WCD Case Study

Tucuruí Hydropower Complex Brazil

Final Report: November 2000

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Please cite this report as follows:
La Rovere, E.L. and Mendes, F.E. 2000. *Tucuruí Hydropower Complex, Brazil*, A WCD case study prepared as an input to the World Commission on Dams, Cape Town, www.dams.org

The WCD Knowledge Base

This report is one component of the World Commission on Dams knowledge base from which the WCD drew to finalize its report "Dams and Development-A New Framework for Decision Making". The knowledge base consists of seven case studies, two country studies, one briefing paper, seventeen thematic reviews of five sectors, a cross check survey of 125 dams, four regional consultations and nearly 1000 topic-related submissions. All the reports listed below, are available on CD-ROM or can be downloaded from www.dams.org

Case Studies (Focal Dams)
- Grand Coulee Dam, Columbia River Basin, USA
- Tarbela Dam, Indus River Basin, Pakistan
- Aslantas Dam, Ceyhan River Basin, Turkey
- Kariba Dam, Zambezi River, Zambia/Zimbabwe
- Tucurui Dam, Tocantins River, Brazil
- Pak Mun Dam, Mun-Mekong River Basin, Thailand
- Glomma and Laagen Basin, Norway
- *Pilot Study of the Gariep and Van der Kloof dams- Orange River South Africa*

Country Studies
- India
- China

Briefing Paper
- Russia and NIS countries

Thematic Reviews
- TR I.1: Social Impact of Large Dams: Equity and Distributional Issues
- TR I.2: Dams, Indigenous People and Vulnerable Ethnic Minorities
- TR I.3: Displacement, Resettlement, Rehabilitation, Reparation and Development

- TR II.1: Dams, Ecosystem Functions and Environmental Restoration
- TR II.2: Dams and Global Change

- TR III.1: Economic, Financial and Distributional Analysis
- TR III.2: International Trends in Project Financing

- TR IV.1: Electricity Supply and Demand Management Options
- TR IV.2: Irrigation Options
- TR IV.3: Water Supply Options
- TR IV.4: Flood Control and Management Options
- TR IV.5: Operation, Monitoring and Decommissioning of Dams

- TR V.1: Planning Approaches
- TR V.2: Environmental and Social Assessment for Large Dams
- TR V.3: River Basins – Institutional Frameworks and Management Options
- TR V.4: Regulation, Compliance and Implementation
- TR V.5: Participation, Negotiation and Conflict Management: Large Dam Projects

Regional Consultations – Hanoi, Colombo, Sao Paulo and Cairo

Cross-check Survey of 125 dams

Acknowledgements

The Research Team would like to acknowledge the collaboration of:

- Elisabeth Monosowski (WCD) and Márcia Gomes Ismerio for their collaboration in the Scoping Phase of this Study;
- Bruce Aylward, Medha Patkar, Thayer Scudder, Jan Weltrop, Achim Steiner, Sanjeev Khagram, Manrique Rojas, Jamie Skinner, and Saule Ospanova from WCD;
- Patrick McCully from IRN for comments on draft versions of the paper and executive summary;
- The members of the Coordinating Group Osmar Vieira Filho (Eletronorte), Marcos V. Freitas (ANEEL), Raimundo Nonato do C. Silva (CEAP), Sadi Baron (MAB) and Henri Acserald (IPPUR/UFRJ);
- The Technical Staff of Eletronorte, CEAP, ANEEL and other institutions for their kind data and information supply;
- Prof. Jean Remy D. Guimarães, (Inst. Biofísica, UFRJ);
- The participants of the Consultative Group meetings at Belém and Tucuruí;
- Many people who sent written submissions and comments both to the Research Team and the WCD;
- All people interviewed during fieldwork; and
- Staff members of LIMA/COPPE/UFRJ, particularly our secretary Sandra Bernardo dos Reis.

This case study was supported by the partnership agreement between United Nations Foundation, UNEP and the World Commission on Dams.

Financial and in-kind Contributors:

Financial and in-kind support for the WCD process was received from 54 contributors including governments, international agencies, the private sector, NGOs and various foundations. According to the mandate of the Commission, all funds received were‘untied’-i.e. these funds were provided with no conditions attached to them.

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Executive Summary

This study is one of eight case studies being undertaken world-wide with a common methodology and approach to inform the World Commission on Dams on the subject of the development effectiveness of large dams. The Tucuruí Hydropower Complex is situated on the lower Tocantins River within the Tocantins-Araguaia River Basin adjacent to the Amazon basin in northeastern Brazil. The project was designed to be constructed in two phases, Phase I construction was started on November 24, 1975 and completed November 10, 1984, and the construction on Phase II began in June 1998 with the first turbine scheduled to be operational by December 2002. The complex was built with the primary motive of producing hydropower although the secondary goal of providing a navigable river route was later introduced.

Several fundamental research questions were put forth by the WCD. These questions, presented below, guided the analysis and the data collection for all the case studies.

1. What were the projected vs. actual benefits, costs and impacts?
2. What were the unexpected benefits, costs and impacts?
3. What was the distribution of costs and benefits, who gained who lost?
4. How were key project decisions made?
5. How did the project evolve in response to changes in policies and decision-making criteria?
6. What lessons can be learned from the experience of this project?
7. How can the development effectiveness of the project be evaluated?

Context, objective and components of the Tucuruí Hydropower Project

Basin Context

The Tocantins river, located completely within the province of Eastern Amazonia, eventually flows into the Amazon river estuary and has an annual volume of 334km^3 and a catchment area of 758,000 km^2 representing 7.5% of the land mass of Brazil. It runs for some 2,500 km before its confluence with the Araguaia River. The Tocantins-Araguaia River Basin has a clearly defined hydrological system, with its dry season culminating in September/October, and flooding that peaks between February and April. Due to lags caused by large floodplains on the upper tributaries of the river, the highest flow figures on the Tocantins are recorded a few weeks later.

The lengthy course of the Tocantins River Basin contributes to a well-defined and stable climatic regime across this region. The north of the region is hot and humid with high rainfall. The temperature peaks at 38°C in August and September, whereas the coldest temperatures are recorded in June (about 22°C), the rainfall can be as high as 2,400 mm with a humidity rate of about 85%. Towards the south of this region the temperature drops as the latitude increases and the rainfall averages around 1,400 mm with a humidity rate of around 70%.

The dam was built at the end of a long stretch of waterfalls, in the Southern Pará Peripheral depression caused by erosion dating back to the late tertiary era. The soils in the vicinity of the Tucuruí complex are acidic and nutrient poor with low natural fertility levels and crops can be grown successfully when it is properly prepared and fertilised.

The flora over much of the basin area is dominated by a Cerrado savannah ecosystem, with mesophilic forest towards the north with a broad transition belt separating the savannah from the Amazon rain forest. The neo-tropics of Amazonia are reported to contain as much as three times more diversity in flora when compared to similar tropics in Africa and Asia. The fauna in the area is characterised by these ecosystems and is believed to be some of the most richly endowed and most diverse in the world. Surveys carried out during the construction of the Tucuruí complex estimated that the area was home to 117 species of mammals, 294 types of birds and 120 types of reptiles and amphibians including a number of threatened and endangered species. The river is estimated to contain some 300 species of fish.

The Socio-Economic Context

Of the number of indigenous groups living in the region, the Parakanã, Asurini and the Parkatêjê groups were living in the area affected by the construction of the dam and the flooding of the reservoir. As with the colonist groups that migrated into the region their livelihoods were based on a number of subsistence and limited market activities in the region. The harvesting of dryland drugs and brazilnuts, the tapping of rubber, and the mining of diamonds and gold were the major economic activities practised by the initial colonists to the region who settled and formed a number of river bank communities along the water-courses of the area. Subsistence agriculture soon became the predominant means of survival for these communities. Fishing was also widespread in the region prior to the construction of the dam, with an estimated catch of 1,534 tons/year for which 900 tons/year came from downstream of the dam and the rest from within the area affected by the reservoir. A project feasibility study conducted in 1974 estimated the population of the reservoir area to be 3,173 inhabitants, of whom 495 lived in towns, 1,614 in villages, 237 in hamlets, 174 on ranches and 653 on smallholdings.

Until the late 1950's, Amazonia, covering over half the territory of Brazil, remained a vast "island", historically characterised by the presence of primary export economies, with low population densities and low national integration. With the move of the nation's capital to Brasília and the development of related road networks, the 1960s heralded a concerted effort at incorporating the region in the dominant economy of the country. With the arrival of the military government in 1964, this effort was accelerated in the interest of national security. The construction of the Belém-Brasília highway in the 1970s provided an impetus for the implementation of large-scale projects including the Tucuruí hydropower complex, steel mills and electro-metallurgical plants. These changes, especially the construction of roads ensured a rapid process of deforestation particularly in the Mid and Lower Tocantins regions, aiding the subsequent introduction of cattle raising into the area. The town of Tucuruí is strategically located in this area, within the political and economic networks linking Amazonia to the Northeast and Central-West Brazil.

Objectives and Components of the Tucuruí Hydropower Complex

The initial drive behind the construction of a hydropower complex was to provide electricity for the town of Belém and the surrounding region. By the time the Tucuruí was under serious consideration, the primary focus of the project changed to one aimed at providing power for the energy intensive electro-metallurgical industry in the region. Ultimately industrial interests drove the building of the Tucuruí complex.

As a secondary purpose, pursuant to a Federal Government decision, the implementation of two locks linked by a canal was considered in order to ensure the navigability of the river from Belém to Santa Isabel, along a stretch some 680 kilometres. This was in reaction to lobbying from commercial ventures in Pará State that wanted the locks to be built in order to ensure that ore from Carajás region could be shipped out along the Tocantins River for export through ports in the Belém region.

The approximate length of the main dam wall is 6,900 meters, which, together with the length of the Mojú and Caraipé Dykes, total some 12,515 meters of dam wall built to form the reservoir. The crown of the earth-wall and rip-rap earth-wall is at a height of 78.00 meters above sea-level, with the concrete structures at a height of 77.50 meters above sea-level, resulting in a minimum freeboard of 2.70 meters and 2.20 meters respectively, in exceptional flood situations. The spillway, the second-largest in the world, was designed to handle a maximum rated flow of 100,000 m^3/s. The reservoir has a total volume of 45.5 km^3 at a depth of 72m and a useful volume of 32 km^3 and it was formed by flooding a total land area of 2,850 km^2.

During Phase I of the implementation of this power complex, only the upstream lock head was built, allowing the remainder of the system for crossing this dam to be built later.

Hydropower accounts for roughly 90% of the total power consumption in Brazil. The Tucuruí Hydropower Complex is part of the integrated hydropower programme for the Tocantins and Araguaia River Basins. Its energy sizing takes into account the final configuration plans for these basins, which includes the implementation of fifteen hydropower projects. Tucuruí produces 4000 MW of power, 70% of all electric power produced in Northern Brazil (6% of all electric power produced in Brazil). Upstream from Tucuruí, the Serra da Mesa Power Plant (1,275 MW) is completed, with the Canabrava and Lajeado Power Plants currently under construction.

Phase II of the project involves the building of a new powerhouse for the installation of 11 additional turbines with a power rating of 375 MW each, and the basic works needed to finalise the locks. As this phase is still under construction, it is not yet possible to assess the impact of the Tucuruí hydropower project as a whole. Rather the WCD case study focus is on the impacts of Phase I and the assessment of decision-making and compliance as they relate to action taken to date on both phases.

Predicted and Actual Impacts of the Tucuruí Hydropower Complex

Design of the Project and Implementation Schedule

A number of changes were made during the implementation phase of the project. The most significant alterations to the characteristics of the project as set forth in the initial feasibility studies and the basic project design are described in the following table.

Table ES.1: Actual vs. planned design characteristics

Predicted	Actual	Reason for Change
In the feasibility study the dam was to be built at a site immediately next to the village of Tucuruí	Instead it was built 7 km upstream	The first site was in closer proximity to the town of Tucuruí necessitating the evacuation of a large part of the town before the start of construction. The geological condition of the second site was better suited for the foundation.
The land inundated to form the reservoir was estimated to be 1,630 km²	The area actually inundated was 2,850 km^2	This estimate were conducted on the basis of aerophotogrammetry, but limited field controls and dense plant cover is said to have caused huge discrepancies in the estimate
The reservoir volume as planned during the study phase was 34,084 hm³ (34.084 km^3)	The volume after construction was 45.5 km³	Same as the above reason
A bottom spillway was to be built.	Only a top spillway was built	
The capacity of the top spillway was to be 100,000 m³/s	It was increased to handle 110,000 m³/s	Due to the exceptionally high flow-rates of Tucuruí in 1980, which outstripped those recorded at any time previously for this location.
The dam was to be built in a way that would not allow river navigation pass the dam	A federal government decision was taken to build a system of locks that would enable navigation	Lobbying from industrial concerns that wanted to ship ore along the river.

Predicted	Actual	Reason for Change
	The river diversion scheme was altered	Construction reasons.
The pumping station was planned to be upstream	It was moved downstream	Construction reasons
Cement imported from Colombia	Brazilian made cement used at a higher cost	Government decision to help local manufacturers.
Startup of the first power generation unit initially scheduled for 1981	Actually took place in November 1984	Mostly due to shortage of funding and added construction due to changes in project characteristics.
The feasibility plan published in 1974 called for clearing 43,000 ha of the 163,000 to be flooded. 1 year later this was stipulated to be 120,000 of the 216,00 ha to be flooded	Only 14,000 ha plus another "small parcel" was cleared	The first alteration was due to changes in project parameters. The reason only 14,000 ha of the 120,000 ha was cleared was due to an alleged corruption scandal between the IBDF (Instituto Brasileiro de Defesa Florestal) and a private company contracted to carry out the task.
The lock system was to be completed to enable the transportation of ore	Construction was delayed indefinitely.	The ore which was to be transported through the locks was instead transported by rail. Funding was lost.

Phase II of the Tucurui Hydropower Complex, and the consequent modifications in the reservoir scheme will change the morphometric characteristics of the lake appreciably over certain periods. Depletion of up to ten meters is likely as the reservoir is drawn down to 62m at its normal minimum– the outtake level for Phase II turbines.

Project Costs

The financial estimates for the Tucuruí Hydropower Complex went through a number of revisions prompted by design modifications, changes in external factors and the delays in implementation and financing. The debt-servicing component was most affected by delays in implementation. Interest during construction (IDC) made up 26.3% of the final cost of the complex. The table below contains a timeline of cost estimates for the project

Table ES.2: Timeline of estimated costs for the Tucuruí complex

(billion US$)	Feasibility study (1974)	Basic Design (1975)	Revision (1978)	Revision (1979)	Revision (1980)	Revision (1981)	Actual Cost (1986)
Without IDC	3.6	4.3	3.8	2.5	3.2	4.7	5.5
With IDC	4.2	5.8	4.3	2.9	3.7	5.4	7.5

The final cost of building the dam came to US $5.5 billion. Including IDC the total cost of Tucuruí was US $7.5 billion. This indicates a 51% cost overrun without IDC and a 77% cost overrun with IDC included as versus the targets laid out in the feasibility study. With the investment of some US $1.27 billion for the power-lines and substations needed to connect Tucuruí to power grids in north and north-east Brazil, the total amount reaches US $8.77 billion, not including interest on these latter investments.

The operations and maintenance costs for the project was initially estimated at 1% of the project cost per annum, a standard practice at the time in the Brazil power sector. The actual O&M costs for the project from 1995 to 1998 averaged US $13.8 million (1998 prices). This is approximately 0.25% of the US $5.5 billion final (without IDC) cost of the project.

The predicted cost for Phase II of the project is US $1.35 billion dollars and the finalisation of the lock system is predicted to cost an additional US $0.34 billion.

The funding for the project was drawn partially from Eletronorte, which contributed 45.7% of the total project costs (without IDC), and the rest from external sources. Of the external sources, Brazilian sources including Eletrobrás, banks and credit agencies contributed 40% of the funds and foreign banks and international credit agencies contributed the remaining 14.3% (rounded figures).

Hydropower Generation

This project was based on the principle that electricity-intensive industries would be eager to use energy from Tucuruí, due to its expected low cost. It was also felt that having serviced markets that were already virtually assured – such as Belém and Marabá – the remainder of the energy produced would meet repressed power demands in Pará, Maranhão and Tocantins States, in addition to the possibility of transmitting power to Northeast Brazil along a line running 1,800 kilometres between Sobradinho and Boa Esperança.

The different prediction for planned energy rating for the project resulting from construction specifications and demand parameters changes are listed in the table below.

Table ES.3: Predicted and actual power ratings for the Tucuruí Hydropower Complex MW)

ENERAM Inventory Study (1972)	Feasibility Study (1974)	Basic Design (1975)	Actual
2,700	3,040	Phase I – 3960 Phase II – 4125	Phase I – 4000 Phase II – not yet installed

The actual energy generation from the plant shows a steady increase from the time of commission in 1984 until 1999.

Table ES.4: Predicted and actual energy generation for the Tucuruí Hydropower Complex (GWH/yr)

Predicted annual production		Actual Average Annual Production		
Feasibility Study	Basic Design	1984-89	1990-94	1995-98
16,197	22,776	10,260	17,538	21,428

Approximately 60% of this energy went to large industrial consumers and the rest to distribution systems in the states of Pará, Maranhão, Tocantins, the Northeast and the South-Southeast system. The latter connection was initiated in 1999 connecting the North-Northeast system with the South-Southeast system via and greatly expanding the potential market for Tucuruí power.

Using project parameters, the initial capital investment in the project, a 50-year life cycle for the project and at discount rates ranging from 8 to 12% the present value of the costs over 30 years for Tucuruí Phase I comes to between US $40 and US $58 per MWh. In 1998 the average end price for the consumer in Brazil per kWh was US $70 implying the possibility of significant economic gains for the project. However, as a result of subsidised prices, large industrial consumers were able to purchase power at US $ 24 per MWh, and thus a financial profit was not realised. These figures suggest that as a whole, the large energy intensive industrial consumers received an annual subsidy from the government budget ranging from US $193 million to US $ 411 million in 1999 depending on the discount rates and productions costs adopted in the calculation. Eletronorte itself confirms that in 1998, it required a subsidy of US $194.2 million from the central government.

Navigation

Right from the start of discussions over the Tucuruí Project, the people of Pará State foresaw an association between these two projects (hydropower and shipping) as an opportunity to stimulate the local economy. To a large extent, the social and political receptivity to the Tucuruí hydropower complex at the regional level was based on the possibility of interconnecting these two ventures. In 1979, when the hydropower project was already at an advanced stage of implementation, the government decided to include the locks in the Hydropower Complex designs. Until 1984, work on the locks progressed normally, but then slowed down, hobbled by a shortage of funding, and finally ground to a halt in 1989. The remaining components for the lock system were slated to be implemented with Phase II of the project. However much uncertainty still prevails over Phase II construction schedule, with regard to the construction of the locks.

Effects on Ecosystems

The prevalent mentality towards ecosystems at the time of project design within the Brazil power sector was dominated by concern towards the effect of the ecosystems on the construction project instead of vice versa. It is apparent that the concept of ecosystem integrity was not a concern at that time, and this was further exacerbated by a lack of knowledge of the impact of dam construction on the environment. In 1977 Eletronorte hired ecologist Robert Goodland in an attempt to bridge this gap. He recommended that Eletronorte prepare a schedule for deforestation, social, cultural, environmental and archeological inventories together with animal rescue programs, ecological preservation measures, water quality controls and multiple use studies. In an effort to comply with these recommendations, Eletronorte signed an agreement with the National Research Institute for Amazonia (INPA - Instituto Nacional de Pesquisas da Amazonia) and entrusted them with the responsibility of carrying out most of the studies recommended.

Since it was commissioned two years after the start of construction on Phase I neither the Goodland report, nor the subsequent studies spurred by it, had sufficient scope to enact significant changes. The period allocated was not sufficient to cover the entire area or to conduct an accurate and representative taxonomic identification of species. The capacity to develop detailed inventories and accurately forecast impacts were compromised. Nevertheless, some forecasts were made and when forecasts are referred to in the following section they refer to those made either by the Goodland report or by the INPA studies.

Water quality. An appreciable drop in the quality of water downstream was forecast. Studies carried out downstream during the 1986 dry season showed very low levels of dissolved oxygen in the water, made worse by low flow-rates. Under these conditions, there were two different types of water flows in 1986 along a stretch of river some forty kilometres long: one flow near the left bank was completely anoxic due to the hypolimnetic nature of the tailrace, while the spillway water had higher oxygen levels. During low flow-rates most of the water is discharged through the tailrace and the quality was of reduced quality for human and environmental uses.

The regularisation of the river flow prevented the seasonal flooding of the riverbanks downstream adversely affecting the natural fertilisation processes. In addition, it was anticipated that the physical barrier of the dam would trap nutrient rich organic matter disrupting the downstream food cycle. The aforementioned impact decreased the natural and agricultural productivity of the flood plain where as the dearth in organic matter had a likewise impact on the number of fish downstream.

Within the reservoir, in relation to the parameters specified by the National Environment Council (CONAMA – Conselho Nacional do Meio Ambiente), the waters are considered of adequate quality for a variety of uses. However, the riverbank sections, most accessible for daily use by the local communities, are not always adequate for human use. Water quality studies indicate that there is trend a towards stabilisation in reservoir water quality.

The eutrophication of the reservoir water immediately after flooding due to the decomposition of the submerged plant matter and leaching of nutrients from flooded riverbanks resulted in a marked increase in the number of floating aquatic macrophytes, covering nearly 25% of the reservoir surface area. The most critical problems with this proliferation were the marked increase in population of mosquitoes and hindrances to navigation and shipping. By 1994 the area covered by aquatic macrophytes decreased to 10% of the reservoir surface area.

The increase in the prevalence of mosquitoes was anticipated due to the filling of the reservoir and the proliferation of aquatic macrophytes. During the years after the reservoir was first flooded, an increase in the number of cases of malaria was noted, which is transmitted mainly by *Anopheles* mosquitoes. A large number of local people also complained that a large increase in the frequency of insect bites (by mosquitoes etc.) was hampering their farming activity during the day. In response, a multidisciplinary and multi-institutional committee was set up to address the problem. Analysing the proliferation of mosquitoes at the Tucuruí Hydropower Complex during the post-filling phase, it was noted that initially there was an appreciable increase in *Anopheles* genus species after the river was dammed in October 1984. During this period, 68,532 *Anopheles* specimens were collected, a figure far higher than that found during the pre-filling phase. Subsequently, a significant increase was recorded in the population of *Mansonia* mosquitoes, whose number are documented to be positively correlated to the proliferation of certain aquatic macrophytes. With the decrease in the reservoir surface area covered by these plants, a decrease in the abundance of mosquitoes was also observed. In a 1990 survey *Mansonia* mosquitoes topped 97% of total culicid catches in the area, compared to a 2.3% share for *Anopheles*.

Fisheries. Although significant fish mortality rates were expected immediately following the initial flooding of the reservoir, information was not available to accurately anticipate the subsequent affects of the dam on the river fauna.

After the initial halting of the river flow, fish deaths occurred among the shallow reaches downstream but were not of the extent expected. Three months later large-scale fish mortality, caused by the tailrace water, was observed including among large schools of migratory species. Even when better quality water was released from the spillways, such large-scale fish deaths were common due to the poor quality of the water from the tailrace. Experimental catch data show the diversity of species of the downstream section was reduced from 164 to 133 (a 19% decline). In part, this was also attributed to the regularisation of the river flow and the subsequent disruption of the floodplain ecosystems. The ubarana (*Anodus sp.)*, a commercially significant fish species, faced near local extinction in the downstream area. As anticipated, the reduction in diversity and the episodes of fish mortality resulted in marked reduction in downstream fish catches for the local population with catch data showing a steady decline from 1981 to 1998.

High fish mortality rates were observed within the reservoir area as well, after the initial closing of the dam. This was as a result of a number of factors, including a) the highly oxygenated ecosystem of the waterfalls which was an important habitat for the juvenile of many species, was inundated by the reservoir, b) as the water rose and the currents slowed the amount of dissolved oxygen fell c) the diversity of niches was reduced and d) the lack of oxygen in the deeper levels due to the decomposition of submerged organic matter. An eventual increase in fish catches was expected due to a widespread proliferation of pelagic species, together with herbivorous and peryphytiverous species in the riverbank areas. In contrast only the piscivores species increased from the pre to the post filling stage, all the other food chain categories were less abundant. Overall the reservoir area saw a reduction from 173 to 123 species (a 29% decline) in the number of fish species from the baseline.

No specific forecasts were drawn up for the region upstream from the reservoir but changes were anticipated to be caused by the flight of species from reservoir area to the unaltered regions upstream.

In experimental catches before and after the filling of the reservoir, of the ten most frequent species sampled before filling, only 5 species were found after filling. The total species composition of the upstream reaches showed a decline of 25%, from 150 to 113 species after filling.

Fish productivity data from the mid-1990s show that the total recorded fish catch increased by over 200% as a whole for the affected area (upstream, reservoir and downstream). The reservoir area catch increased by 900% whereas the downstream fish catch decreased by 45%. In total the number of species sampled declined from 181 to 169, a 7% decline.

Terrestrial Impacts. The submersion of 2,850 km^2 of land including large areas of rainforest for the reservoir was expected to have a significant impact on the land-dwelling and arboreal fauna of the area. To address this concern a Wildlife Working Group (GT Fauna) was set up to prepare the Wildlife Development Inventory Plan (PIAF – Plano de Inventário do Aproveitamento da Fauna) for the Hydropower Complex region. They were designed to produce a basic list of vertebrate species found in this region, including land and aquatic mammals. The total number of species recorded at Tucuruí during the implementation of this Plan reached 120. In the final report published by the working group it was suggested that protected areas capable of maintaining viable communities be established together with a permanent wildlife study group. In some cases increased monitoring activities were suggested with specific bans on hunting and poaching. Subsequently a wildlife rescue operation known as Operação Curupira was initiated to capture, triage and resettle animals forced out of their natural habitats. This was the largest and the most expensive wildlife rescue carried out in Amazonia with a total investment of US $30 million from Eletronorte. This operation resulted in the capture and release of some 280,000 animals. The animals were released in four areas along the banks of the reservoir.

Greenhouse Gases. Sampling of greenhouse gases (GHGs) shows that the Tucuruí reservoir emits substantial amounts of greenhouse gasses and that the emissions are highly variable from year to year. The gross greenhouse gas emissions measured by Rosa et al. for 1998 and 1999 fluctuate from 76.36 to 5.33 tons/km^2/year for methane and from 3 808 to 2 378 tons/km^2/year for CO_2. When compared with GHG emissions for alternative sources of electricity generation the sampled gross emissions from Tucuruí are lower than those for diesel, heavy oil or coal, but of comparable magnitude in the case of natural gas combined cycle plants. However, some theoretical studies reported in the literature present an opposite view and provide higher estimates of gross GHG emissions from Tucuruí. There are no definitive conclusions as to how the net emissions from the reservoir compare with those of alternatives, since pre-impoundment background emissions were not measured and information is not available on how these emissions have (and will) vary over time.

Potential Phase II impacts. The implementation of Phase II of the Tucuruí project is likely to result in additional environmental impacts with reduction in water volumes triggering a number of processes related to the exposure of the banks. Exposed banks may erode or be turned into cropland resulting in the flow of fertiliser, pesticide, and erosion sediments into the lake, exaggerating some of the earlier mentioned effects. The new operating rules for Phase II will however, reduce the time spent by water in the reservoir. Therefore it is possible that the reservoir water quality will improve through more frequent renewal of its liquid mass, reducing the severity of the adverse effects mentioned earlier, although an increase in the portion of water discharged through the tailrace might further reduce downstream waterquality. But, it should be noted that since the phase II turbine intake point is 10m above the phase I intake point, the water leaving the tailrace is likely to be of better quality.

Social and Economic Impacts

The construction and operation of the Tucuruí Hydropower Complex triggered sweeping changes in the social and economic structure and organisation of the segments of society affected directly and indirectly. The severity of the impacts was far greater than initially foreseen.

The possibility of gaining construction or related employment attracted large inflows of migrants increasing the population of the immediate area six-fold. Overall the area doubled its population in ten years, severely straining the social infrastructure of the area and resulting in the emergence of slums (favelas). During the resettlement process, over 14,000 people formerly resident in the areas inundated by the reservoir were relocated in the adjoining areas further aggravating this problem. These mandatory relocation programs and economic migrations adversely affected the structure of lifestyles, social, economic and cultural organisation of rural groups. The establishment of a number of new administrative units and the restructuring of existing towns and villages were carried out to accommodate the displaced and immigrant communities.

A number of displaced people, estimated to be around 3,700, colonised the myriad of islands that were formed by the hilltops when the reservoir was formed. There was no infrastructure on these islands and the lack of tenure was a disincentive for further improvements. In the summer the only water source available was the reservoir, even for drinking. The lack of sanitary infrastructure, clean drinking water and the use of smudge pots to ward off mosquitoes rendered them vulnerable to diseases such as malaria, diarrhoea, verminoses and respiratory problems. In addition these island dwellers were harassed by the former owners of these lands and by loggers.

A subsequent social upheaval was triggered by the completion of the Phase I of the project in 1984. A number of people lost their employment resulting in mass unemployment and out-migration from the area. This backflow extended through 1987 when the population began to grow again especially around Tucuruí through new activities springing up in the trade and services sectors. The infrastructure in the area did not keep pace with these new arrivals. Although the communities around the area expected the project to catalyse the development of the area, these communities living in the shadow of a large hydropower complex did not receive electricity from the project until 1997, when, due to increased pressure from local groups, a step-down substation was constructed to serve the town of Tucuruí. In fact the construction of the Tucuruí prompted expectations that, in addition to Greater Belém, the lower Tocantins region would be supplied by power from the high tension line cutting through this area. However, by June 1998, only the towns of Barcarena (were the aluminium smelter is located) and two other towns were connected to the power grid.

Although the downstream communities did not have to face most of the direct impacts of the process, a number of indirect impacts affected them. Some of these include the disruption of fishing activities due to water quality and quantity changes, disruption of trading activities due to shipping problems, changes in farming activity and the increased health risks similar to those faced by communities adjacent to the reservoir and upstream.

The Resettlement Process

In order to build the Tucuruí Hydropower Complex, Decree No. 78,659 dated November 11, 1976 declared an area to be of public utility for the purposes of expropriation, consisting of a polygon that covered part of the municipal districts of Bagre, Itupiranga, Jacundá, Marabá, São Domingos do Capim and Tucuruí, all in Pará State. In 1979, Eletronorte signed an agreement with INCRA to analyse the compensation payable on the lands and improvements to be affected by the formation of the Tucuruí reservoir, as well as for resettling local communities. The decision process was handled solely by the INCRA with the affected communities merely forced to accept compulsory relocation and arbitrary compensation. These facts triggered latent conflicts and clashes between Eletronorte and the affected group including riverbank communities, settlers from the Transamazon Highway, and urban dwellers from the towns of Jacundá and Repartimento.

The criteria for assessing assets for compensation purposes took only material aspects into consideration, neglecting to include the value of work invested in the land, as well as affected and symbolic values, meaning the cultural logic, and social and historical conditions of local communities. Anyone who did not accept these compensation criteria, or the areas to which they were allocated for resettlement, was urged to sign a waiver. The resettlement process took place late and in a very limited manner with little or no consideration given to the livelihood patterns of the families. This negligence was evident when riverbank communities were resettled inland and when the extractive communities were settled in lands requiring farming.

From the perspective of the affected communities the lackluster performance of the dam authorities in the resettlement process, the outstanding issues and hardships facing the affected people and the consistent delays in government redress resulted in the formation of a number of collective organizations to address these issues.

From Eletronorte's standpoint, the relocations and resettlements were carefully thought out and coherent with regional conditions. They were implemented in partnership with other local and Federal Government agencies, in ways designed to minimise the traumatic effects on resettled communities, while also maintaining conditions for farming and ranching production, as well as inserting those expropriated into the same rural context where they lived previously. The relocation and resettlement projects were based on the active participation of society, such as professional organisations – associations and unions – as well as religious and philanthropic entities such as the Church and Universities. The final assessment by Eletronorte is that the procedures adopted were properly conducted, compared to the practices of power sector utilities at that time, with all commitments fulfilled.

The existence of sectors that are still today dissatisfied with the compensation policies indicate the consequences of the official attitude that denied any conflicts of interest in relation to this project, in the name of a "general interest" defined by "higher levels". The lack of any clear-cut sectoral policies for dealing with social issues meant that the compensation criteria for the segments of society affected by this venture were gradually established in parallel to the displacement and resettlement processes, under pressure from organised grassroots movements. Statements by the river-bank communities – although putting forward perceptions and points of view that at times differ – indicate that the advent of this dam caused sweeping alterations in their lifestyles, either directly or indirectly, while undermining their means of survival. They confirm and reaffirm the urgency of investigating the nature and scope of the impacts caused by the construction and operation of this power plant.

A figure for the total number of people displaced is hard to come by since different reports produce varying numbers but it is likely that the numbers are between 25,000 and 35,000. This is in comparison to the projected relocation of 1750 families in the basic project design.

Continuing problems and inadequacies in the relocation process resulted in mass demonstrations starting in 1981. After considerable pressure, Eletronorte established a parity committee in order to initiate dialog with the grassroots movements involved in the demonstrations. The committee considered the 2 247 cases submitted and resolved 2 121 of these cases. As a result of further lobbying by the grassroots movements an interministerial committee was set up in 1994 to address a number of issues including the remaining 126 cases. The leaders of the grassroots movements state that some of the claims have still not been addressed adequately and that they have been referred to the courts.

Health Impacts

The local health impacts of constructing the Tucuruí Hydropower Complex are significant and mostly negative.

The increase in population caused by the influx of immigrants resulted in a marked upsurge in the incidence of vector transmitted diseases such as malaria, schistosomiasis, etc, as well as industrial accidents, alcoholism, sexually transmitted diseases and AIDS. In 1980 during the implementation stage of the project the infant mortality rates for the Tucuruí municipal district was more than six times of that for the rest of Pará State and nearly five times the infant mortality rate for the whole of Brazil.

The use of defoliants by the Eletronorte sub-contractors from 1980 through 1982, hired to clear paths for power lines, is believes by some to have had a health impact on the communities living in the area. The use of these herbicides caused much controversy at the time, due to claims that their composition was similar to that of the defoliant known as Agent Orange, notorious for its use by the US military in Vietnam. Although toxic, these products were authorised for use by the Brazilian Government, and did not contain the amounts of dioxin that made Agent Orange highly poisonous to human beings.

In areas where these herbicides were used, there were also allegations of widespread deaths among animals and plants, with contamination of wells, inlets and people of all age groups, in addition to reports of miscarriages and symptoms compatible with acute exogenous intoxication: headache, vomiting, dizziness, ocular erythema and sluggishness, followed by hematuria, oliguria and anuria, fever, seizures and tremors, with death in some cases. Eletronorte in their "Livro Branco sobre o Meio Ambiente na Usina Hidrelétrica de Tucuruí" (White Book on the Environment of the Tucuruí Hydropower plant), officially denied all these impacts.

As was mentioned earlier the establishment of the reservoir and the related works resulted in an explosive outbreak of mosquitoes and other insect vectors and pests. In the Tucuruí region, the rise and fall of malaria outbreaks coincided with the construction and operation phases of the hydropower complex. From 1975 onwards, an explosive upsurge in malaria was noted in the Tucuruí Municipal District that extended throughout the entire construction period. As this phase drew to an end in 1984, malaria peaked at around 10,000 cases per year. From 1998 onward, news of the start-up of Phase II of the Tucuruí Hydropower Complex once again drew heavy flows of migrants to this region, already reflected in an upsurge in the number of cases of malaria.

The proliferation of certain aquatic macrophytes is closely related to the incidences of outbreaks of *Mansonia* mosquitoes, the main disease vector for filariasis (or filaria). Therefore when favourable conditions were created for the abundant growth of these water plants, the communities adjacent to the reservoir reported excessive numbers of these mosquitoes. The menace from these insects increased to such a degree that it impeded the day to day farming activities of the communities resulting in the migration of some groups into other areas.

A study on the origins and effects of mercury in tropical reservoirs was conducted in the environs of the Tucuruí reservoir by a group of Finnish scientists. Their findings indicated that on average the mercury levels among the local community members for whom fish from the lake is a significant source of food, was close to the low risk level for neurological damage. Their levels were significantly higher when compared to those of other communities with less reliance on reservoir fish. Although gold mining in the basin was found to be the primary source of mercury found in the reservoir, it is known that dams concentrate mercury already present in the water and that the increased human activity in the area contributed to an increased release of mercury into the water. Most of these results were widely disseminated with a variable degree of accuracy by national and local press at the time of their publication, raising concern among the populace.

Eletronorte however has queried the validity of these studies and as of yet there is there is no definitive proof of impact of the Tucuruí reservoir on mercury concentration levels.

Indigenous People

The Parakanã and Asurini indigenous groups and the "Gavião da Montanha", a local group belonging to the Parkatêjê were affected by the construction and operation of the Tucuruí Dam.

The Parakanã: By the late 1970s, construction of the Tucuruí Hydropower Complex flooded 38 700 hectares of the Parakanã Indigenous Reserve. This led to the removal and relocation of the Eastern Parakanã who lived in three villages in the eastern section of the reserve, as well as the Western Parakanã who live in two villages partly outside the reserve. This involved the relocation of about 247 people (1986 data), all of the known Parakanã. Eletronorte signed a contract with FUNAI (National Indian Foundation) and entrusted them with the task of relocating the Parakanã people. The resettlement process was rife with delays and inadequacies. The indigenous group was split up and relocated several times (some groups as many as four times in a span of 5 years) which eventually resulted in the break-up of the unit and some of them migrated elsewhere due to the unsuitability of the resettlement areas. After repeated attempts at gaining redress for their grievances, the Parakanã in August 1986, threatened to block the Transamazon Highway and employ terror tactics. Negotiations began in Brasilia in November 1986 over what was to become the Parakanã Programme. This programme, an attempt to assimilate the Parakanã in to the mainstream culture, consisted of sub-programs in education, health care, agricultural support, border surveillance, works and infrastructure and administrative backup with a total budget of US$740 000 in 1998. The largest component of the project was a health programme aimed at providing the community with access to emergency and longterm medical care. The border survailance programme consisted of telephone communication links and training of Parakanã youth to identify and resist encroachment. The programme contributed to the expansion of the Parakanã, and their establishment of new villages, which, parallel to their traditional hunting and gathering activities, has been important in maintaining the integrity of the Parakanã Indigenous Reserve.

The Asurini: The Asurini live on the Trocará Indigenous Land just 23 kilometres north of Tucuruí along the Transcametá Highway which runs through the indigenous lands located downstream from the Tucuruí Hydropower Complex. In 1977, these lands were demarcated by PLANTEL (a private company hired by FUNAI), assuring the Asurini a territory of almost 22,000 hectares, which was ratified in November. Located downstream for the Tucuruí dam, the Asurini were exempt from most of the direct impacts of the complex but were subject to a number of indirect effects that had significant impacts on their community. The arrival of large number of migrant workers and well as the resettlement of dam affected people were factors that affected the Asurini and their lands.

In 1998, as part of the actions scheduled for development with the indigenous groups affected by the Tucuruí Hydropower Complex, Eletronorte's advisor on indigenous affairs visited the Asurini and drew up a report stressing the need to carry out further studies on the impacts caused by the Tucuruí Hydropower Complex. The FUNAI requested Eletronorte to set up a working group to study these impacts and establish a support programme similar to that introduced for other groups that the utility considered as being directly affected by this venture (Parakanã Programme and Waimiri-Atroari Programme). Eletronorte argued that "due to budget difficulties" this Project should be postponed to early 1990, at which time they wrote to FUNAI, advising it that "it was still not in an administrative and financial position to start the studies".

In the 1970's an overland route to connect Tucuruí with Cametá was started, cutting through nine kilometres of the Asurini Reserve and in 1997 Eletronorte contemplated running a power line also through their reserve. In both instances the Asurini resorted to the destruction of public infrastructure in order to register their protest. Although in response, the path of the power lines were changed, the road was ultimately built and the Asurini have not been compensated as of yet.

The Gavião da Montanha: Currently living in a single village in the Mãe Maria Indigenous Land, the so-called "Gavião da Montanha" are a local group of the Parkatêjê (a Jê-Timbira speaking-group), also known as the 'Gavião' or 'Gaviões', who have traditionally lived on the right bank of the mid-Tocantins. Until 1973, the members of this group were settled in the indigenous area that had been awarded to them adjacent to Tucuruí.

This area was selected as the works-yard for the construction of the dam and was declared to be a "public utility" through Presidential Decree in 1976. From 1975 onward, the "Gavião da Montanha" were treated as "remaining" by the official agents, and were persuaded to move to other areas and the Mãe Maria Indigenous Land, despite rivalries with the group living there. Although limited in numbers, this group was most unwilling to leave the location where it had settled. In the mid-1970s, pressure from the FUNAI agents was stepped up by threats from the representatives of Eletronorte, the State-run enterprise and the sub-contractors who were starting to build the Tucuruí Dam. Despite specific legislation (Law No 6,001/73, known as the Indian Act) that guaranteed the replacement of these lands, countless attempts were made by employees of the Company to offer individual compensation to the leader of the group in attempts to convince him to move his group away from the location. The accounts told by the members of this group about this period reflect the various incidences of violence to which they were subject to. Psychological pressures and threats of physical violence built up, finally forcing them to move to Mãe Maria.

At meetings with representatives of Eletronorte and local and regional agents of FUNAI, it was agreed that the Gavião da Montanha lands should be replaced through legal means, in addition to a process of compensation for moral and material losses, damages, injury, pain and suffering. Claiming the "unavailability of equivalent lands". Eletronorte agents decided to turn this proposal into an award of rights to the "Parkatêjê Community" by Eletronorte, by means of equivalent cash compensation paying the amounts stipulated and concluding this issue.

Dissatisfied with the procedures adopted both by the Company as well as FUNAI, the leader of the directly affected group, sued Eletronorte and the Federal Government in 1989 for compensation, through the Pará State Society for the Protection of Human Rights (Sociedade Paraense de Defesa dos Direitos Humanos) in order to annul the agreements and compensations. In December 1993, the Federal Courts in Belém, where this case was heard, handed down a decision in favour of the Eletronorte.

Regional, National and Global Effects

At the regional level, Tucuruí was an integral part of the introduction of a modern industrialisation process (mining and metallurgy) into an area formerly dominated by an extractive economy. This resulted in an enclave model that shaped urban growth and underpinned the expansion of small-scale industries, particularly in the Belém region. These enclaves are characterised by the fact that energy from the Tucuruí hydropower complex was available only to selective industries and their immediate surrounding therefore creating distinct enclaves of development in the area.

The migratory labour attracted by the implementation of the dam and the relocation of dam affected people resulted in the urbanisation of the many areas heretofore rural or forested. This urbanisation process was not accompanied by the provision of adequate infrastructure or electricity.

Within this context, Tucuruí is an integral part of the changes in this region, together with projects such as the Transamazon Highway, the Greater Carajás Mining Project, Steel Complexes, the PA-150 Highway, giant farming and ranching projects run by the private sector, etc. Consequently, it is quite impossible to separate out the specific influences of Tucuruí among those of other projects in this region. Expect for some changes associated with specific groups and sectors, a quarter of a century after the construction of this Hydropower Complex, the local and regional economic profile seems mostly unaltered, confirming the evaluation of the low capacity of the Tucuruí power project to foster local and regional development.

At the national level the interconnection with the North/Northeast System through the Tucuruí-Sobradinho power line (1981) was an achievement of strategic national importance. The inauguration of power production enabled Tucuruí to replace thermo-power plants in the Northeast that were providing power to the industries in Belém at a higher cost. In 1998 with the integration to the South/Southeast System through the Tucuruí-Serra da Mesa power line, electricity was sold to Southeast Brazil which has the most dynamic economy in the country. With these integrations into the national power grid, the Tucuruí emerged as a key link in the Brazil energy market.

The implementation of the Tucuruí hydropower complex was a factor in the regional and national policies influencing the globalisation process of Brazil. The presence of mining and metallurgical industries in Eastern Amazonia has fostered this process in three ways;

- In light of the economic crisis in many developed nations, low investment opportunities and subsequent low interest rates, during that time, large infrastructure projects in countries such as Brazil provided attractive investment opportunities.
- With favourable economic conditions and subsidised inputs the state mining company Companhia Vale do Rio Doce CVRD was able to develop into one of the worlds largest iron ore producers with international investments.
- The provision of cheap subsidised power provided incentives for the migration of energy intensive metallurgical industries from developing countries burdened with high energy prices into Brazil.

The globalisation process was evident in this sector with the involvement of trans-national corporations from countries such as United States, Canada, Japan, France etc.

Distributional Impacts of the Tucuruí Hydropower Complex

When the decision was taken to build a power plant in order to underpin the development of the local mining and metallurgical industry, the preliminary distributive effects soon became apparent. The main "beneficiaries" of this process in terms either of quantity of power furnished and tariff paid would be large international aluminium industries (based in Japan, Canada and the USA) and Companhia Vale do Rio Doce (CVRD), and consequently related sectors of the national and regional economy. At a secondary level, initially Northeast Brazil would benefit from the power supplied by the Tucuruí hydropower project, in addition to the towns of Belém, São Luiz and Marabá, extending later to Eastern Amazonia. Finally, the decision-makers believed at that time that the local populace would have no net losses or gains, as communities would be compensated and properly relocated.

The gains for major industries were confirmed, but without widespread positive effects expected for the national and regional economies. Regional development was isolated to enclaves surrounding metallurgical industries. Pressures from its international partners forced Brazil to make concessions, particularly in terms of low energy prices, adversely affecting economic gains at the national level, with little or no return for the region. In counterpart, the power supply functions of the Tucuruí complex expanded rapidly, as it grew into a key link in Brazil's hydropower system and consequently the national economy. Today, about 97% of Pará State and 100% of Maranhão State power demand is supplied by Tucuruí.

Power supply for the localities closer to the Dam, however, was virtually non-existent until 1998/99, when the Tucuruí Linhão power-line reached the towns of Altamira, Santarém and Itaituba and a power line that reaches part of the downstream region was built.

The main "losers" were without doubt segments of the local population – small farmers, indigenous communities and riverbank dwellers whose homes and livelihoods and health were adversely affected by the project. Some of them were subjected to poorly implemented relocation and resettlement processes with inadequate compensation payments, causing material and cultural losses. It should be noted that this process was not homogeneous as well: the downstream populace was not offered mitigatory measures, while the Parakanã indigenous community was awarded a broad-ranging program offering reimbursement for losses and damages, while major land-owners in the Caraipé valley were properly compensated.

Options Assessment and the Decision-Making Process

Four factors heavily influenced the development of hydropower potential in Amazonia. First, the oil price hike in the 1970's provided an incentive for many industrialised countries to shift their primary mining activities to developing countries with cheaper sources of energy; second, the world wide economic recession enabled countries to obtain international loans at low interest rates; third, the development paradigm in Brazil at that time promoted vigorous state intervention and national integration and, fourth, the state drive to nationalise the energy markets dominated by foreign concessionaires. The rapid settlement of Amazonia on a vast scale was considered a top priority for economic, political and national security reasons. With this background the government made provisions for building 79 hydropower plants by 2010, many of them in Amazonia. This led to the launching of the Tocantins Basin Inventory in 1972 and the creation of Eletronorte in 1973, essentially to develop the Tucuruí complex.

The Tucurui Hydropower Complex thus dates back to the "infancy" of sectoral planning. Planning was restricted to a mere procedural or methodological approach that was essentially sectoral, stressing the stages of the study and their respective minimum contents, providing feedback for a decision process where servicing the power market was always the immediate main purpose. Nevertheless, the history of planning in this sector features a number of cases where strictly technical and economic logic was supplanted by political decisions.

The principle that water should be used for multiple purposes, associated with the integrated use of other natural resources, has long been included in Brazil's national development plans. However, it has produced few definitive results. This is due largely to scattershot sectoral priorities, and short-sightedness on the part of both the Federal Government and the sectors involved, as they seem unable to make good use of complementary effects and opportunities for maximising the planned benefits through well-coordinated, multi-sector actions. This explains why the shipping route and lock at Tucuruí were included in the hydropower project only when it was already at an advanced stage. In the same manner; although the principle that all planning should be socially acceptable is explicitly stated in Brazil's national development plan, no vertical communication mechanisms were ever established to ensure that the large development plans coincided with social needs and priorities and the included public opinion.

Inventories of the Tocantins river basin in order to evaluate hydropower production potential were carried out in 1963, 1969 and in 1972. In 1973 funding was requested from ministerial level for the construction of a hydropower dam. Although there was no definite site, two sites were identified (on of them near the town of Tucuruí) as the most favourable sites. By December 1974 two private Brazilian firms concluded the feasibility study for a dam at Tucuruí. The final order for building the dam at Tucuruí came directly from the then military leader of Brazil.

The operation of the Tucuruí hydropower complex is still carried out with a minimal mandate. It is operated with the solitary goal of producing the maximum amount of hydropower possible with little concern for other uses or users of the water.

The decision to build Phase II of the project was taken by Eletronorte under the context that it is merely a continuation of the previous project not warranting separate impact assessments or consultations. The state of Pará environmental authority concurred and exempted Eletronorte from conducting a formal EIA. Affected people movements and international NGOs who state that the new operating rules of Phase II will result in adverse effects contested this ruling. They contend that the changes should be evaluated in light of the new social and environmental condition of the region.

Criteria and Guidelines: Policy Evolution and Compliance

The Legal and Institutional Framework

The legal framework of Brazil's electricity sector in the 1970s consisted of a State holding company: ELETROBRÁS - Centrais Elétricas Brasileiras S/A, and four regional utilities. Eletronorte (Centrais Elétricas do Norte do Brasil S/A) incorporated in 1973 was the last of these four and it serves as an ELETROBRÁS subsidiary in the capacity of a public power services concessionaire. Eletronorte was established and began operation in 1973. The operating area of Eletronorte covers all of legal Amazonia, 58% of the land area of Brazil, and currently includes the States of Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Rondônia, Roraima and Tocantins.

The policy environment in many sectors of Brazil is currently in a state of flux. Under a government decentralisation drive the electricity sector is undergoing modest reorganisation with the establishment of the Brazilian Electricity Regulatory Agency (ANEEL - Agência Nacional de Energia Elétrica) with a mandate to regulate the concession system for public power services. ANEEL, which is was still in the structuring phase at the time this report was written, is to be entrusted with the tasks of authorization, registration, environmental monitoring and evaluation of power plants.

The Evolution of Environmental and Social Policy

Although the current Brazilian environmental law is considered among the most complete in the world, consisting of standards regulating the use of environmental assets and activities that may affect them, as well as standards that introduce environmental protection tools, there was little restriction to Federal Government decision and actions at the time of the Tucuruí decision-making process. After the 1988 Constitution the situation has changed and it would be very difficult to repeat such a decision-making process today.

The construction and start-up of operation of the Tucuruí Hydropower Complex took place prior to the introduction of legal requirements for environmental licensing, under Brazilian environmental law. Nevertheless, some pre-existing legal requirements were not taken into consideration by the authorities and the entrepreneur, such as those covered by the Waters Code enacted into law in 1934, stipulating that hydropower venture should comply with requirements protecting general interests such as: (i) food and the needs of riverbank communities; (ii) public health; (iii) shipping; (iv) irrigation; (v) flood protection; (vi) conservation and free circulation of fish; and (vii) the outflow and disposal of water.

Environmental legislation in effect in Brazil since 1986 requires the approval of prior environmental studies for licensing new large-scale hydropower plants. The final decision on licensing is taken by the State Environmental Agencies only after public hearings are held with various segments of society, in order to discuss the conclusions of the studies. However, this process was not required for Phase II of Tucuruí, as it was considered merely an extension of Tucuruí I.

During its construction phase, measures to deal with social issues were implemented in a reactive manner by Eletronorte, lacking guidance from policies covering the resettlement and compensation for the communities affected, as well as for dealing with emergency situations.

Stakeholder Assessment of the Tucuruí Complex

One of the dynamics stipulated in the methodology of the World Commission on Dams was the completion by the participants of the consultative group, a questionnaire containing questions on the effective contribution of the Tucuruí Hydropower Complex to development. When analysing these results, it should be borne in mind that the number of people present was not a statistically representative sample of the population of social agents involved. Consequently, no statistical inferences should be drawn from these data. The results are summarised below by question:

1. Does the Case Study Preliminary Report undertake an adequate evaluation of the performance of the project in terms of its initial objectives?
   Most participants in the meeting selected the "I agree" alternative.
2. Is the Tucuruí project environmentally acceptable?
   Most people selected the "strongly disagree" alternative, followed by "disagree".
3. Has the project encouraged economic growth and generated wealth?
   The results of this survey indicated a split in the understanding of the role played by the Tucuruí Hydropower Complex as a springboard for the economic growth of this region. There was a virtual tie between the "agree" and "disagree" alternatives
4. Did the proponent comply with the national laws applicable at the time of the development, construction and operation of the project?
   Most people felt that it did not do so.
5. Did those in charge of the project adequately assess the options available at that time before taking the decision to build the dam?
   According to most of the participants in this meeting, those in charge of the project did not properly assess the existing options before taking the decision. But yet again, there was a provison that consideration should be given to the difficult period through which the country was passing.
6. Did those positively affected participate in the decision-taking processes associated with the project?
   About 60% of answers were "strongly disagree" and "disagree". About 24% of answers were "Agree" or "Strongly agree".
7. Did those negatively affected participate in the decision-taking processes associated with the project?
   Most participants opted for the "strongly disagree" and "disagree" alternatives.
8. Do the direct economic benefits generated by the project (electricity) justify the resources invested?
   About 60% of answers were "strongly disagree" and "disagree". Exactly 1/3 of answers were "Agree" or "Strongly agree".
9. Were the benefits deriving from the project fairly distributed?
   Most of the participants opted for the "strongly disagree" or "disagree" alternatives.
10. Did the benefits deriving from the project outweigh the negative impacts that it generated?
    This result was split equally between the "strongly disagree – disagree" and "agree" alternatives.
11. How would you classify the contribution made by the project to development?
    Once again, the replies were split between negative and positive.

Lessons Learned

This section presents the lessons to be learned from this Case Study, proposed both by the members of the team as well as the representatives of the different stakeholder groups who attended the meeting of the Consultation Group held in January 2000. These lessons are divided into general and specific lessons, indicated by the technical staff of the participant in the Consultation Group meeting.

1. Future hydropower projects should be implemented according to a new model, which includes regional and local development objectives right from the initial conceptualisation, rather than being limited solely to power generation for ventures producing benefits outside the region.

2. In order to implement new hydropower projects, studies of the hydropower inventory of the entire basin should be reviewed in advance, incorporating in the location and power choice of each power plant location assessments of the resulting social and environmental impacts of all alternatives.

3. The importance of a prior assessment process for the environmental impacts of various alternative sites demands the introduction and fine-tuning of new public participation mechanisms throughout all stages of large-scale dam design: planning, construction and operation.
4. The implementation of large-scale hydropower ventures requires a development committee to be set up for the entire basin, responsible for conducting the project and disciplining negotiations among the various social agents involved.
5. The criteria for defining the area directly affected by hydropower ventures should be reviewed, particularly those with the right to compensation or royalties. This should not restricted to the percentage of the area flooded, and should also introduce social control mechanisms for the allocation and investment of funding.
6. A lack of scientific certainty regarding the scope and relevance of the environmental impacts and risks of the venture cannot serve as an alibi for its failure to consider them, but should rather urge the adoption of the "precautionary principle" throughout all stages of the project: planning, construction and operation.
7. The lessons learned from the Tucuruí Hydropower Complex case study should be deployed during the planning, construction and operation of new hydropower projects in Amazonia, ensuring that they make a real contribution to the participatory and sustainable development of both the region and the country.

Lessons learned proposed by the participants in the final stakeholder meetings include:

1. Redefinition of the concept of the populace affected, ensuring that this is no longer restricted solely to the population living in the area to be submerged by the future reservoir.
2. Acknowledgement by the project entity that grassroots movements are the legitimate spokespersons for the definition of public policies in taking decisions that affect their lifestyles.
3. The project entity should start off from the principle that community perceptions of impacts affecting their lifestyles, even when lacking scientific proof, should be taken under consideration and be dealt with through social welfare measures and policies.
4. The knowledge already built up of the environmental impacts caused by large-scale hydropower projects should underpin the preparation of social policies for dealing with the associated social issues.
5. Access should be assured to technical information in language appropriate to the public domain, covering the project and its associated impacts.
6. There is a need to establish permanent channels of communication between the project entity and the communities affected by the venture throughout the entire project cycle.
7. Promoting integrated development actions for rural areas, stressing renewable energy projects and upgrading the quality of life for local communities, taking into consideration the fact that the urban populace has easier access to the benefits of these ventures, in addition to poor service levels in rural Amazonia.

Table of Contents

List of Appendices (English) and Annexes (Portugese)

List of Annexes in Portuguese

List of Tables

List of Figures

1. Overview of the World Commission on Dams Global Case Study Programme

The World Commission on Dams (WCD) was set up in order to deal with a key controversy in the worldwide discussion over sustainable development. The Commission offers a unique opportunity to focus on the many assumptions and paradigms underpinning efforts to reconcile economic growth, social equality, environmental preservation and political participation within a global context of change. In a frequently abstract discussion over the real meaning of sustainable development, dams offer a rare opportunity to discuss these critical issues as we move towards the 21st century.

From this standpoint, the general objectives of the WCD are:

- Review the contribution of dams to development and assess alternatives for the use of water and power generation; and
- Establish standards, guidelines and rules – when appropriate – that are acceptable at the international level for the planning, design, assessment, construction, function, monitoring and closure of dams.

One of the products of the WCD is a global review of the contribution made by dams to development. This contribution is defined in a broad-ranging manner, based on the relevance and suitability of dams as a response to the needs which prompted their construction (such as irrigation, power generation, flood control, water supplies, etc.). This definition also includes services and benefits, both forecast and actual, as well as costs associated with results, the distribution of gains and losses among the groups involved, and the general context of their construction and operation. This latter aspect is also related to the decision-taking process, checking the validity of the assumptions based on which the projects were initially drawn up.

With these purposes in view, several in-depth case studies are being prepared in both the more developed and developing nations, analysing dams built over the past few decades. The Tucuruí dam, built on the Tocantins River in Amazonia, was selected as one of these case studies. Completed in 1985, this is the first large dam built in a tropical rainforest, and one of the largest in Latin America.

The main objective of this study is to assess the past experience of the Tucuruí dam (Tucuruí Hydropower Complex, Brazil) in terms of its performance and contributions to development, seeking to identify the main lessons learned with regard to the planning, implementation and operation of the project.[1]

The common methodology adopted by the WCD for these studies calls for the organisation of data collection, with discussion and analysis of the information available on six key issues:

How were the main decisions taken during the project cycle?
What were the expected benefits, costs and impacts, compared to the current actual effects?
What unexpected costs, benefits and impacts were encountered?
What was the distribution of the costs and benefits; who won and who lost?
To what extent did the project meet the criteria and guidelines in effect at the time of the concession, construction and operation of the venture?
What are the main lessons learned from the experience of this project?

These questions, which are general in nature, are common to all the case studies and are adapted to the specific context of each case by defining the scope and discussions with the social players involved in the process. The main stages of the case studies consisted of:

- A brief institutional analysis identifying the various interest groups and institutions involved in and/or affected by the planning, construction and operation processes of the venture;

- Preparation of a Scoping Report, supplying basic information on the topics and issues to be studied in greater depth during the case study, as well as its contents and the approach to be adopted. This Report was analysed at the preliminary meeting of the Consultative Group composed of the main stakeholders identified and some invited experts;
- Completion of the studies scheduled for the Scoping Phase and the consequent preparation of a Preliminary Report with the results of these studies, which was submitted for analysis to the various social players and specialist stakeholders at the second meeting of the Consultative Group;
- The preparation of the Final Report with the final results of the studies carried out by the team and including the various views, suggestions and recommendations put forward at the second meeting of the Consultative Group.

This case study was prepared by Brazilian consultants under the supervision of the WCD Secretariat.

During the study preparation process, all reports were welcomed, whether from individuals or institutions, with comments on the project, as well as additional information. The various views, concerns and standpoints of the social players were recorded during the study, based mainly on listening to comments and reports from individuals, interest groups and institutions involved, and participation in the Consultation Group meetings.

The Working Group of the Tucuruí Hydropower Complex Case Study prepared the Reports using the methodology described above. In general, it followed the normal procedures for studies assessing the environmental and social impacts of projects. The initial Consultative Group meeting was held in Belém on August 9 and 10, 1999, to discuss the Scoping Phase Report. The Consultative Group then held its second meeting in Belém on January 18 and 19, 2000, and discussed the Preliminary Report, preceded by a Preparatory Meeting, held in Tucuruí on January 15 and 16, 2000, which gathered representatives of local social movements.

This Report is divided into seven chapters. Chapter 1 presents the World Commission on Dams and the purposes of the study. Chapter 2 outlines the context for this Case Study, offering a brief overview of its context and the characteristics and objectives of the Tucuruí Hydropower Complex. Chapter 3 offers a sectoral analysis of the performance of this venture from the standpoint of the expected and observed impacts, identified by the studies carried out by the technical staff and consultants, while Chapter 4 analyses the distribution of these effects. Chapter 5 describes the decision-making process which resulted in the construction of the Tucurui Hydropower Complex, and Chapter 6 analyses the development and compliance levels for pertinent legislation and policies. Finally, Chapter 7 lists the different views held by the wide variety of social players involved in this venture, listing a series of lessons that can be drawn from the experience of implementing the Tucurui Hydropower Complex.

2. The Context and Scope of the Case Study on the Tucuruí Hydropower Complex

This Chapter outlines the context of the Tucuruí Hydropower Complex, stressing its main characteristics and objectives.

2.1 The Environmental, Social and Economic Context

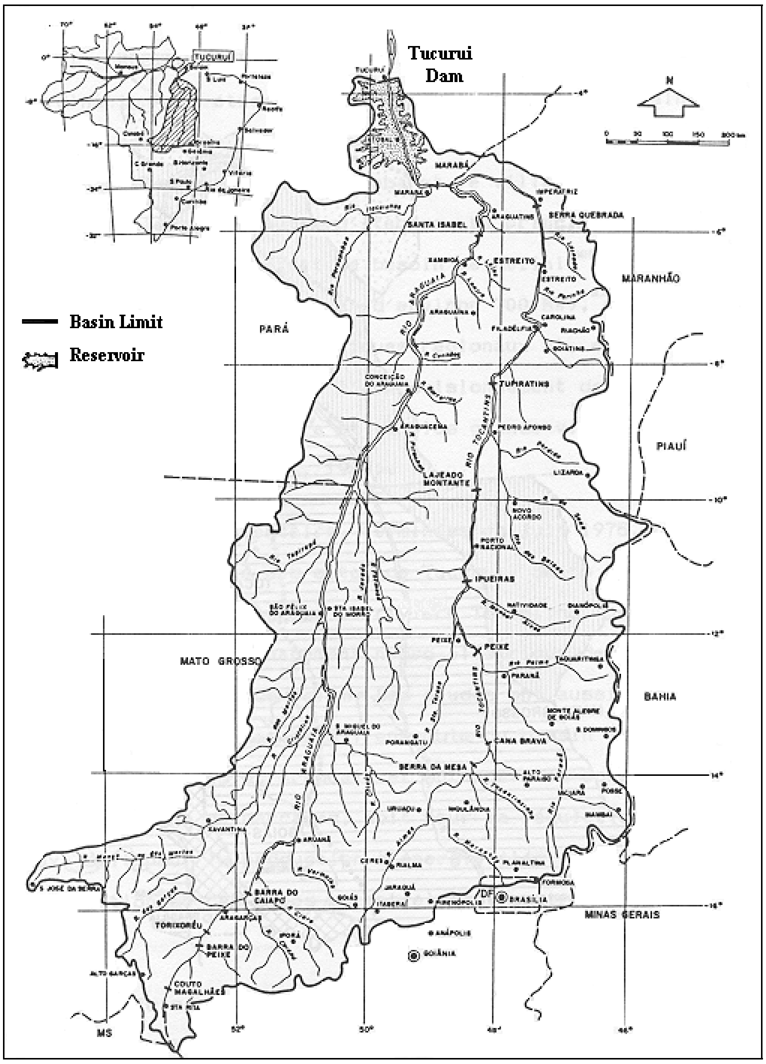
This Section locates the Tucuruí Hydropower Complex within its context, offering an overview of the placement of this venture from the environmental, social and economic standpoints

2.1.1 The Tocantins-Araguaia Basin

The Tocantins-Araguaia river basin is located almost completely between the 2nd and 18th parallels, at a longitude between the 46th and 56th meridians West (see Figure 2.1). Its elongated longitudinal configuration follows two major water courses – the Tocantins and Araguaia Rivers – which join on the northern border of the basin to form the Lower Tocantins, flowing into the Pará River, which in turn is part of the Amazon River estuary.

The Tocantins River basin has an average annual flow rate of 10,900 m^3/second, with an average annual volume of 344 km^3 and a catchment area of 758 000 km^2, representing 7.5% of the land mass of Brazil; the area of this basin is divided among the States of Tocantins and Goiás (58%), Mato Grosso (24%); Pará (13%) and Maranhão (4%), in addition to the Federal District (1%). It borders the basins of some of the largest rivers in Brazil: the Paraná in the South, the Xingu to the West, and the São Francisco to the East. Much of its area lies in Central-West Brazil, from the sources of the Araguaia and Tocantins Rivers through to their confluence on the border of Goiás, Maranhão and Pará States. From here on downstream, this river basin extends into Northern Brazil, and is limited to a mere corridor along the banks of the Tocantins River.

Figure 2.1 Location of the Tocantins – Araguaia Basin



Source: Eletronorte, 1987

2.1.1.1 Hydrography and Hydrology

The Tocantins river basin is formed by the hydrographic systems consisting of the Araguaia and Tocantins rivers, and their tributaries. Outstanding among them are the Mortes and Itaciúma rivers, both on the left bank of the Araguaia river. Running some 2 500km, the Tocantins River is formed by the Almas and Maranhão Rivers, which rise in the Goiás Planalto at an altitude of 1 000m in the heart of Brazil. Its main tributaries through to its confluence with the Araguaia River are (upstream to downstream): Bagagem, Tocantinszinho, Paranã, Manoel Alves de Natividade, Sono, Manoel Alves Grande and Farinha on the right bank, and Santa Tereza on the left bank.

The main tributary of the Tocantins, the Araguaia River is considered to be as important in the general context of the basin. It stands out due to its hydrological characteristics and its role in the process of settling these lands. It rises along the edges of the Serra do Caiapó range of hills on the state border between Goiás and Mato Grosso at an altitude of some 850m. With a length of some 2 115km, much of its course lies parallel to the Tocantins River, running north. These two rivers meet after forming the huge and mainly marshy Ilha do Bananal Island, which is 80km wide and 350km long. The confluence of these two major rivers takes place at an altitude of 70m. The Araguaia river flows into the Tocantins river near São João do Araguaia. Its main tributary is the Mortes river.

The average flow rate for this basin is estimated at 10 950 m^3/second, with the Araguaia River contributing some 5 500m^3/second, 450m^3/second from the Itacaiúnas River, and the Tocantins River contributing 5 000m^3/second before it meets the Araguaia. The average specific flow rate for the Tocantins River drops as far as Porto Nacional (Goiás), and then increases as it moves towards its confluence with the Araguaia, due to the heavy inflow from its right bank tributaries.

It is important to stress the even nature of rainfall distribution all over this basin, as well as the fact that some 30% of the rainfall drains away through its water-courses.

The Tocantins-Araguaia basin has a clearly-defined hydrological system. Its dry season culminates in September/October, with flooding that peaks between February and April (see Table 2.1). Along the Tocantins River, the highest figures are recorded each year in February/March, and in March/April along the Araguaia. This lag is due to the huge floodplains of Ilha do Bananal river island, which slow the progress of the floods.

Table 2.1 Average Monthly Flows of the Tocantins River at Tucuruí (m^3/s)

DISCHARGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVER.
AVERAGE	15 315	20 815	24 319	23 802	15 319	7 684	4 499	3 125	2 340	2 661	4 592	8 815	11 107
MAXIMUM	35 803	44 249	55 300	49 443	33 300	14 344	7 740	5 557	4 377	5 641	10 297	18 561	18 884
MINIMUM	5 590	7 197	10 317	13 463	9 074	3 923	2 276	1 655	1 320	1 267	1 714	2 761	6 068

Source: Eletronorte

The Tocantins river and its tributaries were originally ranked as nutrient-poor clearwater rivers, with low concentrations of irons and sediments.

2.1.1.2 Climate

The lengthy course of the Tocantins River basin is directly related to a configuration that extends latitudinally across South America, in addition to the steady presence of hot, moist, equatorial mainland air masses, which are associated with the intertropical convergence zone. These factors result in relatively homogeneous climate and weather, characterised by seasons which are repeated year after year with very minor variations in terms of temperature, rainfall, air humidity, sunshine, windspeed and other climate parameters.

North of the 6th parallel South, the climate is hot and humid, with annual average temperatures varying from 24ºC to 28ºC, peaking at 38ºC in August and September, and bottoming out in June at 22ºC. South of this parallel, the average annual temperatures drop gradually as the latitude increases. To the far South of this region, in certain areas, due to the orography of the Central Planalto, a tropical high-altitude mainland climate is found, with average annual temperatures hovering around 22ºC.

The wind system in this region is characterised by calms during much of the year and a lack of high winds, explained by its homogenous climate associated with its geo-morphology. The average monthly windspeed is around 1.3 m/s.

In terms of pluviometry, rainfall increases from South to North, ranging from 1 500mm to over 2 400mm. The region with the lowest rainfall is found to the West of Paraná (Goiás). Average annual figures drop West of Carolina (Maranhão), on the border with the Northeast region, reaching 1 700mm to the West along the Xingu River. Seasonal rainfall distribution is divided into two periods during the year: the dry and rainy season. To the far North, the dry season is limited to three months of the year (June, July and August), while throughout the remainder of the region it extends to between five and six months. To the South, the rainy season occurs from September through April, with a few dry spells between January and February known as *veranicos*, which are extremely harmful to temporary crops.

A peak evaporation hub is identified around Carolina, Pedro Afonso Nacional (Goiás). The figures drop towards the North, moving towards the Equator, and Southward towards the High Central

Plateau (Planalto Central). Based on the annual evapometric average for various regional latitudes (Equatorial, Transition, Tropical and High-Altitude Tropical), an average evaporation for the entire region of 905.8 mm is reached.

The area of the basin under study posts very high figures during the rainy season, with an annual average of approximately 76% throughout the region. To the North, relative air humidity exceeds 85% from December through May, falling below this peak during the remaining months but still at high levels. Throughout most of the region, below the 6th parallel South, the annual relative humidity hovers around 70%, with some extremely dry months (July, August) when this figure drops to between 40% and 50%, compared to figures of around 80% from December through April.

This region is typical of mainland latitudes in tropical regions, with no intense cyclones influencing it. Pressures are also evenly distributed due to the altitude, with an annual dispersion of around 5 millibars (mb) recorded throughout the region.

The regional sunshine measurements are not highly representative. However, the few heliographs installed record an average of 2 400 hours of sunshine/year.

2.1.1.3 Geology and Geomorphology

The Tocantins river basin is located completely within the geological province of Eastern Amazonia, characterised by distinct geological environments that have been shaped by the period in which they originated, as well as tectonic events. The area of influence of the Tucuruí reservoir is characterised by two major geological domains: a crystalline base consisting of igneous rocks and meta-sediments, and a sedimentary overburden consisting of sediments deposited during the Mesozoic and Cenozoic periods (Tertiary and Quaternary). The reservoir is located in the contact zone between the crystalline rocks of the Xingu Complex (left bank) and the low level metamorphic rocks of the Tocantins Group (left bank, riverbed and right bank).

The location where the Tucuruí dam was built is located at the end of a long stretch of waterfalls, and may be divided into three tracts: the Pará - Maranhão Southern Planalto; the Lower Amazon Planalto; and the Southern Pará Peripheral Depression. The latter covers almost the entire area of the reservoir. It originated through erosive processes dating back to the late Tertiary. There are various types of terrain in the region, particularly areas with flat soil surfaces, dried-out areas on flat-topped hills, and river plains.

2.1.1.4 Soils

The soils found in the Tucuruí Hydropower Complex region are acid and nutrient-poor, with low natural fertility levels. The main soil types in the region surrounding this venture are: Red-Yellow Podzolic (predominant); Red-Yellow Latosols and Yellow Latosols. The Red-Yellow Podzolic soils are located mainly on the left bank of the reservoir, covering over 60% of its area of influence; despite some constraints, they are favourable for farming activities. The Red-Yellow and Yellow Latosols cover some 25% of the area, and are located mainly on the right bank of the reservoir. Although poor in nutrients, they can be used for farming purposes when fertilised and correctly prepared.

2.1.1.5 Plants and Wildlife

The dominant vegetation over much of the basin under study is *cerrado* savannas, from its Southern border as far as Itaguatins (Goiás), on the Tocantins River, around Conceição do Araguaia (Pará); to the North, this becomes mesophilic forest, constituting a broad transition strip edging the Amazon rainforest itself. An exception is found in the Northwest Goiânia, and from there westwards, with the appearance of the seasonal semi-deciduous forests of Mato Grosso and Goiás.

Local variations in the density, size and composition of forest plantlife are at times due to localised climate variations (microclimates). However, these are usually related to pedological differences in the *cerrado* savannah environment, with frequent patches of more fertile soils originating from limestone base rocks or calciferous sediments.

Wildlife in the Lower Tocantins is considered among the richest and most widely diversified in the world. The habitats that constitute the Araguaia Tocantins river basins come from two major environments: Amazonia and the *cerrado* savannahs. The Amazon rainforest includes transition zones between Perennial and Sub-Perennial rainforests and the *cerrado* savannas, extending to the borders with the *caatinga* drylands of Northeast Brazil, taking into account its various levels of complexity.

Recent studies of Amazonia reveal that there are at least three times more plant species in the neo-tropical region than in the tropics of Africa and Asia. Primary forests in the Amazon environment shelter a wide diversity of wildlife whose survival strategies are well adapted to the forest environment. This includes phytophysionomic communities with specific ecological characteristics, providing a considerable range of niches that are occupied by a complex variety of animals.

A study carried out during the construction of the Tucuruí Hydropower complex estimated that this area was home to 117 species of mammals, 294 types of birds and 120 types of reptiles and amphibians. There are also several endemic species, rare or threatened with extinction. Outstanding among these are the miniature macaw (ararajuba) and the saki monkey. Species with synergetic value are also found, such as peccary, deer, alligator, curassow and tinamou.

2.1.1.6 Fishlife

The Tocantins-Araguaia river valley is home to some 300 fish species, with characinids (piranha), silurids (catfish) and cichlids (angelfish) predominating, with communities living in the Lower, Mid and Upper Tocantins. More detailed information on the fishlife in this region may be found in Section 3.5.9 and in the Annexes.

2.1.2 Historical and Cultural Aspects of the Settlement Process

Extractivism was the main economic activity in the Tocantins-Araguaia river basins. Dryland drugs, rubber, Brazil nuts, diamonds and gold are just some of the natural products that are abundant in this region.

As roads opened up access to this region during the second half of the 20th century, many towns sprang up due to better inter-regional connections, with easier access to steadily-expanding areas of farming and grazing. This took place on an extensive basis, without proper guidelines, and resulting in improper land use.

Since the 1960s, the laying of the Belém-Brasília highway, the implementation of large-scale projects (Tucuruí and Carajás), and more recently the establishment of steel-mills and electro-metallurgical plants, have all brought a rapid process of forest exploitation, particularly in the Middle and Lower Tocantins regions.

At the same time large-scale projects were encouraged by the Amazonia Development Superintendency (SUDAM – *Superintendência do Desenvolvimento da Amazônia*) characterised by vast estates and extensive beef cattle grazing.

In parallel to these ventures, integrated agricultural and agribusiness processing projects were also implemented. Some of them took over large tracts of land in the *cerrado* savannas for planting soybeans and rice.

The region where the Tucuruí Hydropower complex is built has undergone sweeping changes over the past three decades. These will be described from the social, economic and cultural standpoints, in the context of the historical process of settlement in this region. Our analysis will begin in the period immediately prior to the beginning of construction in 1975.

2.1.2.1 Extractivism

As in the rest of Amazonia, the initial exploration of the Middle and Lower Tocantins river was closely linked to extractivism. In a region lacking any road infrastructure, this produced a settlement pattern that followed its water-courses, resulting in a lifestyle typical of riverbank communities.

The river was the means of transportation that integrated extractivist activities with the regional economy, while also supplying food. In parallel, subsistence crops were grown, supplemented by hunting. During the first half of the 1970s, extractivism in this region focused mainly on Brazil nuts, using the rubber trade infrastructure for marketing and establishing labour relationships.

2.1.2.2 Farming and Grazing

Farming and grazing activities followed two basic paths in this region. Firstly, an incipient subsistence agriculture developed, spurred by the demands of extractivism. Secondly, the expanding agricultural frontiers of Maranhão State had been opening up fresh grazing lands in the Mid Tocantins region since the nineteenth century. (Table 2.2).

Table 2.2 Farming and Grazing Indicators

INDICATORS	PARÁ STATE	MUNICIPALITIES THAT BORDER THE DAM
Rural Establishments	254 503	8 987
Total Area of Establishments	23 532 050 hectares	904 998 hectares
Average Area of Establishments	92.46 hectares	100.7 hectares
Crops Area	1 052 562 hectares	56 866 hectares
Average Crops Area	4.13 hectares	6.32 hectares
Crops Area / Total Area	4.47 %	6.28 %
Number of people Employed	1 202 105	41 288
Number of Employed per Crops Area	1.14 per ha	0.72 per ha
Number of Cattle Herds	3 485 368	189 324
Number of Cattle Herds per Total Area	0.14 per ha	0.20 per ha

Source: IBGE 1985

Subsistence agriculture was by far the commonest means of survival, characterised by a labour system based on family smallholdings, with paid work extremely rare. Cash crops have only appeared more recently around Marabá, including rice, although paid work is still rare, even for this crop.

Cattle raising introduced paid labour, launching the integration of rural workers with the market economy.

2.1.3 Institutional Aspects

The driving force behind the changes taking place throughout in this region and Amazonia as a whole was institutional. From the second half of the 20th century onward, the Government stressed its concern with the orderly settlement of Amazonia, and intervened in the spontaneous settlement of this region.

Its various development plans and agencies listed the following purposes and principles for this intervention:

- the existence of natural resources, mainly ores, as a way of adding economic value to Amazonia;
- settlement as a factor in national security;
- elimination of rising social tensions, particularly in Northeast Brazil;
- ensuring the feasibility of adequate settlement conditions for communities in this region; and
- regional economic development based on reshaping crucial key factors such as capital, labour and land.

From this standpoint, the development plans and agencies focused on building basic infrastructure and establishing economic incentive mechanisms, while surveying the economic potential of this region and encouraging settlement projects.

During this process, the construction of Belém-Brasília Highway (BR-010) ushered in a new relationship between Northern Brazil and its industrial hubs. From 1966 onward, with the establishment of the Amazon Development Superintendency (SUDAM) and INCRA, a new policy was launched through incentives and orderly settlement projects made possible by this new highway.

However, it was the construction of the Transamazon Highway (BR-270) during the 1970s that provided the backbone for the main directed settlement drive in Brazil. Organised by INCRA, the Integrated Settlement Project (PIC – *Projeto Integrado de Colonização*) offered 100 hectares of land in Amazonia to families from all over the country.

Meanwhile, the PA-150 highway paved the way for spontaneous settlement legalised by the Pará State Government, resulting in a new land ownership standard.

2.1.4 Overview of the Geopolitical Context

How can the concept and implementation of a road network and a huge hydropower plant be explained, when it is established in the depths of a thinly inhabited and poorly reconnoitred jungle, amid an extractivist economy? The reply to this question suggests the importance of the geopolitical aspects of Government actions in Brazil at the time.

Until the late 1950s, Amazonia remained a vast "island" in the economic archipelago of Brazil, historically characterised by the presence of primary export economies located sporadically along the coastline, headed by a large city-port. The occupation of Amazonia, the largest "island" in Brazil – covering over half the nation's territory – was based on extractivism (Brazil nuts, rubber, timber and fibres for export), and commanded by the Pará State capital, Belém, located at the mouth of the vast Amazon river valley. Its population did not exceed five million inhabitants, with a density of under one inhabitant/km^2. While other "islands" in Brazil were linking up to the dynamic industrial model developing in the Southeast, in the course of this century, Amazonia was still focused outside the country, and was not integrated with the rest of the nation in territorial terms.

Historically, economic initiatives have not flourished in this region since colonial times: ventures launched here by Portugal and later the Brazilian government have always been either minor and/or unsuccessful. But the same cannot be said of the geopolitical strategies which allowed the take-over and control of huge areas of undeveloped land by the Portuguese and later the Brazilian authorities.

During the first half of the 20th century, some Government-run economic initiatives were linked to the rubber boom. The Economic Appreciation Plan Superintendency for Amazonia (SPVEA - *Superintendência do Plano de Valorização Econômica da Amazônia*) and the Araguaia-Tocantins Valley Company (CIVAT – *Companhia Vale do Araguaia-Tocantins*) drew the first real maps of the Tocantins river (Eletrobrás, 1992). Its economic impact was negligible, but the Government's geopolitical discourse did not neglect the importance of the settlement of the “empty space” of Amazonia, encouraging the “march to the West”.

