P_i = \frac{Ef_i}{F_k} \quad (2.1.4.02)$$

Mean Net Head

When undertaking energy dimensioning for hydropower projects, generation of the installed capacity should be assured with the turbine distributor fully open and with the mean net head, corresponding to the level of reservoir drawdown representative of the drawdown level during the operation of the project during the critical period of the reference system. The mean net head is the mean of the net heads calculated for the project under study in simulated operations of the system throughout the critical period of the reference system, as per item 5.3.1, assuming the project is part of the cascade taken as the basis for the energy dimensioning. Estimates can be used in the Preliminary Studies as shown in the formulas in item 4.6.1.

2.2 CRITERIA FOR MULTIPLE WATER USES

By the terms of Act 9.433 of January 8th 1997, the National Policy for Water Resources is based, among other criteria, on the principle that the management of all water resources should always provide for multiple uses of the waters. Although Hydropower Inventory Studies do not go into the same the breadth or detail as river basin plans, in the assessment and comparison of the different cascades in the Final Studies they must still take into account multiple water uses and the interaction between these and the proposed hydropower projects so as to minimize potential conflicts and ensure the most efficient use of the resources available. This being the case, the current uses of the waters should be identified and a long-term scenario should be designed for their multiple uses in the river basin. This is the scenario used for the assessments of the energy benefits and the positive and negative socioenvironmental impacts of the different cascades. The assumptions used to build up the scenario for multiple water uses are also applied to the scenarios for the integrated environmental assessment of the cascade that is selected (chapter 6).

2.2.1 Diagnosis and Scenario for Multiple Water Uses in the River Basin

In order to design a scenario for long-term multiple water uses that is in line with the National Policy for Water Resources, a diagnostic study must first be made of the current uses of the waters in the river basin under study, drawing on pre-existing data and information.

Having done this, a scenario is designed that is compatible with the time frame of the National Policy for Water Resources. One of the cornerstones of this future scenario should be whether the projected uses of the waters in the river basin are actually reasonable. Likewise, the analysis of existing sector plans must be underpinned by the principle of feasibility. Evidently, as the design of a future scenario has a strong subjective element, there must be clear motivations and justifications used throughout, especially when existing plans are not followed in the full.

As such, the primary source of information should be the data gathered in the Planning stage (item 3.1.3), especially: a) estimates of water consumption prepared by the National Water Agency (ANA) and by the state entities with responsibility for water resources; b) the National Plan for Water Resources, state plans for water resources and river basin plans; c) integrated development master plans, irrigation programs, navigation studies, flood control studies, and water supply studies for human, animal and industrial use; and d) non-consumptive uses, such as tourism, leisure, preservation of the landscape and environmental conservation areas; all with a view to obtaining a realistic, balanced portrayal of the potential for development in the water basin.

2.3 SOCIOENVIRONMENTAL CRITERIA

The criteria adopted for the socioenvironmental studies adapt the methodological instruments and widely-used procedures for environmental impact assessments to the requirements and specificities of Hydropower Inventory Studies. These are supplemented by the procedures used in Integrated Environmental Assessments. Together, these criteria (presented below) serve to systematize the information gathered about the main socioenvironmental issues, identifying areas of environmental fragility and socioeconomic potentialities, as well as the main synergistic and cumulative effects resulting from the introduction of the cascade selected. They should also influence the design of the projects and the formulation of the cascade options, while also supplying information for the cost estimate of the construction work and providing the means for the cascades to be compared and selected using a multi-objective approach.

The results of the socioenvironmental studies should indicate guidelines for future studies, environmental licensing, the building of the hydroelectric projects and, in particular, the issues to be focused on during the Feasibility stage.

2.3.1 Study Area

The study area should be defined in such a way as to allow for an analysis of the socioenvironmental processes inherent to the river basin being studied, which should be included in its entirety. It should also make it possible to identify and assess the impact processes resulting from the harnessing of its hydroelectric potential.

The borders of the study area should be defined at the Planning stage, and may be adjusted as the work proceeds. In this process, the specific features of the socioenvironmental processes being addressed should be respected, which often spill out beyond the physiographic limits.

2.3.2 Environmental System

An environmental system is the set of elements in the study area, including their features or qualities, the functions they play in the different processes and how they interact.

When analyzing an environmental system, the physical, biotic, social, cultural, economic and political processes should be taken into account, as well as the way these are interrelated and how they impact on the physical space, all of which requires a multi- and inter-disciplinary approach.

2.3.3 Synthesis Components

An analytical structure is used to represent the environmental system, comprising six elements, called **synthesis components**: aquatic ecosystems (and water resources), territorial ecosystems, ways of life, territorial organization, regional economy and indigenous peoples / traditional communities.

These **synthesis components** are structured according to the interactions amongst different elements from the environmental system. The assumptions behind their conceptual definition and the structuring of their analytical content are:

- to develop an understanding of the integral nature of the processes by which the socioenvironmental elements interact;
- to elucidate the most important issues arising from the interactions between the projects/cascades and the study area; and
- to enhance the capacity to select or differentiate between the different cascades under study.

The term "synthesis component" is intended to express a sense of interaction between the different environmental elements, or **characterization elements**, that comprise the synthesis component in question, giving an idea of the combined processes involved in the analysis. It should be noted that some characterization elements exist in more than one synthesis component, taking on different functions according to the processes inherent to each one. These elements are not grouped under the categories traditionally used in socioenvironmental studies (physical, biotic and human environments), but rather each synthesis component will represent a synthesis of characterization elements from these three categories.

Physical Processes and Features

Physical processes and features are an integral part of all the synthesis components. They have stable interrelations and features, and can be of a permanent or temporary nature. As such, these are the elements which ensure the continuation and interaction of the biological and human relations. As physical processes and features provide support and interconnectivity for the socioenvironmental processes, they are not regarded as a separate synthesis component, but are a basic element in the analyses of the six synthesis components adopted.

2.3.4 Sub-Areas

The studies undertaken at the diagnostic study stage should involve the spatial segmentation of the reference situation in each synthesis component in the study area into sub-units, here called **sub-areas**, by analyzing their similarities and differences. The sub-areas are continuous units of land which contain particular relationships and processes that mark them out from the others and which determine their relationship with the dynamics of the synthesis component in the study area as a whole. By using this methodology it is possible to identify the impacts of each project and how they interact with the synthesis components in each sub-area, while also providing a broad view of the set of impacts caused by the projects in each sub-area and those which extrapolate the borders of these areas.

2.3.5 Sensitivity, Fragility and Potentialities [1]

- The **sensitivity** of an area can be defined as "*the extent to which environmental systems and ecosystems react when they are affected by human action, in such a way that their qualities are altered.*" [2] In this manual, the term is used to identify and map out the most sensitive areas in the sub-areas of the river basin, expressing the integrity of the natural resources, the qualitative aspects of the landscape and the different socioeconomic situations in terms of their different degrees of sensitivity.

1 The definitions presented in the IEA's for Doce river basin, EPE/ Sondotécnica, 2007

2 Iara Verocai, 1990, Vocabulário Básico de Meio Ambiente, RJ, quoted in EPE/ Sondotécnica - AAI do Rio Doce, 2007

- The **fragility** of an area can be defined as "*the degree of susceptibility to damage in the face of given actions.*"[3] In this manual, the term is used to identify and map out impacts resulting from the introduction of hydropower projects in areas characterized as sensitive. This will be done as part of the IEA for the alternative selected.
- The **potentialities** of an area are associated to the existence of aspects that could benefit as a result of the introduction of hydropower projects, i.e. which represent opportunities for developing the socioeconomic conditions in the study area.

2.3.6 Assessment of Socioenvironmental Impacts

The aim of the assessment of socioenvironmental impacts is to help compare and select the cascade options and pinpoint the main socioenvironmental issues related to the individual projects and groups of projects.

In the analysis of the socioenvironmental impacts of any cascade, all the projects are considered jointly.

The criteria adopted for assessing the impacts and obtaining the socioenvironmental impact indexes for the purposes of the proposed studies are set out below:

- **Negative Socioenvironmental Impacts:** potentially unfavorable alterations caused by a project or group of projects on a synthesis component or on the socioenvironmental system, taking the current state of the study area and its development trends as a reference.

  The assessment of negative socioenvironmental impacts should include identifying any unfavorable alterations, any actions which could prevent the impacts from occurring either fully or partially (control), any actions that could mitigate the consequences of the impacts (mitigation) and any actions that may offset the impacts when reparation is not an option (compensation). These actions will be translated into costs, then incorporated into the overall cost of the project as socioenvironmental costs (item 2.7.3). The negative socioenvironmental impacts that cannot be controlled or the residual impacts when some control, compensation or mitigation is possible (degradation costs) will be evaluated and translated into a negative socioenvironmental impact index, which will be associated to the objective of minimizing negative socioenvironmental impacts.
- **Positive Socioenvironmental Impacts:** potentially favorable alterations caused by a hydroelectric project or group of projects, taking the current state of the study area and its development trends as a reference. This only relates to the socioeconomic impacts by which the hydropower projects may make a positive contribution to local or regional socioeconomic development, as described in item 5.4.2.

  Assessments of positive socioenvironmental impacts should include identifying favorable alterations, which are then translated into a positive socioenvironmental impact index. This is one factor that is considered in the final selection of one cascade, which takes place during the Final Studies.

  Any effect the environment may have on the planned projects should, whenever possible, be identified and incorporated into the engineering plans. However, these are not included in the socioenvironmental indexes.
- **Impact Process:** this is a set of alterations that could be triggered by a project or group of projects on the pre-existing natural and social processes in the study area; any given impact process is associated with environmental impacts that are interrelated on the level of the synthesis component.

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3 Angel Ramos, 1987, apud Iara Verocai, Vocabulário Básico de Meio Ambiente, RJ, 1990 – quoted in EPE/ Sondotécnica – AAI do Rio Doce, 2007

- **Impact Indicator:** this is an instrument that guides the assessment of the socioenvironmental impacts of a project or group of projects on a synthesis component, thereby establishing the focus of the analysis. Impact indicators are a combination of one or more variables, or **assessment elements**, used to characterize one or more effects to be expected at a site or sites in a river basin.

  Impact indicators are formulated by identifying the main impact processes and organizing the data into **assessment elements**. These correspond to the previously defined **characterization elements**.

  Descriptions are provided in items 4.3 and 4.8 of the characterization elements and assessment elements that have been devised to cover the vast majority of situations encountered across Brazil. However, the information to be used in each specific study should be selected and supplemented as necessary.

  The assessment elements selected to formulate the impact indicators in each case should be such that the cascades being compared can be effectively differentiated, without losing sight of the overall set of environmental processes involved. It is also important to strike a balance between quantitative and qualitative assessment elements, so that the analysis does not merely include the most readily quantifiable aspects. The assessment elements must also be capable of highlighting the processes that are cumulative and synergistic.

- **Assessment Criteria:** for each of the indicators, assessment criteria must be defined, which serve to determine the degree of impact involved.

- **Socioenvironmental Index:** this is the numerical figure that will represent the intensity of the socioenvironmental impact. It runs on a scale from **zero** (minimum impact) to **one** (maximum impact).

  The negative socioenvironmental index of a project or group of projects is the result of assessing the negative impacts on a synthesis component. Meanwhile, the negative socioenvironmental index of a cascade for the same synthesis component is obtained by combining the negative socioenvironmental indexes of the projects that make up the cascade, using the procedures described in items 4.8, 4.11.2, 5.4 and 5.8.2.

  The negative socioenvironmental index of a cascade represents its total negative impact on the study area, translating the extent to which it meets the objective of minimizing the socioenvironmental impacts. In order to obtain this index, all the negative socioenvironmental indexes for all the synthesis components should be combined, using the procedures and mechanisms set described in items 4.11.2 and 5.8.2.

  The positive socioenvironmental index for the socioenvironmental system under analysis is calculated per cascade option in the Final Studies, using the procedures and mechanisms described in item 5.4.2, which already take account of the cumulative and synergistic effects in the assessment. The positive socioenvironmental impact of a cascade is an aggregate of the indexes for each of the aspects, giving the total positive socioenvironmental impact of the cascade on the study area, as described in item 5.8.3. It should be used in the final selection of one cascade.

Cumulative and Synergistic Impacts

Cumulative and synergistic impacts are caused by the combination of one or more human actions with other past, present or future actions, triggering changes to the environment. Cumulative impacts result from the aggregate interaction of these alterations in a given space with time. Impacts are considered synergistic when the result of these interactions brings about an alteration to a given space that is different than the sum of the alterations.

Cumulative and synergistic impacts should focus primarily on permanent alterations, since temporary impacts will fade with time and their cumulative effect will be reduced.

2.3.7 Integrated Environmental Assessment

The cascade selected in the Final Studies should be the object of an Integrated Environmental Assessment (IEA) with the purpose of highlighting the cumulative and synergistic effects resulting from the negative and positive socioenvironmental impacts brought about by the group of projects it includes, as identified in the Preliminary Studies and taken into account in the selection of the cascade in the Final Studies. This assessment seeks to identify any areas of fragility or potentiality in the river basin under study, and should involve preparing future scenarios for the development of the river basin as described in item 6.5. As a result, guidelines should be prepared to be incorporated in future socioenvironmental studies for hydropower projects, which will serve to enhance future environmental licensing processes and provide recommendations for future projects.

2.4 CRITERIA FOR SELECTING DAM SITES

In the study to find sites suitable for dams, all the sections with rapids and waterfalls should be given special attention, as should any site where there is a marked narrowing of the river valley. Likewise, any restrictions imposed by physical, social and economic factors must also be addressed.

For each dam axis, the maximum water level the reservoir could reach should be calculated.

Maps and river profiles should be prepared for the sites, providing the basic information needed to formulate the different cascade options. The criteria to be adopted in each case will depend on the technical assessment of the topographical, geological, geotechnical, hydrological and socioenvironmental parameters.

2.5 CRITERIA FOR PROJECT LAYOUTS

Each site that is chosen for a hydropower plant has its own unique topographical, geological and hydrological features. As no two sites are the same, designing the right layout is a creative process that is normally the result of an iterative process, where several different cascades are devised, dimensioned and have their costs estimated in order to find the best one. By definition, the best layout for any hydropower project will be the one that manages to organize all the different elements in such a way that an adequate level of safety is assured, as well as ease of operation and maintenance, and all at the lowest overall cost. However, for the sake of standardization and whenever feasible, a set of basic criteria can be used to account for the majority of the solutions used in Brazil. The main recommendation for Inventory Studies is to adopt conservative, robust project layouts.

Project Elements

First, it is important to list all the elements that may be included in the layout of a hydropower project:

- **dam** – this is a structure made of earth or concrete that is built across the river valley from the abutment of one bank to the other with the purpose of raising the water level in the river to the normal maximum level of the reservoir;
- **dike** – usually made of earth, this structure closes off any saddles, so as to prevent any water flowing out of the reservoir;
- **river diversion system** – this is normally next to the dam and has the purpose of diverting the water from the river through canals, galleries, sluiceways, tunnels or even narrowing the river bed so as to allow the structures to be built on the river bed in the absence of water;
- **hydraulic conveyance facilities** – this includes headrace canals, intakes, conduits or tunnels, and possibly also surge tanks or forebays, pressure penstocks, a surface or underground powerhouse, and tailrace canals or tunnels. The purpose of the hydraulic conveyance facilities is to channel the water in such a way that mechanical energy can be transformed into electrical energy;
- **spillway structure** – this comprises an approach channel, a gated or ungated spillway, an energy dissipator and a downstream channel. As with the hydraulic conveyance facilities, the spillway structure can be near or far from the dam, depending on the specific features of the site under study;
- **bottom outlet** – structure containing gates or valves to release the waters downstream from the dam;
- **navigation system** – these are structures that allow cargos or passengers to navigate upstream or downstream, overcoming the difference in water level brought about by the impoundment;
- **fish passage system** – this is a structure that provides the means for aquatic fauna to migrate upstream or downstream, overcoming the difference in level brought about by the dam.

Dam

The location of the dam axis and the hydraulic conveyance facilities are crucial in finding the most economical layout for projects on rivers with marked differences in water levels, including waterfalls and rapids. In these cases, the dam axis should normally be upstream from the concentrated head as this will reduce the height of the dam and therefore its cost.

- **Types of Dam** – In Inventory Studies, the kind of dam to build depends greatly on the topography of the site and the geotechnical conditions of the foundations along the axis, not to mention the availability of building materials nearby. As this stage tends to involve auger boring, inspection pits and occasionally geophysical surveys, the geotechnical information available about the real state of the foundations is very limited. For this reason, projects involving traditional dams should be planned, rather than other kinds, such as concrete arch dams, multiple arch dams or buttress dams. Rockfill dams with concrete facing may be considered, providing there is no doubt as to the quality of the sound bedrock for the foundations of the plinth.

- **Geomechanical Parameters of the Foundations** – As the dam foundations are generally the single most important geological factor, they must have geomechanical parameters that are as good as or better than the parameters for the body of the dam. Based on this criterion, conventional or roller compacted concrete dams should not have soil or weathered bedrock foundations, but only foundations of good quality sound rock. Similarly, the foundations for rockfill dams can be made of weathered rock provided it can provide sufficient support.
- **Impermeability of the Foundations** – When homogeneous soil is used for earthfills, a cut-off trench must be built that reaches the impervious layer of the foundations. For rockfill dams with a central or inclined clay core, the cut-off must be a continuation of the core, going downwards until it reaches the top of the sound bedrock.
- **Materials Management** – Another important geotechnical factor is to strike a balance between the excavations required for the structures, the volumes of rockfill and earthfill and the materials to be used to make up the concrete. As this balance depends on the real construction schedule, there may be a need to keep intermediate stocks or to use extra borrow areas.

  These factors can raise costs and distort the original estimates. For this reason, it is best to aim for a flexible project layout and factor in losses of between 10% and 20% as a function of the use of material from excavations, depending on the size of the construction work. The need to move this material from one bank to the other should also be taken into account.
- **Construction Aspects** – Another important geotechnical factor has to do with the constraints on using different kinds of dam. For instance, earthfill or rockfill dams with a clay core should not be built in regions where it may rain all year round.

River Diversion

The river diversion scheme should be planned to have the capacity to discharge the design flood. The choice of diversion will depend on aspects of the project layout, such as the kind of dam, its height and length, and the kind of spillway, both of which depend on the particular topography of the site, as well as the estimated design flow and the geological features of the region.

Generally speaking, the choice of the diversion system boils down to the choice of the kind of structure to discharge the design flood (item 4.1.2) during the second phase of the diversion. The first phase of diversion, when necessary, comprises cofferdams used for the construction of the structure for the second phase.

The cheapest and most widely used method for diverting a river is to use **sluiceways**. Built through concrete dams or under the ogee crest of the spillway, sluiceways are normally used in **broad river valleys**. Normally, the river is first narrowed by a first-phase lengthwise cofferdam, which excludes water from one section of the river so that the dam or spillway, which will contain the sluiceways, can be built. Next, once the part of the structure needed to divert the river has been built, the river is diverted through the sluiceways, and the narrowed part of the river is cut off with second-phase cofferdams so that the construction of the dam and/or spillway can be completed in this newly dewatered section. Notwithstanding the complexity of the logistics, the use of a definitive structure for diverting the river and the shortening of the construction schedule more than offset the time and cost of building and removing the cofferdams.

Project layouts with abutment spillways normally involve diverting the river through **tunnels**, and are used in **narrow river valleys**. The tunnels, along with the approach and downstream channels, can normally be built without using cofferdams. Once they are built, the river bed is closed off and construction of the dam begins. When dams are planned that will involve diverting the river through tunnels, it is worth checking the economic feasibility of using them as bottom outlets, with a view to reducing the construction costs for the spillway system.

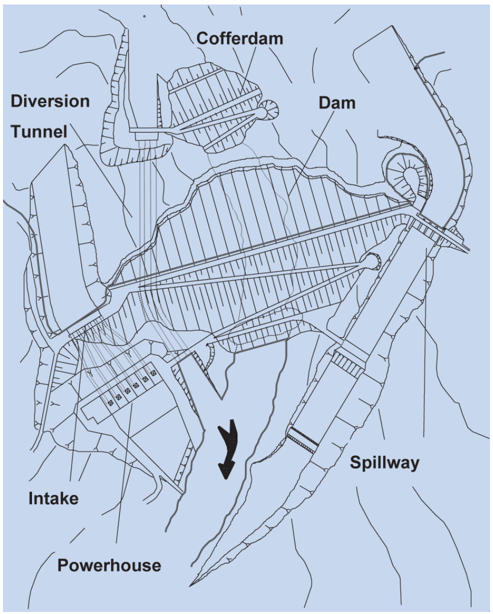


Figure 2.5.01: Typical Layout in a Narrow River Valley
(Foz do Areia Hydropower Plant - Governador Bento Munhoz da Rocha, Iguaçu river, South of Brazil)

Generally speaking, galleries are recommended for areas with small design flows and when there is space on the lower part of the abutment for them to be built in the dry or when it is not geologically feasible to use tunnels.

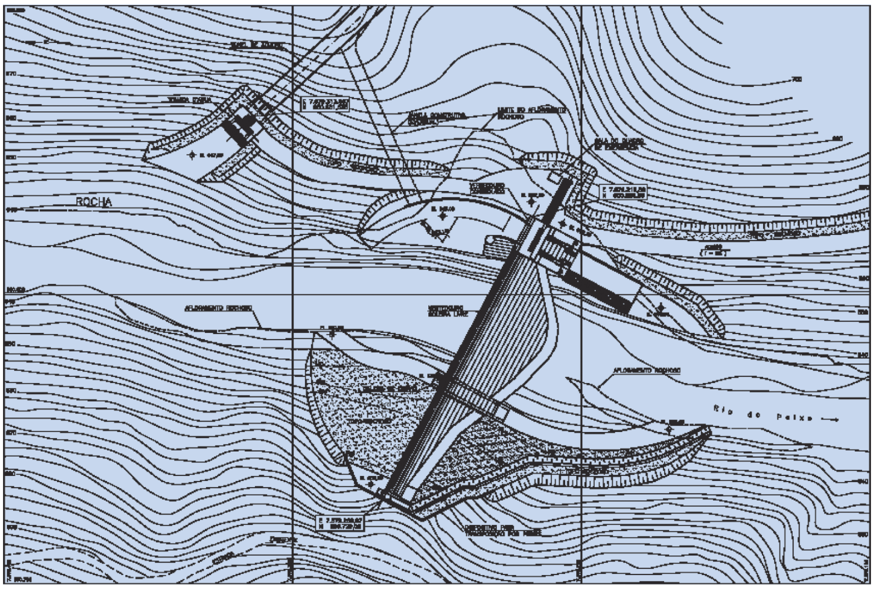


Figure 2.5.02: Design of Picada Hydropower Plant (Peixe River, Southeast of Brazil)

One particular kind of layout in **broad river valleys** with a low dam, when the ogee crest of the spillway is not high enough to have sluiceways built, is to do the diversion in two phases but with the second phase over the leveled or unleveled crest of the spillway.

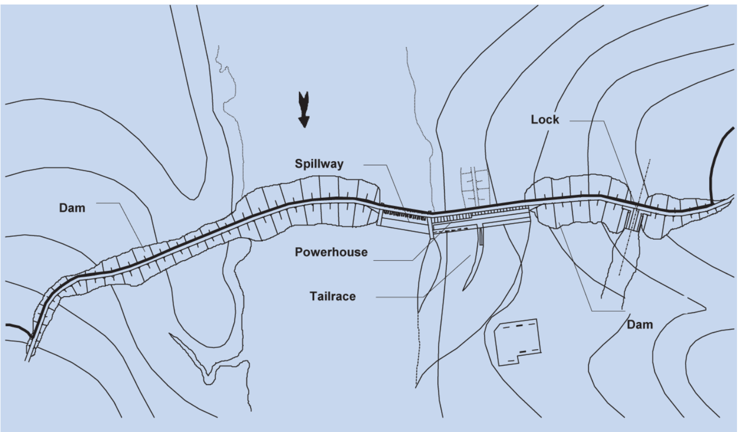


Figure 2.5.03: Typical Layout in a Wide River Valley (Tucuruí Hydropower Plant, Tocantins River, North of Brazil)

Spillway Structure

The spillway structure should be designed to pass the design flood (item 4.1.2) without exceeding the maximum normal water level in the reservoir and reducing the flood storage capacity. This limitation is attenuated at the Feasibility stage, when more information is gathered about the reservoirs, floods and the possibility of discharging flood flows without causing damage downstream. Whenever possible, spillways should be ungated or have tainter gates; normally, there is no need to have emergency spillways or fuse plug spillways to reduce the flood discharge capacity required by the authorities. These limitations are reviewed at the Feasibility stage, when more and better quality information is made available about the topography of the reservoir and the location of the structures, as well as on the floods and the geological state of the foundations. Space permitting, a spillway with a high ogee crest is used; otherwise, use an abutment spillway.

For layouts which have sections with a low flow rate between the dam and the tailrace canal, bottom outlets or valves should be planned to assure that the flows are ecologically and sanitationally acceptable. Using bottom outlets should only be considered if factors downstream require outlet conditions that cannot be met by the ungated surface spillway.

Hydraulic Conveyance Facilities

The hydraulic conveyance facilities should be developed in such a way that the powerhouse or the tailrace canal is downstream from the concentrated head so as to harness the head to the utmost. The total length of the conveyance facilities must also be kept to a minimum to achieve the most practical and economical solution. It is very important to reduce the length of the sections subject to the highest pressures, since the cost per meter of these sections is generally very high, be they pressure penstocks or tunnels. In Inventory Studies, when there is limited information available on the real geotechnical conditions of the bedrock, large-scale underground construction work should be avoided, such as long headrace tunnels, underground surge chambers, pressure tunnels, underground powerhouses and tailrace tunnels.

Navigation System

When the studies indicate that the river is navigable, locks or other navigation facilities should be an integral part of the project from the outset, taking into account the criteria required for river navigation in their layout.

Fish Passage System

Whenever the studies indicate that structures are required to allow aquatic fauna to migrate upstream or downstream, these should be included in the layouts.

2.6 ECONOMIC PARAMETERS

The economic parameters used in Inventory Studies are presented below:

Reference Date for Cost Estimates

This is the date of reference for all the monetary values quoted in the cost estimates.

Useful Life of the Facilities

This is the period of time that a hydroelectric power plant is economically useful, which is normally taken as 50 years.

Discount Rate

This is the rate used to calculate the present value of future disbursements for investments, and to determine the annual costs of these investments. This rate is set by the concession-granting authority. It should be used uniformly throughout the Inventory Study.

Reference Energy Unit Cost (CRE)

This is the generation cost, expressed in R$/MWh, above which any firm energy contributed by a project or group of projects ceases to be economically competitive with other sources of energy. It is the pure energy production cost in the reference system over the long term. This cost is provided by the concession-granting authority.

Reference Peak Energy Cost (CRP)

Expressed in R$/kW/year, this is the value above which the benefit of adding extra peak capacity to conventional power plants ceases to be economically competitive. It is the pure peak capacity cost in the reference system over the long term. This cost is provided by the concession-granting authority.

Reference Unit Cost (CUR)

Expressed in R$/MWh, this is the generation cost above which the energy generated by a plant or group of plant ceases to be economically competitive. It is the long-term cost in the reference system considered for energy production at a capacity factor Fk, by combining the source of energy and the source of peak energy in the reference system. This cost is calculated by the following expression:

$$CUR = CRE + \frac{CRP}{8.76.F_K} \qquad (2.6.01)$$

Annual Operating and Maintenance Cost (COM)

Expressed in R$/kW/year, this is the amount of money required to operate and maintain hydroelectric power plants. In order to estimate it, a mathematical function should be employed that relates installed capacity, P (MW), to the annual operating and maintenance cost, COM (R$/kW/year). The curve presented below is based on information collected by ANEEL for the 2007 review of the Energy Optimization Rate[4].

$$COM = a \times P^{-b} \qquad (2.6.02)$$

4 ANEEL, *Estudo de Custos Unitários de O&M das UHE - Composição da TEO - Tarifa de Energia de Otimização*. Andrade&Canellas, São Paulo, SP, 2006

Where:

P	installed capacity of a hydroelectric power plant, in MW
a	87.343
b	0.3716

The reference date for the COM's used to adjust the curve presented in equation 2.6.02 was December 2006. The concession-granting authority should be consulted to find out if any change has been made to the figures. If not, the COM should simply be updated using the General Price Index (Índice Geral de Preços – Disponibilidade Interna, or IGP-DI).

2.7 CRITERIA FOR DIMENSIONING AND COSTING PROJECTS

The methods used for calculating the size of structures and equipment for the projects in the cascades under study and the costs involved are different in the Preliminary Studies and Final Studies. Details are provided in items 4.10 and 5.7, respectively.

When a group of cascades are selected at the end of the Preliminary Studies, comparisons are made between them and those that are uncompetitive or dominated are rejected. For this reason, even though basic preliminary data can be used at this stage, the more accurate the cost estimate of each project by reducing uncertainties, the more reliable the selection of the cascades to go through to the Final Studies will be.

For this reason, whenever possible, it is recommended that in the Preliminary Studies, the spreadsheets provided be used for dimensioning the structures for the Final Studies. It is enough to have a minimum of data from the field for the purposes of filling any gaps for which assumptions cannot be made.

2.7.1 Calculating the Size of Structures and Equipment

In the Preliminary Studies, the size of most of the structures need not be calculated. The external dimensions of the main structures are determined only for the purposes of designing the general layout of the projects.

For the Final Studies, more in-depth information is gathered on the topographical and geological conditions, which makes it possible to design layouts in greater detail. Not only are the external dimensions of the main structures decided on, but the hydraulic pre-design is done using graphs and equations. The same applies for the equipment.

2.7.2 Estimating Engineering Costs

In the Preliminary Studies, the basic method for estimating costs is to use graphs from which the overall or unit costs are obtained for the construction work, services or equipment as a function of one or more parameters. The aim is to estimate the costs of the construction work and equipment in a simplified manner so that a cost estimate for the project can be formulated quickly and simply using standard costs, without the need to identify the specific features of each site.

In the Final Studies the quantity of services, supplies and equipment are determined for each structure using graphs, formulas and tables. Cost estimates are calculated for each structure by applying unit prices to the quantities of services, supplies and equipment required. Some of the costs of sets of services and equipment are given parametrically using global values.

2.7.3 Socioenvironmental Costs

The socioenvironmental costs that will effectively be included in the overall cost of the projects and incorporated into the cost/benefit indexes must be estimated. These are:

- control costs (incurred to prevent the partial or total occurrence of the negative socioenvironmental impacts of a project);
- mitigation costs (incurred in reducing the consequences of negative socioenvironmental impacts);
- compensation costs (incurred in compensating for socioenvironmental impacts caused by a project when reparation is impossible);
- monitoring costs (incurred in following up and assessing socioenvironmental impacts and programs); and
- institutional costs (incurred in preparing the socioenvironmental studies for the different stages of the project and the studies required for the environmental agencies (EIA/RIMA and PBA) for environmental licensing purposes and public meetings.

In both the Preliminary Studies and the Final Studies, the criterion for estimating socioenvironmental costs involves using global or unit costs. Some unit prices can be obtained from secondary sources and supplemented by field studies, especially the cost of land and rural and urban land development.

2.8 CRITERIA FOR SELECTING CASCADES

The basic criterion for the selection of cascades is to maximize economic-energy efficiency while minimizing negative socioenvironmental impacts. As maximizing economic-energy efficiency generally comes into conflict with minimizing negative socioenvironmental impacts, when cascades are compared and selected these aspects must be evaluated as part of a multi-objective approach.

2.8.1 Preliminary Studies

In the Preliminary Studies, the aim of the comparison and selection of the cascades is to eliminate those that are not competitive either because their economic-energy efficiency, or because of their negative socioenvironmental impacts. The two indexes used to make this comparison are the cost/energy benefit index and the negative socioenvironmental impact index, which are calculated for each cascade using the methods in items 4.11.1 and 4.11.2.

As the aim here is to select a group of cascades to be studied in greater depth in the Final Studies, it is recommended that they should not be compared by taking the aggregate sum of the indexes mentioned above, but by identifying how each cascade stands up in relation to the core objectives of *maximizing economic-energy efficiency and minimizing negative socioenvironmental impacts*. By so doing, the need to establish the relative importance of the objectives is avoided at this stage. The selection should be made (see item 4.11.3) on the basis of eliminating the cascades that fail to meet either objective in isolation, and identifying the undominated cascades from among those that remain (cases in which there is no other cascade with a lower cost/energy benefit index and negative socioenvironmental index).

2.8.2 Final Studies

In the Final Studies, the cascades are compared and selected with a view to identify one cascade to be submitted to the subsequent studies required for planning the expansion of the electricity industry. This choice should be made by ranking the cascades, taking the basic criterion of maximizing economic-energy efficiency while minimizing negative socioenvironmental impacts, while also taking into account any positive socioenvironmental impacts that could be achieved by building the hydropower projects in the river basin.

The cascades should be ranked according to a preference index ***I***, obtained by the weighted sum of the cost/energy benefit index and the negative socioenvironmental impact index. The weights used should be established in such a way as to take into account the relative importance attributed to each of the objectives, reflecting the context in which the analysis takes place and the period when the studies are undertaken (item 5.8.4). In order to define these weights, apart from the opinion of the experts directly involved in the studies, the results of the technical meeting where the partial results are presented at the end of the Preliminary Studies should be considered, as described in item 2.9.

In order to make the final choice of one cascade, it is proposed that an additional analysis be made, by which the positive socioenvironmental impacts in the study area (expressed by the positive socioenvironmental impact indexes) are incorporated to the cascades that have already been ranked, resulting in the modified preference index ***I'***, as described in item 5.8.4.

2.9 COMMUNICATION AND PUBLIC MEETING

The following procedures should be followed with a view to informing and consulting different sectors of society throughout the Inventory Studies:

a) At the planning stage, notify all environmental agencies, water authorities, and any committees, associations or institutions concerned with the management of water resources that the study is taking place; provide a list of objectives, activities involved, analyses and fieldwork to be undertaken in the water basin.

b) At the end of the Preliminary Studies, a technical meeting is held, to be called by the Ministry of Mines and Energy, where the results of the Preliminary Studies are presented.

c) At the end of the studies, a public meeting is held, called by the Ministry of Mines and Energy, to present the cascade selected and the findings of the IEA's and the associated guidelines and recommendations.

2.10 BIBLIOGRAPHY

ANEEL, *Estudo de Custos Unitários de O&M das UHE – Composição da TEO – Tarifa de Energia de Otimização*. Andrade&Canellas, São Paulo, SP, 2006.

ELETROBRÁS, *Manual de Inventário Hidroelétrico de Bacias Hidrográficas*, 1997.

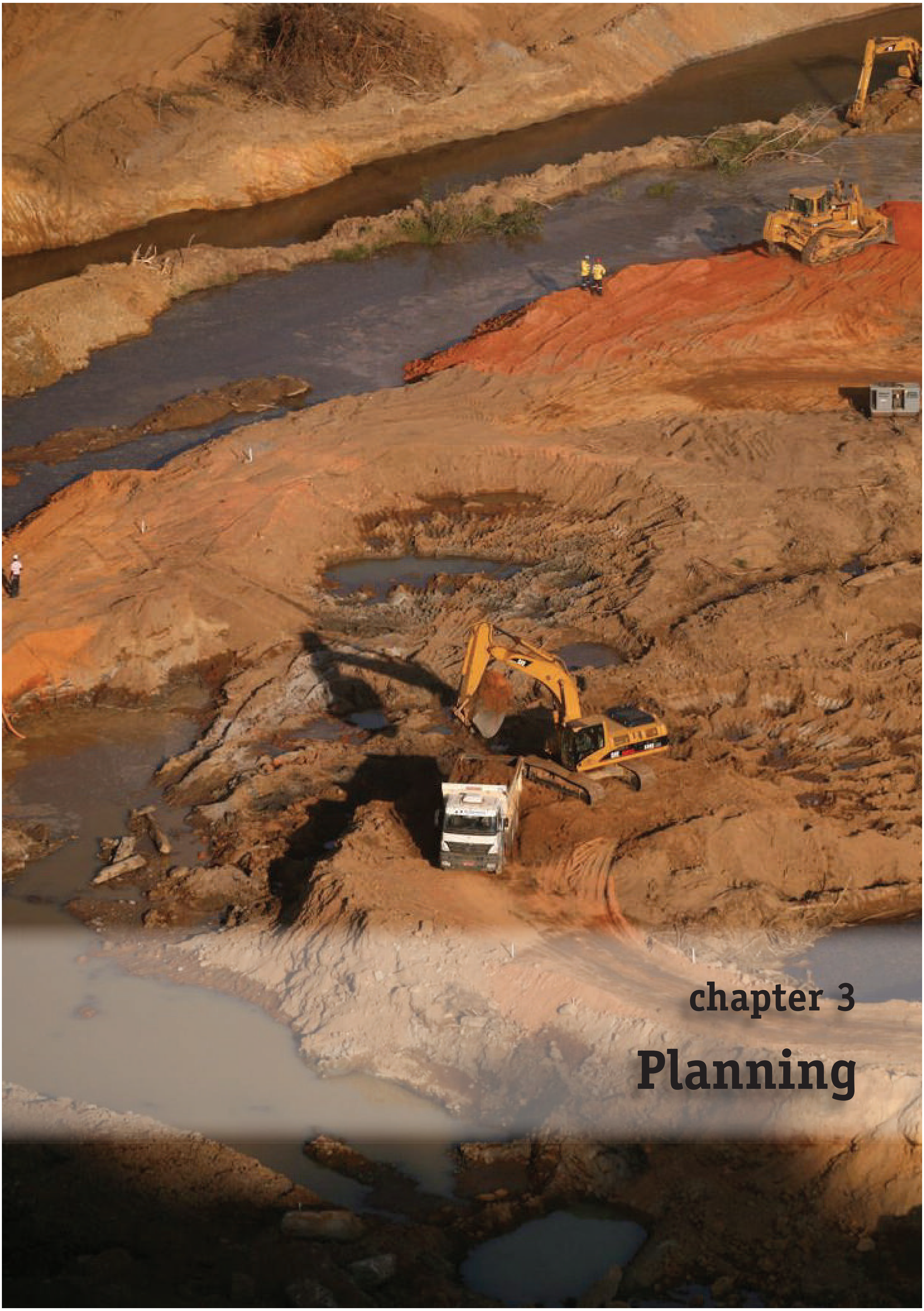
EPE/ Sondotécnica, 2007 – *AAI da Bacia do Rio Doce*.

MINISTRY OF THE ENVIRONMENT, *Plano Nacional de Recursos Hídricos*, 2006. Available at: http://www.mma.gov.br/port/srh/pnrh.

OFFICE OF THE PRESIDENT OF BRAZIL, Act 9.433 of January 8th 1997.

RAMOS, A., 1987, cited in Iara Verocai, *Vocabulário Básico de Meio Ambiente*, RJ, 1990 – quoted in EPE/ Sondotécnica – AAI do Rio Doce, 2007.

VEROCAI, I., *Vocabulário Básico de Meio Ambiente*, Rio de Janeiro, RJ, 1990, quoted in EPE/ Sondotécnica – AAI do Rio Doce, 2007.



chapter 3

Planning

CHAPTER 3

The aim of the Planning phase is to organize the subsequent stages of the Hydropower Inventory Study, which are the Preliminary Studies and Final Studies, as well as the Integrated Environmental Assessment. At the end of this phase, a management report is produced containing an action plan for the Hydropower Inventory Studies, including its schedule and costs.

Local and regional cartographical, geological, geotechnical, hydrometeorological, sedimentometric and socioenvironmental data are gathered at this stage, as well as costs.

By analyzing these data, it is possible to:

- gauge what field studies and investigations will need to be made at later stages;
- identify likely sites for dams;
- propose different cascade options; and
- estimate the energy potential of the area under study.

In this Planning stage, previously identified parameters, restrictions and factors are taken into account, which impose limits on the development of the work.

In relatively well known areas, this phase will be based mostly on bibliographical and documental information gathered from private and governmental entities. Field reconnaissance trips in this phase are of an expeditious nature and are designed only for gathering and confirming relevant information that is quickly and easily obtainable.

In less well known areas, the scarcity of ready information may mean that even at the Planning stage more in-depth field work has to be undertaken in order to obtain results of an acceptable level of accuracy.

During this phase, a communiqué about the studies, describing the activities, analyses and surveys to be undertaken in the river basins, should be issued to the environmental and water resource entities and also to any committees, associations or other institutions involved in managing the water resources, explaining the objectives of the studies, establishing communication channels and making it easier to gather the data which will be needed in due course.

3.1 DATA GATHERING AND ANALYSIS

The best starting point for the data gathering stage is to contact the following institutions, which safeguard information on their particular areas of expertise:

- ANA – Agência Nacional de Águas (National Water Agency): hydrometeorological and sedimentologic data;
- ANEEL – Agência Nacional de Energia Elétrica (Brazilian Electricity Regulatory Agency): data on prior studies and guidelines on the subject;
- CNRH – Conselho Nacional de Recursos Hídricos (National Council for Water Resources): legislation pertaining to water resources and information on river basin committees;
- CONAMA – Conselho Nacional do Meio Ambiente (National Council for the Environment): environmental legislation;
- CONCAR – Conselho Nacional de Cartografia (National Cartography Council): cartography legislation and standards;
- CPRM – Companhia de Pesquisa de Recursos Minerais (Brazilian Geological Survey): hydrometeorological, geological, hydrogeological and mineral data;
- DHN – Diretoria de Hidrografia e Navegação da Marinha do Brasil/Ministério da Defesa (Brazilian Navy's department of hydrography and navigation/Ministry of Defense): cartographic information concerning navigable waterways and licenses required;
- DNIT – Departamento Nacional de Infra-Estrutura e Transporte (National Department of Infrastructure and Transportation): information on transportation infrastructure;
- DNPM – Departamento Nacional da Produção Mineral (National Department of Mining): geological and mineral mapping, and applications for mining activities;
- DSG – Diretoria de Serviço Geográfico do Exército Brasileiro/Ministério da Defesa (Brazilian Army's geography service/Ministry of Defense): planimetric and altimetric information, conventional maps and image maps of the region of interest and others;
- EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária (Brazilian farming and ranching research company): information about the agricultural suitability and use of the land;
- EPE – Empresa de Pesquisa Energética (Energy Research Company): hydropower inventory studies, hydropower planning studies;
- FCP – Fundação Cultural Palmares/Ministry of Culture (Palmares Cultural Foundation): information on *quilombola* communities (former runaway slave communities);
- FGV – Fundação Getúlio Vargas (Getúlio Vargas Foundation): economic and social indicators;
- FUNAI – Fundação Nacional do Índio (National Foundation for Indigenous Peoples): location of and information about indigenous lands and peoples;
- IBAMA – Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis (Brazilian Institute for the Environment and Renewable Natural Resources): environmental information;
- IBGE – Fundação Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics): socioenvironmental, geodetic, topographic, cartographic and remote sensing information, as well as data from the RADAMBRASIL project, among others;
- INCRA – Instituto Nacional de Colonização e Reforma Agrária (National Institute for Colonization and Land Reform): information on plans for human settlements and demarcation of *quilombola* lands;

- INMET – Instituto Nacional de Meteorologia (National Institute of Meteorology): climatic and meteorological data;
- INPE – Instituto Nacional de Pesquisa Espacial (National Institute for Space Research): remote sensing;
- INPRA – Instituto Internacional de Pesquisa e Responsabilidade Socioambiental Chico Mendes (Chico Mendes Institute for Research and Socioenvironmental Responsibility);
- IPHAN – Instituto do Patrimônio Histórico e Arqueológico Nacional (National Institute for Historical and Archaeological Heritage): information on archaeological sites;
- MMA – Ministry of the Environment: information on conservation areas and priority areas for biodiversity conservation;
- state environment agencies;
- state water resource entities: licenses;
- SBE – Sociedade Brasileira de Espeleologia (Brazilian Society of Speleology): recording of caves;
- SEAP – Secretaria Especial de Aqüicultura e Pesca (Department of Fishing and Fisheries): plans;
- SEMA – Secretarias Estaduais de Meio Ambiente (state departments of the environment;
- SEPPIR – Secretaria Especial de Políticas de Promoção da Igualdade Racial (Department for the Promotion of Racial Equality);
- SERH – Secretarias Estaduais de Recursos Hídricos (state departments for water resources);
- SIPAM – Sistema de Proteção da Amazônia (Amazon Protection System): information on cartographic and socioenvironmental information on the Amazon;
- SPHAN – Secretaria de Patrimônio Histórico e Arqueológico Nacional (National Department of Historical and Archaeological Heritage); and
- SRHU/MMA – Secretaria de Recursos Hídricos (Department of Water Resources / Ministry of the Environment): planning and management of water resources.