The territorial integration process of Amazonia began in earnest during the 1960s, under a liberal government eager to unify the Brazilian domestic market under the slogan of “energy and transportation”. The process was accelerated by the transfer of the Federal Capital from Rio de Janeiro to the high inland plateau, imposing tighter political controls over Brazil’s vast hinterlands. As the nation’s newly-built capital, Brasília was the core of a highway network running in many different directions. Particularly important is the federal highway linking it to Belém, whose route runs parallel to the Tocantins River along certain stretches, paving the way for throngs of trail-blazing pioneers already moving spontaneously to this region.

It was only after the military coup in 1964 that the Brazilian government began to formulate and implement a project based on its doctrine of security and development. This ranked Amazonia as a top national priority, a target territory for initiatives designed to consolidate its integration, adding economic objectives to territorial control targets.

Triggered mainly by land ownership issues, social conflicts flared up as newly-laid highways opened up access to this region. The intervention of various entities such as GETAT, INCRA, ITERPA and Eletronorte itself (as shown below), together with severe problems caused by fraudulent land sales by squatter speculators with no titles – known as *grilagem* – also fueled conflicts in a region that was already tense at the time, owing to rebel movements such as the Guerrilha do Araguaia.

Located 350km south of Belém near the Belém-Brasília highway, on the banks of the powerful Tocantins River, the little town of Tucuruí was a perfect node, linking Amazonia to Northeastern and West-Central Brazil. It began to develop a strategic position in the many networks being built to impose tighter economic and political control over the vast territory of Amazonia.

2.2 Purposes and Components of the Tucuruí Hydropower Complex Project

2.2.1 Project Objectives – Phase I

The idea of damming Tocantins river first emerged with a view to supplying power to Belém and the surrounding region. Later on, however, the objective of producing power for energy-intensive industries - and particularly the Albrás Aluminium Project (in association with Japanese capital) - began to take on increased importance. It was the power demand for aluminium production that finally determined not only the site and the characteristics of the Tucuruí dam, but also its works schedule. The Electricity Sector and Eletronorte in particular had little influence in the decision on where and when to build. This situation will be dealt with in greater detail in Chapter 6.

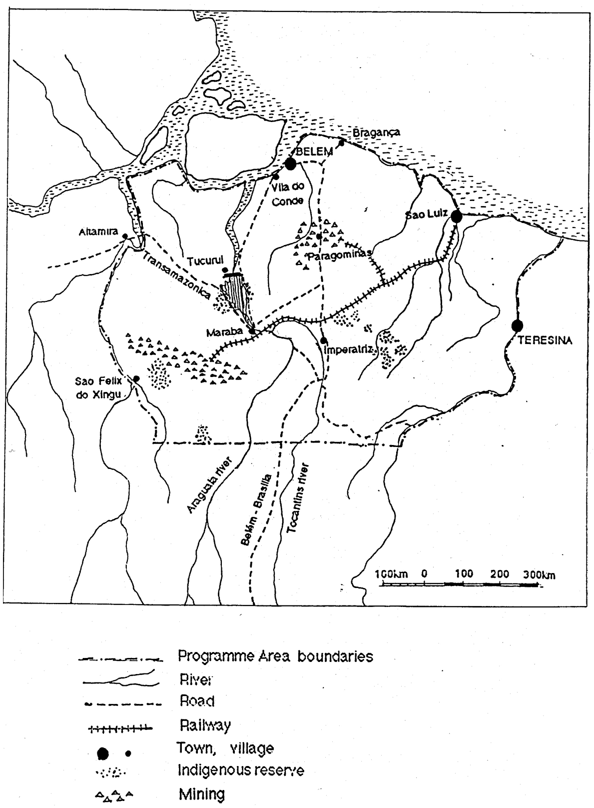
In order to deal with the large power production potential of the site and the existing demand, a two-phase construction schedule was adopted, which meant that it would be possible to almost double the power output with little additional investment and environmental or social impacts. This time schedule was acknowledged by experts in the electricity sector to be a major advantage as the project could be paced to the development of power demands and technological availability.

In the end, the main objective of Phase I of Tucuruí project was to generate electricity in order to meet the demands of industrial complexes being established in the Amazon region, particularly aluminium smelters, which have absorbed more than half of the total energy generated by the power plant so far. During Phase I, with twelve turbines installed, the capacity of the Tucuruí hydropower complex reached about 4 million KW. After the completion of the Phase II, the power output will reach about 8 million KW.

At the preliminary study stage, power production was presented as the single objective of the dam. However, some references were made to the use of the lake for transportation. In fact, by flooding the Itaboca falls, the Tocantins river could be made navigable throughout the year as far as the town of Marabá, provided that locks were built on the dam. This possibility was taken into consideration when the Carajás mining complex was being built. At that time, the public in Pará State was calling for lock-gates to be built in order to ensure that ore from Carajás would be carried along the Tocantins River for export through ports in the Belém region. However, the decision to ship Carajás ore by rail to the Port of Itaqui in Maranhão State was taken by CVRD (the company mining iron ore at Carajás) prior to the final decision on the Tucuruí dam.

The original project made provision for two locks, in order to ensure the navigability of the river from Belém to Santa Isabel, along a stretch some 680km long. If the objectives of regional development had prevailed in the decision-making process that resulted in the Tucuruí hydropower complex, feasibility studies would have been carried out for the lock. This would probably have resulted in a decision different to that taken at the time, which was to build partial lock structures in order to handle large quantities of cargo shipped by river in future.

Figure 2.2 Pará and Carajás Map



Source: Monosowski, 1988

The Tucuruí Project was officially presented by Eletronorte to the National Water and Electricity Department (DNAEE - *Departamento Nacional de Águas and Energia Elétrica*) in 1974/1975, in the form of feasibility studies (Engevix-Ecotec, December, 1974) attached to the application for the concession covering the exploitation of the energy potential of the Tocantins River at that site.

Following the recommendations issued by the Ministry of Mines and Energy that were prompted by the studies carried out by the Coordinating Committee for the Energy Resources of Amazonia (ENERAM), in July 1972 Eletrobrás returned to the studies carried out by this Committee, in order to undertake a systematic inventory of the hydropower resources of the entire Tocantins River Basin.

This was also intended to define the feasibility of hydropower projects which could service the energy markets represented by Belém on the one hand and Brasília and part of West-Central Brazil on the other, in addition to meeting possible future large-scale demands from electro-metallurgical ventures in this region. After its establishment in June 1973, Eletronorte was commissioned by Eletrobrás to continue studying the Tocantins and Araguaia River Basins. Initially, these efforts focused on setting up a project located in the Lower Tocantins - Tucuruí.

Today, energy from the Tucuruí plant is used to supply the power market in a vast region encompassing Belém and Southeastern Pará State, Maranhão State and Northern Goiás State, as well as other parts of Northeastern Brazil, through the interconnection with CHESF (the utility serving that region), as well as Southeastern and Southern Brazil on a supplementary basis, through the interconnection with the FURNAS grid, which recently began operations.

2.2.2 Project Components

The Tucuruí Hydropower Complex is located on the Tocantins River in Pará State, a short distance upstream from the town of Tucuruí, some 300km in a straight line from the town of Belém, the State capital, at approximately latitude 3° 45' South and longitude 49° 41' West (Figure 2.3 and Figure 2.4).

Figure 2.3 Tucuruí Hydropower Complex Reservoir

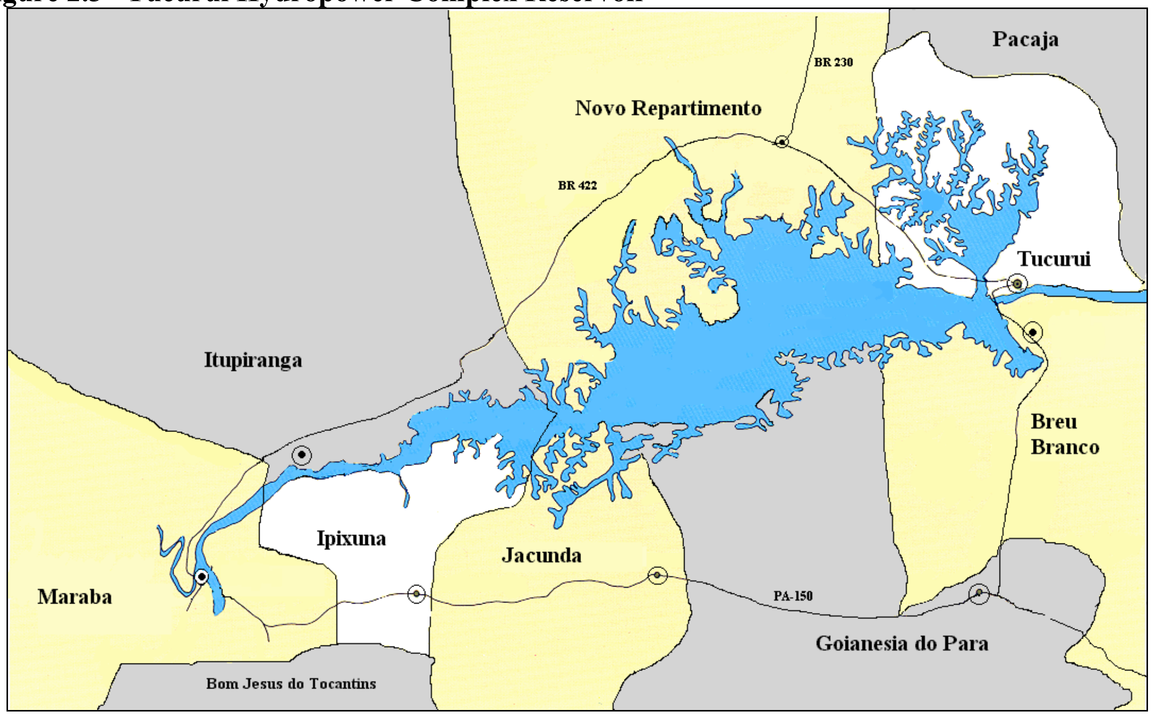
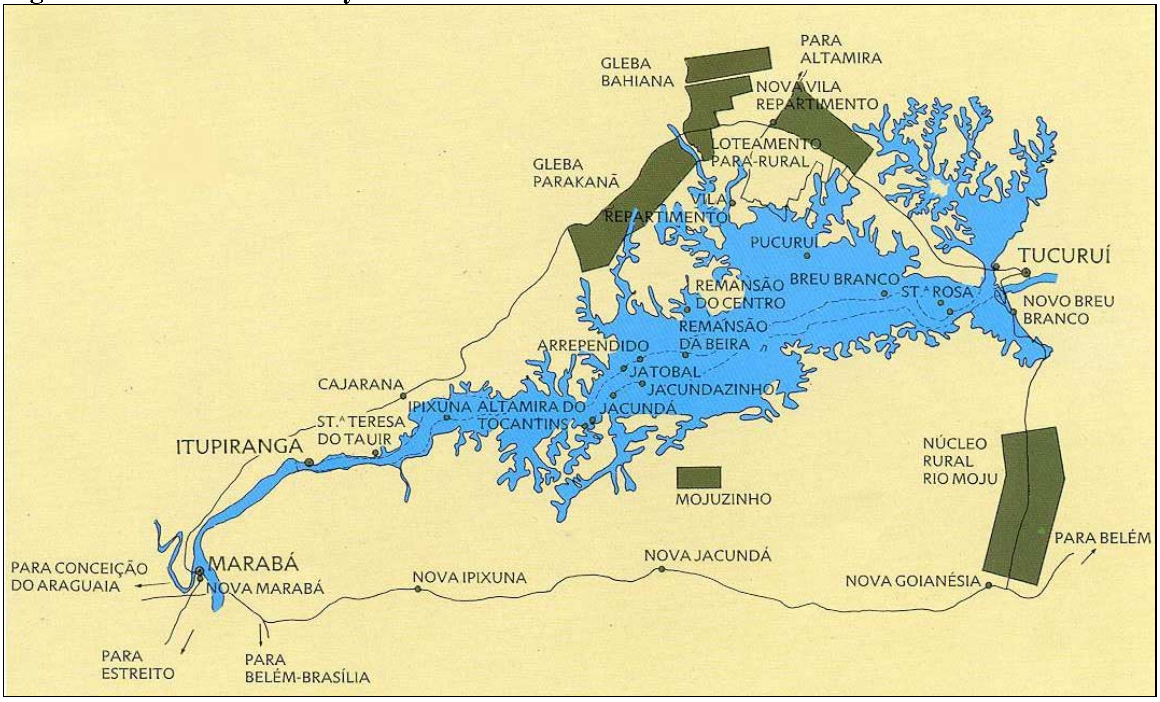


Figure 2.4 Cities flooded by Tucuruí Dam and resettlement areas



Construction began on this project on November 24, 1975, with commercial operations coming onstream on November 10, 1984. Its installed power generation capacity for Phase I is 4 000MW, with twelve hydropower generation units (330MW each) and two auxiliary units (20MW each). Plans provide for the addition of a further 11 units (375MW each) for Phase II, which is already being implemented.

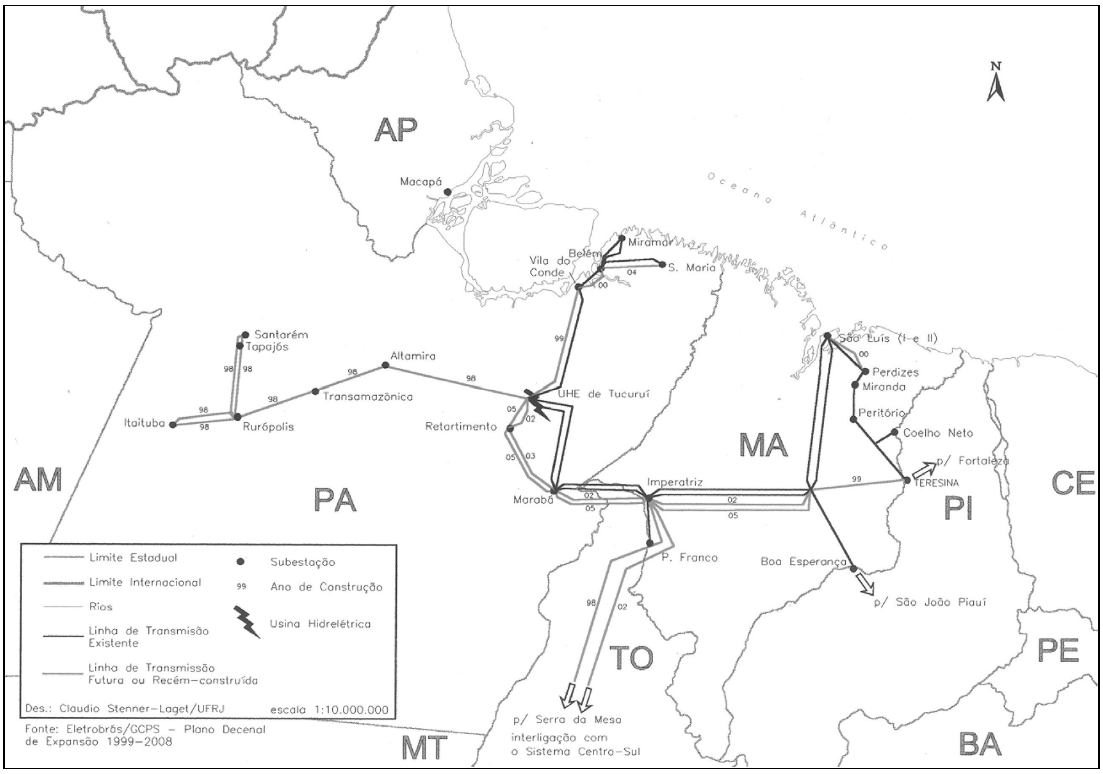
The transmission system carrying the power produced consists of the following lines (Table 2.3 and figure 2.5):

Table 2.3 Transmission Lines

Stretch	Voltage (kV)	Length (km)
Tucuruí – Marabá	500	224
Marabá – Imperatriz	500	184
Tucuruí - Vila do Conde	500	335
Vila do Conde – Guamá	230	50
Guamá – Utinga	230	10
Utinga – Miramar	230	15

Source: Eletronorte

Figure 2.5 Transmission Lines Layout



This power complex is part of the integrated hydropower programme for the Tocantins and Araguaia River Basins. Its scale (in terms of power generation capacity) takes into account the final configuration plans for these basins, which include the implementation of fifteen hydropower projects along the main courses of these rivers (Figure 2.6). This configuration is based on an accumulated useful volume of some 128 billion m^3 of water, with total power generation capacity of around 20 500MW, with 25% of the useful volume and 35% of the power generation capacity assigned to the Tucuruí Hydropower Complex (Phases 1 and 2).

The Serra da Mesa Power Plant was recently completed and has started operations, while the Canabrava and Lajeado power plants are currently under construction on the Tocantins River upstream from Tucuruí.

Figure 2.6 Hydropower plants planned for the Tocantins-Araguaia Basin

Source: Eletronorte

The Tucuruí lock system consists of two locks and a channel that would allow shipping along the Tocantins River and its confluence with the Araguaia River, its main tributary, forming the main inland shipping channel in Central-Western Brazil. During Phase I of this Project, Portobrás (the now-defunct state navigation company) built only the upstream lock-head. The construction of the remainder of the system is currently underway in Phase II.

2.2.2.1 General Arrangements - Tucuruí Dam

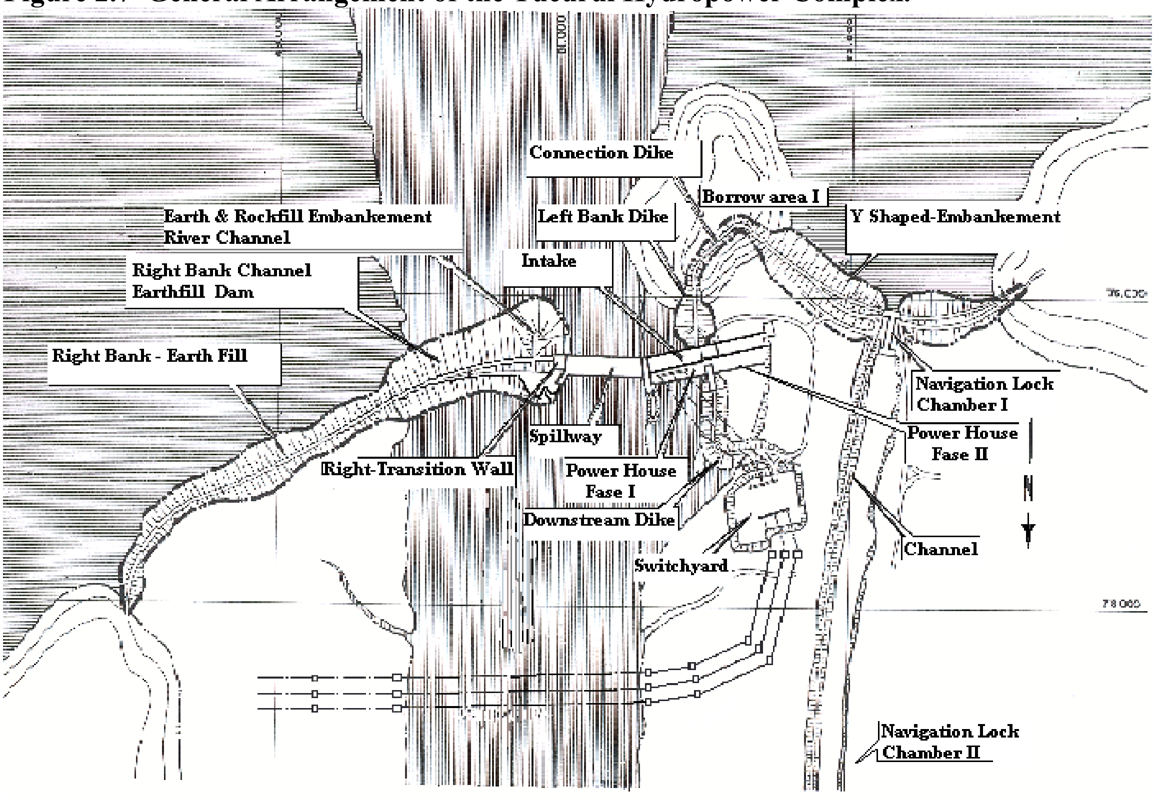
The structures forming the main dam built during Phase I of this project are, in sequence from the right bank (Figure 2.7):

- Earthwall dam on right bank, with a homogenous earth cross-section;
- Earthwall dam on river channel, with a mixed earthwall / riprap cross-section along the entire stretch;
- Right transition wall in concrete;
- Spillway - right transition block, in concrete;
- Spillway fitted with 23 floodgates measuring 20m (l) x 21m (h); left and right walls and afterbay in concrete;
- Spillway-water intake transition block, in concrete;
- Main water intake, in concrete, including penstocks and powerhouse, in concrete, fitted with twelve power generation units (330MW each);

- Auxiliary water intake and auxiliary powerhouse, in concrete, fitted with two power generation units (20MW each);
- Gravity dam and assembly area in concrete;
- Connection wall on left bank, with mixed earthwall/rip-rap cross-section near the structures, and earthwall only along the remaining stretch;
- Connection dike on left bank, with homogenous earthwall cross-section;
- Earthwall dam on left bank, or Y-shaped dam consisting of, in the same sequence, Stretch II in a homogeneous earthwall section, connection walls for lock in concrete with buttresses, with a mixed earthwall / riprap cross-section, lock-head in concrete, and Stretch I with a homogenous earthwall cross-section.
- Township dyke, some 300m from the shoulder of the earthwall dam on the left bank – Stretch I.

The crown of the earth / riprap dam wall is at a height of 78m, with the concrete structures at a height of 77.5m above sea-level, resulting in a minimum freeboard of 2.7m and 2.2m respectively, in exceptional flood situations. These levels are considered to be safe, given the wave formation calculations for the reservoir.

Figure 2.7 General Arrangement of the Tucuruí Hydropower Complex.



During the completion of the dam works, the following facilities were also built:

- Moju Dyke, located some 12 – 14km from the right bank shoulder in a straight line, consisting of a zoned soil section on two topographic saddles;
- Caraipé Dykes (ten) located 12 – 30km away in a straight line from the left bank, with a homogenous earthwall cross-section;
- Downstream Dyke, located downstream from the concrete structures, between the powerhouse for Phases 1 and 2. Built on a mixed earthwall / riprap cross-section, and homogenous earthwall section, in order to shelter the area where the future Phase II of this power plant is planned.

- The approximate length of the main dam wall is 6 900m which, together with the Moju and Caraipé Dykes totals some 12 515m of dam wall forming the reservoir.

2.2.2.2 Major Characteristics

The powerhouse is roofed, with walls, and located downstream at the foot of the water intake. It consists of twelve hydropower generator groups (330MW each) and the ancillary plant equipment, with a total length of 405.60m x 58.47m in width.

Phase II of the power plant will have a configuration that includes a water intake with equivalent dimensions. Its construction is already underway at a pre-established location, and does not affect the normal operations of the current powerhouse. When concluded, a new right bank stretch of wall - Stretch II – will be built and then partially removed, in order to allow water to be pumped to the future powerhouse. Special features have been planned to assure the safety of this operation.

Due to its huge size, the roof of the powerhouse demanded a special scheme to deal with the structural side of this power plant design, as it had to cover vast spans with no intermediate support, provide sufficient lighting levels in the building, and be high enough to allow the travelling cranes and gantries to move around. The solution was to adopt an industrialised prefabrication system based on pre-stressed concrete modules, with beams, gutters, pillars and panels in reinforced concrete, interspersed with aluminium and glass sheets.

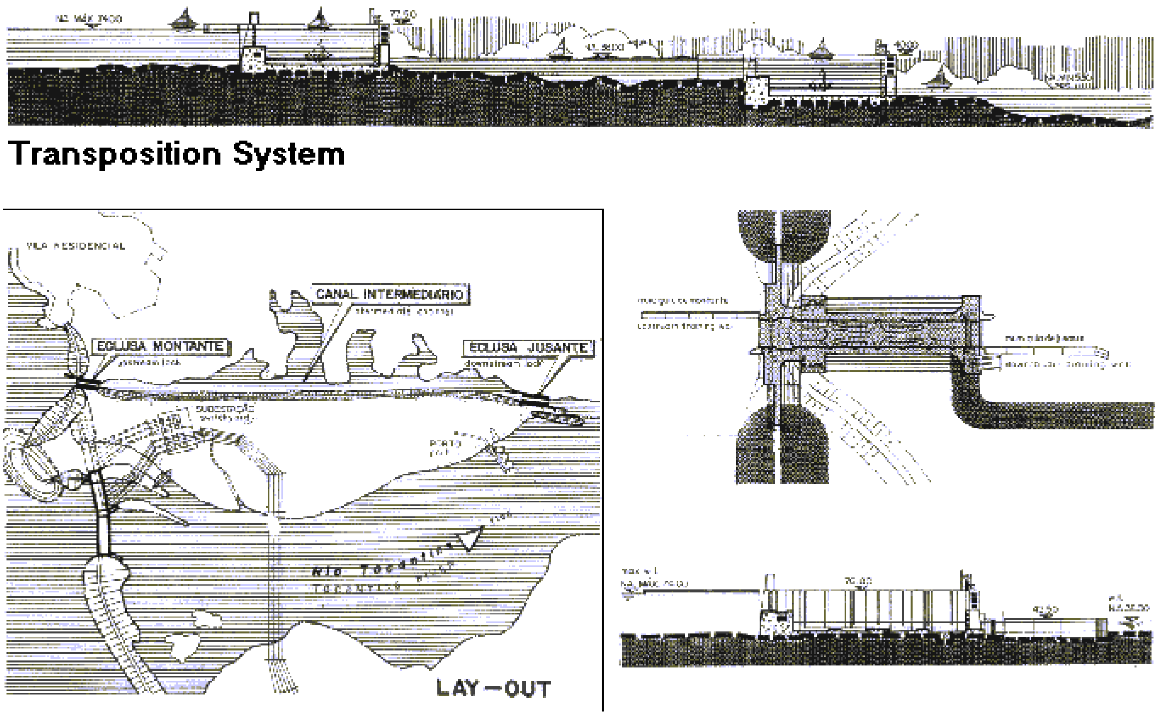
The main generator groups consist of Francis-type turbines (diameter 8 150mm) and air-cooled generators sized to work at a rated speed of 81.80rpm, at a drop varying from 51.40 – 67.60m.The pumping substation is located outside, downstream, and consists of three-phase 13.8-500 kV transformers and handling equipment insulated with SF6 gas.

The spillway is a concrete gravity structure, with a Creager-type profile, ending in a springboard that directs the flow a safe distance away from the foundations, where its force is absorbed by the afterbay, pre-excavated to a depth of 40m. It was planned to handle a rated flow of 100 000m^3/s, with a load of 22.00m at the crest, through 23 chutes with a width of 20m each. However, due to the exceptionally high flow-rates of Tucuruí in 1980 (which outstripped those recorded at any time previously for this location), and in view of the complexity of possible future synoptic situations, as well as the standard precautions, the maximum flow rate was increased to 110 000 m^3/s, with the maximum water level raised to a height of 75.30m.

The final arrangements for the transposition system (Figure 2.8) for the 70m drop created by dam's construction involved a technical and economic analysis of the building and assembly of structures, construction schemes, geological and geotechnical aspects, and a variety of electro-mechanical equipment.

The arrangement consists of two locks with a length of 210m and a width of 33m, with maximum drops of 36.50m and 35.00m respectively, and an intermediate channel some 5.5km in length formed by earthwall dykes and excavations, with a minimum curve radius of 2 000m and a maximum width of 140m, located on the left bank of the river. Lock 1 is a gravity structure located at a site where the main channel of the earthwall dam runs through its head upstream, with a connection between them handled by connection walls. Lock 2 is located such that two-thirds of its structure is surrounded by rock.

Figure 2.8 Lock system



2.2.3 Project Objectives – Phase II

Tucuruí, as already stated, is a two-phase project, with about half of its power plants (and the locks system) to be installed after the Phase I operation with much lower investments than those needed to start power supply in the first phase. The new powerhouse will almost double its power output to around 8,000 KW.

Phase II has recently started construction, following the strengthening of the connections between Tucuruí and the national interconnected power grid through new power lines transmitting electricity to meet demand in Southeastern Brazil. This will ensure a far more cost-effective operation for this power plant, using significant amounts of secondary energy available during the rainy season and favourable hydrological periods.

A secondary benefit from Phase II implementation will be the completion of the locks system, which will ensure navigation along the Tocantins River from the ocean to Marabá and other upstream locations. However, there is much uncertainty concerning the Phase II construction schedule, and particularly the construction of the locks, which depends on financial resources availability from the Ministry of Transportation. While the locks are incomplete and inoperative, the final purpose of the project remains limited to power generation.

Since Phase II is incomplete, it is not yet possible to assess the Tucuruí hydropower project as a whole using the methodology established by the WCD case study. This analysis would be of a different nature, involving an assessment of the future economic, social and environmental impacts, as well as the costs and benefits of the project, and thus going far beyond the scope of a retrospective study focused on the lessons learned through the implementation of the project.

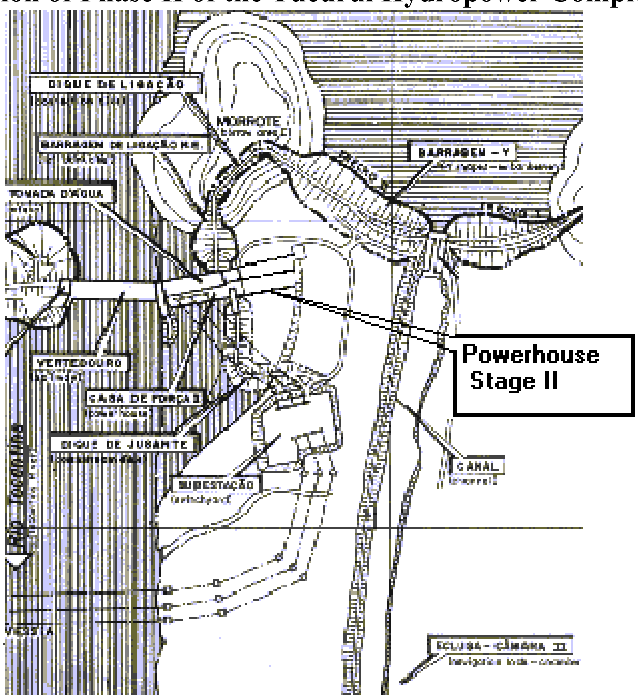
However, some limited aspects of Phase II can certainly be covered in this study, under the constraint represented by the lack of a detailed environmental and social impact assessment study for both Phases I and II. In fact, the environmental licensing of Phase II was exempted from the preparation of an environmental impact assessment (EIA) by a very controversial decision of the Pará State environmental body. The ruling concurred with Eletronorte's argument that Phase II was merely an increase of the installed power generation capacity planned before Phase I construction. It did not take into account the possibility that the changes in the operation of the reservoir induced by Phase II - coupled with the recent interconnection of Tucuruí to the South-Southeastern electrical grid - may also change the environmental and social impacts of the project. The data and documentation available on Phase II, and especially on its environmental and social impacts, are consequently very limited.

2.2.4 Phase II Components

Tucuruí Phase II (Figure 2.9) has been under construction since June 1998, and involves the building of a new powerhouse for the installation of 11 additional turbines (as initially planned in the engineering designs for Phase I), and the basic works needed to complete the locks. This additional installed capacity and stronger interconnections with the national power grid (North/Northeastern and South/Southeastern systems) will probably change the operating rules of the reservoir. Such changes may arise from a different yearly power demand curve allocated to Tucuruí, which is now able to supply energy to the South/Southeastern regions during the Southern Region dry season. This will allow for the use of significant amounts of secondary energy available in Tucuruí and thus improve the cost-effectiveness of the plant. On the other hand, this may also cause additional environmental and social impacts, as noted above. The main technical characteristics of Phase II of the Tucuruí Hydropower Complex are listed below:

- Minimum operating level – Phase II: 62m;
- 11 Francis-type turbines (vertical axis), producing 375MW, each;
- During Phase II, the dam will be filled by breaching the existing Y-shaped dam wall upstream from the water intake and escape channel, over a stretch of 750m up to a height of 55.50m, as well as the existing downstream dyke over a length of 260m, at a height of 7.00m (Eletronorte, 1999).
- Works schedule: construction began in June 1998, with commercial power generation at the new powerhouse (unit 13) scheduled for December 2002.

Figure 2.9 Configuration of Phase II of the Tucuruí Hydropower Complex



3. Predicted and Actual Impacts of the Tucuruí Hydropower Complex

After the description of the main characteristics of this venture, its objectives and the context within which it is located, this chapter presents the main impacts of the construction and operation of the Tucuruí Hydropower Complex.

The first section covers the main changes in the characteristics of the venture, decided after completion of the feasibility studies and the start-up of the works. The second section offers an analysis of the financial expenditures and costs associated with the implementation, operation and maintenance of the complex. The third section shows the evolution of power generation by this venture and the value of this energy. The fourth section covers the impacts of the Tucuruí Hydropower Complex on shipping, suggesting how the lock scheduled for Phase II could affect shipping along the Lower Tocantins River.

The fifth section gives an overview of the main effects of the construction and operation of the Tucuruí Complex on the ecosystems in this region. Section 3.6 describes its effects on local communities. Section 3.7 shows its effects on indigenous societies, and Section 3.8 assesses impacts on the archaeological legacy in the areas directly affected by this Project. Section 3.9 places these impacts within the context of the Tocantins-Araguaia Basin, while Section 3.10 covers regional, national and global effects of the implementation of the complex. Finally, Section 3.11 summarises the impacts, making a clear distinction between foreseen, observed and unexpected impacts.

3.1 Design of the Project and Implementation Schedule

This section shows the main changes in the characteristics of the venture, based on decisions taken after the conclusion of the feasibility studies and the start-up of works.

The reservoir volume as planned during the study phase was 34 084hm³, of which 24 430hm³ would be in the upper layer, corresponding to a depletion rate of 23m to be used for regulating the flow of the river. A submerged area of 1630km² was projected, calculated on the basis of aerophotogrammetry, but with limited field controls[2].

The December 1974 Feasibility Studies Report briefly stated: "The problems caused by the flooding consist of the expropriation of lands, improvements and other buildings and facilities, as well as the relocation of highways. The following locations will be submerged: Breu Branco, Pucuruí, Remansão, Itaboca, Jatobal, Jacundá and Ipixuma. Access to Tucuruí should be relocated along the Transamazon Highway." The population of the reservoir area was calculated at 3 173 inhabitants, of whom 495 lived in towns, 1 614 in villages, 237 in hamlets, 174 on ranches and 653 on small holdings.

This report later noted: "The lack of reasonable minimum housing conditions in this area is justified by various factors: the economic situation, low purchasing power, the structure of the subsistence economy, difficult access and lengthy distances from the main consumer centres and the consequent high cost of construction materials, in addition to the lack of prospects, all indicating that the situation noted today will not undergo any alterations in the near future. *Only construction of the Tucuruí hydropower complex can modify the existing situation* "(our italics).[3]

3.1.1 Comparison between the Main Characteristics of the Project: Planned and Actual

A number of changes were made to the main characteristics of the Tucuruí Hydropower Complex as projected in the feasibility study. The main changes in the characteristics of Phase I, as shown in Table 3.1, were:

- Shift of the main dam wall downstream for technical and economic reasons;
- Adoption of the maximum normal operating level of the reservoir at a height of 72.00m;
- Elimination of the bottom spillway, for technical and economic reasons; and
- Increase in firm energy and installed power for both implementation Phases of this venture.

Table 3.1 Main Characteristics of the Hydropower Complex – Phase I

CHARACTERISTIC	PLANNED AS STATED IN THE FEASIBILITY STUDIES	ACTUAL CONSTRUCTION RESULTS
Catchment area of basin to site	758 000 km²	758 000 km²
Total length of dam wall	4 590 m	11 190 m
Total volume – excavation	9 600 000 m³	50 223 188 m³
Total volume – landfill	41 600 000 m³	41 600 000 m³
Total volume – concrete	4 106 000 m³	6 000 000 m³
Total volume – coffer dams	9 628 000 m³	9 628 000 m³
Planned outflow – spillway	104 000 m³/s	110 000 m³/s
River bed elevation above sea level	5.1 m	5.1 m
W.L. maximum reservoir level	72.00 m (altitude above sea level)	75.30 m (altitude above sea level)
W.L. normal reservoir level	70.00 m (altitude above sea level)	72.00 m (altitude above sea level)
Flooding time till level 72,00	Approx. 6 months	206 days
Total volume – accumulation	34 084 hm³	45 500 km³ (72 m depth)
Useful volume	24 036 hm³	32 000 hm³
Length of reservoir	200 km	200 km
Area of reservoir for normal W.L.	1 630 km²	2 850 km²
Installed power	2 700MW	4 000MW
Firm energy	1 678MW	4 110MW

Except for some changes in the size and volume of certain components and structures, the general concept of the arrangements was maintained.

During the construction works, some basic project features were also altered as follows, due to various factors:

- Alteration in the diversion scheme for the river, for construction reasons;
- Revision of the floods study due to the exceptional flooding in 1980 (68 400 m³/s);
- Federal Government decision to implement the locks system in order to deal with differing river levels, simultaneously with the construction of the plant, affecting the works-yard;
- Shifting the pumping substation on the powerhouse from upstream to downstream, for construction reasons; and
- Shifting the manoeuvring substation from the right bank to the left bank, making good use of easily-available excavation materials, with added advantages due to its proximity to the power plant.

In addition to the various alterations to the project and its designs, other factors also jacked up its costs, as noted in the Technical Memorandum – Tucuruí hydropower complex, 1989:

- replacement of cement imported from Colombia, as initially planned, by Brazilian-made cement;

- review of the construction schedule, resulting in a general review of the construction contract criteria for civil construction works;
- alteration in the construction schedule, postponing the start-up date for power generation at the first unit to December 31, 1983;
- increase in the number of jobs, due to the bringing forward of some of the works originally scheduled for Phase II, as well as alterations in the project designs for Phase I caused by the inclusion the locks on the left bank; and
- adjustments to the pace of implementation of work and payments for corrections due to the shortage of funding (start-up of operations by the first generation plant only in November 1984).

3.1.2 Implementation Schedule

Tucuruí project was planned to be implemented in two phases. The first one would involve the construction of the dam, earthwall and spillway, the flooding of the lake and the installation of the first 12 turbines. The basic infrastructure for the locks system was to be prepared as well.

Most of the final project characteristics were then to be constructed in Phase I, leaving for Phase II the second 11-turbine powerhouse (actually an extension to the left of the existing one) and some minor changes in the dam (without any need to raise the dam height) besides the completion of the locks system.

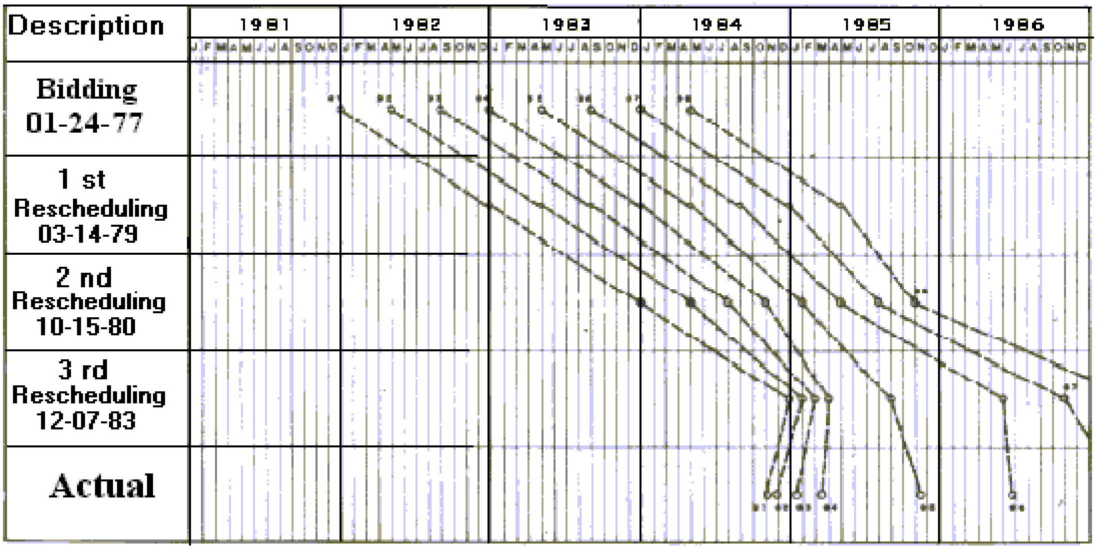
The decision to build Tucuruí in two separate phases allowed for the construction of the dam and the generation of power in a scale matching the needs of the early ’80s. At the same time, this schedule prepared conditions for the construction of Phase II in the future without the necessity of large investments in a new dam or the enlargement of the already built one to meet future (and expected) energy needs. But there was no firm conviction about the exact date when Phase II should be implemented.

There were four programmes that guided the Phase I civil construction planning, based on the programme included in the main civil construction works contract signed in January 1977. As Table 3.1 and Table 3.2 show, the implementation of the Tucuruí Hydropower Complex was rescheduled several times. As a result the start-up of the first power generation unit, initially scheduled for December 1981, in fact took place only in November 1984, almost three years later.

Part of this three-year delay could be eventually made up. For example, it was possible to bring the first four power generation units into operation in less than five months – an outstanding feat for a project of this size – thanks to the previous fabrication and storage of the equipment.

Most of the delays were associated with the shortage of funding and increased amounts of work due to changes in the project characteristics during the construction phase. The issue of the flow of funding will be covered in Chapter 6, set within the historical context of a period when Brazil's electricity sector – almost completely state-run since the late 1950s – was strongly influenced by the fluctuations of Federal Government policies.

Figure 3.1 Rescheduling of the works



Source: Eletronorte

Table 3.2 Milestones – Construction Schedule

ACTIVITY	EXPECTED	ACTUAL
Installation of main contractor	June 1 1976	June 1, 1976
Start-up of concreting	April 1, 1977	February 1, 1977
Start-up of operations, river diversion	June 1, 1978	September 7, 1978
Start-up of diversion for spillway and sluice gates	November 1, 1978	July 1, 1981
Start-up of assembly of groups	August 1, 1979	December 1, 1981
Earthwall dam released	November 1, 1981	September 6, 1984
Start-up of filling the reservoir	November 1, 1981	September 6, 1984
Start-up of operations	December 31, 1981	November 10, 1984

Phase II construction began on June 1998, and the first turbine is scheduled to begin operating in December 2002. To date there is no evidence of significant delays in this schedule.

3.1.3 Clearing Reservoir Area and Logging Activities [4]

When the feasibility studies for the Tucuruí hydropower complex were published in December, 1974, the official decision was to clear 43 000 of the 163 000 hectares to be flooded by damming the Tocantins River (equivalent to 27% of the calculated reservoir area) in order to protect the dam and machinery.

One year later, the basic project design for the power-plant stipulated that 120 000 hectares should be cleared, an area three times larger than that originally planned. As the reservoir area had been expanded to 216 000 hectares at that time, the area to be cleared would cover 55% of the future lake. This larger clearing area was suggested as a result of possible environmental impacts due to the degradation of the submerged biomass. In August 1979 an agreement was signed between Eletronorte and IBDF (*Instituto Brasileiro de Defesa Florestal*, now defunct but at that time a government agency under the Ministry of Agriculture), under which Eletronorte agreed to clear 10 000 hectares of land near the power plant, with IBDF handling the rest of the area, corresponding to 206 000 hectares.

A private venture, Agropecuária Capemi, won the IBDF bidding process to handle the area only to fail to complete its task and submerge in a scandal involving over 100 million US dollars. In the end only about 14 000 hectares were cleared closer to dam by Eletronorte and a small parcel was cleared by Capemi at the Tucuruí Indigenous Post area.

In 1989, Eletronorte licensed the logging companies to extract the submerged wood, by means of a newly-developed local technology. But this process met with many difficulties.To date, some 5% of this timber has been removed through underwater logging techniques. Felling is now taking place at a rate of some 2 500m^3 per month.

Findings

- The initial calculations of the reservoir area were inaccurate, due mainly to the limited field control of the aerophotogrammetric surveys.
- The main alterations to the characteristics of this venture were shifting the dam-wall downstream, the adoption of a depth of 72.00m as the normal maximum operating head of the reservoir, the elimination of the bottom slipway, and the increase in firm energy and installed power for both phases of this project.
- The implementation schedule has been reorganised several times, prompted mainly by a shortage of funding, and increased amount of work required.
- Logging in the reservoir area before it was flooded was adversely affected by the administrative and financial problems of the Company contracted to handle this, which resulted in flooding 2.5 million m^3 of timber with commercial possibilities.

3.2 Financial Costs

This Section presents predicted and actual costs associated with Tucuruí construction and operation.

All figures are presented in 1998 US dollars as required by the WCD methodology. Annex 5 presents exchange rates and the basic figures needed for the calculations.

In the calculations below, the method stipulated by the WCD was used as far as possible for monetary restatements. As a conversion factor for updating amounts in US dollars, the Consumer Price Index for Urban Consumers All Items (Seasonally Adjusted) - as defined by the US Department of Labor, Bureau of Labor Statistics - was adopted. Amounts in Brazilian currency at that time were converted into constant values of 1998 US dollars based on the attached indexes (see Appendix 5). In cases where Brazil's annual inflation rate was extremely high, it proved necessary to work with monthly restatement indexes. In this case, the General Price Index – Domestic Availability (IGP-DI - Índice Geral de Preços - Disponibilidade Interna), issued by the Getúlio Vargas Foundation, was used,.

3.2.1 Predicted Costs

It was not easy to carry out an assessment of costs related to a long-term project in Brazil, particularly in the 1970s and 1980s, when inflation and a changing political scene brought much uncertainty in the Brazilian economy.

A large dam construction (which ended up being Tucuruí) was decided on before any detailed plan for the dam was prepared (see Chapter 5), hence important decisions were not based on realistic cost figures as is usual for most projects of this size. The best figures available for the decision-making process were those from the Feasibility Studies, which were related to a much smaller exploitation with installed capacity of 3 040MW. The ENERAM inventory studies, which were very important in the initial phases of the decision-making process, were associated with an even smaller power plant of 2 700MW at a US$3. 819 billion cost (see Section 3.3.1. below).

It was only after the decision to build a dam at the Tucuruí site was confirmed (at the end of the Inventory Studies, which unusually ended after the Feasibility studies) and the linkage of the aluminium smelter industry with the venture, that the final project in its much larger form came to be, with an installed capacity of about 4 000MW at Phase I and 8 000MW at Phase II, after the completion of other upstream dams. This evolving process makes it difficult to state which costs were the predicted ones. This study of the cost overrun will compare the figures from the Feasibility

Studies with the best available figures for actual costs, because of their relevance in the decision-making process.

3.2.1.1 Inventory Studies

The first attempt to make an inventory of Tocantins-Araguaia Basin (the ENERAM study, see Chapter 5) was completed in 1972, and as a result three alternatives were selected for feasibility studies, based on criteria of size, potential power output, location and cost: Tucuruí, São Félix Alto and Santo Antonio. Table 3.3 summarizes these options and the expected costs.

The first estimate for Tucuruí was that it would cost about $3.819 billion to deliver 2 700MW with a 64.9m dam and the max water level at 70m above sea level.

Table 3.3 Inventory Studies estimates

Dam	Distance from Tocantins mouth (km)	Dam height (m)	Potential Power (MW)	Cost (10^9 US$)	Cost / Power (US$/kW)
Tucuruí	250	64.9	2 700	3.819	1 414
Santo Antonio	714	32.3	786	1.325	1 686
São Félix Alto	1 870	139.7	1 328	2.084	1 569

3.2.1.2 Feasibility Project Studies

Feasibility studies began in 1974, before the inventory studies were concluded, and played a major role in the decision on the final dam and hydropower plant configuration.

As described earlier in Section 3-1, two points were initially deemed possible for Tucuruí exploitation, the first one close to Tucuruí village and the other 7km upstream. Two possible dam arrangements for each axis were also available, with concrete structures located either at the right or the left river margin. As Tucuruí village is located on the left riverbank and the sandy soil in this area was unable to support the load of some predicted structures, no further studies were carried out on this option.

Three options remained, and cost estimates were then made in order to help choose the best one. These cost estimates are presented in Table 3.4. Alternative II-A was elected as it was not only the least expensive one but would also allow for an easier river diverting operation and interfere less with Tucuruí village.

Table 3.4 Feasibility Studies Options Cost Estimates

Feasibility Study Option	Cost estimate (billion US$)
Upstream, left margin	5.413 362
Upstream, right margin	5.898 014
At Tucuruí, right margin	5.656 810

With Tucuruí location decided, studies were drafted for two construction options, the first one with an operational water line at 70m elevation above sea level and another at 80m with different power output and engineering characteristics as described earlier.

Costs were estimated for both options as shown in Table 3.5. The 70m configuration costs were estimated at US $3.699 billion including a temporary village and facilities and its O&M and engineering and administrative costs. With 15% IDC final costs would reach US$4.254 billion. The 80m configuration cost estimates wereUS $4.289 billion and US $4.933 billionwith IDC included.

Table 3.5 Feasibility Studies Cost Estimates (billion US$)

Feasibility Study Option	Cost without IDC	Cost with IDC
W.L. @ 70.0 m (selected)	3.669 294	4.254 188
W.L. @ 80.0 m	4.289 087	4.932 950

A second powerhouse to be built after river flow stabilization by upstream dams was predicted in the Feasibility studies, but no cost estimates were drafted. Also, the chosen configuration for Phase II changed in the Basic and Executive Projects. The same applies to the locks system first envisioned in the feasibility studies. The locks were initially to be built in the right bank of the dam, but in the subsequent studies its location was changed to the left bank. These modifications – actually new projects – impair any comparision between predicted and actual costs.

3.2.1.3 Basic Engineering Project

After the decision to build Tucuruí was made, a basic engineering project was drafted, providing more reliable figures. At that time a 70m elevation was already decided, and the two-phase alternative developed into a 4 000MW – 8 000MW project as more recent and reliable data were available both on hydrology and on the energy demand (owing to the entry of the aluminium smelters).

Four alternatives were assessed, all related to the motorization of the hydropower complex, as indicated in Table 3.6. The 12x330MW (3,960MW) option was selected because of its better cost / installed kW ratio. At the time it was important to compare national and imported assets and their costs, as the external debt was growing steeply and any imports were to be avoided as far as possible.

IDC estimates were growing as well. In these studies a 35.3% IDC figure was adopted, more than twice the 15% IDC considered in the feasibility studies.

Table 3.6 Cost of alternatives assessed in the Basic Engineering Project

Alternative	Cost (10^9 US$, 35.3% IDC included)	US$ / kW
12 x 330MW generators = 3,960MW (selected)	5.820 409	1 470
9 x 330MW generators = 2,970MW	5.495 828	1 850
8 x 330MW generators = 2 640MW	5.396 280	2 044
6 x 330MW generators = 1,980MW	5.200 874	2 627

Table 3.7 shows the cost estimates for the selected option:

Table 3.7 Selected option cost estimates in the Basic Engineering Project

Item	Costs (10^3 US$)	% of total cost (IDC not included)
Land and use	49 568	1.2%
Structures	313 538	7.3%
Dam, Reservoir & Conduits	2 495 704	58.0%
Turbines & Generators	502 799	11.7%
Ancillary Electrical Equipment	75 035	1.7%
Other Power Plant Equipment	66 856	1.6%
Roads, Railways, Bridges	25 729	0.6%
TOTAL DIRECT COSTS	**3 529 230**	**82.0%**
TOTAL INDIRECT COSTS	**773 574**	**18.0%**
TOTAL COSTS w/o IDC	**4 302 804**	**100.0%**
IDC @ 35.3%	1 517 605	35.3%
TOTAL COSTS IDC INCLUDED	**5 820 409**	**135.3%**

3.2.1.4 Call for Tenders and Bidding

Four Brazilian firms competed for the construction of Tucuruí. The bidding process, as is usual in Brazil, consisted of a technical proposal based on terms of reference dictated by Eletronorte and a commercial proposal, including the corresponding construction prices. The winner of the bidding was the company presenting a technical proposal conforming to the terms of reference for the lowest price.

The bidding result is shown in Table 3.8. These prices are for the civil works alone, excluding project engineering and electric equipment costs:

Table 3.8 Bidding on Tucuruí construction

Company	Bid
Camargo Corrêa (winner)	1 771 613
Mendes Júnior	2 175 909
Andrade Gutierrez	2 769 038
C.R. Almeida	3 458 144

Source: Eletronorte

3.2.1.5 Detailed Engineering Project

During the construction of Tucuruí many changes were introduced to the project, as already discussed. These changes, together with financial difficulties in Brazilian economy[5] contributed to changes in predicted costs and expenditures. Table 3.9 shows the evolution of Tucuruí's predicted costs in the years 1978-1981 as indicated by Eletrobrás's annual budgets. Data for the years 1982-85 are unavailable as the methodology adopted for their summarisation does not allow for a comparison with other annual data.

Table 3.9 Evolution of Tucuruí Predicted Costs 1978-1981

	1978	1979	1980	1981
Land and use	196 236	98 673	37 482	32 797
Structures	192 476	116 791	131 664	187 130
Dam, Reservoir & Conduits	1 561 685	1 080 904	1 199 027	1 741 238
Turbines & Generators	637 904	397 283	461 891	436 851
Ancillary Electrical Equipment	60 053	54 421	78 565	81 139
Other Power Plant Equipment	37 853	12 672	10 134	10 281
Roads, Railways, Bridges	42 749	6 742	9 581	12 188
TOTAL DIRECT COSTS	2 728 955	1 767 486	1 928 344	2 501 624
TOTAL INDIRECT COSTS	1 085 275	807 849	1 294 542	2 200 573
TOTAL COSTS w/o IDC	3 814 230	2 575 335	3 222 885	4 702 197
IDC @15%	572 135	386 300	483 433	705 330
TOTAL COSTS IDC INCLUDED	4 386 365	2 961 635	3 706 318	5 407 527

3.2.1.6 O&M Costs

Annual O&M costs for all estimates were set at 1% of total investment costs without IDC. This was the usual procedure in the Brazilian electricity sector at the time.

3.2.1.7 Tucuruí Phase II and locks system predicted costs

Some rough cost estimates for Phase II and the locks system were included in the feasibility studies and basic project. However, these initial estimates have been reviewed due to substantial modifications in the project, as described earlier and are aggregated in the total cost figures available.

Today, with construction already started, more reliable figures are available for the predicted costs of Phase II and the locks system, as shown in Table 3.10 below.

Table 3.10 Tucuruí Phase II and Locks System Predicted Costs

	Phase II Cost	Locks System Cost
Latest Estimates	1.35 billion dollars	387.15 million dollars

Source: Eletronorte

3.2.2 Actual costs

The most accurate data on costs after Phase I completion were drawn from the Tucuruí evaluation study carried out in 1986. Including the amount of US$1.97 billion interest paid during construction, the total cost of Tucuruí Phase I construction reached US$7.51 billion, with the main expenditures incurred being the implementation of the reservoir, dam walls and mains pipes (33.5%), and service on debt (26.3%). (Table 3.11).

It should be stressed that transmission and distribution costs were not included in this amount. After adding investments of US$1.27 billion for the power transmission lines and substations needed to distribute energy to final consumers, the total amount reached US$8.77 billion, without accounting for interest charged during construction of the transmission and distribution facilities.

Table 3.11 Actual costs of goods and services for the implementation of the Tucuruí Hydropower complex

Description	Values [10^3 Cz$ 1986]			Values [10^3 US $1998]		
	Brazilian	Imported	Total	Brazilian	Imported	Total
1.Land & rights-of-way	**1 106 490**		**1 106 490**	**126 800**		**126 800**
Acquisition of Land & Improvements	371 792		371 792	42 606		42 606
Relocation / Resettlement	734 698		734 698	84 194		84 194
2. Structures & Other Improvements	**3 750 831**		**3 750 831**	**429 831**		**429 831**
Improvements – Power-Plant Area	87 130		87 130	9 985		9 985
Power House	2 885 463		2 885 463	330 663		330 663
Workers' Township	778 238		778 238	89 183		89 183
3. Reservoirs, Dams & Mains Pipes	**21 994 798**		**21 994 798**	**2 520 522**		**2 520 522**
Reservoir	1 155 120		1 155 120	132 372		132 372
Diverting the River	2 414 464		2 414 464	276 689		276 689
Dams & Dikes	7 356 307		7 356 307	843 005		843 005
Spillway	6 388 790		6 388 790	732 132		732 132
Water Intake & Mains Pipe	4 653 807		4 653 807	533 309		533 309
Special Buildings	26 310		26 310	3 015		3 015
4. Turbines & Generators	**2 459 856**	**2 551 365**	**5 011 221**	**281 890**	**292 377**	**574 267**
Turbines	1 331 234	1 351 216	2 682 450	152 554	154 844	307 399
Generators	1 109 870	1 200 149	2 310 019	127 187	137 533	264 720
Suction Pipe	18 752		18 752	2 149		2 149
5. Ancillary Electrical Equipment	**285 096**	**580 945**	**866 041**	**32 671**	**66 574**	**99 245**
6. Sundry Power Plant Equipment	**137 781**		**137 781**	**15 789**		**15 789**
7. Roads	**64 893**		**64 893**	**7 436**		**7 436**
8. Airport	**46 657**		**46 657**	**5 347**		**5 347**
9. Direct Costs (1+2+3+4+5+6+7+8)	**29 846 402**	**3 132 310**	**32 978 712**	**3 420 287**	**358 951**	**3 779 238**
10. Works-Yard & Camp-Site	**7 029 480**		**7 029 480**	**805 552**		**805 552**
11. Engineering & Administration Proprietor	**8 335 478**	**3 078**	**8 338 556**	**955 215**	**353**	**955 568**
12. Contingencies	**3 245**		**3 245**	**372**		**372**
13. Indirect Costs (10+11+12)	**15 368 203**	**3 078**	**15 371 281**	**1 761 139**	**353**	**1 761 492**
14. Total Costs without IDC (9+13)	**45 214 605**	**3 135 388**	**48 349 993**	**5 181 426**	**359 304**	**5 540 730**
15. IDC (10% p.a.)	**16 095 296**	**1 116 198**	**17 211 494**	**1 844 461**	**127 912**	**1 972 373**
16. Total Costs with IDC(14+15)	**61 309 901**	**4 251 586**	**65 561 487**	**7 025 887**	**487 216**	**7 513 103**

Source: Adapted from Eletronorte (1988)

O&M actual costs were supplied by Tucuruí operation sector, and are shown in Table 3.12:

Table 3.12 O&M Actual costs for Tucuruí, 1995-1998 (10^3 US$ 1998)

Item	1995	1996	1997	1998
Personnel	8 047	9 075	8 102	7 903
Materials	805	908	810	790
Third-party Services	3 085	3 479	3 106	3 029
Other O&M Expenses	1 475	1 664	1 485	1 449
Total	13 412	15 125	13 503	13 171

Source: Regional Production & Sales Office, UHE Tucuruí

3.2.2.1 Funding

The Tucuruí project funding was subject to many fluctuations and did not flow on a regular basis. The single major source of funding was the Eletronorte budget, supplemented by loans from foreign creditors and transfers from other Brazilian governmental institutions. Table 3.13 below summarises external funding sources and values:

Table 3.13 External Funding obtained for Tucuruí

Source	Total Value (10^3 US$)
Brazilian sources: (Eletrobrás, BNH, Banco do Brasil, Caixa Econômica Federal, FINAME resources for equipoment acquisition)	2 175 311
Foreign sources: (Banque de L'Union Europeenne, Bank of America, National Bank of Canada, Crocker National Bank and a consortium of French banks)	833 094
Total	3 008 405

The external funding amounts to about 54.3% of total project costs (without IDC); the balance of resources was drawn from Eletronorte's own budget.

3.2.2.2 Actual Expenditures Through Time

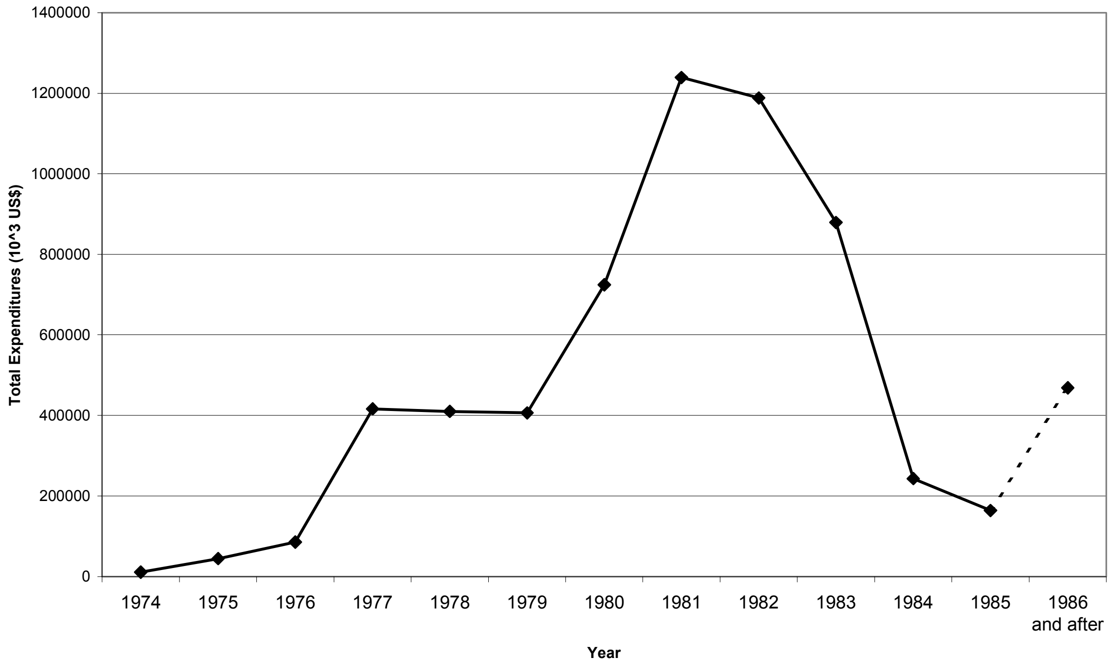
Data on actual expenditures are based on Eletronorte's accounting sector as the main source of information and were presented in the Tucuruí evaluation study carried out in 1986 (Eletronorte, 1988). Raw data expressed in current currency were converted to 1998 US dollars according to the WCD methodology.

Table 3.14 and Figure 3.2 show data on actual expenditures in Tucuruí project.

Table 3.14 Yearly Expenditures 1974-1985 and expenses after 1985 (%)

Year	% of Total
1974	0.17%
1975	0.71%
1976	1.36%
1977	6.63%
1978	6.53%
1979	6.47%
1980	11.54%
1981	19.73%
1982	18.92%
1983	14.00%
1984	3.87%
1985	2.61%
After 1985	7.46%

Figure 3.2 Yearly Expenditures, 1974-1985 and after 1985 (10^3 dollars)



3.2.2.3 Cost Overrun

Predicted costs for Tucuruí were taken from the feasibility studies, and actual costs were drawn from the evaluation study carried out in 1986, as previously indicated. Predicted costs were estimated at US$3.699 billion. Including expected IDC costs would reach US$4.254 billion. Actual costs were estimated at US$5.541 billion. Including IDC actual costs brought the figure to US$7.513billion. Accordingly, cost overrun was 51.0% if IDC are not taken into account; with IDC included, cost overrun reached 76.6% as shown in Table 3.15 below.

Table 3.15 Cost overrun of the Tucuruí Hydropower Complex

	w/o IDC	with IDC
Predicted	3 669 2940	4 254 188
Actual	5 540 730	7 513 013
Overrun	51.0%	76.6%

Findings

According to the Feasibility Studies Report, "the main social and economic problems caused by flooding the reservoir consist of the expropriation of lands, improvements and other buildings and facilities, and the relocation of highways". These costs were estimated in this report at US$5.7 billion for land to be submerged and US$27.2 million for replacing the affected assets (values in 1998 US$).

The total estimated costs (including IDC) changed from US$4.3 billion in the feasibility study in 1974 to US$5.8 billion in the basic engineering project in 1975 and US$5.4 billion in the detailed engineering project (1981 update) against actual costs of US$7.5 billion calculated in the evaluation study (1986).

Including the amount of US$1.97 billion interest paid during construction, the total cost of Tucuruí Phase I construction reaches US$7.51 billion, with the main expenditures incurred being the implementation of the reservoir, dam walls and mains pipes (33.5%), and service on debt (26.3%).
Adding up investments of some US$1.27 billion for the power transmission lines and substations needed to distribute energy to final consumers, the total amount reaches US$8.77 billion, without accounting for interest charged during the construction of the transmission and distribution facilities.

Cost overrun was 51.0% if IDC are not taken into account; with IDC included, cost overrun reached 76.6%

3.3 Hydropower Generation

This Section shows the evolution of power generated by the Tucurui Hydropower Complex, and its value.

3.3.1 Planned and Actual Hydropower Generation

TheBrazilian power sector has been strongly based upon hydropower generation, which since the ’70s accounts for some 90% of total power consumption in the country. Industrial residential and commercial sectors are the most important electricity users, and thus the bulk of the power market is concentrated in the Southeastern/Southern region of the country. In the North of the country, which is not connected to the national grid, thermopower generation has been dominant, and limited to urban centres, with poor coverage of power needs in rural areas. Within this context, the occupation of the Amazon in the ’70s has led to the construction of the first large hydropower plants in the region, such as Samuel, Balbina and Tucuruí.

Due to uncertainties in defining future power demands, as already stressed, no broad-ranging study was ever carried out on the market for power produced at Tucuruí, in order to define the phases of the project and even the capacity of the power plant. This project was based on the principle that electricity-intensive industries would be eager to use energy from Tucuruí, due to low prices. In general, it was felt that having serviced markets that were already virtually assured – such as Belém and Marabá – the remainder of the energy produced would meet repressed power demands in Pará, Maranhão and Tocantins States, in addition to the possibility of transmitting power to Northeast Brazil along a line running 1 800km between Sobradinho and Boa Esperança.

In fact, only two phases were planned for this complex, due to the possibility of regulating the flow of the river with large dams upstream, which would result in higher greater motorisation of this plant in the future in order to produce more firm energy.

Phase I predicted power and energy outputs are presented and compared to the actual outputs in different years in the table below.

Table 3.16 Phase I predicted and actual power and energy outputs

	Installed Power	Energy Generation
Predicted in the Feasibility Studies	2 700MW	16 197 GWh/year
Predicted in the Basic Engineering Project	4 000MW	22 776 GWh/year
Actual 1991	4 000MW	18 034 GWh/year
Actual 1998	4 000MW	20 635 GWh/year
Actual 1999	4 000MW	24 899 GWh/year

Source: Eletronorte

The installed power generation capacity was revised upwards substantially in the basic engineering project. Power generation in fact began in 1985, gradually increasing until stabilising in 1991 when the installation of the turbine-generator equipment was completed, along with stretches of the transmission grid. Until 1998, power generation was kept within a range in the vicinity of the Brazilian hydropower plants average capacity factor of 55 %, but not reaching the 65 % figure estimated in the basic engineering project, with annual variations following fluctuations in hydraulic resources availability and electricity demand. From 1999 onwards, the strengthening of the interconnection of Tucuruí to the Brazilian power system allowed for an increase in the power generation of the plant.

Phase II predicted power output is 4 125MW after the installation of eleven 375MW turbines. The first is scheduled to begin operation in December 2002. After Phase II completion, Tucuruí installed capacity will reach 8 125MW. The basic engineering project estimated an addition of 32 412 GWh/year in the firm energy generated after Phase II, but at that time the predicted increase of the installed capacity in Phase II was 3 960MW. Actual power generation after Phase II completion will depend upon the future configuration of power dispatching and the corresponding changes in the operation rules of the dam. In the near future, a competitive power market is scheduled to emerge in Brazil, according to the new institutional model for the sector structure. It is foreseen that power generation costs at Tucuruí can remain competitive after Phase II and in this case the capacity factor of the plant can be further increased, favoured by the stronger inconnection with the national grid.

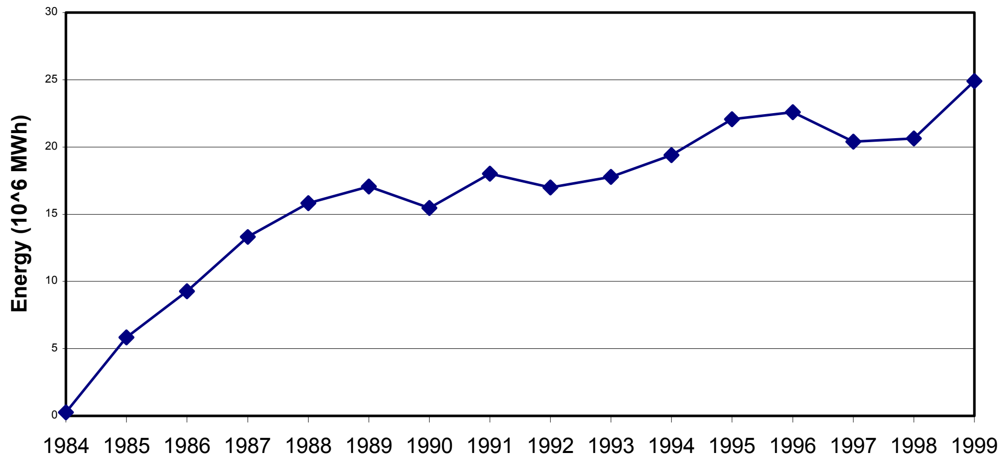
Table 3.17 shows the evolution of power generated at Tucuruí, from 1984 through 1999, also shown in Figure 3.3. Six types of energy users are defined: Industrial Maranhão (major industrial consumers supplied directly by Eletronorte in Maranhão State); Industrial Pará (the same for Pará State); Pará (CELPA); Maranhão (CEMAR) and Tocantins (CELTINS), as State concessionaires; Northeast (CHESF); and South/Southeast/Centre-West (FURNAS), for the interconnection between the two systems, in addition to the "Others" category which includes self-consumption, lighting, the public sector, etc.

Table 3.17 Allocation of Energy Generated by the Tucuruí Hydropower Complex (MWh)

Year	Industrial Maranhão	Industrial Pará	Pará (CELPA)	Maranhão (CEMAR)	Tocantins (CELTINS)	Nordeste (CHESF)	S/SE/CO (FURNAS)	Others	Total
1984	605 203	19 402	1 331 081	833 073	0	-2 953 501	0	434 709	269 967
1985	1 764 114	235 404	1 448 670	902 132	31 531	1 044 255	0	405 338	5 831 444
1986	3 327 394	1 758 261	1 626 677	1 079 879	47 689	835 120	0	582 049	9 257 069
1987	3 550 109	2 677 470	1 888 589	1 157 619	68 426	3 282 078	0	674 522	13 298 813
1988	3 853 772	2 803 408	1 991 818	1 265 659	67 207	5 155 660	0	700 891	15 838 415
1989	4 107 373	3 039 786	2 115 958	1 425 406	77 686	5 609 789	0	692 082	17 068 080
1990	4 302 040	3 749 566	2 275 418	1 524 225	96 430	2 871 927	0	649 126	15 468 732
1991	5 573 432	5 109 677	2 400 748	1 619 759	123 178	2 470 121	0	737 003	18 033 918
1992	5 662 851	5 529 618	2 457 766	1 630 803	145 645	851 490	0	719 498	16 997 671
1993	5 628 374	5 715 353	2 639 377	1 741 098	157 256	1 142 837	0	756 466	17 780 761
1994	5 663 802	5 780 993	2 919 256	1 872 953	188 147	2 064 473	0	920 129	19 409 753
1995	5 672 852	6 195 521	3 248 932	2 102 474	245 271	3 410 326	0	1 207 410	22 082 786
1996	5 705 293	6 724 287	3 547 152	2 281 340	299 179	2 755 882	0	1 283 683	22 596 816
1997	5 607 009	6 590 654	3 849 480	2 555 111	294 481	290 894	0	1 211 789	20 399 418
1998	5 619 023	6 338 249	4 253 218	2 827 229	344 733	-47 767	0	1 300 123	20 634 808
1999	6 064 391	6 025 642	4 424 573	2 961 818	321 432	2 947 679	363 308	1 790 358	24 899 201

Source: Eletronorte

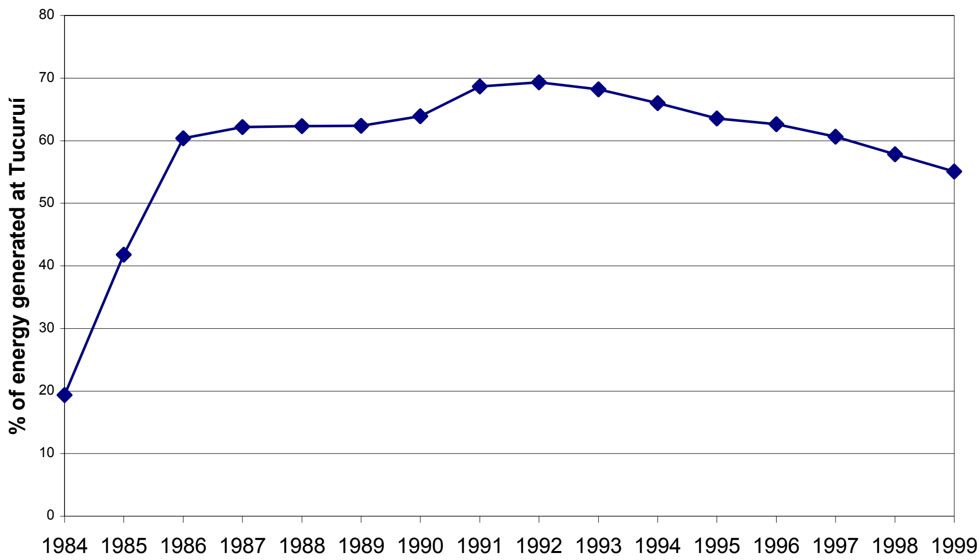
Figure 3.3 Energy Generated at the Tucuruí Hydropower Complex



Source: Eletronorte

Power consumption by major industrial ventures has remained fairly stable since 1991, but its share in the total consumption has been decreasing in recent years due to the increased consumption of other users and of the energy transferred to the State concessionaires, which is rising steadily. (Figure 3.4).

Figure 3.4 Energy Earmarked for Major Industrial Consumers

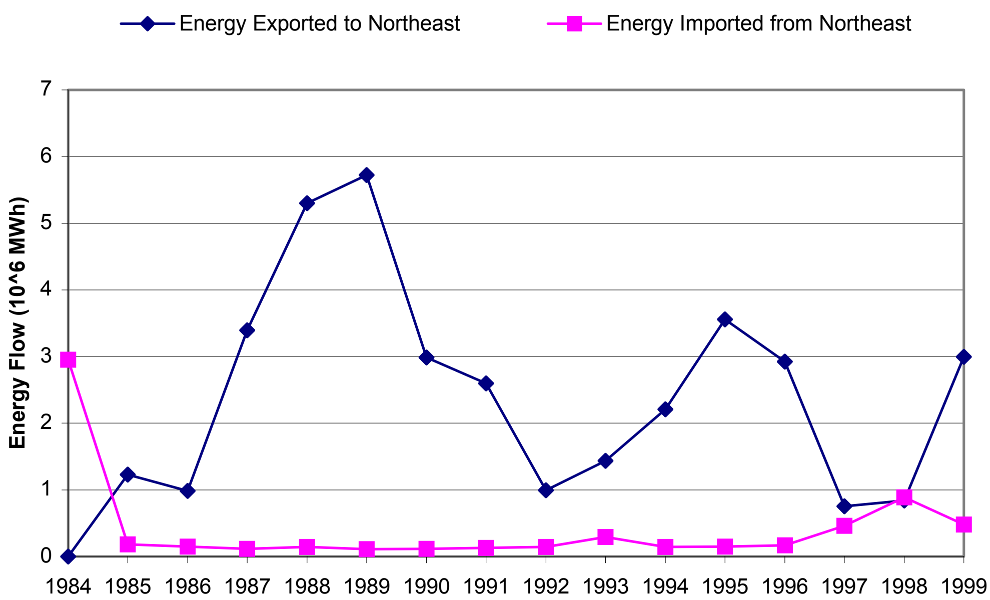


Source: Eletronorte

Energy exchange with CHESF clearly reflects the advantages of an interconnected energy transmission system. As shown in Figure 3.5, before the effective start-up of power production, the balance with CHESF was negative (1984) meaning that the Northeast guaranteed power supplies to the North region before the start-up of operations at Tucuruí. From 1985 onwards, however, Tucuruí has exported energy to Northeastern Brazil. This important North-Northeast flow began to shrink only from 1997 onward with the start-up of operations at the Xingó hydropower complex in Northeastern Brazil. In 1999, a substantial growth of the energy flow from Tucuruí to the Northeastearn region was recorded due to severe water availability constraints in the Northeast.

This entire analysis is undertaken on the basis of average annual output figures. Obviously the operating rules for the dam, industrial practices and seasonal phenomena all influence energy production and consumption processes, determining the real value of the energy generated. It is important to stress that during Phase I operation a substantial waste of secondary energy has been recorded[6].

Figure 3.5 Energy Flow: Tucuruí/Northeast



Source: Eletronorte

It should be stressed that from 1999 onward, the North/Northeast system was interconnected with the South-Southeast system by a new transmission line linking Tucuruí to Serra da Mesa hydropower plant (in Goiás State). This new connection opens up significant new prospects for the future use of power generated at Tucuruí. An interesting aspect of this interconnection is that it allows the connection between Northern, Northeastern and Southern regions of the country, through the Tucuruí node. In the first year after this interconnection, for example, Furnas transmitted about 1 697 GWh to the CHESF system, thus helping to eliminate the Northeast generation deficit.

Table 3.18 shows data on the evolution of gross power generation and consumption by producer class for Brazil, the Northern region and Pará and Maranhão States. Some major features illustrated by
Table 3.18 can be summarised as follows :

- The importance of hydropower in the total power generated in Brazil (87% in 1970 and 84 % in 1998);
- The relevance of Tucuruí power generation today for Northern Brazil (70% of all energy generated in this region) and for Brazil as a whole (6% of energy generated in Brazil);
- The high average annual growth rates for power production in Northern Brazil (twice the national rate);
- The power consumption growth rates for residential and commercial use are higher in Pará and Maranhão States than the national average.

Table 3.18 Gross Power Generation and Consumption for Selected Periods and Areas

Gross Electric Energy Generation in Selected Years - Total

Geographic Unit	Unit	1970	1975	1980	1985	1990	1995	1998	Annual Variation (%)
Brasil	GWh	45.460	76.954	137.023	195.919	235.837	260.678	341.826	7,47
Região Norte	GWh	465	1.085	2.358	8.539	19.216	27.527	26.929	15,60
Norte/Brasil	%	1,0	1,4	1,7	4,4	8,1	10,6	7,9	7,56
Pará	GWh	277	557	156	6.467	15.764	22.523	21.132	16,74
Pará/Norte	%	59,6	51,3	6,6	75,7	82,0	81,8	78,5	0,99
Maranhão	GWh	81	20	--	57	12	3	2	-12,38

Gross Electric Energy Generation in Selected Years - Hydraulic

Geographic Unit	Unit	1970	1975	1980	1985	1990	1995	1998	Annual Variation (%)
Brasil	GWh	39.863	72.093	126.752	181.171	228.377	250.480	286.391	7,30
Região Norte	GWh	--	4	165	6.072	17.518	24.284	22.320	--
Norte/Brasil	%	--	--	0,1	3,4	7,7	9,7	7,8	--
Pará	GWh	--	--	59	5.927	15.614	22.273	20.752	--
Pará/Norte	%	--	--	35,8	97,6	89,1	91,7	93,0	--
Maranhão	GWh	1	--	--	4	3	--	--	--

Gross Electric Energy Generation in Selected Years - Thermal

Geographic Unit	Unit	1970	1975	1980	1985	1990	1995	1998	Annual Variation (%)
Brasil	GWh	5.597	4.861	10.451	14.748	7.460	10.198	14.807	3,54
Região Norte	GWh	465	1.081	2.193	2.467	1.696	3.243	4.503	8,45
Norte/Brasil	%	8,3	22,2	21,0	16,7	22,7	31,8	30,4	4,74
Pará	GWh	277	557	97	540	150	250	380	1,14
Pará/Norte	%	59,6	51,5	4,4	21,9	8,8	7,7	8,4	-6,74
Maranhão	GWh	26	18	--	53	9	3	2	-8,75

Electic Energy Consumption in Selected Years - Total

Geographic Unit	Unit	1970	1975	1980	1985	1990	1995	1998	Annual Variation (%)
Brasil	GWh	37.673	66.013	120.726	173.074	205.354	249.857	287.864	7,53
Região Norte	GWh	365	900	2.289	3.869	8.757	12.563	14.770	14,13
Norte/Brasil	%	1,0	1,4	1,9	2,2	4,3	5,0	5,1	6,13
Pará	GWh	215	444	1.231	2.127	5.908	8.555	9.602	14,53
Pará/Norte	%	58,9	49,3	53,8	55,0	67,5	68,1	65,0	0,35
Maranhão	GWh	42	206	536	2.599	5.629	7.396	7.963	20,60

Electic Energy Consumption in Selected Years - Residential

Geographic Unit	Unit	1970	1975	1980	1985	1990	1995	1998	Annual Variation (%)
Brasil	GWh	8.406	13.264	23.310	32.766	47.884	63.522	79.379	8,35
Região Norte	GWh	148	285	592	1.038	1.938	2.625	3.481	11,94
Norte/Brasil	%	1,8	2,1	2,5	3,2	4,0	4,1	4,4	3,31
Pará	GWh	81	141	301	497	835	1.053	1.301	10,42
Pará/Norte	%	54,7	49,5	50,8	47,9	43,1	40,1	37,4	-1,35
Maranhão	GWh	19	53	154	294	544	705	975	15,10

Electic Energy Consumption in Selected Years - Industrial

Geographic Unit	Unit	1970	1975	1980	1985	1990	1995	1998	Annual Variation (%)
Brasil	GWh	19.345	35.616	69.787	98.604	104.763	117.964	125.144	6,90
Região Norte	GWh	69	212	940	1.424	4.830	7.186	7.817	18,40
Norte/Brasil	%	0,4	0,6	1,3	1,4	4,6	6,1	6,2	10,77
Pará	GWh	39	98	553	950	4.161	6.327	6.896	20,30
Pará/Norte	%	56,5	46,2	58,8	66,7	86,1	88,0	88,2	1,60
Maranhão	GWh	16	62	160	1.984	4.536	5.919	5.979	23,56

Electic Energy Consumption in Selected Years - Commercial

Geographic Unit	Unit	1970	1975	1980	1985	1990	1995	1998	Annual Variation (%)
Brasil	GWh	5.194	9.075	13.806	18.497	29.022	32.142	41.586	7,71
Região Norte	GWh	80	205	425	676	984	1.354	1.754	11,66
Norte/Brasil	%	1,5	2,3	3,1	3,7	3,4	4,2	4,2	3,66
Pará	GWh	51	108	233	349	441	608	735	10,00
Pará/Norte	%	63,8	52,7	54,8	51,6	44,8	44,9	41,9	-1,49
Maranhão	GWh	10	39	104	144	294	350	433	14,41

Source: Anuários Estatísticos do IBGE (1971, 1976, 1981, 1986, 1991, 1996 e 1998)

It should be pointed out that the electricity generated by Tucuruí did not immediately reach consumers in the areas close to the dam. Only in 1998, when the Western Pará State Transmission System (Tramoeste) was built, it was possible to replace energy generated using oil products in the municipal districts along the Transamazon Highway, particularly Altamira, Santarém and Itaituba. The expansion of the Santa Maria substation in 1996 strengthened services in the Lower Tocantins region, allowing new locations to be supplied through the transmission grid run by the local company, and ending the need for rationing in Paragominas. In 1998, the Tucuruí-Cametá power line was completed, followed by the State power grid expansion in 1999, to the benefit of locations in the Mojú-Tailândia axis.