There are other municipal and state entities which also have information of relevance, the most important of which are those that manage water resources.

Information should also be gathered on:

- socioenvironmental impact studies for projects in the river basin;
- socioenvironmental studies (environmental control reports, basic environmental plans, monitoring reports, etc.);
- integrated regional plans, municipal master plans, existing sector plans (e.g. plans for new roads, railroads, waterways, etc.);
- master plans for river basins;
- strategic or integrated environmental assessments of the river basin under study; and
- miscellaneous studies (reports, technical papers, theses, etc.) which address the river basin either directly or indirectly, highlighting the following areas: mineral resources, seismicity, wildlife, vegetation, geology, geotechnics, geomorphology, pedology, hydro-climatology, hydrometeorology, limnology, ichthyology, sociology, economics, anthropology, indigenous peoples, traditional communities, archaeology and paleontology.

3.1.1 Cartography

The quality of the planning depends on the quantity, range, representativeness and consistency of the data available. Generally, the following information should be sought.

- Topographic maps (planimetric and altimetric) and thematic maps – these can be obtained from the public cartography agencies or mapping companies. Lists of charts, maps and plans of the area of interest can be gathered, then they can be selected for each end use according to their scale. An analysis should be made of the reliability of these documents by assessing the method used to produce them and their cartographic accuracy. This is necessary for deciding whether they can be used at later phases;
- Planimetric and altimetric support points – survey of the existence of geodetic services from the responsible entities. The accuracy, availability and integrity of the basic support available should be checked. Geodetic or topographic studies undertaken by government entities or private companies can be used, provided they are compatible with the degree of accuracy required in the technical standards pertaining to the topics that need to be addressed;
- Geographical information systems – information can be obtained from public and/or private companies, which can be selected according to the cartographic data used to prepare it and the quality of the associated database.

Other documents of use, especially for later phases, are:

- Remote sensing images – request information from INPE, IBGE, DSG and other institutions and companies with information of this nature, checking what coverage exists of the area of interest, especially: cloud cover, the dates when the images were taken, what kinds of sensors were used to produce them, the spatial, geometric, spectral and temporal resolutions, the mapping scales available, and the existence of stereo pairs;
- Aerial photographs – request information from public entities or mapping companies. The information should be analyzed for its usefulness at later stages. The existence and availability of aerial photographs of the area of interest should be checked, as well as any mosaics or orthophoto maps, and non-metric aerial photographs; and
- Geoid map – request information from IBGE and universities.

The analysis of the information gathered should be based on clear criteria, not only to check the quality of the information (according to the methods used) but also to verify the projection system used and the feasibility of cross-referencing (the altimetric and planimetric data) between them.

Should it be necessary to make a specific or supplementary survey of the river basin to fill any gaps for the Final Studies, the information should be produced in compliance with the Technical Standards for National Cartography, decree 5.334 of January 6th 2005.

To sum up, by the end of this stage, an assessment should have been made of the documents gathered and a list prepared of any services still needed.

3.1.2 Hydrometeorology

The hydrometeorological and sedimentologic data to be gathered correspond to recorded daily streamflow, sediment discharge and meteorological information – rainfall, winds, sunshine, temperatures, etc. – from the gauging stations that exist in the river basin that can provide reliable data from a sufficiently long period of time. The main information available should be gathered, such as forms to describe the gauging stations, summaries of the streamflow and sediment discharge measurements, records of water level observations or limnigrams, and rainfall records or pluviograms, as well as any analyses of consistency and data gap filling undertaken.

All the gaps in the data for given periods of time or parts of the area under study should also be identified, taking into account any data from the region with similar behavior. The network of river gauging stations should be characterized in terms of the kind of data they gather and their characteristics.

In the absence of data in sufficient quantity or of sufficient reliability, it will be necessary in the Preliminary Studies to produce the monthly average flows and extreme flows based on regional studies or deterministic models, while also drawing on any river gauging or rainfall data available not only from the river basin under study but from contiguous areas with similar hydrological and hydrogeological features.

At the end of this phase, a map of the basin should be prepared showing the existing river gauging stations and possible dam axes for study. The availability of data should be indicated using a bar chart, as well as a list of the stations, the respective periods of data available and the kind of data collection undertaken.

The data needed for the studies can be obtained from ANA, INMET, ANEEL, EPE, state water resource management entities, and companies and entities which use the water resources, such as electricity and water utilities.

In order to better understand the sedimentology of the basin, sedimentometric data and data on the erosion conditions in the basin should be collected using erodibility maps and maps of land use and deforestation, as well as information obtained from the field reconnaissance. The sections of river either upstream or downstream where erosion and silting processes could be critically altered by the introduction of reservoirs should also be identified. It is important to consult studies contained in technical reports of any nature for dam projects.

Should it be necessary to install new river gauging stations, rainfall gauges or sediment measurement devices to supplement the existing ones, their location should be decided upon only after consulting ANEEL resolution 396/98. The entities that operate the hydrometric network in the region and the generation companies that operate in the basin should also be contacted to find out if they have any interest in operating and maintaining these gauging devices.

3.1.3 Multiple Water Uses

The collection of data and information about the different water uses is designed to identify the potentialities of the river basin under study and to assess its compatibility with the National Plan for Water Resources and any river basin plans that may exist, as well as any sector or integrated plans available. The aim is to provide inputs for drawing up the scenario for the use of the water in the river basin, which is necessary for assessing the energy benefits of the cascade options and the socioenvironmental impacts. Table 3.1.3.01 below presents the kind of information that should be collected and the main entities that can supply information on different water uses that may interfere with the hydropower generation project. Future uses of the reservoir should also be considered, including tourism, aquaculture and the legal status of the body of water, which could imply in restrictions on its use.

Table 3.1.3.01 – Water uses and sources of information

USE	SOURCES and INFORMATION	ENTITIES
Irrigation	– National Plan for Water Resources – state plans for water resources – plans for the water resources in the river basin – municipal master plans – record of licenses granted – inventory of irrigable areas – crop irrigation coefficients – consumption statistics – plans for the introduction of irrigation projects – record irrigation projects and their beneficiaries – soil types and crop calendars – farming census (per municipality – IBGE)	SRHU/MMA ANA/MMA IBGE MAPA MI river basin committees regional agencies state entities municipal entities
Livestock Breeding	– National Plan for Water Resources – state plans for water resources – plans for the water resources in the river basin – municipal master plans – record of licenses granted – consumption statistics – requirements for livestock breeding (heads of cattle, horses, asses, sheep, goats and pigs) – farming and ranching census (*Censo Agropecuário*) per municipality – IBGE	SRHU/MMA ANA/MMA IBGE MAPA MI river basin committees regional agencies state entities municipal entities
Flood Control	– National Plan for Water Resources – state plans for water resources – plans for the water resources in the river basin – survey of soil use on the floodplains – survey of works existing for flood control or prevention – large–scale drainage plans – flood control studies for the river basin	SRHU/MMA ANA/MMA IBGE ANEEL ONS MI river basin committees regional agencies state entities municipal entities OTEP
Navigation	– National Plan for Water Resources – state plans for water resources – plans for the water resources in the river basin – municipal master plans – survey of navigable sections and river ports – statistics on the movement of people and goods in the region – river navigation plans	SRHU/MMA ANA/MMA IBGE MI Ministry of Transportation / DNIT state departments of transportation river basin committees regional agencies state entities municipal entities
Human Water Supply	– National Plan for Water Resources – state plans for water resources – plans for the water resources in the river basin – municipal master plans – population growth statistics – urban and rural demographic forecasts – record of licenses granted – agriculture incentive plans in rural areas	SRHU/MMA ANA/MMA IBGE Ministry of Cities river basin committees regional agencies state entities municipal entities water and sewage treatment companies

Sanitation	– National Plan for Water Resources – state plans for water resources – plans for the water resources in the river basin – municipal master plans – record of licenses granted – urban and rural demographic forecasts – National Information and Sanitation System – national basic sanitation survey	SRHU/MMA ANA/MMA IBGE Ministry of Cities river basin committees regional agencies state entities municipal entities water and sewage treatment companies
Industry	– National Plan for Water Resources – state plans for water resources – plans for the water resources in the river basin – municipal master plans – record of licenses granted – plans for thermoelectric power plants – industry census – annual industry survey	SRHU/MMA ANA/MMA IBGE MDIC MME DNPM/MME CNI (Confederação Nacional da Indústria) federations river basin committees regional agencies state entities municipal entities
Tourism and Leisure	– National Plan for Water Resources – state plans for water resources – plans for the water resources in the river basin – municipal master plans – record of licenses granted – tourism plans	SRHU/MMA ANA/MMA IBGE MDIC Ministry of Tourism Ministry of Sports river basin committees regional agencies state entities municipal entities
Aquaculture	– National Plan for Water Resources – state plans for water resources – plans for the water resources in the river basin – municipal master plans – record of licenses granted – sector plan	SEAP/PR MAPA SPU/MPOG MMA ANA Port Authorities
Ecosystem Maintenance	– state plans for water resources – plans for the water resources in the river basin – studies of minimum ecological flow	entities that manage water resources and the environment

3.1.4 Geology and Geotechnics

The geological and geotechnical data to be collected should allow for a characterization of the foundation and excavation conditions for building the structures and the natural building materials to be used for the projects and any information that could supplement the environmental studies. Geological and geomorphological information about the river basin should be collected on sources of erosion, mineral resources, the stability of hillsides, natural and induced seismicity, watertightness and configuration of the reservoirs.

The basic data for the Planning phase are essentially the documents obtained from existing sources in the form of geological and geomorphological maps, geological and geotechnical studies and maps, remote sensing images (radar, multispectral images, etc.) and aerial photographs. The following basic information must be gathered:

- geotechnical data on hydropower plants planned and installed in the region and/or under similar geological conditions to those in the study area, as well as any roads and large-scale works in the region;
- geological maps, geomorphological maps, maps of mining potential and seismotectonic maps, with their scale, coverage area, the entity that produced them and the year in which they were produced; and
- data on mineral resources from DNPM in the form of maps which identify where there are areas of research and mining activities, and lists of these processes.

This information should be submitted to a detailed analysis to check its quality and relevance to the studies. After this is done, the information may, if necessary, be checked on site by air reconnaissance and field trips.

If there are no suitable maps or geological information on the region under study, preliminary photo-geological maps should be prepared of the areas of interest in the rivers to be studied, which will help identify sites or sections that could be impounded, and also to identify the different sections of the floodplain and any geological features of interest.

Table 3.1.4.01 below sets out the geological, geomorphological and geotechnical data required for the Preliminary Studies and Final Studies that should be collected and analyzed during the planning phase.

In the Preliminary Studies, it is only necessary to produce estimates of the geological and geotechnical parameters. During the Final Studies, however, these characteristics must be determined with a high enough degree of accuracy as to assure the integrity of the foundations of the structures and the availability of natural building materials.

By the end of this phase, an assessment should have been made of the documents gathered and a list prepared of any services still needed.

Table 3.1.4.01 – Geological, Geomorphological and Geotechnical Activities Required in the Hydropower Inventory Studies

Planning stage	Preliminary studies	Final studies
– Register and obtain data on: · hydropower plants planned and installed in the region and/or under similar geological conditions to those in the study area, as well as any roads and large-scale works in the region; · geological maps, geomorphological maps, maps of potential mineral deposits and seismotectonic maps – supply scale, coverage area, entity and year; · data on mineral resources from DNPM in the form of maps which identify where there are areas of research and mining and lists of these processes. – Analyze the material available. – Draw up a list of services necessary.	– Make geological interpretations of the remote sensing images and aerial photos with the aim of: · supplementing the existing geological and geomorphological maps; · providing inputs for defining the best sites for dams; · indicating potential sources of natural building materials (sand and gravel deposits in the river bed quarries, borrow areas); · indicating areas of the river basin that are potentially susceptible to erosion; · indicating areas with natural hillside instability around the reservoir; and · carrying out expeditious geological and geotechnical mapping of the dam sites. – Drill at least inspection wells and auger bores at the dam sites – Present geological and geotechnical sections of the prospective dam axes, indicating the likely top of the bedrock and the kinds of materials encountered at the site. – Assess the potential for natural building materials (borrow areas, sand, gravel and quarries). – Undertake geological and geomorphological mapping of the region along the rivers and roads. – Map out mineral resources. – Prepare a seismotectonic map of the basin.	– Supplement the information obtained in the Preliminary Studies on areas of regional interest and potential sites for dams that were approved for the Final Study phase. – Carry out supplementary investigations as required, such as boreholes, trenches, auger bores and geophysical soundings. – Provide comparative parameters between the different kinds of rock existing in the dam foundations. – Assess the mineral resources that could be influenced by the reservoirs, using data from DNPM.

3.1.5 The Environment

The socioenvironmental data should help identify the most significant issues, especially those that could represent constraints or opportunities, influencing the choice of dam sites and identifying the preliminary set of cascade options, while also serving as inputs for the work plan and cost estimates for the next stages.

The data should be collected primarily from public entities, state-owned companies, specialized federal, state and municipal government agencies, universities and research institutes. The information will include academic publications, documents, maps, charts and statistics.

Some of the socioenvironmental aspects can be studied using the same databases as those used for the cartography, hydrometeorology, multiple water use, geology and geotechnics studies, as defined in items 3.1.1, 3.1.2, 3.1.3 and 3.1.4.

Once gathered, the data should be catalogued and assessed as to its consistency and accuracy. It should be checked whether all the basic data is available that could seriously interfere in the schedule of the Hydropower Inventory Studies. This assessment should take into account the data used to formulate the core components defined in preparing the socioenvironmental diagnosis during the Preliminary Studies, as in item 4.3.

Given that socioenvironmental issues are taken into account in the selection of dam sites and the preliminary identification of cascade options, the socioenvironmental issues set out in Table 3.1.5.01 below warrant special attention.

Table 3.1.5.01 – Significant Socioenvironmental Issues

Socioenvironmental issues	Minimum content	Sources of information
groups of indigenous peoples	Locate indigenous lands, indicate their legal status, population and ethnicity	FUNAI, ISA, theses and academic papers, *Anuário Estatístico do Brasil* (Statistical Yearbook of Brazil) published by IBGE, specific legislation
Former *quilombo* communities, groups of ethnic minorities or traditional communities	Locate areas and population sizes	Movimento Negro Unificado (Unified Black Movement), SEPPIR, Palmares Foundation, INCRA, specific literature, specific legislation
Conservation Areas	Locate, classify, characterize, identify legal status and any existing conflicts	INPRA, state environment entities, specific literature, specific legislation
Heritage Properties	Locate historical, cultural, archaeological, landscape, speleological and ecological heritage sites/properties	IPHAN, state and municipal heritage protection entities
Seats of municipal and district authorities	Locate and identify the functional hierarchy and population	IBGE, state and local authorities
Densely populated rural areas	Identify land usage, population density, land ownership and production data	IBGE, local authorities and producers' associations
General infrastructure and basic sanitation	Locate roads, railroads, river ports, landing strips and power lines, nearby bridges and roads	Road maps, IBGE, DNIT, DERs, local authorities and state entities
Existence of minerals of economic and strategic value	Identify existence and classification of mining licenses	DNPM, CPRM, RADAM-Brasil project, state and municipal entities
Mineral water sources	Locate and characterize	DNPM, state and municipal entities
Industrial and agri-industrial facilities	Locate and characterize	EMBRAPA, EMATER, confederation of industries, state and municipal entities, IBGE, MDA.
Commercial fishing	Characterize in general terms (organization of the activity, quantity and species fished, markets for the catches)	IBAMA, state environmental protection entities, IBGE, SEAP.
Rare, endemic or threatened species	Locate and identify on a local and regional level	IBAMA, INPRA, state environmental protection entities, theses and scientific publications
Priority areas for the conservation of biodiversity	Locate and identify on a local and regional level	MMA, INPRA, state environmental protection entities, National Congress Environment Commission

Socioenvironmental issues	Minimum content	Sources of information
Fragile areas or areas of ecological interest	Identify locations, characteristics, uses and area occupation	IBAMA, INPRA, state environmental protection entities, local authorities, municipal and state departments
Ichthyofauna	Migratory routes, breeding grounds, fish farms	Research institutes, universities and environmental entities
Economic activities	Economic activities that could be affected, such as fishing, agriculture, etc., including estimated sums involved	MAPA, SEAP, IBGE, state and municipal departments
Organized Civil Society	Conflicts and means of organization	Main NGOs, social movements and associations that are active in the region

The items identified here are only the main impacts that may take place when a hydropower plant is built. Depending on the specific nature of the river basin, some of the items may be disregarded, while others could arise that require attention.

The following steps are recommended:

- to gather, collate, organize and georeference the data. In this case, the use of geographic information systems provides greater speed and flexibility for the analyses required, while also helping build up the digital database, which is of great importance in keeping information updated and assuring ease of information recovery;
- whenever possible, to gather secondary data to prepare thematic maps using the same coverage area and scale which are compatible with the other maps needed for the Hydropower Inventory Study, all of which should be connected to a single database;
- to prepare a summarized map, which will set out all the information on one single map, providing the first environmental characterization of the river basin, highlighting the aspects that could pose any major restriction and highlighting any existing or potential problems or conflicts. This map should be used when prospective sites are picked for dams and when the study area is demarcated for the subsequent stages, as well as in preparing the work plan for the field reconnaissance.

3.2 IDENTIFICATION OF DAM SITES

A **map of potential dam sites** should be prepared, drawing on the analysis of the data gathered in item 3.1 and the restrictions identified. The potential dam sites should primarily be identified from planimetric and altimetric maps. Additionally, aerial photographs and remote sensing images should be used. At this first research stage, special attention should be paid to all sections of the river with rapids and waterfalls, and all the areas where the river valley narrows sharply. Likewise, attention should be given to the restrictions imposed by the physical and socioenvironmental factors identified.

For each dam axis, it should be determined what the highest water level could be for the reservoir.

Plans and profiles of the river should be made at these sites, which will serve as a basis for preparing the different cascade options. The criteria to be adopted in each case will depend on the technical assessment of the topographic, geological, geotechnical, hydrological and socioenvironmental parameters.

3.3 FIELD RECONNAISSANCE

Once the geological and hydrological data, the physical and socioenvironmental factors of relevance, the planimetric and altimetric maps of the different study areas and the map of potential dam sites have been gathered and prepared, field reconnaissance activities should be planned, which may be aerial, land-based and river-based.

Field reconnaissance must be carried out by a multidisciplinary team with the main aim of confirming, adding and/or ruling out potential dam sites and the effects of the restrictions identified. It should also confirm, add or disregard any of the logistical support points for the future studies.

During the field reconnaissance activities, a detailed examination should be made of the general morphology of the region and compared with the available information. Any sections where there is a sharp narrowing of abutments, gorges or other geographical features of this nature should be studied. The sites previously pinpointed as potentially suited to having dams built on them should be inspected in greater detail and estimates should be made of the maximum head permitted at the sites.

It should be checked whether there are any river gauging stations in the region and what facilities they contain, as well as any sandbanks or stretches of river susceptible to erosion.

The main uses of the water resources should be identified at this stage. These include existing water consumption, fishing areas, any beaches, whether commonly frequented or not, tourist areas, wastewater discharge, transport upstream, downstream or from bank to bank, rainwater drainage networks, etc.

The field reconnaissance for the socioenvironmental aspects should be expeditious, as in the other areas of study. It is important for planning the socioenvironmental studies, as it permits an overview of the river basin as a whole. Particular attention should be given to any aspect that affects the aquatic and terrestrial ecosystems and any local inhabitants that might be affected, as well as the state of any riverside woodlands, and any constructions within the river channel, since these elements could have a direct influence on the complexity of the studies required at the later stages and the length of time needed to do them.

All the observations made by the multidisciplinary team should be consolidated, especially to include new data and to confirm or contradict information from prior studies. The thematic maps and other data should be reviewed so that the new information can be included.

3.4 CASCADE OPTIONS

Taking the information obtained in 3.1, 3.2 and 3.3, the greatest possible number of cascade options should be considered, and the energy potential of each cascade and each individual project should be estimated.

The cascade options should normally include the creation of regulating reservoirs in the upstream stretches. The maximum heights of the dams should be compatible with the physical characteristics and the nature of the foundations at each site.

The cascade options should harness the entirety of the available head, considering the limitations imposed by the physical and socioenvironmental factors identified.

The possibility of diverting part of the flow to other basins or vice versa should be considered if there is anything that justifies such a solution.

3.5 PLANNING REPORT

A technical and management report should be prepared, containing predictions of the results to be achieved and the resources needed to fulfill the objectives of the Hydropower Inventory Study. In order to provide guidelines for the subsequent phases of the Hydropower Inventory Studies (Preliminary Studies, Final Studies and Integrated Environmental Assessment), this report should contain:

- an evaluation of the energy potential;
- an evaluation of the restrictions and constraints imposed on the potential plants; and
- the work plan, including activities, schedule and costs.

3.5.1 Socioenvironmental Aspects and Water Resources

The data gathered on socioenvironmental aspects and on water resources, and the analyses made of these should be consolidated and divulged in a specific item of the report, including:

- a preliminary socioenvironmental characterization of the river basin;
- a preliminary characterization of the multiple water uses and land use, highlighting any existing or potential problems or conflicts;
- any restrictions or constraints imposed on likely hydropower projects;
- the thematic maps; and
- the map that summarizes all the main data.

3.5.2 Work Plan and Cost Estimate

The data gathered and the cascade options formulated are used to decide upon the tentative perimeters of the reservoirs and dam sites. Based on this material, a proposal should be prepared listing and describing the services to be undertaken to fulfill the procedures required for the different phases of the Hydropower Inventory Studies (Preliminary Studies, Final Studies and Integrated Environmental Assessment), containing:

- definition of the study area, as per item 2.3.1;
- definition of the specifications for and estimate of the extent of the mapping work required;
- definition of the number and location of new river gauging stations and rainfall gauges;
- estimate of the number of topological surveys and water depth soundings;
- estimate of the number and kind of geological and geotechnical surveys required;
- estimate of the number of measurements of streamflow and sediment discharges;
- identification of the complementary studies required to fulfill the requirements for formulating the synthesis components, as set forth in item 4.3;
- indication of the surveys to be carried out to estimate the socioenvironmental costs, as set out in items 4.10.1 and 5.7.1;
- cost estimate of the technical meeting and public seminar where the results will be communicated.

If the river basin does not have an adequate network of gauging stations and/or if an intense sediment transportation process is identified, the installation of supplementary gauging facilities should be planned as should campaigns to gather hydrological and sedimentological data for the studies. It is recommended that the campaigns be carried out during the Preliminary Studies so that the results are ready by the beginning of the Final Studies.

Special attention should be paid to scheduling the studies that require longer periods of observation (e.g. factors subject to seasonal variations) or special conditions for them to be undertaken (e.g. logistic support, laboratory tests) to assure that the results are available when they are needed.

Finally, based on the estimate of services to be carried out, schedules, costs, human resources, equipment, structure and logistics required can be prepared and obtained. A technical team should be picked for each task or activity, according to the skills required in each case.

3.6 BIBLIOGRAPHY

AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA, Resolution 396 of December 4th 1998.

CARVALHO, Newton de Oliveira. *Hidrossedimentologia Prática.*

CPRM and ELETROBRÁS, *Centrais Elétricas Brasileiras S.A.*. Rio de Janeiro, RJ, 1995.

CEMIG, *Manual de Hidrometria*, 3v. Belo Horizonte, MG, 1965.

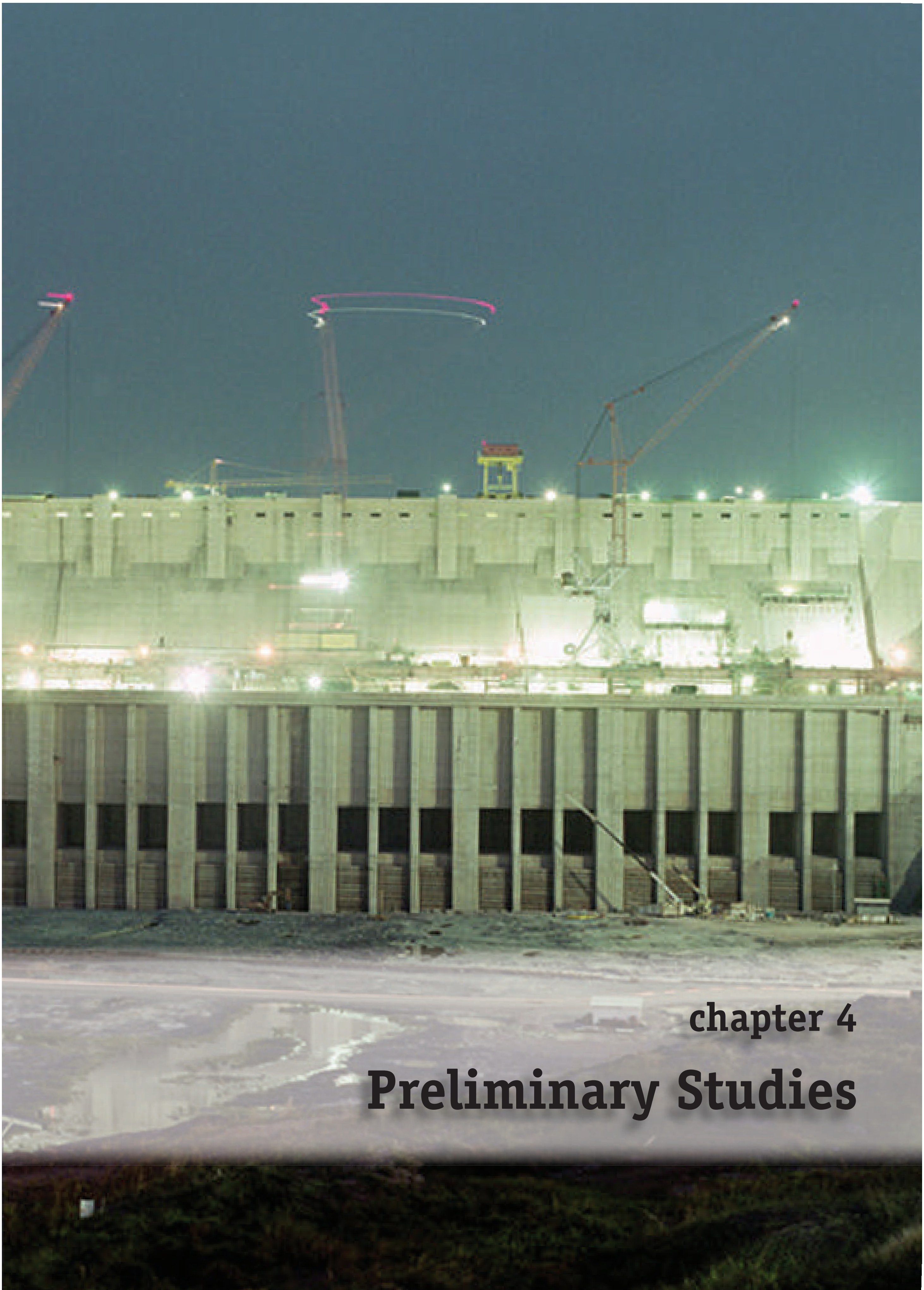
ELETROBRÁS. *Diagnóstico das condições sedimentológicas dos principais rios brasileiros*. Rio de Janeiro, RJ, 1992.

ELETROBRÁS, *Manual de Inventário Hidroelétrico de Bacias Hidrográficas*, 1997.

NORMA TÉCNICA DA CARTOGRAFIA NACIONAL, decree 5334 of January 6th 2005.

WMO, *Guide to Hydrological Practices*. Geneva, Switzerland, 1994.

Yuquian, Long. *Operational Methods for Measurement of Sediment Transport*. WMO, Geneva, Switzerland, 1983.



chapter 4

Preliminary Studies

CHAPTER 4

During the Preliminary Studies, the different cascades for harnessing hydroelectric power are subject to a preliminary, expeditious evaluation, including estimates of the costs and socioenvironmental impacts associated with their use, based on secondary data. The basic data gathering activities and different studies planned in the previous stage are also undertaken, which are not only needed for the preliminary analysis of the cascades, but also provide information necessary for the Final Studies. Besides identifying the possible cascade options, the overall technical specifications of each project are agreed on, including their preliminary design, the dimensions of the main equipment needed, and the estimated installation costs. Using the results of the energy studies, the studies of multiple water uses, the socioenvironmental studies and cost estimates, a shortlist of the most promising cascades is drawn up for more in-depth studies at the next phase. At the end of the Preliminary Studies, a technical meeting is held where the results are presented (item 2.9).

The socioenvironmental studies are carried out with the main aim of incorporating socioenvironmental aspects throughout this stage in order to:

- help draw up the shortlist of cascade options and devise the best design for the projects, taking into account the main socioenvironmental issues identified;
- supply the information needed to estimate the socioenvironmental costs (quantitative costs and corresponding unit prices), by identifying the likely negative socioenvironmental impacts incurred by each project and cascade under study;
- calculate a negative socioenvironmental impact index for each cascade, so they can be compared using a multi-objective approach and the ones to go through to the Final Studies can be selected;
- enable the identification of areas of sensitivity, with a view to indicating critical areas for the introduction of future projects and also areas that offer social and economic potentialities to be addressed in the IEA.

The methodology for assessing socioenvironmental impacts at this stage is presented in this chapter in such a way that it can easily be combined with the energy and engineering studies. There are three main phases of studies: socioenvironmental diagnosis, assessment of impacts per project, and calculation of the negative socioenvironmental impact index for each cascade option. This methodology is incorporated into the SINV system. The data generated at each stage can be stored in the system and then used later on to formulate the socioenvironmental impact indexes used for comparing and selecting the different cascade options at the end of the Preliminary Studies.

The socioenvironmental diagnosis generates basic information on the study area relating to the synthesis components and their characterization elements. The procedures for the diagnoses are set out in item 4.1 (**Data Gathering and Studies**) and item 4.3 (**Socioenvironmental Diagnosis**). The results of these analyses are compiled in maps per synthesis component, which should mark out the areas of sensitivity and any areas with socioeconomic potentialities that could be leveraged by the schemes. This information provides a basis for formulating the different cascade options and for analyzing the projects within these cascades.

According to this methodology, all the projects under consideration for the study are first studied individually. This means that each project is assessed without taking into account the effects of any others in the same river basin. The impacts are identified, predicted and assessed, and impact indexes are attributed to each project and each synthesis component. The procedures for this are described in item 4.8 (**Assessment of Negative Socioenvironmental Impacts per Project**). The impact indicators and assessment elements to be used when evaluating the impacts on each synthesis components are also presented. The information on the impacts is used for estimating the **socioenvironmental costs** (item 4.10.1).

The procedures for obtaining the negative socioenvironmental impact index for each cascade under study are described in item 4.11.2 (**Negative Socioenvironmental Index**). Initially, the indexes for the projects should be combined per synthesis component to obtain the impact index for each cascade on each synthesis component. These indexes are then combined to give the impact index of the cascade in question on the socioenvironmental system, which is a consolidation of the socioenvironmental assessment of the cascade, representing its performance in meeting the objective of *minimizing negative socioenvironmental impacts*.

4.1 DATA GATHERING AND STUDIES

4.1.1 Cartography

In order to prepare the topographic maps and carry out all the surveys required for Inventory Studies, the planimetric and altimetric data must be linked to geodetic marks and benchmarks from the Brazilian Geodetic System (Sistema Geodésico Brasileiro), as defined by the IBGE. The forms to be adopted should be compatible with the levels of precision needed to transpose the coordinates to the marks to be implanted at the sites of interest.

The following documents or their equivalents should be referred to:

- "Especificações e Normas Gerais para Levantamentos Geodésicos" [General Specifications and Standards for Geodetic Surveys] approved by IBGE Resolution PRP-22 of 07/21/83 and ratified by COCAR Resolution 02/83 of 07/14/83, published in the official government publication (*Diário Oficial da União*) on 07/27/83.
- "Especificações e Normas Gerais para Levantamentos GPS: Versão Preliminar" [General Specifications and Standards for GPS surveys: Preliminary Version] approved by IBGE Resolution 5 of 03/31/93, which was included in chapter 2 of PRP-22 (General Specifications and Standards for Geodetic Surveys) of 07/21/83.
- "Padronização de Geodetic marks: Instrução Técnica" [Standardization of Geodetic Marks: Technical Instructions] approved by Service Standard NS-DGC 001/2005 issued in January 2006 by the Geoscience Department of IBGE.
- ABNT NBR 13.133 standard on "Execução de levantamento topográfico" [Conducting Topographic Surveys] issued on 06/30/ 94.
- ABNT NBR 14.166 standard on "Rede de Referência Cadastral Municipal – Procedimento" [Municipal Registration Reference Network – Procedures] of 08/01/98.
- Regulatory instructions for the technical standards for national cartography, established by Decree 89.817 of June 20th 1984, published in *Diário Oficial da União* on June 22nd 1984 and subsequent amendments in Decree 5.334 (01/06/05) which amends the text of article 21 of these instructions.
- IBGE Resolution RPR 1/2005 of February 25th 2005, which alters the characterization of the Brazilian Geodetics System, defining SIRGAS2000 as the source of reference data.
- Ministerial Directive 121/MB of April 23rd 2003 – "Instruções Para Controle dos Levantamentos Hidrográficos Pela Marinha do Brasil" [Instructions for the Control of Hydrographic Surveys by the Brazilian Navy].

The methods recommended for obtaining the basic cartographic data are:

- aerial photogrammetry;
- interferometric radar;
- laser profiling;
- satellite imaging;
- topographic surveys.

The methods listed above should be used either individually or in combination to prepare cartographic outputs that are compatible with the uses required for the inventory study in question. They should take into account the specific features of the region in question, especially the following:

- vegetation: characteristic biome, crops, pasture, etc.;
- topography: whether the region is mostly flat or hilly;
- mean height estimates for the dams;
- interference in towns, cities, villages, roads, railroads, indigenous areas, conservation areas, etc.

In terms of the degree of precision required, the following requirements should be observed.

A topographic map should be prepared at a scale of 1:10,000 with contour lines at five-meter intervals, classified as Class A for its standard of cartographic excellence (Padrão de Exatidão Cartográfica) according to the Brazilian Cartography Standard. In cases where the area to be surveyed is very large or where it can be justified on technical grounds, scales of up to 1:25,000 can be used with ten-meter intervals between the contour lines. When the head of a project is low (around 20 m), the scale should be 1:5,000 with contour lines at five-meter intervals or less.

In view of the intended purpose of these outputs, it should give special attention to hydrography items, providing the correct identification of the main water course and its tributaries, showing the places where there are changes in their slope, narrowings, gorges, rapids and waterfalls, as well as any civil constructions associated to them.

The altimetric survey should represent the relief in such a way that the details are identified that could affect the results of the profiles of the water courses, the calculation of the capacity of the reservoirs and the assessment of the physical interferences the reservoirs would have on the landscape. To this end, the following recommendations should be followed:

- Point features should be added to the tops of all elevations, the bottom of all depressions, in saddles and in areas that are especially flat (which cover over 2 cm on the scale of the map);
- Point features should be added to the water level along the rivers, especially where there is a change in slope, such as at the beginning and end of rapids, at the top and bottom of waterfalls, any lakes or artificial reservoirs, and, whenever visible, at the points of confluence with the main tributaries;
- Point features should be added to engineering structures, such as bridge decks, the crest and foot of dams, berths in harbors, roads and railroads that cross or run parallel to the water courses, etc.;
- Supplementary contour lines whenever the slope of the land creates contours that are more than 2 cm apart on the scale chosen for the map, or wherever the slope changes abruptly, such as edges of plateaus, cliffs, etc.

Any field work that needs more precise data should be done in separate surveys. Below is a list of the main kinds of information to be gathered in this way:

- Longitudinal profile: includes determining the planimetric and altimetric coordinates of the water levels of the river and its main tributaries, and other natural or artificial elements of importance to the studies. The profile design should be referenced to a particular date in order to ensure uniform flows, and should contain the accrued distances from the mouth and point features for each important element. In order to minimize errors during the data gathering process, the survey should ideally be carried out during dry periods, and the dates and times should be recorded for each water level reading taken. Below is a list of the water levels of the main elements to be taken:
  - top and bottom of each waterfall and rapids;
  - mouth of the tributaries;
  - boundaries of conservation areas and indigenous lands;

- bridges, with the coordinates of the abutments and elevation of the deck;
- ferry crossings;
- local communities, traditional mining activities, etc.;
- staff gauges;
- transmission lines, measuring the coordinates of the nearest towers and if possible including the voltage of the line(s);
- other elements deemed of importance.

- Topographic and bathymetric surveys of the river bed and abutments along the prospective dam axes, with cross-sections where necessary to characterize the morphology of the abutments and adjacent areas, providing data to be used in the studies for the project layouts.
- Cross-referencing of the geological/geotechnical investigations with the hydrological surveys.

These studies should be in compliance with the specifications for leveling (Class IIIN) and planimetry (IVP) as set out in ABNT standard 13.133. A list should be supplied of all the feature points, with their planimetric and altimetric coordinates and the date the information was gathered.

Final Outputs

For each site considered and using the topographic data available, the following should be prepared:

- the respective water level elevation / surface area curve and water level elevation / reservoir volume curve for each site for each of the different cascades, to be used in the energy studies, studies into multiple water uses and socioenvironmental studies;
- calculation of the planimetric and altimetric location of the information gathered from the geological and geotechnical investigations, the river gauging stations and the features of interest identified in the socioenvironmental studies; and
- calculation of the drainage areas for all the river gauging stations for each sub-basin of interest and at each potential site for a project.

4.1.2 Hydrometeorology

The hydrometeorology studies are started at this phase so that there is consistent, homogeneous information available on the whole river basin by the time the Final Studies begin, and also to provide information of great enough precision to formulate and shortlist the cascade options during the Preliminary Studies.

The hydrometeorological studies are therefore designed to characterize the elements needed to estimate the energy potential and calculate the dimensions of the structures.

The elements required for estimating the energy potential are the records of the monthly average natural flows and the normal water levels at the potential dam sites.

Physiographic and Climatological Characterization of the Basin

Before the basin can be characterized, aside from its location, several other of its physiographic features must be defined, such as its surface area, perimeter, hypsometric curve, the shape of the basin, drainage density, channel slope, vegetation, pedological features, current land use, relief, and others.

Some of these elements are important for interpreting the results of the hydrology studies, as they can directly influence the hydrometeorology of the basin and consequently the flow characteristics, hydrology and sedimentology of the main water course.

The most representative meteorological data should be gathered: rainfall, temperature, humidity, radiation, winds, evaporation, pressure and any others of significance for characterizing the climate of the region under study.

Net Evaporation

When reservoirs are built, the water balance of water courses is altered. In the area flooded for a reservoir, evapotranspiration is replaced by evaporation.

The monthly net evaporation should be determined for each month of the year, providing twelve values per year expressed in millimeters.

In the Inventory Studies of hydroelectric potential, net evaporation rates should be calculated for each reservoir. This is the difference between the real evaporation of the reservoir and the real evapotranspiration in the reservoir area before it was built. For projects linked up to the National Interconnected System (Sistema Interligado Nacional, SIN), the net evaporation is estimated by using the method set out in the System for Evaluating Net Evaporation from Reservoirs (Sistema de Avaliação da Evaporação Líquida dos Reservatórios – SisEvapo).[1] For projects in semi-arid areas of the northeast of Brazil, the real evaporation of the reservoir is obtained by collecting data from evaporation tanks, while real evapotranspiration in the reservoir area is estimated by the water balance method (ONS, 2004).

The SisEvapo system is being extended to the other river basins in the country. Its use is recommended for reservoirs in basins for which the SisEvapo system is prepared to calculate net evaporation. The information needed to use the system should be included in the final report of the survey. For those basins for which the system is not yet adapted, the methodology should be described in the final report of the survey along with all the data utilized.

Net evaporation should be calculated for all the projects in the basin, including existing ones. It is used to calculate the natural mean monthly flows (in the case of existing projects) and in the energy studies.

Flow Records from River Gauging Stations

The selection of river gauging stations for the hydrology studies should take into account their location in the river basin, the observation period, the existence of data gaps, the consistency of the data and of the rating curves, and the density of stations in the river basin.

The limnimetric and stream discharge readings should be taken into account in determining the rating curves and the series of mean daily and monthly discharge rates.

When there is insufficient data or no data from river gauging stations, a hydrometeorological model of the river basin can be used to fill any gaps and/or extend the natural flows recorded at the stations. As a last resort, when the basic data from the stations are inadequate, data from stations in river basins with similar hydrological features can be used.

The relevant entities should be informed of any alterations found in the rating curves and drainage areas at the official river gauging stations, which should be accompanied by detailed technical justifications.

Records of Mean Monthly Natural Flow

The natural flow is the flow along a section of river in the absence of the action of man in the basin upstream from this section. The kind of action that could affect it is the regulating of the water course by the action of reservoirs, diversions to other river basins and withdrawals for different uses.

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1 CEHPAR/LACTEC. *Programa SisEvapo v2.0. Relatório Técnico*. Curitiba, 63 pages. The SisEvapo system can be obtained from the Ministry of Mines and Energy.

For each dam site under study, a series of mean monthly natural flows must be calculated, which should be derived from the flows recorded at one or more river gauging stations along the same water course or in the same river basin.

The mean monthly natural flows at the planned sites for projects should start from 1931 and go under at least two years prior to the conclusion of the Inventory Study, even in river basins whose projects are not yet connected up to the National Interconnected System (SIN).

In determining the mean monthly natural flows for each project site, the consumptive uses should be estimated (item 4.2.1) and, when applicable, the influence arising from the operation of the reservoirs and the effect of net evaporation on the reservoirs. The monthly values for consumptive uses should be added to the mean monthly natural flow values obtained thus far.

The hydrological data for the projects under study should be compared with the respective data from the other projects in the same river basin, both upstream and downstream, which will allow any negative increments or incompatible intermediate contributions to be identified and consequently corrected.

The methodology used for determining the series of data must be described, with an explanation of how the flows were obtained for each period. When extra data are needed to fill gaps in the readings from river gauging stations, it should be stated in the methodology what studies were carried out, and the months for which the data were added should be flagged.