3.3.2 Financial and Economic Value of Power Generation

An economic and financial review of the performance of the Tucuruí hydro-power complex is not a simple task. Initially, this analysis must distinguish clearly between the components of the economic evaluation and the financial assessment of the investments in question.

Looking at the economic aspects of this venture, several factors hamper an appraisal of whether or not this produced any effective benefits for Brazilian society in general, and for the region around the dam in particular, and make it difficult to gauge the possible future importance of these gains. Outstanding among these factors are:

- difficulty in economically quantifying many of the direct effects of the project, including its environmental impacts;
- difficulty in identifying, assessing and quantifying in monetary terms many of the indirect and secondary effects caused by this enterprise which – in the case of a power generation project that also structures its surroundings, such as Tucuruí – may well be more important than its actual direct effects;
- difficulty in establishing a simple cause and effect relationship between the project and some of the impacts noted in the region, due to the wide variety of processes underway (settlement projects, the laying of roads and highways, railroads, mining operations, etc.);
- the impossibility of forecasting how the region would have developed in a hypothetical "no project" situation, in order to compare the social losses and gains of the decision;
- uncertainty over future decisions, as the social benefits of the venture may extend, particularly when Phase II is implemented.

However, some general estimates can be drawn up of its profitability, although no such estimates were provided in the feasibility studies. One way of assessing the performance of this project is to analyse its social costs per MWh generated, and compare them with costs of other hydropower plants, or other ways of producing energy.

The following hypotheses were taken under consideration (all at US$ 1998 values):

- total investments of US$5.53 billion (without interest);
- investments of US$1.27 billion in power lines and substations (over ten years);
- annual expenditures of 3% of the amount of the investments in operating, maintenance and replacement expenditures;
- analysis horizon of thirty years, taking into account the residual value for the dam and power lines;
- energy generated equivalent to that of Tucuruí, constant at 22 million MWh/year from 1999 through to the end of the analysis period.

According to the above assumptions, the costs per MWh incurred at Tucuruí would vary between US$40 and US$58, based on discount rates of 8% to 12% per year, respectively. For purposes of comparison, the average figure charged per MWh in Brazil in 1998 was US$70 (ELETROBRÁS, 1998). This estimate provides a benchmark cost that would rank Tucuruí as a profitable project, but not to a great extent.

Part of the power generated by Tucurui is supplied at subsidised prices under contracts signed years ago when the decision to build this power complex was about to be made. In order to illustrate the levels of the subsidised rates, one MWh from Tucuruí is sold to large electricity-intensive consumers for roughly US$24, including distribution costs. Compared with the national average tariff of US$70 / MWh, the embedded subsidies become evident, even if one takes into account that electricity prices charged to large industrial consumers are usually much lower than to other sectors such as the residential and commercial users. It should be recalled that most of these contracts are about to expire, indicating that these subsidised tariffs can be reviewed very shortly.

Another way of assessing project benefits, particularly in the region surrounding this venture, would be to analyse the development of average power consumption figures over the past few years. This energy consumption indicator not only reveals the direct effects of building the Tucuruí hydropower complex in terms of electricity generation, but also suggests indirect benefits, such as the increased well-being of the local populace.

Table 3.19 below shows the evolution from 1979 through 1995 in residential and commercial[7] consumption together, in four geographic units affected by the Tucuruí hydropower complex, including the city of Tucuruí, Marabá, the municipal districts downstream from the dam (Baião, Cametá, Limoeiro do Ajuru and Mocajuba), and Pará State as a whole. The main conclusions from an analysis of this table can be summarised as follows :

- the population growth rates for municipal districts closer to the dam (Tucuruí and Marabá) were very high over the period, more than twice the rate recorded for Pará State, contrasting with sluggish growth downstream;
- during the dam-building period, per capita energy consumption at Tucuruí and Marabá was four times higher than the State average, but has dropped to levels close to the State average today;
- the average per capita energy consumption in downstream municipal districts remains very low today, at just over 20% of the State average.

Table 3.19 Population and Power Consumption Indicators in Selected Regions – Pará State (1979 and 1995)

Indicator	Period	Unit	Geographic Unit			
			Tucuruí	Marabá	downstr.[1]	Pará
Population	1979	Inh.	15.384	37.658	114.130	2.906.852
	1995	Inh.	58.679	150.095	146.504	5.448.598
Annual growth		%	8,73	9,03	1,57	4,00
Annual Energy Consumption	1979	MWh	11.878	29.651	1.477	493.320
Residential & commercial	1995	MWh	16.753	56.674	9.315	1.660.039
Annual growth		%	2,17	4,13	12,20	7,88
Annual per capita Energy	1979	kWh/cap.	772	787	13	170
Consumption (com. + res.)	1995	kWh/cap.	286	378	64	305
Annual growth		%	-6,03	-4,49	10,46	3,72

Sources: 1979 data: Anuário Estatístico do Pará 1980 / 1995 data: IDESP/IBGE and CELPA
(1) - Cametá, Limoeiro da Ajuru, Baião and Mocajuba are taken together

In fact, among the four downstream municipal districts in 1979, power was distributed on a regular basis only at Cametá, from diesel generators. It was only recently that a power transmission line was laid to supply part of these downstream districts with energy generated at Tucuruí.

Matters are more complex regarding the financial analysis of this venture. The subsidised rates offered to major industrial energy consumers have not ensured great profitability to Eletronorte. Since 1993, Eletronorte has been forced to reduce its net patrimony steadily to cover its deficit, mainly caused by these subsidies. It estimated its annual subsidies in 1988 alone at US$194.2 million, as posted in its balance sheet (Eletronorte, 1999).

One approach to the calculation of the total amount of these subsidies would be the establishment of a "fair" reference electricity price for the industrial consumers and calculate the difference to the actual prices recorded. The difficulty here is that such a reference price would be rather arbitrary. It is recognized that electricity prices for industrial consumers are usuallly lower than for other consumers. In Brazil, electricity prices for the industrial and other sectors were established on a national basis by the Government, until the late nineties when the restructuring of the sector began. However, electricity prices for very large industrial consumers have often been negotiated on a special case-by-case basis. The case of Tucuruí is unique in the sense that more than half of the energy generated by the plant was sold to large industries.

Another approach consists of comparing the income from the electricity sold to the large industrial consumers with the estimated cost of generating the corresponding amount of energy at the Tucuruí plant. If one considers that in 1999 about 12 000 GWh of Tucuruí power was sold at about US$24/MWh to large industrial consumers, the gross revenue was about US$290 million. The cost to produce such an amount of energy would range from US$484 million to US$701 million, according to our cost estimates between 40 and 58 US$/MWh. The subsidies given to the large industrial consumers in Pará would then range from US$193 million to US$411 million for 1999 alone, depending on the discount rate considered. It can be noted that the value reported for 1988 by Eletronorte coincides with the lower end of this range. In any case, the impact of these subsidised rates on the cost recovery of the project is very important

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3.3.3 Financial Compensation (*Royalties*)

Payment of the ICMS tax (*Imposto sobre Circulação de Mercadorias e Serviços*) brought in through the sale of electricity generated at Tucuruí constituted a significant source of income for the States, which could assign these amounts according to their own priorities. This ICMS tax brought in some R$19.2 million on power sold from Tucurui in 1998, for Pará and Maranhão States alone.

Since 1991, Brazilian law has required royalties to be paid to the Federal Government for the use of water for power generation purposes, commonly known as royalties[8]. The amounts are calculated for each hydro-power plant in proportion to the amount of energy generated over the period, bringing the amount paid by Tucuruí to among the highest in Brazil. The royalties paid by each power plant are divided up as follows: 10% to the Federal Government; 45% to the State(s) where the venture is located; and 45% divided up among the municipal districts affected by the venture. The criteria for the share-out among the municipal districts are controversial, as they stipulate that the percentage assigned to each district must be proportional to the area submerged by the dam.

This has resulted in distortions throughout Brazil. In the case of Tucuruí, the situation is no different: municipal districts downstream from the dam that have been heavily affected by its construction are not awarded any royalties, as no areas were flooded to form the lake. Similarly, the amounts transferred vary greatly among the beneficiary districts: at Tucuruí, the municipal district awarded the highest *per capita* royalties receives nine times more per inhabitant than the lowest-paid municipal district.

Table 3.20 below shows the total amounts transferred by Eletronorte in 1996. There are seven municipal districts benefiting from these transfers, which for some districts – like Novo Repartimento – are among the major revenues for the Town Council (US$3.9 million, equivalent to a *per capita* income of around US$130). The total amount paid out by Eletronorte in 1996 reached US$18 842 790, with the total royalties for 1991 through 1996 exceeding US$102 659 232.

Table 3.20 Municipal Districts in Paraná State: Financial Compensation for the Use of Water Resources

Municipality / State	Population 1996 (inhabitants)[1]	Compensation Share (%)[2]	Received Value in 1996 (US$ 1998)[3]	Per Capita Received Value in 1996 (US$ 1998)
Breu Branco	20 223	2.80	527 410	26.08
Goianésia do Pará	20 882	8.82	1 661 531	79.57
Itupiranga	29 171	2.19	412 688	14.15
Jacundá	39 420	4.20	791 984	20.09
Nova Ipixuna	8 706	1.40	264 115	30.34
Novo Repartimento	30 059	20.70	3 901 166	129.78
Tucuruí	58 679	9.88	1 862 501	31.74
Pará State	5 510 849	50.00	9 421 395	1.71

Sources: (1) Contagem Populacional 1996 (IBGE), (2) ANEEL, (3) Eletronorte
Notes:a) The total amount paid by Eletronorte in 1996 was US$18 842 790. b) The total amount paid by Eletronorte from 1991 through 1996 was US$102 659 232

Findings

- No broad-ranging study was undertaken of the Tucuruí power market in order to define the status of the project and even the capacity of this power plant.
- It began on the basis that there would be much interest among electricity-intensive industries eager to use power generated at Tucuruí, due to low prices that could be offered.
- Any power left over after servicing almost-guaranteed markets such as Belém and Marabá would be used to meet repressed power demands in Pará, Maranhão and Tocantins States, in addition to the possibility of transmitting energy to Northeast Brazil along a power-line running 1 800km between Sobradinho and Boa Esperança.
- Currently, Tucuruí services most of the energy market in Pará, Maranhão and Northern Tocantins States, benefiting some eight million people, over five million of them in Pará State.
- Power swaps between the Northeast and South/Southeast/Centre-West Brazil helped fine-tune the use of water resources throughout Brazil, minimising secondary energy losses during the early years in operation.
- Recently-strung power lines are servicing the areas around Tucuruí that were not supplied with power from this complex.
- The costs per MWh generated at Tucuruí are estimated between US$40 and US$58, based on discount rates of 8% to 12% per year, respectively.
- The amount of subsidy offered to major industrial power consumers is estimated to range between 193 and 411 million dollars per year.
- The funding brought in through the ICMS tax and financial compensation constitutes an important source of income for States and Municipal Districts in this region. Under Brazilian law, downstream municipal districts received no financial compensation.

3.4 Navigation

This Section shows the impacts on shipping caused by damming the Tocantins River, and discusses the projected effects of the locks planned as part of the Tucuruí project.

Building the locks to handle the drop in water level caused by the Tucuruí dam was included in the power plant project in order to ensure year-round commercial shipping on the Tocantins River. The significance of building locks should be analysed with a focus on the decision-taking process and the historic and economic importance of shipping along the Tocantins River.

From the outset, in view of the economic and cultural importance of the Tocantins River, the people of Pará State saw an association between these two projects (hydropower and shipping) as an opportunity to kick-start the local economy.

The settlement of this part of Brazil has primarily taken place along its rivers over many centuries, with villages handling the outflow of products extracted from the forests. After the collapse of the rubber boom, shipping along the lower Tocantins began to pick up again with the transport of Brazil nuts from this State to Belém. Until the Belém-Brasília Highway was built in the late 1950s, the Tocantins River was the only means of access to the Marabá region and Southeast Pará State, and even with the arrival of these highways running north from Marabá, many goods continued to be shipped by river. The main problem, however, was the Itabocas Rapids, which completely blocked this route during the dry season.

Building the hydropower plant on the drop at Itabocas would permanently submerge the rapids. Provided that locks were built on the dam, this would make the Tocantins River navigable all year round between Marabá and Belém, while also providing a regional energy structure. To a large extent, the social and political receptivity to the Tucuruí Hydropower Complex at the regional level was based on the possibility of interconnecting these two ventures: the hydropower complex and river shipping. (*O Liberal*, 1979, mentioned in the 1992 Case Study).

Building locks to deal with the drop in water levels caused by the Tucuruí Dam was included in the plans for this Hydropower Complex, allowing commercial shipping to sail the Tocantins River throughout the year. The importance of building the lock should be viewed in the contex of the decision-making process and the historical and economic importance of shipping along this water-course.

Initially, building the lock was motivated largely on the fact that this project would underpin the use of river shipping to handle the outflow of iron ore from Carajás to the Port of Vila do Conde for export. Alternative transportation was by rail, travelling to the Atlantic on the Pará State coastline or to the Port of Itaqui in Maranhão State.

Still state-owned at that time, the majority shareholder in Carajás – CVRD (Companhia do Vale do Rio Doce) – decided to transport its ore by rail to the Port of Itaqui in Maranhão State. This decision was informed not only by its experience in rail transportation but also by the upstream investments required and the annual costs of maintaining an ore terminal in Pará while also keeping the Tocantins River navigable throughout the year as far as the coast.

The river transportation authorities in the Federal Government refused to accept the possibility of not making good use of the opportunity to build a dam structure and reservoir for energy production that included river transportation along this river, and continued to urge that the lock be built. In 1979, when the hydropower project was already at an advanced stage of implementation, the government decided to include the locks in the Hydropower Complex designs. This was to be handled jointly by the Ministry of Transportation and the Ministry of Mines and Energy.

Work on the lock failed to keep pace with the progress of the hydropower complex. During the 1980s, when the Federal Government finally decided to ship ore from Carajás to the Port of Itaqui by rail, the functions that would have been assigned to this waterway were allocated to the Carajás Railroad. Until 1984, work on the locks progressed normally, but then slowed down, hobbled by a shortage of funding, and finally ground to a halt in 1989.

For some government sectors, the decision to include a large-scale lock was mistaken, increasing the cost of the project (over US$300 million at that time) and bringing forward environmental effects and costs that would only have occurred during Phase II with the flooding of the Caraipé Valley. The inclusion of the locks in this project played a leading role in increasing the costs of this Hydropower Complex (1992 Case Study).

Meanwhile, various sectors of society in Pará State were unhappy about the halting of the works, as the lock project was considered vital for the development of this area. It was also seen as fair compensation for the State, in return for the benefits that energy production would offer the Federal Government. Moreover, the dam blocked existing river routes between Marabá and the coast which, though seasonal and almost negligible in economic terms, constituted a long-standing communications link through the Lower Tocantins, while also offering a low-cost alternative for shipping certain products.

A large proportion of the populace and Government of Pará State continue to lobby for the completion and operation of the locks, and the project is set to be concluded in the next few years. As the Federal Government feels that the failure to complete the locks may be curtailing the economic development of the region, the project was included in the "Brazil in Action" Federal Programme (*Programa Brasil em Ação*).

This waterway is today proving a valuable alternative in fostering more effective use of the massive farming, ranching, forestry and ore potentials of the Tocantins-Araguaia Valley. These have been exploited more intensively over the past few years as settlement frontiers expand northwards, borne forward by the highways.

The output of this region could be channelled to the Vila do Conde River Port, which is in a privileged location for the markets of North America, Europe and the Middle East. Moreover, as the operating costs of the waterway are low, the locks could endow regional products with a keener competitive edge in Brazilian markets.

Findings

- Since the earliest discussions concerning Tucurui, the people of Pará State saw an association between these two projects (hydropower and shipping) as a vital opportunity to kick-start the local economy.
- Construction of the dam blocked existing river routes between Marabá and the coast which, though seasonal and almost negligible in economic terms, constituted a long-standing communications link through the Lower Tocantins, while also offering a low-cost alternative for shipping certain products.
- Initially, the building of the lock was motivated largely on the possibility of ensuring the use of this waterway to handle the outflow of iron ore from Carajás to the Port of Vila do Conde for exports. However, CVRD opted to ship its ore out by rail to the Port of Itaqui in Maranhão State.
- In 1979, when the hydropower project was already at an advanced stage of implementation, the government decided to include the locks in the Hydropower Complex designs.
- Until 1984, work on the locks progressed normally, but then slowed down, hobbled by a shortage of funding, and finally ground to a halt in 1989.

3.5 Effects on Ecosystems

This Section offers an overview of the main impacts of the implementation and operation of Tucuruí on ecosystems in this region. It analyses water quality both upstream and downstream from the dam, the problems of the *várzea* floodland forests, and the growth of aquatic plantlife in the reservoir, terrestrial and aquatic animals, the proliferation of disease vectors, the presence of mercury in this region, and the emission of greenhouse gases by the reservoir.

3.5.1 Impacts Predicted in the Feasibility Studies

Consistent with the mentality prevailing within the Brazilian power sector at the time, the Feasibility Report emphasized the effects of the Amazonian Ecosystem on the dam far more than the impacts of the dam on the local ecosystem. The same tendency was evident with regard to other environmental aspects such as local communities and indigenous societies, all of which were viewed as an obstacle to the successful completion of the venture.

For example, the Feasibility Report mentions that "variations in the water table level caused by the dam wall should speed up the erosion of younger rocks to a moderate extent". The same report noted that some plant life depends upon the flow system of the Tocantins River, with flooding periodically affecting the plant life along its banks, and also that "large-scale deforestation has been taking place, with no counterpart reforestation, with few areas remaining today that have not been devastated".

Regarding wildlife, this report concluded that "the main alterations should affect the fish species whose life-cycle is closely linked to the natural high-water and low-water cycles of the river". It then recommended that "a study of the physical, chemical and biological conditions of the water be carried out in order to prepare a programme ensuring better conditions for the proliferation of desirable fish in the reservoir". [9]

It mentions two aspects of mineral resources: as potential markets for power consumption or as imposing constraints on the damming of the river and on the size of the reservoir. Ore-beds of proven importance and the discovery of others considered promising suggested the possibility of massive reserves in this area.

Initially, the report stated that free-standing mining operations were not major consumers of electric power. "However, ore-processing industries such as aluminium or nickel smelting justify the implementation of major hydropower plants (our underscore)[10]. As major ore-beds in this region hold low-grade minerals, they must be processed close to the beds." (…) "In the current economic situation in Brazil, the rational use of the nation's mineral resources is vital, not only for domestic consumption but also to boost exports, preferably in the form of manufactured or semi-finished products. In order to achieve these objectives, a challenge must be faced, consisting of production at prices that are competitive with those on international markets. This challenge can be dealt with through mineral technology, allowing for the insertion of other economic parameters, such as specialised labour and electricity in the export flows." (…)"The huge bauxite reserves at Oriximiná and their excellent quality indicate that their industrial processing may well underpin the influence of Brazil on the global aluminium and/or alumina markets..." [11]

In the latter case, the Report indicates interference of the future reservoir with areas requisitioned by the Mineral Production Department (Departamento de Produção Mineral) for prospecting and mining diamonds, gold, limestone and sulphur - but is reticent regarding the economic feasibility of these projects.

3.5.2 The Goodland Report and the INPA/Eletronorte Studies

When work began at Tucuruí, international experience of environmental impacts associated with the introduction of large lakes in tropical regions was limited to some African dams, where massive and quite unforeseen problems arose during the planning stage. Although these African lessons proved very useful for Amazonia, they could not be transferred directly due to fundamental differences in the quality of the water bodies, the plant-life submerged by the lake, and the fact that the biota of these two continents is very different. In tropical South America, the construction of the Brokopondo and

Kabalebo projects in Suriname could have provided useful contributions, but little detailed ecological information was available on these two ventures. The decision to build Tucuruí was thus made before most of the impacts could be predicted.

In order to bridge this gap, in 1977, Eletronorte hired the well-known ecologist Robert Goodland. His diagnosis was that Eletronorte should draw up a deforestation programme, together with a social and cultural inventory of the affected communities, in parallel with a survey of the historical and archaeological heritage of this region, an inventory of its wildlife, and a listing of the regional infrastructure, among other studies (Goodland, 1978). He also stressed the need for "*animal rescue and ecological preservation measures, while also recommending water quality controls for the reservoir and the preparation of multiple use studies"* (Eletronorte, 1998).

There was a consensus that, as ecological and biological information on Amazonia was sparse, particularly in the regions selected to build this Hydropower Complex, the assessment of the ecological impacts could only be undertaken on firm, coherent bases after some years or even decades. This is why most of the inferred impacts of the Tucuruí Hydropower Complex were based on a variety of estimates and speculations.

To comply with the recommendations in the Goodland Report, in 1980 Eletronorte signed an agreement with the National Research Institute for Amazonia (INPA - *Instituto Nacional de Pesquisas da Amazonia*), transferring to it the responsibility for conducting studies on climatology, limnology, water quality, plant-life, epidemiology of epidemic diseases and fish-life in the reservoir area.

The efforts of a few dozen researchers resulted in a vast collection of information on the ecosystems of the Araguaia and Tocantins Rivers, as work was carried out not only in the actual lake area, but also along its tributaries. Most of these studies should have been started at least a decade earlier, in order to allow the possible future environmental impacts to be identified, with corrective and compensatory actions being properly planned and implemented.

Despite heroic efforts to carry out broad-ranging botanical and zoological inventories, this project failed to study the entire region, which was too large to cover in the time allotted. Moreover, as local plant and wildlife was extremely diverse, even the simple taxonomic identification of species was a difficult and complex activity, due to the lack of specialists in all the areas concerned. This meant that the knowledge assembled was insufficient to forecast the impacts over time with the necessary accuracy.

The amount of information brought in during the study period resulted in huge numbers of technical reports that later appeared in scientific publications.

The main observation of the researchers (SANTOS et al, 1991), is that the monitoring of modifications in the aquatic environment caused by large-scale projects did not continue adequately after the dam was filled. Normally, the end of civil construction also brings the conclusion of environmental surveys in some aspects. Hence the possibility of carrying out qualitative and quantitative studies of the environmental impacts of major hydropower dams in Brazil has not been properly examined. In the specific case of the Tucuruí Hydropower Complex – as shown by the works covered in this assessment – some areas of study were pursued systematically and with continuity. On the other hand, particularly in the biological community studies, the assessments were halted, or only sporadic studies were carried out.

Although more information is available today on the environmental impacts of this type of intervention, much knowledge was not gathered due to a lack of long-term monitoring of the various ecological aspects of the affected ecosystems.

The following subsections will exhibit the most important predicted and actual impacts on local ecosystems. The basic sources for predicted impacts are the Goodland Report, INPA and Eletronorte studies, except where otherwise stated. Most outcomes are based on the reports generated by Eletronorte's monitoring studies, conducted after impounding except where otherwise stated.

3.5.3 Water Quality in the Reservoir[12]

Water quality in the reservoir was predicted to be very poor in the first years after flooding because of the organic matter degradation. This did occur, especially in some areas where circulation was poor either due to the margin conformation, depth and dead tree occurrence. To some extent, however, some of the most catastrophic predictions (such as the elevated water acidity corroding the powerplant machinery and the death of all fisheries in the lake and downstream) have not occurred.

Today, a trend is being noted by the monitoring system towards stabilization at water quality levels that are almost all compatible with those stipulated in the N° 20 Resolution issued by the National Environment Council (CONAMA – *Conselho Nacional do Meio Ambiente*), which classifies water bodies. Tucuruí lake is classified as a #2 class water body, and their waters are not bound to be drunk directly by people. However, most riparian populations either in the lake and downstream use the water for drinking, livestock drinking, cooking and bathing. Current water quality is probably not adequate for these uses, specially because usually water is captured closer to marginal areas where water quality is at its poorest.

The distribution in space and time of the many variables monitored is similar to that of countless natural Amazon water-bodies that are also in critical situations. These include low levels of dissolved oxygen at deeper levels at certain seasons; periodically higher levels of suspended solids in the water and high turbidity (muddiness); and large amounts of phosphorus and nitrogen affecting the floration of possibly undesirable algae and aquatic macrophytes. Although specific situations may at times exceed the limits imposed by the National Environment Council, they are typical of the large catchment areas of the Amazon.

Two aspects should be stressed and kept under close observation at the Tucuruí Reservoir: the first covers the quality conditions in various parts of the reservoir, which may be divided into three separate sections below. Most available data on water quality in the Tucuruí reservoir came from the studies of Eletronorte and the Themag-Engevix consortium carried out after the dam flooding.

- Upstream Section – initial part of the reservoir with flowing water characteristics, represented by station M5. This region is subject to high current flows, and is permanently well-mixed, with no vertical distinctions in the distribution of the limnological variables.
- Central Chute Section – consists of the central part of the reservoir represented by the M1 and M3 stations. Its marked seasonality is influenced by the inflow of water. During typical periods of heavy rainfall or the high-water season from February through April, the turbulence of the peak flows stirs up the water column completely, homogenising the vertical distribution of dissolved substances. During the dry season in Amazonia from August through October, the water column becomes more stratified, with vertical distinctions in the concentrations and values of its physical and chemical variables. The stratification of the consequence stability of the water column is more marked in the forebay area (greater depth – station M1). A characteristic of this stratification is the presence of an anoxic layer, principally at M1.
- Banks Section – the banks of the reservoir, represented by the MR and C1 stations, whose spatial complexity results in unfavourable limnological conditions compared to the central area. As they are more protected from the action of the wind, they are less affected by the inflow of water (poorer circulation), with more partially submerged trees. These conditions are potentially more favourable for the development of algae (some toxic) and aquatic macrophytes, as well as longer-lasting poor quality deep waters due to low levels of dissolved oxygen.

In general, following the parameters stipulated by CONAMA, the waters of the reservoir are considered suitable for a wide variety of uses. However, the riverbank sections, which are in closer contact with the local communities, are not considered adequate for higher-grade uses such as household water supplies and bathing. Although potability standards are not monitored by Eletronorte, the direct use of waters from these sections for human use should be avoided, without more detailed investigation.

During the initial reservoir formation period between 1984 and 1990, there was an appreciable drop in water quality, particularly during the dry season. However, after this period, a steady but not yet fully stabilised improvement in water quality can be noted. The water quality is still not sufficiently high-grade for some direct uses like drinking or bathing, particularly in more remote stretches of the reservoir such as around Repartimento and Caraipé as mentioned. Although there is an improvement in the water quality in recent years, one must stress the magnitude of the social impacts that arose from the water quality deterioration, as will be discussed later.

The second aspect is to consider the situation downstream, which is severely affected by deeper layers of water upstream that run through the tailrace and have undoubtedly reduced the quality of water for human use. However, these effects have been alleviated by high flow-rates noted during rainy periods, as well as the natural cleansing process of the Tocantins River itself: hence there has been a gradual improvement in the quality of the water further downstream from the dam wall.

Nevertheless, the reservoir water has shown a decrease in the release of chemical compounds – reflected in the downstream water – that in large amounts are potentially hazardous to the environmental balance or dangerous for human use (nitrogen and phosphate compounds, for instance).

The main limnological relationships at the Tucuruí lake are heavily influenced by the massive inflow of water to the reservoir and its role in oxygenating the water column, with the indirect consequences already discussed.

In general, the Tucuruí Reservoir shows no indications of high mortality rates for aquatic organisms (mainly fish) caused by a shortage or absence of dissolved oxygen. Monitored over space and time in the reservoir, the effects of this variable are indirect, related mainly to the release of the compounds mentioned previously by anoxic sediments.

Thirteen years after the lake was formed, the severe oxygen depletion at the bottom of the Tucuruí Reservoir is less marked and continues to improve, particularly since 1990, and hence the formation and/or release of harmful compounds has decreased.

The trends outlined here lead to the inference that the most critical period for this reservoir was its first six years, with more marked fluctuations in the various elements and substances found in the water. It is believed that in this six-year period the reservoir was strongly influenced by, and benefited from, high flow-rates from the tributaries of the Tocantins River, with water being stored for shorter periods in the reservoir. High water temperatures also seem to have speeded up the metabolisation processes of submerged biomass.

This improvement in the reservoir water quality from 1990 onward is also confirmed by shrinkage in the area covered by aquatic macrophytes.

3.5.4 Downstream Water Quality

Water quality studies were carried out downstream from the Tucuruí Reservoir while its flow was halted during *Operação Estiagem* in 1986. They showed low levels of dissolved oxygen in the water, worsened by the absence of backflow.

There were two different types of water flows in 1986 along a stretch of river some 40km long: one flow near the left bank was completely anoxic due to the hypolimnetic nature of the tailrace, while water flowing down the spillway had higher oxygen levels (Bastos et al. 1987). This highlights the importance of establishing operating rules for the spillway gates that mitigate negative downstream impacts, particularly along the left bank.

In 1988 the ENGEVIX-THEMAG Consortium undertook a study entitled the Experiment Assessing the Impact of *Operação Estiagem* on Fish Life Downstream (*Experimento de Avaliação do Impacto da Operação Estiagem sobre a Ictiofauna no Trecho de Jusante*). Its results indicated that the dissolved oxygen levels (0.89 – 2.08 mg/l) observed in net-tanks placed downstream in the overflow channel did not lead to fish behaviour patterns typical of anoxic environments - for example, swimming unusually close to the surface or gulping air frequently.

Negative effects on fish were caused by the indirect effects of anoxia, such as the production of ammonia, methane and toxins by aquatic plants, which severely affected organs such as the liver and heart of some samples analysed.

At the moment, there seems to be no shortage of dissolved oxygen available downstream or similar adverse effects.

Another expected downstream effect was the appearance of an influx of salt water as far as the Belém region, due to the reduction in the flow volumes of the Tocantins River when filling the reservoir. This phenomenon was not noted.

3.5.5 Phase II of Tucuruí and Water Quality

With the operating alterations scheduled for Phase II of the Tucuruí Hydropower Complex, the consequent modifications in the reservoir scheme will change the morphometric characteristics of the lake appreciably over certain periods, with frequent depletions of up to 10m. The reservoir should operate at depths varying from 72.00m as its normal maximum to 62.00m as its normal minimum.

As the more significant outflows are planned mainly for October through December, the flooded area may be exposed again, to an extent of some 20%, equivalent to around 560km^2, according to Eletronorte studies.

This reduction in water volumes may trigger a number of processes related to erosion of its banks with plantlife appearing in the exposed areas, as well as squatters moving to the banks of the reservoir - with the possibility of croplands appearing in the regions to be exposed. This practice could well cause a number of alterations in the quality of the reservoir water, particularly along its banks, due mainly to the use of fertilisers and pesticides.

Enriching these areas with nutrients may worsen the problems noted at the moment along the banks, particularly in the Repartimento inlet. These include the excessive development of aquatic macrophytes, at times associated with the appearance of mosquitoes and undesirable algae floration.

A positive factor is that the new operating rules for Phase II will reduce the periods spent by water in the reservoir. It may thus be expected that its water quality will improve through more frequent renewal of its liquid mass, minimising the effects mentioned above.

The start-up of operations for Phase II with a larger number of turbines in operation will modify the downstream hydrological system even further. According to Eletronorte simulations, some 70% of the total outflow volumes will run through the tailrace, meaning that overspill flows will amount to 30% or less of the volume.

This configuration means that the water quality in the Tocantins River downstream from the dam will, for much of the year, be almost exclusively dependent on the water quality noted at the turbine intake point (at a height of 62m.)

By replacing overflow volumes, this increase in the tailrace outflow may result in a reduction in the average levels of dissolved oxygen, should the water quality in the reservoir remain at its current level. However, as noted in the figure above, the water quality at station M1 has been improving steadily, and consequently no appreciable negative effects are expected in the quality of water downstream from the dam.

3.5.6 Downstream *Várzea* Floodland Forests

Regularisation of the river flow prevented the seasonal flooding of riverbanks downstream, adversely affecting the natural fertilisation of land along the river where crops are planted.

The physical barrier of the dam wall traps nutrient-rich organic matter. This results in two immediate consequences that have already been noted in other reservoirs. The first is the steady impoverishment of *várzea* floodland forest soils, as riverborne nutrients are not replaced. The second is a drop in downstream catches as less nutrients enter the food chain. Also, the physical barrier of the dam wall directly affects fish migration, with regularisation of river flows making this even worse, as the start of the flood season triggers the breeding process for many organisms.

With regard to the latter point, it should be stressed that the water flowing from the reservoir is not always of poor quality. Due to its capacity to retain sediments and nutrients, the reservoir may frequently upgrade the quality of water downstream. However, this retention may adversely affect the downstream food chain.

Poor water quality also stems from high concentrations of substances such as ammonia, hydrosulphuric acid, methane, iron and manganese, with low levels of dissolved oxygen, which may be released when the uptake is in the hypolimnetic zone below the euphoric zone. (Logically this depends on many other factors.)

The Tucuruí Reservoir has encountered some of these problems, particularly the last, mainly during dry periods when much of its outflow comes from the turbines rather than the spillways, discharging poor quality water downstream.

For Phase II operations at the Tucuruí Hydropower Complex, higher outflow volumes - at a level not yet quantified by the concessionaire - will be noted. This should affect the *várzea* floodland forests downstream.

3.5.7 Aquatic Macrophytes

3.5.7.1 Development of Area Covered by Aquatic Macrophytes

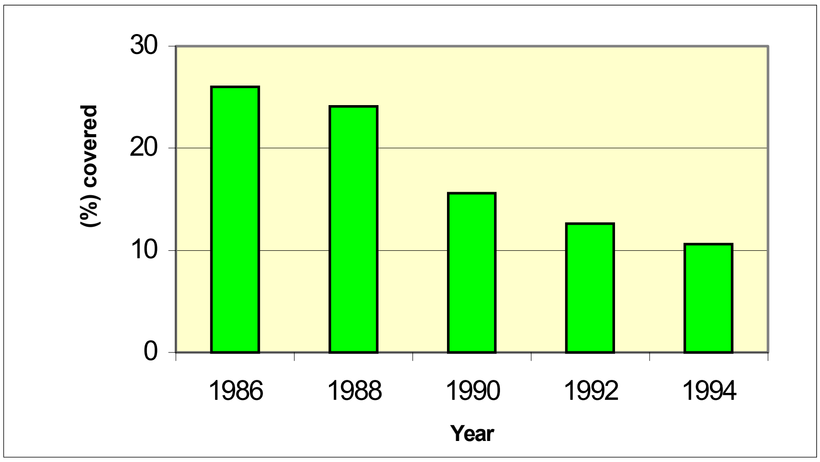
The monitoring and identification of aquatic macrophytes began in August 1993, carried out by the National Research Institute for Amazonia (INPA) in a project entitled Survey and Control of Aquatic Macrophytes (*Levantamento e Controle de Macrofitas Aquáticas*) which was taken over by the ENGEVIX-THEMAG Consortium after the reservoir was filled.

A recent report titled Inventory of the Community of Floating Aquatic Macrophytes at the Tucuruí Hydropower Complex by Satellite Images *(Inventário da Comunidade de Macrofitas Aquáticas Flutuantes na UHE Tucuruí através de Imagens Orbitais*), dated February 1999, shows a drastic reduction in the area covered by aquatic macrophytes in the reservoir.

Figure 3.6 shows this development from 1986 through 1994, with a steep drop noted in the area covered by these plants, from around 25% to almost 10%. It is interesting to note that the sharpest drop in the area covered by macrophytes took place from 1990 onward, when almost all nutrient levels in the reservoir decreased.

The most commonly-found genera in the reservoir are *Salvinia*, *Scirpus*, and *Pistia*. However, *Eichornia* is found in the Igarapé Pucuruí region.

Figure 3.6 Development of the area covered by aquatic macrophytes at UHE Tucuruí 1986 – 1994



At Tucuruí, a steep increase in the appearance of *Salvinia auriculata* began soon after damming in 1984, although these plants began to decline a few months later, reappearing abundantly during the 1986 rainy season.

This species has a high infestation level in reservoirs after the eutrophisation of dammed waters. Even in water with poor conductivity and low concentrations of electrolytes in Amazonia, the effects of leeching from flooded riverbanks and the decomposition of submerged plants have relatively marked eutrophic effects.

In addition to revealing a marked reduction in the area covered by macrophytes, the data in this assessment concerns the biomass of these plants in the reservoir. According to data presented by Novo *et al* (1997) in May 1996 the average macrophyte biomass was 950 ton/km², rising to 2 049 ton/km² in August of the same year. The authors also indicated that the biomass of these plants reached relatively high figures between May 1996 and April 1997 at 6 243 ton/km² for submerged biomass and 1 350 km² for emergent biomass.

3.5.7.2 Effects Associated with Aquatic Macrophytes

Several problems are related to the presence of aquatic macrophytes in reservoirs. However, the presence of these organisms also has some positive aspects relating to the balance of the ecosystem. The most critical problems are related to shipping, bathing and the proliferation of mosquitoes.

According to the technical literature, *Eichornia* and *Pistia* are the main habitats of the *Mansonia sp.*, a mosquito species that proliferated in the reservoir banks and is associated with the macrophyte development. Also, these macrophytes provide excellent habitats for the snail that is host to the schistosomiasis vector.

The environments where the macrophytes proliferate – around the reservoir banks – also offer favourable conditions for the development of algaes (some of which are toxic) as well as the permanent presence of an anoxic layer in the deeper waters. In other, older dams, such as Jupiá for instance – the development of aquatic plant species has been noted, resulting in tremendous losses in terms of hydropower production. The plant concerned is *Egeria densa*, a fast-growing emerging plant species. Here it is important that systematic studies be carried out to monitor the growth of the species in specific ecological niches.

3.5.8 Erosion and Silting-up of the Reservoir

3.5.8.1 Erosion

Prior to the filling of the dam some studies were carried out into the possibility of erosion around the Tucuruí hydropower reservoir. They projected that through the impact of waves or merely through contact with the water, erosion and/or landslips could take place, whose intensity would depend on geological and geotechnical aspects of the surface soils and their plant cover. The soils on the right bank mainly consist of sandy sediments. Fish-life would be highly susceptible to erosion, and the most serious effects would take place along the steeper banks. However, the right bank soils are more clayey, originating from crystal rocks with limonite canga beds, and hence they would be less severely effected.

However, the erosion impacts noted soon after filling the Tucuruí reservoir, and today, are not excessive - only a few cases have been noted, caused mainly by deforestation of the banks at these points.

3.5.8.2 Silting-up

After the waterborne sediment deposit studies carried out on the Tocantins-Araguaia basin, in the region upstream from the Tucuruí Hydropower Complex, it was noted that the variation range for the sediments in suspension in the Tocantins River was far broader than in Araguaia. At the time of these campaigns, run from January through March 1992, the load in the Araguaia remained under 130 000 tons/day with limited dispersion, while the Tocantins showed marked variations, reaching a maximum of around 800 000 tons/day and a minimum of around 100 000 tons/day.

The main waterborne sediment studies undertaken at that time were designed to calculate the useful life-span of the reservoir, represented by the number of years needed for its silting-up to reach a pre-set level established in function of the height of the water intake sill. This level was set at 23m, which is a reasonably safe figure to avoid sediments being swept through the water intakes with abrasive effects on the turbine vanes, as the lower level of the water intake is 27m.

Using the waterborne sediment data surveyed, the Sedres model was applied to the gathered data from sampling. This presented results that indicated a fairly optimistic trend regarding the deposit of sediments at the foot of the dam over the years. It concluded that if the waterborne sediment trends for that time were maintained, the water uptake structures of the Tucuruí Hydropower Complex would be free of any risks associated with sediment deposits at the foot of the dam for 400 years after the start-up of operations.

However, after the dam was closed and the reservoir filled, with the subsequent start-up of operations of the Tucuruí Hydropower Complex, little sediment monitoring took place. This was due mainly to the ample headroom in the useful life of the reservoir, calculated prior to filling.

Currently, due to the lack of waterborne sediment data after filling the reservoir, it is not possible to affirm whether the sedimentation rates and the consequent useful life of the reservoir projected prior to its filling continue to apply. Nevertheless, rising human pressures on the surrounding forest should be noted, bringing rapid deforestation, which could well speed up the sediment deposit process.

There are reports of deposits forming upstream around Praia Alta, near Marabá, causing problems for shipping during more severe low-water periods on the lake, with a return to a normal outflow under normal conditions. This indicate silting-up occurring there due to the slowing of water as it enters the lake [13].

Eletronorte is currently considering a programme to start up a fresh round of studies on this issue, including field campaigns.

3.5.9 Fishlife

Perhaps the most dramatic effect of dams in Amazonia is the submersion of plants and wildlife, with the initial impacts on fish-life causing extremely high mortality rates in some cases, such as Balbina. Although there is widespread agreement on the occurrence of large-scale negative impacts on fish life caused by dams, little is known about the sequence of events after the initial effects of blocking the normal flow of the river. The impacts on fish communities in terms of alterations in general ecological parameters (wealth of species, alpha and beta diversity, equitability) are little known, or at least are not available in scientific literature.

The effects of dams on commercial fish populations and the repercussions for local fishing (both commercial and subsistence) are similarly unknown in most cases. The few exceptions may include the Samuel and Balbina hydropower plants (Santos, 1995; Santos & Oliveira Jr., 1999).

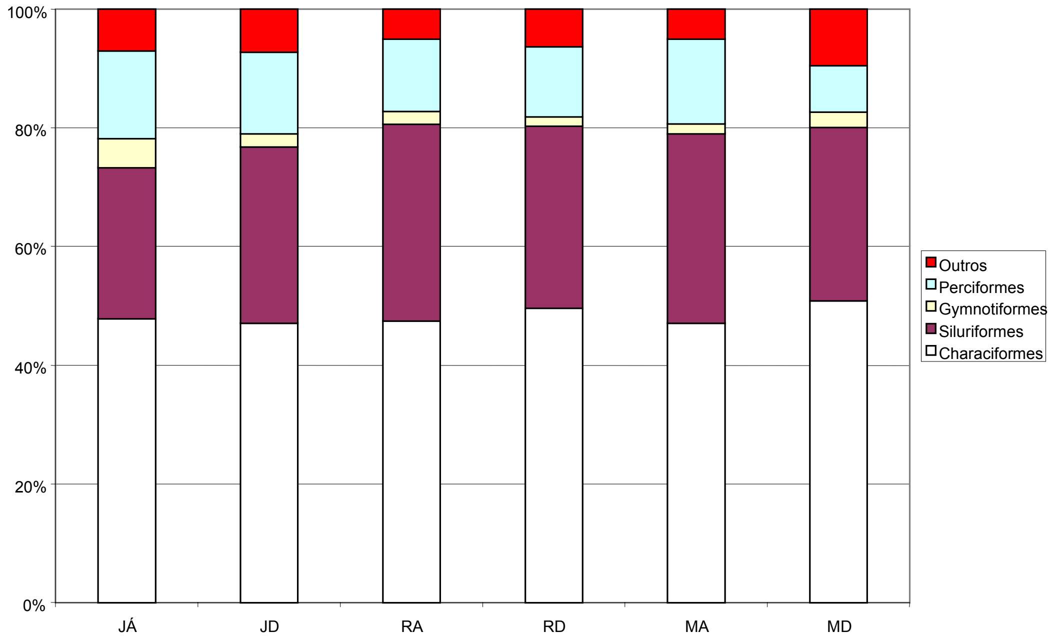
In this context, the Tucuruí Hydropower Complex takes on added importance, as this is the first major dam built in Amazonia whose technical and economic results (power production) are sufficiently important to justify a detailed analysis of the relationship between benefits and high environmental costs.

This study attempts to assess the influence of the construction of the Tucuruí Hydropower Complex on fish in the Tocantins River, and particularly the alterations in general ecological parameters and catches, comparing forecasts drawn up during the pre-flooding phase and later modifications. Comparisons were also carried out with recent information on commercial fishing throughout the area of influence of the reservoir, in order to assess developments and modifications in the population structures of commercial fish species. Based on studies carried out between 1980 and 1984, during the pre-filling phase and from 1985 to 1998 for the post-filling phase, the following information is available on fish life in the Tocantins River, taken from the following sources: Eletronorte/INPA (1981; 1982; 1984; 1985), Santos *et al*. (1984), Merona (1985; 1986/87), Resende (1985), Carvalho & Merona (1986), Leite (1986; 1993), Leite & Bittencourt (1991), Eletronorte (1992; 1999) and Santos & Merona (1996). We stress the difficulty in analysing this information, as it is somewhat inconsistent, with gaps or even contradictory data in the reports, even when they cover the same place and time.

3.5.9.1 Pre-Filling Situation:General Characteristics

There are some 280 species of fish in the Tocantins River within the area of influence of the Tucuruí Hydropower Complex. Distribution of fish species follows the general pattern for freshwater fish-life in Amazonia, with the Characiforms dominant (Figure 3.7). Diversity measured by the Shannon-Weaver index varied between 3.23 and 5.10, averaging out at 4.34. These figures are among the highest found in the rivers of Amazonia, where rates vary between 0.97 and 5.35 (Ferreira, 1993).

Figure 3.7 Relative participation of groups of species in the three areas before and after closing the dam.



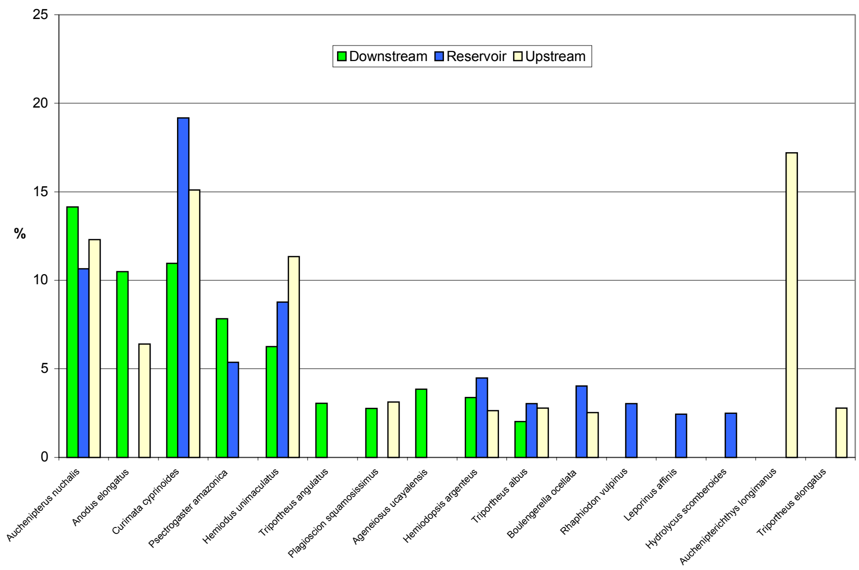
(JA = downstream pre; JD = downstream post; RA = reservoir pre; RD = reservoir post; MA = upstream pre; MD = upstream post).

A very important factor to be analysed in the fish community is its equitability, which indicates the balance of communities over time. Fish communities in the area studied were somewhat homogenous, measured by the Motomura log linear model, with some seasonal variations. However, the communities were generally well-balanced, with a good adjustment of the straight line correlation coefficient (Merona, 1986/87).

Experimental catches along the three reaches of river studies presented the following results for pre-flooding phase: (Figure 3.8)

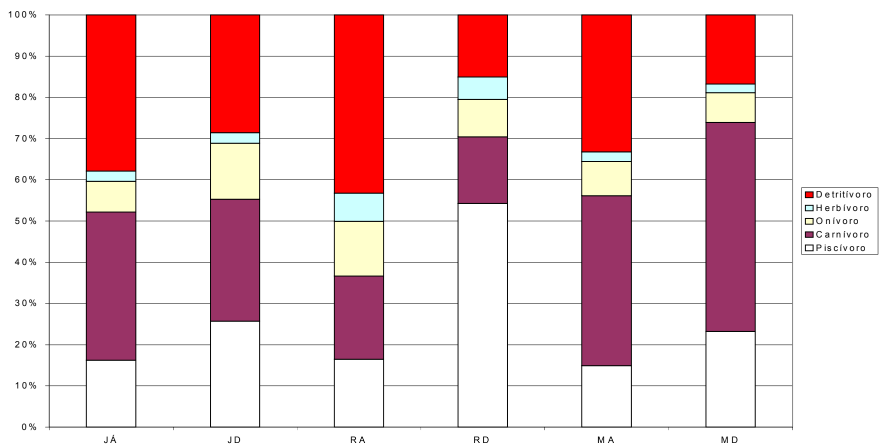
- Reach 1 (downstream from the reservoir): characterised by an abundance of mandi-peruno (*Auchenipterus nuchalis*), branquinha-baião (*Curimata cyprinoides*) and ubarana (*Anodus elongatus*);
- Reach 2 (area to be flooded): characterised by the abundance of branquinha-baião (*C. cyprinoides*), mandi-peruano (*Auchenipterus nuchalis*) and jatuarana *(Hemiodus unimaculatus*);
- Reach 3 (upstream from the reservoir): characterised by the abundance of cachorro-de-padre (*Auchenipterichthys longimanus*), branquinha-baião (*C. cyprinoides*) and mandi-peruano (*A. nuchalis*).

Figure 3.8 Listing of the 10 most important species in the experimental catches for each pre-filling region.



In general, the food chain for the pre-filling fish communities can be divided into the following categories: piscivores, carnivores, omnivores, herbivores and detritivores, reflecting the characteristics of their natural environments, although some differences were noted in the proportions between the reaches and the environments studied. However, carnivores and detritivores were the most frequent: downstream – detritivores 37.9% and carnivores 35.9%; future reservoir region – detritivores 43.3% and carnivores 20.2%; and upstream region, carnivores 41.2% and detritivores 33.2% (Figure 3.9).

Figure 3.9 Relative share in the different food-chain categories for the three areas before and after closing the dam.



(JA = downstream pre; JD = downstream post; RA = reservoir pre; RD = reservoir post; MA = upstream pre; MD = upstream post).

Most species reproduced throughout the area sampled, although two species of Engraulididae (*Pterengraulis sp*. and *Lycengraulis grossidens*) reproduced only in the region downstream from Tucuruí. Another species, ubarana (*Anodus elongatus,* Hemiodontidae), was not found reproducing within the area under study, but as this is a migratory species, it is assumed that it spawns outside the area under study.

Fishing was widespread throughout the region before the power plant was built. Data obtained during the pre-filling Phase Indicate catches of 1 534 tons/year for the area between Marabá and Mocajuba, with 900 tons of this total coming from the region downstream from Tucuruí and the remainder from the two reaches today covered by the reservoir, with output of 319 tons/year, and the region upstream from the reservoir at 315 tons/year.

The main species caught commercially were mapará (*Hypophthalmus matginatus*) – around 30%, curimatã (*Prochilodus nigricans*) – around 35%, jaraqui (*Semaprochilodus brama*) – around 15% and tucunaré (*Cichla spp.*) accounting for the remaining 10%.

3.5.9.2 Post-Filling Situation: General Characteristics

After the environmental impacts during the dam construction phase of the Hydropower Complex (building the coffer dam, deviation of the riverbed, initial deforestation, earth-moving) it was projected that blocking the flow of the river to fill the reservoir would have a series of extremely severe environmental impacts. The projected impacts were of different types, sizes and durations for the reservoir area and the upstream and downstream stretches of the river. Also, the schedules forecast for these problems initially indicated the occurrence of severe impacts downstream from the dam, caused by the blocking of the flow of the river. Subsequently, alterations in the limnological conditions in the reservoir area – suddenly turned into a still water environment – would result in irreversible changes in the structure of fish communities in this region.

3.5.9.3 Forecasts and Observations

Listed below are the main forecasts made and the actual observations for the three sections of the are of influence of the Tucuruí Hydropower Complex (downstream and upstream of the reservoir):

- *Downstream*

  Forecast: Immediately after closing the dam, large-scale fish deaths would occur. *Observation*: with the halt in the flow of water, the shallower reaches of the riverbed dried up and large areas were exposed. Small-scale fish deaths occurred, particularly smaller bottom-dwelling species, mainly Loricariidae, Ophichthyidae and various groups of Gymnotiforms. Many fishes migrated down river and clustered in the deeper reaches or swam up the tributaries, while others were trapped in pools. Large-scale fish deaths were common occurrences in these pools, as evaporation reduced their volumes, and high temperatures lowered the concentration of dissolved oxygen. As the water was not renewed, the fish were more tightly clustered and died. Three months after the dam was closed, when operations started up at the Hydropower Complex, large-scale fish deaths were caused by the tailrace water, which was low in oxygen and contained sulphurated hydrogen gas, due to the intensive decomposition processes of organic matter in the reservoir area. Fish died in the large pool that formed just below the dam, including huge schools of migratory species that had clustered there, or which were swimming up river. With the flow partially re-established, other fish death episodes occurred. Even later, when better-quality water was added from the spillways, large-scale fish deaths were common, caused by the very poor quality of water in the tailrace. Further away from the dam in the Cametá region, no large-scale fish deaths were noted.

  Forecast: The breakdown in environmental stability will result in a reduction in the number of species.
  Observation: In fact, the number of species caught did drop in the experimental catches, from 164 down to 133, equivalent to 18.8% (Figure 3.10). There were also alterations in the relative share of the most frequent species (Figure 3.11).

Figure 3.10 Number of fish species collected through experimental catches in the three areas, before and after closing the dam.

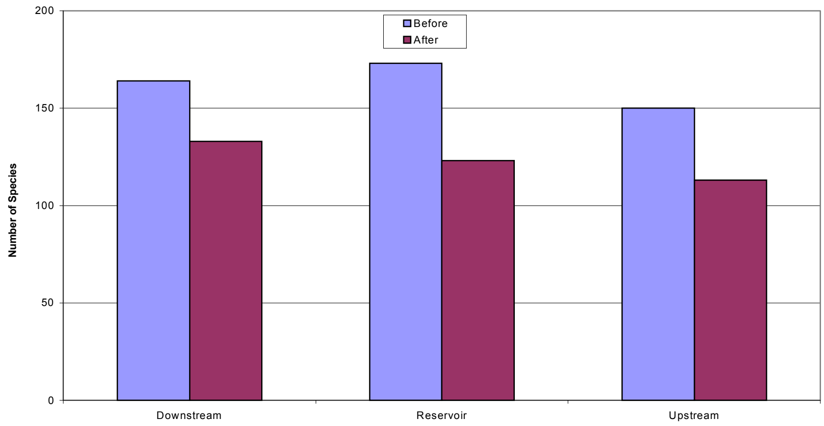
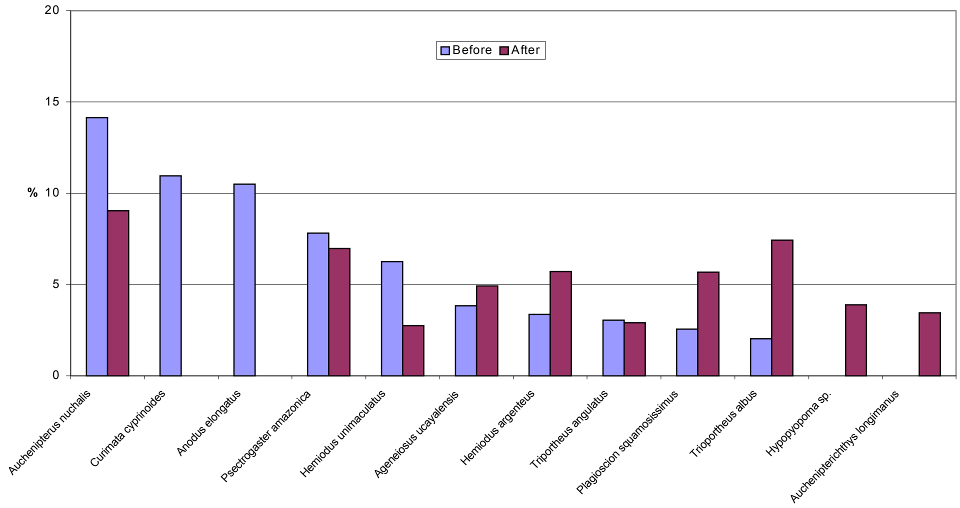


Figure 3.11 Relative share of the ten main species in experimental catches in the downstream area for the pre- and post-filling phases.



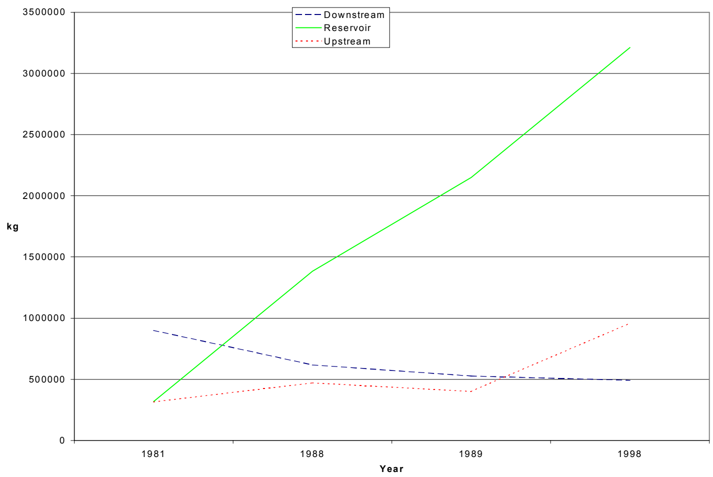
Forecast: Modifications in water quality would decrease the amount of plankton, thus reducing the food resources for various species, many of which are commercially valuable - such as mapará (*H. marginatus*), jatuarana (*Hemiodus spp.*), ubarana (*Anodus elongatus*), curimatã (*Prochilodus nigricans*) and jaraqui (*Semaprochilodus brama*).

Observation: Although it is difficult to check this forecast, it is possible that the reduction noted in the population of these species is connected – at least partly – to the reduction in food supplies caused by poor water quality. Figure 3.11 shows the percentage distribution of the different food-chain categories before and after closing the dam for the downstream region (JA and JD), reflecting the occurrence of variations in the proportions between the food chain categories, with an increase in piscovorous and omnivorous species, while others decreased (detritivores, herbivores and carnivores).

Forecast: There would be a reduction in fishing catches due to shrinkage of the seasonally-flooded bank areas, with a consequent impoverishment of the waters, owing to a decrease in organic matter.

Observation: similar to the previous projection, this is also difficult to confirm, but the reduction in water flows with a consequent shrinkage of the flooded area means that *várzea* floodland forests that were previously submerged on a regular basis are now permanently out of the water, reducing food supplies. Additionally, floodable bank areas which once sheltered fry in fish nurseries are no longer available, although these areas are important for building up fish stocks, with their disappearance also helping reduce these populations. These areas are also a source of food for fish, as the *igapó* inlets provide berries, seeds, insects and other invertebrates consumed by these fish. With their reduction or disappearance, food supplies have also shrunk for these fish. As mentioned above, a drastic drop was noted in commercial catches in the Cametá region, but we cannot state that this was a direct consequence of the reduction in the flooded area. The figures for commercial catches in this region from 1981 through 1998 show a steady drop in output, down from 900 tons/year in 1981 to 492 tons/year in 1998 (Figure 3.12), a drop of 83%. It is possible that these decreases are caused by alterations in the hydrological system of the river after the dam was built, as its ebb and flow is now regulated by the operational activities of the hydropower plant. This may have confused and modified the migratory behaviour of schools of some of the main commercial fish species in his region, helping reduce catches.

Figure 3.12 Catches in the three areas during the pre-filling phase (1981) and post-filling phase (1988, 1989 and 1998).

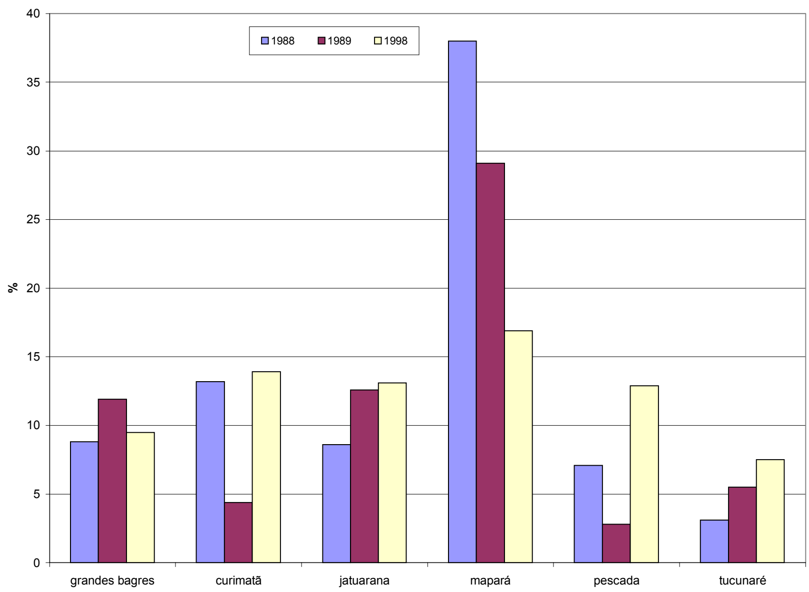


Forecast: The presence of the dam would block the upstream migratory routes followed by a number of species for reproductive purposes, which might be unable to reproduce in the downstream region. The populations of three of the most important commercial fish species (mapará, ubarana and curimatã) would be affected.

Observation: There was a reduction in migratory species of commercial importance in the second year after the dam was closed, as noted in the experimental catches. This is partly attributed to the break in migration routes for species that used to swim up river through the rapids to spawn in the Upper Tocantins and/or the Araguaia River, such as the ubarana (*Anodus elongatus*) and curimatã (*Prochilodus nigricans*). Data from the pre-filling period in the Cametá region indicate a relative share of 37% of the catch for mapará (*Hypophthalmus marginatus*) (Carvalho & Merona, 1986), which fell from 38% to 16.7% between 1988 and 1998 (Figure 3.13). During the pre-filling phase, curimatã accounted for some 35% of the catch, but dropped steeply during this period, bottoming out at 4.4% in 1989, and remaining at almost the same level from 1988 to 1998. The species that was most severely affected was the ubarana (*A. elongatus*), which has almost vanished from this region. This could be explained by the appreciable presence of the species in experimental catches in the upstream region, and its presence in commercial catches along this stretch of river.

It is important to stress that the relative share of the species in fishing catches changed. In 1988, the dominant species was mapará at over 35% of the catch, with curimatã ranking a remote second at around 13%, and bagre, jatuarana, pescada and tucunaré at under 10% each. In 1998, mapará had fallen to around 17%, curimatã was up to 14%, and jatuarana hovered at around 13%, together with pescada. These data indicate the lack of a dominant species, with relative catch shares varying from 16% to 13% among the four main species.

Figure 3.13 Relative share of the main species caught for commercial purposes in the downstream region in 1988, 1989 and 1998.



Forecast: There would be a drop in fishing catches.
Observation: Catch data for the downstream region showed a steady drop from 1981 through 1998 (Figure 3.13); however, we should stress that although the data is not continuous, it clearly reflects a downward trend in the total annual output, which fell from 900 tons/year in 1981 to 492 tons/year in 1998. No data is available on effort, which means that we are working with the total output figures only. It is probable that if the CPUE were to be calculated, the drop in productivity would be even more marked.

- *Reservoir*

Forecast: Species would vanish from the rapids areas, together with others that reproduce only in the region downstream from the dam (*Lycengraulis spp*. and *Pterengraulis spp*.).

Observation: As the waters rose after the dam was closed, the rapids and falls were flooded, resulting in the disappearance of this type of habitat. This caused high initial mortality rates among species living in these environments, which are well adapted to turbulent waters with high oxygen levels. As the water rose and the current slowed, the concentrations of dissolved oxygen fell, resulting in large-scale fish deaths immediately after flooding. In the days immediately after the dam was closed, high fish mortality rates were noted along this stretch of river, particularly cascudo or bodó (Loricariidae), small bagres (Pimelodidae) and other species of small fish that live only in the rapids, such as Characidiinae and some small

Cichlidae (*Teleocichla*). The disappearance of species that reproduce only in the downstream region was not noted, as some examples of these species were captured in the reservoir region.

Forecast: The shift from a flowing to still water environment would result in a shrinkage of niches and over the short term would hence reduce the diversity of communities, which would drop in parallel to the wealth of species.

Observation: There was a reduction in the diversity figures measured by the Shannon-Weaver index, which varied between 4.2 and 5.1 before the damming of the river, dropping to around 3.5. Many species characteristic of rapid areas vanished from the lake region, as well as benthonic species driven away by the lack of oxygen at deeper levels. In the experimental catches, the number of species found dropped from 173 to 123 between the pre- and post-filling phases. (Figure 3.12).

Forecast: Widespread proliferation of pelagic species was expected, together with herbivorous and periphytiverous species in the riverbank areas, making fishing easier.
Observation: Only the piscivores species increased between the pre and post-filling stages, rising from under 20% to over 50% (Figure 3.12). All the other food-chain categories dropped, particularly the detritivores, down from over 40% to 15%. Fishing was banned in the reservoir until late 1985. Catch data from the region to be flooded by the reservoir indicates that output rose appreciably in this region, from 319 tons/year in 1981 to 3 211 tons/year in 1998 – a tenfold increase (Figure 3.13). An outstanding factor is the alteration in the relative share held by the most important species in these catches between 1988 and 1998. In 1998, tucunaré was the most prevalent species with some 69% of the catch, dropping to 22% in 1998; meanwhile, mapará – which barely appeared in 1988 – rose to some 37% of the catch by 1998. Pescada also increased its relative share of the catch, up from 17% to around 29%, remaining the second most prevalent species (Figure 3.14).

Figure 3.14 Relative proportions of the main species caught for commercial purposes in the reservoir region in 1988, 1989 and 1998.

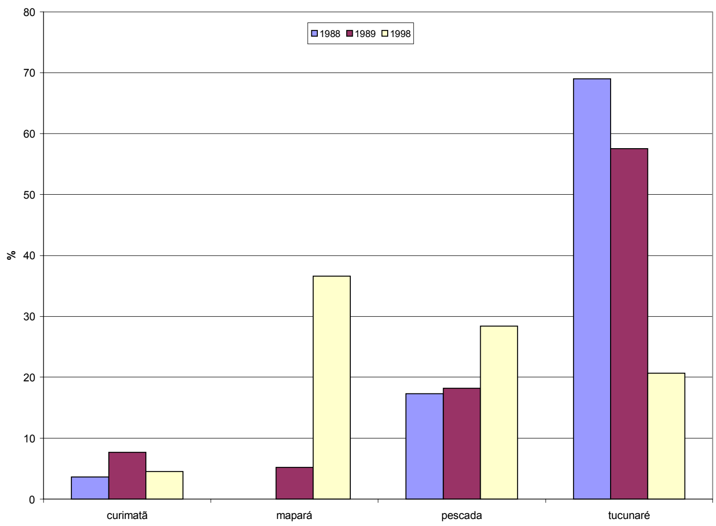
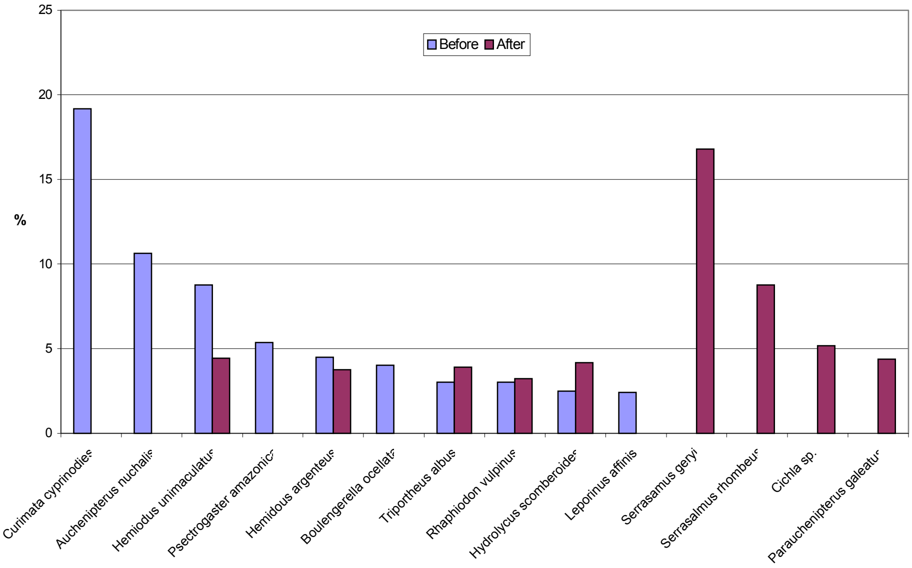


Figure 3.15 Relative prevalence of the ten main species for the experimental catches in the reservoir area during the pre and post-filling phases

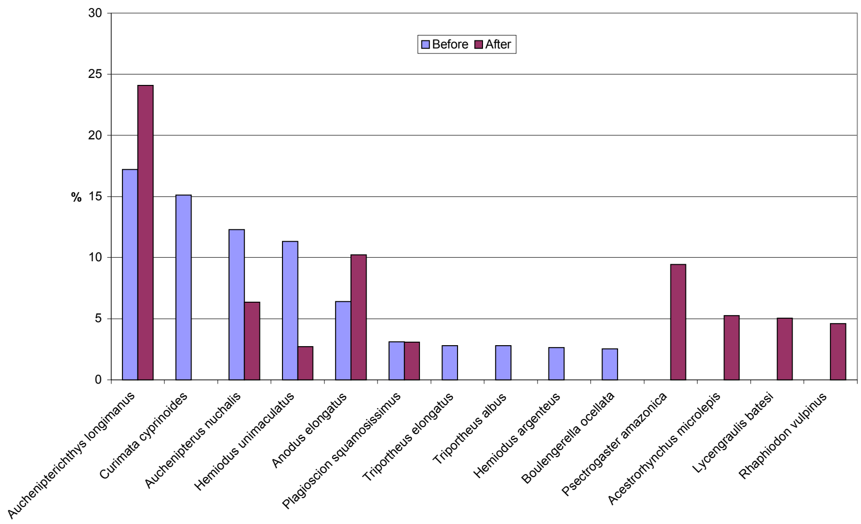


- *Upstream*

No specific forecast was drawn up for the region upstream from the reservoir, but it was believed that changes would take place, caused mainly by the flight of species from the flooded area to regions where the river conditions remained unaltered. The experimental catch data showed that the cachorro-de-padre (*Auchenipterichthys longimanus*) was the most frequent species during both the pre- and post-filling phases. Also, of the ten most frequent species during the pre-filling phase, five were also found during the post-filling stage (Figure 3.15).

Catch data show that the total annual output rose from 315 tons /year in 1981 to 959 tons/year from 1981 through 1998, an increase of over 200% in the catches. The most important species became mapará at 27% of the catch, followed by pescada at 24.5% and curimatã at 13.2%.

Figure 3.16 Relative prevalence of the ten main species in experimental catches in the upstream area during the pre and post-filling phases.



3.5.9.4 Discussions and Conclusions

In general, the forecasts proved correct, although perhaps exaggerated. Alterations occurred in the composition of fish communities, with some species vanishing from the entire area of influence of the hydropower complex (downstream, reservoir and upstream). The total number of species dropped from 181 to 169, but the proportions among the groups of species (Orders) remained almost constant for both Phases in all three areas.

The reservoir was the area which lost the greatest number of species after damming (50), equivalent to over 28%, while the downstream region lost the least (18.8%) although it had the greatest number of species (133) after the filling of the dam. As this stretch of river is suitable for restocking, the improvement in water quality after the initial impact allowed the (re)entry of species into the Tocantins River system, from stocks living in the Amazon River.

In terms of reproduction, no data was available for the post-filling phase, but evidence shows that many migratory species that were thought to have problems with reproductive migration have managed to reproduce in the upstream region and are now among the main species in the reservoir. They include *mapará* (*Hypophthalmus marginatus*), *curimatã* (*Prochilodus nigricans*) and *ubarana* (*Anodus elongatus*).

One of the most surprising discoveries in commercial fishing was the drop in the relative catch of *tucunaré* (*Cichla spp*.) in the reservoir. Dropping from 69% to 21% between 1988 and 1998, it has been supplanted as the most prevalent species by *mapará* and *pescada* (*Plagioscion squamosissimus*). The drop in the *tucunaré* catch may reflect the end of an abundance cycle for foraging species that are its natural prey, whose populations rose during the initial post-flood period. Also, intensive selective fishing for *tucunaré* may also have brought the population down. Information on fishing activities in the reservoir might well explain the drop in catch rates for this species.

The most important commercial fishing species in the Tocantins River continues to be the *mapará* (*H. marginatus*) in the area of influence of the Tucuruí Hydropower Complex. Diminishing catches downstream seem to have been offset[14] by increases in the reservoir, once its limnological conditions stabilised. It is probable that the ample availability of nutrients released by the decomposition of organic matter in the reservoir area, as well as higher light penetration in this area, has resulted in an increase in primary local productivity. As the mapará is a plankton-eating species, it could make good use – directly and rapidly – of increased food supplies provided by the formation of the lake, and proliferate in this environment.

The total commercial catch rose from just over 1 500 tons/year to over 4 600 tons/year, up more than 200%. The downstream region is the only place where fishing has worsened, with catches down more than 80%. This is consequently the area most severely affected by the dam, even though not within the direct area of influence of the reservoir.

Mention has been made of conflicts between commercial and subsistence fishermen living on islands in the lake. During our visit to Tucuruí it was not possible to determine the real situation here - whether there really is a substantive conflict between these groups, or if this is yet another case of opposing interests competing for the same resources. A troubling factor reported by the technical staff at the Eletronorte Environmental Protection Centre (CPA - *Centro de Proteção Ambiental*) is the use of small-mesh (under 70mm) nets that capture the fry of many species. However, they were unable to say whether these nets were used by only one of the groups, or were widespread. Nevertheless, it is important that the use of these nets should be regulated in order to avoid the catching of young or sub-adult fish belonging to species such as *tucunaré*, *pescada*, *mapará*, and others.

Facts such as these indicate that the existing oversight and control structure for fishing activities (under both the previous SUDEPE entity and IBAMA today) in which fishing villages also participate, has proven unable to solve some of the basic problems of this sector, including overfishing and the clandestine use of illegal equipment.

3.5.9.5 Fish Ladders

A controversial omission, which has drawn much criticism, is the authorities' failure to build fish ladders. This fish migration technology is used to minimise the impacts of dams built on rivers all over the world. However, the assumed benefits of this intervention have not been confirmed by monitoring studies in most cases, due to either a lack of analyses or a real absence of significant results.

In the case of Tucuruí, the occurrence of migratory fish species in catches offloaded in the reservoir and upstream over the past few years indicate that these fish populations are reproducing in the area. In view of this, building a fish ladder does not seem to be vital to the maintenance of viable fish stocks upstream; strategies for protecting these species should therefore focus on catch management. Also, fish ladders as an alternative route for upstream migration would probably not be efficient for all species concerned. The *curimatã* (*Prochilodus nigricans*) can swim up small waterfalls and rapids, and would have no difficulty in leaping the steps of a properly designed fish ladder. On the other hand, there are no records showing that the *mapará* (*Hypophthalmus marginatus*) – one of the main commercial fish species – can jump natural obstacles. The characteristics of these species indicate the need to build a particularly long fish ladder with no steps, guided by alternating side walls.

There is no evidence among Amazon fish species of any return to their rivers or birthplaces, as seen among certain species of salmon. This indicates that the damming of the Tocantins River does not have catastrophic effects on migratory species of Amazon fish. The main problem here would be the blocking of gene flows upstream and downstream from the dam, with possible negative effects over the longer term. This means that building the lock system for the Araguaia-Tocantins Waterway at Tucuruí would allow fish to move between the reaches of the river upstream and downstream from the dam, ensuring gene flows between these populations.

3.5.10 Wildlife and Rescue Operations

Outstanding among the many environmental problems caused by the damming of the rivers of Amazonia to build hydropower plants are their drastic impacts on land-dwelling and arboreal wildlife, as reservoirs submerge large swathes of rainforest.

In October 1983, the Wildlife Working Group (*GT Fauna*) was set up to prepare the Wildlife Development Inventory Plan (PIAF – *Plano de Inventário do Aproveitamento da Fauna*) for the Tucuruí Hydropower Complex region. Under the general coordination of the National Research Institute for Amazonia (INPA) in Manaus, this Plan was supported by the Emílio Goeldi Museum, the Pará Federal University (UFPa), the Evandro Chagas Institute (IEC) and the National Primates Centre in Belém, as well as the Butantan Institute in São Paulo. It was implemented from February through September, 1984 as the reservoir was filling, working closely with Eletronorte and the Engevix-Themag Consortium (INPA, 1984). The names of the managers and coordinators of the executor institutes, as well as the administrative and support staff and the committee responsible for preparing the final report of the plan is available at the National Research Institute for Amazonia (INPA) (1984 pages 3-7). The objectives of the plan were: (1) to draw up an ecological inventory of regional wildlife; (2) to use this wildlife inventory for biological studies, including genetic and behaviour studies; and (3) to provide input for biological conservation and rescuing wildlife for relocation during the *Operação Curupira* rescue project (INPA, 1984).

The inventory studies carried out under this plan were prompted by the lack of information on wildlife in the area of the future reservoir. They were designed to produce a basic list of vertebrate species found in this region, including land and aquatic mammals. The scientific community consequently encouraged the capture of mammals and the results were added to the permanent collection of the Emílio Goeldi Museum (INPA, 1984). The total number of species recorded at Tucuruí during the implementation of this Plan reached 120: eight marsupials (opossum; only seven species collected), 11 edentates (sloth, armadillo and anteater; 10 collected), 2 cetaceans (river dolphin), 8 primates, 17 carnivores (river otter, canines and felines, among others); 25 rodents (cotia, paca, etc; 19 collected), 1 lagomorph (rabbit), 5 ungulates (tapir, deer, peccary; 3 collected), and 43 chiropters (bat). Of the 29 species of rare animals or those threatened with extinction, 48% are mammals. In the Final Report produced by the Wildlife Working Group (INPA, 1984) the main threats were identified, and measures were suggested to avoid or minimise these impact, in parallel to effective conservation strategies. It was suggested that environmental protection areas (Parks and Reserves) be established for all threatened mammal species, sized appropriately for maintaining viable communities. In some cases, increased monitoring activities were also suggested, with specific bans on hunting and poaching.

The Wildlife Working Group ranked the establishment of nature reserves as the most important aspect step for conserving wildlife in the Lower Tocantins. These reserves should be different from the release areas, accepting only extremely rare animals and under permanent protection through Federal Law. Using the primates as indicators, the Wildlife Working Group indicated seven areas for these reserves. Five other areas were proposed as reserves by the Engevix-Themag Consortium, with some disagreement between the Consortium and the National Research Institute for Amazonia (INPA) on the feasibility of some areas for wildlife protection.

The Wildlife Working Group also proposed to set up a Permanent Wildlife Study Group (GPEF - *Grupo Permanente de Estudo da Fauna*) whose general objective would be to provide input for Eletronorte/Eletrobrás studies on the effects of hydropower projects in Amazonia, among others, through basic studies of the ecology and distribution of species in their areas of influence. Seven specific objectives focus on zoning, qualitative species surveys, biological studies of selected species and population census, assistance in rescuing wildlife, establishing a local museum with an educational collection of plant and wildlife, and monitoring wildlife during the period after the filling of the dam (INPA, 1984). As a result of the efforts of the Permanent Wildlife Study Group, it was expected that stewardship and protection programmes would be established for rare or particularly vulnerable species, with assessment of rescue operations by monitoring wildlife populations before and after the dam-filling stage.

The wildlife rescue operation known as *Operação Curupira* (see informative brochure [in Portuguese] entitled "*Operação Curupira*", Eletronorte, no date) was a capture, triage and resettlement project for animals forced out of their natural habitats by the submersion of 2 850 km^2 to create the Tucuruí Hydropower Complex dam. As well as rescuing and relocating the animals, this operation also responded to Brazilian scientific entities requesting the donation of animals for research purposes. In terms of the Protected Release Areas, the leaflet (op. cit.) stated that after releasing the rescued animals, Eletronorte was to consolidate this operation, once the reservoir had been completely filled. The adaptation of relocated animals would be monitored, with further resettlement if necessary. The release areas were to be kept under surveillance in order to "prevent predatory activities adversely affecting animals during the settlement and adaptation phase". Eletronorte also proposed to undertake a wildlife observation project on the main islands formed after the filling of the reservoir.

The largest and most expensive wildlife rescue operation ever carried out in Amazonia, *Operação Curupira* absorbed total investments of US$30 million (Peres & Johns, 1991). During this operation, some 280 000 animals were caught and released in four areas along the banks of the reservoir. Its outstanding achievements include the capture of large numbers of medium-size land-dwelling and arboreal vertebrates, including some 40 000 sloths (two species), over 9 700 armadillos (four species), around 26 000 monkeys (five species), 48 000 fruit-eating land turtles (two species), 20 000 iguanas, etc.

Unfortunately, no data is available – except in the case of primates – on the relative abundance or density of animals in the submerged area or the forests in the Tocantins River Basin and neighbouring regions, which would offer a basis for estimating wildlife losses at Tucuruí. Indirect evidence on the wildlife in this region was presented in the study of subsistence hunting by the *Parakanã* people in an area alongside Tucuruí (Emidio-Silva, 1998). Although using only 42% of the area covering 351 697 hectares for hunting purposes, the amount of wildlife protein consumed by the 449 members of this tribe is far higher than the minimum figures recommended by the World Health Organisation. There is no evidence of over-hunting ungulate populations in the *Parakanã* Indigenous Territory, with the exception of white-lipped peccaries (*Tayassu pecari*).

3.5.11 Vectors

Health-linked issues were covered by various inventories, outstanding among which were surveys of insects of interest to medicine, particularly species belonging to the *Culicidae*, *Psychodidae*, *Ceratopogonidae* and *Hemiptera* orders.

Of particular interest in the *Culicidae* order are species linked to the spread of malaria (*Anopheles* spp.), filariasis (*Mansonia* spp.) and arboviruses (*Sabethes* spp.). The Psychodidae order includes species with hematophage habitats, such as Leishmaniasis vectors and others belonging to the Phlebotominae family. The Ceratopogonidae order includes the Simulidae family whose immature forms live in highly-oxygenated turbulent environments such as waterfalls and rapids that are very similar to dam spillways. The females are hematophagous and are thought to spread diseases caused by filaria worms such as Mansonellosis (*Mansonella ozard*) and Oncocercosis (*Onchocercha volvulus*). The Hemiptera order includes the beetle commonly known as *barbeiro,* which carries the etiological agent of Chagas Disease (trypanosomiasis).

The results presented by the National Research Institute for Amazonia (INPA) to Eletronorte (CNPq, 1983) reveal the presence of natural reservoirs, vectors and the etiological agents of these pathologies in the Tucuruí lake region, which underlines the importance of the association between macrophytes and the proliferation of insect vectors (CNPq, 1983). The development of individuals belonging to the *Anopheles* and *Mansonia* genera was related by Tadei *et al* 1983; Tadei (1985a, 1985b, 1986a, 1986b, 1986c, 1987a, 1987b); Tadei *et al*, (1991); Tadei (1996).

One of the most important associations indicated in this document is the relationship between the species of macrophytes and the proliferation of Culicides (*Mansonia* genus) which reproduces efficiently in the roots of these plants.

Among the impacts forecast for Tucuruí by Junk & Nunes de Mello (1987) is the large-scale growth of aquatic macrophytes, which is one of the most alarming phenomena in tropical dams. Already noted in Africa and Asia, it is associated with the appearance of metaxenic diseases such as schistosomiasis and malaria, in addition to water-borne diseases such as cholera, gastroenteritis, enterovirosis, arbovirosis, filariasis, etc.

3.5.11.1 Mosquitoes and Malaria

Cases of malaria at Tucuruí rose with the construction of the Hydropower Complex. After work ended, these figures dropped. This pattern is related to the presence of the vector in the area, as proven in the entomological studies undertaken by the National Research Institute for Amazonia (INPA) in this region. These activities were carried out during the pre and post-filling stages of the reservoir.

Samples during the pre-dam period collected 9 918 anophelines, of which 4 297 were winged and 5 621 in the larval form, with the collections carried out at the Works Yard, at the Permanent Township, the Temporary Township, the town of Tucuruí and at various places along the left bank of the Tocantins River (Tadei et al 1983; Tadei, 1986).

Among the specimens captured, twelve different species were recorded, divided into three sub-genera, identified as follows: *Anopheles (Nyssorhynchus) nuñes-tovari* Gabaldón, 1940; *A.(N) triannulatus* Neiva & Pinto, 1922; *A.(N) oswaldoi* Peryassu, 1922; *A.(N) darlingi* Root, 1926; *A.(N) albitarsis* Lynch Arribálzaga, 1878; *A.(N) rondoni* Neiva & Pinto, 1922; *A.(N) noroestensis* Galvão & lane, 1937; *A.(N) rangeli* Gabaldón, Cova-Garcia & Lopez, 1940 e *A.(N) evansae* Brèthes, 1926; *A. (Arribalzagia) intermedius* Chagas, 1908 e *A.(A) mediopunctatus* Thobald, 1903; *A. (Anopheles) mattogrossensis* Lutz & Neiva, 1911.

Along the highways, the most frequent winged form species was *A. darlingi* (33%) followed by *A. nuñes-tovari* (22%) and *A. triannulatus* (17%). Of the species collected in the larval form, *Anopheles nuñes-tovari* (31%) predominated, followed by *A. oswaldoi* (23%) and *A. triannulatus* (22%). The *A. darlingi* larvae accounted for only 8% of the specimens collected. Collections along the Tocantins River and in the Caraipé valley provided figures similar to those obtained in the highway regions, with *A darlingi* predominant among the winged forms and *A nuñes-tovari* among the larval forms.

Additional collections took place at the works yard, the permanent township and the temporary township, sites within the hydropower complex, and in the town of Tucuruí – which is outside the dam construction site, although subject to heavy influences from this venture caused by both the flow of people and physical proximity. In the construction activities region and the worker townships, the predominant species was *A rondoni* (30.5%), followed by *A oswaldoi* (18.9%) and *A nuñes-tovari* (17.8%). In these areas, *A. darlingi* represented only 4.0% of the individuals collected.

At Tucuruí and its surrounding areas, five of the twelve species in this region were detected, with the following relative frequencies: *A. nuñes-tovari* (34.7 %); *A. albitrassi* (27.3 %); *A. triannulatus* (25.2 %); *A. oswaldoi* (12.7 %), and *A. darlingi* (0.1 %).

The presence of immature forms of *A. darlingi* was noted in various types of nursery, ranging from small pools of water in fallen tree trunks to larger water-bodies in the midst of aquatic plantlife where canarana (*Echinochloa spectabile*) predominated, and a species of *Nymphae sp*. This species prefers relatively clear water, with no larvae being found in turbulent water. After the reservoir was filled, the entomological surveys continued, coinciding with the aquatic macrophytes' development phase on the lake, covering large stretches of its surface. The population density of culicides was modified in relation to the data noted during the pre-filling phase. Initially, an explosive increase was recorded in the anopheline populations, and later in populations of the *Mansonia* genus (Tadei, 1986a; b; Tadei, 1987a ;b; Tadei, 1990; Tadei *et al*, 1991; Tadei 1996).

During the post-filling phase, initially an appreciable increase occurred in the *Anopheles* genus species, immediately after the reservoir was filled in October 1984. During this period, 68 532 *Anopheles* specimens were collected, a figure far higher than that found during the filling phase.

The increase in the population density of anophelines immediately after the reservoir was filled (1985 – 1986) was so intense that four collectors caught some 10 000 anophelines in a single night. Table 3.21 below gives a summary of the results obtained during this phase, for collections between 1985 and 1986.

Table 3.21 Population density of anophelines immediately after filling the reservoir.

MEASUREMENTS	SPECIES											TOTAL
		1	2	3	4	5	6	7	8	9	10	11	
Pre-Filling	L	374	904	1 299	1 362	0	1 874	0	154	0	460	0	6 427
	A	1 023	205	619	431	0	798	0	0	64	20	65	3 225
	T	1 397	1 109	1 918	1 793	0	2 672	0	154	64	460	65	9 652
Post-Filling	L	4	106	401	80	5	1 879	0	7	0	0	0	2 482
	A	147	577	29 033	480	48	35 596	0	4	110	0	55	66 050
	T	151	683	29 434	560	53	37 475	0	11	110	0	55	68 532

**1- Anopheles darlingi*
2- Anopheles albitarsis
3- Anopheles triannulatus
4- Anopheles oswaldoi
5- Anopheles argyritarsis
6- Anopheles nuñez-tovari
7- Anopheles braziliensis
8-Anopheles mediopunctatus
9- Anopheles evansae
10- Anopheles intermedius
11- Anopheles rangeli
L= larvae A= winged T= total

The marked proliferation of anophelines immediately after filling the reservoir was analysed, also taking into account the reproduction sites of the immature forms in association with the different species of macrophytes. The presence of immature forms of anophelines was recorded in the routes of macrophytes that had colonised the water-bodies of the reservoir, collected between March and November 1985, as shown in Table 3.22.

Table 3.22 Species of macrophytes and number of larvae encountered.

Anopheles Species	*Salvinia auriculata*	*Eichhornia crassipes*	*Pistia stratiotes*	*Riccrocarpus natans*	Total
Anopheles Nuñez-tovari	490	174	176	7	847
Anopheles triannulatus	54	21	3	2	80
Anopheles rangeli	4	--	--	--	4
Anopheles evansae	5	--	--	--	5
Anopheles albitarsis	21	12	17	--	50
Anopheles argyritarsis	--	--	--	--	--
Anopheles oswaldoi	5	--	2	--	7
Anopheles benarrochi	1	--	--	--	1
Anopheles mattogrossensis	--	1	1	--	2
Anopheles galvaoi	--	--	--	--	--
Total	580	208	199	9	996

(Modificated from Tadei 1986a)

The collection of winged forms during the same period and in the same sampling area also shows the predominance of *A. nuñez-tovari,* with an absolute and relative distribution shown in Table 3.23

Table 3.23 Number of winged forms of *Anopheles* found.

Anopheles Species	Number of collected Individuals	%
Anopheles nuñez-tovari	14 442	53.10
Anopheles triannulatus	12 628	46.43
Anopheles oswaldoi	40	0.15
Anopheles darlingi	38	0.14
Anopheles evansae	40	0.15
Anopheles mattogrossensis	9	0.03
TOTAL	27 197	100.0

(Modified from Tadei 1986b)

During the same period, SUCAM registered cases of malaria in Itupiranga and Jacundá in the reservoir area (January – October 1986). Other data were collected on a supplementary basis covering the frequency of anopheline species in the winged form at different times, and their incidence related to the period and biting activity standards. The main malaria vector in Amazonia *Anopheles darlingi* showed a bimodal biting activity curve, peaking early in the evening, with another less intense peak at dawn. In the other species, this occurred mainly after nightfall. Following these results, some highly relevant points were raised, such as:

1. *Anopheles darlingi*, which is the main human malaria vector was recorded at all collection points in both the larval and winged forms.
2. The possibility of *A. nuñes-tovari, A. oswaldoi* and *A. triannulatus* being secondary vectors in this region.
3. It was suggested that efficient controls should be imposed on species which are proven transmitters, as well as others with the potential to become secondary vectors, including those mentioned in the previous item, as well as *A. noroestensis* and *A. albitarsis*;
4. As *A. darlingi* has a preference for large water-bodies, a habitat that would be created by the damming of the river, the massive proliferation of this species was indicated, which would replace woodland species due to alterations in habitat.
5. The data from the entomological surveys of the immature forms indicated that the macrophytes were excellent reproduction sites for the anophelines, although *A darlingi* maintained its reproduction sites predominantly along the banks of the lake. The macrophytes on the water-bodies throughout the reservoir were barely used by this species for reproduction, until the 1990 survey.
6. The biting activity of *A. darlingi* presented a behavioural standard that extended throughout the entire night, with a bimodal curve. A higher activity peak was noted at dawn and dusk.
7. In view of the results of the entomological survey, warnings were issued that controlling *A. darlingi* through traditional methods was virtually impossible. Measures additional to the normal routines would be necessary in order to avoid contact between humans and the vector, breaking the malaria transmission chain.

Human malaria records in the town of Tucuruí began in July 1962, and from that year until 1998, the number of positive cases rose appreciably.

3.5.11.2 Proliferation of Mansonia genus mosquitoes

After the river was dammed in 1984, the local communities began to complain about the unusual proliferation of mosquitoes, particularly in rural parts of Novo Repartimento.

This increase in anthropophile mosquito populations during the post-filling phase had serious results, forcing farm families to leave their homes in search of places with fewer mosquitoes. The discomfort was caused by attacks of *Mansonia*, whose attack rates topped 500 mosquito bites per man/hour in the early hours of the evening.

During the post-filling period from 1985 through 1986, observations showed a high density of *Culicídes*, with a significant predominance of species belonging to the *Mansonia* genus, with anophelines and other mosquitoes also occurring.

Data from this time on the attack activities of these mosquitoes show that there were up to 500 mosquitoes per man/hour during the peak activity period.

The population complained repeatedly about attacks by these insects, even during the day, which hampered farming activities. This prompted Eletronorte to sign an agreement with SUCAM which launched a special neighbourhood and home spraying operation in 1988. Although the situation improved somewhat, this operation was halted by operating and financial problems, after which the situation promptly grew worse again.

In 1989, once again at the request of the affected populace, a Multidisciplinary and Multi-Institutional Committee was set up to analyse this problem and suggest solutions. This Committee consisted of technical experts from the National Research Institute for Amazonia (INPA), the Evandro Chagas Institute, the Pará Federal University, Eletronorte, and the Federation of Farm Workers, as well as trade union leaders and representatives of the affected communities. This committee concluded that the severity of this problem had reached "*the proportions of a public calamity, and was due to undesirable environmental effects caused by the formation of the reservoir*".

The Committee also indicated that the cause of the proliferation of mosquitoes was directly related to deadwood left in shallower parts of the lake. In these areas – known as *paliteiros* – higher concentrations of nutrients in the water fostered the proliferation of macrophytes. As this problem was quite likely to extend into other areas, including the *Parakanã* Indigenous Reserve, the Committee felt that immediate pro-active control measures were required.

It thus proposed a Programme based largely on environmental clean-up measures designed to combat immature forms of the insect. This consisted mainly of removing dead trees from the *paliteiros* through underwater logging activities, with mechanical removal of macrophytes and their possible economic use. The committee also stressed the need to install mosquito screens in homes and launch an environmental education programme, in conjunction with biological mosquito larvae control and the financing of research into the biology of the predominant mosquito belonging to the Mansonia genus.

The supplementary studies required to implement the recommendations of this Committee were undertaken, particularly through a survey of population density of the Mansonia and Anopheles mosquitoes, which guided the configuration of the mosquito combat programme (Tadei, 1990).

During the mosquito density survey (Table 3.24), the main efforts were focussed on capturing winged forms that attack people. Sampling was carried out at various sites in the lake area, with collections taken near the roots of macrophytes belonging to the following species: *Salvinia auriculata, Scirpus cubensis, Eichhornia crassipes, Eichhornia azurea, Utricularia foliosa, Pistia stratiotes*, and others located along the banks of the lake near the drowned forests known as "*paliteiros*", or in flooded *igarapés* and river areas. Collections were also taken from floating macrophyte carpets in the lake itself, and at different points on the banks where local roads allowed access, and along the former Transamazon Highway.

Table 3.24 Mosquito density in relation to distance from the lake (mosquitoes per man/hour)

Less than 1 km			1 – 9 km			10 – 19km			20 km or more		
In	Pe	Mf	In	Pe	Mf	In	Pe	Mf	In	Pe	Mf
40	121	288	42	102	130	21	38	102	4	11	4

Note: In= Intra-Domiciliar; Pe= Peri-Domiciliar; Mf= Mid-Forest

The *Mansonia* genus also showed a high dispersion capacity, with examples being captured at a transect over 12km from the lake, across the Transamazon Highway running along its left bank.

In analysis of the proliferation of mosquitoes at the Tucuruí Hydropower Complex during the post-filling phase, it was noted that initially there was an appreciable increase in *Anopheles* genus species after the river was dammed in October 1984. During this period, 68 532 *Anopheles* specimens were collected, a figure far higher than that found during the pre-filling phase. Subsequently, an increase was recorded in the population of *Mansonia* genus mosquitoes, whose 1990 survey (Tadei, 1990) indicated 642 mosquitoes per man/hour during peak activity periods. In total 55 346 specimens of Culicides were collected, distributed through nine genera: *Mansonia, Anopheles, Culex, Aedeomyia, Coquillettidia, Psorophora, Aedes, Chagasia* and *Sabethes*. The results are shown in Table 3.25 below.

Table 3.25: Number of captured mosquitoes

Genus	Captured Individuals	%
Mansonia	53 727	97.07
Anopheles	1 257	2.27
Coquillettidia	182	0.33
Culex	103	0.19
Psorophora	33	0.06
Aedeomyia	28	0.05
Aedes	12	0.02
Chagasia	4	0.01
Sabethes	1	0.002
Total	**53 727**	**100.0**

(Modified from Tadei, 1990).
***Note**: Collections took place around the following locations: Parakanã,* Pucuruí, *Tucuruí, BR-422, Line 45, Line 49, Line 51, Novo Repartimento, Bahiana, Pacajazinho, Bandeirantes, Indigenous Area, Old Transmazon highway, others.*

Among the *Mansonia* genus, the most frequent species was *Mansonia titillans*, at 96% (51 578 individuals) with the lowest figures noted for the following species: *M. pseudotitillans, M. humeralis, M. indubitans* and *M. amazonensis*.

Biting activities showed a bimodal type of conduct for *Mansonia*: 5 / 6 p.m. to 10 p.m. / 12 midnight, followed by an interval, with activities increasing again at 3 / 4 a.m. and peaking around 5 / 6 a.m. Throughout the day activities continued, although at far lower levels than during the night hours. With minor variations, this pattern was recorded at all places studied.

It should also be noted that during the filling phase, the *Anopheles* species were recorded throughout the entire reservoir, with 9 652 examples being collected. The *Mansonia* genus at that time was found in very low densities and at isolated spots with small clumps of macrophytes along the Tocantins River. Based on the results of mapping the population density of *Mansonia, Anopheles* and other culicides in 1990, the following recommendations were made, among others:

- Immediately implement a broad-ranging mosquito control programme upstream from the Tucuruí Hydropower Complex, in view of the severity and extent of this problem.
- Assign top priority to areas classified as highly or moderately affected for the control programmes.

- Suggest that the populace eliminate cracks and gaps in homes, and install screening systems to avoid intra-domicilar infestation.
- Immediately undertake the mapping of the aquatic forms in order to guide the control measures.
- The removal of flooded forests known as *paliteiros* and macrophytes is not recommended, as this would mean launching biological larvae controls before undertaking adequate mapping, as these new habitats not only favour the proliferation of the *Mansonia* genus but also play an important role in the food chain of the lake formed by the hydropower dam.

The current incidence of mosquitoes was briefly evaluated in 1999. The results differed significantly from those of the early 1990s. The area of occurrence for mosquitoes has shrunk greatly in terms of the lake, although there are still places near its banks posting high densities. Along a local road 7 137 mosquitoes were recorded per man/hour between 6 and 7 p.m, with 73 belonging to the *Mansonia* genus. This was because there are still patches of macrophytes along the banks of the lake - but the area of occurrence of macrophytes is currently far smaller than in the past.

For further investigation into the relationship between macrophytes and the proliferation of mosquitoes at the Tucuruí Hydropower Complex, we suggest that a new mapping campaign be launched, similar to the 1990 campaign. This survey is necessary in order to provide firm knowledge of the current scope of this issue. Certainly, the problem is far less extensive today, due to the new ecological balance of the lake. There are no more macrophytes in central areas of the reservoir, and mosquito collections were negative for *Mansonia* in the Base 4 areas.

3.5.12 Mercury Concentration[15]

In the early 1990s, a group of scientists from the University of Helsinki in Finland carried out a series of studies, with the cooperation of Brazilian[16] institutions, aimed at gaining a better understanding of the origins and effects of mercury in tropical reservoirs. As these studies remain the most complete and up-to-date analysis on mercury in the Tucuruí region (Jean Guimarães, personal communication), their findings will be presented here.

A summary of the results of the Finnish studies has been published in Aula *et al* (1994). A series of articles were published covering specific topics in this project (Aula *et al*, 1995, Porvari, 1995, Leino & Lodenius, 1995). This section presents its objectives and findings. The Tucuruí Hydropower Complex lake was selected for the Finnish studies because it was the first large reservoir formed in the Amazon region, where high levels of mercury had already been noted in other studies. The purpose of the Finnish studies was to determine the total mercury levels in a tropical reservoir and its surrounding areas, and to investigate how the building of the reservoir and the primary source of mercury in its water – gold mining – affects these levels. The mercury bioconcentrations in the reservoir and its surroundings were analysed; the study focussed on whether the build-up of mercury in fish justified constraints on its consumption by human beings, and whether the mercury levels could cause problems for local residents eating these catches. There was also an intention to identify the species which could serve as bio-indicators of the present of mercury. Another objective was to estimate how much mercury is stored in the various sections of the reservoir, and how this affects or has affected the current mercury contamination status. Evidence was gathered of seasonal variations in mercury levels in the sediments, sedimentable material and plants, as well as differences in mercury levels in sediments, plants, fish and human hair at different parts of the Tucuruí reservoir and its surroundings.

The Finnish studies indicated that the water hyacinth (*Salvinia auriculata)* is a promising species for monitoring mercury concentrations in the waters of tropical reservoir. The tucunaré (*Cichla spp.*) proved the most useful indicator species, due to its high consumption levels and carnivorous habits, for monitoring both the build-up of mercury in food-chains as well as mercury levels in fish eaten by local communities.

The mercury levels found in the tucunaré collected at seven different points in this region (Murú, Caraipé, Capemi, Base 3, Base 4, Ipixuna and Marabá) averaged 1.1 mg/kg net weight (minimum = 0.99 mg/kg at Capemi, maximum 1.3 mg/kg at Base 3). The maximum safety standard for human consumption in several countries is 0.5 mg/kg (in order to reach the concentration of 50 mg/kg in human hair, the required average daily ingestion of mercury is only 0.3 mg/kg).

The results of the Finnish studies revealed that "*the concentrations of mercury found in hair taken from fishermen at Tucuruí are high enough to cause health problems.*" This work also explicitly stated that "*poisoning by methyl-mercury threatens thousands of people in this region*".

To qualify this statement, it is acknowledged that mercury levels in adult human hair at 50 - 125 mg/kg indicate a low risk of neurological damage. The risks of clearly-defined neurological effects appear only at concentrations of over 125 mg/kg. The average noted for fishermen in the lake area was 47 mg/kg (standard deviation of 10.2), close to the low risk level. However, one individual was recorded with a mercury concentration of 240 mg/kg in his hair. People in this group consider fish caught in the reservoir to be a vital part of their diet (an average of fourteen meals a week with fish). People living in this region with lower fish consumption (for example, the indigenous peoples in the *Parakanã* reserve and the residents of the Eletronorte township) had far lower mercury concentration levels in their hair (8.5 mg/kg and 11 mg/kg, respectively).

According to this study, the main sources of mercury are gold-mining operations upstream from the reservoir. Along its banks, the effects of flooded soil and plantlife of mercury levels can be noted. Even in the Caraipé area, which was previously clear-cut, the mercury levels in tucunaré caught were higher than the internationally accepted standards for human consumption. This is probably due to the mercury in local soils.

Finally, given the alarming results encountered, the Finnish studies recommend that the mercury levels in other Amazon and tropical reservoirs should be analysed.

The main criticisms of the Finnish studies focus on the representivity of the samples collected: few examples of fish were caught, and the locations of the sampling points were close to gold-mining areas (Morais *et al*, 1999). These authors nevertheless stress that studies carried out in reservoirs in other countries revealed increased mercury concentrations up to six times higher than those found in fish of the same species in natural environments, and that these increases have occurred within 10-15 years. A survey is under way at the Curuá-Una reservoir – which is not directly affected by mining activities – in order to clarify this important point.

Despite all this evidence, there is yet no definitive proof of impact of the Tucuruí reservoir on mercury concentration levels. However, it is known that (1) mercury levels are very high in important portions of the ecosystem, such as carnivorous fish; (2) dams tend to build up mercury levels higher than those noted in nearby natural environments; and (3) expanding human activities upstream and along the banks of the reservoir could be increasing the mercury release rate into the reservoir and the water-bodies that supply it. Based on these observations, as a precaution, it is recommended that fresh studies should be undertaken to conclusively establish the role of the reservoir in the build-up of mercury, together with a monitoring programme to introduce a fish consumption control policy in order prevent health problems among the populace. Most of these results were widely disseminated with a variable degree of accuracy by national and local Press at the time of their publication, and raised an understandable but unfortunately ephemeral concern among the populace.

Eletronorte challenged the data collection methodology adopted in the Finnish studies and queried the validity of their results. According to Eletronorte, the figures disclosed by the Press conflicted with the preliminary conclusions of the survey.

3.5.13 Emission of Greenhouse Gases by the Tucuruí Hydropower Reservoir and Thermopower Plants Emissions Avoided

Rising concerns over the possibility of climate changes caused by emissions of greenhouse gases (GHG), particularly those caused by energy production and use, have prompted a series of studies on this issue.

One of these studies covers the emission of greenhouse gases by power production processes. The use of fossil fuels by thermopower plants and bacterial decomposition of submerged biomass in hydropower reservoirs produce different greenhouse gases. However, while thermopower plants fuelled by coal, fuel oil or natural gas produce mainly carbon dioxide (CO_2), as well as some fugitive emissions of CH_4 in the case of natural gas fired plants, the decomposition of organic matter in reservoir waters produces both CO_2 and methane (CH_4).

In order to evaluate the net impact of the Tucuruí dam on global warming, its net GHG emissions must be compared with the GHG emissions from an equivalent thermopower plant, whose necessity was avoided by the construction of the Tucuruí hydropower plant.

The rated power production capacity of the Tucuruí Hydropower Complex is 4 000MW. The GHG emissions from thermopower plants with an equivalent rated power capacity would depend on several factors, including:

- The type of thermopower technology to be used, based on diesel, fuel oil or combined cycle (diesel and natural gas). In Northern Brazil, thermopower plants are generally fuelled by diesel or fuel oil;
- The location of thermopower plants. Unlike hydropower complexes − they can be located near consumption centres or fuel production hubs, thus avoiding large-scale power transmission lines and corresponding energy losses;
- Implementation schedules for thermopower plants. Since construction is obviously shaped by energy demands, it would not be necessary to install the entire potential rated capacity of the Tucuruí Hydropower Complex (4 000MW) at the same time.

When assessing the amount of greenhouse gases issued per MWh of energy produced, it should be noted that both thermopower plants (due to the distributed effect of their operations over time) and their hydropower counterparts (due to the decomposition period for submerged biomass which depends on the year in which the reservoir is filled) produce emissions that vary over time. However, it should be stressed that emissions from the Tucuruí hydropower dam may drop steeply over the years, as suggested by recent measurements, in contrast to thermopower plants producing power equivalent to the output of Tucuruí, whose emission levels remain steady over time.

A number of projects have been undertaken by COPPE/UFRJ in cooperation with the Global Changes Research Coordination Unit under the Ministry of Science and Technology, in order to prepare a national inventory estimating greenhouse gases emissions from Brazil's hydropower reservoirs.

Two methodologies were used to measure CH_4 and CO_2 emissions, according to Rosa (1999): bubbling flow and diffusion flow. Two measurement campaigns were undertaken, one in 1998 and the other in 1999. The results obtained in these two initial campaigns are shown in Table 3.26.

Table 3.26: CH_4 and CO_2 emission coefficients measured at the Tucuruí Reservoir.

Campaign	Bubbling tons / Km^2 year		Diffusion tons / Km^2 year		Total (sum) tons / Km^2 year	
	CH_4	CO_2	CH_4	CO_2	CH_4	CO_2
1998	4.78	0.055	71.57	3 808	76.36	3 808
1999	0.876	0.06	4.45	2 378	5.33	2 378

Source: Rosa et al, December 1999.

These measured emissions represent gross and not net emissions and were taken solely from the reservoir not including any emissions from turbines or spillways. Moreover, these results are preliminary, as they are based on two initial campaigns. Nevertheless, in order to have a gross estimate of these coefficients available for preliminary calculations, the range and the arithmetical means for the two campaigns will be used here.

In addition to the figures measured, Table 3.27 shows some estimated figures obtained from the specialised bibliography, each one with its own methodology.

Table 3.27 CH_4 and CO_2 Emission Coefficients and Total Emissions from the Tucuruí Hydropower Dam

CH_4 Emissions

SOURCE OF INFORMATION	EMISS. COEFFICIENTS (tons CH4 / Km2 year)	CIRCUMSTANCES	EMISSIONS * (tonsCH4 /year)	TOTAL EMISSIONS FROM TUCURUÍ DAM (tons CH4 /year)
Fearnside, 1995 - estimate -	19.67	Open water surface	49,237.94	68,161.90
	63.76	Surface constantly covered by macrophytes	18,923.96	
Fearnside, 2000 - estimate -	---	Bubbling – reservoir emissions in 1988	7,800	650,100
	---	Diffusion – reservoir emissions in 1988	39,900	
	---	Turbines – turbine emissions in 1991 **	602,400	
Lima & Novo, 1997 (INPE) - estimate -	23.07	Open water surface	57,748.82	66,406.47
	29.17	Surface constantly covered by macrophytes	8,657.65	
Rosa et al, December 1999 - measured -	40.85 (average) 5.33 – 76.36 (range)	Same all over the reservoir	---	114,464 (average) 14,924 – 213,808 (range)

CO_2 Emissions

SOURCE OF INFORMATION***	EMISS. COEFFICIENTS (tons CO2/ Km2 year)	CIRCUMSTANCES	EMISSIONS * (tons CO2 /year)	EMISSIONS FROM TUCURUÍ DAM (tons CO2 /year)
Fearnside, 1995 and Fearnside,2000 - estimate -	---	Estimate for 1990	---	9,450,000
Rosa et al, December 1999 - measured -	3,093 (average) 2,378 - 3,808 (range)	Same all over the reservoir	---	8,660,400 6,658,400 – 10,662,400 (range)

It is important to stress that the figures for the Tucuruí Reservoir are gross, meaning that the emissions of both CH_4 and CO_2 – which would exist even without this reservoir – are not taken into consideration. However, ideally only the net increase in emissions caused by the reservoir should be considered as the impact of human activity.

Based on estimates produced for the National Power Conservation Programme (PROCEL - *Programa Nacional de Conservação de Energia Elétrica*) by La Rovere & Americano (1999), greenhouse gases emissions from thermopower plants in Brazil are shown in Table 3.28.

Table 3.28 Greenhouse gases emissions from thermopower plants in Brazil

	NATURAL GAS	COAL	DIESEL	FUEL OIL
Tons C / TJ	15.3	26.2	20.2	21.1
Tons C / Tcal	64.0	109.6	84.5	88.3
Tons CO_2 / Tcal	234.7	402.0	309.9	323.7
Tons CO_2 / GWh	201.9	345.7	266.5	278.4
Efficiency (%)	45%	31%	30%	36%
Tons CO_2 / GWh	449	1115	888	773
Tons CH_4 / TJ	0.0059	0.0006	0.0009	0.0009
Tons CH_4 / Tcal	0.0247	0.0025	0.0038	0.0038
Tons CH_4 / GWh	0.0212	0.0022	0.0032	0.0032
Efficiency (%)	45%	31%	30%	36%
Tons CH_4 / GWh	0.0472	0.0070	0.0108	0.0090
Tons N_2O/ TJ		0.0008	0.0004	0.0003
Tons N_2O/ Tcal		0.0033	0.002	0.0013
Tons N_2O / GWh		0.0029	0.0014	0.0011
Efficiency (%)	45%	31%	30%	36%
Tons N_2O/ GWh		0.0093	0.0048	0.0030

** Combined cycle thermopower plants.*
*** Fuelled by imported coal.*
Source : La Rovere & Americano, 1999

Based on the average annual power generation of 21.4 TWh by the Tucuruí Hydropower Complex over the period 1995-1998 (when its annual generation has reached stabilization) shown in Table 3.29, greenhouse gases emissions from thermopower plants of equivalent annual power generation were calculated using the coefficients in Table 3.28. (Table 3.30).

Table 3.29 Power Generation – Tucuruí Hydropower Complex

YEAR	Power Generation (MWh)	YEAR	Power Generation (MWh)
1984	269 967	**1992**	16 997 671
1985	5 831 444	**1993**	17 780 761
1986	9 257 069	**1994**	19 409 753
1987	13 298 813	**1995**	22 082 786
1988	15 838 415	**1996**	22 596 816
1989	17 068 080	**1997**	20 399 418
1990	15 468 732	**1998**	20 634 808
1991	18 033 918	**TOTAL**	234 968 451

(Average for 1995 – 1998: 21 428 458 MWh /year).

Table 3.30 Emissions from thermopower plants with an annual output equivalent to Tucuruí.

	Natural gas	Coal	Diesel	Fuel Oil
CO_2 Emissions (Ktons / year)	9 621	23 892	19 028	16 564
CH_4 Emissions (Ktons / year)	1.0	0.15	0.23	0.19
N_2O Emissions (Ktons / year)	---	0.20	0.10	0.06

3.5.13.1 Emissions Measured in GWP (Global Warming Potential) Units

In order to quantify the contribution to global warming from different greenhouse gases such as carbon dioxide and methane, a common unit of measurement is required. The Global Warming Potential (GWP) for a specific gas may be defined as the quotient between the instantaneous radioactive forcing of an emission pulse of this gas and radioactive forcing, which is also instantaneous, caused by an equal simultaneous emission of a gas used as a reference, in this case CO_2, integrated over a time horizon (Rosa, Schaeffer & Santos, 1994).

According to the International Panel on Climate Change (IPCC, 1995), the Global Warming Potential (GWP) may be expressed as the radioactive forcing integrated over time based on instantaneous release of one kilogram of a specific gas compared to one kilogram of a reference gas (CO_2). However, the establishment of the GWP equivalent values for the different greenhouse gases is still subject to great uncertainty. While recognizing the scientific controversy over this issue, the IPCC has supplied some provisional values for the GWPs. For a time horizon of 100 years in the atmosphere, and establishing the GWP of CO_2 as equivalent to 1 (one) as the reference gas, then the GWP of CH_4 is 21 (twenty one) while the GWP of N_2O reaches 310 (three hundred and ten), using the IPCC provisional figures (IPCC, 1995) for the GHG emissions from Tucuruí, expressed in CO2 equivalent according to these provisional GWP values.

Table 3.31 below gives the corresponding figures for the GHG emissions from Tucuruí, expressed in CO_2 equivalent according to these provisional GWP values.

Table 3.31 Greenhouse Gases Emissions in Ktons of CO_2 equivalent (range and average figures)

	Tucuruí Hydropower Complex				Equivalent Thermopower Plants			
	Fearn side 1995	Fearnside, 2000 *(average and range)* [(2)]	Lima & Novo	Rosa et al, 1999 *(average and range)*	Gas	Coal	Diesel	Fuel Oil
CO_2 Emissions (Ktons CO_2 /year)	9 450	---	---	8 660.4 6 658.4 – 10 662.4	9 621	23 892	19 028	16 564
CH_4 Emissions [(1)] (Ktons CO_2 eq /year)	1 431.4	---	1 394.5	2 401.7 313.4 – 4 490.0	21	3.15	4.83	3.99
N_2O Emissions [(1)] (Ktons CO_2 eq /year)	---	---	---	---	---	62	31	18.6
Total Emissions [(1)] (Ktons CO_2 eq /year)	10 881.4	36 835.5 30 149.8 – 43 521.2	1 394.5	11 062.1 6 971.8 - 15 152.4	9 642	23 927.8	19 063.8	16 586.6

(1) *Units in Ktons of CO_2 equivalent.*
(2) *Revised Fearnside's estimates (unpublished)*

In the current Brazilian energy context, the most suitable alternative to a hydropower plant (as Tucuruí phase two, for example) could be a combined cycle natural gas unit, at least for short term expansion of the power generation system, subject to natural gas resources availability. However, at the time the dam was built (Tucuruí phase one), there was no natural gas availability nor a grid connection between Brazilian Northern and Southern power systems. Hence the thermopower alternative to Tucuruí at that time would have to burn imported coal or fuel oil, with much higher GHG emissions.

The amount of GHG annual emissions from the Tucuruí Hydropower Complex measured in 1998 and 1999 for the Tucuruí Reservoir by Rosa et al (1999) are appreciably lower than those produced by thermopower plants fuelled by coal, diesel or fuel oil and of the same order of magnitude of the annual emissions from a gas-powered combined-cycle thermopower plant generating the same rated power as Tucuruí.

Other estimates in the above Table (Fearnside, 1995; Lima & Novo) provide lower figures for the methane emissions from Tucuruí. On the other hand, Fearnside's 2000 estimates were revised upwards to include GHG emissions from the spillway and turbines and reach an overall emission amount considerably higher than any thermopower plant.

These preliminary results are far from being definitive, as there remain many uncertainties due to the lack of scientific knowledge on this recent issue. Work is still in progress to reach a final evaluation of net GHG emissions from the Tucuruí dam and the GHG emissions avoided by the construction of Tucuruí when compared to an equivalent thermopower plant.

The key methodological factors that will affect whether Tucuruí will produce more or less GHG emissions than the alternative equivalent thermopower plant are:

- estimate of gross emissions from the reservoir, spillway and turbines
- gross versus net emissions of the Tucuruí plant
- life-cycle analysis (i.e. temporal dimension of emissions from the reservoir)
- the selection of the alternative technology

The rating of the plant – i.e. when Phase II is completed the power generation will double, raising the energy to be offset by the thermopower alternative

Findings

- When work began on Tucurui, international experience on the environmental impacts associated with the introduction of large lakes in tropical regions was limited to some African dams, which could not be transferred directly due to fundamental differences in the quality of the water bodies, the plant-life submerged the lake, and the fact that the biota of these two continents are very different.
- Hired in 1977 by Eletronorte, ecologist Robert Goodland indicated that Eletronorte should draw up a programme for the clearing of the reservoir area, together with a social and cultural inventory of the affected communities. Also required were a survey of the historical and archaeological heritage of this region, an inventory of its wildlife, and a listing of the regional infrastructure, among other studies.
- As ecological and biological information on this region was sparse, most of the inferred impacts of the Tucuruí Hydropower Complex were based on a series of estimates and speculations.
- The information produced by the environmental studies was frequently insufficient to answer simple questions on environmental quality before and after the implementation of this venture, due to: (1) the complexity of the eco-systems involved; (2) lack of basic information on the eco-systems, (3); lack of objectivity in the studies, and (4) poorly systematised information gathered over the years, much of which is scattered among in-house Eletronorte reports, some of them unpublished.
- Due to the characteristics of the river and the results of the modelling at the time the engineering studies were undertaken, it seems that the Tucuruí reservoir is not subject to any immediate risk of silting-up. However, expanding deforestation throughout the region, with consequent increases in the flow of sediments, justifies further monitoring by Eletronorte in the near future.
- A drop in water quality was forecast, caused by decaying organic matter submerged by the dam, with the water held in reservoir. When the reservoir was first filled, there was initially an appreciable drop in water quality, particularly during dry seasons. However, after a few years, a steady improvement in water quality can be noted, although it has not yet stabilised. It is still not of sufficient quality for higher-grade uses such as water supplies and bathing, particularly in more remote stretches of the reservoir.
- A significant drop in downstream water quality was forecast. Studies carried out during the 1986 dry season showed very low levels of dissolved oxygen in the water, owing to low flow-rates. Under these conditions, there were two different types of water flows in 1986 along a stretch of river some 40km long: one flow near the left bank was completely anoxic due to the tailrace while water flowing down the spillway had higher oxygen levels. This highlights the importance of establishing operating rules in order to control and mitigate downstream impacts.
- The proliferation of both floating and emerging aquatic macrophytes was forecast for some parts of the lake. Although these forecasts were confirmed, there is evidence of shrinkage in the infested areas over the long term. The most critical problems were related to shipping, bathing and the proliferation of mosquitoes.
- Alterations were forecast in the structure of fish communities, both upstream and downstream, with effects on catches and the local economy. Qualitative modifications were noted (disappearance of certain species) as well as quantitative changes (variations in the abundance of some commercial fish species), but not on the scale originally foreseen.
- Losses in local biodiversity were forecast, for both plants and wildlife, with the disappearance of endemic species. No conclusive data is currently available confirming this projection.
- Impacts on wildlife in the areas to be flooded were forecast. The number of animals that died during the dam-filling process is unknown, as is the impact of releasing rescued animals among the populations in the release areas and along the reservoir banks.
- Changes were forecast in the regional microclimate due to the presence of a large area covered by water. Only a slight increase in the relative humidity was noted in the area around the reservoir.
- Human health problems were forecast, due to the possible proliferation of disease vectors. An increase in the incidence of malaria (which is transmitted by mosquitoes, mainly the *Anopheles* genus) was noted, during the years following the filling of the reservoir. The proliferation of *Mansonia* genus mosquitoes also caused much disturbance among the local populace..
- When the Tucurui Hydropower Complex was built, no consideration was given to the risk of mercury pollution. Recent studies indicate this risk, with measurements indicating mercury build-ups in various important sectors of the eco-system and the local populace, particularly among fishermen who consume large quantities of fish.

- Another unexpected impact was the emission of greenhouse gases from the dam. So far, measurements of the amount of annual GHG emissions from the Tucuruí Hydropower Plant (Phase I) are appreciably lower than those produced by thermopower plants fired by coal, diesel or fuel oil and of the same order of magnitude of the annual emissions from a gas-powered combined-cycle thermopower plant generating rated power equivalent to the output of the Tucuruí Hydropower Plant (Phase I). However, another estimate supplies much higher figures for the GHG emissions from the dam. Further studies are needed to reduce the important uncertainties about the accounting of net GHG emissions from the dam on a life-cycle basis before reaching any firm conclusion in this comparative analysis

3.6 Social and Economic Effects

3.6.1 Preliminary Effects

In this section the analytical tools of the social sciences are applied to the situations, experiences and perceptions of different social groups. Focused on conditions and experiences among groups of peasants from an anthropological standpoint, this analytical approach highlights economic, social and demographic alterations among these groups, as well as those among residents of small towns, whose lifestyles and social organisations have been altered by the Tucuruí Hydropower Complex.

It is understood that the effects of the dam[17] are seen in countless changes that have been and are still being experienced by these social groups. The standpoint adopted here is very different from those taken by both the enterprise itself and the State regarding this venture.

In the electricity sector's point of view, the notion of impacts is generally informed by the logic of the practical and technical efficiency, in which social effects are expected and consequently accepted quite naturally. In fact, these are successive or cumulative consequences which are not considered *a priori*, but rather derive from actions, interests and diverse factors. These consequences redefine or destructure cultural references.In the approach adopted here, human beings cannot be seen as merely natural beings, but rather as the constructors of cultural projects that shape practices and relationships with other human beings.

It is also clear that local and regional development cannot be measured solely by economic indicators - such as higher tax revenues and a temporary upsurge in employment – but may rather be monitored with regard to social and economic variables reflecting improvements in the quality of life prompted by the project. In other words, it is useful to monitor the project's contribution to development through indicators measuring the well-being of communities in areas directly affected by the project over time. These indicators include permanent employment, the stability of farmers and peasants on the land, improvements in schooling, sanitary conditions and healthcare, housing conditions, recreation, safety and information.

In order to prepare this sub-item, a bibliographic update was undertaken of existing social and economic studies, statistical data surveys and cartography, in addition to an analysis of the primary data both upstream and downstream from the Tucuruí Lake and in the islands region. This procedure was vital to an understanding of the various manifestations of change, including those at the ecological level, although these were not specifically covered by these analyses.

The bibliographic survey yielded a series of sources dating back to the start of this decade which remained relevant, including those related to the resettlement of indigenous and peasant communities (Mougeot, Castro, 1989; Acevedo, 1993) and the organisation of grassroots movements among those affected (Castro 1989; Magalhães 1994, 1997; Almeida, 1989, 1993, 1996[18]; Silva, 1997). However, gaps were noted in the output of information on these issues from universities and scientific research institutes. In general, analyses were *post facto* in response to critical situations, and failed to offer alternatives.

The lack of a database on municipal districts in the area of influence of the Tucuruí Hydropower Complex hampered the surveying of its production, demographic and land-owning structure. The non-existence, diffuseness or inconsistency of the information available posed a difficulty.

The fieldwork consisted of carrying out a survey (directed questionnaires) supplemented by interviews and information collected from institutions in the towns of Tucuruí, Breu Branco, Goianésia, Novo Repartimento and Cametá. Also exhaustive attempts were made to enter into dialogues with various local institutions: Eletronorte, IBAMA, Trade Unions, Associations and the Grassroots Education and Assistance Agri-Ecological Centre (CEAP - *Centro Agroecológico de Assessoria e Educação Popular*), among others.

Three data collection tools were prepared: (i) a questionnaire addressed to heads of family units fitting into the categories of "affected or resettled", "expropriatees" (rural, urban or both) and workers hired by Eletronorte as labourers; (ii) scripted interviews with trade union leaders and representatives of organisations, following a script that assessed the political situations and organisation of "dam affected people"; and (iii) scripted interviews at local institutions with municipal, state and federal agency heads. These questionnaires and interviews, and the methodology used, are described in the Portuguese version of the annexes.

Following literature surveys and the fieldwork in the Tucuruí Hydropower Complex region, three areas of analysis were distinguished: upstream areas, downstream areas, and the islands region.

3.6.2 Spatial and Social Changes Triggered over the Past Twenty Years

The purpose of this study is to present the various spatial and social transformations that have taken place in this region, bearing in mind that alterations in space shape new social relationships at both the material objective and subjective levels. It is thus considered important to focus on the spatial intervention processes and the social relationships deriving from them.

Traditional forms of settlement are deeply rooted in this area. Until the 1970s, the mid-Tocantins region, which includes the municipal districts of Marabá, Itupiranga, Jacundá and Tucuruí, was an important area in the Pará State economy, after the collapse of the rubber boom, due to brazil nut gathering activities. In this area, seasonal movements were noted by peasants, owners of brazil nut groves and traders during Brazil-nut harvest periods, in a society controlled by the regional/local elites.

The Tocantins Railroad runs parallel to the course of the river. Construction began on this line in 1893, and it played an important role in transporting communities and carrying Brazil nuts. Closed in 1973, it was then used only by local peasants, who travelled along its rails on trolley-cars.

The occupation pattern in the area was redefined when the Belém-Brasília Highway was laid during the 1960s, triggering large flows of migrants. New social players – entrepreneurs, ranchers and migrants – began to enter the dynamics of this region. These flows accelerated with the introduction of the Federal Government settlement projects in the early 1970s, guided by the new Transamazon Highway, along which small farmers, loggers, traders and cattle-ranchers were settled.

Assailed by a series of changes, this area was once again subject to de-structuring and re-organisation with the construction of the Tucuruí Hydropower Complex. The artificial lake covers some 2 875 square kilometres. Also, 170km of federal highway were submerged, together with ten schools and thirteen villages and hamlets: Repartimento, Breu Branco, Remansão do Centro, Remansinho, Jatobal, Vila Bela, Ipixuna, Vila Braba, Coari, Santa Tereza do Tauari, Chiqueirão, Areião, Canoal, the Town of Jacundá and part of the lands in the municipal districts of Tucuruí, Itupiranga and Nova Jacundá. The BR-422 highway was shifted and the PA-263 highway was built, linking Tucuruí and the PA-150 highway which is the State highway linking Belém, the State capital to Marabá, the regional hub. In 1976, part of the old railroad was transferred to Eletronorte, with its right of way covering some 67

500 hectares of land. The area between kilometre 25 and 97 of this railroad, called *Cota + 35* by Eletronorte (*cota* meaning elevation above sea level in Portuguese), incorporated four small towns: Santa Rosa, Remanso do Centro, Breu Branco and Tucuruí. These data give a good idea of the size of the area affected.

Downstream from the dam, the project did not result in the division and formation of new municipal districts, but various associated factors discouraged farming, extractivism and fishing. The old Cametá district which was the most important in the Tocantins Valley in terms of economics and population, saw its farming and fishing activities decline, although its lands remained intact. Traditional trading activities were adversely affected by problems with shipping. Founded in 1833, Baião lost no land either, but its farming activities wilted. Mocajuba, which dates back to 1845, saw its harvested lands shrink. It should be stressed that the drop in agricultural activities cannot be blamed on dividing up the land, as these municipal districts together totalled 7 882 square kilometres before the dam was built. Downstream issues will be analysed in greater detail in sub-item 3.6.6.

The upstream area is three times larger than the downstream region, amounting to 27 073 square kilometres, with land division processes taking place after the hydropower project was built. These alterations are directly related to the installation of this power complex, which modified the production base with similar results to those noted downstream. Previously covering a land area of 6 059 square kilometres, Jacundá was reduced to 1 957 square kilometres, while the land-area of Itupiranga was reduced slightly. Subdividing these municipal districts resulted in the appearance of Goianésia do Para, Novo Breu Branco and Novo Repartimento, which are covered in this study. Split off from Baião in 1947, Tucuruí lost all its rural areas – which cover 25 200 hectares – initially to the formation of the lake and then through annexation by Novo Repartimento. It was reduced to little more than an urban area in 1986, consisting of the town of Tucuruí, the Eletronorte township, Repartimento and the original Breu Branco, covering 1 775 hectares. The roads forming the Transamazon Highway speeded up the land settlement process. Including the BR-422 Highway, this backbone covered 100 675 hectares. On the right bank of the reservoir, the PA-150 Highway and the road linking it to the town of Tucuruí - PA-263 – cover 311 025 hectares. This leads to the conclusion that there was an increase of some 400% in rural area settlements from 1979 to 1986, compared to the increase in urban areas over the same period of some 150%.

Indigenous communities, peasants and estate-owners who had established ways of life on this land suffered the consequences of this intervention. Land on the banks of the lake totalling 120 000 hectares was transferred to the Federal Government, and later transferred to the Araguaia-Tocantins Land Executive Group (GETAT - *Grupo Executivo de Terras do Araguaia-Tocantins*).[19] In a joint action with INCRA, Eletronorte signed an agreement with GETAT to separate government lands from private property in this region. Later, GETAT assigned these lands to rural sub-divisions, many of which were used to resettle expropriatees from the reservoir area. The “new island territory” was settled “independently” by the former occupants of the flood-land and upland forests in the Tocantins Valley. This required a series of strategies by the present social groups, who set up the Association of Agri-Extractivist Farm Workers and Subsistence Fishermen (ATRA - *Associação dos Trabalhadores Rurais Agro-Extrativistas e Pescadores Artesanais*). Their leaders began to mount a campaign to establish the Taipava Extractivist Reserve, working closely with Farm Workers Trade Unions in various municipal districts around the reservoir (Acevedo, op. cit, page 5)[20]. Alterations in the territorial settlement of this region took place rapidly and in a disorderly manner, with ELETROBRÁS/Eletronorte observing these dynamics by means of satellite image interpretation (1992, op. cit., page 41). However, other statistical databases and empirical surveys show changes brought about by planned intervention, or dictated by circumstances in various cases.

3.6.2.1 Island Region

The initial estimates drawn from aerial surveys of the area to be flooded, carried out before the reservoir was filled, indicated a lake surface of around 2 430 km^2, forming some 600 islands. Later surveys, based on satellite images of the lake, once it was formed, adjusted these estimates. Once the water level stabilised in the Tucuruí Reservoir in March 1986 in what was formerly the Caraipé Valley, it had flooded an area of 2 850 km^2, and formed some 1 660 hilltop islands. Since then, an intensive settlement process has been underway, particularly on islands offering easy access to the shore and the town of Tucuruí.

An interesting point is that the decision to include the locks system in Phase I made it necessary to flood the Caraipé Valley. The decision to set aside an area for a large lock increased the costs of Tucuruí project by over US$300 million, and also brought forward environmental impacts and costs that would possibly only have occurred during Phase II. Before the formation of the Tucuruí Lake, several islands were noted on the Tocantins River whose residents had developed a very specific life-style organised around their individual characteristics. The formation of the archipelago in the reservoir resulted in a new landscape, with a different ecosystem and a separate settlement process.

The settlement of the islands occurred mainly in a land take-over process by dozens of peasants who lost their croplands and homes when the sluice gates were closed (Acevedo, 1996). The Tucuruí Lake Islands region constitutes an interesting social and economic spatial reality, on the watershed that of the construction of the Tucuruí Hydropower Complex. The island settlement process began as soon as fishermen in the Lower Tocantins – particularly from the Cametá, Mocajubá and Baião municipal districts and areas near Tucuruí – began to seek new ways of carrying out their activities and ensuring the survival of their family groups. These fishermen were pressurised by shrinking catches due to alterations in the hydrological system of the river after the Tucuruí Dam was built, or by the loss of their workplaces and homes. Their statements[21] suggest that dwellers in the Lower Tocantins area began to move into the islands region in order to fish in the hydropower reservoir when the islands were still uninhabited. They put up small shacks for shelter during fishing periods. This led them to discover the potential of this area, not only for fishing, but also for permanent homes and farming. Hence the earliest settlers built homes and began passing information on through their family networks about the availability of land in this area. Since then, a spontaneous shift of the population has taken place, centreing on various areas in the islands region and seeking alternative locations for homes and work. The settlement of the islands represents an alternative mode of spatial and productive reorganisation encountered by those who were adversely affected by the construction of the dam. The identification of these residents offers an outline of the typology of these islands. Most of them are inhabited by people who were affected by the poor catches in the Lower Tocantins area and moved here spontaneously. Although the history of this settlement is driven by the promise of access to land for homes and work, the circumstances differ from family to family. They can be classified into certain categories:

- Islands settled before filling
- Islands shaped by family networks
- Private islands (ranches or recreation areas)
- Preservation area islands

The preservation area islands were established by Eletronorte through a special statute, defined in accordance with environmental projects – germplasm bank island and Release Area 3 island – or due to their strategic position for the safety of the dam, dykes and protection of Release Areas 3 and 4. As at Base 11, plant and wildlife species are being preserved on these islands, forming a type of germplasm bank. Despite the geographical and environmental changes brought by the dam, the islands have preserved the wide diversity of plants and wildlife characteristic of the submerged lands. While this preservation was inherently positive, it has also attracted hunters, poachers, loggers and clandestine fishermen who deplete local wealth. The latter have little respect for the importance of the fish-breeding season. This is very serious, as fish are the primary source of protein for the island dwellers.

Life on the islands is characterised by a series of contradictions. Their residents live on the banks of a river teeming with fish, with most of them surviving on their catches, but the fishing village does not have a marketing policy; hence its residents are at the mercy of middlemen *(atravessadores*) who offer the only guaranteed outflow channel. Clandestine fishermen using large boats and nets, in contrast with the canoes and hooks used by the local residents, continue to defy the IBAMA supervisors. Some local people cannot even state the size of the area where they are settled. Two factors lie behind this lack of concern: the insecurity that they have always felt regarding their ability to settle permanently on these lands, and community use of the resources and land on the islands settled by groups of families. At the official discourse level, the settlement of the islands remains an ill-defined process. As there are no land titles, relationships with the Company and its institutional partners are marked by insecurity, tension, and in some cases outright conflicts expressed through the actions of IBAMA or town halls.

Situations of uncertainty and conflict were mentioned by the local residents, particularly at the start of the settlement process and in recent years, when the "merchandising" and control of this group of islands has become more accentuated. Their residents have frequently clashed with IBAMA which has acted very repressively on the islands, under a agreement with Eletronorte, combating the slash-and-burn practices traditionally used to clear small patches of cropland. According to local residents, these repressive actions ceased only after the Tucuruí Rural Workers Union began to take action in this area. Other people, particularly members of the Assembly of God (*Assembléia de Deus*) church stated that they attempted to respect the rules established by IBAMA, as their religion did not allow followers to become involved in conflicts. However, they also mentioned their feelings of insecurity about the future, as the fact that they have no formal title to the land leaves them very much at the mercy of fortune.

The report on the Tucuruí Hydropower Complex: Main Reservoir Islands and Caraipé (*UHE Tucuruí: Ilhas dos Reservatórios Principal e Caraipé,* Eletronorte, 1977) states that many people feel that IBAMA and Eletronorte are the main source of their problems. In this document, Eletronorte in turn lists the problems that have arisen regarding the use and settlement of these islands, particularly those in the Caraipé Valley, including irregular deforestation, improper removal of timber, burn-offs, cattle-grazing, subsistence agriculture, houses and the hunting of wild animals. It continues: "In view of this situation and in order to reconcile the activities involved in the use and settlement of the islands with the aspects related to power production, fishing, tourism and others, it has become necessary to impose control measures related to the categories listed below".

It continues by listing the permanent preservation islands of interest to the concessionaire and the islands settled by third parties where standards and situations could be defined that would prevent their degradation: (a) Existing forests should be maintained. In degraded areas, native forest species which are of use for extractivism should be planted; (b) Subsistence farming practices may be allowed in deforested areas, particularly in the Caraipé Valley; (c) The introduction of grazing lands should not be permitted under any circumstances whatsoever. On islands that have already been settled with grazing activities, a substitution process should be launched, replacing forage plants with indigenous forest species which are of interest for extractivism. They may seem simple, but these restrictions stirred up the contradictions between the interests of the institutions and private individuals, whose rights to the land are not yet defined. As the land title situation remains blurred, it has caused clashes due to the manner in which the issue of compensation was dealt with by Eletronorte when expropriating land to be flooded. However, the previous proprietors of higher unflooded land felt it still belonged to them. They began to react to the settlement process of the islands by burning down improvements and expelling families living there. Even loggers took part in these violent acts against the island dwellers.

These conflicts heated up when Eletronorte hired companies to remove the submerged timber in the reservoir. Some of these subcontractors – such as the company run by Vitório Adão de Freitas and Tocantins Ltda. – were accused of logging on the islands. Conflicts sprang up between the companies and the local populace, which was prevented from farming by IBAMA which, according to

Eletronorte is responsible for oversight activities. In turn, INCRA did its utmost to avoid intervening in this issue, as it did not feel that finding a solution to this conflict formed part of its responsibilities.

3.6.3 Demographic Dynamics and Urban Infrastructure

3.6.3.1 Growth Rates and Population Size

Eleven municipal districts currently constitute the upstream and downstream areas of the Tucuruí Hydropower Complex: Baião; Cametá; Goianésia do Pará; Itupiranga; Jacundá; Limoeiro do Ajuru; Mocajuba; Nova Ipixuna; Novo Breu Branco; Novo Repartimento and Tucuruí. This region of Tucuruí[22] has undergone quantitative and qualitative alterations in its demographic structure and composition that are directly related to the various planning and implementation stages of the Tucuruí Hydropower Complex. During the period prior to the announcement of the construction of this Hydropower Complex and the series of government interventions through road-building and settlement projects, the most heavily populated district in the entire region was Cametá, with almost 50 000 inhabitants. The remainder had less than 8 000 inhabitants. News of the construction of this Hydropower Complex drew large inflows of migrants, with Tucuruí absorbing a significant portion of them, increasing its population sixfold. Appreciable growth was also noted at Jacundá and Itupiranga, with annual growth rates of around 20.90% and 11.33% respectively. Overall, this region doubled its population in under ten years, and this trend has continued, despite a certain slowing of growth during subsequent decades (Table 3.32).

Table 3.32 Demographic Dynamics Upstream and Downstream from Tucuruí, 1960-96

Municipal Districts	Year					Annual Growth Rate(%)			
	1960	1970	1980	1991	1996	60-70	70-80	80-91	91-96
Upstream									
Jacundá (1)	1 794	2 228	14 868	43 012	39 526	2.19	20.90	10.14	(1.73)
Itupiranga (1)	4 298	5 346	15 641	37 011	29 171	2.21	11.33	8.14	(4.65)
Tucuruí (1)	5 716	8 489	61 140	81 623	58 679	5.54	19.94	2.66	(6.39)
Downstream									
Baião	7 685	7 721	16 261	20 072	20 335	0.05	7.73	1.93	0.26
Mocajuba	7 753	7 522	12 789	18 496	18 763	(0.30)	5.45	3.41	0.29
Cametá	49 250	59 754	79 317	85 187	89 400	1.95	2.87	0.65	0.97
Limoeiro do Ajuru	-	10 074	13 752	16 475	18 006	-	3.06	1.66	1.79
New Municipal Districts									
Novo Breu Branco (2)	-	-	-	-	20 223	-	-	-	-
Goianésia do Pará (3)	-	-	-	-	20 882	-	-	-	-
Nova Ipixuna (4)	-	-	-	-	8 706	-	-	-	-
Novo Repartimento (5)	-	-	-	-	30 059	-	-	-	-
Region under Study	**76 496**	**101 134**	**213 768**	**301 876**	**353 750**	**2.83**	**7.77**	**3.19**	**3.22**

Source: FIBGE. Demographic Census, 1970/80/91 and 1996 Population Headcount.
(1) Remaining Population in 1996 after transfer of the area and the populace to new municipal districts
(2) Established on January 1, 1993, split off from the Tucuruí, Moju and Rondon do Pará municipal districts
(3) Established on January 1, 1993, split off from the Rondon do Pará, Moju and Tucuruí municipal districts
(4) Established in November 1997, split off from Jacundá and Itupiranga
(5) Established on January 1, 1993, split off from the Tucuruí, Jucundá and Pacajá municipal districts

Complex population dynamics emerge from intensive inflows of migrants. According to the data recorded by the official agency and non-governmental organisations, these migrants came from nearby towns[23] in Pará State as well as Maranhão, Ceará, Espírito Santo, Bahia and Paraná States. However, there was some back-flow, particularly the resettlement of over 14 000 inhabitants caused by flooding of the towns or part of them. These mandatory relocation and resettlement programmes had a destructuring effect on the lifestyles and social, economic and cultural organisation of rural groups. The demographic dynamics study reveals the difficulties in stabilising communities in a changing landscape. This instability is caused by the demand for jobs or the shrinkage of the local economy during the operational phase of the Tucuruí Hydropower Complex, as well as the effects of resettlement policies conceived on an immediatist basis. The populace showed some resistance to transfers that broke up its daily working routines and social life.

As a result of rapid growth and the complexity of the social problems this caused, during the early 1990s towns were broken up into smaller territorial units. Most of these cases of political and administrative independence were prompted by pressures from the "expropriatees movement". It was at this time that the new municipal districts were established upstream, such as Goianésia do Pará, Novo Breu Branco, Novo Repartimento and Nova Ipixuna, which were built in order to house the population relocated from their towns of origin. The Breu Branco township was built to replace its namesake which was flooded by the waters of the dam. Known by its former residents as "Old Breu Branco" it was located between Tucuruí and Repartimento, springing up during the building of the Transamazon Highway. This new town became dependent on Tucuruí for all administrative and commercial services. Construction began on "New Breu Branco" in 1980, located at kilometre 11 on the PA-263 highway.

In addition to expropriatees, it also houses migrants who arrived mainly from Northeast Brazil[24], seeking job opportunities at the Tucuruí works-yard. This worsened the situation in the "new territory" even further. It was declared an independent town thanks to the struggles of the community, because its residents felt that "with its former status of a hamlet, they were unable to influence decisions affecting their future[25]". Goianésia do Pará developed from a village that appeared alongside the PA-150 highway. Laying the PA-263 highway also helped increase its population, and it then grew into a district of Rondon do Pará. Declared independent in 1991, its land area was carved out from the Rondon do Pará, Jacundá, Moju and Tucuruí municipal districts.

The inhabited parts of the Jacundá municipal district correspond to long-established villages that emerged through farming and small-scale cattle, hog and poultry raising. According to residents, there were 161 buildings and around 600 people. It was estimated that some 3 000 people lived around this town. With the construction of the Tucuruí Dam, peasants and small farmers were forced to abandon their lands, losing livestock, croplands and grazing lands. With the intervention transferring the populace of this area, New Jacundá sprang up alongside the PA-150 highway, growing rapidly due to its location near this road, which linked it more closely to Marabá than Belém and Goianésia do Pará.. Eletronorte built 81 houses at Jacundá for the expropriatees. This gave rise to the Encoval suburb (named after the Bahian company that built them). The homes were insufficient to house the 300 families; a second township was then built on land in the São Domingos do Capim municipal district. Located at kilometre 157 of the Transamazon Highway, Vila de Repartimento lies on the banks of the Repartimento River in the Tucuruí district. It grew up from the camp-site established by the Mendes Júnior construction company, which laid this highway during the 1970s. With the construction of the Tucuruí Hydropower Complex, its populace was mandatorily relocated, as this area was scheduled for flooding. Its current location was negotiated by the Dam-Affected People Commission with the Pará State Government, which authorised a township to be built at the junction of the BR-442 highway running between Tucuruí and the BR-230 (Transamazon[26] highway). According to local information, the political and administrative independence of this township in late 1991 was part of the list of claims put forward by the "expropriatees movement". Novo Repartimento was carved out from the Tucuruí, Jacundá and Pacajá municipal districts. At the moment, this municipal district is densely populated with an estimated 30 000 inhabitants, mainly migrants, spread throughout the lower social strata – workers in the informal sector, poorly-paid wage-earners, unemployed people, washer-women and maids. Like Tucuruí and Breu Branco, this district is a hub for the circulation and concentration of the work-force seeking to enter the rural or urban market.

From 1991 through 1996, the population shrank. This can be explained by the territorial reorganisation in the upstream municipal district. Sweeping changes caused by work on the Tucuruí Complex had already taken place, leaving deep scars, The job supply offered by the hydropower building was reduced drastically and a large number of workers who came to the region because of the building lost their jobs. In summary, the Tucuruí region features social and spatial contrasts that have been largely neglected in the economic and urbanisation plans drawn up by municipal districts and the Federal Government. With regard to the Lower Tocantins, taken as a micro-region, its rural population is larger than its urban population, scattered among several villages, while in Southeast

Paraná State, taken as the meso-region, where Tucuruí is located, the urban population is larger than the rural sector and clustered in the main towns and certain districts, although the ruralisation process is on the rise. These differences are important for relevant to the guidance of land-ownership, employment and education policies.

3.6.3.2 Islands Region

The first families arrived in the islands region in 1982, even before the lake was formed. Living on the banks of the Caraipé River, they simply moved to the islands that resulted when the flooding took place. In 1984, the Tocantins River was blocked in order to fill the reservoir, and the island settlement process began in 1986. This was part of one of the largest flows of migrants to the Amazon region, triggered by the installation of the Tucuruí Hydropower Complex. The years between 1988 and 1992 saw the arrival of 60% of the families who settled there. It was noted that settlement took place on the basis of family links. For instance, in the Panorama region, the 56 families living there in 1994 were all related. The settlement of one family paved the way for the arrival of other related family groups. According to a survey carried out by the Tucuruí Farm Workers Union (*Sindicato de Trabalhadores Rurais de Tucuruí*) the population of the islands amounts to 3 700 inhabitants. Most of them originate from towns in Pará State. Their shelters consist of small wooden and straw shacks hewn from the forest with minimal adaptation. As their owners are wary of a sudden rise in the water level, they are generally built on piles, with only two rooms, one of them a "lounge" where everyone sleeps, with hammocks often serving as seats during family chats or visits. Some homes have gas stoves, but they have no electricity, using kerosene lamps to light their homes. Few have septic tanks, with sewage dumped in the forest. The few wells on the islands dry up in summer, when the families use only river water for all domestic activities, including drinking.

The infrastructure on the islands is extremely precarious. Only over the past three years has any attention been given to the building of schools, and healthcare facilities are found in only a few places. Residents are neglected throughout this archipelago, lacking electricity, sanitation, schools, hospitals, health care facilities, transportation, telephones and recreation areas. The healthcare services are precarious, and the only initiatives in the public health sector are those run by the National Health Foundation (FNS - *Fundação Nacional de Saúde*). With only one unit in this region, its services consist of a half-yearly spray campaign designed to prevent insect-borne diseases; vaccination following the National Vaccination Calendar; and taking blood samples from persons infected by the protozoa that causes malaria. As in the rest of Amazonia, malaria is very common in the islands region, although cases have been becoming less frequent. There is no other form of healthcare available to these communities. When home remedies fail, families take patients to the hospital at Tucuruí. In addition to malaria, diarrhoea, verminoses and respiratory problems are the most common diseases. Diarrhoea and verminoses are probably related to the quality of the water consumed; respiratory problems are caused by smoke from the smudge-pots that the local residents light to get rid of mosquitoes. Significant levels of hepatitis have also occurred, according to the head of the healthcare unit for the islands. Limited schooling is one of the most pressing social concerns in this region. During the early 1990s there were eight schools in five regions: Panorama, Mocaba, Lago Azul, Vida Nova, Água Fria and São Benedito. Only six of these schools were actually functioning.

3.6.3.3 Urbanisation Process

The expansion of towns is a widespread process throughout the Amazon region. Demographic data reveals that these increases have been more marked in medium-size towns, particularly those near large-scale economic projects. The expansion of municipal centres around the dam (both old and new) follows this pattern. A difference in pace is noted between the upstream and downstream areas, as downstream towns are expanding less rapidly, although this does not reflect any loss of dynamism (Table 3.33).

Table 3.33 Urbanisation Rate Upstream and Downstream from the Tucuruí Hydropower Complex 1960-96

Municipal Districts	Year					Urbanization Rate(%)			
	1960	1970	1980	1991	1996	70	80	91	96
Upstream									
Jacundá	1 794	2 228	14 868	43 012	39 526				
Urban	n/a	549	282	22 081	25 973	-	24.6	51.3	65.7
Rural	n/a	1 679	14 586	20 931	13 553				
Itupiranga	4 298	5 346	15 641	37 011	37 771				
Urban	1 532	1 421	2 799	8 431	10 109	26.6	17.9	22.8	26.8
Rural	1 766	3 925	12 842	28 580	27 662				
Tucuruí	5 716	8 489	61 140	81 623	58 679				
Urban	3 524	5 545	27 261	46 014	47 972	65.3	44.6	56.4	81.8
Rural	2 192	2 994	33 879	35 609	10 707				
Downstream									
Baião	7 685	7 721	16 261	20 072	20 335				
Urban	2 513	2 439	4 110	7 877	9 368	31.6	25.3	39.2	46.1
Rural	5 172	5 282	12 151	12 195	10 967				
Mocajuba	7 753	7 522	12 789	18 496	18 763				
Urban	1 380	2 358	5 563	11 756	12 550	31.3	43.5	63.6	66.9
Rural	6 373	5 164	7 226	6 740	6 213				
Cametá	49 250	59 754	79 317	85 187	89 400				
Urban	7 687	7 912	21 372	30 278	35 508	13.2	26.9	35.5	39.7
Rural	41 563	51 842	57 945	54 909	53 892				
Limoeiro do Ajuru	-	10 074	13 752	16 475	18 006				
Urban	-	859	1 626	2 522	3 312	8.5	11.8	15.3	18.4
Rural	-	9 215	12 126	13 953	14 694				
New Municipal Districts									
Novo Breu Branco	-	-	-	-	20 223				
Urban	-	-	-	-	9 491	-	-	-	46.9
Rural	-	-	-	-	10 732				
Goianésia do Pará	-	-	-	-	20 882				
Urban	-	-	-	-	10 857	-	-	-	52.0
Rural	-	-	-	-	10 025				
Nova Ipixuna	-	-	-	-	8 706				
Urban	-	-	-	-	n/a	-	-	-	-
Rural	-	-	-	-	n/a				
Novo Repartimento	-	-	-	-	30 059				
Urban	-	-	-	-	9 840	-	-	-	32.7
Rural	-	-	-	-	20 219				
Region of the study	**76 496**	**101 134**	**213 768**	**301 876**	**362 350**				
Urban	13 636	21 083	63 013	128 959	174 980	20.8	29.5	42.7	48.3
Rural	59 860	80 051	150 755	172 917	187 370				

Source: FIBGE. Demographic Census – 1970/80/91 and Population Headcount – 1996.

3.1.6.3.3 Upstream Region

An analysis of urbanisation upstream from the power plant at first shows the impact of migration on older towns such as Tucuruí, and then the rapid growth of the townships which sprang up with the establishment of new municipal administrations, as mentioned.

In Southeast Pará State, 385kms from Belém, the town of Tucuruí grew up from the hamlet of Alcobaça (1781), established on the Tocantins River with a dual purpose – fiscal and military shipping along the Tocantins River. The construction of the hydropower complex in this municipal district, with operations beginning in 1984, triggered a rapid process of transformation of urban space, with its total population expanding 566% from 1970 to 1980. The upsurge in trade and industry, particularly in logging, altered the profile of this town. According to data produced by the Brazilian Institute of Geography and Statistics (IBGE – *Instituto Brasileiro de Geografia e Estatística*) in 1970, only 12% of its population had lived there for less than five years; however, by 1980 this percentage had risen to 95%. The urban area of Tucuruí expanded as the Company built townships. Flows of migrants already attracted by the construction of the Transamazon Highway increased as work proceeded on the dam, as is reflected in the expanding populations of Marabá, Cametá and Tucuruí. Demographic data [27] indicate that in 1974 the town of Tucuruí had a population of some 12 000 inhabitants, rising to 30 000 in 1979 (not including 28 000 workers living in the townships and lodgings of Eletronorte). However, this demographic expansion was not accompanied by any improvements in infrastructure and basic public services. For its employees, and particularly its office staff, Eletronorte built a township with all the facilities of a modern town. For some time, the town of Tucuruí was excluded from the benefits offered by this township, particularly healthcare and education. Later, the Company assumed responsibility for tarring part of the town and, thanks to the struggles of trade union leaders and expropriatees the local populace was allowed to use its hospital services, currently under an agreement with the government-run Single Healthcare System (SUS – *Sistema Único de Saúde*) . This rapid upsurge in the population triggered sweeping changes for both older inhabitants and newcomers, as living conditions grew worse. The countryside lacked policies encouraging agriculture, while in the towns no measures were taken to meet rising basic needs intensified by demographic expansion.

Meanwhile, local authorities had no way of underwriting the expenditures necessitated by this increase in the population, as Supplementary Law No. 167 issued by the Federal Government on December 9, 1974 exempted companies from paying Service Tax (ISS - *Imposto sobre Serviços*) when involved in the management, contracting or subcontracting of waterworks or civil construction, if they were hired by official agencies and public service utility concessionaires. This meant that Government budget funding always fell short of the steadily rising needs of this expanding town. On the other hand, the local labour market (which was already restricted, even with the old Tocantins railroad) was in no position to absorb large numbers of migrantsfrom Northeast Brazil. They were drawn by the possibility of jobs during the construction of the Hydropower Complex, but not all of them were successful, due to the human resources policy of the enterprise. This resulted in an appreciable turnover of the labour force with large numbers of jobless who were forced to build their own homes, lacking other options; hence slums (*favelas*) sprang up around Tucuruí. According to the local press at that time, Tucuruí had a severe slum problem, with the exception of the homes and buildings put up by merchants who settled there. Stagnating economic activity impoverished the town, which saw its cost of living rise by around 80%, according to an article in the *Correio Brasiliense* newspaper on July 30, 1979.

3.2.6.3.3 Downstream Region

The demographic figures for downstream towns reflected growth which could be attributed to the relocation of riverbank-dwelling communities who moved to urban hubs seeking work when their traditional forms of subsistence were shattered. One of the oldest towns in Pará State, Cametá was founded in 1636. With seven districts – Cujarió, Pacajá, Guajará, Cametá-Tapera, Mupy, Apepu and Joana Coelys – its population totalled 89 400 inhabitants in 1996, of whom 31 600 lived in towns or villages, and 55 800 in rural areas. Two main roads cut through this old administrative unit: the PA-156 linking this municipal district to Southern Pará State, and the PA-151, running to Belém. Nevertheless, the river network is the main means of transportation for both people and goods, due to the extremely poor conditions of these two access roads, particularly during the rainy season from December until May.

An analysis of population growth in the Cametá district shows that its rural population is larger than its urban population, although this gap has been shrinking steadily since the 1960s, when rural residents accounted for 90.9%, falling to 81.6% in 1970, 73.1% in 1980, 64.5% in 1991 and 60.3% in 1996. The urban population has risen steadily over the past decade, clustered in the main town. Its growth between 1980 and 1991 reached 54.3%. In 1996, almost 40% of the population of Cametá were living in the town. This distribution reflects changes in the local economy, which is now centred less on agriculture and extractivism as the service and trade sectors have expanded.

3.6.3.4 Infrastructure and Energy for Local Development

After the inauguration of the power plant in 1984, there was a backflow among the local population that persisted until 1987, when there some reversal as new activities sprang up in this municipal district, particularly in trade and services. The growth of the population and these economic activities were not accompanied by improvements in the quality of life and well-being of the local populace. Like communities in the Lower Tocantins, the people of this municipal district expected that the hydropower plant would provide a springboard for development and job generation. Taken as an indicator of improvements, particularly by the local populace, the implementation of the road infrastructure fell behind schedule, and roads were only repaired during the past few years, surfaced with a longer-lasting asphalt. Running between Belém and Marabá, the PA-150 was surfaced for the first time in 1984, and more recently in 1998, while the PA-263, a minor road linking to Tucuruí to the PA-150 highway was blacktopped only this year. However, the road running from 55km between Tucuruí and Novo Repartimento is still gravel-surfaced, and in a deplorable condition.

The river transportation system has not expanded, and in the downstream region is facing serious problems. This constitutes a crucial gap in the retail and trade policy for the region organised by the Tucuruí hydropower project. Services and infrastructure are precarious in this region, and, with the exception of Tucuruí, hospital services and educational facilities have shown no appreciable improvement. Teaching and healthcare were transferred to the municipality, and these services took on greater responsibility - but are not in a position to meet the demands of the decentralisation policy relating to schools and hospitals. Another factor inthis situation is the worsening of social problems. Over the past four years, the announcement of Phase II triggered fresh worker migration, particularly in the town of Tucuruí, whose work-yards are unable to offer more than 2 000 jobs. Streaming in from Maranhão, Bahia and Ceará States, hopeful workers are once again seeking jobs and land in the Tucuruí region. Although identifying this demand for jobs, SINE has not examined the possibility of imposing effective controls. Pressures on the job market and housing are reflected in a striking indicator: trespassers and squatters.

The towns of Jacundá, Novo Repartimento, Goianésia do Pará, Breu Branco and particularly Tucuruí clearly reflect the eruption of an urban problem that has at no time been under the control of the municipal authorities, or addressed by any official planning. State agencies and other leaders are clearly quite unable to deal with “disorderly” growth of these urban hubs. The loud demands voiced by the Landless Peasants’ Movement (*Movimento dos Sem Terra*) are also heard in urban areas, seeking plots of land in low-income outlying areas beyond the former expansion zone of the original town of Tucuruí and the planned areas of the townships. Due to the speed of these changes, statistical data have proven unable to express the true rate of growth over the past five years.

While the Hydropower Complex was being built, no discussions were held with local communities over the social and environmental consequences of its implementation. Even today, the town of Tucuruí does not have its own substation run by the State power utility (CELPA) but is instead serviced by a branch line from the Eletronorte substation in the power plant works-yard, while the Company town (*Vila Permanente*) located 13km away from Tucuruí has a substation installed by the Company in order to provide power for consumption by its employees. In addition to Tucuruí, the neighbouring towns of Breu Branco (30km away) and Novo Repartimento (50km away) also have access to power directly from Eletronorte, because there are no CELPA substations to handle distribution, meaning that power supplies are precarious, with constant interruptions.

In 1997, due to pressure from local trade unions and associations, an agreement was signed by Eletronorte with the Tucuruí and Novo Repartimento town councils, providing for the construction of a step-down substation to service the towns of Tucuruí, Novo Repartimento (on the Transamazon Highway), Breu Branco (on the PA-263 highway) and Goianésia do Pará (at the junction of the PA-150 and PA-263 highways). It is expected that this will improve the quality of power supplies. According to a recent study carried out by Tavares (1999), the urban power grid of the Tucuruí municipal district is old and ineffective, but with the new CELPA substation yet to be completed, this problem will be solved. Rural electricity distribution is almost nonexistent as well, which prevents the processing of local farm products. Almost negligible power distribution facilities are limited to ranches and some local roads, such as the Vicinal 51 and the Transamazon Highway in the Novo Repartimento municipal district, the Sagitário Settlement Project, the Pitinga Association of Small

Farmers at Breu Branco, and on the Transcametá highway running between Tucuruí and Cametá as far as 15km out of Tucuruí. In the view of Tavares (1999), a central issue regarding power distribution is the charging of high rates. Interviewees also complain about high power rates. According to the technical explanation, the amounts are justified because the rates are high, and because the State rate share-out is handled jointly, meaning that all the municipal districts pay the same rate regardless of whether they are supplied by the grid or the Hydropower Complex. In fact, everyone pays a high price for electricity.