Studies of Minimum Flows

It is important to assess minimum flows as these values will be used in the studies for the filling and operation of the reservoirs and for defining the discharges downstream to meet the requirements for the multiple water uses and the environmental needs.

The minimum flows should be assessed by analyzing the daily mean flows statistically. Flow duration curves can be presented for identifying the characteristic values and calculating the occurrence probability of the flows and their duration.

When there is no data available, flows can be estimated by drawing correlations with basins of similar hydrological features for which there are data available, or by making an approximate analysis of the rainfall/runoff ratio.

Flood Studies

The only figures needed for designing the structures at this stage are the flood flows for the spillways and diversion works. A statistical analysis should be done of the daily extreme flows, whenever there are reliable records of these data. When such data are not available, the parameters required can be estimated by drawing a correlation with river basins of similar hydrological features for which data are available, or by making an approximate analysis of the rainfall/runoff ratio.

The probable maximum flood, which is required to design the spillway, is calculated as the maximum flow that would occur once in every 10,000 years. For the diversion works, it is normal to adopt the values corresponding to the peak flows with recurrence intervals of 25, 50 and 100 years. As a suggestion, two-parameter exponential distribution and Gumbel distribution can be used for determining flood flows.

Rating Curve in the Tailrace Canal

In the Preliminary Studies, a schedule must be drawn up of the field studies necessary to measure the discharge, inspect the river gauging stations, install staff gauges and carry out echosounding surveys of the topography, which will provide data for the rating curve in the tailrace canal to be used in the Final Studies.

When reliable data are not available for the Preliminary Studies, the water level in the tailrace canal of each project should be estimated, assuming this level as corresponding to a flow that is 10% greater than the mean during the critical period, or the maximum normal water level of the reservoir downstream, if this level is higher.

Studies into Sediment Transport and Silting in Reservoirs

Existing data, information and studies can be used to assess the silting characteristics of the reservoir and predict the useful life of the project, as well as to study what sediment control measures will be needed.

Once the data have been obtained, the next steps in assessing silting include determining the mean annual solid discharge at the project site, obtaining the reservoir's sediment retention efficiency and evaluating its apparent specific weight.

The **mean annual solid discharge** (D_{st}) at the dam site is the sum of the suspended load and bed load. Generally, the bed load does not leave the reservoir through the spillway or through normal discharge processes. Therefore, it is crucial to measure the bed load discharge, especially in the case of small and medium-sized reservoirs.

In Brazil, it is normal only to measure the suspended load discharge. Therefore, total solid discharge should be determined using a coefficient that takes into account the bed load discharge. This coefficient should be adjusted according to experience acquired in other studies.

The solid discharge measurements can be presented in daily or sporadic values. When the data are sporadic, a sediment rating curve is plotted, correlating solid discharge to stream discharge.

When there are no sedimentological data, a value can be adopted by using regionalized data. The *Guia de Avaliação de Assoreamento de Reservatórios*[2] [Guide for Assessing Silting in Reservoirs] contains procedures for regionalizing sediment data. Overall, it is recommended that the mean annual suspended load discharge data from river gauging stations within the river basin itself and/or from neighboring basins should be used in the analysis by correlating them with the respective drainage areas. Sediment load regionalization should be used with caution and must be confirmed by measurements taken *in situ*.

It is recommended that a calculation be made of the amount of solid material transported annually throughout the project's useful life (50 years) so as to foresee any alterations in the production of sediment in the basin arising from the action of man.

The **sediment retention efficiency** (E_r) of a reservoir is the ratio between the solid discharge that is retained in the reservoir and the total outflow discharge.

The **apparent specific weight** (γ_{ap}) of deposits in a reservoir varies with time due to compacting by the weight of the water and the weight of the sediment itself. In order to determine γ_{ap} the grain size of the material transported must be known.

Once the annual mean solid discharge - D_{st}(t/year), the sediment retention efficiency - E_r and the apparent specific weight - γ_{ap}(t/m^3) have been obtained, the annual sediment volume, S_a(m^3/year) can be calculated by:

$$Sa = \frac{D_{st} \times E_r}{g_{ab}} \qquad \left(m^3/s\right) \tag{4.1.2.01}$$

2 Guia de Avaliação de Assoreamento de Reservatórios, ANEEL, 2000.

The silting rate, T_a(year) of a reference sediment volume $V(m^3)$ in the reservoir can be calculated by:

$$T_a = \frac{V}{S} = \frac{V \times \gamma_{ap}}{D_{st} \times E_r} \quad (year) \tag{4.1.2.02}$$

For the purposes of this Manual, the reference sediment volume is the volume that corresponds to the highest of the following three elevations: the sill of the water intake or the sill of the headrace canal or the highest point in the structure designed for sediment retention, when there is one.

- Useful Life of a Project

The useful life of a project is the period of time before which sediment deposits start to interrupt the generation of electricity. This happens when the sediment deposits exceed the reference sediment volume.

In Inventory Studies, this is calculated by taking the volume of sediment for twice the project's useful life. As this is normally 50 years, the sediment volume is calculated for 100 years. So:

$$S_{100} = 100 \times S_a \; (m^3/year) \tag{4.1.2.03}$$

The volume of sediments in 100 years is compared to the reference sediment volume. The volume of sediments calculated should be less than the reference sediment volume. If it is not, steps should be taken to minimize silting in the reservoir.

Effects on Sediment Transport Downstream from Dams

The erosion effects downstream from a dam are primarily a function of changes to flows, reduced solid load transported and the reduced grain size of the bed load downstream from the dam. If this material has a larger grain size, the sediments with a smaller grain size flowing out from the dam will be transported further downstream, and a layer of coarser material will be left, called the "armor layer", which is practically stable. If the material on the river bed is fine, there will be more sediment transported downstream, until a new stable slope is reached for the bed.

Some formulas and models are available in the *Guia de Avaliação de Assoreamento de Reservatórios* that can be used for assessing the degradation the river bed will suffer based on the diameter of the armor layer or the length of the stable slope.

Sediment Control

If structures have to be designed for sediment control purposes, they should be analyzed and designed interactively when the project designs are decided upon (items 4.7 and 5.5).

4.1.3 Geology and Geotechnics

The geological and geotechnical studies help identify the location of likely dam sites and their associated structures, and are also used in the socioenvironmental studies.

Services

In the area of influence of future reservoirs, geological photo-interpretation should be carried out of radar and satellite images and aerial photographs to supplement existing geological and geomorphological maps or be used to prepare new ones. If necessary, the areas of future reservoirs should be inspected by land, water or air with a view to consolidating the data from thematic maps, identifying:

- general geological and geomorphological conditions;
- areas at risk of erosion, identifying present sources of erosion;
- areas with potential instability of the hillsides;
- areas with mineral resources, including traditional mining;
- areas where watertightness could be compromised; and
- areas at risk of natural or induced seismic shocks in the study area.

At this phase, a general geological survey of the area of influence should be undertaken with a view to providing inputs for future study phases.

The main **geological and geotechnical parameters** to be covered at the potential dam sites for design purposes and for preliminary estimates of civil engineering costs are:

- mean soil coverage until the top of the bedrock;
- predominant type of rock;
- general characteristics of the foundations;
- availability of natural construction materials, such as quarries, clay deposits, soil deposits, natural sources of sand and gravel deposits;
- susceptibility to landslides;
- preliminary assessment of silting potential of the reservoir's area of influence; and
- assessment of the degree of mining activity both upstream and downstream from the reservoir's area of influence.

Of particular importance for the dam construction cost estimates are the assessments of the state of the foundations. The foundations should be investigated first with a view to identifying and analyzing their surface geology. Depending on the findings of this analysis and the provisional layout for the structures necessary for the project, other expeditious surveys can be undertaken to confirm the hypotheses formulated. Two methods for these are auger borings and inspection pits. The results are presented in the form of geological and geotechnical sections for each potential dam site.

The estimates of natural building materials available – deposits of sand and gravel, rock and soil – are based on indications of their location, quantity and volume.

Supplementary investigations should be planned for the selected sites to be undertaken in the subsequent study phases.

4.1.4 Environment

The gathering of socioenvironmental data and information should supplement the information gathered at the study planning stage (Chapter 3), addressing the different synthesis components selected to represent the socioenvironmental system and helping in the analysis of the positive and negative impacts and the needs for Integrated Environmental Assessments.

The basic data required are set out per synthesis component in item 4.3. These data are both quantitative and qualitative. Most of the data required can be found in secondary sources (official databases, universities, research centers, etc.). However, the secondary information for some elements and/or components and in some regions should be checked in the field or against existing satellite images or aerial photos or by other means whenever there is not enough to build up a picture of the region for the analyses, and when it is indispensable for the studies to be undertaken.

When field trips have to be undertaken to obtain qualitative and quantitative data on a given aspect, they should only be done after the available sources of secondary data have been exhausted, so that a sufficiently accurate picture of the situation can be built up for the analyses and field trips to be clearly focused. The field work should target issues that have already been identified as necessary for producing the knowledge required.

In order to build up a picture of the region for each synthesis component, involving quantitative and qualitative information, there must be an analytical and interpretative aspect to the work, which means that experienced professionals must be included in the teams.

It is important that as of this stage in the survey, the team should work in integration using an interdisciplinary approach, as this will allow a rounded picture of the synthesis components to be built up and the inter-relationships between the elements in the socioenvironmental system to be identified.

The variables and parameters needed for the socioenvironmental characterization will alter with time and space in a given river basin. To identify the socioenvironmental aspects and their integration, an appropriate scale must be established to give a representation that takes into account most of the indicators.

The scale of the study must be such that the set of projects under analysis can be addressed in conjunction. Different scales from this can also be used to analyze topics and items of particular importance, using existing official maps. The data and information should be compatible with the scale of the study, and thematic maps should be prepared with a suitable scale for the socioenvironmental items of relevance and for the local assessment (e.g. subdivisions of the basin).

The scale to be adopted for the data analysis should be in keeping with a total view of the water basin. Other scales can be used to represent the findings, depending on the theme in question.

The spatial information must be stored in a geographical database that is compatible with the database kept by the concession-granting authority (MME).

4.2 MULTIPLE WATER USES

4.2.1 Diagnosis of Multiple Water Uses

The aim of the diagnosis of multiple water uses is to determine the historical record of withdrawals for consumptive uses for each project site under study, and also to estimate future restrictions on these projects imposed by the use of the waters by other sectors.

The idea is also to identify the potentialities for multiple water uses in the water basin under study and verify this potentiality against the provisions of the National Plan for Water Resources, state plans, water basin plans and any sector and integrated plans available.

Quantitative and qualitative information should be gathered for the diagnosis, most of which are available from secondary sources (table 3.1.3.01). When the secondary data are not up-to-date or are insufficient for the depth of analysis required, field studies should be carried out.

With a view to assessing whether there will be any need to consider the multiple water use scenario at the Preliminary Study phase, it should be identified whether the multiple water uses in the river basin under study could cause any major alteration to the choice or assessment of the different cascade options. This could be if the water use scenario for a given river basin indicates that the water availability is far below the natural flow, or there are major water level restrictions.

Based on the data collected, all the different water uses in the basin should be identified, including those that could have a major interference in electricity generation.

Consumptive Uses

The monthly flows for consumptive use at prospective project sites are the result of summing the flows of all water withdrawals, minus returned waters upstream from the site in question. The effective consumptive flows should be estimated for each of the following uses:

- urban water supply;
- rural water supply;
- livestock;
- irrigation; and
- industrial uses.

In order to determine the monthly consumptive uses, the diagnoses contained in any existing water resource plans should be taken into account. Alternatively, the methods to estimate flows for consumptive uses adopted by the National Interconnected System[3] can be used, or technical studies can be developed in-house. In this case, the methodology should be described and justified in the Inventory Studies report.

As an outcome of this work, the monthly consumptive flows for each prospective dam site under study are prepared, covering the same period as the records for the natural monthly mean flows, i.e. from 1931 until at least two years prior to the conclusion of the Inventory Studies. This means that it will often be necessary to estimate the water withdrawal volumes from years past and extrapolate them to the data obtained.

3 ONS, *Estimativa das Vazões para Atividades de Uso Consuntivo da Água nas Principais Bacias do Sistema Interligado Nacional.* FAHMA-DREER, 2003

If there are any sector plans or water basin plans, the information contained in them should be analyzed from the perspective of multiple water uses with a view to building up a long-term scenario.

For each use – irrigation, urban and rural water supply, livestock and industrial uses – information should be collected on consumption forecasts, identifying the areas where the water uses are concentrated, locating population areas and the places where water withdrawals are needed that will be benefited or hampered by each prospective reservoir.

Non-Consumptive Uses

When it comes to water uses that do not involve any withdrawals but which compete with hydropower generation, efforts should be made to identify where the areas of use are and the consequent restrictions imposed on the electricity sector for ensuring the efficient use of the waters. In general these uses are:

- navigation;
- flood control;
- tourism and leisure;
- aquaculture and fishing; and
- ecosystem maintenance.

If there are any sector plans or water basin plans, the information from these should be analyzed from the perspective of multiple water uses with a view to building up a long-term scenario.

This information includes:

- navigation: number of kilometers and location of sections covered in the plan and influenced by each prospective reservoir, historical freight transportation data, data on the number of people in the region, and programs devised to adapt the waterway infrastructure to meet these requirements;
- flood control: geographic area and location of urban and rural communities protected and benefited by each prospective reservoir and historical data on critical events in the region;
- tourism and leisure: location of tourist areas influenced by the introduction of each prospective reservoir;
- aquaculture and fishing: location and capacity of existing and planned projects that are influenced by each prospective reservoir;
- ecosystem maintenance: identification of sections and respective values of flows required to maintain the ecosystems.

4.2.2 Scenario of multiple water uses in the river basin

The scenario of multiple water uses should start to be built up during the Preliminary Studies, once the diagnosis has been done, and should be finished during the Final Studies. However, in the case of water basins with multiple water uses that could significantly alter the selection and/or assessment of the different cascade options, these studies should be considered at the Preliminary Studies stage. Examples of these are river basins where the scenario of multiple water uses makes it necessary to redesign projects or even rule out dam axes that would otherwise be included in the cascades.

In the Final Studies, the different cascades are compared against the long-term scenario of multiple water uses. Since for each projected scenario it is necessary to undertake several studies, it is acceptable to build up one single scenario, which should be the average or expected scenario and which will not take into account any extremes of abundance or scarcity.

This scenario is built up from a set of physical, social, economic and political data relating to a specific period for the purposes of a future study.

In order to prepare this scenario, the information obtained at the planning phase must be drawn on (items 3.1.1, 3.1.2, 3.1.3, 3.1.5 and 3.3), as must the information from the Preliminary Studies (items 4.1.1, 4.1.2, 4.1.4, 4.2.1 and 4.3).

For the electricity sector, this scenario should be prepared in order to address its long-term planning needs. However, as the National Plan for Water Resources (PNRH) is the basis for the use of all water resources, it is acceptable to prepare a scenario with a time frame that is compatible with the PNRH itself.

The scenario should, for each section of river in the water basin under study, specify the portions of flow and head affected by the multiple uses of the waters in such a way that energy generation is hampered, including:

- net flow losses due to water withdrawals for consumptive uses and diversions to other river basins, when applicable;
- flows uses in operating locks, when applicable;
- flows used for navigation;
- volumes for reservoirs and restriction flows for flood control;
- minimum flows needed downstream to meet multiple water use and environmental needs;
- potential restrictions on reservoir operation as a function of their use for tourism and leisure.

If the basin under study is already covered by a water basin plan that is in compliance with existing legislation, the creation of this scenario of water uses should take into consideration all the uses identified in the plan and projected uses in the future.

It should be noted that all the information, data and assumptions used in drawing up the scenario must be set forth clearly and transparently in a specific item in the final report, which will be used to assess the positive and negative socioenvironmental impacts of the final selected cascade.

Consumptive Uses

The series of consumptive uses obtained in item 4.2.1 should be projected forwards to the last year of the time frame for the long-term scenario. In the energy studies, the twelve values for this year are subtracted from the historic monthly natural flow records.

When building up the scenario of consumptive uses of the waters, a number of references should be used, such as:

- projections made by official entities, such as IBGE and IPEA;
- water resource plans, when available;
- official master plans for development (PPA [multi-year plan], state plans, sector plans, etc.);
- studies already undertaken to meet environmental requirements;
- studies or methodologies for estimating scenarios of consumptive water uses in the river basin, such as the methodology used by the ONS;
- maximum flows that water management bodies designate for other water uses.

A water balance should be prepared that shows the extent to which the waters are affected at each prospective dam site in the study area.

Non-Consumptive Uses

- Navigation

When incorporating navigation activities into the scenario of non-consumptive uses, all water resource plans, waterway navigation plans and different sector plans should be taken into consideration insofar as they influence in some way transportation on the river.

Based on these plans, projections should be estimated of the movements of freight and people on the waterways in the region, and any programs that have been devised as part of broader waterway infrastructure development plans to meet these needs should be consulted.

The sections of river should be identified that will be considered in the plans as waterways, along with the size of the vessels and traffic expected. All the projects under study along these sections should be designed in such a way that vessels can be raised or lowered to sections at different levels, when required.

When sections of river are identified as navigable either before or after the introduction of the prospective reservoirs, sector studies should be used to estimate the type and quantity of vessels to be transported between different water levels.

When flows are interrupted by locks to the point of influencing power generation capacity, calculations of these values should be made based on the type and quantity of vessels and the difference in water level, and presented in the form of a vector of 12 monthly values for each project for use in the energy studies.

- Flood Control

In order to determine the flood storage capacity of the reservoirs for flood control in the long-term scenario for the river basin, the first thing to do is to identify the main existing or planned areas of occupation that are subject to flooding by overspills from the main channel, whether they are upstream or downstream from the projects, during major floods.

Generally speaking, macro drainage plans provide for a set of local works to protect the most vulnerable areas by using reservoirs to reduce flood peaks. An analysis of existing plans and studies will help build up the scenario, which should take account of the total flood storage capacity to be allocated at each site under study.

In the Final Studies, for each cascade option, the total flood storage capacity for each flood control point should be distributed amongst the upstream reservoirs in proportion to the mean annual peak flow and the reservoirs' live storage, using the formula below:

$$Vesp_i = \alpha_i \,.\, Vesp$$

$$\alpha_i = \frac{\overline{Qp}_i \,.\, Vu_i}{\sum_j \left(\overline{Qp}_j \,.\, Vu_j \right)} \qquad (4.2.2.01)$$

where:

Vesp	total flood storage capacity;
α_i	coefficient of the proportion of flood storage capacity in reservoir i;
Qp_i	mean flood peak at the site of reservoir i;
Vu_i	live storage of the reservoir.

If there is more than one flood control point in the basin, then only the largest of the flood storage capacities needed to assure the protection of each flood control point should be taken account for each reservoir. Where the streamflow regime of the basin is seasonal, changes to the flood storage capacities should be considered for each reservoir, starting the rainy season with zero flood storage capacity, reaching the required value only in the month with the most rainfall, and returning to zero at the beginning of the dry season. A curve for the flood storage capacity of each reservoir throughout the year is then plotted.

In the Preliminary Studies, only the flood storage capacity of the month when the critical period of the reference system begins should be taken into account (item 4.6.1).

- Tourism and Leisure

The scenario for tourism uses should be based on official information and take into account the fact that a new reservoir does not necessary imply in an influx of leisure users, as this depends on other agents which are often only private.

This means that when reservoirs are planned for flow regulation or flood control, the tourism potentialities of the region where the reservoir would be built should be identified, as should any potential conflicts that might arise from the shared use of the reservoir banks and impounded waters. The potential restrictions on the operation of the reservoirs should also be identified as a result of their use for tourism.

- Aquaculture and Fishing

When the scenario for aquaculture uses of the reservoirs is prepared, the sector plan and water basin plan should be consulted in order to gather the information needed to characterize the aquaculture facilities and to project their growth in the long term.

Once the characteristics required for the installation of the aquaculture facilities have been established, their location at each planned reservoir can be estimated. Any potential conflicts over the use of the waters should be identified, in terms of their quality, access to the facilities and operation of the reservoirs.

When the flows that are affected by the fish passage systems are significant to the point of influencing the energy generation capacity of the project, these values should be calculated from the sizes of the structures and presented in the form of a vector of 12 monthly values for each project, to be used in the energy studies.

- Ecosystem Maintenance

In order to prepare the scenario for ecosystem maintenance, the ecosystem conservation and preservation requirements should be considered, as well as the needs of any traditional communities living downstream from the intervention in the water course.

When building up this scenario, it is necessary to consider the minimum dilution flows necessary to ensure the body of water stays within the class in which it has been classified, and to minimize the environmental interference that could be caused by altering the streamflow regime.

In order to calculate the flows necessary for maintaining the ecosystems, the regional water management entity should be consulted.

4.3 SOCIOENVIRONMENTAL DIAGNOSIS

The studies to be carried out as part of the socioenvironmental diagnosis aim to:

- supply the information required for formulating the different cascade options and designing the projects;
- build up a reference situation for assessing the positive and negative socioenvironmental impacts of the projects and cascade options;
- provide information necessary to characterize the main socioenvironmental features of the basin (the most sensitive areas, potentialities, main uses of the waters and land, socioeconomic aspects) which give a broad view of the most significant socioenvironmental impacts to be caused by the projects and cascades, highlighting the projects' cumulative and synergistic effects in order to be able to compare the different cascades and fulfill the requirements of the Integrated Environmental Assessment.

The studies should be conducted in such a way as to produce knowledge about the study area so that a reference situation can be created for the purposes of comparing the socioenvironmental impacts inherent to the different cascades. As such, the studies must aim to gain an overall understanding of the current reality in the study area, highlighting its past and future trends and providing a spatial representation of the most significant aspects required to make the comparative analysis. An integrated focus should be adopted in the studies, seeking to lay bare the processes of greatest importance in structuring the socioenvironmental dynamics of the study area over space and time.

It is not necessary to develop an in-depth characterization of the area for these studies. Indeed, the idea is to interpret and process secondary data and a sufficiently large set of primary data to build up a comprehensive reference situation in order to analyze the socioenvironmental impacts of the projects and cascades. This should enable the identification of the most significant socioenvironmental processes affected by the interaction of the project in the region and those aspects that should be looked into in greater depth. In particular, when knowledge of the study area is being built up, it is important to apprehend the views of the different social groups on the issues under analysis.

The diagnosis should be structured and organized according to the synthesis components, which are described in detail in items 4.3.1 to 4.3.7.

The studies are developed by consolidating, analyzing and spatially representing the data and information pertaining to each synthesis component, giving special attention to the issues already identified during the planning phase (Chapter 3). Also, as the synthesis components involve interactions between different elements from the socioenvironmental system, an interdisciplinary approach should be used to integrate the analysis of each synthesis component with that of the others in an overall attempt to comprehend the environmental processes in the study area. This means that the characterization of the synthesis components may take into account the fundamental inter-relationships between their elements.

As an input for the Integrated Environmental Assessment, the socioenvironmental diagnosis should highlight the past and future development trends of the region so that a scenario of its future development can be built up. Also, those socioenvironmental processes that are systemic or are deemed more significant from a regional perspective should be highlighted, while it is also necessary to have a reference situation for the analysis of each project. The following items should be addressed:

- the potentialities of the river basin: its natural resources, main socioeconomic activities, production trends, uses of the waters and land, landscape and tourism aspects, existing plans and programs for the region, and the socioeconomic potentialities that can be leveraged by the introduction of hydroelectric power projects in the region;

- areas under socioenvironmental management: better preserved areas with original vegetation, degraded areas, areas for biodiversity conservation, and areas with restrictions or conditions on their use, such as conservation areas or indigenous lands;
- areas of environmental sensitivity: areas that are most sensitive to the presence of hydroelectric projects should also be identified and located. Whenever possible, a classification should be created for different levels of sensitivity;
- existing and potential conflicts: related to the use of the waters and the soil, the biodiversity conservation strategies, and the policies, plans and programs that exist for the region's development.

  Potential conflicts are understood as problems that in one way or another would be worsened or would arise if a hydroelectric project were built, such as:
- conflicts brought about by the resettlement of urban and rural communities;
- substitution of land uses, breaking down of social relations and economic output;
- property speculation;
- interference in archaeological, historical and cultural heritage;
- areas of conflict over land use;
- interference in the natural resources available for development;
- loss of tourism potential;
- loss of natural resources (minerals, biodiversity);
- conflicts over the multiple uses of the waters (item 4.2);
- interference in indigenous lands and federal, state or municipal conservation areas.

Spatial Representation

As Inventory Studies involve making comparisons between different groups of projects organized in different ways inside a given water basin, the dimension of physical space is of great importance. Meanwhile, in order to fulfill the requirements of the socioenvironmental diagnosis, a reference situation must be built up that can be used for the analyses on two levels: of the projects and of the cascade options that are selected. In this sense, the results of these studies for each synthesis component should be represented spatially using the following procedures:

- georeferencing of the information from each synthesis component in the study area in order to make it feasible to integrate the characterization elements in a single map, making up a reference situation that can provide an understanding of the issues inherent to each synthesis component. The most sensitive areas and areas of conflict should be marked out, and in the case of the synthesis components related to socioeconomic aspects, the areas where the existence of any potentiality that could be harnessed by the introduction of the projects should also be marked out. The synthesis component maps and the thematic maps used to draw them up must be kept in the Geographic Information System (Sistema de Informações Geográficas);
- segmentation of the reference situation for each synthesis component in the study area into sub-areas by making an analysis of their similarities and differences. The sub-areas are continuous units of land which contain particular relationships and processes that mark them out from the others, and which determine their relationship with the dynamics of the synthesis component in the study area as a whole. The indicators and criteria used to segment the area into sub-areas must be given;
- weighting of each sub-area according to the importance of the processes by which it is characterized to the dynamics of the synthesis component in the study area as a whole. The weights are given according to the repercussions of the processes occurring in each sub-area on the study area, highlighting those

aspects that exceed the boundaries of a single sub-area. The weights are attributed on a scale of zero to one, and their sum should equal one. Given the specific features of each synthesis component and each river basin under study, different criteria can be adopted for the weighting of the sub-areas, though these must always be described and justified in the study.

This mechanism makes it possible to formulate a basis for identifying the impacts of each project and how it interacts with the synthesis components in each sub-area, while also giving an overview of the combined impacts of the projects in each sub-area and those that extrapolate the boundaries of these areas.

With this procedure, it is possible to formulate a reasonable basis for analyzing the impact processes inherent to each possible cascade option without, however, failing to address the most significant processes inherent to each project.

Results of the Diagnosis

The map of each synthesis component should be accompanied by a description that highlights the attributes that were instrumental in defining the boundaries of each sub-area, putting each one within the wider context of the study area and its interrelationships with the other sub-areas. This description should also highlight any aspects of note or particularly sensitive areas from a social or environmental perspective, as well as any potentialities that could be leveraged by the introduction of the projects and any existing or potential conflicts, all of which will be used in formulating the different cascades and the design of the projects.

At the end of the diagnosis, the analyses of all the synthesis components must be consolidated. Using an interdisciplinary approach, the interactions between the processes inherent to the synthesis components should be identified and investigated, building up the general scenario of the socioenvironmental conditions within the study area. When deemed necessary, these interconnections can also be represented on a single map (**synthesis map**).

The data, information and findings of the diagnosis are also fundamental inputs for the first stage of the Integrated Environmental Assessment.

The information produced at this stage should be inputted to the SINV system for ease of comparison and selection of cascade options at the end of the Preliminary Studies.

Synthesis Components

The synthesis components adopted to represent the socioenvironmental system are:

- aquatic ecosystems;
- terrestrial ecosystems;
- ways of life;
- territorial organization;
- regional economy; and
- indigenous peoples / traditional communities.[4]

As the physical processes and features provide the support and interaction between the environmental processes, they are not called synthesis components, but viewed as basic elements for the analyses of all the six synthesis components.

4 Decree 6,040 of February 7th 2007 – National Policy for the Sustainable Development of Traditional Peoples and Communities.

Likewise, all the historical, cultural, archaeological, speleological, landscape and ecological heritage is taken as a characterization element and consequently related to the synthesis components.

Items 4.3.1 to 4.3.7 below set out the theoretical framework and content of the physical processes and features for each of the synthesis components, as well as the characterization elements used to structure them. The tables provide a summary of these elements and indicate other sources of information.

4.3.1 Physical Processes and Features

It can be seen from the structure for the socioenvironmental system presented in items 2.3 and 4.3 that while the physical processes and features are not a synthesis component, they are nonetheless an essential element that works in conjunction with these components, in that they are what ensure the continuity and interaction of the biological and human relations.

While the main elements of river basins are their slopes and stream channels, they must be seen from a broader perspective as a complex system that contains processes of diverse natures which interact amongst themselves and which vary with time and space, forming what one might call a landscape unit.

This means that river basins can sometimes behave like a substrate for the occurrence and distribution of plant and animal species and sometimes like a resource and precondition for the development of human activities.

Given that the physical features are inevitably connected to the biological and socioeconomic features, priority must be given in the socioenvironmental diagnosis of the physical processes and features which make these interactions most evident. In this sense, the surveys and the depth of the analyses must be compatible with the contents of the synthesis components.

- **Geological Features** – The geological approach involves gathering and analyzing information that can help identify at least the following aspects: geological units and structures, associated lithologies and mineral potential. A correlation should be drawn between the geological evidence and the socioenvironmental segmentation of the study area. The criteria to be used for segmenting the area geologically are the strength of the materials, elements of the relief that impose some kind of restriction, and the existence of minerals. The information gathered for item 4.1.3 should be given priority in this process.
- **Geomorphological Features** – The main geomophological features and morphodynamic processes should be identified (dissection and deposition forms and processes). The geomorphological segmentation should prioritize the analysis of the different reliefs and processes at play, the degree of stability, erosion and deposition processes. The information gathered for item 4.1.3 should be given priority in this. In order to assist with the analysis of the river habitats, the processes that correlate to the main morphological features should be identified and detailed, such as altitude, channel slope, valley profile (flat-bottomed, V-shaped, U-shaped, wide floor), channel pattern (straight, meandering, braided), presence of rapids and white water, presence of islands, and sedimentation / erosion zones.
- **Pedologic and Edaphic Features** – The main soil types in the area should be identified, detailing their physical, chemical and structural features so as to identify their usage potential and limitations. The soils that are suited to agriculture and forestry should be identified, as should their susceptibility to erosion. The information gathered for item 4.1.3 should be given priority in this analysis.
- **Hydrology and Climatology** – This topic involves describing and characterizing the streamflow regime and climatic features of the study area, the surface waters and the ground waters (or available surface and ground waters). This characterization should be based on the studies from item 4.1.2.

- **Water Quality** – This element is important for the analysis of the following synthesis components: aquatic ecosystems, regional economy and ways of life. As such, the analysis should address the following elements:
  - preservation of biological diversity – water quality indicators should be used to classify the bodies of water according to the ecological features required for ensuring the preservation of their biological diversity, as set out in item 4.3.2;
  - water uses – the water quality indicators used should be capable of characterizing the water potablity and purity levels needed for domestic water supply and economic activities in general;
  - water-borne diseases – the indicators for this item should identify sources of contamination by domestic wastewaters and the regional epidemiological profile.

The study of the water quality should start by identifying the main activities in the basin and any potentially polluting elements discharged into the water bodies. Many of these data can be obtained by consulting the secondary sources kept by environmental entities in some Brazilian states and from water quality entities, when available. However, the spatial location of the activities must be based on the land usage patterns that can be identified in satellite images. Land use should be mapped out using the same criteria as the studies for the Regional Economy synthesis component and the other synthesis components.

When there are no pre-existing water quality data or the data that do exist are insufficient to meet the objectives of this study, preliminary field studies must be carried out, including at least two campaigns at times chosen to capture significant variations that could affect the physical and chemical quality of the waters. These periods could be different depending on the biological and geographical features of the river basin or the human occupation of the region, but could be picked to represent the dry season versus the rainy season, the sowing season versus the harvesting season, etc.

The sampling points must be picked according to: the land use in the river basin; the physical characteristics of the river channels; the hydrological and hydrogeological features (including aquifers); the position of the prospective dams; the optimization of the sampling points in terms of their ease of access and evenness of spatial distribution.

Results of the Diagnosis

An analysis of the abovementioned elements is made, based on which a matrix of physical and natural interrelations is built up.

The association between the geological segmentation and the endogenous processes that formed the relief, superimposed on the external processes defined by the streamflow and climatic patterns, erosion areas, and sediment transport and deposition gives a picture not just of the interactions between these processes but also of the physical segmentation of the landscape that makes up the river basin.

When considering the Aquatic Ecosystem and Terrestrial Ecosystem synthesis components, the physical processes and features in the study area provide the basis for the biological interactions that take place within the landscape, and so are a central element in analyzing the biological and geographical segmentation of the study area, and are translated into details of the different habitats which jointly form the river basin.

When analyzing the Aquatic Ecosystems, the information about the morphology of the river, the altitude, channel slope, channel pattern, valley profile, presence of rapids and white water, presence of islands, sediment accumulation/deposition zones and geological substrate are cross-referenced. The habitats along the river channel should be segmented so as to highlight the physical characteristics of importance for evaluating the biological diversity. The water quality is subject to special analysis in the Aquatic Ecosystems synthesis component.

Physical aspects are of importance to the socioeconomic and cultural aspects in that they are one of the features that define how occupation processes develop and how resources are appropriated, and thus how the territory is organized.

The characterization and analysis of the physical features and processes for evaluating the **Ways of Life**, **Territorial Organization**, **Regional Economy** and **Indigenous Peoples/Traditional Communities** synthesis components is directly linked to the following factors: agricultural suitability under different kinds of territorial management, mining and landscape potentialities, and state of degradation of the resources. The analysis of these features is based on four fundamental elements: **morphodynamic processes** (dynamics of erosion and deposition), **flood dynamics**, **relief segmentation** and **physical and chemical properties of the soils**.

The **morphodynamic processes** represent the whole dynamics of erosion and deposition within the river basin, adding erosion processes to the stream processes. This makes it possible to assess both the effects brought about by the introduction of the projects, and any restrictions imposed on land use or economic activities.

The **flood dynamics** are important not only for understanding the morphodynamic processes, but also with regard to the social groupings that are directly connected to the river. They involve a whole range of social and economic relations that are fundamental to the social reproduction of these groups, which depend on the seasonal variations of the floodplains.

The aim of the **relief segmentation** is to highlight the particularities of the units, providing inputs that will be used in the analysis of the restrictions and potentialities impinging on territorial organization and occupation.

The **physical and chemical properties of the soils** are important for making erodibility analyses and identifying whether the soil is arable.

At the end of this analysis, enough data must have been gathered to characterize the following aspects:

- physical segmentation;
- arable soil and erodibility;
- mineral resources;
- geomorphological heritage; and
- water quality.

This information will be represented on thematic maps with a scale that is compatible with the maps for the engineering studies and maps of the synthesis components, as described below:

- **physical segmentation** – mapping the main features and processes in the natural physical environment, highlighting the particular features of the geomorphological environments with the respective relief segmentation; processes such as erosion and deposition; geological and pedological characteristics of the materials; correlated structures;
- **arable soil and erodibility** – mapping of areas of arable soil and degrees of erodibility;
- **mineral resources** – mapping of the mineral resources (in terms of their mineral potential);
- **geomorphological heritage** – including formations of outstanding beauty, caves, waterfalls, etc.;
- **water quality** – primarily the mapping of stretches of river with markedly different water qualities.

4.3.2 Synthesis Component: Aquatic Ecosystems

The Aquatic Ecosystems synthesis component encompasses a multiplicity of processes and relationships that take place within the biophysical environment. In view of the complexity inherent to any study of ecosystems, conceptual frameworks and methodologies must be developed that ensure the diagnostic analysis is compatible with the scale of the work at the stage of the Inventory Studies that has been reached, without, however, compromising the systemic content of this synthesis component. It was decided that the focus here would be on **environmental factors essential for maintaining biological diversity**, prioritizing those elements that allow for a spatial assessment, and taking as a reference any studies being developed within the area of biogeography.

This synthesis component draws on information relating to the physical and biotic structures and the biological data on species, so as to permit the **identification of the different levels of ecological significance that exist amongst the different habitats that make up the study area**. Ecological significance is understood here as the potential of the system under analysis to present a greater level of biological diversity or endemism than the other subsystems.

In this case, the choice of sub-units of analysis should be made in advance, selecting those areas that represent combinations of natural features, meaning that they contain the ecological processes associated with the functioning and structure of biotic communities. Within this guiding principle, it was decided to adopt the sub-basins as the sub-units of analysis in the drainage network (sub-areas), while understanding that they could be grouped together or kept separate depending on the characteristics of each area studied. The main channel should, however, be considered as a single sub-unit of analysis (sub-area). It can, however, be subdivided in situations where there is any physical interference in its course caused by a geographical barrier that gives rise to systems with independent ecological features.

The characterization elements selected for structuring this synthesis component are described below and shown in summary form in table 4.3.2.02, at the end of item 4.3.2.

Riparian Forest (riverside forests, riparian forests, floodplain forests, igapó forest[5])

Riparian forests are very important for regulating the ecological interactions between the terrestrial and aquatic ecosystems. Their state of conservation and the spatial distribution of the vegetation in the sub-basins within the study area and along the main channel should therefore be investigated.

This can be undertaken using remote sensing equipment at a compatible scale. Field reconnaissance work should be carried out to identify the levels of conservation.

Water Quality

The physical, chemical and biological parameters to be measured should be chosen bearing in mind two guidelines:

- they must allow the rivers' water quality to be measured for the characteristics that could compromise the biodiversity, such as dissolved oxygen, pH, nitrogen and phosphorous content, suspended matter, toxic compounds, heavy metals, phytoplankton, zooplankton and macrobenthos. These are not necessarily the same factors to be investigated when studying water quality for the purposes of public water supplies or for other uses that require higher levels of purity and potability;

5 Igapó forest: part of the Amazon forest that grows near rivers on low-lying ground that is permanently flooded. The trees are tall but have low branches, which means there are rarely any vines or shrubs. (Ref: NETO, E. F. Dicionário Prático de Ecologia, Ed. Aquariana, São Paulo, 2001).

- they must allow simplified models to be used to assess the water quality according to the regional specificities of the river basin under study, taking into account the existence of sources of pollution and their concentration.

The water quality should be classified in order to represent the relative levels of quality encountered, providing a range of water quality levels that illustrates the different biological conditions of socioenvironmental quality.

It is recommended that the sub-areas be classified into three different levels:

Class A – systems whose ecological features are not compromised and in which there is no pollution;

Class B – systems whose ecological features are compromised to some extent by interference from sources of pollution;

Class C – systems whose ecological features are greatly compromised by the intensity of the levels of pollution.

When possible, this classification should be compared with the CONAMA water classification.

If necessary, the water quality analysis may also look into the levels of dominance between indicator species and the build-up of metals in species from different levels in the food chain.

Stream Physiography

The physical variables deemed useful for characterizing the aquatic ecosystems are chosen for their capacity to indicate the variability of the habitats and their capacity to support these systems. These are: stream order, drainage density, physical diversity of the river habitats and presence of river pools.

- **Stream Order**: The relationship between the stream order and the abundance of ichthyofauna implies that in high-order streams there are aquatic communities with greater biodiversity than those in low-order streams. In order to obtain the features that determine the biodiversity, the order of each sub-basin and of the main basin must be known.

Stream systems can be classified differently, but studies that use this as a factor for understanding the ecology of the aquatic fauna have mostly adopted the Strahler method (1952)[6], which is also recommended in this Manual.

According to Strahler, the smaller stream channels with no tributaries are first-order streams; second-order streams arise when two first-order streams join and only receive first-order tributaries. Third-order streams arise from the meeting of two second-order streams, and can receive first- and second-order tributaries; fourth-order streams arise when two third-order systems join, and so on. This system of classification is shown in Figure 4.3.2.01.

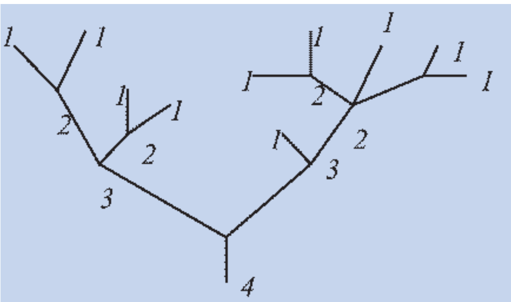


Figure 4.3.2.01 – Representation of Stream Orders in River Basins

6 STRAHLER (1952), "Dynamic Basis of Geomorphology", Geological Society American Bulletin, USA.

This means that each sub-basin should be classified according to its stream order and its status within the set of sub-basins under analysis.

- **Drainage Density**: This is the ratio of the number of confluences and the drainage area of each sub-basin.
- **Physical diversity of the main channel**: The correlation that exists between diversity of habitats and wealth of species leads to the expectation that main stream channels with a high diversity of habitats along its course will have fish communities composed of a greater number of species than could be expected from homogeneous rivers. The recognition of habitats along the river channel in each sub-area begins with studies of the physical features and processes, using variables such as altitude, channel slope, valley profile, thalweg profile, the presence of rapids and white water, the presence of islands, etc. These variables are directly related to the hydrodynamics of the system and the different kinds of processes that take place in the stream channels, and consequently to the aquatic fauna, determining the dispersion and spatial occupation of the species and influencing the structure of assemblages.

The use of the Shannon index (S)[7] is recommended for generating a value to express the relationship between the different habitats in the sub-areas, as shown below:

$$S=\sum_{i=1}^{n} P_i.\log P_i \qquad (4.3.2.01)$$

where:

P_i	percentage of the surface area of the sub-area that is occupied by each habitat identified;
n	number of habitats in the sub-area.

- **Heterogeneity of river habitats**: Once the different habitats that make up the main channel have been identified, it is important to observe the heterogeneity that exists in the drainage area associated to each one, as this is an important factor in assessing their capacity to sustain a high wealth of species. The analysis of this factor can be done by interpreting maps at a scale of 1:50 000 or 1:100 000, considering all the physical features mentioned previously for each habitat analyzed (stream order, drainage density, physical diversity of the river channel, etc.) so as to identify different scenarios of heterogeneity.
- **Ecologically Strategic Habitats**: In many situations, the biological diversity of a given region is enhanced by the presence of unique environmental conditions that operate by buffering impacts and maintaining different taxons and young fauna, while also allowing for the presence of endemic groups and the reproductive success of numerous species.

These habitats of strategic ecological importance include river pools, river beaches, rivers with unique physiography, etc. The analysis begins by confirming the effective use of these habitats in the region under study. Once this has been done, the area or extension of land covered by these systems in each sub-area must be obtained, and its representativeness for the management of the local biodiversity must be assessed.

Biological Data

The focus of this item is on analyzing vertebrates, especially fish, by identifying the main species. Aside from the unquestionable ecological importance of ichthyofauna to river basins, the systemic features necessary for this group of fauna to survive make them excellent indicators of biodiversity.

Given the difficulties inherent to obtaining a biologically representative sample of wealth of fish species in river basins, it is suggested that the analysis of the biodiversity of fish species be done using

7 Shannon (1949) – "The Mathematical Theory of Communication", Urbana, University of Illinois Press, 117 pp.

secondary data that can be supplemented by field work designed to obtain the information listed in table 4.3.2.01.

Table 4.3.2.01

Classification	Geographic Distribution	Meso-Spatial Distribution	Environmental Distribution	Size	Migratory Habits
Species/Genus	Endemic	Headwaters	Still Waters	Large	Non-Existent
	Not Endemic	Lowlands	Running Waters	Medium	Optional
		Intermediate Sections		Small	Necessary

Although there may be many freshwater fish species that need to migrate upstream to complete their reproductive cycles, there is no need at this stage to do a detailed study of their migratory routes to the point of capturing species to tag them, or to study their stages of development and breeding grounds. Information on migratory routes and breeding grounds for the main characiform and siluriform fish can however be obtained in structured interviews with fishermen and riverside communities. This information, which is gathered in the field from people who traditionally use these resources, must be cross-checked against data obtained from the biogeographic analysis undertaken.

As mentioned before, in the areas where river pools are identified, eggs and larvae can be collected for the purposes of species identification. These data are easy to obtain and give a very precise idea of the breeding areas of rheophile species. By combining interviews with a biogeographic analysis and sampling from river pools, a characterization can be made of a satisfactory enough level for this stage of studies.

To supplement the abovementioned data, information should be gathered on fishing activities in the basins and the most productive areas identified. Fishing activities of significant local and regional importance are normally undertaken in fish-bearing rivers. Although this is an important economic activity and provides a source of subsistence for many Brazilian communities, there is a major dearth of reliable information on the real yield of fishing activities. However, it is possible to obtain data, albeit underestimated, for some basins on capture numbers, unloading sites and markets, workforce employed, etc.

In some basins it may be necessary to identify other groups of vertebrates (mammals, reptiles, birds) that could be impacted by the introduction of hydroelectric projects. The flooding of areas used for resting, feeding and breeding by birds, especially migrating species protected by international legislation, and the flooding of turtle breeding grounds, are examples of impacts that could take place. As these are exceptional circumstances, no specific prior study is proposed here. The technical teams involved in the Inventory Studies should decide under what circumstances studies of this nature need to be undertaken.

By cross-referencing the information on the physical diversity of the stream channels, the diversity of the river habits, and the habitats of strategic ecological importance with the biotic features, a representative picture can be built up of the likely fauna species in each river habitat. This makes it possible to identify those habitats where there is a greater concentration of biodiversity and/or where there are migratory, endemic or exclusive species.

Results of the Diagnosis

By collating the characterization elements, it should be possible to understand what factors are essential for maintaining the biodiversity of each sub-area. An integrated analysis of the physical and biotic elements to characterize them and determine their spatial distribution can be used to assess the different degrees of ecological significance existing in the different sub-areas.

In order to represent this component spatially, a map should be drawn up with the sub-areas marked out. Within each sub-area the most significant information from the perspective of ensuring its biodiversity should be represented. Annexed to this map, a characterization should be prepared of each sub-area that highlights its most significant features, points out any areas of sensitivity, and relates it to the other sub-areas and the river basin as a whole. The map will be used in the formulation of the different cascades and in identifying and assessing the impacts, and later in the IEA of the cascade selected.

The relative weights of the sub-areas, representing the importance of the processes they contain to the dynamics of the synthesis component in the study area should also be decided on at this point.

Table 4.3.2.02 – Characterization Elements of the Aquatic Ecosystems Synthesis Component

Synthesis component	Characterization elements	Source
Aquatic Ecosystems	• Riparian forests (riverside forests, riparian forests, floodplain forests, igapó forests, etc.): state of conservation and physical distribution. • Occurrence of macrophytes. • Water quality: – systems whose ecological features are not compromised and in which there is no pollution; – systems whose ecological features are compromised to some extent in response to the interference of sources of pollution; – systems whose ecological features are greatly compromised by the intensity of the levels of pollution. • Stream Physiography: – stream order (Strahler's Index); – drainage density; – physical diversity of the main river channel; – heterogeneity of river habitats; – ecologically strategic habitats. • Biological Data – biology and ecology of the most representative fish species (bibliographic data); – identification and distribution of main migratory routes, breeding grounds and feeding grounds; – identification and distribution of most productive fishing areas (volume captured – historic records, workforce employed); – identification of main species, especially migratory species and those associated to habitats with high hydrodynamics; – occurrence of other vertebrates (e.g. river-dwelling mammals, reptiles, birds).	• satellite images • existing maps and aerial • photogrammetric surveys • academic theses • scientific publications • data on water quality (environmental agencies, ANA, water management departments) • data on river fishing (IBGE, IBAMA, research institutes) • RADAM BRASIL project • general treaties on freshwater fish • supplementary field studies • SEAP • SRHU/MMA

4.3.3 Synthesis Component: Terrestrial Ecosystems

As with the Aquatic Ecosystems synthesis component, the complexity inherent to any study of terrestrial ecosystems makes it necessary to establish conceptual and methodological frameworks to bring the diagnostic analysis into line with the scale of the work needed for the Inventory Studies. This component will also focus on any environmental factors that are instrumental in ensuring the preservation of the biodiversity, prioritizing those elements that give a spatial assessment and taking studies being developed in the area of biogeography as a reference.

The characterization elements for structuring this synthesis component were selected in such a way as to help identify the different degrees of ecological significance that exist in the different habitats in the study area. Ecological significance is understood here as the potential of the system under analysis to present greater biological diversity than the other subsystems. The characterization elements used for this analysis are set out below and summarized in Table 4.3.3.02.

Vegetation and Land Use in the River Basin

The natural plant species in the basin should be identified and mapped out using remote sensing equipment and any pre-existing maps of vegetation or other maps or aerial photogrammetric surveys available. The interpretation and analysis should be done on a scale that will allow the interferences caused by the projects to be assessed. Depending on the size of the river basin, it may be necessary to prepare two maps: one with more systemic features, clumping together similar types of vegetation to try and get an overview of the level of degradation and conservation in the study area, and another looking into the physiognomic features of the flora in greater detail, including the diversity of the flora in each unit of analysis.

It is advisable for a field study to be undertaken to confirm the patterns mapped out and identify the extent and state of conservation of the vegetation. In particular, the extent and state of conservation of the riparian forests should be identified in view of their ecological importance in maintaining gene flow and as a habitat for many species in the terrestrial ecosystems.

The gathering and mapping of information on land use in the study area is carried out within the scope of the Regional Economy synthesis component.

Factors of pressure on ecosystems

In order to identify the factors that exert pressure on the ecosystems, data should be gathered on changes to the way natural resources are exploited and the expansion of farming lands. The studies should take as their point of reference the studies undertaken for the Regional Economy synthesis component, and are used in assessing the sustainability of these activities and the level of pressure exerted by man on the natural ecosystems.

Ecosystems of ecological interest

The ecosystems of particular ecological interest should be identified and mapped out. These are the most important ecosystems according to the function they exert in preserving biological diversity. They include: ecosystems that are important for maintaining population flows, such as riverside forests; ecosystems that support threatened species; ecotones, which serve as transition zones between two phytoecologically different regions, with species interpenetrated in their habitats; and conservation areas protected by law. In order to define these areas, information is used from remote sensing images, maps from the RADAM Project and from SIUC[8], and information on priority areas for biodiversity conservation.

Landscape Ecology

Information should be gathered from which an assessment can be made of the study area's capacity to maintain fauna species and the general level of insularity of the native vegetation. The extent to which the natural vegetation is insular is an indicator of any loss of biodiversity, as there is a strong correlation between biodiversity and area size. Thus, it is suggested that information be obtained by jointly analyzing the aspects relating to landscape ecology and the parameters relating to biodiversity.

There are two phytophysiognomic conditions of importance for preserving terrestrial fauna: (a) unaltered physiognomies that have maintained a high level of integrity and have therefore permitted the survival of the primary fauna species from the area; and (b) physiognomies distributed in patches which, as they provide for different forms of contact between different ecosystems, provide for the coexistence of more or less ombrophilic species.

8 Sistema de Informação de Unidades de Conservação (database on conservation areas).

The overall assessment of the landscape in each sub-area takes into consideration the following: the average form of remaining forest patches, the isolation of the patches, and the physiognomic classification of the patches.

- **Average form of remaining forest patches**: This parameter is used as an indicator of the capacity to sustain fauna, taking as a basis the principle of form and function developed by Thompson (1961). It is therefore expected that systems with a lower perimeter/area ratio have a greater capacity to retain their internal features (in this case, organisms) than systems when this ratio is higher. The average form of forest patches (FM) is given by the following relationship between perimeter (P) and area (Ap):

$$FM = \frac{\sum_{i=1}^{n} \frac{P}{2\sqrt{A\pi}}}{n} \qquad (4.3.3.01)$$

where:

n	number of forest patches.

- **Isolation of forest patches**: By measuring the isolation of patches, represented by the distance between each remaining forest patch, it is possible to assess the level of insularity of the wildlife in a given sub-area. The isolation (**IM**) of each sub-area can be estimated by:

$$IM = \frac{1}{n}\sum d_{ij} \qquad (4.3.3.02)$$

where:

n	number of forest patches in the sub-area, excluding riparian forest;
d_{ij}	distance between one patch i and its neighbor j in the sub-area.

- **Phytophisiognomic classification of patches**: this indicates the diversity of flora in the area under study. The IBGE classification is recommended for this. Any physiognomy that is found to be exclusive to a particular area should be highlighted.

Occurrence and distribution of animal species

Information about the likely occurrence of mammal, bird and reptile species in the study area can be gathered by combining data from expeditious field campaigns with any information available from secondary sources on neotropical fauna. This information is available in the specialized literature.

The assessment of the occurrence of animal species requires the information to be organized according to the categories described in table 4.3.3.01:

Table 4.3.3.01

Classification	Geographic Distribution	Spatial Distribution	Habitat	Status
Species/Genus	Endemic	Peripheral	Soil	Threatened
	Not Endemic	Central	Trees	Vulnerable
			Shrubland	Not Threatened
			Swampland	

This database structure covers a minimum number of aspects to be considered and encompasses taxonomic and ecological variables. It is recommended that new information be added so that ecological features found to be of relevance for better characterizing the wildlife in the area under study can be included.

When this data are related to the data from the physical characterization of the area, it will be possible to identify the likely occurrence of fauna in the different habitats in the study area. Attempts should be made to gather information on the taxonomic diversity of the vertebrates, the threatened species on official lists and the species which are more vulnerable to alterations brought about by man because they are restricted to particular forest patches.

Results of the Diagnosis

By collating the characterization elements, it should be possible to analyze the current status of the Terrestrial Ecosystems and understand what factors are essential for maintaining their biodiversity. The analyses will provide a spatial assessment of the elements required to ensure the continued biodiversity, which can be used to segment the study area into sub-areas according to criteria that give the most faithful representation of the biological processes and elements. These sub-areas may be correlated to a particular sub-basin, a landscape, a phytophysiognomic unit, or to a number of other aspects. Each spatial unit must be defined in such a way that it provides the greatest correlation between the elements and processes it is designed to represent.

In order to represent this component spatially, a map should be drawn up with the sub-areas marked out. Within each sub-area the most significant information from the perspective of ensuring its biodiversity should be represented. Annexed to this map, a characterization should be prepared of each sub-area that highlights its most significant features, points out any areas of sensitivity, and relates it to the other sub-areas and the river basin as a whole. The map will be used in the formulation of the different cascades and in identifying and assessing the impacts, and later in the IEA of the cascade selected.

The relative weights of the sub-areas, representing the importance of the processes they contain to the dynamics of the synthesis component in the study area should also be decided on at this point.

Table 4.3.3.02 – Characterization elements for the "Terrestrial Ecosystems" synthesis component

Synthesis component	Characterization elements	Source
Terrestrial ecosystems	• Phytophysiognomic description of the types of vegetation and land use in the river basin; •Factors that exert pressure on the ecosystems (logging, farming, ranching, deforestation); •Conservation Areas and other areas under legal protection, ecosystems of particular ecological interest, priority areas for biodiversity conservation, ecotones, areas containing rare or threatened species, ecosystems of importance for maintaining population flows (ecological corridors, biosphere reserves); •Landscape ecology (analysis of the form and connectivity of forest patches and their ecological representativeness for conservation of the species they contain); •Characterization of animal species per habitat and identification of endemic, threatened and rare species.	– satellite images – pre-existing maps of vegetation and land use – RADAM BRASIL project – existing maps and aerial photogrammetric surveys – farming census (IBGE) – INPRA, IBAMA, MMA, MAPA – academic theses – scientific publications – data on the development of deforested areas (IBGE, INPE, NGOs) – general literature on neotropical wildlife – supplementary field studies – state environment entities – EMBRAPA, EMATER

4.3.4 Synthesis Component: Ways of Life

This synthesis component encompasses the different ways human beings organize themselves to ensure their physical, social, political, cultural and emotional survival. It relates to the ways people occupy land, exploit the natural resources at their disposal, relate to each other in this process, and produce representations about the land they occupy. Particular world views are central to these forms of organization, as are the ways people view themselves (forms of representation). These are the formats that give meaning to the set of relationships that are re-confirmed on a daily basis – political, economic, cultural, affective, social relations, etc. It is not enough just to characterize a way of life to understand it; one must comprehend the forms mentioned here in their different manifestations, apprehend the most significant elements in the organization of a particular social group, and capture what gives it its particular identity, what gives it its particular place in space and time.

In order to apprehend the identity underlying a particular way of life[9], it is crucially important that a correlation be drawn between the social groups' survival strategies, which have to do with their material structure, and the historically constructed forms of sociality that form their socio-cultural structure. In this sense, the characterization elements selected to formulate this synthesis component must be analyzed in conjunction so that the different ways of life in the study area and the ways they are expressed spatially can be characterized.

These elements should be addressed qualitatively and quantitatively and interactions between them should be identified so as to (re)construct the reality that is under study. It is believed that by assessing this synthesis component it will be possible to address particular questions that are often lost in the midst of more easily quantifiable information; issues which qualify the social reality and, in most cases, tend to be overlooked.

The characterization elements are presented in table 4.3.4.01 and are clustered into the following aspects:

- demographic dynamics;
- living conditions;
- production system;
- social organization;
- institutions.

Demographic Dynamics

The aim of the analysis of demographic dynamics is to identify the behavior of a population by looking at its general features (resident population, sex, age, household status), how it is distributed spatially and its mobility, providing inputs for understanding the other aspects under analysis.

A good way of assessing population mobility is to look at the net migratory balance (difference between the growth rate and the vegetative growth rate), which is a trend indicator that reveals whether the area attracts or repels individuals.

Living Conditions

The analysis of living conditions involves assessing the public and private resources at the group's disposal to meet their basic needs, and the relationship between access to these resources and the available quality of life: healthcare, income, employment, education, sanitation, communication, energy, transport and leisure.

The main sources of information for these characterization elements are statistics provided by government agencies and international organizations such as the WHO or UNDP. However, this information should be supplemented by qualitative data that address the specific strategies employed

9 For instance, there are situations where "proximity to the river" is an important element for organizing time and space for some social groupings. It can help determine their collective identity and understand the combined relationships of which they are comprised, which would characterize a "river-dependent" way of life. However, proximity to the river is not always a determining factor in the collective identity of a social group; it may simply be one amongst many, and not even the main one.

by the social groups to improve their quality of life. A mixture of field studies and reference to academic papers, research and theses from universities and/or research institutes can be used to broaden the scope of information of a qualitative nature.

The Human Development Index (HDI), developed by the UNDP, can also help to formulate a situational diagnosis of the set of information concerning education, income and health (infant mortality and life expectancy).

In particular, when assessing a population's state of health, a situational diagnosis can be obtained alongside a description of the health/disease processes in the region by observing the disease profile (prevalence/mortality), the medical and hospital infrastructure and the endemic disease profile, while correlating these aspects with the socioeconomic indicators and main health indicators (infant mortality, life expectancy, consultations per inhabitant). By doing so, the factors and areas of risk for the people's health can be identified.

Production System

The following elements have to do with production, meaning the ways people and/or social groups produce the goods required to meet their material needs. This includes the ways they exploit natural resources and the way they undertake their production activities, which will indicate how the societies are organized and have developed historically. The elements should also provide the means to identify the patterns of capitalization and decapitalization in the social groups.

The different production systems in the study area are identified by observing how rural and urban output is organized and how they interact, taking into account the natural resources available and the environmental factors in the area.

The information on each of the dimensions within the production system can be researched in secondary sources and supplemented by consulting studies and theses on the topic, as well as gathering data from the field.

- **Natural resources and key environmental factors** – in view of the fact that the basis for the production system is the natural resources available for production purposes, it is necessary to observe the following: floodplains, arable land, flood dynamics, land uses, water uses, mineral uses, forest uses and fishing activities. This information can be obtained from the data gathered and analyses made about the physical processes and features in the study area, and from the following synthesis components: Aquatic Ecosystems, Terrestrial Ecosystems and Regional Economy.
- **Organization of production** – the ways urban and rural production is organized are indicative of the potential links between them, especially those that involve living in urban areas and working in the countryside, or vice versa. The ways production is organized are also indicative of the degree of capitalization involved, which can be observed from the ownership and value of equity, as well as the different forms of income generation.

The information pertaining to the organization of urban production can be gathered primarily from the IBGE census, especially the data on the economically active population and non-economically active population, sector of economic activity, condition and class of monthly average income. Censuses and data produced by states and municipalities should be used whenever they are available.

It should also be noted that in some rural areas, bartering is still common practice and there is little currency in circulation.

Social Organization

The ways people and/or social groupings are organized and define their parameters for coexistence should be observed. This has to do with the way people relate to each other. As this is a predominantly qualitative aspect, the sources of basic information are academic studies produced at universities and research institutes and field studies. It is also worth consulting lists of trade unions, cooperatives and NGOs published by IBGE.

In view of the specific nature of the topics covered in this element, its main function is to characterize how people's relationships are mediated, pointing out situations of conflict, informal associations, and any special relationships that may explain the way certain groups are organized, such as family ties, neighborhood relations, work relations, political relations, etc.

By observing this set of aspects and information about the historical occupation of the land, the main elements can be identified that form the group's socio-cultural identity, its forms of sociality (relationships within itself) and the way it is represented. It is also possible to identify how these forms of sociality are expressed in space (land) and time, giving precedence to certain forms of mediation and/or certain concrete references (geomorphological heritage, buildings, monuments, etc.), by which process they become representative heritage sites for that social group.

When it comes to historical, cultural, landscape, architectural, speleological and ecological heritage, what matters here is the value each social group attributes to it rather than any official recognition or legal status it may have. The importance and significance of each heritage site should be characterized as part of the process of cultural production and reproduction of the social groups. By doing so, the meaning of the heritage to the social group to which it belongs is highlighted, and this can be offset against its historical, cultural, landscape, architectural, speleological or ecological value to the whole set of relationships that give it its identity.

Institutions

The main public entities should be identified, as well as any forms of organized civil society and interest groups operating in the study area. All public policies for social welfare and poverty reduction in the region should also be analyzed.

Results of the Diagnosis

By collating the characterization elements relating to the historically constructed survival strategies and forms of sociality, it should be possible to identify the "ways of life" existing in the study area and apprehend what underlies their identity. It is also important to observe any vulnerability to change in the forms of social reproduction brought about primarily by the existence of situations of contradiction or conflict, conditions of capitalization and decapitalization, and the degree of social organization of the groups.

In order to represent this component spatially, a map should be drawn up collating the information from each characterization element, and this should be analyzed together with the maps containing the information about the physical processes and features in the region and the other synthesis components, in order to mark out the areas in which each way of life exists.

The resulting map should have the sub-areas marked out according to the way the space is occupied by the different ways of life identified. Annexed to this map, a characterization should be prepared of the way of life in each sub-area that highlights its most significant features and relates it to ways of life in the other sub-areas and the study area as a whole. The most sensitive areas to the introduction of new projects should be highlighted, as well as any with potentialities that could be harnessed by the projects. The map will be used in the formulation of the different cascade options, in identifying and assessing the impacts, and later in the IEA of the cascade selected.

The relative weights of the sub-areas, representing the importance of the processes they contain to the dynamics of the synthesis component in the study area should also be decided on at this point.

Table 4.3.4.01 – Characterization elements for the Ways of Life Synthesis Component

Synthesis component	Characterization elements	Source
Ways of life	• Demographic Dynamics: – occupation process (emphasis on demographics); – quantitative population data; – spatial distribution of the population (rural/urban households); – growth rates; – natural growth rates; – migration flow; – factors that attract or repel population flows. • Living Conditions: – quality of life (HDI and other basic indicators); – services available (education, health, energy, communication, sanitation, transport and leisure); – employment conditions, household income distribution, personal income distribution; – analysis of the living conditions of the groups and smallholders; – health indicators, especially water-borne diseases. • Production System: – organization of rural production; – organization of urban production; – mineral, pedological, water, forest and fishing resources available; – environmental factors in the sub-area (flood dynamics, floodplains, areas of erosion, suitability for agriculture, relief segmentation). • Social Organization: – historical occupation processes; – socio-cultural identity (habits, values, beliefs, historical/cultural heritage); – representations; – areas of conflict and social tension; – situations of conflict; – organization of space / time; – forms of sociality. • Institutions: – public entities operating in the area; – forms of civil representation; – interest groups; – vulnerability of local communities to changes brought about by modernity; – public policies for social welfare and poverty reduction in the region.	– Demographic Census (IBGE) – List of health establishments (IBGE) – Health statistics (IBGE) – State Statistics – Farming Census (IBGE) – FUNAI – EMBRAPA – EMATER – INCRA – SEPPIR – MDA – MDS – List of trade unions, cooperatives and NGOs (IBGE) – Social movements and associations that are active in the region – Direct Research – Academic papers, theses and studies

4.3.5 Synthesis Component: Territorial Organization

This synthesis component covers the processes that determine territorial organization and dynamics and consequently the landscape and occupation patterns. It encompasses the man-made forms and objects that are erected in the land and their interrelations, which can be used to understand how the land is used and occupied and how the different parts are interrelated by communication networks and the circulation of goods and people.

The selected characterization elements are designed to gather information on the way the space and the landscape are organized, highlighting the role played by the water bodies in this organization on the circulation fluxes, communication, and the political and administrative organization of the land. This information is presented in summary form in table 4.3.5.01 and organized into the following aspects:

- demographic dynamics;
- land occupation;
- circulation and communication;
- political and administrative organization; and
- territorial management.

Demographic Dynamics

When it comes to demographic dynamics, the aim is to analyze the following two aspects:

- Development of urban and rural populations per municipality.

The behavior of the population should be observed in order to identify the dynamics of population growth per se, emphasizing the contribution of migration flow. The indicators that tend to be used for this are: urban, rural and total growth rates, average geometric rate of annual growth and net migration balance.

- Structure and spatial distribution of urban and rural populations per municipality.

These elements allow an analysis to be made of the spatial distribution of the population, their mobility and the resulting patterns of urban occupation. The statistical indicators that tend to be used for this are: demographic density and level of urbanization.

Land Occupation

The dynamics and factors at play in land occupation should be investigated, and any factors that are related to the water resources should be highlighted. This should be done by observing the following factors:

- Historical process of land occupation in the river basin.

The information to be analyzed should build up a picture of the main processes involved in land occupation processes in the area, the agents responsible for this and the forms of land appropriation used. Local and regional secondary sources as well as interviews are the main sources of information.

- Environmental factors which induce or restrict land occupation.

The area under study should be analyzed to identify any factors that affect human occupation (a) of a restrictive nature, such as areas of erosion, steep slopes, areas that are flooded or prone to flooding, and areas occupied by special facilities (e.g. military facilities, existing power plants, etc.); and (b) of an inductive nature, such as areas set aside for urban occupation that have already been plotted out, areas where roads are to be built, areas supplied by transportation services, areas that are suitable for farming, and areas for new farming settlements.

This information can be taken from the surveys undertaken for the diagnoses of the Physical Processes and Features, Aquatic Ecosystems and Terrestrial Ecosystems, and by consulting government agencies.

- Characteristics and spatial distribution of different kinds of land use and their intensity of use.

The different land uses must be identified and located. Broad categories of land use (e.g. urban, rural) can be taken as a starting point for distinguishing subcategories, whose basic features and intensity of use must be defined. It may be useful to cross-reference the uses actually established with the uses proposed by plans and existing legislation. The expansion trends of urban centers, sanitation infrastructure, communication infrastructure, housing infrastructure, highways, waterways and railways should be analyzed.

Statistical and cartographic information should be gathered from local and regional government agencies on land use, harvests, areas used temporarily and permanently for growing crops, and the extraction of timber and non-timber forest products.

The cartographic information will mostly come from remote sensing images, which will need to be interpreted and analyzed and used to build up a historical record of land occupation. Municipal master plans and territorial organization plans are another rich source of information, and all of this should be supplemented by data gathered in the field.

- Function of water resources in territorial organization.

In order to examine the role of the waters in the local and regional context of the river basin, the physical distribution of the waters should be considered, as should their role in the circulation of people and goods and in the ways the land in the river basin is structured, and the effective uses of the waters.

This analysis is essentially qualitative and interpretative, which means it must be referenced against the historical and regional context and government policies for the region.

- Main water uses and estimate of user numbers per type of use.

The main water uses should be identified and included in a map of an appropriate scale, and the number of users for each type of use should be estimated, highlighting any existing or potential conflicts. After identifying the areas where the greatest concentration of users and agents are located, the causal relationships should be highlighted.

This information, of a primarily qualitative and interpretative nature, must also be gathered in interviews with local and regional agencies responsible for urban, social, environmental and water management.

The information must then be correlated with the information used to build up the scenario of multiple water uses prepared in item 4.2.

- Urban and rural relationships and resulting settlement patterns.

The settlement patterns and relationships between town and countryside specific to the region under study should be identified, using IBGE studies of regional divisions and functional urban regions.

- Existing and planned development programs.

All public and private investments that are either planned or already underway that have a significant impact on local or regional development must be identified and located. The main information of this nature can be gathered from local and regional government agencies and should be supplemented by interviews.

Circulation and Communication

The main flows of people, goods and services within the river basin should be characterized, along with their respective infrastructure and large-scale facilities and the role they play in territorial organization.

The main flows and the directions of these flows should also be represented. The following aspects should be considered:

- Location and characterization of urban areas: diversity and functional hierarchy.

The main urban centers should be located and the capacity and range of their production, consumption and service facilities should be analyzed. This includes local and extra-local large-scale facilities, such as: storage facilities for farm produce and merchandise prior to their transportation; health, education and interurban passenger and freight transport service providers; bank, credit and financing establishments; leisure facilities of importance beyond just the local area; areas that supply vegetable and fruit produce and other merchandise. It should also cover cooperatives, religious institutions and government institutions that provide services.

- Location, characteristics and relative importance of the highway, waterway and railway systems.

The functions carried out by roads, railroads and sections of the water courses used as waterways must be identified, mapped out and qualified. Most of the information required for this can be gathered from maps produced by federal, state and municipal government entities.

- Origins and destinations, and integration between forms of transportation.

The main origins and destinations of the most important routes of people and goods and their respective modes of transportation should be identified. It is necessary to map out the points where the different forms of passenger and cargo transport interconnect (within the larger highway, railway, waterway and airway systems), their capacity and size.

Most of the information can be obtained from the public entities in charge of administrating the transportation systems, covering volume of traffic, cargo flows, number of passengers per period, volume of cargo per period.

Political and administrative organization

Aspects of direct public administration should be examined (especially on a municipal level) and simultaneously related to the land and population in question. The following should be included:

- location of municipal and district seats of government;
- municipal land covered by the river basin and its ratio to the total surface area;
- location and coverage area of main municipal, state and federal public institutions.

The main offices of the local and regional public entities and the services provided by municipal entities in each administrative district should be listed and located.

- Constituency and representation of municipal, state and federal governments.

For each municipality, the number of voters and their ratio to the total population should be identified, as should the total number of local councilors and their proportional representation in terms of numbers of state and federal congressional representatives.

This information can be gathered from local authorities and the regional electoral commission (Tribunal Eleitoral Regional).

Territorial Management

All public policies and legislation pertaining to local and regional development should be identified with a view to characterizing how the political and institutional aspects are interrelated. The municipal, state and federal plans, programs and projects for social and economic development must also be examined.

A study should be made of the main public, private and third sector social agents of significance in the study area.

The most important sources of information are documents produced by the Ministry of Planning, the Ministry of National Integration, the Ministry of the Environment, the Ministry of Agriculture, the Ministry of Social Development and state departments of planning.

Results of the Diagnosis

By collating the characterization elements, it should be possible to understand and characterize the processes instrumental in determining the territorial organization and its occupation patterns. By identifying the levels of urbanization, the presence of urban centers with the capacity to polarize activities, road infrastructure, facilities for the circulation of goods and people, the maintenance of relationships of exchange and/or dependency with other regions, it is important to perceive which are the structural processes within this organization.

The following information should be mapped out in order to provide a spatial representation of the Territorial Organization synthesis component:

- political and administrative boundaries, municipal and district seats of government;
- population density in the municipalities;
- relative distribution and relative growth of the urban population;
- urban centers, functional hierarchy and level of urbanization;
- existing and planned highways, waterways and railways;
- origins and destinations of main flows of goods and people; integration between forms of transport;
- dominant patterns of land use and land occupation;
- intensity of occupation of farming land;
- occurrence of large-scale facilities and capacity to supply areas beyond the local area (silos, warehouses, health facilities, storage, etc.); and
- existing and planned large-scale projects for farming, industry and the extraction of non-timber forest products.

The resulting map should have the sub-areas marked out with a view to classifying the study area according to its level of integration. This integration can be observed by analyzing all the information gathered in conjunction. The following categories can be used:

- areas of incipient integration (low level of urbanization, poor levels of accessibility);
- areas in transition (proximity to roads, occurrence of activities that indicate potential for integration, growing level of urbanization, some integration between modes of transportation);
- integrated areas or areas of consolidated integration (high level of urbanization, urban areas with the capacity to centralize activities, good levels of accessibility, facilities on a scale to meet supra-local requirements).

Annexed to this map, a characterization should be prepared of each sub-area that highlights its most significant features and relates it to the other sub-areas and the study area as a whole. The most sensitive areas to the introduction of new hydropower plants should be highlighted, as well as any with potentialities that could be harnessed by the projects. The map will be used in the formulation of the cascades, in identifying and assessing the impacts, and later in the IEA of the cascade selected.

Table 4.3.5.01 – Characterization Elements of the Territorial Organization synthesis component

Synthesis component	Characterization elements	Source
Territorial organization	• Demographic Dynamics: – development of urban and rural populations per municipality; – structure and spatial distribution of urban and rural populations per municipality; – significant importance relative to total population; – level of urbanization. • Land Occupation: – historical process of land occupation; – environmental factors which encourage or restrict land occupation; – characteristics and spatial distribution of different kinds of land use and their intensity of use; – function of water resources in the territorial organization; – main water uses and estimate of user numbers per type of use; – urban and rural relationships, and resulting settlement patterns; – assessment and location of historical and cultural heritage and the main archaeological, paleontological and speleological sites; – existence of conflicts over land or water use; – existing and planned development programs. • Circulation and Communication: – location and characterization of urban areas: diversity and functional hierarchy; – location, capacity and reach of production, consumption and service facilities; – location, characteristics and relative importance of the highway, waterway and railway systems; – origins and destinations, and integration between forms of transport. • Political and Administrative Organization: – location of municipal and district seats of government; – constituency and representation of municipal, state and federal governments; – area covered by municipal land and its ratio to the total surface area; – location and reach of main municipal, state and federal institutions. • Territorial Management – political and institutional coordination: information on public policies and legislation for local and regional development – municipal, state and federal plans, programs and projects for social and economic development; – main social agents operating in the river basin (NGOs, churches, associations, etc.).	– Census of Demographics, Trade and Services (IBGE) – National Domestic Census (IBGE) (Pesquisa Nacional por Amostra de Domicílio) – Anuário Estatístico do Brasil – IBGE – Farming Census (Censo Agropecuário) IBGE – Municipal Agricultural Produce (Produção Agrícola Municipal) – IBGE – Municipal Ranching Survey (Pesquisa da Pecuária Municipal) – IBGE – Timber and Non-Timber Forest Products (Produtos de Extração Vegetal e Silvicultura) – IBGE – Brazil's Cities and Towns (Cidades e Vilas do Brasil) – IBGE – Division of Brazilian Territory (Divisão Territorial do Brasil) – IBGE – Division of brazil into Homogeneous Microregions (Divisão do Brasil em Microregiões Homogêneas) – IBGE – Division of Brazil into Functional Urban Regions (Divisão do Brasil em Regiões Funcionais Urbanas) – IBGE – List of Special Areas (Cadastro de Áreas Especiais) – IBGE – Municipal Master Plans – University Research and Theses – State Statistics – FUNAI – INCRA, SEPPIR – MMA, INPRA,OEMAS – federal and state conservation areas – Highway maps – Landsat and Spot Images – Environmental and Land Occupation Maps (Mapeamento Ambiental da Ocupação de Terras) – EMBRAPA – List of Health Establishments (Cadastro de Estabelecimentos de Saúde) – IBGE – Ministry of Finance, Internal Revenue Service – State and Municipal Departments of Finance

4.3.6 Synthesis Component: Regional Economy

This synthesis component covers the economic activities of particular importance to the economy and quality of life in the study area and the environmental resources that represent potentialities for supporting future economic activities.

The characterization elements selected for this component are designed to organize and interpret the information in such a way that an economic profile can be built up on a local and regional scale of both the market and subsistence activities, giving a general idea of what activities support the economy in the region in which the study area is situated.

The main assets and economic activities should therefore be identified, and the following aspects should be addressed, which are also summarized in table 4.3.6.01:

- economic activities;
- potentialities of the river basin; and
- municipal finances.

Economic Activities

The economic activities (market and subsistence) that best represent the economy in the region and quality of life of its inhabitants should be listed. However, rather than carrying out a traditional economic analysis, the objective is to:

- build up an integrated view of the economic activities in the study area;
- identify and qualify the relationships established with the natural resources;
- select quantitative indicators for the most significant activities;
- identify and locate within the area under study those activities of importance to the economy that impact on the local residents' quality of life;
- identify establishments and their areas of concentration involved in maintaining a given standard of living (e.g. food industry, essential sectors responsible for employment and income). In other words, the relationship, type and spatial location of these support goods and establishments should be identified;
- identify the economic activities that are directly connected to the river, either because of some functional link or because they are within the drainage basin of the future reservoirs;
- identify the factors that impinge on the location of the main economic activities, and their physical and spatial relationships with the suppliers of inputs and consumers (chronological development).

The characterization should be done on two levels: general and per sector. The general characterization should give a comprehensive overview of the economy in the study area. It should highlight the activities involved in the primary sector, especially those that have any connection with the waters.

The sector characterization should be done after the general characterization has been completed, providing a more in-depth, detailed perspective on the activities considered of especial importance to the study.

The characterization elements for the economic activities should quantify and correlate the following information:

- Production Structure:
  - primary sector: land structure, type of output, number of establishments, number of establishments, workforce, value of output, land area occupied, mining (number of mines and seams being exploited);
  - secondary sector: number of establishments, workforce, gross value, gross value and value of industrial output, development, relations between main industries and sectors;
  - tertiary sector: number of establishments, workforce, total revenues, VAT and service tax revenues (ICMS and ISS).
- Characteristics, capacity to create jobs and income and spatial location of the main industries and establishments.
- Economic activities involved in assuring the standard of living of the local residents (e.g. food industry and industries that require a large workforce).
- Markets served.
- Economic activities related to the water resources; number of people affected per economic use.
- Forms of resource appropriation (intensive/extensive, level of mechanization).
- Social and economic importance of the activities.

This information can be taken from secondary sources. For data on revenues from the circulation of goods and rendering of services, the main sources are the Ministry of Finance, the Internal Revenue, and state and municipal departments of finance.

Primary data must also be produced, which trade unions and cooperatives can help provide.

Resources and potentialities of the river basin

Any environmental resources with potential economic worth that could provide support for future economic activities (potentialities) must be identified, qualified and mapped out. Effective and potential economic uses of the waters must be highlighted.

- Characteristics and respective spatial location:
  - mineral resources;
  - areas of agricultural potential;
  - potential for energy, timber, fishing, non-timber forest products, biological products, genetic products and tourism;
  - species of economic, medicinal and nutritional value;
  - potential and effective uses of the water resources; number of people affected per use;
  - existing and planned development programs; and
  - planned and existing infrastructure and roads.

It is worth noting that the heritage-related aspects (historical, cultural, archaeological, speleological and ecological) are addressed here for their tourism and leisure potential, which is a reflection of their economic potential.

- Environmental factors that induce or restrict economic activities and factors that exert pressure on natural resources.

The analysis of these elements is overwhelmingly qualitative and is based on the information gathered on the physical processes and features, the aquatic ecosystems, terrestrial ecosystems, territorial organization and ways of life.

Municipal Finances

The economic and financial dimension of municipal administration can be assessed by consulting information about public revenues (municipal finances). It is worth identifying the municipal revenues that are directly related to the economic activities, the local population and the land in the municipality in question. The following should be studied:

- municipal tax revenues: taxes and improvement contribution (*contribuição de melhoria*);
- union and state revenues: the revenues to be considered should be those which are directly related to the area in question and the people living there, especially the funds received from the Municipal Fund (*Fundo de Participação dos Municípios*).

It is important to detect any gaps in the information, which will have to be filled for a clearer picture to be built up of any particular issue.

Results of the Diagnosis

By collating the characterization elements, it should be possible to gain an integrated overview of the existing activities and potentialities inherent to the economy of the region where the study area is, and to identify its structural elements.

In order to represent the Regional Economy component spatially, the occurrence of the main elements involved in the different economic activities (areas of production, areas where establishments are concentrated, occurrence of large-scale projects), support resources and potentialities should be compiled. One or more maps can be prepared for this purpose, containing the following:

- areas of farming and ranching;
- large-scale existing or planned farming or forest product extraction projects;
- existing or planned industrial areas and industrial districts;
- areas of agricultural potential;
- areas where the tertiary sector is concentrated;
- areas of original vegetation;
- occurrence of mineral, energy, timber, non-timber forest products, biological or genetic resources; species of economic, medicinal or nutritional value;
- markets served and their relative importance to the local and regional markets;
- areas of tourism and leisure interest; and
- areas under legal protection (conservation areas, indigenous lands).

An overview of the water uses should also be mapped out, indicating the areas of concentrated water use, location of agents responsible for consumptive uses, any points of conflict, and flows of commercial and non-commercial navigation. This information should be brought into line with the information gathered for the Territorial Organization synthesis component (item 4.3.5) and used in building up the scenario of multiple water uses (item 4.2).

The resulting map should have the sub-areas marked out as defined in the introduction to item 4.3, in function, for example, of the occurrence of similar production structures, homogeneous consumption patterns, similar workforce distribution, concentration of economic activities and/or abundance of a given natural resource with economic potential. The most sensitive areas to the introduction of new projects should be marked out, as well as those that offer potentialities that could be harnessed with the introduction of a new project.

Annexed to this map, a characterization should be prepared of each sub-area that highlights its most significant features and relates it to the other sub-areas and the study area as a whole. The map will be used in the formulation of the different cascades, in identifying and assessing their impacts, and later in the IEA of the cascade selected.

The relative weights of the sub-areas, representing the importance of the processes they contain to the dynamics of the synthesis component in the study area should also be decided on at this point

Table 4.3.6.01 – Characterization elements for the Regional Economy Synthesis Component

Component	Characterization Elements	Source
Regional economy	• Economic activities (general and sector characterizations): – description, job and income creation capacity and location of main industries and establishments; – production structure; – primary sector: land structure, economic output, number of establishments, economically active population (EAP), people in employment, value of output, land area occupied; – secondary sector: number of establishments, EAP, people in employment, gross value, value of industrial output, chronological development of main industries and sectors; – tertiary sector: number of establishments, EAP, workforce, total revenues, VAT and service tax revenues (ICMS and ISS); – economic activities involved in assuring the quality of life of the local residents (e.g. food industry and sectors that require a large workforce).; – economic activities related to water resources; – forms of appropriation of resources (intensive / extensive, level of mechanization); – markets served and social and economic importance of the economic activities . • Resources and Potentialities of the River Basin: – Characteristics and respective spatial location; – mineral resources; – areas of agricultural potential; – potential for energy, timber, fishing, non-timber forest products, biological products, genetic products and tourism; 1) species of economic, medicinal and nutritional value; 2) effective and potential uses of the water resources; 3) planned and existing infrastructure; 4) existing and planned development investments and programs; – environmental factors that induce or restrict economic activities and factors that exert pressure on natural resources. • Finances – collection of municipal taxes; – share of federal and state tax revenues.	– Industry, Trade, Services and Farming Censuses – IBGE – Demographic Census – IBGE – Inventory Study (Pesquisa de Estoques) – IBGE – National Study of Basic Sanitation (Pesquisa Nacional de Saneamento Básico) – IBGE – Municipal Livestock Produce – IBGE – Municipal Agricultural Produce – IBGE – Timber and Non-Timber Forest Products (Produtos da Extração Vegetal e Silvicultura) – IBGE – Annual List of Information on Society (RAIS) – IBGE – Register of Plant Species and Products of Economic Importance (Cadastro de Espécies Vegetais e Produtos de Importância Econômica) – IBGE – survey of natural resources (RADAMBRASIL) – IBGE – economic indicators – FGV – register of special areas – IBGE – road maps – satellite images – university papers and theses – state and municipal departments – National Plan for Water Resources – ANA – EMBRAPA – EMATER – MAPA – SEAP – IBAMA – MDA – INPRA

4.3.7 Synthesis Component: Indigenous Peoples / Traditional Communities[10]

The aim of this synthesis component is to highlight the presence of groups that merit special treatment as they are protected by federal legislation for their specific cultural features. It is designed to help gain an understanding of how these groups are organized and how their social and cultural reproduction takes place. In this sense, the approach is similar to that used in the Ways of Life synthesis component.

The selected characterization elements are intended to make it possible to generate knowledge about what lends a given indigenous group its logic and meaning so that the mechanisms of their social reproduction can be understood. In other words, an effort is made to comprehend the relationship between each group's survival **strategies** and **forms of sociality** in order to identify the situations that tend to provide the logic and meaning that underpins their social reality (contradictions/conflicts).

The main sources of information are documents produced by government entities and research institutes, as well as academic papers and theses, all of which is to be supplemented by field research.

The selected characterization elements are described below.

Ethno-Historical Aspects

The aspects grouped here are designed to observe the differences and specificities of the ethnic groups and to generate an understanding of the historically formed relationship between the indigenous group and their environment. The following characterization elements should be addressed:

- archaeological knowledge of the region;
- history of the group.

Demographic Aspects

The demographic behavior of the indigenous population should be characterized in such a way that any changes over time and with regard to the territory can be identified in order to understand how they (re)adapt to new situations, looking in detail at the following characterization elements:

- demographic size and density;
- appraisal of demographic indexes.

Ethno-Ecological Aspects

These aspects are closely related to the cultural traditions from the perspective of the values that underpin the relationship between indigenous groups and the natural environment. They highlight the relationship between the indigenous population and the territory, for which the values that guide this relationship should be observed, as well as the way they appropriate this resource and the others at their disposal. The cultural patterns should be observed, as should the mythologically-founded explanations and sanctions and the world views that make up a group's cultural identity. This identity is formed by the basic parameters of historical heritage, community ties and antinomic relations with national society. The following characterization elements should be addressed:

- values and beliefs;
- sacred sites;

10 The procedures set out here were developed for indigenous peoples, but could be adapted to any group whose cultural features mean that they require special treatment, as is the case of former quilombo communities (originally formed by runaway slaves).

- values underlying the relationship between the indigenous peoples and nature (ethno-ecological values);
- size, nature and historical construction of the territory;
- appraisal of rates of territory loss;
- geomorphological heritage;
- ways by which natural resources (minerals, land, water, forest) are appropriated;
- assessment of the potential of the land for sustaining the group's social reproduction.