However, it is well-known that the problems of rural electrification [28] and local development are not limited to access to power and roads, as technical assistance is also required to train farmers to manage their own production activities and generate income. Without management training programmes providing guidance on what, where and how to produce in rural areas, mere access to energy and roads cannot solve development problems. In this region, the Integrated Development Plan (PID - *Plano Integrado de Desenvolvimento*) initiated by the Lutheran Church, and more recently the Grassroots Education and Advisory Agri-Ecological Centre (CEAP – *Centro Agroecológico de Assessoria e Educação Popular*) have been handling this task, working with grassroots organisations and rural unions. The Integrated Development Plan discussed the feasibility of alternative energy projects for rural areas, due to the long distances that hamper power distribution here, particularly for the islands that formed upstream after the Tucuruí Dam was filled. Local trade unions have proposed the introduction of solar power panels and small diesel engines to handle small-scale demands. According to statements from interviewees, the construction of the Tucuruí Hydropower Complex during the 1980s prompted expectations that, in addition to Greater Belém, the Lower Tocantins region [29] would be provided with power generated at the plant, through the high-tension power-line cutting through this area. However, by June 1998, only the towns of Barcarena (where the ALBRÁS smelter is located), Abaetetuba, Igarapé-Miri and Moju had been connected to the power grid in this region. Free-standing thermopower systems provided electricity to the municipal districts of Oeiras do Pará, Baião, Mocajuba, Limoeiro do Ajuru and Cametá until 1998, when the *Tramoeste* system was inaugurated.

Through the substations at Vila do Conde (Barcarena) and Abaetetuba, with a capacity of 28.2 MVA, the interconnected system services the municipal districts of Abaetetuba, Igarapé-Miri, Barcarena and Moju. Through the Tucuruí substation, a 13.8 KW system also supplies the main towns of Tucuruí, Breu Branco, Novo Repartimento and Goianésia do Pará, as well as Cametá, from 1998 onwards. In 1999, the CELPA sub-station was inaugurated at Breu Branco. Hopes were high among local communities that access to the power grid of the Tucuruí Hydropower Plant from September 1998 onward would ensure the feasibility of projects contributing to the development of not only this town, but the entire region. There is ample potential for many different projects in the agribusiness field which could generate jobs and upgrade income levels among the populace. Local communities also need better technological expertise in order to upgrade production and process local products such as fruit (açaí, cupuaçu, etc.) that are sometimes thrown away due to a lack of electricity. In the fishing sector, representatives of the fishing villages stated that their catch is preserved in formaldehyde, which has serious consequences for their health. Moreover, large quantities of ice from Belém and Abaetetuba are needed to freeze the catch (around 50 tons a month), which increases the price of fish to the end consumer.

3.6.3.5 Financial Compensation (Royalties) for the Use of Water Resources

Law No. 7 990 dated December 28, 1989 introduced financial compensation / royalties on the use of water resources. From this time onward, municipal districts and the respective States whose land were flooded to form the reservoirs of Hydropower Plants with installed rated capacities of over 10MW would receive this type of compensation, at a rate of 6% of the value of the power produced, to be paid by the concessionaires for this service. The amount of financial compensation to be transferred to the beneficiary municipal districts is calculated by the effective power generation of the Hydropower Plant, distributed in proportion to the flooded area in each municipal district. In 1991, Decree No. 1 dated January 11, regulated Law No. 7 990, by stipulating the criteria for the calculation of these payments. According to this legal provision, the monthly distribution of financial compensation would be handled in the following manner (see Table 3.34):

Table 3.34 Distribution of Financial Compensation

(%)	Beneficiaries
45.0	States
45.0	Municipal Districts
4.4	Water Resources Department / Ministry of the Environment, Water Resources and Legal Amazonia
3.6	National Water and Power Department (DNAEE – *Departamento Nacional de Waters e Energy Elétrica*)
2.0	Ministry of Science and Technology

With regard to the Tucuruí Hydropower Complex, from January 1991 through December 1992, for the purposes of financial compensation, the National Water and Power Department (DNAEE – *Departamento Nacional de Águas e Energia Elétrica*) [30], defined the municipal districts and the respective proportions of their areas to form the reservoir: Tucuruí – 1 652 km^2; Jacundá - 562 km^2; Itupiranga - 202 km^2; Rondon do Pará - 700 km^2. However, from January 1993 onward, this share-out was altered due to the newly-established independent municipal districts. This meant that the distribution of the financial compensation was defined on the basis of new proportions for flooded area: Novo Repartimento - 946 km^2; Tucuruí - 432 km^2; Goianésia do Pará - 381 km^2; Itupiranga - 294 km^2; Jacundá - 217 km^2; Breu Branco - 160 km^2 (Table 3.35).

Table 3.35 Distribution of Royalties on Water Resources / Tucuruí Hydropower Complex - 1993 – 1999

Municipal District	**Accumulated Amounts** Apr/93 - Jul/95 (U$)	**08/1995** (R$)	**07/1996** (R$)	**08/1997** (R$)	**08/1998** (R$)	**08/1999** (R$)
Breu Branco	1 029 387.11	40 101.58	53 673.63	51 362.78	33 291.62	38 922.18
Goianésia do Pará	2 664 971.53	126 334.29	169 091.10	161 811.12	95 429.42	122 618.77
Itupiranga	1 737 468.12	51 460.58	68 876.98	40 190.30	23 702.56	30 455.79
Jacundá	1 436 513.57	60 218.39	76 510.97	77 128.74	45 487.30	58 447.35
N.Repartimento	6 498 763.50	296 624.60	376 369.37	379 921.85	224 061.99	287 900.80
Tucuruí	3 010 402.54	141 615.00	179 686.88	181 382.91	106 972.04	137 450.07
Pará State Government	16 509 988.98	721 967.92	S/I	926 567.70	544 676.72	697 004.06

*Source: Accumulated Amounts: Edict No. 521, November 17, 1995, published in the Federal Government Gazette (*Diário Oficial da União Federal*) on November 1995, Published in the Federal Government Gazette (*Diário Oficial da União Federal*) No.221/Sec 1, on November 20, 1995, DOU/SEPLAN (PA) for the other respective months.*

Also known as royalties, these financial compensations introduced differences in income among the "affected" municipal districts. Although Brazilian law bans the use of these funds for hiring permanent staff and paying off debts, it does not indicate how they should be spent. According to discussions underway at the time of drafting this law in the National Congress, tying revenues to specific expenditure headings would violate municipal autonomy. On the other hand, the lack of mechanisms for rendering separate accounts hampers the social control of the allocation of funding. Some municipal districts in other parts of Brazil have managed to tie royalty revenues to investments in infrastructure, stipulated in their basic laws.

3.6.4 Relocation and Resettlement

The starting point for this topic is a discussion of the relocation and resettlement activities in the regions surrounding the Hydropower Complex, viewed as political and social decisions.

The relocation project took place in a conceptual framework of steady adjustment to situations. To some extent, this was a trial balloon, testing out the reactions of the political and social groups involved. The differences in the various settlement processes offered an understanding of the reactions of local communities, and highlighted points of resistance, with cost/benefit analyses carried out individually and for groups.

3.6.4.1 Resettlement Procedures and Implications

The various situations faced by local communities following the construction of the Tucuruí Hydropower Complex were unprecedented in the history of the Amazon region, and have been the subject of many studies and surveys. On the one side of this dynamic process are the agents in charge of the project, who see the hydropower complex through the lens of economic development. The technical practicalities of this venture were unable to take into account the ecological, social, economic and cultural consequences of this process, which still remain unresolved. Its repercussions included exploitation and the illicit sale of titles to abandoned land taken back by the Government (known as *terras devolutas*). There was also improper settlement and use of land, forests and water resources, which destroyed the facility of *várzea* floodland soils and intensified land ownership concentration processes. On the other side of the process are local community groups that have drawn to together to fight for their rights, and are still struggling, and family units that have joined other expropriatees in the lower-income outskirts of larger towns throughout this region, driven by either discouragement or economic pressures.

Empirical evidence in the relevant literature indicates that the formal decision-taking process – particularly in view of the historical context of Brazil and its lack of corporate experience in projects of this nature – failed to take into consideration specific circumstances and the complexity of social relationships, and neglected the possibility of greater participation. In order to build the Tucuruí Hydropower Complex, Decree No. 78 659 dated November 11, 1976 declared an area to be of public utility for the purposes of expropriation, consisting of a polygon that covered part of the municipal districts of Bagre, Itupiranga, Jacundá, Marabá, São Domingos do Capim and Tucuruí, all in Pará State. In 1979, Eletronorte signed an agreement with INCRA to establish the compensation payable for the lands and improvements to be affected by the formation of the Tucuruí reservoir, as well as provisions for resettling local communities.

The decision-making process was handled solely by the concessionaire utility with the affected communities merely forced to accept compulsory relocation and arbitrary compensation. These facts triggered latent conflicts and clashes between Eletronorte and a group comprising a wide variety of social segments which including riverbank communities, settlers from the Transamazon Highway, and urban dwellers from the towns of Jacundá and Repartimento. With the changes in Brazil's national political structure offering greater possibilities of political participation, a new lobbying group with nationwide scope appeared : the Dam-Affected People Association (MAB - *Movimento dos Atingidos por Barragens*). Social issues linked to the implementation of hydro-electric enterprises are being treated more carefully, and the usual procedures reassessed, following the efforts of this movement. The Real Estate Asset Department (SPI – *Departamento de Patrimônio Imobiliário*) of Eletronorte was in charge of setting compensation and resettling communities, following in the footsteps of INCRA for rural areas. To this end, a survey was carried out in 1978 using data-sheets that identified the resident and the property concerned. Compensation was calculated on the basis of these records of land values and improvements. The compensation process was somewhat thorny, as Eletronorte used administrative and financial efficiency criteria whose bases were the legal procedures within the time-frame imposed by the construction period of the Hydropower Complex. The procedure for assessing assets for compensation purposes took only material criteria into consideration, neglecting to include the value of work invested in the land, as well as emotional and symbolic values; that is, the cultural logic informed by social and historical conditions in local communities. Anyone who did not accept these compensation criteria, or the areas to which they were allocated for resettlement, was urged to sign a waiver.

Resettlement took place late and in a very limited scale, compared to the technical measures involved in this project. It is hard to define with any certainty the number of families or people who were resettled. In 1978, a study by BASEVI showed that the project had caused the relocation of 1 750 families totalling 9 500 people. In November 1982, the Eletronorte survey put this figure at 3 152 families, equivalent to some 15 637 people. In the ELETROBRÁS Report (1992, page 80) the figure of 4 407 resettled families is mentioned, 3 407 of them on rural sub-division and 1 000 families in townships established by Eletronorte (Table 3.36 and Table 3.37).

Table 3.36: Estimates of Resettlement in Tucuruí Area

Year	Author	Number of Families	Number of People
1978	BASEVI	1 750	9 500
1982	Eletronorte	3 152	15 637
1992	Eletrobrás	4 407	N/A

Source: Eletronorte

In order to justify these discrepancies, the Company argues that the increase in the numbers of families was caused largely by the huge inflow of migrants to areas surrounding the project, settling in areas that were, in principle, tagged for submersion. It is important to stress that the estimate of the actual numbers of people relocated are generally limited to families with the right to compensation – land-owners and the owners of improvements living on the expropriated lands. Left out of these calculations are the communities who spent certain seasons of the year living on the riverbank in order to ensure their survival. In addition to the upsurge in migrants, Mougeot (1985) included systematic under-numbering as a factor that caused such gaps between the newer figures and the original forecasts. Without taking the flows of migrants into consideration, the number of people relocated until 1980 may well be between 25 000 and 35 000 people. From the time of the survey through to their actual resettlement, from 1983 onwards, people were unable to work their lands or add fresh improvements, according to local statements. However, Eletronorte states that "*the people were not banned from working the land ... through letters addressed to the Bank of Brazil and other development banks in the region, the Company allows these financing institutions to open up lines of credit for expropriated settlers who wished to finance short-cycle crops.*" [31]

Table 3.37: **Eletronorte Resettlement Areas**

Sub-divisions	Locality	Number of Families
Rural Sub-divisions	Rio Mojú	645
	Pararural de Breu Branco	122
	Pararural de Repartimento	288
	Parakanã	737
	Baiana	171
	Jacaré	305
	Bandeirante	96
	Tuerê	114
	Grotão do Ricardo I	65
	Grotão do Ricardo II	60
	Grotão do Ricardo III	66
	Cametauzinho	114
	Arraias	77
	Santa Rosa	183
	Pitinga	208
	Diverso/GETAT/INCRA	156
Sub-total		**3 407**
Urban Sub-divisions	Novo Repartimento	516
	Cajazeiras	75
	Itupiranga	75
	Jacundá	115
	Novo Breu Branco	219
Sub-total		**1 000**
Total		**4 407**

Source: Eletronorte. Tucuruí Hydropower Complex: Case Study. Arquitetura Ambiental Ltda. June 1992.

On the other hand, resettlement took place in areas that frequently proved unsuitable for this purpose, imposed social and economic changes that failed to take earlier forms of survival into account, and ignored interactions between human beings and their surroundings. There are reports of riverbank communities relocated to inland areas, with extractivist groups transferred to lands that required farming and grazing activities. These disjunctures all resulted in the collapse of the resettlement process, reflected in high abandonment rates for the plots of land where expropriated families were relocated, and attempts to sell them in the settlement areas. Eletronorte feels that this trade in land emerged from the basis of the relocation and resettlement schemes. From the standpoint of the relocated populace, other factors forced them to sell or leave.

Among other factors, the interviewees mentioned: the lack of institutional investments in these areas, with precarious infrastructure; the lack of schools, medical facilities and public services deemed vital for any family; distance or difficult access to many areas which almost completely prevented the flow of production; the unsuitability of lands for planting crops, and cases of malaria in the family; and the lack of an assistance project providing support for farming and marketing activities. In January 1980, some affected communities forwarded a list of claims to Eletronorte. They focussed on the amounts and deadlines for receiving compensation; the conditions of the plots earmarked for relocation; and permission to continue their farming activities until the move. Having received no reply, they then circulated round-robin petitions and sent representatives to Brasília. After a number of assemblies and meetings, they finally camped out in front of the head offices of the Eletronorte Real Estate Asset Department (SPI – *Departamento de Patrimônio Imobiliário*) at Tucuruí. Through this action, they managed to secure an initial negotiating forum consisting of "dam affected people" and representatives of Eletronorte. Failing to achieve any concrete results, they decided to barricade access routes to the townships for two days in April 1983. This clash of interests intensified along with the resettlement process, as a larger area was flooded than initially planned. During this phase, 1 500 families had to be urgently relocated, all living in the Jacundá municipal district. Even the new residents of the Gleba Santa Rosa – who had already been resettled – had to be moved again. According to local witnesses, these hurried resettlements were even more traumatic than initial resettlements, and the movement challenging the process was reactivated.

The Federal Government then decided to set up an Interministerial Commission consisting of representatives of the Ministry of Mines and Energy and the Ministry of Justice, Eletronorte, the Araguaia-Tocantins Land Executive Group (GETAT - *Grupo Executivo de Terras do Araguaia-Tocantins*) and the Pará State Planning Bureau (SEPLAN/PA - *Secretaria de Planejamento do Pará*). The Report produced by this Commission, which was established through Interministerial Edict 447-A in July 1985, analysed the appearance and development of social tensions, highlighting the risks of undesirable situations and the need for an emergency plan. The Ministry of Mines and Energy was responsible for assigning funds to underwrite the expenditures incurred by the emergency plan, which provided infrastructure for the resettlement areas and sub-divisions. As these funds were only released the following year by the President's Office, at a time when inflation was soaring, they proved insufficient to resolve this issue. Consequently, the mobilisation of the "dam affected people" group became even more vigorous. Eletronorte supplied urban sub-divisions with infrastructure in the relocated hamlets of Cajazeiras, Jacundá and Novo Repartimento, consisting of sewage, water uptake and distribution systems, power distribution, community buildings including a police precinct, schools, post office, town hall, etc. Also, 1 102 kilometers of local roads were laid to make access easier.

The financial crisis at Eletronorte and a lack of understanding with other Government agencies hampered any firm policy of support - particularly in terms of agricultural incentives – for rural sub-divisions. In addition to changes in the physical environments, sudden breaks in established life-styles had a wide variety of social and cultural impacts. These impacts and their scope have not yet been fully assessed. Community organisations and the regional and national scientific community continue to perceive this issue as crucial to the long-term success of this venture. Organisations acting on behalf of local communities, including rural worker unions, fishing villages, rural workers associations and Government organisations, believe the construction of the Tucuruí Hydropower Complex had very high social costs for these communities. "*Here, the "futures exchange" is already operating, meaning that the output of small farmers is purchased when still standing, according to the prices for the last harvest. This is caused by financial need, as we have no guarantee of price, storage facilities, access roads to ship out the products, nor lines of credit. So the only way out is to sell to the middleman who pays up right there."* (Statement by a trade union advisor at Novo Repartimento, November 1999). "*The shut-down of the railroad was an Eletronorte strategy to vacate the area, as it did not use fair, legitimate criteria for surveying the populace who lived and worked in the area.*" (Statement by a political leader at Novo Repartimento, November 1999).

Religious leaders expressed views similar to those of grassroots movements. They felt that the construction of the Tucuruí Hydropower Complex destroyed cultural assets that characterised the lifestyles of riverbank communities living in areas that were flooded to form the reservoir. Interviewees were not part of a programme included under the project construction scheme, as this was never opened up to participation by local communities. Their experiences were especially traumatic when two relocations were required, or they were forced into situations of penury, hunger or disease. Swarms of mosquitoes and gnats (*muriçocas*) badly affected the quality of life of displaced groups. From Eletronorte's standpoint, the relocations and resettlements were carefully thought out and coherent with regional conditions. They were implemented in partnership with other local and Federal Government agencies, in ways designed to minimise the traumatic effects on resettled communities, while also maintaining conditions for farming and ranching production. Eletronorte planned to settle expropriatees into rural contexts similar to where they had lived previously. The relocation and resettlement projects were based on the active participation of civil society, including professional organisations (associations and unions), universities and the Church. The final assessment of Eletronorte is that the procedures adopted had been adequate and properly conducted, by comparison to the normal practices of power sector utilities at the time, and that all commitments were fulfilled.

3.6.5 Alterations in Production Structure

A quarter of a century after the construction of the hydropower complex, the local and regional economic profile seems unaltered - which suggests the enterprise's limited capacity to foster local and regional development. In terms of new industries, despite the available electricity, the municipal district in the Tucuruí region [32] has only attracted and supplied power to Camargo Correa Metais and a hundred or so sawmills [33], which are among the largest in the State. In some municipal districts such as Jacundá, these sawmills are closing down, having felled all usable forest resources. Agriculture and extractivism tended to stagnate to a marked extent during this period. At Tucuruí, the loss of rural land resulted in a drop in agricultural output. Fishing in the reservoir represented a source of employment and income, but this benefit of the project was unequally distributed, with downstream locations losing their fishing areas. In rural sectors, dairy farming projects are also being announced; two have already been set up, although the herds in these municipal districts are fairly small for these activities.

The construction of the Tucuruí Hydropower Complex triggered sweeping changes in production structures, shifting the area from an agri-extractive base to a single product economy (energy). This has constrained the creation of development conditions at the local level. An examination of the land-owning structure in spatial and demographic terms reveals the scope of these changes. The processes unleashed by the construction of this energy enterprise are cyclical, drawing streams of migrant workers during the construction phases of the plant and basic infrastructure such as roads and new towns. The predominantly agrarian and extractive economy was reshaped through the direct and indirect effects of this venture on communal areas that had traditionally been assigned to extractivism, fishing and crop-growing in both the upland and floodland forests (*várzeas* and *terra firme*). During the 1970s, plant-based extractivist activities expanded in all the municipal districts of the region under study. At Mocajuba, açaí ranked as most important, followed by timber and rubber. At Baião, the main products were timber, rubber, malva and Brazil nuts. The economy of the Itupiranga district was centred on Brazil nuts (1 350 tons in 1977) with timber ranking second. Timber and nuts were the most important products at Tucuruí, with nuts also important in the Jacundá. Timber, nuts, rubber and malva were all channeled to regional and export markets.

Throughout the entire Lower Tocantins, subsistence fishing and shrimp harvesting has been a seasonal activity, both for home consumption and for sale in the markets of riverbank towns. According to data from the IBGE Foundation in 1973, livestock production was based largely on hogs and cattle, particularly in Baião. At that time, Itupiranga had large herds of cattle totalling 2 207 head. Twenty years later, this municipal district was said to have herds of 67 000 head. But the Novo Repartimento municipal district ranked first in cattle numbers, only eight years after it was established, which confirmed local speculation regarding its suitability for extensive grazing activities. The agricultural economy of the Lower Tocantins produced large amounts of rice, cassava, corn and beans prior to the construction of the dam. Some areas also produced cacao, bananas and black pepper. Despite widespread classification of these crops as subsistence agriculture, with a very small market share, the IBGE figures reflect impressive production levels for these municipal districts.[34] The energy venture affects these production activities negatively, particularly those undertaken by groups of peasants; hence there is an ongoing process of impoverishment and flight to urban districts.

As this industrial power complex was built in a predominantly agrarian and extractivist economy, it is worth discussing its relationships with the uses and systems of appropriation traditionally practiced by different social groups: indigenous tribes, settlers, riverbank-dwellers, loggers, cattle-grazers and agribusinesses. The venture has imposed new divisions beyond its physical area. An example of this is the settlement of the reservoir area on the islands whose legal definition is currently under dispute – it has not yet been established whether they are environmental protection areas or extractivist reserves. The hydropower venture superimposed a series of new problems on the existing land ownership structure – concentration, illegal sale and purchase of land and improvements, acts of violence against settlers or squatters known as *posseiros*. Heated conflicts have emerged over land ownership. Indigenous areas not yet demarcated were subject to trespass; unregistered smallholdings taken over by squatters were legally invisible and were consequently not paid compensation during the resettlement programme. The processes of concentration, exploitation of resources and take-over of squatters' titles, as well as the illegal absorption of apparently ownerless land, were all accentuated by progress of the project. *Várzea* floodland forest crops and subsistence fishing lost out badly or were significantly altered when the dam was filled - fish shortages downstream were frequently reported. These changes also affected the limited recreation alternatives available to the local populace.

Tourism earned only a few mentions in Government programmes in the form of location-specific activities, such as a sports fishing tournament with access limited to "fishermen" from outside the area. Steady changes in the land-owning structure represent a break-down of the local land allocation dynamics. This power complex has increased land prices, while boosting demand. New divisions are being imposed, even beyond the physical area of the dam. A good example of this is the reservoir, whose islands have already been settled and are the centre of disputes over their legal classification. [35] It is crucial to understand the impacts of this venture on the lands, both upstream and downstream. One aspect of the reorganisation of land is apparent in the "community relocation processes", as Eletronorte called its dealings with the "expropriatees". A number of people were interviewed in November 1999, who had been assigned rural plots of land and urban units. During the settlement phase for these plots of lands, they encountered problems including long distances to facilities, and shortfalls in infrastructure. According to one of the statements given in the Novo Repartimento municipal district, Eletronorte had promised to give them "a car, school, good brick-built houses, electricity, piped water, a healthcare post and the best of everything", but in practice "the houses were very shoddy, made from softwood and asbestos tiling that heats them up a lot, making people feel really bad". Rural sub-divisions presented similar infrastructure problems, in addition to difficulties encountered in opening up new areas, with no water available for various properties. At Nova Jacundá, people who were assigned ten *alqueires* of land at the Gleba Santa Rosa – which in many cases was smaller their former properties – had to wait for the road to be laid, and frequently fell ill with malaria. This relocation process forced them to start over, and many farmers were unable to obtain compensation for their losses. The new rural and urban settlements were significantly unstable. According to field survey data, many resettled families abandoned or transferred their plots of land, but this was not confirmed with the Asset Sector of the Company or INCRA. An interviewee at Goianésia do Pará stated: "We sold the plot in Goianésia, just like many other farm workers, because there was nothing at Goianésia... the plots were sold because the land was useless… there was no grass for the cattle…". She also said that her family received "a small amount of money, a plot of land in Goianésia, and a wooden house at Breu Branco" (November 1999). These more or less radical alterations in the allocation and use of lands and waters transformed life-styles and local production structures. An examination of these alterations confirms a trend towards stagnation and shifts in agricultural practices.

Based on information from the Agriculture Bureau (IBGE/GCEA - *Secretaria de Agricultura*), data on this area were gathered between 1994 and 1998. In general, the entire Tucuruí region reflected this downtrend. In the downstream area, the Baião and Mocajuba municipal districts noted a marked shrinkage in the area where cassava was harvested, while Baião managed to maintain higher levels than Mocajuba for rice. These are both temporary crops: cassava is grown mainly for domestic consumption, with the sale of small surpluses, while rice is linked to the opening-up process for ranches. Black pepper, which is grown solely for sale, shrank in both these districts. Cacao was grown over an appreciable area. Cametá managed to maintain the area assigned to cassava, while rice shrank slightly. Cacao is the only product that managed to maintain and even extend its area. The economy of this town depends on subsistence and commercial agriculture (particularly cassava, cacao and black pepper), as well extractivism (mainly açaí and timber). Industrial activities are still incipient, being limited to sawmills in the district and the main town, working with their own engines, and various woodworking shops. The inhabitants of the region blame the hydrologic changes for the reduction of açaí and cacau production, and the consequent impact on the local economy.

Upstream from the Tucuruí Hydropower Complex, there was no increase in the area planted with the staples that assure the survival of the local populace. Breu Branco has the largest area planted with cassava at 2 000 hectares with Novo Repartimento ranking second with 1 000 hectares. This cassava area almost doubled at Jacundá, up from 800 to 1 500 hectares, while shrinking at Itupiranga and Tucuruí. Rice covered the largest area in Novo Repartimento, Breu Branco, Itupiranga and Jacundá. Pepper and bananas are cash crops with some fluctuations, but the total areas involved are almost negligible. These data clearly outline the agricultural stagnation already mentioned.

Plant-based extractivism has been practised in all of these districts both before and after the construction of the Tucuruí Hydropower Complex. Laying the PA-150 highway and some local roads fostered the organisation of the extraction and marketing chain for timber. During the mid-1990s, this activity emerged in Jacundá; currently, Breu Branco and Novo Repartimento upstream produced the largest numbers of logs sold. Tucuruí is a leading producer; the logging of submerged timber in the lake has helped increase its output. The old municipal districts located downstream show dynamic extractivist activity. Baião rivals the output of Breu Branco. Fuelwood, like timber, is an important product. This situation is very different to that of the 1960s and 1970s, when the Lower Tocantins region was important for the production and marketing of Brazil nuts. Açaí, a staple food item for riverbank communities, is vanishing from the extractivist economy throughout the region. This reflects the impoverishment of agriculture and poor *várzea* floodland stewardship. Still in the field of plant extractivism, it is notable that local processing activities are sparse. Large sawmills do process some timber; felling, sawing and preparing the planks. The huge heaps of sawdust that result - which could well provide raw materials for the furniture industry - are dumped along the PA-150 highway near Jacundá.

3.6.5.1 Islands Region

Settlement on the newly-formed islands with their vacant land and abundant catches, is almost always linked to fishing activities and information obtained through relationship networks. More recently, this process has also been linked to the sale of squatter titles and improvements. Most of these residents are involved in fishing and agriculture. There are commercial prospects for fishing, as an activity that mobilises the family work-force, including younger children. Subsistence agriculture takes place on small patches of cropland around one hectare in size, providing food for families. Stumps are cleared and *acerro* [36] firebreaks are cut in October and November, followed by planting in January. These small patches of cropland produce manioc, cassava, sweet potatoes, water-melons, pumpkins, beans and other staples. In the Jacundá municipal district, the lake formed 93 islands suitable for gathering and agricultural activities – rice, cassava and beans – as well as fishing, which has become dominant. Forty kilometres from the main town of Jacundá, the hamlet of São Pedro Porto Novo is a hub for fishing activities. It is calculated that some 600 families[37] live on these islands under precarious conditions. Some of the families moved here ten years ago, while others relocated over fifteen years ago. The Z-45 Fishermen's Association operates in the village, and is planning to introduce cold storage facilities to replace its current refrigerator. Members receive one third of their normal wages during the spawning season. However, catches are still small.

This is not the situation on other islands. All the interviewees unanimously stated that, although they were members of the Post 11 Fishermen's Association, they lacked a support policy for the systematic sale of their catches. This is why they sell to the middlemen (*atravessadores*) as these itinerant traders guarantee regular purchases of the catch. Fish prices vary, depending on the presence of middlemen from other places outside Pará State, as well as the time of year. When the water rises during the winter, the amount of fish in the rivers, lakes and pools drops, which increases catch values. When the lakes dry up in Summer, fish are plenteous, forcing the price down. According to the fishermen, they get the best prices for their catch during Holy Week. These islands still shelter ample natural resources. The interviewees [38] stated that they frequently find *guariba* monkeys, armadillos and porcupines, and claim that they avoid killing wild animals, in order to prevent their extinction. Some islands – such as Deus por Nós, for instance – have little virgin forest left, particularly forest containing timber of any commercial value. This island has become too small for its burgeoning population, according to some of its residents. As many people were drawn to this area to fish, they were not concerned with demarcating large areas of forest, and only later cleared small patches of cropland for community use, transforming this area into secondary grasslands known as *capoeira*. The forest is not a generous source of food, either because its potential resources have been gradually destroyed over time by poaching and disorderly use by some residents, or because the land has been declared a preserved area. On almost all the islands visited, small orchards of fruit-trees were noted, including mango, açaí, jackfruit, cashew, cupuaçu, acerola, murucí and others.

3.6.6 Effects on Health

3.6.6.1 Preliminary Impacts

This sub-item analyses certain health-related problems deriving from the implementation and operation of the Tucuruí Hydropower Complex. It reviews the health situation in districts both upstream and downstream from this project, in order to build up an epidemiological profile for the region, as well as assessing the occurrence of arbovirus and human mercury poisoning.

The social, environmental and sanitary effects of the implementation of this project are undeniable. Malaria is a major health hazard, and is considered part of the social costs of the Tucuruí Hydropower Complex. Development projects associated with environmental changes have worsened the sanitary situation. Although the negative impacts on health caused by hydropower projects have been acknowledged, efforts to minimise them before, during and after implementation are limited. In general, health issues are not taken into consideration as key factors in project planning, with a handful of last-minute measures implemented hurriedly to supplement existing health services. Inter-sectoral negotiations are required, defining responsibilities and preparing healthcare strategies that expand available services and programmes, while extending the sanitary infrastructure in the area of influence of these projects. Investments in healthcare should be seen as benefits.

3.6.6.2 Construction Stage of Hydropower Complexes and Health Hazards

The impacts of hydropower plants on health standards are varied and complex. They are not limited merely to demands for services or the appearance of new diseases. Several processes are unleashed, bringing diversified risks at various levels that affect general health conditions and shape epidemiological profiles. During the construction phase, environmental interventions are widespread: deforestation, the setting-up of work-yards, the laying of access roads, and the altering of river courses. All this activity attracts eager streams of migrants, boosting demands for urban infrastructure as slums spring up around urban centres, and altering morbidity and mortality rates for the entire region. During this phase, an upsurge in the incidence of vector-transmitted diseases is noted – malaria, schistosomiasis etc – as well as industrial accidents, alcoholism, sexually transmittable diseases and AIDS. New vectors and parasites may also appear, and mortality rates soar. The construction of hydroelectric complexes in Amazonas State should be analysed as a special case, as they are located in a tropical rainforest that shelters a wealth of biodiversity. It is also home to riverbank communities, indigenous tribes and unique ecosystems that are affected by these projects. High-risk waterborne diseases are often migration-related, their vectors flourishing when Hydropower Plants are built in Amazonia. The ecological conditions of this tropical rainforest facilitate the introduction and proliferation of these diseases: high rainfall and ample moisture; river basins criss-crossed by rivers, streams, creaks and pools; ancillary vectors such as *Anopheles darlingi*; and ample opportunities for contact between vectors and humans working in the forest and living in partially-walled shacks or lean-tos (Moura, Couto, 1996).

The impacts of the construction of Hydropower Plants are shaped by the health conditions of the populace at the start of the project. It is important to stress that communities in a situation of socio-economic exclusion may be more seriously affected or exposed than others in better conditions. Certain changes and their health-related effects are immediate, while others are more drawn-out. Insidiously exposing the populace to chronic health hazards, their repercussions may only become apparent over the medium to long term (Finkelman, et al., 1984). The current approach is to consider the communities located closest to the project as the most severely exposed. In the case of hydropower ventures that produce drastic changes to the environment, these risks may even extend to more remote groups on the outskirts of the area, with types and levels of exposure varying at different stages of the project.

3.6.6.3 Health Problems caused by the Implementation of the Tucuruí Hydropower Complex

Countless health problems have been caused by the implementation of the Tucuruí hydropower project. Particularly outstanding during the implementation stage were the infant mortality rates for the Tucuruí municipal district in 1980 and 1981: 410‰ and 320‰ of live births died before completing one year of age, respectively. The coefficients were far higher than those for Pará State (67‰ and 53‰) and Brazil (82‰ and 76‰) for the years in question.

Another relevant fact is the outbreak of typhoid fever in 1981, with 103 cases at Tucuruí, which accounted for 53% of the cases recorded throughout Pará State (n=193) (MS/CENEPI, 1992). The use of defoliants by the Eletronorte sub-contractors from 1980 through 1982, hired to clear paths for power lines, was another important factor undermining the health status of communities in this area. The following herbicides were used along the routes of the Eletronorte power lines (running 800 kilometers from Tucuruí to Barcarena, Pará State, with a width of 100m) : Tordon 101 BR, Tordon 155 BR and Banvel 450. The use of these herbicides caused much controversy at the time, due to claims that their composition was similar to that of the defoliant known as Agent Orange, notorious for its use by the US military in Vietnam. Although toxic, these products were authorized for use by the Brazilian Government, and did not contain the amounts of dioxin that made Agent Orange highly poisonous to human beings.[39] In areas where these herbicides were used, there were also allegations of widespread deaths among animals and plants, with contamination of wells, inlets and people in all age groups. There were reports of miscarriages and symptoms consistent with acute exogenous intoxication: headache, vomiting, dizziness, ocular erythema and sluggishness, followed by hematuria, oliguria and anuria, fever, seizures and tremors, with death in some cases (Couto, 1983; Castro, 1984). In the *White Book on the Environment at the Tucuruí Hydropower Complex* (*Livro Branco Sobre o Meio Ambiente na UHE Tucuruí*) published by Eletronorte, Eletrobrás and the Ministry of Mines and Energy (1986), Eletronorte denied some of these accusations while acknowledging damage to crops in two cases (for which it stated that it had offered adequate compensation), but blamed pesticide poisonings on the use of other products by farmers, and attributed cattle deaths to nutritional deficiencies.

Another problem related to the use of toxic substances was the experiment carried out by CAPEMI, which ring-barked brazil nut trees on Tocantins island; this forestry technique is designed to kill off trees for future commercial use. Substances such as Tordon 101 BR were used which is allied with sodium arsenate and pentachlorophenol (PCF) as conserving agents. According to reports at that time, the amounts used were relatively minor, and there was no clinical evidence of contamination.

After the formation of the lake, the density of anopheles (*A. darlingi*) and mansonia (*M. titilans*) mosquitoes increased. Swarms of mansonia mosquitoes plagued local communities, as well domestic and wild animals, drastically affecting living standards, and limiting the agricultural activities of all those affected. In certain areas there were especially large swarms of mosquitoes, gnats and other insects due to the filling of the reservoir. When dusk fell, residents were unable to stay outside their homes. Indoors, they burned cloth, straw or other materials in smudge-pots to get rid of the mosquitoes (1994). Swarms of mosquitoes also attacked the indigenous lands of the *Parakanã,* *Tucuruí* and *Pucurui* tribes, as well as the Andorinha and Pic-Marabá lands, which were part of the settlement project run by INCRA. Before the formation of the reservoir, this area was home to 1 227 families, dropping to 678 after the lake was filled in 1990. The other families fled, forced out by swarms of mansonia mosquitoes. The island dwellers have also been affected by these insects. In the report of the First Meeting of the Technical-Scientific Task Group (1997) researchers stated that "*these swarms of mosquitoes were an expected effect that became unexpected, as it had been poorly assessed. More mosquitoes were expected, but it was believed that they would become less numerous as the lake became home to [more fish] species. No monitoring was undertaken merely some very location-specific studies. At peak periods, bite rates of 500 bites an hour were noted, although by mosquitoes that did not carry diseases. There are various types of malaria, and each family has two or three children suffering from this disease, due partly to problems associated with the macrophytes*." According to a report prepared by the National Research Institute for Amazonia (INPA), two alternatives were open to the government for resolving the problem: (a) drainage or elimination of still waters; (b) spraying with low-toxicity products. The technical experts then stated that the local populace turned these solutions down, in contrast to the *Parakanã* tribe, who accepted them with good results.

The members of the Working Group reacted to these statements, explaining that the refusal to accept these solutions among the affected communities was a reaction to the poisoning caused by spraying campaigns. Those attacked by swarms of mosquitoes felt that toxic spraying was just as hazardous to their health. Moreover, this was merely a palliative measure, as it did not eliminate the hatching sites of the mosquitoes. The first alternative - drainage - would have been well received, but was not implemented by the competent agencies.

3.6.6.4 Malaria

Although endemic in Amazonia, malaria is under control in certain areas. However, if economic activities or huge engineering works are undertaken, significant migratory flows are generated, resulting in the exacerbation, recrudescence or loss of control over the spread of this endemic disease and demanding investments in sanitary infrastructure or malaria control services. The building of the Tucurui dam has had marked demographic impacts on the town itself and upstream municipal districts, attracting high-risk immigrants and boosting endemicity in this area. These demographic impacts were not noted downstream. The upstream region is a high-risk area for malaria. Tropical rainforests foster transmission, and high-risk groups constantly travelling through this area – wildcat miners, loggers and farmers – have poor immunity. These groups are exposed to the *A. darlingi* through their work activities or precarious living conditions. The high prevalence of *P. falciparum* – which is generally resistant to anti-malaria drugs – increases malaria morbidity and mortality rates, which are further exacerbated by inadequate healthcare networks and social infrastructure, and ineffective control measures (FNS, 1995). The malaria studies covered the municipal districts upstream from the dam: Itupiranga, Jacundá, Breu Branco and Novo Repartimento, with Baião, Mocajuba and Cametá downstream. Epidemiological data show that malaria was not distributed evenly throughout the area of influence on the Tucuruí Hydropower Complex, with high transmission rates predominant upstream, and low transmission risks downstream.

In the Tucuruí region, the rise and fall of malaria outbreaks coincided with the construction and operation phases of the hydropower complex. From 1975 onwards, an explosive upsurge in malaria was noted in the Tucuruí Municipal District that extended throughout the entire construction period. As this phase drew to an end in 1984, malaria peaked at around 10 000 cases. The presence of appreciable percentages of *P. falciparum* among the positive cases reached an %IF of over 60% at the end of the construction stage, which indicates appalling sanitary conditions during the implementation of a hydropower project. This malaria transmission pattern at Tucuruí, where the dam is located, suggests the massive scope of its effects on the environment, particularly through deforestation and the building of the work-yards. Thousands of workers involved in construction are susceptible to malaria and lack any cultural experience of this disease, or the presence of *A. darlingi*, the predominant malaria vector in Amazonia. Table 3.38 below shows the human malaria figures for the Tucuruí Municipal District for the period 1962 – 1998.

Table 3.38 Figures for human malaria in the Tucuruí Municipal District (1962 – 1998)

YEAR	Positive	*P. falciparum*	*P. vivax*	*P. malariae*	*P. falciparum + P. vivax*
1962	106	93	13	0	0
1963	93	71	22	0	0
1964	28	12	16	0	0
1965	15	12	3	0	0
1966	152	100	52	0	0
1967	111	78	32	0	1
1968	39	21	18	0	0
1969	8	7	1	0	0
1970	251	198	51	2	0
1971	174	116	44	1	13
1972	210	137	68	0	5
1973	600	327	269	0	4
1974	320	119	201	0	0
1975	251	83	167	0	1
1976	1127	367	745	2	13
1977	3387	941	2453	1	42
1978	2762	613	2133	1	15
1979	4953	1272	3652	2	27
1980	3691	1280	2382	1	28
1981	4479	1500	2942	0	33
1982	6992	2982	3924	0	86
1983	8519	4732	3691	0	96
1984	10126	6431	3628	0	67
1985	1411	809	589	0	13
1986	650	285	361	0	4
1987	1063	388	669	0	6
1988	2103	1133	954	0	16
1989	2801	1158	1622	0	21
1990	2165	998	1149	0	18
1991	----	----	----	----	----
1992	7058	2983	4036	2	37
1993	6094	2873	3153	0	48
1994	3439	825	2599	1	14
1995	3117	376	2727	0	14
1996	1567	252	1301	0	14
1997	1423	182	1234	2	5
1998	1895	292	1491	0	12

Source: National Health Foundation.

These indicators show that investments in the local malaria control service infrastructure were insufficient to boost its efficiency and limit morbidity and mortality rates among the local populace. These results should be qualified while by recalling that the populace expanded considerably in this district. Data are available for Tucuruí only for the Demographic Census years (1970, 1980 and 1991), as well as the 1996 population count. It is possible to calculate the Annual Parasite Index (IPA – *Incidência Parasitária Anual*)[40] for these years, which expresses malaria infection levels among the populace in cases per 1 000 inhabitants. Table 3.39 gives the Annual Parasite Index rates for the Tucuruí Municipal District. There is no data available on malaria fatalities.

Table 3.39: Annual Parasite Index rates for the Tucuruí Municipal District – Selected Years

Year	Positive Cases	Population	Annual Parasite Index
1970	251	8 489	29.57
1980	3 961	61 140	60.37
1991	4 612*	81 623	56.50
1996	1 567	58 679	26.70

Source: IBGE, FNS

- estimated data (average 1990-1992)

SUCAM recorded cases of malaria at Itupiranga and Jacundá in the reservoir area, (January – October 1986); a summary of the results is shown in Table 3.40.

Table 3.40 Cases of Malaria in the Reservoir Area, 1986

District	Positive Cases	Population	Annual Parasite Index
Itupiranga (*1*)	409	3 013	135.75
Jacundá (*2*)	482	1 827	263.82

Source: Modification of Tadei, 1986b
(1) Total of 11 places
(2) Total of 13 places

These data show that the Annual Parasite Index rates in the Tucuruí Municipal District returned to levels comparable to those noted before the dam was built, which classified it as a medium to high risk area for catching malaria. However, during the dam construction period, the filling stage and the decommissioning of the works-yards, this was a high-risk area with Annual Parasite Index rates twice as high as the high-risk classification level During the current operations phase of the Tucuruí Hydropower Complex, the incidence of malaria rose steadily due to the formation of the lake and the presence of malaria vectors, together with insufficient or non-existent treatment by the malaria control service, and the failure to clear the lake area and its banks. From 1998 onward, news of the start-up of Phase II of the Tucuruí Hydropower Complex once again drew heavy flows of migrants to this region, already reflected in an upsurge in the number of cases of malaria. In the reservoir area, Itupiranga and Jacundá were in a crisis situation during the 1986 campaign, with malaria levels reflected through Annual Parasite Index rates of 4.5 – 8.8 higher than the limit for areas offering high risks of malaria. The data for both these Municipal Districts – which were partly flooded – shows the levels reached by malaria during the dam construction period and over subsequent years. In association with the vector proliferation and the resettlement of the local populace, these levels were repeated in new towns established upstream, such as Breu Branco and Novo Repartimento. The downstream area (consisting of the Baião, Mocajuba and Cametá districts) has low malaria risks, according to data from the National Health Foundation (FNS – *Fundação Nacional de Saúde*), probably because it was settled in the 1600's. This area's population growth rate is lower than that of the upstream settlements.

3.6.6.5 Environmental Impacts and Occurrence of Arbovirus[41] in the Area of Influence of the Tucuruí Hydropower Complex

From 1983 through 1989, ecological and epidemiological studies of arbovirus were carried out by the Arbovirus Unit at the Evandro Chagas Institute (IEC - *Instituto Evandro Chagas*) covering part of the area of influence of the Tucuruí Hydropower Plant, with the financial and logistical support of Eletronorte at Tucuruí. The purposes of this programme were: (i) to prepare an inventory of the life-cycles and types of arbovirus in the primary forests in the Tucuruí region which could have adverse effects on the development of this region; (ii) to assess the risks to human populations settled in forested areas on the banks of the lake after the dam was built; and (iii) to study the epidemiological changes caused by the construction of this Hydropower Plant on the incidence of arbovirus over the short and medium terms.

The results revealed the appreciable effects of the construction of this Hydropower Complex on both the maintenance of existing arbovirus cycles and the introduction of new cycles. This was shown by the number of isolated samples as well as the diversity of types. Of the 216 samples isolated in this area, 38 were new types of arbovirus - meaning they were as yet unknown to science or had not yet been described in Brazil, though found in other parts of South America. Another aspect to be taken under consideration is the correlation between the appearance of some species of mosquitoes that were found here very rarely before the formation of the lake, and the appearance of new types of viruses. A striking example of this is the case of the Gamboa virus and the *Aedeomyia squamipennis* mosquito, as well as mosquitoes belonging to the *Anopheles nyssorhynchus*, mainly *An.* (*Nys.*)

nuneztovari, *An.* (*Nys.*) *trianullatus* and *An.* (*Nys.*) *oswaldoi*, associated with the appearance of three new members of the *Anopheles* family (Arumateua, Caraipé and Tucuruí), in addition to increased mobility among other members of this group (Tacaiuma, Lukuni and Trombetas virus). This was possibly due to the fact that the conditions created during the formation of the reservoir favoured the reproduction of these species. Exactly what these encouraging factors are remains to be explained, and further studies in this area would be of interest to assess the current situation. Among human beings, no arbovirus were isolated during the pre-filling period, and the number of isolations achieved during the two other phases was not high. However, there were dozens of serological conversions among people whose blood was taken for the second time during the study, which reflects an increase in the circulation of arboviruses among the resident population of Novo Breu Branco and Novo Repartimento.

Finally, it is important to recall that most of the types of arbovirus isolated in the Tucuruí Hydropower Complex region, particularly new strains, have not as yet shown any ability to infect human beings. However, it is important to stress that this study ended a few years after the lake was filled, just as these new ecological and environmental conditions were beginning to stabilise. Hence the possibility cannot be discarded that one or more of these newly-identified arbovirus may become pathogenic in human beings in future. It is thus important that new studies be carried out in this region, which has proven a fertile field for arbovirus studies.

3.6.6.6 Human Mercury Poisoning

Studies carried out in the Tucuruí hydropower lake (as seen in Section 3.5.12) indicate high mercury levels in fish, land animals and human hair. Although the sources of mercury in the reservoir and of mercury poisoning in local communities have not yet been formally investigated, the presence of this heavy metal already indicates the need for monitoring and control. This is now a matter of sanitary concern, due to the risks of mercury methylation and its introduction into the food chain, which could undermine the health of the local populace.

3.6.6.7 Health Situation Upstream and Downstream from the Tucuruí Hydropower Plant

This study was prepared using data made available by the Pará State Health Bureau, covering the period between 1995 and 1997. However, it was not possible to obtain any mortality figures. The municipal districts analysed upstream were: Tucuruí, Itupiranga, Jacundá, Breu Branco, Novo Repartimento, Rondon do Pará, Goianésia do Pará and Nova Ipixuna, with Baião, Mocajuba and Cametá downstream. With regard to health policies, it was noted that these municipal districts are covered by the Single Healthcare System (SUS – *Sistema Único de Saúde*) and comply with NOB/96, while also participating in the State Integrated Agreed Schedule. In terms of management, only the Tucuruí municipal district runs a municipalized healthcare system, while Rondon do Pará, Nova Ipixuna, Baião, Mocajuba and Cametá only offer basic healthcare that has been municipalized. Qualification processes are underway for Jacundá, Novo Repartimento and Breu Branco, while Itupiranga and Goianésia do Pará are the only districts that fail to fit into any scheme whatsoever. All these districts have their own Healthcare Bureaus and their respective Municipal Healthcare Councils.

The healthcare network is polarised between healthcare posts and hospitals, with a need to expand healthcare centres into hubs for the development of basic healthcare programmes. With regard to basic sanitation infrastructure, most of these municipal districts are equipped with public water supplies and garbage collection services. However, there is doubt surrounding the quality of these services, given the many recorded cases of diseases that can be avoided by proper sanitation, such as infectious hepatitis and various types of diarrhoea. The epidemiological profile of the upstream municipal districts reflects the social and sanitary structure of this area. In addition to malaria and Leishmaniasis, which are associated with human incursions into the ecosystems of Amazonia, other illnesses also shape the epidemiological profile of this area, including tuberculosis and leprosy. Of particular prevalence in the downstream municipal districts are diarrhoea-related diseases and infectious hepatitis, as well as cases of tuberculosis and leprosy. National Vaccination Days organised by the Ministry of Health and the State and Municipal Health Bureaus have had positive impacts on diseases that can be prevented by immunisation, and are considered to be a factor in the reduction of infant mortality in Brazil, and specifically in the State of Pará and the municipal districts under analysis. With regard to diseases that can be prevented by proper sanitation, the largest number of cases of infectious hepatitis are recorded in Rondon do Pará, Goianésia do Pará and Cametá. Diarrhoea-related illnesses are more frequent upstream from the dam, at Jacundá and Goianésia do Pará. An analysis of the downstream data reveals a high incidence of diarrhoea-related diseases, which indicates the lack of local sanitary infrastructure and/or the consumption of water from the Tocantins River by communities dwelling along its bank. It is important to stress that during the period under consideration, there are no records of other diseases that can be avoided by proper sanitation, such as typhoid fever, leptospirosis and cholera.

With regard to diseases that can be avoided by vector control, there was a significant outbreak of leishmaniasis in 1995, which subsided during subsequent years. For this same year, there are no upstream records of cases of other diseases that can be prevented by vector control, including human rabies, schistosomiasis, yellow fever, Chagas disease and dengue. However, in 1995one case of schistosomiasis was registered downstream at Mocajuba, possibly imported, as was the only case recorded for 1996, at Cametá. Tuberculosis and leprosy are endemic in Pará State, although classified as diseases that can be prevented by treatment and monitoring. According to the information available, there are cases of tuberculosis in the municipal districts under study, with Tucuruí and Cametá recording the largest number of occurrences. It is possible that the control programmes which improve the diagnosis of this disease were never properly structured in these towns. The districts under study also show significant figures for leprosy, particularly Jacundá, Tucuruí, Rondon do Pará and Cametá.

The sporadic occurrence and/or absence of cases of diseases that can be prevented by immunisation suggests the efficacy of vaccination campaigns run by the municipal districts during the period under analysis, although vaccine coverage offering protection against whooping cough and tetanus should be extended. No cases of diphtheria, measles or poliomyelitis were recorded during this period.

3.6.7 Specific Social Impacts on Downstream Communities

3.6.7.1 Impacts Foreseen by Eletronorte and Measures Implemented

The impacts foreseen by Eletronorte for the downstream reaches of the river were considered as temporary and circumstantial. Its core concern focused on ensuring the survival of communities dwelling along its banks during the two months' halt in the flow of the river, through "temporary measures minimising localised impacts". The social impacts on the downstream reaches of the river were assessed on the basis of a diagnosis carried out around one year after closing the sluice gates so that "*during the reservoir filling period, the effects of the reduction in the flow of the River Tocantins would be alleviated as far as possible*".[42]

The main problems noted by the team commissioned to carry out the social and economic diagnoses were related to public health, basic sanitation, transportation, the possibilities of supplies, and communications. In the next section – Prognosis – these technical experts reveal that they were aware of the "*quantitative and qualitative inadequacy of the data*" and regret the lack of consideration given to issues directly related to ecology.[43] However, in a letter addressed to the Cametá Prelacy dated July 29, 1984, the Eletronorte Procurement Director noted the existence of "*an extensive programme of studies and surveys of the consequences of closing off [the river] which indicate that we will have no problems*" and which, among other measures, guaranteed "*medical aid, vaccination campaigns, extension of existing healthcare posts, and the implementation of new healthcare posts*."

An analysis of the documentation of that period shows that in fact two objectives guided downstream intervention. The first was to offset the direct effects of reducing water levels and ensure the survival of riverbank communities through measures to assure water supplies, medical aid and food. The second objective was intended "*in view of the rumours circulating, to re-establish peace of mind and build up the confidence of the populace*".[44] To achieve this second objective, it was necessary to seek spokespersons among the residents in the various downstream communities. Through a group of social workers, the main leaders in this region were identified, registered and assessed on the degree of their support for the discourse of the power utility. This report was considered a key element in achieving the objective of appeasing local communities by supplying information that would pacify them. The precarious nature of the impact studies is reflected in the lack of clarity – acknowledged by the team – of the information transmitted to the local populace. However, this problem was avoided through the implementation the necessary infrastructure to cover the dam-filling period, as well as promises of fresh investments for this area. In fact, actions under way at the time and the prospects of fresh investments for the region eased the tasks of the social workers, who managed to "soothe the populace" (although only temporarily). The local communities were persuaded that the results of the interventions would be extremely positive. In November 1999, the riverbank-dwellers can still recall their initial reactions to the construction of this dam: "The news was received with open arms, particularly because of the way that this dam was suggested. The people had no idea of its consequences, and there were no discussions with them over the possibility of their being affected by it." (Statement by a local leader in the Lower Tocantins area, November 1999). This enthusiasm was fuelled by news items in the local and national press, which reported the construction of the Tucuruí Hydropower Complex as the arrival of progress and development for this region, with electricity ensuring the feasibility of new plants and industries, creating more jobs and boosting local incomes.

According to the interviewees, if any one dared to speculate about possible adverse impacts in this euphoric atmosphere of expectation, they were promptly criticised as "not wanting development." It is interesting to note that completing the dam was considered a great victory by its builders over the river[45], particularly the engineers working for Eletronorte, Camargo Correa (builder) and the Engevix-Themag consortium (designer). The measures planned to mitigate these social and environmental effects were finally limited to drilling a few shallow boreholes and installing hand-operated pumps. Due to inadequate planning and lack of maintenance, these wells soon dried up.

3.6.7.2 Perceptions of the Impacts among the Affected Population

On the eve of the closing of the floodgates, much contradictory information flew around, prompting much speculation about the possible consequences of the dam. In this context of doubt and misinformation, an Open Letter was prepared, signed by the Cametá Prelacy, listing a series of effects of the dam, at times associated with alarmist and catastrophic views of what could still happen.

- Modifications in the hydrological system of the river increase a permanent, diffuse feeling of insecurity among the riverbank dwellers:

  " (...) last month, I thought that the igarapé pool was going to dry up, but it didn't, it just dried-up half-way. We have no way of knowing whether it's summer or winter; before, we knew that when the water came down it was time to plant"

- The modifications noted in the colour of the water and the disappearance of certain species are causing concern among many fishermen and prompting a feeling of mistrust in relation to the quality of the catch.

  "Before, the Tocantins River had clean, clear water.(...) When I went to clean the fish, it was already rotten: a live fish, just out of the water!"

- The changes foster perceptions that various diseases can be attributed to the dam.

  "There are lots of people dying of diarrhoea because of the dam, and a skin disease that was never seen here before, and there are no doctors to say what it is. There are lots of problems for the women, like cancer of the uterus (...)"

- Changes in water quality affect traditional practices in the region:

"This water wasn't like this, God didn't make it like this. They say that the water must be boiled, but how can we, when the people spend days and days away fishing in the river and the children spend the whole day playing in the water?"

- Differences in viewpoints and values are attributed to divergent interests and objectives:
  "Nature used to provide for the needs of the people. And now it all goes to make Eletronorte rich, for the Government to hand out, for politicians to buy votes. It was a commitment it took on with foreign companies. And where is the electricity that Eletronorte promised?"

Eletronorte questioned the urgency of any problem for which no remedial steps had been implemented, following a series of studies carried out by well-known research institutions. It was only from 1986 onward that a process of negotiation with the downstream communities began to emerge, although this was soon interrupted. With the intention of drawing up the Usage Plan for the Tucuruí Hydropower Complex Reservoir, Eletronorte extended its contract with the Engevix-Themag consortium in 1985. In principle, following ELETROBRAS guidelines, this involved proposing a series of programmes that would facilitate other uses for the reservoir (multiple uses) to ensure its profitability and ease its insertion into the region. Some environmental and social problems should be dealt with here, after which the downstream environmental effects will warrant attention. This process, which involved various Government agencies and almost all local leaders throughout the region, resulted in the definition of a set of emergency steps: (i) the re-opening healthcare posts; (ii) the recycling of healthcare agents; (iii) epidemiological surveys; (iv) research into mosquito proliferation; and (v) water supplies. These actions should have been implemented from July 1988 onwards under the agreement proposed by Eletronorte to SESPA and local town councils. Some measures were merely begun, particularly by SESPA, which had agreed to ensure the feasibility of a water supply system by repairing the existing boreholes and/or drilling new wells. A healthcare plan was launched, but also lacked continuity. A report presented on March 5, 1988 by the Eletronorte technical staff – which launched the Emergency Healthcare Plan – noted a return to the old traditions of the Company. This document denounces the "political nature of the intervention of trade union leaders wishing to oversee the work of Eletronorte" and recommends that the Company "assure its autonomy." The solution arrived at for this problem was to halt work and terminate the programme.

3.6.7.3 General Considerations

Alterations in the conduct of Eletronorte can be noted upstream from the dam; the company was faced with heavy pressure from the affected populace, particularly concerning its resettlement policy, and negotiations were found to be the best way of avoiding a deadlock situation. But this change did not occur downstream, where nothing was negotiated. Attempts to introduce participative planning in order to understand and mitigate downstream environmental problems rapidly ground to a halt. This meant that the quest for Government outreach policies was replaced by a push-and-shove process that let all the Government agencies involved avoid their responsibilities, at least in terms of any effective actions. Under-estimated during the design phase, the impacts of the dam were to be re-assessed only and specifically during periods of drought, when the quality of water downstream worsened appreciably. The various studies on water quality undertaken in this area, specifically between 1986 and 1988 reveal serious problems regarding the physical and chemical characteristics of water supplied to the populace. They also noted the presence of biological contamination along the entire downstream reaches of the river from Tucuruí to Limoeiro do Ajuru, except for the Eletronorte staff township.[46] In a recent statement (1992) it seems clear that the situation had worsened:

"(...) The downstream population used to live off fishing, açaí and black pepper which they grew on the terra firme uplands (...) Pepper prices dropped absurdly (...) People also used to fish for shrimp, mapará, etc. There was an entire line of trade that reached right back to Belém. When the dam closed, several species vanished..." [47]

Some local residents stated that the shrinking catches were due to predatory fishing downstream. [48] In contrast, others felt that the decrease in fishing activity downstream could be explained by the resettlement of fishermen who moved to the reservoir area, forced out by poor catches in this region. Finally, it is important to draw attention to the fact that the statements by the riverbank-dwelling populace – although including perceptions and viewpoints that are at times very different – all indicate that the advent of the dam brought sweeping changes, either directly or indirectly, in the life-styles and means of survival of local communities. They also confirm the need to investigate the nature and scope of the impacts caused by the construction and operation of the power plant. The linkage of studies and planning with the local populace's existing channels of expression and participation is vital to any democratic participative planning model.

3.6.8 Grassroots Movements

3.6.8.1 Perceptions of the Main Changes

The earliest discussions on the effects of the dam began among upstream residents, as there was no suitable forum for this type of discussion downstream, due to the enthusiasm of the populace there about the project. Expectations began to fade as soon as the local populace became skeptical about the benefits of the dam. After the dam was closed and the lake was formed, local residents stated that they began to note that the cacao native to the Lower Tocantins region (which provided much employment for them during the fishing off-season) had began to vanish. Fish also disappeared during the early years after the closing of the dam.

However, most of the local populace did not associate their problems with the damming of the river. Facing many difficulties around the dam, many fishermen left their families and migrated elsewhere in search of work, which led to conflicts with fishermen already living at these places. Others ventured into agriculture, migrating to places such as Acará and Tomé-Açu; while others moved to the outskirts of towns such as Tucuruí, Marabá and Belém. However, as they lacked experience of urban life, they almost always saw their families break up, frequently resulting in prostitution and juvenile delinquency. Others became squatters, trespassing on land and clashing with earlier residents or large-scale land-owners. Some tried to fish in the Northeast of the State, spending long periods away from their homes, with some never returning. One of the earliest impacts noted by the populace was river pollution, followed by the disappearance of fish and shrimp. Various diseases began to appear, such as meningitis (in Baião) as well as gastritis and reproductive difficulties (many miscarriages). According to some sources, people continue to be frequently affected by diarrhoea, intestinal infections and fever. They recall that many people whose homes and work-places were flooded were relocated to areas that were frequently unsuitable for planting crops, and were thus forced to move somewhere else. Another drastic impact on the riverbank populace directly affected the "*varzanteiros*" who planted short-term crops in the *várzea* floodland forests.[49] During the winter, floodwaters would fertilise the soil. The operating rules for the reservoir, being mainly concerned with power generation, modified this natural cycle and created uncertainty and fluctuations in water levels. This greatly affected farming activity, as well as other uses for the várzea floodland forests.

3.6.8.2 Protests, Demands and Negotiations with Local Residents

The interviewees stated that the upstream communities built up alliances and began to make their claims heard, taking part in several protest demonstrations against the implementation of this project. They recall that a major demonstration took place at Cametá in 1981, attended by hundreds of demonstrators, leaders, parliamentary representatives and even Luís Inácio (Lula) da Silva himself[50]. They recall that several meetings were held, particularly with riverbank communities upstream, as well as meetings with families from flooded areas, public protests, motions and lawsuits. The long list of demands presented during these events and at the negotiating table included fair compensation for their properties and improvements, and relocation to other areas where they could once again re-organise their social, cultural and working activities. Over the next few years, other successes were achieved: In 1989, a Parity Committee was established, bringing together Eletronorte and representatives of grassroots movements[51] in order to find solutions to outstanding matters of compensation and resettlement. The committee assessed the real conditions of the expropriatees, defining and suggesting practical measures. According to representatives of the grassroots movements, this committee was set up only after heavy pressure was exerted on Eletronorte. After these negotiations, many of the outstanding matters were taken as resolved by Eletronorte, which proceeded with payments and process reviews: of the 2 247 cases submitted, 126 have not yet been settled through agreements between the parties. According to the Protocol of Procedures signed in September 1990, in the event of a deadlock in the processing of claims, each case should be submitted to the Courts by the interested party. Another result of these talks was that work resumed on the building of roads in the resettlement area, and equipment was acquired, including mechanised patrol facilities, bulldozers and automobiles for the unions.

However, as some of the claims had not yet been met, the grassroots movements continued with their campaign, and soon a new committee was set up through Edict Nº 174, dated November 27, 1991. Eletronorte did not participate in this Interministerial Committee, and it made little progress as its meetings soon ceased. Another Interministerial Committee was established through Edict N° 296 dated June 22, 1994, as a result of lobbying by the grassroots movements that caught the attention of the Ministry of Mines and Energy. This committee made some progress in settling the outstanding matters, and met the leaders of the movements in Tucuruí. It decided on a series of measures including infrastructure works, the acquisition of vehicles for rural unions, and motorised patrol facilities for the Municipal Districts. It also put forward suggestions for compensation in the 126 remaining cases of the expropriatees. However, according to grassroots leaders, some of these cases were not settled satisfactorily and have been submitted to the Courts. As a result of the threat of a major mosquito proliferation in the resettlement areas and the grassroots activism, a Techinical-Scientific committee was formed. In 1989 the Committee published a 38-page report containing an analysis of the problem and recommendations for further action.

In August 1992, the 1st Congress of Lower Tocantins Fishermen was held, whose key objective was to create awareness among the local populace, particularly fishermen, highlighting the problems facing them. Throughout the negotiating process, the downstream populace was ignored by Eletronorte and other State agencies. These neglected communities said that during discussions with the Company, Eletronorte always claimed their demands and accusations were groundless, demanding that they provide proof of the alleged grievances. Their claim-lists always included rural and urban electrification, compensation for losses caused to natural resources and their crops, the organisation of their productive activities, and the restocking the rivers with native species. They stated that Eletronorte had failed to take their demands into consideration until that point. As they had not been mobilised for some time, particularly residents of fishing villages that worked alone, Eletronorte gained an advantage over them. Nevertheless, the movement that emerged from the 1980s onwards was positively assessed, as it was through these processes of struggle that fishermen and local communities began to observe a decline in fish stocks, as well as alterations in the river system and the production cycle of native fruits. They became aware that these crises were not some form of divine retribution, but merely the repercussions of the dam on the Tocantins River. They also felt that the use of dip-nets (*puçá*) - used by many fishermen to destructive effect - also reduced fish populations, although they noted that grassroots organisations had been working towards raising awareness on this issue.

3.6.8.3 Benefits and Outstanding Matters

The interviewees did not acknowledge that they had benefited from the construction of the Tucuruí Hydropower Complex. On the contrary, they said they had been severely affected, as their land had dropped sharply in value.. Any one who did not have definitive title simply abandoned the land or asked a neighbour to keep an eye on the property. The appearance of huge schools of fish in the lake – an unexpected phenomenon – began to encourage fishermen to leave their lands in search of alternative means of survival. As it is difficult for fishermen to work with systems associated with fishing and agriculture from the marketing standpoint, some 40% of the populace simply catches fish.

Some riverbank-dwellers mentioned an improvement in the hydrological system; the tides were very high before the dam was built, swamping their crop plantations and flooding homes, and this no longer occurs. From early 1998, they said, the fish began to appear in larger numbers. Also, many local roads were laid, which allowed people to travel around more quickly. However, transportation is lacking, particularly for handling the outflow of production in areas that are not on bus-routes. This is reflected in the marketing process: riverbank-dwellers either sell to the middleman (*atravessador*) - who collects the products at their homes and pays a lower price - or must pay freight charges and prune their profit margins, which are generally very tight to begin with. Hence it is the traders (*atravessadores*) who make good profits from the farming and fishing industries. In the Pranchinha district on the outskirts of Mocajuba, local residents said that many cases of diarrhoea were occurring. They attributed this to polluted water drawn directly from the river that is fed by both the dam and a heavily polluted pool (*igarapé*) which is even contaminated by hospital waste. In the town itself, the populace faces public safety problems; serious crimes have been committed over the past few years, mainly against elderly residents.

Regarding employment, they feel that the situation has grown worse, as the works-yard was shut down, and its entire workforce laid off. The unemployed population also included former fisherman ruined by shrinking catches. The interviewees felt that the *Linhão* Power-Line Project connecting the towns of Cametá, Baião and Mocajuba to the Tucuruí power grid was an achievement for the grassroots movement, as it was one of the items on its claims list. However, they encountered another serious problem: the high rates charged by the concessionaire, which was privatised. They said that since the power grid was connected up to Tucuruí, the rates have risen sharply. At Baião, some residents recalled problems with water, which was thick and turbid immediately after the floodgates were opened. Since then, local residents have begun to call for the delivery of drinking water. Some hand-operated pumps were installed, but broke down after some time in use without maintenance. The populace then returned to using river water for domestic purposes.

At Vila Itucará, a hamlet on the banks of the Tocantins River forming part of the Baião municipal district, some five hours by boat from the town of Tucuruí, rustic wooden shacks are built well above the level of the river, because its residents fear a rapid rise in the water level at any time. Here, water drawn from the Tocantins River is used directly by local residents, despite the visible presence of scum. The Tocantins River is also their only means of communication. This community travels along the river on scheduled boats, in their own canoes or small dinghies known as *cascos*, carrying their produce and bartering goods with other communities. Some residents stated that the sandbanks have always been there, but there are more of them now and they are more visible along the Lower Tocantins. According to these residents, Eletronorte has forgotten its promises, and their plight is being ignored. The authorities employed soldiers with dogs to deal with demonstrations by grassroots movements calling for healthcare, education, transportation, security, roads and lines of credit for small farmers. So far, very little has been achieved. The local residents feel that only a fraction of their demands have been met, although they almost unanimously affirm that the organisation representing "dam affected people" has negotiated on various occasions with the Company or Federal Government representatives and has had some influence on decisions. This movement gained more popularity at the grassroots level once the local populace noted that the promised benefits of the dam were failing to appear. Following the loss of *várzea* floodland forests, alterations in water and soil quality, and decreases in traditional food resources and marketable surpluses, this population – which once depended on farming and extractivist activities – is now turning to hunting, poaching, fishing and gathering açaí. Shrimp have almost vanished due to destructive fishing and marketing practices.

Considerable tensions and conflicts are starting to appear. Some interviewees recalled that large tracts of land have been appropriated by large-scale ranchers, who sent surveyors into these areas, sub-dividing them and taking them over. They also recall conflicts over property ownership at Jatobal, Uberlândia and Anilzinho (Federal Law, 1974). Cattle-ranchers have taken over huge tracts of land, while logging companies with offices in these municipal districts are devastating the forests even further. Interviewees felt that, so far, none of the municipal districts in the area of influence of the

Tucuruí Hydropower Complex had presented local people with a feasible and coherent development project extending beyond the economic sphere. Government policies to deal with the problems caused by the dam are almost non-existent, or have very location-specific effects. Local residents are unaware of the destinations of funds brought in through royalties, and they feel that there are few beneficiaries compared to the numbers of people adversely affected.

3.6.8.4 Social and Political Insertion of the Venture

The construction of the Tucuruí Hydropower Complex as such did not prompt social conflicts, but produced the "basic conditions" for the appearance of various grassroots movements. When rural and urban workers began to perceive the threats represented by the expropriation of their assets (land and improvements) they began to resist to protect their physical, social and political survival. They developed a communal identity as "those affected by the dam", with the spirit of fighters struggling for their rights. Statements outline the basic identities of these workers. Their life stories include migration, fear of drought and an unceasing quest for land to farm, expropriation, concern over the future of their families, and flight from exhausting and poorly-paid labour on land not their own. The fact that they already owned their own land, acquired through settlement projects or squatting gave them a sense of having certain rights. The grassroots resistance movements are shaped by the threats to their livelihoods, which they had built up with solid land titles and a dream of a secure future for their families. An appreciable portion of these groups was drawn to this region by the construction of the Transamazon Highway in 1975. This is the case with the settlers at Jatobal and squatters who had settled in this region before the dam was built. Many of them belong to groups settled by INCRA or GETAT, and migrated from other States in Brazil. Many were drawn to this region [52] by the "call" of the Federal Government when it was handing out land in Pará in 100-hectare sites along the highways in this State.

The settlement projects of 1970 and 1971 did not immediately issue land titles, and the interviewees stated that they were faced with a series of problems in these settlements, including hunger, tropical diseases and difficulties in adaptation. Their attempts to obtain loans from local banks that made them aware of the need for formal title to their properties. Within this context, Eletronorte and/or its associates BASEVI and INCRA began to represent a real threat, announcing the need to clear these lands of settlers and suspend farming activities, particularly the planting of permanent crops. In 1978, during the planting season in this region, farm workers did not plant their crops, awaiting some clarification from Eletronorte. They stated that the situation was critical by April 1979, because the Company had not released compensation payments and failed to underwrite resettlement projects scheduled for 1981. These and other factors triggered a crisis situation and prompted the appearance of grassroots movements combating the undervaluation lands, the loss of assets, threats of social decline, and the resettlement of people to remote areas that were unsuitable for the reorganisation of their life-styles and production activities.

3.6.8.5 Consequences of Uncertainty and Insecurity

Workers started to express feelings of desperation and count the costs of yet another move. Once again, they had to leave years of work behind them. Not being able to plant their crops was a grave blow to farm workers, particularly as they lacked access to bank loans.

One of the earliest examples of a new community organisation was the practice of round-robin petitions, consisting of documents that were prepared and approved by the community as a whole. This practice extended beyond the individual and the private sphere, expressing the loss disgust and feelings of injustice following the collapse of lifelong projects, and triggered a series of mobilisations and conflicts. In terms of organisation, the political mediation of external social players was deemed vitally important by the interviewees. The Land Pastoral Commission (*Comissão Pastoral da Terra*) offered steady support, although the Farm Workers Union (*Sindicato dos Trabalhadores Rurais*) was not in operation at that time. The National Confederation of Farm Workers (CONTAG - *Confederação Nacional dos Trabalhadores na Agricultura*) fostered an exchange of experiences with other victims' movements, including those at Itaparicá and Itaipu. These mediator institutions underpinned the organisation and establishment of the Resistance Movement, initially manifested through the Expropriatees Commission (*Comissão dos Expropriados*), and the Dam-Affected People Commission (*Comissão dos Atingidos* [53]). A crucial stage in the the movement linking those affected by the Tucuruí Dam began with the intervention and actions of the group of mediators. They had connections with governmental and non-governmental entities: the church, union leaders, and local intellectuals (with or without party political ties). The development of this movement included meetings, assemblies and camp-ins which are clearly recalled by those who took part in the Expropriatees Commissions. During their work with the local populace, the mediators drew popularattention to the low compensation prices paid for the land, resettlements in unsuitable areas, and the need for organisation.

Up to August 1982, several documents were prepared by the expropriatees, and a number of meetings were held with Eletronorte. One of the difficulties highlighted by the interviewees was the difficulty in identifying the persons appointed by the authorities to attend the meetings and handle the claims. At times it was Eletronorte, while at others it was GETAT or INCRA, or even ITERPA. Leaders of trade unions and the "dam affected people" movement felt that it was possible to intervene in Eletronorte policy through grassroots mobilisations and micro-located movements which emerged from the early 1980s onwards, claiming compensation for compulsory resettlement of families. They recalled the turbulent lobbying and negotiations which extended over several years. Initially, Eletronorte merely offered them an area for resettlement – Gleba Moju. The first camp-in brought initial achievements, in 1982.

After pressure from the movement over unstable living conditions among expropriatees, other areas were set aside for building townships or sub-divisions, such as the Gleba Parakanã, Baiana and Cajazeira. Compensation was paid to families settled at the Gleba Moju whose new land was made useless by overhead power lines. Houses were built on the sub-divisions, their residents were offered transport, and rented grazing lands were provided for two years, with areas varying according to the size of their herds. Opportunities were offered to discuss the amount of compensation for the previously flooded areas, such as Gleba Tucuruí. Another striking achievement was the establishment of a Parity Committee in 1989, bringing together Eletronorte and representatives of grassroots movements. This was designed to find solutions to outstanding compensation and resettlement matters.

According to representatives of the grassroots movements, this Committee was set up only after heavy pressure was exerted on Eletronorte. After negotiations, many of the outstanding matters were taken as resolved by Eletronorte, which proceeded with payments and process reviews. As some of the claims of the grassroots movements had not yet been met, they continued with their campaign, and a fresh Committee was set up in 1994. Established to conclude the works of its predecessor, it once again made progress in settling outstanding matters, but there are still cases that have not been dealt with by Eletronorte, which believes they should be resolved on a case-by-case basis in the courts. Of the 2 247 cases submitted, 126 have not yet been settled through agreements between the parties. Local residents recount that, as the settlement of the islands accelerated from 1988 onward, their residents began to clash with IBAMA, the Federal Police and the Eletronorte. Through a range of repressive acts, such as the seizure of fishing tackle, the burning of homes and even imprisonment, they attempted to intimidate these residents. According to their leaders, residents were banned from slashing and burning small areas to plant their crops.

The Tucuruí Farm Workers Trade Union organised a broad-based protest movement in the islands, and all the local residents cleared their croplands by slashing and burning in a single day; hence IBAMA and the Federal Police were no longer able control and repress these activities. The Association of Agricultural and Extractivist Workers and Subsistence Fishermen (ATRA - *Associação dos Trabalhadores Agroextrativistas e Pescadores Artesanais*) was established, and began to work together with the trade union in this area, supported by the regional FETAGRI and the representatives of the National Rubber-Tappers Council (*Conselho Nacional dos Seringueiros*). As mosquitoes proliferated, this movement once again returned to demonstrations, with a huge, drawn-out camp-in protest at SPI/Eletronorte. This resulted in a new area being set aside for resettling families forced out of their homes by swarms of mosquitoes. The introduction of community croplands was another strategy deployed by this movement to force INCRA to demarcate plots of land and transfer these families to their new homes. In 1996, during the Shout of the Earth (*Grito da Terra*[54]) movement, the negotiating list was extended to include construction of the *Tramoest* power-line servicing western Paraná State, together with the *Linhão* power-line in the Lower Tocantins.

A month later, in April 1998, other points were added: (a) construction of the lock at Tucuruí in order to handle shipping along the Tocantins River; (b) construction of a fish ladder to allow free movement of stocks upstream and downstream; (c) electrification of the seven municipal districts around the lake – Tucuruí, Breu Branco, Novo Repartimento, Jacundá, Goianésia, Nova Ipixuna and Itupiranga; (d) monitoring the sanitary and environmental conditions of the lake water; (e) establishing a Council to calculate and invest the royalties paid to the seven municipal districts; (f) preparation of a regional development plan; (g) establishment of a mixed commission to discuss, plan and oversee the implementation of Phase II of the Hydropower Complex, including the preparation of Environmental Impact Studies (EIA - *Estudo de Impacto Ambiental*) and their respective Environmental Impact Reports (RIMA - *Relatório de Impacto do Meio Ambiente*); and (h) discussions with dam-affected people and local society over the privatisation of Eletronorte and its consequences for the region.

After the Shout of the Earth, a regional development plan[55] was drawn up by the seven trade unions in the municipal districts located around the lake, with the assistance of the Pará Federal University (UFPA – *Universidade Federal do Pará*) and technical experts from various entities. Its main objective is to generate income, particularly based on family farming and family-run mini-enterprises. Also, claims are listed for inclusion in the budget for Phase II of the Tucuruí Dam. Access to the power grid is an item high on this claims list, as local residents feel that it is quite unacceptable for power generated at Tucuruí to supply other parts of Brazil, while leaving areas around the dam without power, thereby undermining their potential for small-scale industry.

One must stress the importance and political weight of civil society in the municipal district and its impact – particularly Breu Branco and Novo Repartimento – on the issue of access to electricity. Trade unions, trade associations, trade, farming and grazing associations, training, technical assistance and political entities have all played decisive roles in the introduction of improvements and the extension of the power grid to the Tucuruí region and neighbouring areas, such as the Lower Tocantins. In the Tucuruí district, this is a strategic issue, as the Tucuruí Hydropower Complex is located in this district, as well as part of the Eletronorte management, which allows pressure to be applied by local society in negotiating the extension of these power transmission grids with the Company, just as it negotiated the extension of the urban and rural distribution grid with the local power utility (CELPA) and town councils. Other environmental and social issues arising from the dam's construction are also being discussed, including damming the Tocantins River, the conditions of the lake, and the resettlement of local communities in certain hamlets, which is an as yet unresolved problem.

According to the Mayor of Tucuruí, Phase II of the engineering works should attract a population of some 20 000 people to this district, comparable to the influx noted during construction of the power plant during the 1970s. This process has already begun; after the announced duplication of Tucuruí by the Federal Government, some 5 000 people moved to this district during May 1998 alone. Other concerns over Phase II are (i) that the reservoir maximum water level could be elevated, flooding additional areas and (ii) that water quality downstream would decrease as there would be less water spilled away from the reservoir. Eletronorte repeatedly claims that these concerns are unfounded, but they are recurrent in most meetings showing that the community remains.

According to some interviewees, the organisational process (Commission/Movement) played a leading role in establishing the grounds for struggle and resistance with a permanent face-off with Eletronorte. The issues behind this struggle related to compensation values, living conditions in the resettlement areas, and the failure to clearly define the areas set aside for resettlement. The interviewees believed that their lobbying would redirect Company policy, or at least embarrass it in the public eye.

Discussions over the establishment of the extractivist reserve began seven years ago. Initially, it was presented under the name of the Itaipava Extractivist Reserve. Interviewed in 1999, a trade union leader commented that the establishment of the Extractivist Reserve is another point that elicits different reactions among the grassroots movement. What are the areas where this agreement occurs? The Mayors and fishing villages urge the establishment of an Environmental Protection Area (APA – *Area de Proteção Ambiental*), while Eletronorte, along with the State Government, is in favour of the Reserve. The Ministry of the Environment wants a Reserve. "If it is a reserve, it is to be exploited to the limits. On the islands, no one knows what a reserve is. There are people investing in the islands, putting up a tourism infrastructure," (Chairman of the Farm Workers Union, interviewed in November 1999).

Today there are dozens of associations in the settlement areas that are engaging with the authorities on a range of issues, including the question of 100-hectare plots of land, compensation for periods during which they were prevented from working, reviews of some cases, the opening-up lines of credit for small farmers, legalisation of land titles, infrastructure, the laying or maintenance of local roads, and rural electrification.

The Agri-Ecological Education and Assistance Centre (CEAP - *Centro Agroecológico de Assessoria e Educação*) is an entity that, according to its leaders, has been forging ahead with the efforts it has undertaken through the Integrated Development Project (PID - *Projeto Integrado de Desenvolvimento*). Coordinated by the Lutheran Church, this specialises in the fields of training, production and retailing, as well as environmental issues involving small farmers. It is also co-operating closely with the "dam affected people movement" as most of the grassroots associations connected to this centre include those affected by this project and have taken up the cause as their own.

Findings

- The construction and operation of the Tucuruí Hydropower Complex introduced sweeping changes into the social and economic structure of groups affected directly and indirectly by this venture. The power sector has adopted an unwavering stance, denying the existence of conflicts of interests surrounding the project, and claiming a "general interest" defined by "higher levels".
- The lack of a policy for dealing with social issues meant that the definitions of the criteria for paying compensation and royalties to those affected by the Tucuruí Hydropower Complex were established in parallel to the displacement and resettlement processes, under heavy pressure from organised social movements. The power sector maintained an attitude of refusing to acknowledge the social movements as legitimate spokespersons in defining public policies and participating in decisions that, directly and indirectly, reshape the lifestyles of communities affected by hydropower ventures.
- A change can be noted in the conduct of Eletronorte upstream from the Tucuruí Hydropower Complex, which came under heavy pressure from the affected populace, regarding its resettlement policy. Negotiations emerged as the best way of avoiding deadlock situations.
- The same procedure was not adopted for the downstream region of the Tucuruí Hydropower Complex, where no community claims were negotiated. Attempts to introduce participative planning in order to study and mitigate environmental problems downstream were rapidly halted.
- Underestimated during the detailed design stage of the Project, the downstream impacts were merely reassessed specifically for the dry season, when the drop in downstream water quality was quite clear.
- Statements by riverbank dwellers – despite perceptions and standpoints that are at times divergent – indicate that the advent of the dam brought major changes to their lifestyles, either directly or indirectly, as well as to the means of survival for local communities. They confirm the need to investigate the nature and scope of the impacts of the power plant. In itself, this factor is not sufficient to produce studies and surveys, with consequent explanations to the populace.

- Studies, particularly those focused on water quality, remain unsatisfactory, as they do not provide any technical answers on whether variations in water quality are caused by dam operations. This would alter the classification of these waters as stipulated in CONAMA Resolution 20/86, and increase constraints on their use by riverbank communities. No discussions have ever been held on whether or not the list of parameters analysed are sufficient to assess the extent of the changes brought by the hydropower plant.
- Eletronorte has always based its actions on the results of limnological studies in order to justify its refusal to acknowledge the negative effects of water quality on downstream riverbank communities. But according to the few studies presented, there was a marked drop in the figures for dissolved oxygen, which are incompatible with the standards established in the CONAMA resolution. This suggests a possible re-classification of the river's water quality, even if only during the dry season.
- There is a clear need to reassess the water quality monitoring programme, in order to check the parameters that actually diagnose the changes brought by the dam. This fresh approach should take into account not only the standards established in the CONAMA Resolution, which have not been checked as yet, but should also identify the ways in which water is used by riverbank communities. The parameters of study should cover the full range of indicators for potential impacts of the hydropower plant.
- It is also important to include parameters in the monitoring programme (e.g. mercury levels) that, though not definitively linked to the implementation of the dam, could have marked effects on the health of the local populace.
- Most of the arbovíruses isolated in this region have not as yet shown any capacity to affect human beings. However, as the studies ended a few years after the lake was filled, this potential hazard remains present, as vectors are in continuous contact with the human population.

3.7 Indigenous Societies

3.7.1 Preliminary Aspects

The Parakanã and *Asurini* indigenous groups (both Tupi) and the "Gavião da Montanha", a local group belonging to the *Parkatêjê* (a Jê-Timbira speaking group) were clearly affected by the construction and operation of the Tucurui Dam. As a result of this process, they have built up specific relationships with various agencies associated with the project, including Eletronorte, from the late 1970s onward.

The limitations of this study, due largely to the limited amount of time available to prepare it, prevented any field surveys from being carried out to record the direct opinions of the different indigenous societies affected. The latest data on the performance of the Parakanã Programme (run by Eletronorte since 1987) were made available at the end of the work. The same causes prevented the inclusion of some important problems in the study, such as those involving indigenous societies whose lives were directly affected by the construction of high-voltage transmission power-lines running from the Tucuruí power complex, including the *Parkatêjê* (known as the Gavião de Mãe Maria, in Pará State), the *Krikati* and the *Guajajara*, in Maranhão State.

3.7.2 Parakanã

3.7.2.1 Location and Demographic data

The Parakanã people (who call themselves *Awaeté - awá*, man or human being and *eté*, true) are currently divided into two major local groups. The Eastern group lives in three villages - *Paranatinga*, *Paranowaúna* and *Itayngo'á* - inside Parakanã Indigenous Reserve, consisting of 351 679 demarcated hectares in the Tocantins Basin (Novo Repartimento and Itupiranga municipal districts); the Western group is partly located in the South of the Parakanã Indigenous Reserve, living in the *Maroxewara* and *Inaxyanga* villages, and partly in the Xingu River Basin on the Apyterewa Indigenous Reserve (Altamira municipal district) which has not yet been demarcated, covering some 900 000 hectares.

The *Paranatinga* village is located 130km from Tucuruí along the Transamazon Highway (BR-230) between the Andorinha and Paranatinga Rivers, with access along a local road (8km) off the Transamazon Highway; there is also a landing strip in this village. Its members are part of the group that was initially contacted at the Igarapé Lontra in March 1971. According to data on the Parakanã Programme, which has been run by Eletronorte since 1987, the *Paranatinga* village had a population of 142 people (April 1999), and is the largest group among the Eastern Parakanã. The *Paranowaúna* village had a population of 104 people (April 1999) and is located on the left bank of the Pucuruí River to the North of the area. Access is either by river (rainy season) or along a local road running off the Transamazon Highway (dry season). It is located on the border between the Parakanã Indigenous Reserve and Novo Repartimento municipal district. In early 1999, some of the residents in the *Paranatinga* village moved away to form the *Itayngo'á* village on the Bacuri River, with a population of 61 people (April 1999), according to the data from the Parakanã Programme.

Regarding the Western Parakanã, also according to data from this Programme, there were 96 people living in *Maroxewara* (April 1999). In March 1995, some of its residents moved away to settle at *Inaxyanga* (or Inaxicanga) which had a population of 75 people (April 1999), and was located on the right bank of the Direita River, which is its only means of access during the rainy season. While access and transportation conditions of these new villages hamper assistance to a certain extent (according to the Parakanã Programme staff), it is also true that the environmental conditions of these locations, together with limited contact with other residents in this region have brought better health conditions among these groups than in other villages in the Parakanã Indigenous Reserve

Until the mid-20th century, the Parakanã had sporadic contacts with other inhabitants of in this region, which grew more frequent during the construction period of the Tocantins Railroad during the 1950s, when the Indian Protection Service (Serviço de Proteção aos Índios) set up an Attraction Post (Posto de Atração) at Pucuruí. During the 1970s, the Eastern Parakanã were reached through major government projects such as the National Integration Plan (Plano de Integração Nacional), including the construction of the Transamazon Highway (1970 (1974) and the Tucurui Hydro-Power Complex (1975/ 1983).

The National Indian Foundation (FUNAI) was responsible for contacting the warier groups located near the route of the Transamazon Highway, signing an agreement to this effect with the Amazon Development Superintendency (SUDAM) (cf. CEDI, op.cit:28). In 1971, the Pucurui River Attraction Front near the Igarapé Lontra inlet in the recently- established Parakanã Reserve contacted an initial group of some 200 people who had been in contact with workers on the Transamazon Highway. For these Parakanã, the consequences of the laying of this highway included hunger, prostitution, influenza outbreaks, venereal disease, and many deaths, in addition to the series of transfers undertaken by FUNAI agents. In 1971, the Parakanã Reserve was established.

Another group of forty people were contacted in January 1976 near the upper reaches of the Anapu River, who were taken to Altamira. Suffering from malaria and influenza, this small group was transferred yet again to the Advanced Base at Pucuruí in February 1977, which was known as the Indigenous Area, covering 23 288 hectares, not demarcated, with only 29 people reaching this point, hence 27.5% of this group died (cf. Santos, 1978:8).

3.7.2.2 The Tucuruí Hydropower Complex and the Parakanã Peoples

By the late 1970s, construction of the Tucuruí Hydropower Complex, which was inaugurated on November 1984, flooded 38 700 hectares of the Parakanã Indigenous Reserve (Decree No. 68 913 dated July 13, 1971). This led to the removal and relocation of the Eastern Parakanã, who had been contacted in 1971, located between kilometres 115 and 155 on the Transamazon Highway, as well as the Western Parakanã, contacted in 1976. This involved the relocation of about 247 people (1986 data), all of the known Parakanã.

The following year, in a context of political upheaval sweeping across Brazil, the FUNAI Administration (which was an agency under the Home Ministry) signed service contracts with anthropologists linked to universities covering the field coordination of what were known as "community development projects". Under Contract No 064/77, anthropologist Magalhães dos Santos was appointed the coordinator of the Parakanã Project, to be implemented with groups located at that time in the Parakanã Indigenous Reserve and the Pucuruí Indigenous Post (formerly the Advanced Base). Both these areas would be affected by the construction of the Tucuruí Hydropower Complex and the consequent rerouting of the Transamazon Highway. (cf. Santos, 1992).

By the end of 1997, FUNAI authorised the shut-down of the Advanced Base, replacing it with the newly-established Tucuruí Sawmill Project /FUNAI, whose purpose was to log all hardwoods from both the Parakanã and Pucuruí areas tagged for flooding by the Tucuruí Dam. The Sawmill Project failed to achieve the financial results expected, prompting FUNAI to sign an agreement with the now-defunct Brazilian Forest Development Institute (IBDF - Instituto Brasileiro de Desenvolvimento Florestal). Subsequently, this project and the entire timber inventory of the dam area were handed over to Agropecuária CAPEMI, an agribusiness enterprise that went bankrupt before completing this task.

In 1978, an agreement was signed by FUNAI with Eletronorte covering the implementation of the Parakanã Project, with the objective of providing services to the Eastern group and transferring it to another site by 1979. This Project also included the demarcation of a new territory, despite the preparation of the proposed outline of the new Parakanã area prepared in 1978 by anthropologist Magalhães dos Santos. Scheduled for the following year, this transfer process never took place. Similarly, there was little continuity in the Parakanã Project, as it lasted only one year out of the scheduled four, with the anthropologist responsible for its coordination resigning due to political disagreements over the conduct of the work (the same occurred with the other "community development projects").

In August 1981, the residents of the current *Paranatinga* village began to leave; after a number of transfers, they finally settled at a site above the Igarapé Paranatinga inlet in 1984, 12km away from the Transamazon Highway, where they still reside. In the same year the II Regional Offices of FUNAI in Belém decided to assign part of the area scheduled for flooding in the Parakanã Reserve (known as the Gleba Parakanã), demarcated in 1975, to the settlement of part of the regional population that had also been thrown off their lands by the Tucuruí Reservoir. The Araguaia-Tocantins Lands Executive Group (GETAT - Grupo Executivo de Terras do Araguaia-Tocantins) and Eletronorte finally used the Gleba Parakanã to settle 706 families.

During the second half of 1982, the Parakanã at Pucuruí (Western) were transferred once again to their current home in the *Maroxewara* village on the left bank of the Meio River, in the south of the Parakanã Indigenous Reserve, some 150km from Marabá.

On March 5, 1985, Presidential Decree No 91 028 established the current Parakanã Indigenous Reserve, spanning 351 697 hectares, which was demarcated with resources provided by Companhia Vale do Rio Doce (CVRD), as part of the mitigatory actions of the Carajás Iron Ore Project (Eletrobrás, 1992:77). Consequently, a new area was selected and demarcated, according to the proposal put forward in 1978, but excluding a fish-farming area.

3.7.2.3 Mediation under the Parakanã Programme

In August 1986, after the Parakanã threatened to block the Transamazon Highway, blow bridges and prevent settlers who had been living on the Parakanã sub-division (Gleba Parakanã) since 1977 from working the land, negotiations began in Brasilia in November 1986 over what was to become the Parakanã Programme. This was launched through a Deed of Commitment (No 001/87) and a Deed of Amendment (No 002/88).

Launched in September 1988, this Programme was divided into three stages (short, medium and long term) structured into sub-programmes that were defined by their areas of action: healthcare, education, agricultural support, border surveillance, works and infrastructure, and administrative back-up. In 1990, the agreement between Eletronorte and FUNAI was revised, and the offices of this Programme were transferred from the FUNAI Regional Administration in Marabá (which until then had been in charge of its management) to the town of Tucuruí; in June 1997, 27 people were working for this Programme (in the field and its offices). Despite a high staff turnover, there were 42 people working here by 1999, including staff and coordinators, in the offices and the field. Professionals from a wide variety of areas were involved in the Programme (through the Parakanã Programme Activities Support Association /Associação de Apoio às Atividades do Programmea Parakanã) and staff salaries absorbed 51.25% of its annual administrative costs (14.1% of a total amount of US$737 774.66 in 1998). Together with the funds assigned to operating support (19.4%) and works (4.5%), this accounted for 38% of the Programme expenditures in 1998.

The guidelines of the education sub-programme were geared towards providing the Parakanã with an introduction to dealing with the monetary system, in order to effect balance between production (i.e. gathering activities that were previously undertaken on a subsistence basis) and the targeting of the local market run by middlemen (atravessadores) at low prices, and the controlling of consumption by the Parakanã. The integration of content with the healthcare sub-programme took place with the preparation of specific educational materials and bilingual literacy classes. According to the data in the 1998 Programme Activities Report, the education sub-programme absorbed the same amount of funding (14.2%) as the administration sub-programme.

The healthcare sub-programme absorbed most of the budget funding of the Programme (29.0% in 1998), handling both emergency treatment and curative measures through agreements with local hospitals and others in Belém, as well as preventive medicine consisting of vaccination and entomological control measures designed to deal with the proliferation of malaria-carrying mosquitoes. Since 1990, the coordination of this sub-programme has been assigned to a healthcare professional connected to the Pará Federal University, under an agreement with the Evandro Chagas Institute in Belém, under the Ministry of Health.

The agricultural support sub-programme seeks to encourage the Parakanã to move into the regional market as extractivist-farmers, with activities tied into the village schooling system, in order to reduce their dependence on consumer goods - despite the internal differences that this approach has been generating. The introduction of new crops and farming techniques, as well as experimental forestry activities (such as selling mahogany seeds) is designed "to upgrade the quality of life" of these groups.

The environmental protection and surveillance sub-programme (7.3% of the funds in 1998) seeks to control pressures on the Parakanã territory imposed mainly by loggers, who operate with impunity throughout Southeast Pará State. The surveillance of the borders of the Parakanã Indigenous Reserve, initially handled by two employees hired by the Programme, is now undertaken by groups of young Parakanã who travel to locations vulnerable to trespass after the villagers have been alerted through a telephone system that also keeps the head offices of the Programme in contact with the villages. The expansion of the Parakanã, and their establishment of new villages, in parallel to their traditional hunting and gathering activities, has also been crucial to maintaining the integrity of the Parakanã Indigenous Reserve, and resisting pressures.

An in-depth assessment and critique of the actions of the various sub-programmes would require a detailed field survey, including interviews with dwellers in the Parakanã villages, as well as the Programme staff and local residents who have a variety of relationships with the Parakanã. Though sometimes contradictory, the positions and representations of the spokespersons of local grassroots movements, such as rural workers associations or other groups in organised civil society, would have to be taken into consideration - as well as the opinions of local government representatives (Tucuruí Town Council and other institutions) who operate in this region. This methodology would allow an accurate assessment of aspects involved in the various historical periods of the historical narrative of the entire process.

For the purposes of this report, however, the available data on the implementation and development of the Parakanã Programme is highly schematic, and amounts to an official assessment. Hence comparisons should be made, particularly with Parakanã interpretations of the performance of this Programme. This in turn requires independent systematic evaluations to be undertaken with the cooperation of anthropologists.

3.7.3 *Asurini* do Trocará

3.7.3.1 Location and Land-Ownership

The *Asurini* - a Tupi speaking-group, like the Parakanã - live on the Trocará Indigenous Land 23km north of Tucuruí along the Transcametá Highway (PA-156) which runs through the indigenous lands located downstream from the Tucuruí Hydropower Complex. In 1977, these lands were demarcated by PLANTEL (a private company hired by FUNAI), assuring the *Asurini* a tiny territory of 21 722 hectares, which was ratified in November 1982 (Decree N° 87 845) and registered the following year with the SPU (Union's Patrimony Service) and the Tucuruí Property Registry Office. An area of 14.4 hectares was added to the western border of the Trocará Indigenous Land in May 1990, in a court case filed against a neighbouring rancher who had taken over these indigenous lands to clear them for grazing.

3.7.3.2 The Dam

> *"Located downstream from the Tucuruí Dam, the Asurini was subject to what have been called the indirect effects of the Hydropower Plant, meaning the consequences of the sweeping changes in the social and economic structure of this region, as well as the ecological impacts caused by this Project. The arrival of thousands of people in this town (many of them unable to find jobs with the Project) as well as transfers of part of the regional populace with no fair compensation or resettlement, grew into pressure factors affecting the Asurini lands (*cf. Andrade, 1992*).*

Since work first began on the Tucuruí Hydropower Complex, the *Asurini* have been interacting with this process, whose consequences for them have still not yet been given proper consideration. In 1998 the indigenist advisor of Eletronorte visited the *Asurini* and drew up a report "highlighting the need to carry out further studies on the impacts caused by the Tucuruí Hydropower Complex" (Eletronorte, 1990:185). In August 1989, through correspondence (Letter 001/PMSI No 335/89 dated August 31, 1989), FUNAI requested Eletronorte to set up a working group to study the impacts of the Tucuruí Hydropower Complex on the *Asurini* and establish a support programme similar to that introduced for other groups that the Company considered to be directly affected by this venture (Parakanã Programme and Waimiri-Atroari Programme). The Company argued that "due to budget difficulties" this Project should be postponed to early 1990, at which time Eletronorte wrote to FUNAI, advising it that "it was still not in an administrative and financial position to start the studies" (Eletronorte, idem).

3.7.3.3 The Transcametá Highway

Until 1986, the journey from the *Asurini* village to Tucuruí took two and a half hours by motor-boat, travelling up the Tocantins River; with the extension of the PA-156 Highway (known as "Transcametá" higway), this became almost the only route used – it took forty minutes to reach Tucuruí by road. This overland connection with Cametá was opened during the 1970s, cutting through nine kilometres of the Asurini Reserve. It was only in July 1990 that the *Asurini* learned that the highway was to be extended, when the bulldozers were already gearing up for deforestation. That year, the *Asurini* blocked the highway between kilometres 18 and 29, set fire to two bridges, and demanded compensation for the laying of the Transcametá Highway through their lands, with their losses never having been reimbursed. They waited for these promises to be fulfilled until October, 1990, when they burned another bridge, blocking traffic along this road once again.

In mid-1997, the *Asurini* were once again threatened by yet another "indirect effect" of the Tucuruí Hydropower Complex, through a separate negotiating process involving Eletronorte and a return to topographic work needed in order to string a 69 kV power-line between Tucuruí and Cametá running parallel to the highway, right on the border of the *Asurini* lands. This project had been halted since 1992 when, angry that once again they had not been consulted in advance, the *Asurini* removed the stakes that the surveyors had placed in this area during the topographic survey. In order to avoid the negative impacts of stringing this power-line, the indigenous advisor of Eletronorte proposed that its route be altered, following the border of the Trocará Indigenous Land. This power-line is now in operation.

The demographic rise that occurred among the Asurini – who increased from 191 in 1990 to 253 by June 1997 (according to FUNAI's data) - was not echoed in improving living conditions. The *Asurini* are facing increasing difficulties, due to their limited amount of land and natural resources, on which they depend for survival. Another problem is the ample supply (and therefore low prices) of the products that they gather and sell (regional fruits and Brazil nuts).

3.7.4 "Remaining" 'Gavião da montanha'

Currently living in a single village in the Mãe Maria Indigenous Land (Bom Jesus do Tocantins municipal district) some 30km from Marabá, the so-called "Gavião da Montanha" are a local group of the *Parkatêjê* (a Jê-Timbira speaking-group), also known as the 'Gavião' or 'Gaviões', who have traditionally lived on the right bank of the mid-Tocantins. Until 1983, the members of this group (*Akrãtikatêjê*) were settled in the indigenous area in front of Tucuruí that had been awarded to them by Decree N° 252/1945, which they called "the mountain", after a prominent hill there. In 1983, this became the works-yard for the building of the Tucuruí Hydropower Complex. In 1971, FUNAI shut down the indigenous post that had been established here in the late 1950s to "attract" the much-feared "Gaviões"(Hawks), and provide them with assistance (cf. Arnaud, 1975; Ferraz, 1983, 1998).

From 1975 onward, the "Gavião da montanha" were treated as "remaining" people by the official agents, and were persuaded to move to other areas (including the Kaiapó, in the Xingu River) and the Mãe Maria Indigenous Land, despite rivalries with the group living there (headed by the old and respectful chief *Krôhôkrenhum*). Although limited in numbers, this group was most unwilling to leave the location where it had settled, and was headed by *Rônõre* (today aged around 75), known as "big mama" due to her striking personality, and her son *Paiare*, who remained on these lands.

In the mid-1970s, pressure from the FUNAI agents was stepped up by threats from the representatives of Eletronorte, the State-run enterprise and the sub-contractors who were starting to build the Tucuruí Dam, precisely on the lands of the "Gavião da montanha", which had never been properly recognised as a community as opposed to an indigenous territory (which has a legal sanction) and was declared to be a "public utility" through Presidential Decree in 1976. Despite specific legislation (Law No 6 001/73, known as the Indian Act) that guaranteed the replacement of these lands, many attempts were made by employees of the Company to offer individual compensation to *Paiare* (the oldest son of *Rônõre*) in order to convince him to move away from this location, which had become a works-yard, and was partially invaded by trespassers and squatters. The accounts given by members of this group during this period detail various forms of violence to which they were subject (cf. Ferraz, 1998).

In 1983, during a period of alliances with members of the Mãe Maria group, who took turns to protect *Paiare* and his family, Eletronorte was obliged to take the deep-rooted rights of this group into consideration; however, psychological pressures and threats of physical violence built up, finally forcing *Paiare* to move to Mãe Maria with his family in December of that year.

At meetings - not attended by *Paiare* – between the group and representatives of Eletronorte, as well members of the Mãe Maria group, local and regional agents of FUNAI (which had no powers of decision delegated to it), it was agreed that the lands in question should be replaced by legal means, in addition to a process of compensation for moral and material losses, damages, injury, pain and suffering. Claiming the "unavailability of equivalent lands", Eletronorte agents changed this proposal to an award of rights of the "*Parkatêjê* Community" (the Mãe Maria group) to Eletronorte by means of equivalent cash compensation; amounts were paid and the issue was considered concluded.

Dissatisfied with the procedures adopted both by the Company as well as FUNAI, *Paiare*, as the leader of the directly affected group, sued Eletronorte and the Federal Government in 1989 for compensation, through the Pará State Society for the Protection of Human Rights (Sociedade Paraense de Defesa dos Direitos Humanos) and sought to annul the agreements and compensations. In December 1993, the Federal Courts in Belém, where this case was heard, handed down a decision in favour of Eletronorte. The lawyer representing *Paiare* and his group appealed to have the case transferred to the Federal Regional Tribunal (1st Region, Brasília) before being submitted to the Federal Supreme Court.

Findings

- Although there is no clear-cut policy at Eletronorte for indigenous issues in the Tocantins River region an agreement between Eletronorte and FUNAI (1987) set up the Parakanã Programme, which has had satisfactory achievements in its sub-programmes on healthcare, education, support to economic activities, as well as land protection. However, the three indigenous groups have been handled very differently, with contrasting approaches and resources: for the past twelve years, the Parakanã Programme has channeled funding of some US$500 000/year (on average); the *Asurini* were not taken properly into consideration by the Company; and the "Gavião da montanha" who lost their territory, and were not taken into account collectively, are suing Eletronorte.
- The aim of the Parakanã Programme - to ensure self-sustainability for their activities over a 25-year period - has to be seen in perspective, due to its high human resource costs. Despite the incentive to economic activity, it should be noted that the Parakanã *ethos* is far removed from the demands of "balance between production and consumption" (of industrialized items). Most Parakanã speak only their own language – with the exception of a few members of the younger generation who go to school. This results in eventual misunderstandings with the Programme team, who speak Portuguese. Detailed knowledge of the social organisation systems of Parakanã society (including relationships with tribal elders and the new "working groups", for instance) should be imparted to Programme agents. This should create greater understanding and help establish the strategies of the Programme, which still require independent and systematic appraisal.
- Satisfactory achievements are being observed in healthcare (curing and preventive, tuberculosis and parasitical diseases control, particularly malaria). This has been reflected in a demographic rise. A notable expansion of the Parakanã population has occurred: according to the Programme's agents, the Parakanã had 247 members in 1986, and currently (October 1999) amount to 483 people, distributed in five villages.
- The Parakanã Indigenous Reserve is completely demarcated and free of squatters, although pressures from loggers persist all over southeastern Amazonia.
- The participation of the Parakanã themselves in decision-making processes related to the concept and implementation of this Programme has been limited during the ten (or twelve) years it has been functioning. Many of the activities were undertaken by a sizeable administrative team - 42 people in 1998. This undermines the self-sustainability of the activities of this Programme over the longer term), and the Parakanã are still treated as the object of scheduled actions (sponsored by the Company), rather than as subjects in a historical process. These aspects have been highlighted by a number of experts analysing the relationships engendered by the "impact mitigation" policy for governmental or private projects affecting indigenous lands and societies (cf. Viveiros de Castro & Andrade, 1988; Vidal, 1991, Ferraz & Ladeira, 1991; Santos, 1991, and others).

3.8 Interference with Archaeological Sites

Until the mid-1970s, archaeological knowledge of the region around the Tucuruí Hydropower Complex was limited to some data on the upper Itacaiúnas and Fresco Rivers in the Xingu river basin. This consisted of ceramics belonging to the Tupiguarani and Polychrome Traditions, stored at the Gothenberg Museum and collected by Nirnumendaju at Nazaré dos Patos, downstream from the dam. Archaeological surveys in the Lower Tocantins archaeological region under the National Archaeological Survey Programme for the Amazon Basin (PRONAPABA - *Programmea Nacional de Pesquisas Arqueológicas na Bacia Amazônica*) were launched in 1976 by the archaeological staff of the Emílio Goeldi Museum, covering the stretches between Santa Terezinha do Jamari and Tucuruí, and Tucuruí to Cametá.

In 1977, an archaeological rescue project was launched in the area to be flooded by this dam, under an agreement between the Emílio Goeldi Museum and Eletronorte, with the latter assigned responsibility for providing logistical support to the field work undertaken by the technical teams.

Surveys focused on the sector above the town of Tucuruí that was to be flooded by the dam. These surveys were carried out in three stages between 1977 and 1984, identifying and studying 34 sites, most of which were classified as ceramic habitation sites. Of the total number of sites studied, two were stone workshops and another was a Parakanã village that had been occupied until around 1920.

Most of the sites lay upstream from the Tucuruí Hydropower Complex, while others were located in areas alongside the old Tucuruí-Jacobal railroad and the Tucuruí-Cametá highway. Ceramic and stone artefacts were gathered from 33 sites, with stratigraphic cuts made wherever possible in layers 10 centimetres deep and cut down to stable soil, measuring 2 x 2m with a maximum depth of 90 centimetres. However, no proper excavations were carried out at most of these sites. Over 47 000 ceramic items were collected, including vases and shards. Stone specimens totalled some 4 500 items, including artefacts and chips.

Despite the chronological and cultural gaps in the ceramic series, the reconstitution of the history of autochthonous communities of the last millennium was partially completed, particularly the Ceramist culture. These gaps clearly indicate the need for more research and surveys, in order to include studies of prehistoric and pre-ceramic cultures that must necessarily have existed here, but were not represented at the limited number of sites studied by the staff of the Emílio Goeldi Museum.

Findings

- Archaeological surveys began in this region in 1976, gathering material in the reservoir area and downstream sites until filling began in 1984;
- Despite the chronological and cultural gaps in the ceramic series, the reconstitution of the history of autochthonous communities was partially completed in terms of the last millennium, represented by the Ceramist culture.

3.9 Interactive and Cumulative Effects on the Basin

The interactive and cumulative impacts are the repercussions of impacts of the dam within the river basin. The repercussions of the Tucuruí Hydropower Complex and its effects on the river basin can be noted in its interventions in the Tocantins River, with regard to socio-economic and environmental interactions as well as the use of its hydropower potential.

Very little concern was voiced at the time of the decision-making process (cf. Chapter 6), apart from questions about the potential use of hydropower and possible alterations to water flow downstream. Regarding the first concern, the decision was to make the largest and the closest to the great consumers venture possible. About the second concern, a very large spillway would allow sufficient flow to prevent problems such as seawater intrusion in the localities closer to the mouth of the basin, especially Belém. After the decision-making process, some other considerations arose more clearly in studies carried out by INPA and other institutions, such as the interruption of the fish movements alongside the basin and water quality problems due to the degradation of organic matter. (Cf. Section 3.5).

The only occasion when other uses for the waters of the Tocantins and the Tucuruí reservoir were considered was the inclusion of the lock construction project, that would allow shipping to travel along this stretch of river (which was previously impassable because of the Itaboca rapids at the damming site). This project was not covered by government analyses in the initial studies for the Tucuruí Dam, and was introduced only when the power plant was already at the Feasibility / Basic Project Design stage. As was pointed out in Section 3.5 and Chapter 6, the locks system construction was (and still is) the subject of lengthy discussion and was finally put off until Phase II.

In terms of hydropower production, it is noted that the inventory studies of the Tocantins and Lower Araguaia Rivers undertaken in earlier decades guided the current drop division scheme for making good use of the power potential of this basin, as shown in Figure 3.17. Tucuruí, as the plant located furthest downstream, played a major role in the selection of future upstream sites. Aside from Tucuruí, other power plants operating in this area include Serra da Mesa, with the Luiz Eduardo Magalhães complex currently under construction at Lajeado. It should also be stressed that short-term strategic planning for the power sector (Ten Year Plan: 1999 - 2008) scheduled the following power plants for the Araguaia-Tocantins River Basin, most of them on the main course of the Tocantins, upstream from Tucuruí.(Table 3.41):

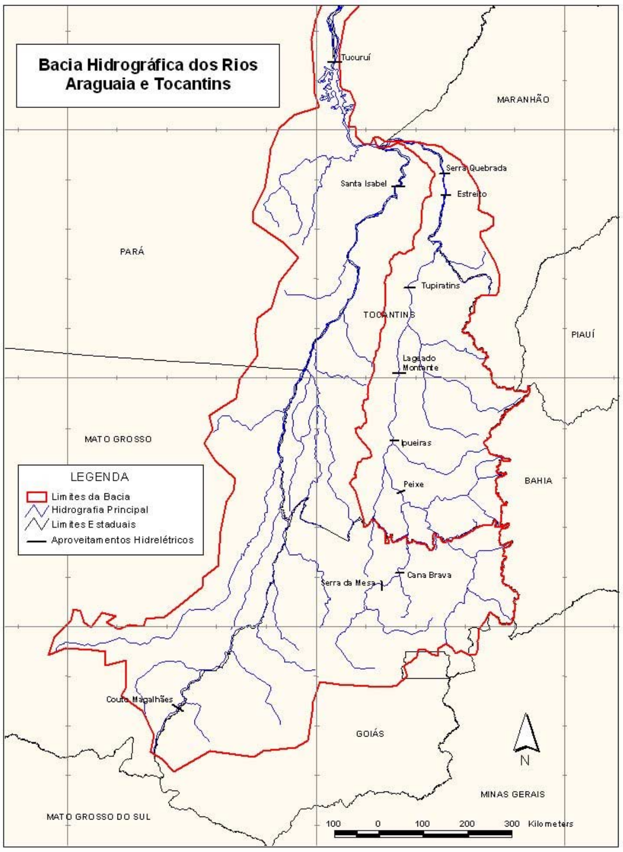
Table 3.41 Hydropower Plants planned for the Araguaia – Tocantins Basin

Power Plants	Basin Area	Power (MW)	Start-up of operations
Lajeado	Mid Tocantins	850	December 2001
Canabrava	Upper Tocantins	450	July 2002
Tucuruí Phase II	Lower Tocantins	4 125	December 2002
Serra Quebrada	Mid Tocantins	1 328	June 2006
Estreito	Mid Tocantins	1 200	October 2007
Couto Magalhães	Upper Araguaia	220	January 2008
Peixe	Upper Tocantins	1 106	February 2008
Tupiratins	Mid Tocantins	1 000	February 2008

Source: Eletrobrás – Ten Year Plan 1999/2008

This programme schedules the consecutive and even simultaneous construction of several large-scale power complexes in the Tocantins Basin, particularly along its middle reaches, where the Lajeado, Serra Quebrada, Estreito and Tupiratins power plants are all planned to be located in Tocantins State. While this programme will maximise the synergies deriving from the construction processes, it will probably result in sweeping changes to pre-existing social and environmental conditions, over a short period of time.

Figure 3.17 Hydropower Plants Planned for the Tocantins -Araguaia Basin



Source: CEPEL

Findings

- The cumulative impacts must take into account future hydropower complexes planned for the Basin
- Tucuruí is the furthest-downstream hydropower plant planned for this Basin
- Besides Tucuruí, Serra da Mesa Hydropower Complex (1 275MW on the Upper Tocantins) is already in operation in the Basin
- The Luiz Eduardo Magalhães (formerly Lajeado) Hydropower Complex is currently under construction on the mid-Tocantins, with the start-up of operations scheduled for December 2001 (850MW) in addition to Phase II of Tucuruí (4 125MW, scheduled for December 2002).
- Projects planned for the short/medium term in the ten-year plan – 1999/2008:
- Mid Tocantins: Serra Quebrada (1 328MW, scheduled for June 2006)
- Estreito (1 200MW, scheduled for October 2007)
- Tupiratins (1 000MW, scheduled for February 2008)
- Upper Tocantins: Canabrava (450MW, scheduled for July 2002)
- Peixe (1 106MW, scheduled for February 2008)
- Upper Araguaia: Couto Magalhães (220MW, scheduled for January 2008)

- The implementation of these dams over a short time period will probably introduce sweeping changes in the pre-existing social and environmental conditions
- The existence of Tucuruí influenced the site selection and sizing of upstream hydropower plants
- Outstanding among the main impacts in the basin associated with damming the river along the downstream stretch are:
- Alterations in the hydrological system due to the operating rules of Tucuruí
- Shipping: Phase I – The interruption of small-scale shipping through the Itabocas Rapids; Phase II – Access for larger vessels through the lock; the first step towards setting up a waterway on the Tocantins
- Fish-life: The blocking of migratory flows between the lower and mid Tocantins
- Intervention in the operating rules of future dams

3.10 Regional, National and Global Effects

It is no easy task to define the effects of the Tucuruí Hydropower Complex at the regional, national and international levels. The first reason for this is that the studies carried out so far have shown little concern with its effects at the national and international levels, focusing only on regional repercussions. Secondly, the methodologies of environmental studies undertaken at the regional level during the construction of the Tucuruí Hydropower Complex didn't allow for any definition of the area of direct influence of this project, as this definition was only reached after the reservoir was filled. Thirdly, it is beyond the scope of this study to undertake a detailed field survey to define this aspect, in addition to the use of a multiplicatory effect methodology for which no data are available.

In general terms, the regional, national and international areas of influence of the Tucuruí dam were defined by the assumption that its core objective was the production and supply of energy, in parallel to changes in spatial organisation.

3.10.1 Effects at the Regional Level

3.10.1.1 Transformations in the Organisation of Space

There is some difficulty in defining the region in question. The usage of the energy generated defines the regional area of influence, namely Eastern Amazonia, with the sub-regional level corresponding to the direct area of influence of the Tucuruí Hydropower Complex.

Two major structural alterations have been caused by this project. At the regional level, there have been alterations to production structures through the introduction of modern industrialisation processes, in an area dominated by an extractivist economy. The mining and metallurgical industries that are directly linked to the presence of this power complex are based on a model of huge enclaves that have little interconnection with their surroundings. Nevertheless, these hubs can certainly influence urban growth and the expansion of small-scale industries, particularly in Belém.

In the sub-region, structural changes took place at the community level, following an intensive urbanisation process in an extractivist forest area. Paradoxically, this urbanisation was not accompanied by energy consumption and industrialisation. Negative social and environmental impacts are associated with these structural changes, as outlined previously.

Once the reservoir was filled, its area of influence was initially divided into four categories (Eletrobrás, 1986), though not following any methodological or conceptual framework. In 1991, the Eletronorte Environment Department drew up the Dynamics Plan for the Tucuruí Geo-Economic Region (Plantuc / RGT - *Plano de Dinamização da Região Geoeconômica de Tucuruí*) which reclassified lands affected by this project. Under this Plan, the Tucuruí geo-economic region would consist of parts of the micro-regions of Marabá and the Lower Tocantins, according to the division established by the Brazilian Institute of Geography and Statistics Foundation (FIBGE – *Fundação Instituto Brasileiro de Geografia e Estatística*).

As already noted (Eletrobrás, 1992), it is difficult to assess the regional effects of the Tucuruí Hydropower Complex using these criteria, as these two micro-regions have been subject to a process of continuous change since 1970, when the scheduled infrastructure network associated with settlement policies for this region began to emerge. All these interventions – Transamazon and PA-150 highways, settlement programmes, large-scale private farming and ranching projects, the Greater Carajás Programme, mining ventures, wood extraction, sawmills and steelmills – triggered a massive migration process with rapid urban growth and changes in the allocation and use of land in Southeast Pará State, Western Maranhão and Northern Tocantins. It is impossible to pinpoint the specific influences and impacts of the Tucuruí complex on this scale, as it was merely one element in the scheduled network. However, as noted above, it should not be forgotten that this power generation complex was the key factor behind the arrival of industry in this region.

3.10.1.2 Power Supplies

One of the most perverse aspects of the history of the Tucuruí Hydropower Complex, (other than the forced removals of communities) has been its failure to supply power to local communities. Its initial power generation was fully and selectively absorbed by major industrial consumers in Northeast Brazil, as well as some towns in Pará, including Belém and Marabá. Regional power supplies expanded very slowly. In the 1985-1991 period, 75% of the energy was absorbed by industry and 25% by the by the Pará, Maranhão and Tocantins State power concessionaires. At present a proportional reduction in the power consumption of the large industrial consumers can be noted, owing to the power demand expansion of other sectors and, more recently, the Tucuruí – South/Southeast system interconnection.

The transmission lines carrying power generated at Tucuruí cut through vast swathes of land which they do not benefit. This tightly-concentrated power consumption was diffused only in 1999, when these power-lines were extended to Altamira, Santarém and Itaituba, where they were warmly welcomed.

Hence a regional energy source initially supported regional industrialization following the Great Projects model, and then, slowly and secondarily, served an important regional power demand, especially in its major centers.

This defines the Tucuruí Hydropower Complex as a venture with little commitment to the municipalities in its own surroundings. Its positive effects in terms of power production are seen in Eastern Amazonia, Brazil in general and trans-national enterprises.

Currently, 97% of the energy consumed in Pará State, 99.9% of the energy consumed in Maranhão State and 40% of the energy consumed in Tocantins States is generated by the Tucurui Hydropower Complex, which reflects the regional importance of this Project. Today, the highest consumption levels are found at ten locations in Eastern Pará State (Table 3.42).

Table 3.42 Regional Consumption (MWh)

Items	Year		
	1984	**1998**	**1999**
Belém	777 838	1 622 858	1 633 851
Ananindeua	44 662	225 500	238 325
Santarém	64 202	133 745	150 519
Marabá	35 448	117 631	125 300
Castanhal	33 085	92 506	100 048
Barcarena	2 517	83 018	89 213
Paragominas	9 394	66 035	71 199
Capanema	53 093	71 884	69 420
Altamira	16 071	35 279	47 221
Redenção		38 980	43 564
Total	**1 036 310**	**2 487 436**	**2 568 659**

Source: Eletronorte.

3.10.2 Effects at the National Level

The greatest influence of the Tucuruí Hydropower Complex is noted at the national level, due to its position in the Eletronorte/Eletrobrás grid.

Ever since it was decided to build a large-scale power plant to service the mining and metallurgical industries, the interconnection of power grids in North and Northeast Brazil was viewed as a national project, as the completion of the basic infrastructure for the grid circuit was a key strategy. However, regional integration did not stop there, as the Tucuruí Hydropower Complex soon took on an important role in supplying power to Southeast Brazil, which has the most dynamic economy in the country.

The North / Northeast interconnected transmission system was inaugurated in 1981, running on alternating current. The future Tucuruí Hydropower Complex was linked to the electricity system in Northeast Brazil by a power line running 1 800km between Belém and the Sobradinho power plant in Bahia State. This initially operated in the opposite direction while Tucuruí was being built, carrying power from the Northeast to the North for the Albrás and Alumar aluminium smelters; it also supplied Belém, whose massive repressed demand could no longer be handled by thermo-power plants, owing to technology or cost constraints.

This transmission line and the Tucuruí Hydropower Plant resulted in a single electricity system covering Eastern Amazonia and Northeast Brazil. In 1979, the first National Plan was drawn up for the power sector – *Plano 95* – which for the first time described two interconnected power systems for Brazil: South/Southeast/Centre-West and North/Northeast. The II National Plan, which was published in 1982, scheduled important projects that expanded the capacity of these large-scale regional interconnections. It also presented the interconnection project for the North and Southeast systems for the first time, with its completion scheduled for 1996 – 2000 (Peiter, 1996).

The Tucuruí Hydropower Complex became a key link in supplying the Brazilian energy market, through interconnecting the North/Northeast and now North/South/Southeast/West-West systems.

3.10.3 Effects at the International Level

While the expansion of the economic frontiers of Amazonia and the Tucuruí Hydropower Complex are closely associated with regional policies, they should also be viewed as part of the globalisation process in terms of both their results and support (Pinto, 1982; Neto, 1990). Their primary global effect was to ensure a steady supply of ores to large-scale ventures.

The emergence of the mining and metallurgical complex in Eastern Amazonia, in which the Tucuruí Hydropower Complex played a central role, has fostered the globalisation process in at least three ways:

- One has already been mentioned, and consists of attractively low-interest loans offered by leading international banks. Swamped by petrodollars and with limited investment possibilities due to economic crises in core nations, the banks found an alternative outlet through making loans to peripheral countries, including Brazil. This trend consolidated the international links that to a large extent financed the implementation of the "scheduled infrastructure network" in Brazil. The sudden hike in international interest rates during the early 1980s strengthened the globalisation process even further by deepening the foreign debt. It is difficult to distinguish between the loans on a case-by-case basis. Some examples in the area under study are World Bank loans, schemes associated with the Carajás Iron Ore Programme, French interests in Tucuruí etc.
- The second factor – which has not been studied or discussed in much depth – is the trans-nationalisation process of the State-run mining giant Companhia Vale do Rio Doce (CVRD), which played a leading role in the implementation of the mining and metallurgical complex. The presence of CVRD in Amazonia (previously operating only in Southeast Brazil) not only created a Brazilian base for negotiating with the trans-nationals but also added a Brazilian base tied to the mining industry. Aside from Alumar (controlled by Alcoa-Billiton), it is the major shareholder in all joint-venture mining enterprises in Eastern Amazonia, which are totally international: Mineração Rio Norte (46%); Albras (51 %); Alunorte (60.8%); and Carajás (100%). During this investment process, it emerged as the world's largest iron ore producer and exporter, with massive investments in Alaska and Asia as well (Becker, 1990).
- The third factor is the eagerness of major powers and/or corporations to invest in Amazonia, as part of the process of shifting electricity-intensive industrial and mining operations to peripheral countries and regions (Pinto 1982; Neto, 1990).

In the case of iron and manganese, a number of US multinationals have become involved, including Union Carbide through Codim and US Steel through Meridional, due largely to concern over uncertain manganese supplies. Precarious supplies also prompted much interest from Alcan, Canada's trans-national aluminium producer, due to the nationalisation of mining companies in newly-independent Guyana in 1966, where the main Alcan bauxite mine was located. This prompted the establishment of the Mineração Rio do Norte mining company on the Trombetas River, as a joint-venture with CVRD and other multinational mining groups.

The Japanese also moved into aluminium production here. When oil-fuelled operations were affected by the 1973 crisis, they began to invest in countries with abundant power supplies and cheap bauxite, such as Australia, Indonesia and Brazil. The Japanese Government strategy encouraged industries to set up *ad hoc* consortia with equal stakes for projects outside the country, thus increasing its bargaining clout. After years of lobbying and negotiations, the Brazilian government was finally forced to bow to Japanese pressures for Alunorte – Alumina do Norte and Albrás – Alumínio do Brasil (a joint-venture between CVRD and the Nippon Aluminium Company). The heaviest demands consisted of the infrastructure – Tucuruí Hydropower Complex, port and towns – for both plants, powered by electricity generously-subsidized by Albrás.

In 1976 and 1977, Tucuruí was financed by a group of French industries and financial institutions, on the condition that it used a significant amount of French goods and services (Neto, 1990). However, due to a lack of other foreign funding, these costs were borne by the Brazilian Government, which was already embroiled in crises, and this delayed the project.

Also, the consultants for the study commissioned by CVRD to assess the potential investments in mining and agriculture in Eastern Amazonia were also Japanese, as this nation had the greatest interest in obtaining low-cost commodities. This later resulted in the Greater Carajás Programme (PGC - *Programa Grande Carajás*, 1980) which grew into a national / regional development programme, including all previous projects and seen by the Government as able to support mining and metallurgy projects through exports, while also rolling over the foreign debt. The Greater Carajás Project was financed by the World Bank, together with European and Japanese institutions, channelling a total of US$1.7 billion into the Carajás Iron Ore Project during the first half of the 1980s. This development continued steadily, despite the foreign debt crisis, thanks to low-cost ten-year iron ore supply contracts signed by CVRD with steel producers in Europe and Japan. A pool of 23 Japanese financial institutions headed by Jeximbank financed Albrás, and two-thirds of the capital costs of Tucuruí (US$4.6 billion) were financed abroad (Greater Carajás Programme, 1985).

By stressing the high costs and financial risks of mining and metallurgical activities, the Brazilian government entrenched the role of multinational corporations in Amazonia. They invested in Brazil, attracted by its political stability, natural resources and supportive approach to large-scale industry. From the international standpoint, the reasons for this trend varied from uncertain supplies and the establishment of production cartels, to constraints on energy and a widespread concern with securing low-cost global ore supplies (Neto, 1990), This was certainly achieved.

Findings

- Studies undertaken have not examined the national and international level, and focus instead on regional dynamics.
- There was a lack of definition of the areas of influence during implementation studies

REGIONAL LEVEL

- Introduction of the modern industrialisation process (mining and metallurgy) in an area dominated by an extractivist economy
- Enclave model that influenced urban growth and the expansion of small-scale industry, particularly around Belém.
- Expansion of urbanisation in an extractivist forest area, not accompanied by increased energy consumption and industrialisation.
- Tucuruí is an important part of the process of boosting the dynamics of this region, which also includes projects such as the Transamazon and PA-150 highways, the Greater Carajás Programme with mining ventures and steel-mills, large-scale private farming and ranching projects, etc.
- It is not possible to separate the specific influences of Tucuruí from those of other projects in this region, such as Carajás.
- Power supplies generated at Tucuruí were initially earmarked mainly for use outside the region

NATIONAL LEVEL

- Interconnection with the North/Northeast system through the power-line running between Tucuruí and Sobradinho (1981)
- Interconnection with the South/Southeast system through the power-line running between Tucuruí and Serra da Mesa (1998): serving the South/Southeast markets during critical moments in the hydrological cycle.

INTERNATIONAL LEVEL

- Power supplies for major mining and metallurgy projects (aluminium)
- Inclusion in the initial stages of the economic globalisation process
- Strengthening the role of multinational corporations in Amazonia

3.11 Summary of Projected, Observed and Unexpected Impacts

This section contains a summary of the main projected, observed and unexpected impacts of the implementation of the Tucuruí Hydropower Complex. An analysis of these impacts reveals some key polarisations.

The first polarisation has been the encouragement and primacy of technical efficiency, in contrast with the inept handling of social aspects associated with this venture. Building a huge power complex in the heart of the rainforest demanded considerable trail-blazing technical efforts by Eletronorte, unsupported by local or international experience. Although the project was successful at the technical level, encountering no major problems, it was certainly not successful in terms of experience of the local populace. Local communities did not participate in the taking of decisions and were poorly informed about interventions, both planned and underway. They were subject to wholesale resettlement, and the relocation programmes were partly responsible for creating the conditions that resulted in vigorous grassroots resistance and social participation movements that had a strong impact on decisions taken during the 1980s.

A second polarisation can be observed in the actual functioning of the power plant. Initially planned to supply energy to the towns of Eastern Amazonia, it developed into a supplier of huge mining and metallurgical projects geared towards exports. The Tucuruí hydropower project brought sweeping changes in the regional economy, notably a shift from agriculture and extractivism to modern industry. However, these alterations did not benefit the region sufficiently to outweigh the the negative impacts associated with the shattering of traditional production systems in the urbanisation process.

Finally, contradictory views should be noted regarding the environmental impacts of the Tucuruí Hydropower Complex. Expressed primarily in statements from the local populace and the arguments of Eletronorte, these contradictions involve a far larger spectrum of players. Eletronorte shares the positions of the Federal and State governments, industries and regional elites, including the political class. Grassroots movements started by dam-affected people have attracted supporters in the church (initially Roman Catholic, and subsequently others), trade unions, and left-wing political parties, particularly the Workers Party.

Table 3.43 below presents the list of projected, observed and unexpected impacts identified:

Table 3.43 Projected, Observed and Unexpected Impacts Identified

Impacts	Projected	Observed	Unexpected
Project Costs without interest **(10^3 US$ 1998)**	4 048 000	5 531 189	
Formation of Reservoir	Area flooded: 1 630 km^2	Area flooded: 2 800 km^2	
	Formation of 600 islands	Formation of 1 660 islands	
			Increase in submerged areas as the reservoir was formed
			Isolation of the riverbank populace with the filling of the reservoir
			Double relocation
			Financial compensation under the Royalties Law for municipal districts with flooded areas
			Internal migration, especially of the downstream populace
			Irregular, disorderly settlement
			Conflicts of use
			Lack of infrastructure
			Swarms of mosquitoes
			Risk of outbreaks of

Impacts	Projected	Observed	Unexpected
			waterborne diseases
Operating Rules	Downstream flow regulation	Occurred as planned	
			Commitment with the floodland culture
Shipping	Extension of navigable stretches of the Tocantins River	Not implemented – lock not built	Since the lock was not built, the river is not navigable, even by small vessels.
Logging	Basic Project planned to clear 120 000 hectares	37 000 hectares	
			More intensive predatory logging activities
Water Quality	Development of water plants, both floating and emergent, in some regions of the lake	Forecasts were confirmed. There seems to be a long-term tendency for the infested areas to stabilize	
	Drop in oxygen concentration in the reservoir in the period immediately after the lake was filled	Temporary depletion of dissolved oxygen, especially downstream	
	Commitment to supply water and food downstream while the dam is being filled	Wells opened	Wells functioned for a short time
	Downgraded water quality downstream		
	Saline seepage near Belém	Not implemented	
			Risk of outbreaks of waterborne diseases
Fish	Appreciable drop in upstream catch	Not implemented	
	Structural changes in composition of fish-life	Qualitative modifications were observed (disappearance of various species in the lake area) as well as quantitative (variations in quantities of some commercial fish species)	
			Loss of fishing areas downstream, with reduction in fish stocks
			Appearance of huge shoals of fish in the lake
Biodiversity	Loss of endemic species & genetic inventory	No reliable data	
	Impacts on animal life in the areas to be flooded		The number of animals that died while the reservoir was being filled is unknown, as is the impact of the release of animals on the resident population, on the release area and on the banks of the reservoir
Micro-Climate	Appreciable alterations in local climate caused by formation of the reservoir	Not observed in the expected proportions	
Global Climate	No effects expected		Greenhouse gas emissions that were beyond scientific knowledge at the time of the decision-making process
Micro-Climate	Appreciable alterations in local climate caused by formation of the reservoir	Not implemented in the proportions planned	
Global Climate			Greenhouse gas emissions
Mandatory Community Relocation	Relocation of 1 750 families (9 500 persons)	Relocation of 4 407 families, with 3 407 on rural land and 1 000 on urban plots	
			Resettlement in inadequate areas (soils unsuitable for agriculture)
			High rates of land abandonment and land sales
			Pressures on local land ownership structure
			Breakdown of social &

Impacts	Projected	Observed	Unexpected
			economic organisation
			Conflicts of interest & grassroots mobilisation
			Process of emigration to other areas, mainly to the islands
Epidemiological Profile	Proliferation of mosquitoes / increase in the number of malaria cases	Increase in the number of malaria cases	
			Swarms of *Mansonia* mosquitoes
			Risk of mercury methylation & introduction into the food chain
			Higher risk of waterborne diseases
			Increase in the risk of new diseases appearing, including arboviruses
Urban infrastructure	Expansion of basic services infrastructure at Tucuruí and re-settlement areas	Demand outstripping supply of basic social services	Plots abandonment in resettlement areas
Indigenous Communities	Resettlement of communities	Resettlement of Parakanã Community	Breakdown of social relationships among indigenous communities in the Tucuruí region
International Economy	Support for global aluminium industry at low cost		
National Economy	Amortisation of foreign debt	Insufficient	High cost due to pressures and concessions to international partners
Regional Economy	Availability of power for industry	Production of power for exports	Supply of selective power without serving the local populace
	Industrialisation	Changes in agri-extractive production structure to industry	Disorderly urbanisation
	Trans-nationalisation of State-run enterprises		Nationwide power supplies
	Expansion of mineral-metallurgy industry		
	Job generation		Intense migration
Local Economy	Job generation	Offer of postings beyond the workforce attracted to the region	Intense migration
	Reduction in productive fishing grounds	Downstream	Increase in fish stocks in the reservoir
		Changes in agri-extractive production structure	Decline in traditional production and economic stagnation, particularly downstream
			Disorderly urbanisation
			Commercial fishing in the reservoir
			Conflicts between subsistence and commercial fishermen
			Drop in production through traditional activities developed in the *várzea* floodlands by the local farmers
			Conflicts of interest due to revaluation of the land
			Expansion of predatory logging
			Conflicts over land ownership
			Disorderly urbanisation
			Intense migration
Cultural and Archaeological Assets	Flooding of archaeological sites	34 archaeological sites identified and studied	

4. Distributional Effects of the Tucuruí Hydropower Complex

4.1 Preliminary Effects

The intended distributive effects of national and regional development soon became apparent when it was decided to build a power plant to sustain the development of the local mining and metallurgical industry.

The main "beneficiaries" of this process would be huge international aluminium industries (in Japan, Canada and the USA) and Companhia Vale do Rio Doce; this would have marked consequences for the national and regional economies. At a secondary level, Northeast Brazil would benefit initially from the power supplied by the Tucuruí hydropower project, initially to the towns of Belém, São Luiz and Marabá, and later Eastern Amazonia.

At the time of the decision-making process the Federal Government technicians believed that the local populace would experience no net losses or gains, as communities would be compensated and be properly relocated. It was envisaged that there would be no losers in the project.

4.2 Actual Effects

The projected gains for major industries were confirmed, but without the positive effects expected for the national and regional economies. Pressure from its international partners forced the Brazilian government to make concessions to industry, notably the setting of low energy prices - and this adversely affected economic gains at the national level, with limited returns materialising for the region. The power supply functions of the Tucuruí complex expanded rapidly, as it grew into a key link in Brazil's hydropower system and consequently the national economy.

Regional power supplies were limited to the towns originally planned. It was only in 1998 that the Tucuruí *Linhão* power-line reached the towns of Altamira, Santarém and Itaituba.

The main "losers" were various sectors of the local population – small farmers, indigenous communities and riverbank dwellers – who were subjected to iniquitous relocation and resettlement processes with inadequate compensation payments, and suffered considerable material and cultural losses. It should be noted that this process was not homogenous: the downstream populace was not offered mitigatory measures, while the Parakanã indigenous community was awarded a broad-ranging programme offering reimbursement for damages caused, and major land-owners in the Caraipé valley were properly compensated.

4.3 Costs and Benefits Distribution Grid

The grid presented below (Table 4.1) establishes the links between the various social and environmental effects, and social segments that benefited or suffered through the implementation and operation of the Tucuruí Hydropower Plant, listed by region.

Table 4.1 Costs and Benefits Distribution Grid

				Local												Regional				National		International	
				Reservoir								Downstream											
			Group or Area	Farmers	Riverbank communities	Townships	Island communities	Indigenous communities	Relocatees	Fishermen	Tourism & recreation	Farmers	Riverbank communities	Townships	Fishermen	Energy concessionaires	Urban Populations in regional hubs	Mining & Metallurgical Industries	Logging Industry	Major Cities	National Population	Global Aluminum Industry	Global Community
Benefits or Winners	Benefits of the Project	Values - direct use	Electricity			*								*			*	*	*	*	*		
			Flow Regulation									?	*		*								
			Larger Catches		*		*	?		*	*												
			Recreation		*	*	*				*						?						
		Impacts on ecosystems	Avoided Local Air Pollution														*						
	Indirect economic & social benefits		Electricity Rates													*							
			Indirect Economic Impacts	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
			Access to social services	*	*	*	*	*	*	*		*	*	*	*								
			Logging			*	*												*				
			Alterations in Production Structure	*		*								*			*	*	*				
			Job Generation			*								*			*	*	*	*		*	
Compensatory Measures				*	*	*		*	*				*	*		*							

** - impact observed*
? – No sufficient information available

(This table continues on the following page)

Costs and Benefits Distribution Grid (*cont.*)

		Group or Area	Local – Reservoir: Farmers	Riverbank communities	Townships	Island communities	Indigenous communities	Relocatees	Fishermen	Tourism & recreation	Local – Downstream: Farmers	Riverbank communities	Townships	Fishermen	Regional: Energy concessionaires	Urban Populations in regional hubs	Mining & Metallurgical Industries	Logging Industry	National: Major Cities	National Population	International: Global Aluminum Industry	Global Community
Costs or Losers / Payers	Project Costs	Construction													*							
		Implantation of Infrastructure													*							
		Resettlement													*							
		Compensation													*							
		Logging													*			*				
		Operation													*							
		Debt Generation													*					*		
	Functions of the Ecosystem & Biodiversity	Mosquitoes & changes in epidemiological profile	*	*	*	*	*	*	*	*	*	*	*	*								
		Proliferation of aquatic macrophytes		*		*			*	*												
		Changes in nutrient flows	*	*					*		*	*		*								
		Alterations to habitats		*			*		*		*	*		*								
		Losses through Smaller Catches										*		*								
		Biodiversity	*	*	*	*	*	*	*	*	*	*	*	*	?	*	*	*	*	*	?	*
		Drop in Water Quality		*					*	*	*	*	*	*								
		Effects on Climate	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Indirect Economic & Social Costs	Cultural Heritage	*	*	*	*	*	*	*	*	*	*	*	*						*		*
		Relocation and Resettlement					*	*														
		Intensive Migration			*	*		*					*			*						
		Forced Social Changes	*	*	*	*	*	*	*		*	*	*	*								
		Unemployment after shut-down of works-yard			*								*			*						
		Alterations in Production Structure	*	*	*	*	*	*	*	*	*	*	*	*								

** - impact observed*
? – No sufficient information available

Findings

PROJECTED

- Beneficiaries: major international aluminium industries, CVRD, national and regional economies, towns of Belém, São Luiz, Marabá and others in Northeast Brazil supplied with energy from Tucuruí.
- Local populace would not experience any net gains or losses, as it would be compensated and/or relocated properly.

OBSERVED

- Major industries clearly benefited.
- The benefits projected for the regional economy did not materialise on the expected scale.
- Energy prices remained low due to pressures from large-scale consumers.
- Tucuruí became an important link in the national hydropower system.
- Energy supplies at the regional level were somewhat curtailed.
- Some segments of the local populace lost out through the inadequate compensation/resettlement process.
- Compensation/resettlement processes were enforced in a variegated and sometimes contested manner - for instance the downstream populace was neglected.

5. Assessment of Options and the Decision-Making Process

Drawing on the impacts associated with the implementation of the Tucuruí Hydropower Complex identified in previous chapters, this chapter offers an overview of the decision-making process governing this venture. Section 5.1 discusses the historical context in which this venture was set, presenting two views: the first focussing on the geopolitical context, and the second on the development of Brazil's electricity sector. Sections 5.2, 5.3 and 5.4 present the decision-making process during three phases of the Project: planning and evaluation, detailed designs and construction, and operations and management.

5.1 Historical Context

The conceptualisation and implementation of this power plant took place within the historical context of late 1960s to early 1980s Brazil, and was characterized by the interaction between global economic factors and a national project implemented by vigorous state intervention. At the global level, the recession of the 1970s is particularly noteworthy, along with sharply increasing oil prices, which had dual consequences for Amazonia and Tucuruí. Firstly, there was a transfer to marginal economies of primary mining activities, particularly electricity-intensive industries. Secondly, the availability of international loans at low interest rates stimulated third world investment.

At the national level, a socially exclusive policy was deliberately introduced by an authoritarian military regime, which presented geo-political projects as the best strategy for the rapid modernisation of Brazilian society and territory. This was deemed vital to achieving economic growth, strengthening the state and boosting the international profile of Brazil.

The quest for technological autonomy and the instrumentalisation of geographical space were key elements in this project. Brazil's two National Development Plans – PND I and II (*Planos Nacionais de Desenvolvimento*) established the guidelines for a conservative wave of modernisation, fostering: (i) the technological development of agriculture, particularly under the II National Development Plan (1975/1979), after the first oil crisis in 1973, the shift of the dynamic core of the economy from durable consumer goods to semi-finished production goods and capital goods, which was shaped by foreign debt and rising exports; and (ii) a rapid national integration, implying the definitive inclusion of Amazonia.

A two-tier technical and political control grid known as the "scheduled network" was imposed on Brazilian territory, designed to sweep away the material, political and ideological obstacles that blocked modern capitalist expansion (Becker, 1990). This was implemented mainly through extending all infrastructural networks to form complete national circuits – roads, telecommunications, energy, and urban facilities – while channelling investments to newly-established growth hubs. This project was also sustained by the large-scale historical mobilisation of the Brazilian populace, which was experienced nationwide due to poverty and repressed wages. Thrown out of work by the modernisation of agriculture and lacking land due to highly-concentrated property ownership patterns, hordes of farm labourers were drawn to these dynamic hubs.

The rapid settlement of Amazonia on a vast scale became a top priority in economic and geo-political terms, as this region was seen as a new frontier that could absorb social tensions, provide fresh resources, expand the domestic market and boost the influence of Brazil in South America. The speedy introduction of the "scheduled network" components of grids and hubs, subsidies for capital investments, and incentives for migration, all ensured the feasibility of rapid settlement of this region, whose frontiers were pushed outward from the Eastern edge of the rainforest.

Due to the economic crisis triggered by the first oil price hike, which worsened during the 1980s following the second oil crisis in 1979, as well as the sudden upsurge in interest rates on the international market, attempts were made to maintain economic growth through exports - by attracting foreign investment, expanding and trans-nationalising state-run enterprises. Under this new strategy, government policy stressed the comparative advantages of Amazonia for exporting products in sectors considered dynamic by the international market, particularly ores. This regional policy implemented by conventional government agencies was succeeded by huge mining projects absorbing massive investment. These consisted of joint-ventures between state-run enterprises and trans-national corporations, and were often managed by global stakeholders. (Becker, 1990).

This is the context surrounding the construction of the Tucuruí Hydropower Complex, during the period between the inventory and feasibility studies (1972) and its inauguration in 1984. In itself, this was a large-scale project to provide energy for massive aluminium production projects and encourage regional industrialisation, while also building up inter-regional links, and even producing power to supply the national Brazilian market. The 2010 Plan drawn up by ELETROBRÁS made provision for the building of 79 Hydropower Plants by 2010, many of them in Amazonia.

During the period in which major projects like Tucuruí were being inaugurated, the authoritarian government was being undermined by economic, fiscal and political crises, and challenged by the appearance of new social players in the regional context.

It became clear that regional policy was not linear and consistent during this period. On the contrary, in order to reach the project targets in these international and domestic conditions, the government would have to implement a series of fast and effective changes to the strategies for various phases, assigning different weights to their components. During this process, the significance of building a large-scale hydropower plant in this region also varied considerably.

5.1.1 The Track Record of the Tucuruí Hydropower Plant

In general, four phases may be identified in the conceptualisation and implementation of Tucuruí, each associated with shifts in government strategy.

5.1.1.1 Amazonia as a Settlement Frontier /Energy for Belém.

Between 1968 and 1974, the main concern of the government regarding Amazonia was to encourage settlement, for the economic and geopolitical reasons already outlined. This phase saw roads being laid, particularly the Transamazon Highway (1970), followed by settlement projects, particularly along this highway and in Rondônia. Regional power supplies were handled by thermo-power plants (with the exception of two small hydropower plants, Coaracy Nunes in Amapá and Curua-Uná near Santarém in Pará) that were unable to keep up with the rapid pace of growth in Belém after the construction of the Belém-Brasília highway, and the expansion of old and new townships in response to planned and spontaneous settlements. The first attempts to make good use of the hydropower potential of Amazonia were undertaken in the late 1960s and early 1970s by the Coordination Committee for the Energy States of Amazonia (ENERAM - *Comitê Coordenador dos Estados Energéticos da Amazonia*), established in 1968. These studies were geared towards servicing Belém, and suggested different options for the location of the power plant, including two sites on the Tocantins River. One was in fact Tucuruí, although no plans were made for a complex the size of today's power plant (Eletrobrás, 1992). Following these studies, Eletrobrás launched the Tocantins Basin Inventory in 1972. Eletronorte was established only in 1973, in the context of these new demands.

5.1.1.2 Amazonia as a Resources / Energy Frontier for large Mining and Metallurgy Projects

Following the first oil crisis (1973) government strategies became more selective and diversified, with increased economic clout. Amazonia was viewed as a massive resource frontier (Becker, 1982). Agribusinesses were encouraged instead of settlement projects; in 1974, the PolAmazônia Programme – which set up agribusiness, mining and metallurgy hubs in association with the II National Development Plan – assigned top priority to areas for investment, instead of laying roads. This region increased in value, particularly Brazil's main mineral province in Pará State, which offered the possibility of easing the economic crisis through ore exports with foreign capital holdings. The development of the mining and metallurgy complex in Eastern Amazonia was projected, and consisted of:

- The Carajás Iron Ore Project (Carajás-Itaqui mines for iron ore mining and steel production);
- The bauxite-alumina-aluminium complex (Trombetas River, Belém);
- Other initiatives associated with exploiting the hydropower potential in the Araguaia-Tocantins Basins.

As the oil crises also affected aluminium producers in Japan and the USA (in the form of high power prices) they became eager to save energy in their respective countries by exploiting the mineral and energy resources of Amazonia. This paved the way for the establishment of large-scale Brazilian and trans-national mining and metallurgical enterprises. Japan's offer to set up Albrás jointly with Companhia Vale do Rio Doce (CVRD) was a decisive move that spurred the decision to build a large-scale power plant. The proposed implementation of Alumar by Alcoa-Billiton provided further encouragement (Becker, 1990).

The dam was also motivated by a need to guarantee power supplies to Belém, São Luiz and Marabá, and link the electricity grid with Northeastern Brazil.

Hence it was mainly the new demand from aluminium production projects that led to the construction of the Tucuruí Hydropower Complex. Work began in November 1975 as part of a daring regional logistics plan. The initial guidelines for these new Government strategies were contained in the II National Development Plan 1975 – 1979, but as noted, they expanded as the economic crisis worsened.

After the second oil crisis, as interest rates soared on the international market, the boosting of ore exports was seen as a way of rolling over Brazil's foreign debt. The Japanese suggested – and CVRD prepared – a proposal for global exports of the natural resources of Eastern Amazonia, focused on ore mining. This proposal resulted in the Greater Carajás Programme (PGC - *Programa Grande Carajás*) which was officially announced in late 1980. This area is endowed with such vast mineral wealth that it is considered a unique geological anomaly.

This development was an example of the selective spatial strategy of the government. Instead of channelling investments to several hubs, it focused on a single centre and the vast lands of the Greater Carajás Programme, covering an area equivalent to 10.6% of Brazil. The inauguration of the Tucurui Hydropower Complex in 1984 thus fell within the pioneering context of this new resources frontier and its large-scale projects. Except for Mineração Rio do Norte (1979), they were all inaugurated during the first half of the 1980s, when the conservative modernisation project was already being phased out.

5.1.1.3 Amazonia as a Grassroots Movement Frontier / Tucuruí Challenged

New highways and power grids, expanding grazing lands, the proliferation of smallholdings, and the boosting of ore exports all had a marked impact on the Eastern Amazonia region. If the 1980s were considered a "lost decade" in economic terms, this was not the case in terms of social activism. The authoritarian project did not go unchallenged, and heated conflicts began to flare up.

They began with the state crisis, followed by the implementation of major projects, particularly Tucuruí, which resulted in the rapid and violent intensification of population resettlement plans. The diversion of the course of the Tocantins River and the filling of the reservoir submerged not only forests but also some indigenous lands, rural communities and townships, including some recent settlements that had sprung up spontaneously along the Transamazon Highway. The relocation and resettlement of native and migrant communities, together with marked environmental impacts, triggered heated clashes and organised and vocal grassroots movements during the 1980s; this had broad-ranging repercussions for regional and national society.

The new regional players moved into a phase of negotiating for their rights with Eletronorte (an engagement which continues to this day).

5.1.1.4 New Scenarios for Amazonia / Energy for Sustainable Regional Development

The Tucuruí Hydropower Complex moved into a new phase as the millennium drew to an end. Amid widespread social and environmental clashes, sweeping changes took place throughout the region. The Amazonia of 1999 is markedly different to the Amazonia of the 1970s. With 20 million inhabitants, it has become more industrialized and urbanized, with 61% of its current population living in towns. Supported by national and international civil society, Amazonian grassroots movements have been successfully lobbying for a new and sustainable development model.

A technical and ecological vector appeared during the 1990s, consisting of local communities NGOs, political groups and international governments, supported by the Ministry of the Environment in Legal Amazonia. Through a number of initiatives, particularly the Pilot Programme for the Protection of Brazil’s Tropical Rainforest, donations from the Group of 7 and the European Union managed by the World Bank with Brazilian counterparts, this was the largest global environmental programme ever implemented in a single country. The technical and ecological vector has been of increasing importance to the implementation of alternative development models and policies (Becker, 1997).

In 1996 the Federal Government resumed the economic and territorial planning of Brazil, after a ten-year hiatus, stressing improvements in infrastructure through integration and development backbones. Amazonia will be the target for the introduction and/or upgrading of various backbones – highways, railroads, waterways, and energy grids of various types.

In this context, the functions of the Tucuruí dam are changing once again. The power complex is currently beginning to meet rising regional energy demands and diversify its range of actions. In short, it is starting to function effectively within the region. In 1999 its power-lines were extended to Altamira and Santarém, an important town located in the Mid-Amazon river valley, instead of servicing only the major State capitals, the giant mining projects and Northeastern Brazil.

In fact, Tucuruí is now a new regional watershed for Legal Amazonia. The Southern and Eastern areas of this region have characteristics markedly different to the Amazon rainforests: soybean plantations in the south, and grazing lands, logging activities and the huge Carajás mining project to the east. To the west of Tucuruí lie vast forests that will be cut through by the new integration and development backbones (Becker, 1999).

Both of these dynamic developments – technical-ecological and the development backbones – need power supplies, and this gives Tucuruí a strategic position in the promotion of regional development. This is the context for a renewal of the project in Phase II, which includes the expansion of its installed power generation capacity, and the completion of work on the lock, which will allow river shipping to reach the upstream stretch of river above the dam.

5.1.2 The Development of Brazil's Electricity Sector [56]

Discussing the Brazilian historical context in which the Tucurui dam emerged also requires an analysis of certain factors that explain extensive state intervention in various sectors, particularly the electricity sector.

From the 1930s onward, Brazil experienced a widespread shortage of capacity for meeting electricity demands; this was vital to urban and industrial growth spurred by irreversible crises in traditional agriculture. The electricity market was served mainly by foreign power concessionaires that launched the development of hydropower in Brazil, and were responsible for the introduction of electricity on a large scale in the nation's global energy grid.[57] The abundant availability of suitable sites for power plants on water-courses resulted not only in the modernisation of Brazil's energy base, but also made it less susceptible to fluctuations in the business climate , which affect imported sources of energy such as coal and oil.

However, though they were financially powerful, these utilities neither planned nor assigned sufficient investments to protect regions already supplied with electricity – and with consequently rising demands – from long periods of rationing that curbed their growth.

The repercussions of the global crises of the early 1930s have been suggested as one of the causes of the problem, but political and institutional reasons were also important. Nationalist sentiments were the driving force behind state reforms that prioritised the electricity sector as a top priority for government intervention. However, the interests of the concessionaires were barely affected by the controls imposed by the grantor authority, which lacked the legal tools to implement them. This was the situation in 1931, when the Provisional Government that took power after the 1930 Revolution established a Legislative Committee responsible for redrafting the Waters Code (1907), following the example of other countries which had regulated their power sectors after the end of World War I.

This measure was supported by the head of the Provisional Government, Getúlio Vargas, who felt that electricity was closely linked to the "broad-ranging and complex problem of national defence…" and thus should be kept under government control. Consequently, rising tensions were noted between government sectors and the concessionaires, who felt threatened by the looming nationalisation of these services. Moreover, in the wake of discussions that began in the National Constituent Assembly, the Provisional Government enacted a series of measures that controlled the exploitation of natural resources. One of them blocked the possibility of rate increases associated with foreign exchange devaluations, imposing new rules and taking over control of electricity rates. On July 10, 1934, the Waters Code was enacted through a Decree, and on July 16 of the same year, Brazil's new Constitution was approved by the Constituent Assembly. Both ushered in a series of provisions giving Brazil's power sector with a new institutional configuration: for instance, it appointed the Federal Government as the grantor authority, and stipulated that concessions could only be awarded to Brazilians or companies established in Brazil. This new constitution also made provision for the phasing-in of the nationalisation of natural resources essential to the economic or military defence of the nation. The Waters Code established a period of one year for reviewing the contracts of the concessionaire companies in operation, failing which any modification to their facilities or rates would be blocked, along with new supply contracts.

The following years saw much controversy over the regulation of this Code, which remained unchanged after the November 1937 Constitution was enacted, which ushered in Brazil's *Estado Novo*, with its authoritarian characteristics and exacerbated nationalism. Despite the gravity of electricity shortages, the weakness of the state when confronting powerful trans-national corporations that dominated this sector prevented it from effectively regulating the Waters Code or nationalising electricity services.

The concessionaires were strongly opposed to these regulations, particularly in terms of the economic and financial schemes; this constrained investment in this sector, already exacerbated by the adverse business climate during World War II. From 1939 onwards, state intervention intensified, prompted by rationing crises. Paradoxically, intervention took the form of lightening legal obligations and removing obstacles to the expansion of systems by these same concessionaires. This even included a suspension of the general review of contracts in order to reduce energy shortfall risks. Nevertheless, these measures proved somewhat ineffective, and power rationing was decreed for some years. During the early 1940s, the Federal Government took the first steps towards drawing up electrification plans designed to ensure power supplies during the post-war period. Concerns to reduce dependence on imported fuels resulted in the preference for hydropower, and this led to the establishment of the São Francisco Hydropower Utility (CHESF - *Companhia Hidrelétrica do São Francisco*) in 1945.

The following year, Brazil's fourth Republican Constitution tied the legal position of the concessionaires to the regulation of the Waters Code, and introduced taxation on energy sources through a single levy which became the main source of revenue tounderwrite the expansion of this sector. But with no major innovations in development guidelines, the early post-war years saw Brazil's industrial output expand at rates of around 11%, in parallel to rising insufficiency of the production infrastructure, mainly in transportation and energy.

Particularly noteworthy is the foreign loan application submitted by the lighting power utility to the World Bank in 1948, which required the endorsement of Brazil's National Treasury and consequently had to be submitted to the National Congress. Despite criticisms of the actions of this group and attempts to make approval conditional on a request for review of the concessionaire contracts, this application was approved by law without this constraint. Nevertheless, rationing in Southeast Brazil became almost chronic, and was also very frequent in other regions.

The government of Marshal Eurico Gaspar Dutra – Brazil's democratically-elected head of state – made little or no progress in seeking solutions to this problem.

The return of Getúlio Vargas as President in the early 1950s revived the notion of protecting economic planning and state-run enterprises as the mainstays of development in Brazil. Simultaneously, the international situation brought the inclusion of Brazil in the financing programme launched by Truman in 1949 to assist projects re-equipping and expanding infrastructure networks. Negotiations between Brazilian diplomats and U.S. authorities resulted in the establishment of the Mixed Brazil-USA Economic Development Commission, which was suggested by Brazil and approved by the U.S. Government in December 1950. This soon concentrated on preparing the financial cooperation scheme between the World Bank and Eximbank, intended to eliminate bottlenecks in the power production chain and other sectors that were slowing the nation's economic development.

It is interesting to note that the Commission suggested that the State should withdraw from the role of "regulator and back-up" in expanding the power sector, and assign a higher priority to its activities in the areas of education, healthcare and transportation. Nevertheless, the programme that it drew up left ample room for state-run enterprises that were being established at that time in some Brazilian States. The Vargas Administration initiative to establish Petrobras – duly approved by Congress – launched Brazil's state oil monopoly and resulted in the suspension of the activities of the Mixed Commission and the breakdown of talks that were underway. They had already borne fruit in the form of a US$102 million loan from the World Bank and Eximbank to the foreign concessionaires and part of the state-run enterprises.

From then on, the Vargas Government strategy was implemented in the form of development-promoting mechanisms, reserving a strategic, dynamic role for state-run enterprises and defining the course of the power sector. This had major influences until quite recently, exemplified by the maxim that "energy supplies should precede and encourage demand".

President Vargas's Economic Advisory Unit drew up four draft bills structuring this sector, all intended to extend domestic financing conditions through the introduction of fiscal resources, establishing the National Electrification Plan which reaffirmed the hydropower option, and also authorized the Federal Government to set up Eletrobrás. The latter was justified by the need for direct State intervention to build large-scale power-plants and string high-voltage power-lines, as well as the fostering of a heavy electrical materials industry in Brazil, with or without the involvement of local or foreign private capital.

The first two draft bills were approved by Congress, but the other two were shelved with the death of Vargas and the subsequent institutional crisis. They remained on the shelf for almost the entire Kubitschek administration: the Plan was criticized by leading national specialists as very conservative in its demand forecasts, and attacked for its stand-alone solutions lacking any "financial logic". There was also resistance to the establishment of Eletrobrás, due to fears that the Fund would hand control to a company that was poorly prepared, and fragmented through minor political projects. [58]

This gave rise to large-scale projects in this sector, which was significantly state-run. The first achievement was the inauguration of Furnas in 1963, which eased the strict power rationing that had been troubling Southeast Brazil. In the wake of massive sectoral projects and other government-backed mega-enterprises, such as the building of the nation's new capital, Brasilia, engineering companies and large construction firms began to expand, providing ample leverage for the manufacturers of heavy electrical equipment.

In 1960, President Kubitschek established the Ministry of Mines and Energy, which absorbed the waters control agencies formerly assigned to the Ministry of Agriculture, as well as the federal power utilities.

In the following year, the National Congress finally approved the establishment of Eletrobrás, with its objectives including studies, projects and designs, as well as the construction and operation of power-plants, power-lines and power distribution facilities. It was officially incorporated in 1962.

With the institutional, political and economic crisis that followed the resignation of President Jânio Quadros and the take-over by the military regime in 1964 which ushered in the 1967 Constitution and later amendments, the dual targets of security and development were added to state administration. Government-run companies acquired outstanding conditions for growth, with a consolidation and expansion of ELETROBRÁS as the sector planning agency and holding company of the federal utilities, endowed with marked institutional and financial autonomy. The private concessionaires that managed to survive were pushed firmly into the background.[59]

With annual demand growth forecasts of well above 10%, firm plans began to take shape, as well as the decision-making process that had resulted in the establishment of several hydropower plants over two decades. They included some of the largest projects of this type in the world, such as Itaipu and Tucuruí.

Central to this process was the participation of a foreign entity that contributed to and influenced the conceptualisation and planning for the expansion of this sector, with appreciable inflows of technology and methodology: Canambra Engineering Consultants Limited. This firm had been set up in 1962 through a consortium of Canadian companies, Montreal Engineering and Crippen Engineering as well as Gibbs & Hill (USA) under the guidance of the World Bank and the Brazilian government, backed by the United Nations Special Fund. The studies that it carried out in Southern and Southeastern Brazil concluded with recommendations urging a wide-ranging vision for the expansion of this sector, interconnecting the generation and transmission systems, particularly since the trend was for power-plants to be built further and further away from consumer centres.

In 1969, the electricity sector structure was consolidated, in a form that persisted until the mid-1990s. On one side of the sector was the National Waters and Electricity Department (DNAEE) which was the regulatory and oversight agency, with Eletrobrás on the other side as the enterprise in charge of planning and implementation of federal electricity policies, with regional subsidiaries (except for Eletronorte, established in 1973). It should be stressed that this configuration reflected the centralisation policy of the Federal Government, as the State utilities were subject to guidelines issued by the two central entities.

From the mid-1970s onwards, due to the first oil crisis, the Brazilian economy felt the first signs of a downturn in the growth cycle that had characterized the previous phase. Nevertheless, in 1974 the Federal Government, headed by General Ernesto Geisel, launched its ambitious II National Development Plan (*II Plano Nacional de Desenvolvimento*). The Plan assigned a massive investment programme to the electricity sector, approving and implementing large-scale ventures designed to provide abundant power supplies to meet energy demands. These ventures were preferably to be funded through foreign loans, rather than through funding brought in by the sector itself, as had hitherto been the case.