Material Conditions for Survival

In view of the fact that indigenous groups and other groups with culturally specific features can be economically autonomous, semi-autonomous or integrated, their forms of production, distribution and consumption must be characterized so they can be classified as to how integrated to the market they are. In order to do so, their forms of economic production must be observed, as must their land use, their knowledge of the fauna and flora, and the efficiency of their use of these vis-à-vis the use of commercial products. The following characterization elements should be addressed:

- socioeconomic dynamics of the interethnic region;
- forms of integration with the market;
- legal status of the territory (indigenous lands that are demarcated, in the process of being demarcated and under application for demarcation; *quilombo* lands that are demarcated, in the process of being demarcated and under application for demarcation, etc.);
- environmental factors impinging on the river basin (floodplains – flood dynamics, areas of erosion, suitability for agriculture, relief segmentation).

Social, Cultural and Political Organization

The ways groups are organized should be highlighted (solidarity/reciprocity vs. rivalries), and it should be identified whether there is any intra-group political unity and/or between different ethnic groups, and to what extent this is represented institutionally. The characterization elements below should provide a good characterization of the relationships between the indigenous people and national society (interethnic relationship), evaluating any changes that may have taken place and their effects on the territory:

- forms of religion and their relationship with the surrounding society;
- ethnic unit;
- interactions with other groups;
- linguistic affiliation;
- reciprocal solidarity / rivalries;
- types and nature of contact with society (interethnic relationship).

Results of the Diagnosis

By collating the characterization elements relating to the survival strategies and forms of sociality, the situations that express the logic that underpins a given group's social realities can be identified (situations of conflict, invasions of territory, status of legal protection, group organization, limits of ethno-ecological conditions).

In order to represent this component spatially, a map should be drawn up representing the information from each characterization element, and this should be analyzed together with the maps containing the information about the physical processes and features in the study area so that the land in which each ethnic group is present can be marked out.

The lands occupied by each group identified should be mapped out in the study area. A description characterizing each ethnic group should be annexed to this map. The most sensitive areas to the introduction of new hydropower projects should be highlighted. Unlike the other synthesis components, sub-areas are not used as a spatial unit of analysis, since the processes involved in this component are not compatible with such a breakdown of the area. This means that for this synthesis component, there is only one spatial unit of analysis, the study area as a whole, in which the indigenous lands and/or lands occupied by traditional communities should be mapped out.

Table 4.3.7.01 – Characterization Elements of the Indigenous Peoples / Traditional Communities synthesis component

Synthesis component	Characterization elements	Source
Indigenous peoples/ Traditional communities	• Ethno-Historical Aspects: – archaeological knowledge of the region; – history of the group. • Demographic Aspects: – demographic size and density; – evaluation of demographic loss rate. • Ethno-Ecological Aspects: – values and beliefs; – sacred sites; – values underlying the relationship between indigenous peoples and nature; – size, nature and historical construction of the territory; – appraisal of rates of land loss; – geomorphological heritage; – ways by which natural resources are appropriated (minerals, land, water, forest); – potential of the land for sustaining the group's social reproduction. • Material Conditions for Survival: – socioeconomic dynamics of the interethnic region; – forms of integration with the market; – legal status of the lands; – environmental factors impinging on the lands (floodplains – flood dynamics, areas of erosion, suitability for agriculture, relief segmentation). • Social, Cultural and Political Organization: – forms of religion and their relationship with the surrounding society; – ethnic unit; – interactions with other groups; – linguistic affiliation; – reciprocal solidarity / rivalries; – types and nature of contact with society at large (interethnic relationship).	– Anuário Estatístico do Brasil – IBGE – Information on indigenous lands available at the land register (Diretoria Fundiária) of FUNAI – Instituto Socioambiental – ISA – Instituto de Pesquisas Antropológicas do Rio de Janeiro – IPARJ – Academic papers and theses – Field Research – SEPPIR – INCRA – MDS – MDA – Fundação Cultural Palmares/ Ministry of Culture – United Black Movement (Movimento Negro Unificado) – IBAMA, INPRA, MMA

4.4 FORMULATING THE CASCADE OPTIONS

Based on the data collected and studied in items 4.1 and 4.2 and the socioenvironmental diagnosis in item 4.3, the sites for dams and cascade options formulated in item 3.4 should be reassessed. At this phase, sites for dams and/or cascades may be added or ruled out.

The height of the dams should be compatible with the topographical, geological, socioenvironmental features at each site, which will also influence the design of the dam sites upstream.

Although the cascade options should ideally harness all the head available, it is important at this stage to use the studies undertaken and the socioenvironmental diagnosis to identify any restrictions that may make any project or cascade unworkable or too costly. These include:

- towns, cities or other communities;
- significant cultural heritage sites;
- industrial areas and/or areas with other important economic activities;
- mineral deposits or mines of high worth and/or strategic importance;
- indigenous lands and lands occupied by former *quilombos*;
- conservation areas;
- areas containing monuments of historical and/or cultural importance; and
- areas of environmental importance, such as primary forests, patches of specific kinds of vegetation or breeding areas of rare species.

Should any of the cascades involve diverting the waters to a different sub-basin, a very careful assessment should be made, since this will have socioenvironmental impacts in both the supplying sub-basin and the receiving sub-basin. These impacts must be carefully assessed at this phase to confirm the advantages or drawbacks.

Generally speaking, the cascade options should include regulating reservoirs along the sections further upstream so that the projects further downstream can benefit from them and the energy potential of the cascade can be enhanced. The formation of regulating reservoirs must be assessed with great care for each river basin. The benefit of each reservoir will be quantified in the energy studies.

4.5 TECHNICAL FORM FOR PROJECTS

The technical form should be filled out for each dam site containing all the pertinent data and information available according to the phase reached in the studies, using the form in Annex E.

4.6 ENERGY STUDIES

The energy studies undertaken during the Preliminary Studies are designed to assess the potential for energy generation of each project under study and the energy benefits for the reference system in question. The aim is to provide a preliminary design of the main features of the reservoirs and turbine-generator sets, and an assessment of each project's economic competitiveness and that of each cascade option as a whole.

When the different projects for an inventory study are decided upon, the characteristics of the turbine-generator sets will not yet have been selected. In order to do this, there are specific procedures for making approximate energy evaluations, which are set out below (items 4.6.1 to 4.6.6). These are only based on productivity coefficients and types of turbines, and assume that all the natural hydropower from the river during the critical period of the reference system will be harnessed, plus the reservoirs' live storage, minus evaporation loss. However, under real operating conditions, the restrictions imposed by the turbine-generator sets and the projects' storage capacities will mean that in some projects, not all the inflow will be harnessed. In other words, the energy values calculated using these simplified procedures are preliminary, and the assessments will have to be repeated in detail in the simulations for the Final Studies (see item 5.3.2).

As the extent of the information available about the hydrology and topography of the river basin is still limited at the Preliminary Studies stage, simplified procedures must be used. This means that net withdrawals for multiple water uses and volumes allocated for flood control taken from the scenario built up for the basin can sometimes be disregarded. They should, however, be considered when they have a major impact on the energy definition/assessment of the different cascade options.

The procedures described in this item consider the most complex cases, where multiple water uses have to be taken into account, though the adaptation to simpler cases is straightforward. This method is included in the SINV system, and its use is recommended for the energy studies.

4.6.1 Firm Energy from a Project

The firm energy from each project can be calculated in the Preliminary Studies by the following equation:

$$Ef_i = 0.0088 \times Hlm_i \times Qlm_i \qquad (4.6.1.01)$$

where:

Ef_i	firm energy from project i, in average MW;
Hlm_i	net mean head of project i, in meters;
Qlm_i	mean stream discharge during the critical period for project i, in m^3/s; and
0.0088	coefficient corresponding to the specific mass of the water (1000 kg/m^3) multiplied by the turbine productivity (0.93), the generator productivity (0.97), the acceleration of gravity (9.81 m/s^2) and the factor 10^{-6}, which allows the energy to be expressed in average MW.

In order to determine Hlm_i and Qlm_i the following parameters must be known:

- **Maximum Normal Water Level** ($NAmxn_i$): this corresponds to the maximum water level in the reservoir under normal operating conditions. For reservoirs with flood storage capacity, the maximum normal level is the maximum volume of the reservoir minus the mean of the flood storage capacity allocated for each month of the project (VEm_i) throughout the critical period of the reference system.

- **Normal Downstream Water Level** ($NAjn_i$): this is the water level in the tailrace canal; in the Preliminary Studies, it can also be taken as the natural water level at the site, for a flow that is 10% higher than the mean flow in the critical period, or the NAmxn of the reservoir immediately downstream if this level is higher.
- **Maximum Gross Head** ($Hbmxn_i$): difference between $NAmxn_i$ and $NAjn_i$.
- **Maximum Drawdown** (di) and Live Storage (Vu_i): depending on the turbines' characteristics, the maximum drawdown of a project studied in the Inventory Studies should not in theory be greater than one third of the maximum gross head. The maximum drawdown should be set for each project using a process that maximizes its firm energy (item 4.6.4), while taking into account the capacity to replenish the reservoir's live storage (item 4.6.6).
- **Normal Minimum Water Level** ($NAmin_i$): this is the minimum water level of the reservoir during normal operating conditions; it is obtained by subtracting maximum drawdown from the maximum normal water level.
- **Minimum Gross Head** ($Hbmin_i$): difference between $NAmin_i$ and $NAjn_i$.
- **Mean Water Level** (NAm_i): the water level in the reservoir after a portion of its live storage, Vd_i, has been drawn down, given by:

$$Vd_i = \left(\frac{0.5\times(Vu_i - Vesp_i)}{Vu_i - Vesp_i + 0.5\times\sum_{k\in M_i}(Vu_k - Vesp_k)}\right)\times(Vu_i - Vesp_i) + Vesp_i \quad (4.6.1.02)$$

where:

Vd_i	portion, corresponding to mean drawdown, to be subtracted from the live storage, in m^3;
Vu_i	live storage of project i, in m^3;
Vu_i - Vd_i	live storage, corresponding to the mean water level, in m^3;
$Vesp_i$	flood storage capacity at the start of the critical period of the reference system at project i;
M_i	group of projects upstream from project i, inclusive;
k	index of the project upstream from project i.

- **Mean Gross Head** (Hbm_i): difference between NAm_i and $NAjn_i$.
- **Maximum, Mean and Minimum Net Heads** ($Hlmxn_i$, Hlm_i, $Hlmin_i$): the net heads correspond to the maximum, mean and minimum gross heads minus the losses of hydraulic load in the headrace canals. In the Preliminary Studies, the hydraulic losses can be taken as 2% of the respective gross heads for short hydraulic conveyance facilities, and 3% for long hydraulic conveyance facilities.
- **Mean Net Discharge at the Critical Period** (Qlm_i): sum of the average natural flows at the project site during the critical period of the reference system, including the flows coming from the live storage of the reservoirs at the site and upstream, minus the evaporation loss and flood storage capacities for flood control corresponding to the beginning of the critical period, and the flows withdrawn for multiple water uses at the site and upstream from it.

$$Qlm_i = Qn_i - Qr_i + T^{-1}\sum_{k\in M_i}(Vu_k - Vesp_k - Evap_k \times Amed_k \times 10^6) \quad (4.6.1.03)$$

where:

Qlm_i	mean net discharge for the critical period of the reference system at the site of project i, in m^3/s;
Qn_i	mean natural flow at the site of project i during the critical period of the reference system, in m^3/s;
Qr_i	mean volume of withdrawals for other water uses at the site of project i and upstream from it during the critical period of the reference system, in m^3/s;

T	number of seconds in the critical period of the reference system of the system;
Vu_k	live storage of project k, in m^3;
$Vesp_k$	flood storage capacity at the start of the critical period for project k, in m^3;
$Evap_k$	total net evaporation for k during the critical period, in m;
$Amed_k$	area of the reservoir at project k, corresponding t NAm_k , in km^2.

Net evaporation can be represented by a single vector that corresponds to the average monthly values. It is determined by the procedure set out in item 4.1.2.

4.6.2 Firm Energy from a Cascade

Once the head and mean net discharge have been set for each project, the preliminary firm energy (Ef) value of the whole cascade option can be defined, as:

$$Ef = \sum Ef_i = 0.0088 \sum Hlm_i \times Qlm_i \qquad (4.6.2.01)$$

In the Preliminary Studies, a cascade's firm energy calculated by the above formula corresponds to the firm energy entering the reference system from the set of projects in the cascade (item 4.6.3).

The firm energy of a cascade option and the individual project within it can be obtained from the "Firm Energy" function, "without simulation" option, in the SINV system. This function also provides the installed capacity of the plants in the cascade under analysis.

4.6.3 Firm Energy Contribution

During the Preliminary Studies, the evaluation of a project or group of projects' energy potential is an *approximate* calculation of the extra firm energy the project or projects can provide for the reference system, assuming that all the other projects in the cascade have already been built, called the last added contribution.

For a cascade as a whole, the firm energy contribution is estimated in the Preliminary Studies by the firm energy of the cascade, whose calculation is shown in item 4.6.2.

The firm energy contribution attributed to each project i in a cascade option can be calculated thus:

$$\Delta Ef_i = 0.0088 \times (Hlm_i \times Qlm_i + \frac{Vu_i - Vesp_i}{T} \times \sum_{k \in J_i} Hlm_k) \qquad (4.6.3.01)$$

where J_i is the group of projects from the reference system that are downstream from i.

The firm energy contribution of a group of projects S can be calculated as:

$$\Delta Ef_S = 0.0088 \times \left\{ \sum_{i \in S} \left(Hlm_i \times Qlm_i + \frac{Vu_i - Vesp_i}{T} \times \sum_{k \in J_i \setminus S} Hlm_k \right) \right\} \qquad (4.6.3.02)$$

where $J_i \setminus S$ is the group of projects downstream from project i that do not belong to the group of projects S.

4.6.4 Optimization of Live Storage

The live storage of the projects within a cascade should be determined by a process of optimization. First of all, the maximum drawdown levels are established for all the projects, corresponding to one third of the maximum gross head at each site. Next, a preliminary firm energy value for the cascade is determined using the procedure set out in the item above.

Once the preliminary value for firm energy has been established, the drawdown of the last reservoir downstream is reduced arbitrarily and its minimum water level is raised. This reduces the regulated flow and increases the mean net head of the group of projects. If this alteration increases the firm energy of the cascade, attempts to reduce the drawdown should be done successively as long as the level of firm energy from the projects increases. Once the live storage of the last reservoir downstream has been fixed, the process is repeated for the last project but one downstream from the group of project, and on successively until the project furthest upstream in the system. Experience from previous Preliminary Studies suggests that it is enough to carry out a single iteration of this kind; however, the analyst is ultimately responsible for deciding whether it is desirable to obtain greater precision in view of the nature of the data at his/her disposal.

The live storage of the reservoirs can be determined using the "Optimize Live Storage" function from the SINV system, which undertakes the process described above. Another choice is to use the "Energy Dimensioning" function, choosing the "without simulation" option from the SINV system to simultaneously dimension the live storage, installed capacity and reference head of the projects.

4.6.5 Installed Capacity

Once the live storage and firm energy have been estimated for each project, their installed capacity must be calculated so that the design and layout of the structures can be defined, as well as estimates of the corresponding costs.

Installed capacity is obtained as a function of the reference capacity factor and the firm energy of the project, as shown below:

$$P_i = \frac{Ef_i}{Fk} \qquad (4.6.5.01)$$

where:

P_i	installed capacity in MW;
Ef_i	firm energy in average MW; and,
Fk	reference capacity factor.

4.6.6 Reservoir Replenishment Time

Once the live storage and installed capacity have been calculated, it is important to check whether the reservoirs will be able to be replenished within 36 months from the end of the critical period. It is worth checking whether this criterion is satisfied. If the live storage does not fulfill this criterion, it should be reduced.

The flow from a reservoir during replenishment is defined as the mean flow of m months (m = 1,..., 36 months) after the end of the critical period, minus evaporation, mean volumes withdrawn for other uses, and the volumes retained for replenishing the reservoirs upstream from the project under investigation, including the project itself.

$$Qdefl_i = Qmed\_m_i - \sum_{k \in Mi} \left[\left(\frac{Evap_k x Amed_k}{2628} \right) + \left(\frac{Vu_k}{Nseg} \right) + Qret_k \right] \quad (4.6.6.01)$$

where:

M_i	group of projects upstream from i, inclusive;
$Qdefl_i$	mean flow from reservoir i during the replenishment period, in m³/s;
$Qmed\_m_i$	mean flow in months "m" after the critical period at project i, in m³/s;
$Evapmlt_k$	mean net evaporation of reservoir k, in mm;
$Amed_k$	area of the reservoir of project k corresponding to the level of reservoir k, minus half of its live storage, in km²;
Vu_k	live storage of project k, in m³;
$Qret_k$	mean flow withdrawn from the reservoir of project k for other uses, in m³/s;
Nseg	number of seconds in the "m" months.

The minimum outflow from a reservoir at the operational phase is defined as the higher of the following: the minimum outflow to meet socioenvironmental requirements, or the outflow required to operate just one generating unit.

$$Qmin\_opi = maximum \left(Qmin\_ambi; \frac{Pi.F_i}{ni.Hlmi.0.0088} \right) \quad (4.6.6.02)$$

where:

$Qmin\_op_i$	minimum outflow during the operating period of project i, in m³/s;
$Qmin\_amb_i$	minimum outflow from project i for socioenvironmental needs, in m³/s;
P_i	installed capacity of project i, in MW;
F_i	factor that represents the minimum operating level of the turbine-generator set at project i (Francis turbine: F = 0.60 and Kaplan or Bulb turbine: F = 0.35);
n_i	number of units at project i (see item 5.8.2);
Hlm_i	mean net head of project i, in meters.

By definition, if the outflow of all the projects is equal to or greater than the minimum outflow (under any hypothesis, with m at anything between 1 and 36 months), the reservoirs can be replenished in the stipulated time period. This means that replenishment time is not a factor that can annul the live storage calculations done previously.

If not, the project that is furthest upstream from amongst the group of projects under study whose outflows are lower than the minimum outflow should have its reservoir's active storage reduced iteratively until that project's outflow reaches the minimum outflow for the operational period.

Next, the installed capacities of the projects should be redimensioned and the evaluation of the replenishment times should be recalculated. This process should be repeated until the outflows of all the projects are greater than their respective minimum outflows, taking into account the minimum flows from the projects that already exist. In the case of existing projects, their minimum flows can be assured by reducing the live storage of the projects that have not yet been built.

The capacity of the reservoirs in a cascade to be replenished in up to 36 months after a critical period can be verified using the "Live Storage Replenishment" function, without simulation, from the SINV system. This function processes the steps above exactly as they are described.

4.7 PROJECT LAYOUTS

In this item, the specific criteria and instructions are given for designing the layouts of the projects in the cascades formulated.

Having gathered and analyzed the local and regional data and information, as set forth in this chapter, a schematic layout should be planned for each project that will allow the approximate dimensions of the structures to be calculated in order to reach a cost estimate.

With the information gathered, it should be possible to prepare a planimetric and altimetric map of the construction site on a scale that is compatible with the space designated for the project. This map must be prepared and should represent the best possible estimate of the local morphology. It is often necessary to interpolate contour lines. At this stage, every effort should be made to characterize to as high a level of precision as possible the profile of the slopes of the abutments and the river valleys and any elevations at sites where headrace tunnels or canals could be built. The same map should also contain basic geological information, such as the thickness of the soil cover and the suitability of the foundations for concrete.

Once the topographic elements have been characterized, the lines and basic contours of the layout should be drawn on top of the map. When designing the layout, the guidelines set out in item 2.5 should be followed, broadly speaking. In order to do so, the approximate dimensions of the main structures must be calculated in order to estimate the associated costs (item 4.10). Once this has been done, the layout of the project should be drawn on the map and the main cross-sections and longitudinal sections should be drawn. At this stage, some adjustments are normally made to the layout to obtain the most suitable configuration, taking into account the degree of precision of the information available at this stage.

At the same time, the area of land to be flooded for the reservoir should be marked out on a map, which should also have any lands, towns or land developments identified.

4.8 EVALUATION OF NEGATIVE SOCIOENVIRONMENTAL IMPACTS PER PROJECT

These studies involve analyzing projects as to the negative socioenvironmental impacts they exert on each synthesis component, which consists of **identifying the impact processes** and **assessing the negative socioenvironmental impacts**.

The aims of these studies are:

- to supply information to help estimate the socioenvironmental costs of the projects;
- to attribute values to the negative socioenvironmental impacts of the projects by using impact indexes, which will serve for calculating the negative environmental indexes of the cascade options, as set forth in item 4.11.2;
- indicate the need to adjust the formulation of the cascades and the basic design of the projects, so as to minimize their negative socioenvironmental impacts;
- to identify the cumulative and synergistic effects throughout the sub-areas.

In the Preliminary Studies, the analyses should be undertaken for each project individually, without taking into account the broader context of the cascades they are part of. This is to prevent making the analysis overly complex and lengthy in view of the number of projects and cascades normally under consideration at this stage. For this reason, a more detailed analysis should only be done in the Final Studies once the most promising cascades have been selected for their economic and energy potential and socioenvironmental impact.

In order to make the evaluation feasible, **impact indicators** have been defined that collate the main impact processes that could affect each synthesis component when the projects are built. The indicators should provide the means to quantify and qualify the effects of pressures on the terrestrial and aquatic ecosystems and on the socioeconomic interactions brought about by the projects, also taking into account the uses of the land and waters in the river basin.

The particularities of the project layouts should also be considered. It is important, for instance, to be aware of any alterations to the streamflow downstream from the dam in the cases of projects that divert water through intake canals or tunnels.

Each impact indicator is associated to a set of **assessment elements**, which organize the information relative to the impact processes. The impact indicators and their respective assessment elements are presented in items 4.8.3 to 4.8.8. By doing this evaluation, it should be possible to qualify and quantify the indicators in the physical space and for future scenarios.

4.8.1 Identification of Impact Processes

The impact processes associated with each project should be identified. The following procedures are recommended:

- cross-referencing the results of the socioenvironmental diagnosis with the information about the prospective projects. It is useful to superimpose the maps that represent the synthesis components and have the divisions into sub-areas and areas of sensitivity marked out and classified with the maps of the project layouts resulting from the engineering studies;

- characterizing the main impact processes that emerge from the interaction between the project and the study area for each synthesis component. This analysis should be systematized per sub-area, since they highlight the processes that already exist in the study area that could be affected by the projects. The areas of sensitivity that are demarcated should also serve as a reference for the evaluation, since the impacts from processes that affect the areas of greater sensitivity should be more significant. This means that projects in the same sub-area will tend to bring about the same impact processes with similar profiles, differentiated by the specific features of the projects and, when pertinent, by any special features at their sites, such as areas identified as being of greater sensitivity;
- selecting the assessment elements capable of characterizing the impact processes identified on each synthesis component, which make the impact indicator capable of differentiating amongst the projects and, subsequently, amongst the different cascades. In selecting the assessment elements, different aspects from the study area and the projects themselves must be covered. A balance should also be struck between quantitative and qualitative assessment elements;
- undertaking interdisciplinary activities to assure the integration of the analyses undertaken for the different synthesis components. This makes it possible to incorporate the interrelationships between the impact processes of different synthesis components through their assessment elements;
- reviewing the characterization of impact processes per synthesis component and the selection of their respective assessment elements as a function of the integration of the analyses. This should give rise to a general description of the impact processes and the assessment elements adopted. At this point, those processes for which control, mitigation or compensation actions should be taken must be highlighted and translated into socioenvironmental costs to be incorporated into the implementation costs (item 4.10.1). Any variations in the layout of the projects that might ameliorate their negative socioenvironmental impacts should also be identified, as should any interference the environment could have on the projects, which will be used in the engineering project and cost estimates. It should be noted that this interference is not calculated for the assessment of socioenvironmental impacts.

4.8.2 Assessment of Negative Socioenvironmental Impacts

An estimate should be made of the intensity of the negative socioenvironmental impacts of each project on the sub-areas defined for each synthesis component, based on the impact indicators and their assessment elements. The impacts that need to be analyzed are those for which no control can be introduced and any other residual impacts left over after controls, mitigation or compensation have been provided. The following procedures are recommended:

a) analysis of the assessment elements for each project, with a view to building up the impact indicators adopted. The analysis should be made per synthesis component, seeking to strike a balance between qualitative and quantitative assessment elements. The assessment elements and the procedures used to build up each indicator should be listed, as should the criteria used for measuring the intensity of the impacts. Again, any areas of greater sensitivity in the sub-areas will be helpful in assessing the intensity of any given impact;

b) attribution of a negative impact index for each synthesis component per sub-area affected and for each prospective project. This activity consists of expressing the intensity of the negative socioenvironmental impact of a project as a numerical figure, which is based on the set of negative impact indicators adopted for each synthesis component. The indexes thus attributed are then aggregated per sub-area. This aggregation is achieved by ranking the indicators according to their importance to the sub-area and giving them relative weights.

The negative impact indexes should be attributed on a continuous scale from **zero** to **one**. **Zero** indicates the **absence of any impact**, while **one** means that the **entire process inherent to the synthesis component in question is compromised**. The intermediate values therefore represent the different degrees to which existing environmental processes are affected by the negative impact indicators chosen for each synthesis component. The criteria used for defining the values of the indexes should be reported.

An example is given in table 4.8.2.01 of the result of an impact assessment of a given synthesis component for a project.

The team that carries out the study should decide on the criteria to be used for attributing the levels of impact, seeking to reach a consensus as to the meaning of the intermediate values so that the results of the assessments of the different synthesis components can be compared amongst themselves. It is recommended that interdisciplinary activities be undertaken so that the criteria used for the river basin under study can be standardized. These should be justified and recorded so that any future reviews or updates of the studies can use the same criteria.

The maximum value on the evaluation scale (one) should not be relative; i.e. it is not the highest value amongst the impacts of the projects in the basin in question, but an absolute value of total impact that may or may not exist in the situation under study.

The criteria used for setting the values of the indexes should be recorded.

It is necessary to set values for the indexes of the projects per sub-area before the indexes of whole alternatives can be built up, which are based on the individual indexes of the projects that make them up, as shown in item 4.11.2.

Table 4.8.2.01– Impact Indexes per project
Example: Synthesis Component – Ways of Life

Sub-areas / Projects	I	II	III	IV	V	VI
A		0.10				
B		0.50	0.65	0.10		
C			0.85		0.35	
D			0.70			
E	0.05	0.05				
F		0.08				
G	0.10					
H	0.10				0.10	
I_1	0.30		0.10		0.30	
I_2	0.85		0.10		0.85	
J			0.60		0.30	
K	0.45				0.30	
L			0.75	0.40	0.60	
M	0.30					0.40
N	0.50		0.90			
O						0.88
P						0.40
Q_1						0.80
Q_2						0.95
R_1						0.90
R_2						0.95

c) analyses of the indexes of the projects per sub-area, which, as they represent the intensity of the negative impact on the synthesis component, supply important indications for the review of the projects' design in order to achieve a better socioenvironmental performance or, in extreme cases, to eliminate individual projects and/or cascades;

d) analysis of the repercussions on the study area of the impact processes in each sub-area, which will be combined to form the indexes for the different cascades, as described in item 4.11.2;

e) interdisciplinary discussions about the evaluations in order to analyze the results, identify any inconsistencies and minimize the degree of subjectivity involved in the judgments used for the different synthesis components. Depending on the outcome of these discussions, the levels of negative impact attributed to each project on the synthesis components may be reviewed.

The relative subjectivity inherent to these evaluations can only be minimized by standardizing the assessment criteria, assessment elements and procedures adopted in the methodology. The repeated application of the methodology and expansion of the database on the electricity sector with the results of monitoring activities are indispensable for future efforts to parameterize the assessment elements and make the values attributed to each of the environmental indexes more objective.

In items 4.8.3 to 4.8.8, the contents that need to be covered and procedures to be adopted for assessing the negative impacts on each synthesis component are set out in detail, with the respective impact indicators presented in tables. These tables are designed to cover the majority of situations encountered in different parts of Brazil, but should be adjusted and/or supplemented with information as necessary for each specific case under study. As Physical Processes and Features are taken to be a basic element for analyzing the synthesis components, as explained previously, they are incorporated into the evaluations of these components as assessment elements, in that they contribute to the impact processes identified.

4.8.3 Aquatic Ecosystems

The impact processes should be identified for each project and for each sub-area. Next, the assessment elements should be identified that best characterize these processes, with a view to estimating the extent to which the characteristics that are fundamental in preserving the biodiversity are affected (**impact indicators**). These elements should encompass aspects relating to the indicators of ecological significance identified in the diagnosis, which are used to identify the areas of sensitivity, as well as the characteristics of the projects, so that it can be estimated what changes the ecosystems are likely to suffer as a result of the planned interventions.

It should also be borne in mind that the assessment elements are used for the basic design of the projects and later when the socioenvironmental costs are estimated and subsequently incorporated into the implementation costs.

At this point, interdisciplinary activities should be carried out with a view to integrating the impact processes identified in one synthesis component with those from the others, drawing on information on the physical processes and features, so that the assessment elements effectively represent the interactions that exist.

The intensity of the socioenvironmental impact of a project on a given sub-area should be estimated by analyzing the degree to which the habitats which harbor biodiversity, migratory, endemic or exclusive species and exceptional situations are affected, and by how much other groups of vertebrates are also affected. In the analysis, the interference on the streamflow regime downstream from the reservoir should also be investigated. The following assessment elements are recommended:

- total area of the aquatic environment to be modified, which should be measured by summing the length of the channel of the main river and its tributaries (km) that is expected to change from being lotic to lentic, i.e. which will cease to be a stream and become a lake. This alteration has a major impact on the water systems, as many of the species will be unable to adapt to the new environment;
- relative stream order – this is the ratio between the stream order observed in the reservoir's drainage area and the maximum stream order observed in the sub-area, using the Strahler method;
- loss of ecologically strategic habitats – these habitats are: river pools, river beaches (used as breeding and feeding grounds for swamp-dwelling wildlife) and rivers with unique physiographic features, such as those that are meandering or braided. The loss of these habitats is assessed by the ratio of the area (in the case of lakes and beaches) or length (in the case of rivers) affected by the project to the total area/length of these habitats in the sub-area;
- impact on migratory routes – the extent to which migratory routes used by rheophiles are affected by the project in each sub-area is assessed by their importance in drawing these rheophiles into the water basin;
- loss of habitats with high hydrodynamic energy – rapids and/or white water – the ratio between the length of the habitats with high hydrodynamic energy affected by the project and the total length of these habitats within the sub-area will give a good estimate of the degree to which species exclusive to these habitats will be impacted;
- loss of riparian forest – this can be estimated by the ratio between the length of riparian forest affected by the project against the total length of riparian forest in the sub-area;
- water quality of the prospective reservoirs – one of the greatest ecological, social and economic repercussions associated with the formation of artificial reservoirs is a phenomenon known as eutrophication. It is a process that reflects the hydraulic and morphometric characteristics of the project, and the hydrological, physiographical and land use aspects in the contributing basin and the area to be impounded. Given the ecological and economic significance of eutrophication, the impact assessment of this variable should be individualized, using simplified models for projecting the water quality in the future reservoirs. The variables that need to be assessed are: morphometry of the reservoir, average depth, residence time, phytomass of the flooded area, and land use in the drainage basin. At the end of the modeling, the different projects are assessed as to the degree to which they will contribute to maintaining the quality of the water in the river basin;
- alteration of natural streamflow regime – this happens with projects with flow regulation capacity. When a hydroelectric plant is in operation, there can be significant reductions in the flow immediately downstream from the dam. In these cases, the aquatic fauna and flora that depend on the natural course of these waters will be altered. The likelihood of this alteration is measured as the ratio between the reservoir's live storage and the average natural flow;
- diversion in the same river basin – this happens in certain cases when the water withdrawn for the power plant is preceded by channels or pipes that divert the flow of a river, leaving a section of the natural river bed with a reduced flow or completely dry. Once the water has gone through the turbines, it returns to its natural course. In order to assess this impact, the length of the section with a reduced flow and the reduction in the flow itself must be calculated; and

- diversion to a different river basin – this happens in certain cases when water which, prior to the building of the power plant, ran along the natural river bed is diverted after the impoundment to another river basin, leading to a reduction in the flow or complete drying up of the section immediately downstream from the dam, and a mixing of waters from different basins in the section of the basin that receives the diverted flow.

Table 4.8.3.01 shows the negative impact indicators and the assessment elements for this synthesis component.

Establishing Levels of Impact

A compilation of the assessment elements should be used in attributing a degree of negative impact for each project on each sub-area. These will be on a scale from **zero** to **one** to reflect the extent to which the features on which the continued biodiversity of the area is dependent will be compromised.

Finally, the repercussions on the study area of the impact processes in each sub-area should be analyzed, taking into account the different degrees of ecological significance and the areas of greater sensitivity identified in the diagnosis.

Table 4.8.3.01 – Impact indicators and assessment elements for the Aquatic Ecosystems synthesis component

Synthesis component	Impact indicator	Assessment elements
Aquatic Ecosystems	Interference in habitats that maintain the biodiversity, migratory, endemic or exclusive species (and other groups of vertebrates)	• Stream order (Strahler method); • Alterations to the total extent of the water environment to be modified; • Loss of Ecologically Strategic Habitats; • Migratory routes affected; • Loss of habitats of high hydrodynamic energy; • Alteration of riparian forest; • Water quality of future reservoirs – morphometric characteristics of the section of river affected; – volume of phytomass affected; – soil types affected; – mean depth; – residence time.
	Interference in the streamflow regime (effects downstream from the reservoir)	• Possibility of eutrophication of the reservoir; sites with a high concentration of heavy metals / with a possibility of biomagnification. • Occurrence of other vertebrates that could be impacted (aquatic mammals, reptiles). • Alteration of natural streamflows – Regulating capacity: mean natural flow to the reservoir and its live storage. • Diversion within same basin – Length of the section with reduced flow; – Reduction of flow. • Diversion to different basin – Mean flow diverted.

4.8.4 Terrestrial Ecosystems

The impact processes should be identified for each project and for each sub-area. Next, the assessment elements should be identified that best characterize these processes, with a view to estimating the extent to which the characteristics that are instrumental in maintaining the biodiversity are compromised. These elements should encompass aspects relating to the indicators of ecological significance and areas of sensitivity identified in the diagnosis, as well as the characteristics of the project, so that the change to the state of the biological systems to be expected from the future intervention can be estimated.

It should also be remembered that the assessment elements are used for the basic design of the projects and later for estimating the socioenvironmental costs, which are an integral part of the implementation costs.

At this point, interdisciplinary activities should be carried out with a view to integrating the impact processes identified with those from the other synthesis components, so that the assessment elements can effectively represent the interactions that exist.

The intensity of the socioenvironmental impact of a project on a given sub-area should be estimated by analyzing the degree to which the ecosystems and species are affected. The following assessment elements are recommended:

- land use in a project's direct and indirect areas of influence. Quantification (in km^2) of the urban areas, the areas occupied by farming and ranching, and the areas with patches of remaining natural vegetation, identifying the different stages of conservation (primary and secondary formations, classified by their different stages of regeneration);
- loss of riparian forest – this can be estimated by the ratio between the length of riparian forest affected by the project and the total length of riparian forest existing in the sub-area;
- loss of vegetation – this is assessed by the ratio between the area of forest affected by the project and the total area of forest existing in the sub-area;
- physiognomic exclusivity – the extent to which the phytophysiognomies exclusive to the sub-area are affected is estimated by the ratio between the surface area containing unique physiognomies affected by the project and the total surface area with unique physiognomies that exists in the sub-area;
- significance of fauna in the area affected – this is estimated as a function of the probability of species occurring whose natural population numbers are in some way under threat;
- conservation areas – direct or indirect interference in federal, state or municipal conservation areas.

Table 4.8.4.01 shows the negative impact indicators and assessment elements for this synthesis component.

Establishing Levels of Impact

A compilation of the assessment elements should be used in attributing a degree of negative impact for each project on each sub-area. These will be on a scale from **zero** to **one** to reflect the extent to which the features on which the continued biodiversity of the area is dependent will be compromised.

Finally, the repercussions on the study area of the impact processes in each sub-area should be analyzed, taking into account the different degrees of ecological significance and the areas of greater sensitivity identified in the diagnosis.

Table 4.8.4.01 – Impact indicators and assessment elements for the Terrestrial Ecosystems Synthesis Component

Synthesis component	Impact indicator	Assessment elements
Terrestrial Ecosystems	Interference in the features that determine the continued biodiversity of the area (impact on ecosystems and species)	• Loss of habitats with a higher degree of ecological integrity • Increased pressure on terrestrial ecosystems (deforestation, hunting, extraction of non-timber forest products, farming, ranching, illegal trade in animal and plant species, etc.) • Loss of riparian forest • Loss of vegetation • Interference in ecological corridors in the area of influence, priority areas for biodiversity conservation, conservation areas, buffer zones and all other protected areas. • Unique physiognomies, integrity of the terrestrial ecosystem. Loss of connectivity, increased fragmentation of the ecosystem • Significance of the fauna in the affected area

4.8.5 Ways of Life

The impact processes should be identified for each sub-area, meaning for each way of life affected by each project.

Once the impact processes have been identified per project and for each sub-area, the assessment elements should be identified that best characterize these processes, with a view to estimating their level of interference on the forms of social reproduction. These elements should encompass aspects relating to the pre-existing forms of social life and the features of the projects, so that the relationship between the vulnerability to change identified in the diagnosis and the kind of intervention to take place can be observed.

It should also be remembered that the assessment elements are used for the basic design of the projects and later for estimating the socioenvironmental costs, which are an integral part of the implementation costs.

At this point, interdisciplinary activities should be carried out with a view to integrating the impact processes identified with those from the other synthesis components, so that the assessment elements can effectively represent the existing interactions.

When estimating the intensity of the socioenvironmental impact of a project on a given sub-area, the following impact indicators should be considered, which will contribute towards the synthesis of the assessment elements:

- extent to which survival strategies are affected, which has to do with interferences in material conditions;
- extent to which the historically constructed society is affected, which has to do with interferences in socio-cultural conditions.

In order to assess the extent to which the *survival strategies* of each way of life in the area are affected, it is necessary to consider:

- changes to aspects that impinge on living conditions:
  - fall in consumption standards caused by a decline in labor conditions;
  - collective consumer goods affected (basic services: education, health, energy, communication, sanitation, transport and leisure);

- changes to basic traditional indicators of quality of life, such as health indicators;
- changes to the epidemiological profile, especially concerning water-borne diseases and/or diseases associated with unsanitary conditions.

- changes to the production systems of each Way of Life, observed by identifying the chances of recovery, based on the following:

- changes to the pre-existing state of capitalization/decapitalization, caused by changes to employment status, value of equity available and impacts on production. In some rural areas, this can most easily be perceived by observing the occupations of the workforce operating in partnership, income, tasks and/or wages in the labor undertaken by the workforce; this will usually include landless workers;
- changes/breakdowns in the networks of relationships which urban social groupings depend on and have at their disposal to assure their survival, and which may have to do with formal employment (formal labor market) or informal employment (part-time work, odd jobs);
- breakdown in the bonds of dependency between the rural and urban populations, which can mainly be seen from the perspective of labor relations (people who live in towns but depend on work in the countryside, or vice versa), as well as the situations in which food security/supply is dependent on rural output;
- changes to environmental factors, which can be seen from the loss of areas of floodplain which are important to riverside communities or the loss of areas suitable for agriculture, which often assure regional food security, as well as the subsistence economy. It is important to take into account any alterations to the streamflow regime in the river downstream from the dam.

The assessment of the extent to which the *historically constructed society* is affected, which expresses the social and cultural aspects of the Ways of Life identified, is carried out by observing the following:

- social ties affected:

- broken bonds of neighborliness or companionship;
- ethnic relations affected;
- aggravation of pre-existing conflict situations;
- breakdown of political relations that depend on the pre-existing social structure;
- effect on the extent of formal and informal organization of society.

- socio-cultural identity affected, and its spatial and temporal manifestations:

- loss of points of reference responsible for the social and cultural organization of the group (cultural manifestations, elements of historical and cultural heritage);
- loss of situations in which proximity to the river (e.g. flood dynamics) is instrumental in the socio-cultural organization.

Table 4.8.5.01 sets out the impact indicators and assessment elements for this synthesis component.

It is important to estimate and identify the number of people to be impacted. This information will be used in calculating the costs associated with the implementation of the projects. However, in this evaluation of the impacts, the aim is to qualify this group and assess the losses they would suffer, thus preventing a duplicate count of aspects already incorporated into the overall costs.

Establishing Levels of Impact

A compilation of the assessment elements should be used in attributing a degree of negative impact for each project on each sub-area. These will be on a scale from **zero** to **one** to reflect the extent to which the forms of social reproduction will be compromised.

Finally, the repercussions on the study area of the impact processes in each sub-area should be analyzed. This analysis should take into account the perception of representative situations which make questions that are apparently local become regional in nature, making the impact process have effects that extrapolate the boundaries of the sub-area, such as situations of contradictions and/or conflicts which are exacerbated by the intervention.

Table 4.8.5.01 – Impact indicators and assessment elements for the Ways of Life synthesis component

Synthesis component	Impact indicators	Assessment elements
Ways of life	Effect on survival strategies	• changes to aspects that structure the living conditions: – number of people or households affected (rural and urban) – collective consumer goods affected; – drops in consumption standards; – changes in indicators of quality of life; – changes to the disease profile; • changes to the production systems of each Way of life. – changes to the pre-existing capitalization/decapitalization conditions; – changes to the network of relationships that the urban social groups depend on to assure their survival; – breakdown of ties of dependency between towns and countryside; – changes to environmental factors.
	Effect on historically constructed society	• social ties affected; • changes to socio-cultural identity and its spatial and temporal manifestations. • interference in historical, cultural archaeological and other forms of heritage.

4.8.6 Territorial Organization

The impact processes should be identified for each sub-area affected by each project, with priority being given to characterizing those that are involved in breaking down flows of communication and the circulation of goods and people, and the land uses and occupations.

Once the impact processes have been identified per project and for each sub-area, the assessment elements should be identified that best characterize these processes, with a view to estimating the extent to which circulation and communication within the study area will be interrupted. This should encompass the elements that structure the way the land is organized and the features of the projects, so that the interference they will have on the degree of integration within each sub-area can be observed.

It should also be remembered that the assessment elements are used for the basic design of the projects and later for estimating the socioenvironmental costs, which are an integral part of the implementation costs. Some of these elements will be used in the assessment of positive impacts in the Final Studies.

At this point, interdisciplinary activities should be carried out with a view to integrating the impact processes identified with those from the other synthesis components, so that the assessment elements that best represent the existing interactions can be selected.

The intensity of the negative socioenvironmental impact of each project on the sub-areas affected should be estimated by analyzing the following impact indicators, which will help collate the different assessment elements:

- interference in the patterns of human settlements and mobility of the local population;
- interference in the flows of circulation and communication;
- interference in the political and administrative organization of the municipalities;
- interference in territorial management.

Interference in the patterns of human settlements and mobility of the local population

This indicator is instrumental in assessing any changes to the historically established settlement patterns within the area of the river basin, and the role any such changes would have in the territorial organization of the study area. Both qualitative and quantitative data should be used for this assessment. When communities need to be resettled, it is worth making comparisons with similar cases that may already have taken place in the same region as the study area.

The following assessment elements should be considered:

- number of people to be resettled and what proportion these are to the total population in the municipality and the river basin (estimate): this is a quantitative estimate of the number of people to be resettled, drawing a correlation with the total population within the study area and the total population living in the respective municipalities, followed by a qualitative analysis of the significance of the estimated resettlements. It could be helpful to make supplementary observations of the spatial location and internal characteristics of the population to be resettled, covering their original occupations (urbanized area, area in urban expansion, rural area, forest area) and original settlement patterns (residents of densely populated urban areas, suburbs, concentrated or widely-spaced settlements, isolated, sparse or clustered communities);
- number, location and features of villages affected, whether partially or totally;
- availability of land for planned resettlements;
- workers' village: planned location, estimated population associated with the works, relationship with the people living in the municipality and the whole study area.

Interference in flows of circulation and communication

The impact processes on flows of circulation and communication should be identified, characterized and qualified by looking at two aspects that sum up the interferences produced and the assessment elements associated with them: accessibility and reversibility of the interferences on occupations, circulation and communication.

Interference on accessibility can be estimated by the following items:

- production, consumption and service facilities affected: the production facilities affected should be identified, highlighting those involved in the processing of primary goods (agro-industrial, alcohol distilleries, etc.) and those that are labor intensive; depots, warehouses and silos; teaching and health establishments (rural and urban, serving people outside the local community); commercial establishments (especially accommodation and food establishments), transportation and communication. The features, spatial location and range of these facilities should be described, as well as the size, profile and location of the people concerned with them and the extent to which they will be affected;
- extent and functions of transportation infrastructure affected: the sections of roads, waterways and railroads affected should be described, mapped out and qualified so as to cover the following items: length, route, number of points of integration between different forms of transportation, towns directly connected to them, corridors and their areas of influence; goods and categories of users that are served by them; main origin and destination points of journeys;
- estimate of number of people affected per loss of transportation infrastructure (and services dependent on it), and proportion of these people to the total population in the municipality and the study area: once the interference in the towns and the transportation network has been identified, it should be estimated how many people will be affected by the loss of transportation infrastructure in such a way that their access to urban facilities will be restricted. This total should be correlated with the total number of residents in the study area and in the respective municipalities;

- estimate of users of water resources affected: the number of people affected should be estimated per use, such as supply, irrigation, fishing, trade, leisure, tourism; the nature and severity of the interference should be qualified per use. In order to use this estimate and the other data on this topic generated for the impact assessment, the information used here must be brought into line with the information on different water uses and the information and projections used in preparing the basic scenarios and alternatives for other water uses in the energy studies (item 4.2.5). Note that the impacts on this assessment element should not be taken into account for those projects/cascades where the pre-defined scenarios are observed. However, while in these studies the main uses considered are irrigation, flood control and navigation, the analysis is broader for the impact assessment, covering all actual and potential water uses;
- transportation integration affected: characteristics of the kinds of transportation integration and means of access affected and repercussions on the flows of circulation and communication.

The reversibility of the interference in the patterns of occupation, circulation and communication can be assessed by the following elements:

- alternatives to the functional relationships and flows of circulation and communication within the river basin that are interrupted – it should be investigated whether there are any alternative means of restoring the situations affected by the impact processes described in the above items. This would include: re-establishing flows interrupted by different elements of infrastructure; assurance of access by restoring interrupted flows or establishing new flows, etc.

The following items should be considered as part of these studies:

- the patterns of occupation that are characteristic in the basin and their expansion trends;
- any short- or medium-term large-scale projects or plans for investments in transportation infrastructure in the study area;
- the possibility of using different modes of transportation by the people affected;
- the availability of lands for relocating affected villages and providing infrastructure, by examining any land that is not answered for in the current occupation dynamics, and any environmental factors that may induce or restrict the new land occupation.

Interference in the political and administrative organization of the municipalities

- Role of the seats of municipal government and public, municipal, state and federal institutions affected: the administrative, political and institutional functions carried out by the institutions and the localities to be relocated should be defined. An essentially interpretative analysis should be made of the set of descriptive data gathered and collated to date.
- Loss of land: surface area and its proportion to the total land area in the municipality and the river basin: the quantitative data on and spatial visualization of the areas to be flooded are the main inputs for the qualitative analysis of the interference to be caused to the political and administrative entities. These interferences may lead to threshold situations, where the continued existence of a municipality may become unfeasible, with knock-on effects on other municipalities, their residents and services.
- Estimate of the total electorate to be resettled and their proportion to the total municipal constituency: this estimate relates to the assessment of the potential for changing the local constituencies.
- Loss of number of local representatives: it should be checked whether the number of representatives on the municipal council will be reduced as a result of the need to resettle local people, given that in some cases the number of people living in a municipality could be greatly altered.

Interference in Territorial Management

The incompatibilities and synergies with the policies, plans and programs for local and regional development should be analyzed with a view to assessing any potential negative or positive impacts or cumulative effects.

Table 4.8.6.01 shows the impact indicators and assessment elements for this synthesis component.

Attribution of Levels of impact

Negative impacts should be attributed per sub-area affected and for each prospective project. A compilation of the assessment elements should be used in attributing a degree of negative impact on a scale from **zero** to **one** to reflect the extent to which the flows of circulation and communication which are instrumental in organizing the land covered by the sub-area will be compromised.

Finally, the repercussions on the study area of the impact processes in each sub-area should be analyzed. This analysis should take into account the analyses from the diagnoses relating to the interactions between the processes in the sub-area and their contextualization in the study area, emphasizing those elements that are instrumental in making the impact processes in a given sub-area spill out beyond its boundaries and reverberating in others.

Table 4.8.6.01 – Impact indicators and assessment elements for the Territorial Organization synthesis component

Synthesis component	Impact indicator	Assessment elements
Territorial organization	interference in the patterns of human settlements and mobility of the local population	• number, location and characteristics of the settlements affected either partially or totally; • availability of land for the planned resettlements; • estimate of the number of resettled people (rural and urban); • workers' village: location, population during works, relationship with local population.
	interference in circulation and communication	**accessibility** • facilities for production, consumption and services affected; • extent and functions of transport infrastructure affected; • extent and functions of transport infrastructure expanded; • estimate of number of people affected by loss of transport infrastructure; • estimate of number of users of water resources affected; • transport integration affected. **reversibility of interferences in circulation and communication** • alternatives to functional relationships interrupted; • alternatives to the circulation and communications affected.
	interference in the political and administrative structure	• loss of land: (surface area and proportion of total are covered by municipality); • estimate of number of electors resettled and proportion of total municipal electorate; • loss of representatives; • role of municipal seats of government and public, municipal, state and federal institutions affected.
	interference in territorial management	• incompatibilities with policies, plans and programs for local or regional development; • synergies with policies, plans and programs for local or regional development.

4.8.7 Regional Economy

The impact processes should be identified for each sub-area affected, with priority being given to characterizing those processes that could reduce the production of wealth and public revenues or inflict damage on resources, as well as any potentialities, so that their consequences on the local and regional economy can be assessed.

Once the impact processes in each sub-area have been identified per project, the assessment elements should be selected that best characterize these processes with a view to estimating the extent to which the foundations of the economy in the study area will be affected. This should encompass the elements that structure the economy in the sub-areas and the characteristics of the projects, so that the interference they will have on each sub-area can be observed.

It should also be remembered that the assessment elements are used for the basic design of the projects and later for estimating the socioenvironmental costs, which are an integral part of the implementation costs. Some of these elements will be used in the assessment of positive impacts of the cascades in the Final Studies.

At this point, interdisciplinary activities should be carried out with a view to integrating the impact processes identified with those from the other synthesis components, so that the assessment elements that best represent the existing interactions can be selected.

The intensity of the negative socioenvironmental impact of each project on the sub-areas affected should be estimated by analyzing the following impact indicators, which will help synthesize the different assessment elements:

- interference in economic activities;
- interference in resources and potentialities;
- interference in municipal finances.

1) Interference in economic activities:

- number and type of establishments affected: when the object of the analysis is the formal sector of the economy, traditional indicators can be used. However, when the informal economy is prevalent, qualitative analyses must be undertaken. This is the case of simple activities for which no regular wages are paid, which are important because: (a) they represent alternative sources of employment and income, which are fundamental for an incipient urban economy; and (b) the impacts they suffer are not always recognized or acknowledged. They are therefore particularly important for assessing the impacts on the forms of labor that are not entirely subject to the capitalist dynamics of production and circulation;
- output affected per sector: this estimate is particularly important in cases where the analyses carried out in the diagnosis indicated the particular importance of one given sector. In these cases, the following should be considered: quantity of output per type of production and land area lost for this output (for the primary sector); value of transformation activities (for the secondary sector); details of the effect of lost income in trade and services on the standard of living (for the tertiary sector);
- river-related economic activities affected: so-called “riverside” economic activities affected, such as pottery works and floodplain agriculture, can be assessed by the value of their output and the number of jobs created;

- social and economic traits in the water basin: the economic activities affected should be characterized according to the role they play in the local and regional economies and their significance in assuring continued living standards;
- loss of employment and income: the number of jobs cut should be quantified and the way this is felt by the local population and number of people in employment should be qualified;
- markets affected: the sectors affected by the loss of output should be estimated, and the impact of this on the markets identified should be qualified;
- occurrence of conditions that sustain the reproduction of activities: the feasibility of resettling or restructuring the activities affected should be assessed in such a way that producers, consumers and land/property owners would not suffer any damages or loss.

2) Interference in resources and potentialities, especially concerning water uses:

- characteristics and size of the resources and potentialities in the river basin that are affected, such as mineral resources, arable areas, extraction of non-timber forest products, energy, tourism, areas of biological and genetic potential, and their relative importance within the study area;
- social and economic significance of the potentialities affected: qualification of their importance for maintaining living standards in the study area;
- existing/potential uses of the water resources affected or made unfeasible and number of people affected: the information used here must be brought into line with the information used for assessing the different water uses and the information and projections prepared for the scenarios of multiple water uses (item 4.2.2). It is mandatory to use this information. Note that the impacts on this assessment element should not be taken into account for those projects/cascades where the pre-defined scenarios are observed. This information will also be used in assessing the positive impacts in the Final Studies.

3) Interference in municipal finances:

- difference in tax revenues and revenue transfers: a fall in revenues is a direct consequence of a fall in tax revenues and monies distributed from shared revenues, which are directly related to the land size, the population size and their economic activities. The task is to estimate the effects arising if activities that generate taxes, transfers and draw-downs (from the Municipal Fund, *Fundo de Participações dos Municípios*) ceased, were made unfeasible or were disrupted;
- total revenues collected as financial compensation for municipalities affected and from ISS (VAT) during construction, for the assessment of positive impacts.

Table 4.8.7.01 shows the impact indicators and assessment elements for this synthesis component.

Attribution of levels of impact

Negative impacts should be attributed per sub-area affected and for each prospective project. A compilation of the aspects assessed using the criteria presented should be used in attributing a degree of negative impact a scale from **zero** to **one** to reflect the degree of interference to which the basis of the economy in the sub-area is subject.

Finally, the repercussions on the study area of the impact processes in each sub-area should be analyzed. This analysis should take into account the analyses from the diagnoses relating to the interactions between the processes in the sub-area and their contextualization in the study area, emphasizing those elements that are instrumental in making the impact processes in a given sub-area extrapolate its boundaries and reverberate in others.

Table 4.8.7.01 – Impact indicators and assessment elements for the Regional Economy synthesis component

Synthesis component	Impact indicator	Assessment elements
Regional economy	Interference in economic activities	• number and type of establishments affected; • value of output affected per sector; • river-related economic activities affected; • social and economic significance of the activities; • job cuts and income reduction; • jobs and income created; • markets affected; • existence of conditions to support the reproduction of activities.
	Interference in resources and potentialities, especially concerning water uses	• characteristics and size of the resources and potentialities in the river basin that are affected (mineral resources, areas suitable for agriculture, extraction of non-timber forest products, tourism, areas of biological and genetic potential); • opportunity for harnessing resources and potentialities; • social and economic significance of the potentialities affected; • existing/potential uses of the water resources affected / made unfeasible and number of people affected; • opportunities for new uses of water resources and number of people benefited.
	Interference in municipal finances	• difference in tax revenues and revenue transfers; • revenues from financial compensation and ISS (VAT).

4.8.8 Indigenous Peoples/Traditional Communities

The impact processes should be assessed for each indigenous land or each area occupied by a traditional community affected per project.

Once the impact processes have been identified, the assessment elements should be selected that best characterize these processes, with a view to estimating their level of interference in the forms of social reproduction present. These elements should encompass aspects relating to the pre-existing features of the communities and the characteristics of the projects, so that the relationship between the project and the thresholds of the pre-existing ethno-ecological conditions can be observed, which may contribute towards exacerbating conflicts, considering the specific history of each group and in view of their relationship with the rest of Brazilian society and the terms of preservation of their territory, which is often subject to invasions.

At this point, interdisciplinary activities should be carried out with a view to integrating the impact processes identified with those from the other synthesis components, so that the assessment elements can effectively represent the interactions that exist.

When estimating the intensity of the socioenvironmental impact of a project on a given indigenous land, the following impact indicators should be considered, which will help combine the assessment elements:

Exacerbation of Conflicts

This indicator has to do with interference in the socio-cultural structure and its interaction with the land. Taking the pre-existing status as previously characterized (pre-existing situations of conflict, trespassers on indigenous lands, legal protection of lands) and considering the ratio of flooded to available land, it can be assessed whether or not there is any negative impact on the political unit, the interethnic relationships (including integration with the market) and/or any historically constructed ties within and between groups. Also, as a final outcome of the assessments, it can be gauged whether the very survival of the group is put in jeopardy by the plans.

The following assessment elements should be used:

- pre-existing conflict situations;
- existence of territorial invasions;
- ratio between flooded/available land;
- legal protection of lands;
- impacts on political unity;
- impacts on interethnic relationships (including integration with the market);
- risk of extinction;
- impacts on ties within the groups and between different groups.

Interference in Ethno-Ecological Conditions

This indicator addresses the material structure of a group and the degree of its dependence on the land. The analysis of ethno-ecological aspects is integrated with the aspects relating to a group's material conditions for survival, as well as their cultural identity. It is therefore worth observing the ratio of flooded land to available land and prior knowledge about the importance of this land to a group's culture and survival to assess whether these factors will have an impact on its material reproduction, the degree of interference in sacred sites and/or sites of cultural and geomorphological heritage, and the ramifications this would have on the set of cultural traditions that give a group its specific cultural identity.

The following elements should be used:

- ratio between flooded land and available land: observe the capacity of the land to provide for a group's material reproduction;
- importance of the flooded land to a group – cultural and/or survival factors;
- interference in sacred sites and/or sites of cultural or geomorphological heritage (with an impact on cultural traditions).

Table 4.8.8.01 shows the impact indicators and assessment elements for this synthesis component.

Levels of impacts should be attributed to the study area for each prospective project. A compilation of the aspects assessed by the impact indicators should be used in attributing a degree of negative impact on a scale from zero to one to obtain an estimate of the extent of the interference in a group's forms of social and cultural reproduction.

Table 4.8.8.01 – Impact indicators and assessment elements for the Indigenous Peoples / Traditional Communities synthesis component

Synthesis component	Impact indicator	Assessment elements
Indigenous peoples / Traditional communities	Exacerbation of conflicts	• pre-existing conflict situations; • existence of territorial invasions; • ratio between flooded/available land; • legal protection of lands; • impacts on political unity; • impacts on interethnic relationships; • risk of extinction; • impacts on ties within the groups and between different groups.
	Interference in ethno-ecological factors	• ratio between flooded / available land (observe the capacity of the land to provide for a group's material reproduction); • significance of the flooded land to the group; • interference in sacred sites and/or sites of cultural or geomorphological heritage.

4.9 STANDARD ELETROBRAS COST ESTIMATE

4.9.1 Concepts

The methodology used in the Preliminary Studies for designing the structures should be simplified and the costs should be estimated in overall terms per structure, resulting in simplified cost estimates for the projects in the cascades formulated. The costs of the civil construction and equipment are grouped together so that the cost of a set of works, structures and services can be obtained more easily and an overall cost estimate can be drawn up quickly.

The main aim of the cost estimate at the Preliminary Studies stage is to give a quick, albeit approximate, idea of the costs of the projects, which will be used in the decision-taking process for selecting or proposing new cascade options.

The methodology used in this Manual generates costs using graphs and tables, and making use of parameters that are either preset or calculated by the user.

The cost tables and graphs and the recommendations in this Manual represent the average values obtained in studies already undertaken for a number of Brazilian hydropower stations. This study provides a synthesis of the overall civil construction and equipment costs for the main structures, using data from projects at the Feasibility Study stage and information from the 1997 Manual.

Any other kinds of structures not normally used in project design, any exceptional cases, or any items that fall outside the cost curves will need to be analyzed specifically by the project engineers.

4.9.2 Preliminary Cost Estimate

The cost estimates in the Preliminary Studies should be based on the main accounts from the Standard Eletrobras Cost Estimate (OPE) and should follow the summarized list below, which contains all the structures and equipment needed, including the indirect costs and interest payable during construction.

Account	Description
10.	land, resettlements, relocations and other socioenvironmental actions
11.	powerhouse (civil construction) and related land developments
12.16.	river diversion
12.17.	dam and dikes
12.18.	spillway
12.19.	intake
13.	turbines and generators
14.	auxiliary electrical equipment
15.	miscellaneous equipment
16.	roads, railroads and bridges
17.	indirect costs
18.	interest during construction

Annex C contains spreadsheet **49ope.xls**, which covers the cost estimate for the Preliminary Studies.

4.10 PROJECT DESIGN AND COST ESTIMATE

In this item the criteria and instructions for dimensioning and estimating the costs of projects are set out. The estimate assumes a preliminary definition of the structures and layouts, as well as the representative mean unit prices of the respective services and equipment.

The unit prices and graphs are expressed in Brazilian Reais and refer to the December 2006 database.

The preliminary cost estimate can be done using the information from spreadsheet **49ope.xls**, in Annex C, or using the tables and graphs presented in items 4.10.1 to 4.10.13.

4.10.1 Lands, Resettlements, Relocations and Other Environmental Actions (account.10)

The components that best express the socioenvironmental costs are identified so they can be included in the installation costs of the plants:

- lands and land developments for the reservoir, construction site, borrow areas and residential compound;
- resettlement of local residents, including indemnity, land acquisition and developments for rural resettlement projects and the relocation of towns and villages, including infrastructure works and social service facilities required in each case;
- recomposition or relocation of regional infrastructure.

The socioenvironmental costs to be estimated are set out below, along with the procedures to be used and the corresponding accounts in the Standard Eletrobras Cost Estimate (OPE).

Acquisition of urban lands and land developments (account .10.10.10)

- identification of the areas of land and land developments to be acquired based on the cartographic and topographic studies. When there is partial interference in towns or villages, it is recommended that the criteria concerning the physical quantities to be used for estimating the costs be defined in advance and set out clearly;
- survey of unit prices per m^2 of urban land, from information collected in the field;
- survey of unit prices per m^2 of urban land development, from secondary sources supplemented by field surveys. The estimate can be made from secondary sources by looking at statistics on the cost per m^2 of floor area, supplied by SINDUSCON and FIBGE, making any adjustments necessary to the specific situations at hand.

Acquisition of rural lands and land developments (account .10.10.11)

- determination of the areas of land to be acquired based on the cartographic and topographic studies;
- land prices from December 2006, expressed in Reais per hectare (R$/ha), can be obtained from secondary sources. Fundação Getúlio Vargas brings out statistics on monthly average prices per hectare for each unit of the federation, separated into four types of land use: land for crops, land for pasture, shrubland and woodland. Some states have more detailed statistics for their own regions. Independent of the particular circumstances, it is important to gather information from the field in the Preliminary Studies in order to calibrate the statistics, especially in regions where the land is known to be more expensive and where the surface area of the reservoirs will be larger. It is also a good idea to survey the

prices of land with and without land developments, given the difficulty of estimating quantities and prices of rural land developments in Inventory Studies. The most recent statistics should be used, and recourse to inflation adjustment should be avoided;

- determination and identification of the land developments to be acquired, using satellite images and aerial photographs to indicate the location and area, in m^2; and qualification on field trips of the most significant land developments by their type and features;
- surveys of prices of rural land developments from December 2006, which should be expressed in Reais/m^2. Given the acknowledged difficulty of obtaining information of this kind, there are two alternative ways of estimating these values. The first consists of estimating the price of rural land developments indirectly by the price of the land, as mentioned above. In this case, the procedure set out in the item above for surveying and identifying the rural land developments does not need to be detailed. The second alternative consists of making an estimate using secondary statistics on the cost per square meter of floor area, supplied by SINDUSCON and IBGE, and adopting this information to the specific situation.

Relocation of roads, railroads, bridges, pipelines, transmission lines and telephone lines (account .10.11)

- the unit costs for the relocation of roads, railroads and bridges are presented in tables B01, B02 and B03 of Annex B. Should any other relocations be required, their costs should be estimated according to the general criteria adopted.

Resettlement of households (account .10.11.20)

- if the environmental studies show clearly that rural households, towns, villages, indigenous communities or any other ethnic groups protected by law will have to be resettled, it is recommended that the socioenvironmental costs of the corresponding programs be estimated. The main cost components of these programs, such as the acquisition of lands and land developments, building of infrastructure, construction of buildings, individual and collective land developments, among others, can be calculated and have their costs estimated based on unit prices, using the same general criteria used for the cost estimates in the Inventory Studies.

Physical-Biota Programs (account .10.15.45)

- a minimum 0.5% of the total cost of the hydroelectric project should be set aside for these programs. CONAMA resolution 371/2006 states that this percentage should go towards programs designed to compensate for any damage to ecosystems, including the establishment of conservation areas. However, depending on the results of the environmental studies, it may be prudent to set aside more than 0.5%, especially for projects in the Amazon, where the cost of these programs tends to be higher.

Socioeconomic Programs (account .10.15.46)

- when the need for programs of this kind is indicated in the socioenvironmental studies, their cost should be estimated on a case by case basis or by setting aside a percentage of the total cost of the environmental programs.

Miscellaneous (account .10.27)

- in order to cover miscellaneous costs, 20% of the sum of account.10.10 (acquisition of lands and land development), account.10.11 (resettlement and relocation) and account.10.15 (other socioenvironmental actions) should be set aside.

Environmental Studies (account .17.22.40.54)

- in order to over these costs, 20% to 30% of the total cost estimated for the engineering studies should be set aside.

4.10.2 Powerhouse (civil construction) and Related Land Developments (account .11)

Installed capacity is calculated as shown in item 4.6.5. The value of the maximum net head is used in Graph 5.7.2.01 of the Final Studies to determine the type of turbine and its maximum power output for the head available. The highest power per unit should be used, assuming a minimum of two units.

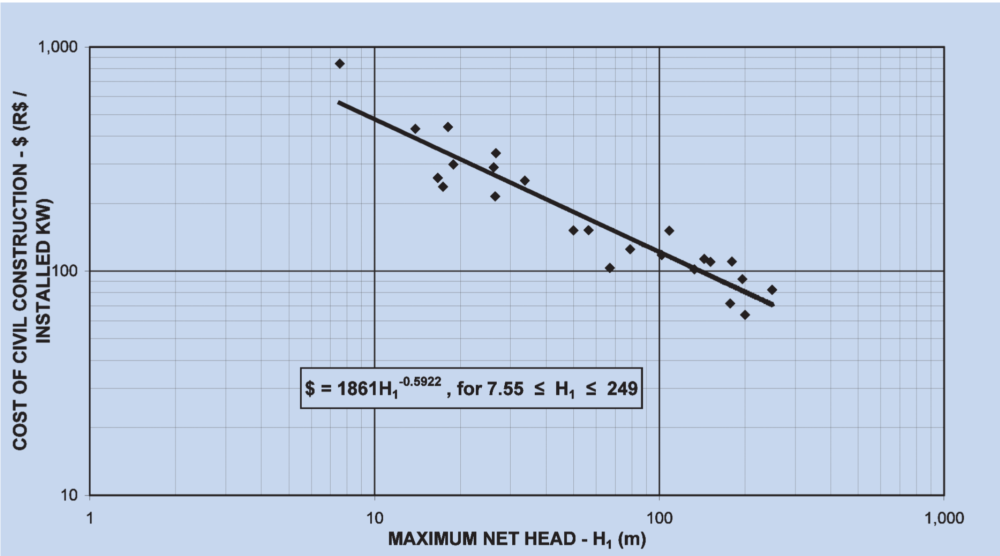
The total cost of this account is the sum of the construction cost of the powerhouse, the cost of the land development for the plant, and the cost of the operators' village.

The **total civil construction cost of the powerhouse** is calculated by multiplying the cost per kW installed by the total power output of the powerhouse. The cost per kW is provided by Graph 4.10.2.01 as a function of maximum net head and installed capacity.

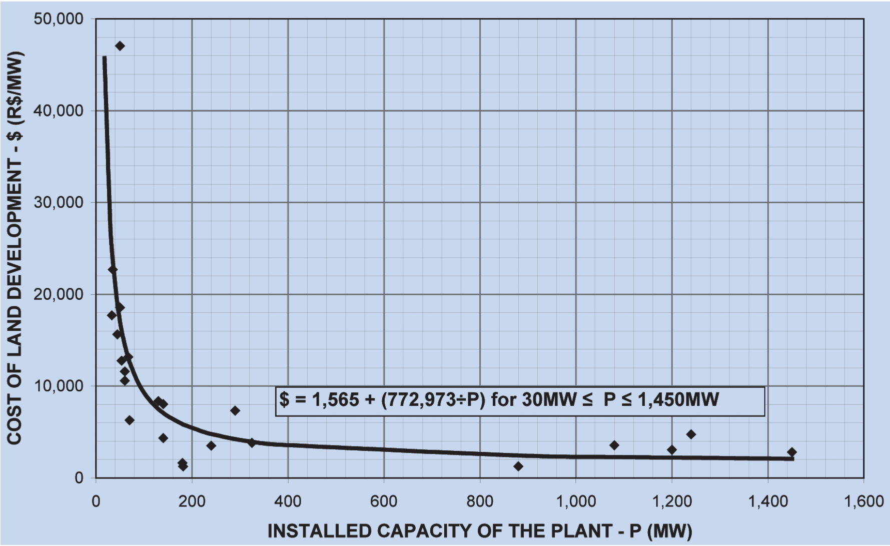
The cost of the **land developments for the plant area** is obtained from Graph 4.10.2.02, where the unit cost per MW is given as a function of the plant's installed capacity.

At this stage of the studies, the workers' village can be considered as part of the construction site, so in this case its costs will be included in the camp item (account.17), or else this cost can be included as a miscellaneous cost (account.11.27).

The amount to be set aside for miscellaneous costs should be 25% of the sum of accounts.11.12 (land development for the plant area) and .11.13 (powerhouse).



Graph 4.10.2.01 – Total cost of civil construction for outdoor powerhouse (PCE, 2007)

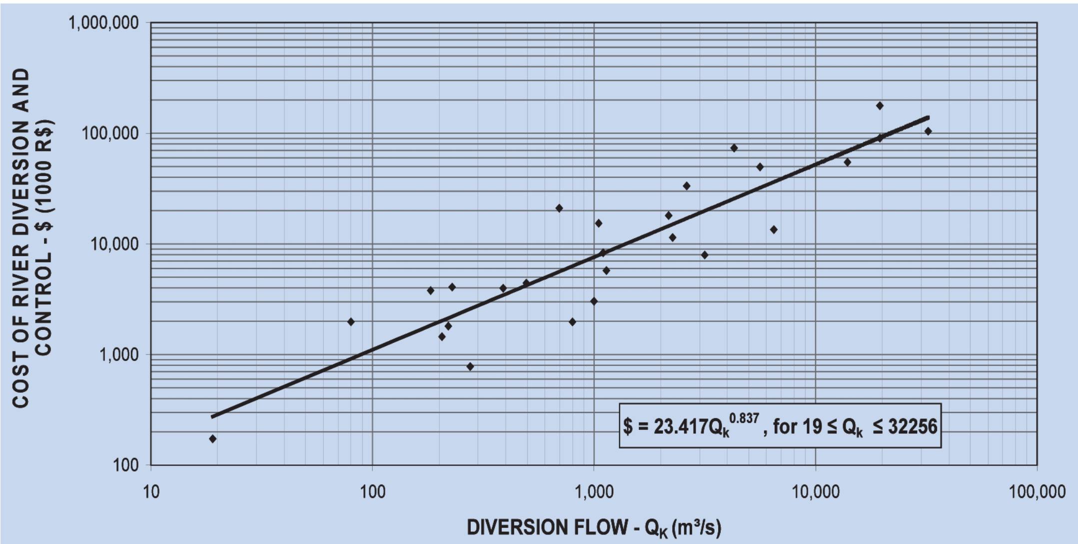


Graph. 4.10.2.02 – Cost of land development in the plant area (PCE, 2007)

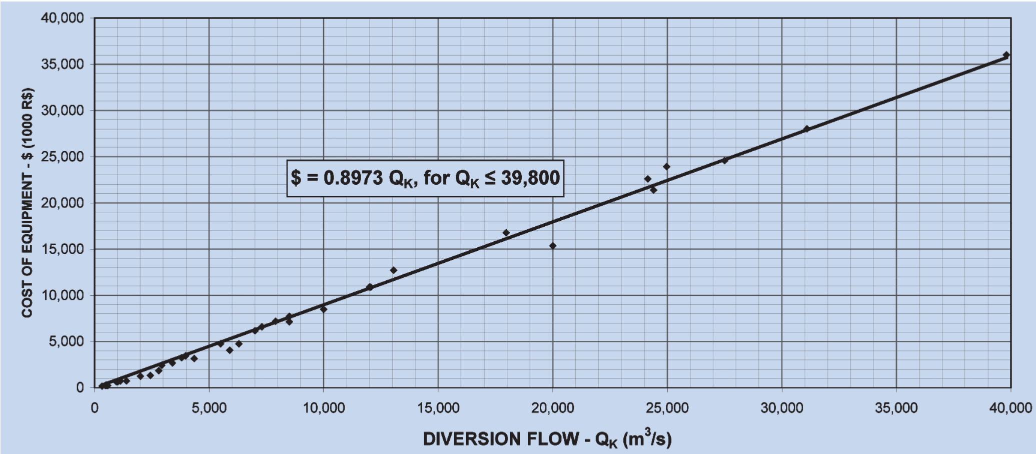
4.10.3 River Diversion (account 12.16)

The river diversion should be designed according to the layout defined for the project. In the Preliminary Studies, the solution does not have to be optimized, nor do details of the diversion scheme have to be established. The idea is to define the approximate size of the main structures used specifically for the diversion, which will have specific costs associated. The **overall cost of civil construction and services** for **river diversion and control** is obtained directly from Graph 4.10.3.01 as a function of the diverted flow.

The **cost of the hydromechanical equipment** is obtained from Graph 4.10.3.02 as a function of the diverted flow, and is valid for sluiceways, galleries and tunnels. An extra 20% should be set aside for miscellaneous costs in this account .12.16.



Graph 4.10.3.01 – Cost of civil construction and services for river diversion and control (PCE, 2007)



Graph 4.10.3.02 – Cost of hydromechanical equipment for river diversion (PCE, 2007)

4.10.4 Dams (account .12.17)

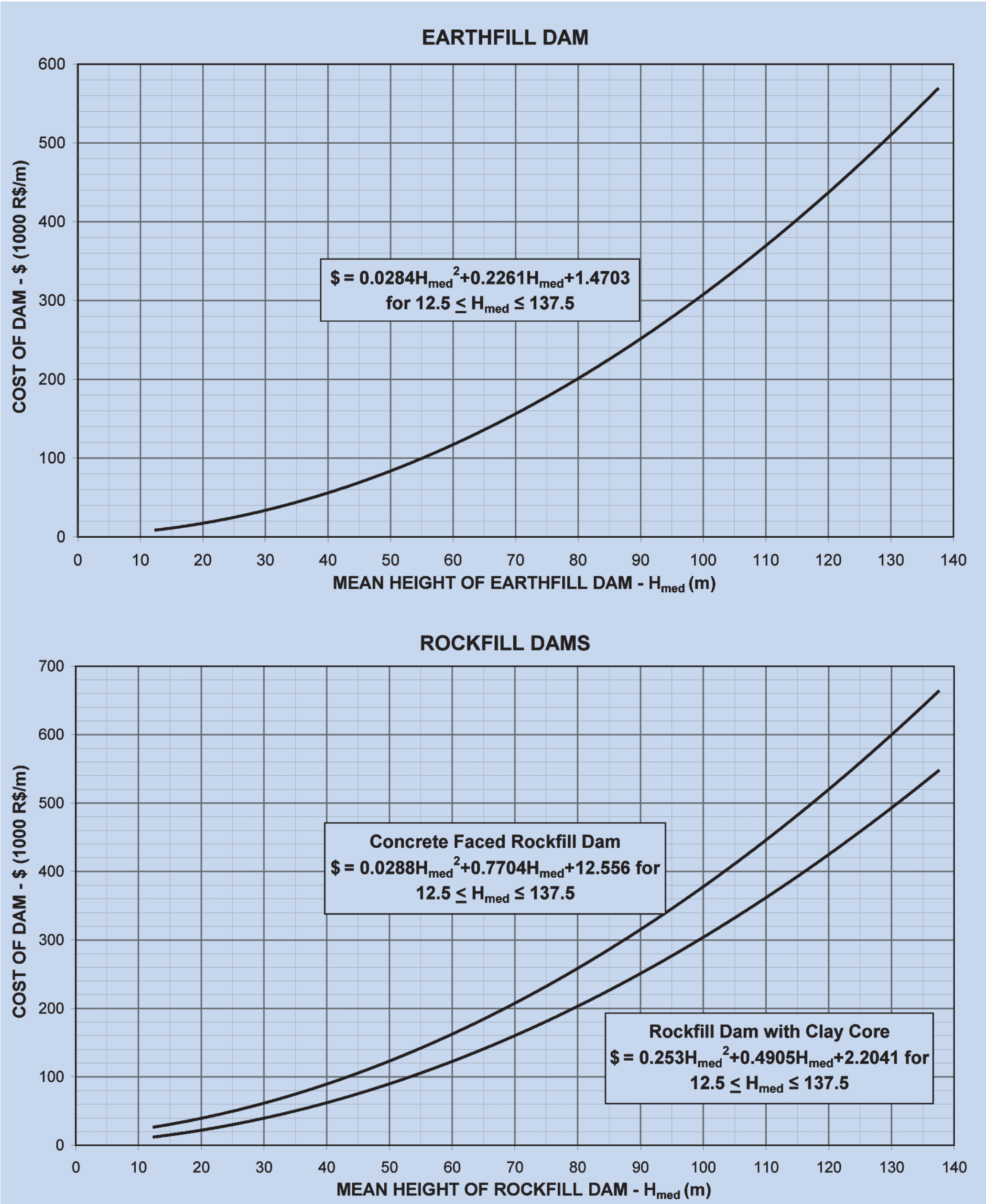
Based on the cross-section of the river valley, determine the mean height and length of the dam structure and obtain the cost corresponding to the kind of dam, using the following graphs:

- Graph 4.10.4.01 – embankment dams;
- Graph 4.10.4.02 – roller compacted concrete dams;
- Graph 4.10.4.03 – conventional concrete dams;
- Graph 4.10.4.04 – transition and retaining walls.

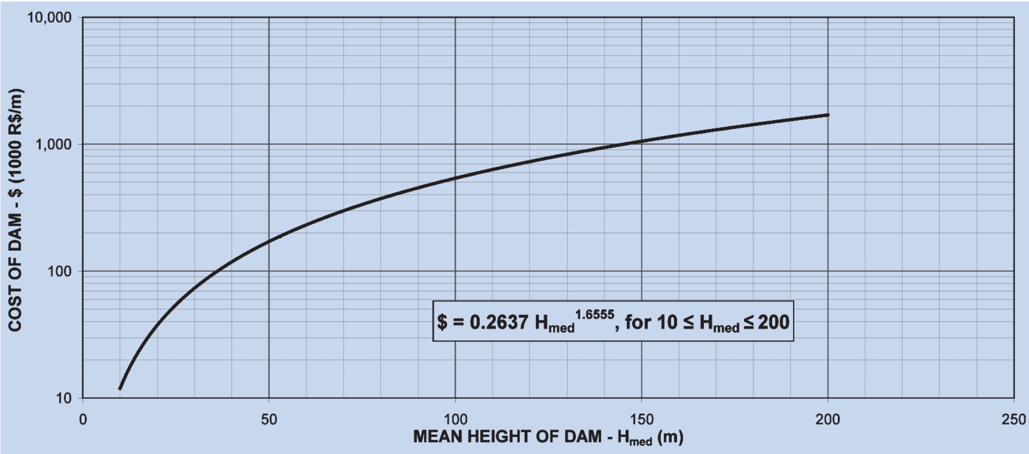
The mean height can be determined graphically by taking short sections of approximately constant height and calculating the weighted average of these values, or using computer methods.

For the concrete walls and transitions, the costs can be obtained using spreadsheet 584m.xls, prepared for the Final Studies, in Annex C. When the input data are not available they can be estimated.

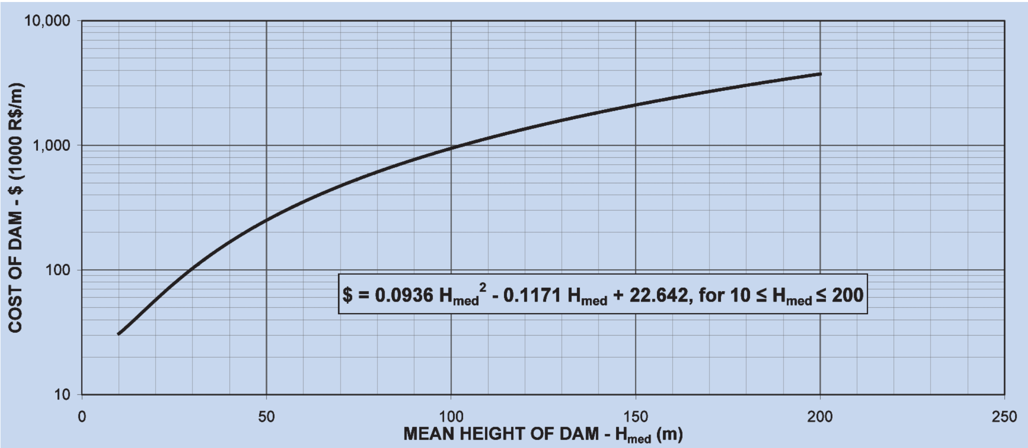
Miscellaneous costs should be calculated at 25% of the total of account .12.17.



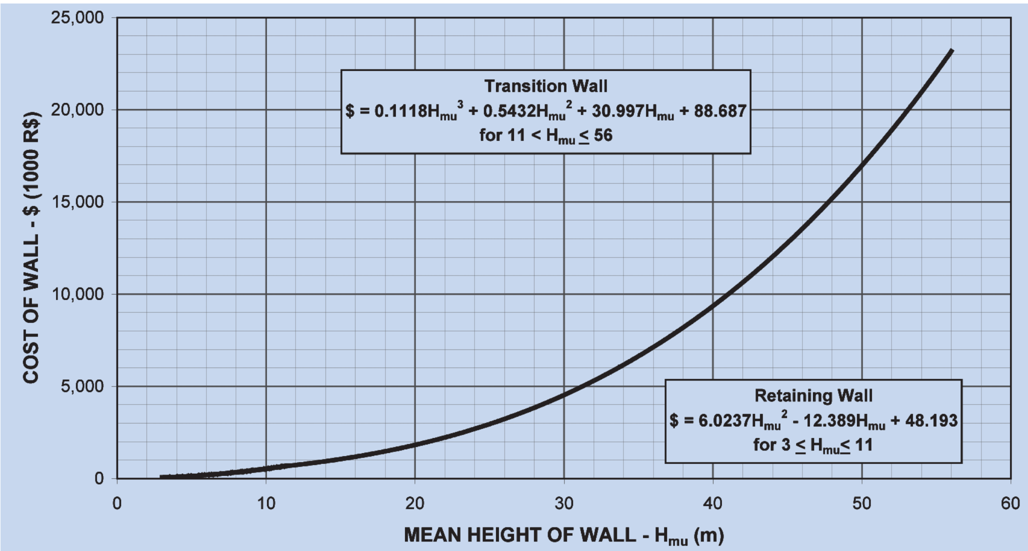
Graph 4.10.4.01 – Cost of embankment dams (PCE, 2007)



Graph 4.10.4.02 – Cost of roller compacted concrete dams (PCE, 2007)



Graph 4.10.4.03 – Cost of conventional concrete dams (PCE, 2007)



Graph 4.10.4.04 – Cost of concrete transition and retaining walls (PCE, 2007)

4.10.5 Spillway (account .12.18)

At this phase, only surface spillways are considered in the design and cost estimate of the civil construction and equipment.

For abutment spillways or low ogee spillways, the **civil construction cost** can be obtained directly from Graph 4.10.5.01, as a function of the flow through this structure.

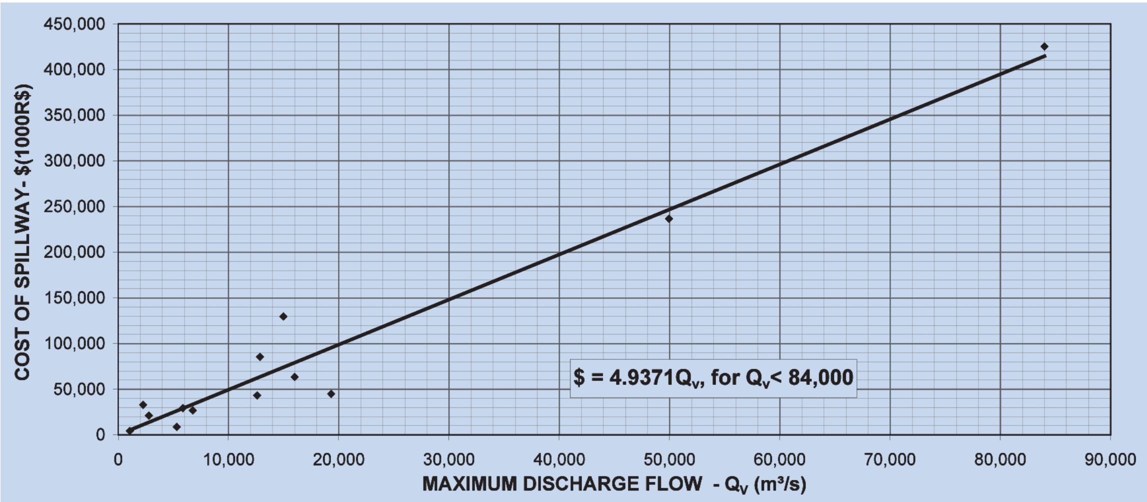
For high ogee spillways, the **civil construction cost** is a function of the maximum discharge capacity and the difference between the maximum water level in the reservoir and the maximum water level downstream, using the following graphs:

- Graph 4.10.5.02 - Civil construction cost of roller compacted concrete spillway with a high ogee crest;
- Graph 4.10.5.03 - Civil construction cost of a conventional concrete spillway with a high ogee crest.