In fact, the II National Development Plan assigned high priority to the foreign relationships of the Brazilian economy, either through its ongoing export drives or by tinkering with its import listings, or even adopting a policy for attracting foreign capital designed to boost export capacities. The strategy of this plan was thus intended to substitute imports and strengthen exports of manufactured products, stressing the expansion of capital goods production and basic input materials, such as steel goods, non-ferrous metals, petrochemicals, etc., which in turn would require a marked expansion in power supplies. In other words, the servicing of electricity-intensive industries was based on the use of ample water resources available in Brazil, which paved the way for opening up new frontiers such as Amazonia.

Backed by tax incentives and subsidized rates, aluminium complexes and the Tucuruí Hydropower Project – both in Amazonia – were the outcome of this logic. The result was ballooning debt for this sector, with other effects on the regional economy as covered in this report.

5.2 Planning and Assessment

5.2.1 Methodological Aspects of Hydropower Plant Planning

The relatively standardized procedures for evaluating projects date back to the 1960s. They were later coordinated into a series of handbooks drawn up and published by Eletrobrás, which were widely used within the electricity sector.

Through these handbooks, studies can be conducted in a coherent and consistent manner in order to guide the expansion planning of the nation's electricity systems, with comparisons and rankings for different projects, and allocate the funds necessary for their implementation. From this standpoint, planning was restricted to a mere procedural or methodological rite that was essentially sectoral, stressing the stages of the study and their respective minimum contents, and providing feedback for a decision process in which servicing the power market was always the immediate main purpose. Nevertheless, the history of planning in this sector features a number of cases where strictly technical and economic logic was supplanted by political decisions, with results that to a large extent explain the crisis that assailed it from the 1980s onward.

Hence the Tucurui Hydropower Complex dates back to the "infancy" of sectoral planning. On the other hand, as indicated several times in this report, its conceptualisation did not relate only to sectoral criteria, due to overlapping extra-sectoral strategies of which Tucuruí was merely one component. Nevertheless, its track-record reveals stages in its technical development that correspond to the power sector "culture", as though the decision process could not do without them, in this specific case.

The systems established by the power sector consisted of the following studies and stages for hydropower complexes:

a) Estimate of Hydropower Potential

This provides a preliminary analysis of river basin characteristics, particularly topographic, hydrological and geological aspects, checking the site's suitability for power generation, with some consideration given to possible environmental constraints.

Based solely on available data, this analysis is prepared in the office, offering an assessment of the river basin potential, with cost estimates and priorities defined for the studies in the subsequent stage.

b) Hydropower Inventory

This stage determines the hydropower potential of a river basin and establishes the best drop division by identifying sites that provide the greatest amount of energy at the lowest production costs, with the least possible effect on the environment. These considerations were introduced into the procedural ritual during the second half of the 1970s.

c) Feasibility Study

This stage defines the overall concept of a specific hydropower plant, with the best drop division established in the previous stage, in terms of technical and economic optimisation, quantifying the associated benefits and costs, including those of an environmental nature. This concept ranges from the sizing of the complex itself to the local and regional infrastructure needed for its implementation, in parallel to studies of the reservoir zone and its area of influence, multiple water uses and the effects on the environment. It also includes economic, financial and market analyses.

Until Brazil's 1988 Federal Constitution was enacted, the feasibility study was the key tool for obtaining Presidential concessions for Hydropower Plants. Currently, it is part of a competitive bidding process for the hydropower plant concession and licensing required under Brazilian environmental law.

d) Basic Designs

This is the stage when the hydropower project – as outlined in the feasibility studies and covered by the concession – is designed in detail, with its budget costing drawn up in a more definitive manner, in order to allow the civil construction contracts to be prepared, as well as the electromechanical equipment supply and assembly agreements. At this stage, environmental studies are also carried out that constitute the Basic Environmental Plan.

e) Executive Design

This is the stage when the detailed drawings are prepared for the civil construction works and the equipment as required for their implementation, fabrication and assembly. The measures required to implement the reservoir are also effected at this stage.

f) Construction

This follows the tender and award stage of the works, generally or preferably with no major modifications to the concept of the project regarding either the general arrangements or the type of structure, or its macro-dimensions. During the construction phase, these alterations necessarily result in contract revisions that increase the budgeted and contracted costs.

g) Commissioning

This stage includes the start of the release for construction of the structures, or part of them, as well as the assembly of the equipment and systems for testing. It is intended to confirm compliance with the technical specifications during the construction, fabrication and assembly stages, record the initial maintenance and control parameters, establish the operating limits of the equipment, and provide specific supplementary training for the technical staff in operations and maintenance.

This description perhaps does not reflect the stress placed on studies carried out during the initial stages, particularly the inventory, which were supposed to produce the hydropower master plans for the basins in question.

These master plans were valuable tools for analysing the alternatives for making good use of water resources, particularly compared to other energy sources. Naturally, they would be more valuable to society if other water uses were taken into consideration, along with conflicts of interest concerning the use of other natural resources in general, all clearly set out for appraisal by the stakeholders.

The principle that water should be used for multiple purposes, and associated with the integrated use of other natural resources, has long been central to Brazil's national development plans. However, its inclusion in the conceptualisation processes of public enterprises has produced few definitive results. This is due largely to scattershot sectoral priorities, and apparent short-sightedness on the part of both the Federal Government and the sectors involved, as they seem unable to make good use of multiplicatory effects and opportunities for maximizing the planned benefits through well-coordinated, multi-sector actions.

This explains why the shipping route and lock at Tucuruí were included in the hydropower project only when it was already at an advanced stage.

Regional insertion strategies were only considered by the power sector during the late 1980s, with little practical effect, as the appearance of neo-liberal tendencies undermined planning functions, while economic crises hindered state-funded infrastructure expansion projects.

On the other hand, it is interesting to note that although the principle that all planning should be socially acceptable is explicitly stated in Brazil's national development plans, no vertical communications mechanisms were ever developed that would assure the accurate adaptation of huge government projects to social needs and priorities, or include the influence of public opinion in these projects. [60]

This is the context in which the most notable resistance to hydropower ventures emerges, even under Brazil's authoritarian regime.

This description highlights the shortcomings in the Tucuruí project planning with respect to environmental studies. This can be partly explained by the following factors: the lack of basic information, which was a widespread problem in Amazonia at that time; the lack of knowledge of large-scale environmental impact evaluation techniques; few legal requirements; and institutional pressure to absorb foreign funding. In fact, reflections on the shortcomings of Tucuruí and other contemporary projects helped ensure that electricity sector proceedings were later fine-tuned, including systematic environmental impact assessments as well as mitigatory and compensatory measures. It is particularly noteworthy that the Tucurui case was also differed in several aspects from accepted practice in the sector at the time. For instance, there were countless alterations in the designs during the construction phase, caused by outside factors, such as the inclusion of the lock, or more detailed information on hydrology, geology, construction material and others, described in great detail in the Technical Memorandum on this venture. This reveals that the decision to begin work was quite possibly taken on the basis of insufficient core data, in view of the size, complexity and special conditions of this venture.

5.2.2 The Decision-Making Process leading to the Construction of Tucuruí

The initial reconnaissance of the water resources of the Tocantins Basin and its main tributary, the Araguaia, was undertaken by the U.S. Bureau of Reclamation through the AID - Agency for International Development - U.S. Department of State, for the Interstate Commission for the Araguaia and Tocantins Valleys (CIVAT - *Comissão Interestadual dos Vales do Araguaia e Tocantins*) in 1964. This Agency has since closed down. Between 1968 and 1972, the former National Navigable

Waterways and Ports Department (*Departamento Nacional de Portos e Vias Navegáveis*), carried out shipping studies along the Tocantins River.

The Amazon Energy Studies Coordination Committee (ENERAM - *Comitê Coordenador dos Estudos Energéticos da Amazônia*) was established in 1968, consisting of representatives from the Ministries of Mines and Energy, Interior, and Planning and General Coordination. It carried out studies designed to provide electricity supplies to the development hubs in this region, particularly Belém. The terms of reference established by Eletrobrás (which was appointed as the Executive Agent of this Committee) required preliminary market studies and an inventory of the existing hydropower plants on the water-courses in this region, as well as the size and the transmission distances compatible with the markets to be serviced[61].

These studies were carried out by a pool of Brazilian consulting firms – SERETE, SPL, HIDROSERVICE and SONDOTÉCNICA – which were hired in November 1969. They were completed by September 1971, in time to allow ENERAM to draw its conclusions in its December 1971 report, presented to the Minister of Mines and Energy, Antônio Dias Leite, who forwarded it to the President of Brazil, General Emílio Garrastazu Médici, in the *Exposição de Motivos 581/72* presented in November 23, 1972.

Among the impacts of this document were (1) the creation of Eletronorte in order to coordinate power supply in the Northern region; (2) the decision that more studies should be undertaken on ways of supplying power to the Belém region, as the options available at the time were either too small (Gurupi river) or too large (Tocantins river somewhere between Marabá and Tucuruí) and (3) the decision that modern and efficient thermopower plants should be built to supply Belém region until the studies on hydropower were finished. The Minister stated in the document that it was *"imprudent (...) to build any hydropower plant at Itabocas (Tucuruí) as the hydropower potential upstream in the basin is still unknown"*.

In July 1972, before the conclusion of ENERAM, Eletrobrás commissioned further studies in order to undertake a systematic inventory-level survey of the hydropower resources of the entire Tocantins River Basin, while also defining the feasibility of hydropower projects that could serve the energy markets of Belém, Brasilia and parts of Central-Western Brazil.. These studies were called "Tocantins Studies" and were commissioned to the Brazilian consulting firms ENGEVIX S.A. and ECOTEC S.A. Once Eletronorte began its operations in June 1973, Eletrobrás assigned to it the responsibility for continuing with the Tocantins and Araguaia River Basin studies.

In the *Exposição de Motivos* N° 632/73, dated September 5, 1973 Minister Dias Leite asked President Médici to assign funding for the development of the final engineering designs for a hydropower plant on the Tocantins River, and grant the construction start-up of the plant that would be selected. It is important to remember that there was no definitive engineering option already decided, but authorization was requested for the construction of *a dam.* Two options were then available: Tucuruí (with a then expected potential of 3 000MW) and Santo Antonio (770MW), close to the city of Imperatriz in the border of Pará and Maranhão states. Both dams would, according to the minister, be able not only to provide energy to Belém and/or São Luiz regions but would also provide energy to the Northeastern Region by means of an interconnection with the CHESF grid.

This request led to the Tucuruí feasibility studies which began in January 1974 and the consequent extension of the studies on the Tocantins basin. In December 1974, the ENGEVIX-ECOTEC consortium completed the Tucuruí feasibility study.

Very early in 1974 the scope of the Tocantins Studies was extended, due to the possibility of building a large-scale aluminium smelter complex near Belém. At that point it was envisioned that the larger Tucuruí option would be feasible as there was finally a power demand that would justify it, and Santo Antonio was postponed.

According to a statement by Engineer Dário Gomes, who played an active role in the decision-making process as a director of Eletronorte, "...*Minister Dias Leite called Eletrobrás, and asked us about the possibility of servicing a large-scale industry that was expected, together with the Brazil-Japan joint venture (ALBRÁS) which could export large quantities of aluminium. On that occasion, the target was a power-plant that could produce 1.3 million kW ...".* Consequently*, "we went out into the field and got everything we could about ENERAM. We had an interesting trip through this region and returned with a report saying that, in order to meet the proposed demand, there was a possibility in the Tucuruí region. This was not located along the water-courses that had been studied earlier, but was rather a single complex that could generate some 3 500MW installed power, with the possibility of expansion to 7 000 MW in a second stage..."*[62]. At that time, then, it was envisioned that it was possible to build Tucuruí as a two-Phase venture, the first Phase immediately and the second in the future when required.

The final order to build Tucuruí came soon after, at the beginning of the General Geisel administration in March 1974, from the new energy minister Shigeaki Ueki after a brief examination of the previous studies. At this point it is important to remember the authoritarian regime of early 1970s - with a President who was a military officer chosen by his peers, and a weak Congress in which the Government had a large majority of support. Decisions involving huge investments and geopolitical consequences like Tucuruí were taken strictly at presidential level.

The Tocantins Inventory was finally completed by ENGEVIX-ECOTEC in June 1975 but at that time the decision to build Tucuruí had already taken. The inventory studies were carried out on the basis of three stretches along the main reach of the Tocantins river, demarcated by restrictions consisting of towns, roads, airports and ore beds in areas that might be flooded. The conclusions indicated the following falls as alternatives: São Félix, Carolina Alto, Porto Nacional, Peixe, Santo Antônio and Tucuruí, accounting for some 80% of the hydropower potential in the area under study: Santa Isabel on the Araguaia river increases this figure to 90%.

5.2.3 Construction Contracts

As there was no time left to commission and develop the basic project in order to tender out the work for competitive bids, and have the main construction company installed in the works-yard by June 1, 1976 in order for power generation to start up in late 1981 as stipulated in the time schedule given in the feasibility studies, the decision was taken to tender out separately in advance the works for Phase I of the diversion of the river while the basic project designs were being drawn up, together with the remaining tender documents.

Consequently, in July 1975, a consortium set up by ENGEVIX and THEMAG, both Brazilian companies was hired, and commissioned to draw up the basic and executive project designs, with the contract signed in November for the coffer dam included in Phase I of the diversion of the river assigned to a Brazilian construction company (Construções e Comércio Camargo Corrêa). This contract also included the laying of permanent roads, earth-moving and the paving of the streets of Phase I of the township, the provision of landfill for the industrial facilities of the works-yard and the building of the landing strip. A Brazilian engineering company (Delphos Engenharia) was hired to build the township itself.

With regard to the main works, in March 1976, Eletronorte summoned the companies interested in pre-selection for the competitive bidding process. They consisted of the following major Brazilian construction companies: Construtora Mendes Júnior, Construtora Andrade Gutierrez, Construções e Comércio Camargo Correa, Cia Brasileira de Projetos e Obras-CBPO, C.R.Almeida-Engenharia e Construção, Cetenco Engenharia and Construtora Rabelo.

The decision published by Eletronorte in Act N° 134/76 dated June 23 1976, pre-selected the first six companies, which were invited to submit bids in compliance with the tender documentation covering the main civil construction works: dams and dykes, concrete structures, townships, mobilisation and installation of the works-yard, operation and maintenance of the works-yard and townships, the diversion the river, the supply of construction materials, and the supply and installation of materials built into the structures.

Two of the six companies did not submit bids, and the prices of the others varied from Cr$7.6 million to Cr$14.9 million. The winner was Camargo Correa, with whom a contract was signed in January 1977, scheduling the start-up of operations of the first power-generation unit in December 1981. Due to rescheduling, this in fact took place in November 1984. The construction contract was signed on a unit price basis, while the agreement for the operation and maintenance of the townships and the thermo-power plant was drawn up as a management agreement.

Regarding permanent plant equipment, since the financing was French in origin, consisting of suppliers credits, the supply contracts were signed through direct negotiations with French manufacturers, (without tender) which in some cases were involved in consortia with Brazilian manufacturers, through the Tucuruí Industrial Grouping (GIT - *Groupement Industriel de Tucuruí*). This was the entity that coordinated the group of suppliers, which included Neyrpic, Creusot-Loire, Althom-Atlantique, Jeumont Schneider, Brown Boveri, CGEE-Althom, Asea Elétrica, General Electric do Brasil, Mecânica Pesada, Industria Eletrica Brown Boveri, Thermatone, Merlin Gerin, Bardella, Badoni, Zanini, and Ishikawajima do Brasil.

The electromechanical equipment assembly was assigned to the Tenenge-Delphos consortium.
The overall management of this venture was handled by Eletronorte, which charged with directing and coordinating the decisions, planning, supervision, control and management of the contracts.
Eletronorte was represented at the work-site by Residência de Tucuruí, which also oversaw the civil construction and electro-mechanical assembly, with quality control ensured by the ENGEVIX-THEMAG consortium.

5.2.4 Construction Arrangements Considered

At that time, Tucuruí was accessed by a branch of the Transamazon highway (not yet surfaced), a landing strip and regular small-vessel shipping lines along the Tocantins river. At the time of the feasibility studies, the Pará State Highways Department had begun to build the highway running between Belém and Marabá, with the link to Tucuruí planned for immediate construction; this indicates a certain amount of early confidence in the conclusions of the study.[63)]

As presented in the feasibility study, the general arrangement of the project works (located some seven kilometres upstream from the town of Tucuruí), consisted of an earthworks dam on the right bank, a spillway, and a power house on the left bank, a dyke along the left bank, and transformers in the power house.

It is interesting to note that these studies covered two alternative sites for this project, the first near the town of Tucuruí and the second some 7km upstream. The factors that led to the choice of the latter site were better conditions for the foundations of the structures, as well as the fact that the other location would require widespread interventions in the Tucuruí urban area,[64] which would delay the start-up of the work scheduled for 1975, and adversely affect the construction schedule.

5.3 Operation and Management

The start-up of operations at the plant required extensive checks, trials and tests; this process was known as the commissioning stage for both the civil construction works as well as the electro-mechanical equipment. This began with the steady release of completed portions of the works and equipment, once assembled, and was intended to ensure that the project designs had been followed, and the construction was of a satisfactory quality.

In a case such as this, commissioning is also intended to provide the operating start-up of the plant, offering employees hands-on contact to ensure familiarity with the various sectors and components. In general, the technical skills of construction and assembly workers are different from those of workers responsible for the operation, maintenance and management of the venture during its normal production phase. Specifically at the time of the start-up of operations of the Tucuruí Hydropower Complex, the commissioning programme was drawn up jointly with the Operations Department, which is a normal procedure in the power sector, as it also prepared the Control, Operations and Maintenance Programme (PROCOM – *Programa de Controle, Operação e Manutenção*).

Eletronorte also drew up a labour force training plan, implemented in 1983 and 1984, covering the activities involved in commissioning, operations and maintenance of the power plant, as well as recruitment and training of mid-level technicians and engineers, and office staff. Initially, a staff 25 engineers and 150 technicians was planned. Training began at the design consortium, with the participation of selected staff in the development of planning and preparation services involved in the commissioning, keeping in close contact with the manufacturers. The group then took courses run by Eletrobrás and FUPAT, as well as on-the-job-training at the CESP, CHESF, Eletrosul power plants and Itaipu power plant. The supervision and control staff, consisting of five engineers, were trained in France, and became instructors for the staff later assigned to the operations and maintenance of this system.

The commissioning of the civil construction works began in June 1985, with the participation of teams consisting of technicians in the operations, design and oversight areas at Eletronorte, and representatives of the design consortium, who formed a reception committee. Based on a detailed inspection of the works, and assuming that the requirements of this commission were fully met, the inspected component was considered to be commissioned. Most of the places and components in the works inspected were classified as acceptable, and consequently were assigned to the routine inspections scheduled by PROCOM. The annual programme covers routine and special inspections, generally half-yearly, undertaken by outside specialists. Unscheduled inspections are also undertaken through the PROCOM system, in addition to the routine activities.

Relatively few anomalies were encountered, none of which offered any risks to the safety or performance of the works, and were rectified by the construction company or simply classified for monitoring, as covered by the PROCOM programme. With regard to the behaviour of the structures during the first years in operation, after the reservoir was filled in March 1985 when it reached the normal maximum operating height of 72.00m, no anomalies were noted in the concrete structures in terms of seepage, leakage, shifting or distortions. Commissioning the electro-mechanical equipment normally requires detailed planning in view of the complexity, size and number of items to be checked, as well as a broad-ranging understanding of the characteristics of their construction and operation, in addition to inherent structural characteristics. These tasks were carried out by a multi-disciplinary group from Eletronorte and the design consortium, which carried out countless scheduled trials and indicated the need for solutions from the manufacturers for some anomalies detected. A fair number of outstanding matters were recorded, due to the size of this venture, which were resolved as they appeared. The main anomalies are described in the Technical Memorandum 1988/1989 and are related to the technical and technological characteristics of certain components. Two of them warrant special consideration, as they resulted in a decrease in the availability of generation units. The first involved the synchronous timing system of the generation units, which was resolved to the satisfaction of Eletronorte. The second was the burn-out of Generator N° 5 on July 20, 1986, with appreciable damage, which required the rotor to be dismantled, with a detailed inspection of the machinery and in-depth studies of the causes and possible solutions. This kept this unit out of operation for several years.

According to information in the above-mentioned Technical Memorandum, the PROCOM programme proved an efficient management tool for controlling operations and maintenance, ensuring higher operative reliability through ongoing controls and analysis; detection of anomalies; rationalisation of the labour force; maintenance of the data-base; definition of responsibilities; and better scheduling of the timing and nature of preventive interventions. The operations and maintenance procedures are described in the manuals.

The PROCOM programme is managed by a secretariat that, among other duties and responsibilities, is in charge of keeping the technical data files on the equipment, the overall management of the plant maintenance services, and the organising of regular assessment meetings of the various players in the control process. These meetings are attended by the heads of the sectors and divisions of the power plants.

5.3.1 Operating Rules

It was obvious that all phases of the studies of the Tucuruí reservoir had a reduced capacity for dealing with waves caused by floods, even taking into account the coordinated operations of the reservoirs planned in sequence along the Tocantins and Araguaia rivers. As an initial consequence, it was clearly necessary to build large-capacity overspill floodgates.

The main hydropower projects studied were São Félix, Peixe, Porto Nacional, Carolina, Santo Antônio and Tucuruí on the Tocantins River, and Santa Isabel on the Araguaia River.

The operation of these reservoirs was studied through simulation, both individually and in series. In the latter case, the outflows discharged from each reservoir are those regulated by the reservoirs upstream, in addition to outflows from the intermediate basin. The outflows discharged from Tucuruí were calculated on the basis of the outflows discharged from the Santo Antônio and Santa Isabel Reservoirs.

The guiding concept behind the operations of this system is not optimisation, but merely focusses on the successive operations of the reservoirs, whose individual objectives were to generate the largest possible amount of firm energy. No attention was paid to other possible uses, such as flood control. However, the studies indicated the possibility of using the overflow margin for limited periods during the rainy season to slow the release of flows higher than the emergency limits downstream.

The operating policy of the Tucuruí power plant was initially geared towards keeping the water levels in the reservoir as high as possible, with the proper precautions to avoid exceeding the maximum levels established by the safety criteria of the works.

All these aspects were consolidated in the operating criteria and rules that constitute the Initial Operating Policy of the Tucuruí Hydropower Plant.

According to the initial investigations, it was established that, in order to avoid any harm to the riverbank communities while allowing shipping conditions downstream from the dam, to preserve the stability of riverbank slopes and around the reservoir, and to avoiding outflows far higher than those registered in the past, the water level should not exceed 72.00m.

Marked variations in the outflow, such as those caused by abrupt intake or outflow of load by the power plant or during spillway manoeuvres, were considered in the survey of the consequences on the downstream stretch. The studies indicate that, in the worst-case simulations, the disturbances were absorbed along a stretch of some 40km downstream from the plant, and from there on were comparable to the effects of natural tides as far as the mouth of the Tocantins River. The practice adopted for the operating policy involve undertaking such sharp alterations when necessary, in stages lasting an hour.

The study of gradual variations in natural outflows determined the maximum acceptable variation rates for outflow from the power plant, noting that a maximum rate of 2 600 m^3/s/day corresponds to the maximum average seven-day variation recorded; but in order to maintain the water level in the reservoir within the safety limits, a maximum daily variation of 3 600m^3/s was adopted. Special attention was given to the final stage of filling the reservoir, adopting a policy of seven days' prior notice in decisions to open or close the spillway floodgates; this would avoid major alterations in the outflow volumes, while at the same time allow the water level to reach the target level gradually. Should the forecast time and decision-making period be less than four days, critical situations may occur that could only be handled by violating operating constraints, through either higher outflow volumes or allowing the reservoir levels to rise above the target level. Hence the decision to open the overspill floodgates is taken four to seven days in advance.

This operating policy was tested out and assessed during the first year in operation of this power plant. The dam-filling phase proceeded in a satisfactory manner, and during the first rainy season, with flow rates reaching 38 000m^3/s, all the rules were maintained without adversely affecting power generation. The downstream communities were advised of the alterations in the river scheme imposed by the operating rules of the power plant.

It was established that the minimum operational Total Outflow Rate (the sum of the spillway flow rate and the tailrace) would be 2 000m^3/s, which would secure shipping along the downstream stretch of the river and maintain the minimum level in the penstocks needed to operate the machinery with no risk of cavitation. This flow rate is higher than the lowest average monthly flow rate recorded (in October 1954) of 1 267m^3/s.

During the design phase, Eletronorte established some operating constraints to avoid problems such as turbine cavitation etc., as well as river shipping and difficulties downstream from the dam associated with rapid alterations in water levels.

The Maximum Outflow Alteration Rate was set at 1 000 m^3/hour, established as the limit above which sharp and undesirable variations in water levels would occur downstream. The Maximum Daily Outflow Alteration Rate was established at 2 600 m^3/day, in order to avoid outflow hydrograms differing greatly from those recorded in the past. However, during periods of wide inflow variation, a flowrate limit of 3 600 m^3/s is permitted.

According to information from Eletronorte, under the current situation, operations at Tucuruí are handled mainly in function of the energy demands from the interconnected system, which covers almost the entire country, excluding only the stand-alone markets in the North and West-West regions.

It should also be noted that flood control – frequently an important aspect of hydropower projects – was not one of the possible uses of the reservoir taken under consideration. As already mentioned, the manner in which the Tucuruí reservoir was built offers limited capacity for dealing with floods, and controlling them was treated as yet another constraint on the operations of the hydropower complex.

The Serra da Mesa reservoir is still at the filling stage, and notwithstanding its vast volume, its location at its headwaters does not indicate any great potential for helping control flooding in the Tocantins basin. Currently being implemented, the Canabrava and Lajeado reservoirs are scheduled to operate on a run of river basis, and neither promise to be of much use for this purpose. In the Araguaia basin, recent studies have indicated the convenience of reducing the size of the Santa Isabel reservoir, which would result in a reduction of its possible use for flood control.

However, the implementation of the waterway should require a study of the operating rules that dovetail the operating system for both stages of Tucuruí with the draught and speed requirements for safe shipping.

The operating rules for Phase II of Tucuruí have not yet been established, but Eletronorte states that there is sufficient time for these rules to be established in collaboration with the competent agencies. The operating rules should be subject to the rules and regulations issued by the National System Operator (ONS - *Operador Nacional do Sistema*) as well as the regulations and oversight authorities of the Brazilian Electricity Regulatory Agency (ANEEL) in addition to the commitments undertaken and the conditioning factors that may be established by the environmental licensing agency (SECTAM/PA).

5.3.2 Phase II and the Locks System

The construction of the Second Phase of Tucuruí was left, as stated before, “to the future”. After the completion of the Tocantins-Araguaia Basin inventory in the 1970s, it was one of the possible future plants to be constructed. It had an intrinsic advantage, in that its dam and lake were already formed and part of the basic engineering project was already complete. Moreover, most of the potential environmental and social adverse impacts had played out already. But due to its size it was an expensive option, with extensive motorisation that would produce much more energy than what was required at the time. In the early to mid-1980s energy demand grew so slowly that Phase I’s last powerhouse only began operations in December 1992.

The political backgroud changed, and now the decision-making process began to take into account a true economic appraisal and a negotiation with the stakeholders, from local communities to consumers, the financial community, the State Government and the now powerful Congress. In the federal government there was a clear planning process with the Eletrobrás Plans, and the priorities were set accordingly.

The growth of local demand of Belém and São Luiz regions and the expansion of Northeast and South/Southeast demand as a result of the economic growth observed after 1994 posed a problem for electricity sector planners, as it was now necessary not only produce more energy but guarantee a robust national electric system that could weather climatic problems.

The national electric system interconnection could, as stated in the Eletrobrás plans, allow an optimisation of power production and distribution, thus assuring a steadier energy supply throughout the year. The system would benefit from different hydrological cycles producing energy, and in such a scenario Tucuruí in the Northern region plays a key role.

The newer institutional framework and the demand growth led to the decision to build Tucuruí II as soon as possible, as it was one of the least expensive large power plants available and most of the problems associated with its construction - such as social and environmental impacts and dam construction - were already solved. In June 1998 the Brazilian government, through the Mining and Energy Ministry and its affiliates Eletrobás and Eletronorte, announced the beginning of the works on the Second Phase of Tucuruí hydropower complex.

This decision was not, however, undisputed. Local comunities restated their claims on the few indenizations still to be paid by Eletronorte and asked about the true repercussions of the new venture. International and local NGOs joined the claims, asking for an assessment of environmental and social impacts of Phase II, as would be necessary by Brazilian law. Surprisingly, the state of Pará environmental authority stated Phase II to be a mere continuation of Phase I and exempted Eletronorte from conducting a formal EIA. Although legally possible, as the state environmental organ is responsible for such requirements, this decision led to a continuous dispute on the legality of the environmental licensing process of Tucuruí Phase II.

Among the major concerns about Phase II are: (i) that the reservoir maximum water level would be elevated, flooding additional areas, and (ii) that water quality downstream would decrease as there would be less water spilled away from the reservoir. Eletronorte repeatedly claims that these concerns are unfounded, but they are recur in most meetings, which indicates that the populace is not yet well informed about the nature of Phase II works and consequences.

The decision to build a locks system was taken in the initial stages of Phase I to help transport iron ore from Carajás Project upstream in the basin by ship. As discussed earlier, CVRD decided to transport ore by rail, and enthusiasm faded in the Federal Government for the idea of improving navigation across the Tocantins. But the locks idea was not fully abandoned: the basic infrastructure for building the locks in the future was actually installed, and the locks were considered to be part of the Phase II of Tucuruí project.

An interesting point is that the decision to building the locks system in Phase I made it necessary to flood the Caraipé Valley. The decision to set aside an area for a large lock increased the costs of Tucuruí project by over US$300 million, and also brought forward environmental effects and costs that would possibly only have occurred during Phase II.

Communities alongside the basin have lobbied for the construction of the locks ever since, and in June 1998 together with the announcement of Tucuruí Phase II, the Government announced the resumption of work on the locks system that was halted in the 1980s. The locks construction is now underway.

Findings

- From 1968 through 1974, the main concern of the government with regard to Amazonia was to encourage its settlement. After the first oil crisis the government's strategy focused on Amazonia as a massive frontier for new resources (Becker, 1982).
- Due to high energy costs in the mid-1970s, there was much interest in Japan and the USA in saving power in their own countries while exploiting the mineral and energy resources of Amazonia. This shaped the conditions needed to set up large-scale Brazilian and trans-national mining and metallurgical enterprises.
- In parallel, efforts were made to assure power supplies for Belém, São Luiz and Marabá, as well as interconnecting this power system to Northeast Brazil.
- In 1996, the Federal Government once again began to stress improvements in infrastructure through the Integration and Development Backbones. Within this context, the function of Tucuruí was altered yet again, now designed to also handle rising regional power demands, diversifying its scope of action.
- As it began before the restructuring of Brazil's electricity sector, the conceptualisation of the Tucuruí project was affected by overlapping extra-sectoral strategies;
- The system established by Brazil's electricity sector to assess hydropower projects consisted of the following stages: estimated hydropower potential; hydropower inventory; feasibility studies; basic design; executive design; construction and commissioning;
- The strategies for the regional inclusion of hydropower plants were only taken under consideration by Brazil's electricity sector during the late 1980s, with little practical effect;
- Through the Agency for International Development (AID - U.S. Department of State), the US Bureau of Reclamation undertook the first reconnaissance of water resources in the Tocantins – Araguaia basin;
- Established in 1968, ENERAM undertook studies of power supplies for the development hubs in this region, particularly Belém;
- In 1972, ELETROBRÁS once again began to prepare studies covering the systematic survey of the hydropower resources throughout the entire Tocantins river basin;
- The initial Tocantins river inventory studies indicated the following falls as alternatives: São Félix, Carolina Alto, Porto Nacional, Peixe, Santo Antônio and Tucuruí;
- The initial studies of Tucuruí indicated two alternative work sites: one near the town of Tucuruí, and the other some seven kilometres upstream.
- With regard to the start-up of operations, relatively few anomalies were encountered, which offered no threats to the safety or performance of the works.

6. Criteria and Guidelines: Policy Evolution and ompliance

This chapter offers an overview of the legal and institutional framework in which the Tucuruí Hydropower Complex operates, and analyses this venture in the light of current legislation and international recommendations.

6.1 Juridical and Institutional Framework

This system offers an overview of the legal and institutional framework surrounding the Tucuruí project, tracing its development and culminating with the current arrangements.

6.1.1 Award of the Concession for this Venture

During the 1970s, the legal framework of Brazil's electricity sector consisted of a State holding company: ELETROBRÁS - Centrais Elétricas Brasileiras S/A, and four regional utilities, of which Centrais Elétricas do Norte do Brasil S/A - Eletronorte was the last to be incorporated. An ELETROBRÁS subsidiary, Eletronorte is the public power services concessionaire, established through Law N° 5 824 dated November 14, 1972, with its Articles of Incorporation published on June 20, 1973, and its operating authorisation issued through Decree 72 548 dated July 30, 1973. Its purpose was to plan and implement the electricity infrastructure – generation and transmission – for all Legal Amazonia.

Known as Legal Amazonia, the operating area of Eletronorte covers 58% of Brazil, and currently includes the States of Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Rondônia, Roraima and Tocantins.

6.1.2 The Law and Environmental Licenses

Until Brazil's 1988 Constitution was enacted, the nation's environmental legislation developed slowly. Although previous constitutions had already guaranteed the right to life and health, as well as the protection of monuments and landscapes, the concept of property rights at the time always constituted an obstacle to state environmental protection policy . Environmental legislation in Brazil consists of many laws, some organised into codes, such as the Waters Code (Decree 24 643/34); Forest Code (Decree 4 771/65) and Fishing Code (Decree 221/67), which also include the rules regulating the use of environmental assets as well as the activities that may affect them, in addition to standards which function as tools for protecting the environment.

Although work began on building the Tucuruí dam in November 1975, at a time when Brazil's environmental legislation was incipient, the legal provisions at the time already imposed constraints on hydropower ventures. For instance, Article 143 of the Waters Code stated that they should comply with requirements protecting general interests such as: (i) food and the needs of riverbank communities; (ii) public health; (iii) shipping; (iv) irrigation; (v) flood protection; (vi) conservation and free circulation of fish; and (vii) the outflow and disposal of water. These restrictions were not always taken into consideration in the case of the Tucuruí Hydropower Complex. For example, there was no stoppage of work on installing the flood gates which would ensure the feasibility of shipping along the course of this river.

Although work began on building the Tucuruí dam in November 1975, handled by Eletronorte at a time when Brazil's environmental legislation was still incipient, the legal provision at that time already imposed constraints on hydropower ventures. For instance, Article 143 of the Waters Code stated that they should comply with requirements protecting general interests such as: (i) food and the needs of riverbank communities; (ii) public health; (iii) shipping; (iv) irrigation; (v) flood protection; (vi) conservation and free circulation of fish; and (vii) the outflow and disposal of water. These restrictions were not always taken into consideration, in the case of the Tucuruí Hydropower

Complex, including the halt of work on installing the flood gates which would ensure the feasibility of shipping along the course of this river.

Although the Environment Bureau – (SEMA - *Secretaria de Meio Ambiente*) was established in 1973, it was only in 1981 that Brazil's National Environmental Policy (PNMA - *Política Nacional do Meio Ambiente*) was established through Law N° 6 938 dated August 31, which also established the National Environmental Council (CONAMA – *Conselho Nacional do Meio Ambiente*) and the National Environment System (SISNAMA - *Sistema Nacional de Meio Ambiente*). This policy stipulated principles and mechanisms for formulating and applying Brazil's environmental law, in addition to defining the adoption of the environmental licensing process, although it did not regulat these. The most important innovation was to reorient environmental management towards upgrading environmental quality, benefiting health and economic development in parallel to environmental protection. The environment was ranked as a public asset to be protected, particularly in terms of the rational use of environmental resources, a principle that was later ratified by Brazil's 1988 Federal Constitution.

It was only in the 1980s, after operations began at the Tucuruí Hydropower Complex (1984) that Resolution 001 issued by the National Environment Council on January 23, 1986, defined the duties, responsibilities, basic criteria and general guidelines of the Environmental Impact Assessment, for activities modifying the environment, based on the Environment Impact Studies (EIA - *Estudos de Impacto Ambiental*) and their respective Environmental Impact Report (RIMA - *Relatório de Impacto Ambiental*). Later, CONAMA Resolution 006 (September 16, 1987) established the general rules for environmental licensing of large-scale projects, particularly power generation enterprises, stipulating that the Prior License (LP - *Licença Prévia*) should be applied for at the start of the feasibility studies; the Installation License (LI - *Licença de Instalação*) should be obtained before issuing a tender for the construction stage; and the Operating License (LO - *Licença de Operação*) should be obtained before filling the reservoir, in the case of hydropower projects.

Although the environmental assessment process has remained almost unchanged since this Resolution was issued in 1987, various laws and institutional operations have been introduced over the past few years, with direct and indirect effects on this process.

The environmental policy structuring process and the environmental spheres of competence of the Government were only defined in terms of the law by Brazil's 1988 Constitution, which devoted a full chapter to the environment. Its Article 24 determines the legislative sphere of competence of the Federal Government, the States and the Federal District over forests, hunting, fishing, wildlife, nature conservation, soil protection and natural resources, environmental protection, pollution control, protection of the nation's historical, cultural, and artistic heritage, in addition to tourist attractions and landscapes. It also assigns liability for damages to the environment to the consumer, to goods and rights with artistic, aesthetic, historical value, or of interest to tourism, and the landscape. The Amazon Rainforest, the Atlantic Rainforest, the Serra do Mar range of hills, the Pantanal Wetlands and the Coastal Zone were all classified as national heritage sites. Another important aspect was the reformulation of the characteristics of property rights; formerly absolute, property rights must now articulate with social prerogatives, including environmental preservation.

However, the most significant changes took place in the institutional sphere. For instance, the National Environment Council – previously defined as the higher agency of the National Environment System, responsible for advising the President of Brazil when formulating the nation's environment policy – was replaced by the Government Council, and took on a new role as the consultative and deliberative agency responsible for advising the higher entity, and for deciding on environmental rules and standards.

In addition to structuring the environmental system, in December 28, 1989 Law N° 7 900 established the juridical figure of financial compensation for the use of natural resources, which made provision for the payment of royalties to municipal districts and states affected by the loss of arable lands. These royalties are paid by the utility concessionaires, in the case of power generation. The overall amount of compensation paid by each power plant depends on the revenues from the energy produced, and its distribution depends on the flooded area in each municipal district.

In 1997, Resolution 237/97 issued by the National Environmental Council altered Resolution 001/86. It established the prior licensing requirement issued by the competent environmental agency for the location, construction, installation, expansion, modification and operations of enterprises considered as effectively or potentially pollutive or able to cause environmental degradation (Article 2), as well as holding public hearings to assess the environmental studies, according to the pertinent regulations.

The following year, Law N° 9 605/98 ruled on the criminal and administrative sanctions imposed to punish conduct harmful to the environment. The following were defined as crimes: building, renovating, expanding, installing or bringing into operation anywhere in Brazil, establishments, works or services that are potentially pollutive, with no license or authorisation from the competent environmental agencies, or running counter to the pertinent legal standards and regulations.

During the economic, industrial and technological stagnation of the 1980s, political advances took place with the appearance of several social players. Public participation in environmental management is today supported by effective tools for defending rights and guaranteeing the participation of society in environmental protection. These include Public Civil Actions, Group Actions and Public Hearings.

The legislative context in which large-scale projects were previously approved and implemented in the Amazon region and other parts of Brazil is very different from the requirements of current legislation. Brazil's historical experience in the management of water resources has prompted changes in both the pertinent legislation as well as the institutional structure for its implementation. From the Waters Code introduced by Decree 24 643 dated September 10, 1934 through to today's management of water resources based on Law 9 433 dated January 8, 1997, Brazil has made much progress in protecting natural resources, particularly water resources.

Federal Law N° 9 433 introduced the National Water Resources Policy, established the National Water Resources Management System and regulated item XIX of Article 21 of the Federal Constitution, promulgated on October 5, 1998. Many of the States had already introduced state legislation compatible with federal laws. Under this new legal system, Basin Agencies and Basin Committees should be set up following the establishment of the National Waters Agency (ANA – *Agência Nacional das Águas*), through a draft bill currently before the National Congress. More attention should be given to multiple uses of water resources, and to the question of charging for water use.

6.1.3 Pre-Existing Institutional Framework

The administrative structure of the concessionaire in charge of dealing with environmental issues has been expanding in the duration this project. At the start of the Tucuruí project, the environmental responsibilities of Eletronorte were almost non-existent, in keeping with environmental policy trends at that time.

The lack of a specific structuring policy designed to deal with social and environmental issues in this region hampered any understanding of the needs expressed, slowed the introduction of environmental studies into planning enterprise, and hindered the establishment of institutional partnerships to carry out studies whose results would help formulate specific policy.

The initial environmental studies were limited to analyses of specific issues under the category of physical environment. The studies undertaken were designed to provide feedback for the engineering designs and guide the use of natural resources in order to meet the needs of the works on this project, and thus did not constitute a real environmental analysis. These studies were carried out by other institutions, and were initially coordinated by various departments of Eletronorte linked to the hydroelectric project sectors, and failed to produce a broad-ranging, well-articulated overview of these environmental problems.

It was during the first half of the 1980s that environmental issues became more important for the power sector, not only as these were central to the requirements imposed by international financing agencies (particularly the World Bank) but also as they were emphasised by the political mobilisation of people affected by other enterprises in this sector, particularly in Southern Brazil.

It was only in 1983 that the Environmental Advisory Unit (*Assessoria do Meio Ambiente*) was established, directly under the Eletronorte CEO, and staffed by technical experts with specialized training in environmental issues - although issues related to healthcare and indigenous communities still remained outside the scope of this unit. Although the inclusion of environmental problems in the structure of the power sector was already identifiable, as shown in the initiatives mentioned before CONAMA Resolution 001/86, it was from this point onwards that more effective measures were implemented.

In 1986, the ELETROBRÁS Environment Committee was established, with the function of advising its Executive Board on socio-economic strategies. During the same year, a Handbook of Studies of the Environmental Effects of Power Systems (*Manual de Estudos de Efeitos Ambientais dos Sistemas Elétricos*) was produced [in Portuguese], containing the general guidelines for shaping the development of environmental studies at each planning phase. More specifically, the feasibility stage was stressed, explaining in detail the environmental aspects and phases to be taken under consideration in preparing the Environmental Impact Studies (EIA - *Estudos de Impacto Ambiental*) and their respective Environmental Impact Report (RIMA – *Relatório de Impacto Ambiental*).

Also in 1986, the first Master Plan for the Protection and Improvement of the Environment at Power Sector Works and Services (I PDMA - *Plano Diretor para Proteção e Melhoria do Meio Ambiente nas Obras e Serviços do Setor Elétrico*) was created, with the purpose of outlining the environmental policy for this sector. The actions covered were grouped into four basic themes (i) environmental feasibility; (ii) regional insertion; (iii) institutional interfaces and networking with society; and (iv) managerial efficiency.

Once this Master Plan was published, organisational measures were implemented, designed to introduce internal structures for this sector, whose functions were specifically geared towards environmental issues.

In 1987, the Eletronorte Environment Division was established, and later renamed the Environment Department. The following year, the Coordination Committee for Environment Activities – Power Sector (COMASE - *Comitê Coordenador de Atividades do Meio Ambiente do Setor Elétrico*) was set up; this is a deliberative entity consisting of 25 concessionaires, the National Water and Power Department (DNAEE – *Departamento National de Águas e Energies Electrical*) and ELETROBRÁS. The second Master Plan for the Protection and Improvement of the Environment (II PDMA) was drawn up within the context of this new sectoral structure, prepared by the Environment Department of ELETROBRÁS and approved by the Coordination Committee (COMASE) in 1990. Based on the principles identified in the first Master Plan, the II PDMA proposed guidelines for: (i) the resettlement of communities; (ii) relationships with indigenous groups; (iii) the conservation of plant and wildlife; and (iv) the use of coal by thermo-power plants. This Master Plan constitutes the current policy of Brazil's power sector.

In 1991, the Environment Department of Eletronorte prepared the Tucuruí Dynamics Plan (PLANTUC - *Plano de Dinamização da Region Geoeconômica de Tucuruí*) that redefined the territory affected by this hydropower complex. This included the stretch upstream from the dam, part of the Tucuruí municipal district, all of the Itupiranga municipal district and parts of Nova Jacundá, Moju and Rondon do Pará municipal districts. Downstream, it included part of the Tucuruí municipal district and all of the Baião, Mocajuba, Cametá and Limoeiro do Ajuru municipal districts. This plan outlined three basic lines of action: specific programme, definitions of sectoral policies, and actions adapting certain activities underway. It also established multi-institutional programmes seeking articulated solutions to social and environmental issues such as:

- the high incidence of aquatic macrophytes along the left bank of the reservoir;
- alterations in the quality of water of the reservoir and the reaches of the river downstream from the dam:
- precarious physical infrastructure in the area: access to facilities, electrification, social equipment, basic sanitation etc;
- Inadequate land use;
- Influence of small-scale wild-cat mining operations in the Araguaia-Tocantins Basin;
- Disorderly exploitation of natural resources;
- Smaller catches downstream and inadequate standardisation and supervision of these fishing activities throughout the area;
- Incomplete land ownership legalisation process;
- Loss of biodiversity.

In fact, the Tucuruí Dynamics Plan (PLANTUC) constitutes a reply to the demands of the affected communities, and is designed to ease situations of conflict by outlining a programme of articulated short, medium and long term actions. The medium and long term actions would be implemented on the basis of shared management of a portion of the royalties to be paid by the agencies benefiting from these funds.

In general, the various plans and programmes were not fully implemented, and the continuity of actions was subject to the availability of funding.

6.1.3.1 The Reservoir Logging Affair

As stressed in Section 3.1.3. as there was excluded any possibility of any problems affecting the power plant operations, Eletronorte discarded the possibility of clear-cutting the area to be flooded over the tracts of land as originally considered. This operation was then considered as not feasible in economic terms, and also did not fit into the work schedule. Probably the aluminium industries inauguration and the Federal Government mandate ending contributed to hasten the closing of the dam, and consequently not clearing the reservoir area as previously planned.

It must be noted that Law N° 3,824 dated November 23, 1960 stipulates that it is mandatory to remove tree-stumps and clean out river basins, weirs, dams or artificial lakes built by the Federal Government, the States or Municipalities, or by private companies awarded concessions, or any other favours granted by the government, which caused much questioning and heated controversy in this case. For instance, it is known that the Pará State Legislative Assembly set up a Parliamentary Commission of Inquiry that was formed in 1991 to analyse the responsibility of Eletronorte in terms of the effects caused by the Tucuruí Lake.

The period prior to closing the dam was characterised by heated controversy headlined in the newspapers, with much speculation on the possibility of maintaining aquatic life in the reservoir, particularly due to an uproar over the alleged use of a chemical defoliant – Agent Orange – by the Company.

According to the press, the Chairman of Eletronorte at that time had aired the possibility of the Company using a product to eliminate the green portion of the plantlife to be submerged. However, studies carried out by the INPA advised against this measure, noting that it would cause problems for wildlife, particularly birds which would disperse this product to more distant locations, with unforeseeable effects. Statements that the Company had used Agent Orange were steadily denied, and Eletronorte even stated that "the United Nations checked if anything had happened" with no proof of the truth of these allegations.

In September 1978, the President of Brazil approved the establishment of an Interministerial Commission, with the participation of Eletronorte, SUDAM, FUNAI, INCRA and the Brazilian Forestry Development Institute (IBDF – *Instituto Brasileiro de Desenvolvimento Florestal*) IBDF, to draw up the logging guidelines for the lake area, based on a forest inventory carried out by SUDAM. According to this inventory, the volume of loggable timber would reach some 12,050,000 cubic meters, which was economically feasible, provided that the problems of tight timing, and the availability of equipment and resources were resolved, to handle the transportation and marketing of this timber.

In August 1979, pursuant to a decision taken by the Interministerial Commission, an agreement was signed by Eletronorte and the IBDF (now shut down but at that time an independent government agency under the Ministry of Agriculture), under which the Company agreed to clear 10,000 hectares of land near the power plant, with the IBDF handling the rest of the area, stipulated at 206,000 hectares.

The IBDF ran two competitive bidding processes as no bidders registered for the first process, probably because this Agency required the companies to have far more capital than some thirty logging companies in this region could put up together. For the second round of bidding, the only company to submit a bid was Agropecuária Capemi, which was declared the winner, for reasons possibly related to the scope of this project, as well as for rather more devious political reasons that might be deduced (sic) as the Company had recently been established and claimed qualification for this tender through the administrative and industrial facilities leased for the Serraria Sawmill Project run by FUNAI.

There are clear indications that CAPEMI did not meet the requirements established by the IBDF, but submitted the National Cooperative Credit Bank (BNCC – *Banco Nacional de Crédito Cooperativo*) as its backer (today shut down) despite the fact that the collateral of US$ 100 million was far higher than the net equity of the Company, and even of the BNCC as well. Nevertheless, this process was approved by the Federal Government.

Having agreed to log 5.6 million cubic meters of hardwoods and clear 65,510 hectares, CAPEMI took out a US$ 100 million loan with the Banque Nationale de Paris and the French financial institution Lazard Frères, both endorsed by the BNCC, in order to defray the operating costs of this clear-cutting project. Despite government benefits that included tax exemptions, CAPEMI failed to complete its task. This was explained by a number of factors: lack of know-how, poor infrastructure, no planning to place the timber on the international markets, limited expertise regarding the characteristics of the timber and how to handle it properly are just a few of them.

These and various other reasons are listed in the documentation which Lazard Frères – responsible for marketing this timber on the international market – forwarded to the Brazilian Government, offering its own version of the "chaos at Tucuruí": "ignoring technical recommendations put forward, lack of experience on the part of the local managers of the Company, lack of organisation on all work-fronts, overestimates of the logging potential in terms of both quantity and quality, and a gap between the commitments undertaken and the actions completed" (*Jornal do Brasil*, January 31, 1983).

After many political upheavals that caused nationwide repercussions and even involved a Parliamentary Commission of Enquiry being set up by the National Congress, CAPEMI abandoned this Project, having logged only the timber located in the Tucuruí Indigenous Post area. It declared bankruptcy almost immediately afterwards, without having paid off its debts to its international creditors and some Brazilian banks, in addition to large amounts owed to small-scale suppliers in the town of Tucuruí.

In 1989, Eletronorte licensed the logging companies to extract the submerged wood, through the appearance of a specific local technology. However, this activity has encountered many difficulties. Since then, some 5% of this timber has been removed through underwater logging techniques. Felling is now taking place at a rate of some 2,500 cubic meters per month, meaning that a complete clean-up would take 1,000 months – or close on a century at this pace.

6.1.4 Recent Changes in the Institutional Framework of Brazil's Power Sector

At the national level, decentralisation is both discourse and reality. Both state and municipal governments have been strengthened by the Brazilian Constitution.

The institutional framework of the power sector has been undergoing significant change. In 1996, Law N° 9 427 dated December 26, 1996 established the Brazilian Electricity Regulatory Agency (ANEEL - *Agência Nacional de Energia Elétrica*) and regulates the concession system for public power services. This regulatory agency is an independent entity operating under a special scheme, linked to the Ministry of Mines and Energy, whose purpose is to regulate power generation transmission and retailing in Brazil. This is consistent with the new role of the state in the power sector, which has shifted from execution to regulation and oversight.

ANEEL Resolution 395/98 established the general procedures for the registration and approval of feasibility studies and the basic design hydropower generation projects, and also issues authorisation for hydropower plants of up to 30MWs. It also stipulates that these studies and project designs should be assessed according to: development appropriate to the stage and scope of the venture; interfaces with the environmental and water management agencies at the Federal and State levels, as well as other institutions involved; the obtaining of pertinent environmental licensing.

This Agency is currently in the structuring phase, with its actions defined on the basis of a management contract signed with the Ministry of Mines and Energy. This is a new element which, associated with current intentions to privatise power generation activities, indicates a trend towards notable change in the power sector.

As Brazil's regulatory agency, ANEEL has already begun studies designed to include environmental aspects in its procedures for awarding hydropower concessions, and is seeking closer links with environmental agencies and the Water Resources Bureau. The inclusion of the environmental variable is reflected in the stress placed by the Agency on encouraging multiple use of reservoirs, and the building of small hydropower plants with a flooded surface of up three square kilometers. Also empasised are the necessary compliances with all legal environmental requirements, and negotiations between the entrepreneurs and all social players involved.

Although Brazil uses less than 30% of its available hydropower potential, there are many obstacles to the expansion of this sector. Hydropower plants have the advantage of using renewable and less expensive energy, thus saving fossil fuels, but they require heavy investments with long maturation periods. These constraints make them unsuitable for privatisation, as private capital is generally unwilling to risk large investments with few expectations of rapid returns.

Thermo-power is a current trend recommended by the World Bank, associated with decentralisation and privatisation, although this alternative burns fossil fuels and produces adverse environmental effects, particularly air pollution.

Thermo-power plants also increase the greenhouse effect through carbon dioxide emissions at levels generally higher than methane and carbon dioxide emissions from hydropower reservoirs - as shown earlier in the specific case of the Tucuruí power complex. This means that any increase in the use of fossil fuels (coal, oil products and natural gas) to the detriment of hydropower would clash with the objectives of the Convention on Climate Change, ratified by over 170 countries, including Brazil.

In order to ensure the feasibility of financing the expansion of hydropower generation, a promising alternative that could be adopted in Brazil is to promote partnerships between the public and private sectors, following in the footsteps of the successful Serra da Mesa Hydropower Plant, also in the Tocantins Basin, where private capital completed a venture launched by a Government-owned power utility (FURNAS).

Ensuring the environmental feasibility of hydropower ventures is also a major challenge for expanding hydropower generation in Brazil, in view of the significant environmental impacts caused by the first few large-scale hydropower plants built in Amazonia, the region with the largest remaining hydropower potential in Brazil, as illustrated in this case study of Tucuruí.

6.2 The Tucuruí Hydropower Complex in terms of current Environmental Legislation and International Recommendations

This section analyses the venture in the light of the current legal and institutional framework.

Tucuruí Hydropower Complex to some extent pre-dated explicit environmental legislation in Brazil, and the failure of the project to include social and environmental variables in its planning also led to the lack of definition of the legal responsibilities of Eletronorte regarding preventive and corrective measures to deal with adverse environmental effects.

The authoritarian stance of the Government, expressed in its lack of consideration for local power structures and pre-existing social relationships in the area of influence of the dam, as well the lack of an environmental culture and knowledge of the Amazon ecosystem, all meant that interventions to mitigate negative impacts were reactive, location-specific and did not always achieve the desired objectives.

It was only in 1998 that the environmental licensing process for the Tucuruí Hydropower Complex was finalized. The Pará State Science and Technology Bureau (SECTAM – *Secretaria de Estado de Ciência e Tecnologia do Estado do Pará*) replied to a query from Eletronorte and requested that the Operating License (LO – *Licença de Operação*) should be applied for, covering Phase I, while the Installation License (LI – *Licença de Instalação*) should be requested for Phase II. Having complied with the legal requirements, through Notification 159 issued on May 22, 1998, this Bureau issued the Operating License for Phase I of the Tucuruí Hydropower Complex, consisting of 12 main turbines (330MW each) and two auxiliary turbines (20MW each) as well as the Installation License for Phase II, consisting of the construction and installation of 11 machines (375MW). In October 1999, these licenses were renewed until September 30, 2001.

It should be mentioned that this Bureau issued the respective licenses on condition that a series of environmental programmes are reformulated and implemented. The programmes earmarked for reformulation concern the control of fish stocks and limnological monitoring, water quality and aquatic macrophytes. The new programmes to be implemented deal with the management and recuperation of degraded areas, integrated oversight activities, an analysis of how fish traverse the dam, environmental education, ecological and economic zoning, health education, and epidemiological surveillance.

In terms of the legal framework for Phase II of the Tucuruí Hydropower Complex, Eletronorte already has the environmental license which will allow a start to be made on this project, as the need to prepare the Environmental Impact Studies has been waived by the competent environmental agency that deemed Phase II of Tucuruí a mere extension of Phase I. The installation license is conditional on the reformulation and implementation of environmental programmes as listed above.

Although it is the prerogative of the licensing agency to assess whether or not environmental studies are required to obtain the necessary environmental licenses, the adverse effects of the implementation operation of Phase I - and the effects that could follow the implementation of Phase II - are already causing concern to part of the populace.

To date, according to reports from local leaders, the populace has not had access to the licensing process for Phase II, and finds no political will at the environmental licensing agency to organise a public hearing to disclose information of direct interest to society and the communities affected by the Tucuruí Hydropower Complex. This is another example of the constraints on public participation in these environmental licensing processes.

When analysing the legal and institutional tools available, as well as the social and economic effects underway in the specific case of the Tucuruí hydropower project, it has been noted that the power sector in general, and Eletronorte in particular, find it hard to move from stipulated guidelines and principles to actual measures and procedures. The basic condition for the inclusion of environmental aspects in the construction and implementation of large-scale ventures is the existence of political will. This is true not only of the procedures adopted by the sector, but also of the mobilisation of civil society and effective actions by the agencies responsible for environmental policy.

The social and environmental problems associated with the Tucuruí Hydropower Complex are highly controversial. It is part of a larger set of interventions in its area of influence which affected both the natural ecosystem and social, economic and cultural relationships. These projects include building the PA-150 and PA-263 highways and various settlement programmes. The resolution of these problems has been thwarted by the long delay in the introduction of social and environmental studies into hydropower project planning.

Some issues – already mentioned in the course of this chapter – should be highlighted, in order to deal with the social and economic effects of hydropower plants. The first is the issue of political will, reflected in the existence of a legal and institutional framework. Although an important tool for guiding sectoral policies, actions and commitments to mitigate and compensate for adverse effects, this framework has proved insufficient to guarantee the acknowledged rights of the social groups affected by hydropower enterprises.

The second issue is the gap between guidelines and effective actions, which stems from the inability of the administrative and executive structures of concessionaires to practically adopt the necessary policies for this sector.

The third issue is the transfer of duties and responsibilities to other agencies, such as INCRA. When no agreement is reached on the procedures to be adopted for the compulsory resettlement of social groups (a process with inherent conflicts of interest), final settlements on compensation for damages are delayed or prevented.

This means that the analysis and approval of dam construction projects and designs, particularly large-scale hydropower projects, is far more complex and demanding under current law; this is particularly apparent when one compares the requirements of the National Environmental Policy with those in effect prior to the construction of the Tucuruí Hydropower Plant. Under today's stringent environmental legislation, it may be even harder to get approval for a new large-scale hydropower project from the social and environmental standpoints than in terms of technical engineering problems, as the latter can be dealt with quite effectively by local engineering skills.

Consideration of environmental impacts prompted a review and republication of the Handbook of the Hydro-Electric Inventory of River Basins (*Manual de Inventário Hidrelétrico de Bacias Hidrográficas*) [in Portuguese] in 1997 by the Ministry of Mines and Energy, the National Water and Power Department, and ELETROBRÁS. The methodology covered in this handbook allows the consideration of environmental aspects to be brought forward to the basin inventory phase, influencing the formulation and choice between alternative drops.

With regard to project funding by trans-national financing agencies (IDB and IRDB), the international scene is currently dominated by the conventions and recommendations approved at the Earth Summit held in Rio de Janeiro in 1992, where two Conventions were approved – the Framework Convention on Global Climate Changes and Biological Diversity, and Agenda 21, which focuses on sustainable development. Although Agenda 21 is not an international convention, project analyses by the financing agencies have been carried out on the basis of the sustainable development objectives contained in this document

Findings

- Current Brazilian environmental legislation is considered to be among the most complete in the world, consisting of rules that discipline the use of environmental assets and activities that could affect them, through standards that introduce tools for defending the environment.
- The construction and start-up of operations at the Tucuruí Hydropower Complex took place prior to the introduction of Brazilian environmental legislation regarding legal requirements for environmental licensing. However, a number of pre-existing legal provisions were not taken into account by the authorities and the entrepreneur, such as those included in the Waters Code, which stipulated that hydropower plants should not adversely affect the food and other needs of riverbank communities, public health, shipping, conservation and free circulation of fish.
- The absence of an interinstitutional policy with clearly-defined spheres of competence and responsibilities was certainly one of the reasons why the institutions involved gradually lagged behind in their responsibilities. Commitments undertaken at various times during the negotiations also required the direct involvement of the populace in the planning, oversight, assessment, definition of priority areas, schedules, funding distribution and staff appointments.

7. Converging and Diverging Views, and Lessons Learned

This Chapter presents the different views held by the stakeholders involved with the Tucuruí Hydropower Project, listing a series of lessons that can be learned from the experience of its implementation.

7.1 Summary of Converging and Diverging Views of the Tucuruí Hydropower Complex

This section presents the converging and diverging views of the study team responsible for preparing the report as well as those put forward during the meeting of the Consultation Group, held in January 2000.

7.1.1 Consolidation of the Technical Report

This item offers an overview of the converging and diverging views identified by the study team.
In order to clarify the presentation of the converging and diverging views, they have been organised under specific topics.

7.1.1.1 Compensation / Resettlement

- According to the social study team, the social costs were the most significant impacts of the implementation and operation of the Tucuruí Hydropower Complex.
- In the view of Eletronorte, "without downgrading the social and environmental impacts that occurred, the regional benefits covering the States of Pará, Maranhão and Tocantins, and even local benefits covering the municipal districts around the reservoir and downstream in the form of safe, reliable and unbroken supplies of electricity, were imcomparably greater than the damages caused to the environment and the communites removed from the flooded areas. Impacts that could not be mitigated or compensated are being gradually reversed by nature itself. The riverbank dwellers and settlers have been properly compensated, and also received financial and material compensation to restart their lives. There is obviously some loss which cannot be measured corresponding to the loss of links with the places where they originally lived. On the other hand, many of those who were resettled were in fact immigrants attracted by the various projects that were being implemented in this region, and who had been living in the affected areas for limited lengths of time. All of them were paid compensation"[65].
- In the view of the leaders of the dam-affected people, there are still matters outstanding with regard to compliance with the agendas for negotiation.[66] They stated that during their first camp-in, they called for: the demarcation of rural plots of land; infrastructure for the new townships at Novo Repartimento and Breu Branco; houses built by Eletronorte; and definition of the maps of the new rural and urban areas. More recent versions of these claims also cover the period when no agricultural activities were permitted by those scheduled for resettlement; review of the compensation processes, and payment of outstanding matters and the allocation of areas of 100 hectares at PIC-Marabá.
- Since the first round of talks, which began with the first camp-in of the dam affected people in 1982, Eletronorte has denied that it promised houses for everyone; it stipulated that crop-planting should be halted, but admits that it advised farmers that no planting should be undertaken during the growth cycle. It states that the amounts of compensation were calculated by local professionals from Pará State hired for this purpose. The amount of compensation was stipulated at CR$1 350/hectare, with a assistance allowance of CR$30 000 for resettlement and compensation for all assets. With regard to the fifty-hectare plots of land, this is justified by the fact that they are located closer to the reservoir, while a hundred hectares were made available in more remote areas. Eletronorte identifies one of the main problems in the compensation and

displacement process as being the lack of organisation of the social segments that were subject to expropriation:

"A number of groups, commission or associations were set up, all with partial representation, lacking autonomy and with no power of representation at the necessary level (...) nevertheless, almost all those compensated happily accepted the amounts paid out." It felt that it had identified all areas to be flooded, as well as improvements, both productive and non-productive. Eletronorte commissioned a listing of prices from a suitable company in Belém indicating fair compensation to be paid to each expropriatee. *"(...) the Company went well beyond the legal stipulations (...) offering these communities living standards far higher than those that they had achieved in the reservoir area (...) As a donation, urban or rural plots of lands were assigned to them, together with other assistance for most of the expropriatees: payment of relocation fees and reusable materials, supply of materials to build their new homes, and help in starting up farming and grazing activities."*[67]

- The current sizing of the flooded area is also a matter of disagreement. For the leaders[68] the simple quantification of the area omits an accurate evaluation of the various sizes of the lake, and the consequences for the communities that received contradictory information: at times they would be displaced, at others they would remain on their lands. They stated that there were some areas from which the communities were removed (Santa Tereza do Taury) and which were not flooded, as well as the opposite - areas on which expropriatees were resettled were then flooded, forcing futher resettlement (Gleba Pucuruí and Santa Rosa).
- Eletronorte[69] blames the inaccuracy in the sizing of the areas to be flooded on the lack of appropriate technology at that time able to carry out the aerial survey. In its assessment, some "impacts" deriving from the construction of the Tucuruí Hydropower Complex are identified, which involve negative effects on the local populace and ecosystem. However, these effects are offset within the political situation of Brazil, or ascribed to the inexperience of the Company in dealing with certain situations.
- The populace affected by the dam and its leaders did not agree that the inaccurate figures for the number of families relocated could be blamed solely on the lack of experience of the Company, and they mentioned other factors that contributed to this problem: inaccuracy/mistakes in the estimates of the area to be flooded; strategies used to vacate the areas, including the shut-down of the Tocantins railroad; the lack of fair, legitimate criteria for surveying the communities in these areas; incentives to withdraw from resettlement implemented by Eletronorte through various methods. They blamed the struggle of the expropriatees on the implementation of the resettlement policy by the Company and felt that the compensation was unfair, prompting them to seek better solution to the outstanding matters which are not accepted as unresolved by the Company.
- Eletronorte claimed that the relocation process was covered by planning based on the following assumptions:

Expropriatees of urban origin: residents in towns and villages that were flooded were awarded homes in new townships built by the Company, and were properly compensated for improvements and the houses where they lived, and were also allowed to make free use of the materials resulting from the demolition of their homes. Some residents in the older urban centres had a type of kitchen garden at the rear of their homes, and the Company also assigned them small allotments close to these new townships.

Expropriatees of rural origin: residents of rural areas that were flooded were awarded rural plots of fifty hectares (the rural module in effect at that time in the region) together with a timber home-building kit for developing their land, assistance in the building of houses, as well as help in clear-cutting one hectare of land, and proper compensation for improvements to the old plot of land. Title-holding land-owners in the flooded areas, with ownership proven by registration with the registry office, were also awarded compensation for the land.

There are some cases of expropriatees, both rural and urban, who did not wish to be resettled under the programme launched by the Company, preferring to return to their places of origin. The Company added a certain amount to the compensation process for these cases, called the *Resettlement Waiver Allowance*.

Similarly, Eletronorte claims that the resettlement process was also covered by planning in which families initially affected by the 35m level would be resettled; these totalling 1 750 families in 1978, according to the survey carried out by the BASEVI subcontractor. The survey of the other families affected by the water level at 72.00m, which was the definitive depth of the reservoir, concluded in 1982, increased this figure to 3 152 families. The final figure reached 4 407 families resettled, 3 407 on rural plots of land and 1 000 in the townships built by the Company [70].

7.1.1.2 Swarms of Mosquitoes

- Eletronorte denied that swarms of mosquitoes made living conditions intolerable for people and animals in one of the most affected areas – the Gleba Parakanã.

  "Dermatological and respiratory diseases caused by smoke could be associated with swarms of mosquitoes. However, the feasibility of human residence was never undermined by the mosquitoes."[71]

- Local leaders [72] advised that the transfer of part of the populace from this plot of land to the Rio Gelado area offers evidence of the gravity of the situation. They feel that their case is proven by the fact that this transfer took place, moving them to an area lacking proper land titles and triggering fierce conflicts with large-scale land-owners.

7.1.1.3 Adverse Effects Downstream

- The riverbank communities claim that the quality of water downstream from the dam is poor; that waterborne diseases have increased; and that *várzea* floodland crops have diminished, with a reduction in the quantity and diversity of fishing catches.
- The decline in the quality and diversity of fish species was noted in the survey carried out by Eletronorte, with a decrease of 80% of the total commercial catch.
- On the basis of limnological studies carried out downstream, Eletronorte states that there was no alteration in the water quality that would alter its classification under CONAMA Resolution 20 - except during dry periods, when mitigatory measures were implemented.

7.1.1.4 Parakanã Indigenous Society

- According to the study team, the participation of the *Parakanã* people in the decision-taking processes related to the Parakanã Programme was limited during its twelve years in operation.

  "The Parakanã are still treated as the object of actions scheduled and stunted by the Company, rather than as subjects of a historical process."

- According to Eletronorte, the Parakanã Programme

  "is an indigenous action resulting from the proposal put forward by a number of technical experts, and does not form part of the actions scheduled and sponsored by the Company, as it merely underwrites these actions on a financial basis."…. "the compensatory measures undertaken in the Parakanã Programme allowed their land to be expanded; it is now demarcated, preserving and protecting them against trespassers and squatters, in addition to providing integrated actions in the areas of healthcare, education and support for farming activities designed to upgrade their general living conditions, according to the aspirations of the Parakanã people themselves. Prior to this Programme, this community was supported

financially by Eletronorte, and was gradually vanishing – down to 247 individuals before 1986 – and depending completely on the food supplied by FUNAI; today, it is expanding at an average rate of 6% a year, reaching a total of 483 people in October 1999".

7.1.1.5 Criteria and Guidelines: Policy Evolution and Compliance

The environmental variable was included too late in the history of the Tucuruí Hydropower Complex. During its construction stage, the measures dealing with social issues were implemented reactively by Eletronorte, lacked political guidelines focused on the resettlement and reimbursement of the communities affected, and the Company was unable to deal with emergency situations.

7.1.1.6 Licensing Process for Phase II of the Tucuruí Hydropower Complex

The leaders of grassroots movements and international NGOs claimed that they had no access to the environmental licensing process for Phase II of the Tucuruí Hydropower Complex, and found no political will on the part of the environmental agency to organise public hearings to disclose information on the project and its effects to the public. Once again there was a limitation of public participation in environmental licensing processes.

According to a representative of the State, Science, Technology and Environment Bureau (SECTAM - *Secretaria Estadual de Ciência, Tecnologia e Meio Ambiente*), the licensing process remains underway, and information is already available, and will be publicised. Eletronorte affirms that there will be no alterations either in dam height or maximum operating water level, which was the major concern of local grassroots movements and international NGOs about Phase II.

7.1.2 Results of the Meeting of the Consultation Group

This item offers an overview of the converging and diverging visions identified during the discussions at the II Work Meeting of the Consultation Group set up to provide support for the Tucuruí Hydropower Complex Case Study. The meeting was held on January 18 – 19, 2000, in Belém, Pará State.

On this occasion, representatives of the following institutions were present (number of representatives):

- ALBRÁS Alumínio (1)
- ANEEL – National Electric Power Agency (2)
- Grassroots Education and Advisory Centre - CEAP (5)
- Cametá Fishing Village (1)
- Engevix-Themag Engineering Consortium(1)
- CESAM Consultancy (1)
- Eletronorte – Centrais Elétricas do Norte do Brasil S/A (8)
- Carajás Forum (1)
- Dam Affected People Movement - MAB (1)
- Luteran Church of Belém – PCLB (1)
- Town Council of Tucuruí, Novo Repartimento e Breu Branco (3)
- Cametá Prelacy (1)
- Pará State Science, Technology, Environment Bureau – SECTAM (3)
- Pará State Planning and Coordination Bureau – SEPLAN (1)

- Rural Workers Union – Tucuruí, Novo Repartimento and Breu Branco (3)
- Pará Federal University - UFPA (3)
- WEED – World Economy, Ecology and Development (1)

As well as the entities listed above, representatives were present on behalf of people whose land was expropriated for the Tucuruí Hydropower Complex, as well as members of the Consultation Group set up to oversee the progress of the Case Study, representatives of WCD (Commissioner Medha Patkar and Senior Advisor Bruce Aylward) and members of the research team.

One of the exercised stipulated in the methodology of the World Commission on Dams was the completion by the participants of a questionnaire containing questions on the effective contribution of the Tucuruí Hydropower Complex to development. A total of 33 participants were randomly divided into four separate groups to complete the questionnaire. When analysing the results, it should be borne in mind that the number of people present is merely a sample of the wide spectrum of social agents involved, and hence no statistical inferences should be drawn from this data. The results are presented below, by question and summarised in Table 7.1:

12. Does the Case Study Preliminary Report undertake an adequate evaluation of the performance of the project in terms of its initial objectives?

Most participants in the meeting selected the "I agree" alternative. However, it should be stressed that this question was interpreted by some participants as referring to the Tucuruí Hydropower Complex, rather than the contents of the Preliminary Report drawn up by COPPE.

13. Is the project environmentally acceptable?

Most people selected the "strongly disagree" alternative, followed by "disagree". However, it should be mentioned that one of the groups highlighted the need to consider whether the notion of "environmentally acceptability" should be relativised by taking into account its meaning in the period in which the project was designed and implemented, rather than considering it solely from a contemporary standpoint.

14. Has the project encouraged economic growth and generated wealth?

The results of this survey indicated a divergence in the understanding of the role played by the Tucuruí Hydropower Complex as a springboard for the economic stimulation of this region. There was an even balance between the "agree" and "disagree" alternatives. Some participants mentioned that in fact the venture has prompted economic growth, though this has been restricted to certain economic sectors. Others felt that Tucuruí did not generate wealth, and queried the usage of this phrase, as it can have different meanings for different segments of society.

15. Did the entrepreneur comply with the national laws applicable at the time of the development, construction and operation of the project?

Most people felt that it did not do so. However, one of the groups stressed that at the time when the Tucuruí hydro-power complex was planned and implemented, the legal aspect was strongly linked to Brazil and the Company's exceptional circumstances at the time.

16. Did those in charge of the project adequately assess the options available at that time before taking the decision to build the dam?

According to most of the participants in this meeting, those in charge of the project did not properly assess the existing options before taking the decision. But yet again, there was a proviso that consideration should be given to the exceptional circumstances in the country at the time.

17. Did those positively affected participate in the decision-taking processes associated with the project?
About 60% of answers were "strongly disagree" and "disagree". About 24% of answers were "agree" or "strongly agree".

18. Did those negatively affected participate in the decision-taking processes associated with the project?
Most participants opted for the "strongly disagree" and "disagree" alternatives.

19. Do the direct economic benefits generated by the project (electricity) justify the resources invested?
About 60% of answers were "strongly disagree" and "disagree". Exactly 1/3 of answers were "agree" or "strongly agree".

20. Were the benefits deriving from the project fairly distributed?
Most of the participants opted for the "strongly disagree" or "disagree" alternatives.

21. Did the benefits deriving from the project outweigh the negative impacts that it generated?
This response was split equally between the "strongly disagree – disagree" and "agree" alternatives.

22. How would you classify the contribution made by the project to development?
Once again, the replies were split between negative and positive. However, it was noted that the word "development" has a very generic meaning.

Table 7.1 Questionnaire Results

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Don't Know
1. The draft study report adequately assesses performance with respect to initial project objectives	3	6	2	16	3	3
2. The project is environmentally acceptable	12	9	4	6	2	0
3. The project has stimulated economic growth and wealth creation	9	3	4	14	2	1
4. The entrepreneur complied with the applicable national laws of the day in the development, construction and operation of the Project	10	11	1	4	4	3
5. The project developers adequately assessed the available options at the time, before deciding to build a dam	15	9	3	4	0	2
6. Positively affected people have participated fully in the decision-making processes associated with the project.	10	10	1	7	1	4
7. Negatively affected people have participated fully in the decision-making processes associated with the project	15	13	2	2	1	0
8. The direct economic benefits generated by the project (i.e.power) justify the funds invested	9	11	2	6	5	0
9. The benefits from the project have been distributed equitably	16	14	1	1	0	1
10. The positive benefits of the project outweigh the negative impacts	15	7	0	10	1	0
Question	Very Low	Low	Neutral	High	Very High	Don't Know
11. How do you rate the development effectiveness of the project?	8	11	0	13	1	0

The results of this survey, when analysed in homogenous groups, with the questionnaires completed by representatives of the four segments who attended the meeting in Belém – Eletronorte, grassroots movements, teaching and research institutions, and other institutions (Federal and State Government, industry etc.) – show a clear-cut polarisation between the representatives of Eletronorte and the grassroots movement. While the former tended to opt for the “agree” and “strongly agree” alternatives, the latter selected the “strongly disagree” and “disagree” options.

In fact, these results were not unexpected, as they indicate opinions at a crucial time. In contrast to other projects already in operation, the Tucuruí Hydropower Complex is still underway; Phase II is currently being implemented. This partly explains the positions adopted, with the recent experiences still fresh in the memory of both the electricity sector and affected communities. The positions here reflect the current situation, and clearly indicate the different views of the social players involved.

Most participants agreed, however, that popular participation in the decision-making process, especially of those who were negatively affected, was insufficient. Most participants agreed that the benefits of Tucuruí Project were not fairly distributed.

An account of the results of the II Meeting of the Consultative Group is presented in the Annexes.

7.2 Lessons Learned

This section presents the lessons to be learned from this Case Study, as proposed both by the members of the team and the social players who attended the meeting of the Consultation Group held in January 2000. These lessons are divided into general and specific lessons, as indicated by the technical staff at the Consultation Group meeting.

7.2.1 General Lessons

This sections begins by presenting the seven lessons learned through the experience of the implementation and operation of the Tucuruí Hydropower Complex, as prepared by the study team in charge of drawing up this Case Study following feedback from the II Work Meeting of the Consultation Group held in Belém, Pará State. Thereafter new lessons learnt, as proposed at the meeting, are presented..

7.2.1.1 Mentioned by the Study Team

Lesson Learned 1

Question	Local and regional integration of hydropower ventures
Project component cycle	Planning
Lesson	**Future hydropower projects should be implemented according to a new model which includes the objectives of regional and local development from the conceptualisation stage onwards; the objectives of these projects should not be limited to power generation for ventures whose benefits are experienced outside the region in question.**
Evidence	The overriding factor in the decision-making processes was the prospect of power consumption by electricity-intensive industries; there was a lack of integration between the benefits of power generation outside the region, and the local and regional development model.

Lesson Learned 2:

Question	Assessment of alternative sites for hydropower projects
Project component cycle	Planning
Lesson	**In order to implement new hydropower projects, a review should be undertaken of the hydropower inventory studies for the entire basin, in advance; and during the identification of the division of the drop (the location and dimension of each plant), an assessment of the social and environmental impacts should take place.**
Evidence	When assessing alternative sites for the Tucuruí Hydropower Complex, at the time the decision was taken, there was no full assessment of the social and environmental impacts of each of these alternatives, due mainly to urgent pressure to choose the alternative that would provide the largest amount of electricity

Lesson Learned 3:

Question	Assessment of alternative sites for hydropower projects
Project component cycle	Planning
Lesson	**The importance of a pre-evaluation process of the environmental impacts and the various alternatives requires the development and fine-tuning of new public participation mechanisms at all design stages of major dam projects: planning, construction and operation.**
Evidence	During all stages of the decision-taking process, as well the construction and operation phases, public participation was restricted or even non-existent, which resulted in a precarious pre-assessment of the environmental impacts.

Lesson Learned 4:

Question	Establishment of Basin Committees
Project component cycle	Planning
Lesson	**The implementation of large-scale hydropower ventures requires the establishment of a development committee for the entire basin, responsible for conducting the project and disciplining negotiations among the various social agents involved.**
Evidence	During the planning and operation stages of the venture, the basin as a whole was not considered, particularly in terms of social and economic aspects, with little integration during negotiations between the various social agents involved. After the implementation, some problems, particularly those associated with navigation in the basin and floodplain use downstream, arose due to this narrow view.

Lesson Learned 5:

Question	Criteria for defining the area affected by hydropower complexes
Project component cycle	Planning
Lesson	**The definition criteria for selecting the area directly affected by hydropower plants should be reviewed, particularly with regard to the right to financial compensation (royalties); the area demarcated should not be limited to a percentage of the area flooded. Social control mechanisms, overseeing the assignment and allocation of funds, should be introduced.**
Evidence	In the studies drawn up for the implementation of Tucuruí, most of the impacts were associated with events only in the area scheduled for flooding. For instance, with regard to the question of royalties, downstream municipal districts subject to environmental impacts were not offered compensation.

Lesson Learned 6:

Question	Assessment of environmental impacts
Project component cycle	Planning
Lesson	**Scientific uncertainty over the scope and relevance of the environmental risks and impacts of the venture should not function as a pretext for failures to take various aspects into account, but should rather impose the adoption of the "precaution principle" throughout all stages of the project: planning, construction and operation.**
Evidence	Several environmental impacts were not properly foreseen, or were not examined by the monitoring programs, such as declines in bathing and drinking water quality, mercury contamination and possible future losses of biodiversity. Due to this lack of information, appropriate mitigatory and/or corrective measures were not undertaken.

Lesson Learned 7

Question	Contribution to regional and national sustainable development
Project component cycle	Planning and operation
Lesson	**The lessons learned from the Tucuruí Hydropower Complex Case Study should be applied in the planning, construction and operation of new hydropower projects in Amazonia, so that they can make real contributions to the sustainable and participative development of the region and the country.**
Evidence	The Tucuruí experience is very important, as the decision-taking process took place in special conditions, including the nature and location of the Project; also, many of its consequences were unprecedented experiences. Many of these experiences can be usefully applied in dams to be built in similar conditions.

7.2.1.2 Indicated by the Participants in the II Meeting of the Consultative Group

Lesson Learned 8:

Question	Assessment of social impacts
Project component cycle	Planning
Lesson	**Redefinition of the concept of the affected populace, ensuring that this is no longer limited merely to the communities living in the area to be flooded when forming the future reservoir.**
Evidence	The downstream populace was excluded from the compensation process.