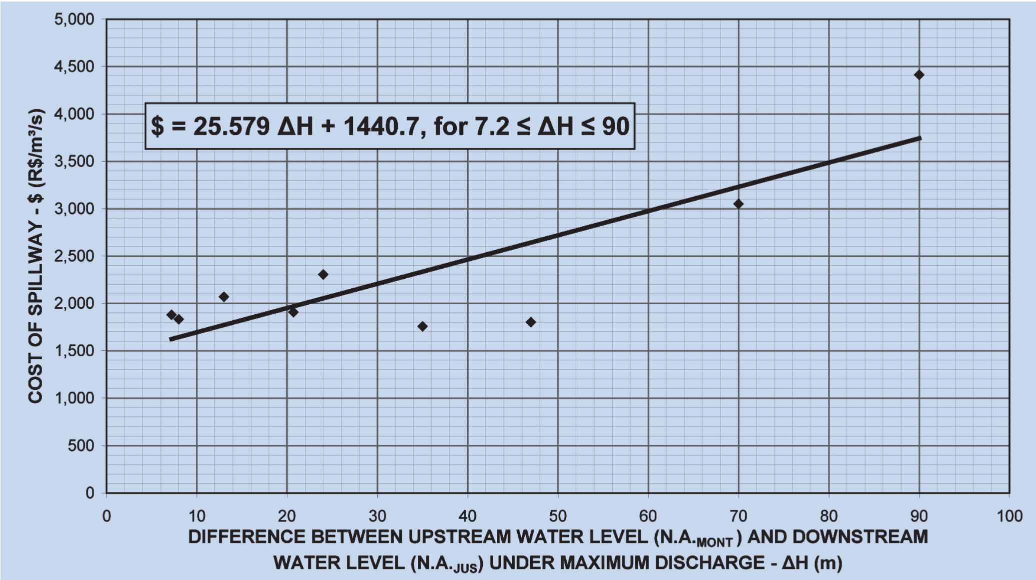
The overall civil construction cost of the spillway is obtained by multiplying the cost per m^3/s by the design flow (Graphs 4.10.5.01 to 4.10.5.03).

The **cost of the equipment** for the surface spillway is given by Graph 4.10.5.04, as a function of the spillway design flow (item 4.1.2).

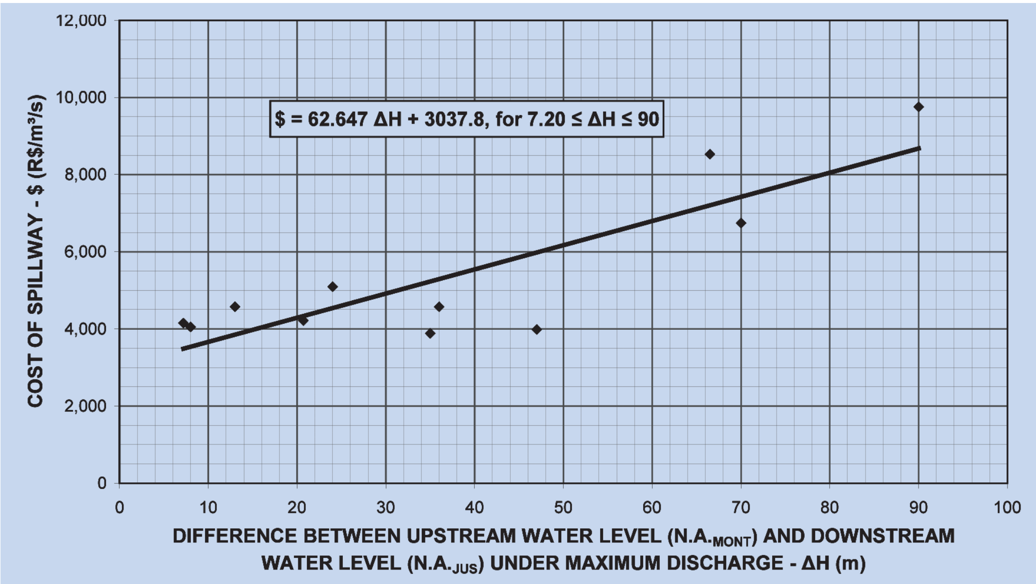
The amount to be set aside for miscellaneous costs should be 20% of the total of account.12.18.



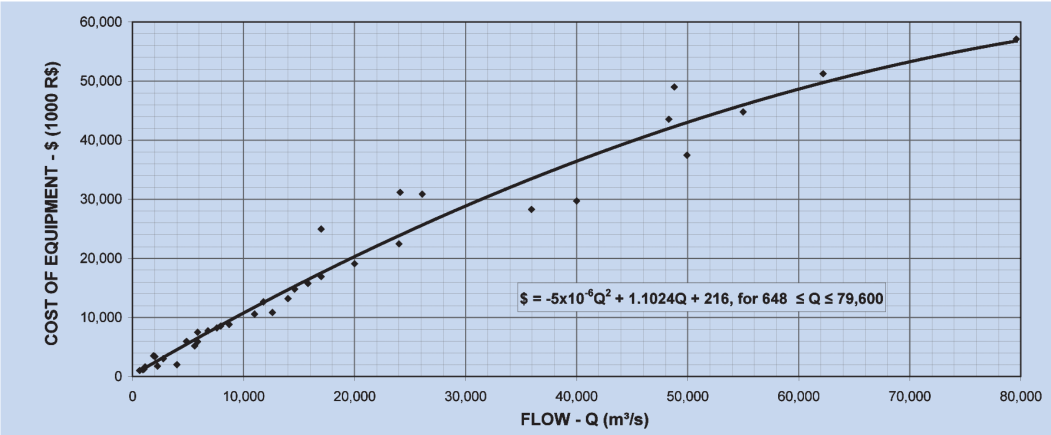
Graph 4.10.5.01 – Cost of civil construction work for spillway with a low ogee crest (PCE, 2007)



Graph 4.10.5.02 – Cost of civil construction work for roller compacted concrete spillway with a high ogee crest (PCE, 2007)



Graph 4.10.5.03 – Cost of civil construction work for conventional concrete spillway with a high ogee crest (PCE, 2007)



Graph 4.10.5.04 – Cost of hydromechanical and hoisting equipment for surface spillway (PCE, 2007)

4.10.6 Intake (account .12.19)

This account is the sum of the accounts for each of the following structures:

1) intake
2) headrace canal
3) intake penstock or tunnel
4) surge tank
5) pressure tunnels/penstocks
6) tailrace canal/tunnel

1) Intake (account .12.19.30)

The civil construction cost for a section of intake should be obtained directly from Graph 4.10.6.01, as a function of the parameter:

$$\frac{Q_a}{(H_t - d)^{\frac{1}{2}}} , \qquad (4.10.6.01)$$

where:

Q_a	maximum utilizable flow per opening of the intake, in m³/s;
Ht	height of a section of intake, in m; and
d	maximum drawdown, in m.

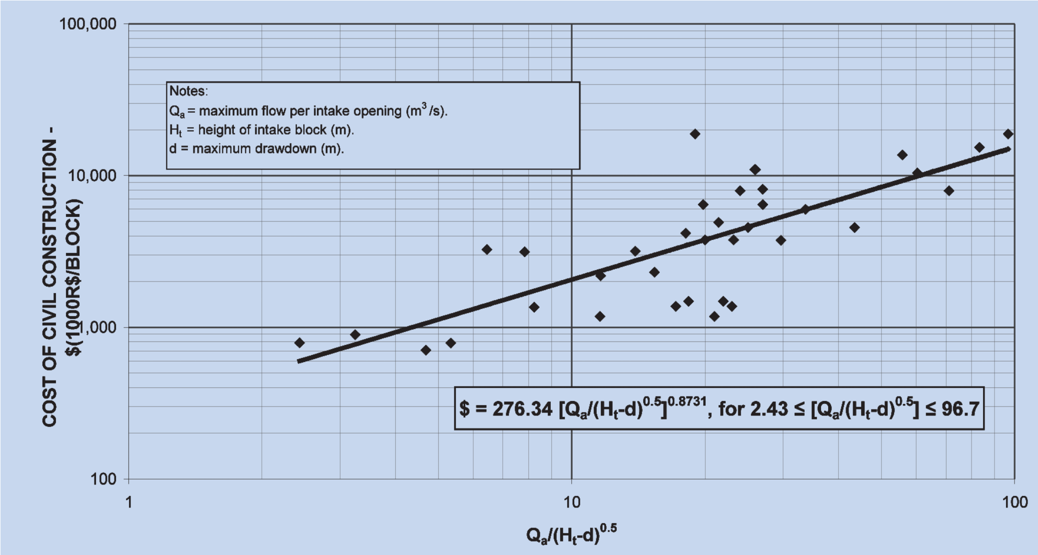
The total civil construction cost of the intake is obtained by multiplying the cost of one block by the total number of units.

The cost of the equipment for the intake is obtained from Graphs 4.10.6.02, 4.10.6.03 and 4.10.6.04, respectively, for use with semi-spiral concrete Kaplan turbines, Bulb turbines and other cases, as a function of the maximum utilizable flow per opening. Each graph has two curves. The cost obtained from curve "A" should be multiplied by the number of water intakes and added to the value obtained from curve "B". For each curve:

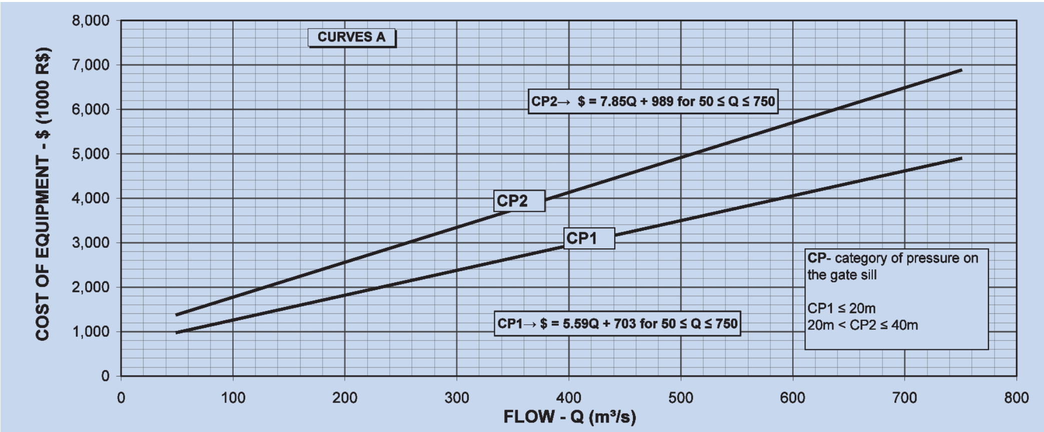
CP – Class of pressure on gate sill:

CP1 ≤ 20m   20m < CP2 ≤ 40m   CP3 > 40m

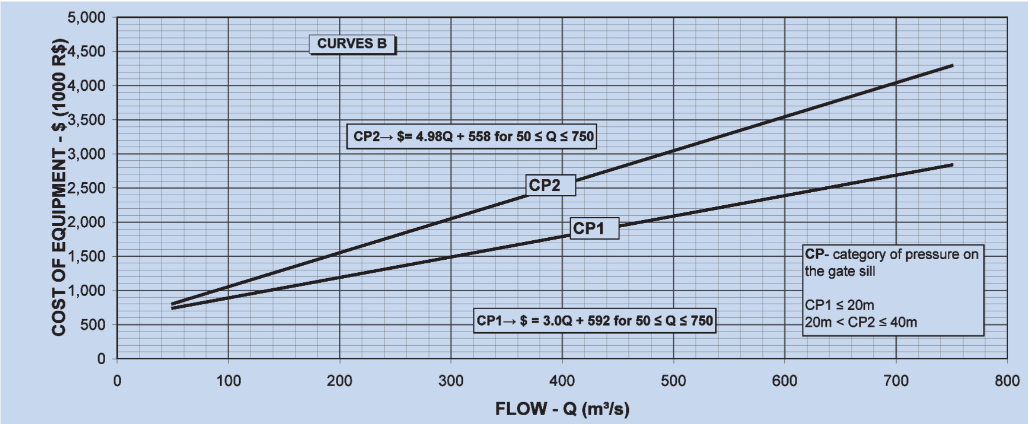
The pressure is obtained by subtracting the elevation of the intake sill from the maximum normal water level in the reservoir.



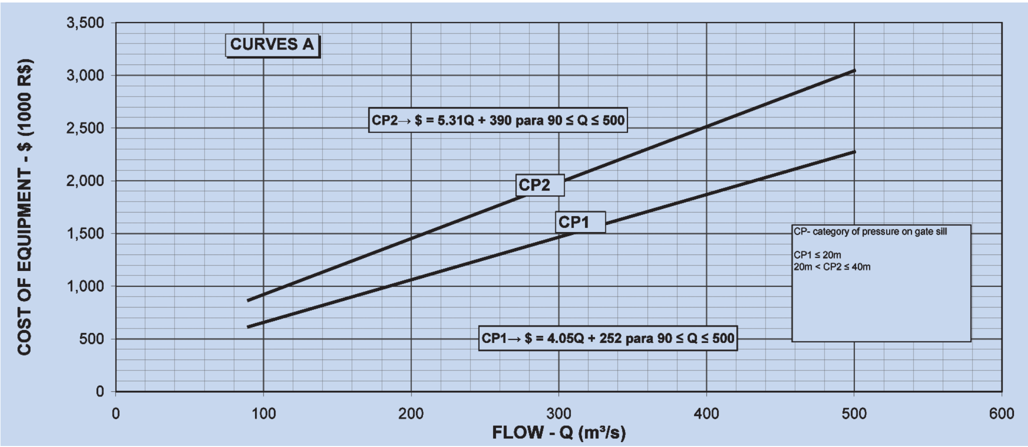
Graph 4.10.6.01 – Cost of civil construction work for intake (PCE, 2007)



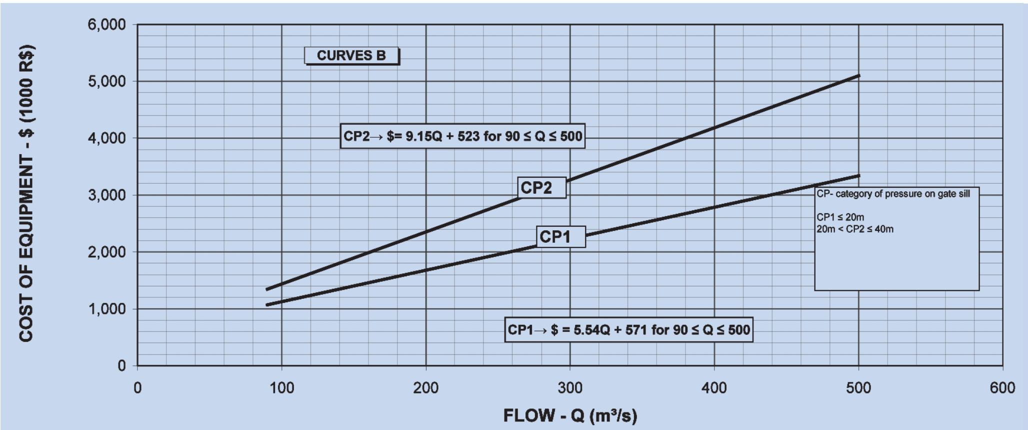
Graph 4.10.6.02 – Cost of intake equipment for Kaplan turbines with concrete semi-spiral casing (PCE, 2007)



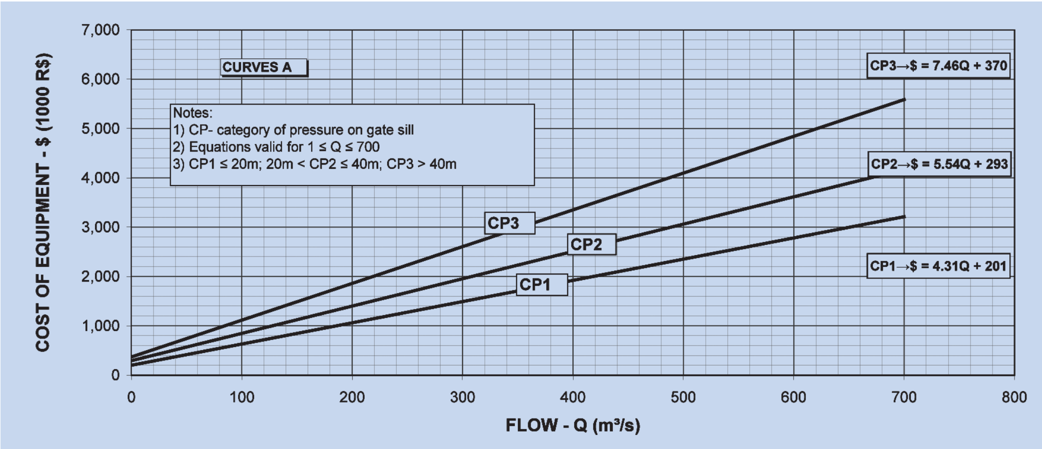
Graph 4.10.6.02a – Cost of intake equipment for Kaplan turbines with concrete semi-spiral casing (PCE, 2007)



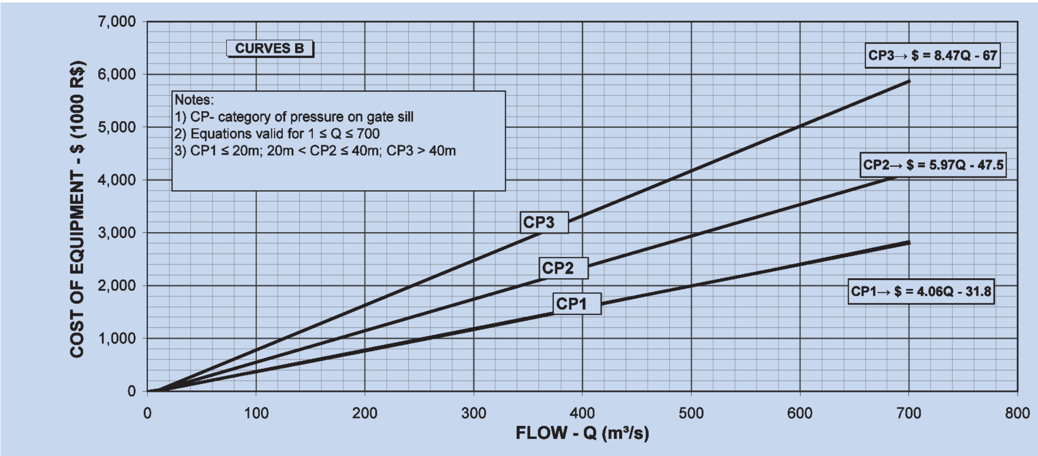
Graph 4.10.6.03 – Cost of intake equipment for Bulb turbines (PCE, 2007)



Graph4.10.6.03a – Cost of intake equipment for Bulb turbines (PCE, 2007)



Graph 4.10.6.04 – Cost of intake equipment for Francis or Kaplan turbines with steel spiral casing (PCE,2007)



Graph 4.10.6.04a – Cost of intake equipment for Francis or Kaplan turbines with steel spiral casing (PCE, 2007)

2) Headrace Canal (account .12.19.31)

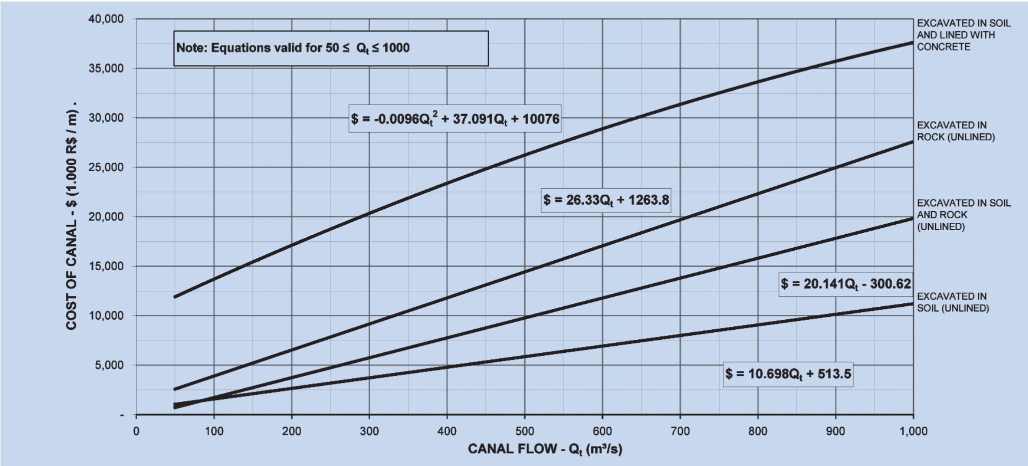
The cost per meter of the headrace canal can be obtained from Graph 4.10.6.05, as a function of the total maximum utilizable flow from the powerhouse. The overall cost is calculated on the estimate of the total length of the headrace canal and its cost per meter.

Total utilizable flow (Qt) is obtained by:

$$Qt = \frac{P}{0.0088 \times H_1} \qquad (4.10.6.02)$$

where:

P	installed capacity of the plant (MW)
H_1	maximum net head (m)



Graph 4.10.6.05 – Cost of the headrace canal (PCE, 2007)

3) Intake Penstock or Tunnel (account .12.19.32)

The cost per meter, both with and without lining, can be obtained from Graph 4.10.6.06, as a function of total maximum utilizable flow and the geological conditions at the site.

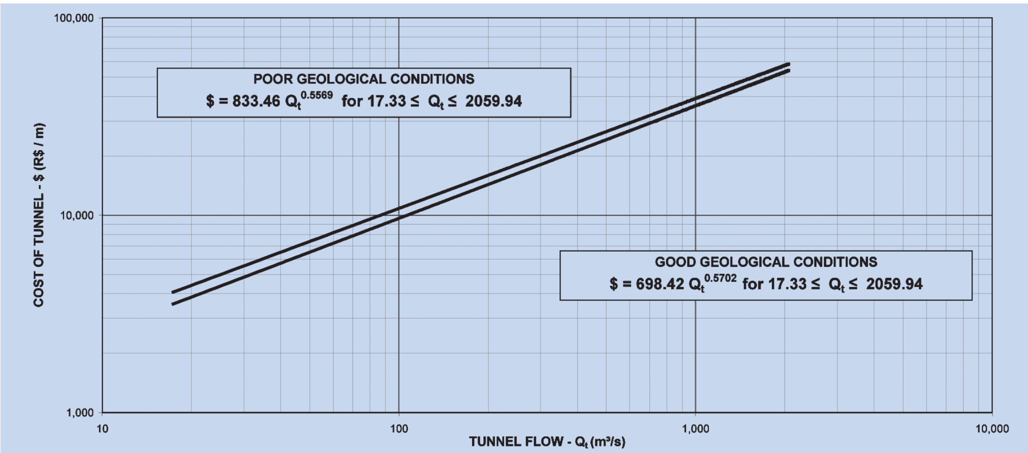
The total utilizable flow (Qt) is obtained by:

$$Qt = \frac{P}{0.0088 \times H_1} \qquad (4.10.6.03)$$

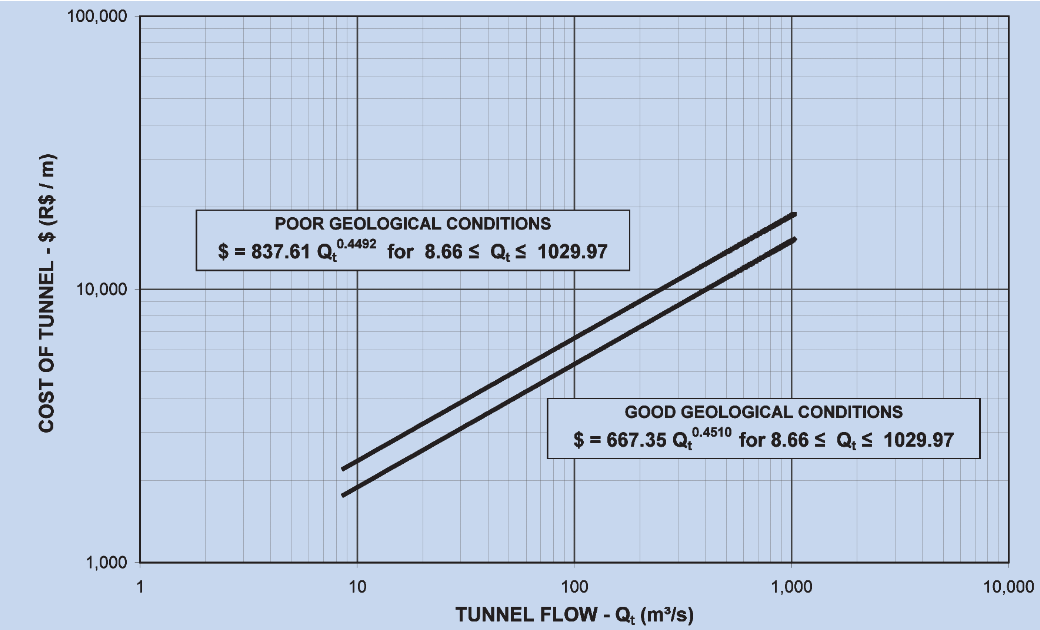
where:

P	installed capacity of the plant (MW)
H_1	maximum net head (m)

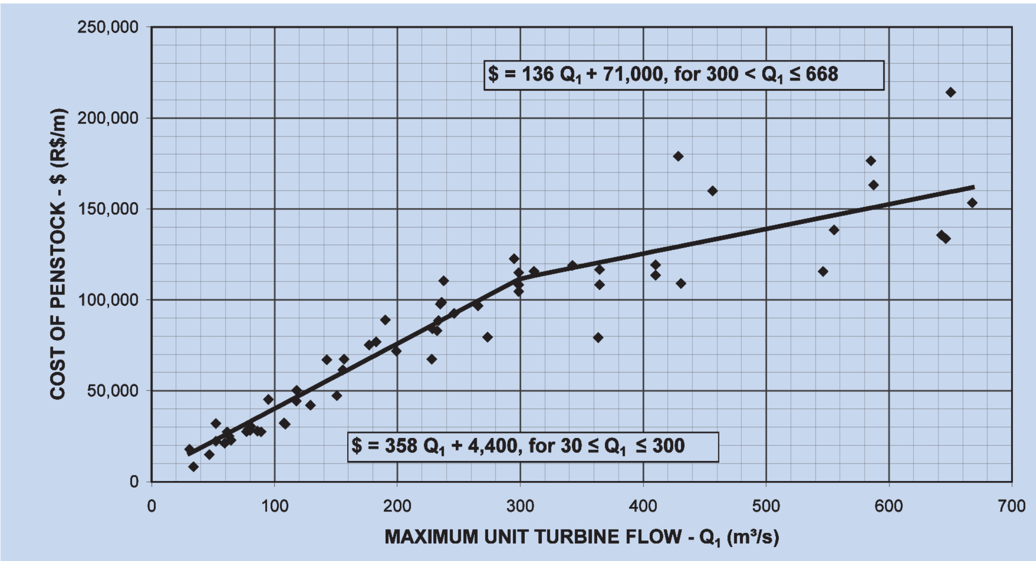
The overall civil construction cost of intake tunnels is obtained by multiplying the cost of the tunnel in Reais per meter by its total length.



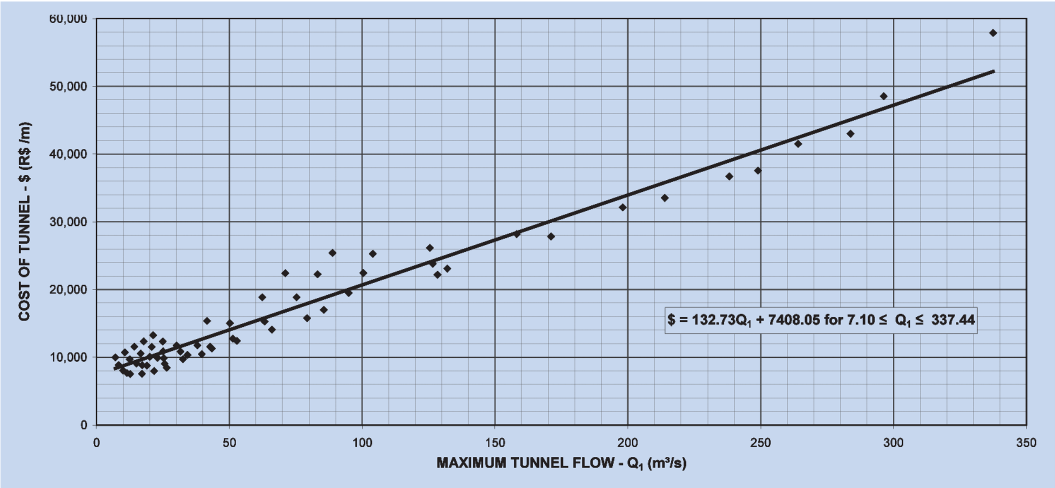
Graph 4.10.6.06 – Cost of lined headrace tunnels (PCE, 2007)



Graph 4.10.6.06a – Cost of unlined headrace tunnels (PCE, 2007)



Graph 4.10.6.07 – Cost of steel surface penstock (without valves) (PCE, 2007)



Graph 4.10.6.08 – Cost of pressure tunnel penstock (without valves) (PCE, 2007)

4) Surge Tank (account .12.19.33)

The cost of the surge tank can be determined using spreadsheet 586ch.xls prepared for the Final Studies, where the costs are obtained as a function of its diameter and maximum height.

5) Pressure Tunnel and/or Penstock (account .12.19.34)

The cost per meter length of the civil construction services and equipment for the pressure penstocks or pressure tunnels is obtained directly from Graphs 4.10.6.07 and 4.10.6.08, respectively, as a function of the turbine flow for each penstock or tunnel. These costs do not, however, cover the use of valves. The cost of this equipment should be estimated by the design engineer using the method presented in chapter 5, Final Studies.

6) Tailrace canal and/or tunnel (account .12.19.35)

The same methodology should be used as that used to estimate the cost of headrace canals and intake tunnels, where the cost is a function of the total flow from the powerhouse and the length of the tailrace canal or tunnel.

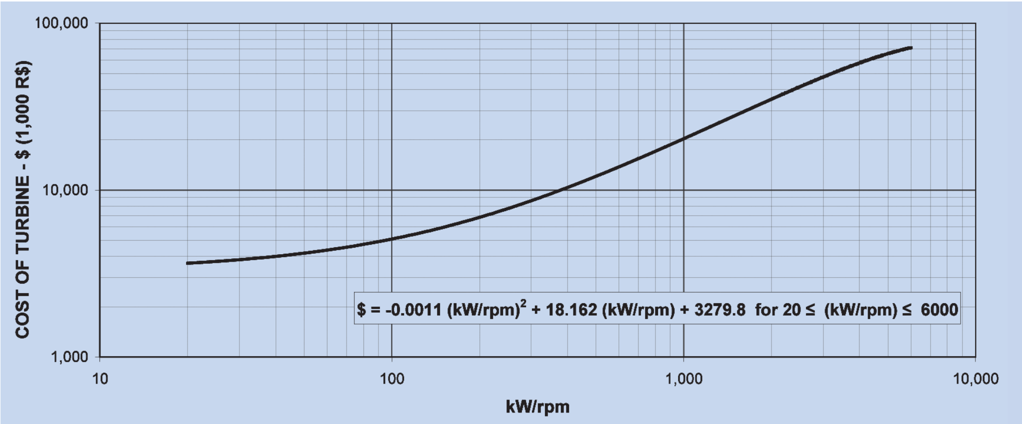
The amount to be set aside for miscellaneous costs should be 20% of the total of account .12.19.

4.10.7 Turbines and Generators (account .13)

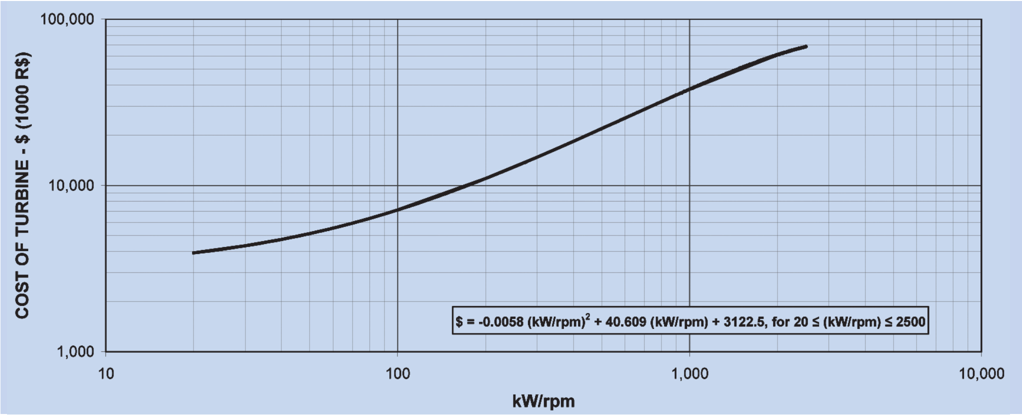
Graphs 4.10.7.01, 4.10.7.02, 4.10.7.03 and 4.10.7.04 give the costs of the turbines as a function of kW/rpm, respectively, for Francis or Kaplan turbines with a spiral casing, Kaplan turbines with a semi-spiral casing made of concrete, and Bulb turbines. The cost of Pelton turbines should be obtained from the manufacturer.

Graphs 4.10.7.05, 4.10.7.06 and 4.10.7.07 show the cost of the generators as a function of kVA/pole, respectively, for vertical axis and horizontal-axis generators, and horizontal-axis generators for Bulb turbines.

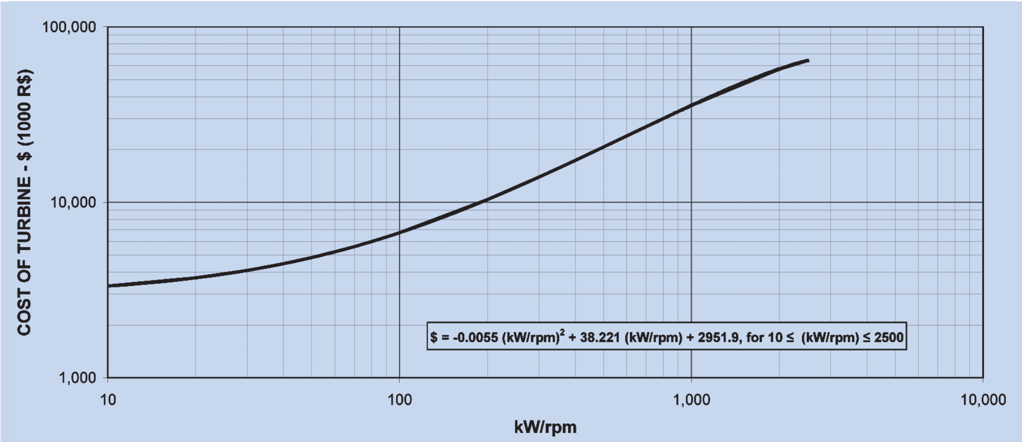
The amount to be set aside for miscellaneous costs should be 10% of the total of account .13.



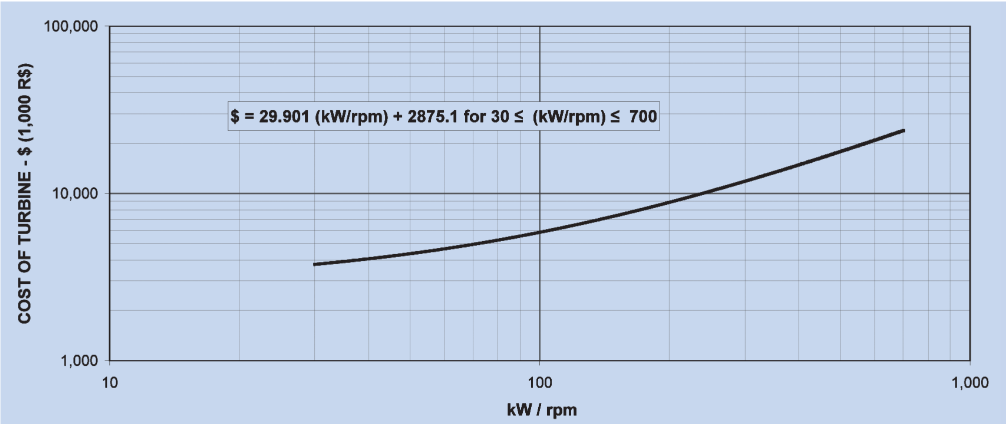
Graph 4.10.7.01 – Cost of Francis turbine (PCE, 2007)



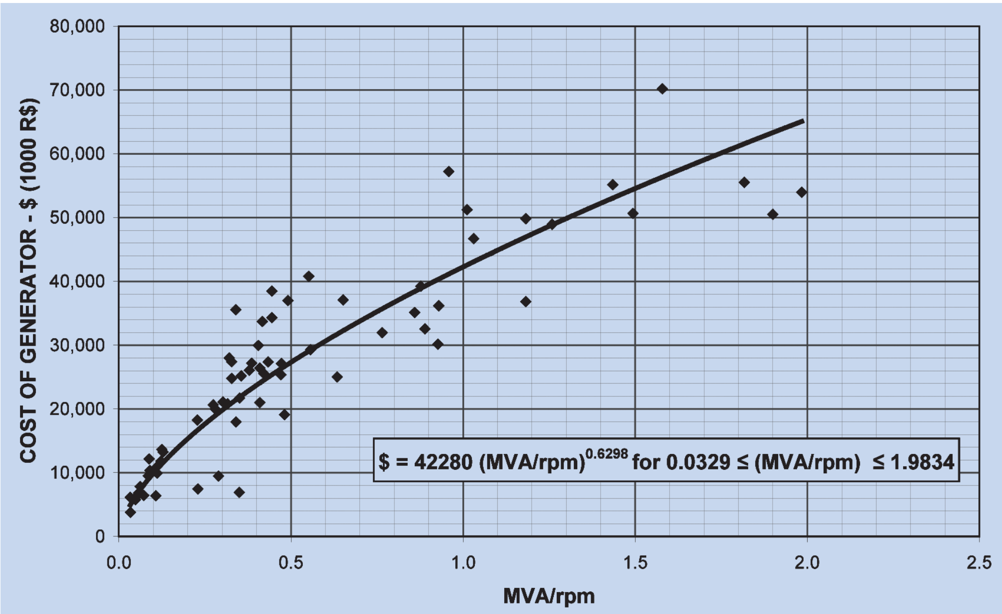
Graph 4.10.7.02 – Cost of Kaplan turbine with steel spiral casing (PCE, 2007)



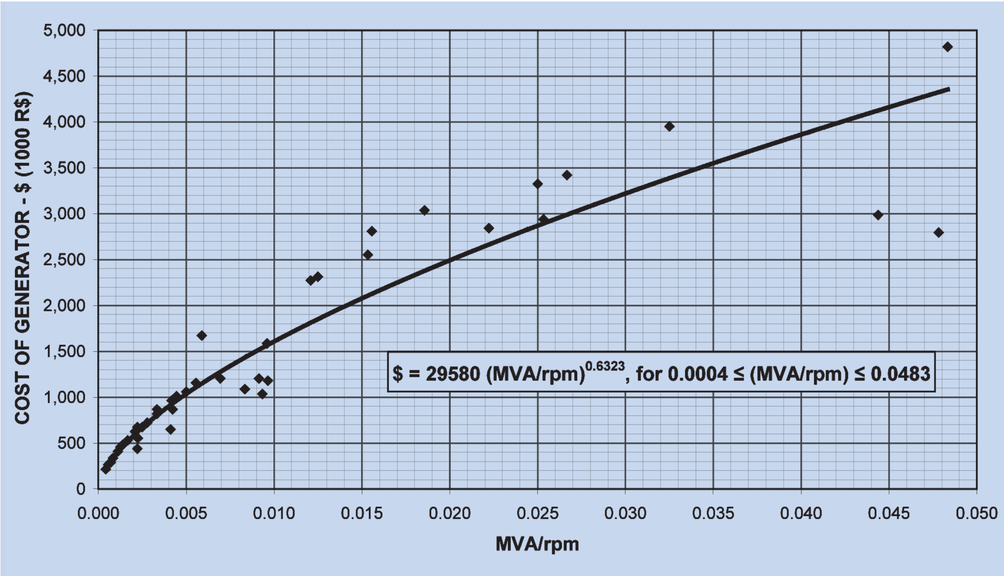
Graph 4.10.7.03 – Cost of Kaplan turbine with concrete semi-spiral casing (PCE, 2007)



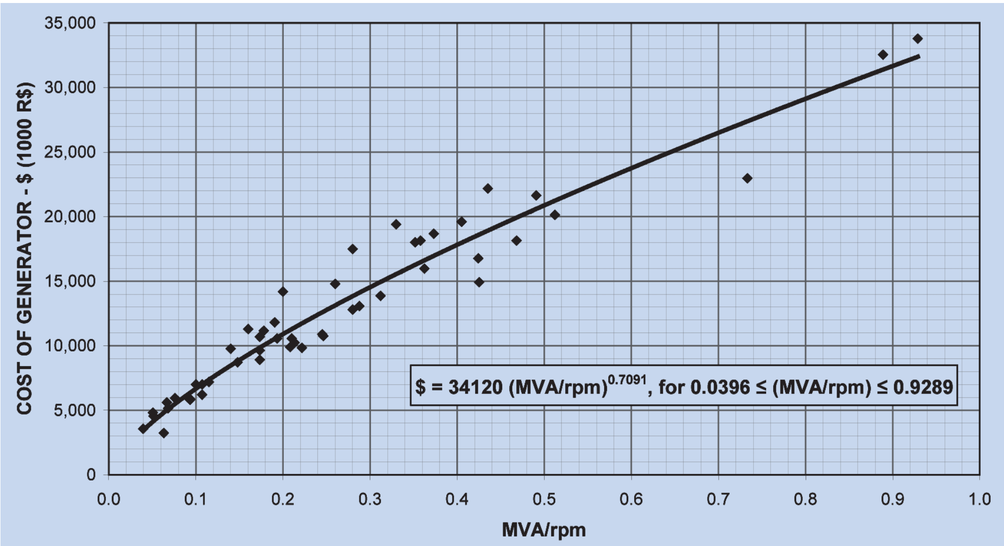
Graph 4.10.7.04 – Cost of Bulb turbine (PCE, 2007)



Graph 4.10.7.05 – Cost of vertical-axis generator (PCE, 2007)



Graph 4.10.7.06 – Cost of conventional horizontal-axis generator (PCE, 2007)



Graph 4.10.7.07 – Cost of horizontal-axis Bulb generator (PCE, 2007)

4.10.8 Auxiliary Electrical Equipment (account .14)

The overall cost of auxiliary electrical equipment for a plant is estimated at 18% of the overall cost of account .13, Turbines and Generators.

The amount to be set aside for miscellaneous costs should be 20% of the total of account.14.

4.10.9 Miscellaneous Plant Equipment (account .15)

The overall cost of the other equipment in the plant, including the cost of the main overhead crane and the hydromechanical equipment and draft tube crane, should be taken as 10% of the overall cost of account .13, Turbines and Generators.

The amount to be set aside for miscellaneous costs should be 20% of the total of account.15.

4.10.10 Roads, Railroads and Bridges (account .16)

The need to build any bridges or roads is identified by consulting road maps of the region and making reconnaissance trips, and their respective classes of construction should be decided on. Based on estimated lengths, the cost of the account can be estimated using the unit prices from tables 4.10.10.01, 4.10.10.02 and 4.10.10.03.

The amount to be set aside for miscellaneous costs should be 25% of the total of account.16.

Table 4.10.10.01 – Cost of Roads (R$/Km) (PCE, 2007)

DNIT CLASSIFICATION		UNIT COST (R$/km)					
		MAIN ARTERIAL ROAD (4-lane divided highway)	PRIMARY ARTERIAL ROAD (2-lane undivided highway)	SECONDARY ARTERIAL ROAD	PRIMARY COLLECTOR ROAD	SECONDARY COLLECTOR ROAD	LOCAL ROAD
TECHNICAL FEATURES	TOTAL LANE WIDTH (m)	14	7	7	6	6	6
	TOTAL WIDTH OF ROADWAY (m)	24	13	11	8	7	6
SOUTH, SOUTHEAST, CENTRAL WEST AND NORTHEAST REGIONS	PAVED	2,600,000	1,500,000	1,300,000	865,000	735,000	558,000
	UNPAVED	1,250,000	760,000	650,000	432,000	345,000	257,000
NORTH REGION, TO THE SOUTH OF THE AMAZON RIVER	PAVED	3,650,000	2,100,000	1,800,000	1,200,000	1,028,000	782,000
	UNPAVED	1,750,000	1,080,000	900,000	605,000	485,000	363,000
NORTH REGION, TO THE NORTH OF THE AMAZON RIVER	PAVED	4,700,000	2,700,000	2,320,000	1,550,000	1,320,000	1,005,000
	UNPAVED	2,240,000	1,400,000	1,160,000	778,000	625,000	463,000

Table 4.10.10.02 – Cost of Railroads (R$/Km) (PCE, 2007)

DESCRIPTION		COST DEC/06
INFRASTRUCTURE		(R$/km)
TYPICAL TOPOGRAPHY	FLAT	1,250,000
	HILLY	1,625,000
	MOUNTAINOUS	2,000,000
SUPERSTRUCTURE		(R$/km)
TYPES OF GAUGE	1,00 m	935,000
	1,60 m	1,100,000
	MIXED	1,265,000
SPECIAL CIVIL CONSTRUCTION		(R$/m)
CONSTRUCTION IN CONCRETE	BRIDGES	20,000
	VIADUCTS	25,000

Table 4.10.10.03 – Cost of Road Bridges (R$/m²) (PCE, 2007)

	UNIT COST (R$ / m²) TYPE OF FOUNDATION			
REGION	DIRECT FOUNDATION	PILES	CONCRETE PILE FOUNDATION EXCAVATED WITHOUT USING COMPRESSED AIR	CONCRETE PILE FOUNDATION EXCAVATED USING COMPRESSED AIR
SOUTH, SOUTHEAST, CENTRAL WEST and NORTHEAST	1,200	1,500	1,700	1,900
NORTH, TO THE SOUTH OF THE AMAZON RIVER	1,700	2,000	2,400	2,700
NORTH, TO THE NORTH OF THE AMAZON RIVER	2,200	2,600	3,000	3,500

4.10.11 Total Direct Costs

The total direct cost is the sum of the accounts from items 4.10.1 to 4.10.10.

4.10.12 Indirect Costs (account .17)

The calculation of this cost, which represents the costs for the construction site and workers' village, engineering costs and the owner's administration costs, is based on percentages of the total direct costs, which vary from region to region:

40%	Amazon region to the north of the Amazon river
35%	Amazon region to the south of the Amazon river
30%	other regions

4.10.13 Total Cost Without Interest

The total cost without interest is the sum of the total direct cost and the indirect costs.

4.10.14 Interest during Construction (account .18)

When determining the interest during construction presented in item 5.7.9, annual interest rates of 10% and 12% were used, and the projects were differentiated according to the construction time, using standard curves of investment payments. The interest rate to be used for calculating interest during construction should be obtained from the concession-granting authority.

4.11 COMPARISON AND SELECTION OF CASCADES

In the Preliminary Studies, the analysis and comparison of cascades is designed not only to eliminate any uncompetitive options, but also to guide any reformulations needed, identifying the characteristics of the basin that are found to be instrumental in minimizing the cost/energy benefit ratio and the negative socioenvironmental impacts.

Based on the assessments, a shortlist of cascades will be selected to go through to the Final Studies that are the most competitive not only in terms of their cost/energy benefit ratio, but also from the perspective of the socioenvironmental impacts, for which it is hoped that the advantages achieved from a more detailed study will offset the effort of carrying it out. The cascades to be studied in greater depth in the Final Studies should be selected using the cost/energy benefit and negative socioenvironmental impact indexes, described in items 4.11.1 and 4.11.2.

4.11.1 Cost/Energy Benefit Index

The economic and energy analyses and comparisons carried out in Inventory Studies are based on cost/energy benefit indexes, which are expressed R$/MWh and are always calculated as the ratio of the cost of obtaining extra firm energy for the reference system and the value of this energy contribution. This index can be calculated individually for each project or for a group of projects in a cascade, and also for a cascade as a whole, as set out below.

Cost/Energy Benefit Index of Projects

The energy benefit from each project in a cascade is measured by the amount of firm energy the project will provide for the reference system, supposing that all the other projects in the cascade have already been built (last added firm energy contribution - item 4.6.3). The cost/energy benefit index for each project is defined as the ratio between its total annual cost and its energy benefit, and is calculated by:

$$ICB_i = \frac{CT_i}{8760 \times \Delta Ef_i} \qquad (4.11.1.01)$$

where:

ICB_i	cost/energy benefit index of plant i, in R$/MWh;
CT_i	total annual cost of plant i, in R$; and
ΔEf_i	extra firm energy provided by the addition of plant i, in average MW, assuming that all the projects in the cascade have been built.

The total annual cost (CT_i) of each plant is calculated by:

$$CT_i = C_i \,.\, FRC + P_i \,.\, COM \,.\, 10^3 \qquad (4.11.1.02)$$

where:

C_i	cost of project i, in R$, determined in the Preliminary Studies, including interest during construction; and
FRC	capital recovery factor throughout the project's useful life, based on the discount rate adopted, defined by the following expression:

$$FRC = \frac{j \times (1+j)^z}{(1+j)^z - 1} \quad (4.11.1.03)$$

where:

j	annual discount rate (item 2.6);
z	useful life of the plant, normally taken as 50 years (item 2.6);
COM	annual operating and maintenance costs of the plant, in R$/kW/year, set in the basic criteria (item 2.6).

Cost/energy benefit index of groups of projects

The energy benefit of a group of projects is measured by the firm energy contribution they would jointly make to the reference system, supposing that all the other projects in the cascade had already been built (item 4.6.3). The cost/energy benefit index for the group is then defined as the ratio between the annual cost of this group and its energy benefit.

Elimination of uncompetitive projects

Given that all the projects from a cascade should be economically advantageous, it is necessary to eliminate any that are uncompetitive. A comparison is made of the cost/energy benefit index of each project (ICB_i) using the reference unit cost (CUR), defined in item 2.6. A hydropower plant is only considered economically competitive if its cost/energy benefit index is lower than the reference unit cost.

When a project is eliminated from a cascade, the cost/energy benefit indexes of the other projects are affected. This means the elimination process should be iterative, ensuring that at the end only the economically competitive projects are included in the cascade under study.

In view of the interdependency of the projects, it is not enough just to check the individual economic-energy competitiveness of the projects in isolation; groups of uncompetitive projects should also be looked for, comparing their cost/energy benefit indexes with the reference unit cost. Groups of at least three projects should be checked, but there is no need to form groups of projects with no hydraulic connection.

The calculation of the cost/energy benefit index of the projects in one cascade option and the elimination of uncompetitive projects can be carried out using the “Eliminate” function, “without simulation” option, from the SINV system. This function gives the ICB of the projects and indicates those whose ICB is greater than their CUR, allowing these highlighted projects to be eliminated and giving rise to a new cascade option.

Review of Cascades

Once the process of assessing uncompetitive projects in a given cascade has been concluded, if any projects are indeed eliminated, it should be assessed whether it is technically and economically feasible to recover part of the head in the sections corresponding to the eliminated projects, raising the height of the dam downstream from the section and shifting downstream the dam axis of the project upstream from the section.

Cost/Energy Benefit Index of Cascades

Since each cascade will make a different firm energy contribution to the reference system, the comparison of the cascades amongst themselves can only be done once these values have been homogenized. This can be done by bringing the output of all the cascade options up to the same output level as the cascade option that makes the highest firm energy contribution, using the reference unit cost.

The cost/energy benefit Index for each cascade, which is the parameter by which they are evaluated, is given by:

$$ICB_a = \frac{CT_a + 8760 \times CUR \times (\Delta Ef^* - \Delta Ef_a)}{8760 \times \Delta Ef^*} \quad (4.11.1.04)$$

where:

ICB_a	cost/energy benefit Index of cascade *a*, in R$/MWh;
CUR	reference unit cost, in R$/MWh;
ΔEf^*	firm energy contribution of the cascade with the highest production from the group under analysis, in average MW;
ΔEf_a	firm energy contribution of cascade *a*, in average MW; and
CT_a	total annual cost of cascade *a*, after all the economically unfeasible projects have been eliminated, in R$.

The firm energy contribution of a cascade should not be calculated as the sum of the last added firm energy contributions of the projects it is made up of, as this would mean summing the benefits of projects more than once. In the Preliminary Studies, the firm energy contribution of a cascade should be calculated as shown in item 4.6.3.

The SINV system has a function called “Energy/Economic Assessment”, which determines the ICB of the different cascades in a given group, using the procedures described in 4.6. In order to use this, choose the “without simulation” option.

4.11.2 Negative Socioenvironmental Index

The negative socioenvironmental index of a cascade should express the magnitude of the negative impact brought about by the set of projects that comprise it on the study area. In the Preliminary Studies, the aim of this index is to rank the cascades as a function of the extent to which they meet the objective of **minimizing negative socioenvironmental impacts**, providing an input for the selection of those that will go through to the Final Studies.

The negative socioenvironmental index of a cascade is calculated in two stages:

- negative impact index of a cascade on each synthesis component (relative to the aggregate indexes of the projects into an index for the cascade in question);
- negative impact index of a cascade on the socioenvironmental system (relative to the aggregate negative impact indexes for all the synthesis components).

Negative impact index of a cascade on each synthesis component (IAC)

The negative socioenvironmental impact index of a cascade on each synthesis component should represent the impact of the set of projects it contains on the synthesis component in the study area, assuming that all the projects from the cascade have been built. As such, it is necessary not only to consider the impact processes from each project in isolation, but also the cumulative and synergistic effects between the projects which affect a given sub-area and the effects between the impact processes in the different sub-areas.

However, these factors would make the analysis extremely complex, given the number of cascades considered in the Preliminary Studies. Instead, a simplification of the cumulative and synergistic effects is used in order to draw up a shortlist of the cascades that merit more detailed analysis in the Final Studies.

At the Preliminary Studies stage, the following procedures are used to calculate the **negative impact index of a cascade on each synthesis component (IAC)**:

- Calculation of the negative impact index of a cascade on the synthesis components in each sub-area

At this stage, a simplified procedure[11] can be used to calculate the cumulative impact index for each sub-area, where **n** is the number of projects in the cascade under analysis that impact on sub-area **j**. Based on the negative impact indexes of each of these projects in isolation $I_{SA}(j,i)$, i =1,..,n, the cumulative impact of all the projects is given by the following iteration:

$$I^{c}_{SA}(j,i) = I^{c}_{SA}(j,i-1) + \left[\left(1 - I^{c}_{SA}(j,i-1)\right)^{*} I_{SA}(j,i)\right], \qquad i = 1, \ldots, n \tag{4.11.2.01}$$

where:

$I_{SA}(j,i)$	impact on sub-area j when only the ith project in the cascade is built;
$I^{c}_{SA}(j,i)$	cumulative impact on sub-area j when projects 1, 2, ..., i are built in the cascade;

where $I^{c}_{SA}(j,0) = 0$ the initial value of the cumulative impact.

After all the iterations have been done (considering all the projects in the cascade in isolation), the cumulative impact on sub-area **j** is given by:

$$I^{c}_{SA}(j) = I^{c}_{SA}(j,n) \tag{4.11.2.02}$$

In the case of the Indigenous Peoples synthesis component, as the unit of analysis is the entire study area the same procedures is used as that for a single sub-area.

- Aggregation of indexes for the sub-areas into a negative impact for the cascade on a synthesis component in the study area.

The negative impact index of a cascade on a synthesis component in the study area **(IAC)** is given by the weighted sum of the impact indexes for the sub-areas:

$$IAC = \sum_{j} I^{c}_{SA}(j) P(j) \tag{4.11.2.03}$$

where:

P(j)	weighting factor for each sub-area i

The weighting factors for the sub-areas, defined at the diagnosis stage, are used to provide relative impact indexes for the sub-areas within the context of the study area. In order to keep the **IAC** between zero and one, the weights **P(j)** should also be attributed on a continuous scale from zero to one, such that the sum of the weights of all the sub-areas will equal one.

In order to calculate the index, it is suggested that a table be prepared as shown below.

In the case of the Indigenous Peoples synthesis component, as the unit of analysis is the entire study area, no weighting is needed.

11 Adapted from EPE/CNEC/Arcadis Tetraplan – "Avaliação Ambiental Integrada dos Aproveitamentos Hidrelétricos na Bacia do Rio Tocantins – Relatório P3 - Avaliação Ambiental Distribuída e Conflitos", March 2007.

Table 4.11.2.01 – Negative impact index of a cascade on the Way of Life synthesis component

Projects \ Sub-areas (Weights)	I (0.07)	II (0.08)	III (0.18)	IV (0.12)	V (0.25)	VI (0.30)	
A		0.10					
B		0.50	0.65	0.10			
C			0.85		0.35		
F		0.08					
G	0.10						
H	0.10				0.10		
I	0.30		0.10		0.30		
M	0.30					0.40	
N	0.50		0.90				
Q_2						0.95	
$I^c_{SA}(j)$	0.801	0.586	0.990	0.10	0.590	0.970	IAC
$I^c_{SA}(j)P(j)$	0.056	0.047	0.179	0.012	0.148	0.291	0.733

- Negative Impact Index of a Cascade on the Socioenvironmental System

The **negative impact of a cascade on the socioenvironmental system (IA)** should express its total negative impact on the study area, i.e. it should consider the impacts caused by the cascade on all the synthesis components.

This index is obtained by the weighted sum of the **negative impact indexes of the cascade on the synthesis component (IAC)**, as calculated previously.

$$IA = \Sigma\, IAC_i \times P_{ci} \qquad (4.11.2.04)$$

where:

P_{ci}	weighting factor for each synthesis component

In order to keep the **IA** between zero and one, the weights $\mathbf{P_{ci}}$ should also be attributed on a continuous scale from zero to one, such that the sum of the weights of all the synthesis components will equal one.

The weighting factors are used to attribute relative impact socioenvironmental indexes for the cascade on the synthesis components in the study area. These weights should represent the relative importance of the impact processes on each synthesis component on the socioenvironmental system, which can be measured by the repercussions of these processes on the other components.

In order to assess this repercussion, the analyses should be considered of the interactions between the synthesis components relative to the socioenvironmental status of the study area carried out in the diagnosis.

This activity is undertaken by the technical team responsible for the studies, which should also consider the views of the different interest groups identified in the region throughout the studies.

Given the interdisciplinary nature of this activity and the great margin for subjectivity involved, it is necessary to systematize the procedures for weighting the synthesis components using specific methods and techniques. These methods should make it possible to represent the subjective assessments in a system of weights, as well as combining the opinions of different assessors.

The "Calculate Negative Impact" function from the SINV system can be used to determine negative socioenvironmental impact indexes for the different cascades per synthesis component, and the negative socioenvironmental impact index of the different cascades on a river basin.

Analytic Hierarchy Process

We present below an adaptation of the Analytic Hierarchy Process model proposed by Saaty (1980), which ranks the synthesis components by comparing them against each other. This is a useful method because it is easy to use and there is a computer system available to apply it.

In order to determine the relative importance of the impact processes from each synthesis component on the socioenvironmental system, it is necessary to set up an indirect measurement scale. The aim of this is to establish, from subjective assessments by the team members, a system of weights for the synthesis components as a function of the relative importance of their impact processes.

The pairwise comparison process proposed by Saaty (1980) enables the relative importance (or priority) of the different synthesis components being compared to be established, in view of their impact processes on the socioenvironmental system. All the components should be compared with all the others.

The weights (or priorities) are attributed by setting up a matrix of the same size as the number of components to be compared, where the elements in the matrix are values on a standard comparative scale which represent the relative importance that the decision makers taking part in the process give to the component on each line (i) against the component in each column (j). Saaty (1980) recommends the comparative scale presented below, though it should be understood that the values are absolute magnitudes and not simple ordinal numbers.

Table 4.11.2.02 – Scale of comparative importance between the synthesis components

Importance of preferred element	Definition	Importance of non-preferred element	Definition
1	equally important	1	equally important
3	slightly more important	1/3	slightly less important
5	more important	1/5	less important
7	much more important	1/7	much less important
9	absolutely more important	1/9	absolutely less important
2,4,6,8	intermediate values	1/2, 1/4, 1/6, 1/8	intermediate values

In the pairwise comparison, the attribution of relative importance implies in a(i,j) = 1/ a (j,i), which means the matrix is reciprocal. In other words, the preferred element is given a number on a scale from 1 to 9 and the non-preferred element is given the reciprocal number. In this case in particular, the attribution of importance should take into account the repercussions of the impact processes from one given synthesis component on the rest.

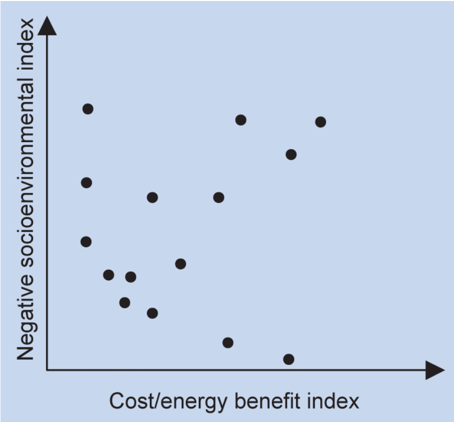
Having drawn up the matrix, calculations are done to obtain the autovector of the highest value which, after it has been normalized, corresponds to the "priority vector", expressing the relative weights between the synthesis components being compared. The synthesis components associated with the highest values are those whose impact processes are deemed to be of the greatest importance.

The priority matrix should represent the general opinion of the decision makers in this process. For cases in which no consensus can be reached, a matrix can be built up of the averages given by the decision makers, where each element is the geometric average of the values attributed by each person. In this case, each decision maker will first build up their own matrix, which will then be inputted into the final matrix representing the group's opinion, obtaining a single "vector of priorities".

As the values are attributed subjectively, it is a good idea to apply consistency tests to the judgments made to assure the reliability of the methods used. If the consistency index is less than 0.1, the judgments can be considered satisfactory (Saaty,1980).

4.11.3 Selection of the cascades

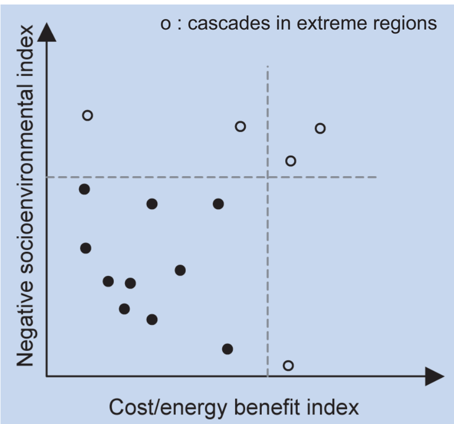
The cascades to be examined in greater depth during the Final Studies should be selected in view of their respective cost/energy benefit index (item 4.11.1) and negative socioenvironmental index (item 4.11.2). They should be compared graphically, where one of the axes indicates the cost/energy benefit index and the other, the negative socioenvironmental index, as shown below.



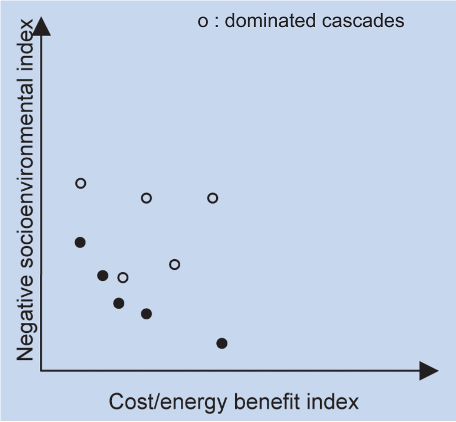
Generally speaking, the cascades to be selected are those that are represented by the points nearest to the bottom left-hand side of the graph, which corresponds to the lowest values for both indexes. The number of cascades selected to go through to the Final Studies will depend greatly on the morphology and extent of the river basin under study. If there is a significant natural head that is distributed evenly throughout the rivers, there may be more cascade options than in cases where there is one pronounced head concentrated in a short stretch of river. Generally speaking, in studies of this nature, there are normally no more than ten basic cascades that go through to the Final Studies. It is reasonable to expect between five and ten.

The following concepts must be used to choose the cascades:

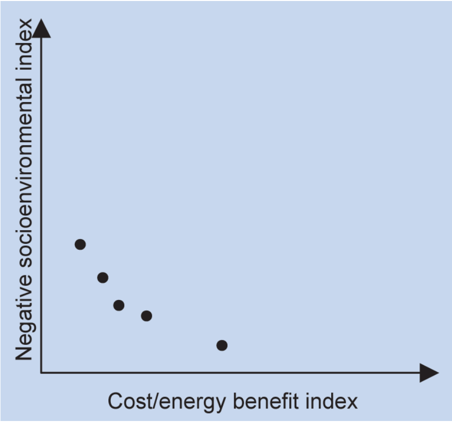
- **Extreme Regions** – The cascades located at the extremities of the graph, representing a high cost/energy benefit index and/or negative socioenvironmental index, should be ruled out.



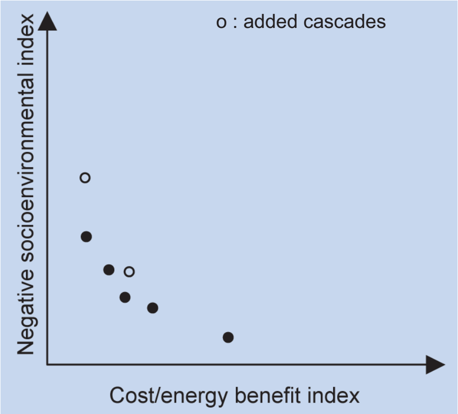
- **Dominated Cascades** – A cascade is dominated (uncompetitive) if there is another one with lower energy cost/benefit and socioenvironmental indexes. All uncompetitive cascades should be ruled out.



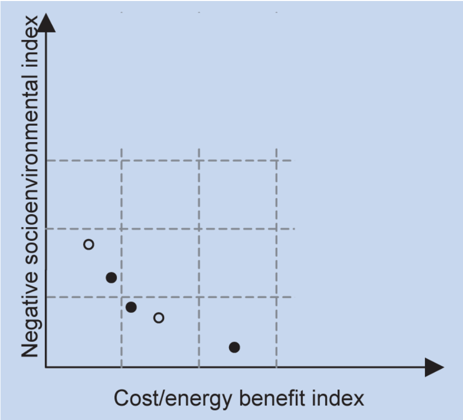
- **Non-Dominated Cascades** – Once the cascades from the extreme areas and those that are dominated have been ruled out, there should just be a few cascades left, which are called the non-dominated or Pareto optimum cascades. These are the cascade options that should go through to the Final Studies.



However, if there is too small a set of non-dominated cascades, a new set of non-dominated cascades can be looked for from the set of dominated ones, always seeking to reformulate them in such a way that their indexes are improved, then adding them to the set of cascades selected.



On the other hand, when the set of undominated cascades is too large, the graph can be split into a grid, and cascade options can be selected according to their relationship with the other cascade options in the same square of the grid.



The SINV system can be used not only to calculate the cost/energy benefit index and negative socioenvironmental impact index of the different cascades, but it also gives a graphic view of the extreme cascades and those that are dominated and non-dominated, making it easier to select which cascades should go into the Final Studies. Therefore, the use of this system is recommended not just for calculating cost/energy benefit and negative socioenvironmental impact indexes, but also for selecting the cascades to advance to the Final Studies.

4.12 BIBLIOGRAPHY

ANEEL, *Guia de Avaliação de Assoreamento de Reservatórios*, Brasília, DF, 2000.

BRUK, Stevan, *Methods of computing sedimentation in lakes and reservoirs*. UNESCO, Programme IPH-II, Project A.2.6.1. Paris, France,1985.

CARRERA, A. *Catálogo de los Mamíferos de la América del Sur. Revista Mus. Argent. Ciencias Naturales*. Bernardino Rivadavia, 4 (1): 1-307, Argentina, 1965.

CARVALHO N.O., Filizola N., Lima J.E.F.W., Santos, P.M., *Guia de Avaliação de Assoreamento de Reservatórios*. Brasília, DF. ANEEL/SIH, 2000.

CARVALHO, Newton de Oliveira, *Cálculo de assoreamento e da vida útil de um reservatório na fase de estudos de inventário*. IX Simpósio Brasileiro de Recursos Hídricos e V Simpósio luso-Brasileiro de Hidráulica e Recursos Hídricos. Rio de Janeiro, RJ, 1991.

CEPEL, *Sistema de Inventário Hidroelétrico de Bacias Hidrográficas – SINV 5.1a - Manual de Metodologia*, 2006. In: Relatório Técnico DP/DEA – 17805/06.

CEHPAR/LACTEC, *Programa SisEvapo v2.0*. Relatório Técnico. Curitiba, 63 pages.

CPRM e ELETROBRÁS, *Hidrossedimentologia prática*. Rio de Janeiro, RJ, 1995.

DNAEE, *Inventário das estações fluviométricas*. Brasília, DF, 1987.

DUMNING, J.S., *South America Birds*. Harrowood Books, Pensylvania, 351 pp., 1987

ELETROBRÁS, *Diagnóstico das condições sedimentodológicas dos principais rios brasileiros*. Diretoria de Planejamento e Engenharia. Rio de Janeiro, RJ, 1992.

ELETROBRÁS, *Manual de Inventário Hidroelétrico de Bacias Hidrográficas*, 1997.

ELETROSUL, *Preços de equipamentos eletromecânicos para o manual de Inventário da ELETROBRÁS/1997*. Florianópolis, SC, 1996.

ELETROSUL, *Preços de obras civis para o Manual de Inventário da ELETROBRÁS/1997*. Florianópolis, SC, 1996.

EMMONS, L.H., *Neotropical rainforest mammals. University of Chicago Press*. 281 pp., Chicago, 1990.

EPE/CNEC/Arcadis Tetraplan, *Avaliação Ambiental Integrada dos Aproveitamentos Hidrelétricos na Bacia do Rio Tocantins – Relatório P3 - Avaliação Ambiental Distribuída e Conflitos*, Rio de Janeiro, 2007.

INTERNATIONAL COMMISSION ON LARGE DANS (ICOLD), *Sedimentation control of reservoirs. Guidelines. Committee on Sedimentation of Reservoirs*. Paris, France, 1989.

MINISTÉRIO DE MEIO AMBIENTE, *Plano Nacional de Recursos Hídricos, 2006*. Available at: http://www.mma.gov.br/port/srh/pnrh.

ONS, *Evaporações Líquidas nas Usinas Hidrelétricas*. 2004.

ONS, *Estimativa das Vazões para Atividades de Uso Consuntivo da Água nas Principais Bacias do Sistema Interligado Nacional*. FAHMA-DREER, 2003.

PCE ENGENHARIAL, *Revisão e ampliação de gráficos e planilhas eletrônicas para o Manual de Inventário de 2007*. Rio de Janeiro, RJ, 2007.

SAATY, T.L., *The analytic hierarchy process: planning, priority setting, resource allocation*. New York. McGraw–Hill, 1980.

SHANNON, C.E., *The Mathematical Theory of Communication.* Urbana, University of Illinois Press, 117 pp., USA, 1949.

STRAHLER, A. N., *Dynamic Basis of Geomorphology*, Geological Society American Bulletin, USA, 1952.

STRAND, Robert I, *Design of small dams. Sedimentation*. Appendix H. US Bureau of Reclamation. Washington, DC, USA, 1974.

WORLD METEOROLOGICAL ORGANIZATION (WMO), *Guide to Hydrological Practices.* Geneva, Switzerland, 1994.

YUQIAN, Long. *Operational methods for measurements of sediment transport*. WMO, IN Carrera, 1965; Emmons, 1990; Dumning, 1988; Nowak, 1991; Vanzolini, 1980; Peters and Donoso Barros, 1970.

Standards and Resolutions

ANEEL, Nota Técnica nº 002/2004 of January 19th 2004 – “Projeto de Revisão das Séries de Vazões Naturais em Bacia Hidrográficas de Interesse do Sistema Interligado Nacional”.

CNRH resolution 37 of March 26th 2004 – “Estabelece diretrizes para a outorga de recursos hídricos para a implantação de barragens em corpos de água de domínio dos Estados, do Distrito Federal ou da União”.

CONAMA resolution 371 of April 5th 2006 – “Estabelece diretrizes aos órgãos ambientais para o cálculo, cobrança, aplicação, aprovação e controle de gastos de recursos advindos de compensação ambiental”.

IBGE service standard NS-DGC 001/2005 of January 2006 - “Padronização de Geodetic marks: Instrução Técnica”.

IBGE resolution no. 5 of March 31st 1993 - “Especificações e Normas Gerais para Levantamentos GPS: Versão Preliminar”.

IBGE resolution PR nº 1, of February 25th 2005.

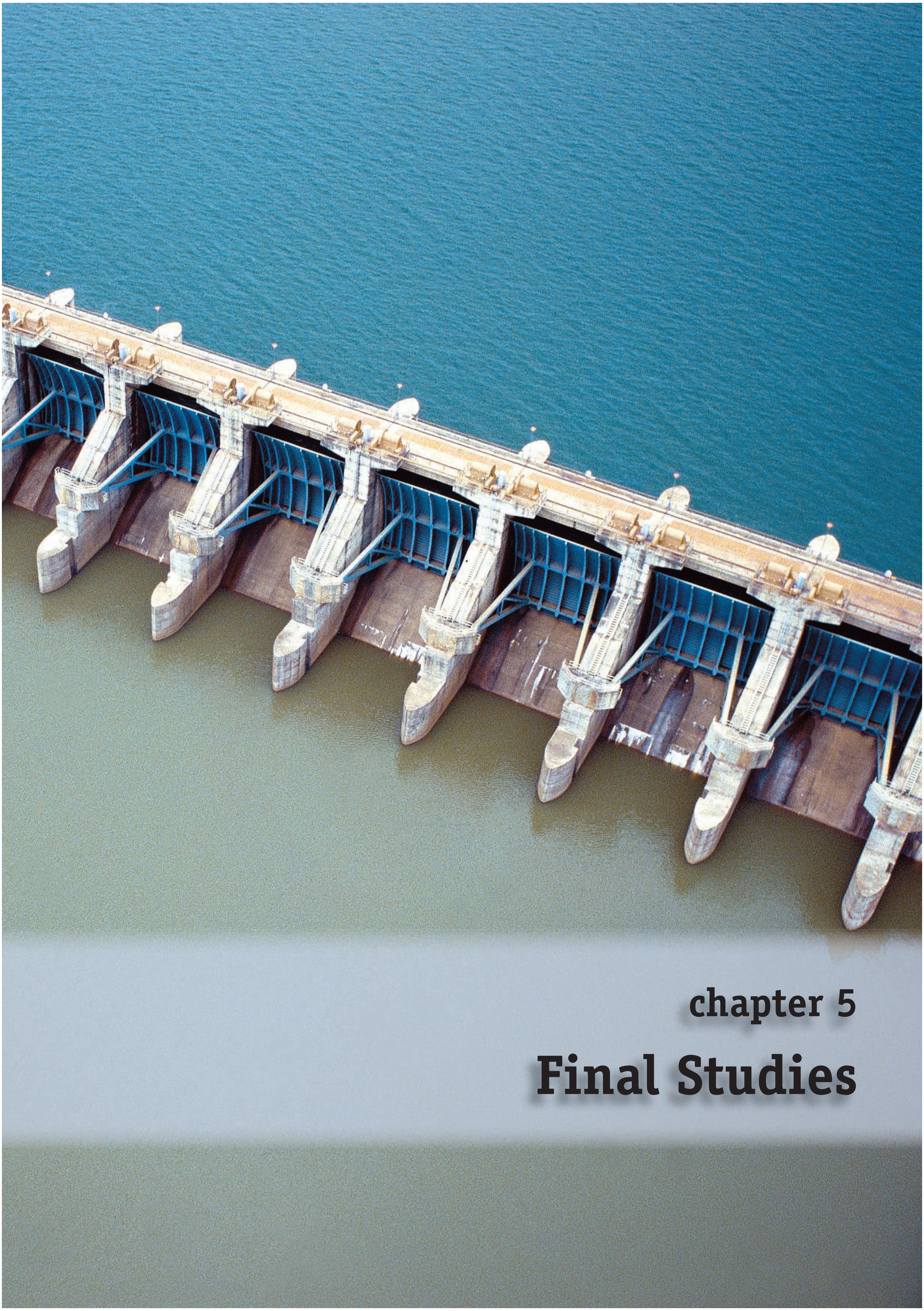
IBGE resolution PR nº 22 of July 21st 1983 – “Especificações e Normas Gerais para Levantamentos Geodésicos”.

ABNT standard NBR 13.133 of June 30th 1994 – “Execução de levantamento topográfico”.

ABNT standard NBR 14.166 of August 1st 1998 – “Rede de Referência Cadastral Municipal - Procedimento”.

NORMA TÉCNICA DA CARTOGRAFIA NACIONAL, Decree 5334 of January 6th 2005.

Portaria Ministerial 121/MB of April 23rd 2003 – “Instruções para Controle dos Levantamentos Hidrográficos pela Marinha do Brasil”.



chapter 5

Final Studies

CAPÍTULO 5

The basic aim of the Final Studies is to choose the cascade and associated structures and equipment that will develop all the hydropower potential of the river basin that can be economically and environmentally harnessed. At this phase, the data and studies from the previous phase are collated, and any studies required to supplement the data on the projects included in the cascades short-listed for the Final Studies are undertaken. This involves making in-depth energy studies, reviewing layouts, drafting designs and making cost estimates of the projects involved. An economic/energy index, negative socioenvironmental impact index and positive socioenvironmental impact index are attributed to each cascade, providing parameters for them to be compared amongst themselves and for the final decision on which cascade to select.

The main aim of the field studies and engineering studies is to improve the detail of the data and undertake basic studies for this stage, in order to:

- make it feasible to design more consistent final layouts for the projects and make any adjustments necessary to the cascades under study;
- supply more accurate information for the purposes of quantifying and estimating the cost of each project in the cascades under study; and
- attribute a cost/benefit index to each cascade option so they can be ranked according to the extent to which they fulfill the precondition of **maximizing power generation and minimizing costs**, furnishing a valuable input for the final selection of one cascade.

The main aim of the socioenvironmental studies is to:

- supplement the socioenvironmental information deemed of importance gathered in the Preliminary Studies in order to design the final layouts of the projects and make any adjustments necessary to the cascades under study;
- supply more accurate information for the purposes of estimating the socioenvironmental costs associated to each project and each cascade;
- include in the socioenvironmental assessment an analysis of the cumulative and synergistic effects arising from the introduction of the group of projects that make up each cascade option;
- make it possible to attribute a negative socioenvironmental impact index to each of the cascades, ranking them according to the extent to which they fulfill the precondition of minimizing negative socioenvironmental impacts;
- attribute a positive socioenvironmental impact index to each cascade, furnishing a valuable input for the final selection of one cascade.

The procedures for undertaking the socioenvironmental studies during this stage are set out throughout this chapter in combination with the procedures for the energy, engineering and multiple water use studies. There are three phases of studies: consolidation of the socioenvironmental diagnosis, assessment of the negative and positive socioenvironmental impacts of the cascades, and attribution of a negative socioenvironmental impact index and a positive socioenvironmental impact index to the cascade options.

During the consolidation of the diagnosis, the issues identified in the Preliminary Studies as being of most importance are supplemented and all systemic processes must be highlighted. The guidelines and recommendations for these are presented in items 5.1 and 5.2. The results and analyses are used to review the maps of the synthesis components, which are then used to make the final adjustments to the cascades.

In addressing the negative socioenvironmental impacts, the studies follow the same basic structure as in the Preliminary Studies, albeit in greater depth and more detail. At this stage, the impact analysis is done for groups of projects rather than for individual projects, so that the cumulative and synergistic effects between the different projects in a given cascade can be incorporated into the impact assessment. This means that the studies for identifying, predicting and assessing negative impacts and attributing impact indexes per synthesis component are done for groups of projects with an impact on the same sub-area. The information produced on negative impacts is taken into account in the review of the socioenvironmental cost estimate and the final layouts of the projects.

The analysis of positive socioenvironmental impacts is very important at this stage, and is undertaken directly on groups of projects in each cascade option. The process for identifying, predicting and assessing the positive impacts and the respective attribution of impact indexes for each of the socioenvironmental aspects selected is also described in item 5.4.

The procedures for obtaining the negative and positive socioenvironmental impact indexes for each cascade are described in items 5.8.2 and 5.8.3.

5.1 DATA CONSOLIDATION AND SUPPLEMENTARY INVESTIGATIONS

The starting point for the Final Studies is the cascade options selected in the Preliminary Studies. The information obtained for each cascade must be supplemented, confirmed or adjusted until it is deemed sufficient to provide a consistent characterization of the total costs of the corresponding construction work, structures and equipment.

In each case, it is up to the analyst to decide the scope of the additional data required based on his/her understanding of the extent to which this will influence the final cost estimate.

5.1.1 Cartography and Topography

The cartographic services undertaken at the final phase of the studies also depend greatly on the features of the river basin, such as its dimensions, slope, vegetation, the extent of human occupation and, obviously, all the data collected and surveys undertaken in the Preliminary Studies.

At this stage, the cartographic data from the Preliminary Studies should be reassessed. Definitive and/or supplementary surveys must be carried out where any fragility is identified.

The following items in particular must be established definitively:

- the longitudinal profiles of the water courses, indicating the water levels at the pre-selected sites and the elevation of any existing civil engineering structures (bridges, tunnels, etc.);
- surveys of saddles around the rim of the reservoir;
- elevation-area and elevation-volume curves for each reservoir;
- topographic features of the preselected sites, including all the elements of all the structures in the layout, as shown in item 2.5, in compliance with class VIPA, from Brazilian standard ABNT 13.133;
- topographic survey of the river bed along the dam axis;
- longitudinal sections along the hydraulic conveyance facilities, the river diversion, the spillway and navigation system and fish passage system (for navigation and migratory species);
- installation of two topographic marks at each project site with their respective azimuth marks, with planimetric and altimetric coordinates linked to the Brazilian Geodetic System;
- planimetric and altimetric coordinates for the geological, geotechnical, hydrometric and environmental investigations undertaken.

Technical Specifications

As for the technical specifications of the georeferenced data, the drawings or images that involve cartographic coordinates will be submitted to the relevant entities following the standards set out in item 4.1.1 of the Preliminary Studies.

Outputs

The following items must be submitted:

- list of official geodetic marks (benchmark and vertex) used as a basis for coordinate transport;
- report on the geodetic marks installed at the project sites identified in the cascade selected and used in the field support services, including photographs, maps of access routes, codes, geographic

coordinates and UTM coordinates corresponding to the datum used and any other relevant technical information;

- descriptive records including: description of the services, equipment used, level of precision, computer programs used;
- schematic drawings on A3 size paper and in a suitable scale of the longitudinal profiles of the rivers under study, indicating their main tributaries (include information about the cascade options studied, operational water levels and all the areas of interest, e.g. indigenous lands, towns, bridges, conservation areas, water withdrawals, etc.);
- planimetric/altimetric plan of the preselected sites obtained using the methodology recommended in item 4.1.1, on A3 paper and using a suitable scale;
- drawings of the topographic cross-section of the river and longitudinal section at the locations of the project structures (including the tailrace canal) at all the sites included in the shortlisted cascades;
- digital file of the planimetric/altimetric plans of the reservoirs;
- electronic spreadsheet used as the basis for preparing the elevation-area-volume curves for the projects in the different cascades;
- technical records of the services used to allocate planimetric and altimetric coordinates to the geological, geotechnical, hydrometrical and environmental studies;
- specific *Anotações de Responsabilidade Técnica* (ARTs) for the services undertaken (field and office).

5.1.2 Hydrometeorology

In the Final Studies, the breadth and depth of the information obtained in the Preliminary Studies should be reviewed. The basic studies to be undertaken at this stage are:

- determination of the rating curve in the tailrace canal at each site selected: field studies should be continued to measure the water levels and flows in order to determine the rating curves at each site; if possible and whenever necessary, staff gauges linked to the benchmark system mentioned in item 4.1.1 should be installed. When it is impossible to make direct measurements at a particular site, the rating curves or some of their points should be estimated by the methods generally used to correlate levels and flows with known values from other staff gauges;
- mean monthly natural flows: all the studies needed to determine the flow records at the dam sites should be reviewed and completed in the light of the new information obtained from the field and other sources;
- determination of extreme flows: data from the Preliminary Studies is reviewed and supplemented; the annual maximum daily mean flows should be determined and analyzed statistically; the flood flow-recurrence time curve should be plotted. Other information than the recorded flows can be used, such as flood marks and the testimony of residents of the area to supplement or complete the historical records.

5.1.3 Consolidation of the Scenario of Multiple Water Uses in the River Basin

The studies that were started in the preliminary phase of the Inventory Studies should be reviewed, supplemented and collated so that a long-term scenario can be built up for the purposes of analyzing the cascade options and making a final selection.

5.1.4 Geology and Geotechnics

In the Final Studies, the focus should be on the selected sites and the areas of the reservoirs which may present specific problems.

At the project sites under study, the following basic information should be supplemented:

- type and geotechnic features of the foundations for the structures; and
- existence, type, characteristics and approximate size of deposits of soil, sand, gravel and rock that could be used as natural building materials.

Taking the data from the Preliminary Studies and the preliminary layout of the structures for the projects, **supplementary surveys** should be undertaken to better define the state of the foundations and the natural building materials and to obtain comparative parameters, such as a basic geological and structural model of the study area, and the results of any known geomechanical tests on the different kinds of bedrock in the foundations. The following are suggestions of programs to be undertaken:

- geological surface mapping;
- manual boreholes, trenches and auger borings; and
- geophysical surveys.

At this phase, it is not normally necessary to drill any mechanical boreholes (percussion or rotary drilling) except in special cases or if the land has a particularly complex geological make-up. In these cases, the investigations, which should be designed according to the dimensions of the construction work and the geological complexity, should determine the thickness of the soil cover on the bedrock, the characteristics of these materials, the depth of the water table and the general characteristics of the foundations so that the type of structure to be built on the site can be chosen and the costs of the processes required can be calculated.

As part of the socioenvironmental studies, the geological aspects should be investigated in greater depth, especially if there are any minerals that could be influenced by the reservoirs (check data from DNPM) and if there are any areas of greater susceptibility to landslides around the reservoir banks. A preliminary assessment should also be made of the silting potential of the reservoir and regional seismicity.

5.1.5 Environment

The aim of this activity is to gather the information required not only to gain a greater understanding of the socioenvironmental issues identified as being of most significance during the Preliminary Studies, but also to identify and characterize the cumulative and synergistic processes that would arise if the group of projects in the study area were built.

The survey of data and information on each synthesis component and each aspect selected for the analysis of the positive socioenvironmental impacts should supplement the analysis from the Preliminary Studies.

Field surveys should be undertaken to supplement the secondary data gathered.