Lesson Learned 9:

Question	Grassroots movements
Project component cycle	Planning and operation
Lesson	**Acknowledgement by the entrepreneur that social movements are legitimate spokespeople and agents in the definition of Government policies, and should influence decisions that affect their lifestyle.**
Evidence	Initially not included in the process due to circumstances at the time, grassroots movements gained force and grew into important negotiators with the entrepreneurs, helping to improve dialogue and ensuring better solutions for all stakeholders.

Lesson Learned 10:

Question	Assessment of social impacts
Project component cycle	Planning and operation
Lesson	**The entrepreneur should proceed from the principle that the perception of the populace regarding apparent impacts on the lives of local communities – even when scientific proof is lacking – should be taken into consideration and be covered by social welfare measures and policies.**
Evidence	Scientifically unproven impacts perceived by the populace – such as the problems of bathing and drinking water – led to unnecessary sources of conflict between the entrepreneur and the affected communities.

Lesson Learned 11

Question	Assessment of social impacts
Project component cycle	Planning and operation
Lesson	**The expertise built up thus far on the environmental impacts of large-scale hydropower projects should underpin the preparation of social welfare policies for dealing with associated social issues.**
Evidence	In the case of Tucuruí, the project's history of successful and misguided decisions could be of much use for future projects with similar characteristics.

Lesson Learned 12

Question	Participation of society in the decision-taking processes
Project component cycle	Planning
Lesson	**The need for guaranteed access to technical information on the project and its associated impacts, in language appropriate to the public domain.**
Evidence	The populace was not properly advised about certain impacts, relating mainly to the environment, such as the issue of downstream water levels and quality. This created unnecessary sources of tension.

Lesson Learned 13:

Question	Participation of society in the decision-taking processes
Project component cycle	Planning and operation
Lesson	**The need to set up permanent channels of communication between the entrepreneur and the communities affected by the venture throughout the entire project cycle.**
Evidence	The communication channels between the populace and the enterpreneur were not clearly established, especially at the beginning of the negotiation process, and this created unnecessary sources of tension, particularly when problems arose.

Lesson Learned 14

Question	Fostering the development of rural areas
Project component cycle	Planning and operation
Lesson	**There should be integrated development actions in rural areas, stressing renewable energy projects and upgrading the quality of life of local communities, given the fact that the urban populace has easier access to the benefits of these ventures, and the poor service levels in rural parts of Amazonia.**
Evidence	Planning did not take specific local characteristics into account, focussing mainly on regional and national interests. Local communities were not explicitly included in the planned development process.

7.2.2 Specific Lessons

7.2.2.1 Planning

- The preparation of the Basin Master Plan should precede the hydropower plant studies.
- Environmental impact studies should include the impacts of the associated transmission lines, in addition to the adverse effects and benefits of the implementation and operation of the dam.
- Economic and environmental feasibility studies should be undertaken at the same stage of hydropower ventures.
- Development approaches and methodologies should be adopted that include public participation from the stage of economic, social and environmental feasibility studies onwards.

- Definitions in the planning stage of a compensation and resettlement policy should be implemented with the participation of local society.

7.2.2.2 *Implementation*

- Preservation areas should be defined and implemented during the construction stage of the venture, thus offsetting losses in plant cover.
- The lead-time required between the preparation of the designs and their implementation should be controlled. In Brazil, projects are generally conceptualised over a period which is very short in relation to the lengthy implementation period: this results in high costs, and in many cases the resizing of the project.
- An Environmental Education Programme should be designed and implemented to prepare the populace for the expected changes, and train them to realise the full potential for the development of production activities under new social and environmental conditions.

7.2.2.3 *Operation*

- Power plant operations cannot be planned on the basis of merely maximizing power generation potential. Operations must include the dam and the reservoir, meaning the various upstream and downstream uses that should be taken into consideration in the operating rules of the hydropower plant.

7.3 Recommendations put forward by Participants in the II Meeting of the Consultative Group

In addition to the new lessons learned, a set of recommendations were drawn up as a result of the discussions at the II Meeting of the Consultative Working Group, listed below:

- Mandatory investments in the alternative sources of energy for generating electricity;
- The establishment of a National Commission on Dams, operating permanently;
- Fine-tuning the processes and tools for disseminating information on the various stages of the project – planning, implementation and operation;
- Identification of the players responsible for the various actions to be implemented during the construction and operation stages of the venture;
- Setting up a Information Management Forum.

Endnotes

[1] The Tucuruí project consists of two phases, with Phase II currently under construction. The WCD methodology attempts to obtain views and lessons from experiences related to dam performance in the past, through analyses of case studies. Aspects related to Phase II will thus only be covered insofar as they are relevant to the construction and operation of the complex to date, within the historical context of the decision-making process.

[2] Limited field controls and dense plant cover caused huge discrepancies in this estimate, as noted by Cadman, J. (1999) in the analysis of the environmental aspects of six hydro-dams in the Amazon region.

[3] The chapters on the social and economic studies and the economic assessment of the assets affected fill only ten pages and do not analyse the effects of work on this project; the phrase quoted reflects the feeling – widespread at that time, especially among the decision-makers – that projects of this type are intrinsically positive. Nevertheless, the project township (designed to house 34 000 people) was built away from the town, with no attention given to the possibility of upgrading it.

[4] Free partial transcription with adaptations from the Tucuruí Hydropower Complex Case Study, Eletrobrás, 1992.

[5] The construction and start-up of this venture took place during a period when Brazilian economy was overwhelmed by various macro-economic and fiscal problems, including four different currencies between 1974 and 1990 (Cruzeiro, Cruzado, Cruzado Novo, Cruzeiro), while annual inflation topped 1,790 % in 1989. See in the Annexes the Brazilian annual inflation and different currencies in the period.

[6] Spilled water due to the lack of energy demand.

[7] It was decided not to take industrial energy consumption into consideration, in order to avoid the electricity-intensive industries skewing the analysis.

[8] In legal terms, royalties are applicable only to the payments related to the Itaipú Hydropower Complex, with other cases being handled as financial compensation.

[9] This Report devotes less than a page to an inadequate prognosis of ecological aspects, merely recommending additional studies as mentioned.

[10] Lacking any arguments to support it, this statement shows that the Report was probably drawn up to merely to comply with legal formalities.

[11] The ELETRONORTE market studies probably included forecast demands from the mining and processing industries. However, this Report is noteworthy due to its affirmations of the feasibility of the hydropower plant, with no economic calculations giving the internal rates of return of the venture at various tariff levels, for instance.

[12] The full text on water quality is in the report *Avaliação das Condições da Qualidade da Água / Limnologia do Reservatório da UHE Tucuruí – PA*, by the consultants José Alexandre M. Fortes e Carlos Eduardo B. Pereira. All references for this text are listed in the Bibliography.

[13] Godoy, P.R.C & Vieira, A. P., *Hidrovias Interiores*, in O Estado das Águas no Brasil, ANEEL, Brasília, 1999.

[14] In general terms, fishing communities were affected in different ways.

[15] This section is an adaptation of Aula et al (1994).

[16] Among which are Eletronorte and Biophysics Department / UFRJ

[17] "Effects" may be understood as the direction and practical outcome of economic, political, and social interventions over time that steadily reshape the social, economic, environmental and cultural organisation of a society.

[18] A summary of the energy issue in Amazonia can be found in the Annals of the Seminar on Energy in Amazonia; Magalhães, Sônia, Britto, Rosyan de Caldas, Castro, Edna Ramos, in. *Energia na Amazonia*, Belém, MPEG, UFPA, UNAMAZ, 1996 (2 volumes).

[19] Information from the local representative of ELETRONORTE / Property Assets Unit, during the field work at Tucuruí, February 1996.

[20] This proposal is currently against setting up an Environmental Protection Area, which is urged by the Tucuruí Town Council and the State Government.

[21] Field survey carried out in October – November 1999 – COPPETEC/UFRJ/WCD.
[22] The Tucuruí region consists of a large social and economic area, that is divided by the stages of the dam.
[23] Data confirmed in the field survey carried out in November 1999.
[24] Cf. PARÁ, State Government,. Breu Branco: SEPLAN, 1993, p. 9.
[25] Ditto .P. 10.
[26] Cf. PARÁ, State Government,. Novo Repartimento, Belém: SEPLAN, 1993, p. 8.
[27] Cf. IBGE apud Eletrobrás, 1992, op. cit., p. 34.
[28] INCRA has a rural electrification plan for rural settlements called LUMIAR, that is being implemented at the Argelim settlement on the Transcametá Highway, 50 kilometres from the town centre, and at Ladário, in the Baião and Pacajá municipal districts.
[29] According to the IBGE classification, the Lower Tocantins region of Pará State consists of the Baião, Mocajuba, Cametá, Limoeiro do Ajuru and Oeiras do Pará municipal districts.
[30] Cf. Official Letter nº 391/93/CGRH/DNAEE, dated September 27, 1993, addressed to Federal Congresswoman Socorro Gomes.
[31] Cf. Comments by Eletronorte on the Preliminary Report for the Tucuruí Hydropower Complex Case Study. January 1999.
[32] The concept of the region built up here stresses the capacity to take economic and political decisions in order to produce a spatial and social division. This process of simultaneous division, aggregation and differentiation responds to the interests of groups, companies and the State, which implement specific actions within arbitrarily-defined divisions.
[33] The listed sawmills are Madeforte Indústria e Comércio Ltda, Madelândia, and Thaliman Madeiras.
[34] See the Preliminary Synopsis – Agricultural Census (*Sinopse Preliminar do Censo Agropecuário*), Pará, 1975. Rio de Janeiro, 1977.
[35] This is the setting for disputes between those calling for the establishment of an Environmental Protection Area (APA – *Área de Proteção Ambiental*) and those urging the introduction of an Extractivist Reserve.
[36] Firebreaks around small patches of cropland cleared by the slash-and-burn method.
[37] The Census was carried out by the Society, Population and Nature Institute (*Instituto Sociedade, População e Natureza*), 1997.
[38] See the field survey carried out in October – November 1999.
[39] The defoliant known as Agent Orange was a combination blended for military purposes of the active principles in Tordon 155 BR (2,4,5-trichlorophenoxyacetic acid) and Tordon 101 BR (2,4-dichlorophenoxyacetic acid) with no constraints on the amount of dioxin appearing as an impurity. The Brazilian version – Tordon 101 BR – does not contain dioxin, and the manufacturer of Tordon 155 BR (Dow Chemical) stated that its dioxin level did not exceed 0.1 ppm, which complies with the herbicide limits established not only in Brazil but also by the EPA in the USA. Similar to Tordon 155 BR, Banvel 450 is manufactured by BASF AG.
[40] This is a standard per capita incidence index, calculated according to the formula [number of positive smears] / [population x 1000]. The National Health Foundation (FNS) ranks areas with Annual Parasite Index rates higher than 30 as high-risk for malaria, while those with Annual Parasite Index rates between 5 and 30 are rated as medium risk.
[41] Arthropod-borne viruses, *i.e.* arboviruses, are viruses that are maintained in nature through biological transmission between susceptible vertebrate hosts by blood feeding arthropods (mosquitoes, psychodids, ceratopogonids, and ticks). Vertebrate infection occurs when the infected arthropod takes a blood meal. The term 'arbovirus' has no taxonomic significance (CDC, 1999).
[42] ELETRONORTE; Control of downstream consequences during the Tucuruí reservoir filling period. Prognosis. July 1983
43 ELETRONORTE; Control of downstream consequences during the Tucurui reservoir filling period.. Prognosis. November 1983.
44 ELETRONORTE. Hydropower reservoir filling period. Report on downstream activities.
45*:"(...) and at this vital moment, as though making a supreme effort, the Tocantins did its utmost to sweep human ingenuity away. Tamed, it fell silent. (...) The flow of the Tocantins River was halted by the power of determination of the Tucuruí Dam-builders (...) And we are proud of having participated*

in this Amazon epic." Minutes of meeting held on September 6, 1984 signed by representatives of Eletronorte, Camargo Correa and the Engevix Themag Consortium.
[46] Emergency actions downstream. Implementation studies of definitive water supply solutions. TUC 10- 26515- RE.
[47] Interview with Aida Maria, quoted in the Tucuruí case study entitled *UHE Tucuruí - Estudo de Caso*.
[48] Interview with Gerson Peres, quoted in the Tucuruí case study entitled *UHE Tucuruí - Estudo de Caso*.
[49] Refers to a traditional farming system based on temporary crops, grown on fertile soils usually accessible only by river. This is part of the *caboclo* culture of riverbank communities. These areas are flooded by freshwater tides from February through April, during the rainy season. This rapid daily flooding system deposits sediments on the surface of the soil, keeping it fertile. The *várzea* floodland soils are consequently among the most fertile in this region, thanks to this natural fertilisation, irrigation and drainage system.
[50] At the time, Lula was the major leadership of workers movement and president of Brazil's Workers Party (PT).
[51] Rural Workers' Unions at Tucuruí, Itupiranga and Jacundá, and the Expropriatees' Association at Velha Jacundá.
[52] Cf. field survey carried out in February 1996.
[53] Even admitting that this is a self-classificatory idea in the struggle process, this study adds social, historical and cultural categories that make it broader-ranging and express a convergence of situations, whether circumstantial or structured, that are adverse to social organisation and traditional life-styles, which began to assail the populace after the advent of the Tucuruí Hydropower Complex.
[54] The shout of the Earth (*Grito da Terra*) is a protest organised periodically by local trade unions and federations, (FETAGRI, *Central Única dos Trabalhadores* – CUT), with the support of the Pará Federal University (UFPA – *Universidade Federal do Pará*) and the Emílio Goeldi Museum. The purpose of the 1996 event was to analyse development and discuss how the Hydropower Complex could contribute to the development of the region, in addition to discussing its expansion and the social, economic and environmental consequences on the region. This event was attended by representatives of local society and organisations, as well as research entities and some State Congressional representatives (José Geraldo, Paulo Rocha and Ana Júlia) as well as a Federal Congressman (Gerson Peres).
[55] This plan was drawn up in August 1997, as a continuation of the activities undertaken at the Intermunicipal Meeting for the Area of Influence of the Tucuruí Hydropower Complex / Pará (*Encontro Intermunicipal da Area de Influence da Tucuruí Hydropower Complex-Pará*) . It is divided into sections that outline the main claims and demands of local society: the Environment and Extractivism; Infrastructure (which includes the electricity issue), Land Sales; Titles and Use, and Farming and Grazing. Each section lists the people in charge, the partners and the implementation deadlines.
[56] Based on LIMA, J.L., *Políticas de Governo e desenvolvimento do setor de energia elétrica: do Código de Águas à crise dos anos 80 (1934-1984)*, Memória da Eletricidade, Rio de Janeiro, 1995.
[57] Trans-national corporations, such as Canada's Brazilian Traction, Light and Power, known more simply as Light, and the American & Foreign Power Company – Amforpin the USA, held a virtual monopoly in Brazil's power sector until the 1960s.
[58] There are records of the prevailing line of thought at that time, in which it was necessary to channel funding to very few projects, draining finances and leaving no opportunity for politicians to undertake new projects. In charge of preparing the Targets Plan for the Kubitschek Government, Lucas Lopes noted in a statement to the Electricity Heritage Centre that the main merit and luck of this electrification project was that it was held up in the Chamber, allowing time for funding to be concentrated in major projects "of the utmost profitability and high repute."
[59] Although Light held most of the market in the Rio – São Paulo Region, until it was taken over by Eletrobrás.

[60] Brazil's National Development plans were generally approved by the National Congress with little or no discussion. For instance, the New Republic Plan for 1985-1989 passed through expiry of deadline.

[61] The terms of reference also stipulated technical and economic feasibility studies for powerplants which, after conclusion of the previous stages, were considered the most economic. This never in fact took place because both the three-year deadline established when ENERAM was set up and the budget allocations expired before this deadline.

[62] Arquitetura Ambiental S/C LTDA, *Hidrelétrica de Tucuruí - Estudo de Caso*, Eletrobrás, Rio de Janeiro, June 1992.

[63] This practice was common, leading to an understanding that, once the decision to implement a specific venture had been taken, the feasibility studies were intended merely to comply with legal formalities or the requirements of the financing agencies.

[64] At that time, Tucuruí had a populace of 6,000 inhabitants with a further 5 200 in the rural area. The urban area was to be occupied by access routes, camp-sites and construction yards, which was why it would be immediately necessary to resettle the entire town, certainly resulting in a considerable delay in the construction schedule. "In addition to the difficulties in the costs of resettling the entire town, social and economic aspects would have to be taken into account, as this is the only town in the region with a minimal infrastructure in terms of trade, primary and secondary education, hospitals and medical posts for servicing the entire urban and rural population." Feasibility Study, December (1974)

[65] Cf. Comments of Eletronorte to the Preliminary Report on the Tucuruí Hydropower Complex Case Study, January 1999.

[66] Cf. The interview with the Executive Coordinator of the CEAP and the Chairman of ATAEPA in November 1999.

[67] Excerpts of interview of Eletronorte by the social and economic team in November 1999.

[68] Cf The considerations and points put forward by CEAP on the basis of the Scope Phase Final Report / WCD December 1999.

[69] Cf. The statement by Dr. Gilberto at the Phase II Meeting in Belém for the WCD Case Study.

[70] Cf. Eletronorte comments on the Tucuruí Hydropower Complex Case Study Preliminary Report, January 1999.

[71] Cf. The comments made by the technical staff of Eletronorte on the Final Report of the Scope Phase of the Tucuruí Hydropower Complex Case Study /WCD.2 September 1999.

[72] Excerpts from the interview with the Executive Coordinator of CEAP during the field survey – Case Study /WCD. November, 1999

References

A PROVINCIA DO PARÁ. *Reserva extrativista será criada em Tucuruí*. Belém, 9/6/1994 e Caderno 2, p. 8, 9/7/1994.

ACEVEDO MARIN, Rosa Elizabeth Hidroélectrique de Tucuruí: réorganisation sociale des paysans de la Région des Iles à Tucuruí.Belém: UFPA/NAEA, s/d. (mimeo)

ACEVEDO MARIN, Rosa Elizabeth. *Amazonie brésilienne: le coût écologique des barrages*. Ecologie Politique. Paris, Ed. La Découverte, nº 11/12, 1994.

ACSELRAD, H. 1998. Mercado de terras e meio ambiente em áreas de grandes projetos de investimento – o caso da Usina Hidrelétrica de Tucuruí. Rio de Janeiro: IPPUR/UFRJ, (mimeo)

ACSELRAD, H. 1991 "Planejamento autoritário e desordem sócio-ambiental na Amazônia: crônica do deslocamento de população em Tucuruí" in Revista de Administração Pública. Vol 25 (4): 53-68, out./dez.

AGUDELO, S.F. 1990. El Paludismo en America Latina. México. Ed. Universidad de Guadalajara.

AHLF, W; Clamano, W & FORSTNER, U 1990. "Biogeochemical Studies on the Distribution of Heavy Metals in the Elbe Estuary" in Chambers, PL & Chamber, CM Eds. Estuarine Ecotoxicology. Japaga Pub: Ashford

AJARA, Cesar et al 1991. "O Estado do Tocantins: Reinterpretação de um Espaço de Fronteira" Revista Brasileira de Geografia, V.53, n.4, IBGE: Rio de Janeiro,

ALMEIDA, Alfredo Wagner Berno de 1996. "Refugiados do Desenvolvimento. Os deslocamentos compulsórios de índios e camponeses e a ideologia da modernização." Travessia maio-agosto 1996 pp. 30-35.

ALMEIDA, Alfredo Wagner Berno de 1986. "Estrutura fundiária e expansão camponesa". In ALMEIDA JR. (org.), Carajás. Desafio político, ecologia e desenvolvimento. São Paulo: CNPQ/Brasiliense, pp. 265-293.

ANDRADE, Lúcia A.A. 1992. "O corpo e o cosmos. Relações de gênero e o sobrenatural entre os *Asurini* do Tocantins". Dissertação de mestrado. São Paulo: FFLCH/USP.

ANDREWS, RNL & TURNER, AG 1987. "Controlling Toxic Chemicals in the Environment" in Lave, LB & Upton, AC Eds. Toxic Chemicals, Health, and the Environment – Baltimore: The John Hopkins Univ Press.

APHA 1975. Standard Methods For The Examination of Water and Wastewater. Baltimore: American Public Health Association.

ARIAS, J.R. 1983. "Estudos de ecologia e controle ambiental na região do reservatório da UHE de Tucuruí." Relatório do segmento Impacto do reservatório no aumento de doenças endêmicas. (Leishmaniose e Doença de Chagas). Volume 7. Convênio INPA & Eletronorte. INPA. Manaus. p12.

AUBERTIN, Catherine 1993. "Extractivisme végétal et préservation de la forêt amazonienne." in Cahiers du Brésil Contemporain. nº 167, pp. 21-38.

AULA, I. BRAUNSCHWEILER, H.; MALIN, I. 1995 "The watershed flux of mercury examined with indicatos in the Tucuruí reservoir in Pará, Brazil." in The Science of the Total Environment vol 175 (97-107).

AULA, I. et al. 1994 "Levels of mercury in the Tucuruí reservoir and its surrounding area in Pará, Brazil." in Watras, C.J. & Huckabee, J.W. ed/s. Mercury Pollution: Integration and Synthesis. USA: Lewis Publishers.

BARATA, R.C. 1995. "Malária no Brasil. Panorama Epidemiológico na última década." in Cad. De Saúde Pública, RJ, 11 (1): 128-136, jan/mar.

BARROS, Ana Cristina, VERISSIMO, Adalberto ed/s. 1996. A expansão da atividade madeireira na Amazônia: impactos e perspectivas para o desenvolvimento do setor florestal no Pará. Belém: IMAZON.

BASTOS, U.P. et al. 1987 Efeitos ambientais associados a operação da Usina Hidrelétrica de Tucuruí, durante o período de estiagem de 1986. Eletronorte.

BECKER, B. K 1990. Amazônia. Ática: SP.

BECKER, B. K 1997. "Novos Rumos da Política Regional." in: A Geografia Política do Desenvolvimento Sustentável. Org. Becker, B e Miranda, M. EDUFRJ: RJ.

BECKER, B. K 1999. Cenários de Curto Prazo para o Desenvolvimento da Amazônia. Mimeo. Brasília: MMA/Secretaria de Coordenação da Amazônia:

BECKER, B. K. 1982. Geopolítica da Amazônia. A Nova Fronteira de Recursos. Zahar: RJ.

BECKER, B., NASCIMENTO, JAS, COUTO, RCS. 1996. "Padrões de desenvolvimento, hidrelétricas e reordenamento do território na Amazônia." In: Energia na Amazônia. Belém. MPEG / UFPA / UNAMAZ.

BEIJER, K & JERNELÖV, A 1986. "General Aspects of and Specific Data on Ecological effects of Metals" in Friberg, L et al Ed., Handbook on the Toxicology of Metals. Vol 1. Elsevier Pub. N. York. 253-268.

BERTRAM, HP; KEMPER, FH & ZENZEN, C 1985.– "Man - a Target of Ecotoxicological Influences" in Nürnberg, HW Ed. Pollutants and Their Ecotoxicological Significance. J. New York: Wiley & Sons

BIANCHINI Jr., I – 1997. "The degradation process of organic matter in reservoirs." in: ROSA, L.P. & SANTOS, M. A dos, (ed/s) - Hydropower plants and greenhouse emissions. Rio de Janeiro: COPPE.

BIRLEY, M.H. 1992. Diretrices para prever las consecuencias de las obras de desarrollo de los recursos hidricos en cuanto a las enfermedades transmitidas por vectores. OMS/ FAO/ PNUMA/ CNUAH.

BOND, W.J. & ROBERTS, M.G. 1978. "The colonization of Cabora Bassa, Mozambique, a new man-made lake, by floating aquatic macrophytes." in Hydrobiologia 60:243-259.

BRASIL Manual de Legislação. 1999. Segurança e Medicina do Trabalho 42a ed. Ed. Atlas. São Paulo.

BRASIL. Decreto n. 68.913 de 13 de Julho 1971 (Cria a Reserva Indígena Parakanã).

BRASIL. Decreto n. 87.845 de 22 de Novembro de 1982 (Homologação da Área Indígena Parakanã)

BRASIL. Decreto n. 91. 028 de 5 de Março de 1985 (Área Indígena Parakanã)

BREDER, R; NÜRNBERG, HW; GOLIMOWSKI, J & STOEPPLER, M 1985. "Toxic Metal Levels in the River Rhine" in Nürnberg, HW (ed). Pollutants and Their Ecotoxicological Significance. N. York: J. Wiley & Sons

BROWN, A.W.A. & DEAM, J.O. 1973. "Health aspects of man-made lakes" in ACKERMANN, W.C.; WHITE, G.T. & WORTHINGTON, E.B. (eds.) Geophysical Monograph. 17 (755-764) Washington: American Geophysical Union..

BRUYNING, C.F.A.- 1978. "Man-made lakes, irrigation and schistosomiasis." in: PANDAY,R.S.(ed). Proceedings of the Symposium Man-Made Lakes and Human Health. Paramaribo: University of Suriname. 23-25 de outubro de. p. 21-25.

CALDAS, L.Q. 1999. "Risco potencial em Toxicologia Ambiental." in Gestão e Avaliação de Risco em Saúde Ambiental. RJ. Ed. FIOCRUZ.

CARVALHO, J. P. Fontenelhe de- 1994. Relatório Programa parakanã, dezembro, pp. 21

CARVALHO, J. P. Fontenelle de – 1986. Relatório sobre Indenização aos Índios Parakanã, Belém: 4 SUER/FUNAI, dezembro

CARVALHO, J.L.; MERONA, B. 1986. "Estudos sobre dois peixes migratórios do baixo Tocantins, antes do fechamento da barragem de Tucuruí." Amazoniana, 9(4): 595-607

CASTELLANOS, P.L. 1990. "Sobre el concepto de salud-enfermidad. Descripción y explicación de la situación de salud." in Boletín Epidemiológico. OPS.

CASTRO, E. 1989. "Resistência dos atingidos pela barragem de Tucuruí e construção de identidade." in HÉBETTE, J., CASTRO, E. (Org). Na trilha dos Grandes Projetos. Cadernos NAEA, Belém, UFPA/NAEA, nº 10, p. 41-70

CASTRO, Edna M. Ramos de- 1993. "Modelo econômico e modos de vida: confrontos e alternativas no sul do Pará ", in A.C.Diegues (org.), A dinâmica social do desmatamento na Amazônia: populações e modos de vida em Rondônia e Sudeste do Pará . São Paulo: UNSRID/NUPAUB. pp. 20-59

CASTRO, Edna M.R. e HEBETTE, Jean 1989. *Na trilha dos grandes projetos, modernização e conflito na Amazônia.* Belém: NAEA/UFPa.

CDC - Centers for Disease Control and Prevention, National Center for Infectious Diseases, Division of Vector-Borne Infectious Diseases. **Detailed information on arboviral encephalitides.** http://www.cdc.gov/ncidod/dvbid/arbor/arbdet.htm, October 1999.

CEDI - 1985**.** Sudeste do Pará - Povos Indígenas do Brasil, vol. 8. São Paulo: Centro Ecumênico de Documentação e Informação.

CEPEL - Rel.111/99 - A Incorporação da Dimensão Ambiental ao Planejamento da Expansão do Setor Elétrico

CEPEL – REL.681/99 – Análise Ambiental dos Empreendimentos Previstos no Trecho do Médio Tocantins no Planejamento da Expansão (2000/2009)

CIMI NORTE II/CPT Norte II/CONTAG. Tucuruí urgente. Outubro 1984, pp. 3. Memo.

CNPq – 1985. Estudos do Impacto do Reservatório de Tucuruí, no aumento das doenças endêmicas da região. Manaus. CNPq/INPA.

COMISSÃO MUNDIAL DE BARRAGENS. 1999. Estudo de caso da UHE-Tucuruí (Brasil). Relatório da 1. Reunião do Grupo de Trabalho. Fase Escopo, Belém, 9-10/8/99, pp.26

COMISSÃO MUNDIAL DE BARRAGENS. 1999. Usina Hidrelétrica de Tucuruí. Estudos de caso da CMB. Relatório final da fase de Escopo, Agosto, pp. 42.

COMISSÃO PRÓ-ÍNDIO. 1979. Indios Parakanã: o desino de um povo. pp.2. Memo.

COREY O , G. 1988. Vigilancia en Epidemiologia Ambiental. México. CPEHS/OPS/OMS. Serie Vigilancia 1.

COUTO, RCS. 1991. Buscando Ouro, Perdendo Saúde: Um estudo sobre as condições de Saúde no garimpo do Cumarú-PA. Tese de mestrado. ENSP/FIOCRUZ.

COUTO, RCS. 1995. "Hidrelétricas e Impactos sôbre a Saúde na Amazônia: Um estudo sobre a tendência da malária na área da Usina Hidrelétrica de Tucuruí-Pará. Brasil." in Anais do IV Encontro Anual da Seção Brasileira da International Association for Impact Assessment – IAIA. Belo Horizonte.

COUTO, RCS. 1996. Hidrelétricas e Saúde na Amazônia: Estudo sobre a tendência da malária na área do lago da Hidrelétrica de Tucuruí, Pará. Tese de Doutorado. ENSP/FIOCRUZ.

CPTA – 1989 - Biblioteca do Exército – 1977. Energia – Comissão de Planejamento da Transmissão da Amazônia. "Transmissão da Amazônia: Perspectivas e Estudos a Serem Realizados". X Seminário Nacional de Produção e Transmissão de Energía Elétrica, Curitiba.

CRUZ NETO Raimundo Gomes da- Tucuruí expropriados pela Eletronorte. Marabá-Pa, s.d., pp. 8

DÉGALLIER, N, TRAVASSOS DA ROSA, A.P.A.1992. "Modifications of arbovirus transmission in relation to construction of dam in Brazilian Amazonia." in Ciência e Cultura. vol 44 (2/3), mar/jun.

DÉGALLIER, N.; TRAVASSOS DA ROSA, A.P.A.; HERVÉ, J-P.;VASCONCELOS, P.F.C.; TRAVASSOS DA ROSA, J.F.S.; SÁ FILHO, G.C. & PINHEIRO, F.P. – 1989. "Modifications of arbovirus eco-epidemiolgy in Tucurui, Pará, Brazilian Amazonia, related to the construction of a hydroelectric dam." Arbovirus Research in Australia, Proceedings 5th Symposium, Queensland Ìnstitute of Medical Research, Brisbane, Australia, (124-135.)

DÉGALLIER, N.; TRAVASSOS DA ROSA, A.P.A.; VASCONCELOS, P.F.C.; HERVÉ, J-P.; SÁ FILHO, G.C.; TRAVASSOS DA ROSA, J.F.S.; TRAVASSOS DA ROSA, E.S. & RODRIGUES, E.S. 1992. "Modifications of arbovirus transmission in relation to construction of dams in Brazilian Amazonia." Ciência e Cultura (J. Brazilian Assoc. Advanc. Sci.) *44*(2/3):124-135.

DEPLEDGE, MH - 1990. "Interactions Bbetween Heavy Metals and Physiological Processes in estuarine Invertebrates." in Chambers, PL & Chamber, CM ed/s. Estuarine Ecotoxicology. Ashford, Ireland: Japaga Pub.

DIÁRIO DO PARÁ. 1994. Madeira será retirada do fundo do lago de Tucuruí. Belém, 8/8/1994, Caderno I, p. 11.

DIEGUES, A. Carlos (org.) 1993. A Dinâmica Social do Desmatamento na Amazônia: Populações e Modos de Vida em Rondônia e Sudeste do Pará . São Paulo: Núcleo de Apoio à Pesquisa sobre Populações Humanas e Áreas Úmidas Brasileiras/ UNRISD (United Nations Research Institute for Social Development).

EISENBERG , J.F & THORINGTON, R.W. 1973. "A preliminary analysis of a neotropical mammal fauna." in Biotropica, 5: 150-161

EISENBERG, J.F. 1980. "The density and biomass of tropical mammals." in SOULÉ M.E. & WILL COX, B.A. (Eds) Conservation Biology: an Evolutionary-Ecological Perspective. Sunderland, Massachusetts: Sinauer Press. (35-55)

EISENBERG, J.F. 1981. The Mammalian Radiation. Chicago: University of Chicago Press,

EISENBERG, J.F; O´CONNELL, M.A. & AUGUST, P.V. 1979. "Density, produtivity and distribution of mammals in two Venezuelan habitats." in EISENBERG, J.F. (Ed) Vertebrate Ecology in the Northern Neotropics. Washington, D.C: Smithsonian Inst. Press. (187-207)

ELETRONORTE/THEMAG 1987. Estudos de Inventário do Médio Tocantins. Brasília.

ELETROBRAS 1987. Plano 2010: Relatório Geral. Plano nacional de energia elétrica

ELETROBRÁS / DNAEE – 1997. Instruções para Estudos de Viabilidade de Aproveitamentos Hidrelétricos. Brasília.

ELETROBRÁS / DNAEE – 1997. Manual de Inventário Hidrelétrico de Bacias Hidrográficas. Brasília

ELETROBRÁS. 1992. UHE Tucuruí. Estudo de Caso. Rio de Janeiro: Arquitetura Ambiental Ltd.

ELETROBRÁS/GCPS/CTEM – 1998. Premissas Básicas para Elaboração dos Estudos de Mercado de Energia Elétrica, ciclo 1998. Rio de Janeiro: Relatório de Premissas Básicas. Brasil, Regiões e Unidades da Federação.

ELETROBRÁS/GRUPO COORDENADOR PARA OPERAÇÃO INTERLIGADA. 1987. Plano Nacional de Emergia Elétrica 1987 – 2.010 – Plano 2.010. Rio de Janeiro: Relatório Geral.

ELETROBRÁS/GRUPO COORDENADOR PARA OPERAÇÃO INTERLIGADA. 1993. Plano Nacional de Energia Elétrica 1993 – 2.015 – Plano 2.015. Rio de Janeiro.

ELETROBRÁS/MME. 1982. Plano de Suprimento Aos Requisitos de Energia Elétrica Até o Ano 2000. Rio de Janeiro.

ELETROBRÁS/MME 1974. Plano de Suprimento de Energia Elétrica Até o Ano 1990. Rio de Janeiro.

ELETROBRÁS/MME 1978. Plano de Suprimento de Energia Elétrica Até o Ano 1995. Rio de Janeiro.

ELETROBRÁS/MME 1999. Plano Decenal 1999/2008. Rio de Janeiro.

ELETROBRÁS/MME 1987. Plano Nacional de Energia Elétrica - 2010. Rio de Janeiro.

ELETROBRÁS/MME Plano Nacional de Energia Elétrica - 2015. Rio de Janeiro 1991

ELETRONORTE - Aproveitamento Hidrelétrico de São Félix. UHE Serra da Mesa. Projeto Básico. Brasília, 1986

ELETRONORTE – 1991. Departamento de Meio Ambiente,. Projeto para Monitoramento e Avaliação do Programa de Controle de Mosquitos na Reserva, Indígena Parakanã., Brasília, pp. 9.

ELETRONORTE - Estudo para Integração e Evolução do Sistema de Tucuruí com outras Fontes de Geração do Baixo Tocantins. Brasília, 1980

ELETRONORTE - Estudos Tocantins. Inventário Hidrelétrico das Bacias dos rios Tocantins e Baixo Araguaia. Brasília, out/1977.

ELETRONORTE – Inventário da comunidade de macrófitas aquáticas flutuantes na UHE Tucuruí através de imagnes orbitais. Tucuruí. Eletronorte. 1998.19p.

ELETRONORTE Programa Parakanã, Relatório de atividades 1998, Tucuruí .Memo.

ELETRONORTE Programa Parakanã, Tucuruí, junho 1997. Memo.

ELETRONORTE, 1990. A Atuação da Eletronorte Junto às Comunidades Indígenas nas áreas de Influência de seus Empreendimentos. Assessoria Indigenista - EEASI -, pp. 222.

ELETRONORTE. 1998. Meio Ambiente. UHE Tucuruí. Programa de Limnologia/Qualidade da água. Brasília: Engevix-Themag.

ELETRONORTE. 1985. Relatório Operação Curupira. Centrais Elétricas do Norte do Brasil S.A

ELETRONORTE. 1989. Relatório da Operação Jamiri. Departamento de Estudos de Efeitos Ambientais, Divisão de Ambiente Terrestre. Centrais Elétricas do Norte do Brasil S.A.

ELETRONORTE. (sem data). Folheto informativo "Operação Curupira".

ELETRONORTE. 1992. UHE Tucurui. A pesca em sua região de influência: evolução das capturas 6 anos após o enchimento do reservatório. TUC-10-26448-RE. Paginas não numeradas.

ELETRONORTE. 1974. Aproveitamento hidrelétrico de Tucuruí. Estudo de viabilidade: aspectos sócio-econômicos e desapropriação. ENGEVIX S.A E ECOTEC

ELETRONORTE. 1998. Eletronorte - 25 anos. Rio de Janeiro: Eletronorte.

ELETRONORTE. 1991. Relocações na área do reservatório. Jun.

ELETRONORTE/CONSÓRCIO ENGEVIX-THEMAG. 1986. UHE Tucuruí – Programa de estudos ecológicos de macrófitas aquáticas

ELETRONORTE/CONSÓRCIO ENGEVIX-THEMAG. 1987. UHE Tucuruí - Relatório interpretativo das variáveis biológicas: fitoplâncton e zooplâncton.

ELETRONORTE/CONSÓRCIO ENGEVIX-THEMAG. 1989. UHE Tucuruí - Relatório interpretativo das Variáveis Limnológicas (Maio/85 a Abril/88)

ELETRONORTE/CONSÓRCIO ENGEVIX-THEMAG. 1987. UHE Tucuruí – Relatório síntese dos estudos limnológicos na região da usina hidrelétrica de Tucuruí.

ELETRONORTE/CONSÓRCIO ENGEVIX-THEMAG. 1988. UHE Tucuruí - Relatório técnico de Limnologia (julho/86 a junho/87)

ELETRONORTE/CONSÓRCIO ENGEVIX-THEMAG. 1985. UHE Tucuruí – Verificação da curv-cota x volume do reservatório de Tucuruí

ELETRONORTE/CPA. 1999. Boletim de controle mensal do pescado. Fichas de dados brutos. Set. 1997 a out. 1999. Impresso.

ELETRONORTE/ELETROBRÁS/MME. 1984. Livro Branco. Sobre o Meio Ambiente na Usina Hidrelétrica de Tucuruí. Brasília.

ELETRONORTE/ELETROBRÁS/MME. 1988. Cenários Energéticos para a Amazônia.

ELETRONORTE/ELETROBRÁS/MME. Hidrelétricas na Amazônia.

ELETRONORTE/ELETROBRÁS/MME. UHE Tucuruí. A maior usina hidrelétrica genuinamente nacional. Folder.

ELETRONORTE/ENGEVIX. 1984. Aproveitamento Hidrelétrico de Marabá. Estudos Tocantins. Santa Isabel/Marabá. Brasília.

ELETRONORTE/GETAT/FUNAI, Ata de Reunião sobre a Comunidade Indigena Parakanã, 18 de outubro de 1984 pp.3. Memo

ELETRONORTE/INPA. 1981. "Estudos de Ecologia e Controle Ambiental na Região do Reservatório da UHE de Tucuruí. Ictiofauna." Relatório Semestral. Janeiro – Junho 1981. INPA. Manaus, AM. 141 pp.

ELETRONORTE/INPA. 1982. "Estudos de Ecologia e Controle Ambiental na Região do Reservatório da UHE de Tucuruí. Ictiofauna." Relatório Semestral. Julho – dezembro 1982. INPA. Manaus, AM. 110 pp + gráficos e tabelas.

ELETRONORTE/INPA. 1984. "Estudos de Ecologia e Controle Ambiental na Região do Reservatório da UHE de Tucuruí. Ictiofauna." Relatório Semestral. Julho – dezembro 1984. INPA. Manaus, AM. 41 pp.

ELETRONORTE/THEMAG 1987. Estudos de Inventário do Médio Tocantins. Brasília.

EMMONS, L.H. 1984. "Geographic variation in densities and diversites of non-flying mammals in Amazônia" in Biotropica, 16(3): 210-222

ENGEVIX. 1987. Entrevista com o Serviço de Patrimônio Imobiliário da Eletronorte. Rio de Janeiro, Mai.

ENSP/FIOCRUZ. 1994. Estudo sobre as interferências das ações do setor elétrico na saúde das populações: Análise das principais questões de saúde determinadas pelas atividades do setor elétrico no Brasil. Modalidade Hidreletricidade. Projeto de Pesquisa.

FAUSTO, Carlos. 1991. Os Parakanã: Casamento Avuncular e Dravidianato na Amazônia. Dissertação de mestrado. Rio de Janeiro: PPGAS/ Museu Nacional/ UFRJ.

FAUSTO, Carlos. 1995. "De Primos e Sobrinhas: Terminologia e Aliança entre os Parakanã (Tupi) do Pará" in E.B. Viveiros de Castro (ed.) Estruturas Sociais Ameríndias: os Sistemas de Parentesco. Rio de Janeiro: Editora da UFRJ, pp.61-119.

FEARNSIDE, P.M. Environmental Impacts of Brazil's Tucuruí Dam: Unlearned Lessons of Hydroelectric Development in Amazonia. Environmental Management, 26 (2), in press.

FEARNSIDE, P.M. 1997. "Greenhouse gas emissions from Amazonian hydroelectric reservoirs: the example of Brasil's Tucuruí dam." in Hydropower Plants and Greenhouse Gas Emissions, COPPE/UFRJ,

FERRARI, L.P. – 1985. Planejamento do Setor Elétrico no Contexto Econômico Brasileiro: da CANAMBRA ao Plano 2000. Rio de Janeiro: COPPE/AIE/UFRJ.

FERRAZ, Iara . 1983. "Os *Parkatêjê* das matas do Tocantins: a epopéia de um líder Timbira". Dissertação de mestrado. FFLCH/USP.

FERRAZ, Iara. 1997. Experiências de comercialização entre grupos Tupi do sudeste do Pará. Brasília: GTZ/FUNAI, mimeo.

FERRAZ, Iara. 1998. De 'Gaviões' a 'Comunidade *Parkatêjê*': uma reflexão sobre processos de reorganização social. Tese de doutoramento. PPGAS, Museu Nacional/UFRJ.

FERRAZ, Iara e LADEIRA, Maria Elisa. 1991. "Os povos indígenas da Amazônia oriental e o Programa Grande Carajás - avaliação e perspectivas". In Jéan Hébette (org.), O cerco está se fechando - o impacto do grande capital na Amazônia. Rio de Janeiro / Petrópolis/Belém: Vozes, FASE e NAEA/UFPa., pp. 130-141.

FERREIRA, E. SANTOS, G.M. & JEGÚ, M. 1988. "Aspectos ecológicos da ictiofauna do rio Mucajaí, na área da ilha Paredão, Roraima, Brasil." in Amazoniana X(3): 339-352

FERREIRA, E.J.G. 1993. "Composição, distribuição e aspectos ecológicos da ictiofauna de um trecho do rio Trombetas, na área de influência da futura UHE Cachoeira Porteira, estado do Pará, brasil." in Acta Amazonica, 23 (suplemento): 1-89

FIINKELMAN, J., CARCAVALLO, R.U, NÁJERA-MORRONDO, J A. 1984. Consideraciones epidemiológicas in: Las represas y sus efectos sobre la salud. OPS/OMS.

FISCHER, H.B. & PARSLEY, P.E. 1979. "Amazon lakes: water storage and nutrient stripping by algae." in Limnol. Oceanogr., n.24, 547-553,

FITTKAU, E. J. 1971. "Okologische Gliederung des Amazonasgebietes auf geochemischer Grundlage. Münster. Forsch." in Geol.Paläont. 20/21:35-50

FNS/MS. 1995. Controle da malária. Diretrizes técnicas. Brasília.

FOUCAULT, M. 1997. "Segurança, território e população" in Resumo dos Cursos do Collège de France (1970-1982). RJ. Jorge Zahar Ed.

FOULCAULT, M. 1997. "É preciso defender a Sociedade." in Resumo dos Cursos do Collège de France (1970-1982). RJ. Jorge Zahar Ed.

FOULCAULT, M. 1997. "Nascimento da biopolítica." in Resumo dos Cursos do Collège de France (1970-1982). RJ. Jorge Zahar Ed.

FUNAI, 1990. Termo e Compromisso entre a comunidade indígena do P.I. Trocará e a FUNAI

FUNAI. Carta 001/PMSI n. 335/89, de 31.08.89 (para a Eletronorte)

FUNAI. CT. n. 203/ CORPI/90. Chefe da Coordenadoria de Patrimônio Indígena. Processo Asuriní. Brasília, 16 de outubro 1990.

FUNAI. Produção extrativista Parakanã. Tucuruí, junho de 1997.

FUNAI. Relatório anual de atividades – 1995. Tucuruí.

FUNAI. Relatório do Programa Parakanã – 1992. Belém

FUNAI/ASPLAN. 1981. Relatório do Projeto Parakanã, "Ante-projeto extrativismo: castanha-do-Pará" Belém, Maio, pp. 9. Memo.

FUNAI/DGPC 1º. Encontro Parakanã.,Tucuruí, Pará, 15/19 de dezembro 1980, pp.51.

FUNAI/ELETRONORTE, 1987. Termo de Compromiso n. 001/87

FUNAI/ELETRONORTE, 1988. Termo Aditivo n. 001/87, ao Termo de Compromisso n. 001/87

FUNAI/ELETRONORTE, 1988. Termo Aditivo n. 002/88, ao Termo de Compromisso n. 001/87

FUNRNAS/FINEP - Bacia do Alto Tocantins. Inventário de Recursos Hidrelétricos nos Formadores e Ttributários do Curso Superior. Vol.I , Rio de Janeiro, 1984

FURCH, K. 1984. "Water chemistry of the amazon basin: The distribution of chemical elements among freshwater." in SIOLI, H. The Amazon: limnology and landscape ecology of a mighty tropical river and its basin. Dr. Junk Publishers 107-200.

GILBERT, SG & Grant-Webster, KS – 1995. "Neurobehavioral Effects of Developmental Methylmercury Exposure." in Environmental Health Perspectives 103 (suppl. 6),

GOODLAND R. 1991. Avaliação do meio ambiente: a nova política ambiental do Banco Mundial. In: A desordem ecológica na Amazônia. Belém, UNAMAZ/UFPA.

GOODLAND, R. 1977. Environmental assessment of the Tucuruí Hydroeletric Project, rio Tocantins, Amazonas. Brasília: Eletronorte.

GOODLAND, R. 1978 Environmental assessment of the Tucurui hydroproject, rio Tocantins, Amazonia, Brazil. Brasília: Eletronorte.

GRIBEL, R. 1993. "Os mamíferos silvestres e as grandes barragens na Amazônia". In Ferreira, E.J.G.; Santos, G.M.; Leão, E.L.M. & Oliveira, L.A. (eds) Bases Científicas para estratégias de preservação e desenvolvimento da Amazônia. vol. 2. Instituto Nacional de Pesquisas da Amazônia.

GRIBEL, R. MOREIRA, G.; MARTINS, M; LEMES, M.; COLARES, E. & EGLER, S. 1987. "Destinos da fauna de Balbina." In Ciência hoje, 31(6): 76

GUATTARI, F. 1990. As três ecologia. SP. Papirus ed.

GUIMARÃES, JRD & MALM, O. 1996. Estudos de Campo sobre a Metilação de Mercúrio em Ambientes Aquáticos na Região de Poconé. Relatório Final - Projeto de Avaliação de Riscos à Saúde na Região Amazônica Relacionados com a Contaminação Ambiental por Mercúrio - OPAS/ECO-GTZ .

GULINO, E. & PELLEGRINI, N.J.M. 1987. "Salud publica en el area de Itaipu." in: IIº Seminário da Itaipú Binacional sobre o meio ambiente. Foz do Iguaçu. p. 65-80.

HACON, S. 1993. "Mercúrio no Meio Ambiente: Os Riscos para o Homem." in Câmara, VM Ed. Mercúrio em Áreas de Garimpos de Ouro. Série Vigilância 12. Programa de Saúde Ambiental. ECO/OPAS/OMS México. p. 25-36.

HEBETTE, Jean. 1989. "O Grande Carajás: um novo momento da história moderna da Amazônia paraense" in Cadernos do NAEA, Belém: UFPA/NAEA, n.10, pp. 7-40.

HEIDE, J.VAN DER. 1982. Lake Brokopondo. Filling phase limnology of a man-made lake in the humid tropics. Amsterdam: Vrige Universiteit te Amsterdam. Tese de doutorado.

HENRIQUES, R.P.B. 1988. "Salvamento ou massacre?" in Ciência hoje, 46(8): 64-66

HENRY, R. & TUNDISI, J.G. 1988. "O conteúdo em calor e a estabilidade em dois reservatórios com diferentes tempos de residência." in TUNDISI, J.G. Limnologia e manejo de represas. EESC-USP/CRHEA/ACIESP, p.299-322.

HUMPHRYS, S.;TIKASINGH, E. S. & DAVIES, J. B.- "The simulidium blackfly problem in Guyana, South America." in: PANDAY,R.S.(ed). Proceedings of the Symposium Man-Made Lakes and Human Health. Paramaribo. University of Suriname. 23-25 de outubro de 1978.

IBAMA/CNPT/CIPES. 1994. Levantamento sócio-econômico da Região das Ilhas (Relatório). Belém, Pará.

IBDF/CAPEMI. 1980. Contrato IBDF/CAPEMI para a Exploração de lotes florestais na área do futuro Reservatório daUHET, Serviço Público Federal, 26 de agosto,pp. 13.

IESA – 1984. Alto Tocantins. Relatório Final. Vol.I , Rio de Janeiro.

INPA. 1984. "Plano de inventário e aproveitamento da fauna da região do reservatório da UHE de Tucuruí." Relatório Final. Convênio Eletronorte/CNPq/INPA, Manaus, 123p.

INSTITUTO SOCIEDADE, POPULAÇÃO E NATUREZA – ISPN. Levantamento sócio-econômico no Lago da Usina Hidrolétrica de Tucuruí. Brasília, dez. 1997 (Relatório Final)

JOHNSON, BL. 1993. Environmetal Neurotoxicology National Research Council Ed. National Academic Press, Washington, DC. 145p.

JUNK, W.J. & HOWARD-WILLIAMS, C. 1984. “Ecology of aquatic macrophytes in Amazonia.” in: SIOLI, H. (ed.). The Amazon, Limnology and landscape ecology of a mighty tropical river and its basin. Dordrecht: W. Junk., p.269-293.

JUNK, W.J. & MERA P.A.S. 1982. “Levantamento e controle de macrófitas aquáticas.in: Estudos de ecologia e controle ambiental na região da UHE de Tucuruí. Relatório Técnico 1980-1981. Manaus: INPA.

JUNK, W.J. & NUNES DE MELLO, J.A.S. 1987. “Impactos ecológicos das represas hidrelétricas na bacia amazônica brasileira.” in Tübinger Geographische Studien 95: 367-389.

JUNK, W.J. 1982. “Zur Entwicklung aquatischer Makrophyten in Curua-Una, dem ersten Stausee in Zentralmazonien.” Arch. Hydrobiol. 95 (1/4): 169-180.

LA ROVERE, E. L. 1998. “Cenários e Oportunidades para uma Política Energética da Região Amazônica.” in Amazônia 21. Uma Agenda para um Mundo Sustentável. Conferência Internacional. Anais.

LA ROVERE, E.L.; AMERICANO, B.B. 1999. GHG Emissions Avoided by PROCEL – The Brazilian Program for Electrical Energy Efficiency, PPE/COPPE/UFRJ, Eletrobrás.

LA ROVERE, E. L.; PINGUELLI ROSA, L. (coord.) 1992. A Política Energética Nacional e as Atividades da CPTA. Coppe, PPE/UFRJ, Rio de Janeiro.

LACERDA, L.D; PFEIFFER,WC; MARINS, RV; RODRIGUES, S.; SOUZA, CMM & BASTOS, WR. 1991. “Mercury Dispersal in Water, Sediments and Aquatic Biota of a Gold Mining Tailing Deposit Drainage in Poconé, Brazil.” in Water, Air and Soil Pollution, 55: 283-294.

LEINO, T & LODENIUS, M. 1995. “Human hair mercury levels in Tucuruí area, state of Pará, Brazil.” in The Science of the Total Environment 175: 119-125.

LEITE, R.A.N. 1986. “Estudos de Ecologia e Controle Ambiental na Região do Reservatório da UHE de Tucuruí. Sub-projeto Identificação do potencial da pesca – Ictiofauna.” Relatório Setorial. Janeiro a Junho 1986. Convênio INPA/Eletronorte. Manaus, Am. 53 p.

LEITE, R.A.N. 1986. “Estudos de Ecologia e Controle Ambiental na Região do Reservatório da UHE de Tucuruí. Sub-projeto Identificação da Ictiofauna e potencial da pesca.” Relatório Setorial. Julho a Dezembro 1986. Convênio INPA/Eletronorte. Manaus, Am. 160 p.

LEITE, R.A.N. 1993. Efeitos da Usina Hidroelétrica de Tucuruí sobre a composição da ictiofauna das pescarias experimentais de malhadeiras realizadas no baixo rio Tocantins (Pará). Dissertação de Mestrado. INPA/FUA. Manaus, Am. 133 p.

LEITE, R.A.N.; BITTENCOURT, M.M. 1991. “Impacto das hidroelétricas sobre a ictiofauna da Amazônia: o exemplo de Tucuruí.” in Val, A.L.; Figliuolo, R.; Feldberg, E. Bases Científicas para Estratégias de Preservação e Desenvolvimento da Amazônia: Fatos e Perspectivas. Vol. 1. INPA. Manaus, AM. p: 85-100

LILIENFELD, D.E. 1994. Foundations of Epidemiology. New York: Oxford University Press.

LIMA, I.B.T.; NOVO, E.M. 1999. Multitemporal TM image analysis to asses the apatial and temporal dispersion of floating macrophytes in Brazilian hydroelectric reservoirs. INPE.

LIMA, J.L. 1995. Políticas de Governo e desenvolvimento do setor de energia elétrica: do Código de äguas à crise dos anos 80 (1934-1984), Memória da Eletricidade, Rio de Janeiro.

LLANO, R.G. – “Energia Elétrica para a Amazônia.” in Anais do Seminário sobre o Modelo Energético Brasileiro – Manaus, setembro de 1979. Manaus. Eletronorte. 1979. p.22-189. (mimeo).

LOBATO PARAENSE, W. 1983. Estudos de Ecologia e controle ambiental na região do reservatório da UHE de Tucuruí. Relatório setorial do segmento “Impacto do reservatório no aumento de doenças endêmicas (Esquistossomose)”. Volume 4. Convênio INPA & Eletronorte. INPA. Manaus. Julho-dezembro 1983. 5p.

LUSTOSA, Caio. 1980. “ Parakanã terra de Barragem” in Ciência e cultura, 32(3), SBPC, pp. 325-327

LUZ, E. 1987. “Controle de grandes endemias.” in IIº Seminário da Itaipu Binacional sobre meio ambiente. Foz do Iguaçu. p. 43-50.

MAGALHÃES, S., BRITTO, R. C. & CASTRO, E. (orgs.) 1996. Energia na Amazônia. Belém: MPEG/UFPA/UNAMAZ.

MAGALHÃES, SÔNIA. 1994. “As grandes hidrelétricas e as populações camponesas.” in D’INCÃO, M. e SILVEIRA, I.(Orgs.) Amazônia e a crise da modernização. Belém: MPEG.

MALCOLM, J. R. 1990. “Estimation of Mammalian Densities in Continuous Forest North of Manaus.” in GENTRY, A. H. (ed.). Four Neotropical Forests Yale University Press.

MALM, O & GUIMARÃES, JRD. 1996. Avaliação da Contaminação dos Peixes nos Corpos Hídricos Próximos à Cidade de Poconé - MT. Relatório Final - Projeto de Avaliação de Riscos à Saúde na Região Amazônica Relacionados com a Contaminação Ambiental por Mercúrio - OPAS/ECO-GTZ . Março de 1996. 69 p.

MASCARENHAS, B.M. & PUORTO, G. 1988. “Nonvolant mammals rescued at the Tucuruí Dam in the Braziliam Amazon.” in Primate Conservation, 9: 91-93

MELLO, S. 1999. “Hidrelétricas. O sofisma da energia limpa.” in Saneamento Ambiental, no.59-jul/ago.

MERONA, B. 1986/87. “Aspectos ecológicos da ictiofauna do baixo Tocantins.” in Acta Amazonica, 16/17: 109-124.

MERONA, B. 1985. “Les peuplements de poissons et la pêche dans le Bas Tocantins avant la fermeture du barrage de Tucuruí.” in Verh. Internat. Verein. Lomnol., 22: 2698-2703

MERONA, B. 1986/87. “Aspectos ecológicos da ictiofauna no baixo Tocantins.” in Acta Amazonica, 16/17(número único): 109-124

MINISTÉRIO DO INTERIOR. 1980. Diagnóstico da Bacia dos Rios Araguaia e Tocantins. PRODIAT: Brasília.

MINTER-FUNAI. 1979. Projeto Parakanã: Versão II. Ref. Memo. n. 038/79- CE-PP., pp.30.

MIRANDA, E. de A.. et al. “Para repensar Tucuruí: uma revisão bibliográfica.” in MAGALHÃES, S.B.;BRITTO, R. DE C. & CASTRO, E.R de (org) Energia na Amazônia. Volume II. 1996. p. 817-824.

MITCHELL, D.S. & TUR, N.M. “The rate of growth of *Salvinia molesta* (*S. auriculata* Auct.) in laboratory and natural conditions.” J. appl.Ecol.12:213-225, 1975.

MOLINEAUX, L., GRAMICCIA, G. 1980. The Garki Project. Research on the Epidemiology and Control of Malaria in the Sudan Savana of West Africa. Geneva: WHO.

MONOSOWSKI, E. 1991. L’Evaluation et la Gestion des Impacts sur l’Environment de Grands Projets de Developpement: le barrage de Tucuruí en Amazonie, Brézil. Tese de Doutorado, Ecole des Hautes Etudes en Sciences Sociales: Paris.

MONTEIRO, M. DO S. CARDOSO. A questão fiscal dos municípios do Sul e Sudeste do Pará. Belém: UFPA/NAEA/FIPAM XII, 1997 (mimeo)

MOORE, MN. 1990. “Lysosomal Reactions to Environmental Stress and Pollution.” in Chambers, PL & Chamber, CM Eds. Estuarine Ecotoxicology. Japaga Pub. Ashford. Ireland.

MORAIS, S.S.; ROULET, M.;SOUZA PASSOS, C.J.; DUCHEMIN, E. 1999. “Mercury contamination in fish of na old amazonian reservoir (Cuaruá Uma)” in *Proc. Of the Hydrological na Geochemical Processes in Large Scale River Basins*, Manaus.

MORENO, I. H. 1996.Estrutura da comunidade planctônica do reservatório da UHE-Balbina (Floresta Tropical Úmida – Amazonas) e sua relação com as condições limnológicas apresentadas na fase de enchimento e pós-enchimento (1987-1990). Universidade Federal de São Carlos. Tese de doutorado.

MORENO, I. H.; et al. 1990. Estudos comparativos das concentrações de nitrogênio e fósforo observados nos períodos anterior e posterior a formação do reservatório da UHE Tucuruí-PA. Resumos do III Congresso da SBL, 1990.

MOUGEOT, LUC. “Planejamento Hidroelétrico e reinstalação de populações na Amazônia: primeiras lições de Tucuruí, Pará.” in AUBERTIN, C. (org.) Fronteiras. Brasília: UnB; Paris:ORSTOM,1988.

MOURA, R.C.S. Diretrizes para atuação do Setor Elétrico nas questões de Saúde em empreendimentos hidrenergético na Amazônia. Relatório de Consultoria. Eletronorte/IMTM/PNUD.

NETO, Antonio Pereira, 1990. Relatório Acerca da Situação dos Índios *Asurini* do P.I. Trocará e a Rodovia PA 156 que Atravesa aquela Área indígena. Chefe DPF, Belém 4ª. SUER/FUNAI, pp.4.

NETO, F.T. 1990. Development Planning and Mineral Mega-projects: Some Global Considerations. In The Future of Amazonia Destruction or Sustainable Development? Ed. Goodman, D. and Hall, A. N. York: St Martin’s Press.

NOVO, E.M.L.M. et al. 1997. “Avaliação de imagens orbitais de radar no estudo de ambientes aquáticos e de origem antrópica na Amazônia: Lago Grande Monte Alegre e reservatório da UHE Tucuruí.” in Primeiro Relatório Técnico. São Paulo, FAPESP (96/4523-0), outubro de 1997. 98p.

O LIBERAL. Projeto hidrelétrico é reavaliado. Belém. 14/10/99.

O LIBERAL. Reserva. Belém, 6/6/1994.

OCHIAI, EI. 1987. “Global Metabolism of Elements: Principles and Applications in Bioinorganic Chemistry.” XI. J. Chem. Ed. 74:926-930.

OHLE, W. 1937. “Kolliodgele als Nährstoffregulatoren der Gewässer.” Naturwissenschaften, 25:471-474.

OLIVEIRA, Cornélio Vieira de – 1986. Relatório sobre o Programa Parakanã. Belém: 4ª. SUER/ FUNAI, novembro 1986, pp. 6.

OMS. Development of water resources and health risks studies for the establishment of a forecasting and preventive methodology.

OMS. 1994. Enfermedades parasitarias y desarrollo hidráulico. Necesidad de una Negociación intersectorial. Ginebra.

OMS. 1994. O controle da esquistossomose. Ed. Fiocruz.

OOSTBURG,B.F.J. 1978. “Brokopondo, Kabalebo and Health Care” in PANDAY,R.S.(ed). Proceedings of the Symposium Man-Made Lakes and Human Health. Paramaribo. University of Suriname. 23-25 de outubro de 1978. p. 47-50.

ORDÓÑEZ, B.R. 1984. Enfermidades de alto riesgo asociadas com grandes presas. In: Las represas y sus efectos sobre la salud. OPS/OMS.

PAGOTTO, CLAC – 1980. Distribuição de Mercúrio nos Sedimentos da Região da lagoa de Maricá, Munícipo de Maricá, RJ. Tese de Mestrado. Instituto de Química. UFF. Junho 1980. 84p.

PAIM, J.S., ALMEIDA FILHO, N. 1998. “Saúde Coletiva: uma nova saúde pública ou campo aberto a novos paradigmas?” in Rev. Saúde Pública, 32 (4):299-316.

PANDAY, R.S. & PANDAY-VERHEUVEL, M.P. 1978. “The Brokopondo barrage lake and human health in Suriname” in PANDAY,R.S.(ed). Proceedings of the Symposium Man-Made Lakes and Human Health. Paramaribo. University of Suriname. 23-25 de outubro de 1978. p. 36-38

PAYNE, A.I. 1988. The ecology of tropical lakes and rivers. John Wiley & Sons.

PEITER, P. C. 1996. “O Planejamento do Setor Elétrico e a Formulação do Projeto de Transmissão da Amazônia.” in Energia na Amazônia, vol. II, org. Magalhães, S. B., Britto, R. C. e Castro, E. R. Museu Paranaense E. Goeldi/UFPa/Associação das Univ. Amazônicas, Belém.

PERES, C. 1999. “The structure of nonvolant mammal communities in different Amazonian forest types.” in Mammals of the Neotropics: the Central Neotropics (J. F. Eisenberg & K. H. Redford, eds.). University of Chicago Press, Chicago, pp 564-581.

PERES, C.A. & JOHNS, A.D. 1991-1992. “Patterns of Primate Mortality in a Drowing Forest: Lessons from the Tucuruí Dam, Brazilian Amazonia.” in Primate Conservation, (12-13): 7-10.

PFEIFFER, WC; LACERDA, LD; MALM, O; BASTOS, WR; SOUZA, CMM & SILVEIRA, EG. 1989. “Mercury Contamination in Inland Waters of Rondonia, Amazon, Brazil.” in Science of Total Environment. 87/88:223-240.

PGC. 1985. Programa Grande Carajás: Histórico, Objetivos, Atividades e Legislação. Brasília: PGC.

PILGRIM, W. 1998. “Observations on Methylmercury in Freshwater Fish: Predicting Associated Ecosystem Risks.” in Proceeding of the conference on Mercury in Eastern Canada & the Northeast States, Fredricton (unpublished)

PINTO, L. F. 1982. Carajás, O Ataque ao Coração da Amazônia. Rio de Janeiro: Marco Zero.

PINTO, Lúcio F. 1999. “Grandes Projetos: Cavalos de Tróia na Amazônia.” in Agenda Amazônica. Ano I N. 2, Belém, outubro, 1999.

PINTO, Lúcio F. 1999. “Tucuruí: a grande obra ainda é uma incógnita.” in Jornal Pessoal. Belém: Ano XIII, N. 223, 2ª Quinzena de Novembro de 1999.

PIRES, J.S.R. et al. 1990. Aspectos limnológicos do reservatório da UHE Tucuruí: parâmetros físicos e químicos relacionados aos padrões de estratificação observados no período de junho de 1985 a fevereiro de 1988. Resumos do III Congresso da SBL, 1990.

PORVARI, P. 1995. “Mercury levels of fish in Tucuruí hydroelectric reservoir and in river Mojú in Amazonia, in the state of Pará, Brazil.” in The Science of the Total Environment 175: 109-117.

REDFORD, K.H. & ROBINSON, J.G. 1987. “The game of choice: the patterns of Indian and colonist hunting in the Neotropics.” in American Anthropologist, 89(3): 650-667.

RESENDE, E.K. 1985. “Estudos de Ecologia e Controle Ambiental na Região do Reservatório da UHE de Tucuruí. Sub-projeto Identificação da Ictiofauna e avaliação do potencial da pesca.” Relatório Setorial. Janeiro a Junho 1985. Convênio INPA/Eletronorte. Manaus, Am. 83 p.

RIBEIRO, J.S.B. 1996. “Aspectos limnológicos da UHE Tucuruí.” in MAGALHÃES, S. B.; BRITTO, R. DE C. & CASTRO, E. R. de (org). Energia na Amazônia. Volume. I.. Belém. Museu Paraense Emílio Goeldi e Universidade do Pará. 1996. p 259-281.

RIBEIRO, J.S.B. 1996. “Aspectos limnológicos da UHE Tcuruí.” in: Magalhães, S.B.; Britto, R.C.; Castro, E.R. (orgs.). Energia na Amazônia. Vol. 1. Museu Paraense Emílio Goeldi/Universidade Federal do Pará/Associação de Universidades Amazônicas. Belém, Pa. p: 259-281

RIBEIRO, MIGUEL A C. 1998. A complexidade da rede urbana amazônica: três dimensões de análise. Rio de Janeiro:UFRJ/PPGG. (Tese de Doutoramento)

RIZZO, JOSÉ A. 1981. Flora do Estado de Goiás. Brasília: Editora Universidade de Brasília.

ROBINSON, J.G. & REDFORD, K.H. 1989. “Body size, diet, and population variation in Neotropical forest mammal species: predictores of local extinction?” in REDFORD, K.H. & EISENBERG, F.J. (Eds) Advances in Neotropical Mammology. Sandhill Crane Press, Gainesville, Florida: 567-594

ROSA, L.P., & SHAEFFER, R. 1988. “Impactos ambientais e conflitos sociais: Um paralelo entre usinas hidrelétricas e nucleares.” in Impacto de grandes projetos hidrelétricos e nucleares. COPPE/ CNPq/Ed. Marco Zero.

ROSA, L.P. 1989. “Hidrelétricas e Meio Ambiente na Amazônia. Análise crítica do Plano 2010.” in Revista Brasileira de Energia, vol.1.

ROSA, L.P. et al. 1999. “Inventário das emissões de gases de efeito estufa derivadas de reservatórios hidrelétricos.” XV Seminário Nacional de Produção e Transmissão de Energia Elétrica, 1999.

ROSA, L.P.; SANTOS, M.A. 2000. Thematic Study on Greenhouse Gas Emissions from Large Dams, World Commission on Dams.

ROSA, L.P.; SIGAUD, L; LA ROVERE, E.L. (orgs.) 1995. Estado, Energia Elétrica e Meio Ambiente - O Caso das Grandes Barragens, PPE/COPPE/UFRJ, PPGAS/Museu Nacional, Fundação Ford, Rio de Janeiro.

ROSS, E. 1978. “Food taboos, diet, and hunting strategy: The adaption to animals in amazon cultural ecology.” Current Anthropology, 19: 1-19

ROTHMAN, K.J. 1987. Epidemiologia Moderna. Madri: Ediciones Diaz de Santos.

SACHS, I. & MENDES, A D. 1998. “A inserção da Amazônia no Mundo.” in: Amazônia 21. Uma Agenda para um Mundo Sustentável. Brasília. Conferência Internacional. Anais.

SANTOS, A. dos et al. 1983. Estudos limnológicos no sistema Tocantins-Araguaia. Qualidade da água. Relatório Técnico. Manaus. INPA.

SANTOS, A. 1982. Limnologia do Sistema Tocantins-Araguaia - Aspectos físicos e biogeoquímicos. São Carlos (Tese de doutorado).

SANTOS, A.C. Magalhães L.dos- 1982. Os Parakanã: quando o rumo da estrada e o curso das águas perpassam a vida de um povo. Dissertação de Mestrado. São Paulo: Universidade de São Paulo.

SANTOS, A.C. Magalhães L.dos- 1991. “As Nações Indígenas e os Projetos Econômicos de Estado: a Política de Ocupação do Espaço na Amazônia”, in Jean Hébette (org.), O cerco está se fechando: o impacto do grande capital na Amazônia. Petrópolis: Ed. Vozes, pp. 89-113.

SANTOS, A.C. Magalhães L. dos- 1994. Os Parakanã: Espaços de Socialização e suas Articulações Simbólicas. Tese de Doutorado. São Paulo: Universidade de São Paulo.

SANTOS, A.C. Magalhães L.dos. 1977. Elaboração Projeto Parakanã: Transferência das Comunidades do Posto Indigena Pucurui e Reserva Parakanã, dezembro 1977, pp. 21

SANTOS, A.C. Magalhães L.dos. Relatório de Atividades: Projeto Parakanã, Primeira Etapa, Julho1978, pp. 17. Memo.

SANTOS, A.C. Magalhães L.dos. Relatório de Atividades: Projeto Parakanã, Segunda Etapa, Outubro 1978, pp.13.

SANTOS, G.M. “Impactos da hidrelétrica samuel sobre as comunidades de peixes do rio Jamari (Rondônia, Brasil)” in Acta Amazonica, 25(3//4): 235-246 1995.

SANTOS, G.M.; JEGU, M.; MERONA, B. 1984. Catálogo de peixes comerciais do Baixo rio Tocantins. Eletronorte/CNPq/INPA. Manaus, Am. 83 p.

SANTOS, G.M.; MERONA, B. 1996. “Impactos imediatos da UHE Tucuruí sobre as comunidades de peixes e a pesca.” in Magalhães, S.B.; Britto, R.C.; Castro, E.R. (orgs.). Energia na Amazônia. Vol. 1. Museu Paraense Emílio Goeldi/Universidade Federal do Pará/Associação de Universidades Amazônicas. Belém, Pa. p: 251-258.

SANTOS, G.M.; OLIVEIRA JR., A.B. 1999. "A pesca no reservatório da hidrelétrica de Balbina (Amazonas, Brasil)" in Acta Amazonica, 29(1): 145-163

SANTOS, G.M; JEGÚ, M. & MERONA, B. 1984. "Catálogo de Peixes Comerciais do Baixo Tocantins." Projeto Tucuruí. Eletronorte/CNPq/INPA, Manaus, AM. 83p.

SAWYER, D.R., Sawyer, D. R.T.O. 1987. Malaria on the Amazon Frontier: Economic and Social Aspect of Transmission and Control. CEDEPLAR. Relatóro de Pesquisa.

SCHÄFER, A. 1985. Fundamentos de Ecologia e Biogeografia das águas continentais. Porto Alegre: Editora da Universidade (UFRS)/GTZ.

SCHALLER, G.B. 1983. "Mammals and their biomass on a Brazilian ranch." Arq. Zool. São Paulo, 31: 1-36.

SEPLAN. 1980. Plano Anual de Trabalho: Baião. Governo do Estado do Pará, Sistema Estadual de Planejamento, Belém-PA.

SEPLAN. 1980. Plano Anual de Trabalho: Itupiranga. Governo do Estado do Pará, Sistema Estadual de Planejamento, Belém-PA.

SEPLAN. 1980. Plano Anual de Trabalho: Mocajuba. Governo do Estado do Pará, Sistema Estadual de Planejamento, Belém-PA.

SESPA. 1999. Diagnóstico Situacional da Saúde no Estado do Pará. Belém: Núcleo Estadual de Epidemiologia.

SESPA. 1999.Unidades e leitos cadastrados – SIH/SUS.

SESPA/NIS. 1996, 1997, 1998. 1999. Informações Epidemiológicas para o Estado do Pará.

SILVA, José Ignácio Araújo 1980. O Desenvolvimento da Agricultura na Comunidade Indígena, Tucuruí, dezembro 1980, Memo.

SILVA, M. DAS GRAÇAS DA. 1997. Planejamento territorial, deslocamento compulsório e conflito sócio-ambiental: mosquito e pistolagem na barragem de Tucuruí. Rio de janeiro: IPPUR/UFRJ (dissertação de mestrado)

SIOLI, H. & KLINGE, H. 1969. "Solos, tipos de vegetação e águas na Amazônia." in Boletim do Museu Paraense Emílio Goeldi, (1): 27-41

SOARES, Manoel, C. P., Menezes, Raimundo C. Martins, Sandro J. Pensabat, Gilberta. 1994. " Epidemiologia do virus da hepatites B, C e D na tribo indígena Parakanã, Amazônia Oriental brasileira" in Boletim. Oficina Sanitária Panam. 117(2).

SUCHANEK, TH; RICHERSON, PJ; MULLEN, LH; BRISTER, LL; BECKER, JC; MAXSON, AE & SLOTTON, DG. 1997. The Role of the Sulphur Bank Mercury Mine Site (and Associated Hydrogeological Processes) in the Dynamics of Mercury Transport and Biocumulation within the Clear Lake Aquatic Ecosystem. Interim Final Report. IX Superfund Program. Univ. California. US Government.

SUER/FUNAI/Procuradoria da República Indenização dos índios do P. I. Trocará, CT. NR/ Belém, 4ª.SUER/FUNAI/Procuradoria da República, 13 de maio 1991, pp. 4.

SUS. Norma Operacional Básica do Sistema Único de Saúde. NOB/96.

TADEI, W. P. 1985. Estudos de ecologia e controle ambiental na região do reservatório da UHE de Tucuruí. Relatório semestral. Julho-dezembro 1985. Convênio INPA x Eletronorte. Manaus. INPA.

TADEI, W.P. 1985. Estudos de ecologia e controle ambiental na região do reservatório da UHE Tucuruí.. Relatório Setorial do sub projeto Impacto do reservatório no aumento de doenças endêmicas – vetores da malária. Janeiro-junho 1985. Convênio INPA x Eletronorte. Manaus. INPA. 1985a.

TADEI, W.P. 1986. Estudos de ecologia e controle ambiental na região do reservatório da UHE Tucuruí. Relatório setorial do segmento "Doenças endêmicas- vetores da malária". Julho-dezembro 1986. Convênio INPA x Eletronorte. Manaus. INPA. b.45p.

TADEI, W.P. 1990. Mapeamento terrestre da proliferação de mosquitos a montante da UHE Tucuruí. Relatório Técnico. Manaus. INPA & Eletronorte. 102 p.

TADEI, W.P. 1996. "O gênero *Mansonia* (Diptera:Culicidae) e a proliferação de mosquitos na Usina Hidrelétrica de Tucuruí." in MAGALHÃES, S.B.;BRITTO, R. DE C. & CASTRO, E.R.de (org)- Energia na Amazônia. Volume 1. Belém. MPEG & UFPA, 1996. p 311-318.

TADEI, W.P. 1996. "O Gênero *Mansonia* (diptera: culicidae) e a proliferação de mosquitos na Usina Hidrelétrica de Tucuruí." In: Energia na Amazônia. Belém. MPEG/UFPA/UNAMAZ.

TADEI, W.P. 1987. "Estudos de ecologia e controle ambiental na região do reservatório da UHE Tucuruí. Relatório de avanço e acompanhamento semestral do segmento. Doenças endêmicas- vetores de malária." Janeiro-junho 1987. Convênio INPA x Eletronorte. Manaus. INPA. 1987a. 20p.

TADEI, W.P. 1987. Estudos de ecologia e controle ambiental na região do reservatório da UHE Tucuruí. Relatório de avanço e acompanhamento semestral do segmento. Doenças endêmicas- vetores de malária. Julho-dezembro 1987. Convênio INPA x Eletronorte. Manaus. INPA.

TADEI, W.P.; MASCARENHAS, B.M. & PODESTÁ, M.G. 1983. "Biologia de anofelinos amazônicos. VIII. Conhecimento sobre a distribuição de espécies de *Anopheles* na região de Tucuruí-Marabá (Pará)." in Acta Amazonica 13 (1): 103-140.

TADEI. W.P. 1986. Estudos de ecologia e controle ambiental do reservatório da UHE Tucuruí. Relatório Setorial do segmento "Impacto do reservatório no aumento de doenças endêmicas – vetores da malária. Janeiro-junho 1986. Convênio INPA x Eletronorte. Manaus. INPA.

TAMBELLINI, AT., & CÂMARA, V.M. 1998. "A temática saúde e ambiente no processo de desenvolvimento do campo da saúde coletiva: aspectos históricos, conceituais e metodológicos." in Ciência & Saúde Coletiva, 3(2):47-59.

TAVARES, M. GORETTI C. 1999. A dinâmica espacial da rede de distribuição de energia elétrica no Estado do Pará (1966-1996). Rio de Janeiro: UFRJ/PPGG, (Tese de Doutoramento)

TEIXEIRA, M. GRACINDA. 1996. Energy policy in Latin America: social and environmental dimensions of hydropower in Amazônia. Rio de Janeiro: UFRK; Inglaterra: Centre for Social e Economic Research on the Global Environment, Averuby.

TERBORGH, J. & WINTER, B. 1980. "Some causes of extinction." in SOULÉ, M.E. & WILCOX, B. (Eds). Conservation Biology: na Evolutionary-Ecological Perspective. Sinauer Press, Sunderland, Massachusetts: 119-133.

TRAVASSOS DA ROSA, A.P.A.; TRAVASSOS DA ROSA, J.F.S.; HERVÉ, J-P.; VASCONCELOS, P.F.C.; DÉGALLIER, N. & RODRIGUES, S.G. 1992. "Arboviruses in Serra Norte, Carajás Region, Pará, Brazil." in Ciência e Cultura (J. Brazilian Assoc. Advanc. Sci.) 44(2/3):158-161.

TRAVASSOS DA ROSA, J.F.S.; TRAVASSOS DA ROSA, A.P.A.; DÉGALLIER, N. & VASCONCELOS, P.F.C. 1992. "Caracterização e relacionamento antigênico de três novos *Bunyavirus* do grupo Anopheles A (Bunyaviridade) dos arbovírus." in Rev. Saúde Pública S. Paulo., 26(3):173-178.

TUNDISI, J.G. 1988. "Impactos ecológicos da construção de represas, aspectos específicos e problemas de manejo." in Tundisi, J. G. (ed.). Limnologia e manejo de represas. Vol.I. Tomo 1. EESC-USP/ACIESP, p.1-90.

VAINER, C.B. E ARAÚJO, FREDERICO G. B. 1992. Grandes projetos hidrelétricos e desenvolvimento regional. Rio de Janeiro: CEDI.

VALENÇA, W.F.S. 1991. A Dimensão Urbana dos Impactos da Hidrelétrica de Tucuruí. Tese de Mestrado. RJ:COPPE, UFRJ.

VASCONCELOS, P.F.C. & DÉGALLIER, N. 1991. "Les maladies de l'environnement dans le contexte de l'écosystème amazonien." in Actes du Colloque Éco-Développement Amazonien Traditiones et Environnement, organisé par le Conseil Général de la Guyane 19-21 Avril 1991, p.46-49.

VASCONCELOS, P.F.C.; TRAVASSOS DA ROSA, A.P.A.; DÉGALLIER, N.; TRAVASSOS DA ROSA, J.F.S. & PINHEIRO, F.P. 1992. "Clinical and ecoepidemiological situation of human arboviruses in Brazilian Amazonia." in Ciência e Cultura (J. Brazilian Assoc. Advanc. Sci.) 44(2/3):117-124.

VIDAL, Lux B. 1991. "Os índios da Amazônia - um desafio recíproco" in Jena Hébette (org.).O cerco está se fechando: o impacto do grande capital na Amazônia. Petrópolis: Ed. Vozes, pp. 54-77.

VIEIRA FILHO, J.P.Botelho. 1985. "A Saúde dos índios Assurini do Trocará - diretrizes para a Assistência à Saúde". Relatório à Cia. Vale do Rio Doce. São Paulo, mimeo.

VIVEIROS DE CASTRO, Eduardo B. e ANDRADE, Lucia M . M. de - 1988. "Hidrelétricas do Xingu: o Estado contra as sociedades indígenas". in Leinad Ayer O .Santos e Lucia M.M. de Andrade (orgs.), As Hidrelétricas do Xingu e os povos indígenas. São Paulo, Comissão Pró-Índio de São Paulo.

WATANABE, C. 1975. Mercury WHO Technical Report Meeting.

WHO. 1983. Health impact of different energy sources. Regional Office for Europe Copenhagen.